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Graphics Advances Aid Flood Engineers

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Abstract: In the last decade options[2] have been suggested to the Log-Pearson III (LP3) computation for predicting design flood behavior in semi-arid conditions. Observations from an ongoing study of seven watersheds are presented. Areas ranged from 25 to 3,200 sq. mi., with record lengths from 40 through 73 years. Computer graphics on log-normal (LN), extreme value (EV), and log-extreme value (LEV), along with mathematical estimates for 10- and 100-year floods, are presented. Differences between the behavior of the largest 1/5 of annual floods, from more frequent annual maxima, are illustrated.

Background: During the 1940's and 1950's many agencies concerned with 100-year flood predictions (Q100) were using Gumbel's National Bureau of Standards, and Columbia University work. Gumbel's application on the EV distribution appeared in hydrology texts and was used by the USGS, Bureau of Reclamation, Bureau of Public Roads, and others. Even today, the National Weather Service uses EV as its probability model for estimating storm rainfall which can produce Q100. In 1967 the Water Resources Council (WRC), under pressure from the Bureau of the Budget, recommended in Bulletin 15 that the 1924 Log-Pearson III (LP3) statistical analysis be used. This technique normally forces convex or concave statistical curves through data which plot into very different patterns. We used the method of moments described in Bulletin 15 for our calculations.

It may be that LP3 is particularly unsuitable in semi-arid regions because annual floods contain many low maximum flows, which can cause strongly negative coefficients of skewness of the logs (CSL). CSL also varies greatly between closely spaced stream gages. This makes the WRC Bulletin CSL map of questionable value. Some flood experts can fine-tune regional and weighted CSL's to produce reasonable Q100's from LP3. In all cases, the fitted curve and annual maxima should be plotted by Cunnane's compromise formula.

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[2] Space does not permit a bibliography. Some references are located in "Linearizing Large Flood-peaks on Small Arid Watershed," by these authors and F.A. Lopez in the ASCE 1990 National Conference on Hydraulic Engineering.

Unfortunately, novices may rely on simple numerical computer output. Busy engineers may be called upon to speedily determine the return period of an oversized flood. Immediately following a flood disaster, local flood agencies may need to estimate the event return period. If a local agency has a personal computer database, appropriate software, and trained personnel, estimates can be completed within a few days. This paper shows how much variation can be expected after executing different numerical computations for semi-arid watersheds. New computer graphics programs offer an opportunity to appreciate Q100 variation in semi-arid regions. The authors wish to thank Gert Aron and Dard de Roulhac for providing the computational and graphics programs, respectively, and F.A. Lopez for modifying them.

Relative Consistency Among Four Statistical Models: Table 1 was generated by dividing each 10-year flood estimate (Q10) by Q10 obtained from LP3, using station skew. In this way LP3 was always assigned an arbitrary 1. LN, EV, and LEV can readily be compared to LP3 and each other as ratios. The ratios do not vary much across the seven watersheds, but do increase systematically from LP3, to LN, to LEV, to EV as shown at the bottom of Table 1. Big floods are seldom measured within this accuracy.

Table 1. Relative size of Q10's from three methods, expressed as ratios to LP3 estimate.

Watershed	Square Miles	Years	LN	EV	LEV	Aver.
Sabino Creek, Tucson, AZ	25.5	57	1.06	1.05	1.14	1.08
Santa Cruz River, Lochiel, AZ	82.2	40	1.52	1.35	1.67	1.54
Eagle Creek, Morenci, AZ	613	45	1.01	1.16	1.09	1.09
Rillito Creek, Tucson, AZ	918	68	1.00	1.11	1.05	1.05
San Pedro River, Charleston, AZ	1,219	78	0.97	1.40	1.01	1.13
Santa Cruz River, Continental, AZ	1,662	45	1.01	1.23	1.11	1.12
Gila River, Virden, NM	3,203	62	0.98	1.30	1.01	1.10
Average			1.0	1.23	1.15	

The last column shows the averages of LN, EV, and LEV Q10's on each river are 5, 8, 9, 10, 12, 13, and 54% greater than the LP3's. This is another indication that LP3 under predicts even 10-year floods. There is insufficient evidence to determine whether LN, EV, and LEV, are sensitive to watershed size.

"Increases" in Flood Estimates with Watershed Size: Engineers are interested in how Q10 and Q100 estimates change with watershed size. Our sample is too small to aid them with such relationships. Some appreciation for the unusual properties of semi-arid desert flood series can be gained by discussing the specimen computations.

Table 2 summarizes results from computational fitting of LN, EV, LEV, and LP3. Q10's for the 1,662 and 3,203 sq. mi. watersheds are smaller than Q10 from 918 or 1,219 sq. mi. This phenomena is related to channel losses and/or areal distribution of storm rainfall in semi-arid areas. Whereas Q10's from all four models increased from 35 through 600 sq. mi., a general decrease occurred as drainage areas increased towards 3,000 sq. mi., particularly for Q100.

Table 2. Computational estimates, in cfs, from four statistical models.

Watershed	Drainage Area Sq. Mi.	Computer Q10 cfs				Computer Q100 cfs			
		LN	EV	LEV	LP3	LN	EV	LEV	LP3
Sabino Creek, Tucson, AZ	25.5	4,262	4,170	4,582	4,029	13,439	7,580	36,381	9,693
Santa Cruz River, Lochiel, AZ	82.2	6,540	5,807	7,218	4,315	23,718	10,734	75,278	5,141
Eagle Creek, Morenci, AZ	613	12,703	14,537	13,895	12,522	44,441	27,581	134,757	40,715
Rillito Creek, Tucson, AZ	918	14,927	16,640	15,694	14,927	35,648	29,848	75,067	35,648
San Pedro River, Charleston, AZ	1,219	17,169	25,590	17,880	17,792	35,590	48,118	66,188	50,388
Santa Cruz River, Continental, AZ	1,662	14,444	17,504	15,544	14,275	40,282	32,742	99,924	37,494
Gila River, Virden, NM	3,203	16,143	21,299	17,057	16,413	40,169	39,915	88,102	45,631

Instability Grows for Q100 Estimates: Examination of table 3 is one way of appreciating the variability between LN, EV, LEV, and LP3 in the case of Q100. For each river the first three estimates were divided by the corresponding LP3. These ratios, like 1.39, 0.78, and 3.75 in table 3, give an indication of how three well known statistical determinations compare with each other and LP3. More sophisticated examinations could be used if a full-scale investigation was undertaken. The case of the Gila River, on the last line of table 3, shows simply that LEV's Q100 was virtually twice that of LP3. LN and EV were slightly smaller, which may persuade some analysts to use them. Others may question using LEV, though theoretical reasons exist why LEV may give oversized Q100 estimates.

Table 3. Ratios of Q100 to Station-LP3 for three models.

Watershed	LN	EV	LEV	Average
Sabino Creek, Tucson, AZ	1.39	0.78	3.75	2.0
Santa Cruz River, Lochiel, AZ	4.61	2.09	14.64	7.1
Eagle Creek, Morenci, AZ	1.09	0.68	3.31	1.7
Rillito Creek, Tucson, AZ	1.00	0.84	2.11	1.3
San Pedro River, Charleston, AZ	0.70	0.95	1.31	1.0
Santa Cruz River, Continental, AZ	1.07	0.87	2.67	1.5
Gila River, Virden, NM	0.88	0.87	1.93	1.2
Average, excluding Santa Cruz River, Lochiel, AZ	1.02	0.83	2.51	

The Santa Cruz at Lochiel gave anomalous scatter between the four models, which require further study. Values listed in these tables should not be used in estimating the best Q100. The authors would appreciate correspondence from practitioners with established rules-of-thumb relating Q100 to Q10 in similar regions. Our tentative average for six rivers suggest that LN and LP3 produce similar Q100's. EV estimates may be 15% smaller; LEV averages about 2.5 times EV's value. Another approach taken was to express Q100 as a multiple of Q10. Such Q100/Q10 for our seven watersheds were 1.78, 1.64, 1.90, 1.99, 1.88, 1.87, and 1.87, respectively, which averaged 1.85 for EV.

Searching Alignment of Large Observed Flood Series: Recently, the difficult task of estimating Q500 was mandated for flood plain administrators. We estimated Q500 for our watersheds; table 4 summarizes the results in the form of two multipliers. The first Q100/Q10 could bring a user from the relatively stable Q10 to a less stable Q100. Q500 averages 1.6 times Q100. The last column shows how variable the overall ratio to estimate Q500/Q10 really is. Over or underestimating Q500 can have serious societal consequences.

Table 4. Q100/Q10 and Q500/Q100 for some Arizona watershed LP3s.

Watershed	Q100/Q10	Q500/Q100	Q500/Q10
Sabino Creek, Tucson, AZ	2.41	1.50	3.6
Santa Cruz River, Lochiel, AZ	1.19	1.02	1.2
Eagle Creek, Morenci, AZ	3.25	1.83	6.0
Rillito Creek, Tucson, AZ	2.39	1.58	3.8
San Pedro River, Charleston, AZ	2.83	1.88	5.3
Santa Cruz River, Continental, AZ	2.63	1.64	4.3
Gila River, Virden, NM	2.78	1.76	4.9

Attention to the Plotted Largest Observations: Improved understanding of how larger floods can behave will come by integrating patterns in observed flood plots with statistical analyses. In arid areas, a 70-year record may only contain 5 or 10 items involving the same runoff processes that operate during design floods. Figure 1 shows two rivers with 40- and 45-year records. In both cases, the mathematically fitted line (shown as the solid line) did not represent the trend of the larger quarter data points. In one case, this computed line passes significantly below the three largest points which, together with the next three, are closely fitted by an eye-fitted straight line (shown as a dashed line). Q100 changes from 27,600 cfs computed to 75,000 cfs eye-fitted. In another watershed the computed Q100 changed from LN 23,720 cfs to an eye-fitted LN of 13,000 cfs.

Dashed lines were drawn through the linear configurations of big floods. We consider eye-fitted lines give far better estimates of Q10, Q100, and Q500 than can be done by statistical fitting for these examples.

Figure 2 shows that all seven watersheds display separation and misalignments of large floods. In the Santa Cruz at Lochiel case, the influence of different plotting paper was also shown.

Summary: Computations from four recognized statistical models can produce somewhat similar Q10's for semi-arid regions. LP3 answers are smaller than LN, EV, or LEV. In the case of Q100, three or four statistical distributions should be computed and, more importantly, graphical examination should be added to show variation, along with consideration of individual flood incidents, physical runoff properties, and partial-duration series.

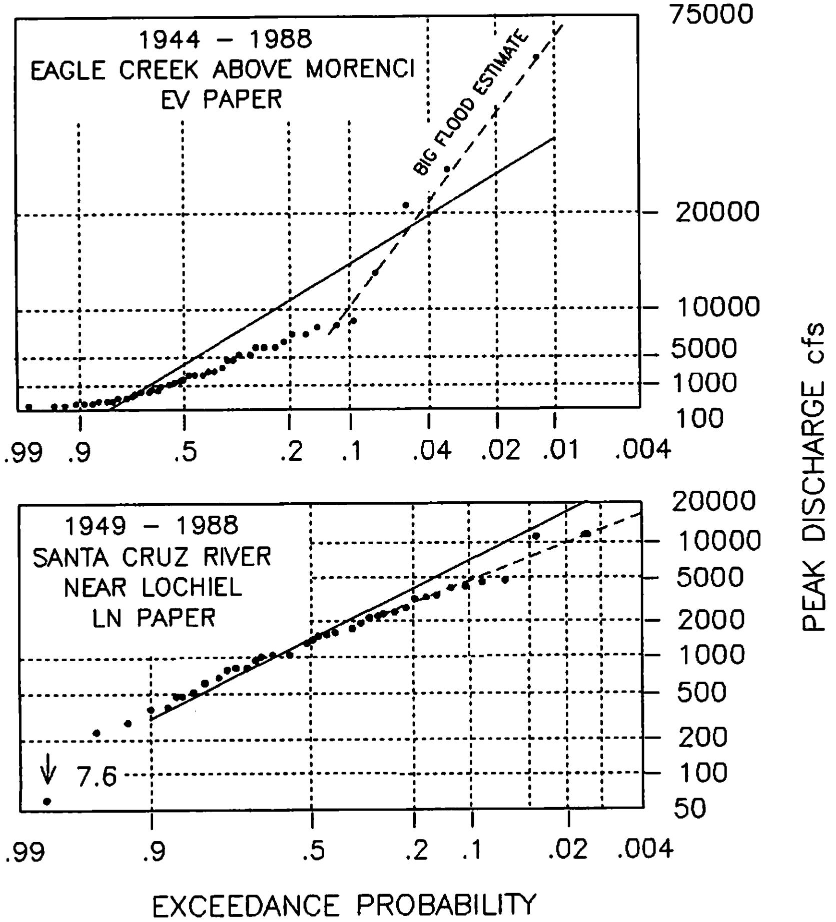

Figure 1. Two Arizona examples where the alignment of the larger events were overlooked by computations of total annual series.

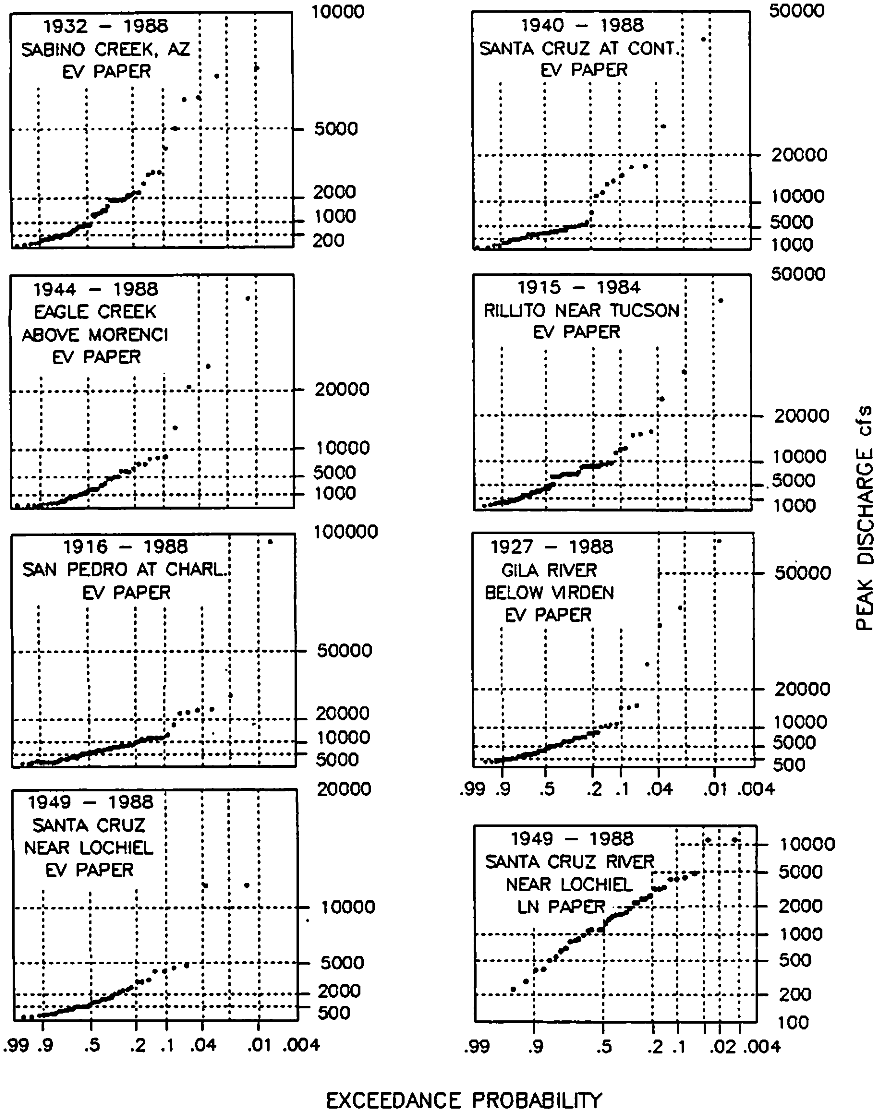

Figure 2. Long series on seven Arizona Watersheds displaying different orientations of large floods than do the more numerous non-flood annual maxima.