BYRON SHIRE COUNCIL

BRUNSWICK VALLEY FLOOD PLAIN MANAGEMENT STUDY

HYDROLOGY REPORT

JULY 1984

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HYDROLOGY

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1. INTRODUCTION

The Brunswick River has a catchment area of 220 km^2, which includes an extensive flood plain in the lower reaches where most of the population is centred, particularly in the towns of Mullumbimby and Brunswick Heads. Much of Mullumbimby is flood-prone and the growth potential of Brunswick Heads is severely restricted by a lack of flood-free land.

There is pressure for further development near the towns but, before this can proceed, the interaction between development and flood behaviour needs to be examined. Accordingly, Byron Shire Council commissioned Laurie, Montgomerie & Pettit Pty. Ltd. in association with Webb, McKeown & Associates Pty. Ltd. to undertake a study of flooding in the valley, and to examine possible development options using a mathematical hydraulic model of the flood plain.

It was recognised that even the most sophisticated hydraulic model would be of little use unless the input data were accurate. Therefore, Council directed that considerable time and effort be concentrated on defining the hydrologic regime of the area so as to produce the best possible estimates of flood hydrographs for use with the hydraulic model. This report presents the findings of the hydrologic investigation.

The investigation involved:-

- o evaluation of available data, both rainfall and streamflow
- o calibration and testing of a mathematical rainfall-runoff model using historical data
- o estimation of the 20 year, 100 year and extreme flood hydrographs.

2. SUMMARY AND CONCLUSIONS

Rainfall and runoff data for the Brunswick Valley were used to determine the 20 year and 100 year recurrence interval flood hydrographs. An extreme flood hydrograph was estimated from procedures recommended by the Bureau of Meteorology.

Peak flows were estimated by two methods: direct frequency analysis of the runoff record at the gauging station at Durrumbul; and a frequency analysis of rainfall records in the area which were converted into flows using a calibrated runoff routing model.

The effectiveness of the frequency analysis of runoff data was restricted by the limited amount of data available and the method was only used as a check on the order of accuracy of the runoff model results.

The runoff routing model was calibrated using the well documented records available from several large floods in the 1970's. Rainfall data from five stations near the catchment were analysed to determine the 20 year and 100 year rainfall patterns for input into the model.

Using the calibrated runoff routing model and the design rainfall patterns a series of design hydrographs were derived. These are detailed in Figures 19 to 21. It is recommended that these hydrographs be adopted as input to the hydraulic model.

3. APPROACH TO THE PROBLEM

The objective of this study was to derive the design hydrographs for the 20 year, 100 year and extreme floods within the Brunswick Valley. These hydrographs will later be used to study flood behaviour in the valley by means of a mathematical hydraulic model.

There are many ways of approaching this objective, as illustrated by the detailed summary of fifteen methods provided by Webb and O'Loughlin (Reference 1).

The Reference recommends that frequency analysis of streamflow data is the best method for determining peak flows, provided a sufficient length of record is available. The length of record available from the gauging station on the Brunswick River at Durrumbul is just sufficient to attempt such an analysis, however it is not possible to obtain a completely homogeneous data base from the record. A frequency analysis was carried out but, because of the recognised shortcomings of the data, the results were used only as an order of accuracy check.

Other approaches recommended in Reference 1 are unit hydrographs or runoff routing models which have been derived or calibrated using recorded rainfall and streamflow data.

The unit hydrograph approach has a major drawback in that the results derived at a gauging station are not easily transferable to

other points on the river system. The approach also is not capable of accepting spatially varied rainfall.

Three runoff routing models were compared by Webb and O'Loughlin who concluded that no method is appreciably superior to the others. Therefore the model developed by Boyd et al (Reference 2) was preferred as it is the simplest to set up and use. This preferment is supported by recent work by Boyd (Reference 3) and Sobinoff, Pola and O'Loughlin (Reference 4). The Boyd Model was used in this study.

As with all such models, the Boyd Model can only be used with confidence if it is first calibrated and tested using historical rainfall and runoff data. There were several well-recorded floods in the Brunswick catchment in the 1970's with major events occurring in October 1972, March 1974, February 1976 and March 1978.

For each of these storms all available daily read rainfall data in the vicinity of the catchment were plotted and used in the compilation of an isohyetal map to define the spatial rainfall distribution. The available pluviograph data were also analysed to produce temporal rainfall patterns for each storm. Streamflow records were obtained from the gauging station at Durrumbul which produced good records for all the floods in question. This information provided a substantial data base for calibration and testing of the Boyd Model.

Estimates of design rainfall depths of given frequencies and durations were obtained by several different procedures outlined in Chapter 2 of Australian Rainfall and Runoff (AR&R) (Reference 5). The results from the various procedures were critically examined to determine the design figures to be adopted for the 20 year and 100 year events. The rainfall depth for the extreme flood was obtained from recent work reported by the Bureau of Meteorology (Reference 6).

A design temporal pattern was determined from the available pluviograph data using the technique recommended by Pilgrim et al (Reference 8).

The adopted design rainfall figures were input to the calibrated runoff routing model to produce design flow hydrographs at various locations. As a final check, the results from the runoff routing model at Durrumbul were compared with the estimate of peak flow derived by frequency analysis of the Durrumbul data.

4. DATA SOURCES

4.1 Rainfall

4.1.1 General

The Brunswick Valley has a sub-tropical climate fed by humid air from the warm North Tasman and Coral Seas throughout most of the year. Flood-producing rains in this area are generally caused by either east coast depressions or tropical cyclones.

East coast depressions have the greater potential to produce intense rainbursts and may form over either the ocean or inland areas. A supply of warm, moist air is drawn from the ocean towards the land producing intense rainfall over the coastal region. Depressions may form at any time of the year but they are more common during the summer months when the air is more humid and sea surface temperatures higher.

The incidence of tropical cyclones in north eastern NSW is low compared to the incidence of east coast depressions. However, cyclones must be taken into account in any analysis of flooding. The cyclone season officially extends from November to April but most activity occurs during the period from January to March. Typically four or five cyclones may affect the north eastern coastal areas of Australia in a season, though this figure can vary markedly.

4.1.2 Recording Stations

While there are only two rainfall recording stations in the Brunswick Valley, at Mullumbimby and Brunswick Heads, there is a good network of stations on the periphery of the catchment in the Tweed and Richmond River Basins. Figure 1 shows the official Bureau of Meteorology rainfall stations in the vicinity and Table 4.1 indicates how long each station has been in operation.

Unfortunately, much of the historical record is now only available in the form of monthly totals and as such is of little value for this study. The number of years for which daily rainfall figures are available at key stations is also shown on Table 4.1.

Some of the stations house equipment which produces a continuous graph of rainfall. These "pluviograph" records are essential for determining the temporal distribution of rainfall within a given 24 hour period. Three pluviographs have operated at various times in the area of interest and these are also noted in Table 4.1.

TABLE 4.1

RAINFALL STATIONS

Station No.	Station	Years of Operation	Years for which Daily Record Available
58002	Bangalow Hotel	1900-1975	41
58007	Byron Bay P.O.	1892-	
58009	Cape Byron Lighthouse	1950-	
58011	Chillingham	1950-	
58013*	Condong CSR Sugar Mill	1887-1972	
58019	Uki (Doon Doon)	1952-	21
58040	Mullumbimby P.O.	1898-	22
58060	Whian Whian	1943-	
58067	Tomewin Composite	1913-	
58070	Rosebank (Repentance Ck)	1957-	
58072*	Federal	1904-	27
58103	Brunswick Heads	1965-	
58107	Burringbar (Harnett)	1965-1978	
58114	Mullumbimby (Huon Brook)	1965-1977	
58125	Nimbin (Mount Nardi)	1965-	
58133	Corndale 2	1968-	
58137	Kingscliff (Urban Committee)	1969-	
58158*	Murwillumbah (Bray Park)	1972-	
58165	Rosebank (Minyon)	1975-	
58167	Uki (Tweed River)	1975-	

* Pluviograph records available for:

Condong CSR Sugar Mill	1953-1972
Federal	1965-
Murwillumbah (Bray Park)	Oct 1972-

4.1.3 Individual Storms

Rainfall information on individual storms was required for calibration of the hydrologic model. However, such information was only of value if there was a corresponding runoff record from the river gauge at Durrumbul (Section 4.2). Hence only storms which occurred since 1971, when an automatic recorder was installed at Durrumbul, were considered.

Four events were intially chosen; the three highest floods recorded at Durrumbul: in October 1972, March 1974 and March 1978, and another flood which occurred in February 1976. The rainfall for the latter event was concentrated in the south of the valley giving very high flows in Simpsons Creek but only moderate flows at Durrumbul.

The available rainfall information for the four storms is presented on Figures 4 to 7. Isohyets derived from these data are also shown on the Figures. Mass curves from the available pluviograph stations are presented on Figures 8 to 11.

4.1.4 Long Term Records

Long term daily rainfall figures were required for estimating the 20 year and 100 year intensities. To be useful for this purpose at least 20 years of record were needed from which the maximum one day and three day falls for each year could be extracted. For this study, data were obtained from four stations with from 20 to 40 years of complete daily record. The stations chosen were Bangalow Hotel, Uki (Doon Doon), Mullumbimby PO and Federal. Analysis of the data from these stations is covered in Section 7.1.

There are other stations with suitable record length but those chosen provide a satisfactory spatial coverage of the

region. The quality of the record was also taken into consideration. In this respect the Whian Whian gauge, which is well located, was rejected because it was not read on weekends and hence many readings taken on Mondays were in fact three day totals.

4.2 Streamflow

Streamflow data within the catchment are sparse with only two gauging stations in operation. Details of these stations are given in Table 4.2 and their locations shown on Figure 1.

TABLE 4.2

STREAM GAUGING STATIONS

Stream	Station	Began	
		Non recording	Recording
Brunswick River	Durrumbul	November 1954	October 1971
Marshalls Creek	Billinudgel		August 1971

The gauge on the Brunswick River at Durrumbul was installed in 1954 as a staff gauge, which was read once each day. It was converted to continuous automatic recording in 1971. Major floods in the valley since then occurred in October 1972, March 1974, February 1976 and March 1978. The recorder operated satisfactorily for all four of these events and a good record of river height was available.

Several major floods also occurred during the period 1955-1971, in particular the flood of February 1956. However, as there was generally only one reading a day for these events, the data were considered to be of little use for this study and were not analysed.

Streamflows were calculated from gauge heights by means of a height-discharge relationship (rating) derived from spot measurements of flow. This was done by the Water Resources Commission, who operate the station. The Commission advised that it considered the rating of the Durrumbul gauge to be very good. Therefore, the flow hydrographs, which are reproduced as Figures 12 to 15, were accepted as accurate.

The total flow indicated by the hydrographs was considered as runoff with no allowance made for baseflow in the river. This is a common practice which is justified because the baseflow generally represents an insignificant proportion of the total volume of flow during a flood.

The other gauge, at Billinudgel on Marshalls Creek, is in the tidal zone and has not been rated. Consequently the data from this gauge were not considered for the puproses of this study.

5. THE MODEL

As discussed in Section 3, computer modelling of the rainfall-runoff process on the catchment was carried out using a programme developed by Boyd et al (Reference 2).

To use this model, the catchment was divided into sub-catchments using watershed lines. Within the model each sub-catchment was represented by a storage with the storages linked together to represent the natural linkage of the sub-catchments.

Two types of storages were used.

- o ordered basins - where flow was calculated from rainfall on the sub-catchment
- o inter-basins - where flow was calculated from rainfall on the sub-catchment and from the flow from upstream basins.

The amount of storage represented by each basin was calculated from the sub-catchment area, the flow through the basin and a calibration parameter ("C").

Before the model could be used to derive design hydrographs a representative value of "C" for the Brunswick Valley had to be determined. This was obtained from consideration of the observed historical storms as detailed in Section 6.

Two arrangements of sub-catchments were used as shown on Figures 2 and 3. Arrangement A was used for calibration against the actual flow hydrographs at Durrumbul while Arrangement B was used to derive design flow hydrographs throughout the catchment.

For each run of the model the following data were required:

- area of each sub-catchment (km^2)
- average depth of rainfall on each sub-catchment (mm)
- temporal rainfall pattern
- initial loss (mm)
- continuing loss (mm/h).

6. HISTORICAL FLOODS

6.1 Storm of October 1972

6.1.1 Rainfall Depth

The flood producing rainfall occurred during the 48 hrs up to 9am on 29th October. Rainfall totals for this period were available for sixteen stations in the vicinity of the catchment as shown on Figure 4. Also shown is the isohyetal pattern derived from the data.

6.1.2 Temporal Rainfall Pattern

Two pluviographs were operational during the storm, at Federal and Murwillumbah. Mass curves for both stations are shown on Figure 8.

6.1.3 Streamflow

A good record of flood heights was available from the recorder at Durrumbul and the derived flow hydrograph is shown on Figure 12.

The flood had only one major peak, 282 m^3/s on 28th October, which was preceded by a slow hydrograph rise and followed by a minor peak on 29th October. The total volume of runoff during the storm period was 12 500 ML.

6.1.4 Fitting

It was not possible to match the observed peak flow using

either of the observed temporal patterns. It appears that the flood producing rainfall burst was a localised event not reflected at the pluviograph stations.

While it would have been possible to synthesize a pattern based on the shape of the hydrograph this would have introduced an artificial component into the study. Since the remaining floods gave good results it was decided to abandon further work on the 1972 event.

6.2 Storm of March 1974

6.2.1 Rainfall Depth

The period of flood producing rainfall was within the 48 hours up to 9am on 11th March. Rainfall totals for the storm were available for fifteen stations in the vicinity of the Brunswick catchment. The rainfall recorded for each of the stations is shown on Figure 5 together with the derived isohyetal pattern.

The record for Brunswick Heads was not considered in preparing the isohyetal map as no reading was recorded on 10th March.

6.2.2 Temporal Rainfall Pattern

Two pluviographs were operational during the storm, at Federal and Murwillumbah. The mass curves for both are reproduced on Figure 9. Either of these stations could

have been used to provide a temporal pattern for the Durrumbul catchment as they are approximately equidistant from the area and are meteorologically similar. The Murwillumbah temporal pattern gave a better fit to the observed hydrograph and was therefore adopted.

6.2.3 Streamflow

A good record of flood heights was available from the recorder at Durrumbul. The derived flow hydrograph is shown on Figure 13.

The flood had three distinct peaks - the highest occurred in the middle and reached 300 m^3/s. The total volume of runoff was 16 000 ML.

6.2.4 Fitting

As there was a reasonable amount of rainfall before the flood producing burst, initial loss was adopted as 0mm. A balance of volumes between the rainfall depth and the flow at Durrumbul indicated that continuing loss was 4mm/h.

The Boyd Model was then run varying "C" to produce a peak flow close to that observed. The best fit gave a value of 2.2 for "C".

6.3 Storm of March 1978

6.3.1 Rainfall Depth

The period of flood producing rain was within the 48 hours to 9am on 19th March. Data for this period were available at fourteen stations and the rainfalls recorded for these are indicated on Figure 7. There were some missing or faulty records for this storm and in preparing the data the following assumptions were made.

- Byron Bay -

  No rainfall was recorded on the 19th but 97.4mm was noted on the 20th. The 19th was a Sunday and it would appear the reader did not read the gauge that day and hence the reading for the 20th covers a 48 hour period. The record from the adjacent gauge at Cape Byron indicated that most of the rain in this 48 hour period indeed fell on the 19th. It was therefore assumed that the 97.4mm recorded against the 20th fell on the 19th.

- Whian Whian -

  No record was available for the 18th or 19th but 431mm is recorded against the 20th. Again it was clear that the gauge was not read over the weekend and that the bulk of the reading for the 20th actually fell in the 48 hours to 9am on the 19th. The nearest gauge, at Minyon, in fact recorded no rainfall on the 20th. It

was therefore assumed that the 431mm fell in the 48 hours to the 19th.

- Brunswick Heads -

  Similarly to Whian Whian and Byron Bay, this gauge was not read on Sunday. The nearest gauge, at Mullumbimby, indicated that negligible rain fell on the 20th. Therefore it was assumed that the 322mm recorded fell in the 48 hours to 9am on the 19th.

An isohyetal map of the March 1978 storm is drawn on Figure 7.

6.3.2 Temporal Rainfall Pattern

Pluviograph records were available for both Federal and Murwillumbah. These are reproduced on Figure 11 along with data for Mullumbimby PO where three-hourly readings were taken for much of the storm.

6.3.3 Streamflow

The flow hydrograph of the flood is shown on Figure 15. As with the March 1974 event, this was a triple-peaked flood with the largest peak of 279 m^3/s occurring in the middle. The total volume of runoff was 11 200 ML.

6.3.4 Fitting

Figure 11 indicates that the Mullumbimby pattern lies between the two pluviograph records. Because of this and the central location of Mullumbimby in the catchment the record from that site was, with one adjustment, adopted. The one exception was the interpolation of a point at 2400 hours on the 17th as shown on Figure 11.

As there was considerable rain before the flood, initial loss was taken as 0mm. Comparison of rainfall and runoff volumes indicated that continuing loss was of the order of 4mm/h.

The value of the "C" which gave the best fit to the peak was again found to be 2.2.

6.4 Comparison of 1974 and 1978 Floods

Table 6.1 compares the results of the fitting procedures for the 1974 and 1978 floods. The fitting parameters for the two are identical which is a remarkable result. These parameters were applied to the 1976 event as a final test.

TABLE 6.1

RESULTS OF CALIBRATION RUNS

	1974	1978
Initial Loss (mm)	0	0
Continuing Loss (mm/h)	4	4
Parameter "C"	2.2	2.2
Observed Volume (ML)	16 000	11 200
Modelled Volume (ML)	16 700	11 400
Observed Peak (m^3/s)	299	279
Modelled Peak (m^3/s)	296	285

6.5 February 1976

6.5.1 Rainfall Depth

The period of flood producing rain was in the 24 hours up to 9 am on 29th February. Rainfall totals for fifteen stations were available for this period and are shown on Figure 6 along with an isohyetal pattern derived from them. The heavy rainfall to the south over the Simpsons Creek catchment is evident in the Figure.

6.5.2 Temporal Pattern

Pluviograph records were available for both Federal and Murwillumbah. As a pattern from Murwillumbah had been used in fitting the 1974 flood that pluviograph was again used. This choice was reinforced by the fact that the total fall recorded at Murwillumbah was more representative of the

catchment average than Federal.

6.5.3 Streamflow

A good record of the flood was available at Durrumbul and the derived streamflow hydrograph is shown on Figure 14.

6.5.4 Test

The parameters derived for the 1974 and 1978 floods were input to the model to test their applicability to the 1976 flood. The resultant hydrograph is shown on Figure 14 and the key attributes of the observed and modelled hydrographs are compared in Table 6.2.

TABLE 6.2

RESULTS OF TEST ON FEBRUARY 1976 FLOOD

	Observed	Modelled	Percentage Difference
Volume (ML)	6300	5650	- 10
Peak (m^3/s)	144	170	+ 18

This fit was considered to be reasonable and the calibrated parameters were therefore adopted.

7. DESIGN STORMS

7.1 Design Rainfall Depth - 20 year and 100 year

Several methods are available for determining average rainfall intensity for a storm of given frequency and duration, a number of these are detailed in AR&R (Reference 5). For this study three methods were used to derive independent estimates of rainfall.

Method (a) Generalised Procedure

Details of this procedure are given in Sections 2.5 and 2.6 of AR&R. The procedure involves reference to maps of NSW to obtain rainfall intensities for four given combinations of frequency and duration. These values can then be manipulated using graphs and equations to obtain the rainfall for the required frequency and duration.

Method (b) Rainfall Intensity - Frequency - Duration Curves for Representative Stations

Details of this procedure are given in Sections 2.2 and 2.3 of AR&R.

Basically a number of representative stations are listed and formulae given to estimate the required rainfall. The only station listed which meets the representative station requirements for the Brunswick Valley is that at Condong.

Method (c) Procedure in Regions of Strong Rainfall Gradient

Details of this procedure are given in Section 2.7 of AR&R. It is recommended for strong gradient areas as the generalised procedure is unreliable in such circumstances. However, the method is applicable to any rain gauge with a suitable length of record. The one-day and three-day annual maxima are analysed statistically to produce average intensities for four combinations of frequency and duration. Rainfalls for other frequencies and/or durations are then derived from these using the graphs supplied for Method (a). The method was applied to data from gauges at Mullumbimby, Doon Doon, Bangalow and Federal.

The above procedures provided the basis for obtaining design rainfall of any frequency and duration within the requirements of the study. The next step was to determine the critical storm duration for the catchment, i.e. that which would produce the highest flood peak at a particular point for a particular frequency. The particular point chosen for this exercise was the ocean entrance. Rainfall durations between 6 hours and 24 hours were tested and the critical storm duration found to be 12 hours.

Results from the various methods for 12 hour storms of 20 year and 100 year frequency are shown in Table 7.1. Also shown in

the Table are results for storms of 24 hour and 72 hour duration. These were included to allow a check of the derived figures against observed events.

TABLE 7.1

DESIGN RAINFALL FIGURES

(mm)

Method	Station	12 Hours			24 Hours			72 Hours			
		20y	100y	2y	20y	50y	100y	2y	20y	50y	100y
a)		209	269								
b)	Condong	266	353								
c)	Mullumbimby	300	384	209	396	463	518	317	626	749	850
	Doon Doon	323	406	242	434	502	564	382	734	871	986
	Bangalow	258	336	180	326	377	427	274	461	518	583
	Federal	316	432	175	384	463	528	230	468	569	648

The generalised results were significantly lower than the figures derived from local data. This confirmed a trend observed in various other parts of the State. Due to this and the consistency of the results for Method (c), the generalised values were not further considered.

Table 7.2 shows the result of an accuracy check of the frequency figures from the local stations. At three of the stations where daily figures were available for the period of record, the number of exceedances of the estimated design values

were calculated. It should be noted that the design figures are for the 24 or 72 hours of maximum rainfall whereas the recorded figures are for fixed periods ending at 9am on any given day. The exceedances indicate that the values derived from Method (c) are within acceptable statistical limits.

TABLE 7.2

OBSERVED EXCEEDANCES OF DESIGN FIGURES

Station	Years of Record	24 Hours				72 Hours			
		2y	20y	50y	100y	2y	20y	50y	100y
Mullumbimby	22	14	-	-	-	12	-	-	-
Doon Doon	23	10	1	-	-	10	2	-	-
Bangalow	42	22	-	-	-	20	2	1	-

The 12 hour, 20 year and 100 year depths for the individual stations listed under Methods (b) and (c) on Table 7.1 are plotted in Figures 17 and 18 together with isohyets derived from them. Though the isohyetal patterns are based on limited data they show the same general orientation as for the individual storms plotted on Figures 4 to 7. This indicates that the variations between design results at the different stations can be explained in terms of observed rainfall patterns. The isohyets on Figures 17 and 18 were adopted for design.

7.2 Extreme Rainfall

An estimate of the extreme 12 hour rainfall was derived from information contained in Reference 6. The Brunswick catchment falls within the "Queensland Coast" zone defined in Figure 11 of the reference. From Figure 10 in the reference, the adjusted 24 hour rainfall for the area of the Brunswick catchment (220 km^2) was estimated as 1320mm.

As the Brunswick Valley is a relatively flat coastal area no adjustment was made for distance from the coast or topography. However, the maximum 24 hour persisting dewpoint in the region is 25^oC (Reference 7) while the information from Reference 6 is normalised to 28^oC. Therefore, the rainfall was adjusted by the ratio of precipitable water at the two dewpoints as follows:-

Precipitable water at 25^oC (W_{25})	81.0 mm
Precipitable water at 28^oC (W_{28})	104.4 mm
Adjustment factor (W_{25}/W_{28})	0.78
Therefore, extreme 24 h rainfall	1030 mm

An examination of observed storms in the Brunswick region indicated that, on average, the maximum 12 hours of a 24 hour burst contained 70% of the total rainfall. Applying this to the calculated extreme 24 hour fall gave an extreme 12 hour fall of 720mm. This fall was assumed to be uniform over the catchment.

7.3 Temporal Pattern

The design temporal pattern was derived from observed storms using the method described by Pilgrim et al (Reference 8). A total of fifteen 12 hour rainfall bursts were analysed to obtain the pattern shown in Figure 16.

8. DESIGN FLOODS

The 20 year, 100 year and extreme design flood events were derived using the calibrated Boyd Model and the derived rainfall depths and temporal pattern. A summary of the adopted design parameters is given in Table 8.1.

TABLE 8.1

DESIGN PARAMETERS

Boyd Runoff Routing Parameter "C"	2.2
Initial Loss	0 mm
Continuing Loss	4 mm/h
Critical Storm Duration	12 h
20 Year Rainfall Depth	Figure 17
100 Year Rainfall Depth	Figure 18
Extreme Rainfall Depth	720 mm
Temporal Pattern	Figure 16

The resultant flows at Durrumbul, Mullumbimby and Brunswick Heads are shown on Table 8.2 on Figures 19 to 21.

TABLE 8.2

DESIGN FLOOD PEAKS

(m^3/s)

	20 year	100 year	Extreme
Durrumbul	292	391	820
Mullumbimby	658	897	1 910
Brunswick Heads	1 520	2 110	4 760

TABLE 8.3

DESIGN FLOOD VOLUMES

(ML)

	20 year	100 year	Extreme
Durrumbul	9 820	12 700	24 800
Mullumbimby	72 900	30 000	57 800
Brunswick Heads	54 300	73 200	147 000

Observed peak flows at Durrumbul are listed in Table 9.1. The 20 year peak flow derived from the model has only been exceeded once in the period of record, in 1974. However, the peaks recorded in 1972 and 1978 were close to the estimated 20 year flow.

The volumes presented in Table 8.3 do not match the observed volumes as listed in Tables 6.1 and 6.2. This is because the modelled floods were derived as single peaked events whereas observed floods are typically multi-peaked as indicated in Figures 12 to 15. The effect of the initial peak especially will have to be considered in the hydraulic modelling stage of the study. However, as the hydraulic nature of the Brunswick is more channel dominated than storage dominated the peak flow is more relevant than total volume to the derivation of peak flood levels and velocities.

9. FREQUENCY ANALYSIS OF FLOW RECORD

The most direct way of determining the peak flood flow of a given frequency is to analyse the recorded flood flows using statistical means. If this method is to be applied for rare events such as the 20 year or 100 year flood then a considerable length of record is required. Pilgrim & McDermott (Reference 9) adopted the criteria that at least 15 years of record were required before an estimate of the 20 year flood could be given and at least 25 years before an approximation of the 100 year flood could be derived. They emphasised that the latter case would still only give a rough estimate.

As detailed in Section 4.2 there is only one station in the Brunswick Valley which provides a record of streamflow. This is at Durrumbul on the Brunswick River. From 1955 to 1969 the river height at the station was read daily from a gauge board while from 1972 onwards it was automatically recorded.

Daily flows were calculated from the gauge height readings as described in Section 4.2. Table 9.1 lists the peak daily flows and instantaneous peak flows for each year of record.

It should be noted that prior to 1970 the maximum average daily flows were sometimes based only on one reading, taken at 10am. In these cases the maximum average daily flow and the peak instantaneous flow are the same (e.g. 1956, 57, 60, 62, 66, 67,

68). At other times, additional readings were taken and the maximum average daily flow based on these plus the 10am reading (e.g. 1955, 58, 59, 61, 63, 64, 65).

Since 1972 the maximum average daily flow was based on a number of points selected from the continuous record.

TABLE 9.1

RECORDED PEAK FLOWS AT DURRUMBUL

Year	Maximum Average Daily Flow (D) (m^3/s)	Instantaneous Peak (I) (m^3/s)	Ratio I/D
1955	88.6	118	1.33
1956	124	124	1.00
1957	11.0	11.0	1.00
1958	70.8	101	1.43
1959	72.2	101	1.40
1960	2.21	2.21	1.00
1961	45.3	161	3.55
1962	101	101	1.00
1963	70.8	94.0	1.33
1964	32	35.7	1.12
1965	77.9	90.6	1.16
1966	14.2	14.2	1.00
1967	101	101	1.00
1968	44.2	44.2	1.00
1969	4.5	-	-
1970	-	-	-
1971	-	-	-
1972	100	282	2.82
1973	74	206	2.78
1974	127	299	2.35
1975	33.1	65.6	1.98
1976	67.3	144	2.14
1977	27.7	61.0	2:20
1978	98.9	279	2.82
1979	24.7	66.6	2.70
1980	64.4	107	1.66

1987

234

Q_{100} new = 299

Q_{100} old = 391

Another problem with daily readings is illustrated in Table 9.1 by the discrepancy in the ratio of instantaneous peak to maximum average daily flow between the records taken up to 1968 and those taken since 1971. With the exception of 1961 the highest ratio of instantaneous peak to maximum average daily flow in the earlier period is 1.43. In the later period the lowest ratio is 1.66. The reason for the low ratios prior to 1970 is that even where more than one reading was taken, the chances of actually reading the gauge at the peak of the flood would be remote. On the other hand an automatic recorder, provided it is working, will always show the flood peak.

Therefore the two periods do not present a homogeneous set of data with regard to instantaneous peak flows and cannot be combined for statistical analysis.

The situation with regard to average daily flows is somewhat better. While the two recording methods will produce different results it is generally accepted that maximum average daily flows computed from the different methods can be treated as a homogeneous set.

There are thus 23 years of maximum average daily flow data available. As noted previously, Reference 9 recommends that at least 25 years of data should be available before an estimate of the 100 year flood can be made. In this case however, it was considered reasonable to make an estimate from 23 years of data as

this procedure was intended only as a check on the order of accuracy of the modelling results.

The 23 years of daily maxima are listed in Table 9.2 in descending order of magnitude along with the plotting position of each flow. The plotting position is defined as $\frac{N + 1}{R}$ where N is the number of years of record and R is the "rank" of the flood with the largest being rank 1 etc.

Table 9.2 reveals some descrepancies incurred by using daily flows. The 1972 and 1978 floods which have the second and third highest instantaneous peaks are relegated to fifth and sixth place. This highlights the difficulties inherent in the non-homogeneous data set.

TABLE 9.2

RANK AND PLOTTING POSITION OF MAX. DAILY FLOWS

Rank (R)	Year	Maximum Daily Flow (m^3/s)	Plotting Position
1	1974	127	24.0
2	1956	124	12.0
3	1962	101	8.00
4	1967	101	6.00
5	1972	100	4.80
6	1978	98.9	4.00
7	1955	88.6	3.43
8	1965	77.9	3.00
9	1973	74.0	2.67
10	1959	72.2	2.40
11	1958	70.8	2.18
12	1963	70.8	2.00
13	1976	67.3	1.85
14	1980	64.4	1.71
15	1961	45.3	1.60
16	1968	44.2	1.50
17	1975	33.1	1.41
18	1964	32.0	1.33
19	1977	27.7	1.26
20	1979	24.7	1.20
21	1966	14.2	1.14
22	1957	11.0	1.09
23	1960	2.21	1.04

These values were analysed using the Log Pearson Type III distribution as described in Chapter 9 of Reference 5. Reference 10 examined a total of ten different frequency distributions and determined that the Log Pearson Type III produced the best overall results for accurate and consistent estimation.

The parameters of the distribution for the Brunswick data along with the "standard error of estimate" (Section 9.2.10, AR&R) are given in Table 9.3.

TABLE 9.3

DAILY MAXIMA AT DURRUMBUL

LOG-PEARSON TYPE III PARAMETERS

Parameter	Value	SEE
Mean	1.6871	0.0946
Standard Deviation	0.4106	0.0669
Skew	-1.8323	0.4813

These values are based on $\log_{10}$ of the flows.

The distribution showed a high negative skew which the SEE confirmed as significant. Given the nature of the available record it was not possible to reach definite conclusions on the reason for this significant skew. It may truely reflect the situation on the catchment or it may be caused by an anomalously wet period or it may reflect the poor quality of the daily read data.

There is considerable discussion regarding the use of skew in frequency distributions. Reference 11 recommended a value of -0.72 be adopted for the whole of Queensland. This was tested and found suitable on the Logan and Albert Rivers, a short distance to the north of the Brunswick (Reference 10). Tasker (Reference 12) suggested a compromise between the regional skew and the calculated skew based on the following equation:-

$$g' = wg + (1-w)\,\bar{g}$$

where g = calculated skew = -1.82

$\bar{g}$ = regional skew = -0.72

w = N/100 = 0.23

this gave an average skew for Durrumbul of g' = -0.98.

Both the calculated skew and the "average" skew were examined in this analysis. The distribution and the 5% and 95% confidence limits using both values are listed in Table 9.4. There is a 90% chance that the true value lies within the two confidence limits.

TABLE 9.4

DAILY MAXIMA AT DURRUMBUL

LOG-PEARSON TYPE III FIT

a) g = -0.98

Recurrence Interval	Flows (m^3/s) Fit	Confidence Limits 5%	95%
1.01	2.83	2.99	0.77
2	56.7	79.6	40.3
5	109		
10	142	248	97.2
25	178		
50	202		
100	231	535	137

b) g = -1.83

Recurrence Interval	Flows (m^3/s) Fit	Confidence Limits 5%	95%
1.01	1.75	2.98	0.75
2	63.8	89.7	45.4
5	103		
10	118	206	80
25	128		
50	132		
100	134	311	80

Table 9.1 indicates that during the period of automatic recording the ratio of instantaneous peak to maximum day ranged from 1.66 to 2.82 and the mean was 2.38. The mean was applied to the 100 year daily maxima estimates to produce an estimate of the instantaneous 100 year peak. The results are shown in Table 9.5.

TABLE 9.5

ESTIMATED 100 YEAR PEAK FLOWS AT DURRUMBUL

FROM FREQUENCY ANALYSIS

(m^3/s)

Skew		Flow	Confidence Limits 5%	95%
"average"	-0.98	550	1273	326
"calculated"	-1.82	319	740	190

The results further emphasise the difficulties involved in working with the limited data available. The best fit for the calculated skew is outside the 95% confidence band for the average skew. The

two best fit estimates do, however, straddle the modelled 100 year peak of 391 m^3/s and give some greater confidence in that result.

The modelled result, based on good calibration and extended rainfall records is certainly to be preferred to the results from frequency analysis.

10. REFERENCES

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12. TASKER, G.D., Flood Frequency Analysis with Generalised Skew Coefficient, Water Resources Research, Vol. 14, No.2, 1978.

FIGURES

FIGURE 1

LOCALITY PLAN

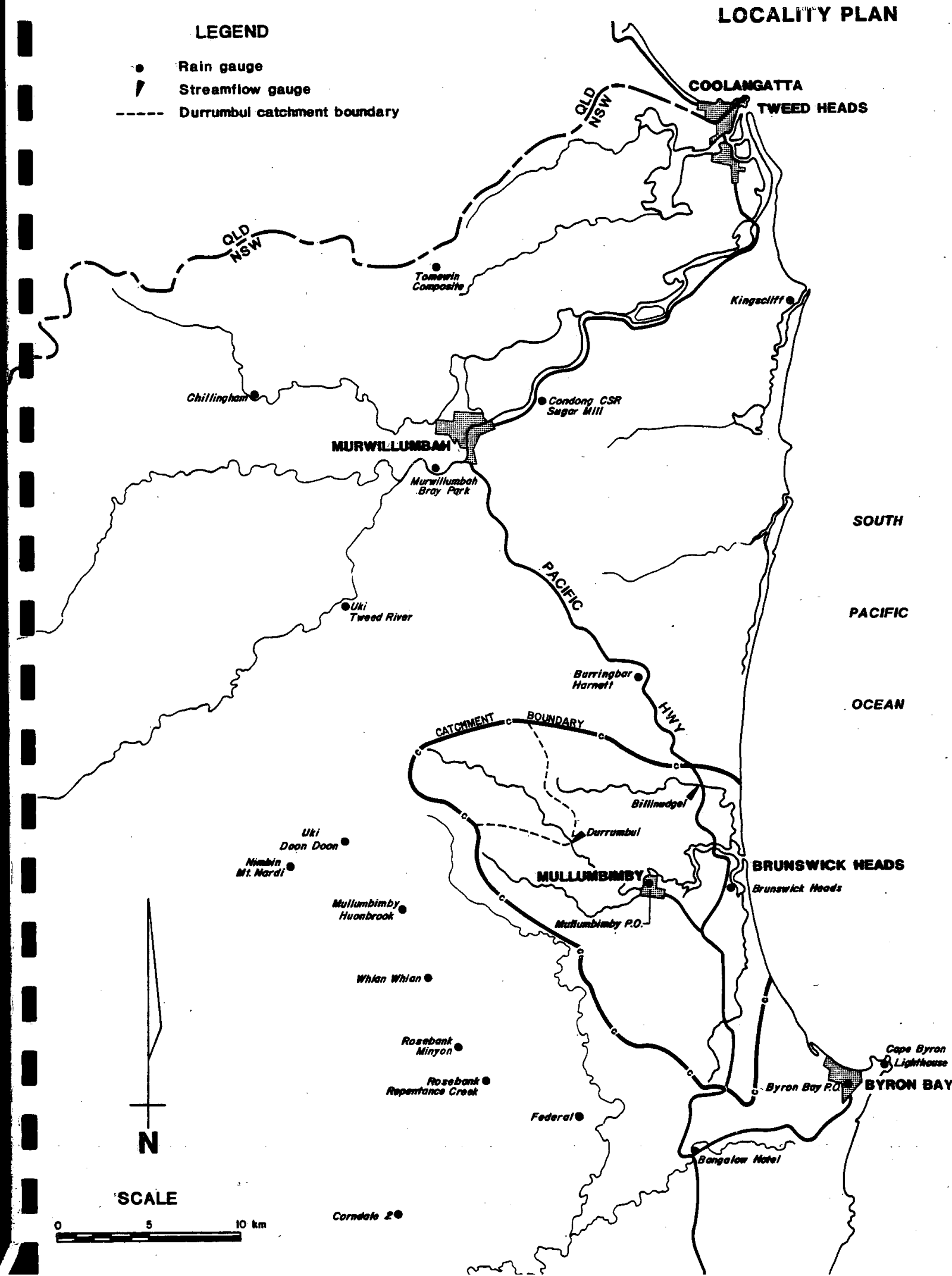


FIGURE 2

BOYD MODEL SUB-AREAS ARRANGEMENT A DURRUMBUL CATCHMENT

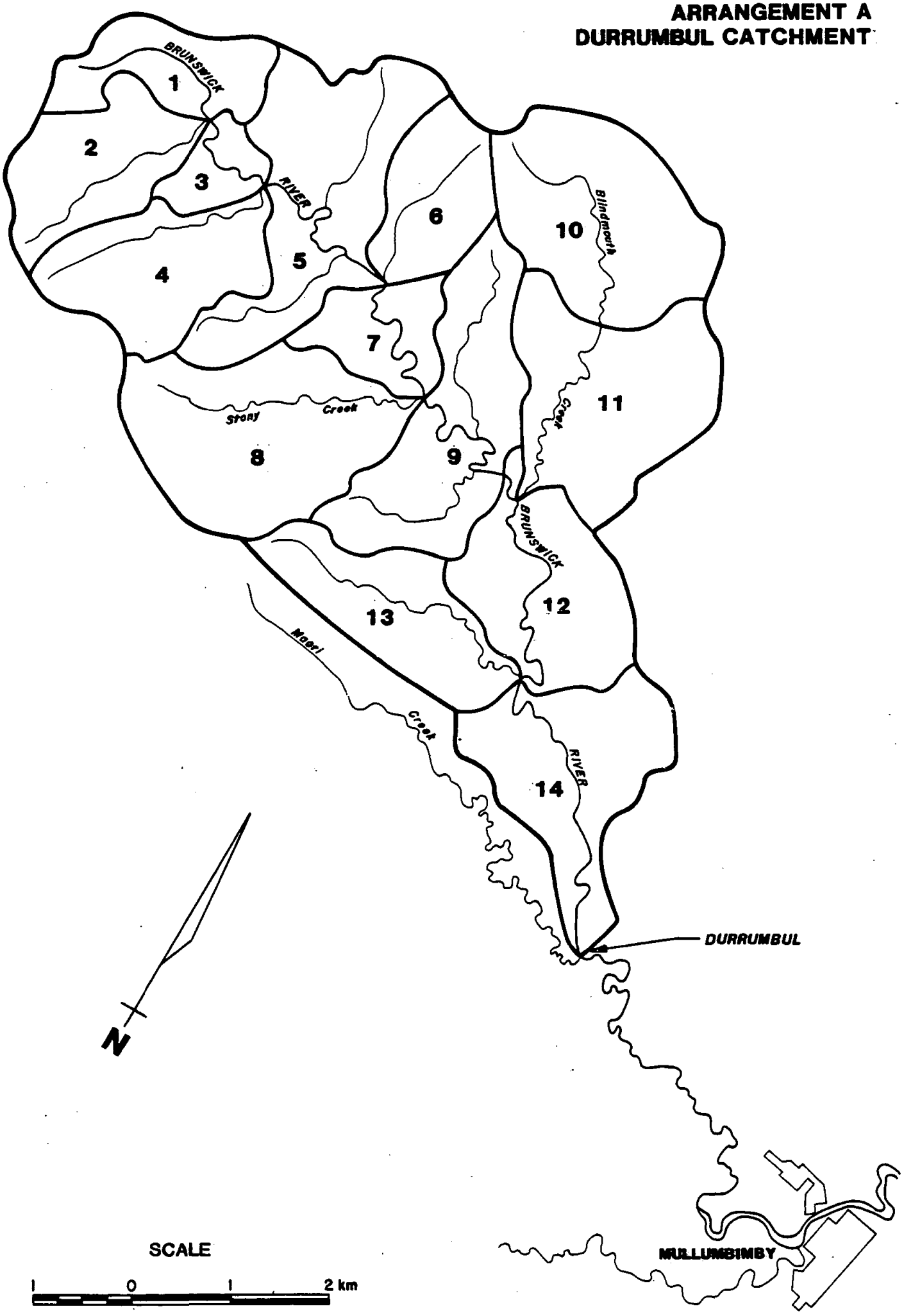


FIGURE 3

BOYD MODEL SUB-AREAS ARRANGEMENT B TOTAL CATCHMENT

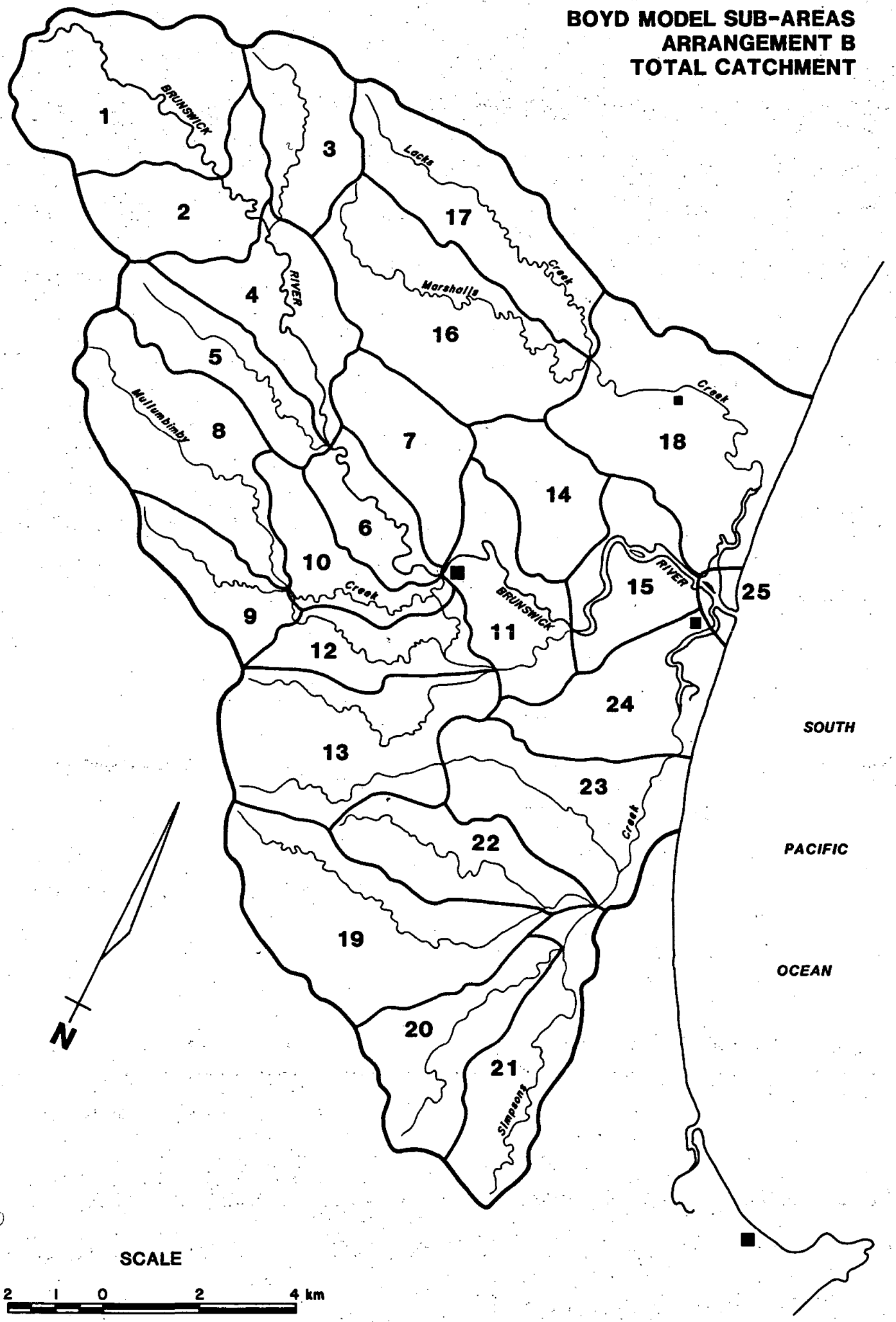
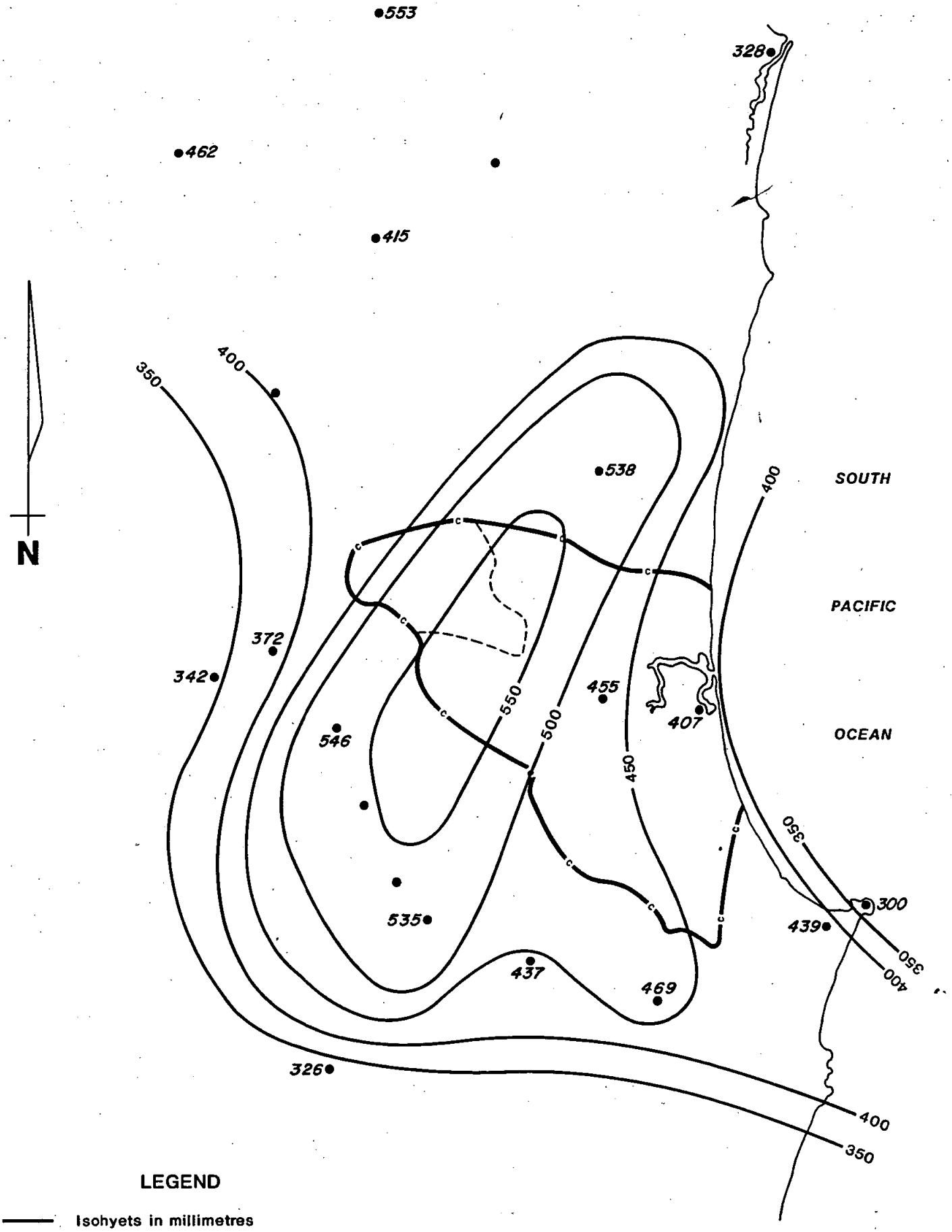


FIGURE 4

ISOHYETAL MAP OCTOBER 1972



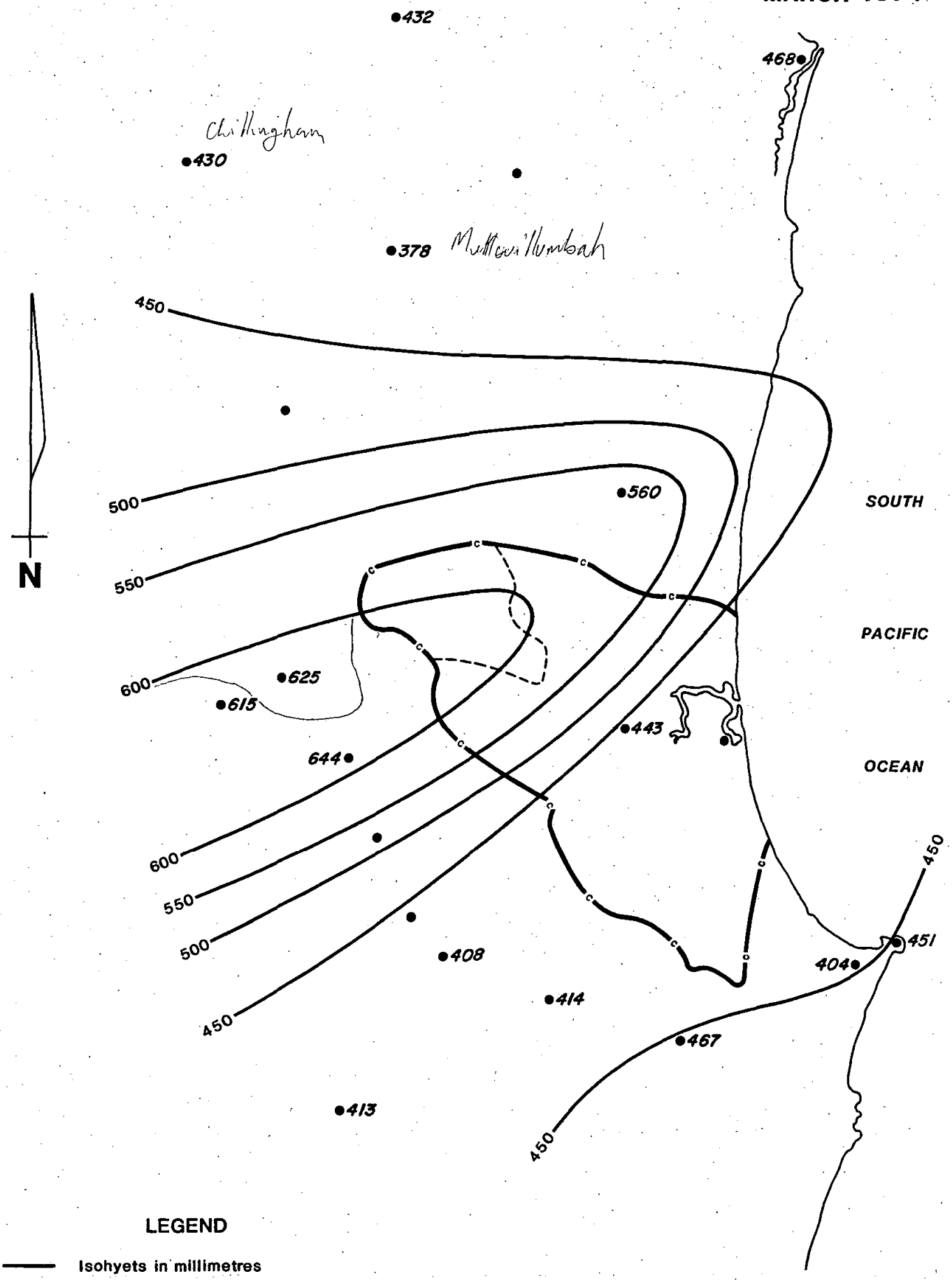
LEGEND

———	Isohyets in millimetres
•413	Rain gauge with rainfall in millimetres
—c—	Brunswick Heads catchment boundary
- - - - -	Durrumbul catchment boundary

NOTE: Values shown are for 48 hours up to 9am on 29th October 1972

FIGURE 5

ISOHYETAL MAP MARCH 1974



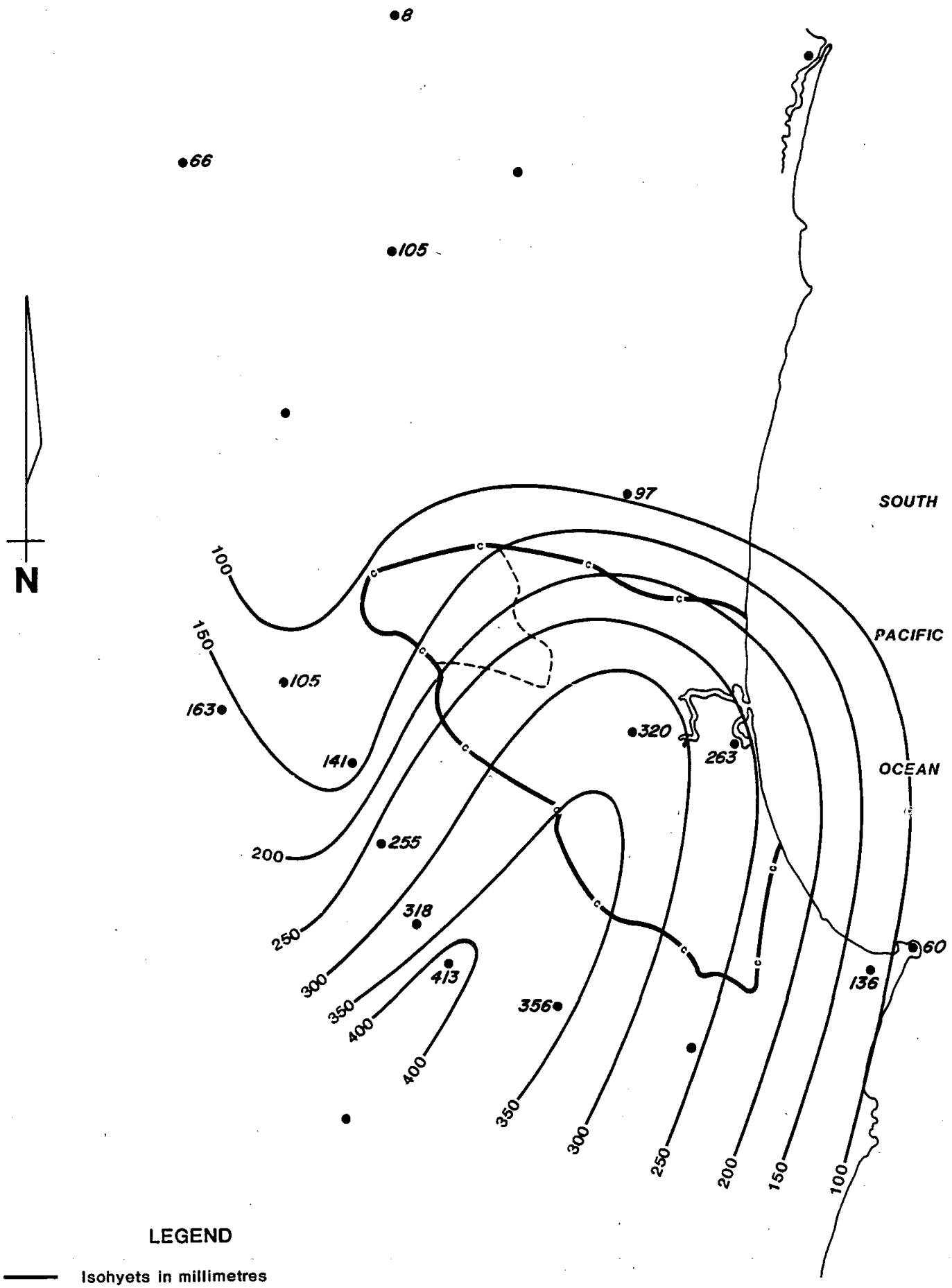
LEGEND

- Isohyets in millimetres
- ●413 Rain gauge with rainfall in millimetres
- —c— Brunswick Heads catchment boundary
- ----- Durrumbul catchment boundary

NOTE: Values shown are for 48 hours up to 9am on 11th March 1974

FIGURE 6

ISOHYETAL MAP FEBRUARY 1976



LEGEND

Isohyets in millimetres

•413 Rain gauge with rainfall in millimetres

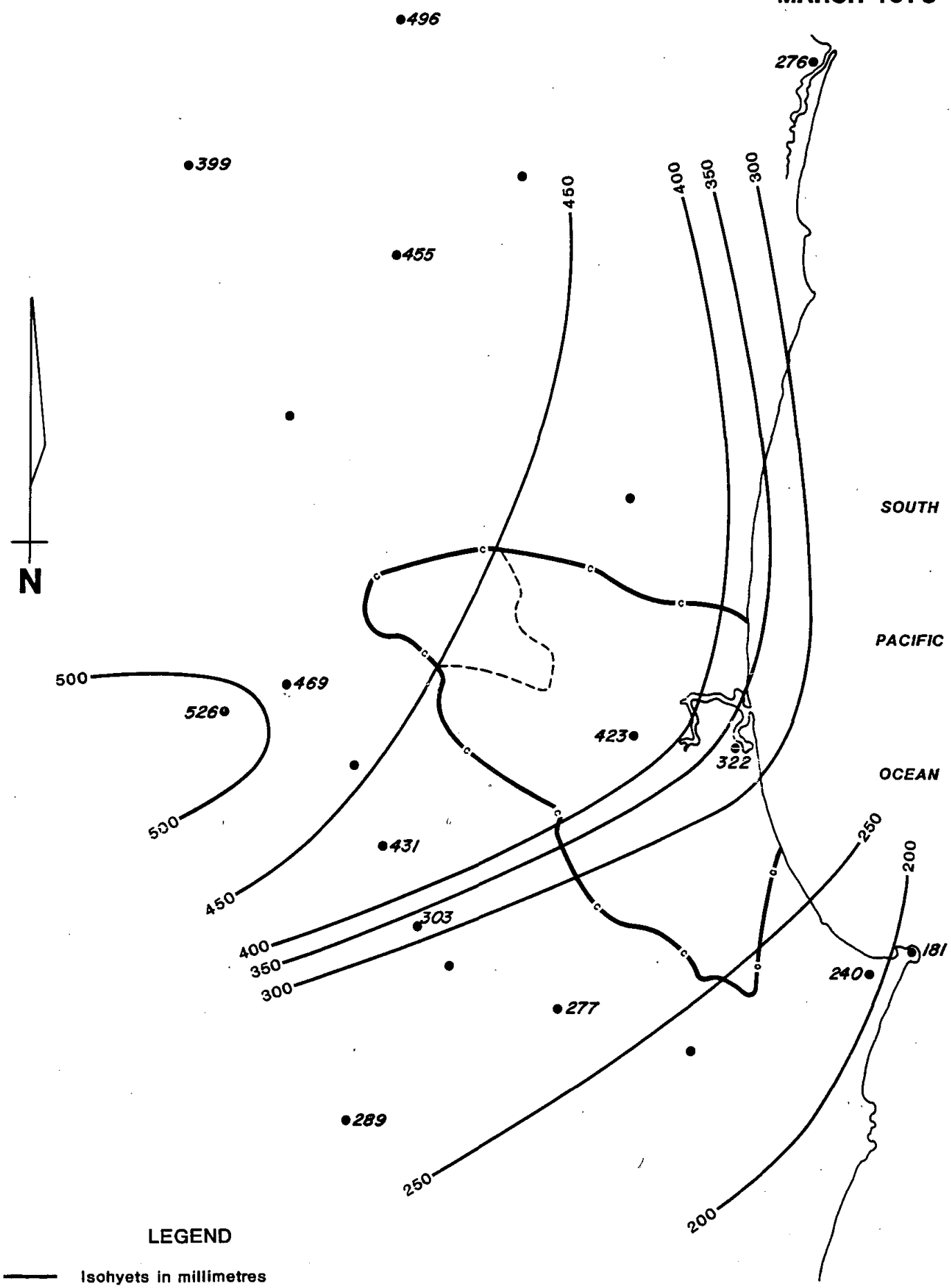
Brunswick Heads catchment boundary

Durrumbul catchment boundary

NOTE: Values shown are for 24 hours up to 9am on 29th February 1976

FIGURE 7

ISOHYETAL MAP MARCH 1978



LEGEND

Isohyets in millimetres

413 Rain gauge with rainfall in millimetres

Brunswick Heads catchment boundary

Durrumbul catchment boundary

NOTE: Values shown are for 48 hours up to 9am on 19th March 1978

FIGURE 8

RAINFALL MASS CURVES
OCTOBER 1972

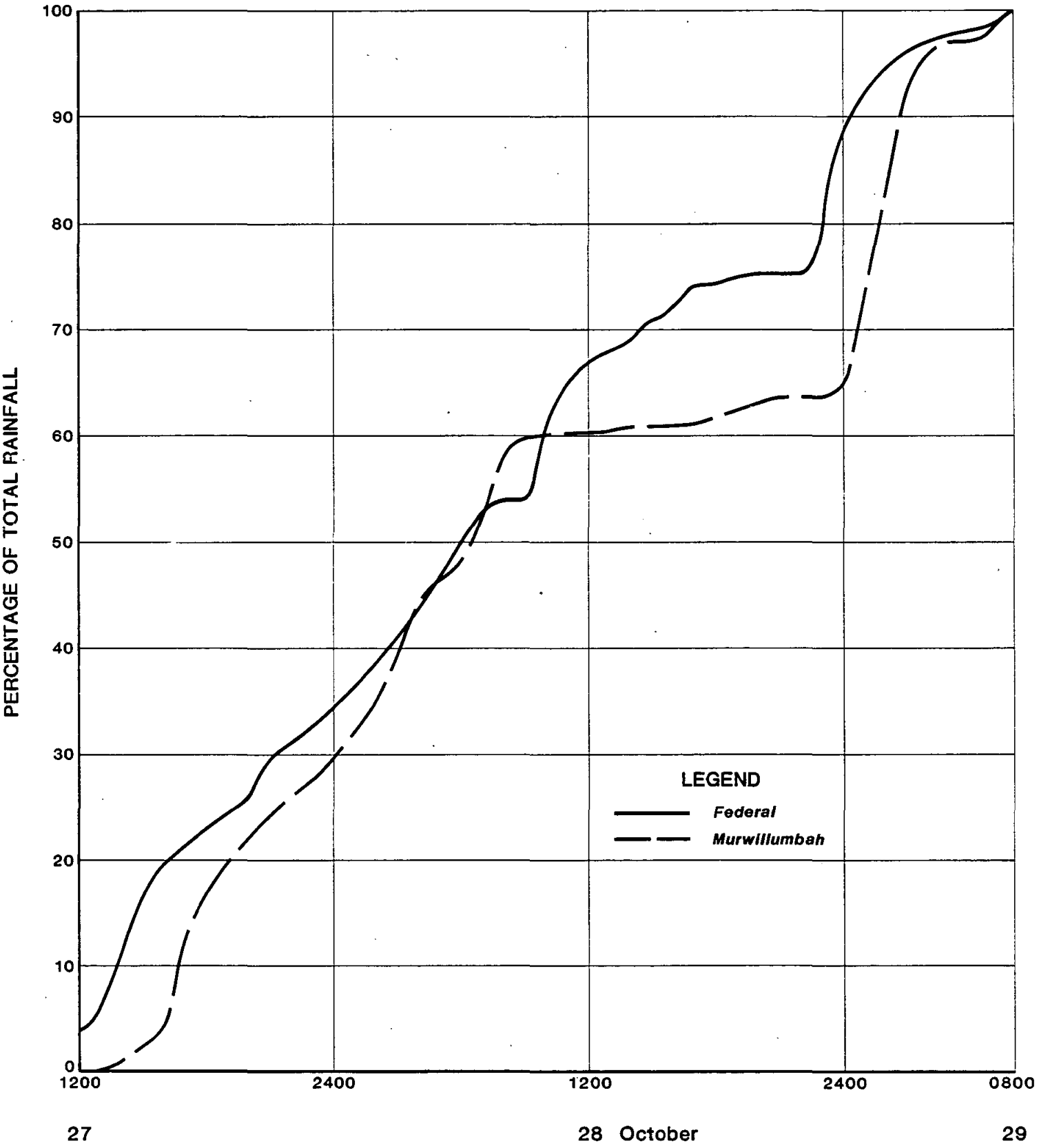


FIGURE 9

RAINFALL MASS CURVES
MARCH 1974

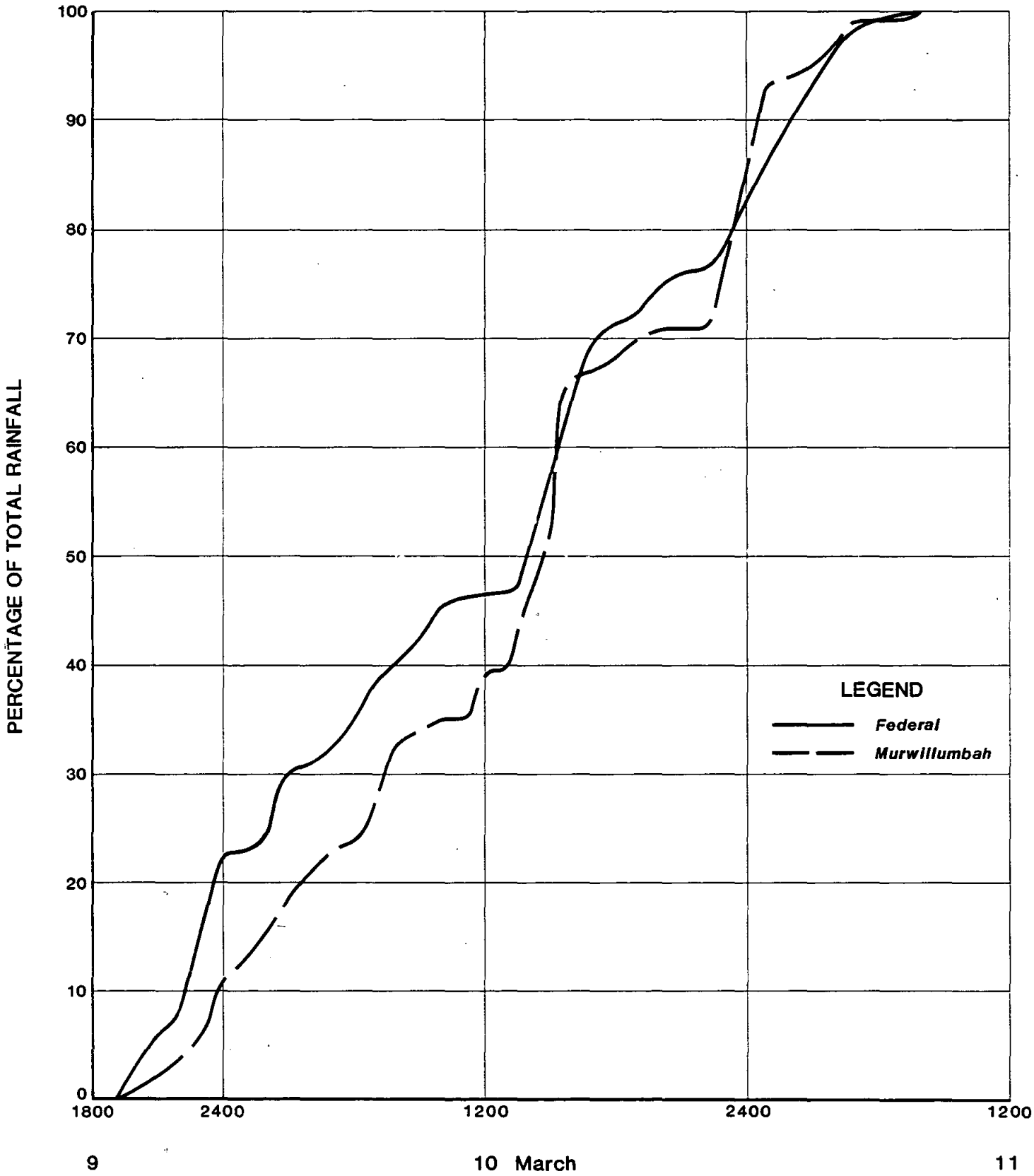


FIGURE 10

RAINFALL MASS CURVES
FEBRUARY 1976

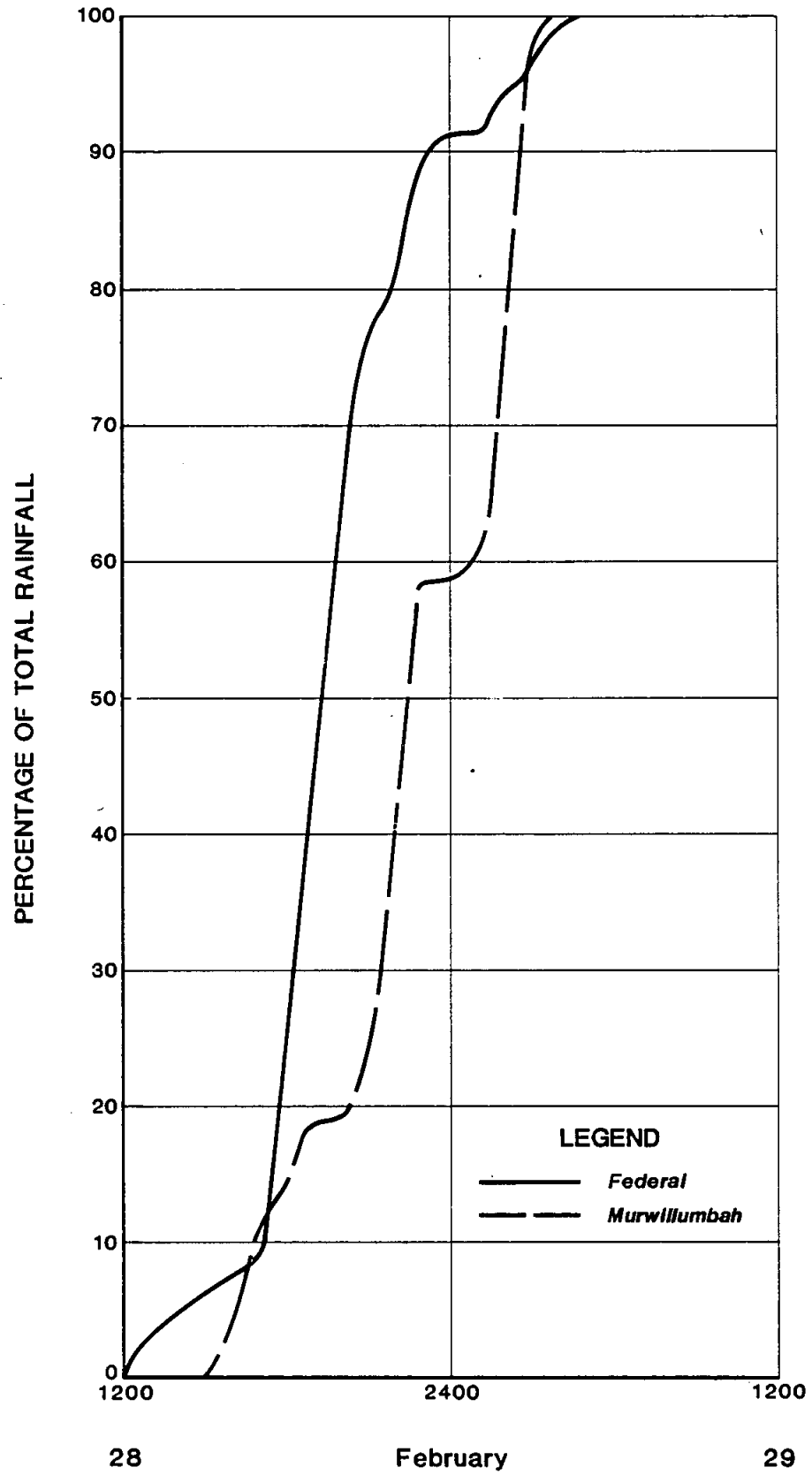


FIGURE 11

RAINFALL MASS CURVES
MARCH 1978

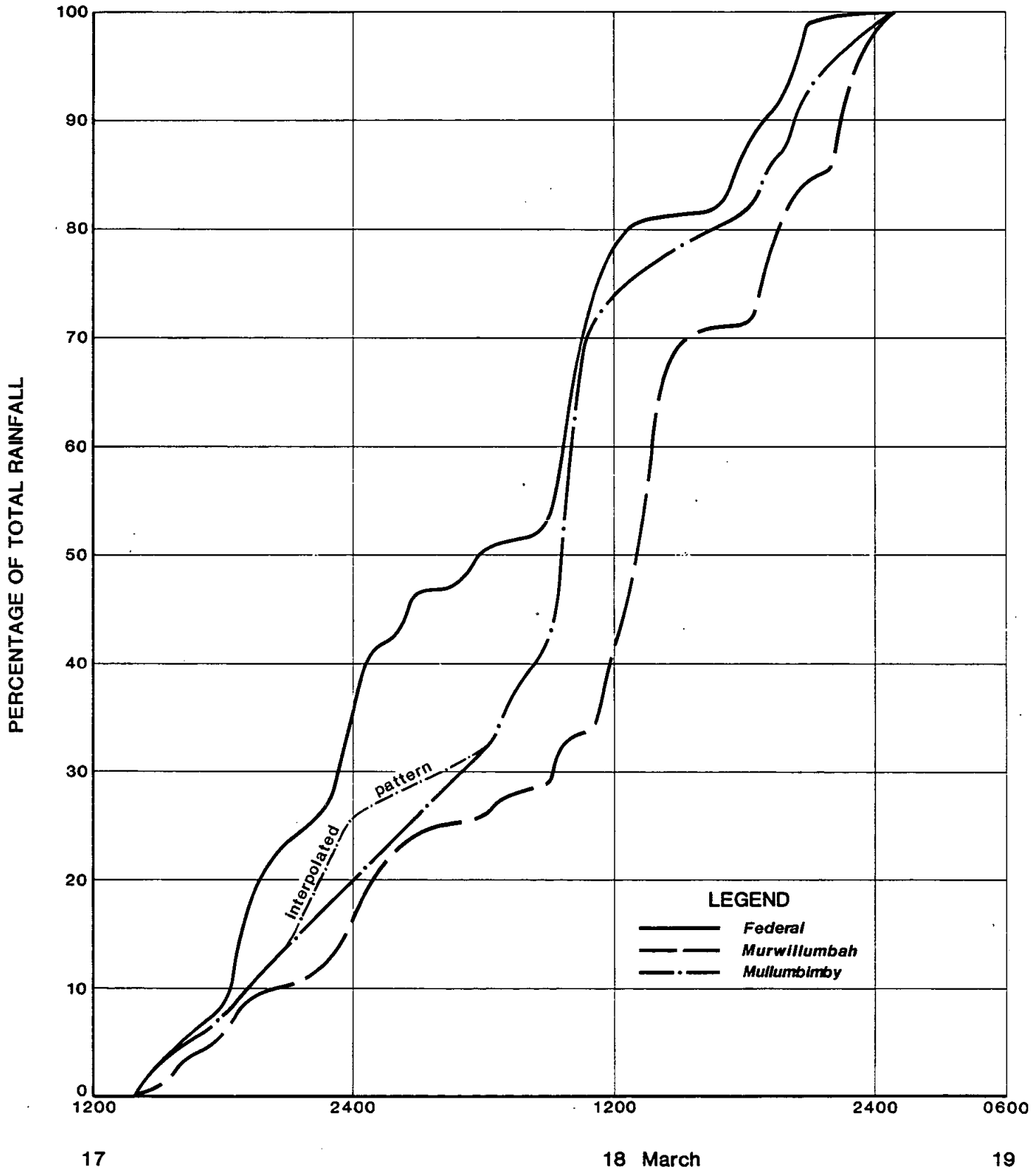


FIGURE 12

FLOW HYDROGRAPH AT DURRUMBUL OCTOBER 1972

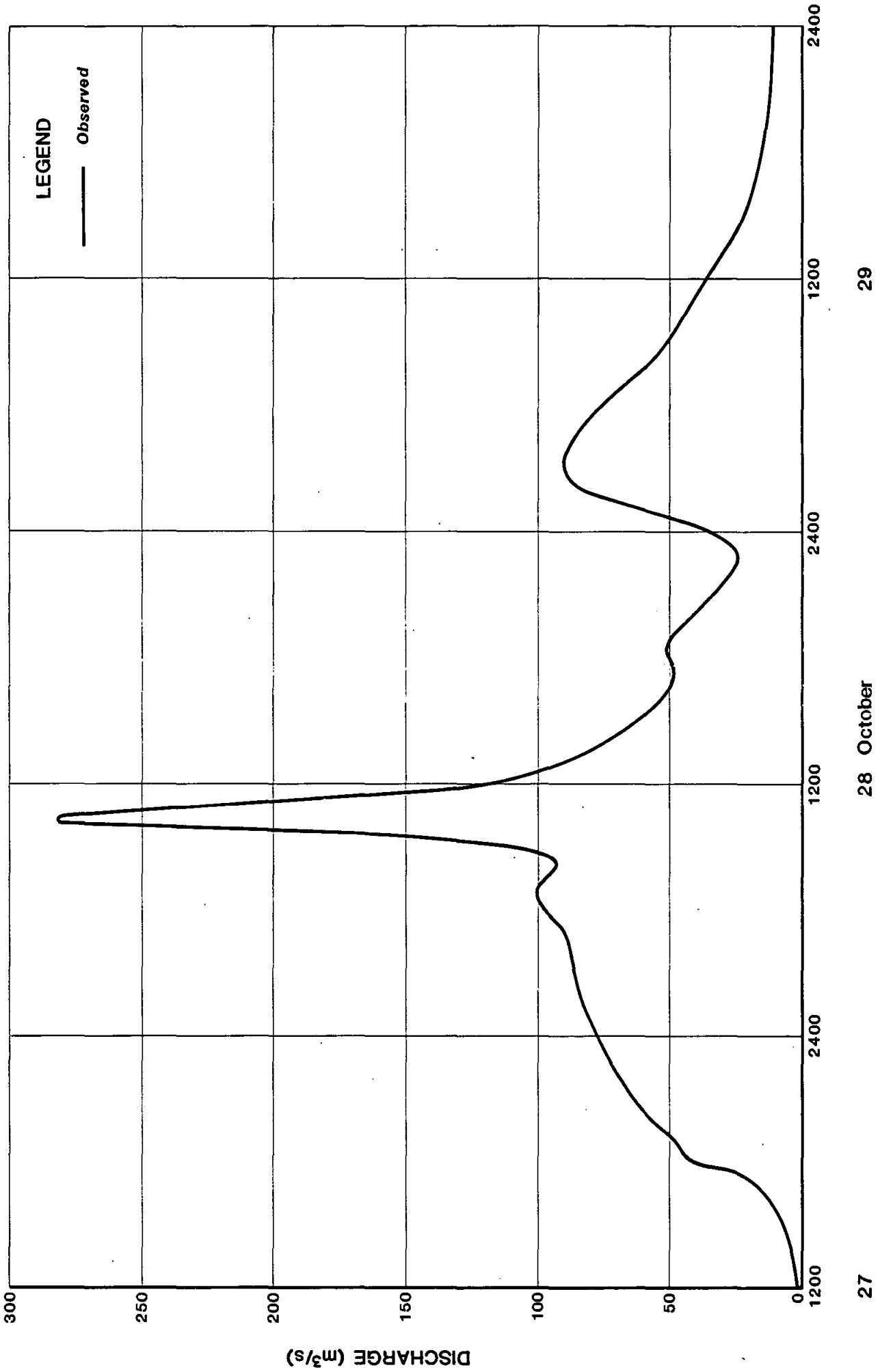


FIGURE 13

FLOW HYDROGRAPHS AT DURRUMBUL MARCH 1974

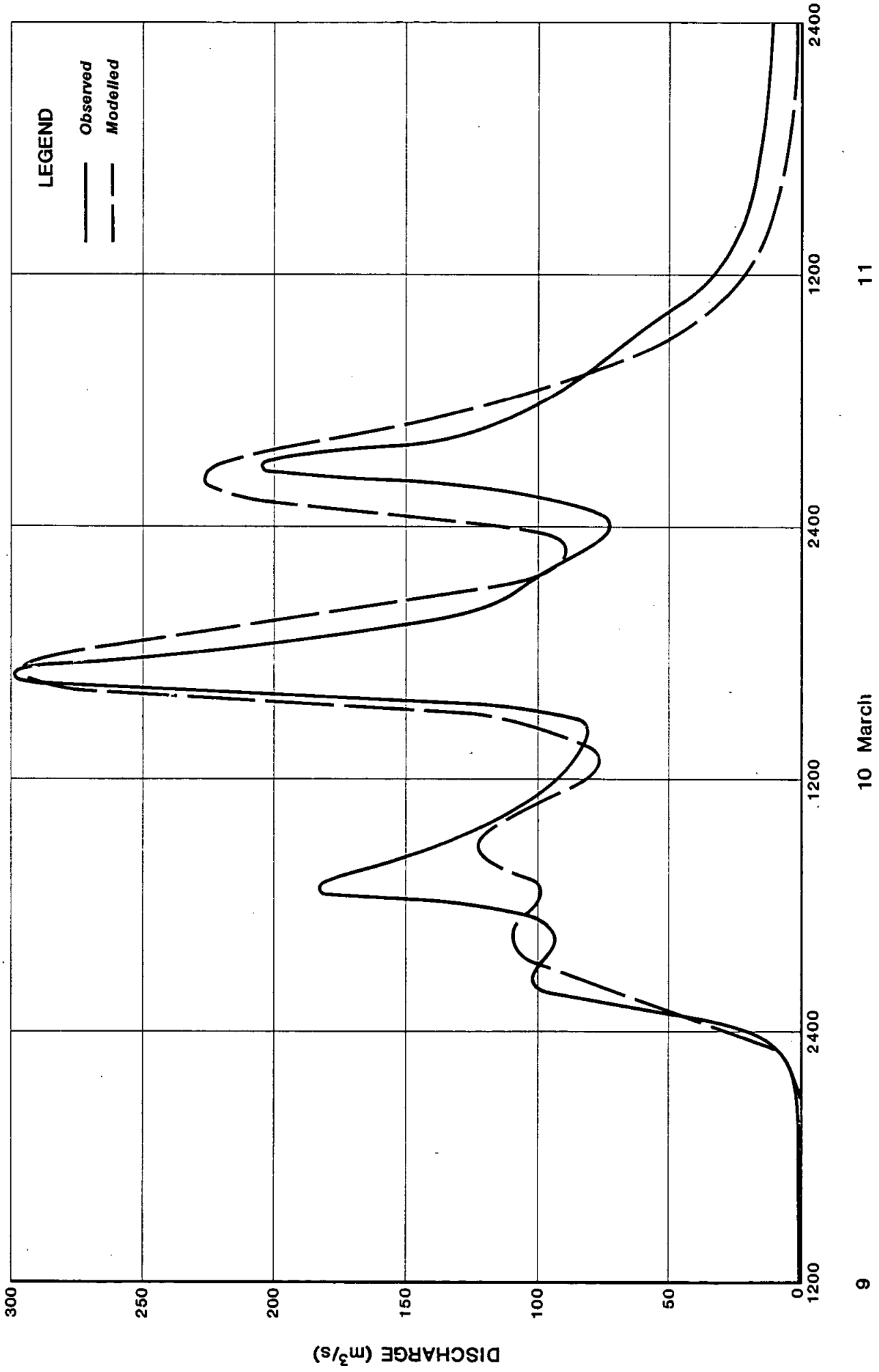


FIGURE 14

FLOW HYDROGRAPHS AT DURRUMBUL FEBRUARY 1976

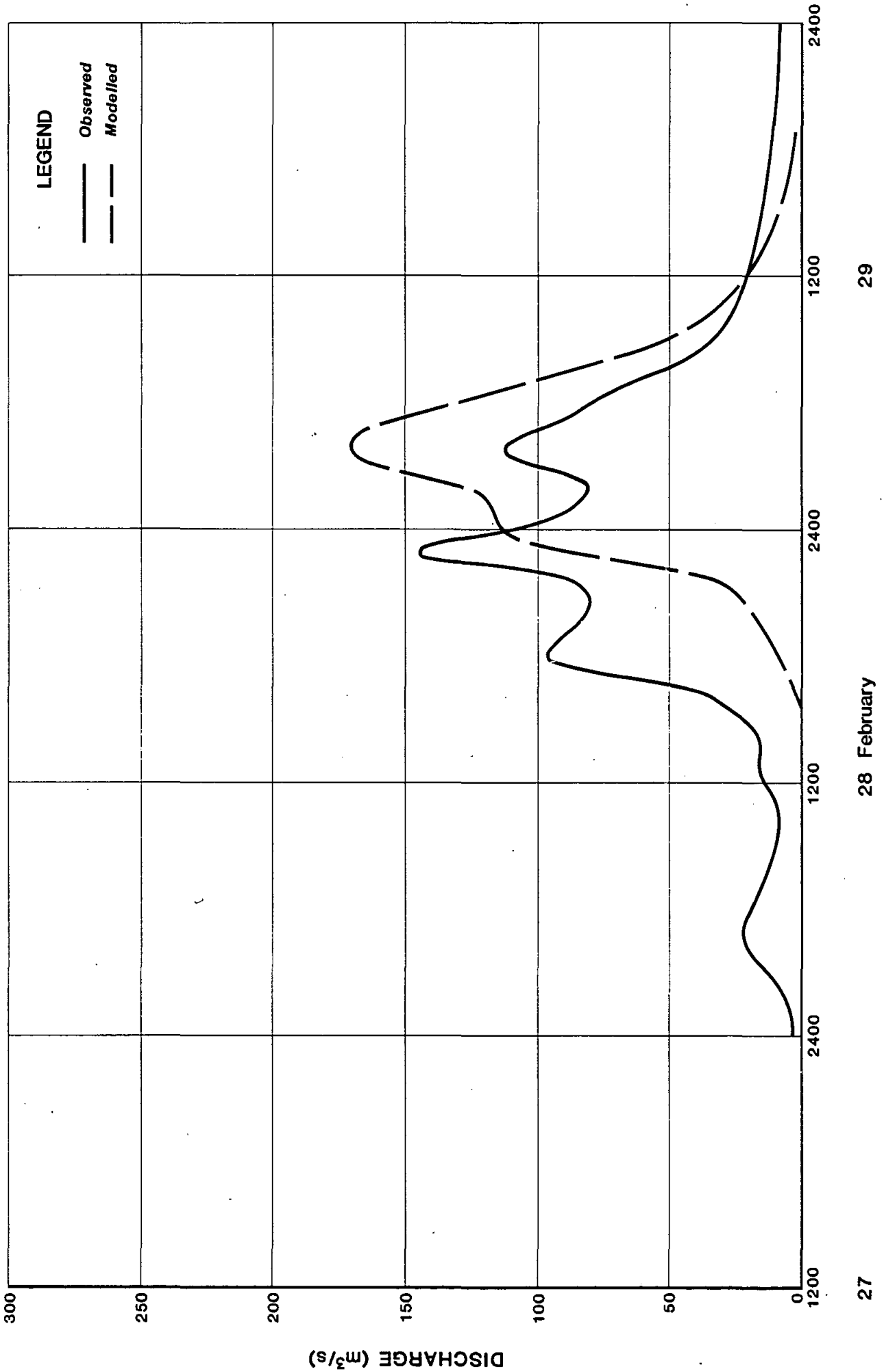


FIGURE 15

FLOW HYDROGRAPHS AT DURRUMBUL MARCH 1978

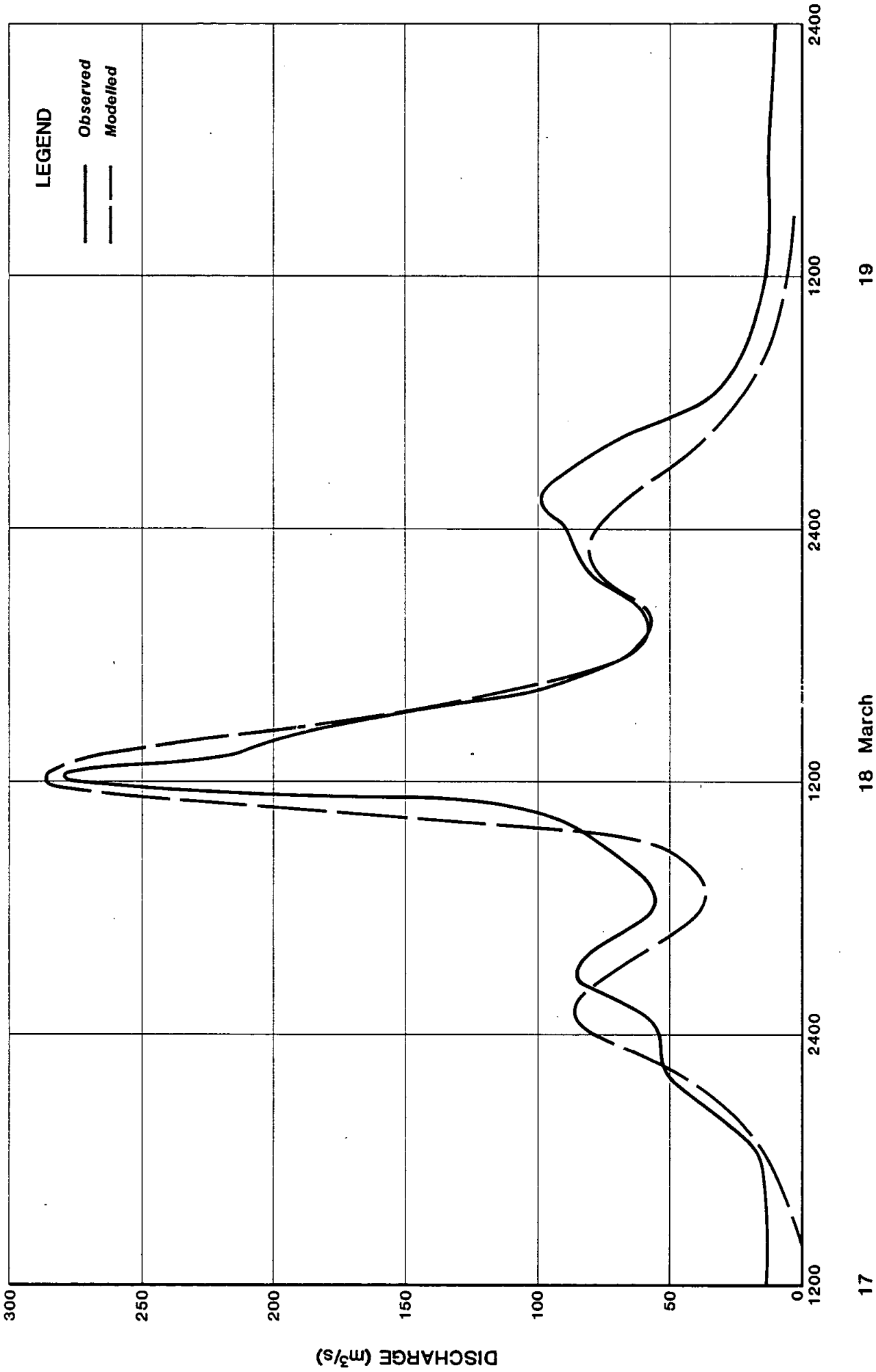


FIGURE 16

DESIGN RAINFALL MASS CURVE

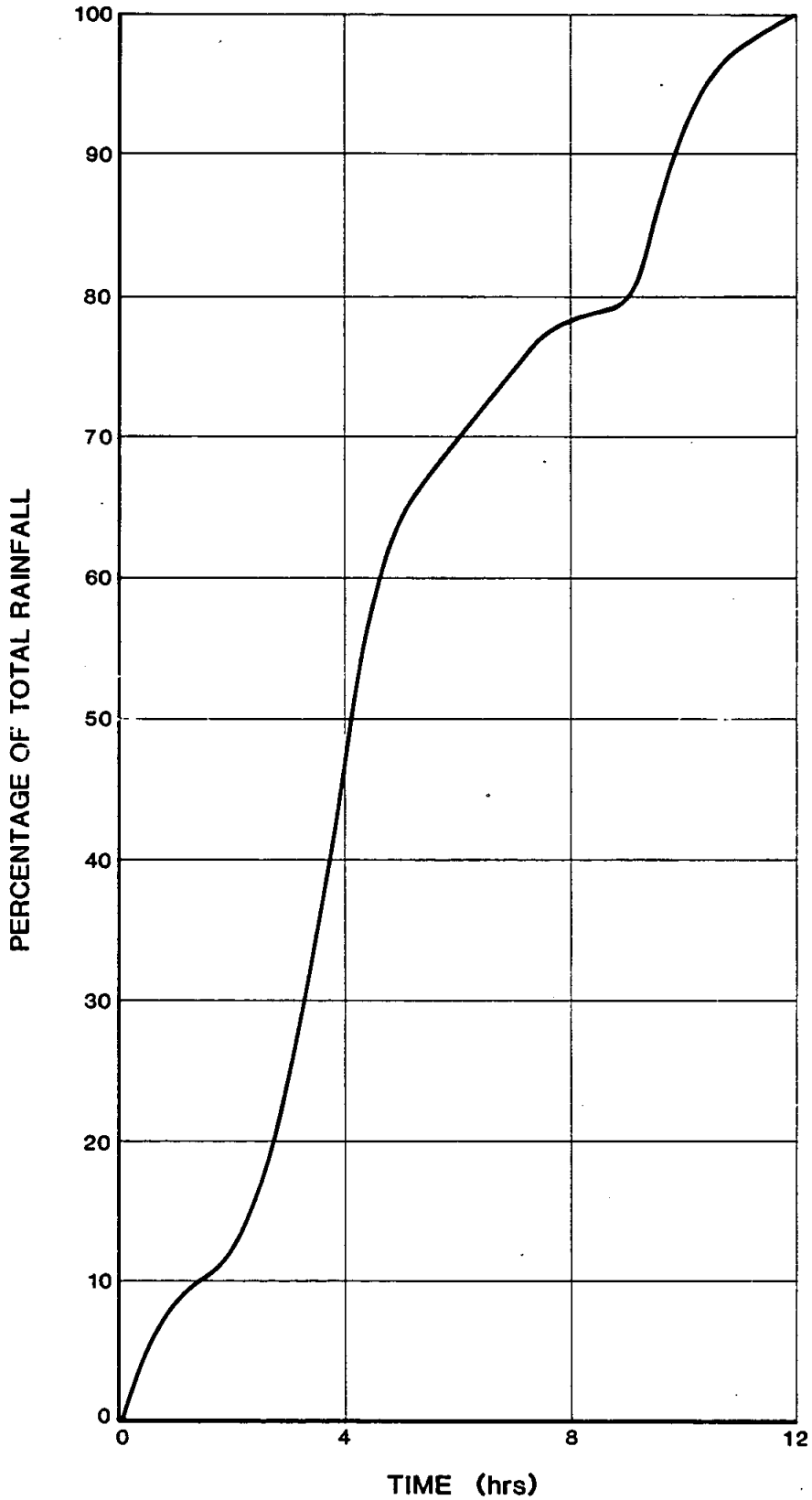
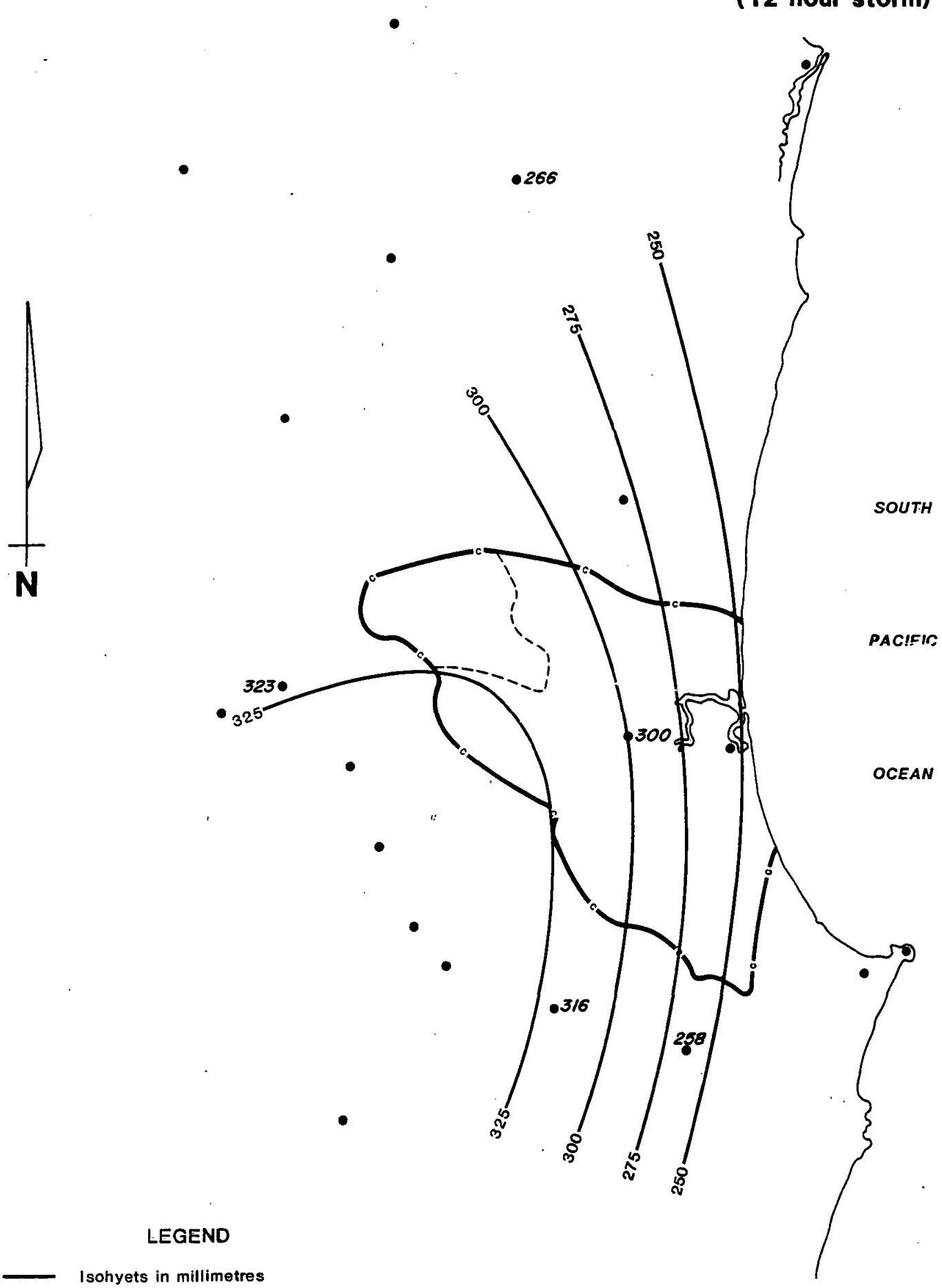


FIGURE 17

20 YEAR DESIGN ISOHYETS
(12 hour storm)

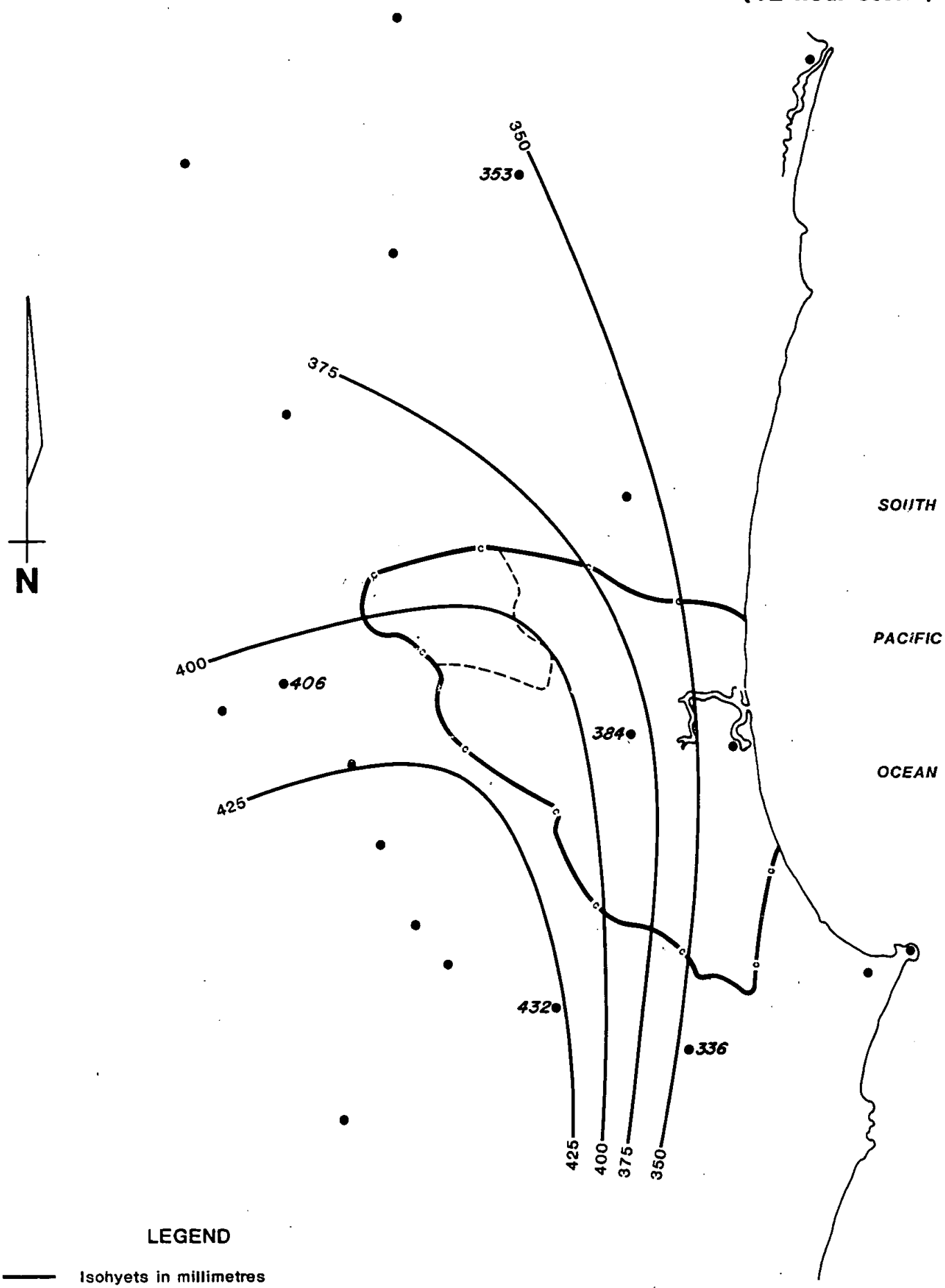


LEGEND

———	Isohyets in millimetres
●413	Rain gauge with rainfall in millimetres
—c—	Brunswick Heads catchment boundary
-----	Durrumbul catchment boundary

FIGURE 18

100 YEAR DESIGN ISOHYETS
(12 hour storm)



LEGEND

———	Isohyets in millimetres
•413	Rain gauge with rainfall in millimetres
—c—	Brunswick Heads catchment boundary
- - - - -	Durrumbul catchment boundary

FIGURE 19

DESIGN HYDROGRAPHS
20 YEAR FLOOD

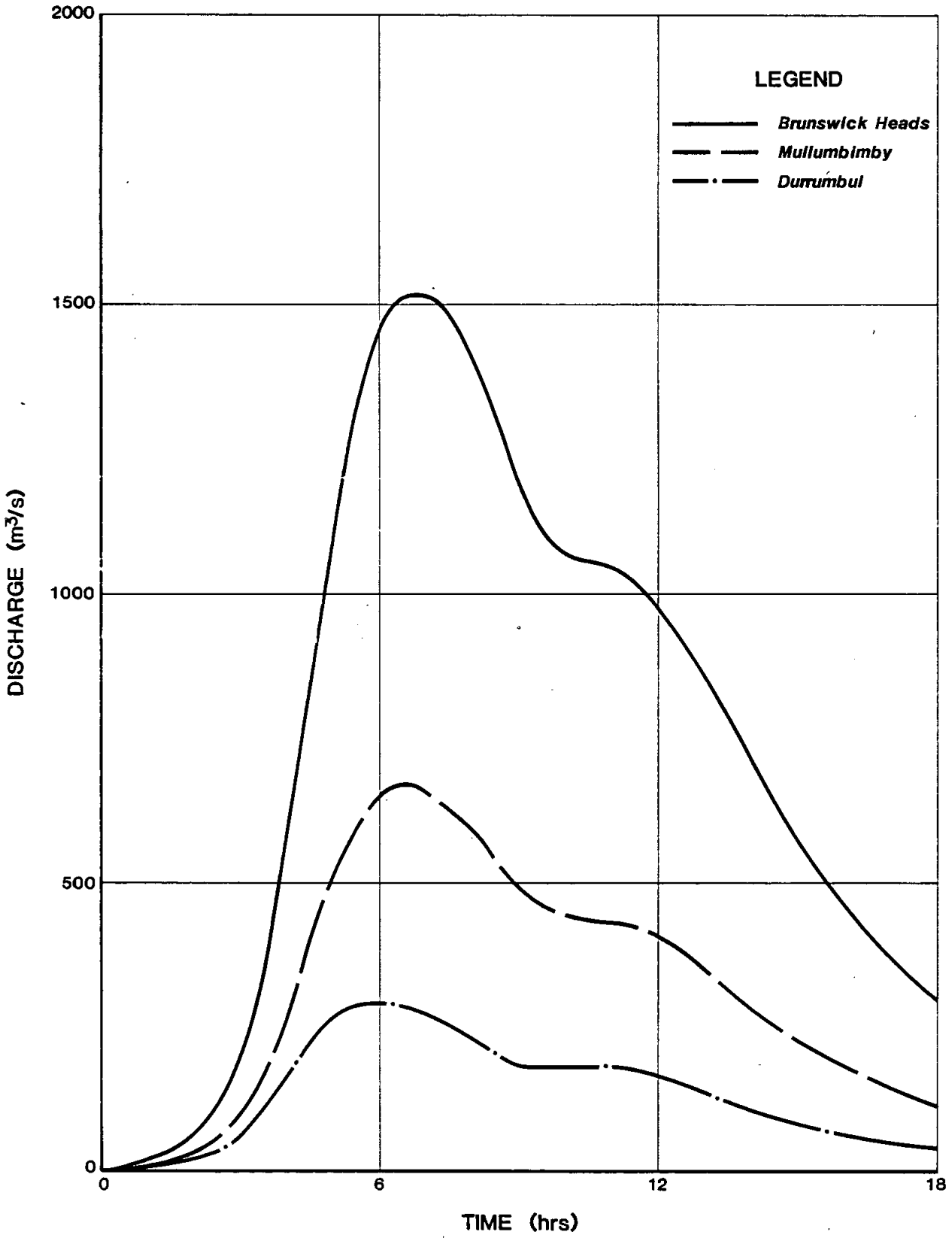


FIGURE 20

DESIGN HYDROGRAPHS
100 YEAR FLOOD

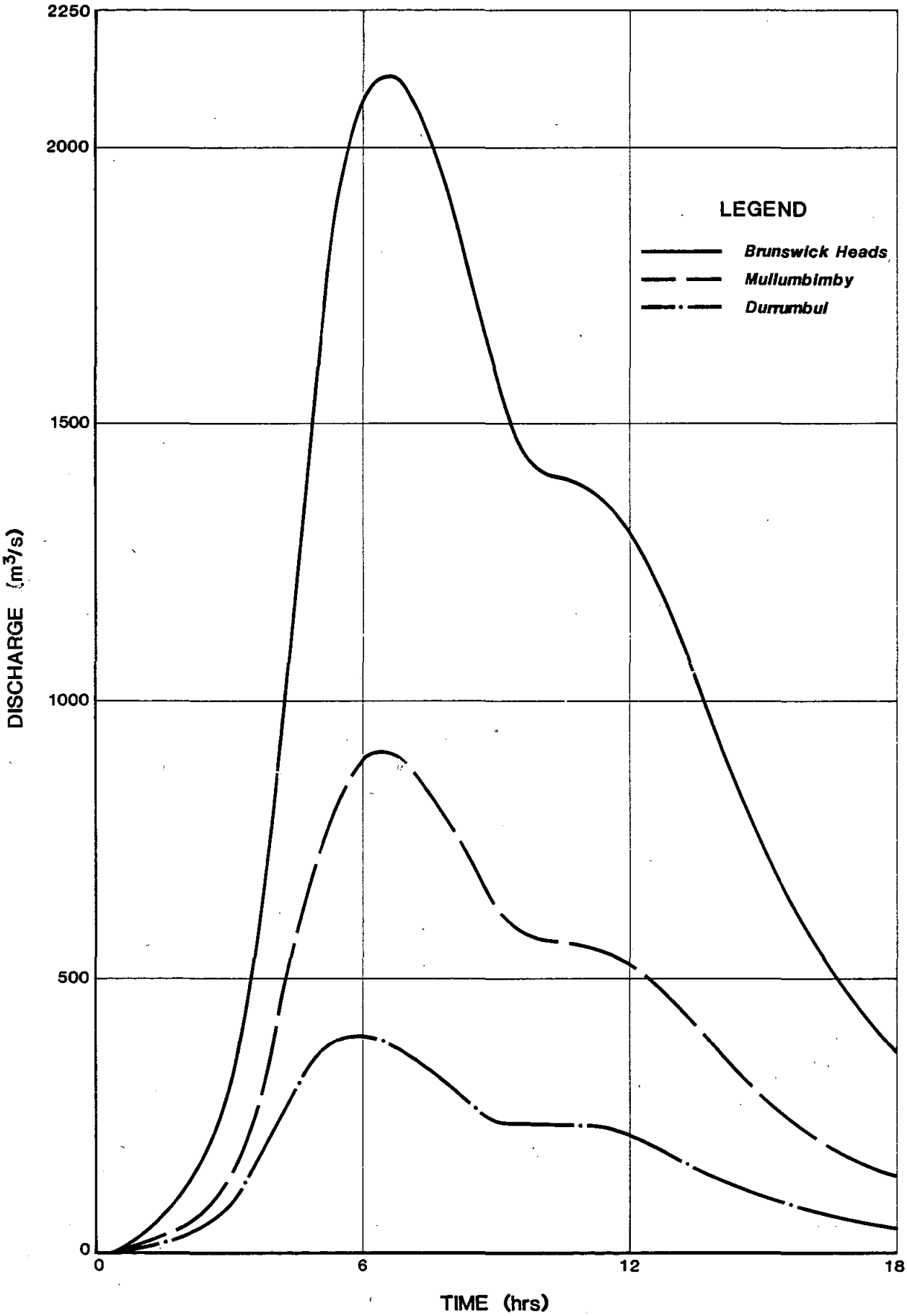


FIGURE 21

DESIGN HYDROGRAPHS
EXTREME FLOOD