REGIONAL FLOOD FREQUENCY ANALYSIS FOR SMALL NEW ZEALAND BASINS
2. FLOOD FREQUENCY GROUPS

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ABSTRACT

One hundred and seventeen small New Zealand drainage basins with areas of less than 100 square kilometres were used for a regional flood frequency study. Each basin had annual maximum flood peak series of length 10 or more years. L-moment statistics of the flood series and basin physical characteristics were used to classify the basins into six non-geographic flood frequency groups. Dimensionless flood frequency growth curves for each group offer robust alternatives to geographical regionalisation and flood contour maps.

INTRODUCTION

Floods are arguably the most common and devastating natural catastrophes (Wallis, 1988). Reliable flood frequency information is required for developments near rivers and streams as part of their design and protection. Small drainage basins rarely have water-level records and engineers must rely on regional flood-frequency methods to estimate flood exceedance probabilities.

A review of regional flood frequency in New Zealand was conducted between 1987 and 1989 (McKerchar and Pearson, 1989, 1990), and a design procedure for estimating flood peak quantiles for ungauged drainage basins was developed during this review. The procedure prescribes the 2-parameter extreme value type 1 (EV1) distribution for annual maximum flood peaks, in conjunction with contour maps of two flood statistics, which enable flood quantile estimates to be derived for any basin, gauged or ungauged, in New Zealand. This approach is a form of index flood procedure: one map provides mean annual flood estimates (Q_m, "index flood") and the other provides dimensionless 1/100 annual exceedance probability (AEP) flood estimates (Q_{100}/Q_m). (AEP = 1/T, where T is return period in years).

For drainage basins with areas less than 10 square kilometres the design procedure is less precise. This reflects the predominance of larger catchments with longer annual maximum flood series, with more spatially averaged hydrological response masking out the individuality of smaller basins with shorter series; and the larger variability in stage-discharge rating curve extrapolation associated with smaller basins.

In this paper robust regional flood frequency estimation procedures developed by Wallis (1980, 1988) are applied to small basins to derive dimensionless flood frequency growth curves for groupings of physically similar small basins. The 5-parameter Wakeby distribution fitted by L-moments or probability-weighted moments is a robust, accurate and efficient regional flood frequency procedure for *homogeneous* groupings of catchments, (Kuczera, 1982; Hosking *et al.*, 1985; Wallis and Wood, 1985; Cunnane, 1989). These qualities of Wallis' (1980) regional flood frequency procedure are preserved even when there is significant correlation present amongst annual series of a region's drainage basins (Hosking and Wallis, 1988) or when the region is heterogeneous (Lettenmaier *et al.*, 1987). Hosking and Wallis (1991) have developed statistical tests based on L-moments to investigate the homogeneity of a given group of drainage basins. These tests, based on the L-moment ratios L-CV, L-skewness and L-kurtosis, may be used to monitor the homogeneity of selected groups.

The initial problem is to choose candidate homogeneous groups of basins. Traditionally regional groupings have been used (e.g. Natural Environment Research Council, 1975; Beable and McKerchar, 1982). Acreman and Wiltshire (1989) review all approaches, including the use of groups of physically similar basins not necessarily in the same geographic regions. Homogeneous groupings of small basins are sought in this paper using a method proposed by Wiltshire (1985) which monitors the effect on flood frequency of splitting basins into physically similar groupings. Wiltshire's method is advanced by using L-moments (Hosking, 1990) of flood series to monitor the flood frequency behaviour. L-moments have been shown to be reliable statistics for discerning differences and confirming similarities in flood frequency groupings and regions (Wallis, 1988, 1989; Hosking, 1990; Hosking and Wallis, 1990; Chowdhury *et al.*, 1991; Pearson, this issue).

METHOD

Wiltshire (1985) groups basins first by splitting a set of basins into two groups using a single partitioning value of a physical characteristic, for example, into wet and dry basin groups on the basis of average rainfall. Measures of flood frequency variability are then derived for each group, and aggregated into one measure, corresponding to the group partitioning value. (Wiltshire used four flood frequency variability measures based on fitting the generalised extreme value (GEV) distribution to each group.) This procedure is repeated using a range of partition values. The optimum grouping is achieved at the basin characteristic value where the group variability statistic for flood frequency is minimum. This process can be repeated with other basin characteristics, and for multiple partitions of the basins.

This study used 117 small New Zealand basins (i.e. area less than 100 km^2), each with n = 10 or more years of annual maximum flood peaks (see Appendix). The longest annual series has 29 flood peaks. (This flood-set is the subset of McKerchar's (this issue) set of basins with 10 or more years of record.)

Basin characteristics investigated were basin area (A), and areally averaged rainfall, soil, hydrogeology and slope statistics. The rainfall statistic (I_{24}) is the 24-hour rainfall total of 5-year return period (20% annual exceedance probability (AEP) event) derived from Tomlinson's (1980) maps. I_{24} ranges from 45 mm to 440 mm for the small basins used in this study. The soil property is depth-weighted-macro-porosity (DWP) estimated from soil survey information by M. J. Duncan (pers. comm., 1991): it ranges from 1% for impermeable basins to 29% for porous basins. The hydrogeology index (H) was developed by Hutchinson (1990) using a national land resources inventory. H ranges from 1 for low to 8 for high bedrock infiltration capacity and transmissibility. A slope measure (S) used by Hutchinson (1990) was also used. It is the areally-weighted mean slope extracted from the national land resources inventory and ranges from 2° to 35° for basins in this study. More detailed information on these basin characteristics is given in McKerchar (this issue).

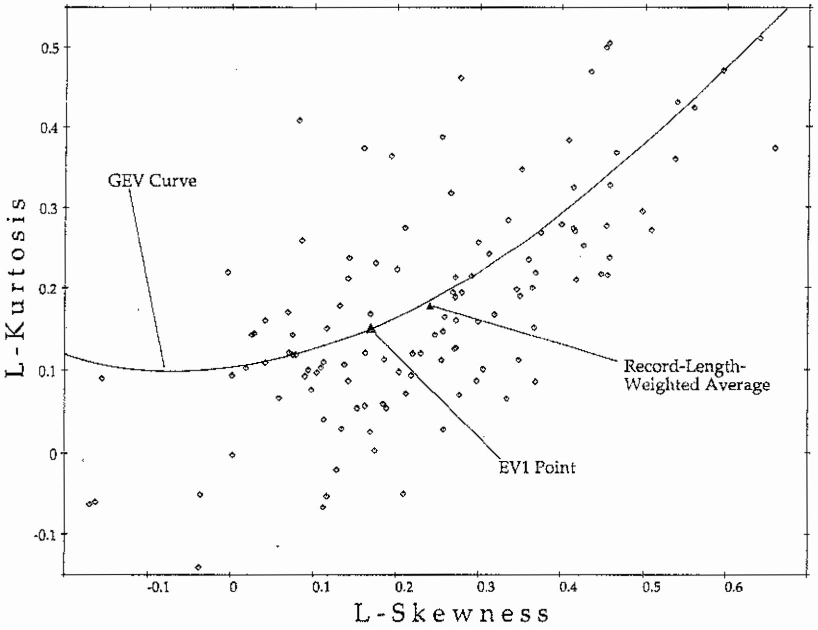

FIG. 1—L-kurtosis and L-skewness for 117 small New Zealand basins. The GEV distribution curve to the left of the EV1 point is EV3, and to the right of the EV1 point is EV2.

The flood frequency variability measure proposed in this paper for use in Wiltshire's basin grouping procedure is based on L-moments of annual maximum flood peak data. This avoids fitting a statistical distribution to the flood data (at this stage) and takes advantage of the superior properties of L-moments (Hosking, 1990). The L-skewness–L-kurtosis plane serves as a useful tool for discerning heterogeneous regions (Wallis, 1988, 1989) and is the basis of the flood frequency variability measure required for basin grouping. L-skewness and L-kurtosis are the L-moment ratios λ_3/λ_2 and λ_4/λ_2 respectively, where λ_r is the r-th population L-moment (see Hosking, 1990, for definitions). λ_1 is the mean and λ_2 is a measure of scale.

Unbiased estimators (l_r) of λ_r, that are linear combinations of the flood data, are used in this paper (Hosking, 1990; Pearson, this issue). Figure 1 shows estimates (l_3/l_2, l_4/l_2) of L-skewness and L-kurtosis for the 117 small New Zealand drainage basins. Also shown is the record-length-weighted average ($[l_3/l_2]^*$, $[l_4/l_2]^*$) = (0.242, 0.178). L-moments and L-moment ratio estimates for each basin are given in the Appendix.

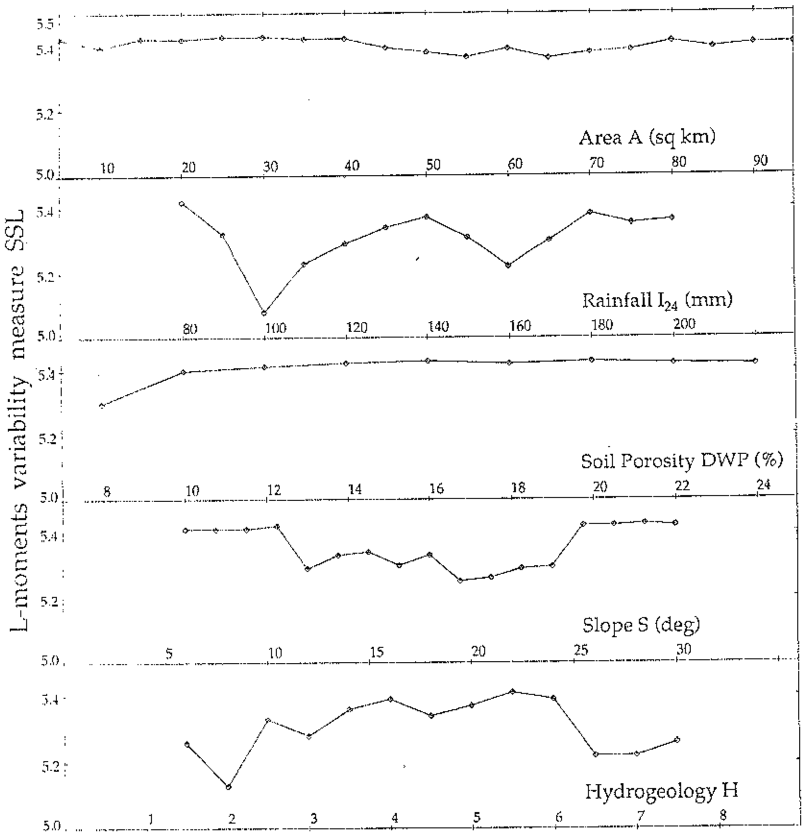

FIG. 2—Variation in L-moment variability measure SSL as the partition point for two-way grouping changes for basin characteristics A, I_{24}, DWP, S and H.

The proposed measure of flood frequency variability for basin groupings is the overall sum of squares of deviations of individual basin L-moment ratio estimates (l_3/l_2, l_4/l_2) from their group record-length-weighted average points,

$$SSL = \sum_{j=1}^{m} \sum_{i=1}^{n_j} ([l_3/l_2]_{i,j} - [l_3/l_2]^*_j)^2 + ([l_4/l_2]_{i,j} - [l_4/l_2]^*_j)^2$$

where there are m groups, each comprising n_j basins with group record-length-weighted averages $[l_3/l_2]^*_j$ and $[l_4/l_2]^*_j$. SSL is the summation over all groups of squared Euclidean distances between individual points and group averages in the L-skewness–L-kurtosis plane. SSL is similar to Hosking and Wallis' (1991) V_3 statistic (based on L-skewness and L-kurtosis) for testing homogenity of given groups of basins. Their other two statistics for this purpose are V_1 (based on L-CV = l_2/l_1 alone) and V_2 (based on L-CV and L-skewness). These three test statistics each indicate that the group of 117 small New Zealand drainage basins is heterogeneous, with an average tendency toward an EV2 distribution (as shown in Figure 1), with shape parameter k = -0.11 (upward curvature on an EV1 plot).

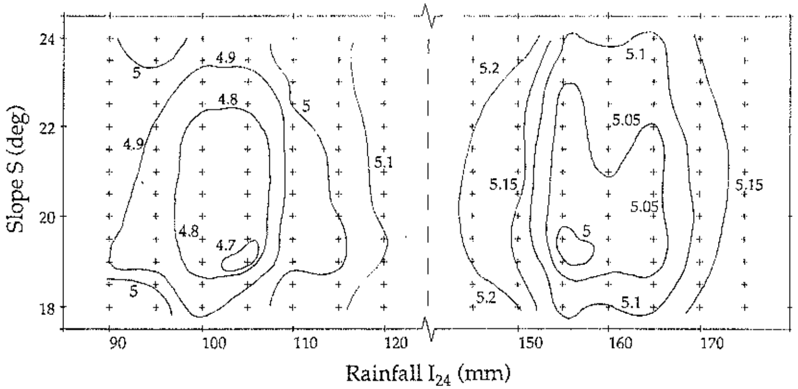

FIG. 3—Surface of L-moment variability measure SSL in the I_{24}–S plane, for four-way flood frequency groupings.

FLOOD FREQUENCY GROUPS

Figure 2 shows the change in value of the L-moment test statistic SSL as the partitioning points for two groups on the A, I_{24}, DWP, H and S basin characteristic axes are each varied. Minima in the trace of SSL occur at 100 mm and 160 mm for rainfall I_{24}, indicating that 2 partitioning points or 3 groups might be required for I_{24}. Slope S and hydrogeology H exhibit SSL traces with well-defined minima, at S = 19.5° and H = 2. Grouping basins according to basin area A and soil porosity DWP only slightly reduces SSL, implying that for small New Zealand basins, basin area and soil do not influence flood frequency as much as rainfall, slope and hydrogeology.

For the groups identified in the above procedure, Hosking and Wallis (1991) test statistics indicate the following:

- — the low rainfall group is nearly homogeneous and has high EV2 tendencies (k = -0.21).
- — the medium rainfall group is heteorgeneous with respect to V_1 and V_2, homogeneous for V_3, and is medium EV2 (k = -0.12).
- — the high rainfall group is heterogeneous and is low EV2 (k = -0.05), nearly EV1.
- — the low slope group is heterogeneous and is low EV2 (k = -0.07).
- — the high slope group is mainly heterogeneous (V_1 and V_2, not V_3) and is high EV2 (k = -0.15).

Following Wiltshire (1985), a further degree of sophistication can be introduced by a simultaneous four-way grouping based on two catchment characteristics. Figure 3 shows the SSL surfaces produced when the basins were divided into four groups according to rainfall I_{24} and slope S. Two distinct mimima are evident, indicating that a six-way split of the 117 basins at partitions $I_{24} = 105$ mm and 155 mm and $S = 19°$ is optimum. Table 1 defines the six groups and gives Hosking and Wallis (1991) homogeneity test statistics. Each group is homogeneous at least with respect to V_3, and so Wiltshire's (1985) method using SSL has achieved its objective.

TABLE 1—Six-way partition for flood frequency of 117 small New Zealand catchments based on rainfall I_{24}, slope S and L-moments of flood data.

Group	Definition		Number of Basins	Weighted average L-moment ratios l_3/l_2	l_4/l_2	Homogeneous V_1	V_2	V_3	EV2 k
1	$I_{24}<105$mm	S<19°	12	0.214	0.190	Y	Y	Y	-0.07
2	$I_{24}<105$mm	S≥19°	9	0.476	0.352	Y	Y	Y	-0.43
3	$105\leq I_{24}\leq 155$mm	S<19°	20	0.238	0.142	N	N	Y	-0.10
4	$105\leq I_{24}\leq 155$mm	S≥19°	29	0.260	0.204	N	Y	Y	-0.14
5	$I_{24}>155$mm	S<19°	24	0.186	0.141	N	N	Y	-0.03
6	$I_{24}>155$mm	S≤19°	23	0.214	0.150	N	Y	Y	-0.07

A flood-frequency distribution can now be fitted to each group using group L-moment ratio estimates. All groups, except group 5, require at least a three parameter distribution such as the EV2. To treat each group similarly, the 5-parameter Wakeby distribution (Wallis, 1980) is used to produce dimensionless flood frequency growth curves (Q_T/Q_m) for each of the six groups in Table 1. Using the Wakeby distribution, the 5 parameters allow the upper tail to be specified independently of the lower tail, and, in the L-kurtosis–L-skewness space (Fig. 1), group average points are not forced to move to the nearest 3-parameter distribution curve or 2-parameter distribution point. The Wakeby distribution used with L-moments is a robust procedure (Wallis and Woods 1985; Cunnane, 1989). Even though it has five parameters, the bulk of independent data used in pooling floods from different basins or regions, ensures the Wakeby distribution is sensibly fitted. The Wakeby is fitted to the six groups in Table 1 using record-length-weighted averages of group L-moments ratios λ_2/λ_1, λ_3/λ_2, λ_4/λ_2 and λ_5/λ_2, based on unbiased estimates of the λ_r (Wallis, 1980, 1988; Hosking, 1988; Hosking and Wallis, 1990).

Figure 4 shows the Wakeby distribution fitted to each group, using the Gumbel reduced variate horizontal scale for each plot, for which an EV1 distribution plots as a straight line. Wakeby plots for groups 1 to 4 (low to medium rainfall) are steep, and three exhibit upward curvature for larger discharges (EV2 tendencies), whereas for groups 5 and 6 (high rainfall) the Wakeby curves are flatter and show opposite curvature (EV3 tendencies). Also shown in Figure 4 are mean McKerchar and Pearson (1989, 1990) map Q_{100}/Q_m values for each group, with 95% confidence intervals for each mean. For the low and medium rainfall groups (1–4), the map estimates are below the Wakeby plots. Map estimates are based on the EV1 distribution (straight line on EV1 plot) whereas many of the annual maximum flood series from small drainage basins exhibit EV2 tendencies (upward curvature). This explains the difference between map and Wakeby estimates (Fig. 4) for groups 1 to 4. Straight line EV1 distributions underestimate discharges of high return period for groups 1 to 4, but are satisfactory for high rainfall groups (5 and 6).

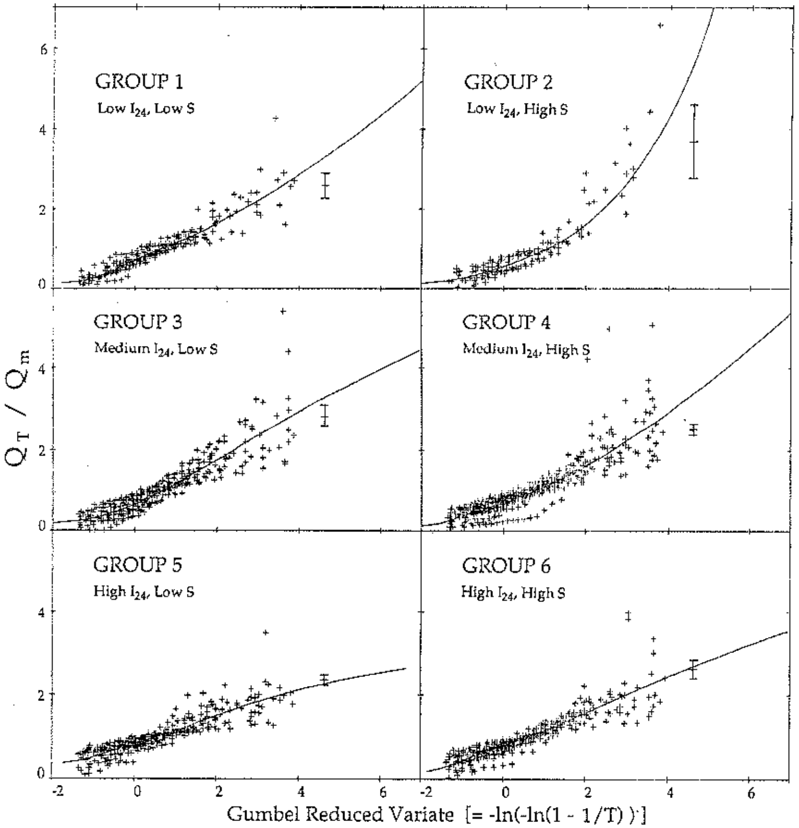

FIG. 4—Dimensionless flood frequency Wakeby distribution plots with annual flood peak data for six rainfall-slope (I_{24}–S) groups defined in Table 1. 95% confidence intervals are shown for mean McKerchar and Pearson (1989, 1990) Q_{100}/Q_m map values for each group.

Figure 5 shows the six Wakeby dimensionless flood frequency growth curves (also summarised in Table 2). The similarity of these curves for groups 1 and 4 indicates that they could be merged into one group. Patterns exist in the distribution of the growth curves. As rainfall increases the curves become flatter,

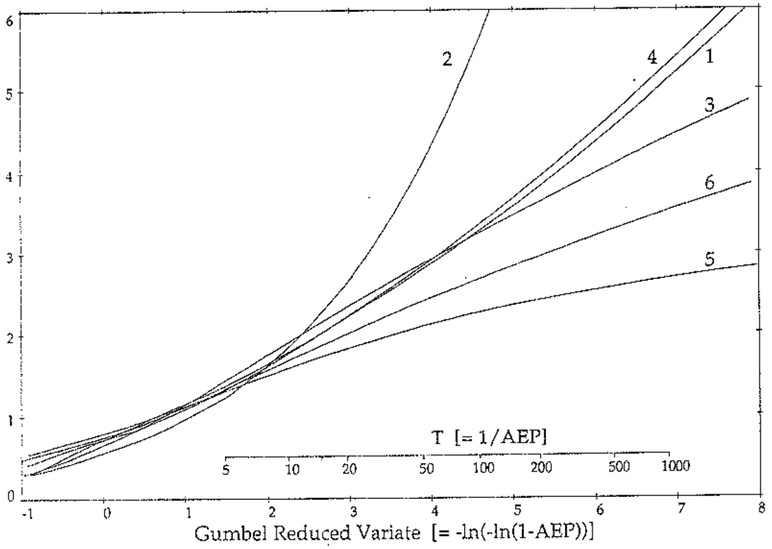

FIG. 5—Comparison of dimensionless Wakeby flood frequency curves for six rainfall-slope (I_{24}–S) groups defined in Table 1.

and for fixed rainfall, basins with higher average slopes have steeper flood frequency curves.

TABLE 2—Dimensionless flood frequency quantiles for the six flood frequency groups defined in Table 1.

Group	Average I_{24} (mm)	Average S (deg)	1/AEP (=T, years): 5	10	20	50	100	1000
1	79.4	14.2	1.38	1.78	2.20	2.80	3.28	5.13
2	86.1	26.5	1.25	1.84	2.63	4.11	5.66	15.7
3	127.5	12.0	1.45	1.90	2.33	2.87	3.25	4.42
4	127.6	24.8	1.34	1.76	2.21	2.84	3.36	5.32
5	205.6	12.0	1.32	1.59	1.82	2.09	2.26	2.68
6	198.5	26.8	1.35	1.68	2.00	2.40	2.68	3.52

MEAN ANNUAL FLOOD GROUPS

McKerchar and Pearson (1989, 1990) used contour maps of $Q_m/A^{0.8}$ to estimate Q_m. Wiltshire's (1985) grouping procedure is used with $Q_m/A^{0.8}$ to investigate its potential for estimating Q_m. The proposed $Q_m/A^{0.8}$ variability measure for monitoring different basin groupings partitioned by basin characteristics is (similar to SSL above),

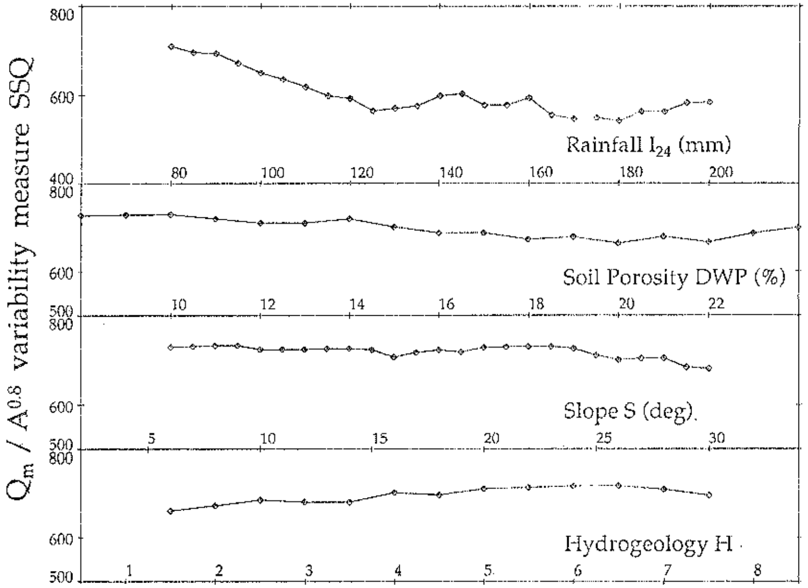

FIG. 6—Variation in $Q_m/A^{0.8}$ variability measure SSQ as the partition point for two-way grouping changes for basin characteristics I_{24}, DWP, S and H.

$$SSQ = \sum_{j=1}^{m} \sum_{i=1}^{n_j} ([Q_m/A^{0.8}]_{i,j} - [Q_m/A^{0.8}]^*_j)^2$$

where there are m groups, each comprising n_j basins with group record-length-weighted average $[Q_m/A^{0.8}]^*_j$. Figure 6 shows the variation of SSQ with different partition points for two-way groups based separately on rainfall I_{24}, soil DWP, hydrogeology H and slope S basin characteristics. I_{24} and DWP SSQ traces exhibit minima. Four-way partitions using these two characteristics lead to well-defined and reduced SSQ minima. Again, the best grouping found was a six-way grouping, defined in Table 3.

Table 3 shows desirable patterns between the group definitions and the behaviour of record-length-weighted average $Q_m/A^{0.8}$ values for each group. As rainfall I_{24} increases, $Q_m/A^{0.8}$ increases, and as soil porosity DWP increases, $Q_m/A^{0.8}$ decreases.

The Q_m predictive powers of the six-way grouping are compared with the McKerchar and Pearson (1989, 1990) contour map approach. Computing relative errors between either group or map approach estimators and observed Q_m values from the 117 basins, gives bias and root-mean-square-error values of 52% and 132% respectively for the six-way grouping approach, and 16% and 75% for the contour map approach. Therefore, the map approach is superior for estimating Q_m. Improvement in Q_m estimation for small New Zealand drainage basins is

TABLE 3—Six-way partition for Q_m of 117 small New Zealand catchments based on rainfall (I_{24}) and soil (DWP) basin characteristics.

Group	Definition		Number of Basins	Weighted Average $Q_m/A^{0.8}$
1	$I_{24}<125$mm	DWP<20%	37	1.57
2	$I_{24}<125$mm	DWP≥20%	7	0.81
3	$125\leq I_{24}\leq 177.5$mm	DWP<20%	32	3.52
4	$125\leq I_{24}\leq 177.5$mm	DWP≥20%	11	1.51
5	$I_{24}>177.5$mm	DWP<20%	25	5.49
6	$I_{24}>177.5$mm	DWP≥20%	5	2.31

further discussed by McKerchar (this issue); he recommends map Q_m estimates for small ungauged basins.

DISCUSSION

The robustness and accuracy of the Wakeby regional procedure for the six flood frequency groups may be illustrated using the longer annual maximum flood series (similar to Potter and Lettenmaier, 1990). Subsamples of 10 floods are randomly selected from each drainage basin with annual maximum series of length 20 or more years. Groups of the subsamples are used with the Wakeby regional procedure to obtain group Q_{100}/Q_m estimates. This is repeated 100 times for each group. Mean Q_{100}/Q_m estimates, with 95% confidence intervals for the mean, are given in Table 4. Although only 10 floods are used from each site per run, the results for the six groups are not significantly different from group Q_{100}/Q_m estimates in Table 2. Larger differences for groups 1 and 5 are caused by smaller group sizes in the resampling exercise. The result for all basins with 20 or more years of record, considered as one group, emphasises the need for more than one group: at least three group Q_{100}/Q_m resampling means (groups 2, 3, 4) are significantly different to the one-group mean, and to each other.

Both rainfall and slope influence upper-tail steepness of flood frequency curves for small New Zealand basins. Lower rainfall I_{24} groups are associated with steeper frequency curves (Fig. 5) than higher I_{24} groups. As explained by Wiltshire (1985), annual flood peaks from basins in drier regions are more variable than those from wetter regions. Greater variability in annual floods is directly related to steepness of flood frequency curves. A physical explanation for steeper average basin slopes relating to steeper flood frequency curves might be that steeper slopes are faster draining, and offer less storage opportunities, and hence antecedent wetness conditions are more variable, translating into more variable annual flood peaks and so steeper flood frequency curves.

The flood-set of 117 small New Zealand basins displays much variability in the L-skewness–L-kurtosis plane (Fig. 1) and in the dimensionless plots of the observed floods (Fig. 4). This is expected from small basins where the ratio of maximum current-meter-gauged stage to maximum automatic water-level recorded stage is usually low (since the flashiness of small basin flooding means there is little time for field teams to be on site for current-meter flood gaugings), implying that variability of annual floods derived from stage-discharge rating curves is high between basins (Potter and Walker, 1985). The lengths of record for these basins are relatively short, ranging from 10 to 29 years, with an average of 16 years, also implying greater flood frequency variability. Therefore averaging methods will be superior to looking at individual sites, and so at-site flood frequency methods will be less reliable than the robust, accurate and efficient regional scheme (Wallis 1980, 1988) used for the six groups in this paper. The closeness of group flood frequency curves (Fig. 5) for groups 1 and 4, and, to a lesser extent group 3, and the high variability of the annual flood series, indicates that these groups could be amalgamated into one group for practical purposes.

TABLE 4—Regional flood-frequency results from randomly resampling (100 times) 10 annual maximum floods (from basins with 20 or more floods) for different groups.

Group	Number of basins	Q_{100}/Q_m (Table 2)	Number of basins with $n \geq 20$	Mean Q_{100}/Q_m Estimate	Mean Q_{100}/Q_m 95% Confidence Interval
1	12	3.28	4	2.68	±0.11
2	9	5.66	1*	5.94	±0.42
3	20	3.25	9	3.02	±0.09
4	29	3.36	12	3.63	±0.12
5	24	2.26	5	2.55	±0.09
6	23	2.68	10	2.58	±0.09
All	117	—	41	2.74	±0.04

*GEV distribution used in place of Wakeby as only one basin in group.

Use of the L-skewness–L-kurtosis variability measure (SSL) in Wiltshire's (1985) basin grouping procedure identified six homogeneous groups, where homogeneity was with respect to L-skewness and L-kurtosis (V_2, V_3, Hosking and Wallis, 1991). Homogeneity in terms of L-CV was not achieved for four groups (3 to 6). Better results may have been obtained if L-CV was incorporated into the L-moments variability measure (SSL). Similarly, drainage basin characteristics, such as stream drainage network variables, may also have led to better results.

Defining flood frequency groups re-introduces the problem of edge-effects associated with traditional geographical regionalising. Wiltshire (1986) suggests using a weighted average of flood quantile estimates for basins near group edges (in catchment characteristics space) to alleviate this problem, where the weights are determined by the distance of the basin from the group averages in the characteristics space. This approach assumes that flood frequency behaviour will vary smoothly in the characteristics space, and has led to nearest neighbour regional schemes ("1-site-region" approach of Acreman and Wiltshire, 1989, or "region of influence" method of Burn, 1990). However, with the high variability in this flood-set, nearest neighbour schemes were not suitable for this study, since most emphasis is usually placed on the closest basin in catchment characteristic space. For small basins for which flood frequency estimates are required, between-group averaging could be used when a basin's I_{24} and S characteristics place it at the edge of two or more groups. Otherwise the defined groups in Table 1 and Figs. 4 and 5 can be used directly as a robust alternative to the McKerchar and Pearson (1989, 1990) procedure.

Examples: Estimation of 100-year flood peak discharge

1. Kumeu River at Maddren (45315) in Auckland has A = 46.46 km², I_{24} = 125 mm and S = 15° (see Appendix of McKerchar, this issue). This basin is therefore in flood frequency group 3 (from Table 1), which has a dimensionless 100-year flood quantile of 3.25 (from Table 2). From 6 annual flood peaks (1984–89), the at-site Q_m is 40.3 m³/s. The McKerchar and Pearson (1989) map Q_m estimate is 32.3 m³/s. The pooled at-site and map Q_m estimate is 33.7 m³/s (pooling described in McKerchar and Pearson). Multiplying the pooled Q_m estimate by the dimensionless 100-year flood quantile (3.25) gives a 100 year flood estimate of [3.25] × [33.7] = 110 m³/s for this basin.
3. Moutere Catchment 5 (57405) in Nelson has A = 0.0696 km², I_{24} = 105 mm and S = 18° (from Appendix). From Table 1, this basin is in flood frequency group 3, but close to being in groups 1, 2 and 4. Because this basin is located at the edges of group 3, a weighted-average quantile estimate is required. The weights for each group quantile are the reciprocals of the dimensionless Euclidean distance in the I_{24}–S space between the group averages (given in Table 2) and the Moutere values. The distances can be made dimensionless by dividing by Moutere's I_{24} and S values (105 mm and 18°). For group 1, the weight is:

$$\{[(105-79.4)/105]^2 + [(18-14.2)/18]^2\}^{-0.5} = 3.1$$

Similarly, weights for groups 2, 3 and 4 are 2.0, 2.5, and 2.3 respectively. Hence, the 100-year dimensionless quantile estimate for this basin is {(3.1)(3.28) + (2.0)(5.66) + (2.5)(3.25) + (2.3)(3.36)}/(3.1 + 2.0 + 2.5 + 2.3) = 3.77. This can be used with the at-site Q_m (.0297 m³/s) derived from 24 annual flood peaks to give a 100-year flood peak estimate of 1.12 m³/s.

CONCLUSIONS

Six flood frequency groups were defined on the basis of areally averaged rainfall I_{24} and slope S basin characteristics using Wiltshire's (1985) method with an L-moments measure of flood frequency variability. Wakeby distributions were fitted to each group, providing robust dimensionless flood frequency estimators for small ungauged New Zealand drainage basins.

Appendix: Rainfall I_{24}, slope S, hydrogeology H, and depth-weighted-soil-porosity DWP basin characteristics, and annual flood peak L-moments for 117 small (Area A ≤ 100 km²) New Zealand basins, each with "n" annual flood peaks. Site numbers from Walter (1990).

Site	A	I_{24}	S	H	DWP	n	Unbiased	L-moments;		L-moment ratios:	
	(km²)	(mm)	(deg)		(%)		$l_1 = Q_m$ (m³/s)	l_2 (m³/s)	l_3/l_2	l_4/l_2	l_5/l_2
3506	11.10	140	8.54	1.00	9.70	22	53.60	9.260	0.026	0.143	-0.048
4901	12.50	200	18.9	1.00	10.0	20	61.09	16.39	0.079	0.119	-0.022
5513	0.6300	190	18.0	1.00	13.0	10	3.090	1.040	0.218	0.094	0.083
5515	0.1550	190	18.0	1.00	10.1	11	0.6400	0.2200	0.113	0.041	-0.191
5516	0.1260	190	18.0	1.00	10.1	11	0.7600	0.2500	0.174	0.003	-0.158
5519	13.90	190	15.7	1.02	9.00	10	51.80	17.63	0.059	0.066	0.158
6501	8.130	195	24.3	5.04	10.0	12	18.53	9.590	0.560	0.424	0.269
7202	9.570	135	10.1	4.40	6.40	10	26.34	9.930	0.306	0.101	0.234
7604	11.08	125	9.02	3.13	1.20	27	31.15	8.120	0.273	0.127	0.055
7805	82.40	130	10.7	5.18	5.40	15	118.2	40.11	0.116	-0.054	-0.035
7811	11.96	125	8.21	5.76	7.10	10	21.50	9.240	0.320	0.168	0.099
8203	0.3000	120	1.50	8.00	13.1	18	1.480	0.5200	0.292	0.216	0.149
8604	40.72	150	24.5	2.17	11.8	11	69.15	24.91	0.457	0.505	0.521
9228	7.920	150	33.2	3.31	11.0	19	42.24	18.29	0.498	0.295	0.156
14610	57.13	160	15.0	6.16	22.1	22	17.89	3.620	0.300	0.159	0.066
14625	73.89	160	19.7	7.01	26.7	14	23.94	4.920	0.298	0.088	-0.102
14627	68.80	200	19.8	6.00	20.0	23	34.67	8.350	0.220	0.120	0.040
1014641	75.98	190	20.0	6.24	28.3	15	20.21	6.340	0.184	0.059	0.089
1014645	0.8100	160	5.50	8.00	29.3	11	2.020	0.3100	0.086	0.260	0.253
1014646	0.9200	160	5.50	8.00	29.3	11	1.530	0.1600	0.090	0.093	-0.039
15453	45.05	200	30.9	4.66	28.2	10	43.88	10.49	0.193	0.363	0.233
15534	2.670	150	23.2	8.00	19.6	23	1.860	0.5600	0.247	0.143	0.005
19734	30.50	160	24.1	4.91	20.7	11	37.51	11.23	0.361	0.235	0.109
21410	50.29	155	26.5	5.30	16.9	21	56.62	15.23	0.280	0.194	0.128
21601	21.41	165	27.9	4.09	14.1	14	45.91	13.01	0.203	0.098	-0.133
22901	18.44	170	20.3	4.49	8.60	11	21.68	7.920	0.075	0.119	-0.076
23005	0.5200	165	23.0	6.00	22.1	21	1.330	0.3300	0.003	-0.003	-0.087
23209	23.39	95	16.7	2.57	11.5	25	10.22	3.640	0.230	0.120	0.013
23210	53.73	160	17.1	4.78	12.2	26	59.25	18.37	0.134	0.029	-0.026
23220	84.60	150	17.7	4.99	14.6	12	83.60	29.05	0.366	0.200	-0.066
29242	40.25	160	31.7	1.51	15.7	20	111.3	25.52	0.368	0.152	-0.069
29244	36.32	105	24.9	3.98	11.2	22	31.38	8.160	0.075	0.143	-0.016
29246	75.78	200	35.0	1.48	14.8	10	282.0	50.76	0.335	0.065	-0.106
29250	15.57	140	28.5	1.06	16.7	20	32.81	10.13	0.255	0.387	0.213
29254	78.75	180	35.2	1.49	14.4	12	330.2	57.15	0.094	0.100	0.029
29259	0.2300	90	22.4	4.03	9.60	11	0.2200	0.0700	0.459	0.327	0.392
20605	79.73	120	23.4	1.92	13.3	10	76.36	17.14	0.109	0.103	0.278
29808	87.24	200	34.9	1.00	14.7	22	285.1	57.19	0.153	0.054	-0.010
29841	43.84	110	25.9	1.42	16.5	12	69.00	17.68	0.201	0.224	0.130
29843	37.95	135	32.0	1.00	15.4	10	85.28	12.19	0.019	0.103	-0.153
30516	9.100	100	17.5	2.34	9.70	21	7.420	2.490	0.336	0.284	0.149

Site	A	I_{24}	S	H	DWP	n	Unbiased	L-moments;	L-moment ratios:		
	(km²)	(mm)	(deg)		(%)		$l_1 = Q_m$ (m³/s)	l_2 (m³/s)	l_3/l_2	l_4/l_2	l_5/l_2
30701	44.69	110	19.2	2.51	7.40	22	38.11	12.40	0.352	0.346	0.221
30802	38.47	125	19.9	2.62	9.70	15	53.63	13.15	0.273	0.161	0.022
32001	16.80	80	18.9	2.95	12.5	11	18.23	5.330	0.128	-0.022	0.000
1032517	56.60	115	26.6	1.80	14.5	11	99.50	17.75	-0.039	-0.142	0.045
1232564	62.30	130	20.0	4.11	15.0	10	71.68	16.45	0.082	0.408	0.089
32735	61.58	80	8.90	4.67	10.7	11	33.32	11.46	0.376	0.269	0.056
32754	99.50	85	26.5	4.24	10.1	13	65.72	22.66	0.466	0.367	0.219
33114	53.11	100	10.9	7.43	25.2	22	3.570	0.5300	-0.004	0.221	0.049
33115	32.78	115	22.0	5.94	13.9	21	17.72	3.680	0.212	0.072	-0.037
33117	20.63	145	10.2	6.39	15.9	22	27.47	5.390	0.112	0.110	0.015
33307	81.84	115	16.1	6.66	25.5	13	47.75	12.04	0.259	0.165	0.101
33347	27.14	125	24.3	5.61	23.0	24	28.07	6.220	0.142	0.088	-0.022
34308	84.63	280	5.26	7.77	15.6	12	149.5	26.48	0.415	0.324	0.359
35004	49.60	200	8.11	7.26	13.0	15	73.01	9.240	0.042	0.109	-0.186
35506	59.60	200	5.59	7.47	14.6	12	104.9	23.33	0.071	0.121	0.190
36001	30.98	200	7.88	4.77	12.1	20	36.91	8.230	0.370	0.220	0.035
38401	24.92	170	20.2	7.23	9.80	10	55.14	8.820	0.277	0.460	0.210
39201	59.10	280	15.6	6.60	10.2	10	329.5	43.32	0.449	0.218	0.097
39402	49.03	180	10.6	7.85	14.5	14	61.94	21.65	0.595	0.470	0.309
39403	37.78	240	6.37	7.41	11.5	14	81.46	19.29	0.537	0.359	0.169
39504	77.34	260	8.95	7.19	14.8	12	174.7	33.38	0.098	0.077	-0.140
39508	19.24	320	10.7	6.16	12.9	17	53.90	5.360	-0.156	0.091	0.039
39510	10.92	280	9.45	6.41	11.1	13	67.36	9.640	0.272	0.189	0.245
40703	14.11	120	19.5	6.30	14.0	19	4.310	0.6800	0.104	0.097	-0.006
41301	95.10	135	25.5	4.94	10.7	11	51.64	14.43	0.210	0.275	0.380
41601	8.790	105	23.4	3.70	9.50	19	6.620	1.420	0.160	0.373	0.153
1043434	21.59	150	19.8	7.50	26.1	21	4.160	1.450	0.415	0.274	0.195
1043466	95.89	170	15.7	6.91	16.9	27	38.9	5.500	0.116	0.151	0.122
1043476	0.0450	110	18.0	8.00	28.9	11	0.1500	0.0800	0.401	0.279	0.038
1143407	1.690	145	24.1	7.46	23.1	14	0.6000	0.2300	0.459	0.237	0.060
1143409	0.3400	145	24.9	7.30	9.50	21	0.2300	0.1600	0.659	0.373	0.095
1143427	3.110	140	21.9	4.82	11.8	18	2.680	1.020	0.351	0.190	0.072
1143428	14.64	120	10.1	7.99	9.20	19	3.770	0.7400	0.143	0.237	0.151
1443462	9.990	120	20.3	6.93	19.4	17	5.760	2.260	0.269	0.194	0.060
43602	17.86	120	9.77	7.70	20.1	24	12.51	5.760	0.349	0.112	0.031
43807	12.50	120	8.37	5.10	6.80	13	23.85	12.42	0.370	0.087	0.000
45702	8.210	190	22.1	4.00	6.10	21	32.73	8.900	0.175	0.231	0.155
45903	0.8800	175	11.5	4.00	2.40	10	2.030	0.5200	-0.164	-0.061	0.052
46609	12.13	170	16.0	1.32	10.3	15	56.98	25.57	0.209	-0.051	-0.158
46645	3.360	160	9.08	4.56	13.9	10	9.280	0.9400	0.029	0.145	-0.035
46662	0.3900	155	11.5	4.00	2.10	13	2.340	0.5700	0.137	0.107	-0.053
46663	0.0142	155	11.5	4.00	2.10	13	0.1800	0.0400	-0.037	-0.052	0.093
47527	10.03	155	17.6	4.00	10.2	24	23.48	6.330	0.266	0.317	0.240
48015	21.78	135	26.2	1.00	8.80	14	75.06	17.53	0.272	0.214	-0.031

Site	A	I_{24}	S	H	DWP	n	Unbiased	L-moments;	L-moment ratios:		
	(km²)	(mm)	(deg)		(%)		$l_1 = Q_m$ (m³/s)	l_2 (m³/s)	l_3/l_2	l_4/l_2	l_5/l_2
52916	46.81	290	35.4	1.48	21.7	20	97.27	12.88	0.132	0.179	-0.021
56901	46.59	200	28.0	1.06	13.0	26	47.46	10.15	0.162	0.121	0.006
57014	82.38	110	23.6	7.96	13.2	20	61.63	17.11	0.142	0.213	-0.124
57022	5.140	90	23.1	8.0	14.7	13	2.760	0.8200	0.539	0.431	0.356
57023	2.790	90	29.9	8.00	14.7	10	1.210	0.3600	0.409	0.383	0.202
57101	58.00	110	18.3	8.00	6.90	24	61.66	23.45	0.162	0.057	-0.001
57402	0.0396	105	11.5	8.00	6.40	24	0.1300	0.0500	0.112	-0.068	-0.035
57405	0.0696	105	18.0	8.00	6.40	24	0.3000	0.1400	0.417	0.271	0.208
57512	0.0344	195	23.0	8.00	6.40	22	0.2000	0.0700	0.313	0.242	0.102
58301	17.25	165	28.9	1.02	21.0	29	30.02	9.210	0.277	0.070	0.011
60104	65.02	105	31.1	1.07	13.9	23	73.93	32.08	0.188	0.054	0.086
63501	1.690	200	30.9	1.00	14.7	12	3.340	1.820	0.457	0.217	0.211
64606	74.04	210	29.5	1.49	20.1	15	92.67	10.43	0.002	0.094	0.026
64610	41.91	160	23.1	3.08	11.5	22	35.13	13.41	0.300	0.257	0.100
66405	0.9000	105	30.5	1.00	22.5	19	0.6800	0.3000	0.347	0.198	0.130
66603	2.180	95	28.6	3.24	13.2	11	1.180	0.6200	0.435	0.468	0.506
66604	3.260	95	25.6	3.65	13.4	12	1.420	0.8300	0.428	0.253	0.154
68529	6.190	90	29.3	1.90	23.7	11	2.760	0.7900	0.169	0.025	-0.126
68602	55.00	110	12.8	5.23	14.7	21	10.48	6.420	0.455	0.277	0.199
69621	22.97	80	24.5	2.19	17.8	24	16.72	8.830	0.640	0.511	0.369
71122	50.08	80	8.55	8.00	20.1	17	3.960	1.470	0.453	0.499	0.459
71129	99.63	140	24.1	3.93	22.0	27	22.09	6.100	0.271	0.126	0.054
71178	78.70	60	28.8	1.16	18.7	19	38.19	20.14	0.509	0.272	0.126
73501	45.00	100	18.9	1.33	10.2	27	44.33	15.26	0.169	0.169	0.183
74353	24.06	45	15.7	1.00	10.0	18	3.010	1.410	0.258	0.028	0.012
74360	2.860	65	11.5	3.00	8.10	12	2.030	0.5900	0.42	0.161	-0.123
74367	0.5800	70	9.23	1.00	5.60	11	2.020	0.6700	0.185	0.113	0.085
74701	9.590	60	16.5	1.68	6.40	19	6.770	2.130	0.070	0.171	-0.002
80201	71.60	78	17.2	3.61	8.90	12	30.53	12.31	0.419	0.211	0.169
87301	97.80	440	29.3	2.77	19.9	11	389.2	68.82	-0.171	-0.064	0.041
90605	4.380	220	14.9	7.06	17.7	17	28.85	5.870	0.257	0.147	0.085
91412	0.6600	110	30.5	8.00	14.7	11	0.8200	0.2500	0.255	0.112	0.079

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