FLOW REGIMES OF NEW ZEALAND RIVERS*

M. Parde†

ABSTRACT

Data from major flooding in New Zealand are presented and comparable figures are given for some overseas floods. The rainfalls responsible are considered.

Average annual discharges and mean seasonal variations are also discussed, with particular reference to rivers with lake-influenced regimes.

INTRODUCTION

Owing to its hilly relief and abundant, though unevenly distributed, precipitation, New Zealand has no lack of water resources. In the South Island the Southern Alps form a barrier to the south-east of which the rainfall is remarkably low in contrast to the north-west. Range in rainfall may be as much as 10-400 inches. The North Island has a more even distribution with an extraordinary annual mean and only limited areas of insufficient rainfall. This causes considerable variations in mean discharges of New Zealand rivers (Fig. 1).

The influence of snow must not be ignored, although the greater proportion of hills and lower mountains receives no snow.

Thus, in New Zealand are found all the possible varieties of seasonal flow regimes to be expected in an oceanic zone in medium latitudes.

Regional flood characteristics are difficult to define, since similarity of seasonal rainfall, of topography or of mean flow is no guarantee of similarity of flooding. Data are insufficient for full analysis but the frequently devastating flooding in New Zealand can certainly not be compared with that in Norway of Scotland where heavy rains produce floods which do comparatively little damage. The maxima of a large number of the rivers are comparable with those of the Ardeche and the Gardon and of the great rivers of the U.S.A.

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* A fuller version of this paper appeared in French (**Le regime des rivieres en Nouvelle - Zelande**) in the **Revue de Geographie Alpine.** Tome XLVIII, 1960. The paper contains only data compiled before 1960.

† Professeur a la Faculte des Sciences, Grenoble.

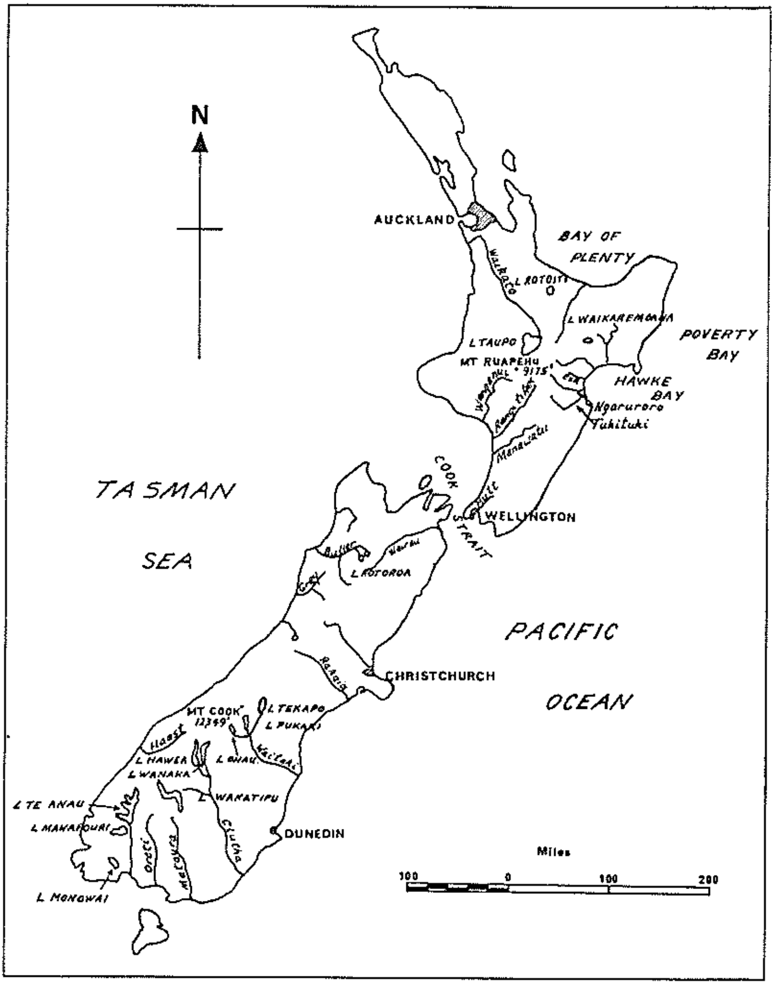

Fig. 1 — LOCATIONS of major lakes and rivers of New Zealand.

FLOODS

Comparative Significance of Maximum Discharge Figures

In Table 1 an attempt is made to characterise the excessive rainfalls and floods to which both islands are exposed. This table alone is inadequate as flood peak discharges at different points on the channel have no linear relation with catchment areas at these points. For this reason coefficients have been derived which, without remaining constant for any number of catchments, are sufficiently alike within a given catchment, region or sub-region to characterise the relative violence of floods. It is not, however, possible to state that the coefficient is more accurate than ±20% over a complete range of catchment areas from 4 to 400,000 sq. miles.

Table 1 gives comparative magnitudes for the coefficient

$$K = q\ A^{-\frac{1}{2}}$$

Where q is the maximum peak discharge in cubic feet per second, A is the catchment area in square miles.

TABLE 1 — Maximum River Discharges and Coefficients — New Zealand.

	Date	A sq. miles	q cusecs	Q cusecs/ sq. mile	$K = qA^{-\frac{1}{2}}$	$C = qA^{-\frac{3}{4}}$ Dickens coefficient *
			NORTH ISLAND			
East Coast (Gisborne, Poverty Bay, Hawke's Bay etc).						
1. Waiapu at Rotokautuku	May 1924	620	230,000	371	9,237	1,840
2. Waipaoa at Kanakanaia	May 1948	606	140,000	231	5,686	1,147
3. Kopuawhara	Feb. 1938	16	33,907	2,168	8,477	4,238
4. Mangakotukutuku at No. 5 Bridge.	Feb. 1938	7	24,200	3,460	9,146	5,630
5. Wairoa at Town Bridge	May 1948	1,415	404,100	286	10,742	1,760
6. Mohaka at Viaduct	Apr. 1938	900	225,000	250	7,500	1,364
7. Esk below Railway Bridge	Apr. 1938	77	64,670	840	7,369	2,490
8. Waipu at Ferry Bridge	Mar. 1920	35	30,416	870	5,140	2,110
9. Tutaekuri at Dartmoor	Apr. 1938	308	96,500	314	5,499	1,320
South-West Coast						
10. Manawatu at Fitzherbert Bridge	Mar. 1880	1,573	176,000	112	4,437	704
11. Rangitikei at Mangaweka	Apr. 1897	1,076	232,000	216	7,071	1,234
12. Wanganui at Town	Apr. 1897	2,850	219,000	77	4,103	562
Bridge	May 1904	2,850	219,000	77	4,103	562
West Coast						
13. Mangakahia	Feb. 1917	98	71,200	727	7,193	2,280
14. Waikato at Mercer	Feb. 1907	4,362	60,000	13.8	908	113

* The comparative basis used in New Zealand is the Dickens Rating, $C = qA^{-\frac{3}{4}}$ and values for C are also included in the table.

TABLE 1 (Cont'd) — Maximum River Discharges and Coefficients — New Zealand.

	Date	A sq. miles	q cusecs	Q cusecs/ sq. mile	$K=qA^{-\frac{1}{2}}$	$C=qA^{-\frac{3}{4}}$ Dickens co-efficient *
SOUTH ISLAND						
South-East Coast (Marlborough, Canterbury, Otago.)						
1. Pelorus below Pelorus Bridge	Feb. 1954	143.5	59,500	415	4,966	1,434
2. Waimakariri at Traffic Bridge	May 1950	1,241	195,000	157	5,537	930
3. Rakaia at Automatic Gauge	Dec. 1947	892	160,000	180	5,357	975
4. Waitaki at Power Station	Feb. 1931	3,750	85,000	23	1,388	177
5. Lake Wakatipu at Inflow	Nov. 1948	1,150	120,000	104	3,538	608
6. Clutha at Alexandra	Sep. 1878	4,751	117,000	24.6	1,697	204
Westland						
7. Hollyford below Marion Camp	Feb. 1952	25	36,000	1,472	7,360	3,290
8. Karangarua at Suspension Bridge	—	142	89,900	633	7,542	2,170
9. Haast at Haast	May 1950	510	260,000	510	11,515	2,430
10. Hokitika at Kaniere Bridge	Feb. 1940	445	160,000	360	7,583	1,650
11. Grey at Brunner	Feb. 1940	1,470	186,700	127	4,870	789
12. Buller at Berlins	May 1950	2,282	437,300	191	9,154	1,325
	Nov. 1926	2,282	437,300	191	9,154	1,325

Table 2 gives comparative magnitudes of K for catchments between 1,930 and 5,800 square miles.

TABLE 2 — Coefficients for some Rivers Outside New Zealand

Location	Date	$K=qA^{-\frac{1}{2}}$
France:		
1. Agout	Mar. 1930	3,410
2. Middle and Lower Tarn	Mar. 1930	3,410
3. Garonne at Toulouse	Jun. 1875	3,980-4,265
4. Lot, Dardagne, Durance, Upper Loire, Allier	—	2,275-2,840
5. Marne, Yonne	—	512-682
6. Cevennes region (Ardeche, Gardon Upper Ceze, Vidourle)	—	7,110-8,525
Some Mediterranean rivers (during autumn)	—	7,110-8,525
Italy (and perhaps Spain)	—	7,110-8,525
Japan (certain rivers)	—	11,370-14,210
U.S.A., Texas	—	14,210-17,050

Major Floods in New Zealand

Table 3 gives coefficients for selected serious floods in some New Zealand rivers.

TABLE 3 — Major Flood Coefficients

River	Date	$K = qA^{-\frac{1}{2}}$
	NORTH ISLAND	
1. Wairoa*	May 1948	10,741
2. Mohaka	Apr. 1938	7,502
3. Esk	Apr. 1938	7,388
4. Tutaekuri	Apr. 1938	5,513
	SOUTH ISLAND	
1. Buller	Nov. 1926	9,150
	May 1950	9,150
2. Haast	May 1950	11,082
3. Hollyford	Feb. 1952	7,218

For numerous New Zealand rivers K is greater than 5,000 - 6000. It appears that the most damaging flooding occurs in the east of the North Island.

Note that for small catchments (e.g. Hollyford) K underestimates the strength of the flood.

Large Floods Reduced By Lakes

Comparison of these with major floods referred to above shows a noticeable contrast. Coefficients for typical lake-reduced floods in New Zealand are given in Table 4.

TABLE 4 — Coefficients for Lake-reduced Floods in New Zealand — with a comparable continental flood listed below each of the first two.

River	Date	q	K
1. Waikato at Mercer	Feb. 1907	60,000	909
(Yonne-Seine	Jan. 1910	42,500	—)
2. Clutha at Alexandra ...	Sep. 1878	117,000	1,697
(San-Galicia	—	155,400	1,766)
3. Clutha at Balclutha ...	Sep. 1878	180,000	2,035
4. Waitaki at Power Station ...	Feb. 1931	85,000	1,387

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* This exceeds the coefficient for major flooding of the Ardeche at Vallon (7,729-8,354). There is possibly a mistake in the maximum discharge of the Wairoa which has a hypothetical maximum 20% smaller.

The upper Clutha is controlled by Lakes Hawea, Wanaka and Wakatipu. Further down stream from Alexandra this lake-control is lost and a higher coefficient is obtained.

The lower Waitaki is used for hydro-electric purposes. Lakes Pukaki, Tekapo and Ohau control the 1,535 sq. miles above them, from a total of 3,750 sq. miles at the power station.

Floods Not Reduced By Lakes

Many South Island rivers (especially Buller, Haast and Hollyford) have lesser floods which are higher than can be observed anywhere in Europe, except perhaps in small exposed Mediterranean catchments. Typically high values of K are given in Table 5.

TABLE 5

River	Date	K
1. Pelorus above Pelorus Bridge ...	Feb., 1954	4,944
2. Waimakariri at Traffic Bridge ...	May, 1950	5,570
3. Rakaia at Automatic Gauge ...	Dec., 1947	5,359
4. Mataura at Gore	Mar., 1913	4,854
5. Oreti at Winton	Mar., 1913	3,041
6. Grey at Brunner	Feb., 1940	4,871
7. Karamea at Mouth	— 1914	4,416

In many North Island catchments a serious water excess is indicated by values of K between 3,980 and 4,550. Examples are given in Table 6.

TABLE 6

River	Date	K
1. Hutt at Lower Hutt	Dec., 1939	4,501
2. Manawatu at Fitzherbert Bridge ...	Mar., 1880	4,444
3. Wanganui at Town Bridge ...	Apr., 1897	4,109
	May, 1904	4,109

Rainfalls Responsible

New Zealand's exceptional flood discharges are caused, not only by rugged terrain, but also by intense rainfall. (Only a small, central, inland area of the North Island and western areas of South Canterbury and Otago are unlikely to be subject to intense rainfall). Rainfall can exceed 4 in. per day — a figure reached, in France, only in the mountainous areas and the Mediterranean sector. Over half the country is likely to receive 6 in. of rain (or 8 in. in elevated areas). Not only are these rainfalls intense, (Table 7), but they occur with a greater frequency than those of France, for example.

TABLE 7 — Some Heavy Rainfalls Experienced in New Zealand.

Area	Date	Rainfall (inches) and Duration
1. Tutira	25 Apr. 1938	12/14 hours
2. Morere	25 Apr. 1938	10/14 hours
3. Puketitiri	23 Apr. 1938	9.14/24 hours
	24 Apr. 1938	15.39/24 hours
	25 Apr. 1938	14.87/24 hours
4. Putorino	23 Apr. 1938	4.00/24 hours
	24 Apr. 1938	16.50/24 hours
	25 Apr. 1938	11.60/24 hours
5. Rissington	11 Mar. 1924	20.14/10 hours
	11 Mar. 1924	9.0/2.75 hours
6. Eskdale	11 Mar. 1924	16.5/9 hours
7. Milford Sound	10 Apr. 1939	22/24 hours
8. Near Milford Sound	10 Apr. 1939	18.35/24 hours
9. Otira	25-26 May 1950	16.25/24 hours
10. Silverstream (Aorere)	3 Apr. 1931	23.5/24 hours
11. Rai Valley	3 Apr. 1931	16/24 hours
12. Emscote, Stag & Spey	6 May 1923	19.7/24 hours
	7 May 1923	10.85/24 hours

Figures for the south-east coast of the North Island are exceptional even in comparison with the rainy Cevennes region of France.

Figures 2 and 3 show rainfall distribution for Hawke's Bay floods in 1924 and 1938.

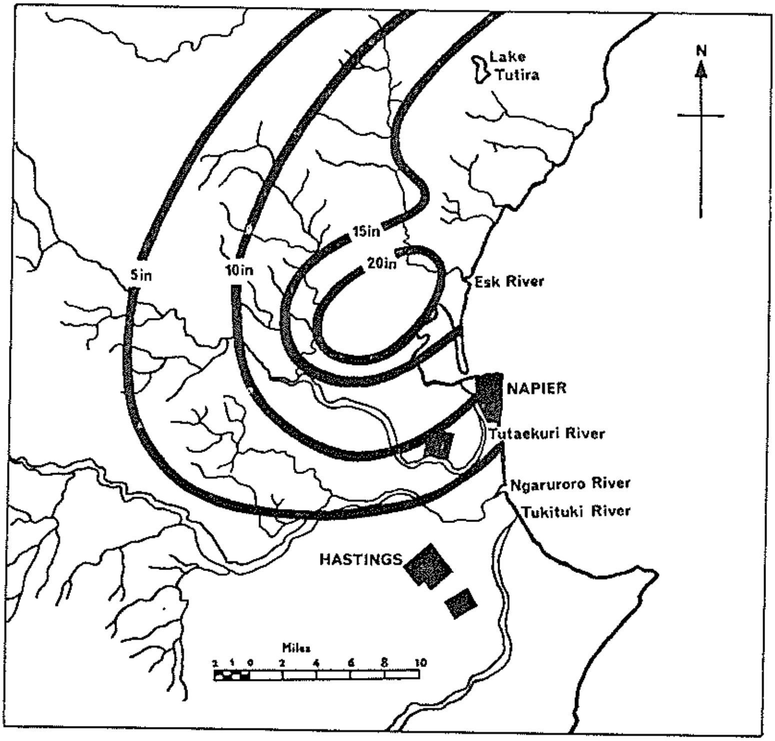

Fig. 2 — HAWKE'S BAY FLOODS 1924. Rainfall distribution of 10-11 March.

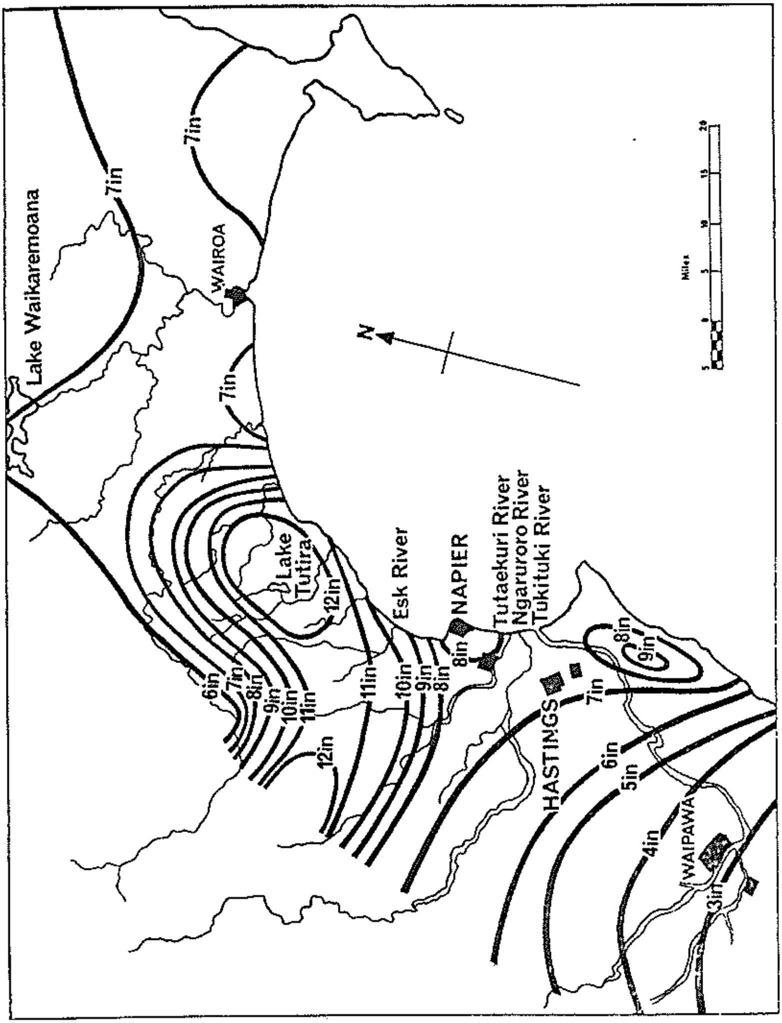

Fig. 3 — HAWKE'S BAY FLOODS, 1938. Rainfall distribution of 24 April.

AVERAGE ANNUAL DISCHARGES

South Island

In general, less information is available than for floods. The following information is mostly from Benham (1951) and Newham (pers. comm.). Table 8 gives data for a few South Island rivers, the regimes of which are affected by lakes.

TABLE 8 — Average Annual Inflows.

Catchment	Lake or Station	Inflow (cusecs/sq. mile)	Catchment Area (sq. miles)
Clutha	Wakatipu	5.23	1,150
	Wanaka	7.39	982
	Alexandra	2.94	6,012
	Hawea	3.99	567
Waitaki	Pukaki	9.06	523
	Ohau	5.405	420
	Tekapo	5.17	611
Waiau	Manapouri	7.50	1,858
	Te Anau	9.61	1,534
	Monowai	8.33	67
Buller	Rotoroa	6.55	145

The south-eastern foothills, which contain most of the large lakes, are protected by the Alps from rain-bearing winds. Precipitation in the Alps is, however, so great that discharge is large even in those areas which subsequently traverse a low rainfall area.

The Clutha crosses an area which contains few high peaks, but includes the driest region of New Zealand (Central Otago). The Waitaki catchment contains the high peaks Mt Tasman (11,475ft), Mt Cook (12,349ft) and Mt Sefton (10,359ft). The high catchment of Lake Pukaki appears to be best placed to benefit from the very heavy rain which falls on these mountains. In the extreme south-west of this region the catchments of Lakes Te Anau and Manapouri, with peaks of from 4,920ft to 5,900ft are not sheltered from north-westerly rains. Movement of cloud masses is thus freer in the upper parts of these catchments; and the sea, the source of the high humidity, is closer. It is not surprising, therefore, that inflows are impressive. Lake Rotoroa, further in the north, is situated in a wet mountain catchment of the Buller and has an inflow of considerable volume for an area so far from the sea.

Large average annual discharges are also to be expected in Westland. The average annual precipitation of 21.1ft for Milford Sound is affected by the full force of rain-bearing winds. Precipitations are probably even higher further west and the average annual precipitation may be 23ft (equivalent, because of the angle of the rain, to 26.3ft). Evaporation losses appear to be between 20 and 23 in. The specific average annual discharges of 10-20 sq. mile areas should thus be 22-23 cusecs/sq. mile. These figures are indirectly confirmed by the unexpectedly high discharges from the lakes to the south-east of the Southern Alps.

It may be assumed that between a quarter and a third of the rivers in the south-east of the South Island (where rainfalls are less than 30 in.) have specific average annual discharges as low as 0.55-0.65 cusecs/sq. mile. Even at Alexandra (on the Clutha) which is only 80 miles from Milford Sound, annual rainfall is less than 14.5 in.

Table 9 gives comparative figures from various overseas rivers.

TABLE 9

River	Station	Country	Inflow (cusecs/sq. mile)
Combined Isere & Drac	Grenoble	France	c 2.75
Rhone	Lyon	France	c 2.75
Reuss	—	Switzerland	c 3.85
Limmat	—	Switzerland	c 3.85
Tessin	—	Italy	c 4.05
Saone	—	France	1.28
Seine	near Paris	France	0.64
Missouri	—	U.S.A.	0.146-0.156
Garry	—	Scotland	6.56
Norddalsely	South of Nordfiord	Norway	14.64
Isonzo	Canale	Italy	7.87
Isonzo	Log	Italy	6.4
Puelo	—	Chile	7.13
San Pedro	—	Chile	11.35

Figures of 6.5 to 7.5 cusecs/sq. mile, or more, are not found in Europe, except for Norway, certain small Alpine catchments, very small areas in the Pyrenees and the larger catchments in the western highlands of Scotland. High average annual discharges are also obtained in the coastal regions of Washington and Oregon in the U.S.A. and in Canada between Vancouver and Alaska. Figures from Southern Chile (Marie de Roche:Bruyne L'Endesa, pers. comm.) are even more remarkable. Discharges of 16.5 to 18.5 cusecs/sq. mile are obtained in several small Chilean catchments at optimum altitude and with the greatest exposure to the north or north-west. These imply average annual precipitations of the order of 24ft (or an equivalent 20ft on catchments consisting entirely of steep slopes of western exposure).

North Island

Nowhere in the North Island is average annual precipitation lower than the 33.5 to 35.5 in. deposited in the lower Rangitikei and Ruamahanga areas north-east of Wellington and the Hastings and Waipukurau areas further east. The major rivers in these areas discharge less than 1 cusec/sq. mile.

In nearly half the North Island, discharges are between 1 and 3 cusecs/sq. mile (with precipitations between 40 and 60 in. and losses—because of temperature and latitude—between 21 and 30 in.) For the other half, discharges are higher and more varied. rising to about 6.5 cusecs/sq. mile in the north-east of the Huiarau and Raukumara ranges and to the south of Mt Ruapehu (19.175

ft). At the most westerly point, Mt Egmont (8,260ft) appears to receive up to 17ft of rainfall. The the north-west mean annual discharges of 4.5 to 6.5 cusecs/sq. mile are obtained on the Mokau River and of 3.5 to 4.5 cusecs/sq. mile north of Dargaville.

It is likely, therefore, that average annual discharges vary from 10-150 cusecs/sq. mile in the North Island, and from 10-2,000 in the South Island.

MEAN SEASONAL VARIATIONS

The following surmises for the South Island are based on monthly mean discharges for 16 rivers which are influenced by their flow through lakes.

South Island Glacial Flow Regimes

In Europe glacial areas are rarely found below 13,100 ft, but in New Zealand glaciers extend much lower than this. (The highest mountain in New Zealand is the 12,349 foot Mt Cook). This is because the precipitation on the Southern Alps of New Zealand (where the glacial flow regimes are found) is greater than that of a comparable European range and the snowfall of Mt Cook is thus two or three times that of a mountain such as Mont Blanc, which has a latitude two degrees above that of Mt Cook. Thus the volume of snow remaining on a New Zealand mountain after the thaw will be greater than that on a French mountain (assuming similar intensities of thaw). The Tasman Glacier has, in three-quarters of a century progressed to an altitude of 2,395 ft and its extremity is snow at 2,350ft. These figures are in marked contrast to those of the Aletsch Glacier in Switzerland (extremity at 4,875ft) and the Lower Aar Glacier in Switzerland (extremity 4,130 ft). The lower "eternal snowline" of New Zealand's Southern Alps is between 7,210 and 7,540 ft, while that of the French Alps is mostly between 9,500 and 10,020 feet.

An ultraglacial regime can be observed at the inflow of Lake Pukaki where the highest monthly coefficient (relation of average monthly discharge to average annual discharge) occurs in February, exceeding not only that of January but also the high discharges of March and December. Because of retention of snow and ice the minimum coefficient is found in August. Less markedly glacial regimes are found at the outlets of Lakes Tekapo and Ohau (also close to the highest mountains) and the lower Waitaki River (which receives run-off from three ice-fed catchments). The short rivers which discharge into the sea north-west of the Southern Alps also have ultraglacial regimes since, on that side and owing to very great precipitation, the glaciers descend to a remarkably low altitude (Fig. 4).

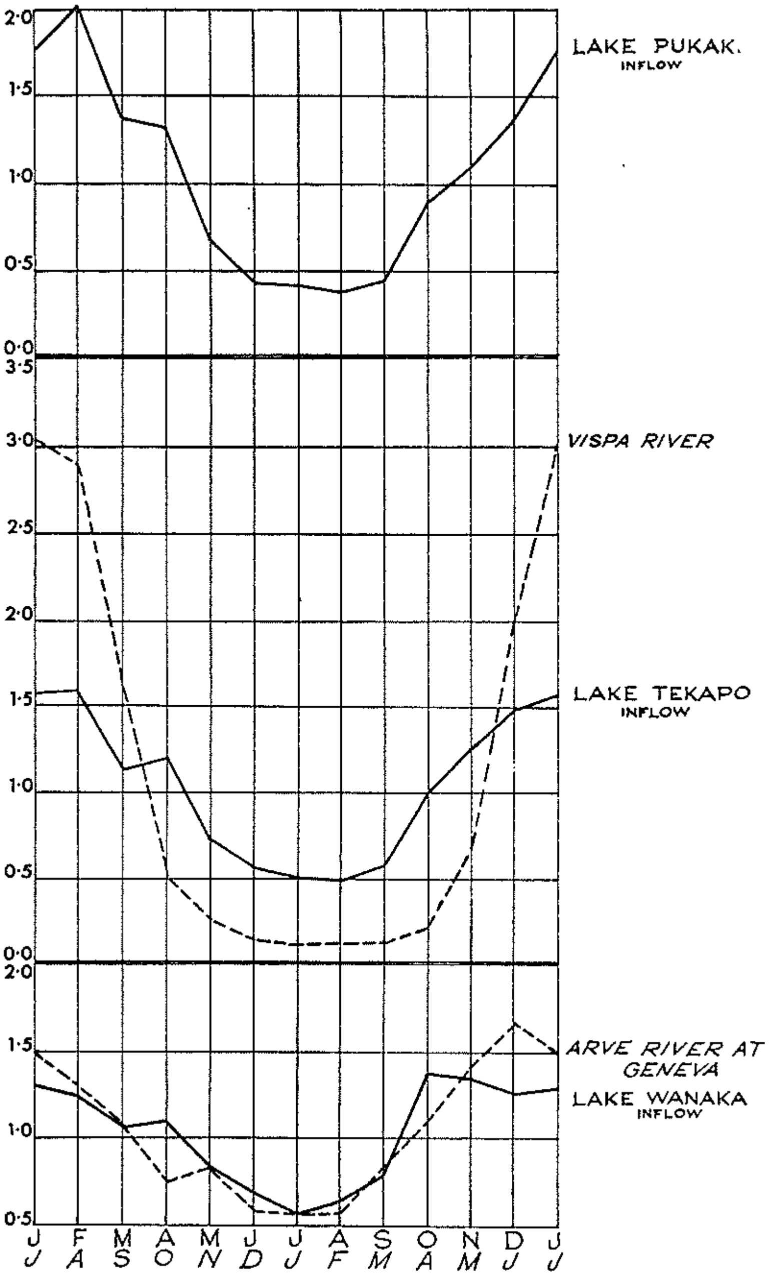

Fig. 4 — MONTHLY COEFFICIENTS (ratio of mean monthly discharge to average annual discharge) for some rivers with glacial regimes in New Zealand and Europe. Broken lines refer to European rivers.

South Island Snow and Allied Regimes

The sub-alpine lakes to the south-west of Lake Ohau are fed by relatively small mountains and, except for the source streams close to Mt Aspiring (9,959 ft) up stream from Lake Wanaka, do not have purely snow regimes. In the region near Lake Wakatipu peaks of up to 9,200 ft are still found and absolute snow regimes are moderated by maxima in December. Lower down at the lake inflows the influence of altitude in reducing the regimes is less noticeable. Wanaka experiences a maximum in October (with a high coefficient also in November) and Wakatipu (in spite of the influence of Mt Aspiring) in November. For both lakes snow, and perhaps even ice, discharges are still high in January and February. They appear to have a transitional snow-rain-ice regime with maxima over a long period and of a kind unknown in central and western Europe. The lower Arve in Switzerland also has high average discharges, but over a shorter period and with a much later maximum.

Lakes Te Anau and Manapouri (with tributaries at about 5,000 ft have mid-October maxima and summer discharges appreciably smaller than those of spring. The lower elevations of this southern sector exhibit phenomena also found, though less strikingly, in Lakes Hawea, Wanaka and Wakatipu. Average monthly discharges for March and April experience an intensification almost certainly due to rainfall (before the retention of atmospheric water as snow). This appears to be a transitional snow regime, nearly snow-rain (the European pre-alpine type) with a predominance of rain where the snow has melted early. A similar regime is found for Lake Rotoroa to the north. A maximum occurs in November, followed by December, then October, with a plentiful supply still in January-February and a marked increase in rainfall in April and May (this differs from Wakatipu which shows a drop). Further south, the Lake Monowai catchment (with some mountains over 5,000 ft but a mean altitude lower than for more northerly catchments) has an October maximum. The effects of peak rainfall in May do not equal those of spring melting of snow. A minimum occurs in December. This is clearly a snow-rain regime, comparable to those of rivers in the Jura or Central Ranges of Europe (Fig. 5).

Influence of Seasonal Rainfall Distribution in the South Island

The above outline analysis must be considered with monthly variations of rainfall. For a specific region and altitude, temperature governs the seasonal regime. Large discharges are observed, for example, during the cold season in low altitudes with little or no snow because of low evaporation and during the warm season in high altitudes because of melting of snow and ice. Extreme

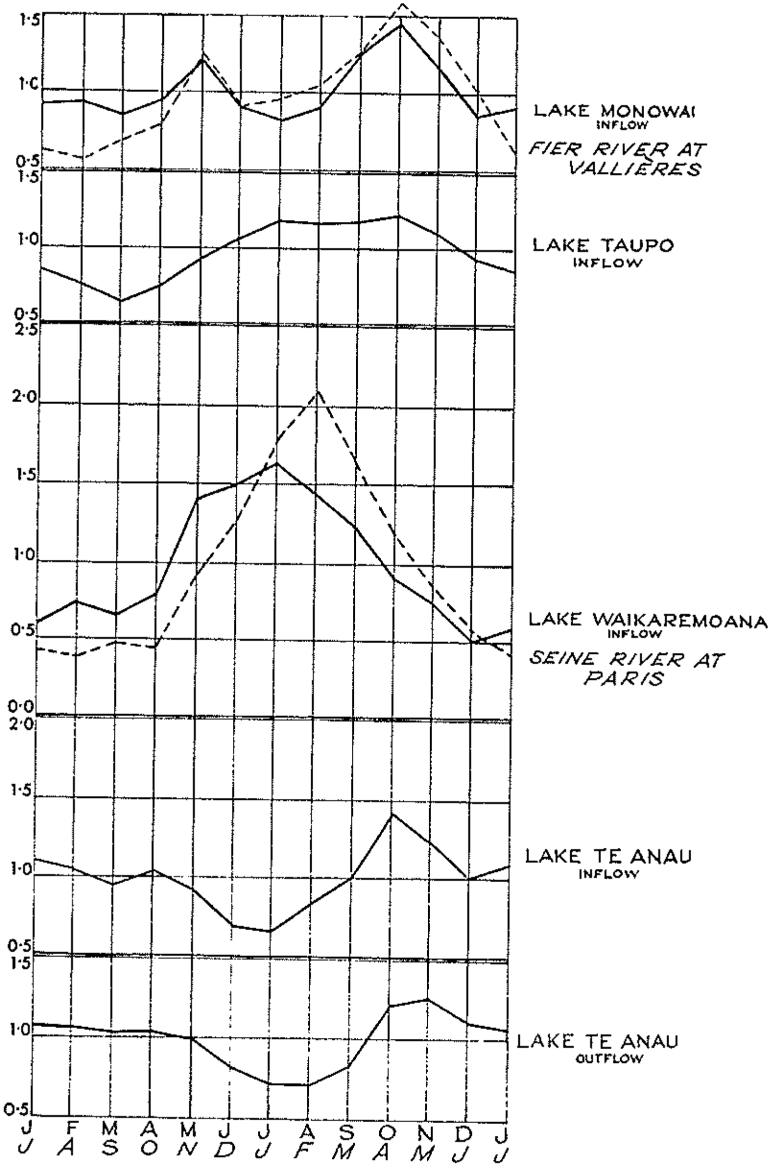

Fig. 5 — MONTHLY COEFFICIENTS (ratio of mean monthly discharge to average annual discharge) for some rivers with traditional rain-snow regimes in New Zealand and Europe. Broken lines refer to European rivers.

seasonal rainfalls can either change of favour these tendencies, e.g., a region with low winter precipitation, but a summer precipitation in excess of evaporation, will experience maximum seasonal flows in the period of greatest evaporation. Heavy summer precipitations and snow retention in winter will cause maximum flows in summer. Very high winter precipitations and extensive drought in summer (as in Mediterranean rainfall regimes) will increase the winter flow excess caused by evaporation in summer.

Changes, though not fundamental, are observed even in regimes where thermal influence is either dominant (simple regimes) or considerable (complex regimes). There may be a shift in maximum from one month to the next or the cancellation of the autumn peak (observed in Central Europe and parts of the United States) or an increase over the maximum due to snow melting (as in the Alps of France and the Appennine Mountains) or a reinforcement of the maximum or a disappearance of glacial characteristics in regions where ice melting supplies little more run-off than precipitation. There is much room for study of these features in New Zealand.

North Island

High latitudes in the North Island are subject to climatic conditions which reduce the snow factor and increase evaporation effects. The inflow of Lake Waikaremoana provides a contrasting regime to the glacial ones discussed above. Relatively low altitudes make the snow factor negligible. Copious winter rains cause a maximum in July, followed by June and then August. The minimum occurs in December.

Typical rainfall regimes are found in many North Island rivers with catchments below 3,250 ft. The effects of ground water retention cause increased flow during months when precipitation is in excess of evaporation and retard by 2 to 4 weeks the overall maxima and minima. Although little study has been done on the problem, it seems clear that topography, depth, fissuration and slope of formations, porosity, depth of surface weathering and vegetation must be considered in these areas which escape the influence of snow and which have such widely varied geological characteristics.

Lake Taupo inflow, derived partly from the highest and snowiest North Island mountain (Mt Ruapehu) shows only slight snow influence. A July to October maximum (with spring — September to October — figures slightly higher than those of winter — July to August) and a March (end of summer) minimum are observed. The inflow of Lake Arapuni, with a larger catchment, has a similar regime, but with a more pluvial bias because of lower altitudes. The equalizing effect of a natural reservoir is observed on both lakes. At Lake Taupo the maximum monthly coefficient changes from 1.14 at the inflow to 1.20 at the outflow and the minimum from 0.85 to 0.68. A shift is seen in the whole fluvial system, causing minimum flows in April instead of March. At Lake Arapuni the maximum coefficient changes from 1.06 in July to 1.10 in August, 1.02 in November, 1.01 in December and 1.03 in January. The minimum changes from 0.98 to 1.06, 0.98, 0.97, 0.99 respectively. The maximum monthly discharge occurs during September and October. This is possibly due to snow melting near Ruapehu with the retardation effect of the lake and subterranean retention of maximum winter rain.

Lake Rotoiti presents an even greater problem. As altitudes over 2,600 ft do not occur in this catchment (latitude 38 degrees) the snow cannot apparently play any appreciable role. High water levels are observed, however, from June to November, with a maximum in October too high to be attributed solely to rainfall. The October maximum may be due to retardation by subterranean flow or to slight snow retention in July-August.

Little information is available about the regimes of small rivers (not equalised by lakes) which drain the Ruapehu and Egmont mountains.

Study of the figures shows a marked lack of range in monthly coefficients. Whereas the monthly coefficients of the glacial regime at the inflow of Lake Pukaki vary from 0.36 to 2.01, those of a similar glacial regimes in Europe would have a range of 0.2 to 3.00. A transitional snow regime in the Pyrenees would have coefficients varying from 0.40-0.60 to 1.75-0.00, but those of Lake Monowai range from 0.80 to 1.42 and of Te Anau from 0.70 to 1.40. This equalisation of monthly coefficients stands in contrast to the violence of flooding and appears to be a characteristic of New Zealand hydrology.

Two reasons can be offered to explain this. The first is a consideration of the porous nature of the basic rocks in most catchment areas and the consequent high retention. The second is a climatic consideration — the better a river is supplied by annual precipitation, the less its discharge varies from month to month. The relationship between flow and precipitation is not a linear one (mainly because of evaporation and surface retention). The well balanced monthly distributions of precipitation predominating in both islands of New Zealand thus reinforce the tendency to level out monthly coefficients.

Glacial regimes present an exception to this tendency. The soils of these catchments have smallers powers of retention and the evaporation influence becomes negligible.

CONCLUSION

The high mountain ranges rising near warm seas and causing large humid air masses, make New Zealand hydrology markedly different from that of other countries with very high rainfalls. World record average annual discharges are found in catchments of between 20 and 40, or 400 and 600 sq. miles in the South Island of New Zealand.

Although in New Zealand, as in many other countries, seasonal variations in rainfall are not very great, those of discharges are. This may be attributed to varying altitudes, relative temperatures, the effects of retention and melting snow, and seasonal variations in evaporation. The whole range of regimes for temperature zones is to be found in New Zealand because of the wide variety of altitudes. Of all the regions in the high, seasonally well-distributed rainfall category, only New Zealand is subject to such devastating floods.

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