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NOTES ON THE HYDROLOGY OF THE WAIKATO RIVER

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GENERAL

The catchment area of the Waikato River is 5,500 square miles. If its source is accepted as being the Upper Waikato, then its distance to the sea at Port Waikato including its journey through Lake Taupo is 266 miles. It rises, together with the Whangaehu, the Rangitikei and the Wanganui, between the volcanic region of Ruapehu 9,000 ft. above sea level and the Kaimanawa Ranges 5,000 ft. above sea level.

The river flows northwards for 34 miles into Lake Taupo, losing its identity into the Tongariro for the last 26 miles to the lake. It emerges from Lake Taupo resuming its proper name and, still flowing northwards, passes for more than 100 miles through a series of lakes formed by hydro-electric dams to Cambridge. From here it continues through a deeply incised channel to Ngaruawahia where it is joined by its major tributary, the Waipa River. From Ngaruawahia to the mouth, a distance of 60 miles, shallow lakes and peat swamps predominate on both sides of the river, many of them protected and drained and developed into rich dairy farms. From Mercer, 35 miles downstream of Ngaruawahia, where slight tidal effects are discernable at low flows, the river changes its general northerly direction to a westerly one and, still 9 miles from the mouth, enters the delta. Here it is fragmented into many channels before emptying into the broad expanse of Maioro Bay and finally emerges by two fairly narrow channels into the sea on the west coast, 25 miles south of Manukau Heads.

Figure 1 shows a longitudinal section of the river from the source to the sea.

It is convenient to consider the river in three sections:

(a) From the source to Lake Taupo.

(b) From Lake Taupo to Ngaruawahia.

(c) From Ngaruawahia to the sea.

UPPER WAIKATO - SOURCE TO TAUPO

The catchment of the Tongariro at Turangi is 298 square miles. Much of the catchment and particularly the Kaimanawa Range, is covered in heavy bush containing large numbers of native trees and wide areas of mountain beech. The remainder of the catchment is either grassland or steppes of manuka and fern, while the higher reaches of the Ruapehu-Ngaruahoe-Tongariro mountains consist of sandy, ash-covered rocky ground with little or no vegetation. Ruapehu and Ngaruahoe are snow covered to approximately 4,000 feet during late winter and early spring. This snow cover retreats rapidly in early summer but Ruapehu remains capped by some small permanent snow fields and glacial ice throughout the summer months.

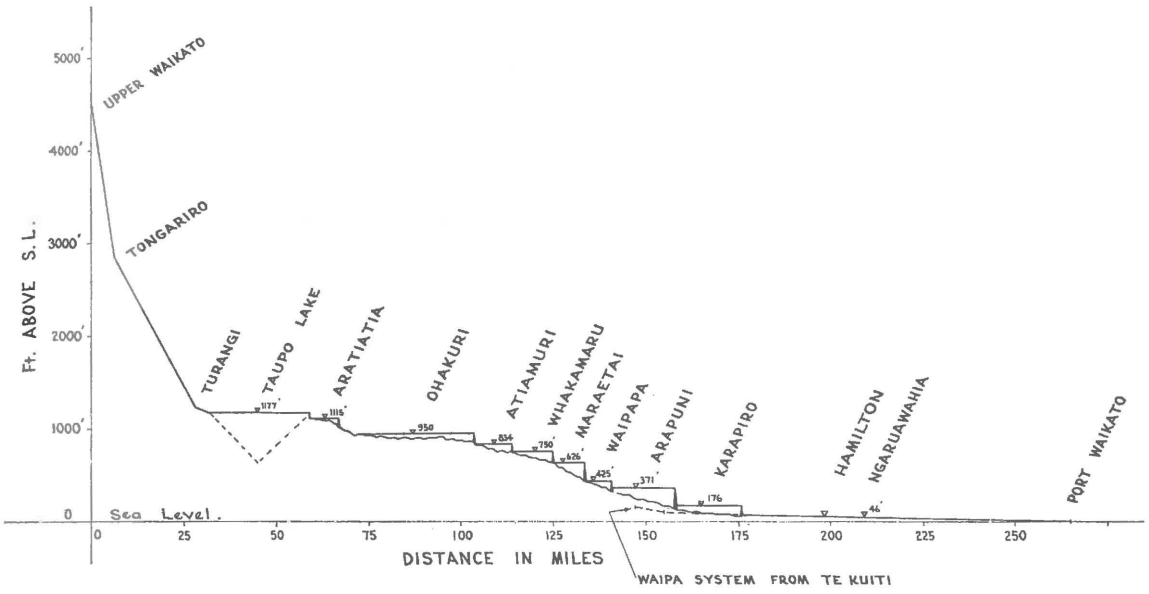


Figure 1: Longitudinal profile of Waikato River.

Annual rainfall varies from almost 169 inches at Ruapehu chairlift at 5,750 feet, to 113 inches at Chateau Tongariro 3,670 feet, and 55.8 inches at Hautu 1,260 feet. The following table indicates the monthly rainfall distribution.

	Jan.	Feb.	Mar.	Apl.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Tongariro Hatchery. 1,350 ft. 1941-58	4.36	5.22	4.10	5.36	6.72	8.13	7.26	6.79	5.36	7.28	5.69	6.60
								Total 72.87				
Rangipo 1,700 ft. 1927-58	5.70	6.16	4.69	7.01	7.44	8.44	7.73	7.66	6.29	7.99	6.92	6.92
								Total 82.99				
Okupata 3,260 ft. 1954-58	5.44	8.52	6.62	7.69	11.65	10.10	8.31	9.73	5.19	8.54	8.50	12.11
								Total 102.40				
Chateau Tongariro 3,670 ft. 1927-58	7.97	8.80	6.61	9.63	10.10	10.97	9.63	9.54	8.48	10.87	9.91	10.63
								Total 113.14				

Runoff is indicated by the following table taken from Sir Alexander Gibbs Report on Investigations, Tongariro River Power Development.

TONGARIRO at TURANGI — YEARLY FLOWS AND LONG TERM MEAN FLOW

Year	Rainfall Inches	Runoff Cusecs	Runoff Inches	Apparent Loss
1949	103.8	1936	88.1	15.7
1950	84.7	1406	64.0	20.7
1951	102.9	1839	83.7	19.2
1952	121.8	2187	99.8	22.0
1953	113.7	2048	93.2	20.5
1954	90.0	1642	74.8	15.2
1955	113.8	2808	94.7	19.1
1956	124.7	2279	104.0	20.7
1957	97.0	1782	81.1	15.9
1958	119.3	2030	92.6	36.7
1959	92.6	1736	79.0	13.6
1960	93.6	1735	79.2	14.4
Average	104.9	1892	86.2	17.1

The value of 1880 cusecs has been adopted (1964) for the average flow at Turangi; this runoff is equivalent to 83% of annual rainfall.

From Turangi the river flows through 6 miles of (braided) delta into Lake Taupo, 1,170 feet above sea level. At the outflow to the lake the catchment increases to 1,270 square miles but of this the lake itself contributes 236 square miles. The volume per foot of lake storage is 76,150 cusec days. Such tremendous storage, combined with a controlled outlet, can and does have considerable effect in modifying the natural flows from the upper catchment. The value of 4,260 cusecs is the average discharge from Lake Taupo during the period 1941-1960, that is, since the control gates have been in operation.

MIDDLE WAIKATO - TAUPO TO NGARUAWAHIA

The Waikato Catchment between Lake Taupo and Ngaruawahia is 1,950 square miles. The land cover is made up as follows:

Grasslands	1,090 square miles
Tussock, scrub and fern	220 square miles
Indigenous Forests	190 square miles
Exotic Forests	435 square miles
Swamp	15 square miles

These figures were derived from a map prepared by the Ministry of Works in 1963.

Land development in this part of the Waikato valley was retarded initially by an undiscovered cobalt deficiency and later by pre-occupation with World War II, until the immediate post-war years when the demands for rehabilitation settlement resulted in a rate of development from native to productive pastures unprecedented in New Zealand. There is evidence that this change in land cover has led to greater surface runoff, especially in increased peak discharges and this is now being analysed in an experimental catchment. Up to now the easier land has been developed and further progress can only be made in less fertile and steeper areas. The figures shown above indicate the large areas of land still with protective tree and scrub cover, and they underline the hydrological impact that widespread and haphazard development or change would have on the catchment.

From Lake Taupo the river emerges through control gates whose maximum discharge is 10,000 cusecs. It passes through eight hydro-electric lakes in the following order and with the following detail:

Lake	General Level (Ft. above S.L.)	Lake Catchment (Sq. Miles)	Catchment in Square Miles from Lake Taupo
Aratiatia	1,110	0.22	—
Ohakuri	950	5.00	630
Atiamuri	836	0.85	740
Whakamaru	750	2.75	962
Maraetai	627	1.95	1,189
Waipapa	427	0.61	1,287
Arapuni	323	3.60	1,383
Karapiro	176	3.00	1,707
Total		17.98	1,707

It can be seen therefore that the lakes can have only a minimal effect on the natural flow pattern.

The following statistics of rainfall and runoff refer to the catchment between Taupo and Hamilton rather than Taupo and Ngaruawahia, because of the complicating effect of the Waipa flows at Ngaruawahia.

The average rainfall, and its distribution between Taupo and Hamilton for the period 1921-1960, derived from weighted means, is as follows:

	Jan.	Feb.	Mar.	Apl.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Rainfall in inches	4.18	4.36	3.29	4.69	5.48	5.96	5.27	5.02	4.32	5.17	4.39	4.35

Yearly Mean: 56.42

In the same region, and for the same period (that is, between Taupo and Hamilton), the following monthly average flows were recorded at Hamilton.

Catchment: 3,178 square miles

	Jan.	Feb.	Mar.	Apl.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Runoff in cusecs	7600	7690	7300	7020	7670	8350	8990	9170	8980	9010	8500	7820

Yearly Average Flow: 8180 cusecs

Runoff in inches	2.76	2.52	2.65	2.46	2.78	2.93	3.26	3.33	3.15	3.27	2.98	2.84

Yearly Mean Runoff: 34.94 inches

The following per cent runoff can therefore be derived.

	66.0	57.8	80.6	52.4	50.7	49.2	61.8	66.3	73.0	63.3	68.0	65.3

Yearly Mean: 62%

LOWER WAIKATO - NGARUAWAHIA TO THE MOUTH

At Ngaruawahia the Waikato is joined by its major tributary, the Waipa River. The Waipa River has a catchment of 1,180 square miles and rises in the Rangitoto Ranges over 100 river miles from Ngaruawahia. The total Waikato catchment at Ngaruawahia now becomes 4,400 square miles.

From Ngaruawahia the river flows through the Hakarimata-Taupiri Range, whose peaks scarcely exceed 1,000 ft., to Huntly, and then through a series of alternating low basins and rolling hills to the sea.

The low basins include peat swamps and shallow lakes where there was formerly a complex interplay of flow to and from ponding, together with tributary catchment flows. This is being modified by the River Control Scheme now being constructed, which will allow further development in the area.

The following tables show the average monthly discharges at Ngaruawahia and Mercer for the periods when automatic water level recorders became available. Discrepancies exist because of the different years used for the records.

Station: Ngaruawahia—Catchment 4,400 square miles—1960-1966

	Jan.	Feb.	Mar.	Apl.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Flow in cusecs	8540	9180	10380	8980	11170	14050	16570	14510	14430	12670	11460	9820
Runoff in inches	2.24	2.17	2.72	2.36	2.91	3.70	4.34	3.80	3.80	3.32	3.01	2.57

Mean Yearly Runoff: 36.94 inches

Station: Mercer—Catchment 5,288 square miles—1964-1966

Flow in cusecs	10150	11560	13330	9690	13170	15240	20750	20920	17950	14570	12200	9850
Runoff in inches	2.12	2.28	2.78	1.96	2.75	3.08	4.33	4.36	3.62	3.04	2.46	2.05

Total Yearly Runoff: 34.83 inches

No weighted mean rainfalls have been developed for the total catchment.

HYDROLOGICAL OBSERVATIONS

The Waikato Valley Authority was formed in 1957 and among other things it was charged with the collection of hydrological data; to this end it has established, as well as staff gauges, numerous automatic water level recorders at reasonably close intervals throughout the catchment—Figure 2 indicates the position of the main stations. It has also developed Rating Curves (discharge/water level relationships) at key points throughout the catchment. This, of course, has included flood gaugings and the measurement of low flows, the latter being aimed particularly at determining minimum discharges for future record in relation to catchment water resources.

However, the scope of this article is such that the emphasis has been placed on general hydrological descriptions, mean flows and simple water balances rather than extreme high or low flows.

Initially much of the hydrological emphasis had to be concentrated on the evaluation of the limited data available and this, together with hydrological measurements made during the first two years were directed towards the determination of Design Flood discharges and levels both for the Waikato and the Waipa Rivers.

Much valuable data was derived from the 1958 flood, the second highest flood of the century, which occurred within these two years.

RIVER BED SURVEYS

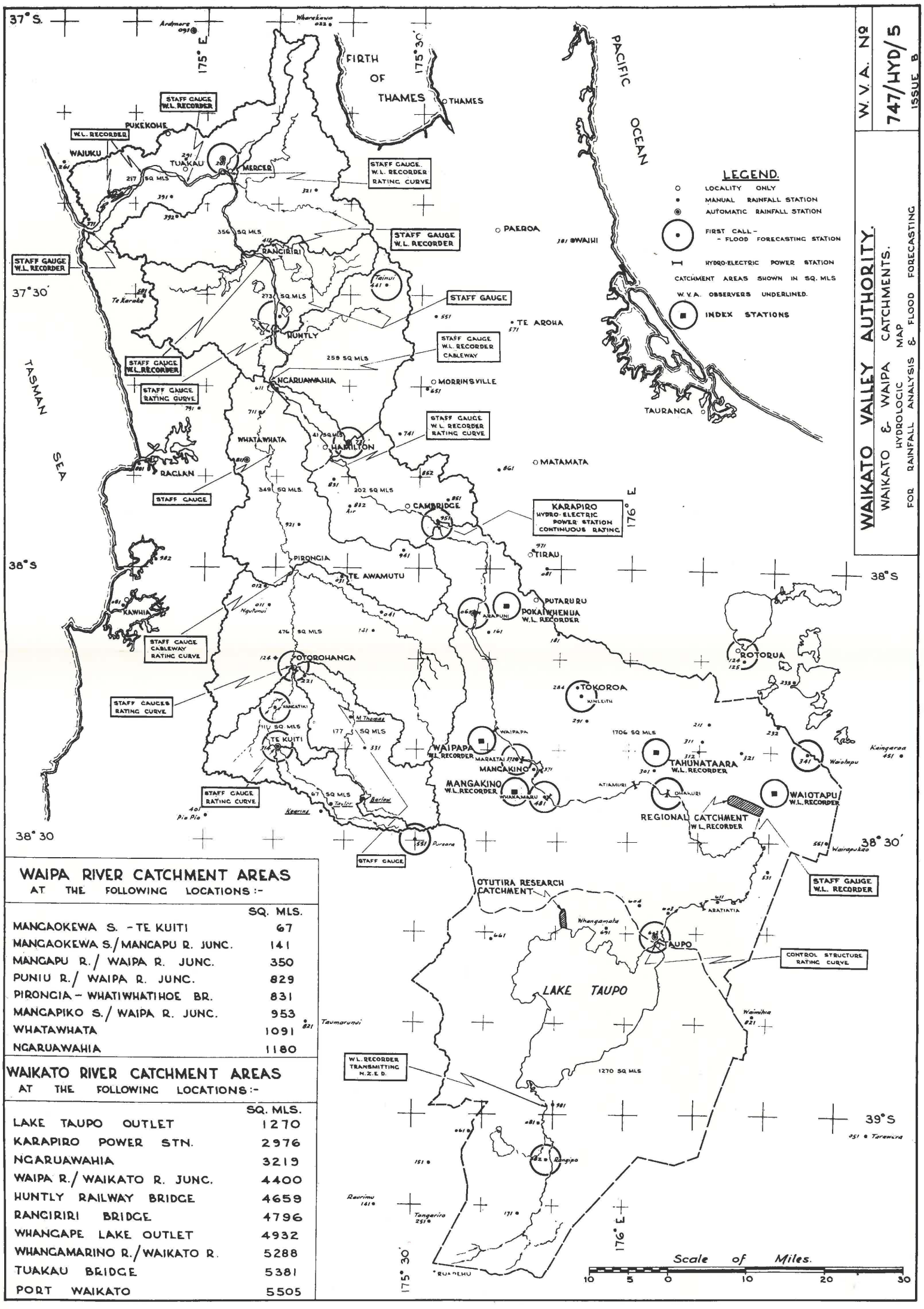
The Authority has also enlarged the scope of the original river sections so that now these exist at approximately 35 chain intervals in the lower Waikato, and at greater intervals on the Waipa River. As well as being necessary for hydraulic analysis, the periodic surveys of these sections are keys to the behaviour of the river bed, and comparison is possible at intervals since the original survey of the Waikato River by the Department of Lands and Survey in 1913.

Bed Form Surveys

Naturally, this has led to an examination of the changing shapes of the bed itself from the point of view of determining quantitative bed loads and of relating bed forms to channel geometry, flow pattern and type of material in the bed, ultimately with the aim of defining a stable channel. To this end the Authority has established four research reaches: at Huntly, Churchill East, Meremere and the Whitebait Factory at the entrance to the delta. Each reach is approximately a mile long and longitudinal sections are taken at 40 feet intervals across the stream. Since this can involve over 20 sections, a mile long, in a series of observations reasonably close in time, the work is only possible by using an echo sounder. The study is in its initial stages but since the writer has no other knowledge of similar studies on such a large prototype, it might be interesting to note some preliminary results.

At Huntly, over a reach which is 1,200 feet wide, and where the bed material has a mean diameter of between 0.7 mm. and 1.0 mm. between June 1966 and January 1967, a wall varying in height from 7 feet to 9 feet has been observed to move downstream 660 feet. This is an average movement of about 3 feet a day. (During normal flow of 12,000 cusecs the depth of water on the upstream edge of the face would not exceed 2 or 3 feet). During the above period 15 sets of observations were made of the movement of the face. This was to enable a correlation to be attempted between discharge/rate of travel/and bed load. The displacement of the face between measurements can be calculated, and in this reach this is assumed to be the quantity of bed load movement. An interesting aspect of this feature is that the upstream level of the bed level has remained relatively unaltered in the six months of observation.

At Churchill East, in a reach approximately 900 feet wide and in bed material similar to that at Huntly, the bed forms have an entirely different character and consist of dunes 250 feet to 300 feet long and approximately 5 feet high. The movement varies between 8 to 20 feet a day. It is again possible, by measuring areas swept by the dunes, with allowance for change in bed level, to evaluate bed load. Each dune is identified and mapped from the time it enters the reach to the time it leaves. Intervals of soundings are here dictated by the necessity of identifying dunes which tend to deform as they pass through the reach. In this reach there is a positive correlation between discharge and bed load.



WAIPA RIVER CATCHMENT AREAS
AT THE FOLLOWING LOCATIONS :-

	SQ. MLS.
MANGAOKEWA S. - TE KUITI	67
MANGAOKEWA S./ MANGAPU R. JUNC.	141
MANGAPU R./ WAIPA R. JUNC.	350
PUNIU R./ WAIPA R. JUNC.	829
PIRONCIA – WHATIWHATIHOE BR.	831
MANGAPIKO S./ WAIPA R. JUNC.	953
WHATAWHATA	1091
NGARUAWAHIA	1180

WAIKATO RIVER CATCHMENT AREAS
AT THE FOLLOWING LOCATIONS :-

	SQ. MLS.
LAKE TAUPO OUTLET	1270
KARAPIRO POWER STN.	2976
NGARUAWAHIA	3219
WAIPA R./ WAIKATO R. JUNC.	4400
HUNTLY RAILWAY BRIDGE	4659
RANGIRIRI BRIDGE	4796
WHANGAPE LAKE OUTLET	4932
WHANGAMARINO R./ WAIKATO R.	5288
TUAKAU BRIDGE	5381
PORT WAIKATO	5505

Figure 2: Location of recording stations for hydrological data, in the Waikato and Waipa catchments.

At Meremere where the reach is over 1,000 feet wide, studies have been confined to mapping the bed and producing contour maps at weekly intervals, while at the Whitebait factory the control survey is not yet completed.

CATCHMENT RESEARCH

The Authority is associated with the Ministry of Works and Department of Agriculture in the development of Experimental Basins for the detailed study of rainfall runoff relations under conditions of changing land cover.

One such basin has been adopted in the pumice plateau on the north-western shore of Lake Taupo. It has an area of 740 acres which, apart from about 30 acres in grassland, is covered with native scrub growth. The catchment is meticulously instrumented and in such a way as to enable the basin to be examined both as a whole and in sub-catchments. Data is to be collected for a period up to 5 years in its natural state, when the catchment will be developed into grass under various forms of land management. The hydrological effect of these changes will then be assessed.

A comparison is already possible between a small grassed catchment of 11 acres and the main body of the catchment under the cover of scrub.

The following preliminary observations are given by the Hydrological Section of the Ministry of Works and are comparisons of the 11-acre grassed catchment with the 740-acre total basin:

(a) Peak storm flows from the grassed catchment produce approximately 3 times the peak flow of the total basin.

(b) Total volume of storm runoff from the grassed catchment is approximately 4 times that of the total basin.

(c) The percentage of runoff to rainfall in the grassed catchment is 4%.

(d) The percentage of runoff to rainfall in the total basin is 1%.

Since detailed observations of surface runoff have commenced only in January 1967, no elaborate conclusions can be drawn at this stage.

ACKNOWLEDGMENTS

I am grateful to the Chief Engineer of the Waikato Valley Authority, Mr H. C. C. Jones, for permission to publish these notes and to reproduce the attached maps.

I must also acknowledge the data that I have used from Sir Alexander Gibbs' "Report on Investigations, Tongariro River Power Development".