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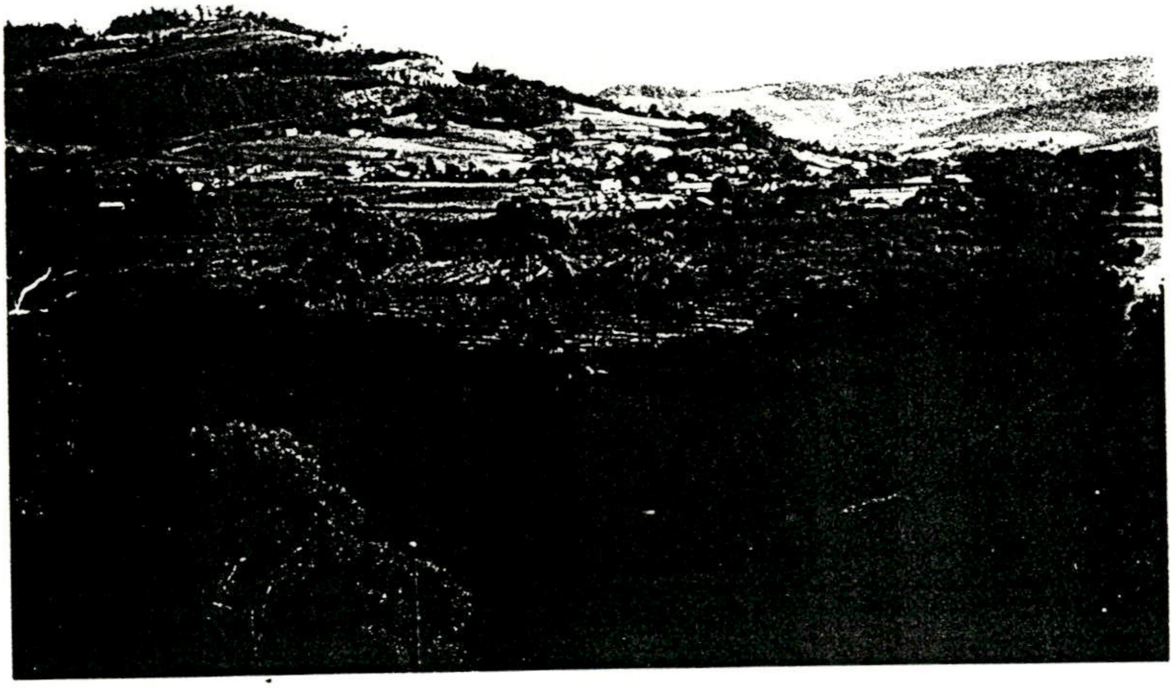

HUON RIVER

FLOOD PLAIN STUDY

STAGE 1 REPORT

GHD

DEPARTMENT OF RESOURCES AND ENERGY
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HUON RIVER FLOOD PLAN STUDY
STAGE 1 REPORT

AMENDMENTS - NOVEMBER 1993

INSERT THE FOLLOWING PAGES:

. P22A	4.6.2	DISCUSSION - HISTORICAL FLOOD PEAKS
. P34A	7.1	RECOMMENDATION
. P35A		ADDITIONAL REFERENCES

THEN INSERT THIS PAGE AFTER THE CONTENTS PAGE.

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HUON RIVER

FLOOD PLAIN STUDY

STAGE 1 REPORT

JULY 1991

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DEPARTMENT OF RESOURCES AND ENERGY

RIVERS AND WATER SUPPLY COMMISSION

HUON RIVER FLOODPLAIN STUDY

EXECUTIVE SUMMARY

This Report details the first stage of a flood study of the Huon River at Huonville, commissioned by the Rivers and Water Supply Commission. The overall aim of the study is to produce floodplain maps of the Huonville township for major storm events. In the first stage, a runoff routing computer model of the river catchment is set up and calibrated, and the results compared to an analysis of historical floods.

Resulting design river floods at Huonville are:

Average Flood Return Incidence (Years)	**Peak Flow** (m^3/s)
20	1875
50	2100
100	2375

The first stage also comprises survey of sections across the floodplain and establishment of an uncalibrated backwater profile computer model. This backwater model will be used in the second stage of the study to predict levels of flood inundations within the study area for design storms.

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HUON RIVER FLOODPLAIN STUDY

GLOSSARY OF ABBREVIATIONS

AEP	Annual Exceedance Probability (expressed as a percentage)
ARI	Average Return Incidence (expressed in years)
RWSC	Rivers and Water Supply Commission
HEC	Hydro-Electric Commission
B of M	Bureau of Meteorology
IFD	Rainfall Intensity - Frequency - Duration Data
ARR	"Australian Rainfall and Runoff" (Institution of Engineers, Australia, 1987)
RORB	Name of Runoff Routing Computer Programme
HEC-2	Name of Backwater Profile Computer Programme
IL	Initial Loss (mm)
CL	Continuing Loss (mm/hr)
k_c, m	RORB Calibration Parameters

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1.0 INTRODUCTION

Gutteridge Haskins & Davey Pty Ltd (GHD) was commissioned by the Rivers and Water Supply Commission in March 1991, to conduct the first stage of a study into the flooding of the Huon River at Huonville. The study is funded by both State and Federal Government funds managed by the Rivers and Water Supply Commission (RWSC) and the Municipality of Huon.

The ultimate aim of the study is to produce floodplain maps for the township of Huonville showing the extent of the 1% annual exceedance probability (AEP) flood inundation and flood level contours for the 1%, 2% and 5% AEP events. Such maps will provide vital assistance to the Municipality in planning and controlling land development in the Huonville area.

The complete study is to be undertaken in two stages, comprising:

- Stage 1 - including the collection of hydrologic data, flood frequency analysis, establishment and calibration of a hydrologic model, determination of the 1%, 2% and 5% (AEP) events, cross sectional survey and establishment of a hydraulic model for future flood profile investigations; and

- Stage 2 - including the collection of available historic flood level data, calibration of the hydraulic model, determination of the 1%, 2% and 5% flood profiles and flood extent mapping.

This report presents the investigations undertaken for Stage 1 of the study. The study area is generally defined as the reach of the Huon River from Ranelagh downstream to Egg Islands and is shown in Figure 1.

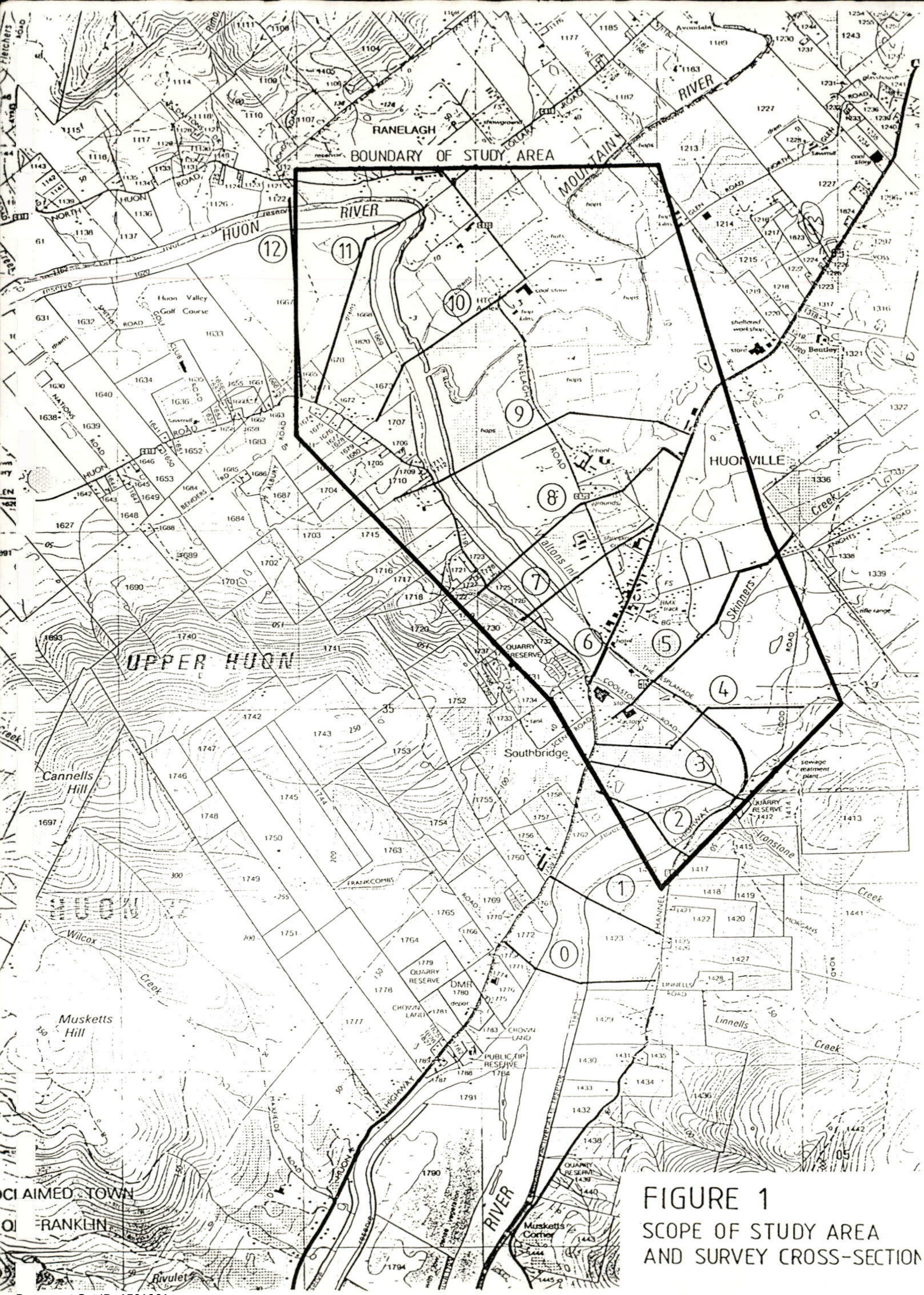


FIGURE 1
SCOPE OF STUDY AREA AND SURVEY CROSS-SECTION

2.0 HUON RIVER CATCHMENT

The Huon River catchment is shown in Figure 2. The figure also indicates the main population centres and watercourses.

The catchment area upstream of Huonville is approximately 2470km^2. The catchment rises from about 5m AHD at Huonville to above 1100m at its highest ridges.

Some 268km^2 or 11% of the catchment was 'diverted' when Lake Pedder was flooded in 1972 at Scotts Peak Dam (refer Figure 2). From Scotts Peak to Huonville, the Huon River mainstream is approximately 102km long. Major tributaries to the Huon River include the Cracroft, Picton and Arve Rivers generally draining the southern areas of the catchment, and the Weld and Mountain Rivers draining the northern areas. It is estimated that the Huon River is affected by tidal movements as far upstream as Ranelagh or Glen Huon.

Areas in the south and west of the catchment are included in the Southwest National Park, and the majority of the Hartz Mountains National Park is located in the catchments of the Picton and Arve Rivers.

The catchment generally upstream of the Arve River junction is within the Southwest Conservation Area which includes the South Weld and Tahune Forest Reserves. Eastern areas of the catchment consist largely of private freehold land. Population centres are located primarily in the eastern areas.

As a result, the catchment consists of substantially native forest and no significant change in this is expected.

Steep valleys characterise the catchment, with significant floodplains located along many of the major watercourses.

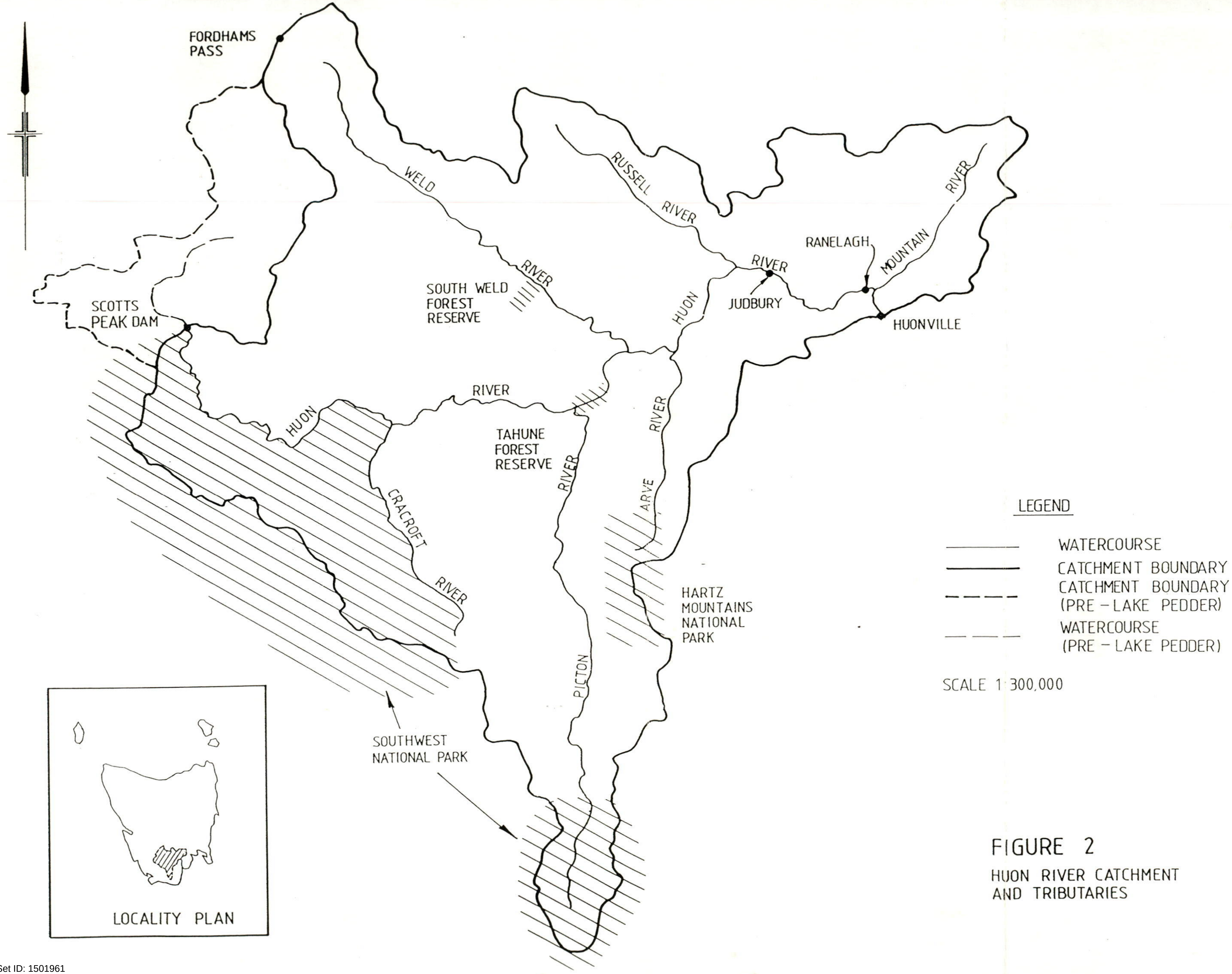


FIGURE 2

HUON RIVER CATCHMENT AND TRIBUTARIES

3.0 HYDROLOGIC DATA

This chapter describes the available data relevant to this study. Assistance in data collection was provided by various Government bodies including the Municipality of Huon, the RWSC, the HEC and the Department of Roads and Transport.

3.1 Survey Information

Survey information obtained is summarised as follows:

- Catchment Plan - Tasmap 1:100 000 topographic maps, 10 metre contour intervals.
- For Preliminary Definition of Survey Cross-Sections at Huonville - Tasmap 1:5000 orthophoto maps, 5 metre contour intervals.
- Bridge Details at Huonville - DMR Drawing N°s 1070H-1, F2.1/1.
- Huon Highway Road Profile - DMR Drawing N°s 1105-7/L1, 02-4, 0L-5.

Field survey of the floodplain for purposes of establishing the backwater profile model is described in Section 5.2.

3.2 Streamflow Data

Streamflow records are available for several gauging stations in the downstream reaches of the Huon River. Table 3.1 summarises the available data. The locations of the stations are shown on Figure 3.

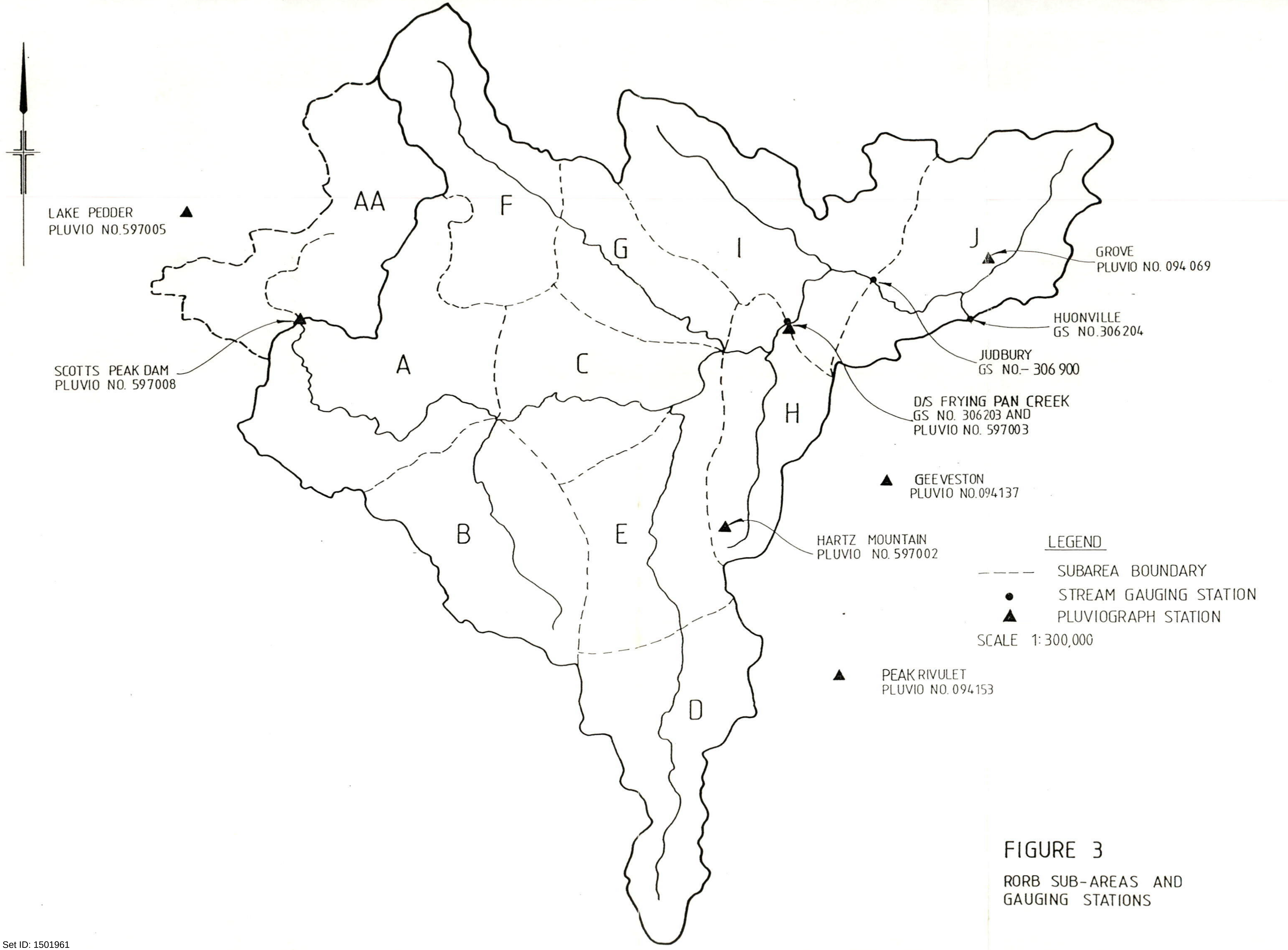


FIGURE 3

RORB SUB-AREAS AND GAUGING STATIONS

It is evident from the above description that hydrologic modelling of the catchment involves some complexities in estimating catchment behaviour and response. Such complexities arise because the catchment:

- is large in areal extent;
- exhibits large variations in elevation and topography;
- is generally remote and inaccessible for purposes of data collection; and
- exibits wide rainfall variations and significant partial area effects.

These complexities give rise to inherent difficulties in the modelling process, which necessarily involves a degree of averaging, and in the process introduces anomalies in prediction. This report highlights those areas where such factors are particularly relevant.

TABLE 3.1

Streamflow Data

Index N°	Station	Catchment Area (km^2)	Period of Record	Gauging Authority
306204	Huonville	2738/2470	1960 - 1983	RWSC
306203	U/S Frying Pan Creek	2107/1839	1948 - Date	RWSC
306900	Judbury	2468/2200	1921 - 1948 1990 - Date	RWSC

Records at Huonville near the Highway Bridge give river levels in chart form only. The river is tidal at this point and a rating curve cannot therefore be produced to convert river level to flow. These records are useful only in making a qualitative assessment of historical river floods and were not used for calibration of the hydrologic model.

The early streamflow records at Judbury were also not used for model calibration due to a lack of adequate rainfall records in the catchment prior to 1948. In June 1990, a gauging station was re-established at Judbury. Records were obtained for two rainfall events in this period for purposes of comparison with the Frying Pan Creek station. The rating curve for the Judbury station is relatively new and is reported by the RWSC to require additional calibration. A history of the Judbury station is given in a report compiled by M L Williams and A Nazanow of the HEC (1981).

As a result, the streamflow gauging station upstream of Frying Pan Creek, although situated some 25 kilometres upstream of Huonville, is the most appropriate source of continuous streamflow record. Tabulations were initially obtained for maximum instantaneous river flows at this station for each month in the record period. From these records, the annual series of flow maxima could be established and several flood events selected for calibration of the flood routing model. Six flood events were consequently selected to enable a reliable calibration and verification of the hydrologic model.

3.3 Rainfall Data

A thorough search of available rainfall pluviograph data was undertaken and several stations of varying periods of record were identified. Pluviograph stations in the vicinity of the Huon River catchment are summarised in Table 3.2. The locations of the stations are shown in Figure 2.

TABLE 3.2

Rainfall Data

Ref	Index Nº	Station	Period of Record	Gauging Authority
1	094137	Geeveston (Forestry)	1979 - Date	B of M
2	094069	Grove (Research)	1960 - Date	B of M
3	597002	Hartz Mountain	1959 - 1974	HEC
4	597003	Huon at Frying Pan Creek	1958 - 1979	HEC
5	597005	Lake Pedder	1959 - 1970	HEC
6	094153	Peak Rivulet	1975 - Date	HEC
7	597008	Scotts Peak Dam	1972 - Date	HEC

These stations give continuous pluviometer traces of rainfall for the periods given, from which temporal patterns of specific storms may be derived for calibration of the flood routing model. In this instance, the choice of flood events was restricted to the period 1958 to date.

It is clear that, for the size of the catchment, the number and distribution of pluviograph stations is limited. For any one storm event in the period 1958 to present, there are at most four pluviograph records available, and, at worst, only two to model rainfall over a 2500km^2 catchment. There is also a significant area between Scotts Peak Dam and the pluviographs east of the Picton River, where no pluviograph or daily rainfall records exist.

Rainfall Intensity - Frequency - Duration (IFD) data was derived for the catchment using the procedures described in Australian Rainfall and Runoff [ARR (Institution of Engineers, Australia, 1987)]. The IFD data is further described in Section 4.4.

3.4 Future Data Requirements

The requirements for data necessary for Stage 2 of the investigation is noted for future reference. Such requirements will primarily include the collation of all available historic flood level information. Both local and Governmental sources will be relied upon for this purpose.

4.0 FLOOD DISCHARGE ESTIMATION

4.1 Modelling Approach

A runoff-routing model was developed to cover the whole of the Huon River catchment upstream of Huonville. This enabled quantification of flood flows at points of interest within the study area and other upstream sites.

Runoff routing was also considered a vital component of the flood discharge estimation phase of the study because:

- it enabled a check to be undertaken of the independent flood frequency analysis at Frying Pan Creek;
- it enabled an acceptable method by which flood discharge estimates at Huonville could be generated following calibration at an upstream site; and
- it enabled the generation of flood hydrographs (as opposed to instantaneous flood peaks), which give estimates of the duration of flooding. This will be useful when taking tidal effects into account and should unsteady hydraulic modelling (not presently proposed) become desirable.

Parameters for the model were determined from both direct calibration of selected storm events at Frying Pan Creek and from regional relationships developed by others. The use of regional relationships was necessary due to the general lack of rainfall data within large parts of the catchment itself. Flood frequency analysis was used to assist selection of appropriate design loss parameters for the model.

Using the established hydrologic model and design rainfalls, flood hydrographs were determined along the Huon River for the 100 year, 50 year and 20 year average recurrent interval (ARI).

4.2 Model Selection

In the runoff routing method of flood estimation, the rainfall excess hyetograph for a storm is routed through a model representing the storage effect of a catchment. The technique can be considered an alternative to the unit hydrograph method, and in Australia has virtually replaced it; ARR gives full details of the several runoff routing procedures now available.

The runoff routing model RORB developed by Laurenson and Mein (1983), was selected as the hydrological modelling tool for this investigation. The latest version is PC compatible and provides users with great flexibility for the modelling of catchments. Amongst other things, the model includes the following features:

- Temporal and spatial variability of rainfall over a catchment.
- Variable losses within a catchment.
- Non-linearity of catchment response to rainfall.

All of these factors assist in the modelling of the response of a large catchment, such as that of the Huon River.

Apart from catchment geometry and topographic data, the model requires four parameters as input. Two of these parameters are catchment parameters, k_c and m. The parameter m describes the degree of non-linearity of catchment response to rainfall excess. The parameter k_c, the catchment storage co-efficient, describes the response time of the catchment to rainfall excess, and so influences hydrograph shape. The remaining two parameters are related to loss modelling. The RORB programme allows catchment losses to be modelled either by the traditional initial loss/continuing loss approach or the initial loss/volumetric runoff co-efficient approach.

4.3 Establishment of the Hydrologic Model

A catchment model was developed for the Huon River catchment using the available contour maps listed in Section 3.1. The catchment was subdivided into 10 sub-areas ranging in size from 175km^2 to 361km^2. Sub-area boundaries were constructed normal to the direction of contours and along ridge lines. Main tributaries were identified and modelled as separate streams.

An illustration of the catchment sub-areas and channel network is shown in Figure 3.

To establish the RORB model, nodes are placed on a main stream near the centroid of each sub-area; the rainfall excess hyetograph for the sub-area is assumed concentrated at this node. Nodes are also placed at stream confluences and at the entry and exit points of major storages. Conceptual storages between each pair of nodes are used to model the storage effects of river reaches and reservoirs if present.

The conceptual storages are described by the equation:

$S = k_c k_r Q^m$, where:

S	is the volume of water in temporary storage;
k_c	is a catchment parameter;
k_r	is a reach parameter, usually taken as proportional to reach length;
Q	is the discharge from the storage; and
m	is an exponent controlling the non-linearity of catchment response.

In a typical RORB calibration such as for the Huon catchment, the parameters k_c and m are found by trial and error fitting to observed data. In addition, the storm loss parameters are determined for each event to give the correct volume of runoff.

The RORB programme allows catchment losses to be modelled either by the traditional initial loss (IL)/continuing loss (CL) approach or the IL/runoff co-efficient approach. The latter approach is generally adopted for partly urbanised catchments, but both methods of catchment loss modelling have proven to be satisfactory on rural catchments.

The IL/CL approach has a distinct advantage over its counterpart in situations where a reliable flood frequency curve cannot be derived for low AEPs due to a short period of streamflow record. The probabilistic loss parameters may be determined from estimates of peak discharges for frequent events where the flood frequency estimates are more reliable. A representative set of parameters can then be selected for predicting flood events of longer recurrence intervals.

In view of the period of streamflow records at Frying Pan Creek, the IL/CL approach was adopted for this study.

4.4 Model Calibration

4.4.1 GENERAL

From the available rainfall and streamflow records, six (6) significant flood events were selected for calibration. As mentioned in Section 4.2, the model has four parameters which must be determined. When calibrating to observed hydrographs, only the IL needs to be specified. The programme calculates the CL rate required to balance the volume of rainfall excess with the volume of the observed runoff. The other two parameters, k_c and m, are related to the modelling of the storage effects of the catchment, as detailed in Section 4.3. In practice, m has a normal range between 0.6 and 1.0. k_c is calculated, and displayed, for the entire area of the catchment area being modelled.

For the Huon River catchment, the determination of k_c is considered in three stages:

- Calibration to recorded events on the catchment.
- Consideration of k_c values determined from published regional relationships.
- Selection of the appropriate k_c value.

4.4.2 MODEL CALIBRATION TO RECORDED EVENTS

The six (6) events selected for calibration are given in Table 4.1 below with their recorded peak flows at the Frying Pan Creek gauge.

TABLE 4.1

Calibration Events

Date of Event Peak	**Peak Flow at Frying Pan Creek** (m^3/s)	**Pluviograph Station Number Reference** (from Table 3.2)
3 July 1990	1463	1, 2, 6, 7
14 August 1980	1553	1, 2, 6, 7
28 August 1975	1528	2, 4, 7
18 May 1975	1990	2, 4, 7
10 December 1968	1355	3, 4, 5
23 April 1960	1924	3, 4

Rainfall totals recorded at the pluviograph stations are given in Table 4.2. The August 1980 event had three distinct rainfall bursts and was modelled to account for different loss parameters in each burst. Base flows were separated from the observed hydrographs for calibration. The methods described in ARR were adopted for this purpose.

TABLE 4.2

Pluviograph Stations

Station	Jul 1990	Aug 1980			Aug 1975	May 1975	Dec 1968	Apr 1960
		B1	B2	B3				
Geeveston	69.4	23	40	6	NR	NR	NR	NR
Grove	80.4	19	13	0	83	23	NR	NR
Hartz Mountain	NR		NR		NR	NR	38	280
Huon at FPC	NR		NR		99	39	29	195
Lake Pedder	NR		NR		NR	NR	83	NR
Peak Rivulet	69.4	32	51	11	NR	NR	NR	NR
Scotts Peak Dam	71.6	44	90	0	113	69	NR	NR

NR: Not Recorded

Note that calibration of the December 1968 and April 1960 event are based on a "pre-Lake Pedder" catchment. Resultant k_c estimates were adjusted for the loss of catchment area to obtain values applicable to the present catchment.

The results of the calibration runs are summarised in Table 4.3 (commentries and examples of fit run hydrographs are provided in Appendix A). In all cases, the general form of the hydrograph and timing of the peak discharge at Frying Pan Creek was well reproduced. Some difficulties were encountered in balancing rainfall excess volumes with the measured hydrograph due to the absence of rainfall data in the normally high rainfall areas of the catchment. A best estimate was adopted in these situations.

TABLE 4.3

Calibration Results

Event	Adopted IL (mm)	Derived CL (mm/hr)	Peak Discharge Observed (m^3/s)	Peak Discharge Predicted (m^3/s)	k_c	m
July 1990	10	0.12	1432	1432	16	0.8
August 1980	5, 10, 5	0.62 0.69 0.41	1417	1447	40	0.8
August 1975	0	0	1485	1436	20	0.8
May 1975	0	0	1877	1873	45	0.8
December 1968	18	0.51	1312	1323	40 (38)	0.8
April 1960	5	1.09	1921	1938	60 (57)	0.8

In the course of trialling various combinations of k_c and m for each storm, a graph of k_c versus m was plotted, in accordance with the parameter interaction curve method proposed by Weeks (1980). The resulting curves for each storm event did not exhibit a common intersection point. This lack of coincidence of intersections is not uncommon when calibrating from real data, as explained in ARR Section 9.5.2.6.

Adjustment in k_c for area for the 1968 and 1960 events can be undertaken using the equation:

$$k_c \text{ (without Pedder)} = k_c \text{ (with Pedder)} \times \frac{[A \text{ (without Pedder)}]^{0.5}}{[A \text{ (with Pedder)}]^{0.5}}$$

$$= k_c \text{ (with Pedder)} \frac{[2469]^{0.5}}{[2737]^{0.5}}$$

$$= k_c \text{ (with Pedder)} \times 0.95$$

Adjusted values are shown in brackets.

4.4.3 REGIONAL RELATIONSHIPS

(i) ARR gives an expression for calculating k_c derived by the Hydro-Electric Commission for catchments in western Tasmania (refer ARR Section 9.6.2).

For m = 0.75, k_c is given by the following equation:

$$k_c = 0.86\ A^{0.57}$$

Where A is the catchment area (km^2).

For a catchment area of 2470km^2 at Huonville, this gives a k_c value of 73.8.

Using the following relationship between m and k_c (ARR Section 9.6.2), an estimated k_c for the different values of m may be calculated.

$$k_c(m) = k_c\ (0.8)\ (Qp/2)^{0.8\ -\ m}$$

Where	Qp	=	Peak Discharge (m^3/s)
	$k_c(m)$	=	k_c value for m under consideration.

As a result, for an m of 0.80 and adopting the May 1975 event peak:

$$73.9 = k_c\ (0.8) \times (1990/2)^{0.8\ -\ 0.75}$$

$$\therefore \quad k_c\ (0.8) = 52.2$$

At any point along the river k_c is dependent on both the upstream catchment area and the flood flow peaks. This k_c value is some 30% higher than those derived from RORB calibration runs, suggesting that the above ARR relationship was developed for medium sized catchments and may lose its validity as A becomes very large.

(ii) Morris (1982) [Ref Section 8] provides an alternative relationship for Tasmania given by:

$k_c = 4.86\ A^{0.32}$, for m = 0.75

For the Huon catchment, this results in a k_c value of 59.2. Adjusting this value for an m of 0.8 gives a k_c of 42.0.

4.4.4 SELECTION OF RORB PARAMETERS

The selection of final RORB parameters must take into account the results of flood routing calibrations as well as the reported regional relationships.

The regional relationship in ARR and Morris assume an m value for Tasmania of 0.75. For a catchment as large and variable as the Huon River catchment, the adopted m value can depend upon rainfall distribution.

A storm event centred on the flatter, upstream reaches of the catchment would be expected to produce more linear catchment response, and therefore a higher m value, than a storm over the steeper, downstream reaches. This effect is evident in the RORB calibration runs, where high m values gave a better fit of the hydrograph shape for several storm events. Given the linear tendency of parts of the catchment, an m value of 0.80 was finally selected.

A range of k_c values were obtained as a result of the calibration runs. The variations are to be expected due to the poor quality and quantity of rainfall data available. For m = 0.80, a corresponding value of k_c = 40 may be selected as an average of the better RORB fit runs. This is in close agreement with the Morris regional relationship.

Based on the above, the following RORB parameters were adopted for the Huon River catchment upstream of Huonville.

m = 0.80 k_c = 40

4.5 **Probabilistic Flood Discharges**

The calibrated RORB model was used to generate probabilistic flood hydrographs for the 5%, 2% and 1% AEP year events from probabilistic rainfall of the same recurrence intervals.

As a result of the size and location of the catchment, probabilistic rainfall data varies significantly from one side of the catchment to the other. This is evidenced by the frequency-duration contours of rainfall intensity in ARR Volume 2. For the purpose of generating design rain storms, the catchment was divided into four subsections and rainfall IFD data was derived for the centre point of each. The resultant tables, giving design rainfall intensities for each frequency and duration, are attached to this report in Appendix B.

From these rainfall intensities, design storms were generated using temporal patterns in ARR Volume 2. In order to obtain a preliminary estimate of the critical storm duration for each frequency, 50 year and 2 year ARI design storms of varying duration were run through the calibrated RORB model. For both frequencies the critical duration lay on a flat curve between 36 and 40 hours. A 36 hour design temporal pattern is given in ARR design Volume 2, and was consequently adopted for RORB design runs.

Areal distribution of design rainfall is a subject largely unresearched in Australia. The intensity values derived are strictly applicable only to a point and will not apply simultaneously over a large catchment. An appropriate reduction factor should be allowed. ARR Figure 2.6 gives areal reduction curves for design storms to 24 hour duration for catchments up to 1000km^2 in area. This figure was extrapolated for this study to give an overall intensity reduction of 0.87 for a 36 hour storm over 2500km^2 catchment area.

To summarise, probabilistic discharges were generated by entering design rainfall storms to the calibrated RORB model. These were obtained by factoring 36 hour storms in 4 subsections of the catchment by 0.87, and entering design rainfall depths in the appropriate sub-areas of the catchment model.

4.6 **Flood Frequency Analysis**

A flood frequency analysis of the catchment was carried out using historical flood peak discharges recorded at the Frying Pan Creek gauging station.

A series was set up using maximum instantaneous river flows for each year since 1948. Values for 1952, 1959, 1961, 1962 and 1976 were not used due to incomplete or missing records in these years. The flood series was plotted as shown in Figure 4. A Log Pearson III distribution was fitted to this data, along with 5% and 95% confidence limits, in accordance with the procedures in ARR. Flows for a range of AEP's may, therefore, be expressed as $\text{Log } Q_y = 3.066 + 0.1176K_y$, where:

Q_y = 1 in y AEP discharge; and
K_y = frequency factor for skew co-efficient of 0.4.

These fitted curves are also shown on Figure 4.

4.6.1 DISCUSSION

Of the 37 discharge values which make up the annual series, only one falls outside the 5% and 95% confidence limits. The two very low flows effectively drop the fitted distribution for low ARI's, however this end of the curve is of little consequence in predicting major flood discharges. The highest instantaneous flow on record, $2223m^3/s$ measured in 1948, exceeds an ARI of 50 years.

A skew co-efficient of 0.392 was derived statistically from the annual series. This number was adopted to calculate the fitted distribution and confidence limits, as opposed to using average regional skewness from Map N° 7d in ARR Volume 2, which gives a considerable variation in skew across the catchment.

4.6.2 DISCUSSION HISTORICAL FLOOD PEAKS

Livingston (1987) reports the existence of two peak flood level peggings for the historical floods of 1901 and 1914 at a site known as "The Hermitage" (Wallis family property). This site is located on the Huon River flats, in the vicinity of Judbury Falls, some 15km upstream of Huonville. Livingston has computed flows in this location for these events (based on these estimated levels) at 2940m3/s and 2240m3/s for the 1901 and 1914 flood respectively.

Review of Livingstone (1987) and a companion reference Nazarov (1987), indicates that:

- the source of the 1914 (and 1948) data remains unclear.
- estimates were based on 1:25000 map contours.
- the 1901 flood was the most severe flood event since the mid 1800's. (Ref Tasmania Mail November 1901).
- Wallis family records exist prior to 1901.

Due to the uncertainty regarding the accuracy of these historical peaks and the unknown relationship between flows at Judbury Falls and Huonville, these flows have not been included for the purposes of flood frequency analysis in this study. However, it is recommended that this data be reviewed by undertaking a detailed investigation into "The Hermitage" record including site cross-sectional survey and assessment of the complete Wallis family records.

Should it be proved that these historical peaks are accurate, and that comparable discharge levels occurred in Huonville, the 1 in 100 AEP design discharge at Huonville could be increased by up to 10%. However, this effect will depend upon the detailed 1901/1914 discharges estimated, the adopted historical period and the assumed attenuation effects between Frying Pan Creek, Judbury and Huonville.

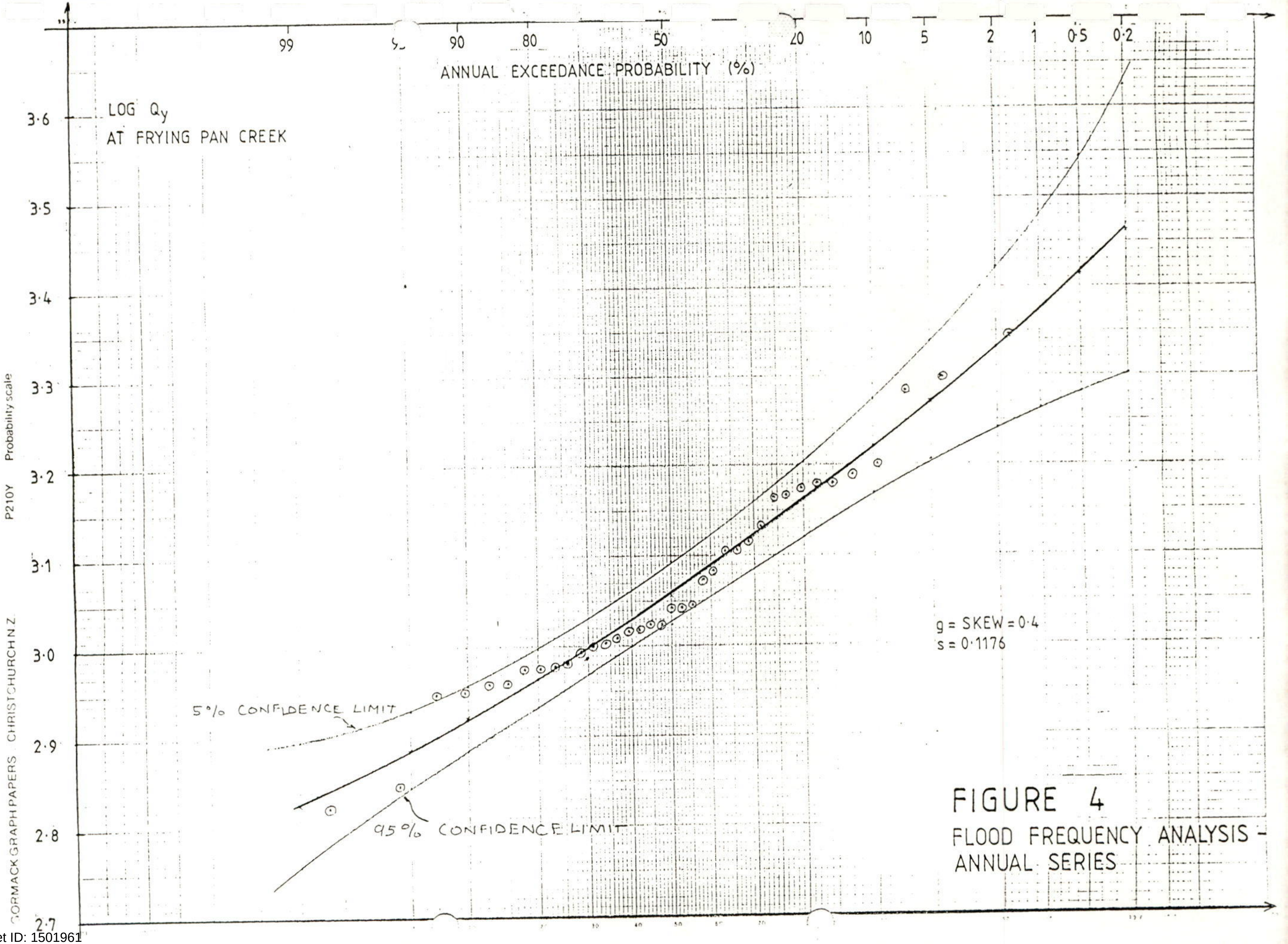


FIGURE 4
FLOOD FREQUENCY ANALYSIS - ANNUAL SERIES

From the flood frequency analysis alone, the 20, 50 and 100 ARI discharges at Frying Pan Creek are given in Table 4.4.

TABLE 4.4

Discharges from Flood Frequency Analysis at Frying Pan Creek

ARI	Q_y (m^3/sec)
20	1870
50	2150
100	2370

In carrying out the flood frequency analysis, consideration was given to the reduction in catchment size following the impoundment of Lake Pedder in 1972. As discussed in Section 4.3, it is difficult to model the downstream effects of such a catchment reduction on an actual historical event, without knowing the exact distribution and depths of rainfall in these events. As such, it is very difficult to introduce an adjustment to each of the values of pre-1972 river discharge peaks in the annual series, to bring them in line with the present catchment configuration.

The catchment area upstream of the dam amounts to little more than 10% of the (then) total catchment area. Influence on peak discharges by flood runoff from this area would be expected to be lessened by the relatively flat grassy plains in the upper reaches of the catchment and the long duration of the critical storm events. In contrast, the steeper sections of the catchment further downstream would result in runoff more directly affecting peak discharge.

As a consequence of the above factors, it was decided to adopt the pre-1972 discharge values for flood frequency analysis in an unadjusted form. There has been no apparent change in peak river flows since 1972. To test this hypothesis, trial RORB runs for the catchment both with and without the Lake Pedder sub-area were carried out for historical and design storms.

The peak flows without the sub-area varied between an increase of 4% to a decrease of 10%. It is therefore concluded that the assumption adopted is reasonable and justifiable.

4.7 Reconciliation of RORB with Flood Frequency Analysis

Flood discharge estimation is usually carried out by combining and comparing results from rainfall based methods and from flood frequency analyses (refer Section 4.3). Rainfall based methods, in this study RORB design runs, are generally adopted for prediction of large and extreme floods. The ARI where the transition occurs from one method to the other, is dependent upon catchment size, the length of historical records and the statistical distribution of such data.

A procedure given in ARR 12.6.4, states that flood frequency analysis should be more accurate up to an ARI of y years, where:

$$y = F\, N^{0.5} \exp(0.02\, N) \text{ years}$$

Where F is a factor derived from station skew (0.04) and standard deviation (0.118). In this instance, F = 1.99 and N is the number of years of records (37). Hence:

$$y = (1.99)\,(37)^{0.5} \exp(0.02 \times 37)$$

$$= 25 \text{ years}$$

Thus, frequency analysis can be expected to provide a more reliable estimate than a rainfall based method for all floods smaller than a 25 year ARI event.

Ideally, the two estimates should coincide at the same discharge around the transition point. In practice, the flood frequency curve may be used to assist in the selection of probabilistic loss parameters for design runs in the RORB model. As explained previously, the calibration of the model to historical events assists only in the selection of parameters k_c and m. Values of initial loss (IL) and continuous loss (CL) may be selected from previously researched regional relationships and by attempting to achieve continuity between the two estimating methods.

4.8 Adopted Flood Frequency Curve and Flood Discharge Estimates

Figure 5 shows the flood frequency curve with results from RORB design runs superimposed. The transition AEP of 1 in 25 is indicated. An initial loss of 10mm has been selected from regional guidelines and continuous loss has been varied between 1.0mm and 3.0mm/hr. A CL of 2.5mm/hr is suggested for Tasmania in ARR.

It is evident that the statistically based flood frequency curve intersects runoff based curves for increasing CL as AEP decreases. It should, therefore, be possible to derive a closer approximation to the flood frequency curve by progressively varying continuous loss in RORB design runs. A decrease in loss rate with rainfall intensity could be expected in a large catchment with design storms of long duration and relatively low intensity subject to high temporal and spatial variability. This is particularly the case as the loss rates for the more frequent events are of the same order of magnitude as the rainfall intensity, thereby reducing moisture availability for infiltration. In order to obtain a relationship between CL and AEP, RORB design runs where matched to the flood frequency curve by varying CL for AEPs above 4%, and the results extrapolated to AEPs of 2% and 1%.

Continuous losses were found to vary from 1.4mm/hr for 2 year ARI to 4.2mm/hr for 100 year ARI.

With final values of parameters m, k_c, IL and CL selected, the RORB model was further utilised to predict peak river flows for the whole catchment at Huonville. Results are listed in Table 4.5.

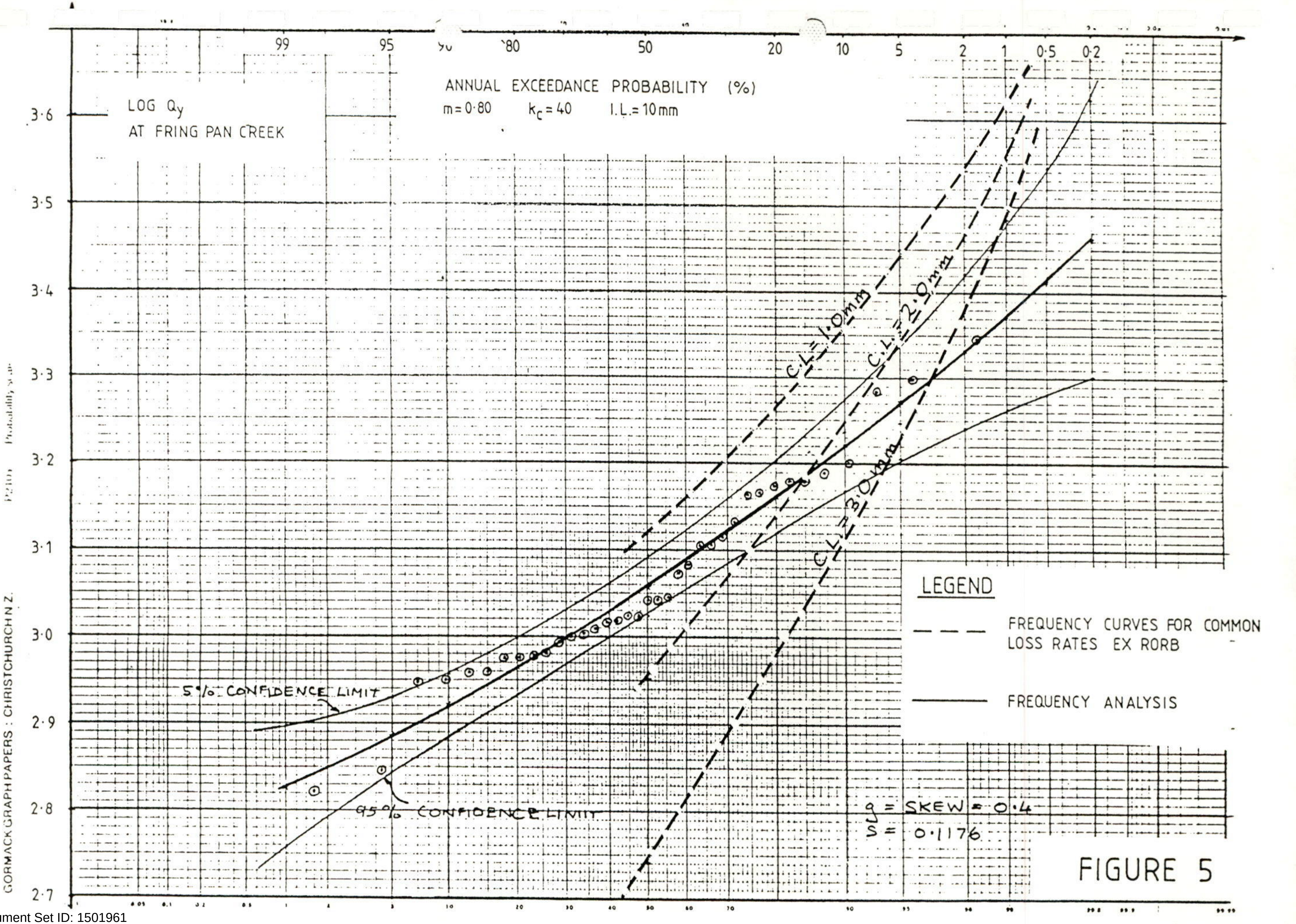


FIGURE 5

Document Set ID: 1501961
Version: 1, Version Date: 29/10/2018

TABLE 4.5

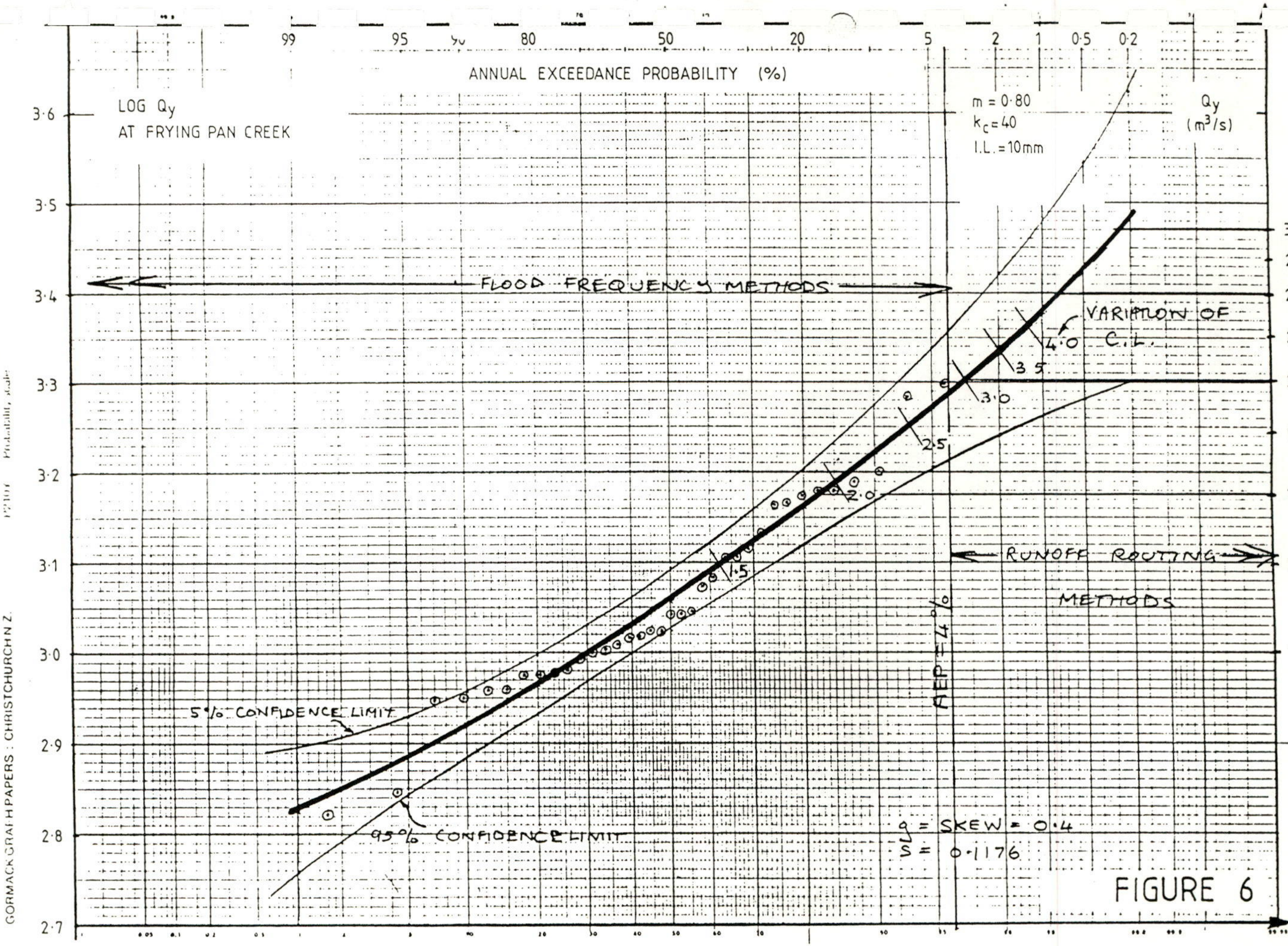
Final RORB Design Runs

m = 0.80 k_c = 40 IL = 10

ARI		Frying Pan Creek	Huonville
2 Year	CL = 1.4 mm	1135 m^3/s	1090 m^3/s
5 Year	CL = 1.8 mm	1470 m^3/s	1440 m^3/s
10 Year	CL = 2.2 mm	1625 m^3/s	1595 m^3/s
20 Year	CL = 2.7 mm	1900 m^3/s	1875 m^3/s
50 Year	CL = 3.5 mm	2120 m^3/s	2100 m^3/s
100 Year	CL = 4.2 mm	2400 m^3/s	2375 m^3/s

It is interesting to note the slight flood peak attenuation which occurs between Frying Pan Creek and Huonville, a result which is supported by the few simultaneous river flow records at Frying Pan Creek and Judbury.

The resulting adopted flood frequency curve, made up from statistical data for ARI less than 25 years, and runoff routing results for ARI greater than 25 years is given in Figure 6.



ANNUAL EXCEEDANCE PROBABILITY (%)
99
95
90
80
50
20
5
2
1
0·5
0·2
LOG Qy
AT FRYING PAN CREEK
m = 0·80
kc = 40
I.L. = 10mm
Qy
(m³/s)
3·6
3·5
3·4
3·3
3·2
3·1
3·0
2·9
2·8
2·7
3000
2750
2500
2250
2000
1750
1500
1250
1000
FLOOD FREQUENCY METHODS
VARIATION OF C.L.
4·0
3·5
3·0
2·5
2·0
1·5
RUNOFF ROUTING METHODS
AEP = 4%
5% CONFIDENCE LIMIT
95% CONFIDENCE LIMIT
g = SKEW = 0·4
S = 0·1176
GORMACK GRAPH PAPERS : CHRISTCHURCH N.Z.

FIGURE 6

5.0 HUON RIVER HYDRAULIC MODELLING

5.1 General Description

Hydraulic modelling of the watercourses was carried out using the HEC-2 steady flow backwater profile model. This model was developed by the US Army Corps of Engineers and has been used extensively in river hydraulic studies by GHD. The model has the capability to model the energy losses associated with flow through culverts and bridges and can simulate the three flow characteristics of low flows, pressure or orifice flow and weir flow at road and railway crossings of the streams. The model also subdivides the cross sections of the watercourse into the main channel and floodplains thus enabling a more detailed representation of hydraulic characteristics of the watercourse.

The establishment of the HEC-2 model to study the hydraulic characteristics of the floodplain in the vicinity of the study area was based on survey data of the watercourses, as described in Section 5.2.

Boundary geometry for the analysis of flow in the floodplain is specified in HEC-2 in terms of ground surface profiles, or cross sections, and the lengths of reach between them.

In addition to defining the boundary geometry of flow in the floodplain it is necessary to specify energy loss co-efficients and areas of ineffective flow. The model parameters that require calibration are as follows:

At each Cross Section:

- Manning's "n" - left overbank.
- Manning's "n" - main stream.
- Manning's "n" - right overbank.
- Ineffective flow areas - left bank.
- Ineffective flow areas - right bank.

Between Cross Sections:

- Expansion transition co-efficient.
- Contraction transition co-efficient.

At Bridges and Culverts:

- Pier shape co-efficient.
- Wier flow co-efficient.
- Orifice flow co-efficient.

5.2 Survey

Survey of the floodplain between Ranelagh and the northern end of the Egg Islands was carried out in the following steps:

(i) The floodplain was inspected in the field to assess the direction of overbank flow during flood, local vegetation and other features which may affect the backwater model and to determine accessibility for survey work.

(ii) Some 13 cross sections were selected and drawn, as far as possible, perpendicular to the direction of stream flow lines. These cross sections, shown in Figure 1, generally extend to the 15 metre contour and include one section coinciding with the Huon Highway and bridge alignment. For the purposes of outlining the scope of work to the surveyor, the sections were drawn up on 1:5000 maps of the district, enabling intersection points to be set out from existing features.

An additional section across Mountain River was included to enable modelling of any breakaway flows from the main channel in extreme events.

(iii) Survey was carried out to the following requirements:

- Up to 100 survey points per cross section.

- Station elevations to be ±0.05m, stated to the nearest 0.05m, levels to AHD.

- Minimum spacing of points within main channel to be 15 metres, or for maximum changes in elevation of 0.5 metres.

- Steel markers to be placed in the field to mark the extremities of each cross section at the left and right bank.

- Cross sections to use the convertion of "looking downstream", having offsets commencing from the extreme left point.

- Photographs to be taken at each cross section recording typical land use and any special features.

- Data consisting of offset and elevation of each survey point was presented in graphical, tabulated and digital format, for conversion to the HEC-2 input file.

Data for cross section 6 involving the highway and bridge vertical alignments was derived from copies of design drawings from the Department of Roads and Transport.

5.3 Model Establishment

The basic HEC-2 input was set up from the cross-section data of some 1200 survey points, supplemented by additional program "cards" detailing preliminaries, flow conditions, extent of river channel, distance between adjacent sections and bridge geometry.

A copy of the basic input file is attached in Appendix C. During the calibration process variables such as overbank roughness and mode of flow through the bridge will be changed depending on historic river levels.

6.0 FUTURE STAGES OF THE STUDY

Following completion of Stage 1 of the Study, as documented in this Report, commissioning of Stage 2 is now anticipated. Stage 2 of the Study will essentially comprise the following tasks:

- **Data Collection** of available historic flood data and tidal information.
- **Calibration** of the hydraulic model, HEC-2, to observed floods.
- **Prediction** of flood profiles for the selected probabilistic events.
- **Mapping** of areas liable to flooding for the selected events.

7.0 DATE

This Stage 1 Report is dated 10 July 1991.

7.1 RECOMMENDATIONS

It is recommended that "The Hermitage" data be reviewed by undertaking an investigation into the records including site cross-sectional survey and assessment of the complete Wallis family records.

8.0 REFERENCES

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Bureau of Meteorology (1988)

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- RORB - Version 4
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- Runoff Routing Model Parameter Evaluation for Ungauged Catchments
  Symposium on Hydrology and Water Resources, 1982
  Institute of Engineers, Australia

Livingston (1987)

- Huon at Judbury Flood Frequency
  HEC Water Resources Department

Nazarov (1987)

- Investigation into the Huon at Judbury Rating Curve.
  HEC Water Resources Department, May 1987.

APPENDIX A

RORB Calibration Notes & Hydrographs

APPENDIX A

RORB Calibration Notes & Hydrographs

The following commentaries detail the difficulties encountered in calibrating each event. the major problem associated with the data appears to be the considerable variation in temporal and spatial patterns of rainfall throughout the catchment.

(1) **July 1990**

Description

Rainfall over 54 hours recorded at 4 pluviographs:

	Total
Scotts Peak Dam	71.6mm
Grove	80.4mm
Geeveston	56.5mm
Peak Rivulet	69.4mm

Apparent direction of storm from east.

Problems in Initial Fit Run

Calculated hydrograph rising too soon, k_c values very low. This indicates that rainfall between dam and eastern catchment was higher and later than assumed. Temporal pattern for central sub-areas changed to Scotts Peak Dam pattern.

Best Fit Result

m = 0.80 k_c = 16 IL = 10mm CL = 0.12mm
to match peak flow only.

Comments

Generally poor fit as a result of high rainfall unrecorded in central catchment areas.

(2) **August 1980**

Description

Rainfall in three bursts over 126 hours recorded at 4 pluviographs:

	Totals
Scotts Peak Dam	44, 91, 0mm
Grove	19, 13, 0mm
Geeveston	23, 40, 6mm
Peak Rivulet	32, 51, 11mm

Apparent direction of storm from south-west.

Problems in Initial Fit Runs

Good fit for main peak, calculated minor peaks lagging slightly with m = 0.80. Better fit for all peaks with higher m values.

Best Fit Results

m = 1.0	k_c = 11	IL = 5, 10, 5mm	CL = 0.62, 0.69, 0.41mm
m = 0.9	k_c = 21	IL = 5, 10, 5mm	CL = 0.62, 0.69, 0.41mm
m = 0.8	k_c = 40	IL = 5, 10, 5mm	CL = 0.62, 0.69, 0.41mm

Comments

Very good fit probably due to even distribution of rainfall across western and central sub-areas.

(3) **August 1975**

Description

Rainfall over 128 hours recorded at 3 pluviographs:

	Total
Scotts Peak Dam	113mm
Grove	83mm
Frying Pan Creek	99mm

Apparent direction of storm not clear, but intensity is higher in the west.

Problems in Initial Fit Runs

Programme could not initially balance inflow with recorded net streamflow, suggesting more rainfall than assumed fell in sub-areas. Rainfall depths increased in the stormwater of the catchment in ensuing runs. With 0mm initial loss, k_c values are low and calculated hydrograph is early. Rainfall intensity increased in Picton River catchment.

Best Fit Results

m = 0.80 k_c = 20 IL = 0mm CL = 0mm

Comments

Very poor fit due to high variation in rainfall distribution across catchment.

(4) **May 1975**

Description

Rainfall over 144 hours recorded at three pluviographs:

	Total
Scotts Peak Dam	69mm
Grove	23mm
Frying Pan Creek	39mm

Problems in Initial Fit Runs

Programme could not initially balance inflow with recorded net streamflow. Rainfall input increased in central and south western sub-areas.

Best Fit Results

m = 0.80	k_c = 45	IL = 0mm	CL = 0mm
m = 1.00	k_c = 11.5	IL = 0mm	CL = 0mm

Comments

Better fit of calculated hydrograph shape with m = 1.0.

(5) **December 1968**

Description

Isolated bursts of rainfall over 22 hours recorded at three pluviographs:

	Total
Lake Pedder	83mm
Hartz Mountain	38mm
Frying Pan Creek	29mm

Apparent direction of storm from west. Western rainfall intensity high.

Best Fit Results

m = 0.80	$k_c = 40$	IL = 18mm	CL = 0.51mm
m = 0.90	$k_c = 22$	IL = 20mm	CL = 0.32mm
m = 1.00	$k_c = 11$	IL = 20mm	CL = 0.32mm

Comments

Good fit. Bulk of inflow probably from westernmost sub-areas causing actual hydrograph to lag.

(6) **April 1960**

Description

High intensity rainfall over 84 hours recorded by two only pluviographs in east of catchment.

	Total
Hartz Mountain	280mm
Frying Pan Creek	195mm

Apparent direction of storm from east.

Problems in Initial Fit Run

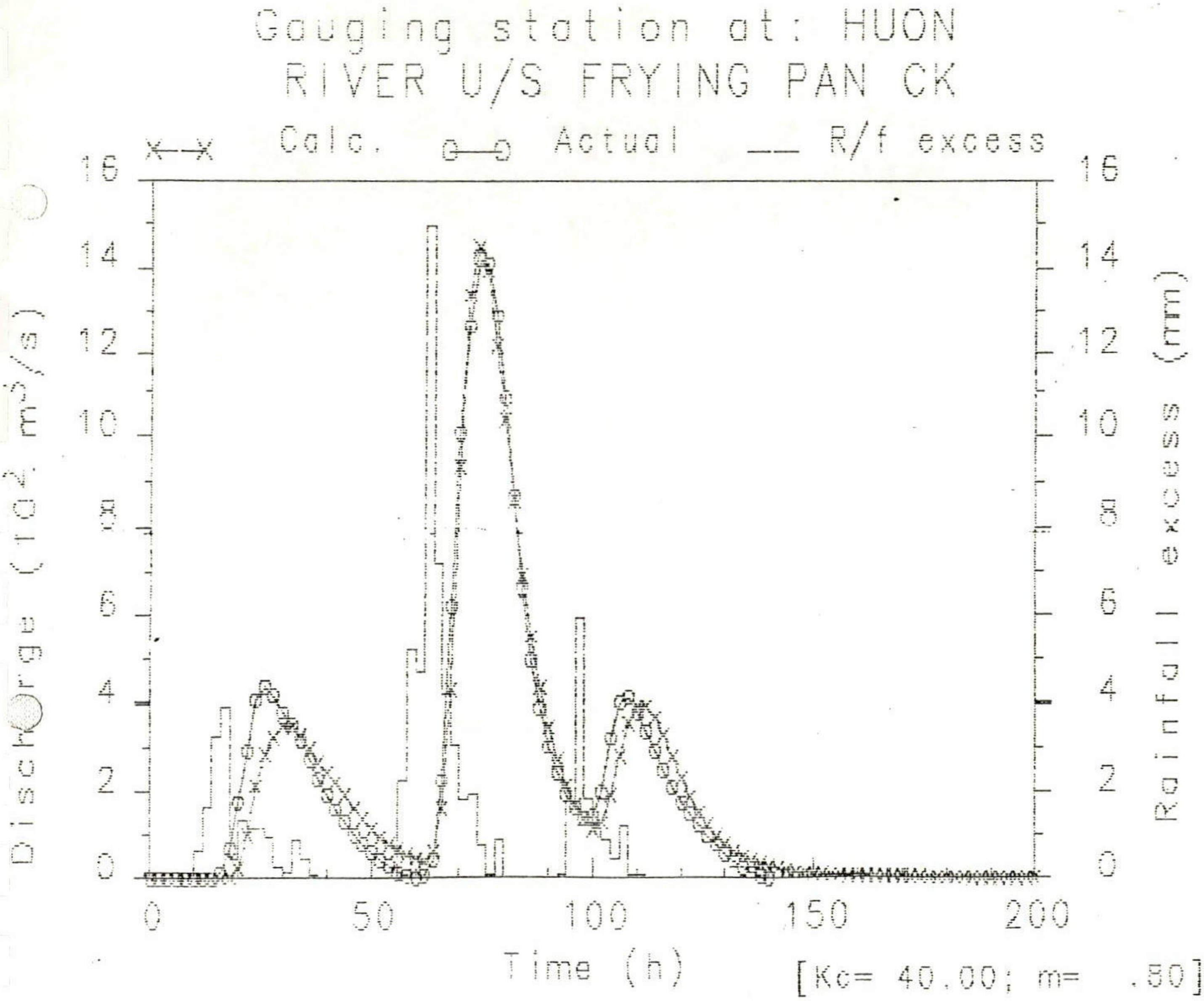
Distribution and intensity of rainfall in western sub-areas unknown. with high intensity rainfall across whole catchment, k_c too high and calculated hydrograph lagging. Better fit obtained by halving rainfall in western sub-areas.

Best Fit Results

m = 0.80	k_c = 80	IL = 5mm	CL = 1.09mm
m = 1.0	k_c = 20	IL = 5mm	CL = 1.09mm

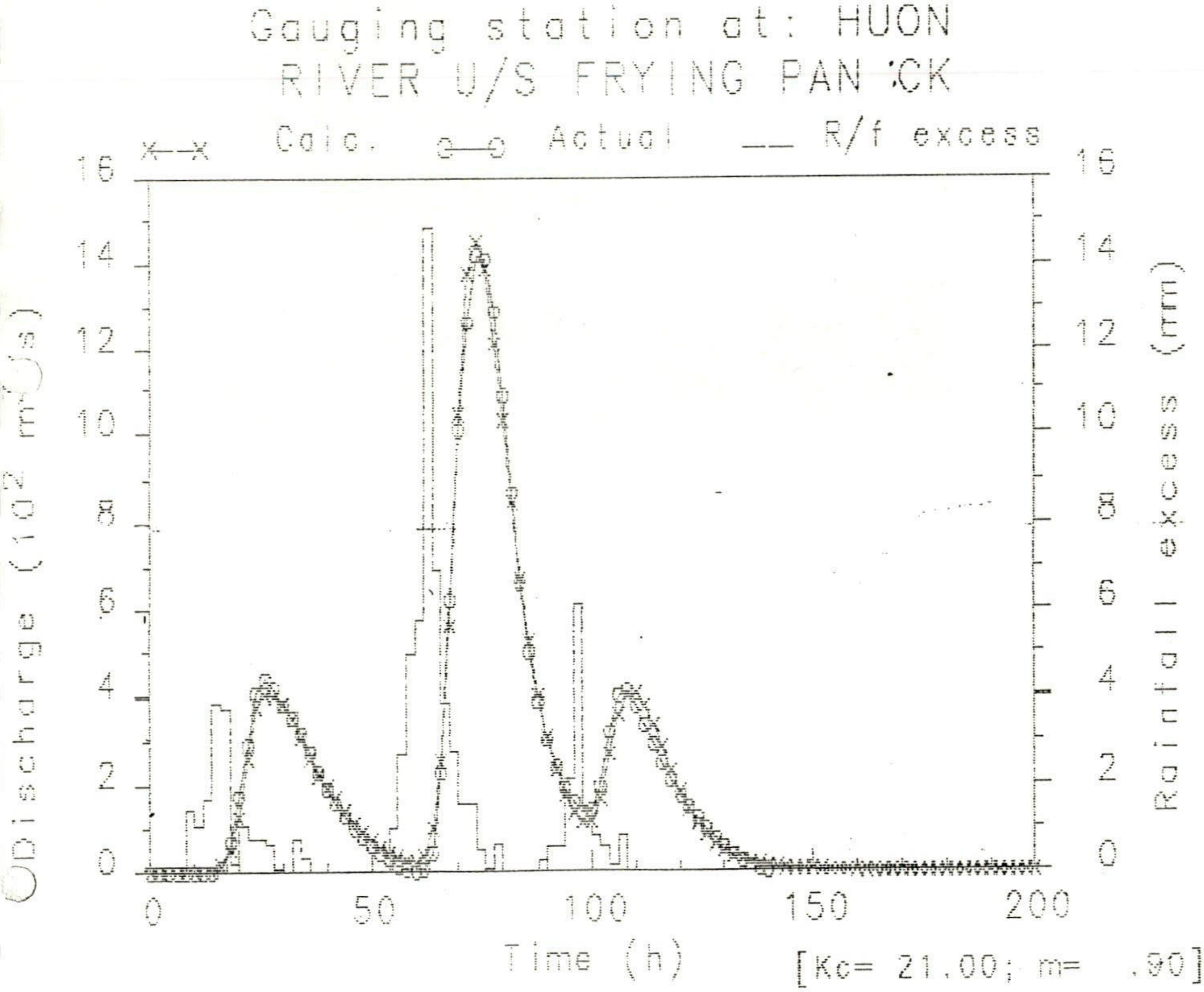
Comments

Lack of pluviograph data makes results unreliable.



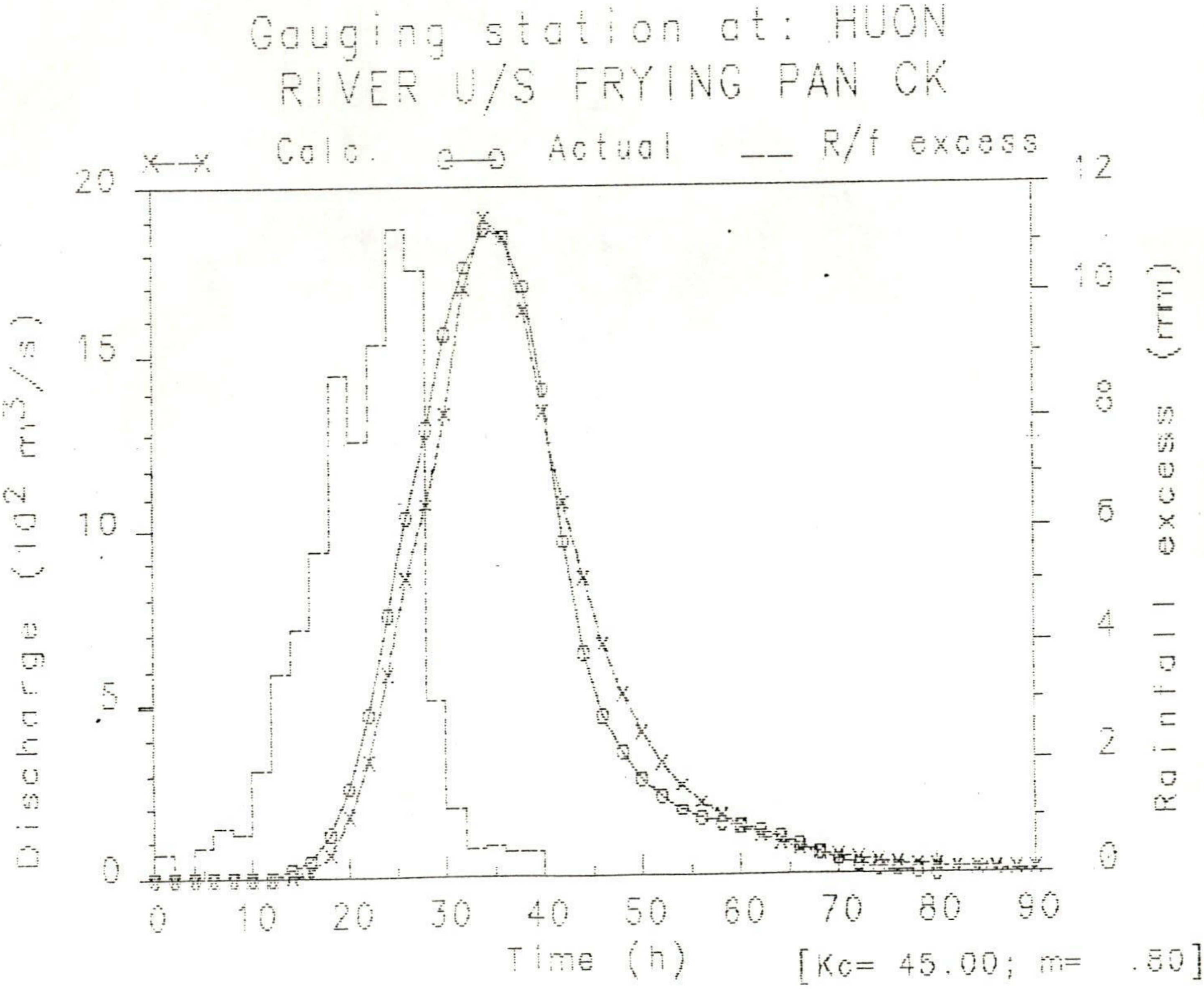
Gauging station at: HUON
RIVER U/S FRYING PAN CK
Calc.
Actual
R/f excess
Discharge (10^2 m^3/s)
Rainfall excess (mm)
Time (h)
[Kc= 40.00; m= .80]

AUG. 1980

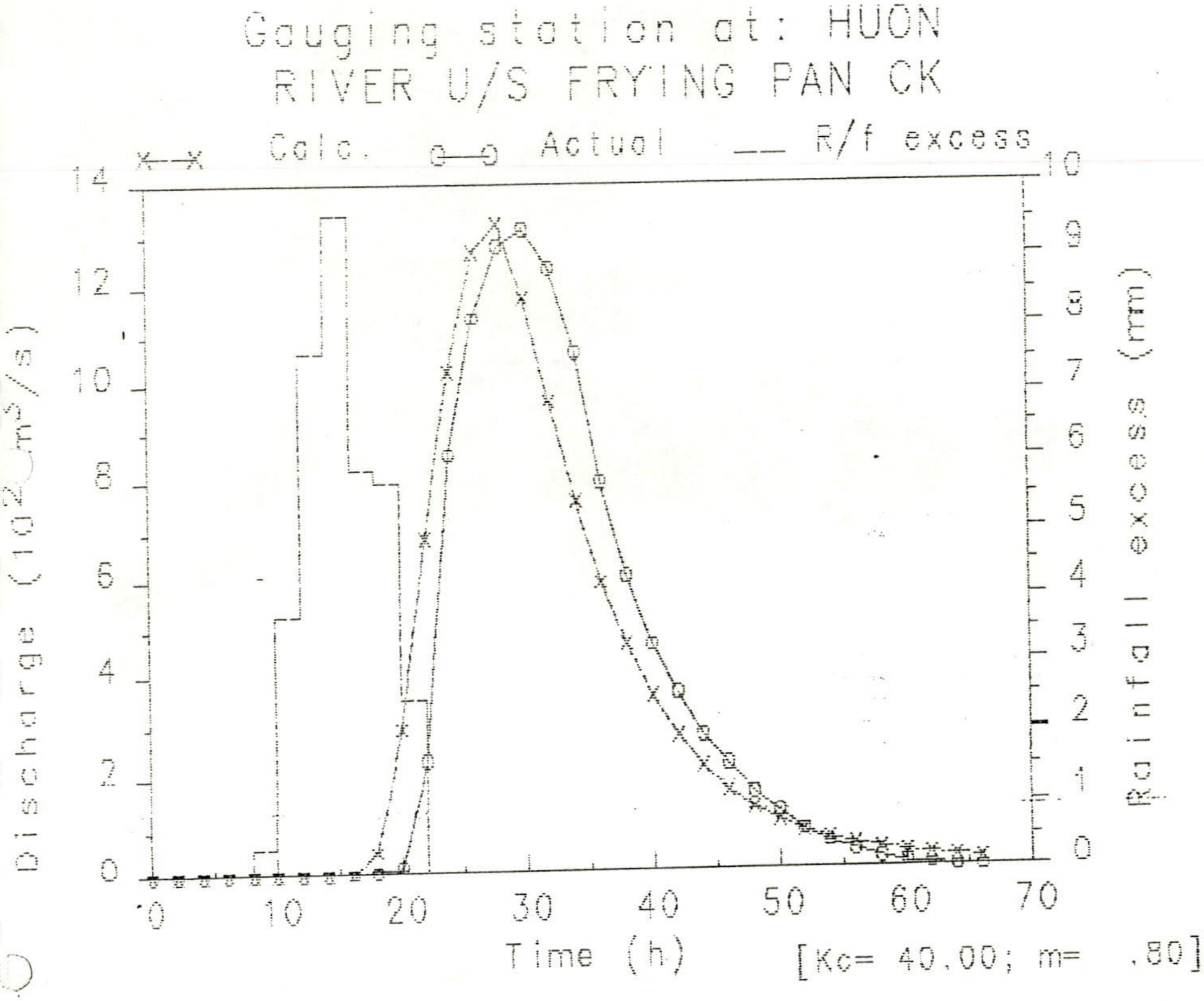


Gauging station at: HUON
RIVER U/S FRYING PAN CK
x—x Calc. o—o Actual __ R/f excess
Discharge (10² m³/s)
Rainfall excess (mm)
0
2
4
6
8
10
12
14
16
0
50
100
150
200
Time (h)
[Kc= 21.00; m= .90]

AUG. 1980

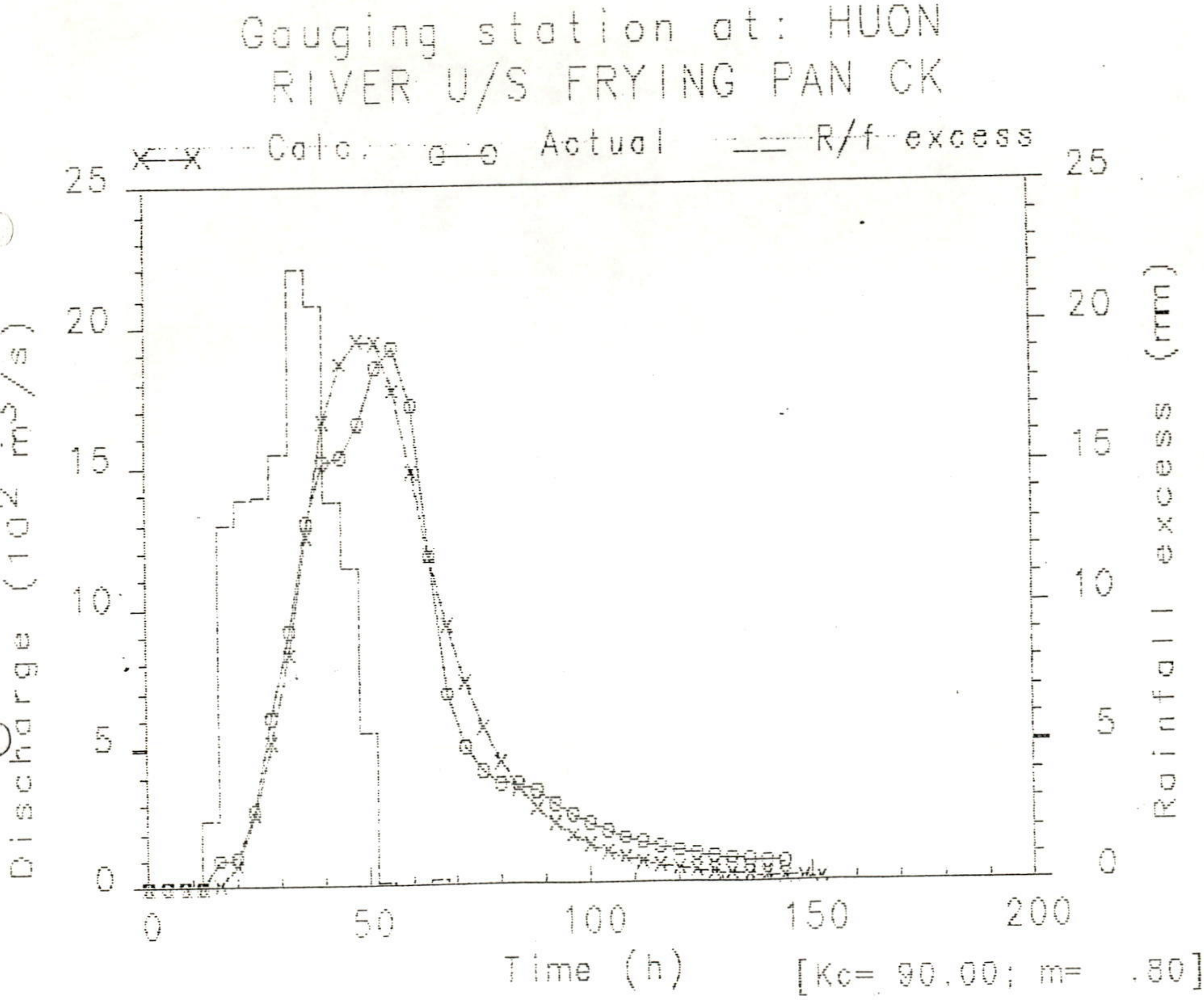

Gauging station at: HUON
RIVER U/S FRYING PAN CK
Calc.
Actual
R/f excess
Discharge (10^2 m^3/s)
Rainfall excess (mm)
Time (h)
[Kc= 45.00; m= .80]

MAY 1975



Gauging station at: HUON
RIVER U/S FRYING PAN CK
Calc.
Actual
R/f excess
Discharge (10² m³/s)
Rainfall excess (mm)
Time (h)
[Kc= 40.00; m= .80]

DEC. 1968



APR. 1960
(BEFORE ADJUSTMENTS
IN DISTRIBUTION OF RAINFALL)

APPENDIX B

IFD Tables

```
------------------------------------------------------------
| Program for determining IFD design rainfall information |
|          - based on AR&R(1987) sect 2.3                  |
|         (C) 1988 WP Software (062 815811)                |
------------------------------------------------------------
```

*** INPUT DATA ECHO ***

```
HUON AREAS A,B,C
 2 year,  1 hour intensity:        15.000000 mm/hr
 2 year, 12 hour intensity:         4.200000 mm/hr
 2 year, 72 hour intensity:         1.300000 mm/hr
50 year,  1 hour intensity:        28.000000 mm/hr
50 year, 12 hour intensity:         7.100000 mm/hr
50 year, 72 hour intensity:         2.500000 mm/hr
Skewness:     7.100000E-01
Geographical factor for 6 minute,  2 yr storm:          3.840000
Geographical factor for 6 minute, 50 yr storm:         14.920000
```

*** OUTPUT IFD TABLE ***

Rainfall Intensity (mm/h) for HUON AREAS A,B,C

Duration	Average Storm Recurrence Interval (years)						
	1	2	5	10	20	50	100
6m	29.91	41.41	60.85	76.35	97.80	132.14	163.73
7	28.39	39.20	57.21	71.49	91.24	122.74	151.60
8	27.08	37.30	54.11	67.38	85.71	114.84	141.44
9	25.95	35.65	51.43	63.83	80.95	108.07	132.75
10	24.94	34.20	49.08	60.72	76.80	102.18	125.22
11	24.04	32.90	46.99	57.98	73.14	97.00	118.61
12	23.23	31.73	45.13	55.52	69.87	92.41	112.76
13	22.49	30.67	43.44	53.31	66.94	88.29	107.52
14	21.82	29.71	41.90	51.31	64.29	84.57	102.81
15	21.20	28.82	40.50	49.48	61.88	81.20	98.54
16	20.63	28.00	39.22	47.81	59.67	78.12	94.64
17	20.10	27.25	38.03	46.27	57.64	75.30	91.08
18	19.61	26.54	36.93	44.84	55.77	72.70	87.81
20	18.72	25.27	34.95	42.29	52.42	68.07	81.98
25	16.91	22.71	30.99	37.20	45.79	58.94	70.56
30	15.51	20.74	27.99	33.38	40.83	52.18	62.14
35	14.39	19.17	25.62	30.38	36.97	46.95	55.65
40	13.47	17.88	23.70	27.95	33.86	42.76	50.48
45	12.70	16.80	22.10	25.94	31.30	39.32	46.26
50	12.04	15.88	20.74	24.24	29.14	36.45	42.74
55	11.46	15.08	19.57	22.79	27.30	34.00	39.76
60	10.95	14.38	18.55	21.53	25.71	31.90	37.19
75	9.83	12.88	16.56	19.17	22.84	28.27	32.91
90	8.98	11.75	15.06	17.41	20.71	25.58	29.73
2.0h	7.78	10.16	12.95	14.92	17.71	21.80	25.28
3.0	6.34	8.25	10.45	11.99	14.16	17.36	20.06
4.0	5.48	7.12	8.96	10.25	12.08	14.75	17.01
5.0	4.89	6.34	7.96	9.08	10.68	13.01	14.97
6.0	4.46	5.78	7.22	8.22	9.66	11.74	13.48
8.0	3.86	4.98	6.20	7.04	8.24	9.98	11.44
10.0	3.45	4.44	5.51	6.24	7.29	8.81	10.08
12.0	3.14	4.05	5.00	5.65	6.59	7.95	9.08
14.0	2.85	3.68	4.57	5.18	6.05	7.32	8.38
16.0	2.62	3.39	4.22	4.80	5.62	6.82	7.82
18.0	2.43	3.15	3.94	4.48	5.26	6.40	7.35
20.0	2.28	2.95	3.70	4.22	4.96	6.04	6.96
22.0	2.14	2.78	3.50	3.99	4.70	5.74	6.61
24.0	2.02	2.63	3.32	3.80	4.48	5.47	6.31
36.0	1.55	2.03	2.59	2.98	3.54	4.37	5.07
48.0	1.27	1.67	2.15	2.49	2.98	3.69	4.30
60.0	1.08	1.42	1.85	2.16	2.58	3.22	3.76
72.0	.94	1.24	1.63	1.90	2.29	2.86	3.36
40.0		1.91	2.44	2.82	3.35	4.14	4.81

```
-------------------------------------------------------------
| Program for determining IFD design rainfall information |
|          - based on AR&R(1987) sect 2.3                 |
|         (C) 1988 WP Software (062 815811)               |
-------------------------------------------------------------
```

*** INPUT DATA ECHO ***

```
HUON AREAS F,G
 2 year,  1 hour intensity:       15.200000 mm/hr
 2 year, 12 hour intensity:        4.850000 mm/hr
 2 year, 72 hour intensity:        1.350000 mm/hr
50 year,  1 hour intensity:       27.500000 mm/hr
50 year, 12 hour intensity:        6.950000 mm/hr
50 year, 72 hour intensity:        2.450000 mm/hr
Skewness:     7.450000E-01
Geographical factor for 6 minute,  2 yr storm:         3.875000
Geographical factor for 6 minute, 50 yr storm:        14.940000
```

*** OUTPUT IFD TABLE ***

Rainfall Intensity (mm/h) for HUON AREAS F,G

Duration	Average Storm Recurrence Interval (years)						
	1	2	5	10	20	50	100
6m	30.63	42.25	61.31	76.48	97.55	131.25	162.23
7	29.06	39.97	57.62	71.59	90.97	121.84	150.12
8	27.72	38.03	54.48	67.44	85.41	113.94	139.97
9	26.55	36.34	51.76	63.86	80.64	107.17	131.31
10	25.51	34.84	49.38	60.74	76.47	101.29	123.80
11	24.59	33.51	47.27	57.97	72.80	96.12	117.21
12	23.75	32.32	45.38	55.50	69.53	91.53	111.38
13	22.99	31.23	43.67	53.28	66.59	87.42	106.16
14	22.30	30.24	42.12	51.26	63.94	83.71	101.47
15	21.67	29.33	40.70	49.43	61.52	80.35	97.22
16	21.08	28.50	39.40	47.74	59.31	77.28	93.35
17	20.53	27.72	38.20	46.19	57.28	74.46	89.81
18	20.03	27.00	37.09	44.76	55.41	71.87	86.55
20	19.11	25.70	35.09	42.20	52.06	67.26	80.76
25	17.25	23.07	31.09	37.09	45.43	58.18	69.42
30	15.82	21.06	28.06	33.25	40.48	51.46	61.08
35	14.68	19.46	25.68	30.24	36.62	46.26	54.65
40	13.73	18.14	23.74	27.81	33.52	42.10	49.53
45	12.94	17.04	22.12	25.80	30.97	38.69	45.36
50	12.26	16.10	20.75	24.10	28.82	35.84	41.88
55	11.67	15.28	19.58	22.65	26.99	33.42	38.93
60	11.15	14.57	18.55	21.39	25.40	31.33	36.40
75	10.15	13.21	16.67	19.11	22.59	27.70	32.04
90	9.39	12.18	15.26	17.41	20.50	25.01	28.83
2.0h	8.29	10.69	13.24	15.00	17.55	21.25	24.35
3.0	6.94	8.89	10.82	12.14	14.06	16.84	19.14
4.0	6.11	7.79	9.37	10.43	12.01	14.26	16.13
5.0	5.54	7.03	8.38	9.28	10.63	12.54	14.12
6.0	5.11	6.47	7.65	8.43	9.62	11.29	12.67
8.0	4.51	5.67	6.63	7.25	8.22	9.57	10.68
10.0	4.09	5.12	5.93	6.45	7.28	8.42	9.35
12.0	3.77	4.71	5.42	5.87	6.59	7.59	8.40
14.0	3.39	4.25	4.92	5.36	6.04	7.00	7.78
16.0	3.08	3.88	4.53	4.95	5.61	6.53	7.28
18.0	2.84	3.58	4.21	4.62	5.25	6.14	6.86
20.0	2.64	3.33	3.94	4.34	4.95	5.80	6.51
22.0	2.46	3.12	3.71	4.10	4.69	5.52	6.20
24.0	2.31	2.94	3.51	3.89	4.46	5.27	5.93
36.0	1.72	2.21	2.70	3.03	3.52	4.22	4.81
48.0	1.38	1.78	2.22	2.52	2.95	3.58	4.11
60.0	1.15	1.50	1.89	2.17	2.56	3.13	3.62
72.0	.99	1.29	1.65	1.90	2.26	2.79	3.25

40 0 — 2·07 2·54 2·86 3·33 4·00 4·58

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| Program for determining IFD design rainfall information |
|          - based on AR&R(1987) sect 2.3                  |
|        (C) 1988 WP Software (062 815811)                 |
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*** INPUT DATA ECHO ***

HUON AREAS D,E,H
 2 year,  1 hour intensity:       14.800000 mm/hr
 2 year, 12 hour intensity:        5.000000 mm/hr
 2 year, 72 hour intensity:        1.550000 mm/hr
50 year,  1 hour intensity:       27.500000 mm/hr
50 year, 12 hour intensity:        7.800000 mm/hr
50 year, 72 hour intensity:        2.800000 mm/hr
Skewness:     6.300000E-01
Geographical factor for 6 minute,  2 yr storm:          3.830000
Geographical factor for 6 minute, 50 yr storm:         15.060000
```

*** OUTPUT IFD TABLE ***

Rainfall Intensity (mm/h) for HUON AREAS D,E,H

Duration	Average Storm Recurrence Interval (years)						
	1	2	5	10	20	50	100
6m	29.69	41.05	60.52	75.78	96.68	129.71	159.70
7	28.18	38.85	56.88	70.92	90.14	120.40	147.76
8	26.89	36.98	53.78	66.81	84.63	112.57	137.76
9	25.76	35.34	51.10	63.26	79.89	105.87	129.21
10	24.77	33.90	48.75	60.16	75.76	100.05	121.81
11	23.87	32.61	46.67	57.42	72.11	94.93	115.32
12	23.07	31.45	44.80	54.97	68.86	90.39	109.57
13	22.34	30.41	43.12	52.76	65.95	86.32	104.43
14	21.67	29.45	41.59	50.76	63.31	82.65	99.81
15	21.06	28.57	40.19	48.94	60.92	79.32	95.62
16	20.50	27.76	38.91	47.28	58.72	76.29	91.81
17	19.97	27.01	37.72	45.74	56.71	73.51	88.32
18	19.48	26.31	36.62	44.32	54.85	70.94	85.11
20	18.60	25.06	34.65	41.78	51.53	66.38	79.41
25	16.80	22.51	30.70	36.71	44.96	57.40	68.24
30	15.42	20.56	27.72	32.91	40.05	50.76	60.02
35	14.31	19.00	25.36	29.93	36.23	45.62	53.70
40	13.40	17.73	23.44	27.52	33.16	41.51	48.66
45	12.63	16.66	21.85	25.53	30.62	38.14	44.56
50	11.98	15.74	20.50	23.85	28.50	35.33	41.13
55	11.40	14.95	19.34	22.41	26.68	32.94	38.23
60	10.90	14.26	18.33	21.16	25.11	30.88	35.74
75	9.96	12.98	16.58	19.07	22.55	27.61	31.86
90	9.23	12.01	15.26	17.49	20.62	25.17	28.97
2.0h	8.19	10.61	13.36	15.24	17.88	21.70	24.88
3.0	6.90	8.90	11.06	12.52	14.60	17.57	20.03
4.0	6.11	7.84	9.66	10.88	12.63	15.11	17.16
5.0	5.56	7.11	8.71	9.76	11.29	13.45	15.22
6.0	5.14	6.57	7.99	8.93	10.30	12.23	13.80
8.0	4.55	5.80	6.99	7.77	8.91	10.52	11.83
10.0	4.15	5.26	6.30	6.97	7.97	9.37	10.50
12.0	3.84	4.86	5.79	6.38	7.28	8.52	9.53
14.0	3.48	4.42	5.29	5.85	6.69	7.86	8.81
16.0	3.20	4.07	4.89	5.43	6.22	7.33	8.23
18.0	2.97	3.78	4.57	5.08	5.83	6.89	7.75
20.0	2.78	3.54	4.29	4.78	5.50	6.51	7.34
22.0	2.61	3.34	4.06	4.53	5.22	6.19	6.99
24.0	2.47	3.16	3.85	4.31	4.97	5.91	6.68
36.0	1.89	2.43	3.01	3.39	3.95	4.73	5.39
48.0	1.55	2.00	2.50	2.84	3.32	4.01	4.59
60.0	1.32	1.71	2.16	2.46	2.89	3.51	4.03
72.0	1.15	1.50	1.90	2.18	2.57	3.13	3.60
40		2.29	2.84	3.21	3.74	4.49	5.12

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| Program for determining IFD design rainfall information |
|          - based on AR&R(1987) sect 2.3                 |
|         (C) 1988 WP Software (062 815811)               |
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*** INPUT DATA ECHO ***

HUON AREAS I,J
 2 year,  1 hour intensity:        13.900000 mm/hr
 2 year, 12 hour intensity:         3.600000 mm/hr
 2 year, 72 hour intensity:         1.000000 mm/hr
50 year,  1 hour intensity:        24.500000 mm/hr
50 year, 12 hour intensity:         5.900000 mm/hr
50 year, 72 hour intensity:         1.900000 mm/hr
Skewness:     5.700000E-01
Geographical factor for 6 minute,  2 yr storm:         3.870000
Geographical factor for 6 minute, 50 yr storm:        15.170000
```

*** OUTPUT IFD TABLE ***

Rainfall Intensity (mm/h) for HUON AREAS I,J

Duration	Average Storm Recurrence Interval (years)						
	1	2	5	10	20	50	100
6m	28.67	39.42	57.60	71.53	90.45	119.84	146.12
7	27.20	37.28	54.05	66.80	84.13	110.92	134.77
8	25.94	35.46	51.03	62.81	78.81	103.45	125.30
9	24.85	33.86	48.42	59.38	74.24	97.07	117.24
10	23.87	32.46	46.14	56.38	70.27	91.53	110.26
11	23.01	31.21	44.12	53.73	66.78	86.68	104.16
12	22.22	30.09	42.30	51.36	63.67	82.38	98.77
13	21.51	29.07	40.67	49.24	60.88	78.53	93.96
14	20.87	28.14	39.19	47.32	58.37	75.07	89.63
15	20.27	27.29	37.84	45.57	56.08	71.94	85.73
16	19.72	26.50	36.60	43.97	54.00	69.08	82.18
17	19.21	25.77	35.45	42.50	52.08	66.47	78.93
18	18.73	25.10	34.40	41.14	50.32	64.07	75.95
20	17.88	23.88	32.50	38.70	47.17	59.80	70.67
25	16.14	21.42	28.70	33.88	40.96	51.43	60.37
30	14.79	19.54	25.84	30.26	36.34	45.26	52.83
35	13.72	18.04	23.58	27.44	32.76	40.51	47.05
40	12.84	16.81	21.76	25.17	29.89	36.73	42.48
45	12.09	15.77	20.24	23.29	27.53	33.65	38.75
50	11.46	14.90	18.96	21.71	25.55	31.07	35.66
55	10.91	14.13	17.85	20.36	23.87	28.89	33.05
60	10.42	13.47	16.90	19.19	22.42	27.02	30.82
75	9.28	11.98	14.99	16.99	19.83	23.86	27.17
90	8.43	10.87	13.57	15.37	17.91	21.51	24.48
2.0h	7.23	9.31	11.58	13.08	15.22	18.24	20.73
3.0	5.81	7.46	9.23	10.40	12.07	14.42	16.34
4.0	4.97	6.38	7.86	8.83	10.23	12.19	13.80
5.0	4.40	5.64	6.93	7.78	9.00	10.70	12.10
6.0	3.99	5.11	6.26	7.02	8.10	9.63	10.87
8.0	3.41	4.36	5.33	5.96	6.87	8.15	9.18
10.0	3.03	3.86	4.71	5.26	6.05	7.16	8.06
12.0	2.74	3.50	4.25	4.74	5.45	6.44	7.24
14.0	2.47	3.15	3.85	4.31	4.97	5.89	6.64
16.0	2.25	2.88	3.54	3.97	4.58	5.45	6.15
18.0	2.08	2.66	3.28	3.69	4.27	5.08	5.75
20.0	1.93	2.48	3.06	3.45	4.00	4.78	5.42
22.0	1.80	2.32	2.88	3.25	3.77	4.52	5.13
24.0	1.70	2.19	2.72	3.07	3.58	4.29	4.88
36.0	1.27	1.64	2.07	2.36	2.77	3.35	3.83
48.0	1.02	1.33	1.70	1.95	2.29	2.79	3.21
60.0	.86	1.12	1.44	1.66	1.97	2.41	2.77
72.0	.74	.97	1.25	1.45	1.72	2.12	2.45
40.0		1.54	1.95	2.22	2.61	3.16	3.62

APPENDIX C

HEC-2 Programme Input File

```
T1   HUON RIVER FLOOD PLAIN STUDY
T2   STAGE 1
T3        50 YEAR DESIGN STORM
J1    -10       0       0       0  0.0014       1       1    2100     4.0
J2     -1       0      -1
J3     38      42      14      26       1
J5    -10     -10
J6      1
NC   0.04    0.04   0.025     0.1     0.3
X1      0     100     420     673
GR 22.30     0.0   19.30    44.0   17.55    70.0   17.20    72.0   15.95    89.0
GR 15.15    97.0   14.20   111.0   13.25   122.0   12.80   126.0   12.45   132.0
GR 12.30   133.0   11.45   141.0   11.15   144.0   10.95   146.0   10.10   155.0
GR  8.80   173.0    7.70   185.0    6.65   195.0    6.45   197.0    5.50   205.0
GR  5.45   207.0    5.00   207.5    5.25   208.0    5.20   209.0    4.55   213.0
GR  4.25   215.0    3.95   217.0    3.65   218.0    3.20   221.0    2.55   228.0
GR  2.20   232.0    1.70   235.0    1.65   239.0    0.75   252.0    0.25   303.0
GR  0.45   321.0    0.75   341.0    0.30   381.0    0.90   400.0    0.35   420.0
GR  0.00   423.0   -0.35   425.0   -2.50   435.0   -2.80   444.0   -3.60   459.0
GR -4.60   474.0   -4.80   489.0   -4.90   504.0   -5.00   520.0   -4.90   535.0
GR -5.00   550.0   -5.50   565.0   -5.00   580.0   -4.80   595.0   -4.80   610.0
GR -4.90   625.0   -5.00   640.0   -4.60   655.0   -3.80   668.0   -1.00   670.0
GR  0.00   672.0    0.50   673.0    1.00   678.0    0.95   686.0    1.35   690.0
GR  2.00   693.0    2.50   695.0    2.85   699.0    3.50   702.0    3.95   706.0
GR  4.50   710.0    5.25   715.0    5.75   720.0    6.55   725.0    7.10   729.0
GR  7.85   736.0    8.50   741.0    9.05   742.0    9.40   747.0   10.05   757.0
GR 10.40   765.0   10.85   781.0   11.50   797.0   12.10   813.0   11.95   822.0
GR 11.65   824.0   11.30   829.0   11.15   839.0   11.35   855.0   12.05   879.0
GR 12.85   895.0   13.15   912.0   14.05   924.0   14.55   930.0   14.85   931.0
GR 15.05   933.0   15.40   936.0   15.85   936.4   16.20   937.0   16.40   939.0
X1      1      94     489     637     460     580     540
GR 16.74     0.0   16.40     2.0   16.25     3.0   16.00     6.0   15.85     9.0
GR 15.60    12.0   15.35    14.0   15.15    16.0   14.95    18.0   14.65    20.0
GR 14.35    22.0   14.00    24.0   13.60    25.0   13.25    27.0   12.95    28.0
GR 12.60    29.0   12.25    31.0   11.85    33.0   11.45    34.0   11.00    37.0
GR 10.55    39.0   10.20    42.0    9.70    45.0    9.45    49.0    9.05    51.0
GR  8.70    54.0    8.15    57.0    7.60    60.0    7.00    63.0    6.50    66.0
GR  6.05    70.0    5.10    78.0    4.60    86.0    3.85    94.0    3.10   105.0
GR  2.20   120.0    1.40   139.0    1.00   156.0    0.55   175.0    0.40   194.0
GR  0.30   220.0    0.25   241.0    0.20   258.0    0.20   271.0    0.20   305.0
GR  0.15   327.0    0.55   349.0    0.30   381.0    0.25   414.0    0.25   423.0
GR  0.25   440.0    0.30   464.0    0.65   482.0    1.43   487.0    0.15   489.0
GR -0.90   491.0   -4.70   506.0   -5.40   521.0   -6.30   535.0   -7.40   544.0
GR -8.20   557.0   -8.80   572.0   -9.80   587.0   -9.40   597.0   -9.00   607.0
GR -4.00   622.0   -2.00   629.0    0.15   637.0    5.45   642.0    5.85   643.0
GR  7.08   644.0    7.75   646.0    8.15   648.0    8.55   649.0    9.15   652.0
GR  9.45   654.0    9.85   657.0   10.30   659.0   10.65   661.0   11.15   663.0
GR 11.50   665.0   12.00   668.0   12.45   670.0   12.80   673.0   13.15   676.0
GR 13.50   679.0   13.45   680.0   14.05   682.0   14.57   682.5   15.30   683.0
GR 15.70   683.9   16.10   684.0   16.45   685.0   16.65   686.0
X1      2      99   108.0     278     450     580     600
GR 15.90     0.0   15.10     1.0   14.30     3.0   14.20     5.0   13.45     7.0
GR 12.40     8.0   12.00    14.0   10.85    16.0   10.45    17.0   10.05    18.0
GR  9.75    19.0    9.45    20.0    9.20    21.0    8.85    22.0    8.50    23.0
GR  7.95    24.0    7.55    25.0    7.05    27.0    6.65    28.0    6.20    29.0
GR  5.90    30.0    5.45    31.0    5.10    33.0    4.55    34.0    4.20    35.0
GR  3.60    36.0    3.20    38.0    2.80    39.0    2.40    42.0    1.95    44.0
GR  1.45    46.0    1.00    49.0    0.90    53.0    0.70    66.0    0.80    78.0
GR  1.10    90.0    0.95   101.0    0.70   105.0    0.60   107.0    0.30   108.0
GR  0.20   108.0   -0.70   109.0   -1.70   113.0   -4.10   117.0   -7.50   130.0
GR -5.30   145.0   -4.70   160.0   -3.90   175.0   -4.00   190.0   -3.90   205.0
GR -4.30   220.0   -4.50   235.0   -3.30   251.0   -1.10   265.0    0.20   278.0
GR  0.50   287.0    1.41   289.0    0.60   293.0    0.55   306.0    0.15   323.0
GR -1.91   345.0   -0.05   365.0   -0.10   386.0   -0.10   405.0   -0.05   425.0
GR -0.05   446.0    0.10   453.0   -1.47   471.0    0.25   484.0    1.10   487.0
GR  1.75   490.0    2.50   493.0    3.20   496.0    3.85   499.0    4.40   502.0
GR  5.15   509.0    6.45   524.0    6.95   529.0    7.60   538.0    8.35   543.0
GR  9.25   549.0    9.65   552.0   10.40   558.0   10.80   564.0   11.60   570.0
GR 11.80   574.0   12.60   583.0   13.05   596.0   13.85   622.0   14.40   633.0
GR 15.30   650.0   15.90   660.0   16.90   676.0   17.90   691.0   18.20   695.0
GR 18.65   702.0   19.00   705.0   19.85   709.0   21.31   728.0
X1      3      78      37     138     450     220     430
GR 20.25     0.0   19.70     1.0   10.55     8.0    9.00    10.0    7.55    12.0
GR  6.20    15.0    5.45    19.0    5.05    26.0    4.90    31.0    4.55    33.0
GR  3.60    35.0    2.80    36.0    0.30    37.0   -0.30    39.0   -3.20    43.0
GR -9.80    58.0   -9.80    67.0   -9.60    82.0   -9.40    95.0   -5.30   107.0
GR -5.10   122.0   -0.60   137.0    0.30   138.0    0.55   139.0    0.40   144.0
GR  1.05   147.0    1.35   148.0    0.90   150.0   -0.25   152.0    0.30   152.2
GR  0.55   176.0    1.15   194.0    1.65   204.0    1.30   220.0    0.75   236.0
GR  0.80   241.0    1.05   244.0    1.50   256.0    1.45   276.0    1.25   297.0
GR  1.10   317.0    1.05   336.0    0.80   357.0    0.85   377.0    1.15   407.0
GR  1.00   432.0    1.05   464.0    1.10   500.0    1.25   522.0    0.90   563.0
GR  1.45   597.0    1.00   608.0    1.35   625.0    2.10   640.0    2.80   646.0
GR  3.20   649.0    3.95   653.0    4.60   657.0    5.35   662.0    6.10   667.0
GR  6.95   673.0    7.65   677.0    8.50   683.0    9.10   688.0    9.75   692.0
GR 10.15   693.0   10.50   694.0   10.40   696.0   10.50   698.0   11.55   700.0
GR 11.95   705.0   12.65   710.0   13.30   716.0   13.85   723.0   14.20   731.0
GR 14.20   743.0   14.70   756.0   15.20   768.0
```

X1	4	100	610	767	550	150	500			
GR	15.30	0.0	14.40	3.0	13.50	7.0	12.50	12.0	11.65	19.0
GR	12.05	25.0	10.95	30.0	10.00	31.0	10.45	42.0	9.75	45.0
GR	8.95	57.0	7.70	72.0	6.95	81.0	6.25	90.0	5.70	98.0
GR	5.00	116.0	4.30	122.0	3.70	128.0	3.25	132.0	2.60	149.0
GR	1.95	166.0	1.40	184.0	0.80	210.0	0.65	218.0	0.35	221.0
GR	0.80	222.0	0.80	238.0	-0.50	240.0	0.55	244.0	0.90	246.0
GR	0.55	261.0	0.65	289.0	0.55	314.0	0.70	337.0	0.25	360.0
GR	0.50	379.0	0.85	436.0	1.05	503.0	1.55	558.0	1.45	588.0
GR	1.30	607.0	1.00	608.0	0.35	610.0	-0.10	611.0	-2.40	614.0
GR	-3.00	625.0	-3.50	640.0	-2.50	655.0	-2.70	670.0	-3.10	685.0
GR	-3.20	700.0	-3.70	715.0	-3.80	730.0	-3.90	745.0	-4.00	760.0
GR	-0.50	766.0	0.35	767.0	0.35	769.0	0.80	770.0	0.95	770.0
GR	1.85	786.0	2.30	787.0	2.35	792.0	2.75	797.0	3.65	811.0
GR	4.35	823.0	4.60	826.0	5.25	836.0	5.85	842.0	6.00	847.0
GR	5.65	857.0	5.15	862.0	4.35	866.0	3.95	868.0	3.55	870.0
GR	3.10	873.0	2.65	875.0	2.15	878.0	1.80	882.0	1.60	888.0
GR	2.00	891.0	2.70	900.0	3.40	927.0	3.15	977.0	3.25	1021.0
GR	3.75	1026.0	4.15	1029.0	4.65	1032.0	5.80	1041.0	7.00	1057.0
GR	8.15	1068.0	9.50	1077.0	10.55	1084.0	11.35	1087.0	12.35	1094.0
GR	13.50	1102.0	14.35	1109.0	14.70	1113.0	15.00	1116.0	20.60	1246.0
X1	5	100	1192	1328	400	200	280			
GR	15.15	0.0	14.95	9.0	13.75	11.0	14.80	14.0	14.05	39.0
GR	13.25	70.0	12.95	102.0	11.40	141.0	11.15	195.0	10.75	203.0
GR	11.45	211.0	10.85	244.0	10.40	277.0	9.60	309.0	8.85	342.0
GR	8.35	370.0	7.75	379.0	7.40	405.0	7.30	421.0	6.65	460.0
GR	7.35	492.0	6.70	532.0	6.35	565.0	5.65	595.0	4.50	617.0
GR	4.65	661.0	4.85	699.0	4.75	726.0	4.15	732.0	4.15	739.0
GR	3.95	746.0	3.85	755.0	4.15	767.0	4.25	780.0	4.05	805.0
GR	3.80	820.0	3.20	854.0	2.70	885.0	2.40	909.0	2.20	928.0
GR	1.85	942.0	1.30	953.0	0.85	961.0	0.60	979.0	0.75	991.0
GR	0.30	991.2	0.70	991.5	0.85	1018.0	1.60	1027.0	1.80	1081.0
GR	0.85	1087.0	0.35	1102.0	0.00	1103.0	0.50	1105.0	0.50	1124.0
GR	1.95	1129.0	2.80	1141.0	1.95	1147.0	2.15	1153.0	2.50	1158.0
GR	2.75	1164.0	2.15	1170.0	1.70	1179.0	1.15	1186.0	0.90	1191.0
GR	0.35	1192.0	-0.60	1193.0	-1.80	1196.0	-2.80	1201.0	-1.50	1211.0
GR	-2.00	1221.0	-2.70	1231.0	-2.70	1246.0	-2.80	1261.0	-3.40	1276.0
GR	-5.10	1291.0	-3.90	1306.0	-2.90	1324.0	0.35	1328.0	2.40	1329.0
GR	3.05	1338.0	3.40	1359.0	3.85	1367.0	4.30	1375.0	4.75	1391.0
GR	5.40	1406.0	6.45	1415.0	7.00	1421.0	7.85	1427.0	8.85	1433.0
GR	9.40	1435.0	9.95	1438.0	10.60	1441.0	11.10	1443.0	11.60	1446.0
GR	12.15	1448.0	12.75	1450.0	12.30	1453.0	13.85	1456.0	14.40	1461.0
NC	0	0	0	0.3	0.5					
X1	61	85	1415	1572	320	200	210			
GR	17.69	0	17.11	20	16.74	40	16.44	60	16.15	80
GR	15.88	100	15.51	120	15.18	140	14.83	160	14.39	180
GR	13.89	200	13.37	220	12.99	240	12.56	260	12.07	280
GR	11.53	300	11.26	320	10.99	340	10.78	360	10.52	380
GR	10.2	400	9.98	420	9.75	440	9.46	460	9.12	480
GR	8.87	500	8.56	520	8.20	540	7.84	560	7.54	580
GR	7.37	600	7.16	620	7.03	640	6.84	660	6.77	690.5
GR	6.56	721	6.34	751.4	6.13	781.9	6.05	812.4	5.94	842.9
GR	5.54	873.4	5.1	903.8	4.67	934.3	4.23	964.8	3.80	995.3
GR	3.44	1025.8	3.61	1056.2	4.31	1086.7	4.62	1117.2	4.24	1147.7
GR	3.90	1169.0	3.42	1199.5	3.07	1230.0	2.92	1260.5	2.81	1290.9
GR	2.69	1321.4	2.64	1336.7	2.97	1361	3.30	1386	4.37	1412.9
GR	4.35	1413	0.25	1415	-0.50	1416	-3.00	1426	-2.80	1437
GR	-2.70	1449	-3.60	1460	-2.40	1471	-2.70	1483	-2.60	1494
GR	-2.30	1506	-3.10	1516	-3.20	1529	-3.30	1539	-3.20	1552
GR	-3.90	1561	-1.0	1570	0.25	1572	7.55	1576	7.80	1604
GR	8.80	1625	8.85	1654	10.10	1679	10.60	1698	10.85	1712
X1	62				80	80	80			
X3	10						2.6	7.48		
SB	1.25	1.6	1.4	0	160.0	8.4	1133	0	0	0
X1	63				10	10	10			
X2	0	0	1	6.30	2.64					
X3	10						2.6	7.48		
BT	-27	500	8.87		540	8.20		580	7.54	
BT		620	7.16		660	6.84		721	6.56	
BT		781.9	6.13		842	5.94		903.8	5.10	
BT		964.8	4.23		1025.8	3.44		1086.7	4.31	
BT		1147	4.24		1199.5	3.42		1260.5	2.92	
BT		1321.4	2.69		1361	2.97		1386	3.30	
BT		1417	4.37		1439	4.89		1462	5.38	
BT		1485	5.85		1508	6.30		1531	6.72	
BT		1554	7.11		1577	7.48		1604	7.80	
X1	64				20	20	20			
NC	0	0	0	0.1	0.3					
X1	7	100	725	823	280	420	400			
GR	6.85	0.0	6.75	7.0	6.90	54.0	6.60	66.0	6.40	107.0
GR	5.80	164.0	5.60	215.0	5.30	264.0	5.45	276.0	5.40	287.0
GR	4.85	295.0	5.00	309.0	4.35	331.0	4.45	369.0	4.55	372.0
GR	4.10	381.0	3.55	384.0	3.80	400.0	4.15	409.0	4.00	425.0
GR	4.00	440.0	4.20	453.0	4.45	463.0	4.35	478.0	4.30	493.0
GR	4.45	505.0	4.15	516.0	3.35	539.0	2.65	558.0	2.10	571.0
GR	1.60	582.0	1.10	594.0	1.00	596.0	1.05	611.0	1.00	618.0
GR	0.75	620.0	-0.25	621.0	-1.05	622.0	-3.75	640.0	-0.95	657.0
GR	-0.25	658.0	0.25	658.0	0.65	671.0	1.25	684.0	1.75	697.0

GR	1.85	713.0	1.75	724.0	0.40	725.0	-0.30	725.0	-1.10	726.0
GR	-4.50	739.0	-4.50	755.0	-4.20	769.0	-3.60	789.0	-2.20	813.0
GR	-0.45	822.0	0.40	823.0	0.50	824.0	0.90	829.0	0.65	834.0
GR	0.50	840.0	0.40	850.0	0.45	857.0	0.65	871.0	0.60	879.0
GR	0.65	887.0	0.30	896.0	-0.05	897.0	0.40	899.0	0.60	902.0
GR	0.75	908.0	0.70	909.0	1.15	910.0	1.55	911.0	2.05	912.0
GR	2.65	913.0	2.90	918.0	2.65	923.0	2.35	924.0	2.80	928.0
GR	3.40	929.0	3.90	929.3	4.50	930.0	5.65	931.0	5.75	932.0
GR	6.55	934.0	7.45	935.0	7.95	936.0	8.53	937.0	9.90	939.0
GR	10.45	939.0	11.20	940.0	11.70	941.0	12.65	942.0	13.65	943.0
GR	14.35	944.0	15.55	945.5	16.05	946.0	16.85	947.0	17.70	948.0
X1	8	100	1168	1273	320	290	280			
GR	11.60	0.0	11.40	6.0	11.35	52.0	11.95	87.0	11.80	134.0
GR	11.10	144.0	10.75	170.0	10.40	207.0	10.05	219.0	9.85	228.0
GR	9.50	252.0	9.10	269.0	8.50	287.0	8.20	306.0	7.90	324.0
GR	7.95	380.0	7.80	381.0	7.40	391.0	7.10	396.0	6.75	466.0
GR	7.00	515.0	7.25	571.0	6.85	626.0	6.70	645.0	6.20	670.0
GR	5.85	677.0	5.45	678.0	5.05	710.0	4.95	711.0	5.10	712.0
GR	5.25	757.0	5.50	802.0	5.40	862.0	5.35	902.0	5.20	945.0
GR	5.05	947.0	5.30	953.0	5.25	967.0	5.10	990.0	4.80	996.0
GR	4.55	1002.0	4.30	1006.0	3.95	1008.0	3.60	1011.0	3.25	1014.0
GR	2.50	1019.0	1.75	1023.0	1.25	1030.0	0.75	1038.0	0.50	1045.0
GR	-0.20	1045.0	-2.60	1047.0	-3.90	1061.0	-1.10	1072.0	-0.20	1073.0
GR	0.70	1075.0	1.15	1101.0	1.60	1116.0	2.05	1131.0	2.00	1150.0
GR	1.20	1168.0	0.40	1168.0	-0.80	1169.0	-2.00	1182.0	-3.20	1197.0
GR	-3.30	1214.0	-3.20	1230.0	-3.30	1244.0	-3.60	1257.0	-0.70	1272.0
GR	0.40	1273.0	0.65	1274.0	1.10	1275.0	1.55	1277.0	1.35	1305.0
GR	0.90	1324.0	0.45	1363.0	0.20	1367.0	0.60	1372.0	1.10	1397.0
GR	1.50	1409.0	1.90	1420.0	2.55	1426.0	3.05	1429.0	3.65	1434.0
GR	2.95	1437.0	4.10	1439.0	4.35	1441.0	4.70	1442.0	5.30	1443.0
GR	5.70	1444.0	6.20	1445.0	7.30	1448.0	8.00	1451.0	9.40	1453.0
GR	10.65	1454.0	11.80	1457.0	12.95	1458.0	14.15	1460.0	15.50	1462.0
X1	9	100	1439	1512	550	680	640			
GR	14.95	0.0	14.95	3.0	16.40	16.0	17.30	28.0	18.30	43.0
GR	19.20	54.0	20.25	67.0	20.60	70.0	19.60	87.0	18.85	109.0
GR	17.50	161.0	17.30	161.5	16.45	166.0	15.70	168.0	6.15	185.0
GR	8.40	212.0	10.45	216.0	10.00	221.0	9.50	227.0	8.75	236.0
GR	8.10	239.0	7.50	239.4	5.75	247.0	6.10	260.0	5.90	283.0
GR	5.25	285.0	5.80	296.0	6.35	303.0	6.65	333.0	5.80	342.0
GR	5.40	389.0	5.45	435.0	5.45	493.0	5.20	557.0	4.85	557.2
GR	5.40	558.0	5.00	579.0	4.75	653.0	4.35	702.0	3.90	750.0
GR	3.75	792.0	4.60	817.0	5.35	821.0	5.68	826.0	5.35	831.0
GR	4.80	833.0	5.15	835.0	5.60	850.0	6.15	882.0	6.35	929.0
GR	5.85	1007.0	5.20	1014.0	4.90	1021.0	4.45	1027.0	3.80	1032.0
GR	2.70	1039.0	1.77	1048.0	1.95	1082.0	1.45	1147.0	2.30	1191.0
GR	1.85	1232.0	1.10	1243.0	0.45	1250.0	1.05	1264.0	1.05	1314.0
GR	1.70	1377.0	1.30	1385.0	1.80	1396.0	2.20	1427.0	1.75	1434.0
GR	1.39	1437.0	1.00	1439.0	0.35	1439.0	-0.40	1440.0	-3.50	1455.0
GR	-4.00	1465.0	-5.80	1481.0	-5.90	1495.0	-2.60	1507.0	-0.70	1511.0
GR	0.35	1512.0	0.80	1517.0	1.45	1520.0	2.15	1521.0	3.29	1523.0
GR	3.70	1524.0	4.35	1534.0	4.70	1583.0	5.10	1599.0	5.85	1616.0
GR	6.75	1630.0	7.45	1642.0	8.20	1650.0	8.90	1655.0	9.85	1671.0
GR	10.95	1674.0	11.90	1685.0	13.40	1700.0	14.90	1711.0	26.75	1779.0
X1	10	100	685	783	700	500	650			
GR	15.85	0.0	15.25	38.0	15.00	51.0	14.55	65.0	14.15	81.0
GR	13.80	95.0	13.40	141.0	13.15	178.0	12.50	181.0	11.90	184.0
GR	11.30	187.0	10.55	190.0	10.20	192.0	9.75	194.0	9.20	195.0
GR	8.80	196.0	8.30	198.0	7.80	199.0	7.25	201.0	6.80	202.0
GR	6.30	204.0	5.75	206.0	5.10	209.0	4.80	211.0	4.20	212.0
GR	3.40	214.0	2.90	216.0	2.60	241.0	2.30	308.0	1.90	349.0
GR	1.65	393.0	1.45	474.0	1.55	501.0	2.00	534.0	1.50	554.0
GR	2.00	589.0	2.00	643.0	2.50	653.0	2.45	667.0	1.90	673.0
GR	1.50	676.0	1.30	680.0	0.85	682.0	0.35	685.0	-0.50	686.0
GR	-2.00	692.0	-2.50	704.0	-2.10	718.0	-2.80	733.0	-3.20	753.0
GR	-3.50	767.0	-2.80	781.0	0.35	783.0	1.00	785.0	1.30	786.0
GR	1.90	789.0	2.40	790.0	2.90	792.0	2.95	796.0	2.80	813.0
GR	2.40	834.0	1.85	856.0	1.90	875.0	1.70	896.0	1.70	918.0
GR	1.65	942.0	1.50	962.0	1.55	986.0	1.20	1018.0	0.60	1019.0
GR	-0.25	1019.4	0.55	1022.0	1.35	1032.0	1.60	1040.0	2.05	1089.0
GR	2.50	1091.0	3.20	1094.0	3.65	1095.0	4.25	1097.0	4.75	1098.0
GR	5.30	1099.0	5.75	1101.0	6.45	1102.0	7.20	1104.0	7.75	1105.0
GR	8.25	1106.0	9.10	1108.0	9.65	1109.0	10.25	1110.0	11.20	1112.0
GR	11.50	1113.0	11.80	1113.6	12.35	1114.0	12.95	1116.0	13.45	1118.0
GR	13.90	1119.0	14.35	1120.0	14.80	1121.0	15.20	1122.0	20.20	1138.0
X1	11	100	23	135	840	450	900			
GR	17.60	0.0	15.30	3.0	14.30	4.0	13.45	5.0	12.70	6.0
GR	11.70	7.0	10.60	8.0	9.75	9.0	8.95	10.0	7.95	11.0
GR	6.85	13.0	6.00	14.0	5.25	15.0	4.15	17.0	3.05	18.0
GR	2.20	20.0	1.45	22.0	0.60	23.0	-0.70	25.0	-2.50	38.0
GR	-8.60	56.0	-6.80	79.0	-4.40	92.0	-2.50	112.0	0.30	134.0
GR	0.60	135.0	0.85	136.0	1.25	137.0	1.70	139.0	2.25	143.0
GR	2.80	146.0	3.30	149.0	3.50	154.0	4.00	166.0	3.40	212.0
GR	3.15	229.0	2.60	261.0	2.75	323.0	2.65	355.0	2.25	397.0
GR	1.60	409.0	2.25	424.0	2.30	460.0	2.15	471.0	2.50	502.0
GR	2.10	548.0	1.50	550.0	0.85	553.0	1.45	556.0	1.90	558.0
GR	2.40	560.0	2.70	580.0	2.35	595.0	1.65	597.0	2.10	599.0
GR	2.45	605.0	2.35	622.0	2.65	643.0	3.50	669.0	3.40	711.0
GR	2.90	752.0	2.60	801.0	2.55	831.0	2.25	859.0	2.55	909.0

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GR  1.80    915.0    2.20    917.0    2.35    917.0    2.45    918.0    2.45    937.0
GR  2.90    955.0    2.60    991.0    2.20   1008.0    2.00   1038.0    2.30   1073.0
GR  2.10   1113.0    2.35   1141.0    2.90   1155.0    4.05   1171.0    4.95   1179.0
GR  5.60   1184.0    5.95   1186.0    6.30   1188.0    6.60   1190.0    6.90   1192.0
GR  7.25   1194.0    7.55   1197.0    7.90   1200.0    8.40   1204.0    9.05   1205.0
GR  9.40   1207.0    9.80   1208.0   10.30   1210.0   10.75   1212.0   11.20   1214.0
GR 12.40   1217.0   13.15   1220.0   13.90   1222.0   15.15   1225.0   31.65   1284.0
X1    12      100    24.0       95     740      360     670
GR 15.15      0.0    14.0      1.0   14.05      3.0   13.35      5.0   12.50      6.0
GR 11.75      8.0   11.45      8.3   10.95      9.0   10.10     11.0    9.50     12.0
GR  8.85     13.0    7.45     14.0    7.05     15.0    6.40     15.7    5.20     15.9
GR  4.80     16.0    4.20     17.0    3.60     20.0    2.80     20.4    2.05     22.0
GR  0.75     24.0    0.65     24.0   -1.10     25.0   -2.40     39.0   -3.50     54.0
GR -3.20     64.0   -3.40     72.0   -3.00     79.0   -0.70     94.0    0.65     95.0
GR  1.55     96.0    2.35     97.0    2.60     98.0    3.25    100.0    3.50    102.0
GR  3.90    104.0    4.15    114.0    4.55    128.0    3.85    150.0    2.95    159.0
GR  2.10    180.0    1.50    192.0    1.55    251.0    1.20    266.0    0.85    268.0
GR  1.15    271.0    1.55    282.0    2.05    284.0    2.35    286.0    2.85    290.0
GR  3.25    291.0    3.65    294.0    4.20    298.0    4.10    329.0    3.60    354.0
GR  3.90    382.0    3.25    414.0    2.80    425.0    3.10    445.0    2.60    463.0
GR  3.20    474.0    3.75    482.0    3.60    509.0    3.20    544.0    2.80    563.0
GR  3.25    595.0    2.85    620.0    2.25    664.0    2.35    730.0    2.20    796.0
GR  1.95    797.0    2.30    798.0    2.55    832.0    2.05    834.0    2.55    836.0
GR  2.60    862.0    3.60    899.0    4.40    921.0    4.00    923.0    4.35    926.0
GR  4.60    951.0    5.95    968.0    6.60    972.0    7.15    974.0    7.60    977.0
GR  8.00    978.0    8.50    980.0    8.95    982.0    9.40    985.0    9.90    986.0
GR 10.50    987.0   10.95    989.0   11.40    990.0   11.90    991.0   12.30    992.0
GR 12.75    993.0   13.30    996.0   13.85   1000.0   16.20   1002.0   32.65   1044.0
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