BULAHDELAH

Flood Appraisal

October, 1991

PUBLIC WORKS

Coast and Rivers Branch

BULAHDELAH

Flood Appraisal

Report No. 90018

ISBN 0730574962

FOREWORD

The State Government's Flood Policy is directed at providing solutions to existing flooding problems in developed areas and to ensuring new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the policy the management of flood liable land remains the responsibility of Local Government. The State subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities.

The policy provides for technical and financial support by the Government through the following four sequential stages:

1. Flood Study - determine the nature and extent of the flood problem.

2. Floodplain Management Study - evaluates management options for the floodplain in respect of both existing and proposed development

3. Floodplain Management Plan - involves formal adoption by Council of a plan of management for the floodplain

4. Implementation of the Plan - construction of flood mitigation works to protect existing development.

   use of Local Environmental Plans to ensure new development is compatible with the flood hazard.

In view of the lack of recorded flood data, a detailed Flood Study was not considered to be practicable at this time. The Bulahdelah Flood Appraisal was therefore carried out in lieu of a detailed Flood Study. It constitutes the first stage of the management process for the Myall River floodplain in the vicinity of Bulahdelah. It was prepared for Great Lakes Shire Council to assess flood behaviour under current conditions.

GLOSSARY

Annual Exceedance Probability	refers to the probability or risk of a flood of a given size occurring or being exceeded during a given year. A 90% AEP flood has a high probability of occurring or being exceeded; it would occur quite often and would be relatively small. A 1% AEP flood has a low probability of occurrence or being exceeded; it would be fairly rare but it would be relatively large.
Australian Height Datum (AHD)	a common national plane of level corresponding approximately to mean sea level
catchment	the area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
design flood	a flood of a known magnitude or probability of exceedance, used for engineering design or planning purposes.
development	the erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.
discharge	the rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow which is a measure of how fast the water is moving rather than how much water is moving.
flood	relatively high streamflow which overtops the natural or artificial banks in any part of a stream or river.
flood liable land	land which would be inundated as a result of a standard flood.
floodplain	the portion of a river valley, adjacent to the river channel that is covered with water when the river is in flood.

flood storage — those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.

hydraulics — the study of water flow; in particular the evaluation of flow parameters such as stage and velocity in a river or stream.

hydrograph — a graph which shows how stream discharge varies with time at a particular location.

hydrology — the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.

mathematical/computer models — the mathematical representation of the physical processes involved in runoff and streamflow. These models are usually run on computers because of the complexity of the relationships.

peak discharge — the maximum discharge occurring during a flood event.

probable maximum flood — the flood calculated to be the maximum which is likely to occur.

probability — a statistical measure of the expected frequency of occurrence of flooding. See also Annual Exceedance Probability.

runoff — the portion of rainfall that actually ends up as streamflow, also known as rainfall excess.

stage — equivalent to water level. Both are measured with reference to a particular datum and location.

stage hydrograph — a graph that shows the variation in stage with respect to time. It must be referenced to a particular location and datum.

BULAHDELAH FLOOD APPRAISAL

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDICES

Appendix A.	Recorded Flood Levels
Appendix B.	Channel Cross Sections
Appendix C.	Detailed Model Results

1.0 SUMMARY

This flood appraisal was carried out for Great Lakes Shire Council, to define the nature and extent of the flood hazard at Bulahdelah under existing catchment conditions. It was carried out in lieu of a detailed flood study because of the shortage of recorded flood data.

The study area extends along the Myall River between a location 0.43 km downstream of the Pacific Highway bridge, and some 2 km upstream of the bridge at Lee Street.

Although the catchment has a history of flooding, reliable long term streamflow records are not available. In the absence of such records, it was necessary to establish design flood behaviour by numerical rainfall-runoff modelling.

Historical data from the October 1985 flood was used for model calibration, and data from the November 1987 flood was adopted for verification.

The runoff-routing program Watershed Bounded Network Model (WBNM) was selected for hydrologic modelling of the catchment. Discharge hydrographs were produced for the 1985 and 1987 floods and for the 1%, 2% and 5% Annual Exceedance Probability (AEP) floods.

The numerical hydraulic modelling system MIKE 11 was selected for simulating flood behaviour. The system includes an implicit, finite difference program for unsteady flow computations. The system is suitable for modelling floodplains, bridges and hydraulic structures.

The hydraulic model required upstream and downstream boundary conditions. Upstream boundary conditions were generated with the WBNM model, and downstream boundary conditions were established by extending the hydraulic model to the confluence of Muirs Creek, 5.5 km downstream of the highway bridge.

Data from a water level recorder (maximum height only) near Muirs Creek was available for the calibration and verification floods. Model testing demonstrated that the peak 1%, 2% and 5% flood heights in the study area were not sensitive to variations in the downstream boundary condition.

Flood behaviour throughout the study area for the 1%, 2% and 5% AEP floods is shown at Figures 11 to 14.

2.0 INTRODUCTION

The township of Bulahdelah is located on the Myall River, about 70 km north of Newcastle where the Myall is crossed by the Pacific Highway.

Approximately 0.5km upstream of the highway bridge, the Myall River has its confluence with its major tributary, the Crawford River. At this location the Myall and Crawford Rivers have catchment areas of 240 km^2 and 125 km^2 respectively.

The Myall River catchment is a narrow valley bounded by peaks up to 400m high. The steep and heavily timbered slopes of the catchment form part of the Bulahdelah and the Myall River State Forests. The narrow valley floor comprises of farmland down to Bulahdelah where it widens out into a floodplain. The Crawford River also rises in the Myall River State Forest. Its valley is wider and flatter than that of the Myall.

From Bulahdelah the Myall River flows some 15km down to the Myall Lakes. The lakes are drained by the lower reaches of the Myall River which flows parallel to the coast and south to Port Stephens.

Bulahdelah has a history of flooding. The largest floods on record are those which occurred in 1897 and 1927. Smaller floods were recorded in 1947 and 1953. More recently, less severe floods occurred in 1985 and 1987.

This study was undertaken for Great Lakes Shire Council, to assist it in developing a Floodplain Management Plan for the area. Since Bulahdelah is an entry point to the Myall Lakes, development of the township and the surrounding area, particularly tourist related development, is increasing. The aim of the study is to define the nature and extent of the flood problem at Bulahdelah under existing conditions. The approach taken involved estimating the flows in floods of differing probabilities of occurrence, based on rainfall statistics. These flows were then used to estimate the levels and the velocities of these floodwaters throughout the study area.

3.0 AVAILABLE DATA

3.1 Previous Studies

A report on the Lower Myall River Flood Analysis (Ref. 1) was published by the Public Works Department in February 1980. This study was undertaken to define the flood behaviour of the Myall Lakes and the Lower Myall River, between the Lakes and the Ocean.

A brief study was prepared in 1986 by Sinclair Knight & Partners (Ref. 2) which investigated the hydraulic impact of a proposed relocatable housing estate on the Myall River at Bulahdelah upstream of the Crawford River confluence.

3.2 Maps and Survey Data

Topographic maps at a scale of 1:100,000 with 20m contour intervals, and at a scale of 1:25,000 with 10m contours are available for the catchment. These maps have been utilised to define subcatchment boundaries and other catchment characteristics.

A number of cross sections were surveyed by the Department in 1987 and 1988. These sections, which are shown in Appendix B, were used for hydraulic modelling.

3.3 Historic Flood Data

Recorded flood levels within the study area are presented in Appendix A

The largest flood recorded at Bulahdelah occurred in 1897. The flood reached a level of RL 5.5m AHD on the upstream side of the highway bridge. Further information on this flood is limited.

The next largest flood on record is the 1927 flood, which peaked at RL 5.1m at the bridge. At the confluence of the Myall and Crawford Rivers, approximately 500m upstream, a flood level of RL 6.4m was reported. The limited records available on floods in 1947 and 1953 indicate they were lower than the 1927 flood.

Most information on flooding is available for the more recent floods which occurred in October 1985 and November 1987. Both floods peaked at RL 3.7m at the highway bridge, however the 1985 flood was higher upstream of the bridge. The 1985 flood was a result of a more intense rainfall burst which produced higher river flows. Rainfall from the 1987 storm was less intense, but involved a greater rainfall volume. Although river flows were less than the 1985 flood, backwater influences from Myall Lakes were more significant.

Stage hydrographs for the 1985 and 1987 floods are available from the automatic water level recorder which is located at the highway bridge. Peak heights from maximum height recorders at the bridge, Muirs Creek and at Lee Street, the upper limit of the study area, are available. Some debris mark data within the vicinity of the town are also available.

A compilation of historic flood heights is represented on Figure 3.

3.4 Meteorological Data

Both daily rainfall and pluviograph data are required to adequately describe the areal and temporal distribution of rainfall for individual runoff producing storms.

There are no pluviographs located within the Myall River catchment, the closest are those located at Upper Johnsons Creek and Nabiac. Other pluviographs are located at Maryville (Newcastle), Williamtown and Taree.

Long term daily rainfall records are available within the catchment from the Bureau of Meteorology station at Bulahdelah Post Office. Other Bureau of Meteorology stations are located around the boundary of the catchment. Although Bulahdelah Post Office is the only official station within the catchment, other information was available from unofficial gauges located at Upper Myall (Tank Creek), Markwell (Deep Creek) and Rosenthal (Gloucester Road). Isohyetal maps of the 1985 and 1987 flood rainfalls were based on both the official and unofficial stations (Figures 5 and 6). A list of stations within and adjacent to the catchment is given in Table 1.

Table 1 List of Daily Rainfall Stations

Station Name	Bureau of Meteorology No.
Bulahdelah P.O	060 002
Upper Myall (Tank Ck)	-
Markwell (Deep Ck)	-
Rosenthal (Gloucester Rd)	-
Forster P.O.	060 013
Krambach	060 021
Craven	060 042
Clarence Town	061 010
Nelson Bay RSL	061 054
Stroud	061 071
Paterson	061 096
Chichester Dam	061 151
Dungog	061 017
Waukivory	060 062
Bulby Bush	060 003
Bungwahl (Burraduc)	060 047

4.0 METHODOLOGY

4.1 General

Long term streamflow records are not available for the Myall River. The Department of Water Resources maintained a stream gauging station at Markwell between 1969 and 1979. An automatic water level recorder was installed immediately downstream of the highway bridge in 1985 by the Public Works Department. There are insufficient records available for a reliable flood frequency analysis, so flood flows were estimated by using hydrologic modelling.

Flood behaviour for these synthesised flood flows was determined using the numerical hydraulic modelling system MIKE 11. The hydraulic model was calibrated using data recorded in the 1985 flood. Data recorded from the 1987 flood was used for model verification.

4.2 Hydrologic Modelling

The Watershed Bounded Network Model (WBNM) developed by Boyd et al (Ref. 4) was used to compute runoff hydrographs. Peak flow estimates were also estimated independently by using both the Cordery-Webb synthetic unit hydrograph method and the Probabilistic Rational Method.

Design rainfall intensities and temporal patterns were calculated in accordance with the 1987 edition of Australian Rainfall and Runoff (Ref. 3)

Hydrologic modelling is discussed in detail in Section 5.

4.3 Hydraulic Modelling

Flood behaviour was determined using the numerical hydraulic modelling system MIKE 11 (Ref. 5). The system was developed by the Danish Hydraulic Institute on the basis of its earlier program, SYSTEM 11 HD. It includes an implicit, finite difference program for unsteady flow computations, and is suitable for modelling floodplains, bridges and hydraulic structures.

In establishing a model, it is necessary to ensure that it simulates actual flooding conditions. This is achieved by calibrating and verifying the model against known historic events. The 1985 flood was used for calibration purposes, and the 1987 flood was selected for verification.

The hydraulic model was used to produce 1%, 2% and 5% Annual Exceedance Probability (AEP) flood profiles. Tailwater levels were established by extending the model downstream of Bulahdelah, to the confluence of Muirs Creek. A maximum height recorder at this site provided peak flood levels for the 1985 and 1987 floods.

Model testing showed that flood profiles in the study area were not sensitive to variations in assumed tailwater conditions for the 1%, 2%, and 5% AEP floods.

Hydraulic modelling is discussed in detail in Section 6.

5.0 RAINFALL-RUNOFF ANALYSIS

In the absence of both continuous long term flood data and a relationship between river stage and discharge at Bulahdelah, it was necessary to adopt a study approach using hydrologic modelling.

The Watershed Bounded Network Model (WBNM) is a hydrologic runoff-routing method developed by Boyd et al (Ref. 4). It was used to produce runoff hydrographs both for the 1985 and 1987 flood events and for the conditions associated with the 1%, 2% and 5% AEP floods. Peak flow estimates were also produced independently by using both the Cordery-Webb synthetic unit hydrograph method and the Probabilistic Rational Method.

WBNM requires the catchment to be divided into a number of subcatchments for the analysis. Each of these subcatchments is represented in WBNM as a single storage element. The Myall River was divided into 5 subcatchments and the Crawford River into 3 subcatchments, mainly on the basis of topographic boundaries. The subcatchment plan is represented on Figure 2.

When sufficient data is available, WBNM can be calibrated against past floods by adjusting the storage delay parameter "C", the initial rainfall loss and the continuing rainfall loss rate. Alternatively, WBNM also has a relatively extensive data base for estimating model parameters when it is used with ungauged catchments.

As existing streamflow records are limited, it was decided to adopt a recommended default value for C of 1.29. The value was determined by optimising the fit of peak discharge for some 250 storm events on 33 catchments (Ref. 4, 8). The value was also adopted for the Forster-Tuncurry Flood Study (Ref. 6) after it gave satisfactory results for available data on the Wallamba and Wang Wauk Rivers.

5.1 Derivation of Hydrographs for Historic Events

Flow hydrographs for historic events were required to enable calibration and verification of the hydraulic model. The October 1985 flood was used for calibration and the November 1987 flood for verification purposes.

Rainfall isohyets were constructed from available daily rainfall stations for both storm events. These event isohyets, shown on Figures 5 and 6, indicate the variation of rainfall over the catchment. Table 2 indicates assumed rainfall totals for each subcatchment.

TABLE 2 Rainfall Totals (mm) for Historic Events

Subcatchment (see Fig.2)	October 1985	November 1987
1	135	140
2	145	160
3	160	170
4	140	180
5	110	195
6	170	225
7	110	220
8	105	210

A rainfall temporal pattern for the 1985 storm was determined by considering the available pluviograph records. Data was available from Maryville, Williamtown, Nabiac and Taree (Figure 7).The adopted temporal pattern for this event reflects the closer proximity of the Nabiac and Taree pluviographs. For the 1987 storm, records were available from the pluviographs at Maryville, Williamtown, Upper Johnsons Creek, Nabiac and Taree (Figure 8). The Upper Johnsons Creek data was selected for the 1987 event because of the proximity of this station to the study area.

An initial rainfall loss of 21 mm and a continuing loss rate of 2.5 mm/hr, were adopted for the 1987 flood and for the 1%, 2% and 5% AEP floods. These are accepted default values for a catchment of this size and were selected in the absence of other data. Zero initial loss, together with a continuing loss rate of 2.5 mm/hr, was used for the 1985 flood, as there had been considerable rainfall prior to this event.

Flow hydrographs, shown on Figure 9, were calculated using WBNM. Although there was more rainfall associated with the 1987 event, the peak flow is less than the 1985 event. This is a result of the different storm temporal patterns.

5.2 Rainfall Estimation

Rainfall intensities for the 1%, 2% and 5% AEP storms were calculated in accordance with the 1987 edition of Australian Rainfall & Runoff (Ref. 3). Rainfall Intensity - Frequency - Duration (IFD) values for the catchment are presented in Table 3.

TABLE 3 Design Rainfall Intensities for Bulahdelah (mm/hr)

Duration	Annual Exceedance Probability					
(hr.)	50%	20%	10%	5%	2%	1%
1	34	45	52	60	71	79
3	18	24	27	32	37	42
6	12	16	18	21	25	28
9	9.5	12	14	17	20	22
12	8.0	11	12	14	17	18
18	6.2	8.2	9.4	11	13	15
24	5.1	6.9	7.9	9.2	11	12
36	3.9	5.3	6.1	7.2	8.6	10
48	3.2	4.4	5.1	6.1	7.2	8.2
72	2.4	3.3	3.8	4.5	5.5	6.3

These rainfall intensities are average values over the whole duration of the storm. Since an actual storm consists of a pattern of short duration rainfalls of varying intensities, it is necessary to assign a probable temporal distribution to the rainfall for design conditions. The temporal patterns adopted for this study are those recommended in the current edition of Australian Rainfall and Runoff (Ref. 3).

An initial rainfall loss of 21 mm and a continuing loss of 2.5 mm/hr (Ref. 3) were subtracted from the design rainfall to produce rainfall excess.

5.3 Watershed Bounded Network Model Analysis

To determine the critical rainfall duration which produces maximum flows, storm durations of 12, 18, 24, 36, 48 and 72 hours were considered. The 36 hour storm was found to produce maximum flows for the 1% AEP flood. The effect of storm duration is indicated in Table 4.

TABLE 4 Effect of Storm Duration (1% AEP Flood at Bulahdelah)

Duration (hr.)	Flow (m^3/s)
12	1,800
18	1,800
24	1,700
36	2,100
48	2,000
72	1,400

Runoff hydrographs for the 1%, 2% and 5% AEP events were determined using the 36 hour critical storm duration for both the Myall and Crawford Rivers separately and combined. Hydrographs are shown in Figure 4, with peak flows summarised in Table 5.

TABLE 5 Peak Flow Estimates (m^3/s)

Location	1% AEP	2% AEP	5% AEP
Myall River (Upstream of Crawford R.)	1,400	1,200	930
Crawford River	750	640	520
Myall River (Bulahdelah bridge)	2,100	1,800	1,500

5.4 Verification of Results

Peak flows for the 1%, 2% and 5% AEP floods were estimated independently by the Cordery-Webb synthetic unit hydrograph method and also by the Probabilistic Rational Method.

The Cordery-Webb design method has been developed from rural catchment data in eastern New South Wales. A synthetic unit hydrograph was developed for the method from catchment characteristics, based on relationships developed from an analysis of 21 catchments throughout New South Wales.

The Probabilistic Rational Method is a design procedure for estimating peak flows for rural catchments. The method is based on the statistical interpretation of flood frequency data for some 300 catchments.

A summary of results from the three methods is presented in Table 6. Although the WBNM gives slightly higher peak discharges than the other two methods, it was preferred as it is the more physically realistic model and has been adopted for flood studies in other nearby catchments.

TABLE 6 Comparison of Peak Flow Estimates (at Bulahdelah Bridge)

Method	1% AEP Flow (m^3/s)
WBNM	2,100
Cordery-Webb	1,700
Probabilistic Rational	1,800

6.0 FLOOD LEVEL ANALYSIS

6.1 Method

Flood behaviour was determined using the numerical hydraulic modelling system MIKE 11 (Ref. 5). The system was developed by the Danish Hydraulic Institute on the basis of its earlier program, SYSTEM 11 HD. It includes an implicit, finite difference program for unsteady flow computations, and is suitable for modelling floodplains, bridges and hydraulic structures.

The Bulahdelah model consists of seven surveyed cross-sections (shown in Appendix B) and the Pacific Highway bridge long sectional details.

Discharge hydrographs were input to the model at the upstream boundary, and at the confluence of the Crawford River. The downstream boundary consists of a stage hydrograph.

6.2 Calibration of Model

Calibration of the hydraulic model with recorded flood data is desirable to ensure that the model is representing the actual flood behaviour. The best data available was for the October 1985 flood, which was used for calibration.

The discharge hydrographs calculated for the 1985 flood (Figure 9) were used as upstream boundary conditions for the hydraulic model. A stage hydrograph was adopted as the downstream boundary condition. The downstream hydrograph was determined by using the recorded flood level from the Muirs Creek gauge, a calculated time difference for peak flood heights at the bridge and Muirs Creek and the general shape of the recorded hydrograph at Bulahdelah.

The model was initially run with Manning's roughness coefficients based on text book values (Ref. 7). This parameter was then adjusted until computed flood levels most closely matched recorded flood levels.

A constant Manning's "n" of 0.037 for the main channel and 0.050 for the floodplain was found to give best results. The value for the channel is slightly higher than might normally be expected, but is still within the range of acceptability. A significant proportion of mud and snags have been reported in the river channel near the bridge. These higher values of Mannings "n" may be reflecting the condition of the river channel.

The calculated flood profile for the October 1985 event is shown in Figure 10. A comparison of the recorded and calculated flood hydrographs is at Figure C1.

6.3 Verification

The November 1987 flood was adopted for verification of the hydraulic model. This flood was tested with the hydraulic model, using the model parameters adopted for calibration.

The 1987 event was characterised by relatively low flows but high total rainfall volume. As a result, flooding was influenced by conditions experienced further downstream, around Myall Lakes. This is evidenced by the flat flood gradient recorded in the vicinity of Bulahdelah.

The upstream and downstream boundary conditions were developed with similar procedures to those used for the 1985 flood, however the Muirs Creek gauge was overtopped in this event. A maximum flood level at this gauge of RL 2.90m was adopted. This level is 0.27m above the top of the gauge.

A comparison of the computed flood profile and recorded flood levels is shown on Figure 10. A comparison of the recorded and calculated flood hydrographs is at Figure C2. Given the limited data and nature of this flood, the agreement is reasonable.

6.4 Design Flood Levels

The design flood hydrographs calculated with WBNM (as outlined in Section 5.3) were input to the hydraulic model to produce 1%, 2% and 5% AEP flood profiles. However no data was available regarding suitable downstream boundary conditions for the 1%, 2% and 5% AEP floods. The adopted approach involved testing the sensitivity of the hydraulic model results to a range of possible tailwater conditions at the Muirs Creek confluence.

The trial tailwater curves are shown at Figure C3 and C4. They were determined with regard to:

- flood heights recorded at Muirs Creek in the 1985 and 1987 floods,
- the relative timing of flood peaks at Bulahdelah, Muirs Creek and in the Myall Lakes,
- the design peak flood levels at the Myall Lakes from Reference 1, and,
- the general shape of the stage hydrograph at Bulahdelah.

The 1% AEP flood hydrograph at the Highway Bridge proved to be insensitive to the range of tailwater conditions tested. The maximum calculated height for the 5% AEP flood at the bridge was relatively insensitive to tailwater conditions. It varied up to 200 mm within the range of conditions tested. The results of testing the sensitivity of calculated flood levels to various tailwater conditions is shown at Figures C3 and C4.

A single tailwater curve with a peak level of 3m AHD was adopted for modelling the 1%, 2%, and 5% AEP floods. A more detailed approach was unwarranted because of the relative insensitivity of flood levels upstream of the Highway Bridge. The adopted curve is shown on Figures C3 and C4.

Design flood behaviour is shown on Figures 11 to 14. Detailed results of flood heights and velocities are included in Appendix C.

6.5 Discussion of Results

The largest flood on record is one which occurred in 1897. A flood level of RL 5.5 m AHD was reported in the vicinity of the Highway Bridge. This level is some 50mm lower than the calculated 1% AEP flood.

The next highest flood on record is the 1927 event, which had a reported flood level of RL 5.0 m. This level is some 100mm lower than the level calculated for the 2% AEP flood. Flooding was also reported nearby on the Wallamba River in 1927. The flood on the Wallamba River was estimated to be of a similar magnitude to the 1% AEP event (Ref. 6).

7.0 ACKNOWLEDGEMENTS

This study was undertaken by the Coast and Rivers Branch of the Public Works Department, New South Wales and was funded by the State Government.

In compiling this report the Public Works Department has been assisted by information from the Bureau of Meteorology, Roads and Traffic Authority, Great Lakes Shire Council and local residents.

8.0 REFERENCES

1. "Lower Myall River Flood Analysis", PWD Report, February 1980.

2. "Relocatable Housing Estate, Myall St, Bulahdelah, Hydraulics Report", Sinclair Knight & Partners, 1986.

3. "Australian Rainfall & Runoff - A Guide to Flood Estimation", Institution of Engineers Australia, Revised Edition, 1987.

4 "WBNM: A General Runoff Routing Model" Boyd, M. J., Bates, B. C., Pilgrim, D. H., and Cordery, I. (1987). Programs and Users Manual. Water Research Laboratory Report No.170.

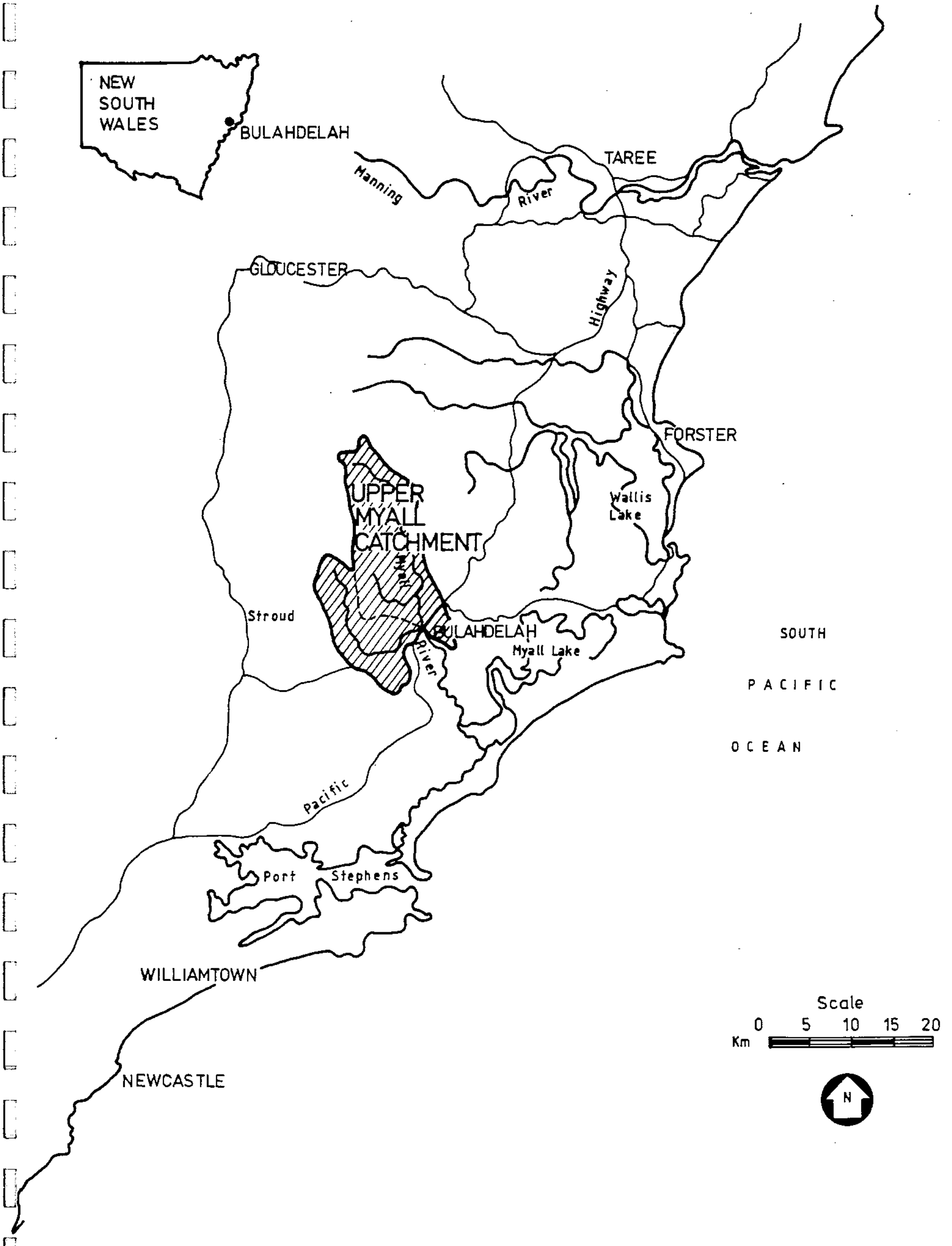
5. "MIKE 11 Users Guide", Danish Hydraulic Institute, October 1988.

6. "Forster-Tuncurry Flood Study", PWD Report No 88036 September 1989.

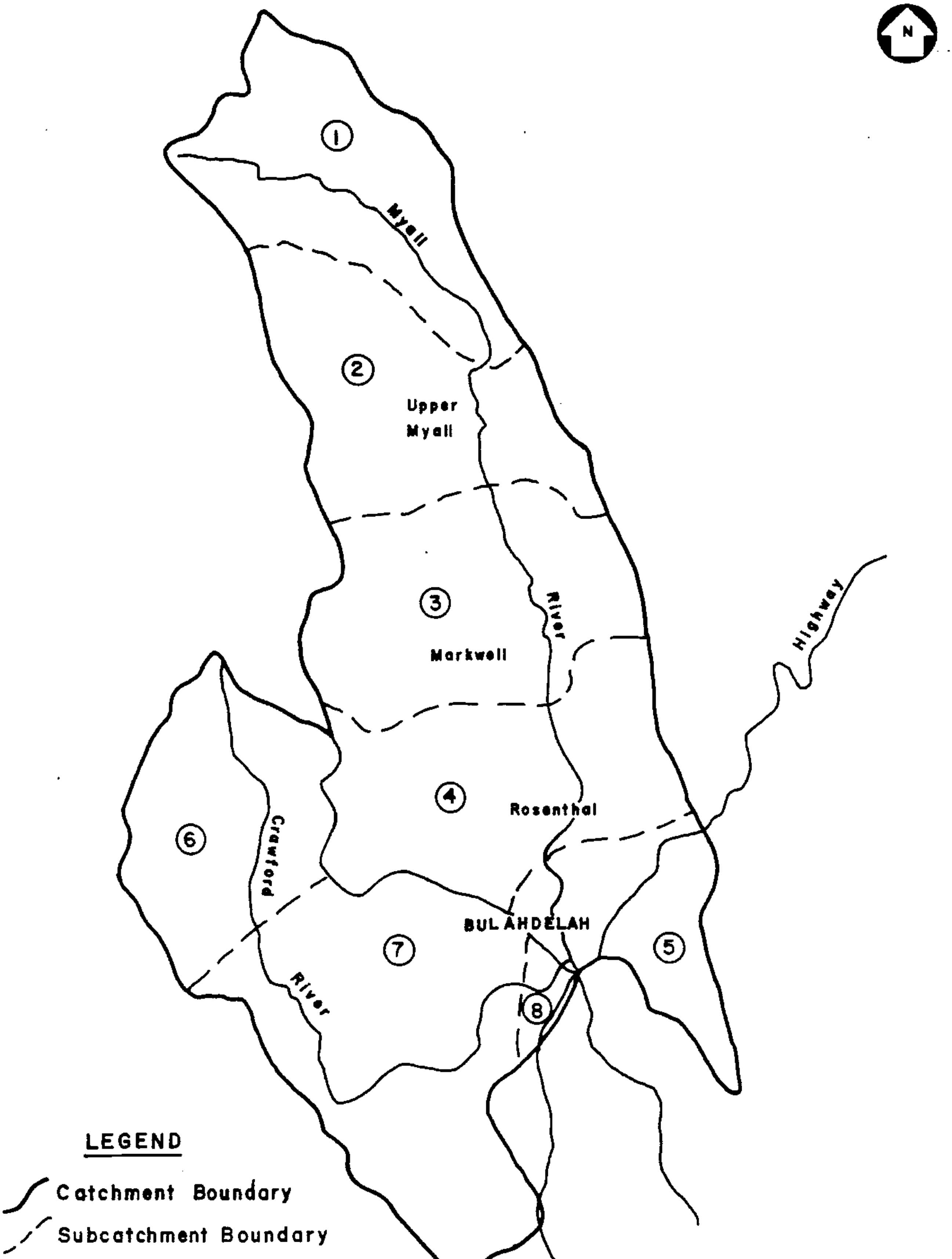
7. "Open Channel Hydraulics", Chow, Ven Te, 1983.

8. "WBNM: A General Runoff Routing Model" Boyd, M. J., Bates, B. C., Pilgrim, D. H., and Cordery, I. (1987). 4th National Local Govt Engg Conference, IEA.

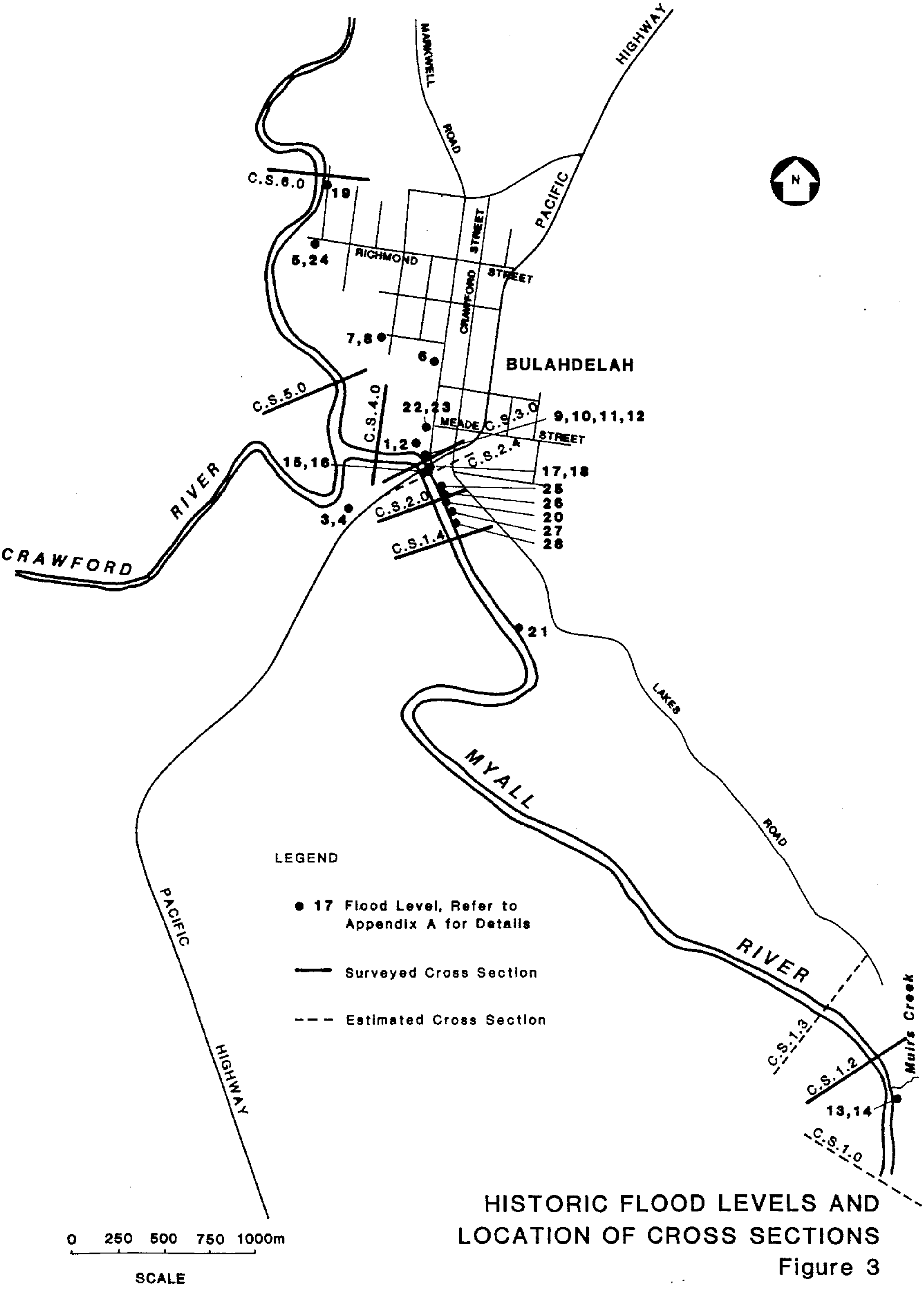
FIGURES



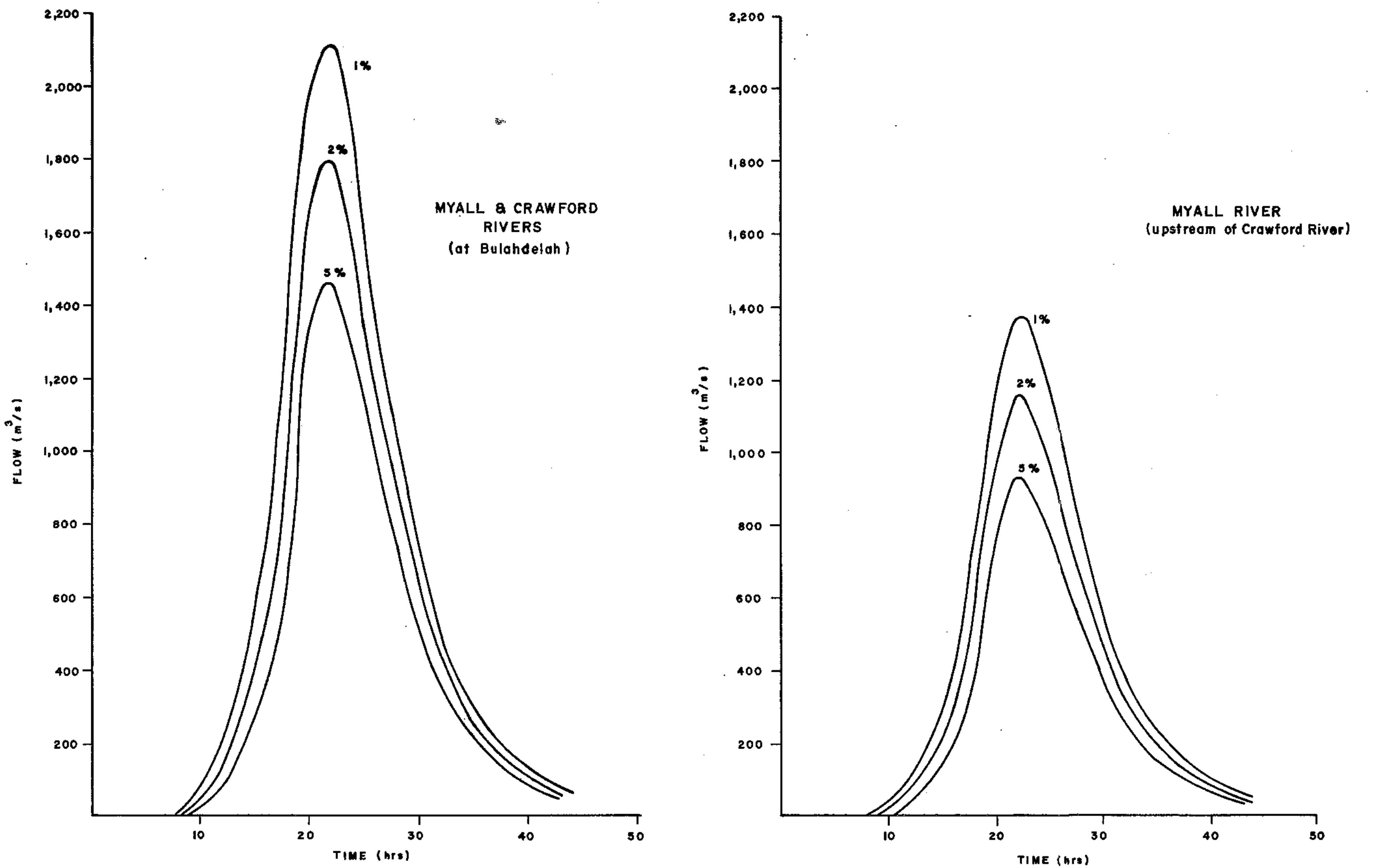
LOCALITY SKETCH
Figure 1



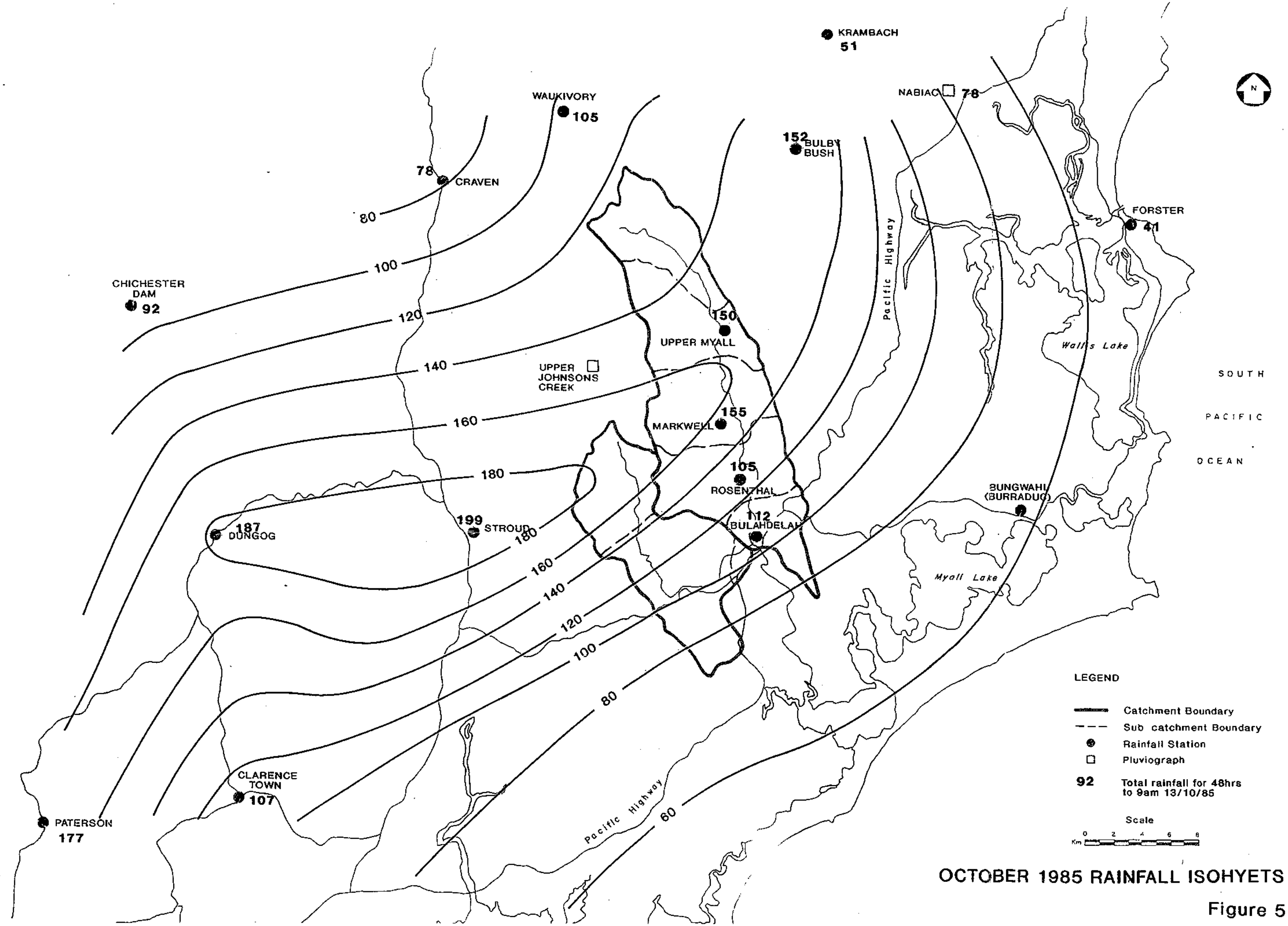
CATCHMENT PLAN
Figure 2



HISTORIC FLOOD LEVELS AND LOCATION OF CROSS SECTIONS
Figure 3

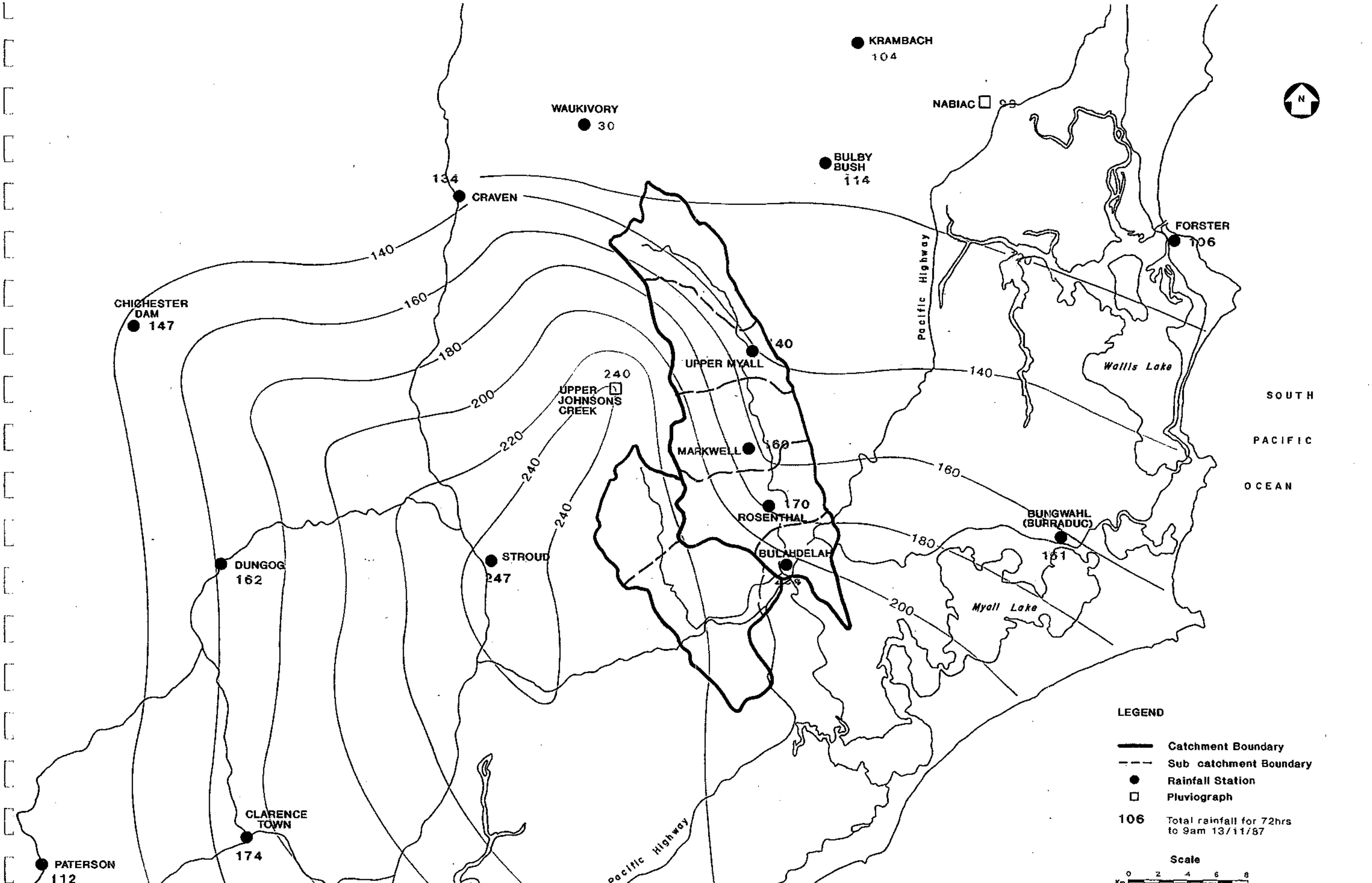


DESIGN FLOW HYDROGRAPHS
Figure 4



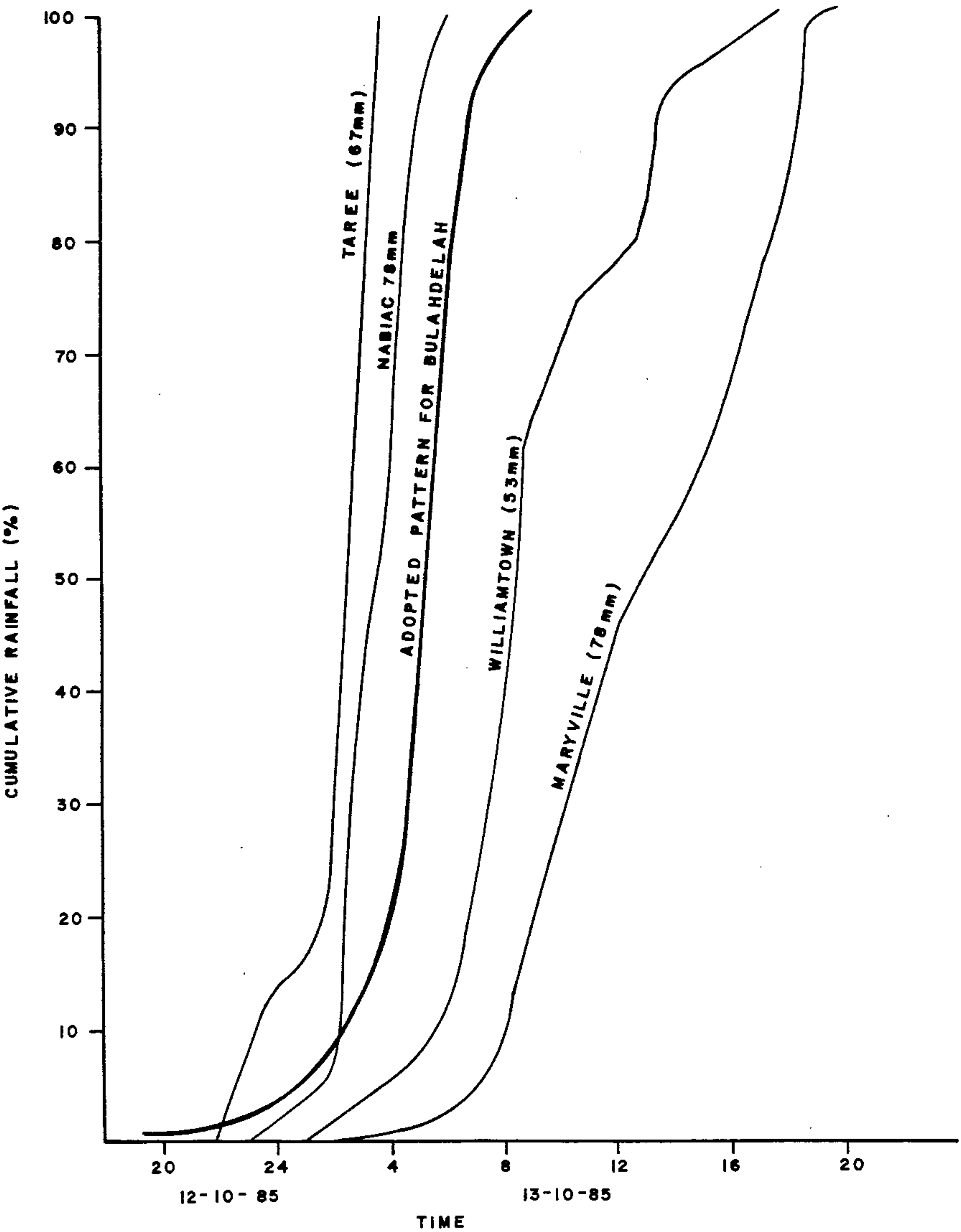
OCTOBER 1985 RAINFALL ISOHYETS

Figure 5

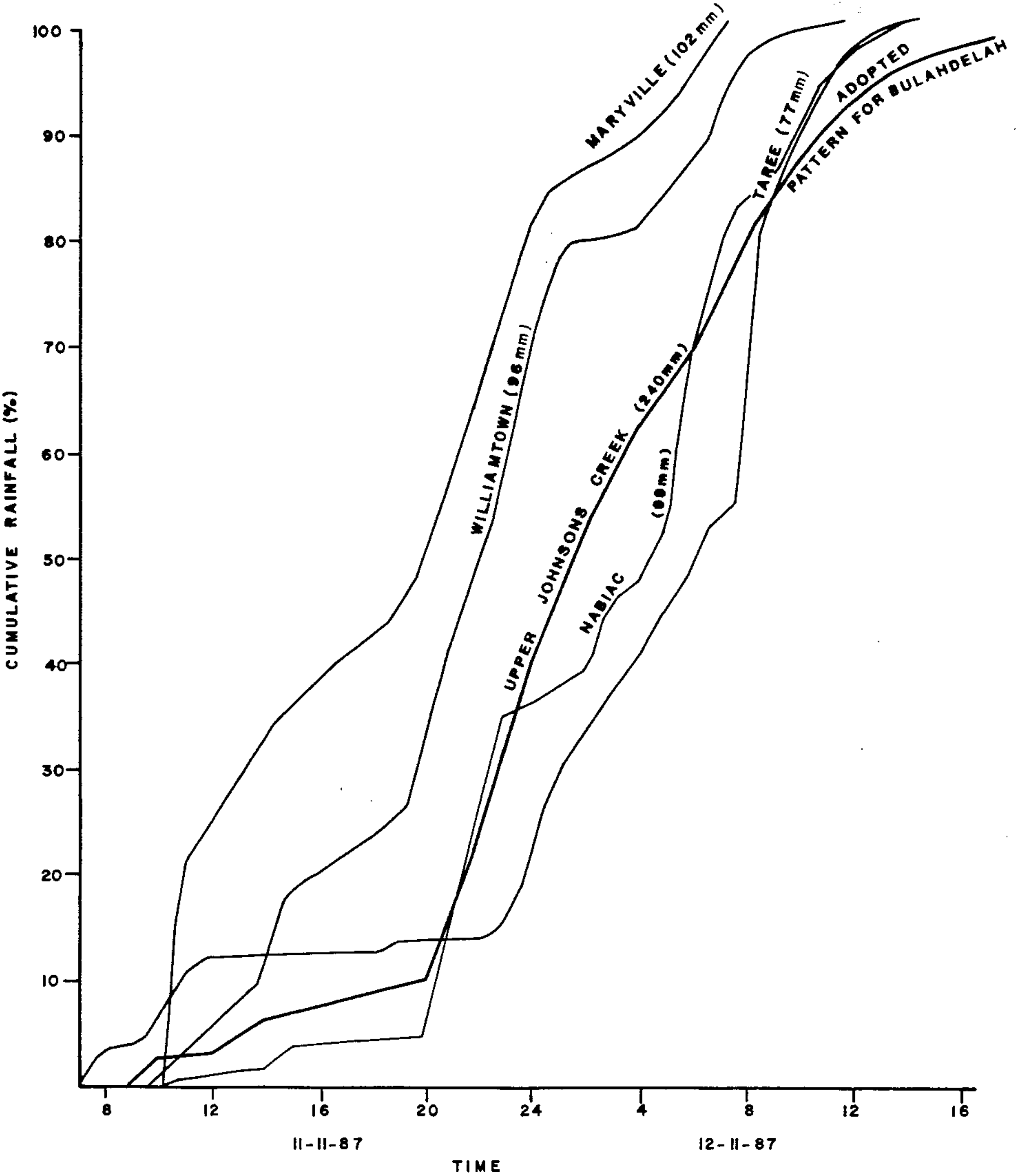


NOVEMBER 1987 RAINFALL ISOHYETS

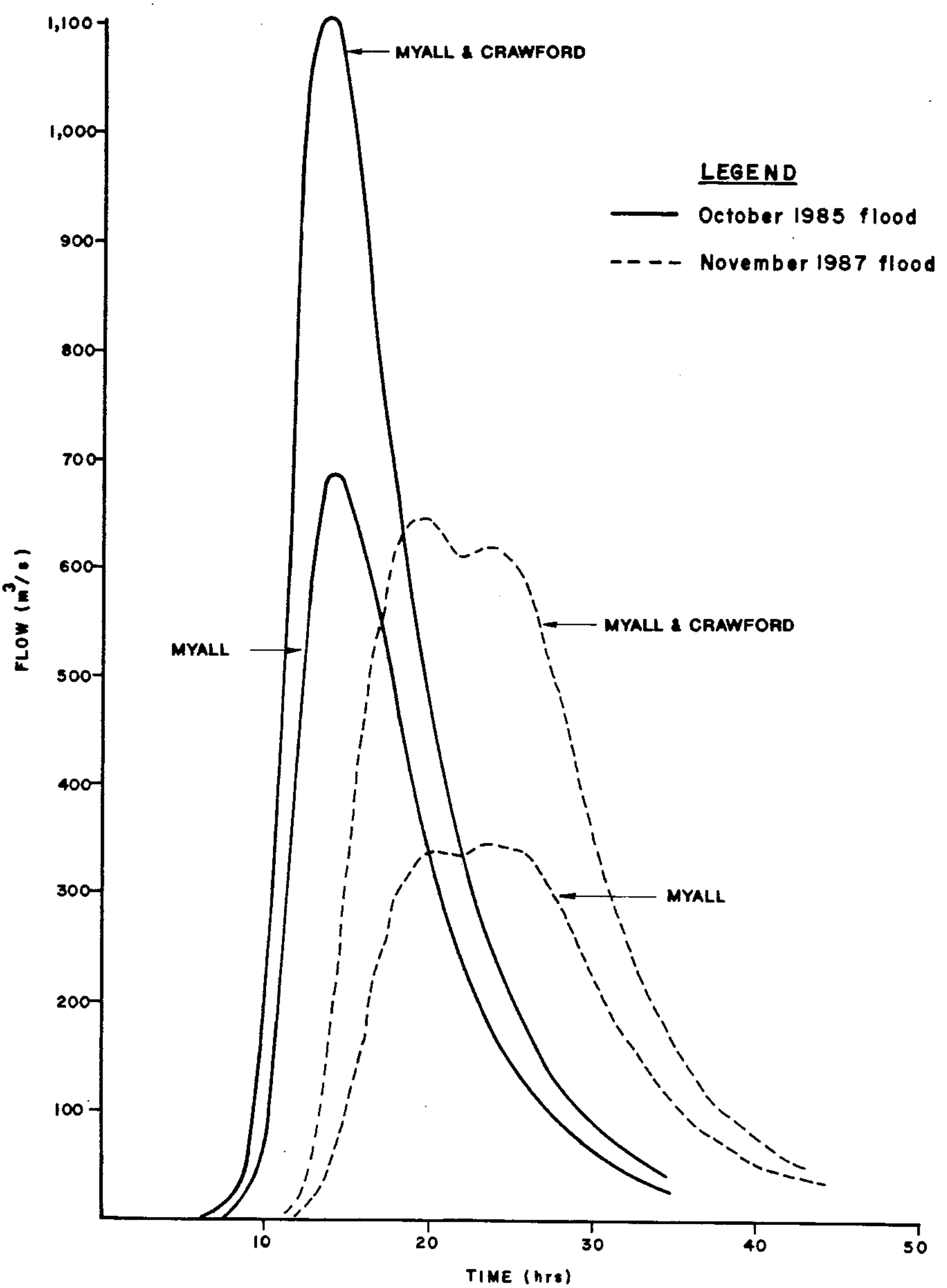
Figure 6



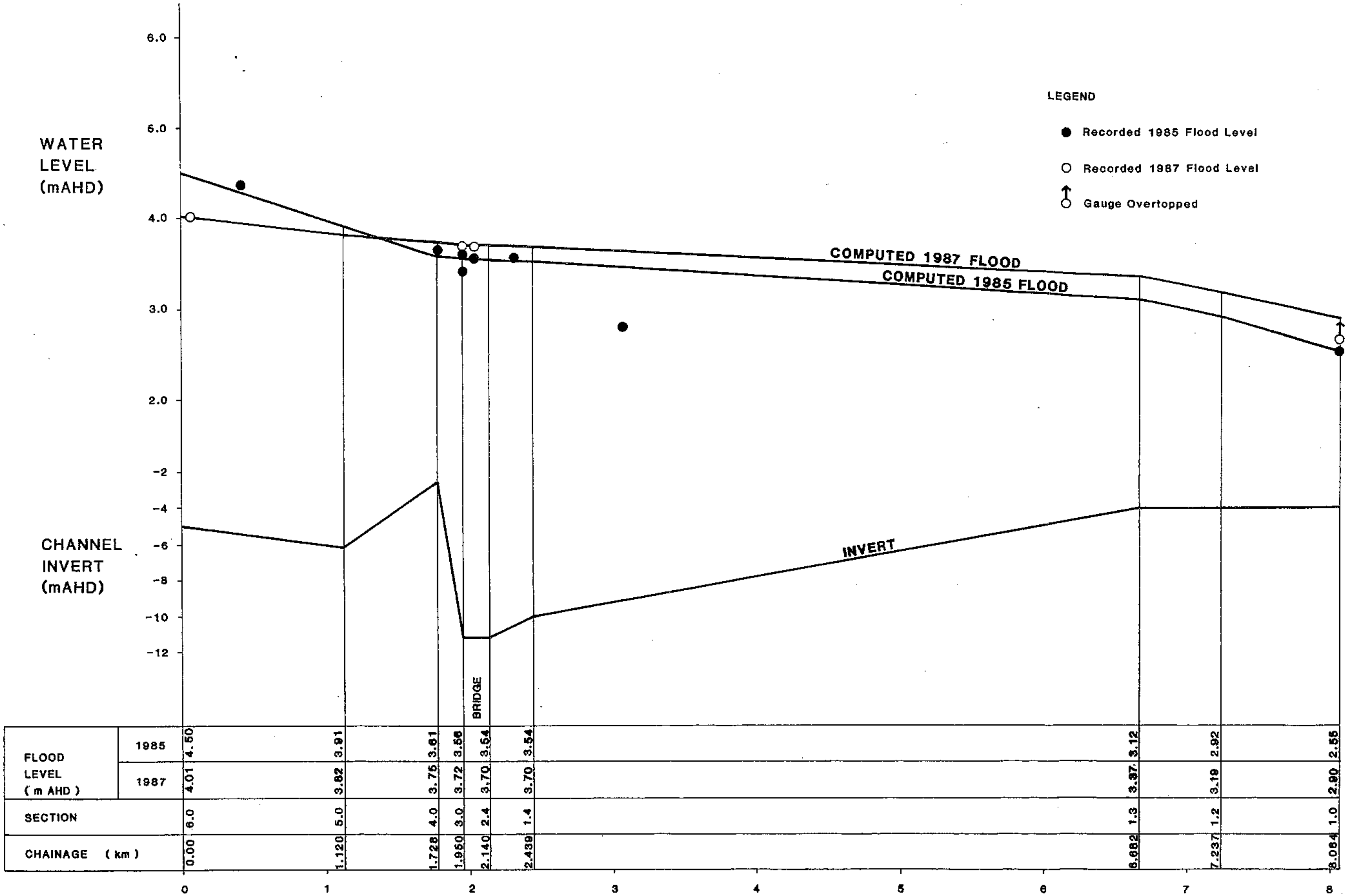
OCTOBER 1985
PLUVIOGRAPH RECORDS
Figure 7



NOVEMBER 1987
PLUVIOGRAPH RECORDS
Figure 8

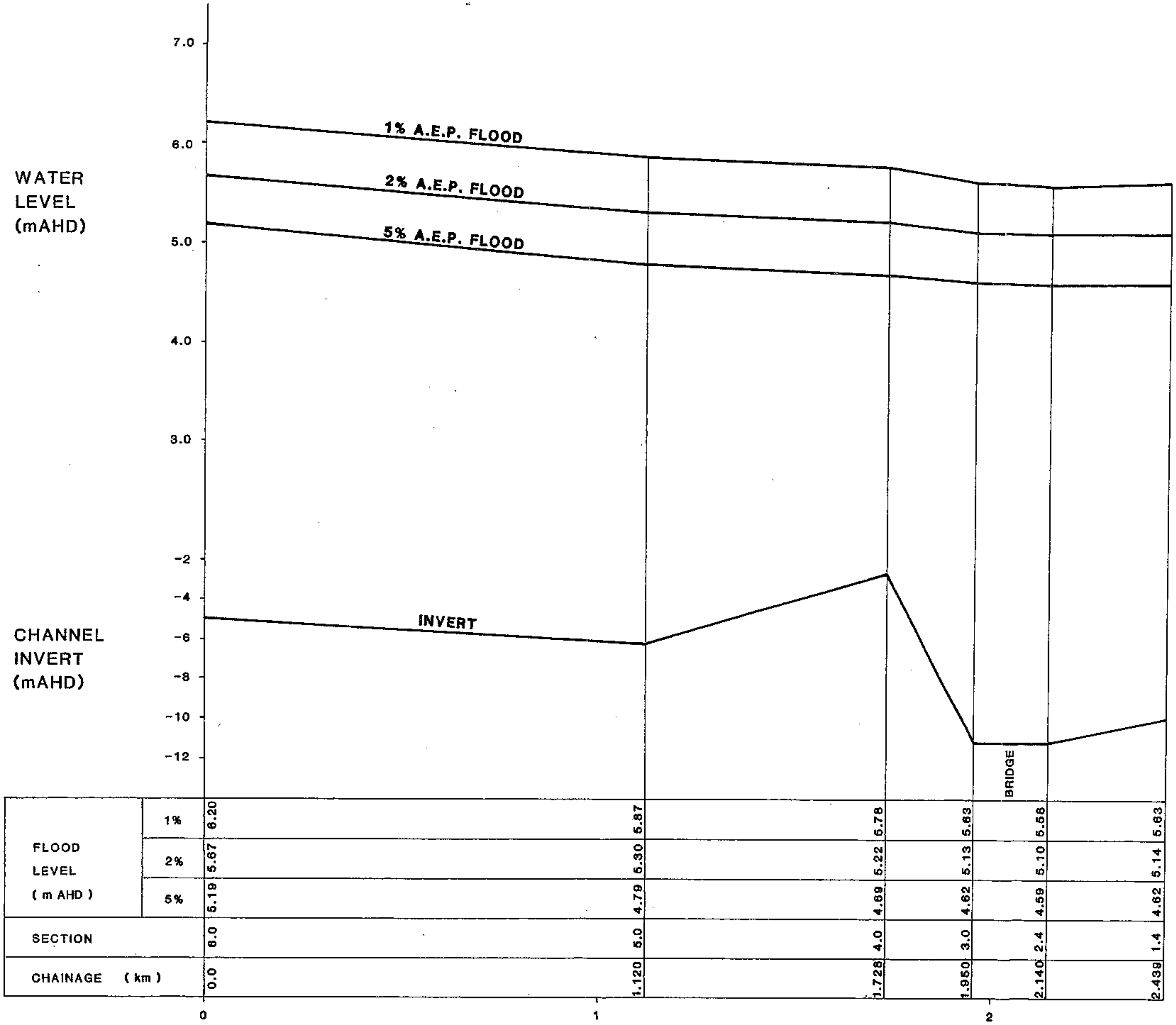


CALCULATED FLOW HYDROGRAPHS
Figure 9



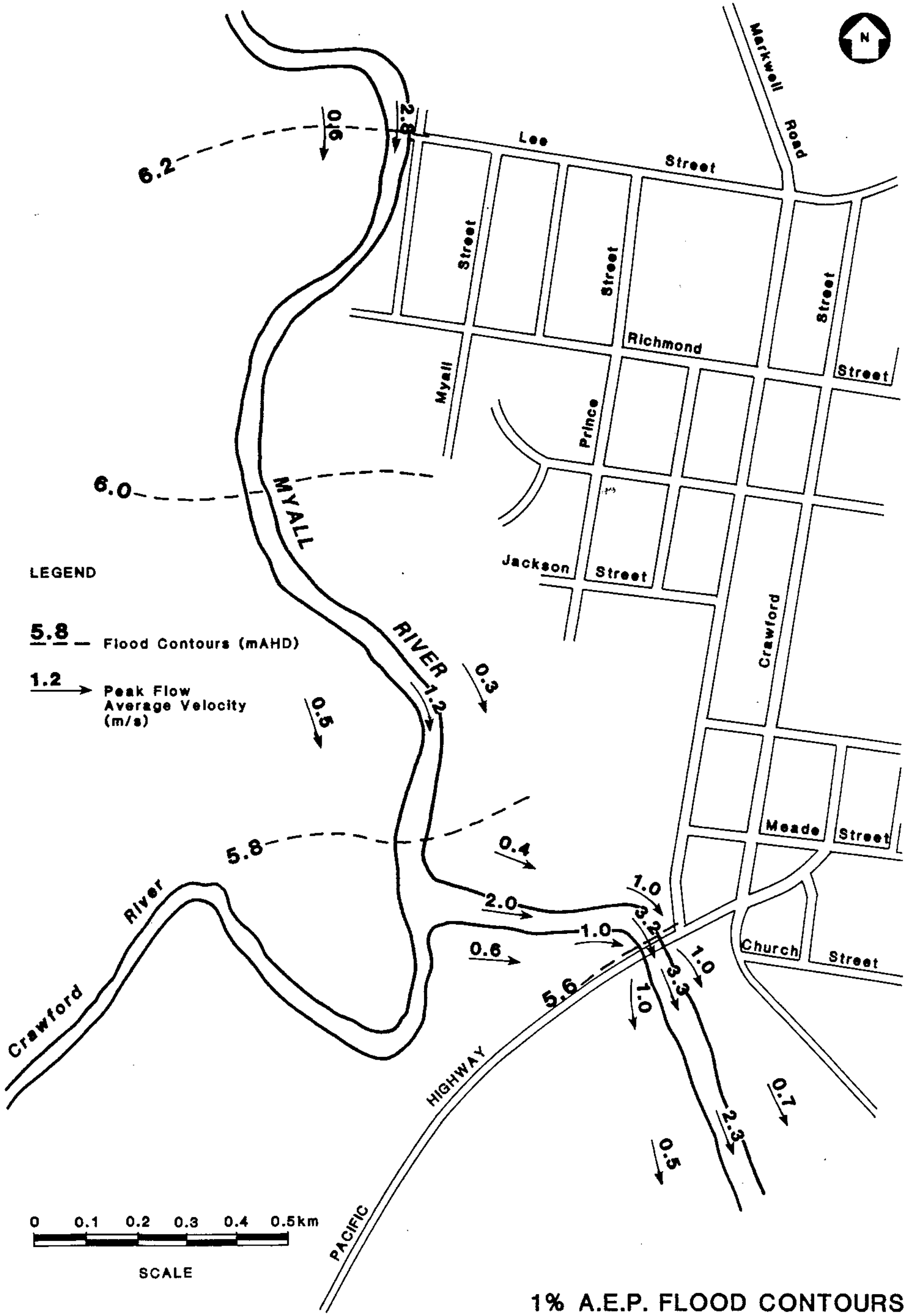
CHAINAGE (km)	0.00	1.120	1.728	1.950	2.140	2.439	6.682	7.237	8.064
SECTION	6.0	5.0	4.0	3.0	2.4	1.4	1.3	1.2	1.0
FLOOD LEVEL (m AHD) 1985	4.50	3.91	3.61	3.56	3.54	3.54	3.12	2.92	2.55
FLOOD LEVEL (m AHD) 1987	4.01	3.82	3.75	3.72	3.70	3.70	3.37	3.19	2.90

HISTORIC FLOOD PROFILES
Figure 10

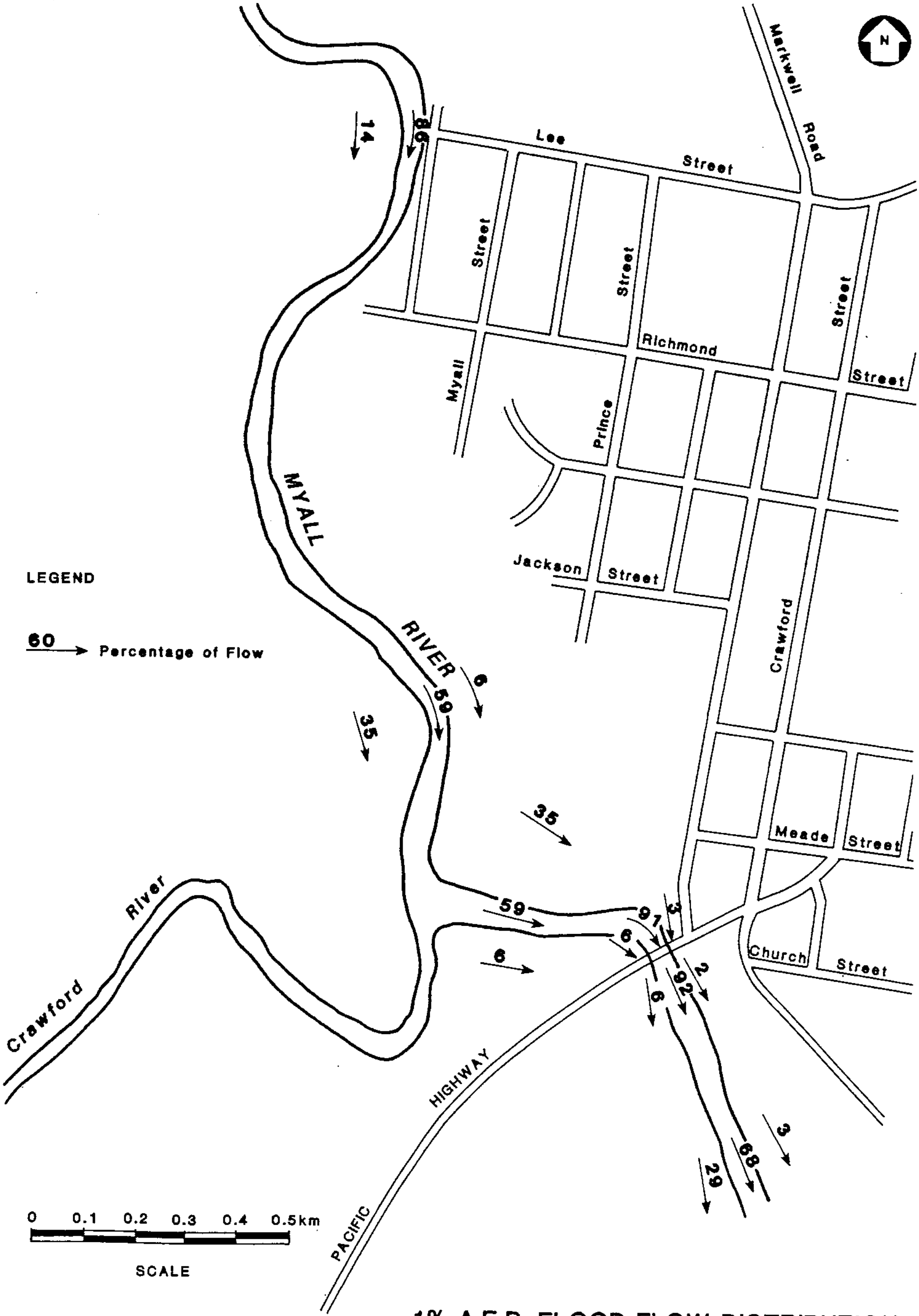


FLOOD LEVEL (m AHD)	1%	6.20	5.87	5.78	5.63	5.58	5.63
	2%	5.67	5.30	5.22	5.13	5.10	5.14
	5%	5.19	4.79	4.69	4.62	4.59	4.62
SECTION		6.0	5.0	4.0	3.0	2.4	1.4
CHAINAGE (km)		0.0	1.120	1.728	1.950	2.140	2.439

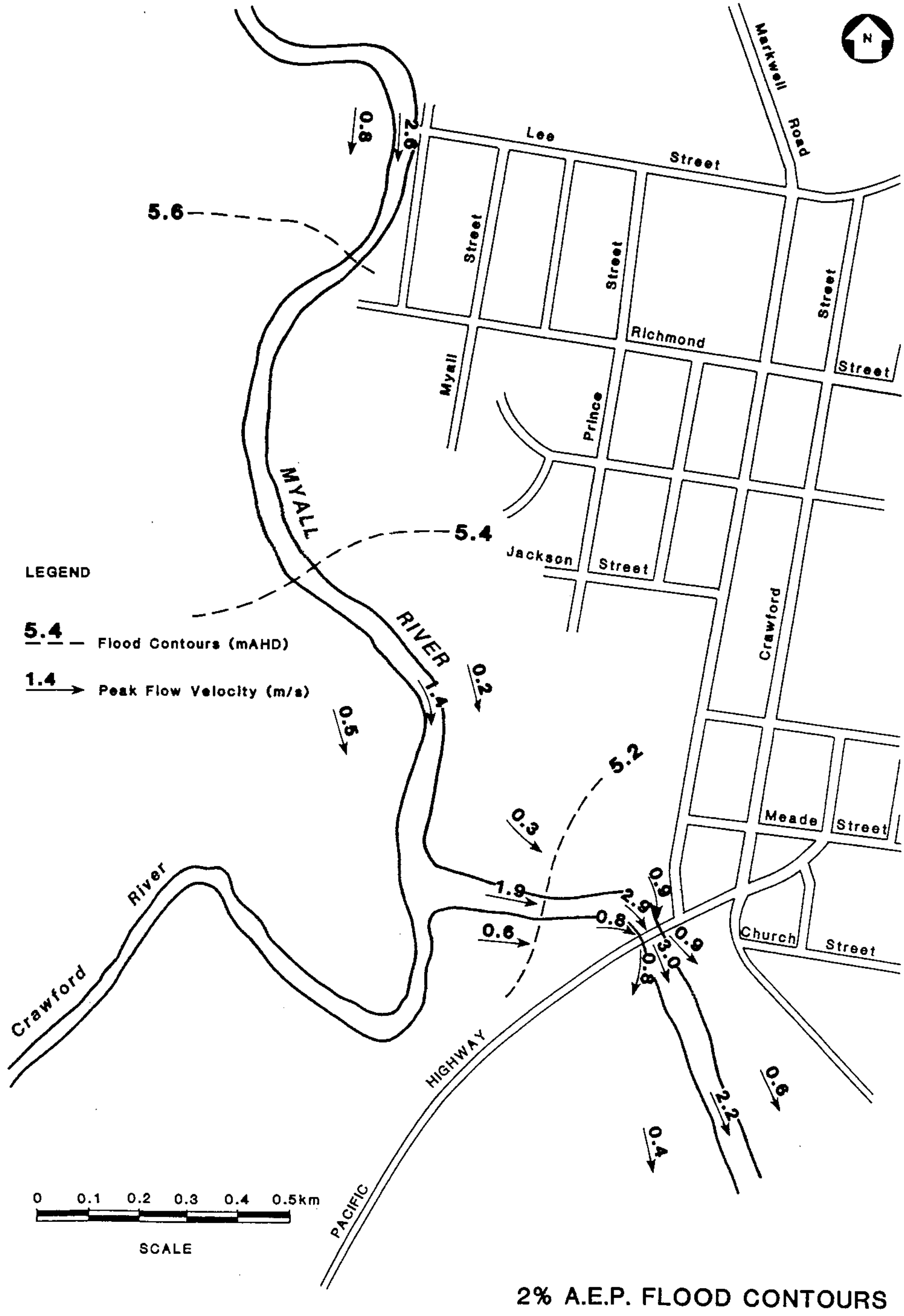
DESIGN FLOOD PROFILES
Figure 11



1% A.E.P. FLOOD CONTOURS
Figure 12.A

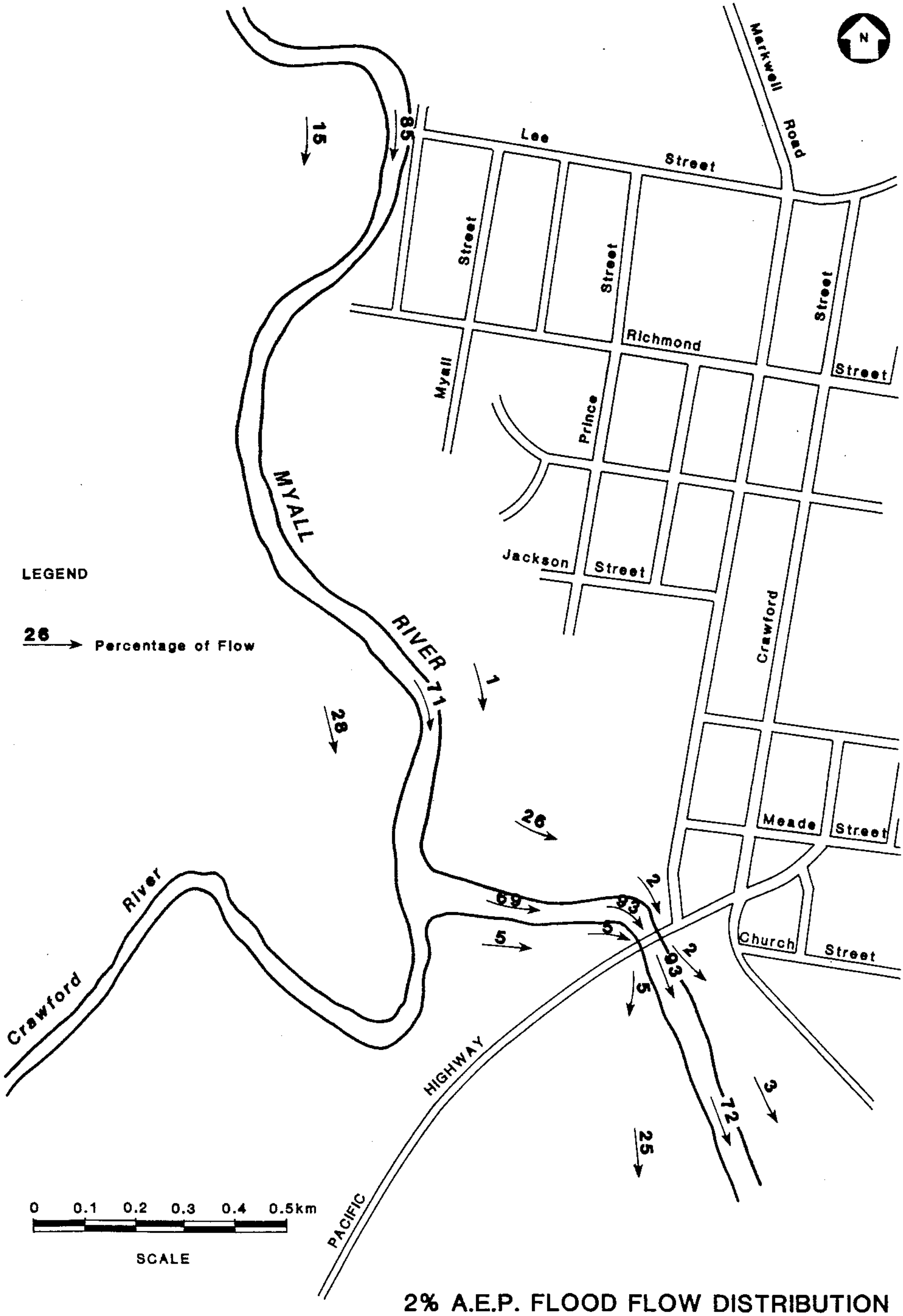


1% A.E.P. FLOOD FLOW DISTRIBUTION
Figure 12.B



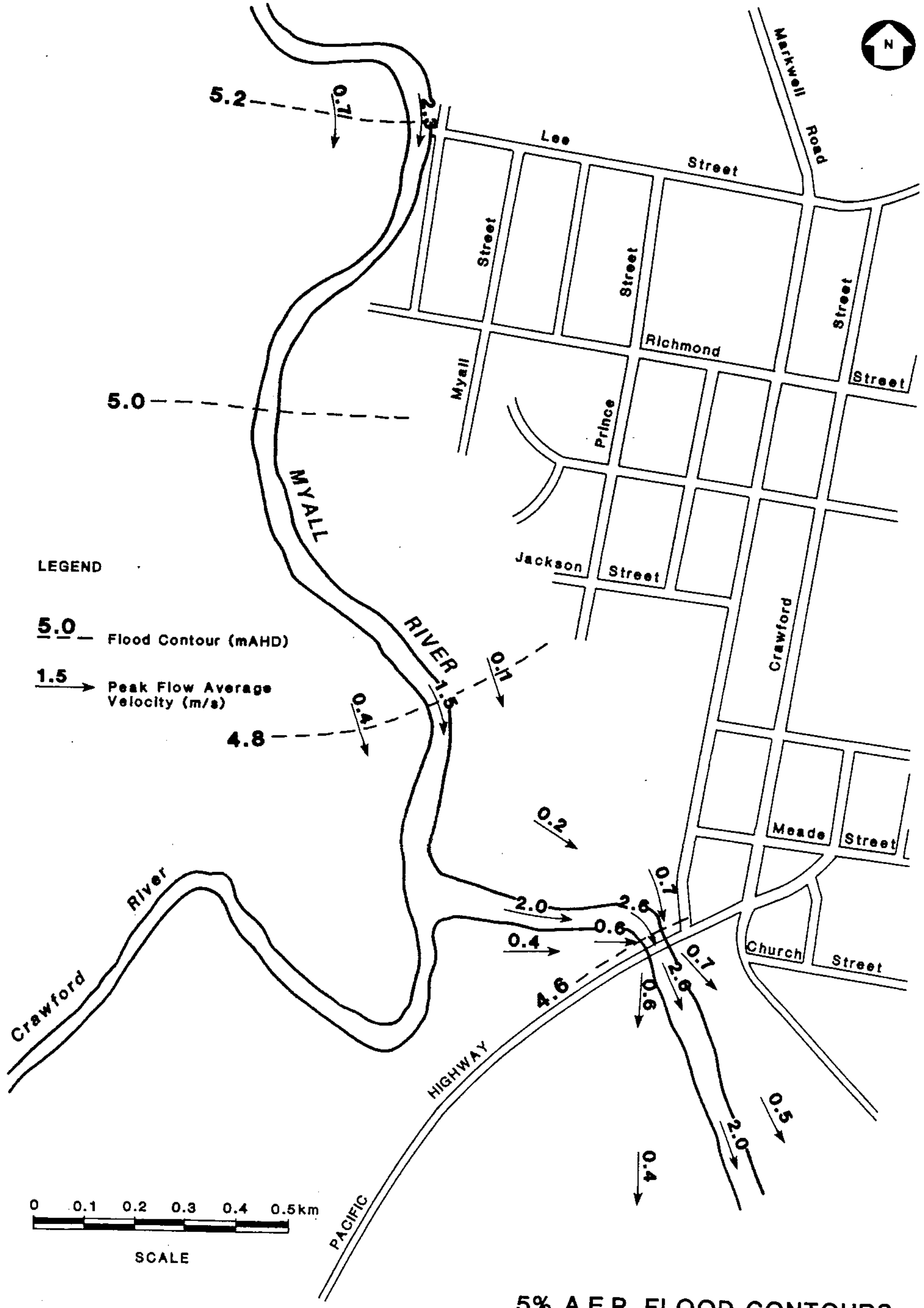
2% A.E.P. FLOOD CONTOURS

Figure 13.A

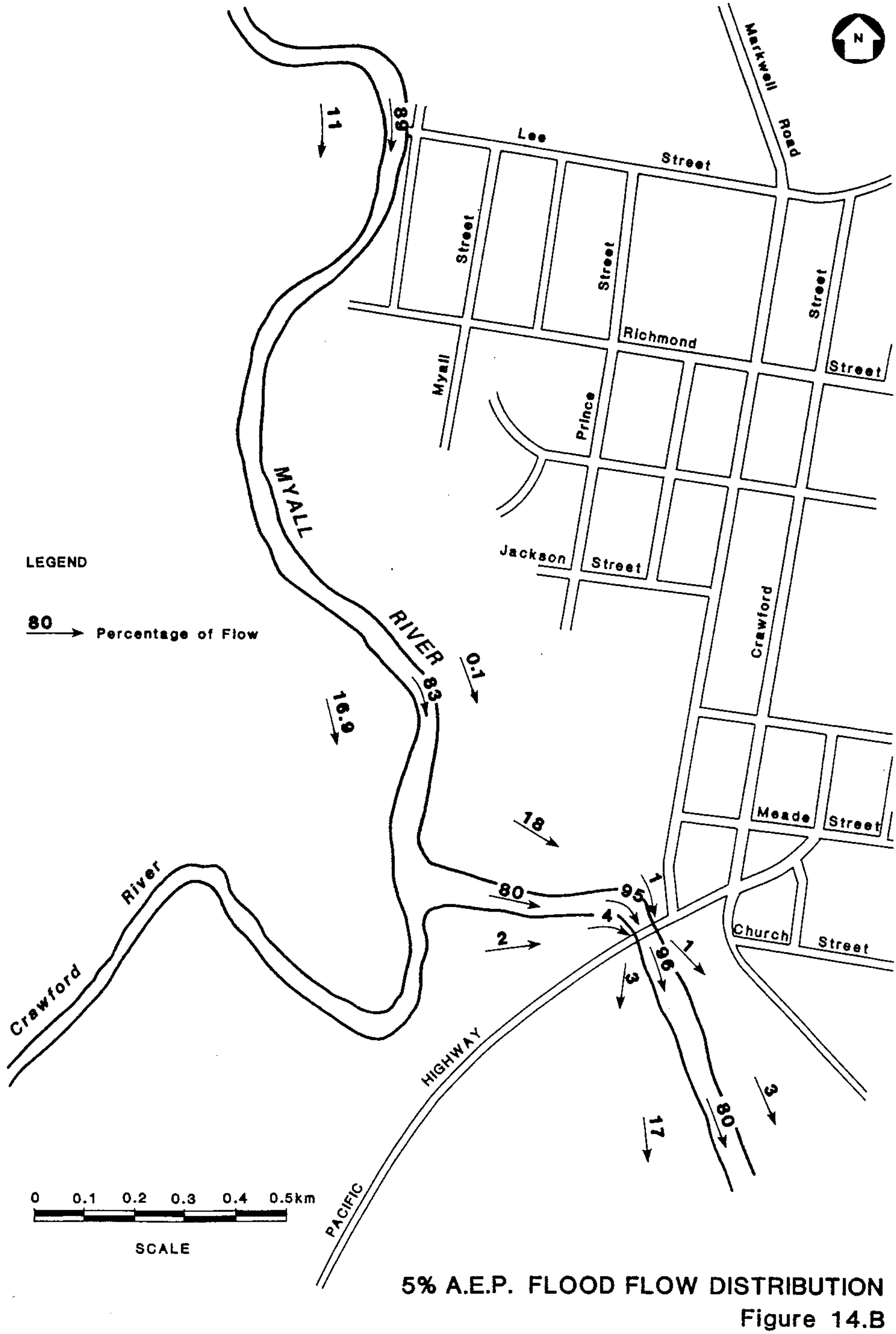


2% A.E.P. FLOOD FLOW DISTRIBUTION

Figure 13.B



5% A.E.P. FLOOD CONTOURS
Figure 14.A



5% A.E.P. FLOOD FLOW DISTRIBUTION

Figure 14.B

APPENDIX A

Recorded Flood Levels

APPENDIX A

RECORDED FLOOD LEVELS

REFERENCE No:	SOURCE	DATE	LEVEL (m AHD)	COMMENT
1	RTA (*)	1927	5.1	Near highway bridge site
2	RTA (*)	1897	5.5	Near highway bridge site
3	PWD (*)	1927	6.5	Near water supply weir,
4	PWD (*)	1947	6.5	but location uncertain
5	Occupant	1927	5.5	Cnr Richmond, River Sts
6	Occupant	1947	5.5	Cnr Jackson, Stroud Sts
7	Occupant	1927	5.5	Cnr Jackson, Princes Sts
8	Occupant	1953	5.2	Cnr Jackson, Princes Sts
9	RTA ?	1927	5.1	Reported flood levels at
10	RTA ?	1893/95	4.9	bridge site. From PWD
11	RTA ?	1956	4.7	file HR 1056/29, bridge
12	RTA ?	1946	3.9	calcs, dated 2-6-1960
13		Nov 1987	>2.62	PWD Max Ht Recorder No 1
14		Oct 1985	2.28	PWD Max Ht Recorder No 1
15		Nov 1987	3.74	PWD Max Ht Recorder No 3
16		Oct 1985	3.68	PWD Max Ht Recorder No 3
17		Nov 1987	3.68	PWD Auto Recorder
18		Oct 1985	3.44	PWD Auto Recorder
19		Nov 1987	4.02	PWD Max Ht Recorder No 4
20	Occupant	Oct 1985	3.63	200m D/S Highway Bridge Mr Newcombe
21		Oct 1985	2.83	1000m D/S Highway Bridge STP Operator
22	Occupant	Oct 1985	>2.55	Nr Stroud @ Meade Sts Mr Laughton
23	Occupant	Oct 1985	3.75	Cnr Stroud @ Meade Sts Mr Laughton

REFERENCE No:	SOURCE	DATE	LEVEL (m AHD)	COMMENT
24	Occupant	Oct 1985	4.45	Cnr Richmond @ River Sts D and P Relf
25			3.48	Believed to be flood debris marks from the Oct 1985 flood. 125m to 375m D/S Highway Bridge.
26			3.67	
27			3.57	
28			3.62	

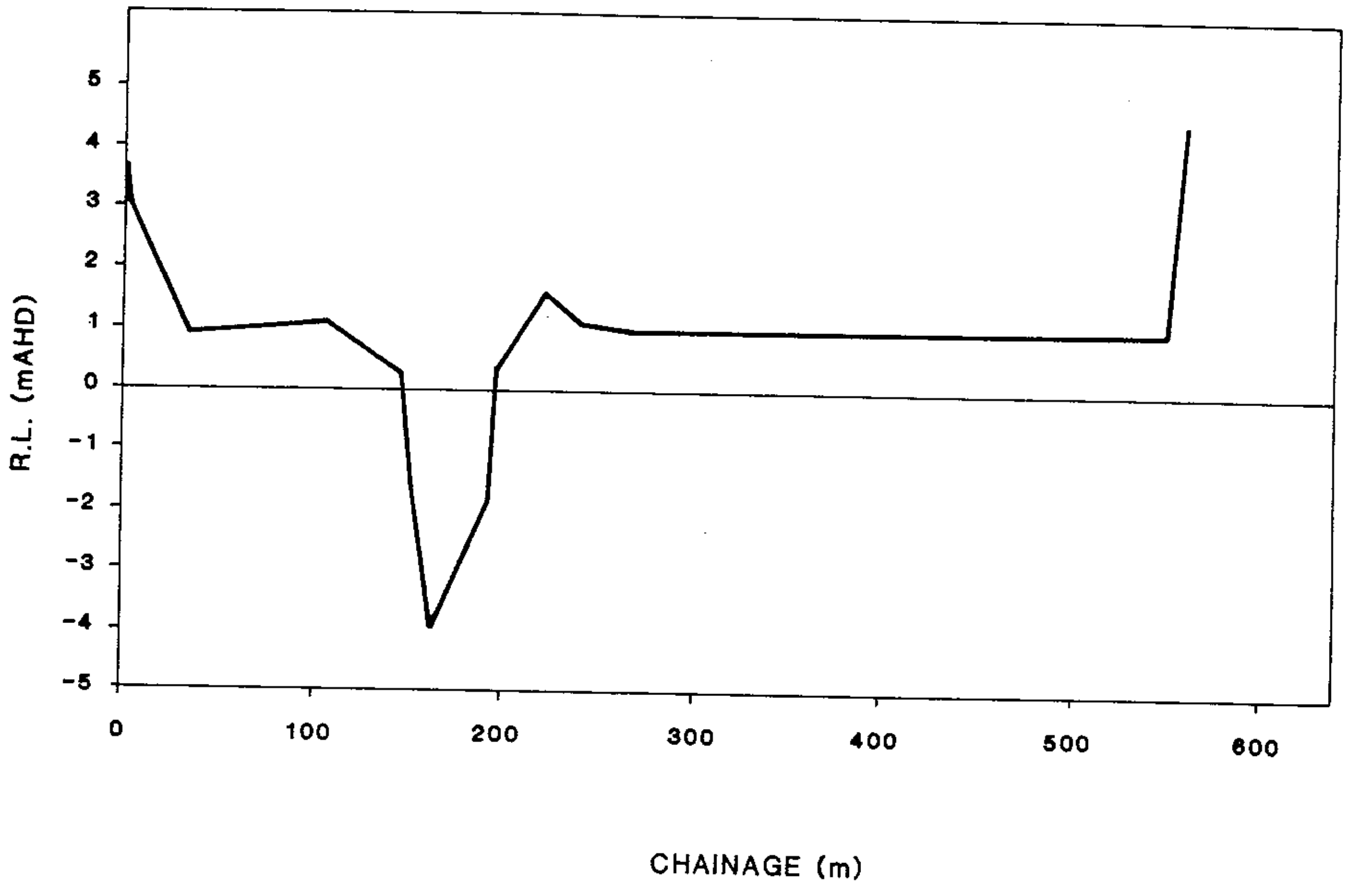
NOTES

* From water supply investigations by PWD.

APPENDIX B

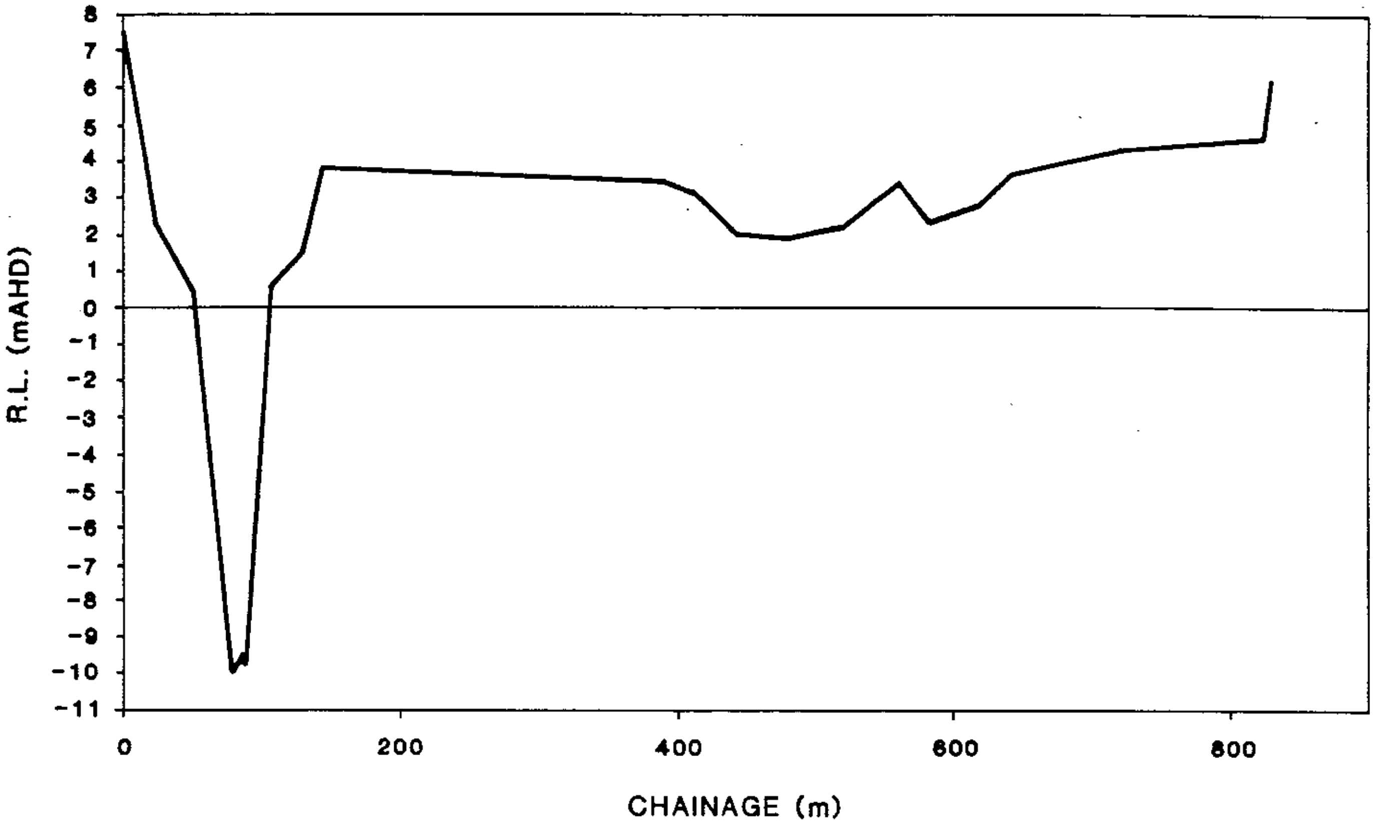
Channel Cross-Sections

CROSS SECTION 1.0, 1.2 & 1.3

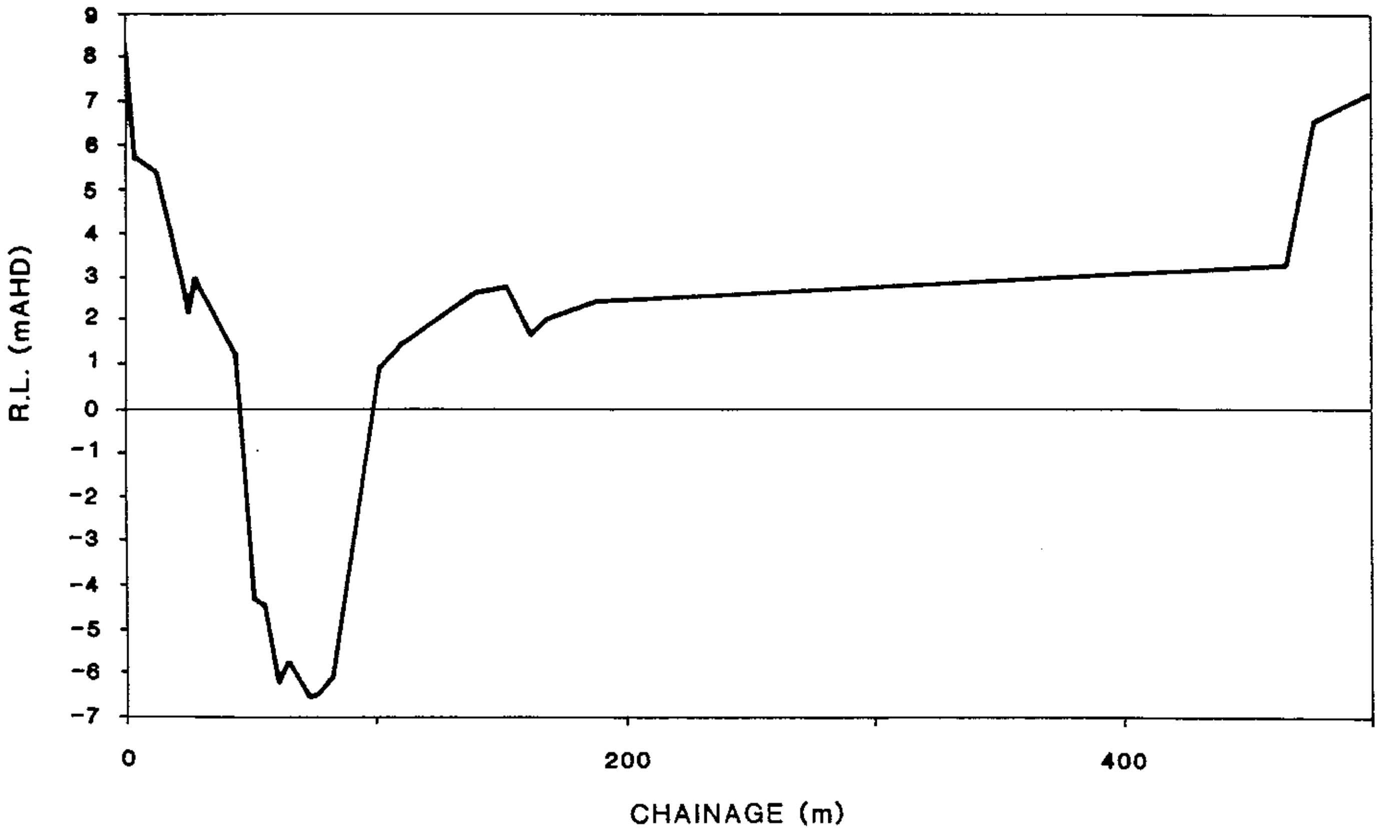


CHANNEL CROSS SECTIONS
Figure B1

CROSS SECTION 1.4

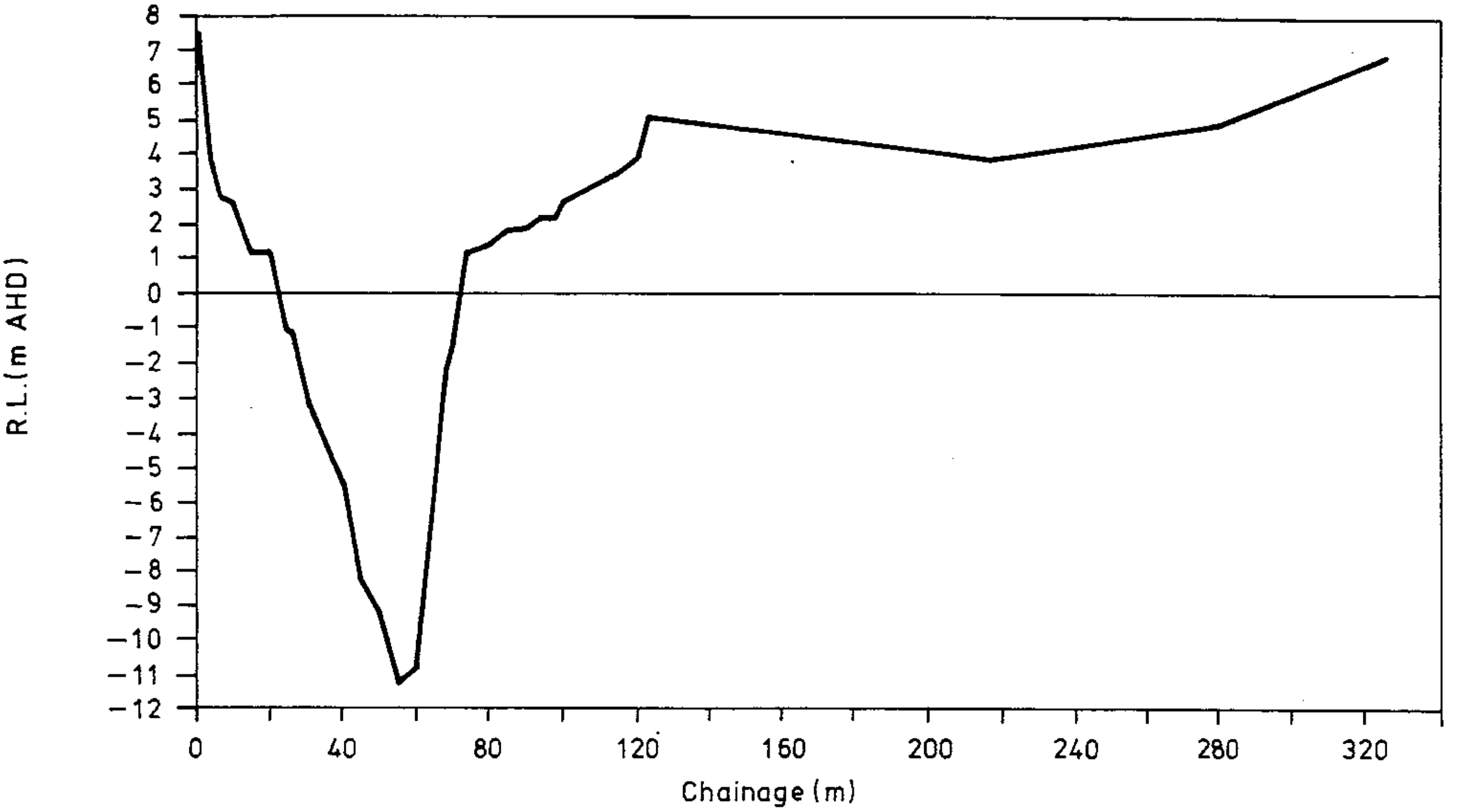


CROSS SECTION 2.0

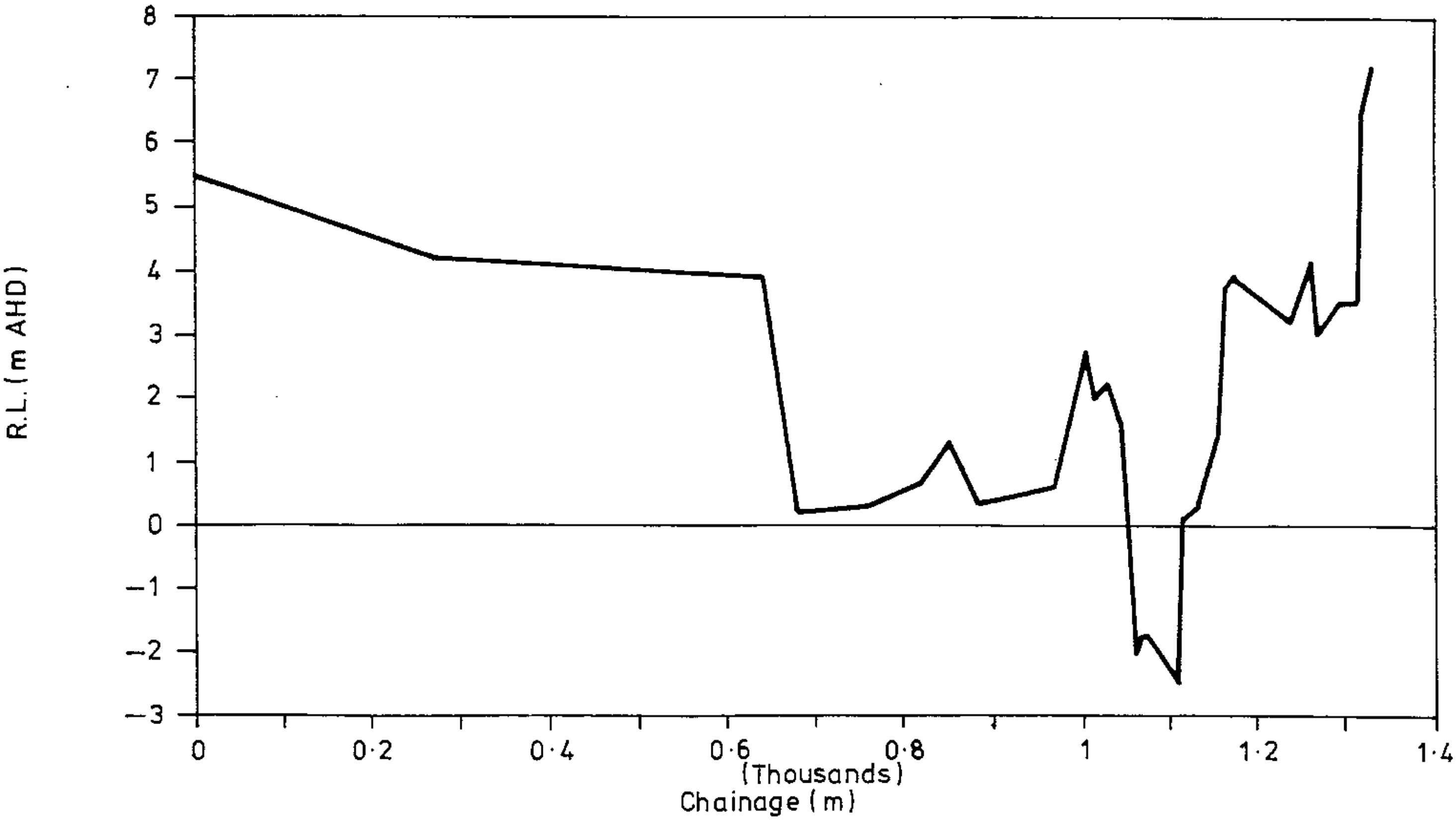


CHANNEL CROSS SECTIONS
Figure B2

CROSS SECTION 2.4 & 3.0

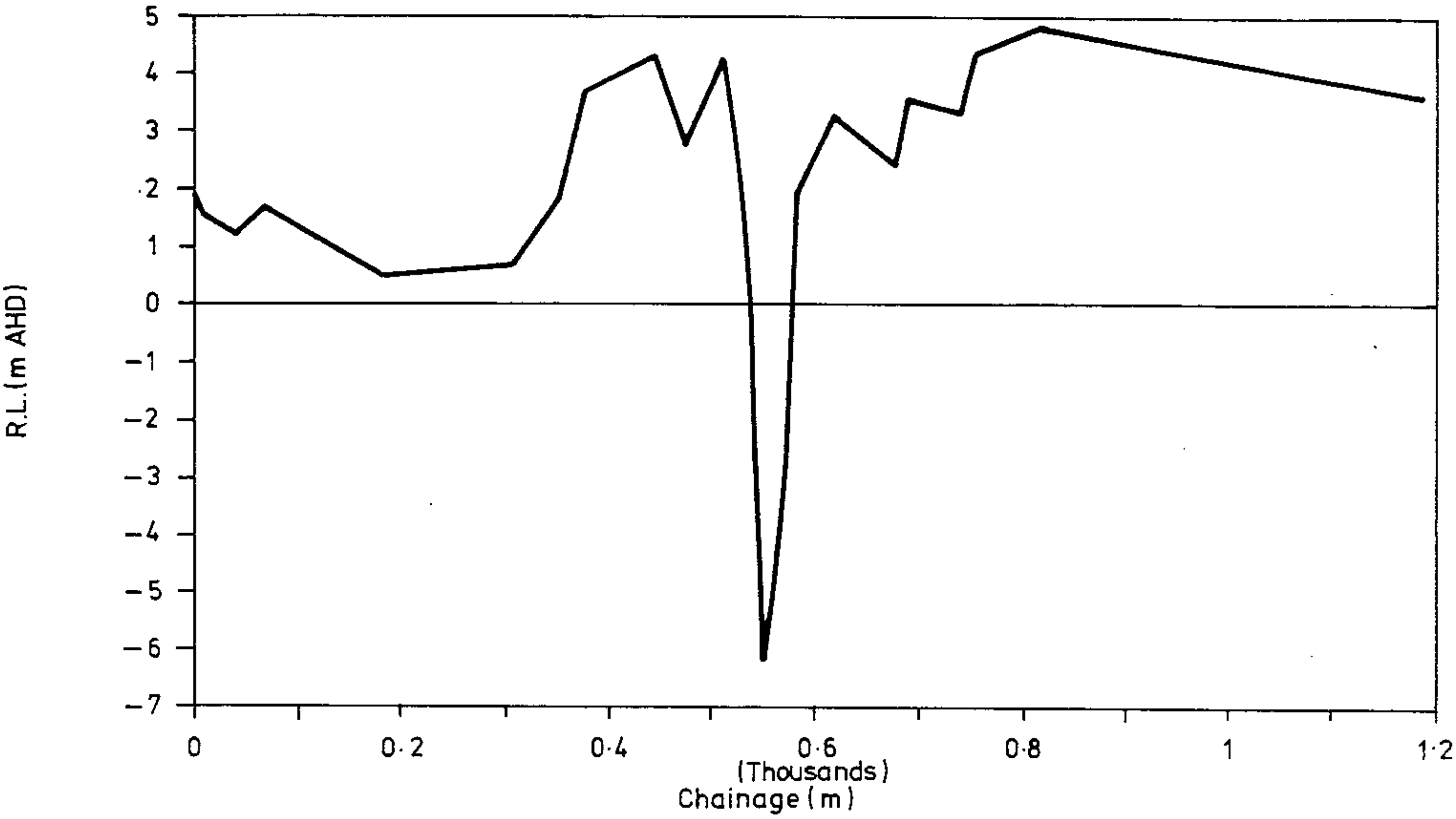


CROSS SECTION 4.0

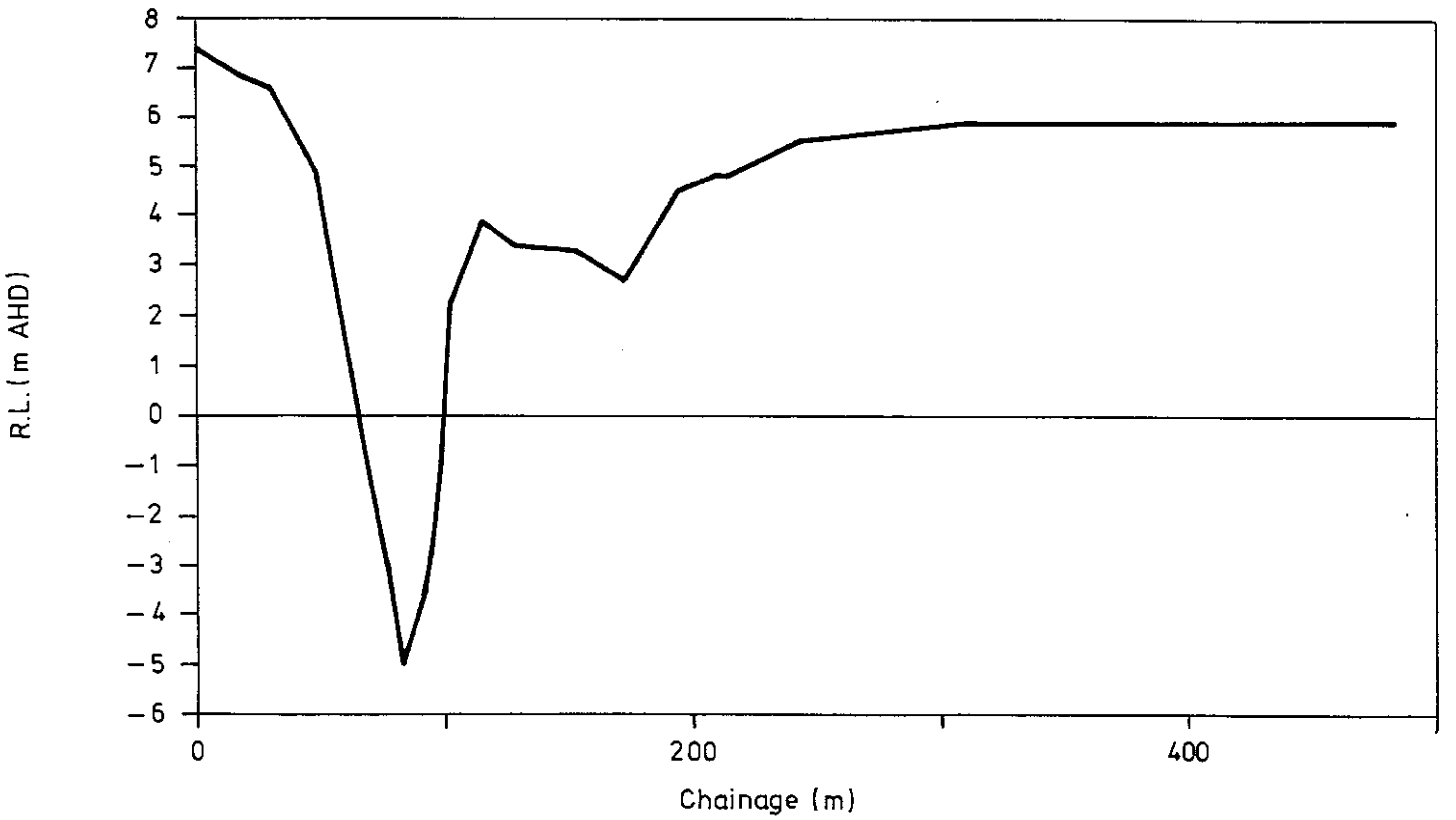


CHANNEL CROSS SECTIONS
Figure B3

CROSS SECTION 5.0



CROSS SECTION 6.0



CHANNEL CROSS SECTIONS
Figure B4

APPENDIX C

Detailed Model Results

APPENDIX C

DETAILED MODEL RESULTS

TABLE C1

Design Flood Levels (m AHD)

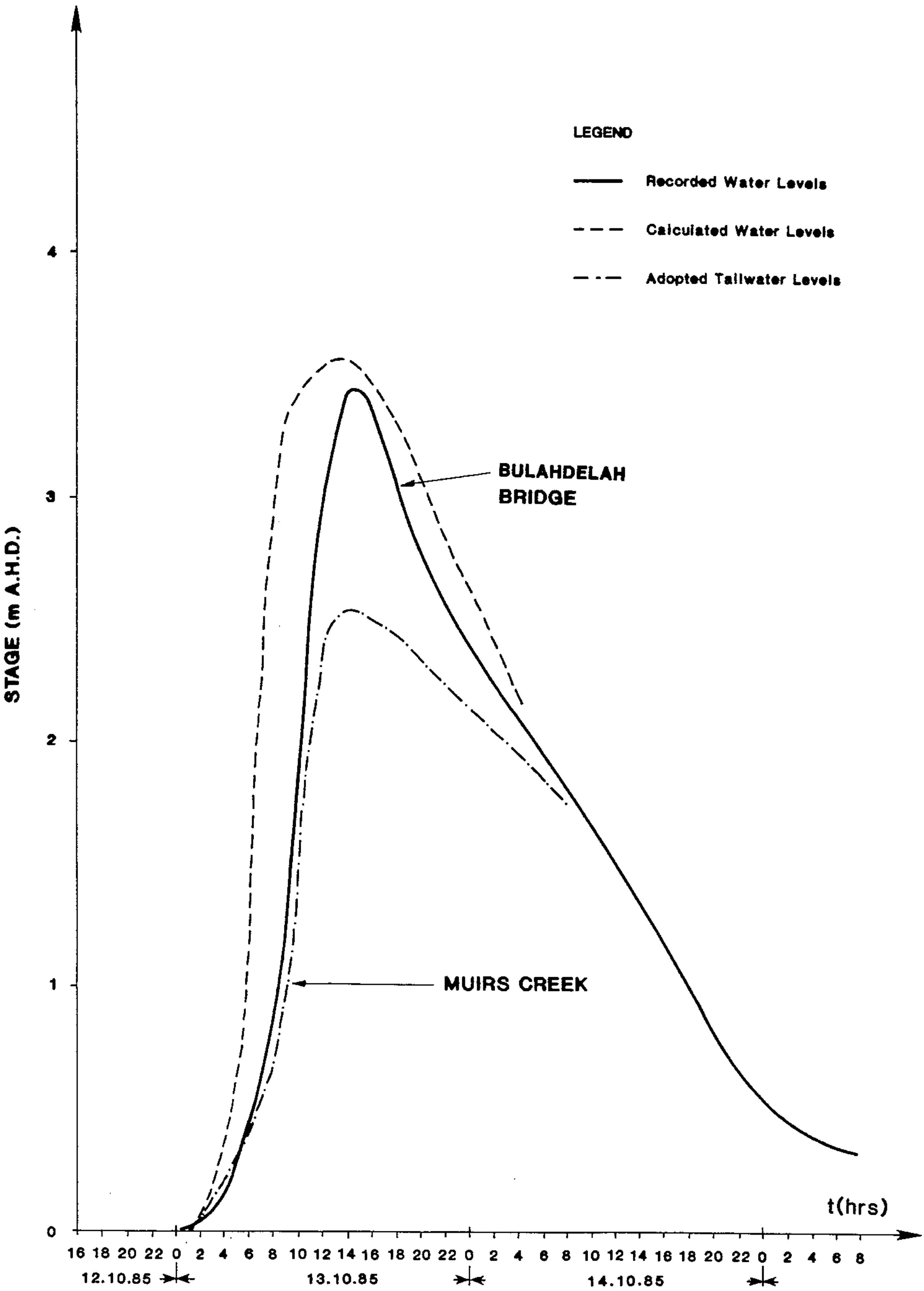
Cross Section (See Fig. 3)	1% AEP	2% AEP	5% AEP
1.4	5.63	5.14	4.62
2.4	5.58	5.10	4.59
3.0	5.63	5.13	4.62
4.0	5.78	5.22	4.69
5.0	5.87	5.30	4.79
6.0	6.20	5.67	5.19

TABLE C2

Design Flood Velocities (m/s)

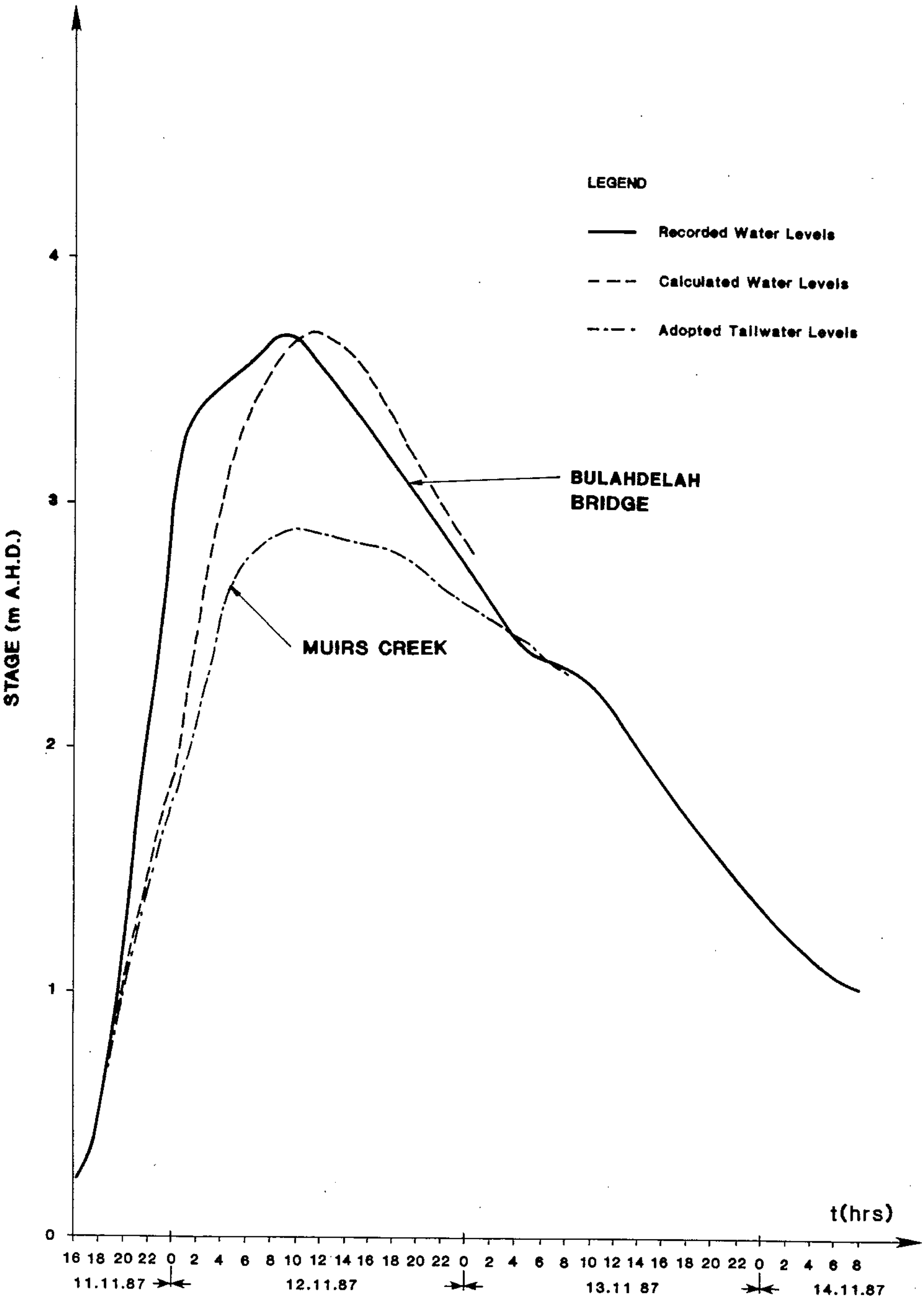
Cross Section (See Fig. 3)	1% AEP			2% AEP			5%AEP		
	LHB	CHAN	RHB	LHB	CHAN	RHB	LHB	CHAN	RHB
1.4	0.7	2.3	0.5	0.6	2.2	0.4	0.5	2.0	0.4
2.4	1.0	3.3	1.0	0.9	3.0	0.8	0.7	2.6	0.6
3.0	1.0	3.2	1.0	0.9	2.9	0.8	0.7	2.6	0.6
4.0	0.4	2.0	0.6	0.3	1.9	0.6	0.2	2.0	0.4
5.0	0.3	1.2	0.5	0.2	1.4	0.5	0.1	1.5	0.4
6.0	-	2.8	0.6	-	2.6	0.8	-	2.3	0.7

LHB = Left Hand Bank (looking downstream)
CHAN = Main Channel
RHB = Right Hand Bank (looking downstream)

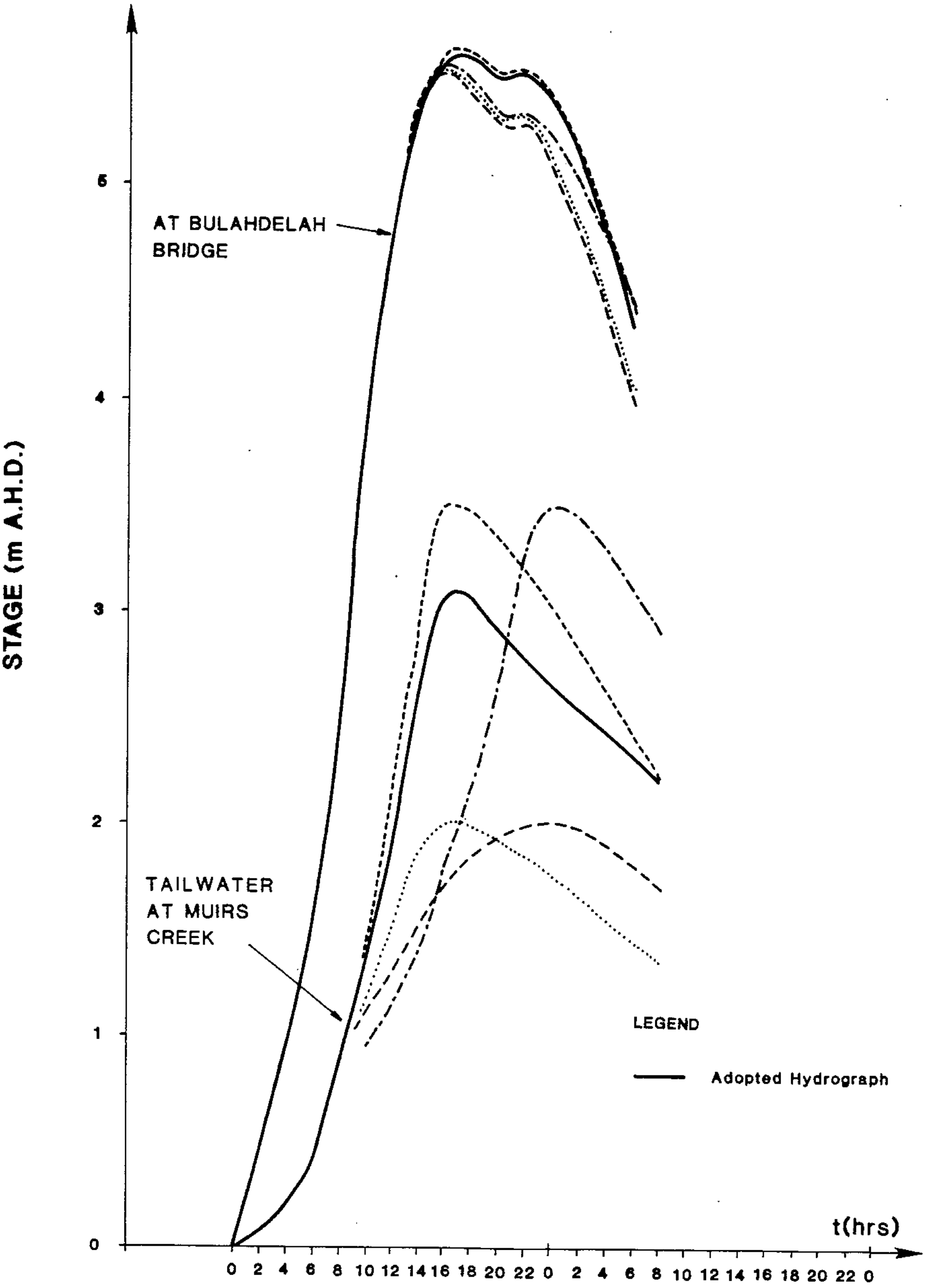


OCTOBER 1985 FLOOD HYDROGRAPHS

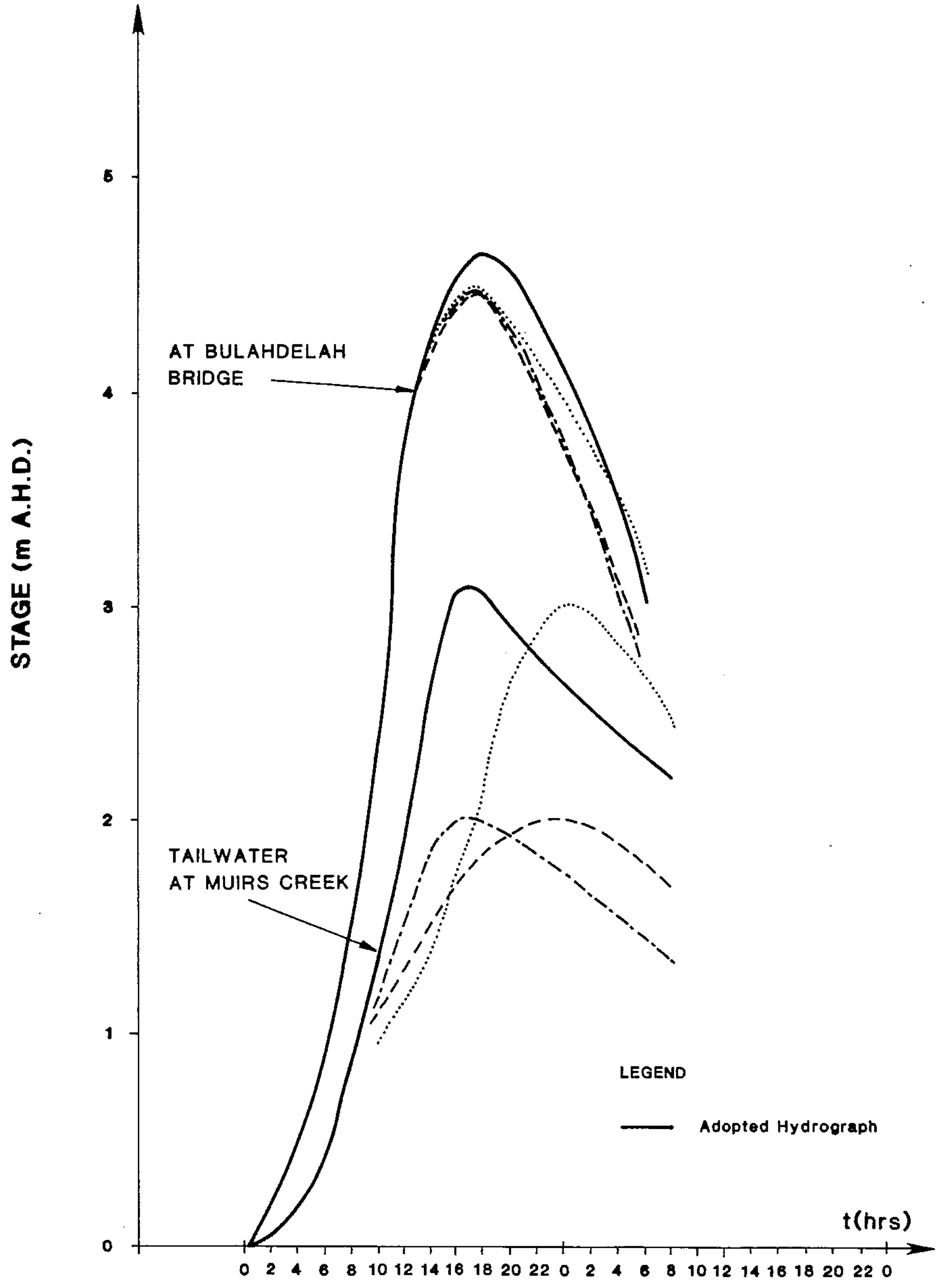
Figure C1



NOVEMBER 1987 FLOOD HYDROGRAPHS
Figure C2



1% A.E.P. FLOOD –SENSITIVITY TO TAILWATER LEVEL
Figure C3



5% A.E.P. FLOOD-SENSITIVITY TO TAILWATER LEVEL

Figure C4