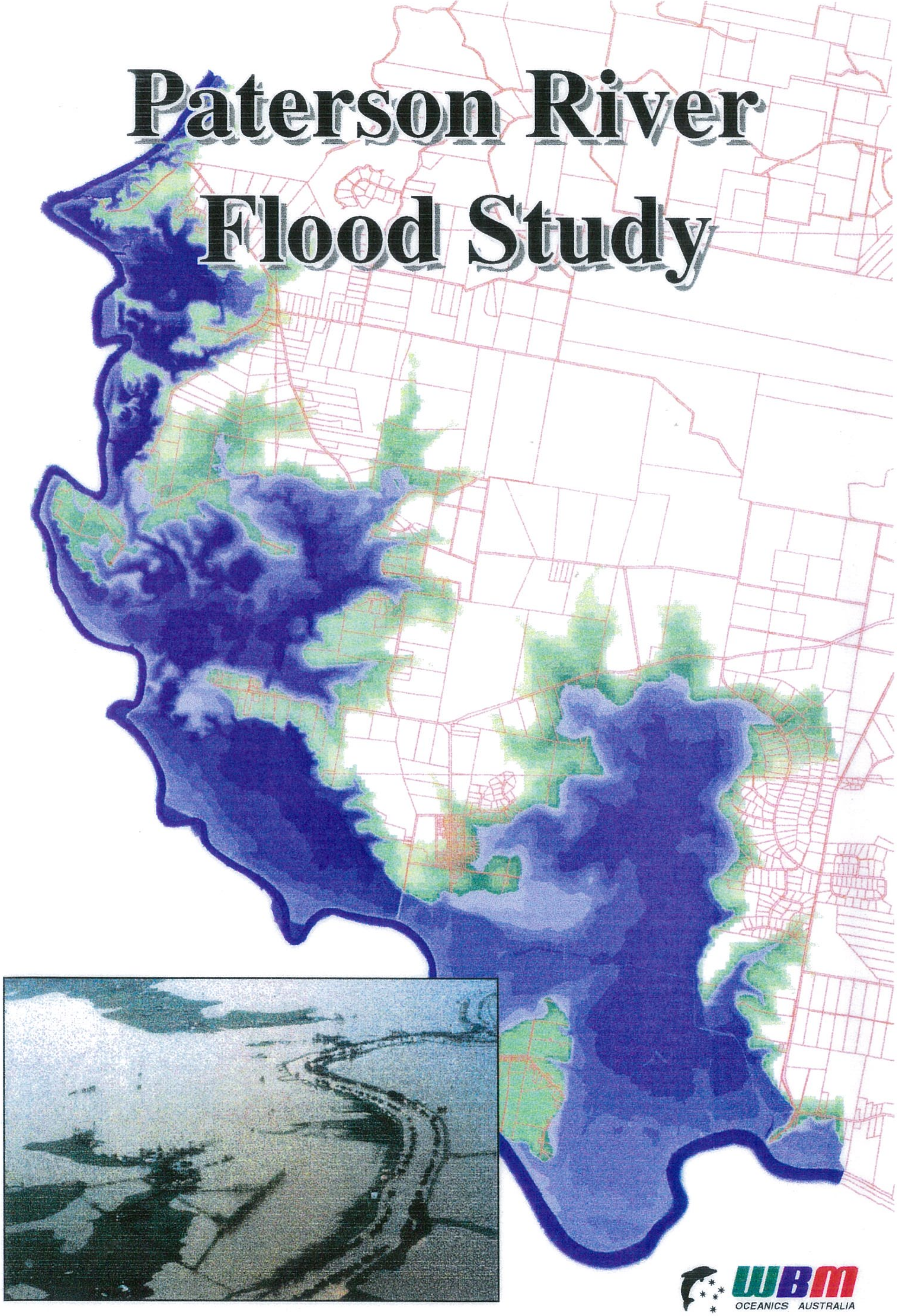
Paterson River Flood Study



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Paterson River Flood Study

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Synopsis:
Report for the Paterson River Flood Study covering the development and calibration of computer models, establishment of design flood behaviour and flood mapping.

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FOREWORD

The State Government's Flood Policy is directed towards providing solutions to existing flooding problems in developed areas and ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas. Policy and practice are defined in the Government's Floodplain Development Manual.

Under the Policy the management of flood liable land remains the responsibility of Local Government. The State Government 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 State Government through the following four sequential stages:-

Stages of Floodplain Management

	Stage	Description
1	Flood Study	Determines 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 developments.
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 environmental plans to ensure new development is compatible with the flood hazard.

This study represents the first of the four stages. It has been prepared for Port Stephens Council, Maitland City Council and Dungog Council to understand and define the existing flood behaviour and establish the basis for floodplain management activities.

EXECUTIVE SUMMARY

Background

The Paterson River is located within the Hunter Valley of New South Wales. The river flows in a general north-south direction from its source in the Barrington Tops to its confluence with the Hunter River near Morpeth. The long narrow catchment, characterised by forests in the steeper upper areas and pastures in the remainder, drains an area of approximately 1,000km^2.

The Paterson is initially a steep mountain stream. As it flattens out it exhibits meandering patterns and the floodplain starts to become more pronounced. It is not until downstream of Paterson township that major floodplains start to develop. These floodplains occur intermittently, separated by ridges which have a controlling influence on flood flows. From a few kilometres upstream of Woodville the floodplains become substantial all the way through to the Hunter River.

A very pronounced and substantial levee system exists with nearly all of the major floodplains "protected" to some extent by man-made levees. The levees, which were mostly built in the late 1960s and early 1970s, have a major influence on flood behaviour.

The Paterson River has experienced substantial flooding in recent history, including the 1955 Hunter River dominated flood and the 1978 Paterson River dominated flood.

In response to developing a greater understanding of flooding in the lower Paterson River, Port Stephens Council commissioned WBM Oceanics Australia to carry out a flood study. Additional support and funds were provided by the Department of Land and Water Conservation, Maitland City Council and Dungog Council.

Study Stages

The various stages of the study were:

- Carry out an historic flood information survey and site inspections.
- Collection of additional topographic survey data.
- Develop computer models.
- Calibrate and verify models to historical floods.
- Establish design flood behaviour.
- Present the results of the design floods in a variety of non-technical and technical formats.

Historical Flood Information Survey

An extensive survey of residents within the study area was conducted to gather historical data from those who have experienced Paterson River floods and to identify local concerns within the region. The local knowledge of the flooding in both the Paterson and Hunter Rivers was found to be invaluable. A number of flood heights were identified and surveyed. Copies of some 85 photographs showing various floods were also obtained.

Computer Models

Computer models are the most accurate, cost-effective and efficient tools to model a river's flood behaviour. For this study, two types of models were developed:

- A hydraulic model which simulates the flow behaviour in the river and over the floodplains, producing flood levels, flow discharges and flow velocities. The model developed extends from upstream of Gostwyck Bridge to Green Rocks (on the Hunter River).

- A hydrologic model of the Paterson River catchment which simulates the catchment rainfall-runoff processes, producing the river/creek flows which are used in the hydraulic model.

Information on the topography and characteristics of the catchments, rivers, creeks and floodplains were built into the models. The models were calibrated to the historical floods of March 1978 and March 1977 and verified to the flood of March 1995. The calibration and verification illustrated the models' abilities to reproduce historic flood patterns. Comparisons with comments on flooding patterns received during the historic flood information survey were also consistent with the hydraulic model's performance.

Of particular note are the hydraulic effects of Scotts Dam. The hydraulic model and discussions with local residents highlighted its influence on elevating flood levels around Woodville.

Design Floods

Design floods are hypothetical floods used for planning and floodplain management investigations. A design flood is defined by its probability of occurrence. It represents a flood which has a particular probability of happening in any one year. For example, the 1% or 1 in 100 year flood is a best estimate of a flood which has 1 chance in 100 of occurring in any one year. This probability or risk still exists even in a year following the occurrence of a 1% flood, although on average would occur once in every 100 years. It should be acknowledged, however, that planning for the 1% AEP flood does not guarantee protection for the next 100 years.

Design flood flows in the Paterson River were assessed using two independent methods. One used the hydrologic model to determine design flood flows at Gostwyck. The other, a flood frequency analysis, examined 46 years of flood recordings in the Gostwyck area, providing estimates of peak flows for different probability floods. The final Paterson River design flows were determined by a critical assessment of the results from both methods. For the Hunter River, the results from similar previous studies were used to define the design flood conditions.

Design floods in the Paterson River are represented by two separate flood events:

- a Paterson River dominated flood and
- a Hunter River dominated flood.

The two separate events were used as it is extremely unlikely that, for example, both the Paterson and Hunter rivers would experience a 1% flood at the same time. Historical examples of these types of floods are the March 1978 flood (Paterson dominated) and the 1955 flood (Hunter dominated).

Design flood levels, flows and velocities for 1%, 2% and 5% AEP Paterson and Hunter River dominated floods along with estimates of an extreme flood were determined. The peak design levels, flows and velocities were taken as the maximum of the two dominated floods. As would be expected the Paterson River dominated flood gives the highest flood levels in the upper areas of the study area, while the Hunter River dominated flood produces the peak levels in the lower floodplains.

The design flood results are presented in a variety of map formats showing flood levels, flows, depths and velocities. The table on the next page lists the peak design flood levels at selected locations within the study area.

For the Port Stephens Council area, flood depth and extent maps were produced with the aid of a three-dimensional ground surface model. These maps show that within Port Stephens Council, 38km^2 (3,800 hectares) of land is inundated in a 1% AEP flood event and 35km^2 in a 5% AEP flood. In the case of the 1% AEP flood, 33km^2 is inundated by more than two metres deep of water and 15km^2 by more than five metres. Using information on the flood depth and velocity a provisional flood hazard map was produced showing areas of high and low hazard.

Recommendations on appropriate 1% flood levels to be used for development control are provided for the entire study area.

Flood Levels for Development Controls

	Design Flood Level (mAHD)			
Location	**1%**	**2%**	**5%**	**Extreme**
Gostwyck Bridge	18.1	17.1	15.4	25.6
Paterson River, "Gostwyck"	16.8	16.2	14.5	24.8
Paterson River, "Tillimby"	15.6	14.5	13.0	22.9
Paterson Railway Bridge	13.7	13.2	11.8	20.9
Paterson Road Bridge	11.4	10.6	10.0	15.0
Paterson River, "Stradbroke"	9.7	9.6	8.7	13.7
Floodplain north of "Stradbroke"	10.5	10.0	9.2	13.9
Floodplain south of "Stradbroke"	9.2	8.7	8.0	12.2
Floodplain, Mindaribba	7.4	6.9	5.4	10.8
Floodplain, Iona	7.5	6.8	6.3	10.8
Paterson River, Woodville	7.4	6.9	6.4	10.8
Floodplain north of Dunmore House	7.4	6.9	4.6	10.8
Floodplain between Woodville & Scotts Dam	7.4	6.8	6.3	10.8
Floodplain north-east of Largs	7.4	6.8	6.3	10.8
Paterson River, Scotts Dam	6.9	6.5	6.1	9.9
Paterson River, Hinton	6.7	6.3	6.0	9.7
Floodplain, Hinton	6.4	5.6	5.0	9.3
McClement Swamp	6.1	5.4	4.9	8.6
Floodplain, "Hinton Vale"	6.1	5.4	4.9	8.6

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GLOSSARY

Australia Height Datum (AHD)	National survey datum corresponding approximately to mean sea level.
catchment	The catchment at a particular point is the area of land which drains to that point.
design floor level	The minimum (lowest) floor level specified for a building.
design flood	A hypothetical flood representing a specific likelihood of occurrence (for example the 100 year or 1% probability flood). The design flood may comprise two or more single source dominated floods.
development	Existing or proposed works which may or may not impact upon flooding. Typical works are filling of land, and the construction of roads, floodways and buildings.
discharge	The rate of flow of water measured in terms of volume over time. It is not the velocity of flow which is a measure of how fast the water is moving rather than how much is moving. Discharge and flow are interchangeable.
DTM	Digital Terrain Model - a three-dimensional model of the ground surface.
effective warning time	The available time that a community has from receiving a flood warning to when the flood reaches them.
flood	Above average river or creek flows which overtop banks and inundate floodplains.
flood awareness	An appreciation of the likely threats and consequences of flooding and an understanding of any flood warning and evacuation procedures. Communities with a high degree of flood awareness respond to flood warnings promptly and efficiently, greatly reducing the potential for damage and loss of life and limb. Communities with a low degree of flood awareness may not fully appreciate the importance of flood warnings and flood preparedness and consequently suffer greater personal and economic losses.
flood behaviour	The pattern / characteristics / nature of a flood.
flooding	The State Emergency Service uses the following definitions in flood warnings: **Minor flooding**: causes inconvenience such as closing of minor roads and the submergence of low level bridges.

	removal of stock and/or evacuation of some houses. Main traffic bridges may be covered. **Major flooding**: extensive rural areas are flooded with properties, villages and towns isolated and/or appreciable urban areas are flooded.
flood frequency analysis	An analysis of historical flood records to determine estimates of design flood flows.
flood fringe	Land which may be affected by flooding but is not designated as a floodway or flood storage.
flood hazard	The potential threat to property or persons due to flooding.
flood level	The height or elevation of flood waters relative to a datum (typically the Australian Height Datum). Also referred to as "stage".
flood liable land	Land inundated as a result of the standard flood.
Floodplain	Land adjacent to a river or creek which is periodically inundated due to floods.
flood proofing	Measures taken to improve or modify the design, construction and alteration of buildings to minimise or eliminate flood damages and threats to life and limb.
floodplain management	The coordinated management of activities which occur on flood liable land.
flood source	The source of the flood waters. In this study the Paterson River and Hunter River are different sources of flood waters.
floodplain management standard	A set of conditions and policies which define the benchmark from which floodplain management options are compared and assessed.
flood standard	The flood selected for planning and floodplain management activities. The flood may be an historical or design flood. It should be based on an understanding of the flood behaviour and the associated flood hazard. It should also take into account social, economic and ecological considerations.
flood storages	Floodplain areas which are important for the temporary storage of flood waters during a flood.
floodways	Normally artificial flowpaths which carry significant volumes of flood waters during a flood.
freeboard	A factor of safety usually expressed as a height above the flood standard. Freeboard tends to compensate for factors such as wave action, localised hydraulic effects and uncertainties in the

	design flood levels.
high hazard	Danger to life and limb; evacuation difficult; potential for structural damage, high social disruption and economic losses.
historical flood	A flood which has actually occurred.
hydraulic	The term given to the study of water flow in rivers, estuaries and coastal systems.
hydrograph	A graph showing how a river or creek's discharge changes with time.
hydrology	The term given to the study of the rainfall-runoff process in catchments.
low hazard	Flood depths and velocities are sufficiently low that people and their possessions can be evacuated.
management plan	A clear and concise document, normally containing diagrams and maps, describing a series of actions which will allow an area to be managed in a coordinated manner to achieve defined objectives.
peak flood level, flow or velocity	The maximum flood level, flow or velocity occurring during a flood event.
probable maximum flood (PMF)	An extreme flood deemed to be the maximum flood likely to occur.
Probability	A statistical measure of the likely frequency or occurrence of flooding.
Runoff	The amount of rainfall from a catchment which actually ends up as flowing water in the river or creek.
Stage	See flood level.
stage hydrograph	A graph of water level over time.
TIN	Triangular Irregular Network - a mass of interconnected triangles used to model three-dimensional surfaces such as the ground (see DTM) and the surface of a flood.
Velocity	The speed at which the flood waters are moving. Typically, modelled velocities in a river or creek are quoted as the depth and width averaged velocity, ie. the average velocity across the whole river or creek section.
water level	See flood level.

LIST OF ABBREVIATIONS

AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARI	Average Recurrence Interval
AR&R	Australian Rainfall and Runoff
cm	centimetre
cumecs	cubic metres per second
DLWC	Department of Land and Water Conservation
DTM	Digital Terrain Model
GIS	Geographic Information System
km	kilometre
m	metre
m^3/s	cubic metres per second
PMF	Probable Maximum Flood
PSC	Port Stephens Council
PW (or PWD)	NSW Public Works (or Public Works Department) (now Department of Public Works and Services)
RTA	Roads and Traffic Authority of NSW
TIN	Triangular Irregular Network

1 INTRODUCTION

1.1 Background

The Paterson River is located within the Hunter Valley of New South Wales. The river flows in a general north-south direction from its source in the Barrington Tops to its confluence with the Hunter River near Morpeth. The long narrow catchment is characterised by forests in the steeper upper areas and pastures in the remainder, draining an area of approximately 1,000km^2. The largest tributary is the Allyn River which also starts on the Barrington plateau and flows parallel to the Paterson before joining it at Vacy.

The Paterson is initially a steep mountain stream. As it flattens out it exhibits meandering patterns and the floodplain starts to become more pronounced. It is not until downstream of Paterson township that major floodplains start to develop. These floodplains occur intermittently, separated by ridges which have a controlling influence on flood flows. From a few kilometres upstream of Woodville the floodplains are substantial all the way through to the Hunter River.

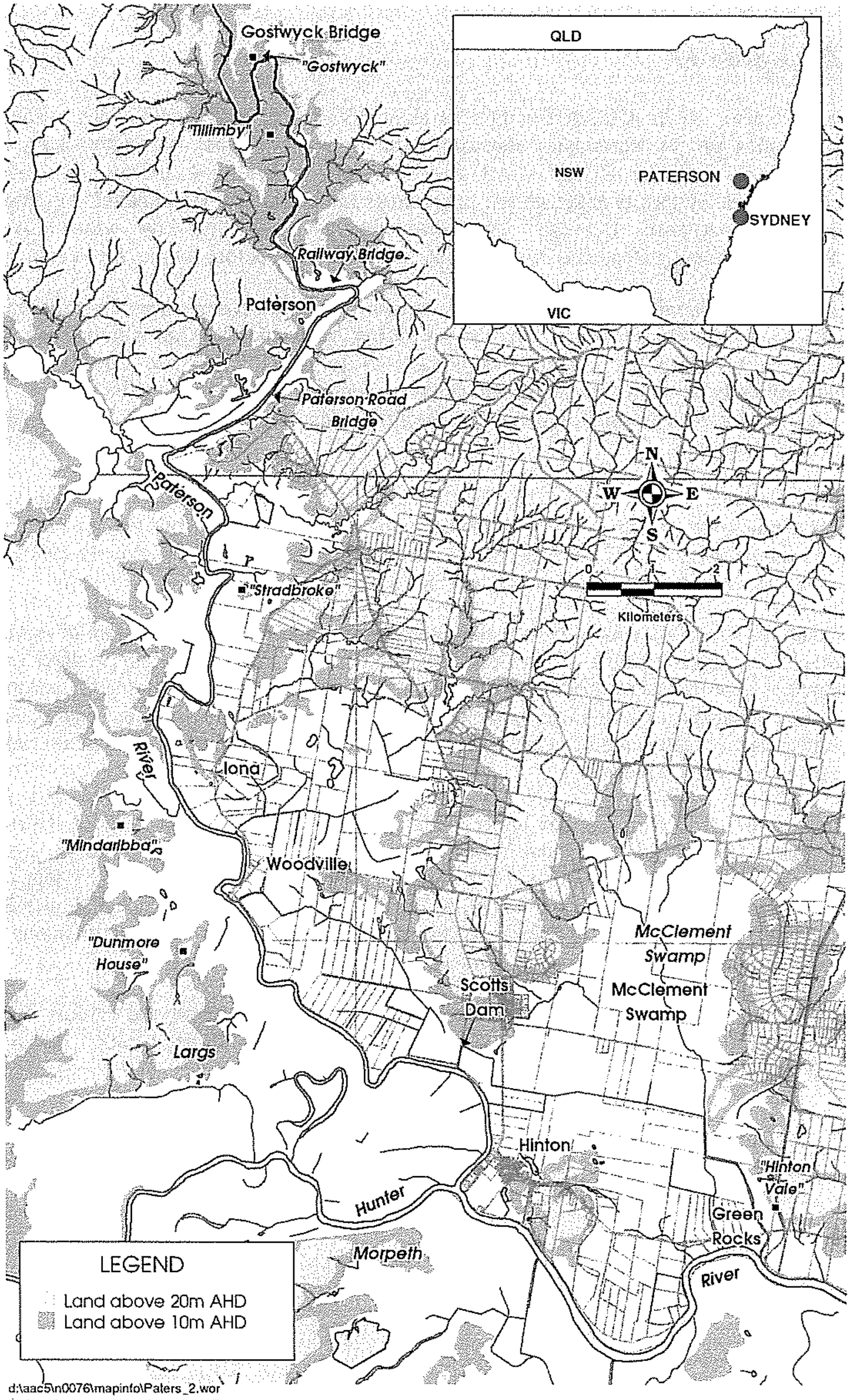
The other major characteristic, besides the natural topography, is the very pronounced and substantial levee system. Nearly all of the major floodplains are "protected" to some extent by man-made levees. The levees, which were built in the late 1960s and early 1970s, have an influence on flooding, particularly for the more frequent floods.

Consideration of options to reduce flooding impacts, and planning for future development requires an understanding of the flood behaviour. Once flood behaviour is understood, a strategic approach to controlling development on flood prone land, assessing the advantages and disadvantages of flood mitigation options, flood proofing properties and buildings, educating and safeguarding communities and protecting the natural environment can be carried out with confidence.

In response to develop a greater understanding of flooding in the lower Paterson River, Port Stephens Council commissioned WBM Oceanics Australia to carry out this flood study. This report presents the findings of the study which examines the flood behaviour of the Paterson River downstream of Gostwyck Bridge to its confluence with the Hunter River, including the floodplains to the east of Hinton (see Figure 1.1). The investigations draw upon and supplement similar studies carried out for the Hunter River.

The study was commissioned by Port Stephens Council with support and funding from the Department of Land and Water Conservation (DLWC), Maitland City Council and Dungog Council.

Figure 1.1 Paterson River Flood Study Area



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1.2 Floodplain Management

Generic Approach in NSW

Floodplain management in NSW generally follows the guidelines in the Floodplain Development Manual (Ref 6) developed by the NSW State Government. It states that implementation of flood policy requires a floodplain management plan which ensures:

- the use of flood liable land is planned and managed in a manner compatible with the assessed frequency and severity of flooding;
- flood liable lands are managed having regard to social, economic and ecological costs and benefits, to individuals as well as to the community;
- floodplain management matters are dealt with having regard to community safety, health and welfare requirements;
- information on the nature of possible future flooding is available to the public;
- all reasonable measures are taken to alleviate the hazard and damage potential resulting from development on floodplains;
- there is no significant growth in hazard and damage potential resulting from new development on floodplains; and
- appropriate and effective flood warning systems exist, and emergency services are available for future flooding.

The steps involved in formulating a floodplain management plan are:

- establishing a floodplain management committee;
- recognising and understanding the principal factors concerned with flooding;
- selecting a flood standard (which is a set of design flood conditions for use in subsequent studies);
- identifying and evaluating the options appropriate for managing flood affected areas;
- preparing a floodplain management plan which is comprised of the best combination of the options available for dealing with the problem; and
- developing a strategy to implement the management plan.

Figure 1.2 illustrates the process of producing and implementing a floodplain management plan as described in the Floodplain Development Manual (Ref 6).

Figure 1.3 shows the main steps to produce a floodplain management plan.

Application to this Study

Port Stephens Council initiated the floodplain management process for the Paterson River by forming an interim committee and commissioning this study. A full committee to consider future floodplain management strategies is planned to be formed at the study's completion.

Figure 1.2 Floodplain Management Process in NSW

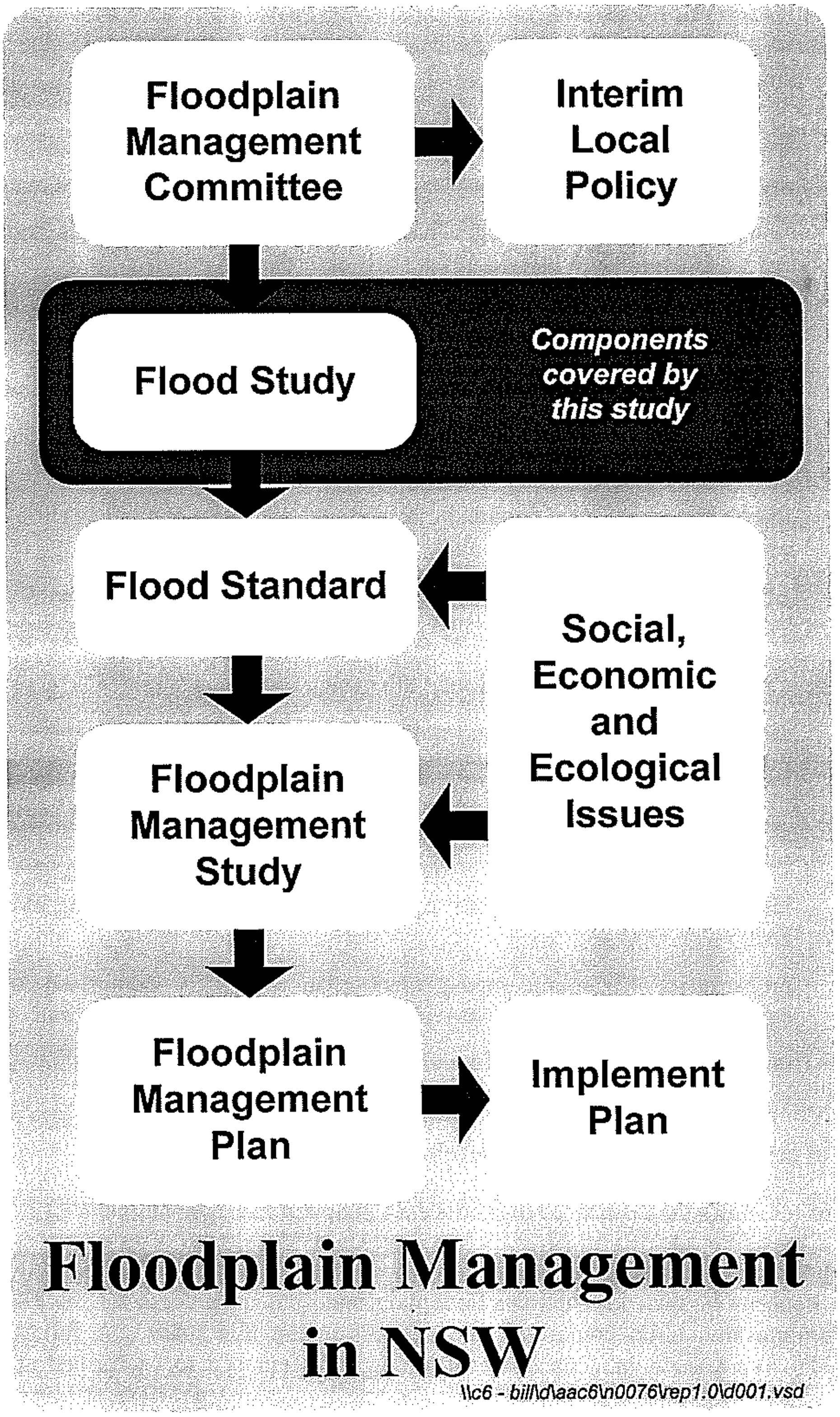
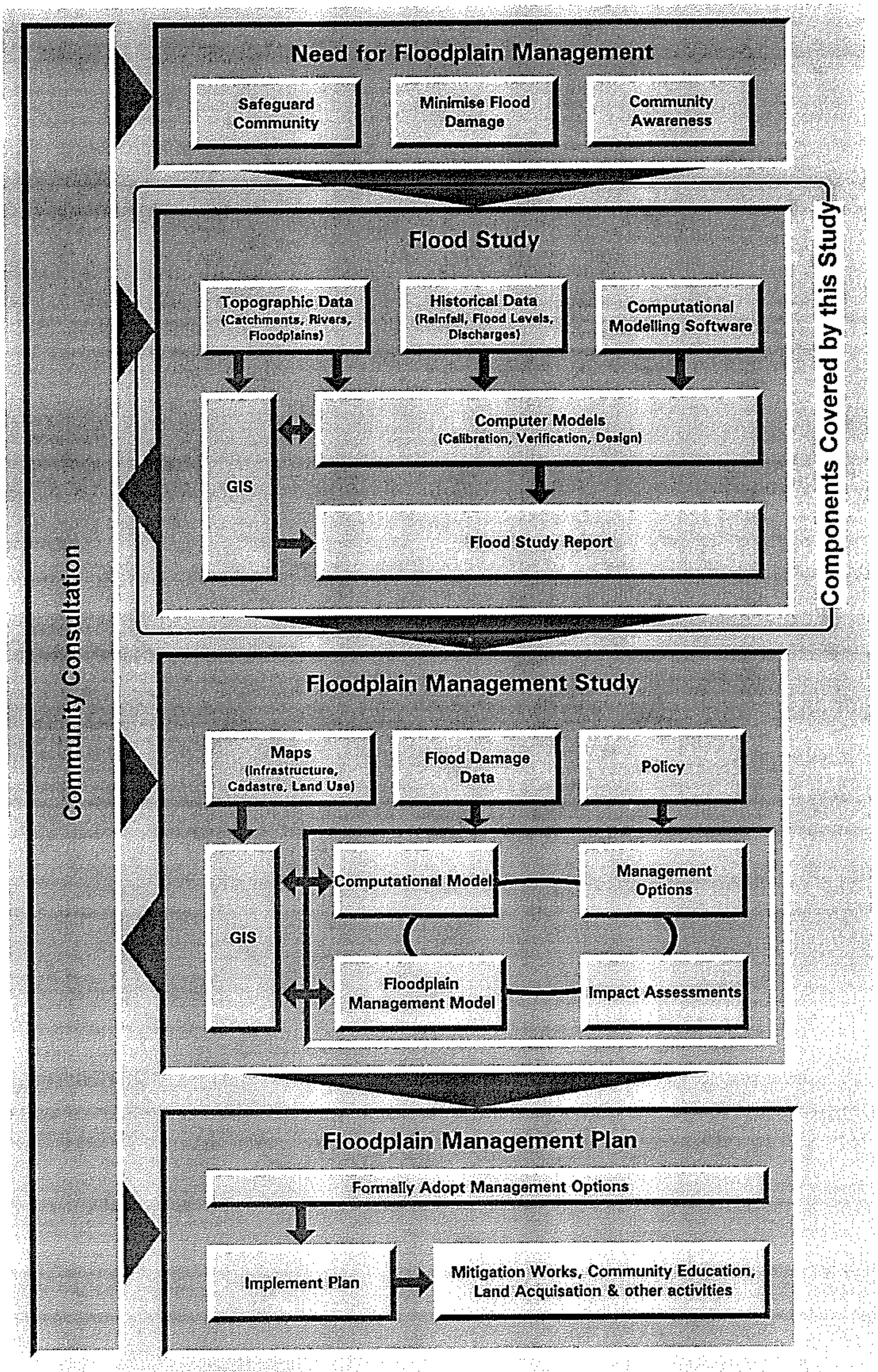


Figure 1.3 Steps in the Floodplain Management Process



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1.3 Previous Studies

Flood investigations carried out for the Hunter River have addressed various aspects of Paterson River flooding, particularly in the lower reaches below Woodville. No detailed flood investigation of the Paterson River has previously been carried out.

The relevant Hunter River studies are:

- The Lower Hunter Valley Flood Study reports (Oakhampton to Green Rocks), NSW Public Works Department, 1990 to 1995 (Ref 7, Ref 8 and Ref 9).
- Hunter Valley Flood Plain Management Study as part of the series of New South Wales Coastal Rivers Flood Plain Management Studies, 1981 (Ref 10).

1.4 Study Objectives

This study examines and defines the flood behaviour of the Paterson River from Gostwyck Bridge to the Hunter River, including the floodplains on both banks and those in common with the Hunter River east of Hinton.

The objectives are:

- Review relevant studies previously carried out.
- Identify the nature and extent of historical floods.
- Develop predictive tools (computer models) which reproduce historical flood behaviour.
- Define best estimates of the 1%, 2% and 5% AEP design floods and for an extreme flood.
- Produce maps showing the likely extent of inundation, flood depths and flow distribution for the design floods.
- Produce maps showing provisional flood hazard and hydraulic categories.

1.5 About This Report

This report documents the Study's objectives, results and conclusions. It is divided into a main report which presents the Study in a relatively non-technical manner, and several appendices primarily containing additional data.

The **Main Report** consists of the following sections.

1 **Introduction**
Introduces the background and objectives of the study.

2 **Study Methodology**
Presents a general discussion on the study methodology.

3 **Historical Flood Information**
Discusses the collection and findings of the historic flood information survey.

4 **Computer Models**
Presents the development and calibration of the hydrologic and hydraulic models developed for the study.

5 **Design Floods**
Presents the derivation of the design floods.

6 **Presentation of Results**
Presents the design flood results in a variety of graphic and map formats.

7 **References**
List of references cross-referenced in text.

The **appendices**, which are contained in the remaining sections, are:

8 **Appendix A: Available Data**
Lists the data sources available prior to the study commencing.

9 **Appendix B: Historical Flood Survey**
Presents a summary of the information collected during the historic flood information survey.

10 **Appendix C: Additional Survey Data**
Presents the additional topographic survey data collected during the study.

11 **Appendix D: Hydrologic & Hydraulic Model**
Describes the calibration and verification of the hydrologic and hydraulic models.

12 **Appendix E: Flood Frequency**
Discusses the flood frequency analysis carried out and presents the resulting curves.

13 **Appendix F: Design Flood Results**
Presents the results of the 1%, 2% and 5% AEP design floods and the extreme flood in map format.

14 **Appendix G: 3D Flood Surface Modelling**
Presents additional information on the 3D flood surface modelling.

2 STUDY METHODOLOGY

The general approach and methodology employed to achieve the study objectives involved:

- Compilation and review of available information.
- Site inspections.
- Identification of historical changes to topography.
- Collection of historical flood information.
- Collection of Additional Topographic Survey Data.
- Setup of Hydrologic (Catchment Runoff) Model.
- Setup of Hydraulic Model.
- Calibration and Verification of Models.
- Establish Design Flood Conditions.

The above tasks are elaborated on in detail below.

Compilation and Review of Available Information

Available information on topographic data (ie. ground levels and river bathymetry), hydrographic data (ie. rainfall, stream flows and flood levels) was collated and reviewed. Examples of data types are:

- Rainfall (daily totals and pluviograph) records for historic flood events.
- Flood level and/or stream flow station records.
- Peak flood observations collected by State and Local Governments.
- Surveys of river cross-section profiles.
- Details on flood control and drainage structures.
- Topographic data such as ground contours and spot heights.
- Geographic Information System (GIS) data such as cadastre, roads, towns, waterways, land use, etc.

Site Inspections

An initial site inspection was carried out to determine additional data needs. Site inspections were then carried out throughout the course of the study to readily confirm computer modelling assumptions.

Identification of Historical Changes to Topography

Any significant changes to the river and floodplain topography, particularly the construction or modification of levees, may have a major influence on flood behaviour. The extent and timing of these changes were identified so that the computer models could be adjusted accordingly.

Collection of Historical Flood Information

Acquisition of additional flood information was obtained through consultation with local residents. For this study, a door-to-door survey was conducted to collect, verify and update existing historical flood information. A standard questionnaire was used to ask residents about their knowledge and experiences of flooding. Questionnaires were left with residents who could not be contacted, and also distributed to key organisations.

Collection of Additional Topographic Survey Data

The accuracy of the computer models and the study's findings is largely dependent on the accuracy of the topographic data used to set up the models. Areas of deficient data were supplemented by additional surveys.

Based on an initial site inspection, additional topographic surveys were commissioned to establish the:

- longitudinal profiles of levee crests, in particular man-made levees, and
- topography of the western floodplains.

Setup of Hydrologic (Catchment Runoff) Model

A hydrologic model of the river's catchment is needed to calculate the quantity and rate of catchment runoff during a flood event. The model produces estimates of the discharges in the river and its tributaries during the course of a flood. These discharges are used as inputs to the hydraulic model (see below).

For this study the hydrologic model covered:

- the Paterson River catchment upstream of Gostwyck Bridge;
- side catchments feeding into the Paterson River downstream of Gostwyck Bridge and
- the catchment of McClement Swamp.

The model takes into account the variations in catchment topography, rainfall and land surface characteristics and can include the effects of structures such as dams. Separate models may be needed to represent historical changes in catchment characteristics.

Setup of Hydraulic Model

A hydraulic model is needed to accurately calculate flood levels and flow patterns down the river and over the floodplains. The model also handles the complex effects of backwater, overtopping of levees, bridge constrictions, any tidal influences, river confluences and other hydraulic behaviour.

For this study, the hydraulic model incorporates:

- sections of an existing hydraulic model of the Lower Hunter River from Oakhampton to Green Rocks (Ref 7 and Ref 9);
- the Paterson River from upstream of Gostwyck Bridge to its Hunter River confluence;
- the eastern and western Paterson River floodplains;
- improved representation of the northern Hunter River floodplains between Hinton and Green Rocks;
- hydraulic structures representing levees and flood gates.

Calibration and Verification of Models

The hydrologic and hydraulic models are calibrated and verified to historical flood events to establish the values of key parameters and confirm that the models' are capable of reproducing real flood events.

Historical events were selected using the following criteria:

- Ideally the event is one of those already used for the Lower Hunter River flood studies as the conditions and backwater influence of the Hunter River on the Paterson River need to be known and quantified. Alternatively, sufficient data on flood levels in the Hunter River must be available to define the downstream conditions.
- The availability, completeness and quality of rainfall, stream flow, flood level and other hydrographic data.
- The amount of data collected during the historical flood information survey - events which have substantially more information will be given priority.
- The variability of events - preferably the events will cover a range of flood conditions.

Table 2.1 presents a summary of possible calibration and verification events.

Table 2.1 Suitable Calibration & Verification Flood Events

Event	Comments
1955	Represents a major flood of the lower floodplain heavily dominated by flooding in the Hunter River. There is no useful rainfall or stream flow data to calibrate the hydrologic model, therefore, there could be difficulties in confidently defining the upstream inflow hydrographs. Another major problem is the details of the levee system before and immediately after the 1955 flood are sketchy and regarded as inadequate for hydraulic modelling.
1972	Represents a moderate size flood. Would be good for the hydrologic and hydraulic model verification.
1977	Represents a moderate size flood. Would be good for the hydrologic and hydraulic model verification.
1978	Represents a major flood in the Paterson River, particularly in the upper reaches, with only minor influence from the Hunter River. Good data exists for the hydrologic and hydraulic model calibration.
1985	Represents a major flood in the Paterson River with an excellent record of peak flood heights recorded around Paterson showing the flood was slightly lower than the 1978 flood. Unfortunately no pluviograph records were readily available from the Bureau of Meteorology.
1990	Medium flood with reasonable amount of data, however, this flood was not modelled for the Hunter River studies.
1995	As for the 1990 flood but with additional pluviograph and stream flow gauge sites.

The general steps of the calibration and verification process are:

- Identify and scrutinise available data for suitable calibration and verification events.
- Select the most appropriate events.
- Process data for selected events and incorporate into the hydrologic and hydraulic models.

- Carry out preliminary calibration and verification of the hydrologic and hydraulic models - if there are significant topographical changes between different events, separate models will be set up, each model representing the topography and land use at the time of the event.
- Carry out final calibration and verification of the models using an iterative process which seeks to find the best combination of hydrologic and hydraulic parameters.

Establish Design Flood Conditions

The calibrated and verified hydrologic and hydraulic models are modified, if necessary, to represent present day conditions, including topographical and vegetative changes, and then used to establish present day design flood conditions.

Design floods are statistical events representing some probability of occurrence. For example, the 1% AEP or one in a hundred year flood is the best estimate, based on data recorded to date, of a flood which has 1 chance in 100 of occurring in any one year.

Design floods are derived by consideration of:

- predictions of the rainfall quantity, variability and intensity of storms for different durations as documented in AR&R (Ref 4);
- identification of the storm duration(s) which produce the highest flood levels;
- examination of long periods of stream flow records (flood frequency analysis); and
- differences in timing and magnitude between a Paterson River flood and a Hunter River flood.

The above considerations require that a range of storm durations and Hunter River conditions are modelled to define the design flood conditions for a specific probability of occurrence.

Sensitivity tests were also carried out to establish the relative importance of different hydrologic and hydraulic factors.

3 HISTORICAL FLOOD INFORMATION

3.1 Previously Collected Information

Information on flooding within the study area has been previously collected during surveys after floods and during the Hunter River studies. The following sources yielded useful data:

- Port Stephens Council records.
- Compendium of Data - Lower Hunter Valley Supplementary Flood Study (Ref 8).
- Department of Land and Water Conservation (formerly Public Works Department) Newcastle Office records.

Historical flood levels relevant to this study were collated and incorporated into a geographical database (see Section 9).

To supplement these data an historical flood information survey was carried as discussed in the next section.

3.2 Historical Flood Information Survey

An extensive survey of residents within the study area was conducted in late July through to mid-August, 1996 to gather historical data from those who have experienced Paterson River floods and to identify local concerns within the region. Questions covered a number of issues ranging from the degree of flood inundation to costs incurred as a result of flooding. The locals knowledge of the workings of both the Paterson and Hunter Rivers was found to be invaluable in developing and understanding of the interactions between the two rivers. A number of flood heights were identified thanks to local knowledge and accurate flood marks (these were surveyed and are presented in Section 2.2.3 and Appendix B).

A total of 11 days was spent interviewing local residents and completing questionnaires. A total of 88 questionnaires were completed, 27 of which had experienced flood inundation on their property in one or more floods. Nine of these properties had experienced severe flooding, including the flooding of homes.

Key observations on flood behaviour arising from a number of knowledgable residents are:

- The Butterwick area provides a major ponding area, or storage area, for flood waters. Water breaks the Paterson River levees at specified low points south of the Woodville Bridge and is held in by high land to the east and north-east and by Scotts Dam to the south-east. Water is unable to escape and slowly backs up through Woodville into the Butterwick swamp area. Once the water level reaches a certain height, it flows over Scotts Dam and, as the river water level subsides, the water slowly escapes through the floodgates. Therefore, water backed up in the Butterwick swamp area usually only reaches a certain level before it is able to escape. The water is slow to recede, most residents reporting up to one week before most of the flood waters have drained.
- An exception to the above description is in the case of the 1955 flood. The Hunter River experienced major flooding causing a large flood to travel up the Paterson River. Scotts Dam no longer acted as a major control, possibly explaining the exceptionally high flood levels experienced around Woodville.

- The tendency of the Paterson River to flow 'backwards' when the Hunter is in flood was observed by several residents.
- When the Hunter River is in flood at the same time this effectively leaves Paterson River flows with no where to go. This causes the most severe flooding as the Paterson River flows are unable to escape.

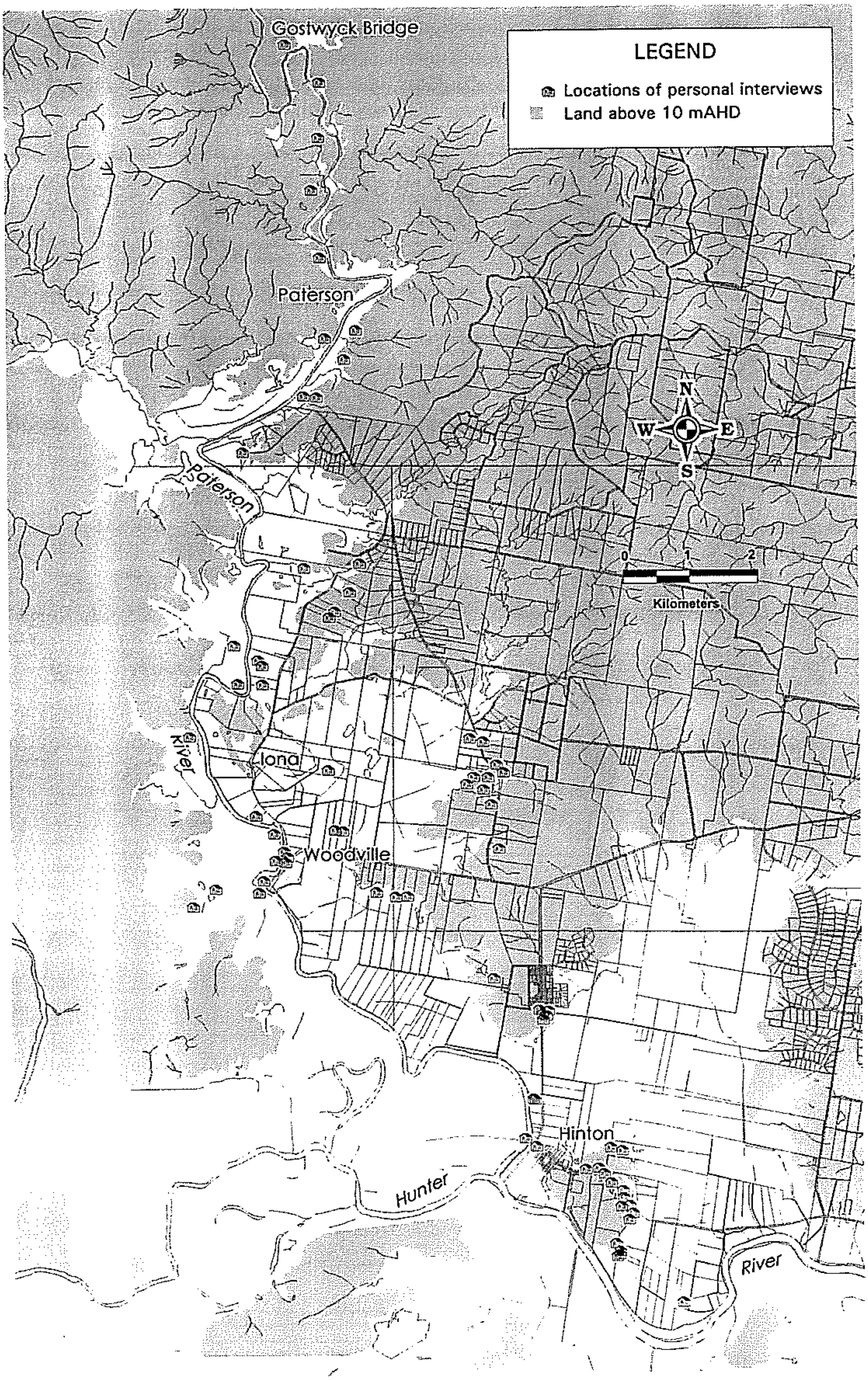
An extension to the survey was carried out on August 15, 1996, extending from the township of Paterson to Gostwyck Bridge. The observations noted were:

- Deposition of large deposits of sand on floodplains (with excess sand having to be trucked/bulldozed away in many instances) has been experienced. This is believed to be due to the straightening of the Allyn River in the 1970s and the removal of trees on the river banks in previous years thereby increasing the speed of flood waters and increasing scouring effects in the Allyn.

Figure 3.1 illustrates the locations of residents interviewed during the survey.

A collection of some 85 photographs showing various floods were also kindly loaned for copying. The copies have been provided to Port Stephens Council for their records.

Figure 3.1 **Locations of Residents Interviewed during the Flood Information Survey**



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3.3 Historical Flood Levels

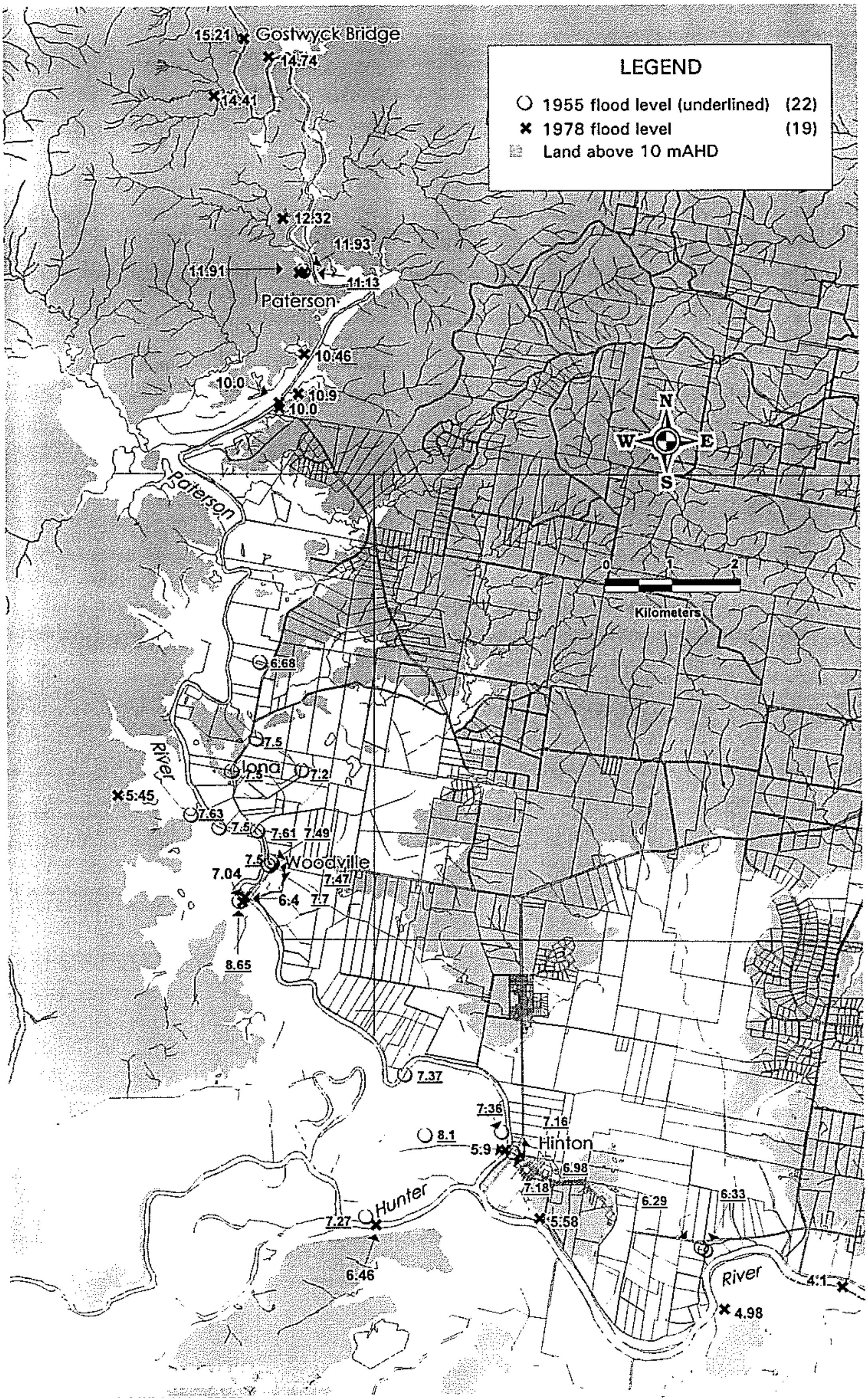
A geographic database of historical flood levels based on information gathered from previous studies, local and state government records and the historic flood information survey was compiled. The database contains all records from the flood information survey and records from selected floods for other sources (ie. those floods used for the validation of computer models - see Section 4.6).

Table 3.1 presents a breakdown on the number of historical flood level records collected and built into the database. Figure 3.2 illustrates the locations and levels for the 1955 and 1978 events.

Table 3.1 Sources of Historical Flood Level Recordings

Flood	Number of Flood Level Recordings		
	Flood Survey	Other Sources	Total
1955	11	11	22
1972	2	1	3
1977	0	6	6
1978	11	8	19
1985	0	14	14
1990	3	4	7
1995	0	4	4
Other	8	0	8
Total	35	48	83

Figure 3.2 1955 and 1978 Historical Flood Levels



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3.4 Historical Flooding Patterns

Developing an appreciation of the flooding processes on the Paterson River is an important step in defining the flood behaviour and developing appropriate computer models.

A general understanding of the different patterns of flooding, or flood behaviour, was obtained based on consultations with local residents and others, and an understanding in flood hydraulics.

Flood Sources

For the Paterson River, floods originate from one or more of the following sources:

- rainfall over the Paterson and Allyn River catchments;
- flooding of the Hunter River causing a back flow and/or backwater effect in the Paterson (this would be more influential in the lower reaches) and
- localised rainfall not being able to drain because of high river levels and/or constrictions caused by the flood drainage structures.

Flood Magnitudes and Behaviour

The different magnitudes and modes of flood behaviour of the Paterson River are:

- **Minor Flooding:** For minor floods, the floodplains may have virtually no interaction with the river except to temporarily hold localised rainfall. Some backing up of water may occur as flood waters try to propogate up side creeks and onto the floodplain where flood gates do not exist.
- **Moderate Flooding:** In moderate floods, floodplains may act as a temporary storage of river and creek waters until the river falls and flood waters can drain away. For a short peaky flood which overtops the levees for a relatively short time, the peak flood levels on the floodplain may be well below those in the river. In longer duration floods, there may be sufficient time for the floodplains to fill, causing flood levels to be similar on both river and floodplain. In these types of floods the floodplains' storage capacity is particularly important. Small floodplains will fill up very quickly, while large ones may take the duration of the flood to fill or indeed may never fill.
- **Major Flooding:** For major floods, floodplains may not only be a temporary storage for flood waters, but can also be a major carrier, transporting water down the floodplain and back into the river further downstream. Where flood waters are returning to the river, it is important to note that flood levels on the floodplain can be higher than those in the river. In these floods, both floodplain storage and conveyance characteristics are important.

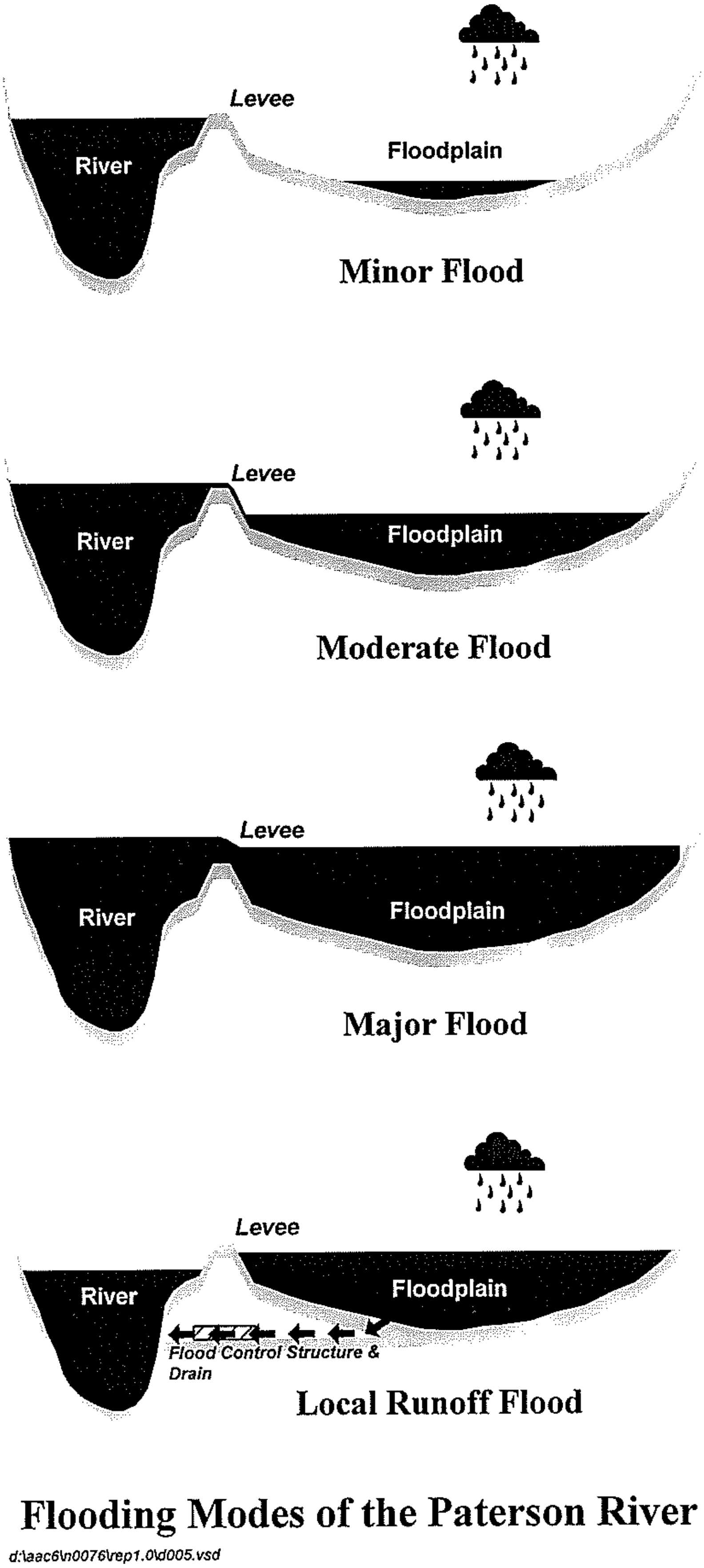
The State Emergency Service (SES) classifies major, moderate and minor flooding according to the following gauge height values:

Table 3.2 SES Flood Classification

Station	Flood Classifications (gauge readings)		
	Minor	**Moderate**	**Major**
Gostwyck (210079)	9.1	10.7	12.2
Paterson	6.1	7.6	9.1

Figure 3.3 illustrates these different modes of flooding.

Figure 3.3 Examples of Flooding Behaviour of the Paterson River



4 COMPUTER MODELS

4.1 Introduction

Computer models are the most accurate, cost-effective and efficient tools to model a river's flood behaviour. For this study, two types of models were used:

- A hydrologic model of the Paterson River catchment.
- A hydraulic model extending from upstream of Gostwyck Bridge to Green Rocks (on the Hunter River).

The **hydrologic model** simulates the catchment rainfall-runoff processes, producing the river/creek flows which are used in the hydraulic model.

The **hydraulic model** simulates the flow behaviour of the river and floodplains, producing flood levels, flow discharges and flow velocities.

Both of these models were calibrated interactively.

Information on the topography and characteristics of the catchments, rivers, creeks and floodplains are built into the models. For each historic flood, data on rainfall, flood levels and river flows are used to simulate and validate (calibrate and verify) them. The models produce as output, flood levels, flows (discharges) and flow velocities.

Development of a computer model follows a relatively standard procedure:

- Discretisation of the catchment, river, floodplain, etc (see discussion below).
- Incorporation of physical characteristics (catchment areas, river cross-sections, etc).
- Setting up of hydrographic databases (rainfall, river flows, flood levels) for historic events.
- Calibration to one or more historic floods (calibration is the adjustment of parameters within acceptable limits to reach agreement between modelled and measured values).
- Verification to one or more other historic floods (verification is a check on the model's performance without adjustment of parameters).

Once the model's development is complete it may then be used for:

- establishing design flood conditions;
- determining levels for planning control;
- modelling "what-if" management options to assess the hydraulic impacts;
- monitoring the implementation process.

Model Discretisation

Model discretisation is necessary to reduce the real-world, which is infinitely changing and continuous, to a mathematical world which is segmented or discrete. As an example, the river's catchment may be broken up into, say twenty separate elements (sub-catchments), where each element represents a catchment area of similar character in its slope, vegetation and so on.

The smaller the elements become, the closer the model approaches the real-world. However, as the number of elements increases, the model becomes more difficult to set up, cumbersome to use and not cost-effective. Also, there is a point where increasing the number of elements may not provide any additional benefit in model accuracy.

In constructing the model, the engineer or scientist must design the number, size and location of elements to take into account:

- location of available data (eg. river section surveys);
- location of recorded data (eg. river flow gauging site);
- location of controlling features (eg. dams, levees, bridges);
- desired accuracy to meet the study's objectives;
- limitations of the computer software (ie. the number of elements the software can handle, and more importantly, to keep within the constraints of the mathematical solution); and
- limitations of the computer hardware (ie. don't develop a model which takes forever to run - fortunately, with today's computers, this is rarely a constraint).

4.2 Data Sources

A variety of data was collected, collated and used to develop the different model databases or used to develop model parameters. The sources of data are:

- Topographic maps (1:25,000 and 1:100,000).
- Hydraulic model developed for the Hunter River flood investigations (Ref 7 and Ref 9) - the model includes a coarse representation of the Paterson River and its floodplains.
- Historic flood information (as discussed in Section 3).
- Photogrammetry of the floodplains within Port Stephens Council (see Section 4.3).
- Topographic surveys collected for the study which include:
    - ◊ cross-sections of the western floodplains;
    - ◊ levee crests between Paterson and Hinton on both sides of the river and
    - ◊ river and floodplain cross-sections between Gostwyck Bridge and Paterson.
- Rainfall data for historic events from the Bureau of Meteorology.
- Stream flow data for historic events from the Department of Land and Water Conservation.
- Flood level data for historic events from the Department of Land and Water Conservation and the historic flood information survey (see Section 3.3).
- Aerial photography.
- Discussions with Lostock Dam operators and data supplied by them.

For further information on these data, refer to Sections 8, 9, and 10.

4.3 Digital Terrain Model (DTM)

A digital terrain model (DTM) is a three-dimensional (3D) representation of the ground surface.

The DTM developed for this study covered the eastern floodplains of the Paterson River within Port Stephens Council. It also includes the northern floodplains of the Hunter River around McClement Swamp.

The DTM was based on the following sources of data:

- contours from the aerial photogrammetry;
- the levee crest survey; and
- the 20m contour from the 1:25,000 topographic map series.

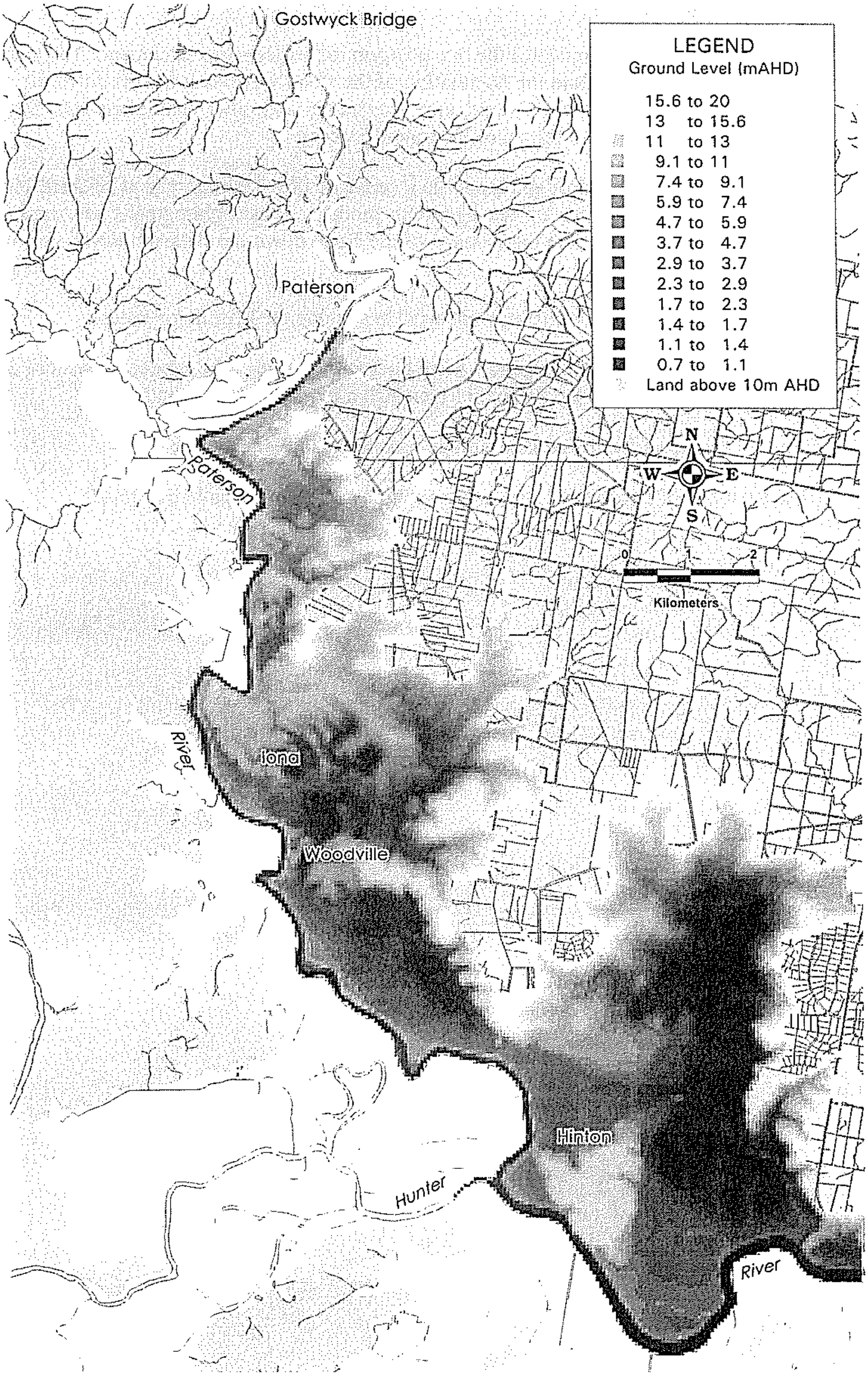
The DTM is constructed as a TIN (Triangular Irregular Network) which is a mass of interconnected triangles. For each triangle, the ground level is defined at each of the three vertices, thereby defining a plane surface over the area of the triangle. Where there are significant variations in the ground surface slope and elevation the density of triangles is greater.

The resulting TIN, which consists of approximately 125,000 triangles based on 63,000 ground level points, is further discussed and presented in Section 10.

Figure 4.1 presents a shaded view of the eastern floodplains produced from the DTM. The lighter areas represent the higher ground while the darker shades depict the lower areas (refer to the map legend).

The Paterson and Hunter Rivers have been incorporated by lowering the ground levels along the watercourses to a nominal level (-2.0 mAHD). This has been done to illustrate the location of the rivers in the DTM.

Figure 4.1 Shaded View Depicting Ground Levels of the DTM



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4.4 Hydrologic (Catchment Runoff) Model

The hydrologic model simulates the rate of storm runoff from the catchment. The amount of runoff from the rainfall and the attenuation of the flood wave as it travels down the river is dependent on the catchment's slope, area, vegetation and other characteristics. Structures such as Lostock Dam also influence the runoff process.

The output from the hydrologic model is a series of flow hydrographs at selected locations such as at the boundaries of the hydraulic model. These hydrographs are used by the hydraulic model to simulate the passage of the flood down the Paterson River and over the floodplains.

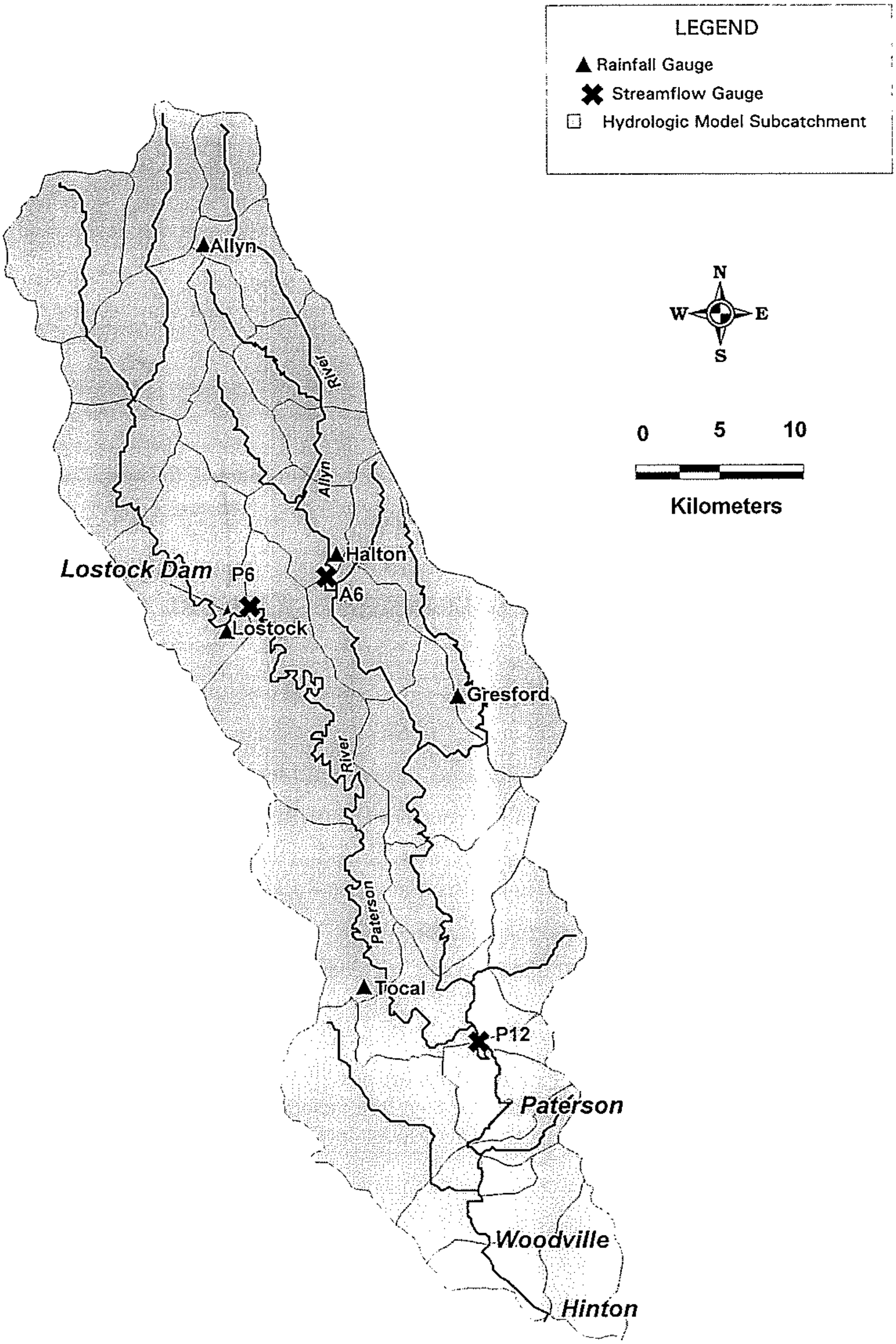
The RAFTS-XP (Ref 11) software was used to develop the hydrologic model.

Figure 4.2 illustrates the hydrologic model network design. The model consists of 31 sub-catchments feeding into the Paterson River, Allyn River and side tributaries.

Lostock Dam's spillway and lake storage was included in the model.

The locations of rainfall and stream flow stations are also shown in Figure 4.2.

Figure 4.2 Hydrologic Model Network



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4.5 Hydraulic (River & Floodplain) Model

The hydraulic model simulates the dynamic flooding behaviour between the Paterson and Hunter Rivers, minor creeks and the floodplains. The substantial levee system of the Paterson and Hunter Rivers requires that the model must be capable of simulating the dynamic interaction between river and floodplain.

The one-dimensional river modelling software, MIKE 11, was used to setup the quasi two-dimensional hydraulic model. MIKE 11 represents a river system as a set of interconnected branches, each branch representing a flowpath. Hydraulic structures were incorporated to represent the five Paterson River bridge crossings, the artificial levees and the flood drainage culverts.

Figure 4.3 presents the development stages and the major inputs to each stage while Figure 4.4 summarises the inputs and outputs of the model.

The flood model developed for this Study extends from upstream of Gostwyck Bridge to the Hunter River confluence, and includes the eastern and western floodplains and the McClement Swamp floodplains. The model includes sections of the existing Hunter River model extending from approximately 2km upstream of Morpeth to Green Rocks.

Figure 4.5 illustrates the hydraulic model network. The model branches are shown as the dashed lines.

For further information on the model setup refer to Section 11.2.1.

Model Inputs and Outputs

Inputs at the model's boundaries are:

- rainfall and runoff from the Paterson River catchment;
- river flows in the Hunter River upstream of Morpeth;
- flows on the northern and southern Hunter River floodplains upstream of Morpeth; and
- water levels in the Hunter River at Green Rocks.

Model outputs are flood levels, flows, velocities describing the flood behaviour over time for a given flood event. Flood events may be historical (eg. the March 1978 flood) or statistical (eg. the 100 year or 1% AEP event).

Interface with Hunter River Model

The lower reaches of the Paterson River are heavily influenced by the flow conditions in the Hunter River. The hydraulic model therefore includes sections of the Hunter River and its floodplains based on the Hunter River Model developed for the Hunter River studies (Ref 7, Ref 8 and Ref 9).

Figure 4.3 Hydraulic Model Development Process

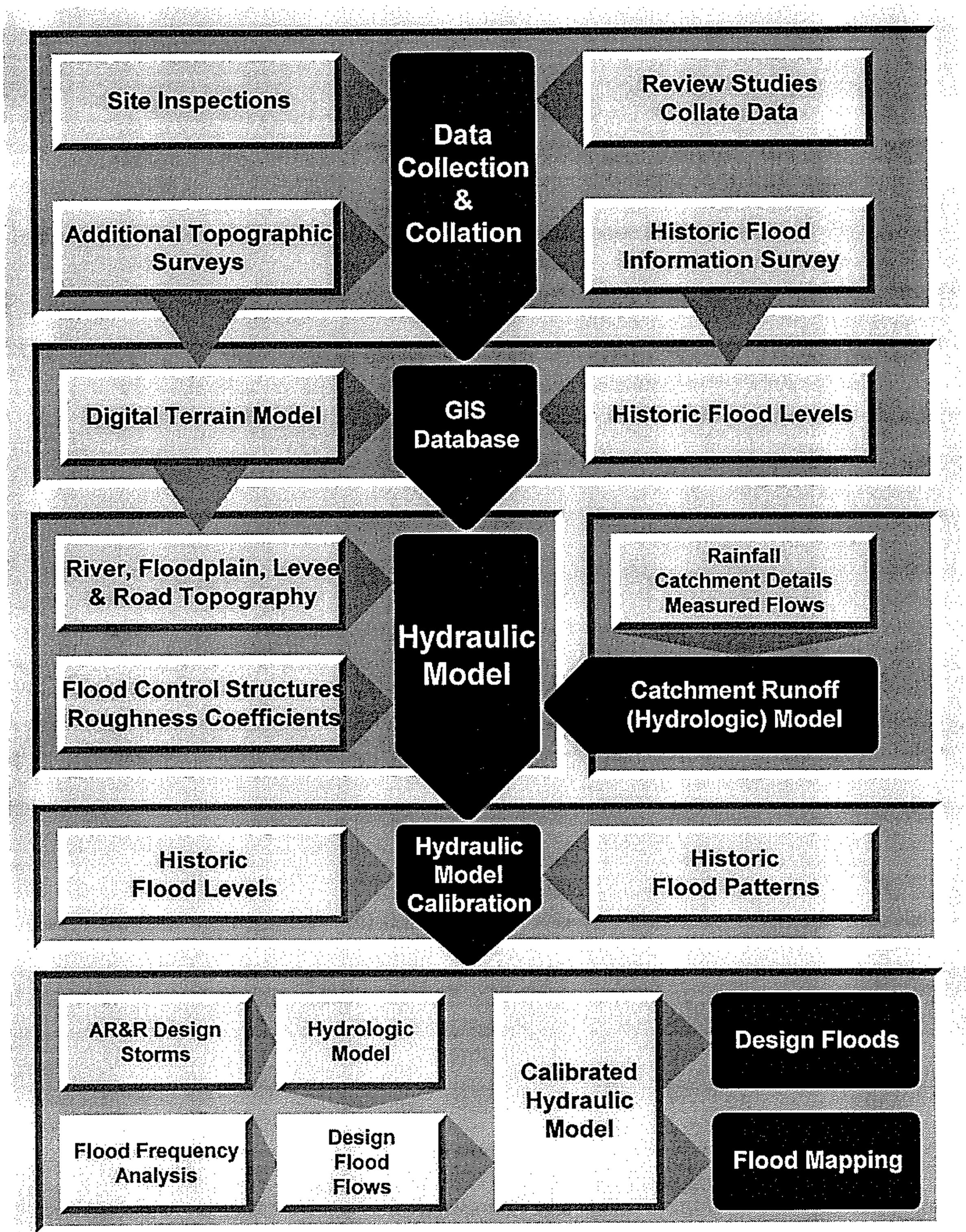

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Figure 4.4 Inputs and Outputs of the Hydraulic Model

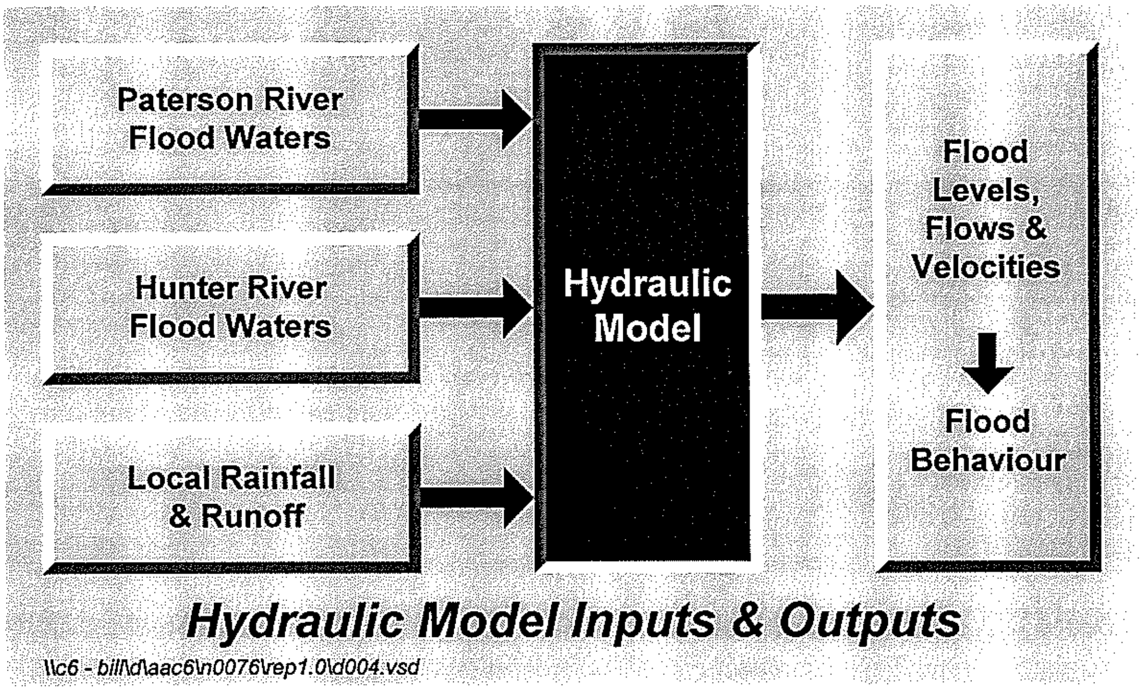
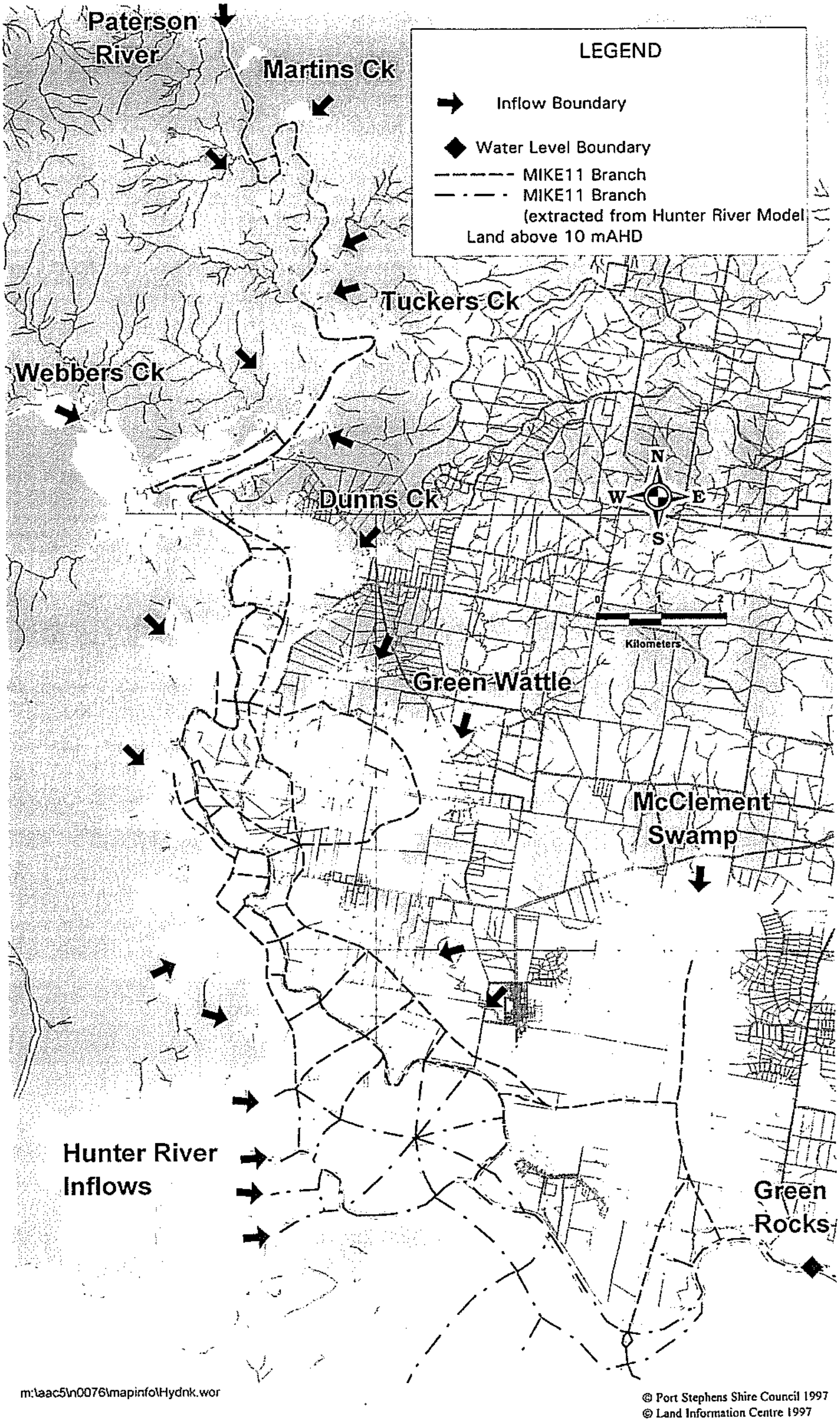


Figure 4.5 Hydraulic Model Network and Boundaries



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4.6 Model Validation to Historic Floods

The hydrologic and hydraulic models were calibrated to recorded flows and flood levels during the floods of March 1978 and March 1977 and verified using the March 1995 event.

These events were selected on the following basis:

- The March 1978 flood is the largest Paterson River flood on record and has one of the better hydrographic data sets. It was therefore selected as the primary calibration event.
- The March 1977 flood was a smaller flood than 1978, but also had one of the better data sets. It represents a good calibration event, given its different magnitude, to compliment the 1978 flood.
- The March 1995 flood was of similar magnitude to 1977. It was selected as the best verification event on the grounds of the data set available and its recent occurrence nature. This flood has not been simulated in the Hunter River model, necessitating the use of recorded stage hydrographs at Morpeth and Green Rocks as model boundaries. There was little or no major overland flow in the Hunter during this event.

Other historical floods were examined, but were rejected because of insufficient data.

The 1955 flood was not used because of insufficient data on the levee system at the time, and the occurrence of levee failures. In addition no suitable rainfall data was available for the hydrologic model.

The 1985 flood was also difficult to use as there was no rainfall pluviograph records readily available. A preliminary run of the 1985 event in the hydraulic model was carried out by using the recorded heights at Gostwyck as the upstream boundary. This run was used to verify a number of good flood level peak recordings around Paterson.

For details on the models' calibration and verification refer to Section 11.

The results of the 1978 and 1977 calibration and 1995 verification show that the hydrologic and hydraulic models satisfactorily reproduce historical floods. There was also agreement between flooding patterns in the hydraulic model and comments on flood behaviour received during the historic flood information survey. The most prominent of these is the issue of Scotts Dam and its influence on flooding around Woodville.

4.6.1 Flooding around Woodville

Based on historical observations and the hydraulic model results, floodplain levels in the Woodville area are very much controlled by the damming effect of Scotts Dam and backwater effects from the Hunter River. The flood typically first breaks the Paterson River levees between Woodville and Scotts Dam. Once the floodplain is full and Scotts Dam begins to flow, the flood level at Woodville is around 6.2mAHD. This is due to the high crest level of Scotts Dam (5.8mAHD) and possible backwater effects from the Hunter River. It should be noted that during major floods, the floodplain becomes a major flowpath and higher flood levels will occur at Woodville.

The hydraulic effect of Scotts Dam is substantial. The crests of the river levees upstream and downstream both lie well below that of Scotts Dam (5.3 and 5.1 versus 5.8mAHD) and carry most of the flow to and from the floodplains. For waters which break the river levees downstream of Scotts Dam the water escapes to McClement Swamp and out to the Hunter River. For waters which break upstream of Scotts Dam, the waters can not escape towards McClement Swamp and therefore back up all the way through to Woodville. The result is that flood levels above Scotts Dam can be over a metre higher than below it.

5 DESIGN FLOODS

5.1 Introduction

Design floods are hypothetical floods used for planning and floodplain management investigations. They are based on having a probability of occurrence specified either as:

- Annual Exceedance Probability (AEP) expressed as a percentage or
- an Average Recurrence Interval (ARI) expressed in years.

This report uses the AEP terminology. Refer to Table 5.1 for a definition of AEP and the ARI equivalent.

Table 5.1 Design Flood Terminology

ARI[1]	AEP[2]	Comments
100 years	1%	A hypothetical flood or combination of floods which represent the worst case scenario likely to occur on average once every 100 years.
50 years	2%	As for the 1% AEP flood but with a 2% probability or 50 year return period.
20 years	5%	As for the 1% AEP flood but with a 5% probability or 20 year return period.
Extreme Flood / PMF[3]		A hypothetical flood or combination of floods which represent an extreme scenario. It is only used for special purposes (eg. design of a dam spillway) where a high factor of safety is recommended. In this study, an extreme flood based on a three times the 1% AEP event for the Paterson River and the PMF from the Hunter River model (Ref 9) was used.

1 Average Recurrence Interval (years)
2 Annual Exceedance Probability (%)
3 A PMF (Probable Maximum Flood) is not necessarily the same as an Extreme Flood.

In determining the design floods it is necessary to take into account:

- The critical storm duration of the catchment (small catchments are more prone to flooding during short duration storms while for large catchments longer durations will be more critical. For example, the Paterson would not experience a major flood from a 1% AEP 1 hour duration storm - it is more prone to storms extending over several hours to a couple of days).
- Whether flooding occurs from the Paterson River, the Hunter River or a combination of both.
- The relative timing and magnitudes of a Paterson River flood and a Hunter River Flood.

The following sections examine these questions in further detail.

5.2 Paterson River Design Flood Flows

The design flood flows at Gostwyck for the Paterson River were established independently using two methods:

- using the calibrated hydrologic model with recommended design rainfall in AR&R (Ref 4), and
- carrying out a flood frequency analysis at Gostwyck Bridge.

The final design flood flows were developed by assessing the results of the two approaches and adopting a representative peak flow at Gostwyck. Consultation and an agreement on the adopted flows was made with DLWC officers.

5.2.1 AR&R Design Storms

The design rainfall and temporal patterns for the Paterson catchment as recommended in AR&R (Ref 4) were input to the calibrated hydrologic model.

Of note is that the spatial distribution of rainfall in AR&R shows an almost constant average rainfall intensity over the whole catchment which differs from the calibration events which show higher rainfall in the upper, northern end of the catchment. However, to be consistent with AR&R a constant average rainfall intensity was applied over the whole catchment for each design storm event.

Table 5.2 shows the average design rainfall intensities based on AR&R. The table also shows the March 1978 intensities for comparison. As can be seen, at Allyn the 1978 rainfall exceeded the AR&R 1% AEP rainfall for the 36, 48 and 72 hour durations, but at Lostock and Tocal the rainfall was less than the 5% and 10% rainfall respectively.

Table 5.2 Average Rainfall Intensities (AR&R and March 1978)

Duration (h)	Average Rainfall Intensity (mm/h)						
	AR&R				March 1978[1]		
	1%	2%	5%	10%	Allyn	Lostock	Tocal
6	22.7	20.2	17.1	14.7	16.6	9.2	6.8
12	15.5	13.8	11.6	10.0	14.4	7.7	5.2
24	10.4	9.2	7.8	6.7	10.0	6.2	4.3
36	8.1	7.2	6.1	5.2	8.6	5.6	3.7
48	6.8	6.0	5.1	4.3	8.8	4.7	3.2
72	5.2	4.6	3.9	3.3	7.3	3.8	2.7

[1] Maximum average rainfall intensity for the given duration.

The hydrologic model parameters adopted for the design floods were based on the hydrologic model calibration and verification. For the initial and continuing rainfall losses, values of 20mm and 2mm/h were adopted.

Table 5.3 shows the peak flows calculated for Gostwyck for different durations. For the 1%, 2% and 5% AEP events the 48 hour duration gives the highest flow closely followed by the 36 hour storm. For the 10% AEP flood the 36 hour gives a slightly higher flow than the 48 hour.

Examination of the 1% AEP 36 and 48 hour duration events show that they have within them a 24 hour burst which is greater by 10% in average rainfall intensity than that for the 24 hour event. The 24 hour event has a total of 250mm whilst the 36 and 48 hour storms have 24 hour bursts with totals of 275mm. Therefore, although the 36 and 48 hour storms produce higher flows, the peak flow originates from the 24 hour bursts within these events.

Table 5.3 Design Flood Flows at Gostwyck based on AR&R Rainfall

Duration	**Peak Flow at Gostwyck (m^3/s) based on AR&R Rainfall**			
(h)	**1%**	**2%**	**5%**	**10%**
6	1488	1241	930	711
12	2025	1705	1340	1062
24	2311	1951	1549	1227
36	2746	2315	1860	**1471**
48	**2773**	**2334**	**1863**	1462
72	2087	1753	1388	1062

The design flows also indicate that the March 1978 flood at Gostwyck has a peak flow less than the 10% AEP event. To check the validity of these design flows a flood frequency analysis on historical flow records at Gostwyck was carried out and is presented in the next section.

Areal Reduction Factor

Hydrologic model runs were also carried out with the application of an areal reduction factor. The areal reduction factor takes into account the unlikelihood that larger catchments will experience rainfall of the same design intensity (eg 1% AEP) over the entire area. The selection of the factors have been based on that provided in AR&R, Figure 2.6 for a catchment area of around 1000km^2.

Table 5.4 presents the revised peak flows for the 24, 36 and 48 hour durations. The areal reduction factor was applied directly to the rainfall intensity.

Table 5.4 Design Flood Flows with Areal Reduction Factor

Duration (h)	Reduction Factor	Peak Flow (m^3/s) with Areal Reduction Factor			
		1%	2%	5%	10%
24	0.92	2052	1718	1363	1068
36	0.93	2472	2080	1666	1313
48	0.94	**2534**	**2124**	**1692**	**1324**

5.2.2 Flood Frequency Analysis

A flood frequency analysis was carried out to provide an alternative assessment of peak design flood flows at Gostwyck. The annual series analysis method was adopted as recommended in AR&R. This approach takes the peak recorded flow for each year of records to produce estimates of flows for different AEPs.

The stream flow gauge at Gostwyck has records for the years 1928 to 1946 and 1969 to 1995, a total of 46 years. During these periods three separate gauge locations were used all within 2.5km of each other. No complete records were available for the period 1947 to 1968.

After examination of the data it was clear that there were inconsistencies between the three gauges (see Section 12 for more details). These inconsistencies were largely resolved by:

- re-surveying the datums of the gauge boards at each site;
- developing approximate correlations between the gauge's height and Gostwyck Bridge; and
- developing a common rating curve at Gostwyck Bridge.

A reliable flood frequency analysis was then possible now that all records were consistent with each other, ie. they are based on the same rating curve and the recorded flood levels are all to the same datum.

A series of curves were produced based on the full 46 years of data. Two flood frequency curves were used to help derive representative peak design flood flows at Gostwyck:

- Annual series analysis based on all 46 years of data (Skew of -0.3).
- Annual series analysis based on all 46 years of data (Skew of -0.5).

The results of these scenarios are presented in the next section and in Section 12.

5.2.3 Adopted Design Flood Flows at Gostwyck

The design flood flows at Gostwyck were determined on the basis of an assessment of the results from the hydrologic model using AR&R design rainfall and the flood frequency analysis (see previous sections).

In deriving the peak flow, the following were taken into consideration:

- the flood frequency analysis has more weight for more frequent events such as the 10% AEP flood; and
- there is much greater uncertainty for the rarer events such as the 1% AEP flood thereby necessitating a more cautious assessment for these events.

Table 5.5 presents the peak flows from the hydrologic model and the flood frequency analysis along with the adopted flow.

Table 5.5 Adopted Design Gostwyck Flood Flows

	Design Flood Peak Flow (m^3/s)			
Case	**1%**	**2%**	**5%**	**10%**
Hydrologic Model	2773	2334	1863	1471
Hydrologic Model with Areal Reduction	2534	2124	1692	1324
FFA (Skew=-0.3)	2850	2210	1500	1050
FFA (Skew=-0.5)	2380	1930	1390	1010
Adopted	**2500**	**2050**	**1450**	**1050**

The shape of the Gostwyck Bridge flood hydrograph was based on the equivalent 36 hour AR&R duration storm.

For the side tributaries flowing into the Paterson River downstream of Gostwyck Bridge the 36 hour hydrograph was also adopted and factored in the same manner. Table 5.6 presents the 1% AEP peak inflows for the major creeks and other minor creeks.

Table 5.6 Side Tributaries' Peak Design Flood Flows

Tributary	1% AEP Design Flood Peak Flow (m^3/s)
Total of Inflow Peaks from Gostwyck Bridge to Paterson	211
Webbers Creek	323
Dunns Creek	51
Green Wattle Creek	113
McClement Swamp	68
Total of other Inflows to Paterson River's Eastern Floodplains	46
Total of other Inflows to Paterson River's Western Floodplains	124

5.3 Combining Paterson & Hunter River Floods

The Paterson River floodplains within the Study Area experience flooding from two main sources:

- A flood in the Paterson River.
- A flood in the Hunter River causing waters to back up into the Paterson and on to the floodplains.

In combining these flood sources there are two key considerations:

- their relative magnitudes and
- their relative timing.

Relative Magnitudes of Flood Sources

The magnitude of each flood source is determined independently using statistical analyses. Therefore, using the 1% AEP flood as an example, it is not statistically correct to represent the 1% AEP design flood as the combination of a 1% AEP Paterson River flood and a 1% AEP Hunter River flood. The probability of both sources occurring, each with a 1% AEP magnitude, has a lower probability than the 1% AEP event (for example, it may be a 0.5% AEP event).

On the other hand, it is very unlikely that one of the flood sources occurs without the other occurring to some (lesser) degree, as historical evidence indicates.

As yet, there is no definitive answer on how to combine the magnitudes of the three sources.

This issue is examined in Ref 9 which concluded to "arbitrarily adopt a slightly lower frequency of occurrence on the Paterson River to that on the Hunter River for design".

For this study, it was decided to adopt the combinations shown in Table 5.7, based on the approach adopted in the previous studies and on discussions with DLWC officers. For example, the 1% design flood is made up of two floods:

- A 1% AEP Paterson River flood combined with a 2% AEP Hunter River flood.
- A 1% AEP Hunter River flood combined with a 2% AEP Paterson River flood.

Sensitivity testing was also carried out to clarify the importance of the relative magnitudes of the Paterson and Hunter flood waves (see Section 13.2).

Table 5.7 Design Flood Matrix

Paterson River Flood	Hunter River Flood				
	PMF	**1%**	**2%**	**5%**	**10%**
Extreme		Extreme			
1%	Extreme		1% AEP[1]		
2%		1% AEP[1]		2% AEP	
5%			2% AEP		5% AEP
10%				5% AEP	

[1] For example, the 1% AEP flood is made up of two floods: a 1% Paterson combined with a 2% Hunter; and a 1% Hunter combined with a 2% Paterson.

Relative Timing of Flood Sources

The likelihood of both a Paterson River and Hunter River flood peaking together is very improbable given the different sizes of the catchments and length of the rivers. As would be expected and as history has shown, the Paterson typically peaks before the Hunter at their confluence.

Examination of the records has given best estimates for the relative lag of the Hunter River (at Oakhampton) compared to the Paterson River (at Gostwyck), as 15 hours (Ref 7) and 12 hours (Ref 9).

Given the more recent nature of Ref 9, a 12 hour lag was adopted for the design floods. Sensitivity tests were carried out to test the importance of the magnitude of the lag (see Section 13.2).

Hydraulic Model Peak Boundary Values

Table 5.8 presents the different design flood peak flows and levels for the hydraulic model's boundaries.

For the extreme flood at Gostwyck Bridge it was required that the flows be based on three times that of the 1% AEP flood (Ref 5).

Table 5.8 Peak Boundary Values for Design Floods

Flood Source	**1%**	**2%**	**5%**	**10%**	**Extreme**
Flow Boundaries:	**Peak Flow (m^3/s)**				
Paterson River (Gostwyck)	**2,500**	**2,050**	**1,450**	**1,050**	**7,500**
Hunter River (~2km upstream Morpeth)	2,280	1,940	1,910	1,890	5,830
Hunter River (Northern Floodplain)	1,810	990	360	0	10,890
Hunter River (Southern Floodplain - Raworth Control)	950	510	390	230	5,580
Hunter River (Southern Floodplain - downstream Howes Lagoon)	840	590	550	550	2,510
Hunter River plus Floodplains[1] (~2km upstream Morpeth)	**5,630**	**3,980**	**3,190**	**2,580**	**24,700**
Water Level Boundaries:	**Peak Level (mAHD)**				
Hunter River (Downstream model boundary)	5.2	4.6	4.3	4.1	6.7

[1] Peak discharge based on maximum instantaneous peak of combined river and floodplain flows.

6 PRESENTATION OF RESULTS

6.1 General Approach

This section presents the results of the hydraulic modelling of the design floods. The presentations are designed to provide a simple and clear picture of the study's findings.

Shown on each map are one or more layers of GIS data provided by Port Stephens Council or digitised for this study. The layers enhance their visual appearance and provide a more rapid appreciation of location and scale. The layers presented are:

- cadastral (ie. property boundaries);
- river and creek lines;
- 10 and 20m contours - these layers were digitised from the 10 and 20 m contour lines on the 1:25,000 topographic maps and should not be interpreted as the limit of flooding or as the exact location of the 10 and 20 m height bands.

6.2 Interpretation of Results

The interpretation of the maps and other presentations in this report should be done so with an appreciation of any limitations in their accuracy. While the points below highlight these limitations, it is important to note that the results presented provide an up-to-date reliable and accurate prediction of design flood behaviour. Points to remember are:

- Recognition that no two floods behave in exactly the same manner.
- Design floods are a **best estimate** of an "average" flood for their probability of occurrence (see discussion on "Uncertainty in Design Flood Levels" below).
- The ground contours used to generate the DTM have an order of accuracy of ±0.2 to 0.5m depending on the density of vegetation and other factors. Flood depths and flood extents, which are determined from the DTM, should be interpreted accordingly.
- Approximations are made by computer software in processing raw data.

Uncertainty in Design Flood Levels

All design floods are based on statistical analyses of **recorded** data such as rainfall and flood levels. The longer the period of recordings, the greater the certainty. For example, derivation of the 100 year ARI (1% AEP) rainfall from 5 years of recordings would have a much greater error margin than from 100 years of recordings.

Similarly, the accuracy of the hydrologic and hydraulic computer models is dependent on the amount and range of reliable rainfall and flood level recordings for model calibration. An uncalibrated model's results have a greater error margin than a calibrated model. However, by using standard model parameters and carrying out sensitivity tests which vary these parameters within conventional bounds, an uncalibrated model can still be used with confidence by experienced modellers.

The error margin in this study is regarded as moderate due to:

- a reasonable amount of rainfall and flood level data;
- calibration and verification of the both hydrologic and hydraulic models to three historical events; and
- the model parameters being generally typical of those used elsewhere.

Data which would significantly reduce the error margin are:

- continued long-term collection of rainfall and river flood levels (more gauge sites would always be beneficial);
- peak flood levels on the floodplain (the installation of peak flood height recorders is relatively inexpensive);
- peak flood levels upstream, downstream and along major river bends - there is a shortage of good data for determining additional head losses because of sharp river bends (see discussion on bend losses in Section 11.3.2; and
- stream flow gauging during flood time.

Until a longer period of data exists and more floods occur from which to check the accuracy of the hydrologic and hydraulic models, the error margin will remain unchanged.

What is meant by "peak"?

Unless otherwise stated, presentations in this report are based on peak values of flood level, velocity and flow. Therefore, using flood levels as an example:

- the peak level does not occur everywhere at the same time and therefore the values presented are based on taking the maximum which occurred at each computational point in the model during the entire flood;
- therefore, a presentation of peak levels does not represent an instantaneous point in time, but rather an envelope of the maximum values which occurred;
- in some areas the peak level is caused by the Paterson River flood while in others by the Hunter River flood.

6.3 Design Flood Levels

Table 6.1 shows the peak design flood levels at selected locations. For more detailed presentations showing the peak flood levels, flows and velocities in map format see Section 13.

Table 6.1 Peak Design Flood Levels at Selected Locations

	Design Flood Level (mAHD)				
Location (see Figure 1.1)	**1%**	**2%**	**5%**	**Extreme**	**MIKE 11 Point[1]**
Gostwyck Bridge	18.1	17.1	15.4	25.6	PATERSON 78.500
Paterson River, "Gostwyck"	17.2	16.2	14.5	24.8	PATERSON 80.500
Paterson River, "Tillimby"	15.5	14.5	13.0	22.9	PATERSON 82.660
Paterson Railway Bridge	14.1	13.2	11.8	20.9	PATERSON 85.300
Paterson Road Bridge	11.1	10.6	10.0	15.0	PATERSON 88.300
Paterson River, "Stradbroke"	10.1	9.6	8.7	13.7	PATERSON 92.900
Floodplain north of "Stradbroke"	10.5	10.0	9.2	13.9	PATERSON_LB 92.200
Floodplain south of "Stradbroke"	9.1	8.7	8.0	12.2	PATERSON_LB 93.600
Floodplain, Mindaribba	7.4	6.9	5.4	10.8	PATERSON_RB 97.500
Floodplain, Iona	7.4	6.8	6.3	10.8	PATERSON_LB 98.900
Paterson River, Woodville	7.4	6.9	6.4	10.8	PATERSON 100.000
Floodplain north of Dunmore House	7.40	6.9	4.6	10.8	PATERSON_RB 99.300
Floodplain between Woodville & Scotts Dam	7.3	6.8	6.3	10.8	PATERSON_LB 101.450
Floodplain north-east of Largs	7.4	6.8	6.3	10.8	PATERSON_RB 100.900
Paterson River, Scotts Dam	6.9	6.5	6.1	9.9	PATERSON 105.480
Paterson River, Hinton	6.7	6.3	6.0	9.7	PATERSON 107.000
Floodplain, Hinton	6.4	5.6	5.0	9.3	PATERSON_LB 105.300
McClement Swamp	6.1	5.4	4.9	8.6	MCCLEMENT_FP 10.000
Floodplain, "Hinton Vale"	6.1	5.4	4.9	8.6	MCCLEMENT_FP 13.500

[1] Computational point identifier in the MIKE 11 hydraulic model.

6.4 1% AEP Flood Levels for Development Controls

Port Stephens, Dungog and Maitland Councils require guidance on appropriate flood levels for development controls within the floodplain. For example, minimum fill levels are typically based on the 1% AEP design flood level, while minimum floor levels are based on the minimum fill level plus an additional freeboard (typically 300 to 500mm).

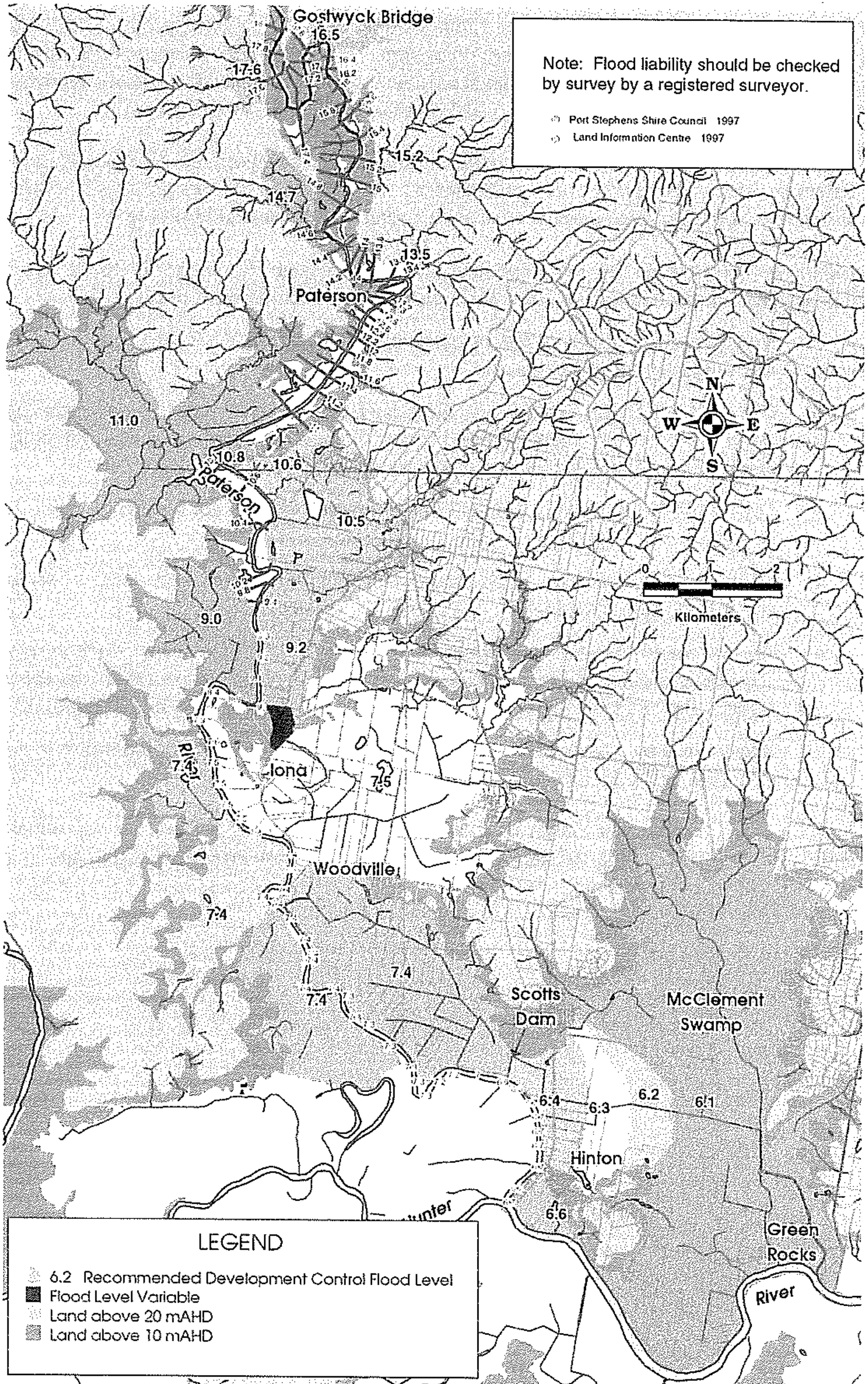
Based on discussions with Council officers and due to the hydraulic characteristics of the Paterson River floodplains, the presentation of the 1% AEP design flood levels was simplified by identifying zones or areas with a relatively "constant" flood level.

Figure 6.1 illustrates the recommended 1% AEP design flood levels to be used for development controls. Interpretation of the flood levels should be as follows:

- River levels are determined by interpolating between the nearest levels upstream and downstream of the location.
- On the floodplains flood levels have been assigned to zones as indicated by the flood level within each coloured area. The flood level shown is typically the maximum level calculated in the area rounded up to one decimal place.
- For floodplain levels not included in a coloured area, the adjacent river level should be used.
- From Gostwyck Bridge to Paterson flood contours have been used to determine appropriate flood levels.
- Areas marked "Flood Level Highly Variable" are overland areas which experience a steep hydraulic grade and flood levels will be highly dependent on the local topography and flow patterns. It is recommended to err on the side of caution.
- Areas close to overtopped levees may experience localised and complex hydraulic effects possibly leading to higher flood levels.

It is important to note that the levels presented in Figure 6.1 are for present day conditions and could possibly change substantially if actions such as lowering of Scotts Dam or other major works were carried out.

Figure 6.1 1% AEP Flood Levels for Development Controls



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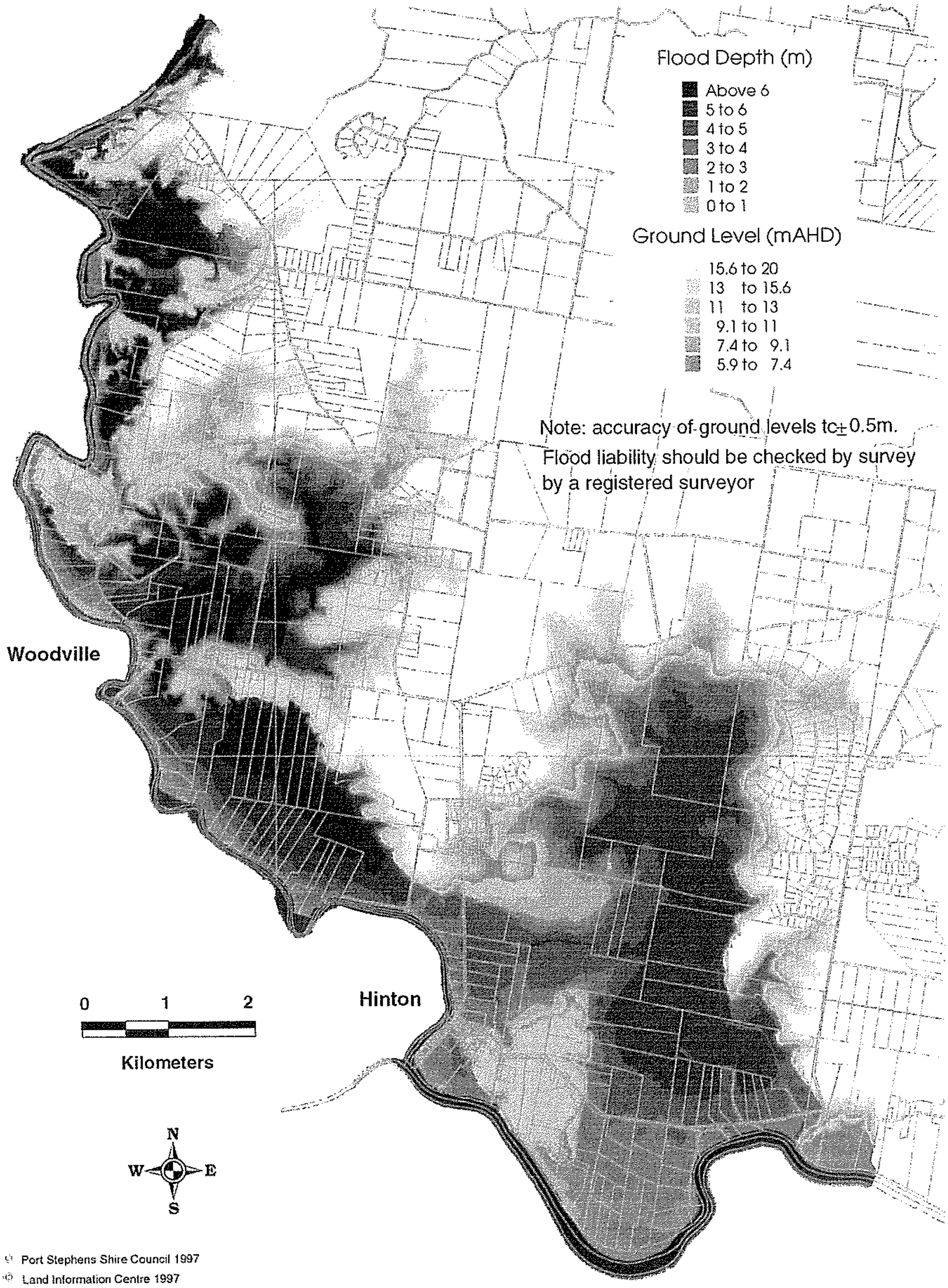
6.5 Flood Depths & Flood Extent

Flood depth maps and the extent of flooding were determined by subtracting the ground levels of the DTM from the flood levels of the 3D flood surface (see Section 14). The end result is a 3D flood depth surface where positive values indicate the depth of flooding and negative values indicates the ground remained flood-free. The zero contour line of the surface represents the estimated extent of inundation.

The 3D flood depth surface was modelled as a TIN using the same resolution and triangulation as that used for the DTM.

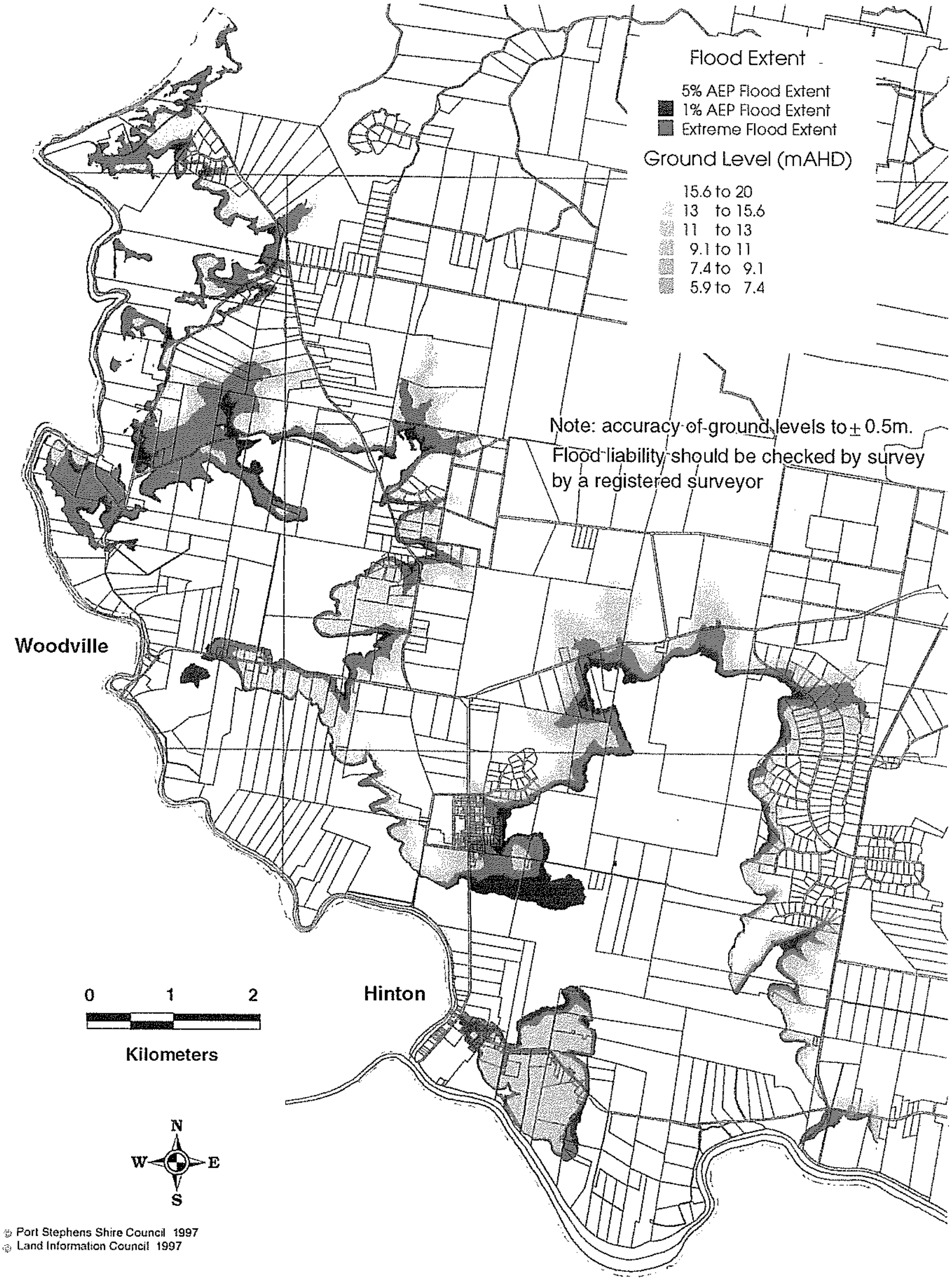
Figure 6.2 shows the flood extent and the depth of flooding in 1m intervals for the area covered by the DTM. Figure 6.3 shows the flood extents for the extreme, 1% AEP and 5% AEP floods.

Figure 6.2 1% AEP Flood Depth & Extent Map



Note: accuracy of ground levels to ±0.5m. Flood liability should be checked by survey by a registered surveyor

Figure 6.3 Extreme, 1% AEP and 5% AEP Flood Extents



Note: accuracy of ground levels to ± 0.5m. Flood liability should be checked by survey by a registered surveyor

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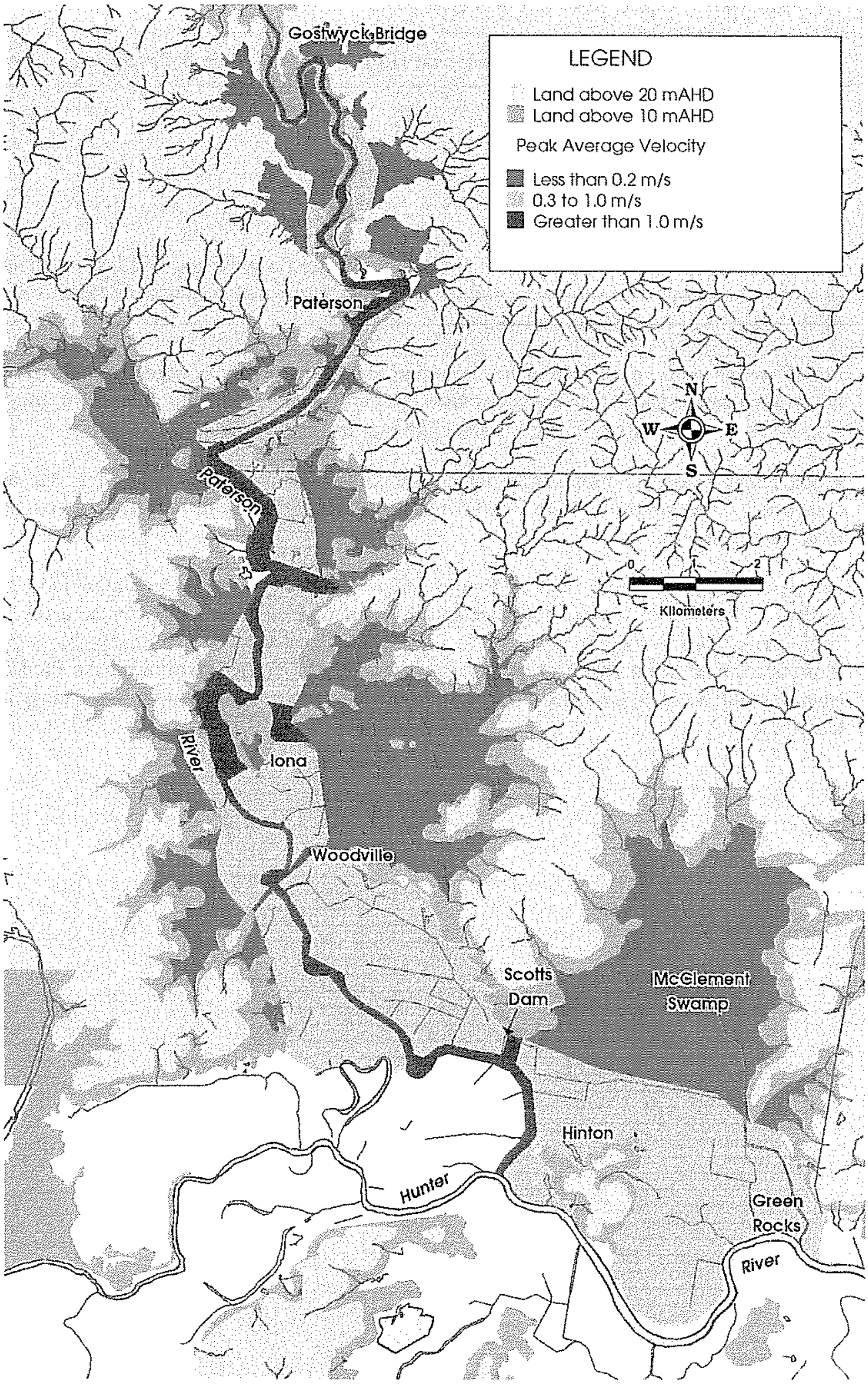
6.6 Flood Velocities

Figure 6.4 shows the peak flood velocities for the 1% AEP flood likely to be experienced over the floodplains and down the river. The figure does not show any localised (high) velocities which occur from obstructions, during overtopping of levees, etc. The velocities shown are indicative of the average water velocity across the river or floodplain.

Figure 6.4 Peak Flood Velocities



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6.7 Provisional Hydraulic Categories

The NSW Floodplain Development Manual (Ref 6) defines three hydraulic categories for flood liable land:

- floodway;
- flood storage and
- flood fringe.

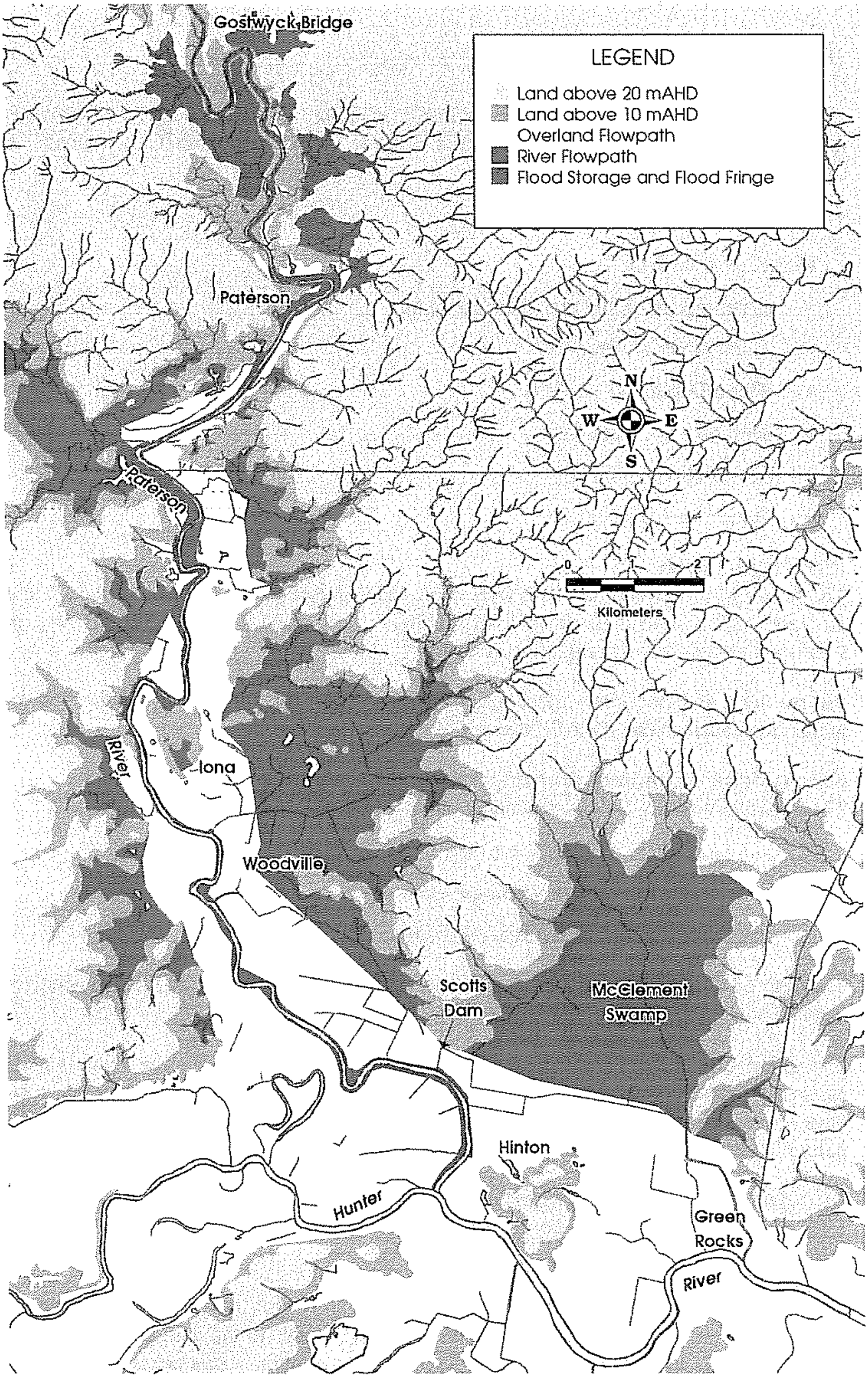
Floodways are areas where a significant volume of water flows during flood time. Blockage or partial blockage of a floodway will cause a significant redistribution of flows which is likely to have adverse effects elsewhere.

Flood storage areas are those that are important for the temporary storage of flood waters. If the storage capacity of these areas is reduced, by either embankments or land fill, they will also cause a redistribution of flood waters and may adversely effect other areas.

Flood fringe areas are those areas which are flood prone but do not fall into the above categories. Development within flood fringe areas will generally have little or no impact on flooding elsewhere.

Figure 6.5 presents provisional hydraulic categories. The flood storage and flood fringe categories have been lumped together as differentiation of these areas can be a relatively complex exercise subject to criteria on what constitutes an unacceptable impact. Identification of flood fringe areas would most likely be carried out during the Floodplain Management Study (see Figure 1.2) under the guidance of the Floodplain Management Committee.

Figure 6.5 Provisional Flood Hydraulic Categories



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6.8 Provisional Hazard Categories

6.8.1 *Defining the Flood Hazard*

The flood hazard or risk is based on a number of factors listed and described below. For a more detailed discussion refer to Appendix B of the NSW Floodplain Development Manual (Ref 6).

The factors influencing flood hazard are:

- Size of the Flood
- Rate of Rise - Effective Warning Time
- Community Awareness
- Flood Depth and Velocity
- Duration of Inundation
- Obstructions to Flow
- Access and Evacuation

Size of the Flood

The severity of the flood hazard is largely related to the relative size of the flood. The more frequent, minor flood is associated with relatively low flood hazards while the rare, major floods are associated with high flood hazards.

For planning and floodplain management purposes, flood hazards are normally based on a major flood such as the 1% AEP event.

Rate of Rise - Effective Warning Time

The effective warning time is dependent on:

- the rate at which floodwaters rise;
- efficiency of the flood warning system and
- awareness and promptness of the community to act.

The rate of rise is primarily related to the catchment size, but is also influenced by the catchment slope, soil types and land use.

In a small catchment floodwaters will rise and peak not long after the rainfall and will subside quickly. Larger catchments respond more slowly with the flood peaks occuring days or weeks after the rainfall event. Urbanised catchments will respond more quickly than naturally vegetated catchments.

The effective warning time for smaller catchments is typically under an hour while for larger catchments it may be several days or even weeks.

Community Awareness

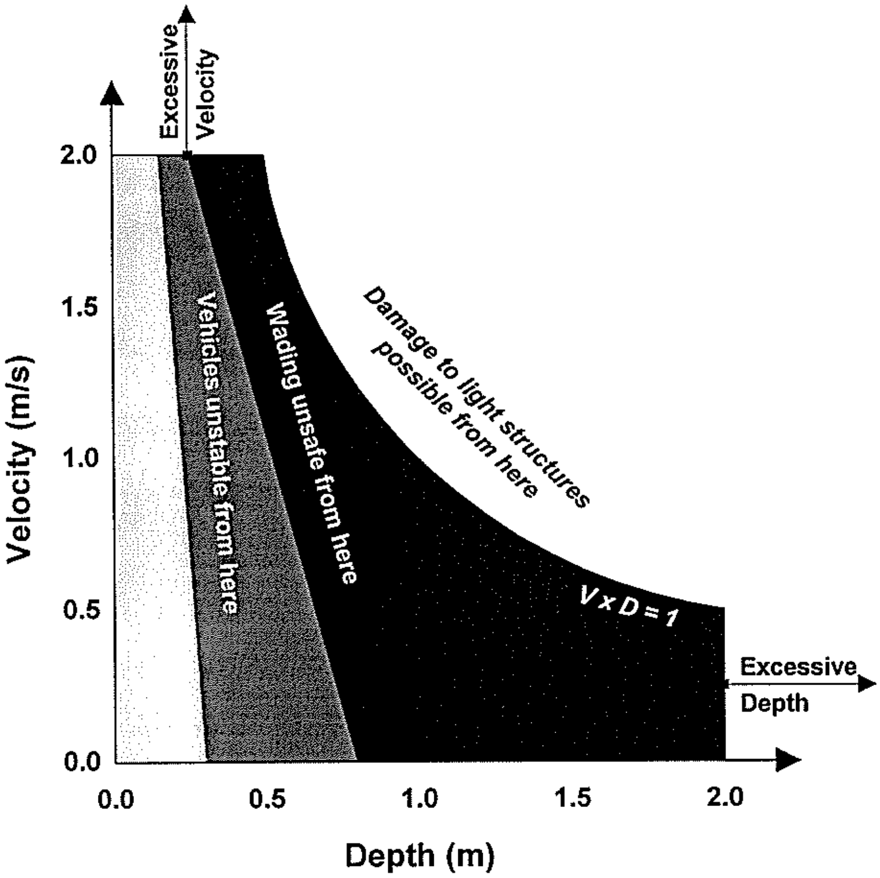
The flood awareness of the community is an important factor in minimising flood damages and social disruption. An "aware" community will be wise to the dangers of flooding and, where possible, safeguard possessions. The level of community awareness is also related to past experience, and will usually be low if there has not been a flood in recent times.

Flood Depth and Velocity

The flood hazard level is often determined on the basis of the predicted flood depth and velocity. A high flood depth will cause a hazardous situation while a low depth may only cause an inconvenience. High flood velocities are dangerous and may cause structural damage while low velocities have no major threat.

The multiplication of depth and velocity gives a convenient measure of flood hazard. A small depth and small velocity gives a low hazard while a high depth and high velocity gives a larger value and a high hazard. Figure 6.6 illustrates velocity depth relationships as presented in the NSW Floodplain Development Manual (Ref 6) while Figure 6.7 presents the graph used for allocating provisional flood hazards.

Figure 6.6 Velocity Depth Relationships (Ref 6, p38)



Velocity Depth Relationships

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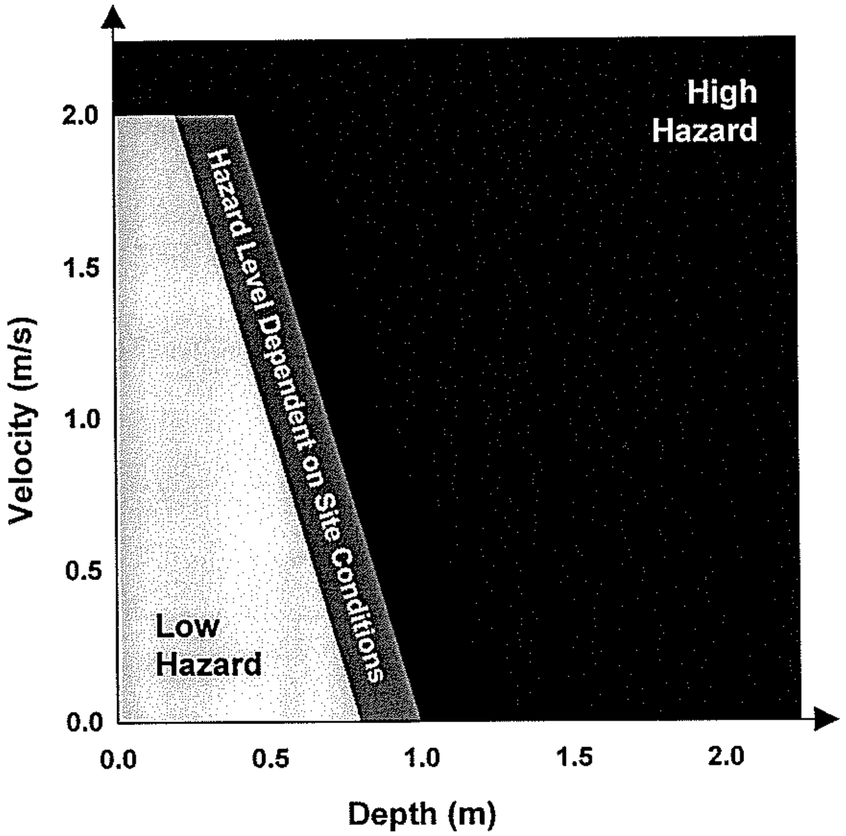
Figure 6.7 Provisional Hazard Categories (Ref 6, p38)



Provisional Hazard Categories

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Duration of Inundation

The greater the duration of flood inundation the greater the impacts on damages (particularly agricultural damages) and the disruption to the community. In areas where floodwaters take days or even weeks to recede the disruption to services and supplies, loss of commercial business, increased stress and anxiety and loss or damage to livestock and crops can be greatly exacerbated.

The duration of inundation is closely related to the duration and size of the flood in the river or creek. However, floodplains can experience prolonged inundation if the drainage from the floodplain to the river is poor.

Obstructions to Flow

Obstructions to flow cause localised increases in velocities and therefore increase the flood hazard. This can be particularly acute in urban areas where flow velocities between buildings can be high.

Access and Evacuation

Damages resulting from a flood may be exacerbated if access is difficult and evacuation is hampered because of:

- high depths and velocities along access routes;
- problems associated from wading (uneven ground, obstructions such as fences);
- distance to flood-free ground;
- number of people and vehicular capacity of evacuation route;
- inability to contact evacuation or emergency services;
- unavailability of suitable equipment (boats, heavy trucks, etc) and
- Poor community awareness of evacuation procedures.

6.8.2 Provisional Flood Hazard Map

Figure 6.8 presents a provisional flood hazard map based on the velocity and depth conditions in Figure 6.7. For simplicity, the high hazard category on Figure 6.8 includes the "grey" area between low and high hazard in Figure 6.7.

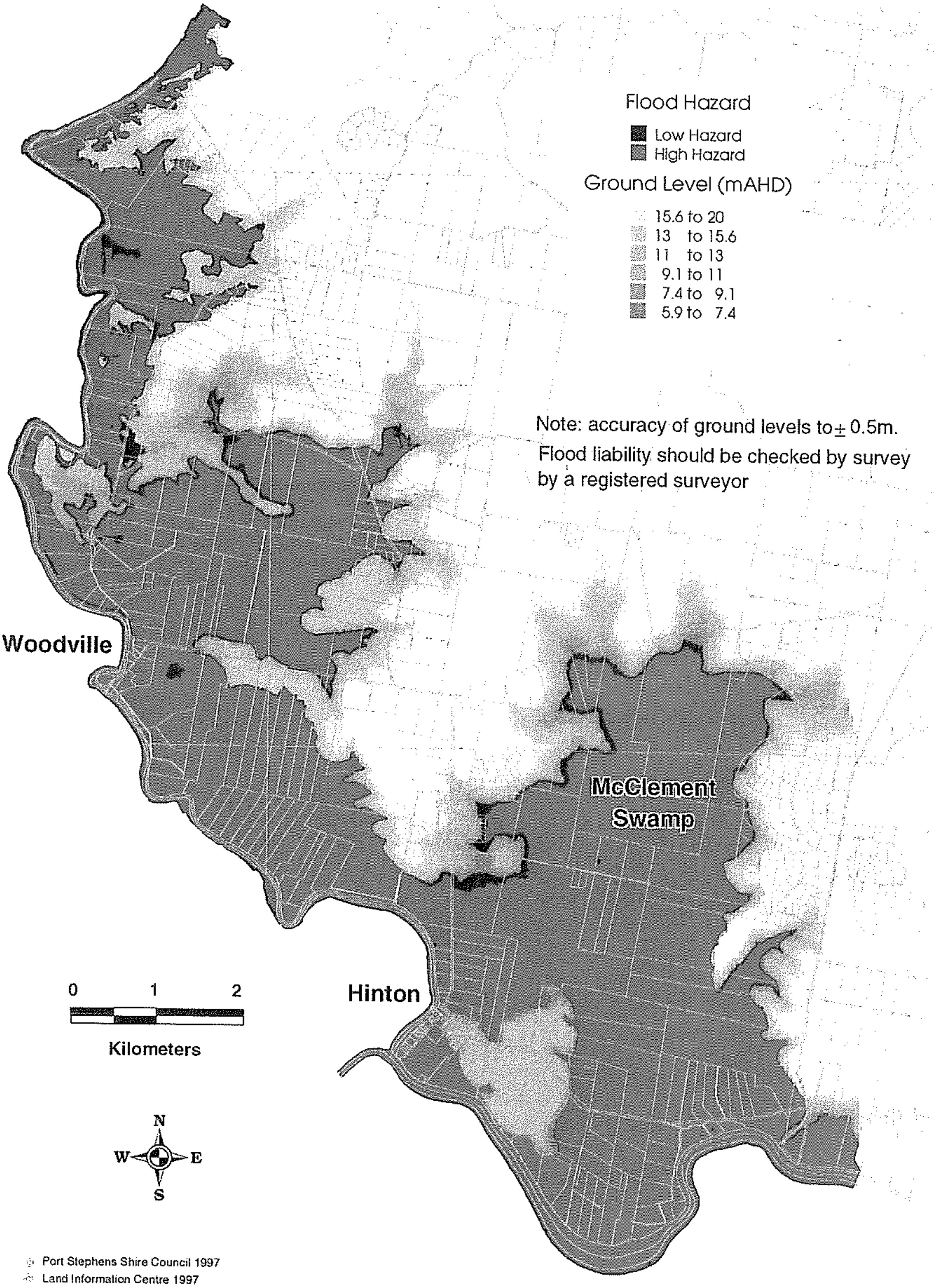
The hazard map has been based on the hydraulic model results for the 1% AEP design flood. On the floodplains the hazard is almost entirely depth controlled as much of the depth of inundation is greater than two metres.

The map does not and can not depict localised high hazard areas because of:

- obstructions to flow causing high localised velocities;
- or along minor creeks and drains where excessive depths occur.

The map provides a preliminary overview of the general flood hazard for planning and decision making purposes.

Figure 6.8 Provisional Flood Hazard Categories



Note: accuracy of ground levels to ± 0.5m. Flood liability should be checked by survey by a registered surveyor

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7 ACKNOWLEDGMENTS & REFERENCES

7.1 Acknowledgments

This study was jointly funded by the NSW Government, Port Stephens Council, Maitland City Council and Dungog Council. The study was undertaken by WBM Oceanics Australia on behalf of Port Stephens Council.

In completing this report, WBM Oceanics Australia has been assisted by advice and information from the Port Stephens Council, Maitland City Council, Dungog Council, The Department of Land and Water Conservation, The Bureau of Meteorology and Manly Hydraulics Laboratory, and residents of the Paterson River area.

7.2 References

Ref 1 **Bradley, J.N. (1978)** *Hydraulics of Bridge Waterways* U.S. Department of Transportation, Second Edition, March 1978

Ref 2 **DHI (1995)** *MIKE 11 Version 3.11 Reference Manual* 1st Edition, 1995, Danish Hydraulic Institute

Ref 3 **FPCO (1994)** *Flood Management Model - Final Report Volumes I & II* Flood Plan Coordination Organisation (FPCO), Bangladesh. Report by Danish Hydraulic Institute and others, October 1994

Ref 4 **IEAust (1987)** *Australian Rainfall and Runoff* Institution of Engineers, Australia, 1987

Ref 5 **PSC (1996)** *Brief for Paterson River Flood Study* March 1996, Port Stephens Council

Ref 6 **PWD (1986)** *Floodplain Development Manual* PWD 86010, ISBN 724030115, December 1986, NSW Government

Ref 7 **PWD (1990)** *Lower Hunter Valley Flood Study (Oakhampton to Green Rocks)* PWD 89014, ISBN 073055, March 1990, NSW Government

Ref 8 **PWD (1993)** *Compendium of Data - Lower Hunter Valley Supplementary Flood Study (Oakhampton to Green Rocks)* June 1993, Report by Webb, McKeown & Associates Pty Ltd for PWD, NSW Government

Ref 9 **PWD (1994)** *Draft Lower Hunter Valley Supplementary Flood Study (Oakhampton to Green Rocks)* September 1994, Draft Report by Webb, McKeown & Associates Pty Ltd for PWD, NSW Government

Ref 10 **Sinclair Knight & Partners (1981)** *Hunter Valley Flood Plain Management Study* New South Wales Coastal Rivers Flood Plain Management Studies, 1981

Ref 11 **WPS (1994)** *RAFTS-XP User Manual* WP Software, 1994

8 APPENDIX A: AVAILABLE DATA

The following data were identified and used during the course of the study:

- 1:25,000 topographic maps.
- 1:100,000 topographic maps.
- Rainfall data for historic events from the Bureau of Meteorology. The availability of the data is shown in Table 8.1.
- Stream flow data for historic events from the Department of Land and Water Conservation (originally Department of Water Resources). The availability of the data is shown in Table 8.1.
- Flood level data for historic events from the Department of Land and Water Conservation (variety of sources).
- Aerial photography for producing the photogrammetric contours.
- MIKE 11 model data from the Hunter River model. The MIKE 11 Hunter model was supplied by Department of Land and Water Conservation.

Table 8.1 Availability of Rainfall and Stream Flow Records

Pluviograph Recorder	1971	1972	1977	1978	1985	1990	1995
Upper Allyn			x	x		x	x
Lostock	x	x	x	x			
Tocal			x	x			
Halton							x
Gresford						x	x
Streamflow							
Gostwyck			x	x	x	x	x
Lostock	x	x	x		x	x	x
Halton	x	x	x	x	x	x	x
Lostock Dam Storage							x
Daily Rainfall							
Paterson	x	x	x	x	x	x	
Lostock Dam	x	x	x	x	x	x	
Upper Allyn						x	x
Tocal	x	x	x	x			
Halton							x
Gresford						x	x

9 APPENDIX B: HISTORICAL FLOOD SURVEY RESULTS

The 88 responses received during the survey were collated and entered into a GIS database. The responses have been handed over to Port Stephens Council for their records along with some eighty copies of photos kindly loaned during the survey. Figure 9.1 shows some flood patterns noted during discussions with residents on flooding of the Woodville area (see discussion in Section 4.6.1)

Table 9.1 presents the historical flood levels surveyed after identification of the flood marks along with flood levels collected from other sources.

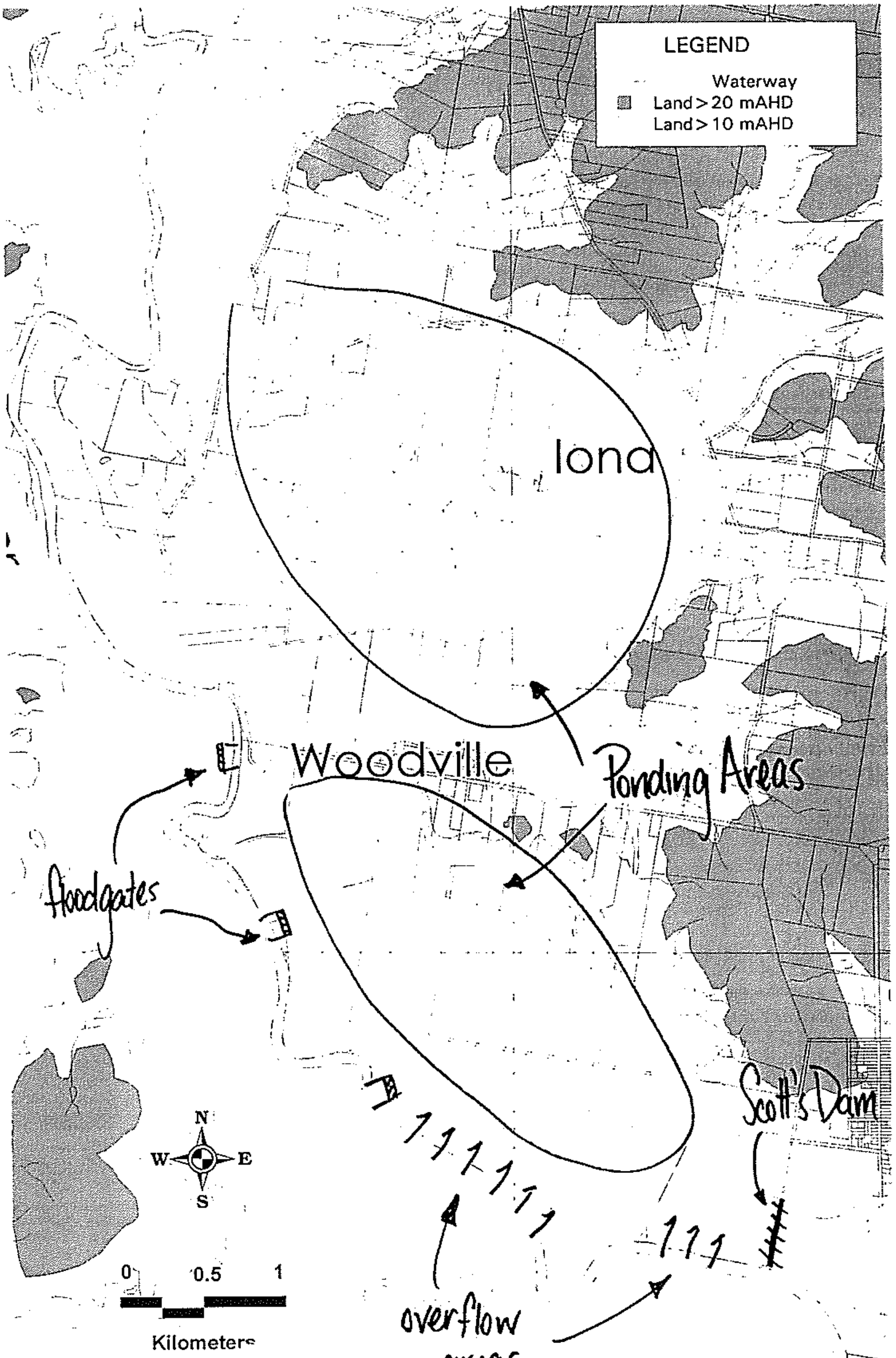
Table 9.1 Flood Height Survey Results

ID	Easting	Northing	Flood Level	Accuracy (m)	River or Floodplain	Flood Year	Description of Mark	Source
1	363652.41	1377291.31	6.29	± 0.02	Floodplain	1955	Mark cut into hayshed post showing peak water height of 1955 flood.	CRH Survey for WBM
2	363591.21	1377328.76	6.33	± 0.02	Floodplain	1955	P.W.D. flood marker on powerpole near Gordon Gibbs' hayshed.	CRH Survey for WBM
3	362300.52	1378205.84	3.82	± 0.1	Floodplain	Most floods 1970's onward	Water rises about 0.1 above the dam wall in most floods.	CRH Survey for WBM
4	362384.76	1378466.89	3.81	± 0.1	Floodplain	Most floods 1970's onward	Water reaches change in grade on the side of the hill and generally goes no further.	CRH Survey for WBM
5	362296.51	1378670.90	3.91	± 0.1	Floodplain	Most floods 1970's onward	Water goes over the spillway of this Dam.	CRH Survey for WBM
6	360558.03	1379043.91	7.36	± 0.02	Just on the edge of the levee	1955	Brian Moran estimates that flood height was 6' 6" (1.98) above floor level of old "Federation Style" house.	CRH Survey for WBM
7	360716.67	1378748.79	6.98	± 0.02	Floodplain	1955	P.W.D. 1955 flood mark on power pole.	CRH Survey for WBM
8	360734.77	1378740.82	7.18	± 0.04	Floodplain	1955	Watermark on cardboard in window of workshop.	CRH Survey for WBM
9	361924.87	1379073.73	4.64	± 0.05	Floodplain	1990, 1992	Water just reaches the top of the fence in the "Hayshed" paddock.	CRH Survey for WBM
10	354763.52	1384079.20	5.45	± 0.02	Floodplain	1978	Mark painted on culvert under railway line, origin unknown, possibly the S.R.A.	CRH Survey for WBM
11	355880.32	1383763.54	7.63	± 0.05	Floodplain	1955	Watermark on concrete silos.	CRH Survey for WBM
12	356303.82	1383573.85	7.50	± 0.05	Floodplain	1955	Greg Cook's house has been raised to be just above the 1955 flood level. House is very close to levee bank.	CRH Survey for WBM
13	0.00	0.00	6.39	± 0.05	Floodplain	1972	Flood came to the top of right levee No. 7.	CRH Survey for WBM
14	356612.20	1382487.37	6.47	± 0.02	Floodplain	1972	Cross bar of clothes line.	CRH Survey for WBM
15	356602.27	1382478.96	8.65	± 0.1	Floodplain	1955	14' (4.265) up power pole.	CRH Survey for WBM
16	356631.68	1382494.40	7.04	± 0.05	Floodplain	1978	On road on the line between sign post and orange tree.	CRH Survey for WBM
17	357101.76	1383047.68	7.47	± 0.02	Floodplain	1955	P.W.D. 1955 flood marker on power pole near Woodville Church.	CRH Survey for WBM
18	0.00	0.00	6.90	± 0.1	River	Most Paterson River floods	Most Paterson River floods are contained within the levee banks near Cliff Hicks' fruit stall, generally 0.3 m below the top level of the levee bank.	CRH Survey for WBM
19	356883.25	1383526.43	7.61	± 0.05	Floodplain	1955	Flood was level with the roof of galvanised iron shed.	CRH Survey for WBM
20	356918.16	1383504.62	6.27	± 0.02	Floodplain	1971, 1972, 1977, 1978, 1985, 1990	½" (0.013) above concrete brick fence is equilibrium flood height for most floods. When water reaches this point, it is flowing 0.3 above Scotts Dam.	CRH Survey for WBM
21	356479.18	1383643.07	6.05	± 0.02	Floodplain	1989	Flood level was 1 m below floor level.	CRH Survey for WBM
22	356935.85	1386042.75	6.68	± 0.1	Floodplain	General flood level including 1955	Low point on ground between rises.	CRH Survey for WBM
23	356772.00	1387295.61	9.20	± 0.05	On southern end of left levee No. 4	1990	Water level with third rail of gate used to gain access to left levee No. 4.	CRH Survey for WBM

ID	Easting	Northing	Flood Level	Accuracy (m)	River or Floodplain	Flood Year	Description of Mark	Source
24	357242.09	1386926.28	9.67	± 0.05	Floodplain	1989	0.05 below road at pipe crossing.	CRH Survey for WBM
25	357622.35	1390644.94	10.46	± 0.02	Floodplain	1978	Mark carved in side of weatherboard shed.	CRH Survey for WBM
26	357527.29	1390061.18	10.90	± 0.5	Floodplain	1978	1978 flood reached fig tree. Level taken on natural bank near fig tree. Large side slope so 1978 flood level could be lower than 11.11.	CRH Survey for WBM
27	357236.03	1389852.75	10.00	± 0.02	River	1978	Stump of small Coral tree.	CRH Survey for WBM
28	357234.28	1389927.46	10.00	± 0.02	River	1978	Half way up pump control box.	CRH Survey for WBM
29	0.00	0.00	10.00	-	River	1978	Generally about 1.0 m above left levee No. 5 in the region of the "Tocal Bend".	CRH Survey for WBM
30	358724.93	1391564.46	10.87		River	1990	Metal peg in ground	Second CRH Survey for WBM
31	357559.64	1391841.47	11.11		River	1946	Groove cut in rock	Second CRH Survey for WBM
32	357550.98	1391852.31	11.93		River	1978	Groove cut in rock	Second CRH Survey for WBM
33	357305.41	1392663.33	12.32		River	1978	3" to 6" above floor level of shed (+/- 0.05m)	Second CRH Survey for WBM
34	356275.25	1394486.79	14.41		River	1978	2" above fence post (+/- 0.05m)	Second CRH Survey for WBM
35	357104.3	1395063.46	14.74		River	1978	Water mark on power pole	Second CRH Survey for WBM
36	356844.60	1385227.30	5.95		Floodplain	1990	Flood level on fence at intersection of Iona and Paterson Roads	Fax from PSC dated 30.9.96
37	357997.90	1384632.30	5.84		Floodplain	1990	Flood level on corner fence post of property	Fax from PSC dated 30.9.96
38	357561.00	1384428.40	7.20		Floodplain	1955	Flood level at underside of timber board in old dairy	Fax from PSC dated 30.9.96
39	356567.80	1384583.80	5.92		Floodplain	1990	Flood level at rear of No 35 Paterson Rd	Fax from PSC dated 30.9.96
40	357561.00	1384428.40	5.63		Floodplain	1990	Flood level on wall of dairy	Fax from PSC dated 30.9.96
41	359100.00	1379900.00	7.37		River	1955	Clout in shed post (1m above ground), the shed is on the bank of the Paterson River	Compendium of Data - LHV FS
42	359400.00	1379000.00	8.10		Floodplain	1955	2" (50mm) above doors of house	Compendium of Data - LHV FS
43	360800.00	1378800.00	7.16		Floodplain	1955	350mm above window sill of workshed. Cross-check with ID 9 - good correlation.	Compendium of Data - LHV FS
44	358500.00	1377800.00	7.27		River	1955	11.5" (292mm) above floor of house which is on the bank of the Hunter River	Compendium of Data - LHV FS
45	357050.00	1383010.00	7.70		Floodplain	1955	Water level in Post Office	Compendium of Data - LHV FS
46	357080.00	1383070.00	7.49		Floodplain	1955	1955 flood marker on e.p. next to the Church	Compendium of Data - LHV FS
47	357630.00	1391860.00	11.91		River	1978	Flood mark carved in rock. Cross-check with ID 33 - 0.52m higher!!	Compendium of Data - LHV FS
48	357630.00	1391860.00	11.13		River	1946 & 1955	Flood mark carved in rock. Cross-check with ID 32 - good correlation (2cm).	Compendium of Data - LHV FS
49	357630.00	1391860.00	11.26		River	1972 or 1973	Flood mark carved in rock	Compendium of Data - LHV FS
50	357040.00	1383020.00	7.50		Floodplain	1955	Woodville Post Office	PSC Memorandum gdb16031.mem, 17.3.95
51	356500.00	1384420.00	7.50		Floodplain	1955	Woodville School of Arts	PSC Memorandum gdb16031.mem, 17.3.96
52	356870.00	1384900.00	7.50		Floodplain	1955	Nail in power pole near green W/B house owned by Frank Herbert	PSC Memorandum gdb16031.mem, 17.3.97
53	358640.00	1377700.00	6.46		River	1978	Morpeth Staff Gauge	Compendium of Data - LHV FS
54	361110.00	1377790.00	5.58		River	1978	Hinton Hill Staff Gauge	Compendium of Data -

ID	Easting	Northing	Flood Level	Accuracy (m)	River or Floodplain	Flood Year	Description of Mark	Source
								LHV FS
55	363920.00	1376430.00	4.98		River	1978	Duckenfield Staff Gauge	Compendium of Data - LHV FS
56	365710.00	1376760.00	4.10		River	1978	Gardiners Staff Gauge	Compendium of Data - LHV FS
57	360600.00	1378800.00	5.90		River	1978	Hinton Bridge Staff Gauge	Compendium of Data - LHV FS
58	356670.00	1382560.00	6.40		River	1978	Dunmore Bridge Staff Gauge	Compendium of Data - LHV FS
59	356730.00	1395340.00	15.50		River	1978	Gostwyck Staff Gauge (Flood Report)	Compendium of Data - LHV FS
60	358640.00	1377700.00	6.78		River	1977	Morpeth Staff Gauge	Compendium of Data - LHV FS
61	363920.00	1376430.00	5.18		River	1977	Duckenfield Staff Gauge	Compendium of Data - LHV FS
62	360600.00	1378800.00	5.74		River	1977	Hinton Bridge Staff Gauge	Compendium of Data - LHV FS
63	360130.00	1380000.00	5.98		River	1977	Scotts Dam Staff Gauge	Compendium of Data - LHV FS
64	356670.00	1382560.00	6.33		River	1977	Dunmore Bridge Staff Gauge	Compendium of Data - LHV FS
65	356730.00	1395340.00	12.97		River	1977	Gostwyck Staff Gauge (Flood Report)	Compendium of Data - LHV FS
66	358560.00	1391610.00	10.74		River	1985	Flood Level Good (Level No. 11)	Survey Instruction 5/7544
67	358220.00	1391620.00	11.27		River	1985	Flood Level Good (Level No. 10)	Survey Instruction 5/7544
68	357910.00	1391640.00	11.24		River	1985	Flood Level Good (Level No. 9)	Survey Instruction 5/7544
69	358310.00	1391440.00	10.44		River	1985	Flood Level Reasonable (Level No. 12)	Survey Instruction 5/7544
70	358090.00	1391310.00	10.28		River	1985	Flood Level Reasonable (Level No. 13)	Survey Instruction 5/7544
71	357900.00	1391130.00	10.32		River	1985	Flood Level Doubtful (Level No. 14)	Survey Instruction 5/7544
72	357790.00	1391080.00	10.53		River	1985	Flood Level Good (Level No. 8)	Survey Instruction 5/7544
73	357800.00	1390870.00	10.43		River	1985	Flood Level Reasonable (Level No. 7)	Survey Instruction 5/7544
74	357750.00	1390790.00	10.25		River	1985	Flood Level Excellent (Level No. 6)	Survey Instruction 5/7544
75	357630.00	1390620.00	10.14		River	1985	Flood Level Excellent (Level No. 5)	Survey Instruction 5/7544
76	357460.00	1390390.00	9.97		River	1985	Flood Level Appears Doubtful (Level No. 4)	Survey Instruction 5/7544
77	357370.00	1390250.00	10.09		River	1985	Flood Level Reasonable (Level No. 3)	Survey Instruction 5/7544
78	357230.00	1390100.00	10.06		River	1985	Flood Level Good (Level No. 2)	Survey Instruction 5/7544
79	357170.00	1390020.00	9.98		River	1985	Flood Level Reasonable (Level No. 1)	Survey Instruction 5/7544

Figure 9.1 Flood Patterns noted during Interviews with Residents



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10 APPENDIX C: ADDITIONAL SURVEY DATA

10.1 Photogrammetry Eastern Floodplains

Port Stephens Council commissioned the contouring of the eastern Paterson River floodplains using aerial photogrammetry. The contours are at 0.5 to 1.0m intervals (depending on the steepness) and cover all likely flood prone land. Additional breaklines were also produced along features such ridges, gullies and drains.

Figure 10.1 illustrates the contours and breaklines.

10.2 Field Surveys

The crests of all Paterson River levees (man-made and natural) between Paterson and Hinton were surveyed. The crest of cross-floodplain levees such as Scotts Dam and elevated roads were also surveyed. Levels were taken at any change in vertical grade or horizontal alignment.

Close coordination with the surveyor was maintained during the survey to ensure the critical alignment from a flood hydraulic perspective was picked up.

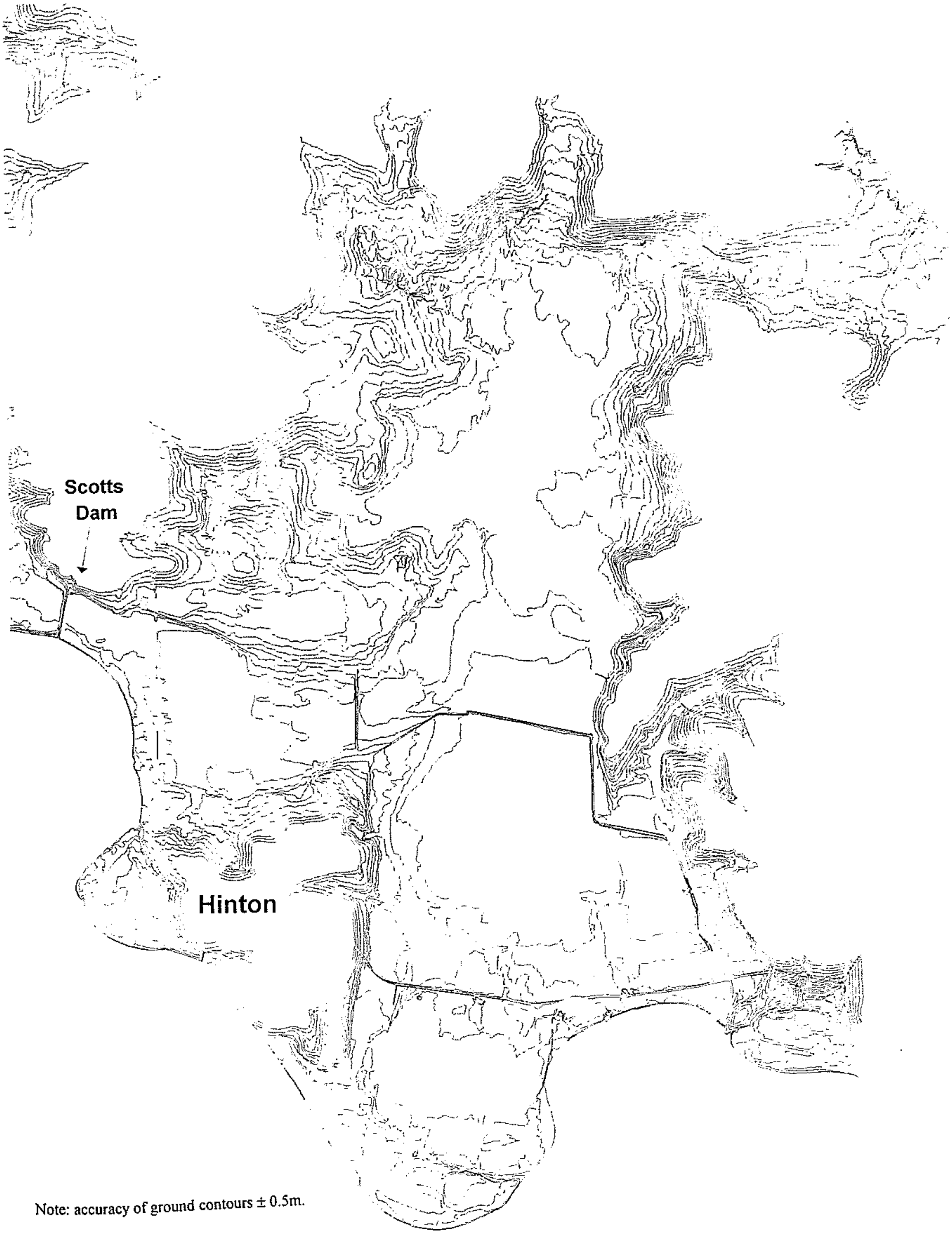
The levee crest surveys were used to define the geometry of the levee structures in the hydraulic model and were used as breaklines in the DTM.

Nine sections across the western floodplains were surveyed to define more accurately the topographic characteristics. The sections were identified on-site with the surveyor and were surveyed at the same time as the levee crest survey.

Four extra river sections and two overland sections were surveyed between Gostwyck and Paterson. These sections filled gaps in the data in this area. The sections were identified on-site with the surveyor.

Figure 10.2 presents the extent of field survey.

Figure 10.1 Example of Photogrammetric Ground Contours (McClement Swamp)



Note: accuracy of ground contours ± 0.5m.

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Figure 10.2 Additional Topographic Surveys of Levees, River and Floodplains

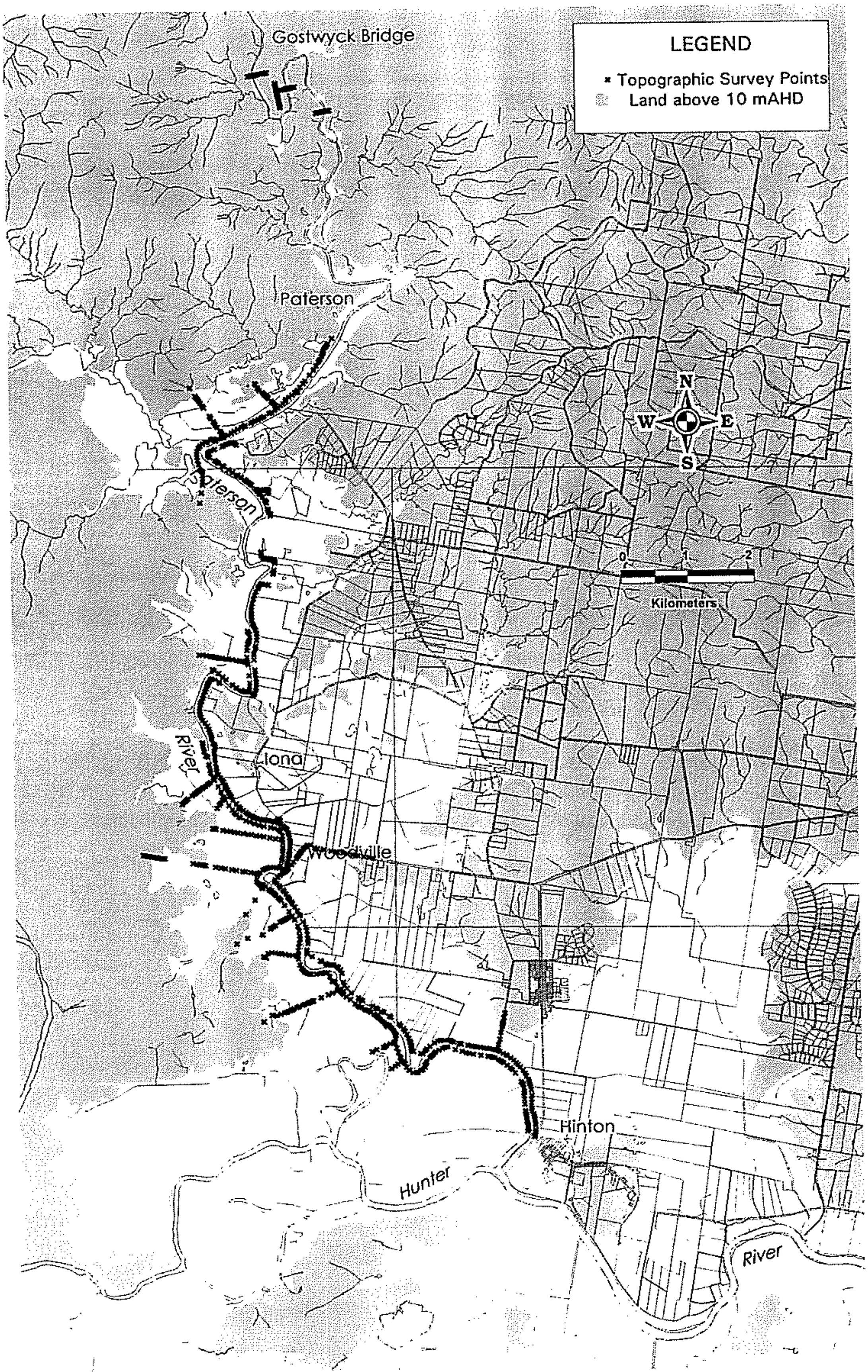

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Figure 10.3 Example of the DTM TIN (McClement Swamp Area)

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11 APPENDIX D: HYDROLOGIC & HYDRAULIC MODELS

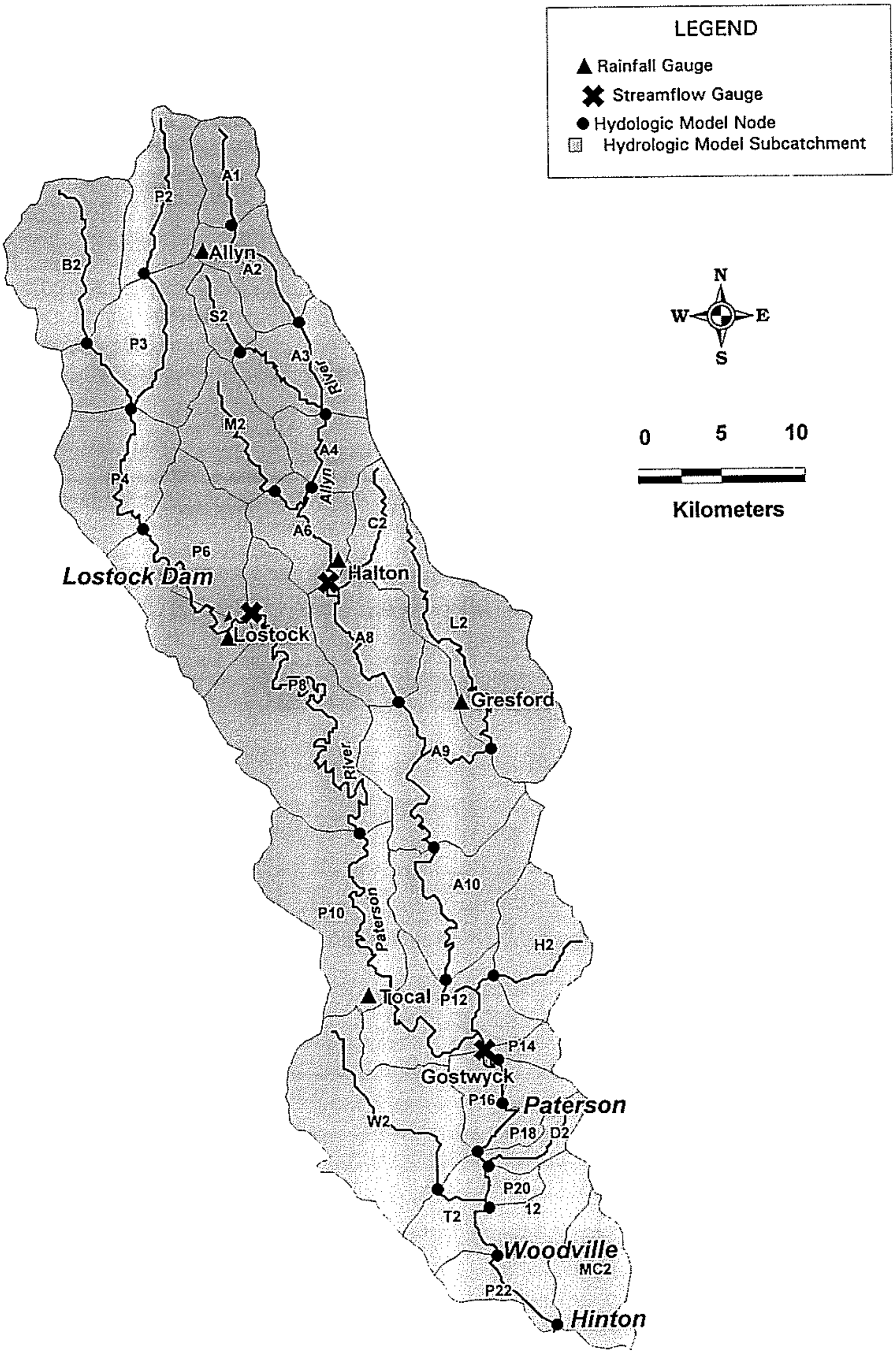
11.1 Hydrologic Model

The RAFTS-XP software was used to develop the hydrologic model. The model schematisation is shown in Figure 11.1.

Details of the model are:

- 31 sub-catchments over the entire Paterson River catchment including the McClement Swamp catchment. The catchment area, slope and vegetation of each sub-catchment were used to define its hydrologic characteristics.
- Muskingum-Cunge channel routing along the flatter reaches was used to model the attenuation of the flood wave as it travels down the Paterson and Allyn Rivers. Approximate river and floodplain sections were incorporated based on information from topographic maps and site inspections.
- Lostock Dam was incorporated as a basin. Flow over the spillway and the storage characteristics were modelled using stage-discharge and stage-storage curves supplied by the Lostock Dam operators. The two release valves through the dam were included in the model but are relatively inconsequential during a significant flood.
- Model outflows were exported to the hydraulic model from Node P12 at Gostwyck on the Paterson River and from all side tributaries between Gostwyck and McClement Swamp.

Figure 11.1 Hydrologic Model Network



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11.2 Hydraulic Model

11.2.1 Model Setup

The one-dimensional river modelling software, MIKE 11, was used to setup the quasi two-dimensional hydraulic model. MIKE 11 represents a river system as a set of interconnected branches, each branch representing a flowpath. Along each branch cross-sections define the typical topography of the flowpath. Hydraulic structures can be incorporated between cross-sections or as connections between two branches, for example, as a levee between river and floodplain. MIKE 11 sets up water level computation points at the cross-sections and branch connection points. Discharge and velocity computation points are located at hydraulic structures or midway between the water level points.

MIKE 11 solves the 1-D St Venant equations for free-surface fluid flow. The equations of continuity (mass conservation) and momentum conservation are applied at the computation points and solved using an implicit solution scheme. For further details refer to the MIKE 11 Reference Manual (Ref 2).

The steps involved in setting up the hydraulic model were:

- Decide on the location of the model boundaries. The boundaries are the outer points of the model where, for example, the river flows from the catchment are defined.
- Design the branch network and define the location of structures.
- Develop a cross-section database. Cross-sections were extracted from the:
    - ◊ existing Hunter River MIKE 11 model;
    - ◊ DTM; or
    - ◊ additional topographic surveys.
- Incorporate floodplain storage volumes over the eastern floodplains using the DTM. This was carried out by calculating the flooded area at different elevations for flood storage cells providing an accurate definition of the floodplain storage. The flooded areas for each cell were transferred to the cross-section database.
- Incorporate the details of each hydraulic structure (bridges, levees and flood gates).

Table 11.1 lists the branches which were extracted from the Hunter River model.

Data Extraction from the DTM

Figure 11.2 illustrates the location of cross-sections extracted from the DTM or from the ground field survey, for use in the hydraulic model. It also shows the storage cells used to extract floodplain storage characteristics from the DTM. Floodplain storage was determined by calculating the flooded surface area at height increments of 0.5 to 1.0m. This data was then imported into the MIKE 11 cross-section database.

Hydraulic Structures

The most influential structures are the levees along the river banks. These were modelled essentially as a broad-crested weir link between the river and floodplain. The cross floodplain levees, which were modelled in a similar manner, were also very influential in the level of inundation on the floodplain.

The bridges at Gostwyck, Paterson (both the railway and road bridges), Woodville and Hinton were modelled as MIKE 11 structures. Their geometry and head losses due to abutments and piers were based on design drawings obtained from the Roads and Traffic Authority, NSW and State Rail, NSW. As MIKE 11 only models bridges in a very simple manner, the head losses across the bridges were checked and adjusted to give similar values to those predicted using the "Hydraulics of Bridge Waterways" guidelines (Ref 1).

Each flood gate structure was modelled as a separate flap-gated MIKE 11 culvert structure based on information supplied by the Department of Land and Water Conservation, Newcastle Office. While these structures have no real influence on peak design flood levels, their incorporation is potentially useful for future investigations into floodplain drainage problems.

Table 11.1 Branches Extracted from the Hunter River Model

Branch	U/S Chainage	D/S Chainage	TOPO-ID
HUNTER	12.260	23.350	TOPO.84
WOODBERRY	0.000	0.020	INTER
BR141	0.050	0.150	TOPO.84
BR142	0.000	0.765	TOPO.84
BR144	0.000	0.115	TOPO.84
BR145	0.000	0.065	TOPO.84
BR146	0.000	0.115	TOPO.84
BR147	0.000	0.065	TOPO.84
BR148	0.000	0.115	TOPO.84
BR149	0.000	0.065	TOPO.84
BR150	0.015	0.115	TOPO.84
BR152	0.000	0.115	TOPO.84
BR153	0.000	0.065	TOPO.84
BR158	0.270	0.540	TOPO.84
BR159	0.000	0.115	TOPO.84
BR160	0.000	0.065	TOPO.84
BR162	0.000	0.115	TOPO.84
BR163	0.000	0.065	TOPO.84
BR165	0.000	1.815	TOPO.84
BR183	0.000	0.715	TOPO.84
BR186	0.000	0.115	TOPO.84
BR187	0.000	2.855	TOPO.84
BR189	0.000	0.830	TOPO.84
BR190	0.000	0.715	TOPO.84
BR191	0.000	1.500	TOPO.84
BR192	0.000	0.740	TOPO.84
BR193	0.000	0.030	TOPO.84
BR194	0.000	0.115	TOPO.84
BR195	0.000	0.065	TOPO.84
BR198	0.000	1.800	TOPO.84
BR200	0.000	0.060	TOPO.84
BR201	0.000	0.030	TOPO.84
BR210	0.000	0.580	TOPO.84
BR212	0.000	1.790	TOPO.84
BR215	0.000	0.080	TOPO.84
BR216	0.000	0.150	TOPO.84
BR225	0.000	0.220	TOPO.84
BR226	0.000	0.160	TOPO.84
BR228	0.000	0.440	TOPO.84
BR229	0.000	0.030	TOPO.84
BR230	0.000	0.030	TOPO.84
BR231	0.000	0.065	TOPO.84
BR233	0.000	0.680	TOPO.84
BR234	0.000	0.700	TOPO.84
BR235	0.000	0.900	TOPO.84
BR236	0.000	0.620	TOPO.84
BR237	0.000	0.900	TOPO.84
BR238	0.000	0.320	TOPO.84
BR239	0.000	0.200	TOPO.84
BR241	0.000	0.030	TOPO.84
BR242	0.000	0.030	TOPO.84
BR273	0.000	0.700	TOPO.84
BR278	0.000	0.115	TOPO.84
BR279	0.000	0.065	TOPO.84
BR280	0.000	0.700	TOPO.84

11.2.2 Sensitivity Tests & Checks

A range of sensitivity test and checks on the hydraulic model was carried out during the course of the model calibration. The checks were carried out confirm the input data as accurate and sensitivity tests were carried out to develop a feel for the most influential hydraulic parameters. Examples of test and checks carried out are:

- Checks for any irregularities in the MIKE 11 conveyance values along the Paterson River.
- Influence of varying the MIKE 11 head loss coefficients on critical structures such as levees.
- Cross-check on the floodplain storage in the MIKE 11 model with that calculated directly from the DTM - this was an important check to ensure that there was no accidental duplication of storage.
- Mass balance checks.
- Sensitivity of computational parameters such as the timestep, DELTA value, etc.
- Comparison checks on the flood levels and discharges from the existing Hunter River model to ensure the hydraulic model's boundaries on the Hunter are appropriate.

Figure 11.2 Locations of Cross-Sections & Storage Cells

11.3 March 1978 Calibration

11.3.1 Hydrologic Model

The March 1978 flood is the largest flood on record. The flood resulted from heavy rain over the catchment on the 18th and 19th, particularly during the day time on the 19th.

Three pluviograph records within the catchment were available providing a good definition of the rainfall. The pluviographs were supplied by the Bureau of Meteorology with a sample interval of 6 minutes which provides a good resolution of the rainfall pattern. Figure 11.3 shows the pluviographs for the three stations. The locations of the three stations are shown in Figure 11.4.

Based on the 24 hour totals of these records, from 6:00am on the 19th, an estimate of the variation in rainfall over the catchment was made and is presented in Figure 11.4. As can be seen, substantially more rainfall fell in the upper sections of the catchment. Table 11.2 shows the total rainfall at each gauge for this period.

Table 11.2 March 1978 Rainfall for 24h from 6:00am on the 19th

Station	Rainfall of Main Burst (mm)
Allyn	241
Lostock	143
Tocal	99

The pluviograph data and assumed rainfall distribution were input to the hydrologic model.

In calibrating the model, emphasis is placed on reaching agreement between recorded and calculated flows with respect to:

- the magnitude of flow and
- the timing and shape of the hydrographs.

It is important to note that recorded stream flow data is only an estimate based on recorded flood levels, and can be inaccurate to ±30% or more, especially for large flood events. What is known to a greater certainty is the shape of the hydrograph, therefore calibration should also concentrate on this in addition to the magnitude of the flows.

The model calibration centred around the adjustment of the rainfall losses, the sub-catchment PERN values and the Manning n values for the river reaches. The final values adopted, as shown in Table 11.3, were found to give the best result. For discussion on these parameters refer to the RAFTS-XP User's Guide (Ref 11).

Table 11.3 March 1978 Hydrologic Model Calibration Parameters

Parameter	Value	Comments
Initial Loss (mm)	40	
Continuing Loss (mm/h)	2.0	
PERN	0.10	Spatial variations of the PERN value (higher in the more densely vegetated areas and lower in cleared areas) were tested but were not found to give a better calibration. The value of 0.10 equates to a B value of 3.0
BX	1.0	
n (river)	0.05	As only a very approximate shape of the river was used the value should be treated as nominal.
n (floodplain)	0.10	As only a very approximate shape of the floodplain was used the value should be treated as nominal.

Figure 11.5 Figure 11.6 show the calibration results. A separate graph is shown for each of the three stream flow gauge sites located in Figure 11.4. On each graph depicts the rainfall and stream flow as follows:

- the histogram at the top shows the assumed rainfall at the site in mm/h (note that excess rainfall, the net rainfall after removing the initial loss and continuing loss, is shown as solid black);
- the recorded flow is shown as the thin dashed line; and
- the calculated flow is shown as the solid thin line.

The calibration plots show a good correlation at all three sites. Both the magnitude and shape of the recorded hydrographs is reproduced, in particular that at the Gostwyck gauge.

11.3.2 Hydraulic Model

The March 1978 flood is the largest flood recorded in the township of Paterson. In the lower reaches around Woodville it was also a major flood but was lower than the 1955 flood.

A selection of the peak recorded flood levels for the flood are shown in Table 11.4. Flood hydrographs at Gostwyck, Woodville and Hinton were also available for calibration.

Table 11.4 March 1978 Peak Flood Levels (mAHD)

Location	Recorded	Comments	Calculated [1]
Gostwyck Bridge Flood Gauge	>15.2	Flood went slightly above highest gauge board.	15.3
Upstream of Railway Bridge (Paterson)	11.9		12.0
Paterson Road Bridge	10.0		10.0
Woodville Gauge	6.4		6.4
Hinton Gauge	5.9		5.9

1. Run identifier PR78_190

The hydraulic model boundaries were based on:

- the RAFTS-XP hydrographs from the hydrologic model calibration described above;
- Hunter River flows upstream of Morpeth extracted from the Hunter River MIKE 11 model March 1978 calibration; and
- Hunter River levels at Green Rocks extracted from the Hunter River MIKE 11 model March 1978 calibration.

Figure 11.7 illustrates the hydraulic model calibration to peak levels recorded along the Paterson River and Figure 11.8 shows the calibration to recorded stage hydrographs at Gostwyck Bridge, Woodville and Hinton.

A few peak flood levels on the floodplains were obtained for the March 1978 event during the flood information survey (see Section 9). These were assessed for reliability and used to check the hydraulic model's performance on the floodplain. Table 11.5 shows the measured and calculated values.

In the case of the railway bridge level, the floodplain was still filling when flood waters started to recede, hence its value is lower than both those of the river and on the opposite floodplain above Woodville.

The Woodville level is largely controlled by the damming effects of Scotts Dam. During the historic flood information survey residents pointed out that the backwater effects of Scotts Dam propagate all the way up to Woodville and into the Butterwick area. The hydraulic model further supports this claim, showing that Scotts Dam does have a major damming effect.

Table 11.5 March 1978 Peak Floodplain Level (mAHD) Calibration

Floodplain Location	Measured	Calculated	Nearby River Level
Railway Bridge Crossing between Largs and Tocal	5.45	5.3	7.0
Woodville	6.27	6.1	6.8

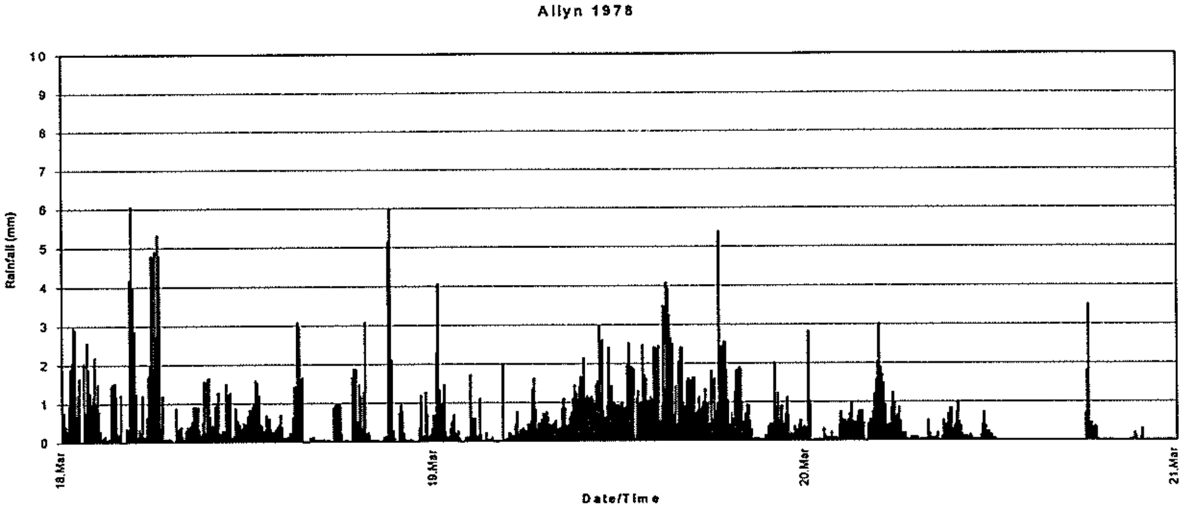
Calibration of the hydraulic model was dominated by adjustment of the Manning n values along the river. With regard to this the following points were noted:

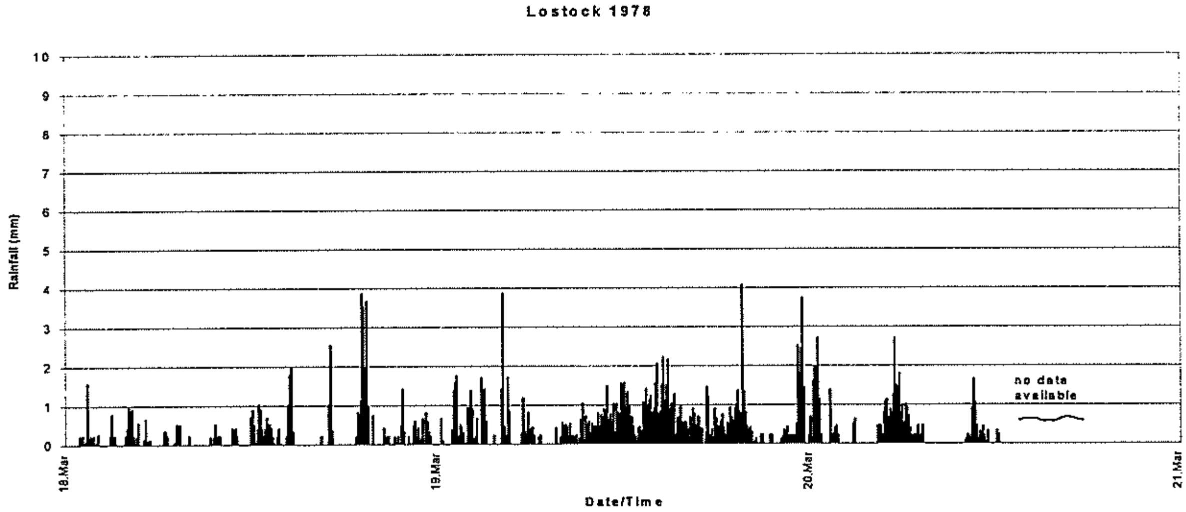
- Using conventional Manning n values (0.025 to 0.040) it was not possible to reproduce the steep flood gradient from Gostwyck Bridge to Woodville with calculated flood levels falling below those recorded. A constant Manning n value of 0.05 was needed to reproduce the steep gradient. (This observation was further supported during calibration and verification to the 1977 and 1995 events.)
- One possibility for this is the inflow from the hydrologic model is too low, however, given the good rainfall records and that the volume and shape of the hydrologic model calibration was closely reproduced at Gostwyck, this possibility can not be strongly supported (this opinion is further enhanced with the satisfactory calibration and verification of the hydrologic model to the 1977 and 1995 events.
- Examination of the recorded peak levels around Paterson during the March 1978 event and the slightly lower 1985 flood shows significant head losses occur around the river bend downstream of the Paterson Railway Bridge. In situations such as this, substantial additional losses known as bend losses can occur as the flood waters force their way round the bend.
- Major bend losses are not normally included in conventional Manning n values. Also the mathematical formulae for bed resistance (Manning equation) and bend losses differ slightly. As MIKE 11 does not have any direct facility for applying bend losses, the best and only option is to include them using a higher Manning n value.
- Unfortunately, there is little information literature in the area of bend losses in natural rivers. The best approach is to examine recorded levels where available.
- Based on the 1995 and 1985 recordings desktop calculations indicate that a constant Manning n of around 0.06 is required for a length of 1,400 metres along the river around Paterson which included the bend. Higher Manning n values resulted for shorter lengths.
- The approach adopted was to apply higher Manning n values at the river bends and use more conventional values along straighter river reaches. The more severe bends, such as that at Paterson, attracted Manning n values of 0.07, whilst least severe bends were given 0.05. Straighter sections were given values ranging from 0.035 to 0.045.

Other points noted during the calibration are:

- The calibration to the Woodville floodplain level mentioned previously was further improved by improving the calibration at the Hinton gauge. Increasing the Manning n from Morpeth to Green Rocks in the Hunter Model to 0.035 gave a better calibration at Hinton. This also improved the calibration to the Woodville floodplain level which is strongly influenced by the Paterson River level at Scotts Dam (just upstream of Hinton).

Figure 11.3 March 1978 Pluviograph Records





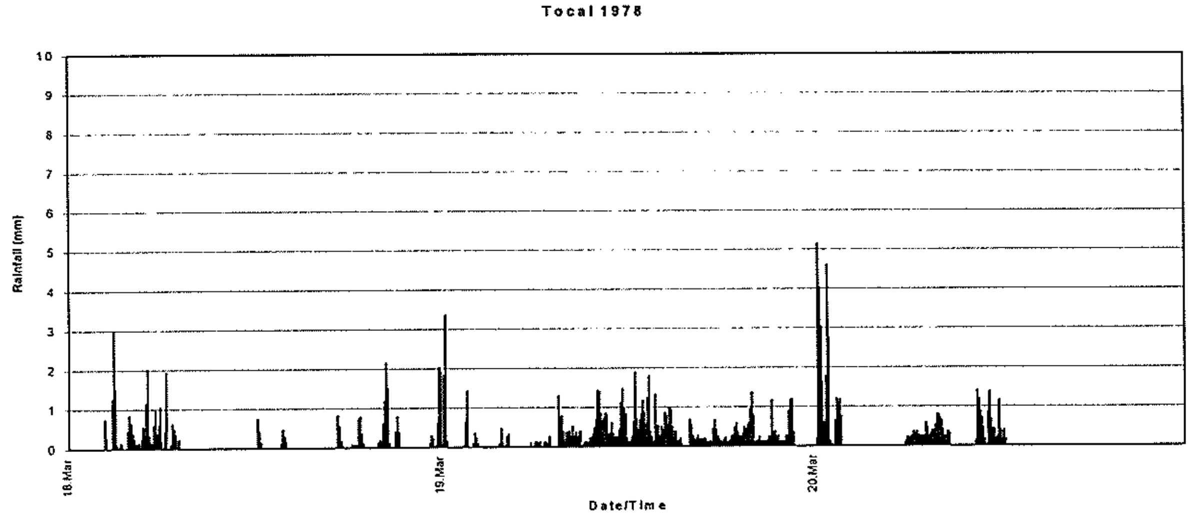
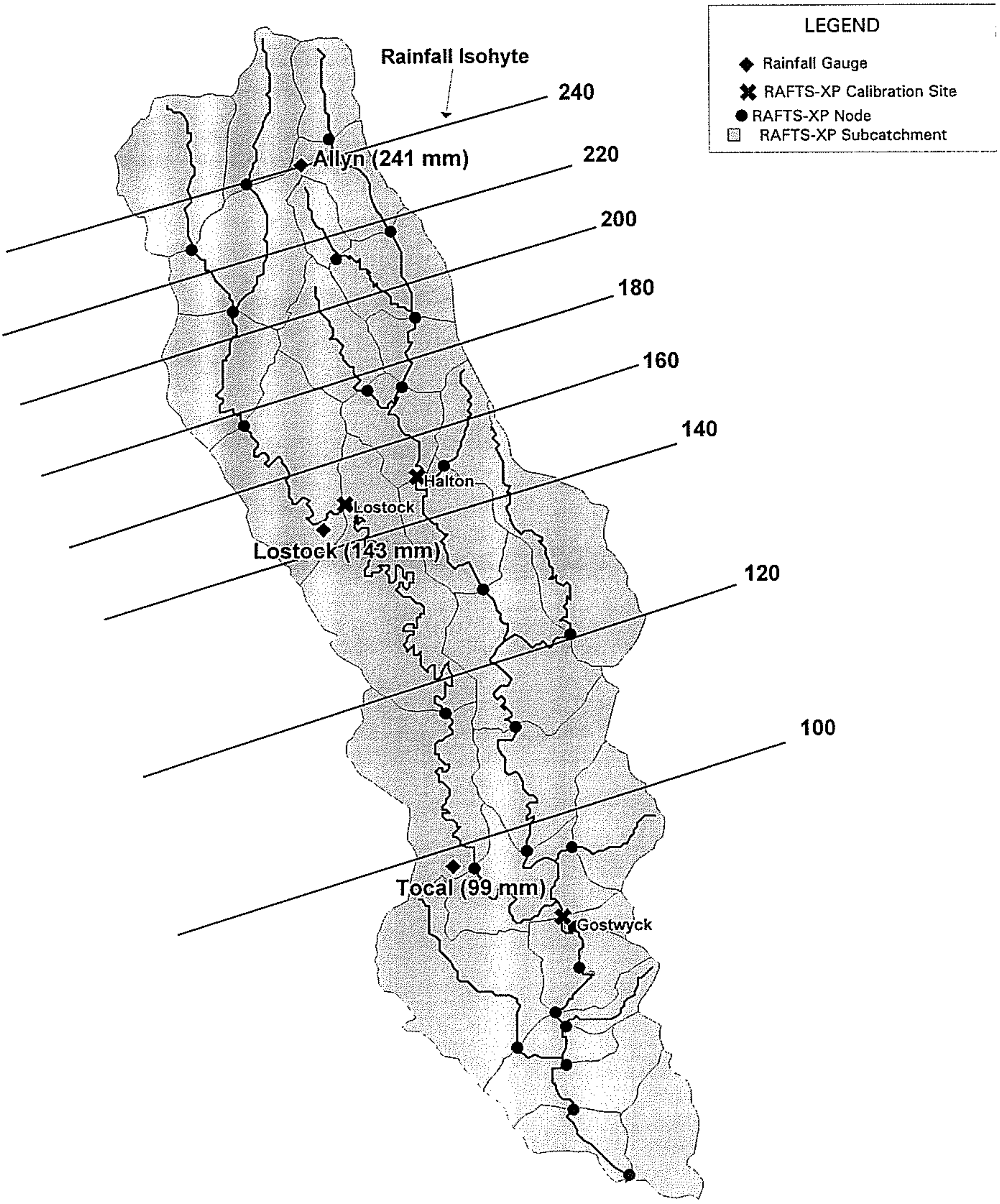


Figure 11.4 March 1978 Rainfall Distribution (24 hours from 06:00 19.3.78)



d:\aac5\n0076\mapinfo\RainDist_78.wor

Figure 11.5 March 1978 Hydrologic Model Calibration (Allyn & Gostwyck)

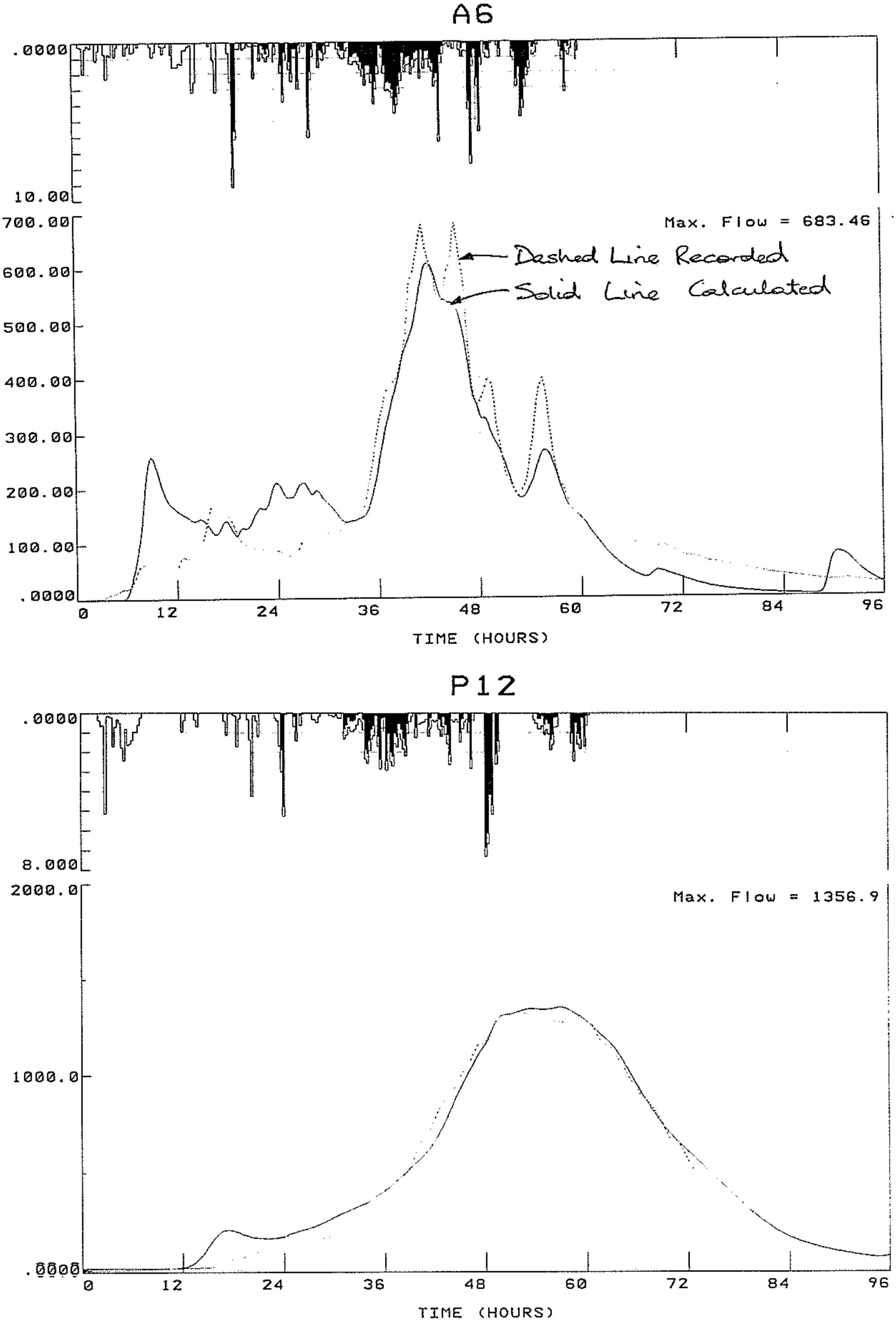


Figure 11.6 March 1978 Hydrologic Model Calibration (Lostock Dam)

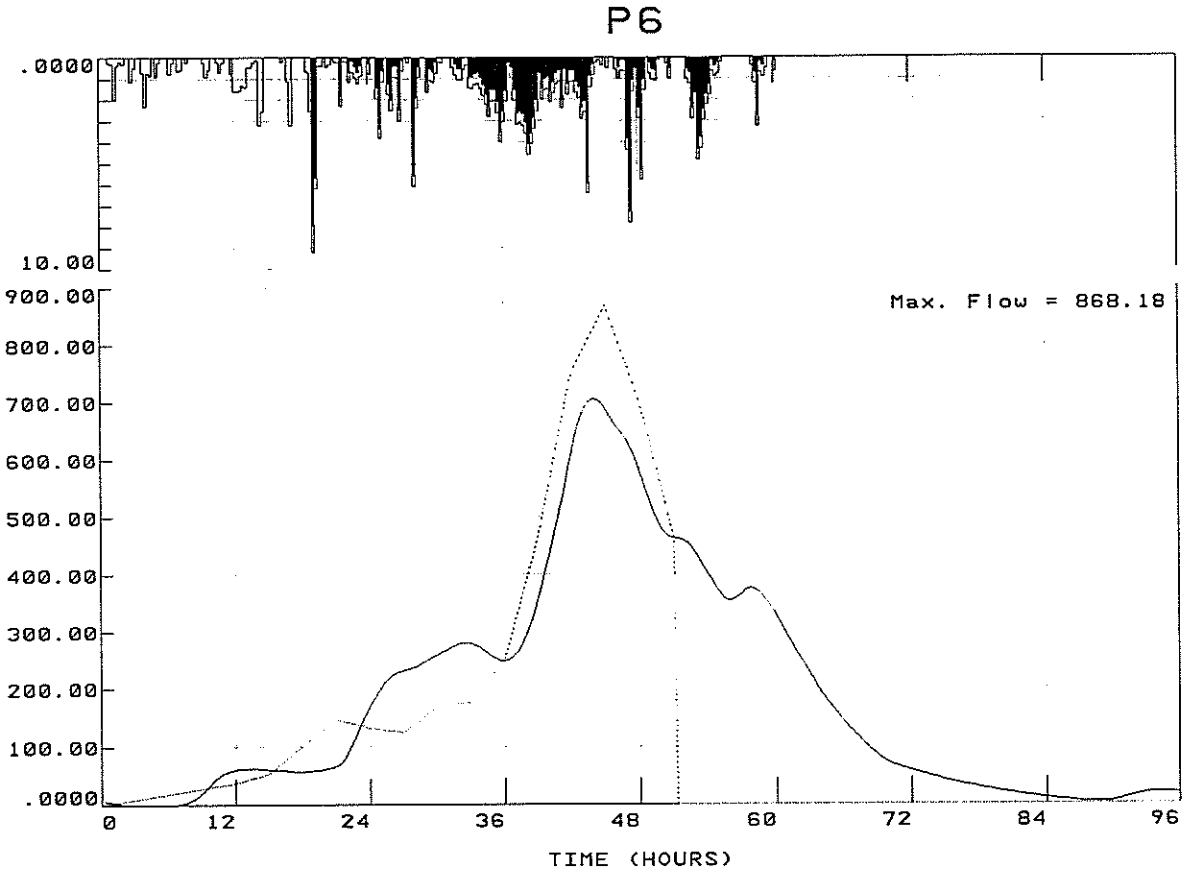


Figure 11.7 March 1978 Hydraulic Model Calibration (Longitudinal Profile)

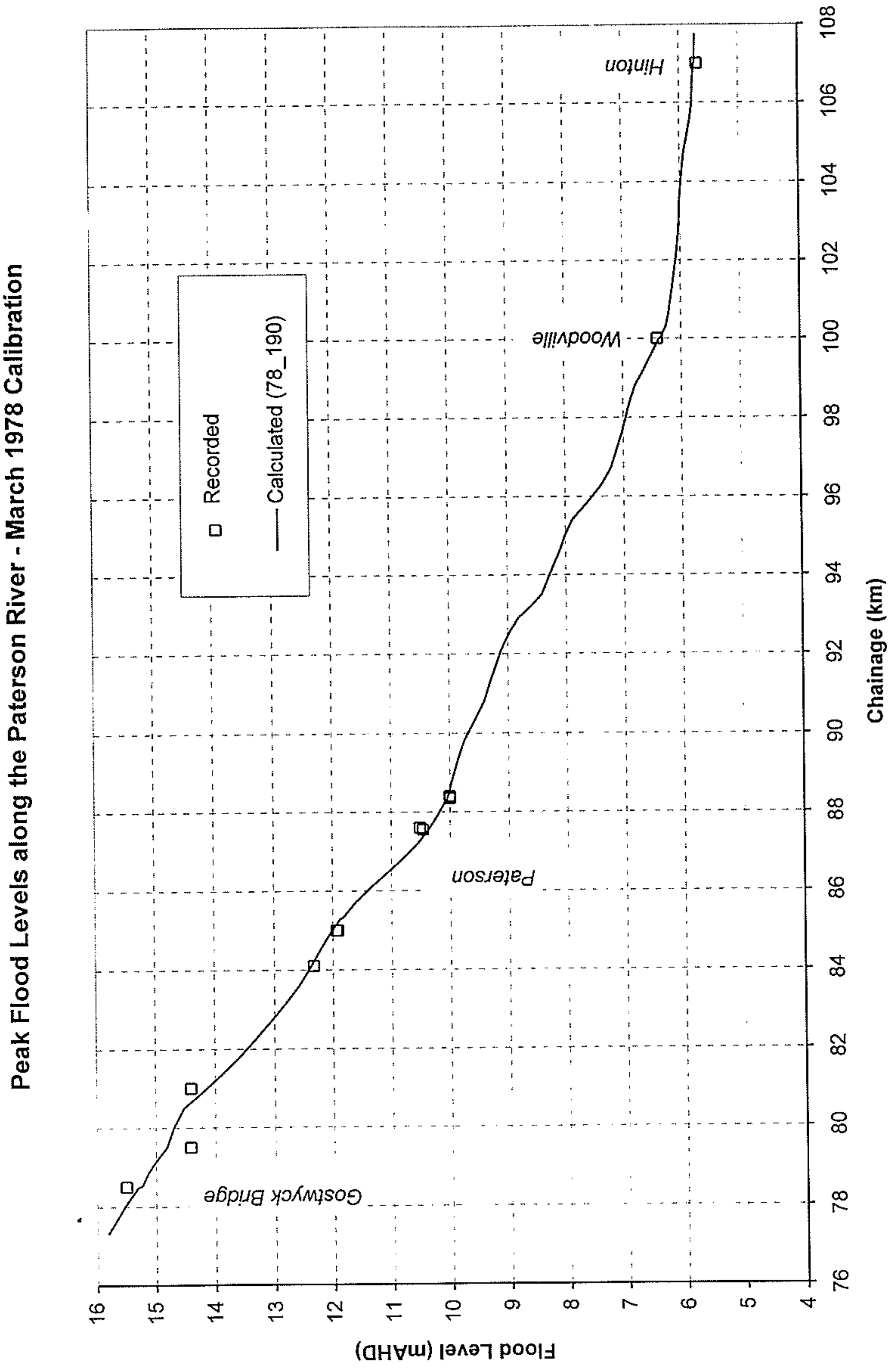
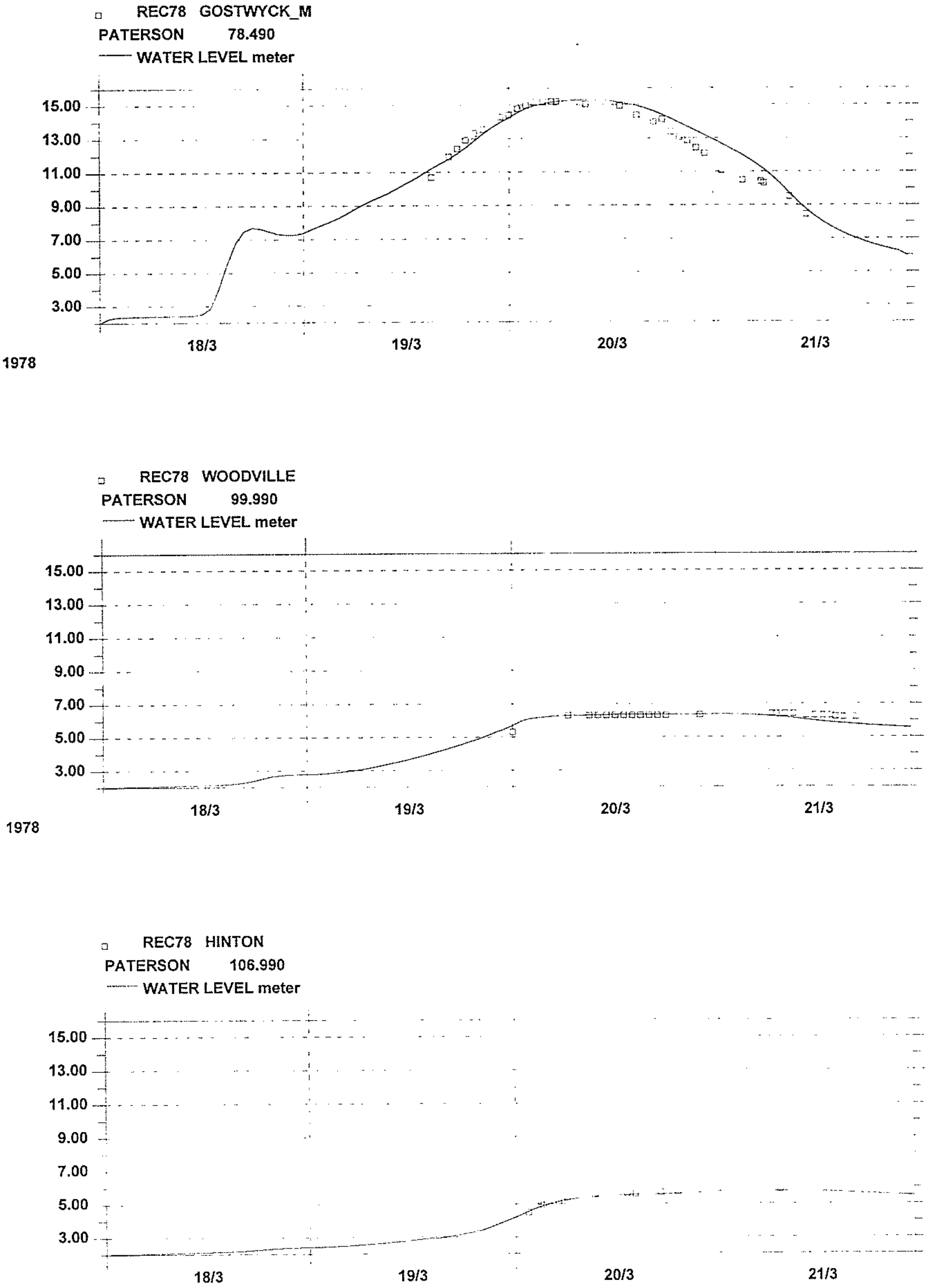


Figure 11.8 March 1978 Hydraulic Model Calibration (Recorded Hydrographs)



11.4 March 1977

11.4.1 Hydrologic Model Calibration

The March 1977 flood resulted from heavy rain over the catchment during the first few days of the month, with the heaviest falls occurring on the 3rd.

Three pluviograph records within the catchment were available, although one record was incomplete. As for the 1978 event the pluviographs were supplied by the Bureau of Meteorology, with the sample interval of 6 minutes providing a good resolution of the rainfall temporal patterns. Figure 11.9 shows the pluviographs for the three stations. Their locations are shown in Figure 11.10.

Based on the daily total of these records for the 3rd an estimate of the variation in rainfall over the catchment was made and is presented in Figure 11.10. As for the 1978 event, more rainfall fell in the upper sections of the catchment, but not to the same degree. Table 11.6 shows the total rainfall at each gauge for the main burst on the 3rd.

Table 11.6 March 1977 Rainfall for 24h from 0:00am on the 3rd

Station	Rainfall of Main Burst (mm)
Allyn	143
Lostock	96
Tocal	>112 (incomplete record)

The pluviograph data and assumed rainfall distribution were input to the hydrologic model.

With the exception of the initial rainfall loss, the same parameters as used for the 1978 calibration were used. The initial loss adopted for the 1977 flood was 20mm.

Figure 11.11 and Figure 11.2 show the calibration results for each of the three stream flow gauge sites (see March 1978 for discussion on graph formats).

The calibration plots show a satisfactory correlation at all three sites.

11.4.2 Hydraulic Model Calibration

A selection of the peak recorded flood levels for the flood are shown in Table 11.7. Flood hydrographs at Gostwyck, Woodville, Scotts Dam and Hinton were also available for calibration.

Table 11.7 March 1977 Peak Flood Levels (mAHD)

Location	Recorded	Calculated [1]
Gostwyck Bridge Gauge	13.0	13.4
Woodville Gauge	6.3	6.3
Scotts Dam Gauge	6.0	6.1
Hinton Gauge	5.7	6.1
Morpeth Gauge	6.8	6.1

1. Run identifier PR77_185

As for the March 1978 event, the hydraulic model boundaries were based on the RAFTS-XP hydrographs and flows and levels extracted from the Hunter River MIKE 11 model March 1977 calibration.

The same hydraulic model parameters as used for the March 1978 flood were used for the March 1977 calibration runs. To further test the accuracy of the hydraulic model, it was also simulated using the recorded flows at Gostwyck instead of the RAFTS-XP calculated flows.

Figure 11.13 illustrates the hydraulic model calibration at each of the flood gauge sites.

Figure 11.9 March 1977 Pluviograph Records

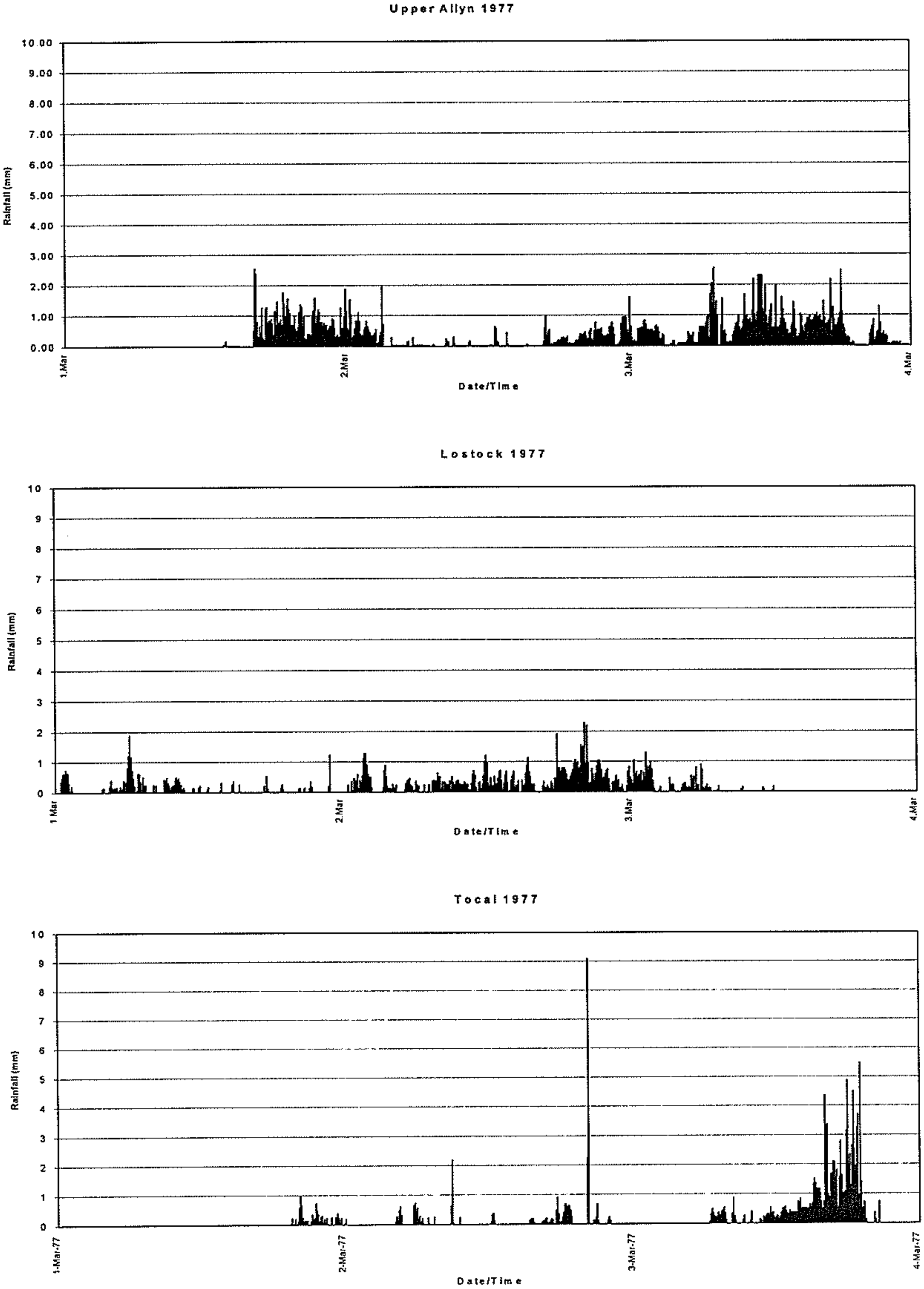
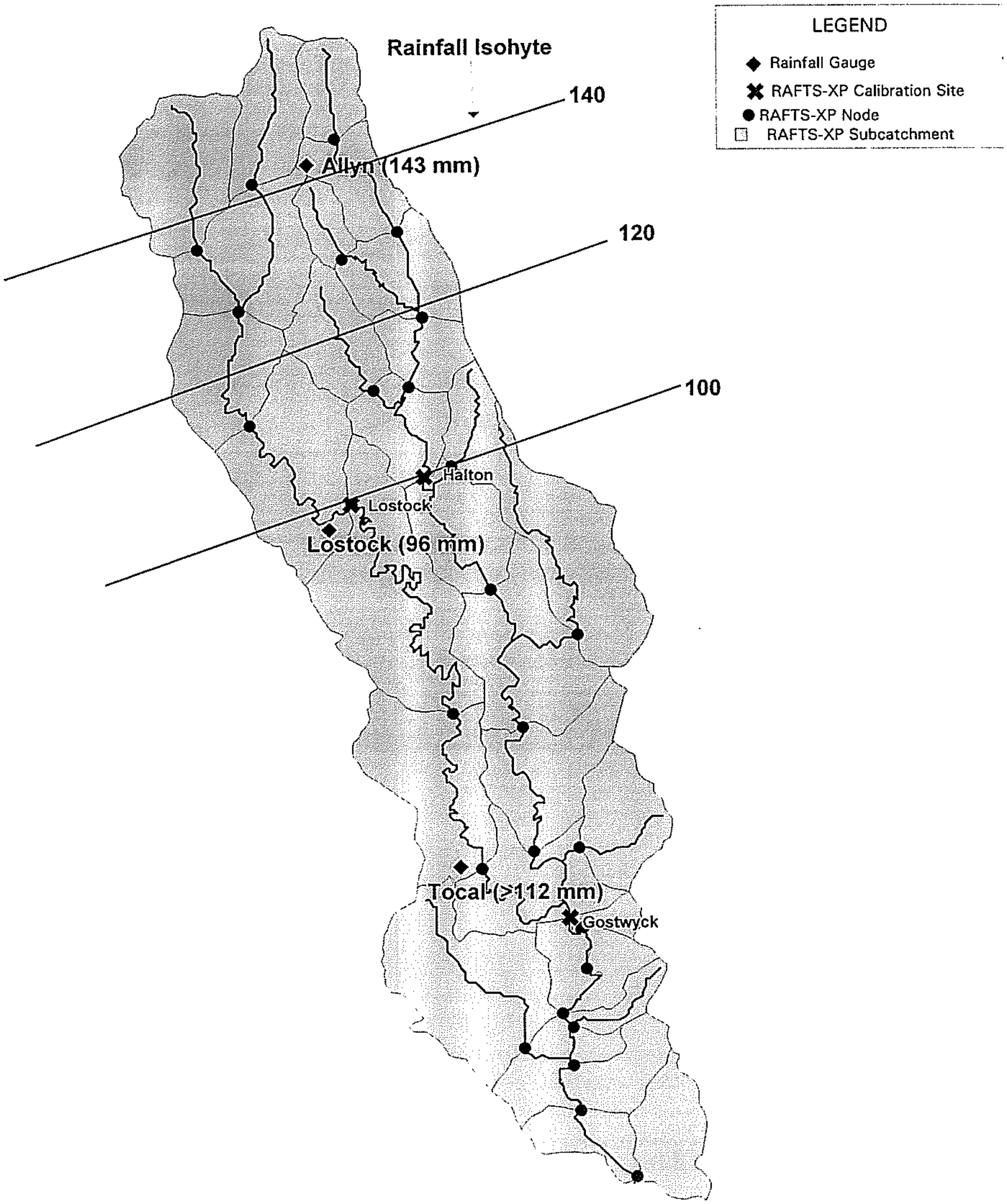
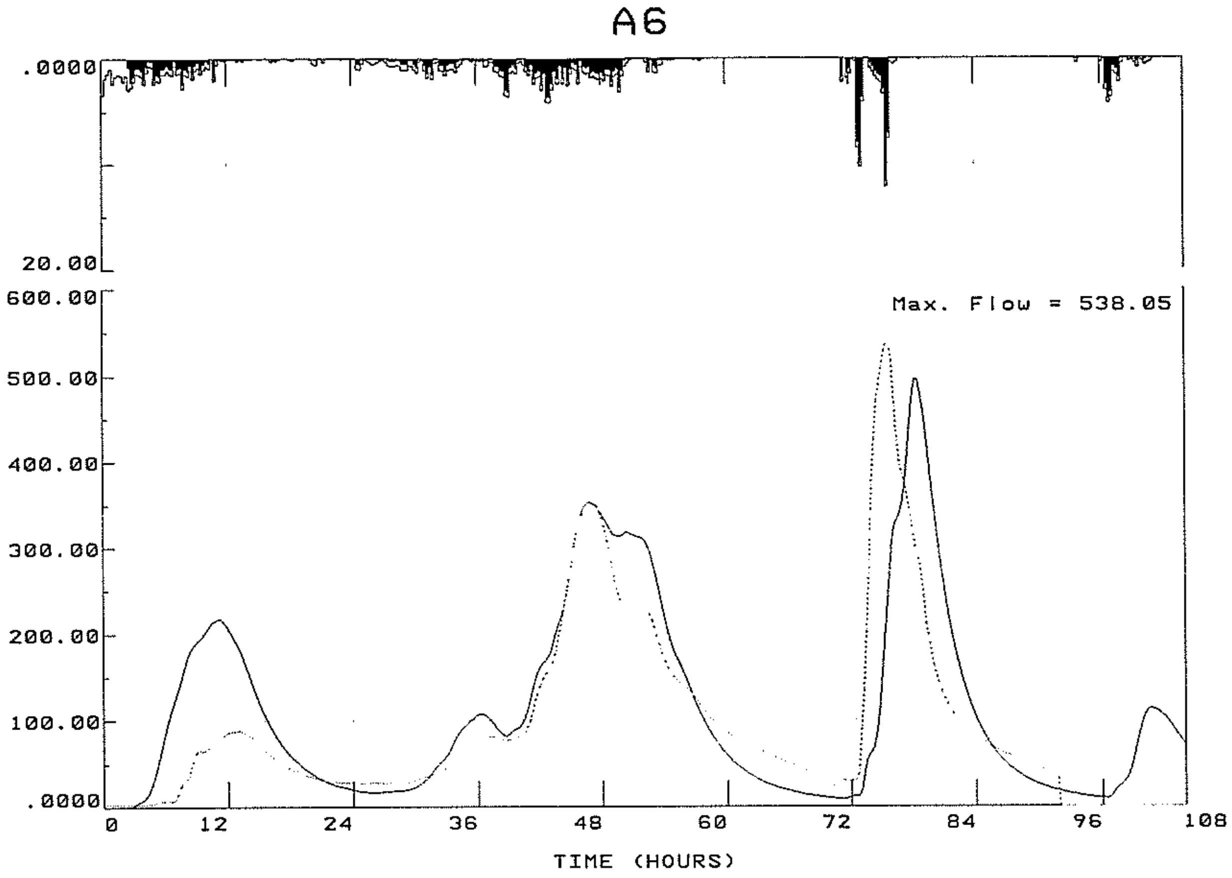


Figure 11.10 March 1977 Rainfall Distribution (24 hours from 00:00 3.3.77)



d:\aac5\n0076\mapinfo\RainDist_77.wor

Figure 11.11 March 1977 Hydrologic Model Calibration (Allyn & Gostwyck)



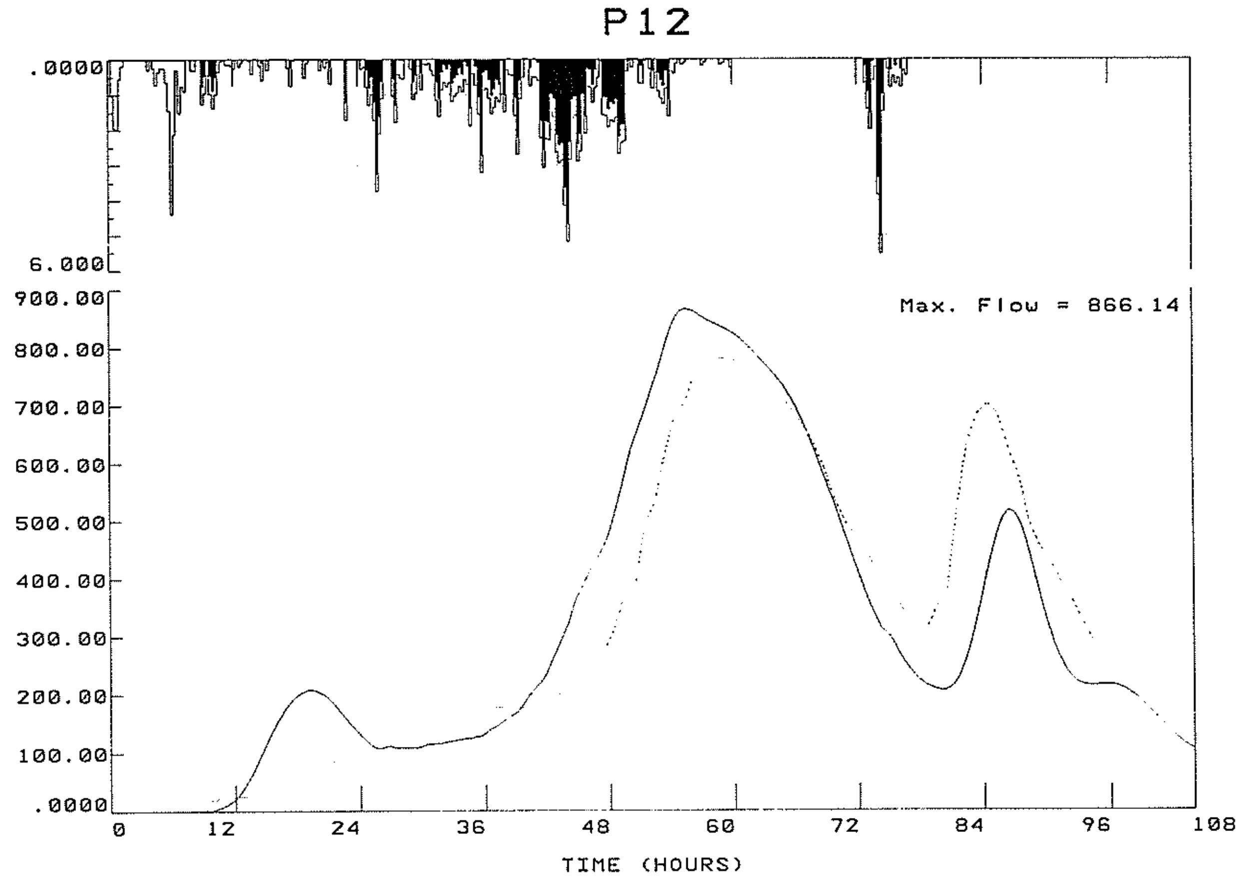
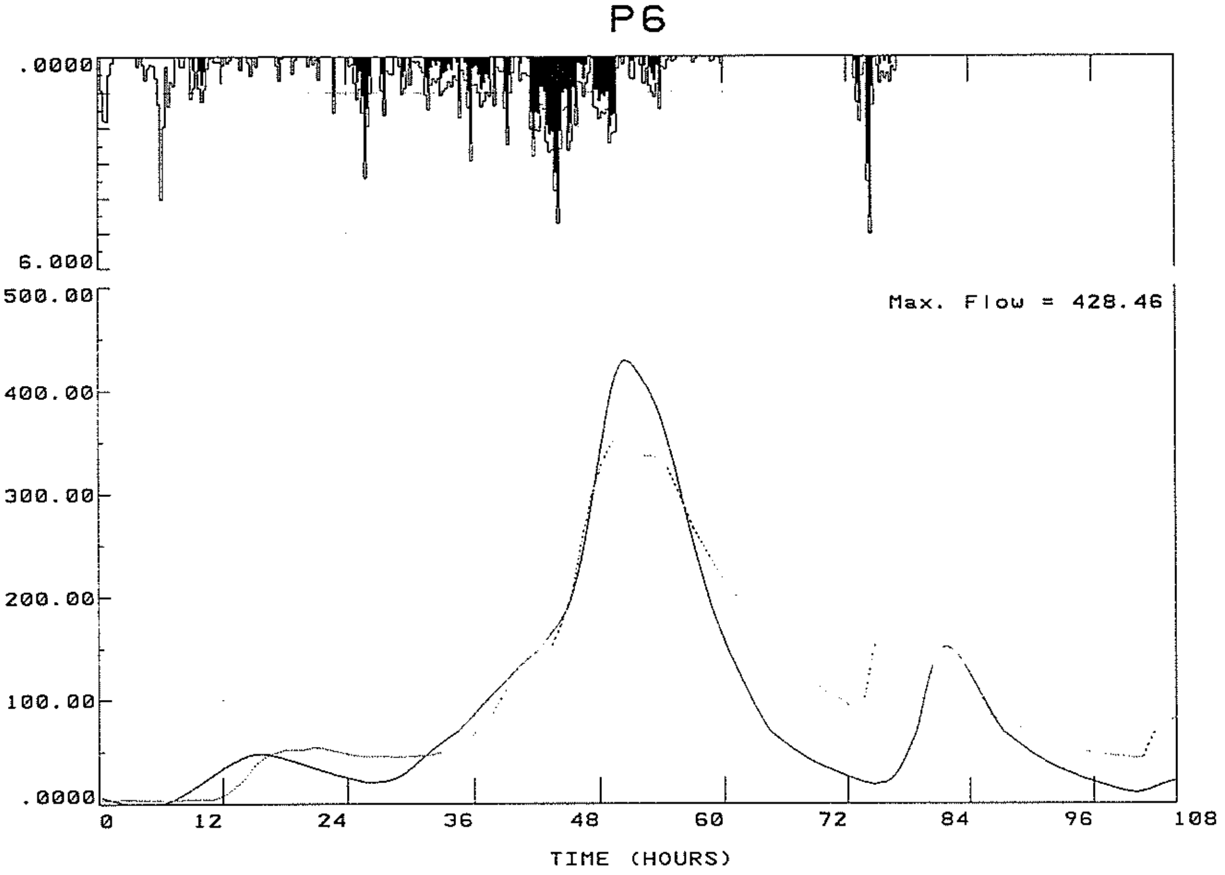
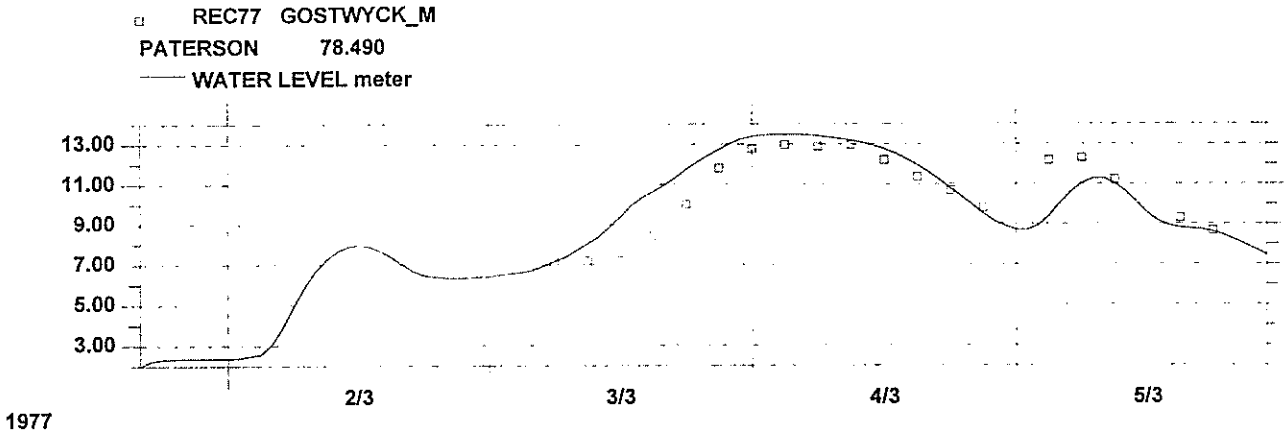


Figure 11.12 March 1977 Hydrologic Model Calibration (Lostock Dam)




REC77 GOSTWYCK_M
PATERSON 78.490
WATER LEVEL meter
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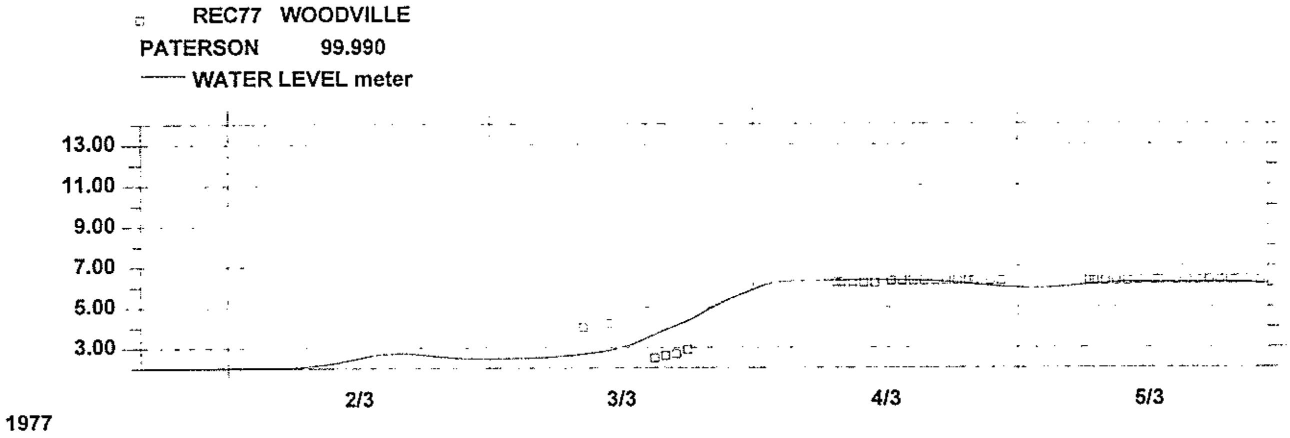
11.00
9.00
7.00
5.00
3.00
2/3
3/3
4/3
5/3
1977


REC77 WOODVILLE
PATERSON 99.990
WATER LEVEL meter
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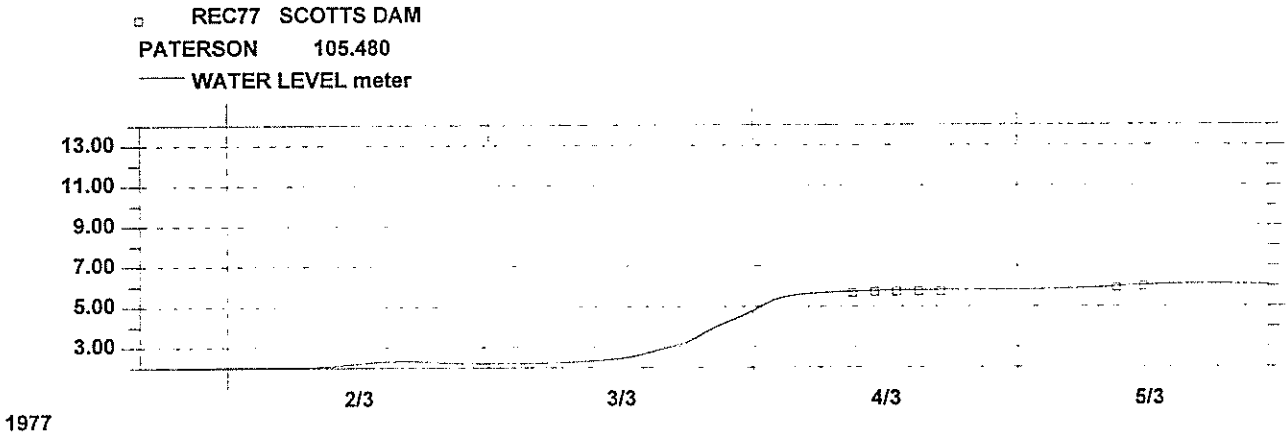
11.00
9.00
7.00
5.00
3.00
2/3
3/3
4/3
5/3
1977


REC77 SCOTTS DAM
PATERSON 105.480
WATER LEVEL meter
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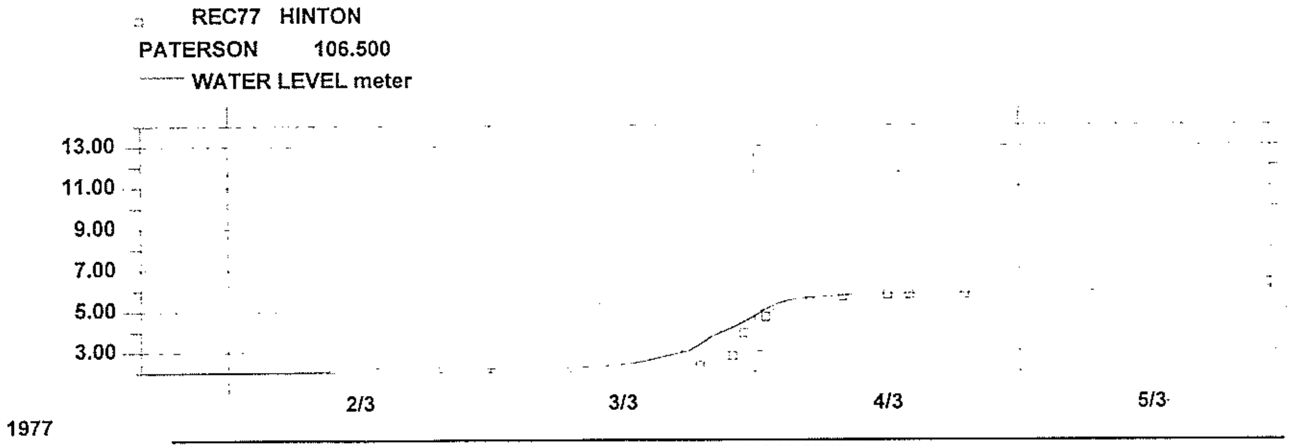
11.00
9.00
7.00
5.00
3.00
2/3
3/3
4/3
5/3
1977


REC77 HINTON
PATERSON 106.500
WATER LEVEL meter
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11.00
9.00
7.00
5.00
3.00
2/3
3/3
4/3
5/3
1977

11.5 March 1995 Verification

11.5.1 *Hydrologic Model Verification*

The March 1995 flood resulted from rain over the catchment from the 3rd to the 9th, with the heaviest falls occurring on the 3rd and 4th.

Three pluviograph records within the catchment were available from the flood warning system operated by the Bureau of Meteorology. The pluviograph data was relatively coarse with the sample interval varying from a few minutes to several hours, which unfortunately does not provide a good resolution of the temporal patterns. Figure 11.14 shows the pluviographs for the three stations.

Based on the daily total of these records and also for Dungog for the 48 hours from 9:00am on the 3rd an estimate of the variation in rainfall over the catchment was made and is presented in Figure 11.10. As for the calibration events, more rainfall fell in the upper sections of the catchment, in this case by a factor of approximately two. Table 11.8 shows the total rainfall at each gauge for the main burst on the 3rd and 4th.

Table 11.8 March 1995 Rainfall for the 48 hours from 9:00am on the 3rd

Station	Rainfall of Main Burst (mm)
Allyn	179
Halton	92
Gresford	96
Dungog	106

The pluviograph data and assumed rainfall distribution were input to the calibrated hydrologic model without any changes to the model parameters. The initial loss adopted was 10mm.

Problems were encountered using the Halton pluviograph because of its poor resolution during the main burst - approximately two-thirds (64mm) of the rainfall is lumped together in one pluviograph reading spanning 34½ hours. The hydrologic model interprets this as a constant rainfall of less than 2mm/h which after extracting the continuing loss of 2mm/h leaves no excess rainfall. The Halton pluviograph was therefore deemed inappropriate and was discarded.

The coarseness of the other pluviographs caused similar problems, but to a much lesser extent.

Figure 11.16 and Figure 11.17 show the verification results for each of the three stream flow gauge sites.

The calibration plots show a satisfactory correlation at all three sites.

11.5.2 Hydraulic Model Verification

A selection of the peak recorded flood levels for the flood are shown in Table 11.9. Flood hydrographs at Gostwyck Bridge, Paterson Railway Bridge, Woodville and Hinton were available for calibration.

Table 11.9 March 1995 Peak Flood Levels (mAHD)

Location	**Recorded**	**Calculated**	
		Hydrologic & Model Flows [1]	Recorded Gostwyck Flows [2]
Gostwyck Bridge Gauge	10.3	11.0	10.6
Paterson Railway Bridge	7.3	7.9	7.5
Woodville Gauge	4.1	4.3	4.0
Hinton Gauge	2.6	2.8	2.6
Morpeth Gauge	2.5	2.5	2.5

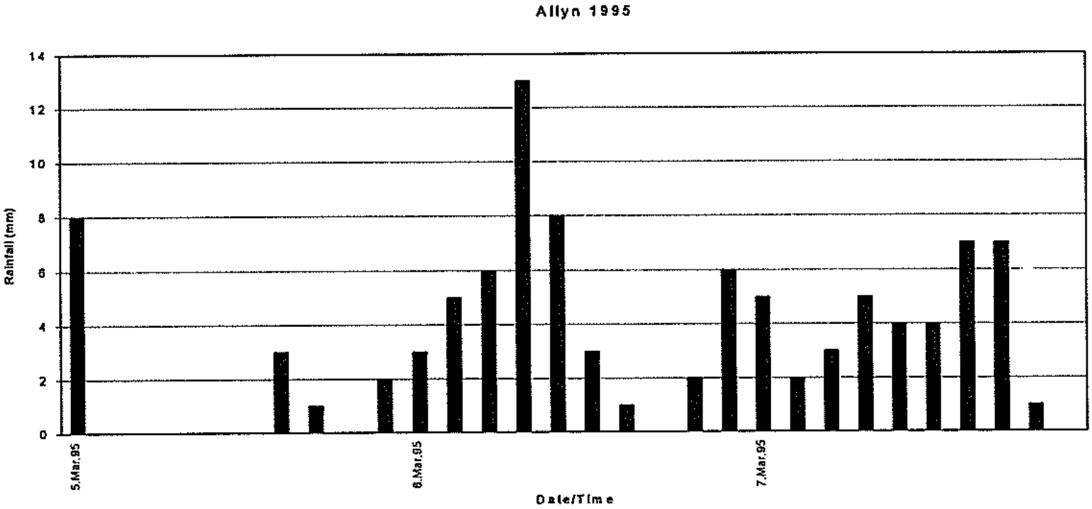
1. Run identifier pr95_186
2. Run identifier pr95_124

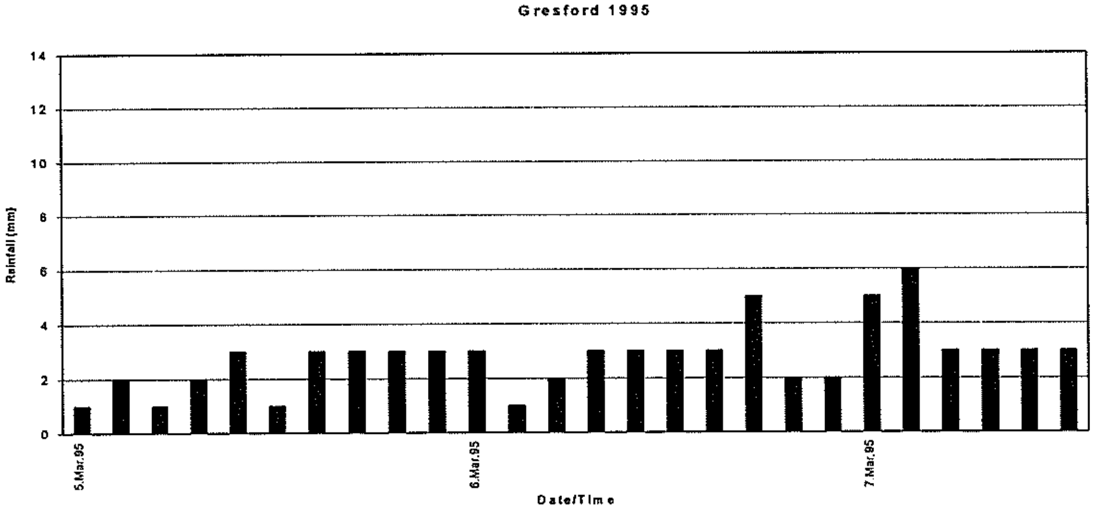
As for the calibration events, the hydraulic model boundaries were based on the RAFTS-XP hydrographs. Hydrographs at Morpeth and Green Rocks were used to set the flow conditions in the Hunter River.

The calibrated hydraulic model was used unchanged for the verification. The only change was a modification to an overland flowpath at the bend immediately downstream of Gostwyck Bridge where a substantial mound of earth was pushed up after the 1978 flood. The mound was picked up during the field surveys so its geometry could be defined in the hydraulic model. To further test the accuracy of the hydraulic model, the 1995 event was also simulated using the recorded flows at Gostwyck instead of the RAFTS-XP calculated flows.

Figure 11.18 illustrates the hydraulic model calibration at each of the flood gauge sites using the hydrologic model flows and Figure 11.19 shows the calibration using the recorded flow hydrograph at Gostwyck.

Figure 11.14 March 1995 Pluviograph Records


Allyn 1995


Gresford 1995

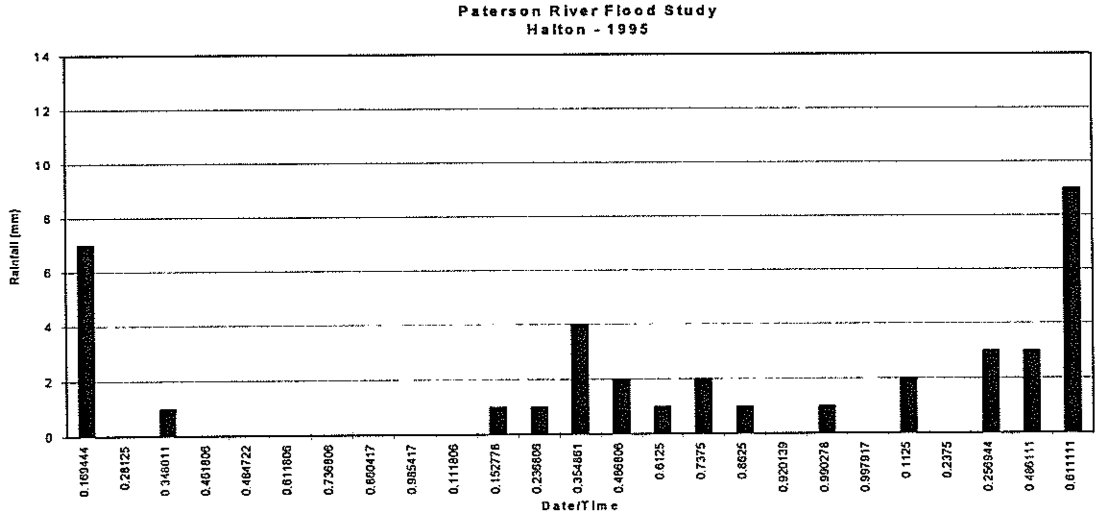
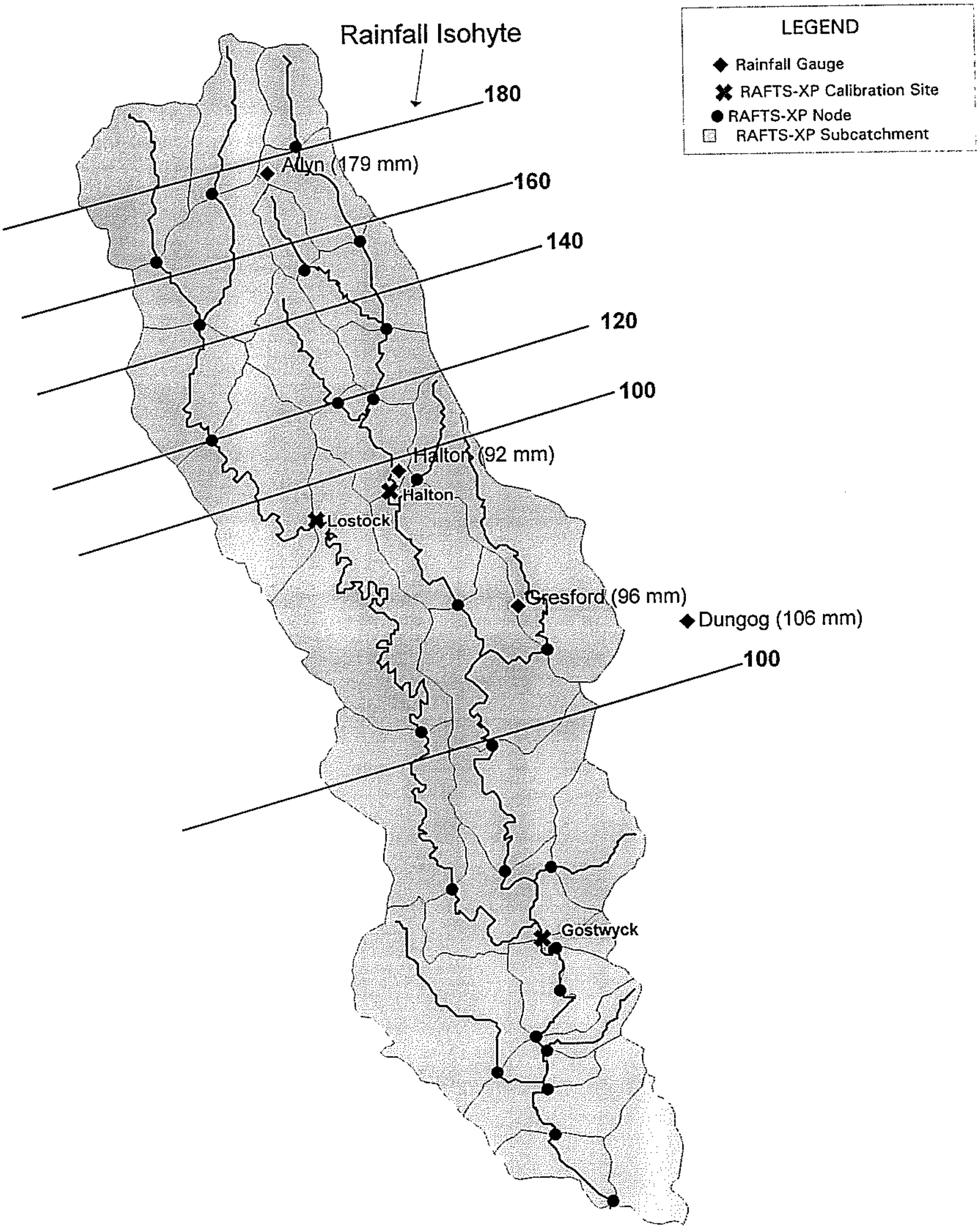
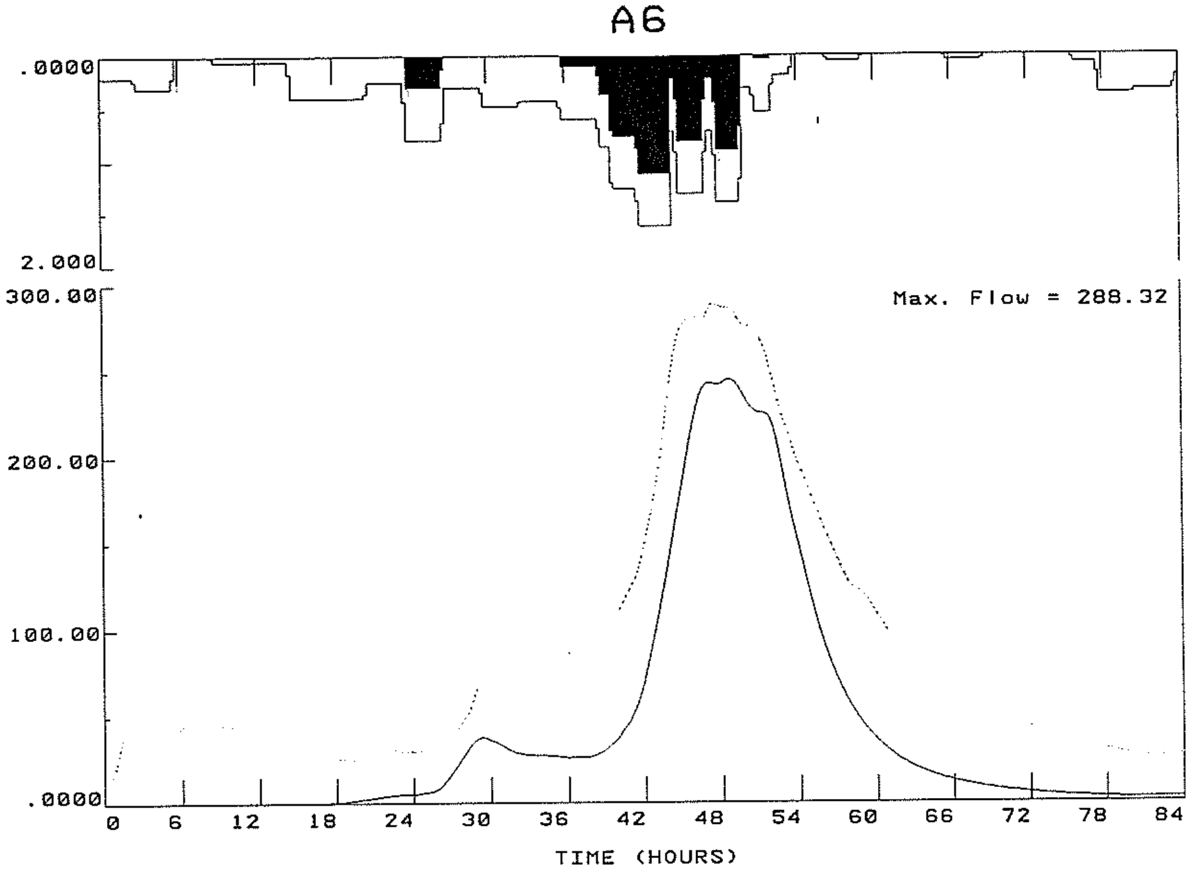

Paterson River Flood Study
Halton - 1995

Figure 11.15 March 1995 Rainfall Distribution (48 hours from 09:00 3.3.95)



d:\aac5\n0076\mapinfo\RainDist_95.wor

Figure 11.16 March 1995 Hydrologic Model Calibration (Allyn & Gostwyck)



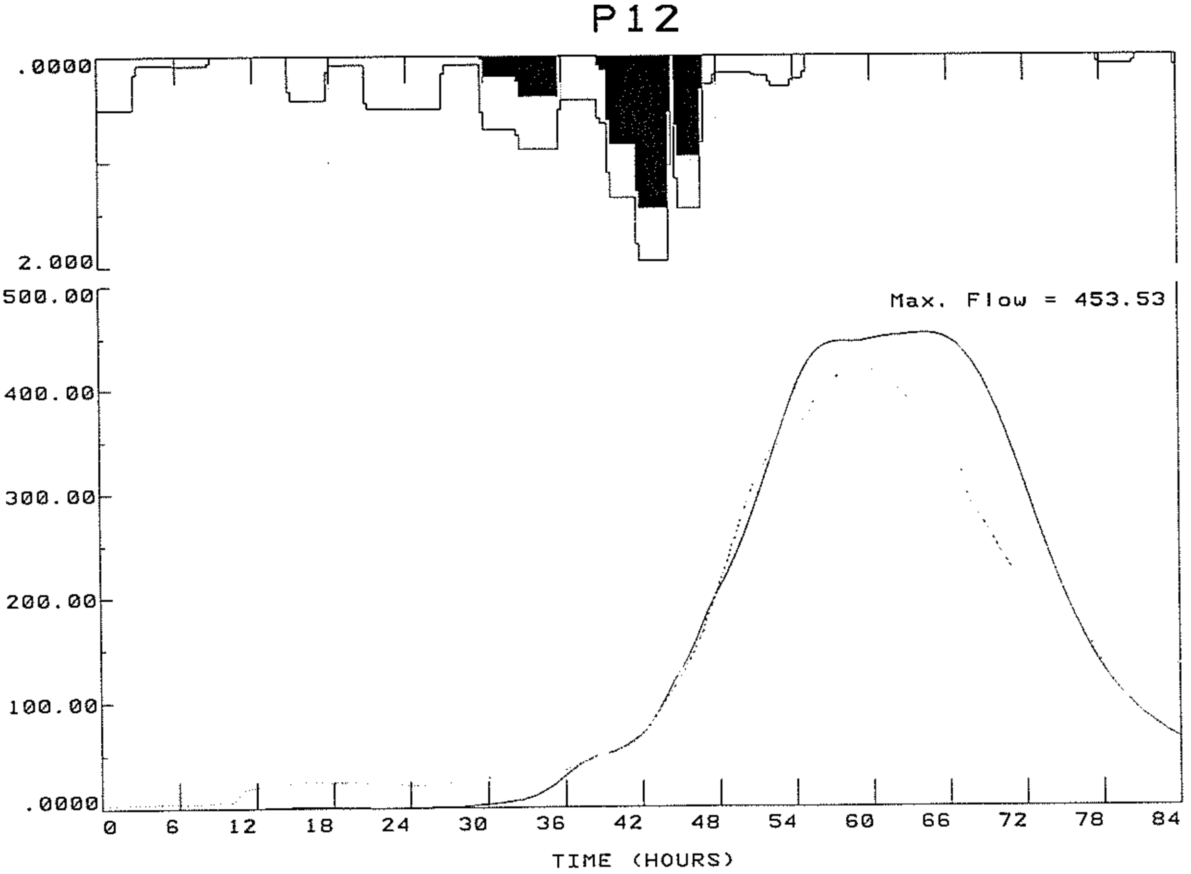


Figure 11.17 March 1995 Hydrologic Model Calibration (Lostock Dam)

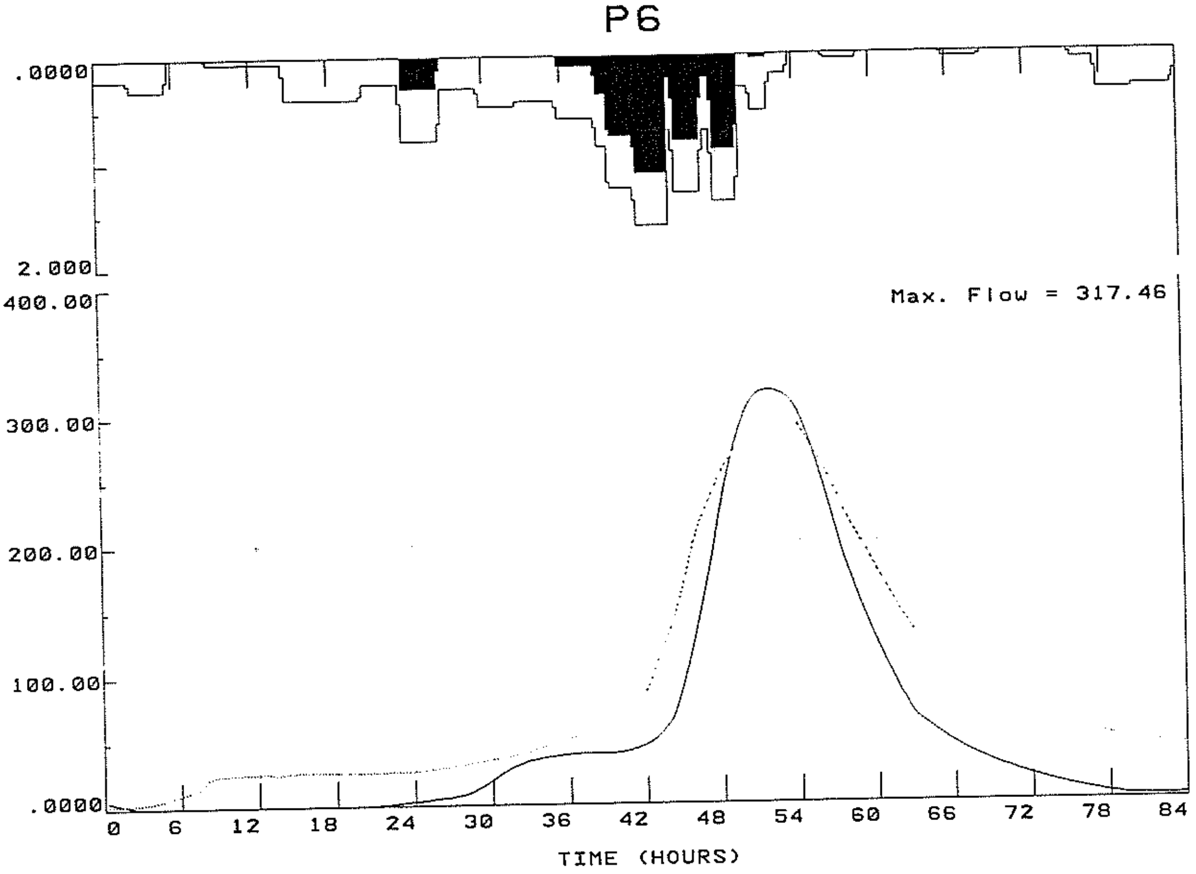


Figure 11.18 March 1995 Hydraulic Model Calibration (Hydrologic Model Flows)

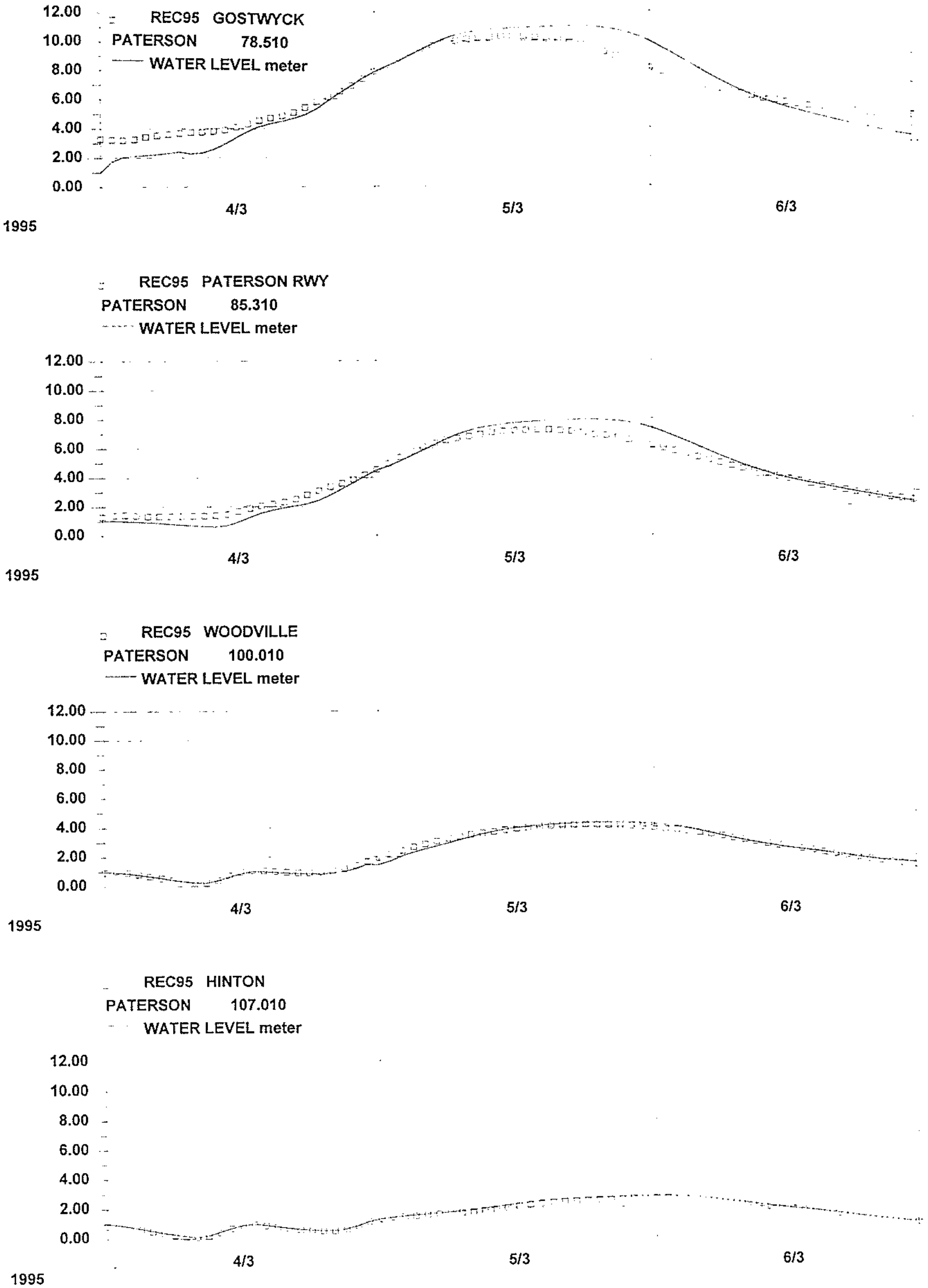
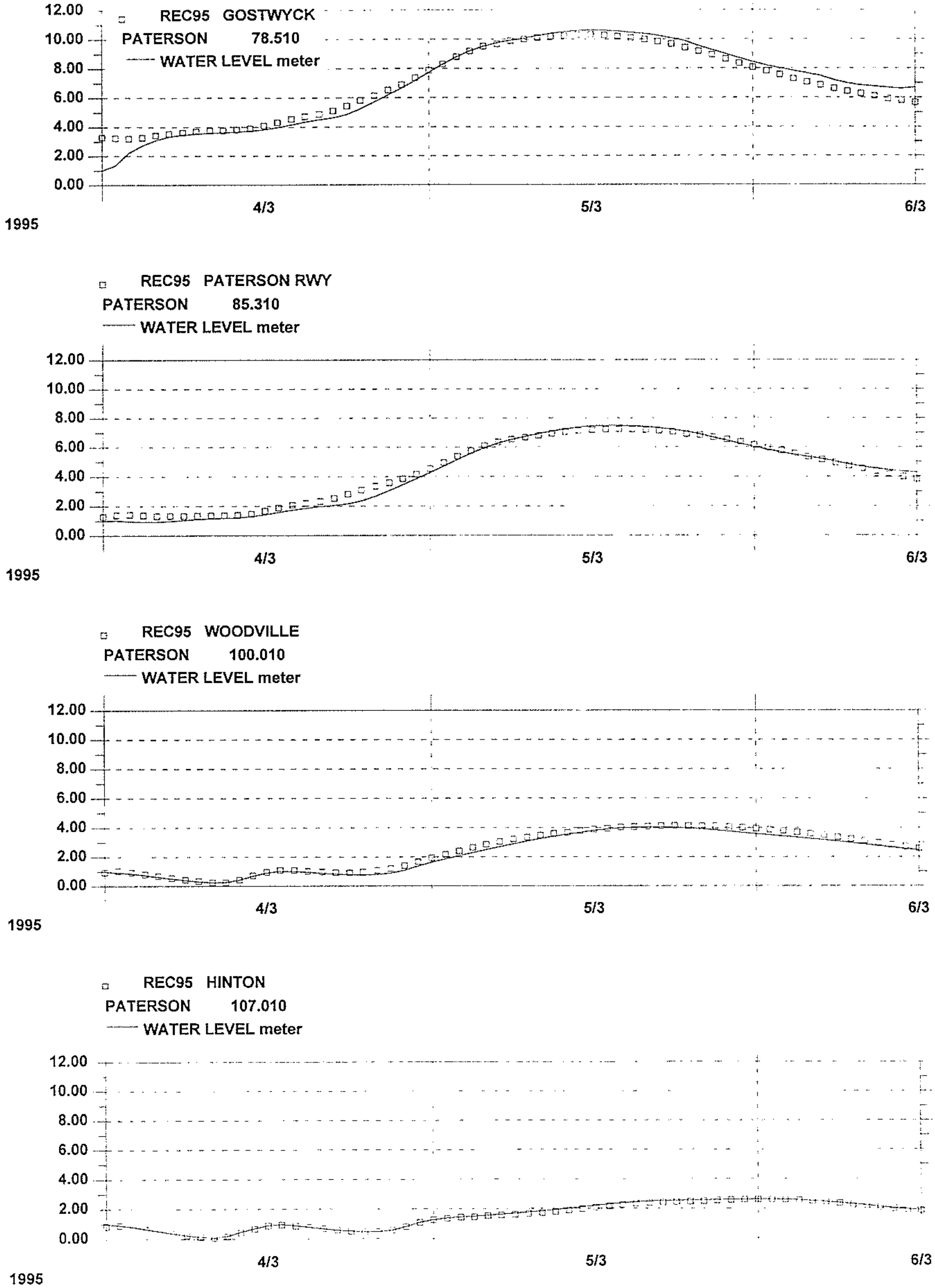


Figure 11.19 March 1995 Hydraulic Model Calibration (Gostwyck Recorded Flows)



12 APPENDIX E: FLOOD FREQUENCY ANALYSIS

A flood frequency analysis was carried out to provide an alternative assessment of peak design flood flows at Gostwyck. The annual series analysis approach was adopted as recommended in AR&R.

The stream flow gauge at Gostwyck (Station No. 210079) has records for the years 1928 to 1946 and 1969 to 1995, a total of 46 years. After examination of the data for consistency the following points were noted:

- There is concern over the consistency of the records as the peak flow for the 1946 flood was substantially higher than for the March 1978 flood, yet reliable flood records at Paterson indicate the 1978 flood to be a larger flood.
- Further investigations by DLWC officers found that the Gostwyck flow records are based on three different gauge locations with each gauge having its own rating curve (to convert flood levels to flows). The first site was located at Gostwyck Bridge from 1928 to 1946, the second approximately 1.5 km further upstream from 1969 to 1977 and the third approximately 4 km upstream of Gostwyck Bridge from 1977 to present day.
- Further examination of the flood levels also questioned the accuracy of the AHD datums for all three gauges.
- A reliable flood frequency analysis is not possible unless all flow records are consistent with each other, ie. they are based on the same rating curve and the recorded flood levels are all to the same datum.

A consistent data set was obtained by:

- Re-surveying remaining gauge boards at each site (where possible) and local bench marks on which the gauges were levelled (this was carried out by DLWC and PSC staff).
- Transferring all flood levels from the 2nd and 3rd gauges to Gostwyck Bridge by comparing flood levels recorded at the gauge site and at the Gostwyck Bridge flood gauge for the same flood.
- Developing a common rating curve at Gostwyck Bridge based on the ratings at each of the three gauge sites, a recent curve developed by Manly Hydraulics Laboratory for their automatic gauge installed in 1989 and the calculations from the calibrated hydraulic model.
- Re-calculate the peak stream flows for each year using the Gostwyck Bridge flood levels and common rating curve.
- Carry out a flood frequency analysis using the revised flows.

The Log-Pearson III curve as recommended by AR&R was used to fit the historical flows with an adjustment for expected probability (see Chapter 10 in AR&R - Ref 4). The plotting position used for the points was based on that also recommended by AR&R (see Section 10.4.5 in AR&R).

A series of curves were produced based on the full 46 years of data.

Two scenarios are presented in the following table and figures:

- Annual series analysis based on all 46 years of data (Skew of -0.3).
- Annual series analysis based on all 46 years of data (Skew of -0.5).

For the analysis a skew of -0.5 was automatically calculated as the best fit, however, this is quite a high value based on other similar analyses. To test the sensitivity, several other skew values were examined. The results showed only a slight change in the skew value causes a large change in the peak flow values for the rare events such as the 1% AEP flood. A skew of -0.3, which also provides a good fit, is presented here to illustrate this point.

Table 12.1 presents the peak flow values from the two scenarios.

Figure 12.1 shows the recorded flow versus estimated or actual Gostwyck Bridge flood level, the stage-discharge (level-flow) curve as computed by the hydraulic model and the adopted rating curve.

Figure 12.2 to Figure 12.3 illustrate the calculated curves for the two scenarios described above. The figures also show the 95% and 5% confidence limits.

The complete list of flood records for the 46 years is shown in Table 12.2.

Table 12.1 Gostwyck Bridge Peak Flows from Flood Frequency Analyses

	Peak Flow (m^3/s)			
Scenario	**1%**	**2%**	**5%**	**10%**
All Years (Skew = -0.3)	2850	2210	1500	1050
All Years (Skew = -0.5)	2380	1930	1390	1010

Table 12.2 Gostwyck Bridge Revised Flood Records

Year	Gauge[*]	Gauge Zero (mAHD)	Records from Gauge Site			Adjusted to Gostwyck Bridge	
			Level (m)	Flow (cumecs)	AHD (mAHD)	Level (mAHD)	Flow (cumecs)
1928	1	-0.300	11.96	682	11.66	11.66	539
1929	1	-0.300	14.17	1495	13.87	13.87	951
1930	1	-0.300	13.87	1274	13.57	13.57	885
1931	1	-0.300	13.03	929	12.73	12.73	711
1932	1	-0.300	8.05	273	7.75	7.75	208
1933	1	-0.300	5.79	166	5.49	5.49	100
1934	1	-0.300	8.53	306	8.23	8.23	234
1935	1	-0.300	4.72	120	4.42	4.42	57
1936	1	-0.300	8.23	286	7.93	7.93	217
1937	1	-0.300	5.69	160	5.39	5.39	96
1938	1	-0.300	9.22	354	8.92	8.92	275
1939	1	-0.300	6.10	176	5.80	5.80	112
1940	1	-0.300	3.35	64	3.05	3.05	21
1941	1	-0.300	6.48	190	6.18	6.18	129
1942	1	-0.300	12.65	824	12.35	12.35	643
1943	1	-0.300	5.49	150	5.19	5.19	88
1944	1	-0.300	4.19	95	3.89	3.89	38
1945	1	-0.300	11.13	549	10.83	10.83	443
1946	1	-0.300	14.63	1798	14.33	14.33	1079
1969	2	+0.995	10.11	422	11.11	10.21	381
1970	2	+0.995	7.62	206	8.62	7.72	206
1971	2	+0.995	12.62	767	13.62	12.72	710
1972	2	+0.995	13.41	849	14.41	13.51	873
1973	2	+0.995	7.20	188	8.19	7.30	185
1974	2	+0.995	10.09	567	11.08	10.19	379
1975	2	+0.995	9.81	361	10.80	9.91	353
1976	2	+0.995	12.41	688	13.40	12.51	671
1977	2	+0.995	12.99	799	13.98	13.09	779
1978	3	+3.290	14.37	1324	17.66	15.50	1440
1979	3	+3.290	9.05	377	12.34	10.30	390
1980	3	+3.290	2.99	37	6.28	4.24	50
1981	3	+3.290	5.26	125	8.55	6.51	145
1982	3	+3.290	7.89	303	11.18	9.14	292
1983	3	+3.290	3.79	63	7.08	5.04	82
1984	3	+3.290	11.60	1020	14.89	12.85	733
1985[†]	-		13.60	N/A	16.89	15.20	1344
1986	3	+3.290	7.67	283	10.96	8.92	275
1987	3	+3.290	8.79	383	12.08	10.04	364
1988	3	+3.290	10.50	624	13.79	11.75	550
1989	3	+3.290	7.74	286	11.03	8.83	270
1990	3	+3.290	13.37	1111	16.66	14.70	1190
1991	3	+3.290	2.37	20	5.66	3.36	27
1992	3	+3.290	7.34	254	10.63	7.22	181
1993	3	+3.290	4.95	110	8.24	6.31	136
1994	3	+3.290	2.54	31	5.83	3.85	37
1995	3	+3.290	9.13	421	12.42	10.32	392

[*] Gauge 1 was at Gostwyck Bridge; Gauge 2 at approx 1.5km upstream of Gostwyck Bridge and Gauge 3 at approx 4km upstream of Gostwyck Bridge.

[†] Based on recorded peak at Gostwyck Bridge staff gauge (Ref 8).

Figure 12.1 Gostwyck Bridge Recorded Flows and Adopted Rating Curve

Rating Curves

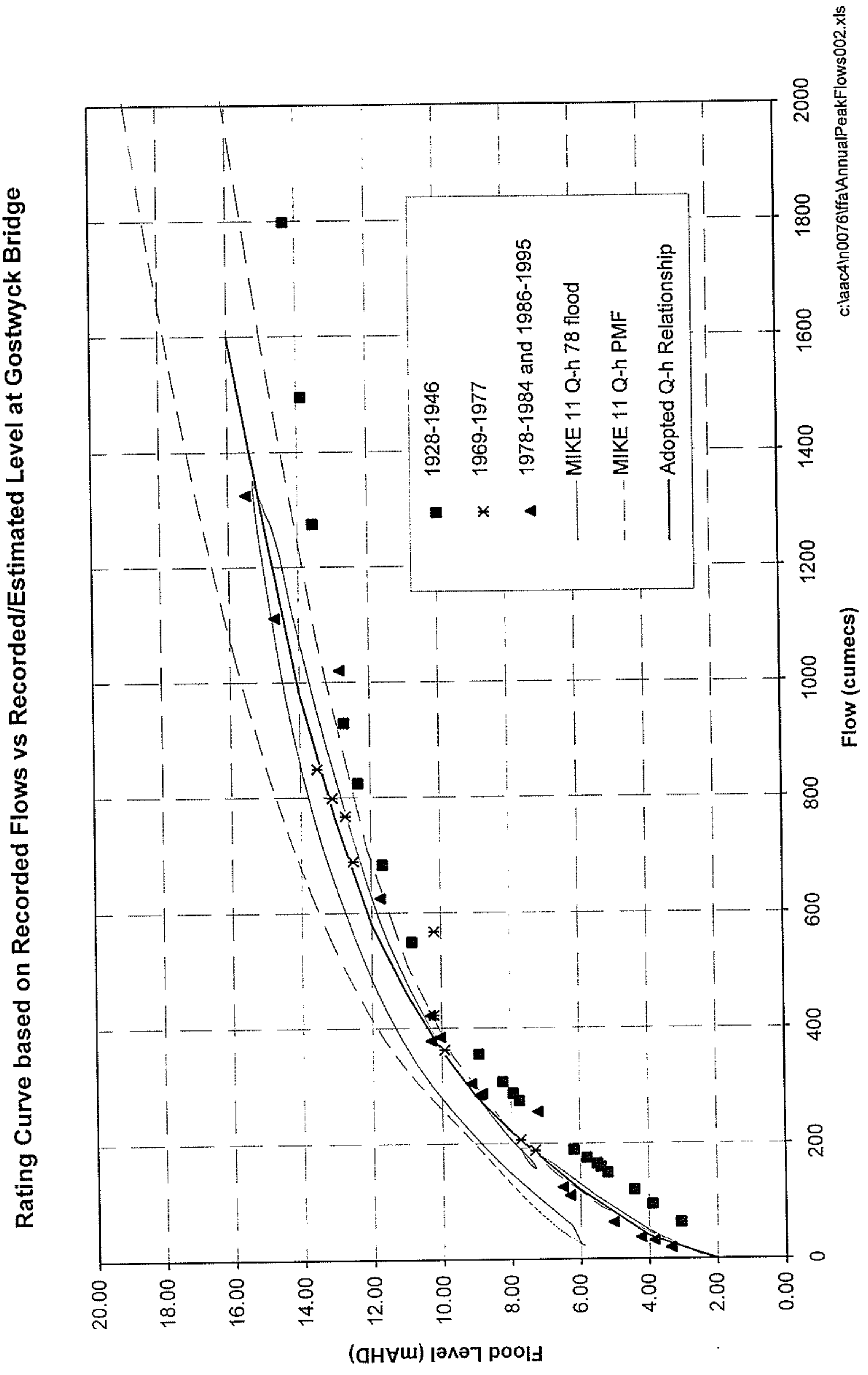


Figure 12.2 Gostwyck Bridge Flood Frequency Curve (All Years - Skew = -0.3)

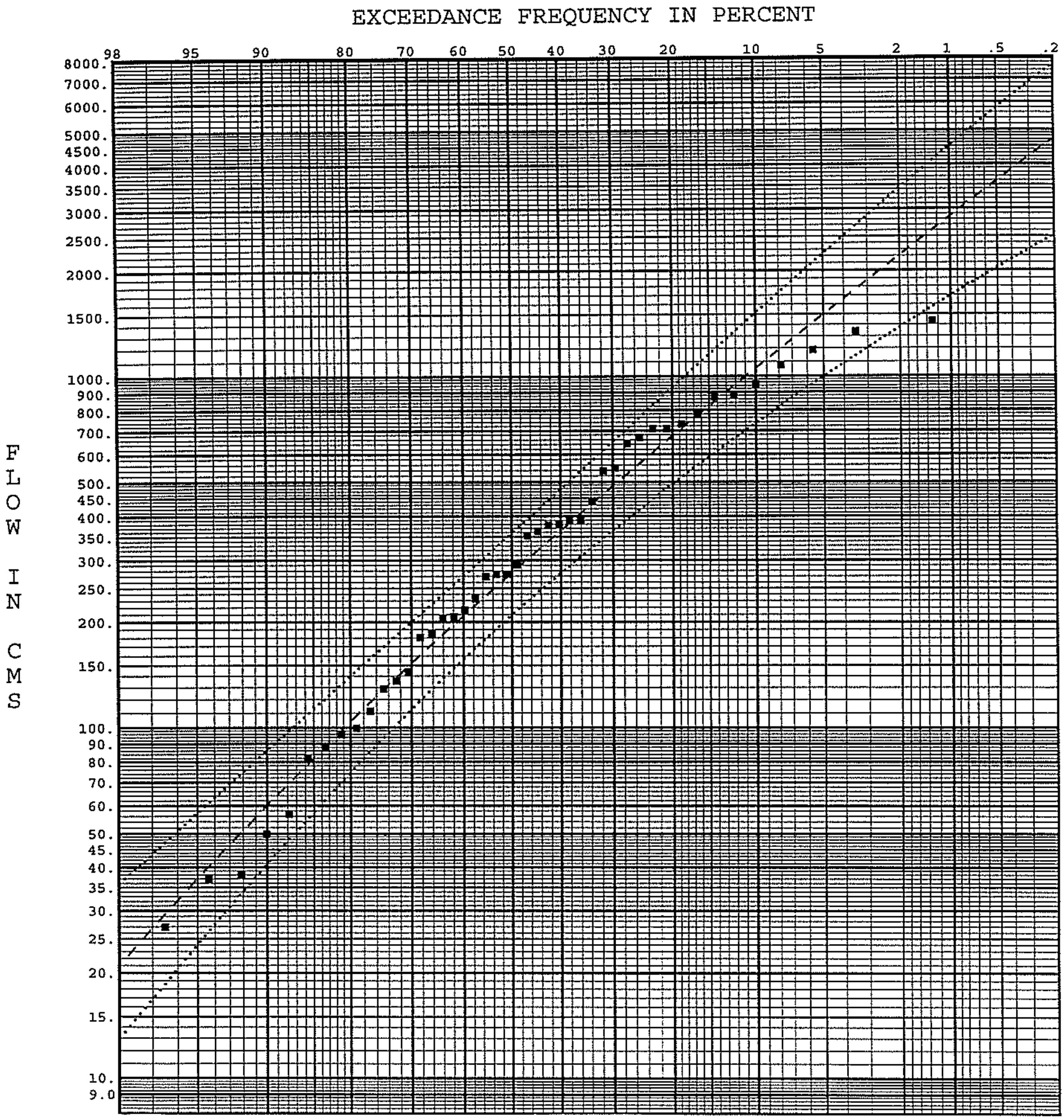
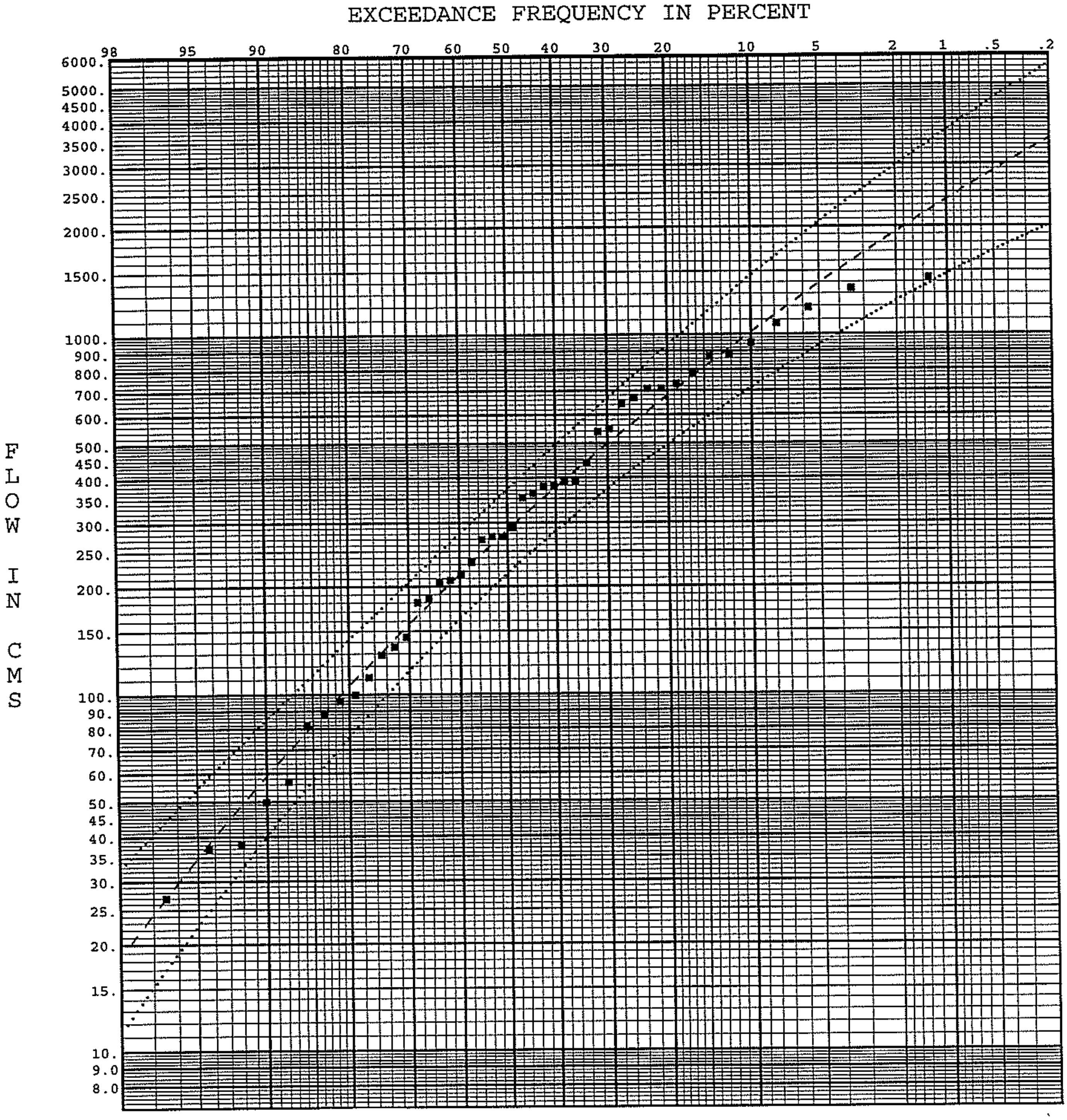


Figure 12.3 Gostwyck Bridge Flood Frequency Curve (All Years - Skew = -0.5)



13 APPENDIX F: DESIGN FLOOD RESULTS

13.1 Graphical Presentation of Results

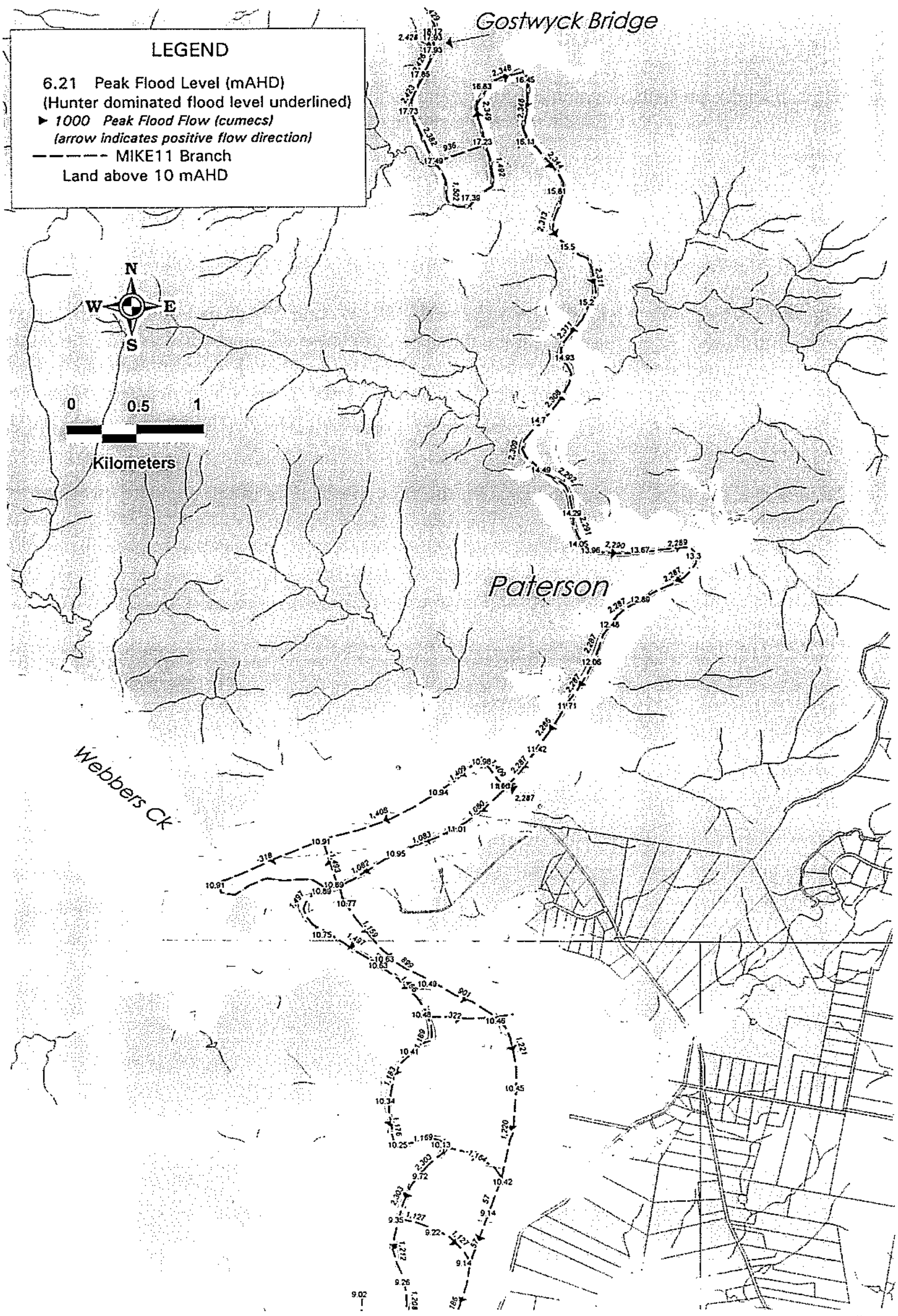
This appendix presents in graphical format the results of the design flood simulations. The study area has been subdivided into three regions for reasons of clarity. The regions are labelled:

- Gostwyck Bridge to Iona
- Woodville to Hinton
- McClement Swamp

Figure 13.1 to Figure 13.12 illustrate the peak 1%, 2% and 5% design and extreme flood levels and flows. The values shown are the maximum value which occurred during both the Paterson dominated flood and the Hunter dominated flood. They do not represent an instant in time but rather an envelope of the flood peaks. Peak levels which occurred from the Paterson dominated flood are depicted differently to those from the Hunter dominated flood (refer to the map legend).

Note that if the flow is given as negative the flow direction is in the opposite direction to that indicated by the arrow.

Figure 13.1 1% AEP Design Flood Peak Levels & Flows (Paterson to Iona)



m:\aac5\n0076\mapinfo\100yrq&h.wor

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Figure 13.2 1% AEP Design Flood Peak Levels & Flows (Woodville to Hinton)

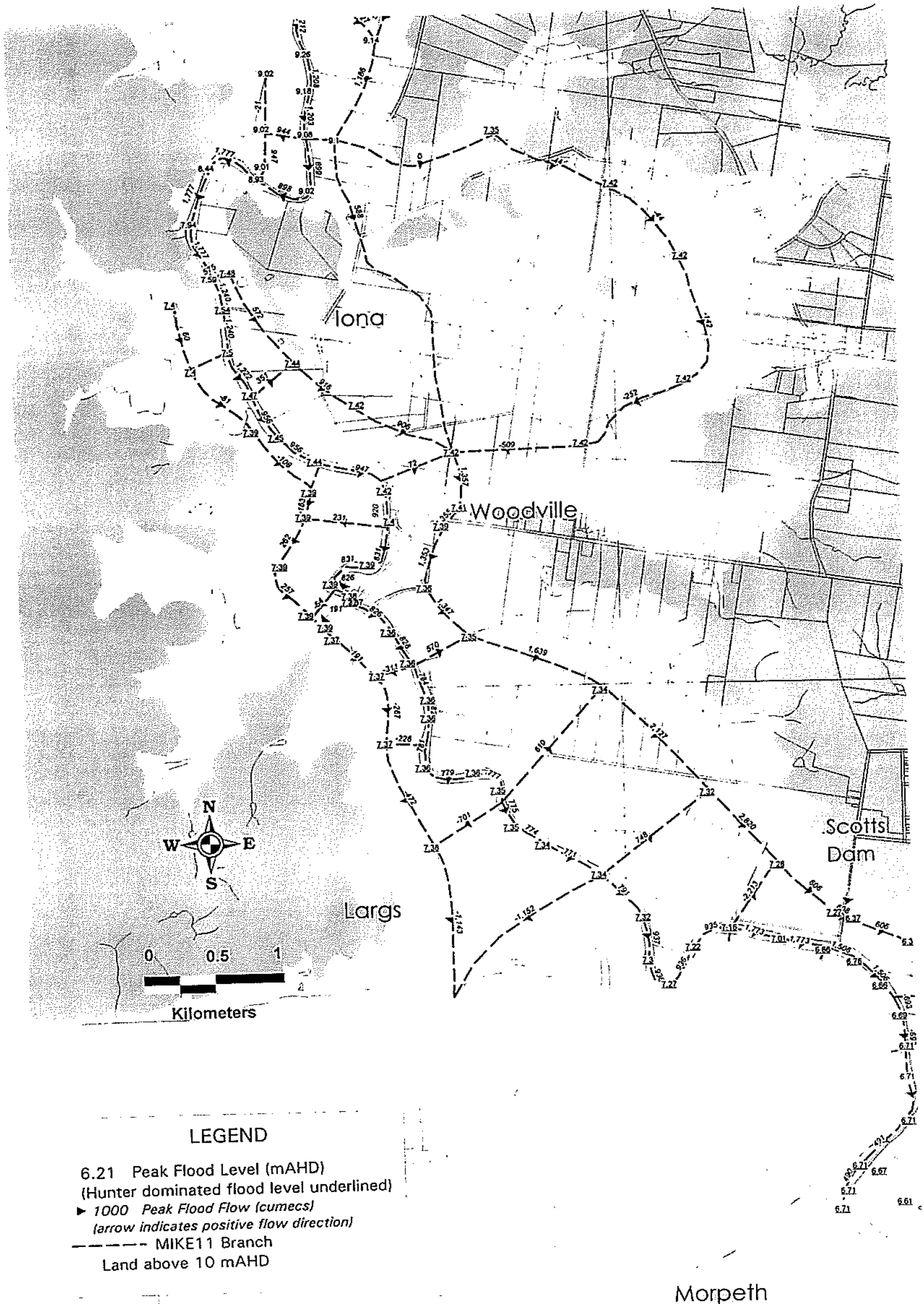

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Figure 13.3 1% AEP Design Flood Peak Levels & Flows (McClement Swamp)

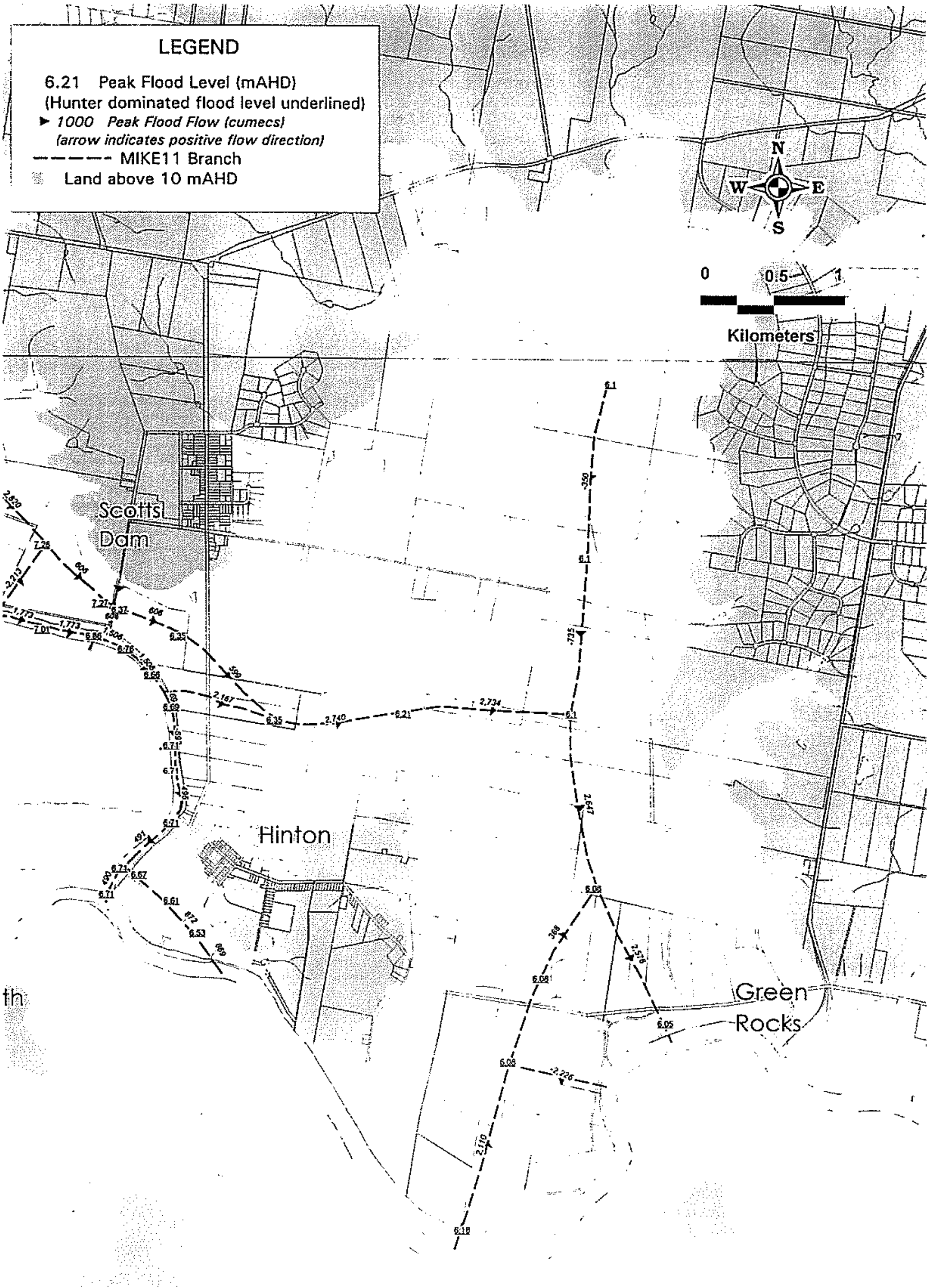

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Figure 13.4 2% AEP Design Flood Peak Levels & Flows (Paterson to Iona)

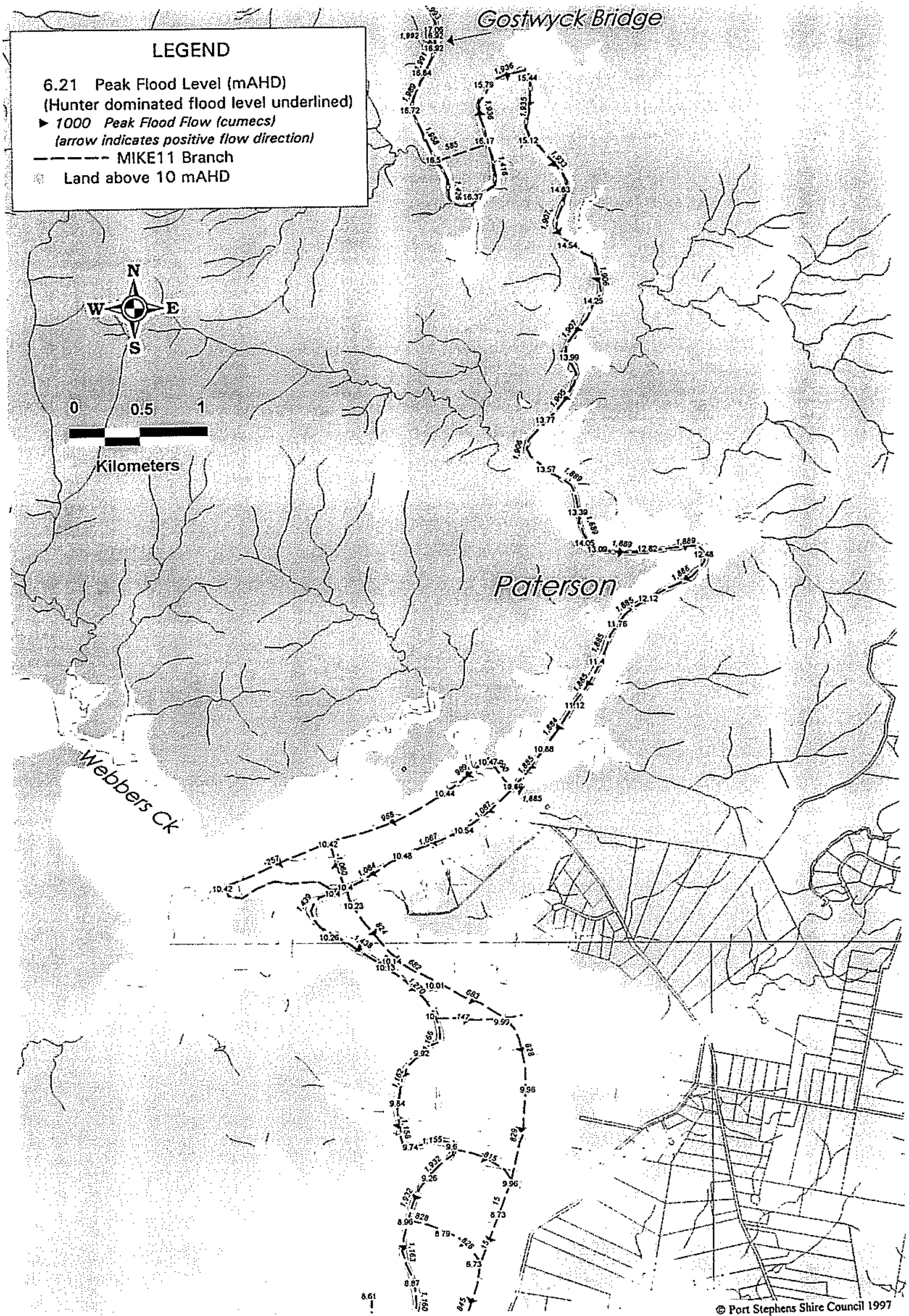

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Figure 13.5 2% AEP Design Flood Peak Levels & Flows (Woodville to Hinton)

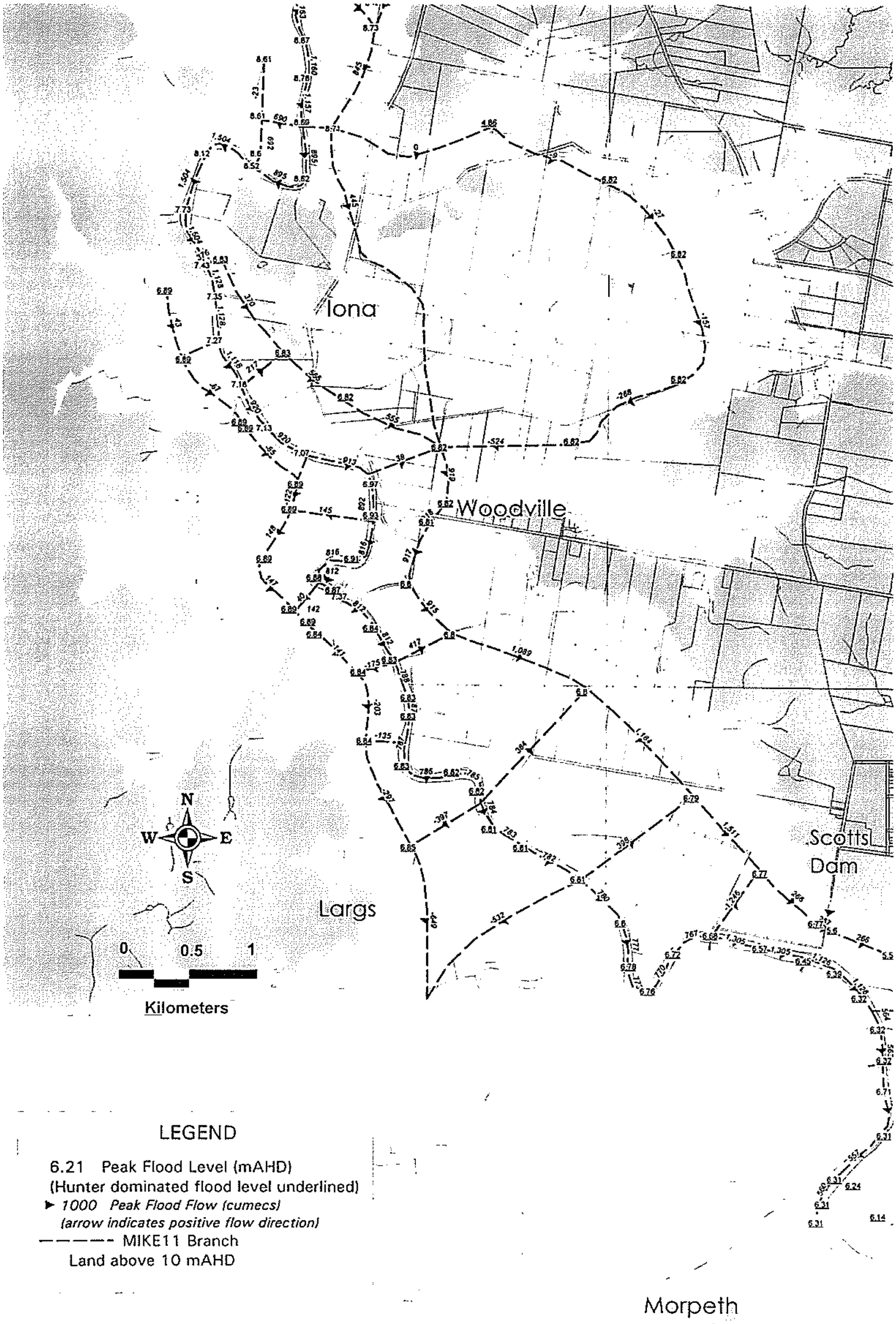

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Figure 13.6 2% AEP Design Flood Peak Levels & Flows (McClement Swamp)

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Figure 13.7 5% AEP Design Flood Peak Levels & Flows (Paterson to Iona)

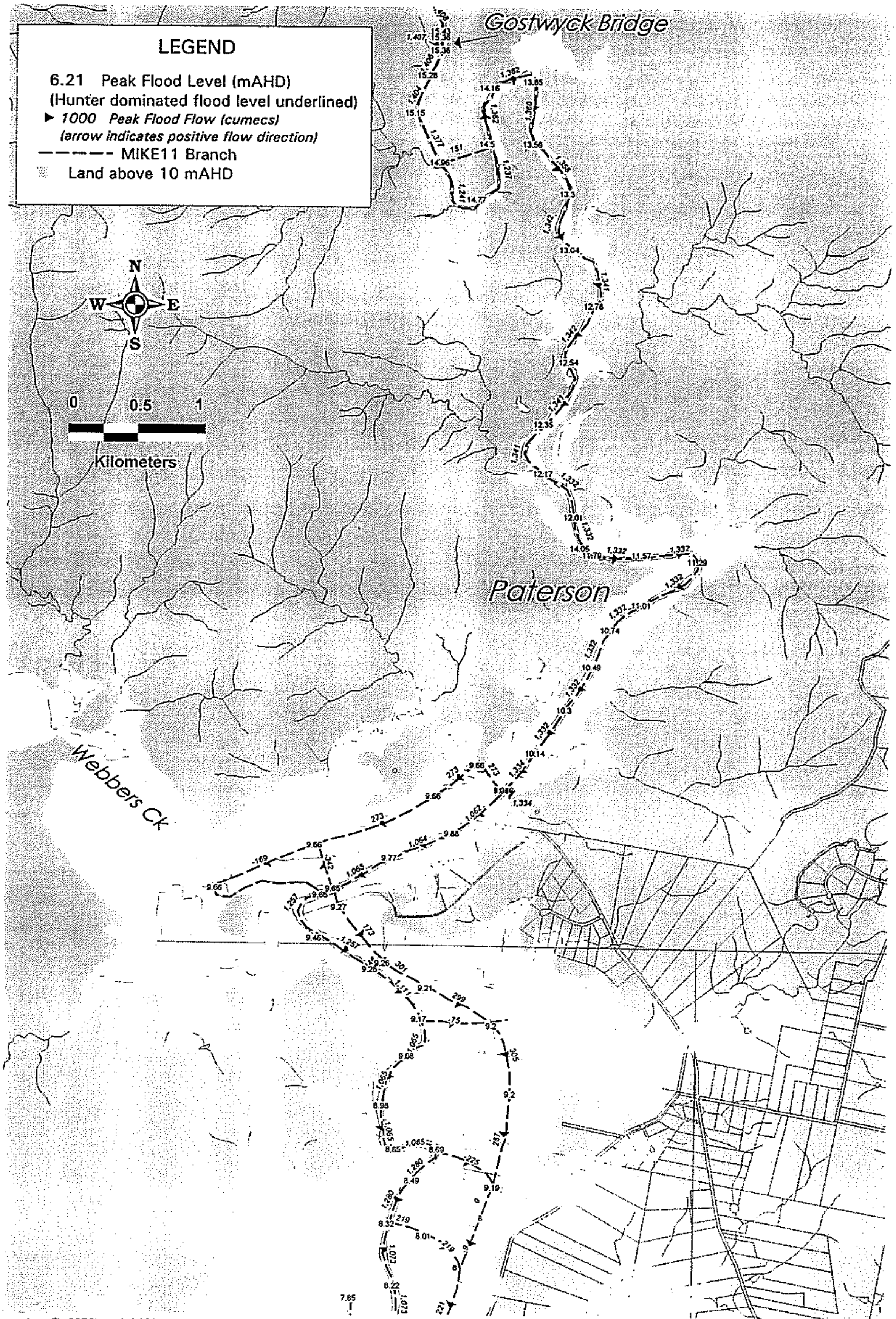

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Figure 13.8 5% AEP Design Flood Peak Levels & Flows (Woodville to Hinton)

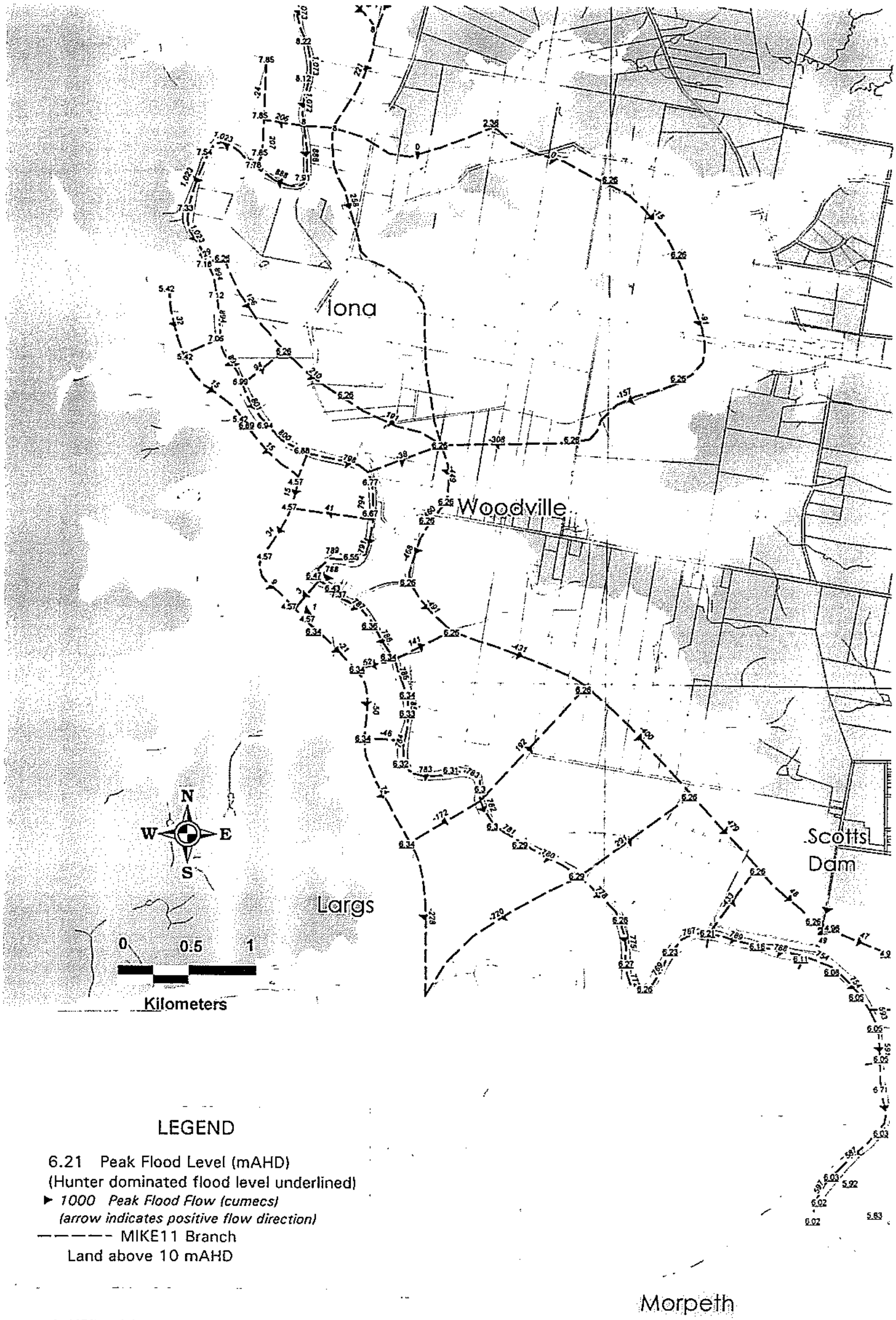

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Figure 13.9 5% AEP Design Flood Peak Levels & Flows (McClement Swamp)

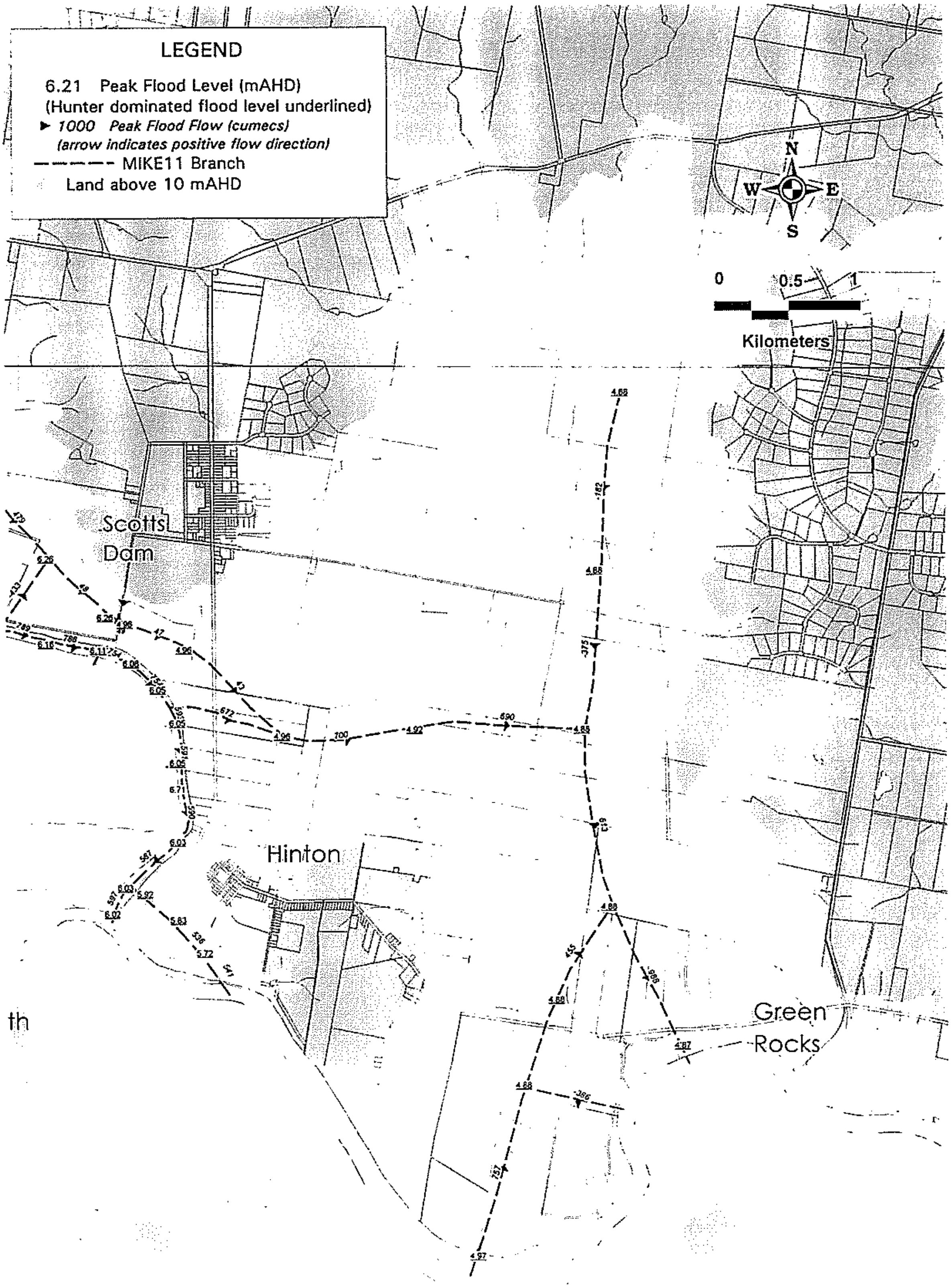

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Figure 13.10 Extreme Flood Peak Levels & Flows (Paterson to Iona)

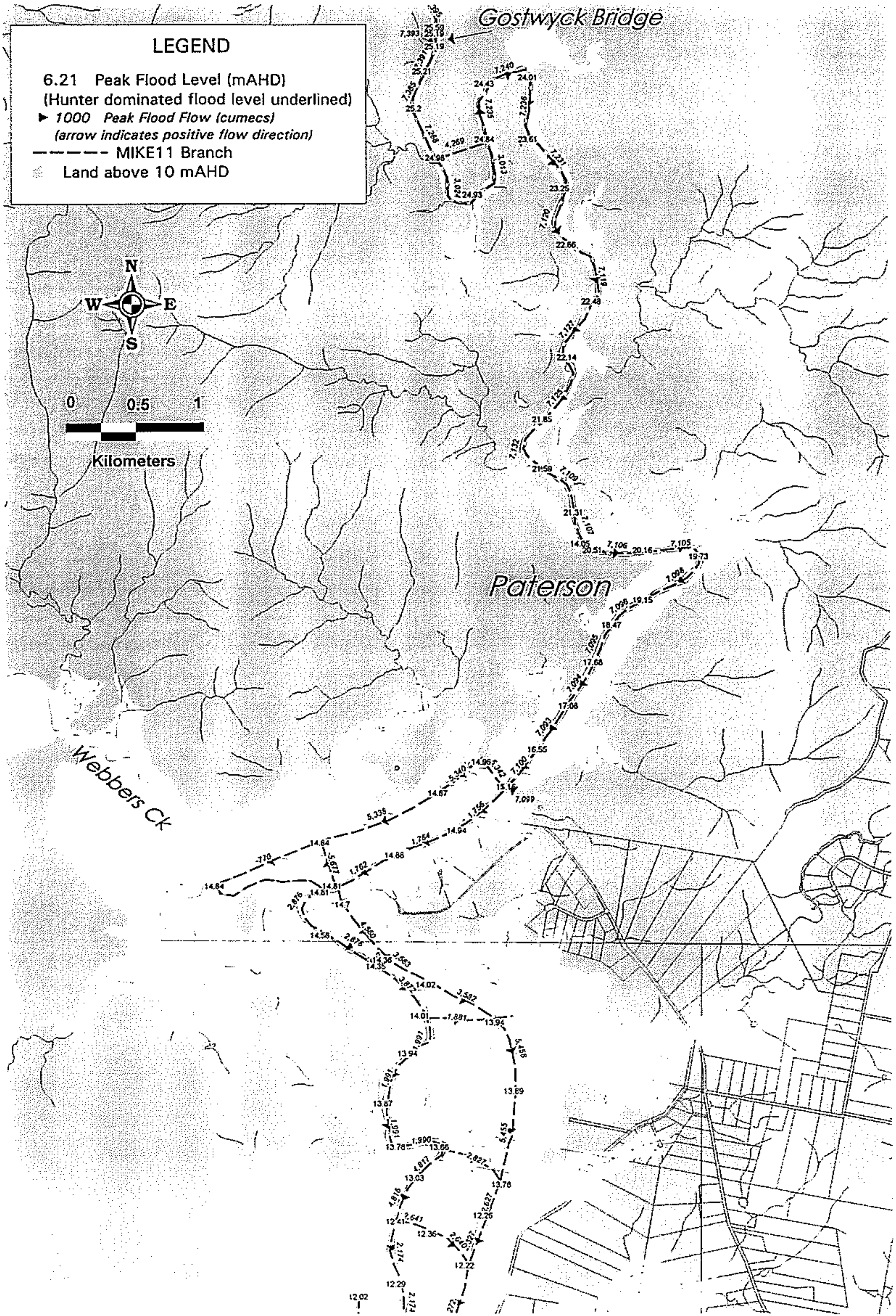

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Figure 13.11 Extreme Flood Peak Levels & Flows (Woodville to Hinton)

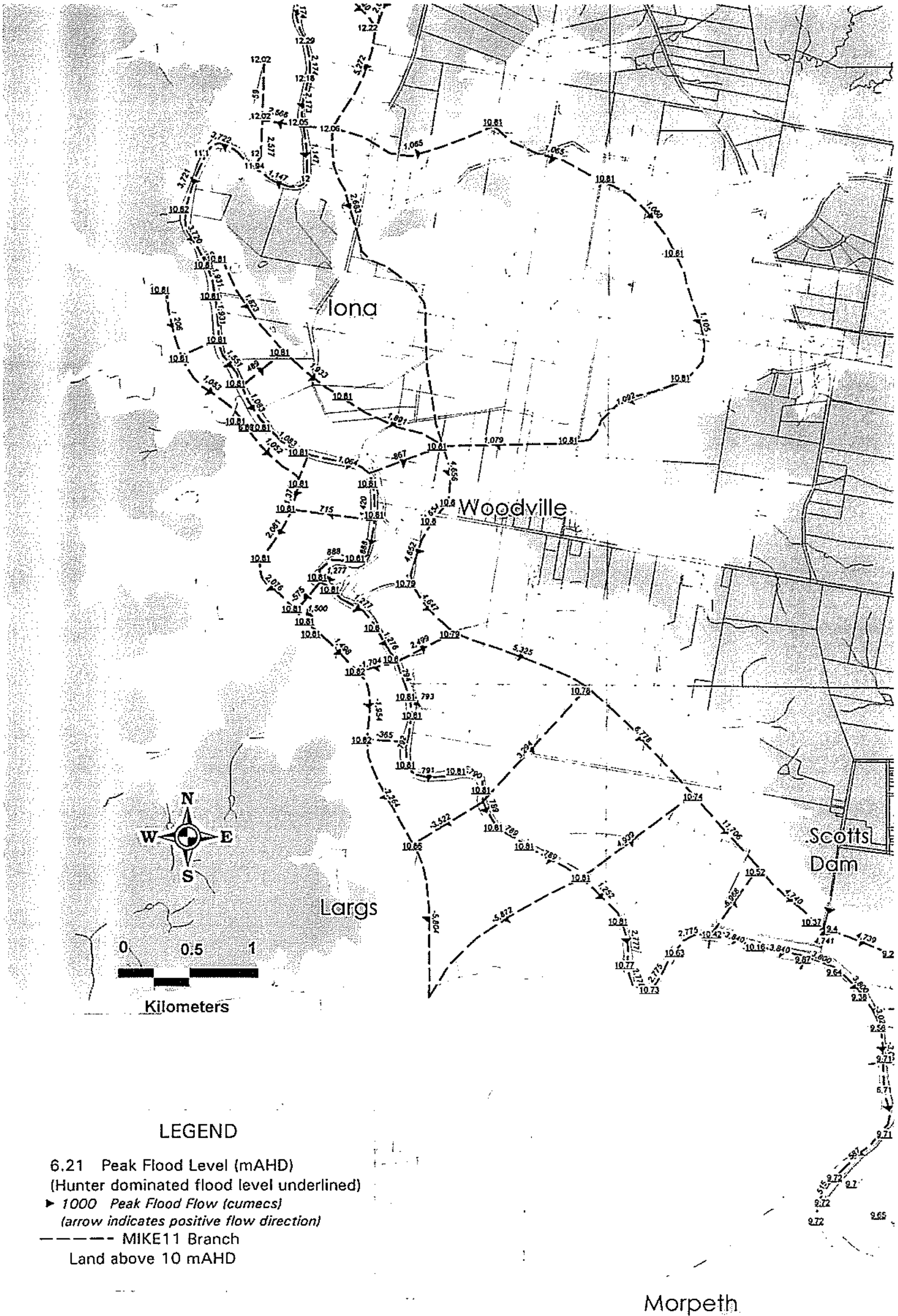

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Figure 13.12 Extreme Flood Peak Levels & Flows (McClement Swamp)

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13.2 Sensitivity Tests

Sensitivity tests were carried out using the 1% AEP flood to identify the importance of varying the relative magnitudes of the floods in the Paterson and Hunter and in the relative timing of their flood peaks. Table 13.1 describes the tests carried out.

The results of the tests are presented in Table 13.2. In each case the change in peak flood levels is based on a comparison with the 1% AEP design flood results as tabulated in Table 6.1.

Table 13.1 Sensitivity Test Descriptions

Test ID	Description	Run ID(s)[1]
SA1	1% AEP flood in both the Paterson and Hunter Rivers (instead of the 1% / 2% combination).	P01H01C
SA2	1% AEP flood combined with a 5% AEP flood (instead of the 1% / 2% combination).	P01H05C & H01P05C
SB1	24 hour lag between Oakhampton and Gostwyck (instead of the 12 hour lag).	P1H2-L12 & H1P2-L12
SB2	Zero lag between Oakhampton and Gostwyck (instead of the 12 hour lag).	P1H2XL12 & H1P2XL12

[1] MIKE 11 simulation identifier.

Table 13.2 Sensitivity Test Results

	Change in Peak Flood Level (m)				
Location	**SA1**	**SA2**	**SB1**	**SB2**	**MIKE 11 Point**[1]
Gostwyck Bridge	0.00	0.00	0.00	0.00	PATERSON 78.500
Paterson River, "Gostwyck"	0.00	0.00	0.00	0.00	PATERSON 80.500
Paterson River, "Tillimby"	0.00	0.00	0.00	0.00	PATERSON 82.660
Paterson Railway Bridge	0.00	0.00	0.00	0.00	PATERSON 85.300
Paterson Road Bridge	0.00	0.00	0.00	0.01	PATERSON 88.300
Paterson River, "Stradbroke"	0.00	0.00	0.00	0.02	PATERSON 92.900
Floodplain north of "Stradbroke"	0.00	0.00	0.00	0.01	PATERSON_LB 92.200
Floodplain south of "Stradbroke"	0.00	0.00	0.00	0.04	PATERSON_LB 93.600
Floodplain, Mindaribba	0.10	-0.17	-0.39	0.27	PATERSON_RB 97.500
Floodplain, Iona	0.11	-0.20	-0.44	0.28	PATERSON_LB 98.900
Paterson River, Woodville	0.09	-0.16	-0.38	0.26	PATERSON 100.000
Floodplain north of Dunmore House	0.10	-0.17	-0.39	0.27	PATERSON_RB 99.300
Floodplain between Woodville & Scotts Dam	0.09	-0.15	-0.37	0.26	PATERSON_LB 101.450
Floodplain north-east of Largs	0.09	-0.15	-0.35	0.26	PATERSON_RB 100.900
Paterson River, Scotts Dam	0.04	-0.08	-0.18	0.19	PATERSON 105.480
Paterson River, Hinton	0.04	-0.07	-0.15	0.17	PATERSON 107.000
Floodplain, Hinton	0.06	-0.10	-0.22	0.25	PATERSON_LB 105.300
McClement Swamp	0.05	-0.08	-0.17	0.22	MCCLEMENT_FP 10.000
Floodplain, "Hinton Vale"	0.05	-0.07	-0.16	0.22	MCCLEMENT_FP 13.500

[1] Computational point identifier in the MIKE 11 hydraulic model.

14 APPENDIX G: 3D FLOOD SURFACE MODELLING

14.1 3D Flood Surface

Production of any map depicting flooding requires a knowledge of the three-dimensional (3D) shape of the flood's surface. Except in areas where flood waters pond, a flood surface is not flat, but is downwardly sloping in varying degrees from its upstream to downstream end. The severity of the slope varies according to the flood wave's physical nature and the topographical characteristics of the river and floodplains.

As presented previously, the flood levels at discrete points down the river and over the floodplains were determined for historical and design floods using the hydraulic computer model. In generating a 3D flood surface it may be incorrect to simply interpolate in a straight line between these points. If there is a river meander between two river points or a levee between river and floodplain points a direct interpolation along a straight line between the points will yield misleading flood levels.

The flood level along a line which is perpendicular to the direction of flood flow is not perfectly horizontal, but close enough for the objectives of this study. For example, along a line from bank to bank perpendicularly across a river will closely follow a horizontal flood level. The 3D shape of a flood surface can therefore be defined as a series of these "horizontal water level lines" placed down the river and floodplains (see Ref 3) at sufficient frequency to pick up the presence of river meanders, levees and other features.

Using these lines the 3D flood surface model is created as a TIN (triangular irregular network) in a similar manner to how the topography of the ground surface is represented in the DTM (see Section 4.3).

Figure 14.1 illustrates an example of the horizontal water level lines and the resulting TIN developed for the Paterson River.

Figure 14.1 3D Flood Surface TIN