Analysis Techniques: Flow Duration Analysis Example

Information to get started:

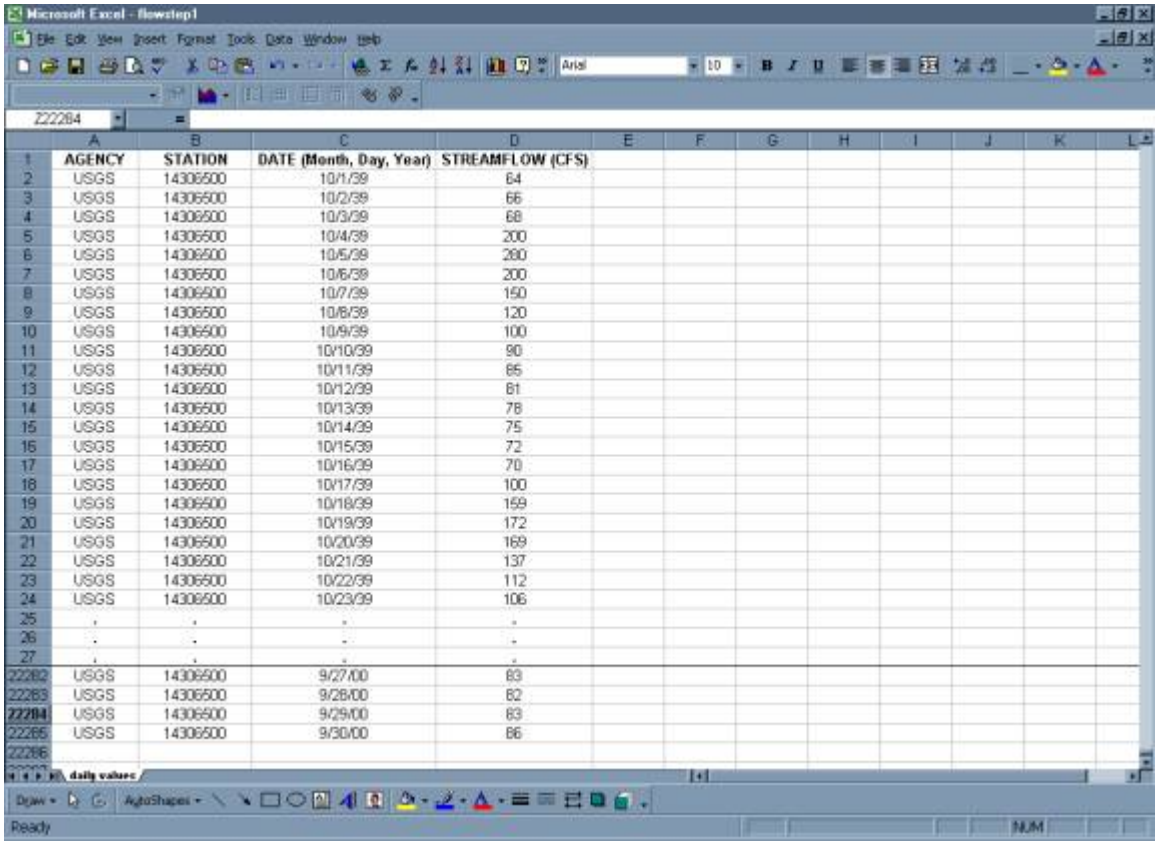
- The lesson below contains step-by-step instructions and "snapshots" of what each step looks like when carried out in a Microsoft Excel workbook. Blue shading of information in the Excel illustrations denotes changes made from the previous step. Dots placed in three consecutive rows indicate that a portion of data is hidden from sight.
- You can download an Excel workbook containing the complete data set by clicking on the "Download Data" link below. It contains each calculation step on a separate worksheet. To move between steps, click on the tabs at the bottom of the excel window.
- When you download the file, it may open in your browser window. You may wish to use the "save as" function to save the file to a local drive and then reopen it in Excel. This will make it easier to flip between the online lesson and the example workbook.
- Finally, we want to remind you that the techniques explained on this site are statistically based; therefore results must be viewed as predictions and not as facts. Please use the techniques and the information obtained from them responsibly!

Download Data

Step 1: Select the time step value (day, month, etc.)

- For the Alsea Example and Tutorial, the analysis will be done using a daily time step.

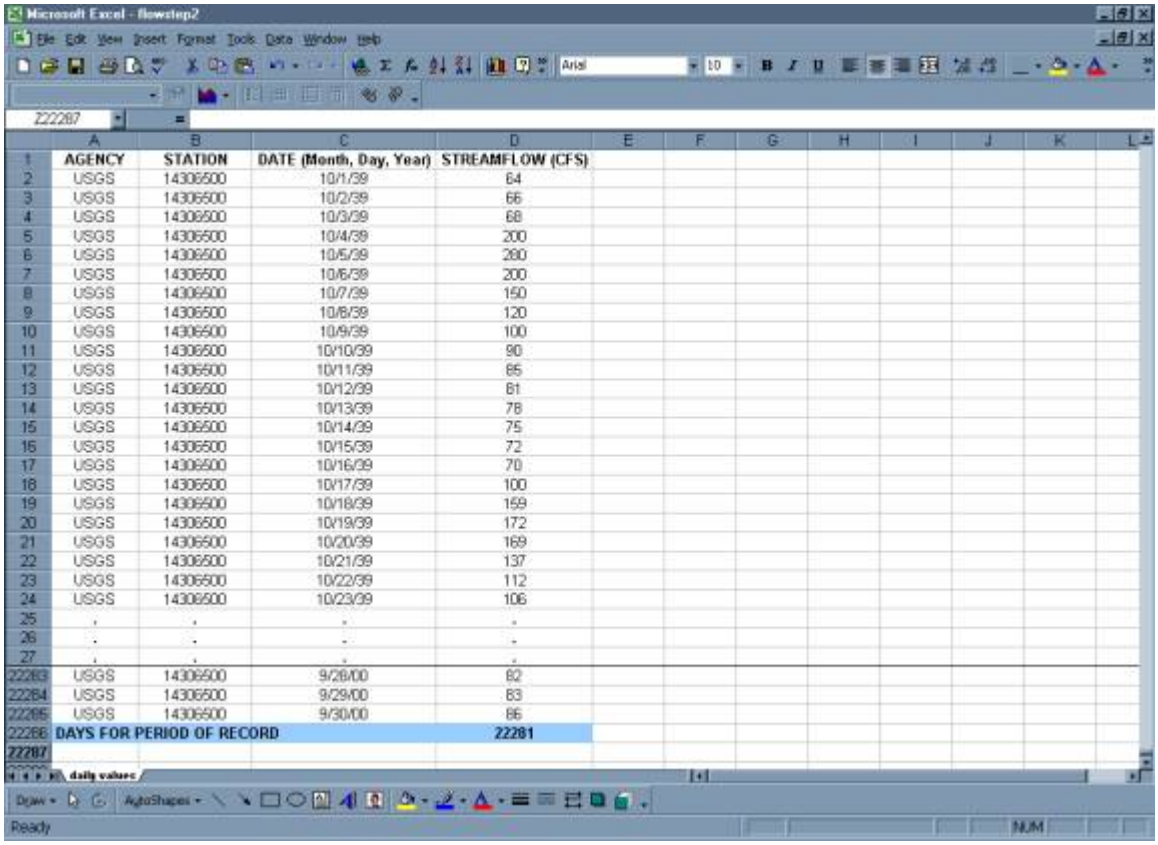
Step 2: Download the chronological record of discharge (daily values).



Microsoft Excel - flowstep1

	A	B	C	D
1	AGENCY	STATION	DATE (Month, Day, Year)	STREAMFLOW (CFS)
2	USGS	14306500	10/1/39	64
3	USGS	14306500	10/2/39	66
4	USGS	14306500	10/3/39	68
5	USGS	14306500	10/4/39	200
6	USGS	14306500	10/5/39	280
7	USGS	14306500	10/6/39	200
8	USGS	14306500	10/7/39	150
9	USGS	14306500	10/8/39	120
10	USGS	14306500	10/9/39	100
11	USGS	14306500	10/10/39	90
12	USGS	14306500	10/11/39	85
13	USGS	14306500	10/12/39	81
14	USGS	14306500	10/13/39	78
15	USGS	14306500	10/14/39	75
16	USGS	14306500	10/15/39	72
17	USGS	14306500	10/16/39	70
18	USGS	14306500	10/17/39	100
19	USGS	14306500	10/18/39	159
20	USGS	14306500	10/19/39	172
21	USGS	14306500	10/20/39	169
22	USGS	14306500	10/21/39	137
23	USGS	14306500	10/22/39	112
24	USGS	14306500	10/23/39	106
25	.	.	.	.
26	.	.	.	.
27	.	.	.	.
22282	USGS	14306500	9/27/00	83
22283	USGS	14306500	9/28/00	82
22284	USGS	14306500	9/29/00	83
22285	USGS	14306500	9/30/00	86
22286				

Step 3: Compute the total number of time step intervals in the period of record.



Microsoft Excel - flowstep2

	A	B	C	D
1	AGENCY	STATION	DATE (Month, Day, Year)	STREAMFLOW (CFS)
2	USGS	14306500	10/1/39	64
3	USGS	14306500	10/2/39	66
4	USGS	14306500	10/3/39	68
5	USGS	14306500	10/4/39	200
6	USGS	14306500	10/5/39	280
7	USGS	14306500	10/6/39	200
8	USGS	14306500	10/7/39	150
9	USGS	14306500	10/8/39	120
10	USGS	14306500	10/9/39	100
11	USGS	14306500	10/10/39	90
12	USGS	14306500	10/11/39	85
13	USGS	14306500	10/12/39	81
14	USGS	14306500	10/13/39	78
15	USGS	14306500	10/14/39	75
16	USGS	14306500	10/15/39	72
17	USGS	14306500	10/16/39	70
18	USGS	14306500	10/17/39	100
19	USGS	14306500	10/18/39	159
20	USGS	14306500	10/19/39	172
21	USGS	14306500	10/20/39	169
22	USGS	14306500	10/21/39	137
23	USGS	14306500	10/22/39	112
24	USGS	14306500	10/23/39	106
25	.	.	.	.
26	.	.	.	.
27	.	.	.	.
22283	USGS	14306500	9/28/00	82
22284	USGS	14306500	9/29/00	83
22285	USGS	14306500	9/30/00	86
22286	DAYS FOR PERIOD OF RECORD			22281
22287				

daily values

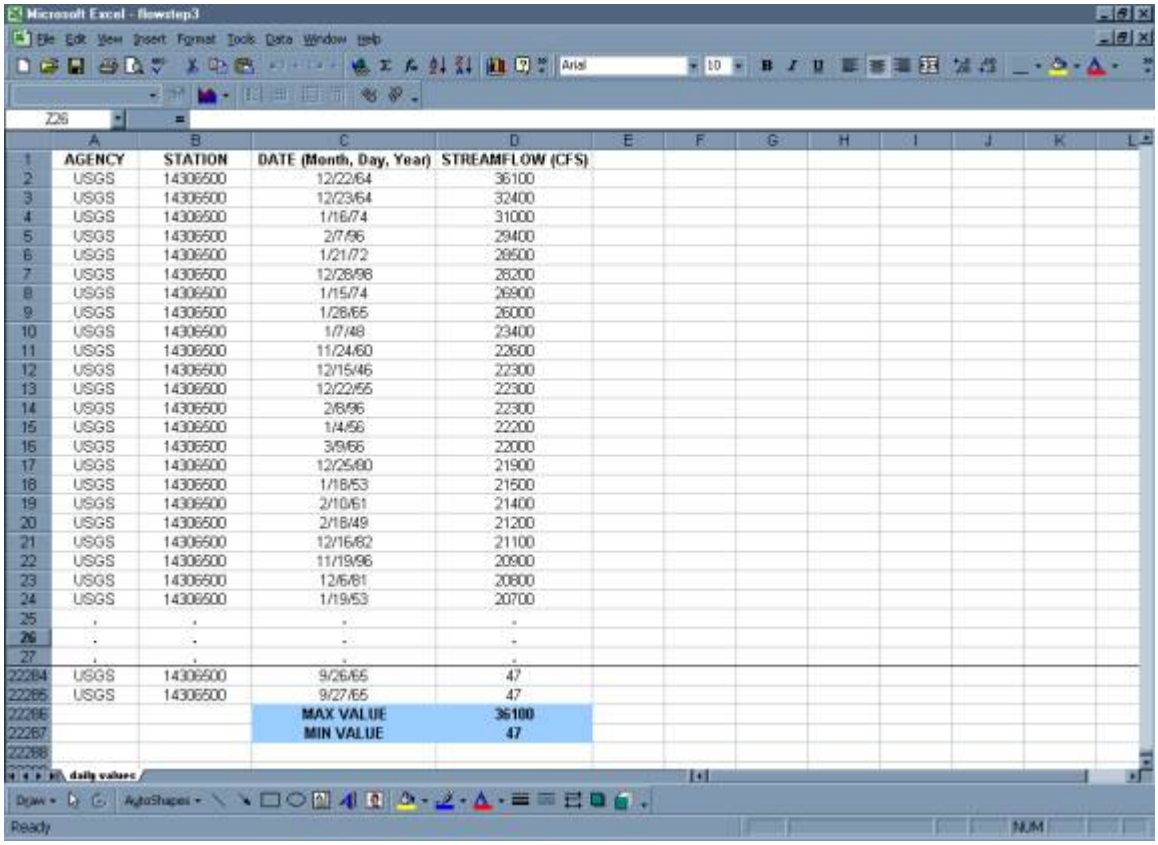
Ready

NUM

Step 4: Rank Discharge by Magnitude.

- Use the "sort" command to rank the entries by discharge, from largest to smallest.

- Calculate the average value of the variable of interest within each time step (average daily value) for the period of record and note the largest and smallest of these average values.

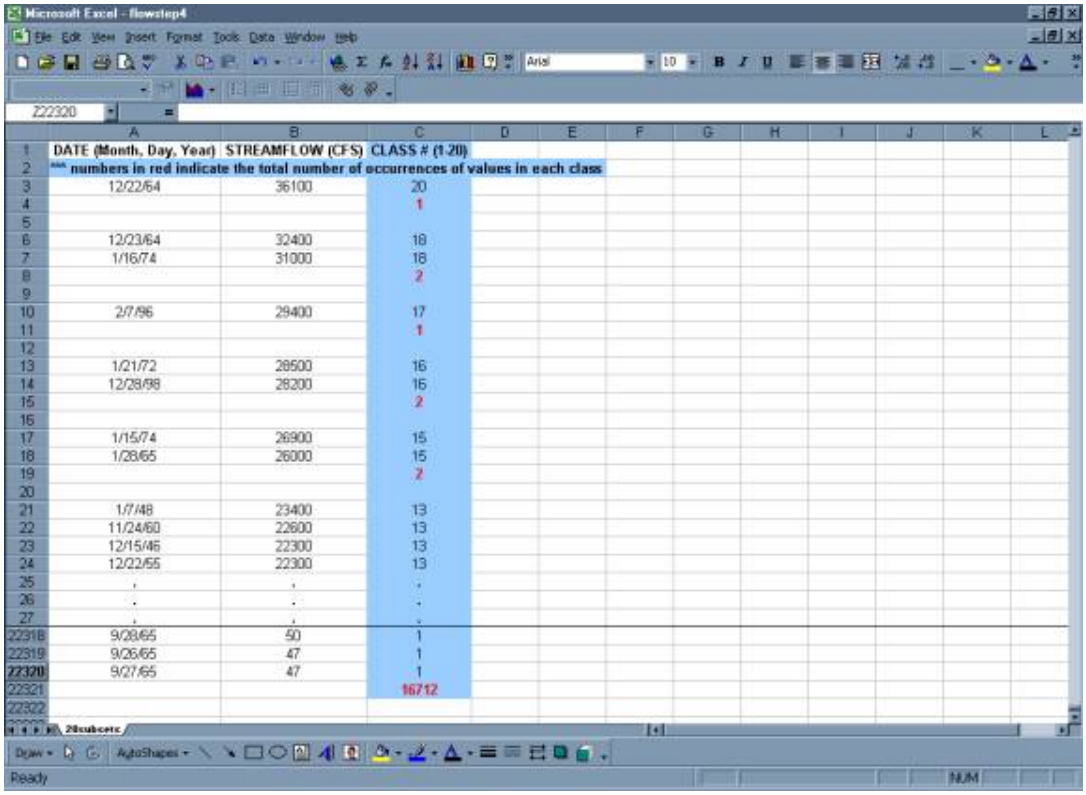


	A	B	C	D
1	AGENCY	STATION	DATE (Month, Day, Year)	STREAMFLOW (CFS)
2	USGS	14306500	12/22/64	36100
3	USGS	14306500	12/23/64	32400
4	USGS	14306500	1/16/74	31000
5	USGS	14306500	2/7/96	29400
6	USGS	14306500	1/21/72	28500
7	USGS	14306500	12/28/96	28200
8	USGS	14306500	1/15/74	26900
9	USGS	14306500	1/28/65	26000
10	USGS	14306500	1/7/48	23400
11	USGS	14306500	11/24/60	22600
12	USGS	14306500	12/15/46	22300
13	USGS	14306500	12/22/55	22300
14	USGS	14306500	2/6/96	22300
15	USGS	14306500	1/4/56	22200
16	USGS	14306500	3/9/66	22000
17	USGS	14306500	12/25/80	21900
18	USGS	14306500	1/18/53	21500
19	USGS	14306500	2/10/61	21400
20	USGS	14306500	2/18/49	21200
21	USGS	14306500	12/16/82	21100
22	USGS	14306500	11/19/96	20900
23	USGS	14306500	12/6/81	20800
24	USGS	14306500	1/19/53	20700
25	.	.	.	.
26	.	.	.	.
27	.	.	.	.
22284	USGS	14306500	9/26/65	47
22285	USGS	14306500	9/27/65	47
22286			MAX VALUE	36100
22287			MIN VALUE	47

Step 5: Divide the range of average values into classes (class sizes need not be equal)

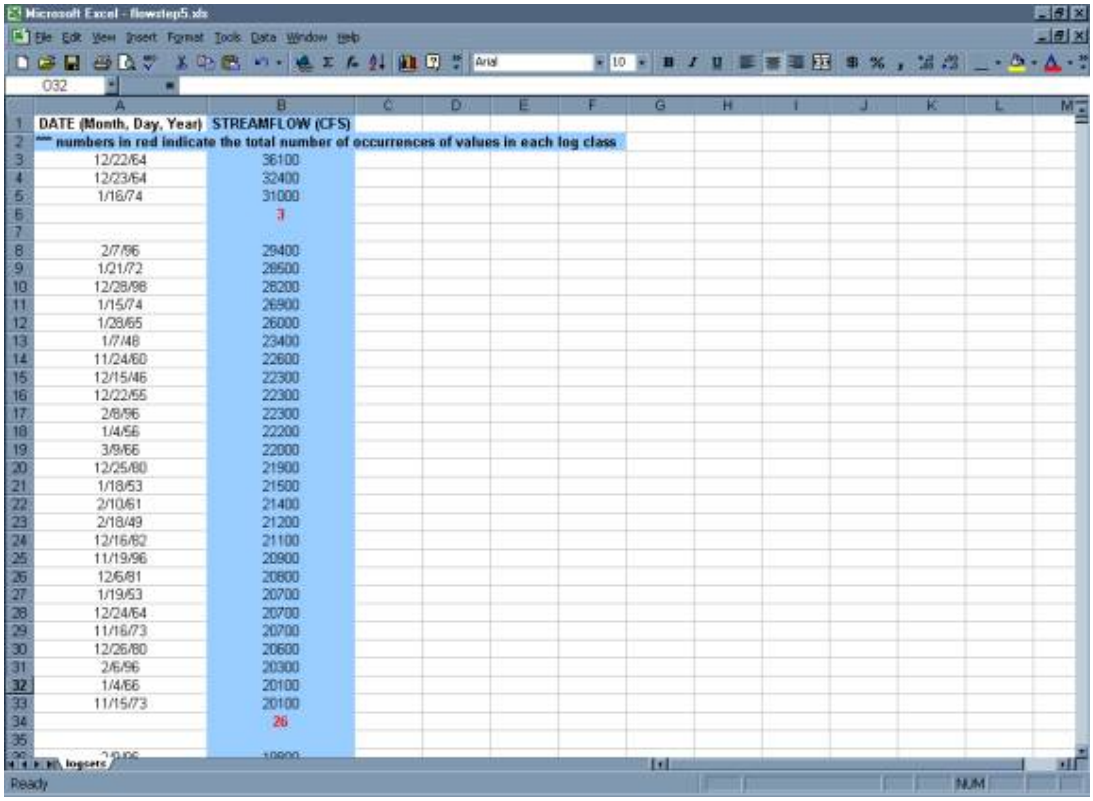
- It is recommended to have between twenty to thirty class intervals for the period of record. Classes can either be equal interval or based on log cycles. Log cycles are often used to sort data because the probability of choosing appropriate interval spacing is higher than if the data were separated into 20 to 30 equal classes. Log cycles are often used to sort data because the probability of choosing appropriate interval spacing is higher than if the data were separated into 20 to 30 equal classes. A histogram of the sorted data should take on a general bell shape. If the shape appears drastically different from the bell shape, the data may need to be resorted into smaller or larger intervals. If improper intervals are chosen, the amount of information the flow duration curve can provide is diminished.
    - For the equal interval method, determine the discharge range for each class by dividing the max discharge value by the desired number of size classes. In the example data, the max discharge value is 36,100 cfs. That value divided by 20 is 1805. So for twenty size classes with equal intervals in each class, the smallest size class will be discharges between 0-1805 cfs. The second size class will be 1806-3610 cfs and so on, up to the max value.
    - For classes based on log cycles, select classes of discharge values based on a spacing of 1, 1.5, 2, 3, 4, 5, 7, 10, or on multiples of 10 of these values. For the example data, the size classes will be 10-14 cfs, 15-19 cfs, 20-29 cfs on up to 30,000-39,999 cfs.
- Use the ranked data to count the total number of occurrences of values in each class.

20 Equal Class Intervals:



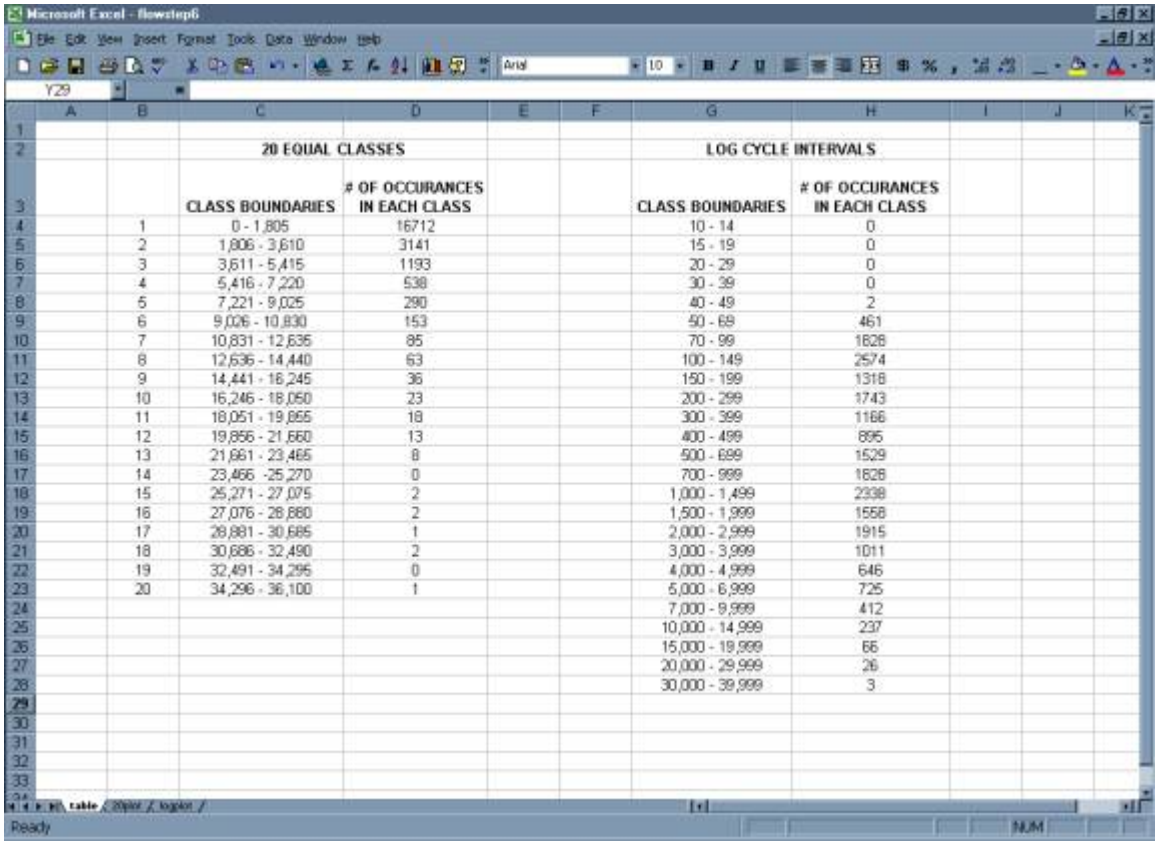
	A	B	C
1	DATE (Month, Day, Year)	STREAMFLOW (CFS)	CLASS # (1-20)
2	*** numbers in red indicate the total number of occurrences of values in each class		
3	12/22/64	36100	20
4			1
5			
6	12/23/64	32400	18
7	1/16/74	31000	18
8			2
9			
10	2/7/96	29400	17
11			1
12			
13	1/21/72	28500	16
14	12/28/98	28200	16
15			2
16			
17	1/15/74	26900	15
18	1/28/65	26000	15
19			2
20			
21	1/7/48	23400	13
22	11/24/60	22600	13
23	12/15/46	22300	13
24	12/22/55	22300	13
25	.	.	.
26	.	.	.
27	.	.	.
22318	9/28/65	50	1
22319	9/26/65	47	1
22320	9/27/65	47	1
22321			16712
22322			

Using Log Cycles:



	A	B
1	DATE (Month, Day, Year)	STREAMFLOW (CFS)
2	*** numbers in red indicate the total number of occurrences of values in each log class	
3	12/22/64	36100
4	12/23/64	32400
5	1/16/74	31000
6		3
7		
8	2/7/96	29400
9	1/21/72	28500
10	12/28/98	28200
11	1/15/74	26900
12	1/28/65	26000
13	1/7/48	23400
14	11/24/60	22600
15	12/15/46	22300
16	12/22/55	22300
17	2/8/96	22300
18	1/4/56	22200
19	3/9/66	22000
20	12/25/80	21900
21	1/18/53	21500
22	2/10/61	21400
23	2/18/49	21200
24	12/16/62	21100
25	11/19/96	20900
26	12/6/81	20800
27	1/19/53	20700
28	12/24/64	20700
29	11/16/73	20700
30	12/26/80	20600
31	2/6/96	20300
32	1/4/66	20100
33	11/15/73	20100
34		26
35		

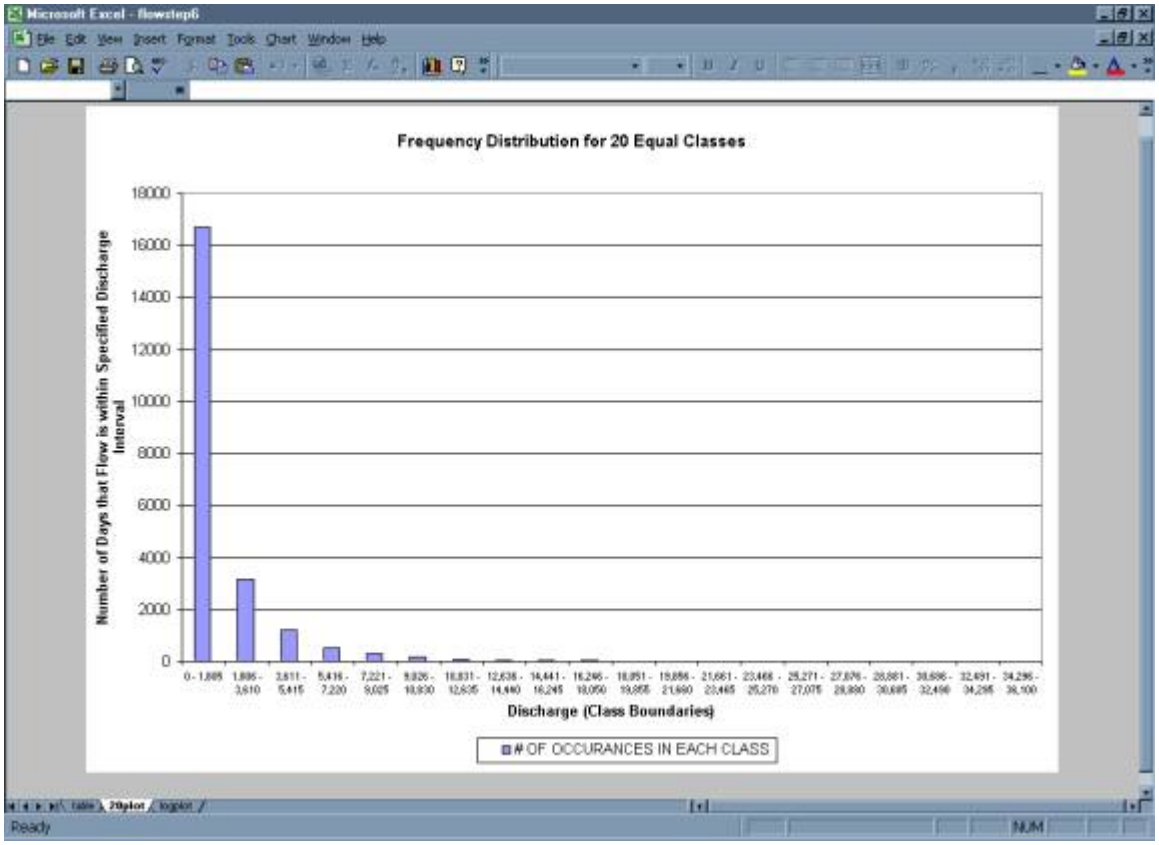
- Summarize the results in a table.

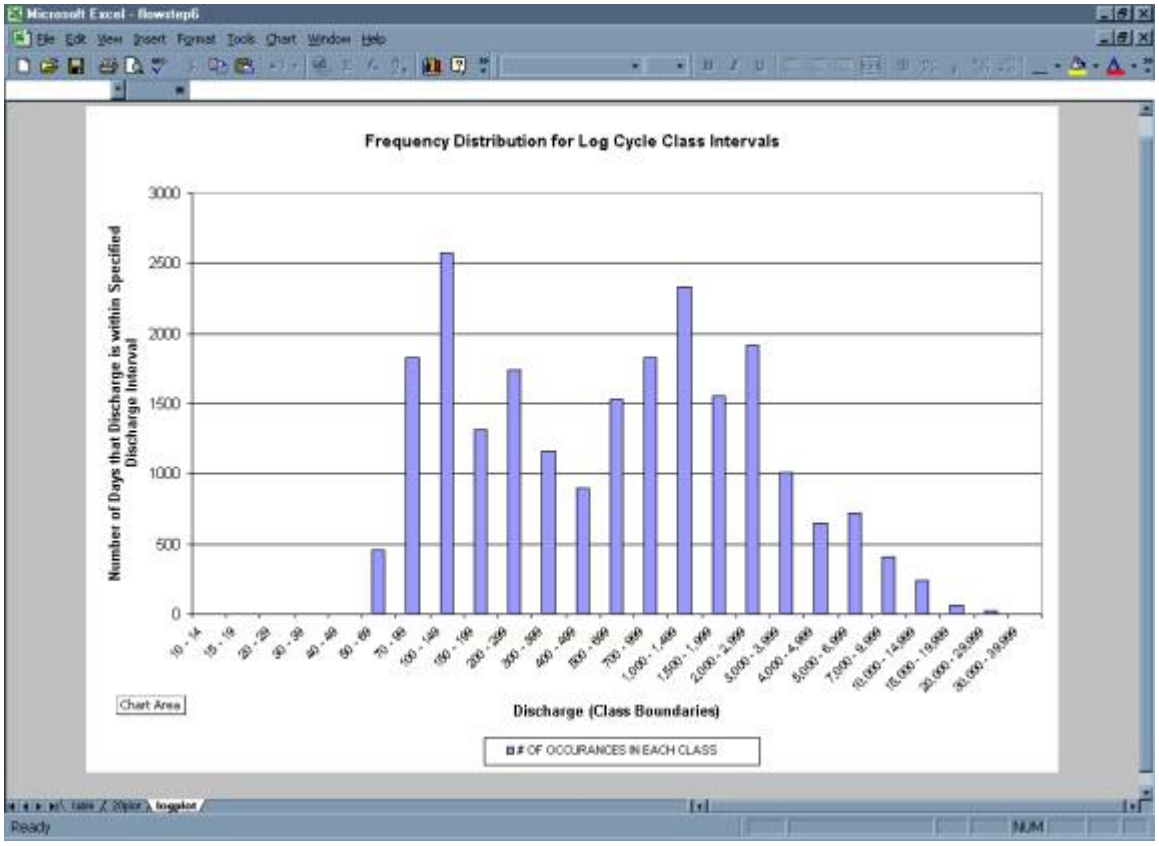


Microsoft Excel - flowstep6

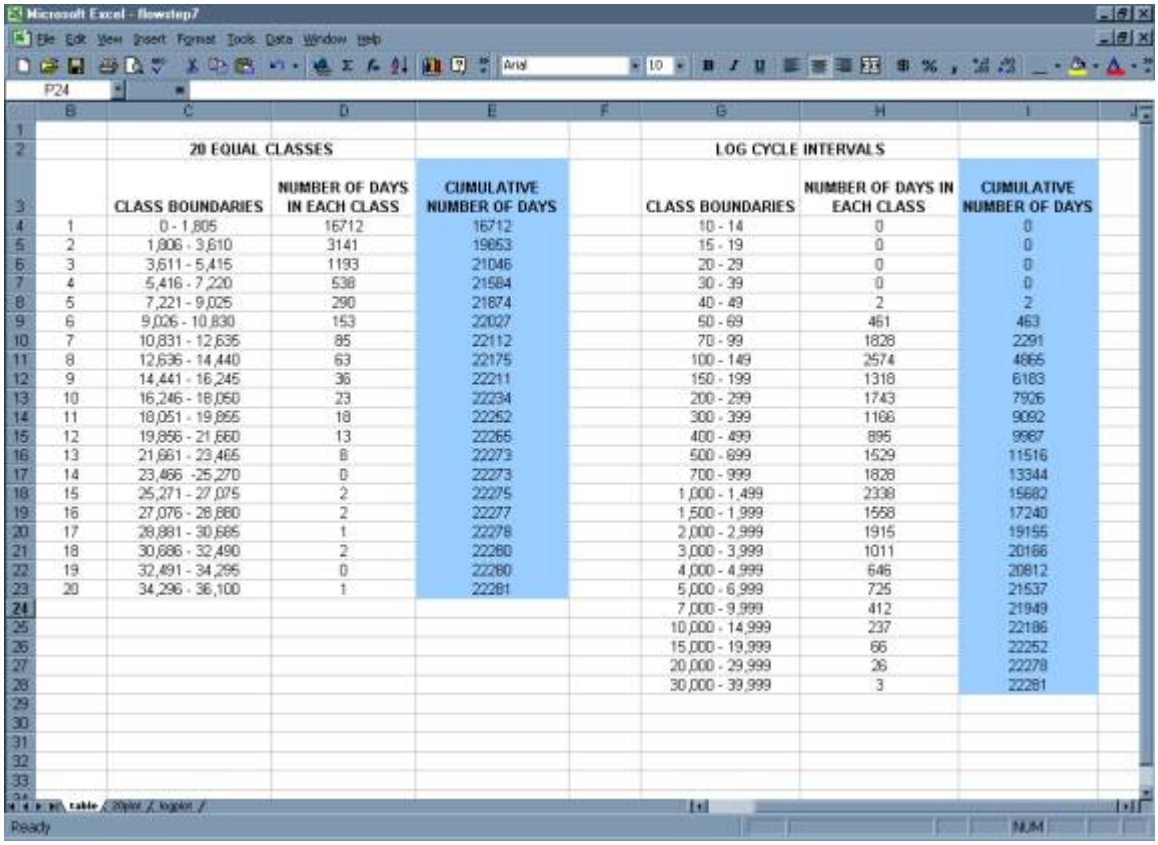
		20 EQUAL CLASSES			LOG CYCLE INTERVALS	
		CLASS BOUNDARIES	# OF OCCURANCES IN EACH CLASS		CLASS BOUNDARIES	# OF OCCURANCES IN EACH CLASS
1	1	0 - 1,805	16712		10 - 14	0
2	2	1,806 - 3,610	3141		15 - 19	0
3	3	3,611 - 5,415	1193		20 - 29	0
4	4	5,416 - 7,220	538		30 - 39	0
5	5	7,221 - 9,025	280		40 - 49	2
6	6	9,026 - 10,830	153		50 - 69	461
7	7	10,831 - 12,635	85		70 - 99	1828
8	8	12,636 - 14,440	63		100 - 149	2574
9	9	14,441 - 16,245	36		150 - 199	1318
10	10	16,246 - 18,050	23		200 - 299	1743
11	11	18,051 - 19,855	18		300 - 399	1166
12	12	19,856 - 21,660	13		400 - 499	695
13	13	21,661 - 23,465	8		500 - 699	1529
14	14	23,466 -25,270	0		700 - 999	1828
15	15	25,271 - 27,075	2		1,000 - 1,499	2338
16	16	27,076 - 28,880	2		1,500 - 1,999	1558
17	17	28,881 - 30,685	1		2,000 - 2,999	1915
18	18	30,686 - 32,490	2		3,000 - 3,999	1011
19	19	32,491 - 34,295	0		4,000 - 4,999	646
20	20	34,296 - 36,100	1		5,000 - 6,999	725
					7,000 - 9,999	412
					10,000 - 14,999	237
					15,000 - 19,999	66
					20,000 - 29,999	26
					30,000 - 39,999	3

- A plot of the total number of occurrences in each class versus discharge gives a frequency distribution.


Microsoft Excel - flowstep6
File Edit View Insert Format Tools Chart Window Help
Frequency Distribution for 20 Equal Classes
Number of Days that Flow is within Specified Discharge Interval
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Discharge (Class Boundaries)
OF OCCURANCES IN EACH CLASS
Ready
NUM


Microsoft Excel - flowstep6
File Edit View Insert Format Tools Chart Window Help
Frequency Distribution for Log Cycle Class Intervals
Number of Days that Discharge is within Specified Discharge Interval
3000
2500
2000
1500
1000
500
0
Chart Area
Discharge (Class Boundaries)
OF OCCURANCES IN EACH CLASS
Ready
NUM

Step 6: Beginning with the upper boundary of the highest class, add up the total number of values that are greater than the lower boundary for each successive class.



Microsoft Excel - flowstep7

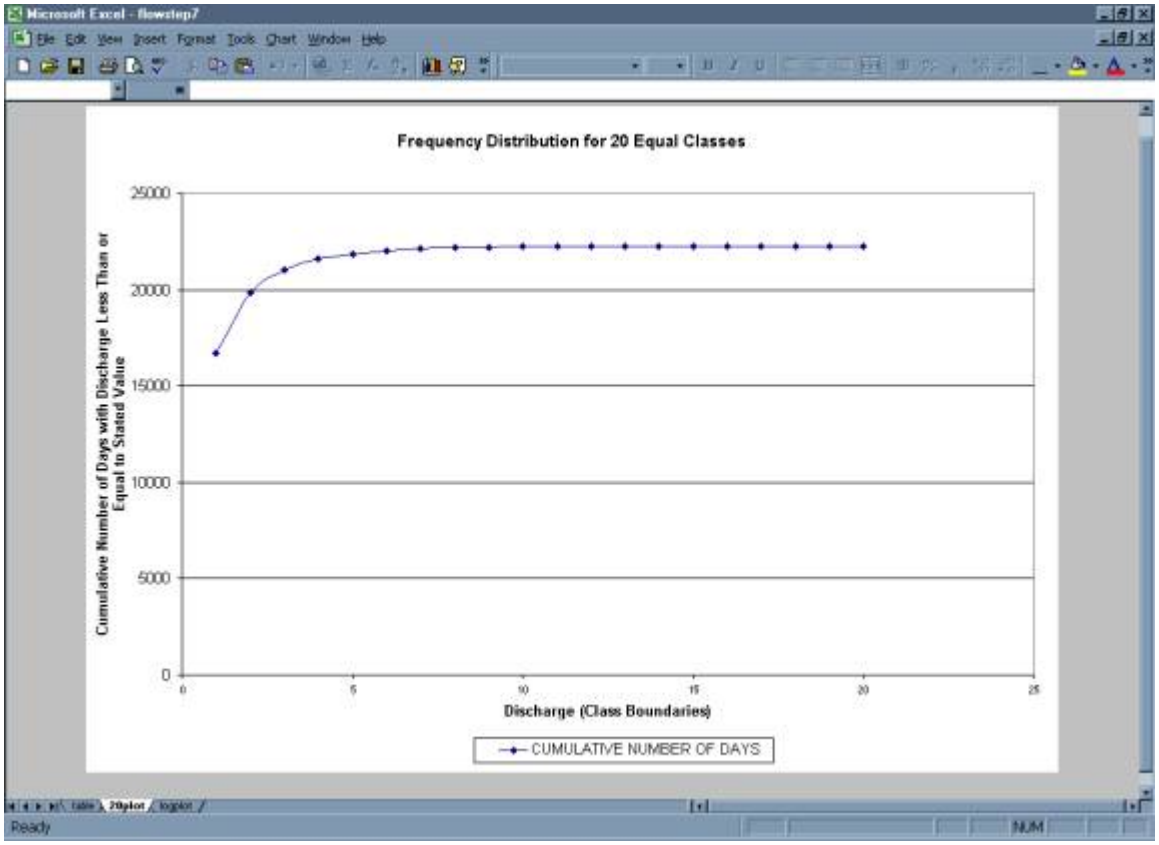
File Edit View Insert Format Tools Data Window Help

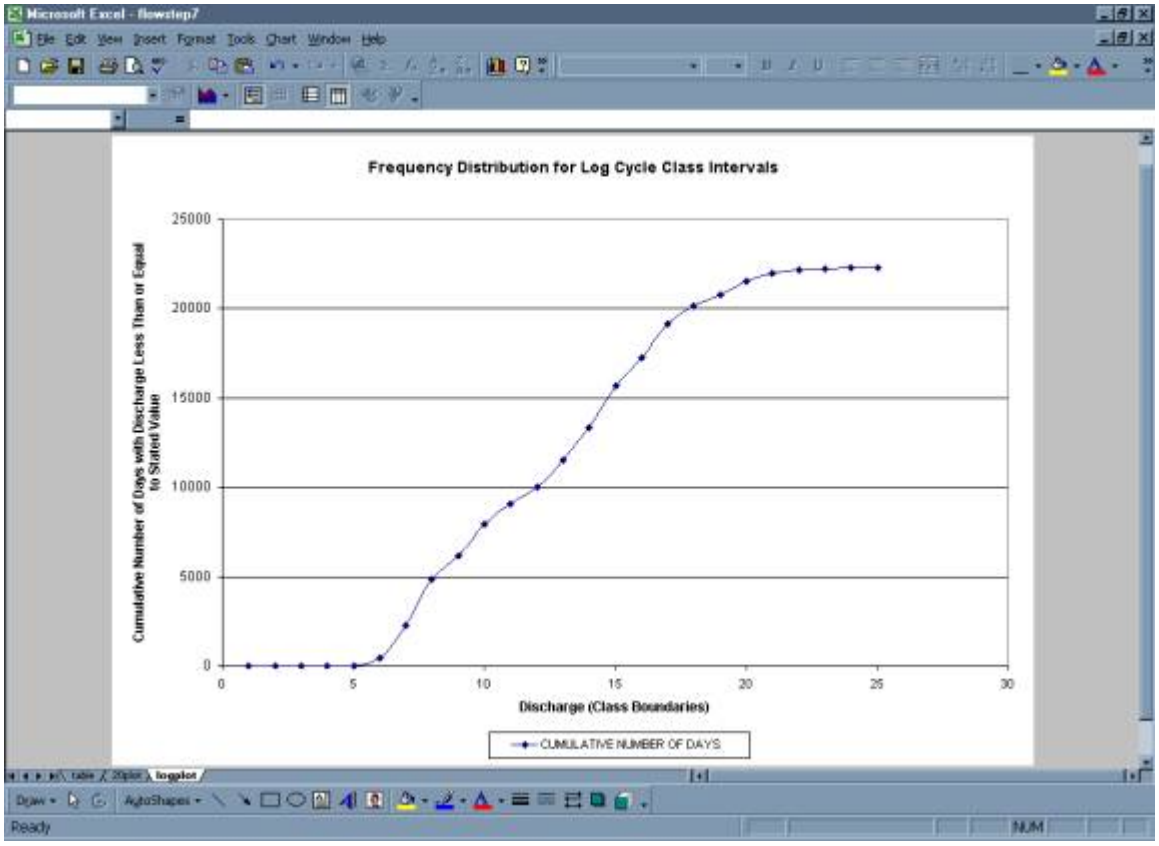
P24

		20 EQUAL CLASSES				LOG CYCLE INTERVALS		
		CLASS BOUNDARIES	NUMBER OF DAYS IN EACH CLASS	CUMULATIVE NUMBER OF DAYS		CLASS BOUNDARIES	NUMBER OF DAYS IN EACH CLASS	CUMULATIVE NUMBER OF DAYS
4	1	0 - 1,805	16712	16712		10 - 14	0	0
5	2	1,806 - 3,610	3141	19853		15 - 19	0	0
6	3	3,611 - 5,415	1193	21046		20 - 29	0	0
7	4	5,416 - 7,220	538	21584		30 - 39	0	0
8	5	7,221 - 9,025	290	21874		40 - 49	2	2
9	6	9,026 - 10,830	153	22027		50 - 69	461	463
10	7	10,831 - 12,635	85	22112		70 - 99	1828	2291
11	8	12,636 - 14,440	63	22175		100 - 149	2574	4865
12	9	14,441 - 16,245	36	22211		150 - 199	1318	6183
13	10	16,246 - 18,050	23	22234		200 - 299	1743	7926
14	11	18,051 - 19,855	18	22252		300 - 399	1166	9092
15	12	19,856 - 21,660	13	22265		400 - 499	895	9987
16	13	21,661 - 23,465	8	22273		500 - 699	1529	11516
17	14	23,466 -25,270	0	22273		700 - 999	1828	13344
18	15	25,271 - 27,075	2	22275		1,000 - 1,499	2338	15682
19	16	27,076 - 28,880	2	22277		1,500 - 1,999	1558	17240
20	17	28,881 - 30,685	1	22278		2,000 - 2,999	1915	19155
21	18	30,686 - 32,490	2	22280		3,000 - 3,999	1011	20166
22	19	32,491 - 34,295	0	22280		4,000 - 4,999	646	20812
23	20	34,296 - 36,100	1	22281		5,000 - 6,999	725	21537
24						7,000 - 9,999	412	21949
25						10,000 - 14,999	237	22186
26						15,000 - 19,999	66	22252
27						20,000 - 29,999	26	22278
28						30,000 - 39,999	3	22281

table / 20plot / logplot /

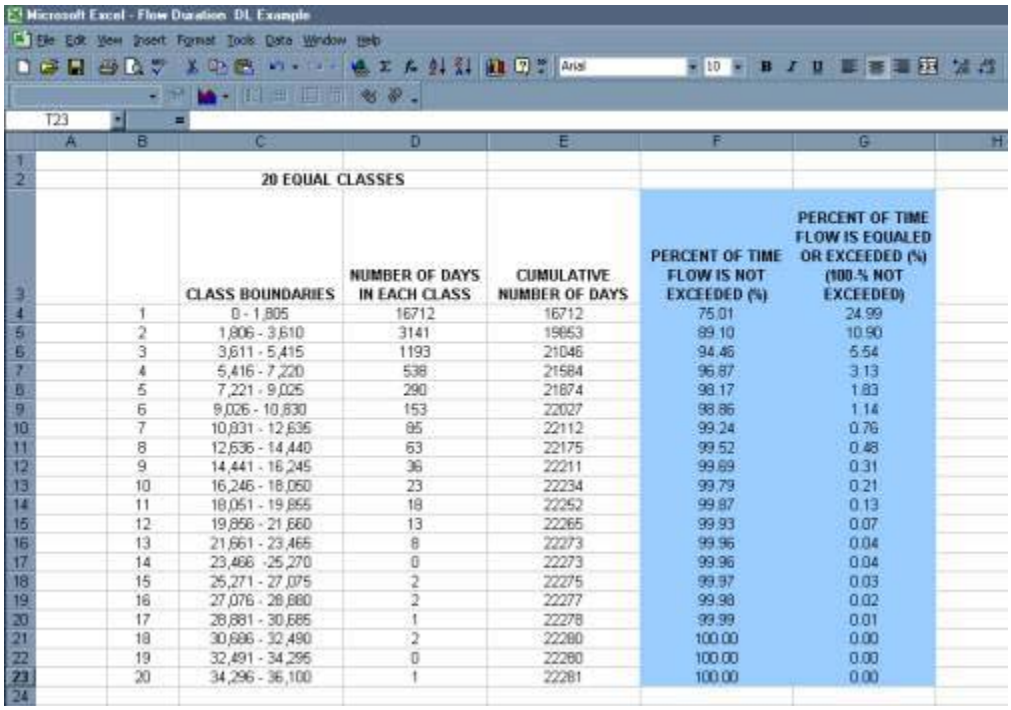
Ready NUM


Microsoft Excel - flowstep7
File Edit View Insert Format Tools Chart Window Help
Frequency Distribution for 20 Equal Classes
Cumulative Number of Days with Discharge Less Than or Equal to Stated Value
25000
20000
15000
10000
5000
0
0
5
10
15
20
25
Discharge (Class Boundaries)
CUMULATIVE NUMBER OF DAYS
Ready
NUM


Microsoft Excel - flowstep7
File Edit View Insert Format Tools Chart Window Help
Frequency Distribution for Log Cycle Class Intervals
Cumulative Number of Days with Discharge Less Than or Equal to Stated Value
25000
20000
15000
10000
5000
0
0
5
10
15
20
25
30
Discharge (Class Boundaries)
CUMULATIVE NUMBER OF DAYS
Ready
NUM

Step 7: The cumulative number of occurrences is converted to a percentage of the time.

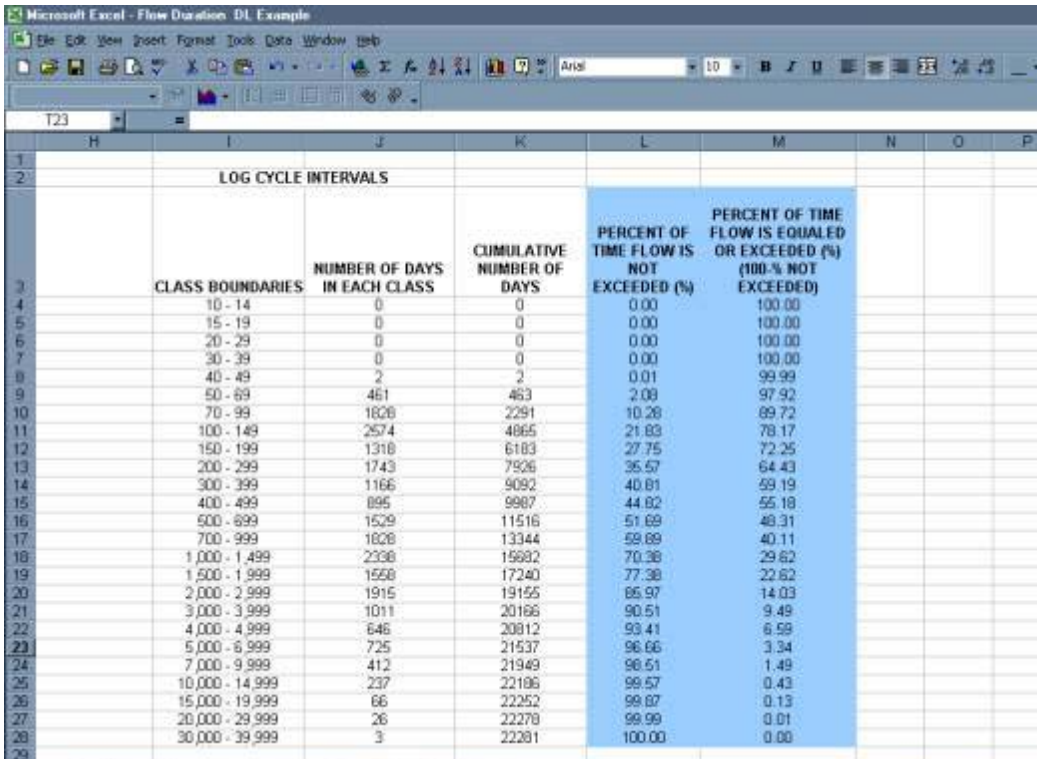
- Divide the values developed in Step 6 by the total number of time steps from Step 2; this gives the frequency with which the lower values of each class have been equaled or exceeded in the period of record.



Microsoft Excel - Flow Duration DL Example

20 EQUAL CLASSES

	CLASS BOUNDARIES	NUMBER OF DAYS IN EACH CLASS	CUMULATIVE NUMBER OF DAYS	PERCENT OF TIME FLOW IS NOT EXCEEDED (%)	PERCENT OF TIME FLOW IS EQUALED OR EXCEEDED (%) (100-% NOT EXCEEDED)
1	0 - 1,805	16712	16712	75.01	24.99
2	1,806 - 3,610	3141	19853	89.10	10.90
3	3,611 - 5,415	1193	21046	94.46	5.54
4	5,416 - 7,220	538	21584	96.87	3.13
5	7,221 - 9,025	290	21874	98.17	1.83
6	9,026 - 10,830	153	22027	98.86	1.14
7	10,831 - 12,635	85	22112	99.24	0.76
8	12,636 - 14,440	63	22175	99.52	0.48
9	14,441 - 16,245	36	22211	99.69	0.31
10	16,246 - 18,050	23	22234	99.79	0.21
11	18,051 - 19,855	18	22252	99.87	0.13
12	19,856 - 21,660	13	22265	99.93	0.07
13	21,661 - 23,465	8	22273	99.96	0.04
14	23,466 -25,270	0	22273	99.96	0.04
15	25,271 - 27,075	2	22275	99.97	0.03
16	27,076 - 28,880	2	22277	99.98	0.02
17	28,881 - 30,685	1	22278	99.99	0.01
18	30,686 - 32,490	2	22280	100.00	0.00
19	32,491 - 34,295	0	22280	100.00	0.00
20	34,296 - 36,100	1	22281	100.00	0.00



Microsoft Excel - Flow Duration DL Example

LOG CYCLE INTERVALS

	CLASS BOUNDARIES	NUMBER OF DAYS IN EACH CLASS	CUMULATIVE NUMBER OF DAYS	PERCENT OF TIME FLOW IS NOT EXCEEDED (%)	PERCENT OF TIME FLOW IS EQUALED OR EXCEEDED (%) (100-% NOT EXCEEDED)
4	10 - 14	0	0	0.00	100.00
5	15 - 19	0	0	0.00	100.00
6	20 - 29	0	0	0.00	100.00
7	30 - 39	0	0	0.00	100.00
8	40 - 49	2	2	0.01	99.99
9	50 - 69	461	463	2.09	97.92
10	70 - 99	1828	2291	10.28	89.72
11	100 - 149	2574	4865	21.83	78.17
12	150 - 199	1318	6183	27.75	72.25
13	200 - 299	1743	7926	35.57	64.43
14	300 - 399	1166	9092	40.81	59.19
15	400 - 499	895	9987	44.82	55.18
16	500 - 699	1529	11516	51.69	48.31
17	700 - 999	1828	13344	59.89	40.11
18	1,000 - 1,499	2338	15682	70.38	29.62
19	1,500 - 1,999	1558	17240	77.38	22.62
20	2,000 - 2,999	1915	19155	85.97	14.03
21	3,000 - 3,999	1011	20166	90.51	9.49
22	4,000 - 4,999	646	20812	93.41	6.59
23	5,000 - 6,999	725	21537	96.66	3.34
24	7,000 - 9,999	412	21949	98.51	1.49
25	10,000 - 14,999	237	22186	99.57	0.43
26	15,000 - 19,999	66	22252	99.87	0.13
27	20,000 - 29,999	26	22278	99.99	0.01
28	30,000 - 39,999	3	22281	100.00	0.00

Step 8: Finally the diagram is turned so that discharge is given on the vertical axis and Exceedence Frequency is given on the horizontal axis.