Estimating Flood Frequency

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Introduction

Flood frequency is the concept of the probable frequency of occurrence of a given flood. For the design of engineering works, for example, it is not sufficient to say that the maximum observed flood was, say, 900 m^3/s; it is also necessary to say what is the frequency of occurrence of this flood.

If the 900 m^3/s flood referred to above is a size that occurs on average once in every 10 years, then for instance any bridge designed to cope with this would be under-designed by most sensible standards, and we could expect that it might not last very long. Normally the design problem is an economic one, involving the capital and on-going costs of a conservatively large structure versus the greater risk of loss of a smaller and cheaper one.

As well as engineering works like bridges, dams, etc, flood frequency information is commonly applied to controlling land use and settlement on flood-prone areas, and has many other applications.

There are several ways of describing flood frequency, all using statistical probability.

1. Assigning *return periods* to particular floods was traditionally used, but is an unhelpful term when trying to explain its meaning to the public and others. An example of a return period is when a flood has a 1 % probability of occurring in a given year (i.e. 1 chance in 100) and is thus described as a 100-year flood event. This term suggests the common but mistaken notion that there should be an interval of 100 years between such events. In fact, the probability of having two 100-year floods within 10 years is almost 10 %.
2. The *annual exceedence probability* (AEP) is also used. This is simply the probability that a particular flood size will occur in any given year. As for the example above, the 100-year flood will have an AEP of 1 % (or 1 chance in 100). Explaining the probability to the public in this way is usually better.
3. The *probable maximum flood* (PMF) concept is sometimes used for engineering applications. Again, this is similar to the above two methods, and often uses the 100-year / 1 % probability, as many designs are based on this. However PMF also implies a lower probability than 1 %, and values as low as 0.1 % will be used for some applications. Trying to derive a PMF is usually very risky unless there is a very long record.

For the purposes of this exercise we will use return period, but also use annual exceedance probability, as this is the reciprocal of return period and the two terms are thus simple to relate.

Method

1. Obtain a list of annual maximum flood flows for the site. Note that these must be instantaneous values, i.e. not any sort of mean flow.
2. Rank them from largest to smallest
3. For each one, calculate the recurrence interval (T) according to the Gringorten plotting position formula:

$$T = \frac{n + 0.12}{m - 0.44}$$

where: T = recurrence interval
n = total number of years of record used
m = magnitude or rank

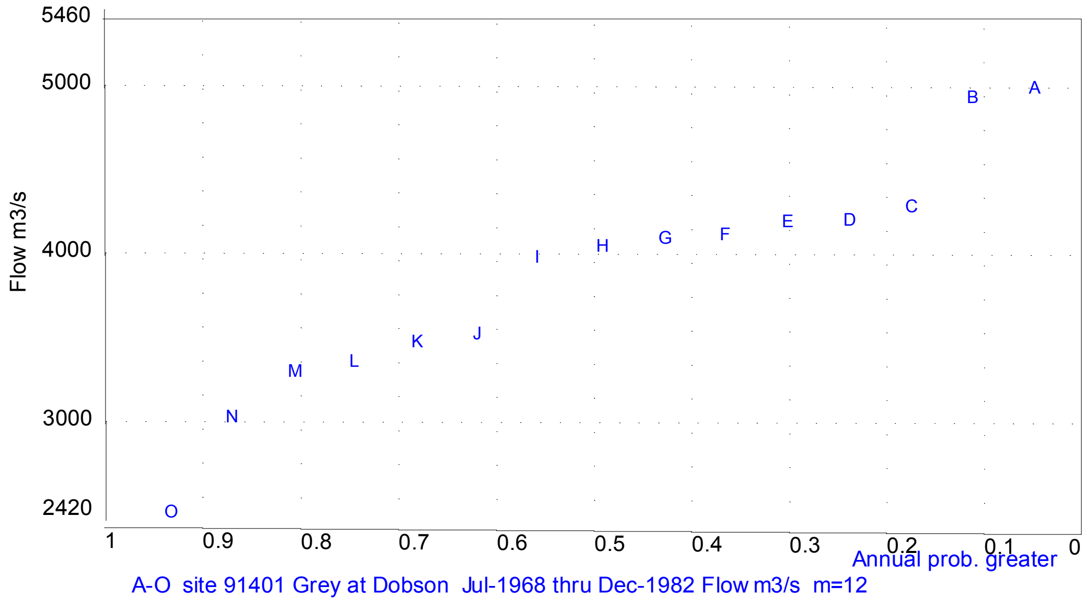
4. Plot T vs. flood size (m^3/s) on Gumbel Probability graph paper.
5. Fit a straight line by eye to the data. Disregard the largest flood or two if these deviate from the line more than the smaller floods.
6. To estimate the flood frequency of a particular flood, go from the flood size across the graph to the line, then drop down to the recurrence interval ordinate to read the return period.
7. Calculate the reciprocal of the return period (1/return period) to get the annual exceedance probability.

Example: Grey at Dobson 1968 to 1983

Year	Peak discharge m^3/s	Magnitude (rank) m	Recurrence interval (years) T
1970	4825	1	27
1977	4772	2	9.7
1969	4159	3	5.8
1972	4081	4	4.2
1975	4074	5	3.3
1980	3996	6	2.7
1973	3978	7	2.3
1979	3958	8	2.0
1982	3940	9	1.76
1974	3731	10	1.55
1968	3639	11	1.43
1976	3430	12	1.31
1981	3427	13	1.20
1978	3274	14	1.11
1971	2420	15	1.038

From the graph, the size of flood with a return period of 100 years or an annual exceedence probability of 1 % is 7634 m^3/s.

XF Plot 1968 to 1982

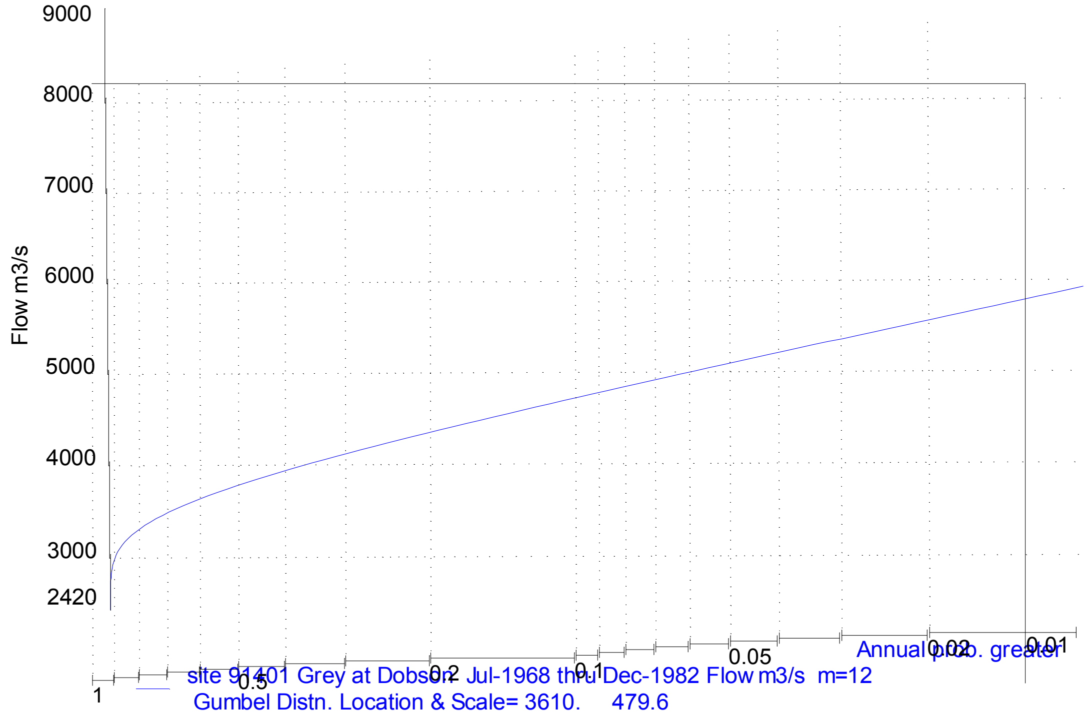


XF Table 1968 to 1982

Site 91401 Grey at Dobson
From 24-Jul-1968 11:45:00 to 31-Dec-1982 24:00:00
Data selected from months July to June inclusive

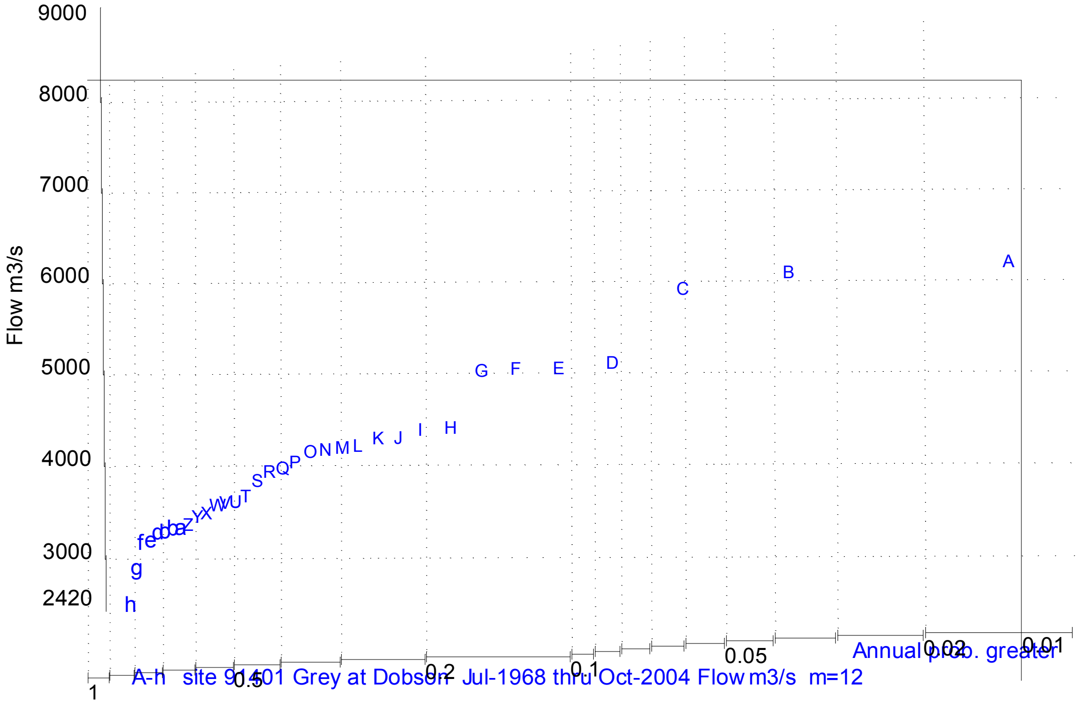
12 mth Partition starts yyyymm	Recorded Value at yyyymmdd:hhmmss	maximum measured Flow m3/s		(Alpha=0.440) ann. Prob. 1/y	ret. per y
197007	19700831:131900	4899.1	A	0.037	27
197607	19770119:030000	4841.4	B	0.103	10
196807	19690413:155500	4203.1	C	0.169	6
197207	19721008:023000	4125.6	D	0.235	4
197407	19750402:071003	4117.8	E	0.302	3
197907	19800124:234500	4039.7	F	0.368	3
197307	19731121:202736	4021.6	G	0.434	2
198107	19820123:064500	3975.2	H	0.500	2
197807	19790506:211500	3908.5	I	0.566	2
197507	19760715:211500	3463.4	J	0.632	2
198007	19800826:200046	3417.5	K	0.698	1
197707	19780328:211102	3302.9	L	0.765	1
198207	19821225:211500	3242.6	M	0.831	1
196907	19690908:065936	2977.6	N	0.897	1
197107	19711003:202600	2420.5	O	0.963	1
	Mean =	3797.1			

FRED Plot 1968 to 1982



FRED Plot -1968 to 2004

XF plot -1968 to 2004



XF Table -1968 to 2004

~~~ NIWA Tideda ~~~ SunWater Demo 17-APR-2005 09:32
~~~ XFPLOT ~~~
Reading data from C:\Program Files\NIWA\Tideda\Working\EVENTS.DAT
(Source file is C:\aaJF\US visit 2004\Tideda Info\Tid Data\Gym.mtd)
Site 91401 Grey at Dobson
From 24-Jul-1968 11:45:00 to 12-Oct-2004 13:30:00
Data selected from months January to December inclusive

12 mth Partition starts yyyymm	Recorded Value at yyyymmdd:hhmmss	maximum measured Flow m3/s		(Alpha=0.440) ann. Prob. 1/y	ret. per y
199701	19971216:120000	5950.8	A	0.015	66
198801	19880913:150000	5840.4	B	0.042	24
199801	19981019:221500	5670.0	C	0.069	14
197001	19700831:131900	4899.1	D	0.096	10
199401	19940105:023000	4844.5	E	0.123	8
197701	19770119:030000	4841.4	F	0.150	7
198401	19841123:204500	4814.3	G	0.177	6
198301	19830710:031500	4228.2	H	0.204	5
196901	19690413:155500	4203.1	I	0.231	4
197201	19721008:023000	4125.6	J	0.258	4
197501	19750402:071003	4117.8	K	0.284	4
198001	19800124:234500	4039.7	L	0.311	3
197301	19731121:202736	4021.6	M	0.338	3
197901	19791203:114301	4000.9	N	0.365	3
198201	19820123:064500	3975.2	O	0.392	3
199601	19961013:161500	3866.7	P	0.419	2
200001	20001228:150000	3809.5	Q	0.446	2
197401	19740414:210000	3771.7	R	0.473	2
196801	19681030:050800	3678.0	S	0.500	2
200201	20020618:033000	3517.4	T	0.527	2
197601	19760715:211500	3463.4	U	0.554	2
198101	19810920:143000	3448.9	V	0.581	2
199301	19930613:170000	3422.3	W	0.608	2
200101	20011207:050000	3342.7	X	0.635	2
197801	19780328:211102	3302.9	Y	0.662	2
200401	20040109:180000	3224.1	Z	0.689	1
200301	20030701:031500	3221.9	a	0.716	1
198901	19891215:222541	3217.7	b	0.742	1
199501	19950926:094500	3185.8	c	0.769	1
199201	19920809:113000	3177.6	d	0.796	1
199101	19910817:114500	3091.2	e	0.823	1
199901	19991006:200000	3070.0	f	0.850	1
199001	19900726:170000	2806.8	g	0.877	1
197101	19711003:202600	2420.5	h	0.904	1
198701	19870118:130000	2385.4	i	0.931	1
198601	19860406:163000	2364.9	j	0.958	1
198501	19850718:150000	1794.8	k	0.985	1
	Mean =	3761.0			

FRED Table -1968 to 2004

Site 91401 Grey at Dobson

From 24-Jul-1968 11:45:00 to 12-Oct-2004 13:30:00

Moments L1= 3761.0 L2= 526.5 T3= 0.104 T4= 0.187

L-moments estimates of distributions's parameters:

Location = 3322.5 Scale = 759.6 100yr/2.33yr = 1.812

Data selected from months January to December inclusive

12 mth partition starts yyyymm	Recorded value at yyyymmdd:hhmmss	maximum measured Flow m3/s		-- Gumbel Distribution -- Flow m3/s	1.96 std. dev.	ann. prob. 1/y	ret. per. y
				8569.2	1494.9	0.001	1000
				6816.7	994.1	0.010	100
				6286.4	845.1	0.020	50
199701	19971216:120000	5950.8	A	5950.8	752.1	0.031	32
198801	19880913:150000	5840.4	B	5840.4	721.8	0.036	28
199801	19981019:221500	5670.0	C	5670.0	675.4	0.044	22
				5578.6	650.7	0.050	20
				5031.9	507.3	0.100	10
197001	19700831:131900	4899.1	D	4899.1	474.0	0.118	8
199401	19940105:023000	4844.5	E	4844.5	460.6	0.126	8
197701	19770119:030000	4841.4	F	4841.4	459.8	0.127	8
198401	19841123:204500	4814.3	G	4814.3	453.2	0.131	8
				4461.9	372.1	0.200	5
198301	19830710:031500	4228.2	H	4228.2	325.2	0.262	4
196901	19690413:155500	4203.1	I	4203.1	320.6	0.269	4
197201	19721008:023000	4125.6	J	4125.6	307.1	0.293	3
197501	19750402:071003	4117.8	K	4117.8	305.8	0.296	3
198001	19800124:234500	4039.7	L	4039.7	293.5	0.322	3
197301	19731121:202736	4021.6	M	4021.6	290.8	0.329	3
197901	19791203:114301	4000.9	N	4000.9	287.9	0.336	3
198201	19820123:064500	3975.2	O	3975.2	284.3	0.345	3
199601	19961013:161500	3866.7	P	3866.7	271.1	0.386	3
200001	20001228:150000	3809.5	Q	3809.5	265.4	0.409	2
197401	19740414:210000	3771.7	R	3771.7	262.1	0.425	2
				3761.0	261.3	0.430	2.33
196801	19681030:050800	3678.0	S	3678.0	256.0	0.465	2
200201	20020618:033000	3517.4	T	3517.4	252.0	0.539	2
197601	19760715:211500	3463.4	U	3463.4	252.7	0.564	2
198101	19810920:143000	3448.9	V	3448.9	253.0	0.571	2
199301	19930613:170000	3422.3	W	3422.3	253.8	0.584	2
200101	20011207:050000	3342.7	X	3342.7	257.6	0.622	2
197801	19780328:211102	3302.9	Y	3302.9	260.2	0.642	2
200401	20040109:180000	3224.1	Z	3224.1	266.9	0.680	1
200301	20030701:031500	3221.9	a	3221.9	267.1	0.681	1
198901	19891215:222541	3217.7	b	3217.7	267.5	0.683	1
199501	19950926:094500	3185.8	c	3185.8	270.8	0.698	1
199201	19920809:113000	3177.6	d	3177.6	271.7	0.702	1
199101	19910817:114500	3091.2	e	3091.2	282.1	0.742	1
199901	19991006:200000	3070.0	f	3070.0	284.9	0.752	1
199001	19900726:170000	2806.8	g	2806.8	327.9	0.861	1
197101	19711003:202600	2420.5	h	2420.5	409.3	0.962	1
198701	19870118:130000	2385.4	i	2385.4	417.5	0.968	1
198601	19860406:163000	2364.9	j	2364.9	422.3	0.971	1
198501	19850718:150000	1794.8	k	1794.8	564.7	0.999	1
	Mean =	3761.0					

End of process