MANUHERIKIA RIVER FALLS DAM

SPILLWAY CAPACITY AND DESIGN FLOOD STUDY

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INTRODUCTION

As part of the Ministry of Works and Development's dam surveillance programme we were asked to review the flood hydrology and spillway capacity and adequacy of the Falls Dam. This is an irrigation storage reservoir situated at the head of the Manuherikia River. Because this is a rock-fill dam with a glory hole spillway we considered that we should use the best possible methods for estimating design floods and at least two independent methods. The two methods used were flood frequency methods, extending the regional method of Beable and McKerchar and unit-graph methods using data derived from the neighbouring lower Waitaki catchments and runoff-rainfall relationships for both the Lower Waitaki and Manuherikia River.

HISTORY

The Falls Dam was built in about 1935. No continuous hydrological record was available at the site but concurrent gaugings at the dam site and at the Ophir site of the Manuherikia River were made. These were used to estimate monthly mean flows and design flood flows from the flow record of the Manuherikia River at Ophir. The design flood was based on the River Commission's estimate of the 1878 flood at Ophir. This transferred to the damsite gave a design flood of $408m^3/s$. Model tests of the spillway showed that it had a maximum capacity of $439m^3/s$.

TABLE 1 : ANNUAL FLOOD SERIES MANUHERIKIA RIVER AT OPHIR

Year	Maximum flow (m^3/s)	Year	Maximum flow (m^3/s)
1878	821	1971	126
1919	495	1972	134
1920	54	1973	329
1921	128	1974	146
1922	125	1975	138
1923	222	1976	264
1924	162	1977	55
1925	75	1978	317
1926	80	1979	82
1927	150	1980	356
1928	136	1981	63
1930	125	1982	160
1957	161	1983	251
1958	396		

mean annual flood = 177 m^3/s

The mean annual flood at the d/s forks site (1977-83) was adjusted to the long term mean annual flood by comparison with the Ophir site.

mean annual flood d/s forks (1977-83) = 41.7 m^3/s

mean annual flood ophir (1977-83) = 183 m^3/s

therefore mean annual flood d/s forks (long term)

$$= \frac{41.7}{183} \times 177$$

$$= 40.3 \ m^3/s$$

No flow records either into or out of the Falls Dam are obtainable but a water level recorder was established in 1975 and records flows from about half the catchment of the Falls Dam.

FLOOD FREQUENCY ANALYSIS

The annual flood series of the Manuherikia at Ophir (Figure 1) was used to derived a relationship between floods of given frequency and the mean annual flood. The regional relationship given by Beable and McKerchar (1982) was fitted to these points and were used to give the flood frequencies for the Falls Dam (Figure 2). A check was made to see that they were consistent with the annual flood series of the Manuherikia at d/s forks (Figure 2), the site above the Falls Dam.

The catchment area of the d/s forks site is 174 km^2 and this yields 230 l/km^2 in the mean annual flood. This is used to estimate the mean annual flood for the 364 km^2 catchment of the Falls Dam. Examination of storm isohyets showed that the additional catchment was likely to have a similar specific discharge to the catchment above the d/s forks site.

$$\text{Mean annual flood Falls Dam} = 40.3 \times \frac{364}{174} = 83.7\ m^3/s$$

TABLE 2 : FLOOD FREQUENCY ANALYSIS - MANUHERIKIA RIVER

Return period (years)	Ophir (m^3/s)		Falls Dam (m^3/s)	d/s forks (m^3/s)
mean annual flood, Q	177	ratio with Q	83.7	40.3
5	265	1.49	125	60
10	350	1.97	165	79
20	440	2.49	208	100
50	560	3.16	265	127
100	660	3.73	312	150
200	766	4.33	362	175
500	910	5.14	430	207

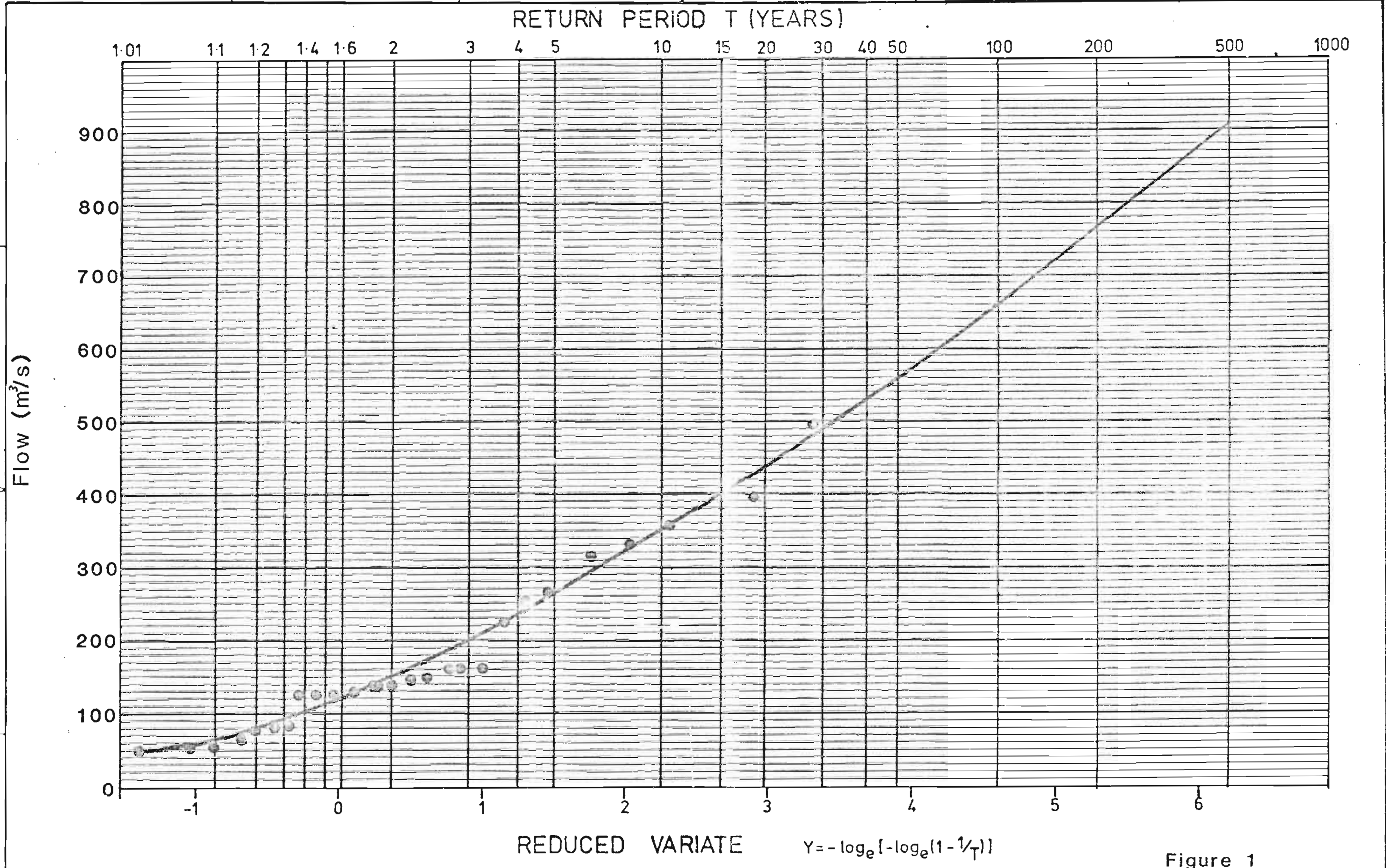

Figure 1

Ministry of Works and Development

POWER

Manuherikia at Ophir.

GUMBEL FREQUENCY ANALYSIS

AMENDMENTS	BY	APPD	DATE	BY	CHECKED	DATE	APPROVED	ORIGINAL SCALES	FILE	JOB	CODE	SHEET	REVISION

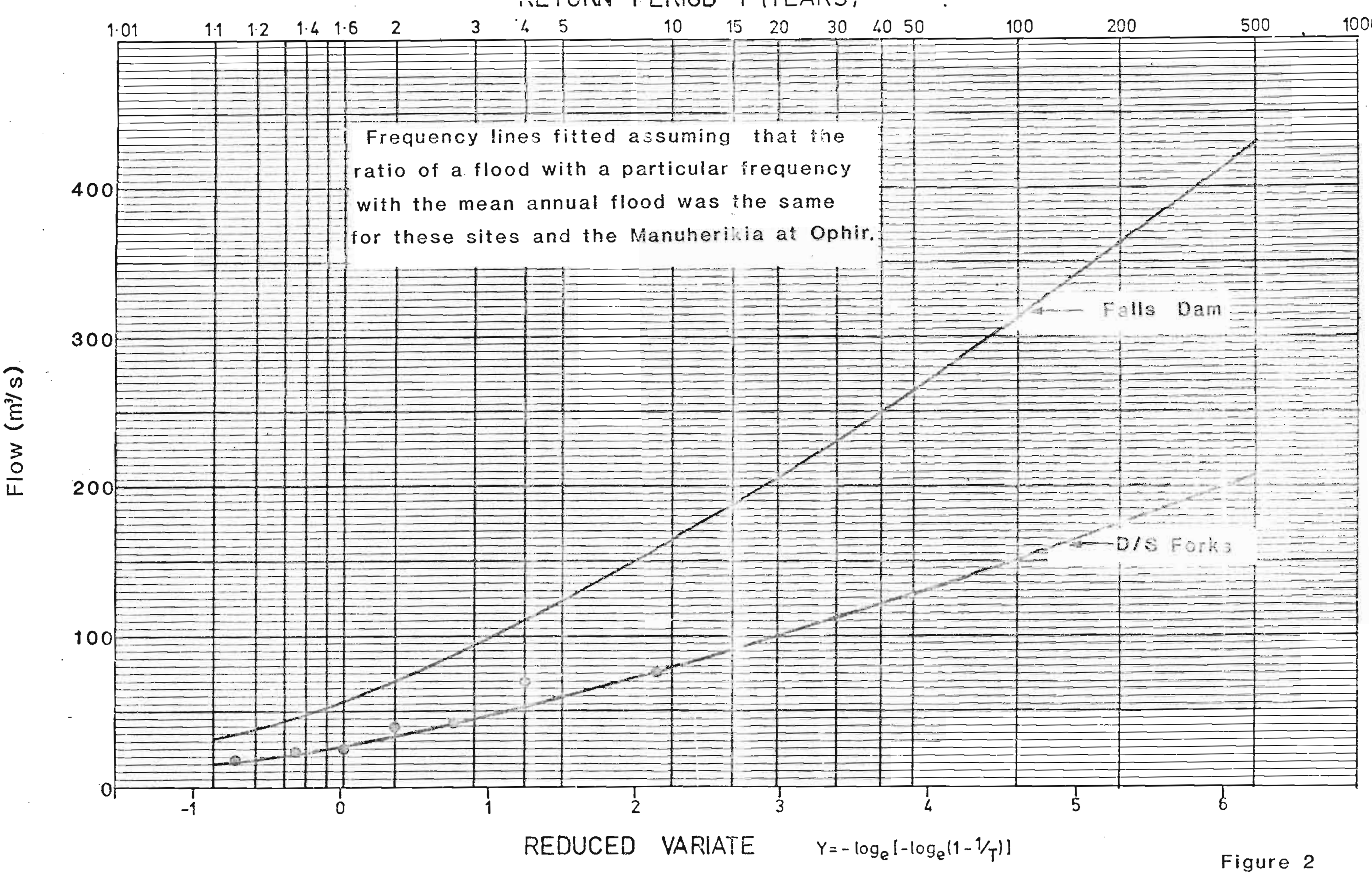

Figure 2

AMENDMENTS	BY	APP'D	DATE	
BY	CHECKED	DATE	APPROVED	
Ministry of Works and Development	POWER	Commissioner		
Manuherikia at D/S Forks and Manuherikia at Falls Dam. GUMBEL FREQUENCY ANALYSIS	ORIGINAL SCALES	FILE		
JOB	CODE	SHEET	REVISION	

ORIGINAL SIZE mm

LOCAL OR TRACING NO.

W 295 - A 3

Jun 1976

Whole numbers = mm

Decimalised expressions = m

Table 2 shows the results of the flood frequency analysis where the floods of specified return period have been obtained by multiplying the mean annual flood by the ratio of the Ophir flood of that return period to the Ophir mean annual flood. These frequency curves are plotted on Figures 1 and 2.

FLOOD ESTIMATION BY UNIT GRAPH

Estimation of design flood hydrographs has three main steps in the method :

1 Design storm, volume and temporal pattern
2 Rainfall-runoff relationship
3 Unit hydrograph.

1 The volume of the design storm was taken from an isohyetal map drawn to the 9 am to 9 am 500 year point rainfalls for all raingauges in and about the catchment. Topography and aspect were taken into account and it was assumed that storm isohyets would be similar to those of mean annual rainfall. The daily 500 year rainfall (9 am to 9 am) was converted to 24 hour by multiplying by 1.13. The 500 year 24 hour rainfall of 147 mm was derived by planimetering the isohyets over the Falls Dam catchment. (Figure 3)

It was conservatively assumed that 500 year rainfalls of 1 hour, 3 hour, 6 hour and 12 hour durations would occur within the 24 hour 500 year rainfall. Tomlinson's "The frequency of high intensity rainfalls in New Zealand, Part 1" were used to define the ratios of the various durations to the 24 hour rainfall. This showed that 75.5% of the rainfall can fall within a 12 hour period and, within this 12 hours, 54.5% can fall in a 6 hour period, 39% in 3 hours and 23% in one hour.

Maximum One Day Rainfall 500 Year Return Period.

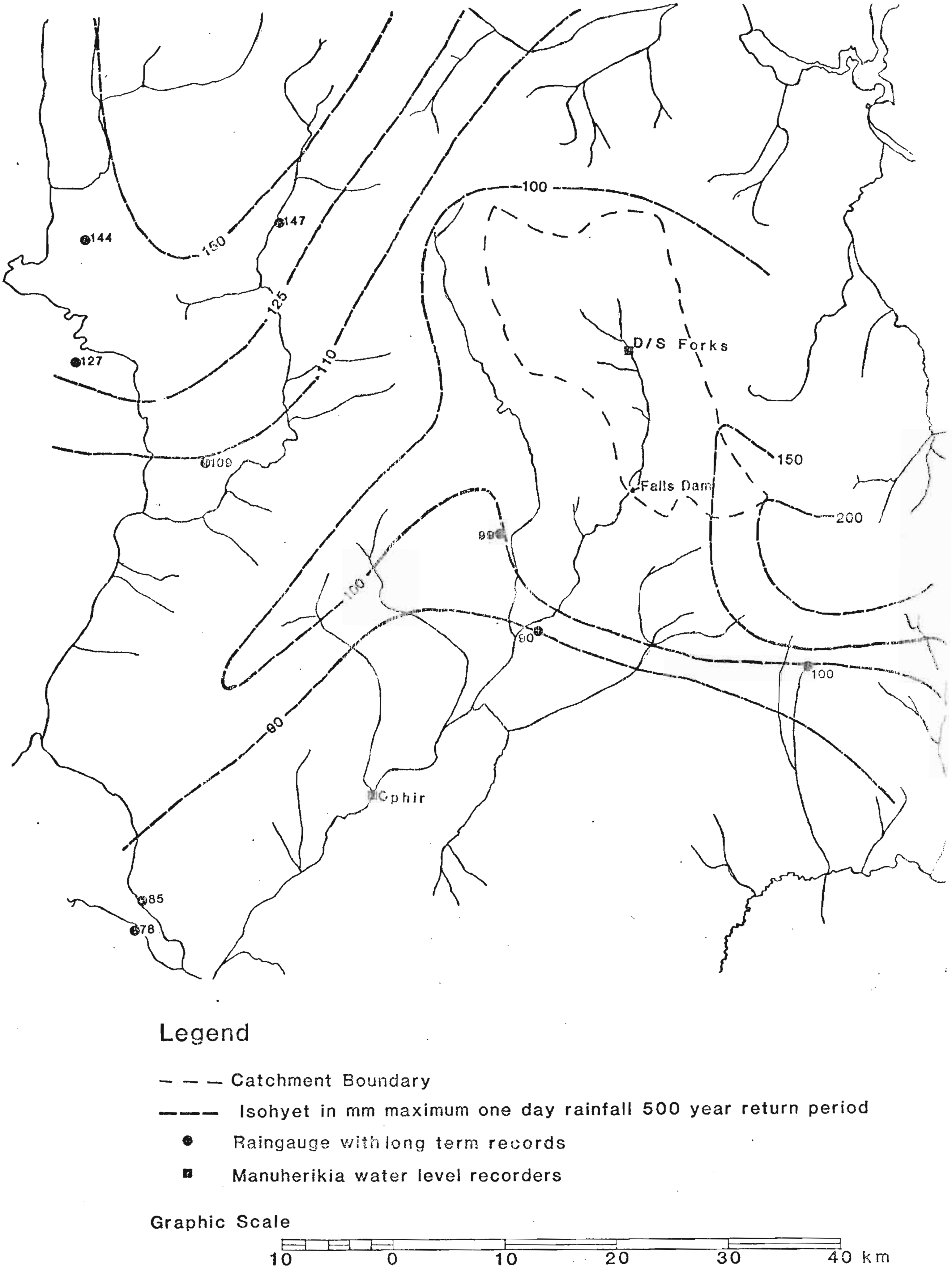

Figure 3

TABLE 3 : DESIGN STORM - 24 HOUR

Time (hrs)	rainfall (mm) incremental	accumulated
0 - 6	15	15
6 - 12	21	36
12 - 13	33	69
13 - 15	24	93
15 - 18	23	116
18 - 24	31	147

Thus the maximum rainfall intensity within the design storm, and the one which creates peak runoff, is 33 mm in one hour and 57 mm over the 3 hour period.

Rainfall-runoff relationships were derived for the Manuherikia at Ophir 8/1190/16/1804/7 in the report "Clutha Power Development - Design Floods and Flows" and relationships for the Hakataramea, Otekaieke and Maerewhenua have been derived for the Lower Waitaki hydrological study (8/11101/16/1804/1).

These four relationships predict remarkably similar storm runoff volumes for a rainfall of 147 mm, ranging from 23 mm for the Otekaieke to 47 mm for the Hakataramea with an intermediate value of 41 mm for the Manuherikia at Ophir. It was realised that the storm runoff generated by the design rainfall was one of the most important aspects of this study so the few recorded floods at the d/s forks site of the Manuherikia were analysed and the results compared with the rainfall-runoff relationship for the much larger catchment at Ophir. The runoff from the smaller higher altitude catchment was very similar to that at Ophir. The rainfall runoff curve was extrapolated following the Hakataramea curve and a runoff of 50 mm obtained for the Falls Dam and d/s forks catchments.

Applying a runoff of 50 mm to the temporal pattern of the design storm (table 3) and assuming a uniform loss rate the following pattern of storm runoff was calculated.

TABLE 4 :

Time (hrs)	Storm runoff (mm) incremental	accumulated
1	2.8	2.8
2	2.8	4.8
3	2.8	7.6
4	7,1	14.7
5	7.1	21.8
6	28.1	49.9

Unit hydrographs were derived for the Lower Waitaki catchments of the Hakataramea, Otekaieke and Maerewhenua Rivers. When the unit graph flow ordinates were scaled according to their catchment areas they were virtually the same. This was then used as a form of regional dimensionless unit graph which when multiplied by the catchment area of the Falls Dam gave the Falls Dam 1 hour unit hydrograph.

This unit hydrograph was transformed into a flood hydrograph for six successive periods of one hour rainfalls with the highest at the end of the storm. (Table 4). Baseflow was added giving a flood hydrograph with a peak discharge of 468 m^3/s.

FLOOD ROUTING

The design flood hydrograph was routed through the reservoir assuming a reservoir area of 1.11 km^2 and a computed discharge-level rating curve (Figure 4) for the glory hole spillway. This gave only a 7% reduction in peak outflow because of the relatively small lake area. If the design flood had been

Falls Dam Spillway Rating

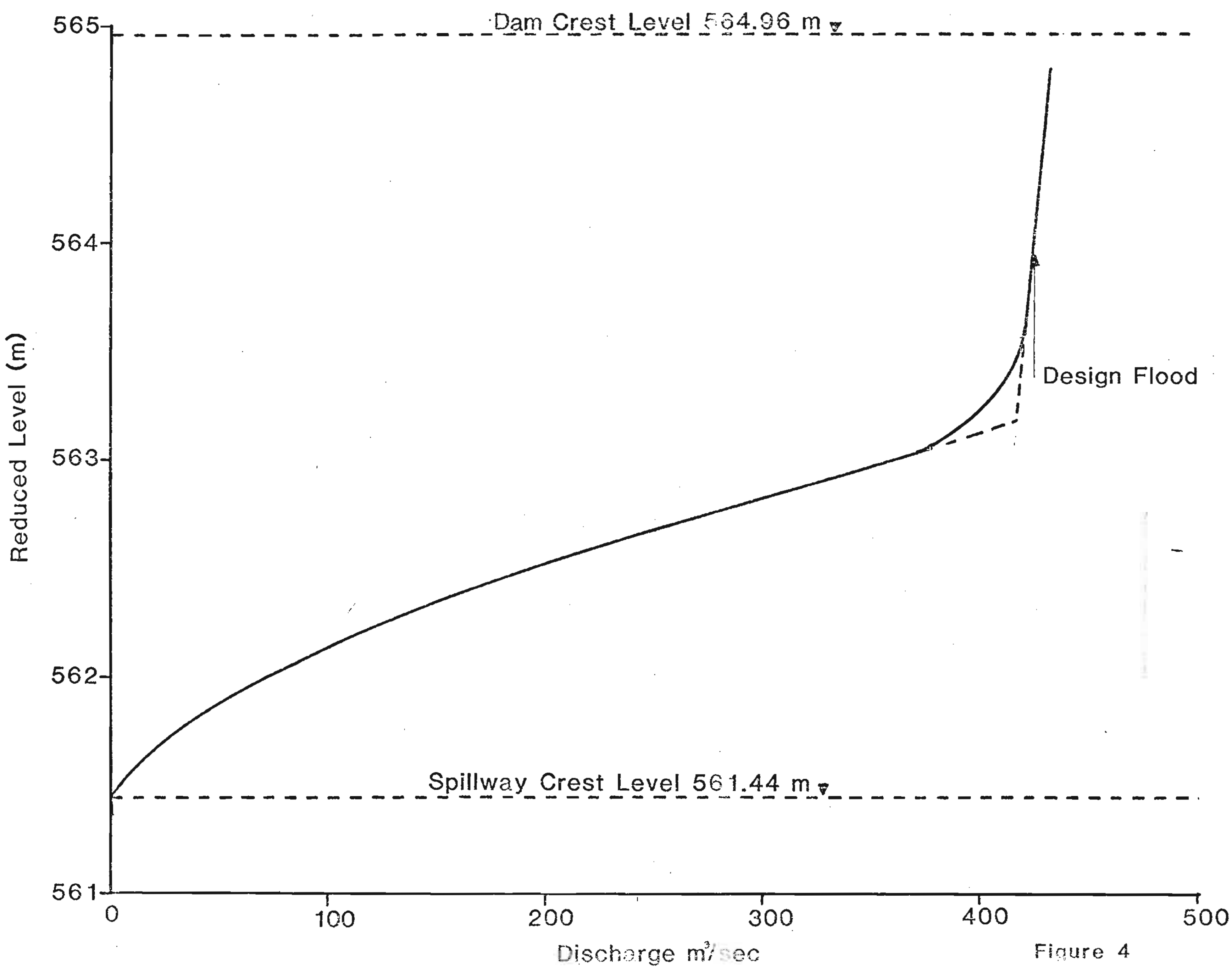

Figure 4

much larger the reduction would have been greater because the flory hole spillway is just on the verge of "choking".

Floods in excess of the 500 year unit graph design flood will cause the glory hole spillway to choke and reservoir levels will begin to increase quite sharply. A series of flood routing trials were carried out to determine the magnitude of the flood which would cause overtopping of the Falls Dam. This showed that a flood 30% larger than the design flood with its runoff volume of 50 mm and peak discharge of 468 m^3/s would just rise to the crest of the dam at 564.96 m.

PROBABLE MAXIMUM FLOOD

No specific study of the PMF was made however use was made of the PMF study in the 'Clutha design floods and flows' report to estimate likely magnitudes of the PMF. In the Upper Clutha catchment the 2 day 500 year rainfall was estimated to be 279 mm and the 2-day probable maximum precipitation 336 mm. This is a 20% increase in rainfall. In the Clutha an initial storm was assumed as well as extreme amounts of runoff from rainfall. Applying these types of assumptions to the Falls Dam is likely to increase the 500 year design flood hydrograph by about 30% which would make overtopping of the dam by the PMF a possibility.

DISCUSSION

The Falls Dam is an irrigation reservoir formed by a rock-fill dam with a glory hole spillway. The combination of rock-fill and glory hole spillway make the dam susceptible to failure in events which exceed those for which it was designed.

This study has evaluated the design flood by both statistical and unit-hydrograph methods. The former giving a 500 year flood with a peak discharge of 430 m^3/s the latter a flood hydrograph with a peak of 468 m^3/s. Routing these floods through the reservoir reduces the peak to 393 m^3/s and 415 m^3/s respectively so that the maximum discharge capacity of the glory hole spillway (430 m^3/s) is not exceeded. The maximum quoted here is derived by calculation and is slightly less than the maximum of 439 m^3/s derived by model test.

This is about 1.75 m of storage between the crest of the dam and the point at which the spillway reaches its maximum capacity. This considerable amount of flood storage sllows the 500 year design flood inflow to be increased by 30% before the dam crest is reached.

Although the probable maximum flood has not been computed comparison with the remainder of the Clutha catchment indicates that it is likely to be 30% larger than the 500 year flood and thus may overtop the dam.

No consideration has been given to the operating policies for the reservoir. A reservoir used for irrigation storage is probably full in the period September to November and in the Manuherikia catchment this is the time when major floods are likely to occur because of the saturated nature of the ground. Thus the assumption made in flood routing, that the reservoir was full at the beginning of the flood, is quite a reasonable one.

CONCLUSION

Flood estimates have been made for the Falls Dam by the best means available with the existing database. These estimates agree quite closely with those made during the dam's design in the late 1920s.

The 500 year flood passes safely through the reservoir and spillway with about 1.75m of freeboard. An increase of up to 30% can be sustained without overtopping the dam however it is likely that the probable maximum flood would be of this order or higher. Overall, considering the size of the dam and its remote location, I would be quite happy about the standard of flood protection provided by the spillway and existing freeboard.