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REGIONAL HYDROLOGY OF THE CLUTHA RIVER

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The Clutha River has the largest catchment (21 400 km^2), and largest mean discharge (533 m^3/s) of all New Zealand rivers. Alone, the Clutha discharges into the sea approximately 6 percent of all the water to leave the South Island.

The catchment may be considered to consist of three regions: an alpine and subalpine region west and north of the three lakes, draining 125 km of the Southern Alps; a central area of block mountains of moderate altitude (maximum 1200–2000 m), and arid valleys and gorges with limited areas of fertile terraces and fans; and a coastal zone of lower-altitude, rolling, and flat country, including the delta area east of Balclutha.

The hypsometric curve for the catchment (Fig. 1) shows that 9300 km^2, or about 43 percent of the catchment, lies above 1000 m altitude. This area provides most of the seasonal snowmelt runoff in spring and early summer months. The permanent snowline is at around 2400 m, and only 90 km^2 of the Clutha catchment is above this level compared with 275 km^2 in the neighbouring Waitaki catchment. Hypsometric curves for the subcatchments fall roughly into the three regions mentioned (Fig. 2). The Pomahaka River is representative of the coastal zone with only 25 percent of its area higher than 500 m, and a maximum altitude of 1576 m. The Manuherikia, Lindis, and Nevis Rivers represent the central catchment area with 20–40 percent of their areas above 1000 m, and maximum elevations up to 2300 m.

The Shotover River, and the catchments of Lakes Wanaka, Hawea and Wakatipu, are the alpine zone with 80 percent of the catchment areas above 500 m and 20 percent above 800 m (Table 1).

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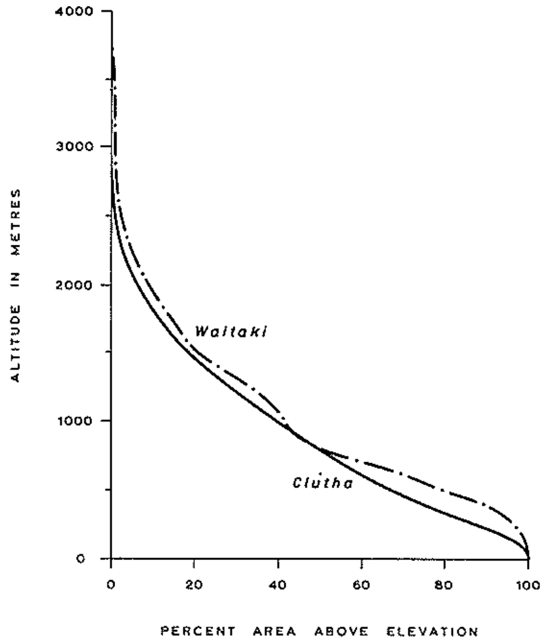

FIG. 1 — Hypsometric curves for the Clutha and Waitaki catchments.

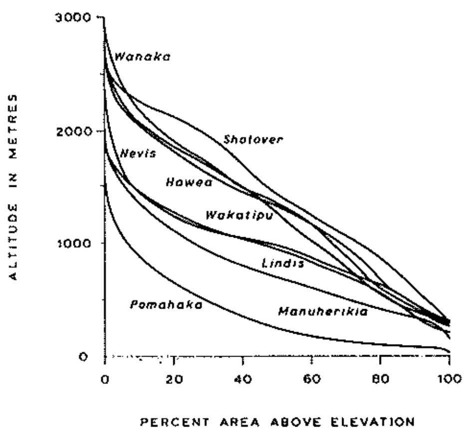

FIG. 2 — Hypsometric curves – Clutha subcatchments.

TABLE 1 — Physiographic statistics.

Catchment	*Catchment area (km²)*	*Elevation*			*Lake area (km²)*	*Mean annual discharge (m³/s)*
		Min. (m)	*Median (m)*	*Max. (m)*		
Clutha R.	21390	0	792	3036	–	533
L. Hawea	1456	323	1326	2508	119	62
L. Wanaka	2579	279	1356	3036	192	203
L. Wakatipu	7904	311	1274	2819	293	174
Shotover R.	1053	305	1448	2525	–	
Nevis R.	735	302	981	2343	–	–
Lindis R.	1058	198	951	1924	–	–
Manuherikia R.	3134	135	701	2086	–	15
Pomahaka R.	2137	23	259	1576	–	–
L. Roxburgh	15571	131	–	3036	1	492

These three lakes, which together provide approximately 75 percent of the flow at Balclutha and more than 80 percent of the flow at Alexandra, obviously have a strong influence on the hydrology of the Clutha system. They release clean, regulated water into the river system at an altitude that implies large quantities of potential energy. Their storage would be relatively easily increased or controlled, and their altitude potentially commands virtually all the irrigable land in the catchment.

OCCURRENCE OF THE WATER RESOURCE

The systems of cold fronts, depressions, and anticyclones which control the climate of New Zealand are strongly modified in the Clutha catchment by the mountains of Fiordland and the Southern Alps. The intermontane basins of the central catchment have dry climates with seasonal extremes of temperature usually associated with continental land masses.

Central Otago is renowned for low rainfall, high summer temperatures and hard frosts in winter. With increasing altitude, and also approaching the east coast, temperature ranges decrease and precipitation increases. Close to the main divide the precipitation gradient is particularly steep.

Precipitation

Data for the annual precipitation map (Fig. 3) were obtained from the N.Z. Meteorological Service (1973a). Isohyets in areas of high altitude are necessarily approximate since only 15 percent of the rainfall stations used are at altitudes greater than 500 m, and none is over 1000 m. Further, only 16 of the stations occur in the

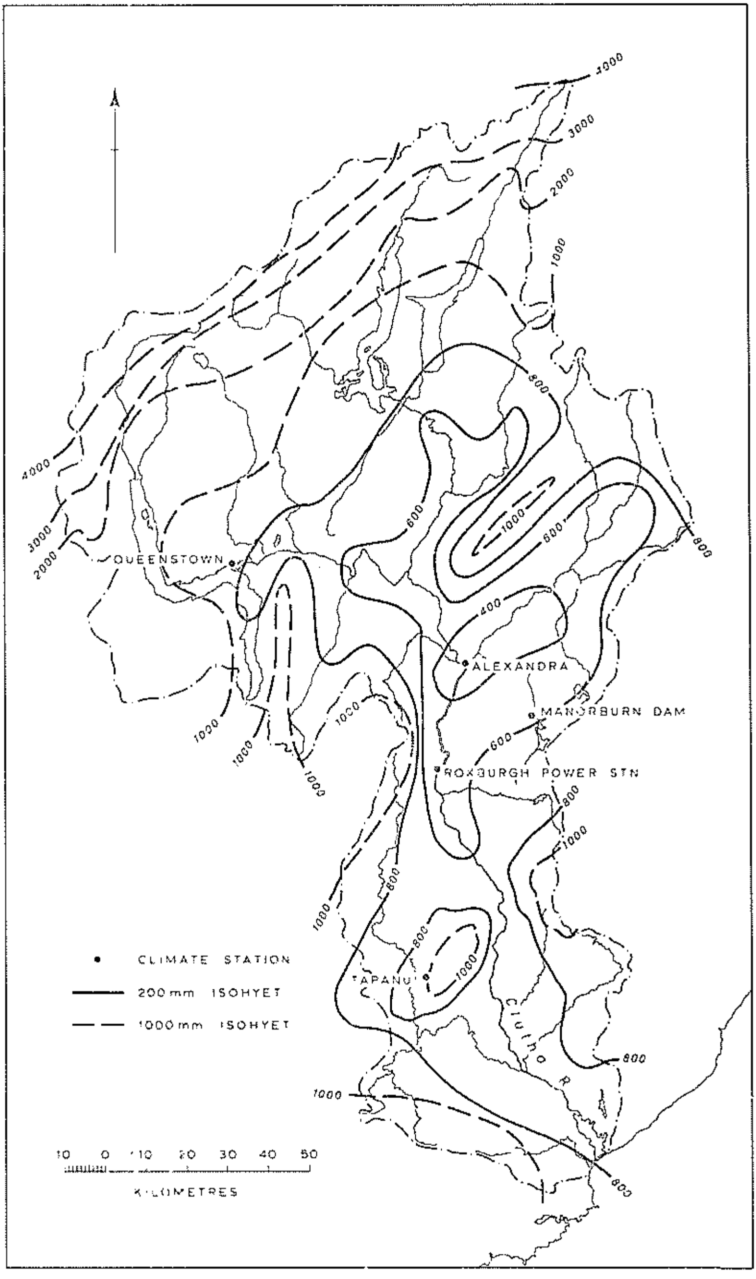

FIG. 3 — Mean annual precipitation – Clutha catchment.

area north and west of a line joining the three lake outlets. This represents a serious gap in the sampling of inputs of water to this catchment, since at least two-thirds of the catchment precipitation occurs at altitudes greater than 1000 m. A proportion of this precipitation will occur as snow, and its appearance in the streams and rivers is therefore delayed for varying periods, with important implications for water use and control.

Station annual mean precipitation ranges from 339 mm at Alexandra to 3870 mm at Haast Pass. At Milford Sound, outside the catchment but only 125 km due west of Alexandra and perhaps indicative of precipitation along the Southern Alps, the mean annual precipitation is 6236 mm.

Variations of precipitation in and close to the Clutha catchment have been studied to only a limited extent (Mark, 1965; Mark and Rowley, 1974; Hutchinson, 1968). Precipitation has been shown to increase with altitude up to around 1000 m and then to decrease slightly, though this may be a result of problems of catch efficiency in exposed conditions rather than a real effect.

Other topographic factors such as exposure, aspect, and distance from the coast have all been recognized as affecting precipitation but knowledge at present does not allow quantitative inferences of useful reliability.

The glaciers of the Clutha catchment account for about 6 percent of the total glacier volume of the South Island compared with about 45 percent in the Waitaki catchment (Table 2; Anderton, 1973). Glacier regimes are clearly less important in the Clutha than the Waitaki, but seasonal snow accumulation and melt dominate the annual water balance and streamflow pattern.

Measurements of snow accumulation are quite sparse: a short record of snow-course observations at Coronet Peak, and a longer, more useful record on the Fraser catchment (Gillies, 1964), begun by the Otago Catchment Board and now continued by the Ministry of Works and Development. The earlier work showed that snow cover was continuous above about 1400 m by September and up to 0.25 m of water was stored at the beginning of the thaw. The area could be considered representative of most of the block mountains of the central catchment. The alpine areas west of the lakes remain without quantitative observations.

Water Balance

Average monthly precipitation and water-balance data for nine climatological stations in or close to the catchment are shown in Fig. 4. These are from the N.Z. Meteorological Service climato-

TABLE 2 — Glacier resources of the Clutha. (Source: Anderton, 1973, Table 2.)

Catchment	*Glacier area (km^2)*	*Glacier volume (km^3)*
Clutha R.	77.7	3.78
L. Wakatipu	38.1	2.22
L. Wanaka	32.5	1.32
L. Hawea	4.2	0.12
others	2.9	0.12

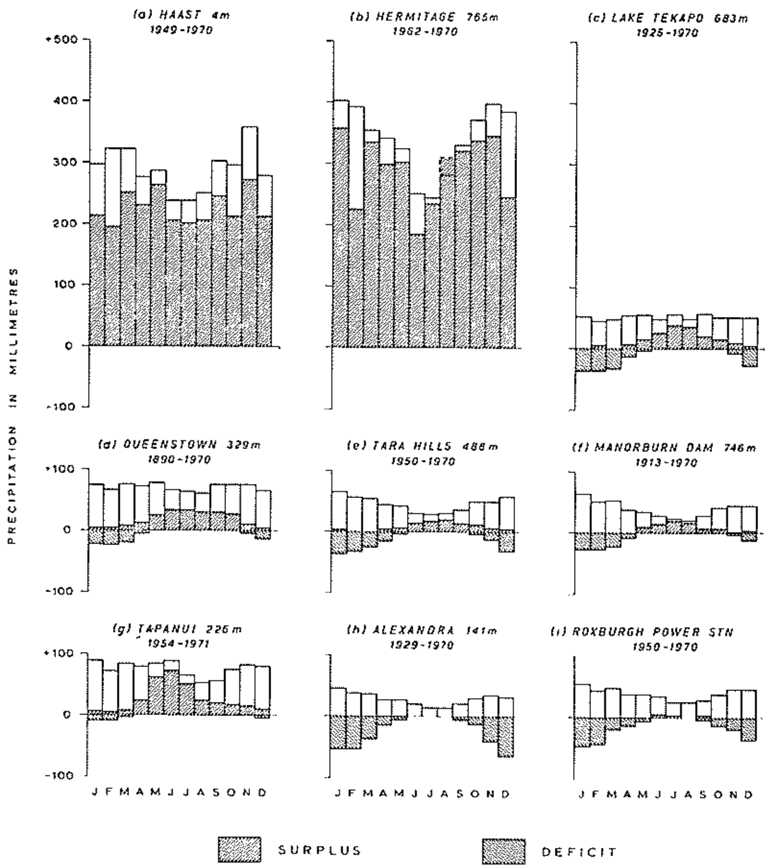

FIG. 4 — Mean monthly precipitation and water balances at selected climatological stations.

logical summaries to 1970 (N.Z. Meteorological Service, 1973b).

The data are based on an accounting of estimated daily potential evapotranspiration, daily rainfall, and soil moisture storage, assuming a maximum water-holding capacity of the soil of 75 mm. Surpluses and deficits may occur in the same month, since daily data have been used in the calculations.

The monthly distribution of precipitation at the wettest and driest stations has a marked summer maximum, but at stations with intermediate rainfall (Queenstown and Tapanui) there is no strong seasonality. Surpluses and deficits are, however, strongly seasonal in the low rainfall areas. Alexandra shows no surpluses and large deficits through the summer, while Roxburgh Power Station has a similar pattern of deficits with small surpluses in three winter months.

Comparing Manorburn Dam with Alexandra reveals some of the effects of altitude in the central catchment region: precipitation distribution and amount are similar, although considerable snow may occur at Manorburn Dam in June, July and August. Deficits are slightly less at Manorburn Dam and occur in only six months compared with eight months at Alexandra. In the six months from May there is a constant water surplus at Manorburn Dam. Throughout the Clutha Valley much of the water used for irrigation comes from small streams and tributaries with water-balance patterns similar to Manorburn Dam.

In the intermediate-rainfall areas variable water deficits are common in summer months but surpluses are likely to occur almost throughout the year.

The relatively large area of high-altitude country along the Southern Alps is tentatively represented by the stations of Haast and The Hermitage. Monthly precipitation is several times that at other stations, and although a seasonal cycle of potential evapotranspiration undoubtedly exists, the variation of water surplus is controlled by precipitation. Deficits do not occur in any month.

Streamflow

Streamflow records are available from 1930 at Lake Hawea outlet, and at Alexandra Bridge. Lake Wanaka has been monitored since 1933, and a short period of record for the Manuherikia River from 1920–30 is available. The Clutha has been measured at Lake Roxburgh, Clyde, and Balclutha since the mid 1950s.

The data here have been taken mainly from the Ministry of Works (1970) "Hydrological Statistics".

TABLE 3 — Statistics of annual discharge.

River and Site	*Period of record*	*Years*	*Mean (m^3/s)*	*Std dev. (m^3/s)*	*Coeff. of variation (%)*
Clutha at L. Roxburgh	1956–64	8	488	129.6	26.5
L. Wanaka outflow	1933–73	39	192	30.0	15.6
L. Hawea outflow	1930–71	40	62	17.4	28.2
Clutha at Alex. Br.	1930–56	26	492	65.8	13.3
Manuherikia at Ophir	1919–30	11	15	4.3	28.4
Clutha at Balclutha	1954–67	13	533	127.2	23.8

TABLE 4 — Statistics of monthly discharge.

Month	*Period*	*Min. (m^3/s)*	*Mean (m^3/s)*	*Max. (m^3/s)*	*Std. dev. (m^3/s)*	*Coeff. of var. (%)*
Clutha River at Lake Roxburgh:						
January	1957–64	332	529	1098	252	48
February	1957–64	301	532	1421	374	70
March	1957–64	261	450	974	220	49
April	1957–64	203	434	889	216	50
May	1957–64	215	501	1070	290	58
June	1957–64	277	431	724	141	33
July	1957–64	269	387	493	88	23
August	1957–64	234	396	558	107	27
September	1958–64	251	384	522	94	24
October	1958–64	421	497	657	85	17
November	1958–64	432	680	1167	221	32
December	1958–64	341	653	1397	315	48
Lake Wanaka outflow:						
January	1934–73	115	230	401	69	30
February	1934–73	88	218	571	95	43
March	1933–73	87	210	433	87	42
April	1933–73	80	198	362	71	36
May	1933–73	86	185	314	68	37
June	1933–73	87	148	248	40	27
July	1933–73	81	121	168	28	23
August	1933–73	64	120	268	45	38
September	1933–72	63	157	554	92	59
October	1933–72	104	210	374	68	33
November	1933–72	140	259	506	78	30
December	1933–72	148	262	502	72	27
Lake Hawea outflow:						
January	1931–71	3	59	148	34	58
February	1931–71	4	60	147	34	57
March	1931–71	4	52	122	31	60
April	1931–71	1	62	143	32	51
May	1931–71	5	66	170	36	55

TABLE 4 (*continued*)

Month	*Period*	*Min.* (m^3/s)	*Mean* (m^3/s)	*Max.* (m^3/s)	*Std. dev.* (m^3/s)	*Coeff. of var.* (%)
June	1931–71	3	70	243	54	77
July	1931–71	2	72	245	60	83
August	1930–71	5	56	212	45	80
September	1930–71	5	45	153	28	61
October	1930–70	2	55	143	34	62
November	1930–70	2	72	169	40	55
December	1930–70	2	67	177	38	56
Clutha River at Alexandra Bridge:						
January	1930–56	316	571	875	139	24
February	1930–56	249	557	963	184	33
March	1930–56	228	506	962	181	36
April	1930–56	271	501	854	163	33
May	1930–56	236	470	774	160	34
June	1930–56	259	403	597	90	22
July	1930–56	174	351	478	76	22
August	1930–55	216	327	541	81	25
September	1930–55	242	396	620	101	26
October	1930–55	274	565	986	183	32
November	1930–55	372	634	1244	198	31
December	1930–55	417	610	870	121	20
Manuherikia River at Ophir:						
January	1920–30	5	13	41	11	85
February	1920–30	3	9	19	6	62
March	1920–30	3	11	22	7	64
April	1920–30	3	10	23	6	55
May	1920–30	4	16	63	16	103
June	1020–30	6	12	34	8	68
July	1920–30	7	14	30	6	47
August	1920–30	8	15	23	5	36
September	1920–30	8	23	39	11	50
October	1919–30	8	31	73	18	57
November	1919–30	6	18	27	6	35
December	1919–30	6	14	33	8	56
Clutha River at Balclutha:						
January	1955–67	314	566	1211	259	46
February	1955–67	279	550	1553	335	61
March	1955–67	221	497	1097	232	47
April	1955–67	230	494	1069	230	47
May	1955–67	262	596	1201	294	49
June	1955–67	344	540	887	160	30
July	1955–67	302	450	560	72	16
August	1954–67	278	438	688	117	27
September	1954–67	292	395	576	93	24
October	1954–67	338	494	641	79	16
November	1954–67	424	662	1191	206	31
December	1954–67	348	682	1501	289	42

Means and standard deviations of annual discharge at the main stations are shown in Table 3. Approximately 75 percent of the Clutha flow is generated along the Southern Alps catchments of Wakatipu, Wanaka, and Hawea. Although periods of record are not coincident, it may be significant that the coefficient of variation at Alexandra is 13 percent while at Balclutha it is 24 percent. This may be due to the fact that most of the lower-altitude country, with runoff patterns directly dependent on the variable annual rainfall, drains into the Clutha below Alexandra.

Statistics of monthly flows are given in Table 4. The seasonal patterns of streamflow for the major tributaries and the main river are illustrated by expressing mean monthly water yield as a percentage of mean annual yield at each station (Fig. 5). Flow patterns from the three lake catchments contrast with that on the Manuherikia River, which is generally representative of the rivers draining the central catchment block mountains. On the former, minimum flows occur in late winter before the spring thaw which gives maximum flows in November and December. A second period of higher flows occurs in late autumn and early winter. On the Manuherikia the spring peak flows are more extreme, and earlier. Summer flows are very low and there is a slight rise in flow in early winter. The pattern at Balclutha is necessarily dominated by the lakes. Maximum yield is in December (10.5 percent of annual yield) and the minimum is in September (6.5 percent) just before the spring snowmelt appears. The rising water surplus of the low-altitude areas is reflected by a second rise in May (9.4 percent).

Floods

Major storms, or storms coincident with snowmelt throughout the upper catchment areas produce the most devastating floods. Most floods on the Clutha show similar characteristics – a modeately rapid rise, a prolonged peak, and a slow recession. While the storage characteristics of the lakes have beneficial effects for localized storms, once they reach a high level they retain a flood potential for a considerable time. Flood peaks at Balclutha of around 3700 m^3/s have occurred six times in the last 60 years. The 1957 flood peaked in November and continued well into the following year. The greatest flood occurred in 1878, with an estimated peak flow of 5700 m^3/s and very high flows for three weeks.

UTILIZATION OF THE WATER RESOURCE

Hydro-electric Power Development

While the Waitaki River has been intensively developed in recent years, the Clutha River has had little change. Only the

Roxburgh power station on the main river and the Lake Hawea control dam have gone into operation so far. Roxburgh has a maximum capacity of 320 MW, and only limited storage in its own lake and at Lake Hawea so that monthly generation patterns vary little from natural river flow patterns.

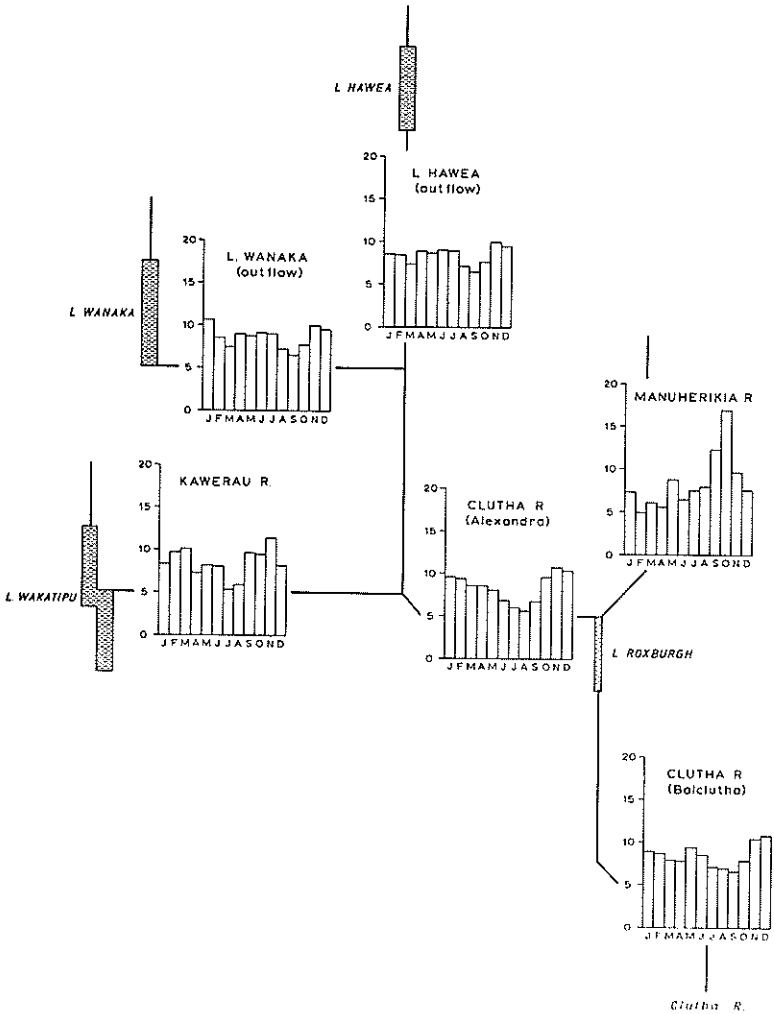

FIG. 5 — Mean monthly water yield at selected flow stations – expressed as percentages of respective mean annual yields.

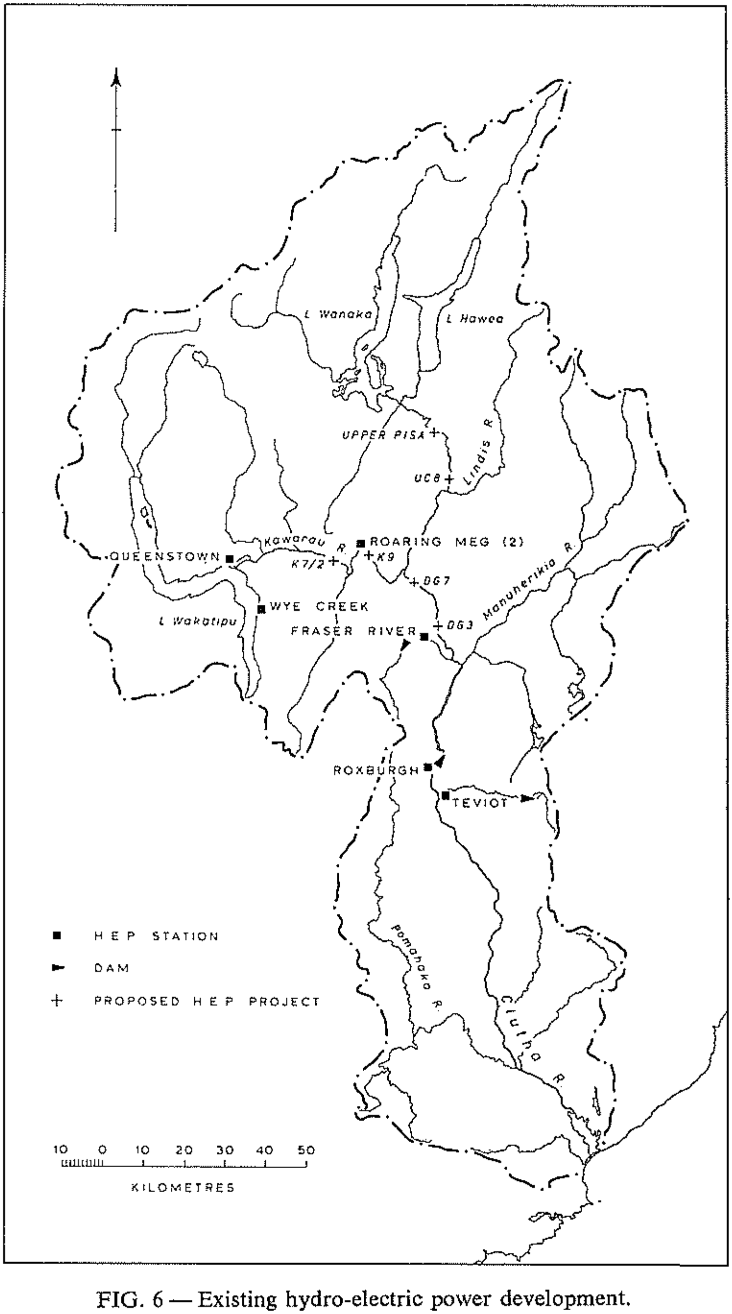

FIG. 6 — Existing hydro-electric power development.

TABLE 5 — Present hydro-electric power stations.

Station	Authority	Date of commission	Head (m)	Capacity (MW)
Roxburgh	NZED	1956	45	320
Fraser River	OCEPB	1954	243	2.5
Roaring Meg (2)	OCEPB	1936	300	2.00
		1947	125	0.25
Teviot	OCEPB	1924	117	0.8
Wye Creek	OCEPB	1927	309	0.4
Queenstown	OCEPB	1924	155	0.06

TABLE 6 — Irrigation schemes.

Name	Date of commencement	Area irrigated (km^2)	Source of water	Volume water supplied ($m^3 \times 10^6$)
Ida Valley	1917	49.9	Manorburn Reservoir	19.1
			Poolburn Reservoir	
Galloway	1920	10.8	Manuherikia River	9.2
			Manorburn Dam	
			Lower Manorburn Dam	
Manuherikia	1922	19.9	Manuherikia River	23.3
			Falls Dam	
			Chatto Creek	
Earnscleugh*	1922	8.7	Fraser River	16.9
Blackmans Extension*	1955	3.1	Fraser Dam	2.1
Last Chance	1923	9.7	Butchers Dam	7.3
Conroys	1935	2.0	Conroys Dam	–
			Butchers Creek	
			Shingle Creek	
			Gorge Creek	
Ardgour	1923	5.3	Lindis River	4.3
Teviot River	1924	14.3	Teviot River	10.2
			L. Onslow Reservoir	
Tarris	1925	10.9	Lindis River	10.0
Hawkdun–Idaburn	1929	35.8	Eweburn and Idaburn Dams	10.8
			various creeks	
Arrow River	1930	13.0	Arrow River	7.3
Omakau	1936	57.8	Manuherikia River	23.5
			Falls Dam	
			various creeks	
Pisa Flats*	1955	10.5	Clutha River	9.9
			various creeks	
Ripponvale*	1956	4.9	Kawarau River	3.4

* Pumping forms a significant part of distribution – all other schemes are predominantly gravity.

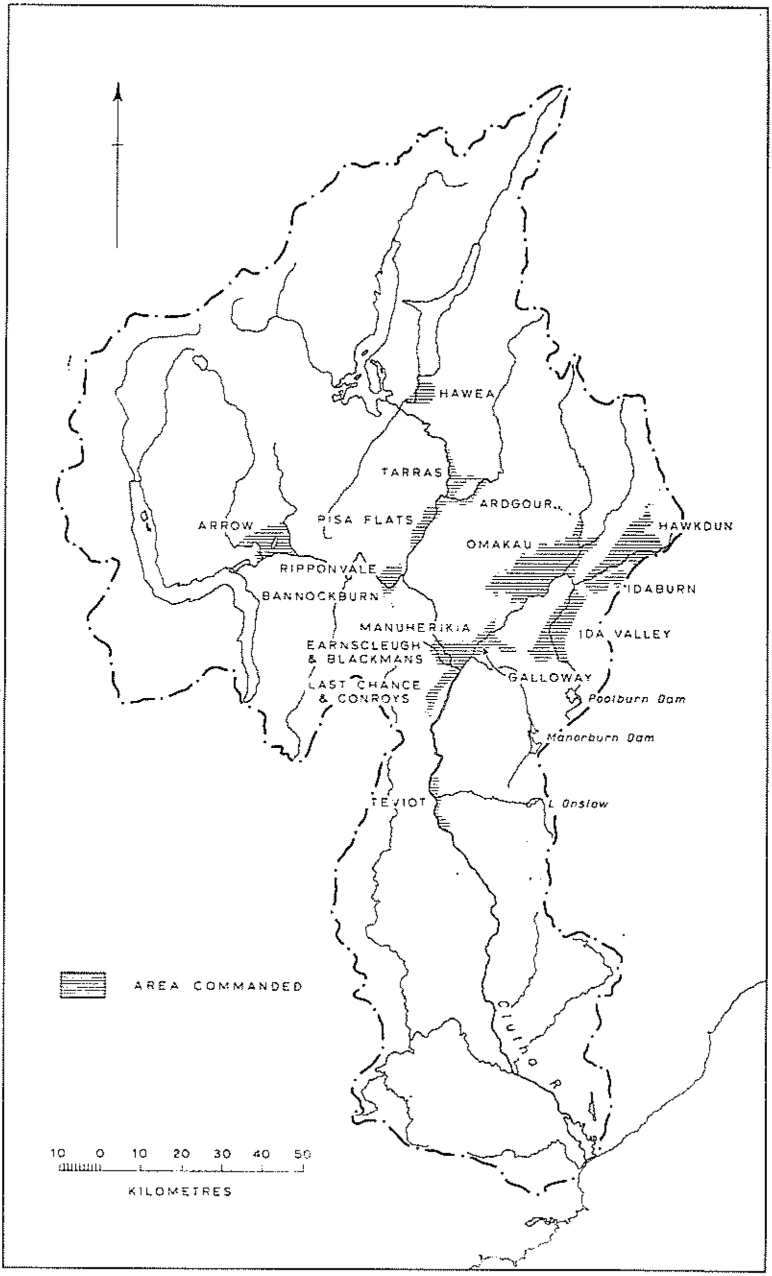

FIG. 7 — Existing government irrigation schemes.

There are several smaller stations within the Clutha catchment, operated by the Central Otago Electric Power Board, often in conjunction with irrigation schemes. The combined output of these statons is just over 6 MW, and all operate on tributary rivers rather than the Clutha itself (Fig. 6 and Table 5).

Irrigation

For the most part, major irrigation schemes developing supplies from the main rivers have not progressed for economic reasons. Considerable pumping would be necessary to raise water to the irrigable areas, since the river is well entrenched. In Central Otago several small schemes have been developed on small tributaries, some using races and rights established during the periods of gold mining. A number of private schemes are operated but the largest are operated by the Ministry of Works and Development and shown in Fig. 7 and Table 6. The irrigation season is from October to April, and on small creeks and streams this includes the periods of lowest flow.

Frequently, demand exceeds supply on these schemes. It is inevitable that as agricultural and hydro-electric developments progress, more and more conflicts of use will arise on the Clutha – particularly in view of the fact that hydro-power dams will create new water levels from which land previously uneconomic to irrigate may then be reached.

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