DAVID CASSON.

MURRURUNDI, BLANDFORD AND WILLOW TREE

FLOODPLAIN MANAGEMENT STUDY

MARCH 1998

Prepared by:

Job No: NX518

Lyall & Macoun Consulting Engineers
Level 6, 2 Help Street
Chatswood NSW 2067

Tel: **(02) 9413 3411**
Fax: **(02) 9413 3471**
Email: **lmce@netro.com.au**

Job No: NX518	Date: 03/06/98	Principal: SJP
File: J:\NX518\DOCS\MURRFPMS.DOC	Rev: 3.0	Reviewer: BWL

TABLE OF CONTENTS

LIST OF FIGURES

APPENDICES

MURRURUNDI, BLANDFORD AND WILLOW TREE FLOODPLAIN MANAGEMENT STUDY

SUMMARY

Murrurundi Shire Council commissioned this Floodplain Management Study in accordance with the procedures set out in the NSW Government's current Floodplain Development Manual. This report includes recommendations for inclusion in a Floodplain Management Plan which, after consideration and amendment by Council and the community, will be adopted for the three townships of Murrurundi, Blandford and Willow Tree. This Plan will provide the basis for future management of flood affected land and any funding assistance sought by Council from the State and Commonwealth Governments.

The NSW Flood Prone Lands Policy requires that floodplain management be based on the merits of the situation affecting each community rather than setting a single State-wide standard. In recent years it has also been recognised that there is a gradation of flood risk which decreases towards the edge of the floodplain and that a range of different land uses are possible at different locations on the floodplain. For each land use, the social, economic and environmental issues need to be assessed on their merits and this may lead to different planning flood levels being adopted for different land uses. Central to this approach is the requirement that the Floodplain Management Plan must reflect the aspirations and needs of the local community.

This study summarises the available information relating to flooding in the three townships of Murrurundi, Blandford and Willow Tree. It describes the physical setting and flood producing mechanisms, identifies the flood extent and the resulting flood damages for floods of various average recurrence intervals (ARI). The transport linkages, planning instruments and the existing flood emergency system are also examined. The study draws upon previous investigations including the Murrurundi, Blandford and Willow Tree Flood Study completed in 1997 by Lyall & Macoun Consulting Engineers, as well as historic flood data supplied by Council.

Detailed analysis of flood flows and levels throughout the three townships together with a survey of the floor level of each building within the floodplain indicates that most of the properties affected by flooding are located in Murrurundi. Table S-1 summarises the numbers of properties within each township which are "affected" by the 100 year ARI flood. These are shown in column A and include properties where flood water is on the land as well as those where flood water is above floor level. Also shown, in column D, are the numbers of properties which are "damaged", that is, flood water above floor level.

The Floodplain Management Committee has held a number of meetings to review the technical information presented in this report and to consider the merits of various floodplain management measures. As a result of these meetings, the recommended definitions of land to which planning controls should apply are:

Floodplain: land which is subject to inundation by the extreme flood event. This represents the maximum extent of land likely to be flooded.

Floodways: areas which carry a significant discharge during a flood and are areas where there would be danger to life and limb, difficulties in evacuation and buildings could sustain major structural damage.

Table S-1
Total Number of Properties Affected
100 yr ARI Flood

Township	No. of Properties Flooded					
	Residential		Commercial/ Industrial		Public	
	A	D	A	D	A	D
Murrurundi	36	24	37	29	8	3
Blandford	11	2	0	0	4	2
Willow Tree	1	0	0	0	5	0

The Floodplain Management Committee also considered the merits of various floodplain management measures which are reviewed in this report. This assessment took account of a range of economic, environmental and social factors as well as community views. Consultation with the community indicated that the community perceives that the severity of flooding has increased over time due to the deposition of shingle in the invert of the Pages River leading to an increase in flood levels. Any works which attempt to alleviate this perceived problem are strongly favoured by the community. Also favoured is the rebuilding of the existing levee on the right bank of the Pages River upstream of Arnolds Bridge, denoted the Adelaide Street Levee in this report. However, while these works will considerably reduce the risk of flooding in Murrurundi, they are not justified on economic criteria alone. In general, other major structural measures are neither economically justifiable nor favoured by the community. Based on the merits of the various floodplain management options, the Committee consider that the Murrurundi, Blandford and Willow Tree Floodplain Management Plan should include the following main elements:

- Zoning and building controls;
- Voluntary purchase of a small number of properties;
- Removal of bed material from the Pages River;
- Rebuilding of Adelaide Street Levee;
- Flood preparedness and response measures.

An important measure is the proposed revision of planning controls for development in the floodplain and floodway. To account for flooding conditions in the three townships, a graded set of planning controls are proposed which depend on the location of the site and the type of development proposed. The proposed controls are summarised in Table S-2 for residential development and Table S-3 for commercial development.

In addition to the planning controls summarised in Tables S-2 and S-3, the draft Floodplain Management Plan which is summarised in Table S-4 includes:

- Rebuild existing levee at Adelaide Street and remove bed material in waterway of Arnolds Bridge.
- Controls on filling and fences where they could affect flood levels or flows.
- Preparation of guidelines for flood compatible construction materials and methods.
- Measures to improve flood warning and communications.
- A range of measures to maintain flood awareness and preparedness within the community.

Table S-2
Proposed Residential Planning Controls

Floodway:	(i)	No new dwellings, or extensions to existing dwellings allowed. Repairs only allowed.
	(ii)	Replacement only allowed with consent of Council.
	(iii)	Investigation and possible implementation of a voluntary purchase scheme for most severely affected residences
Floodplain	(i)	Minimum floor levels to be at least 500 mm above the 100 year ARI flood level for that land.
	(ii)	The minimum floor level for a rural building is to be at or greater than the 100 year ARI flood level for that land.

Table S-3
Proposed Commercial Planning Controls

Floodway:	(i)	Redevelopment permitted only with the consent of Council.
	(ii)	Minimum floor level equal to the 100 year ARI flood level for the area. Measures to flood proof building against ingress of floodwaters up to 500 mm above 100 year ARI flood level to be encouraged.
	(iii)	Any new construction to include flood compatible materials up to 500 mm above the 100 year ARI flood level.
	(iv)	The building must also contain provision for all stock to be lifted to elevated shelving, a loft or mezzanine floor situated 500 mm above the 100 year ARI flood level.
Floodplain	(i)	Redevelopment permitted only with the consent of Council.
	(ii)	Minimum floor level equal to the 100 year ARI flood level for the area.
	(iii)	Any new construction to include flood compatible materials up to 500 mm above the 100 year ARI flood level.
	(iv)	The building must also contain provision for all stock to be lifted to elevated shelving, a loft or mezzanine floor 500 mm above the 100 year ARI flood level.

Table S-4
Summary Murrurundi, Blandford and Willow Tree
Draft Floodplain Management Plan

Measure	Required Funding	Comments
Implement recommended planning controls based on defined floodplain area and floodway zone. Amend LEP to define a floodway zone and adopt Floodplain Management Plan as a DCP.	Council costs only	• Restrict development in floodway and high hazard areas. • Floor level controls. • Controls on fencing in floodway. • Controls on filling.
Develop guidelines for flood compatible construction on the floodplain.	Council costs only	• Guidelines for flood compatible construction materials and methods. • Under slab drainage requirements for house slabs.
Investigate and, if warranted, implement a voluntary purchase scheme to remove selected residential development in floodway areas.	$190,000	• Procedures for implementing scheme are presented in Section 6.1.3. Estimated cost is for the four worst affected residences.
Investigate, design and implement re-building of existing levee upstream of Arnolds Bridge, together with removal of bed material in bridge waterway.	$360,000	• This scheme is called CM1 in the report and provides 100 year ARI security against overtopping of levee.
Improve flood warning system and emergency response procedures.	$10,000	• Consult community about required warning time and accuracy • Prepare warning and evacuation procedures for Public Schools at Blandford and Willow Tree • Prepare flood signs • SES to complete Local Flood Plan
Implement flood awareness and education program	Council costs only	• Flood advice on S 149 certificates. • Install flood height markers. • Distribute flood information booklet with rate notices. • Hold events to create an awareness of floods larger than historical.
Flood data collection	Council costs	• Collect further data after each flood.

1. INTRODUCTION AND BACKGROUND

1.1 Introduction

Murrurundi Shire Council commissioned this Floodplain Management Study in accordance with the procedures set out in the NSW Government's Floodplain Development Manual, originally released in 1986.

The manual describes the procedures to be followed by local government authorities in arriving at a comprehensive Floodplain Management Plan that will provide the basis for any State Government and Commonwealth assistance sought by Council in implementing the Plan. The process is shown diagrammatically in Figure 1.1.

Council has to date completed the following steps:

- Established a Floodplain Management Committee. The Committee is composed of Local and State Government, State Emergency Service and community representatives.

- Carried out a Flood Study for Council which was submitted as a draft in February 1997. Council has advised that the study results have been accepted as providing a satisfactory basis for undertaking the Floodplain Management Study.

This Floodplain Management Study will address the following items:

- Recommend appropriate planning flood levels.

- Collect data on social, economic and ecological issues.

- Prepare a detailed Floodplain Management Study. The Study recommendations, once adopted by Council, will form the basis of the Draft Floodplain Management Plan. A draft of the Floodplain Management Study was presented to the Committee in December 1997. Feedback from the Committee and community representatives has been incorporated in this final report.

Consultation with the community in Murrurundi, Blandford and Willow Tree has been carried out as part of this study. This has involved publishing newspaper articles, holding meetings with local residents and the Floodplain Management Committee.

1.2 Overview of Report

This Floodplain Management Study for Murrurundi, Blandford and Willow Tree covers the following topics:

The **Summary and Recommendations** preceding this report summarises the report and presents the recommended floodplain management plan for the three townships.

Chapter 2, **The Murrurundi, Blandford and Willow Tree Floodplains**, describes the existing situation in relation to the physical setting and flood producing mechanism, flood extent and resulting flood damages, transport linkages, planning instruments, and the existing flood emergency system. It draws upon previous investigations including the draft Murrurundi, Blandford and Willow Tree Flood Study (LMCE, 1997).

Chapter 3, **Existing Floodplain Management Measures**, contains an assessment of measures currently in place in the study area.

Chapter 4, **Potential Floodplain Management Measures**, presents an appraisal of potential measures that may be incorporated in the Floodplain Management Plan. These measures may be subdivided into three categories:

- property modification - planning controls, voluntary purchase or flood proofing of flood prone property and planning measures to control future development.
- response modification - flood warning and emergency response procedures.
- flood modification - structural measures such as levees, channel works and dams.

Chapter 5, **Selection of Floodplain Management Measures**, outlines a range of considerations to be taken into account in the selection of the mix of measures recommended for inclusion in the Floodplain Management Plan.

Chapter 6, **The Draft Floodplain Management Plan**, summarises the recommended elements for inclusion in the Plan and provides information on funding and implementation.

Throughout this report figures are presented at the end of each chapter.

Several technical appendices have been prepared which provide background information:

Appendix A A brief summary of the Flood Study.

Appendix B An assessment of urban flood damages in Murrurundi, Blandford and Willow Tree.

Appendix C A summary of the consultation with relevant authorities and residents carried out as part of the study.

Appendix D An appraisal of existing emergency management procedures.

Appendix E Recommended amendments to LEP.

1.3 Definitions

There are a number of terms that have specific meaning in relation to floods and floodplain management. The following definitions reflect current government policies that are relevant to Murrurundi, Blandford and Willow Tree:

Floodplain: is the area of a river valley, adjacent to the river channel, which is subject to inundation by the *probable maximum flood* or an extreme flood event. This represents the maximum extent of land likely to be inundated. Floodplain management plans should encompass all of the floodplain.

Floodways: are areas which carry a significant discharge during a flood. They are areas which, even if only partially blocked, would cause significant redistribution of flow or a significant increase in flood levels. Floodways are often areas of deeper flow or where high velocities occur.

Planning flood levels are levels, as defined in a floodplain management study, for the purposes of setting appropriate flood related controls applicable to a particular use of the land. Selection of planning flood levels is based on an understanding of flood behaviour and the associated flood risk. It takes into account the social, economic and environmental consequences associated with floods of different severities. Note that a planning flood level does not necessarily define the extent of the floodplain, which is defined by the *probable maximum flood* (PMF)

Residual flood risk is the remaining flood risk faced by different sections of the community after all floodplain management measures identified in the Floodplain Management Plan have been implemented. The hazard associated with the residual flood risk must be managed by appropriate emergency management and response measures. (**Note:** The residual flood risk is not necessarily the same for all sections of the community. Adopted floodplain management measures may afford different levels of protection to residential and business areas. Floodplain land which is not subject to controls defined by planning flood levels will also face a residual flood risk which must be managed by appropriate emergency management and response measures.)

Probable maximum flood (PMF): the largest flood that could conceivably occur at a particular location. It is not physically or financially possible to provide general protection against this event. The PMF defines the extent of the floodplain (ie. the maximum extent of land likely to be inundated). The extent, nature and potential consequences of flooding associated with the PMF event must be addressed in the floodplain management study. The PMF event may form the basis of evacuation planning and the identification of refuge areas. Consideration should be given to adopting the PMF event as the one which defines the planning flood level for high risk development as well as the emergency services planning, (ie for determining the location and floor levels of new telephone exchanges, police stations, hospitals, etc).

Flood hazard: potential risk to life and limb caused by flooding.

Average annual damages (AAD): the average damage per year that would occur from flooding over a very long period of time.

1.4 Flood Frequency

In this report the frequency of floods is generally referred to in terms of their Average Recurrence Interval (ARI) in years. The frequency of floods can also be referred to in terms of their Annual Exceedance Probability (AEP).

The approximate correspondence between these two systems is:

ANNUAL EXCEEDANCE PROBABILITY (AEP) %	AVERAGE RECURRENCE INTERVAL (ARI) YEARS
1	100
5	19.5
20	4.5
50	1.4

The probable maximum flood (PMF) occurs as a result of the probable maximum precipitation (PMP). The PMP is the result of the optimum combination of the available moisture in the atmosphere and the efficiency of the storm mechanism as regards rainfall production. The PMP is used to estimate PMF discharges using a rainfall - runoff routing method.

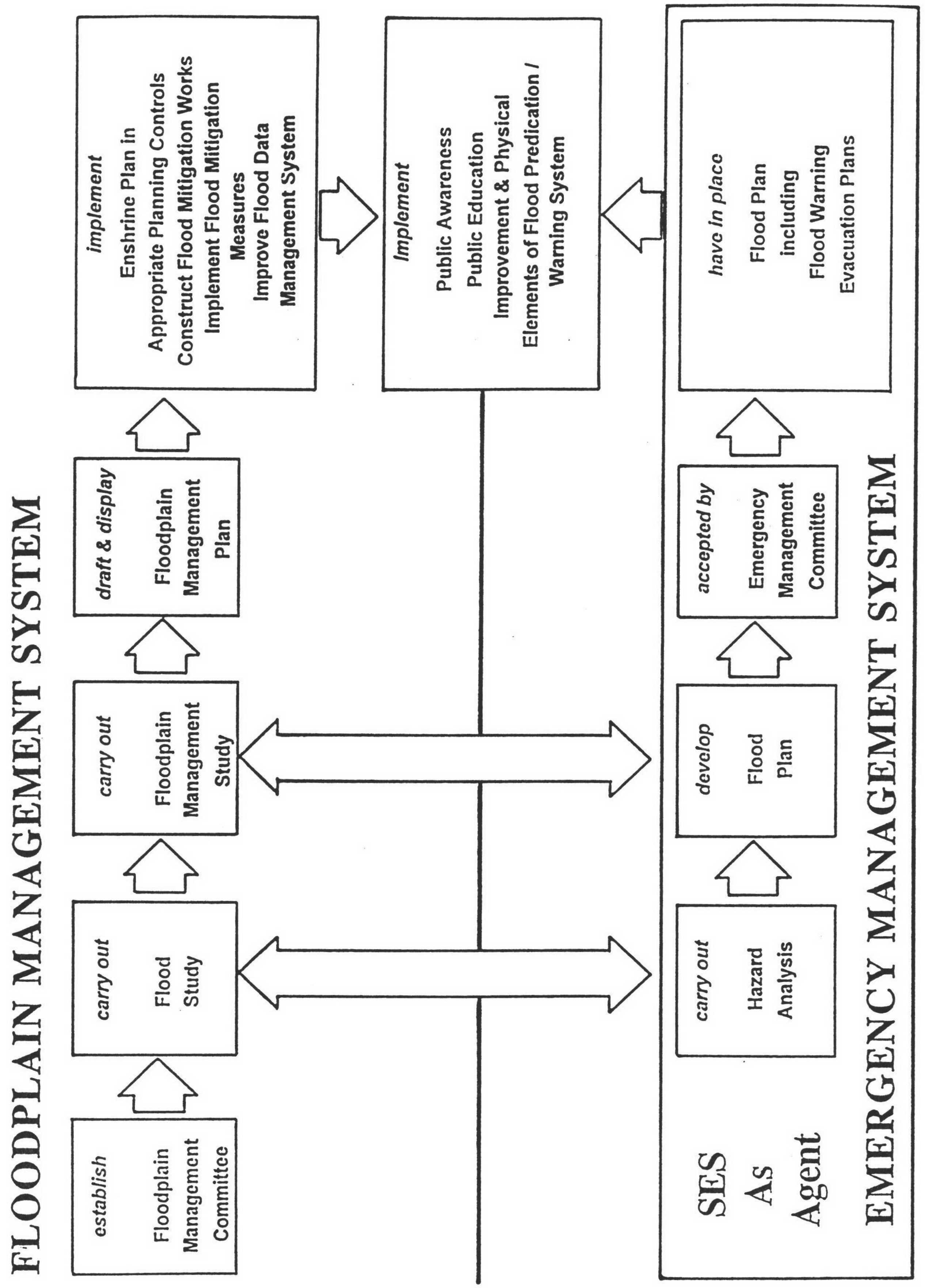
The PMF is an extremely rare flood that is much greater than events that usually would be considered as a Designated Flood for the purpose of a Floodplain Management Study. However, it is sometimes analysed to determine the consequences of an event greater than the Designated Flood so that appropriate planning and response measures may be included in the Floodplain Management Plan.

1.5 Flood Level Accuracy

Flood levels for "design" floods of specified ARI are derived by computer modelling using hydrologic models to estimate flood flows and hydraulic models to estimate the corresponding flood levels. These models use observed flows and flood levels for calibration prior to being used for estimating design flows and levels. Nevertheless, these models are not a perfect representation of all the complex physical processes occurring during a flood. While the computer models are capable of providing flood level estimates to two or three decimal places, levels are usually rounded to one decimal place (0.1 m) for practical purposes. In this report flood levels derived from modelling are quoted to the nearest 0.1 m.

1.6 Department of Land & Water Conservation

Until May 1995, the Department of Water Resources (DWR) was responsible for the implementation of the NSW Government's Flood Policy in non-tidal areas of NSW. That organisation had formerly been called Water Resources Commission (WRC) and, earlier still, the Water Conservation and Irrigation Commission (WCIC). In May 1995, the floodplain management responsibilities of DWR and Public Works were merged under a new organisation, the Department of Land and Water Conservation (DLWC).



MURRURUNDI, BLANDFORD & WILLOW TREE
FLOODPLAIN MANAGEMENT STUDY

Figure 1.1

Integrated Floodplain Management System

2. THE MURRURUNDI, BLANDFORD AND WILLOW TREE FLOODPLAINS

2.1 General

This chapter describes the main characteristics of flooding in the study area and goes on to provide an assessment of the economic and social impacts of floods. This background information provides a basis for consideration of options for reducing flood impacts which are discussed in subsequent chapters.

2.2 Floodplain Definition and Topography

2.2.1 Murrurundi and Blandford

Murrurundi and Blandford are located on the New England Highway in the catchment of the Pages River (Figure 2.1). The Pages River has its source near the eastern end of the Liverpool Range where it flows in a south-easterly direction to join the Hunter River in its headwater region several kilometres upstream of Aberdeen.

Murrurundi is surrounded on its northern and southern sides by steeply rising hillsides which are drained by several gullies which have contributed to local flooding problems. Two local gullies, Unnamed Gully and Cohens Gully drain the foothills on the northern side and flow through a residential portion of the town before crossing the New England Highway (Mayne Street) and joining the Pages River.

Halls Creek drains the southern foothills and after crossing the Great Northern Railway and Haydon Street joins the right bank of the river just upstream of the Mayne Street crossing at Arnolds Bridge. Victoria Street gully joins the right bank of Halls Creek on the southern side of the railway. Until recently, flood runoff from this drain crossed the railway embankment and contributed to flooding problems in the residential area on the southern side of Mayne Street between Adelaide and Victoria Streets. A levee was constructed along the northern bank to retain flow in the drain. The total catchment of the Pages River and its tributaries upstream of Arnolds Bridge amounts to 72 km^2 in area.

Figure 2.2 shows the extent of the 100 year ARI flood in Murrurundi, the area in which high hazard conditions exist for that flood (see Section 2.4) and the existing land use zoning. Also shown is the indicative extent of the floodplain, as defined by the area inundated by the probable maximum flood (PMF).

Downstream of Arnolds Bridge, flows are conveyed in an easterly direction around the northern side of the town for a distance of 5 km to the New England Highway crossing at Benhams Bridge. A short distance downstream of Murrurundi, Campbells Creek, another tributary draining the southern foothills, joins the Pages River. The river continues in a generally easterly direction between the New England Highway and the railway and is joined by Murulla Creek about a kilometre upstream of the Blandford Bridge. At Blandford, the Pages River is joined by Warlands Creek which flows in a southerly direction from Wallabadah Rocks. This stream drains heavily

dissected country to the north of Blandford, falling from an elevation of 960 m to 410 m over a distance of 20 km to the junction. Warlands Creek has a catchment area of 103 km^2.

Figure 2.3 shows the extent of the 100 year ARI flood and high hazard area in Blandford, as well as the current land use zoning and the indicative extent of the floodplain.

Downstream of Blandford, the Pages River continues for a further 4 km on the northern side of the New England Highway to the stream gauging station located near the "Manaree" homestead. Just upstream of the gauging station, Scotts Creek joins the left bank. The total gauged catchment amounts to around 300 km^2.

2.2.2 Willow Tree

Willow Tree is situated on the New England Highway in the catchment of Borambil Creek.

Borambil Creek rises on the northern slope of the Liverpool Range in the Namoi River Basin, and falls from an elevation of 1134 m to 420 m over a distance of 16 km to the junction with Chilcotts Creek. Chilcotts Creek drains the eastern portion of the catchment, commencing near Loders Pinnacle at an elevation of over 1000 m and flowing over a distance of 15 km to cross the New England Highway and Great Northern Railway. From this point, it swings northwards and flows parallel with Borambil Creek before joining that stream about a kilometre upstream of the Merriwa Road. At the junction with Chilcotts Creek, the total catchment area is 163 km^2 of which Borambil Creek contributes 49 km^2.

The Merriwa Road crosses Borambil Creek at the Hams Bridge and from this point flows are conveyed in a north-westerly direction in a more open floodplain past the Willow Tree township. Two local tributaries join the right bank of Borambil Creek below Hams Bridge and at the downstream end of the township the total catchment area of Borambil Creek and its tributaries comprises 182 km^2.

Figures 2.4 shows the extent of the 100 year ARI flood and high hazard area in Willow Tree as well as the current land use zoning in the township and the indicative extent of the floodplain.

2.3 Flood History

The study area has been subject to nine significant floods over the past 40 years since the record flood of October 1949 as shown on Table 2.1 which was extracted from the Flood Study Report. The ranking of these floods is tentative only, as several floods predate the establishment of the Blandford stream gauge and the gauge was damaged during the January 1991 event.

TABLE 2.1
SUMMARY OF AVAILABLE RAINFALL - RUNOFF DATA FOR ANALYSIS OF HISTORIC FLOODS

Date of Flood	Assessed Rank	Blandford G.S.		Rainfall Data		Comments
		Gauge Peak m	Peak Discharge m^3/s	Pluviographic	Daily	
17 October 1949	2	Not Available	Not Available	Not Available	15 Stations	This flood predates the establishment of the Blandford stream gauge and Scone pluviograph
22 February 1955	4	7.92	920	Scone	20 Stations	A 1993 survey of the stream cross-section at the gauging station shows the 1955 peak as 7.92 m
31 January 1971	6	7.62	830	Not Available	Not Collected	Peak was 8.4 m on chart but gauge reader assessed peak at 7.62 m
23 January 1976	7	7.45	780	Scone Gowrie North	20 Stations	Bristol pressure recorder chart obtained from DLWC Parramatta. RORB model testing was undertaken using Scone and Gowrie North pluviographs.
30 January 1984	3	8.0	950	Not available	20 Stations	No data available on temporal distribution of rainfall.
5 January 1991	9	Gauge Damaged	Not Available	Scone	23 Stations	The steam gauge was damaged by this flood and hence the peak discharge and hydrograph shape are not known.
9 February 1992	5	7.74	870	Murrurundi Scone	22 Stations	RORB Model testing was undertaken using Scone and Murrurundi rainfalls. The pluviograph at Blandford failed.
25 January 1996	1	8.32	1030	Murrurundi Blandford Scone	15 Stations	RORB Model calibration was undertaken for this flood. Temporal rainfall data were also available at the Murrurundi P.O. and from SES.
October 1996	8	7.0	680	Murrurundi Blandford	14 Stations	RORB Model calibration was undertaken for this flood.

Murrurundi is the most flood prone township with residential development on both sides of the Pages River vulnerable to inundation. The most severe flood occurred in January 1996 when one person was drowned by flash flooding on Warlands Creek and properties in Murrurundi and Blandford were inundated. Investigations described in the Flood Study assessed the peak of the January 1996 flood at Murrurundi as approximating that of the 100 year ARI design flood. Further downstream at Blandford, rainfall intensities were less and the flood approximated the 50 year ARI event.

High flows were also experienced in January 1996 on Borambil Creek. However, damage on this stream was confined to fencing on the floodplain and surcharging of culverts on local tributaries. At Willow Tree, the January 1996 flood peak was close to the 100 year ARI design flood.

Flows broke the right bank of Borambil Creek just upstream of Hams Bridge and flowed across Merriwa Road as sheet flow. A diversion bank had been constructed on the river side to protect the Public School. Water entered the school grounds but damages were not significant. Apart from Merriwa Road and areas near the Bowling Club, the township is not affected by major floods.

Heavy thunderstorm rainfall also fell on the evening of 6 October 1996, resulting in flash flooding on the Pages River catchment. Flows were much smaller on Borambil Creek. The peak discharge was equivalent to a 10 year ARI peak at Blandford. At Murrurundi, flow entered the township via the breach in the levee running along the right bank upstream of Arnolds Bridge. Because rainfalls were high in the upper reaches of the catchment above Murrurundi, the frequency of the flood peak was relatively higher at that location, with the modelled peak discharge approximating the 50 year ARI design flow.

Because of their steep bed slopes, the streams in the study area rise very quickly and flooding is of a "flash flooding" nature. At Murrurundi, the time of rise of the January 1996 flood was approximately two hours and the event lasted about eight hours. A similar situation was experienced on Borambil Creek at Willow Tree.

Floods are more prevalent in the warmer months, with the highest frequency of occurrence in the January - March period, while spring and early summer have been relatively flood free. Generally major floods in the Hunter Valley have resulted from the occurrence of well developed tropical cyclones with at least several consecutive days of rainfall (W.C.I.C., 1969). Such cyclonic rainfall may arise from ex-tropical systems which originate in the Coral Sea and move south along the coast. Alternatively, deep cyclonic depressions may form over inland tropical Australia which move in a south-easterly direction. On rare occasions, these depressions may penetrate as far south as the upper Hunter River valley, as occurred in February 1955. Local convective storm action is often associated with these events, during which several hours of intense rainfall may be experienced. From inspection of the data, this appears to be the case especially in the higher areas of the upper Hunter catchment. The summer floods of 1955, 1976, 1984, 1991, 1992, and January 1996 in the study area were all typical of this flood producing mechanism.

High intensity, short duration convective thunderstorms may also occur, bringing intense rain for short periods over limited areas. Thunderstorm activity is largely confined to the late spring,

summer and early autumn months. The October 1996 storm was typical of this flood producing mechanism.

East coast low-pressure systems are prevalent in the autumn and winter months and produce heavy rain over the lower Hunter Valley. However, these systems tend not to penetrate far inland and rainfalls reduce sharply away from the coast. This mechanism does not appear to have been responsible for flooding in the present study area.

2.4 Characteristics of Flooding

2.4.1 Flood Behaviour – Pages River

2.4.1.1 Design Floods

This section reviews flood behaviour in the Murrurundi and Blandford areas in the event of a number of "design floods" which were analysed using the hydraulic models developed for the draft Flood Study (LMCE, 1997). They range in severity between a minor flood (5 year ARI) and a major (100 year ARI). Typical cross sections of the streams illustrate flood levels for the various floods (Figures 2.5-2.7).

In addition to the main river branch, the hydraulic models incorporate a number of branches which simulate flow in flood runners, as well as weirs which simulate the passage of flow out of the channel and across roads such as the New England Highway.

Minor Flood

Most of the flow is contained within the river for the 5 year ARI, which increases in discharge from 150 m^3/s just upstream of Murrurundi to 340 m^3/s downstream of the junction with Warlands Creek. At this magnitude of flooding the flow is conveyed in the immediate vicinity of the river in the Murrurundi area. Flow velocities in the Pages River range between 1.5 and 2.8 m/s. There is little overbank flow in the Pages River further downstream at Blandford. On Warlands Creek the peak discharge upstream of Barsham bridge is 140 m^3/s. Most of this flow is conveyed through the bridge waterway, but a small surcharge amounting to 14 m^3/s is conveyed across the bridge approach road (Timor Road) and rejoins Warlands Creek further downstream. No flow crosses the New England Highway and there is no exchange of floodwaters between Warlands Creek and the Pages River downstream of Blandford.

Medium Flood

At the 20 year ARI, peak flows upstream of Murrurundi and downstream of Blandford are 250 and 670 m^3/s respectively. In the Murrurundi area peak water levels are about 600 mm higher than for the 5 year ARI flood. None of the flood runners and weirs function, indicating that the flow is contained within the immediate confines of the river. Flow velocities increase slightly with the increased depth, ranging between 2 and 3 m/s on the Pages River. On Warlands Creek, the peak discharge on the upstream side of Barsham Bridge is 300 m^3/s of which about 90 m^3/s surcharges the Timor Road. Most of this flow returns to Warlands Creek downstream of the

bridge, but a small amount, about 14 m^3/s, passes over the New England Highway and through the school grounds to the Pages River. There are no other exchanges of flow between the two main streams. In the Blandford area, flood levels are about 1.5 m higher than for the 5 year ARI event but are still contained within the creek system.

Major Floods

At the 100 year ARI, peak flow at Murrurundi amounts to 420 m^3/s and increases to a peak of 1000 m^3/s downstream of Blandford. Warlands Creek contributes 440 m^3/s to the flood peak. These discharges are slightly higher than for the January 1996 event. However, flood levels and the distribution of flood flows are quite similar to this historic event.

In Murrurundi, there is a transfer of flow across the New England Highway from the Pages River to a flood runner which is located on the northern side of the road. Peak flow returning to the Pages River via this flow path at Wilson Park amounts to 60 m^3/s and flow velocities up to 1.5 m/s are experienced. The combination of depth and velocity of flow in the flow path results in high hazard conditions being experienced locally.

The right bank levee just upstream of Arnolds Bridge is surcharged and the peak discharge conveyed along Mayne Street amounts to 30 m^3/s at a maximum velocity in the street near the intersection with Adelaide Street of 5 m/s. Adelaide and Mayne Street together operate hydraulically as a high hazard floodway.

Flood behaviour in the Blandford area for the 100 year ARI is similar to that experienced for the January 1996 flood. Flow crossing the New England Highway near Timor Road and heading towards the Pages River amounts to 50 m^3/s and there is an exchange of flows between the two streams downstream of the township similar to that experienced in for January 1996.

No flow occurs across the New England Highway on the western end of Arnolds Bridge in Murrurundi for the 50 year event. The Adelaide - Mayne Street floodway operates with a small flow of 10 m^3/s due to surcharging of a low spot in the levee. It is understood that the levee was constructed shortly after the February 1955 flood to prevent Mayne Street operating as a floodway during major flood events and that no surcharges of the levee were experienced in the 40 years since its construction, apart from the two experienced during the January and October 1996 floods. (The October 1996 flood occurred when the levee had been breached by the January 1996 event). Since 1955 there have been several other large floods experienced on the Pages River, with the largest experienced in January 1984. At the Blandford gauging station, this flood recorded a peak discharge of 950 m^3/s (Table 2.1) which was slightly less than a 50 year ARI peak discharge.

2.4.1.2 Probable Maximum Flood

Peak flood levels upstream of Arnolds Bridge are 3 m higher than for the 100 year ARI and downstream of the bridge, the increase in peaks is about 3-4 m depending on location. The total discharge at Arnolds Bridge amounts to 4300 m^3/s, of which 700 m^3/s is conveyed through and over the waterway, 3000 m^3/s is conveyed along the flow path on the northern side of the highway and 600 m^3/s surcharges the right bank levee and flows along Mayne Street.

The peak flood level downstream of the junction with Warlands Creek is 5.3 m higher than for the 100 year ARI. Further upstream on the Pages River at Blandford Bridge the increase is 4.5 m. On Warlands Creek, PMF levels are 3.5 m higher near Barsham Bridge and in the range 3-4 m higher in the Blandford township. A large proportion of the flow amounting to 4500 m^3/s is conveyed across the floodplain from Warlands Creek to Pages River downstream of Blandford.

Flows used in the hydraulic modelling to derive the above results were obtained from the RORB hydrologic model used in the non-linear mode. Recent research suggests that catchments behave in a linear manner for extreme flood events. When the RORB model was run in a linear mode, peak flows were reduced somewhat. Peaks were 8 per cent less at Murrurundi and 17 per cent less at Blandford gauging station. Hydraulic modelling with these flows would result in slightly lower flood levels. However, for the purposes of this investigation the non-linear flows were adopted for PMF analyses on the grounds of safety.

2.4.2 Flood Behaviour - Borambil Creek

2.4.2.1 Design Floods

Minor Flood

Most of the flow is contained within the creek for the 5 year ARI. About 280 m^3/s of the peak discharge at Hams Bridge is conveyed through the waterway of that structure. The balance is conveyed over the right bank upstream of the bridge. This overflow is conveyed along a flood runner towards the school, where it is deflected by the diversion bank and crosses the Merriwa Road and flows over the right floodplain before rejoining Borambil Creek about 200 m downstream of the road.

Just downstream of Hams Bridge the flow is at bankfull with a depth of 4.5 m and a velocity of 1.8 m^3/s. Further downstream, the depth of flow reduces to around 3.5 m with a corresponding increase in velocity to around 3 m/s reflecting the steep gradient and low hydraulic roughness of the stream.

Medium Flood

For the 20 year ARI, the peak discharge at Hams Bridge increases to 550 m^3/s, of which 410 m^3/s is conveyed through the bridge and the balance flows over the right bank of Borambil Creek and thence across the Merriwa Road. The peak depth of flow over the stream bank is about 1.5 m and the depth across the road is about 300 mm.

Most of the flow returns to the main stream downstream of the loop in the channel which is located about 1.3 km downstream of Merriwa Road. At that section 500 m^3/s is conveyed in the channel and 70 m^3/s on the right floodplain. Floodplain flow is about 300 m wide and averages about 500 mm in depth, conveyed at 0.5 m/s velocity.

Further downstream, the right floodplain becomes more confined. The width of floodplain flow is about 100 m and further downstream the flow rejoins the main channel.

There is a minor floodrunner on the left floodplain which commences at the cutoff 1.7 km downstream of Merriwa Road, and continues a further kilometre. At the 20 year ARI, about 10 m^3/s are conveyed as a shallow flow up to 80 m in width.

These floodrunners and the main channel operate as independent streams at the 20 year ARI.

Major Flood

For the 100 year ARI, the peak discharge at Hams Bridge increases to 925 m^3/s. About 525 m^3/s is conveyed through the bridge waterway and the remainder flows over the right bank of Borambil Creek towards the school. The stream bank is submerged to a depth of 2 m. The water surface elevation on the creek side of the diversion bank is 327.4 m and on the school side is 326.5 m. The elevation of the bank increases from 326.4 m at Merriwa Road to 326.9 m about 50 m to the east (upstream) and 327.8 m a further 60 m east. Much of the bank is overtopped and function as a broad crested weir. The depth of flow over Merriwa Road is 600 mm.

Some of the flow crossing the road rejoins Borambil Creek at the loop in the channel. The flow distribution about 1.3 km downstream of Merriwa Road is 700 m^3/s in the main channel and 250 m^3/s on the right floodplain. Peak flow velocity in the channel is around 3-4 m/s in the middle reaches of the model, and 1.8 to 2 m/s on the floodplain.

At the 100 year ARI the width of flow is around 400 m at a location about 1.3 km downstream of Merriwa Road, reducing to 200 m in the relatively constricted area at 1 km downstream and increasing to around 450 m as the floodplain widens downstream of the Bowling Club.

2.4.2.2 Probable Maximum Flood

Peak flood levels are generally about 4 m higher than for the 100 year ARI. Downstream of the township the peak discharge is 9380 m^3/s which is close to the 8790 m^3/s peak flow at Hams Bridge after allowing for lateral inflow from the local tributaries, indicating that there is little attenuation of flow due to floodplain storage effects.

2.4.3 Rates of Rise, Duration of Flooding and Travel Times

Streams within the Shire of Murrurundi have steep gradients and floods typically rise quickly. On the Pages River floods rise at a rate of around 1.5 m/hr. At the township of Murrurundi, floods peak over a period of around two hours or less and recede over a period of up to 10 hours. Due to the nature of flooding within the township, i.e. breakouts at the height of major flooding, the time of inundation of roads and properties would be expected to be in the order of 1 hour.

Once past Murrurundi, floods travel the 7 km length of river to the township of Blandford. The time of travel of the flood wave is of the order of around one hour, leading to times to peak of around three hours or less at the township. At Blandford, Warlands Creek, which joins the Pages River from the right bank has a catchment area similar to the Pages River at the township. Rates of rise of the creek are around 2 to 3 hours, and high flows usually coincide with high flows

in the Pages River. Due to the early break out of floodwaters from Warlands Creek in the vicinity of Barsham Bridge, expected durations of inundation within the Norvill Park area are in the order of 5 hours.

West of the ranges, at the township of Willow Tree, Borambil Creek has a catchment area similar to the Pages River at Blandford. The rate of rise of floodwaters is in the order of 2 to 3 hours with the recession of the flood extending over a period of around 10 hours.

2.5 Flood Hazard and Floodway Definition

For floodplain management purposes it is necessary to subdivide the floodplain into areas that firstly, reflect the impact of development on flood behaviour (i.e. hydraulic effects) and secondly, the impact of flooding on the development (i.e. hazard effects). Sub-division of flood liable land on these two bases are referred to as 'hydraulic categories' and 'hazard categories' respectively.

The concept of Flood Hazard is dealt with at length in the Floodplain Development Manual (1986), in particular Appendix B, where the provisional flood hazard for a nominated flood at a particular location is a measure of the combination of depth and velocity. Figure 7 in the Manual (reproduced as Figure 2.8 in this report) shows how depth and speed of flow are related to the provisional hazard ratings, and the interface between High and Low hazard zones.

The hydraulic modelling results (see Appendix A) were used to determine provisional hazard zones for the study area for the 5, 20 and 100 year ARI flood. These zones consist of:

- **high hazard** - comprising areas where the depth and speed of floodwaters are such that buildings could sustain major structural damage and in extreme cases, light framed houses could be washed away and there would be difficulties in evacuation and danger to life and limb.

- **low hazard** - areas subject to depth of flooding of less than 0.8 m. The speed of the flood waters are such that able-bodied adults would have little difficulty in wading.

The provisional hazard can be increased or reduced to obtain the final hazard after consideration of a number of factors. Flood hazard and flood damage can be reduced by evacuation if adequate **warning time** is available. Murrurundi and Blandford have a potential warning time which is limited to 1-2 hours. The **rate of rise of floodwaters** also affects the degree of hazard and damage caused by a flood. Situations in which floodwaters rise rapidly are potentially far more dangerous and cause more damage than situations in which flood levels increase in a slow and gradual manner. The rate of rise on the Pages River is rapid, at around 1.5 m/hour (see Section 2.4).

The **duration of flooding** or length of time a community is cut off by floodwaters can have a significant impact on the costs and disruption associated with flooding. The duration of flooding on the Pages River and Borambil Creek is quite short and would be several hours for a major event.

Flood awareness greatly influences the time taken by flood-affected people to respond to flood warnings. In communities with a low degree of flood awareness flood warnings are liable to be ignored and residents may be confused about when to evacuate, what to take and where it should be taken. It is expected that towns on the Pages River and Borambil Creek have a very high degree of awareness for floods up to 100 year ARI due to the recent history of flooding. The major flow paths through the townships are apparent to most residents. They become active at major levels of flooding. It is likely that most of the present population can be regarded as being highly flood-experienced and needing only periodic reminders of the threat which floods can pose rather than full scale flood education programs. Should long flood free periods occur, however, as has been the case in the past, this situation will change.

The level of damage and disruption caused by a flood is also influenced by the difficulty of **evacuating** flood-affected people and property.

Generally, evacuation from the flood prone areas of Murrurundi and Blandford can be effected via roads leading directly to higher ground. Some developments would be likely to form 'islands' between the various floodways operating through the towns. In the case of Willow Tree flooding is confined to a narrow strip along Merriwa Road and evacuation is not a problem.

The amount of **flood damages** to the contents of a building depends largely upon the depth to which the building is flooded. The damages in Murrurundi, the most floodprone of the townships are due to comparatively shallow inundation of property. Commercial damages are larger than residential, but the total damages which would be incurred in a major flood would be relatively small.

On consideration of these factors, it would appear that there is no justification for reducing the hazard zones and therefore it is recommended that the provisional hazard rating should be used as the basis for the final hazard zones.

The boundaries of the recommended hazard zones for the 100 year ARI flood are reproduced on Figures 2.2 to 2.4. It should be noted that the hazard zones shown refer specifically to the 100 year ARI flood and will vary with the magnitude of the flood.

Tables 2.2 to 2.4 provide an estimate of the number of properties located in the high and low hazard zones for the 100 year ARI flood.

For the purpose of the Floodplain Development Manual, there are three categories of flood liable land:

- floodways
- flood storage
- flood fringe

The manual states that it is not practicable to provide explicit quantitative criteria for defining floodways and flood storage areas, as the nature of each study area is different. The following guidelines are given for delineating these areas:

(1) Floodways are those areas which convey a significant proportion of the total flow and where partial blocking will adversely affect flood behaviour.
(2) Flood storages are those areas outside floodways, which if completely filled would cause peak flood levels or downstream peak discharges to significantly increase.
(3) Flood fringe is the remaining area of land affected by flooding. Development in the flood fringe would not have a significant effect on the pattern of the flows and levels.

It is to be noted that hydraulic categorisation of the floodplain is often undertaken using the hydraulic model of the stream. Investigations are carried out on floods at or around the magnitude of the Designated Flood Event (DFE). Analysis was undertaken in the Flood Study to obtain an estimate of flooding and flood storage areas. A range of floods was investigated, including minor events much smaller than would be considered as a DFE.

In some hydraulic computer programs, for example the HEC-2 program developed by the US Army Corps of Engineers, there is the capacity for automatic reduction in the width of flow along the study reach until a significant increase in peak flood level (eg. 100 mm) is achieved. This feature is not available for MIKE 11, which was used in the Flood Study, and the reduction in width has to be undertaken on a trial and error basis. MIKE 11 is a fully dynamic model, in contrast to HEC-2 which is steady state. In some situations, typically in steep streams where velocities are high, a reduction in the width of flow along the study reach results in increases in levels in some areas and reductions in levels in others. This was found to be the case in the present study area, particularly in the case of the medium flood events and consequently the results achieved could only be used as a guide in hydraulic categorisation.

For the 5 year ARI, the flow is conveyed within the stream banks or their immediate vicinity. Flow velocities in the channel are high, generally in the range 2 to 3.5 m^3/s. There is little overbank flow and development of floodplain storage. The floodway is the main channel, which is closely approximated by the areas identified as high hazard areas for this flood. These areas are identified in diagrams contained in the Flood Study.

For the 20 year ARI, a trial run of the model was undertaken assuming that the area outside the limit of inundation of the 5 year ARI flood was blocked. Compared with design 20 year ARI flood levels, the blocked levels ranged between - 0.23 m and 0.26 m, but were generally less than 0.1 m higher. Additional reduction in the width of flow would be required to achieve a general increase of 0.1 m in flood levels. The high hazard area for the 20 year ARI approximates the extent of inundation of the 5 year ARI flood. Therefore, it is considered reasonable to adopt the 20 year high hazard area as a reasonable appreciation of the extent of the floodway for the 20 year flood also.

In the case of the 100 year ARI, however, hydraulic analysis indicated that large increases in flood level would be experienced if flows were constrained to the extent of the 5 year ARI and also if the flood runner on the northern side of the New England Highway at Murrurundi were blocked. For this flood also, the high hazard area is considered to be a reasonable estimate of the extent of the floodway in the Pages River. The flood runner has also been categorised as a floodway.

For each of the above frequencies, the flood storage and fringe areas are represented by the zone between the floodway and the flood limit.

TABLE 2.2
PROPERTIES LOCATED IN PROVISIONAL HAZARD ZONES - 100 year ARI FLOOD
MURRURUNDI TOWNSHIP

	HIGH HAZARD / FLOODWAY AREA		LOW HAZARD AREA	
	Flood Affected A	Damaged D	Flood Affected A	Damaged D
Residential	23	18	13	6
Commercial/Industrial	29	28	8	1
Public	3	1	5	2
TOTAL	**55**	**47**	**26**	**9**

TABLE 2.3
PROPERTIES LOCATED IN PROVISIONAL HAZARD ZONES - 100 year ARI FLOOD
BLANDFORD TOWNSHIP

	HIGH HAZARD / FLOODWAY AREA			
	Flood Affected A	Damaged D	Flood Affected A	Damaged D
Residential	1	1	10	1
Commercial/Industrial	0	0	0	0
Public	0	0	4	2
TOTAL	**1**	**1**	**14**	**3**

TABLE 2.4
PROPERTIES LOCATED IN PROVISIONAL HAZARD ZONES - 100 year ARI FLOOD
WILLOW TREE TOWNSHIP

	HIGH HAZARD / FLOODWAY AREA		LOW HAZARD AREA	
	Flood Affected A	Damaged D	Flood Affected A	Damaged D
Residential	0	0	1	0
Commercial/Industrial	0	0	0	0
Public	0	0	5	0
TOTAL	**0**	**0**	**6**	**0**

2.6 Floodplain Land Use Zoning

Land use within the Murrurundi Shire is generally regulated by the Murrurundi Local Environmental Plan (LEP), 1993. There are no Development Control Plans accompanying the Local Environmental Plan.

Appendix E provides Council with a summary of the land use planning controls which currently apply to flood liable land in the Shire, and provides a series of options for the consideration of Council for amendment of the existing controls. They are summarised as follows:

1) Council should resolve to prepare an amendment to the LEP 1993 to:

- Add an objective related to control of development on flood liable land (Clause 2(1)(c))
- Add a further objective (2(1)(d)) which would allow Council to adopt the Floodplain Management Plan for each township as a Development Control Plan
- Amend the definition of "flood liable land" (Clause 5) to refer to a separate series of maps showing flood information which are not tied to the LEP map. This will allow Council to amend such maps in the light of future flood experience without the need for a formal amendment of the LEP.
- Amend the objectives for three zones to include mention of flooding considerations in the Table to Clause 9.
- Strengthen Clause 19 to provide greater control of development on flood liable land.

2) As part of the preparation and exhibition of the draft LEP, Council should also exhibit the Floodplain Management Plan for each township as a Development Control Plan.

3) Council should also consider strengthening planning controls on land which is identified as "floodway" or "high hazard" by further amending the LEP 1993 to include a new zone – Environmental Protection 7(f) Floodway.

   The area which would be affected by this proposal is shown on Figures 2.2 to 2.4 and is denoted "high hazard".

It is to be recognised that all existing, "lawful" development within the proposed 7(f) zone which would be prohibited by the amending LEP would, upon gazettal of the amending LEP, be "non-conforming uses" and as such will have "existing use rights" pursuant to the Environmental Planning and Assessment Act, 1979. It is also to be understood that significant development "rights" will be removed from vacant land within the newly created 7(f) zone.

It is recommended that Council implement a voluntary purchase scheme for land within the 7(f) zone as part of the rezoning of that land. Such a scheme will provide for compensation to landowners.

2.7 Flood Damages

A detailed assessment of damages resulting from floods ranging between 5 year ARI and PMF was carried out and is reported in Appendix B. Depths of inundation were derived from a floor level survey undertaken for this study as well as the hydraulic modelling undertaken in the Flood Study. Damages for various categories of property: residential, commercial and industrial, public buildings and community assets and infrastructure were assessed using well recognised techniques developed and tested in numerous urban and rural flooding situations in NSW. There is little information available on historic flood damages in the Murrurundi shire. Accordingly, it was necessary to transpose data on damages experienced as a result of urban flooding in other centres. To that extent the damages are "potential" damages rather than damages actually experienced. A small percentage reduction was made to allow for property evacuation which may allow for property evacuation which may reduce the damages actually experienced to values below these potential damages. The resulting damages and numbers of affected properties in the three townships are summarised in Tables 2.5 to 2.7

TABLE 2.5
FLOOD DAMAGES IN MURRURUNDI, BLANDFORD AND WILLOW TREE ($x10^3)

Flood Event ARI (years)	Residential	Commercial	Public	Total
5	0	0	0	0
20	12	0	14	26
50	120	205	43	368
100	245	435	95	775
200	554	850	400	1,804
PMF	4,550	5,240	3,505	13,295

TABLE 2.6
TOTAL NUMBER OF RESIDENTIAL PROPERTIES AFFECTED BY FLOODING

Flood Event ARI (years)	Murrurundi		Blandford		Willow Tree	
	A	D	A	D	A	D
5	0	0	0	0	0	0
20	2	0	1	1	0	0
50	21	14	7	1	0	0
100	36	24	11	2	1	0
200	60	41	21	10	1	1
PMF	127	121	46	45	23	20

Key A - Flood affected property (includes flooding in allotment and above floor flooding)
D - Damaged property (above floor flooding)

TABLE 2.7
TOTAL NUMBER OF COMMERCIAL, INDUSTRIAL AND PUBLIC BUILDINGS AFFECTED BY FLOODING

Flood Event ARI (years)	Murrurundi		Blandford		Willow Tree	
	A	D	A	D	A	D
5	0	0	0	0	0	0
20	0	0	1	1	1	0
50	31	21	4	2	2	0
100	45	32	4	2	5	0
200	58	45	4	4	6	5
PMF	69	69	7	7	15	15

Key A - Flood affected property (includes flooding in allotment and above floor flooding)
D - Damaged property (above floor flooding)

Average annual damages (also termed expected damages) are determined by integrating the area under the damage-frequency curve. They represent the time stream of average damages, which would be experienced year by year and are shown on Table 2.8. Using an appropriate discount rate, average annual damages may be expressed as an equivalent present worth value of damages and used in the economic analysis of potential flood management measures.

For example, the cumulative average annual value at Murrurundi of damages for all floods up to the 100 year ARI level is around $11,000. A flood management scheme which has a 100 year ARI level of protection will eliminate damages up to this level of flooding. If the scheme has no mitigating effect on larger floods, then these damages represent the benefits of the scheme.

Under current Treasury guidelines, economic analyses are carried out assuming a 30 year economic life for the project and discount rates of 7% pa. (best estimate) and 11% and 4% pa. (sensitivity analysis).

For a discount rate of 7% pa, the present worth value of damages up to the 100 year ARI level at Murrurundi is $140,000. Therefore a scheme costing up to $140,000 could be economically justified if it eliminated damages up to the 100 year ARI level. More expensive schemes would have a benefit/cost ratio less than 1, but may still be justified according to a multi-objective approach which considers other criteria in addition to economic feasibility (see Chapter 6).

Unless the scheme is designed to give protection against all flood events up to the probable maximum flood (PMF), there will be residual damages, which will still be experienced under post-scheme conditions. From Table 2.8, the cumulative average annual value of damages for all floods at Murrurundi would be of the order of $41,000. Therefore the residual damages for a scheme with a 100 year ARI design flood is $41,000 - $11,000 = $30,000 per annum. These annual damages have a present worth value of $370,000 at a 7% discount rate.

The present worth value of damages in the three townships for all floods is about $720,000 for the 7% pa. discount rate.

TABLE 2.8
CUMULATIVE AVERAGE ANNUAL DAMAGES ($x10^3)

Flood Event ARI (years)	Murrurundi	Blandford	Willow Tree
5	0	0	0
20	0	2.3	0
50	6	3.5	0
100	11	4	0
200	19	5	0.4
PMF	41	11	6.4

2.8 Social Effects

The draft *Floodplain Development Manual (1986)* categorises flood damages as either tangible or intangible, with damages further subdivided into direct and indirect.

Essentially, tangible damages relate to the impact of flooding on the economic operation of the townships while intangible damages or losses relate to the social impact of that flooding.

Social, or intangible, issues which arise from flooding include:

- inconvenience
- isolation
- disruption
- psychological disturbances as a result of anxiety and trauma, and
- physical ill-health

It is not possible to measure these costs in financial terms.

2.9 Ecological Considerations

The river channels and floodplains in the study area have been extensively modified by human activities over the past 150 years. These activities comprise clearing the floodplains for settlement and pastoral usage, construction of road and pedestrian crossings as well as bank stabilisation, river training and levee works. Bank stabilisation works undertaken by DLWC (then Water Conservation and irrigation Commission) on the Pages River near Murrurundi in the 1950's and in subsequent years are outlined later in Chapter 3. More recently the Hunter Valley Catchment Management Trust has undertaken bank stabilisation works in the township (Section 5.4). Minor flood protection and diversion levees have been constructed in each township as discussed previously in this chapter and in Chapter 3.

EPA were contacted and invited to provide comments regarding environmental and ecological aspects of flooding to be incorporated in the study. The main issues raised by EPA were general concerns relating to:

- inundation of sewage treatment plants and irrigation facilities
- the need to educate local residents so that they understand that flooding is a natural phenomenon on floodplains and accept that flood management works merely decrease the risk of flooding

2.10 Administration and Political Considerations

The floodplains within the study area lie within the townships of Murrurundi, Blandford and Willow Tree, the NSW State seat of Upper Hunter and the Federal electorate of Hunter.

Administrative interfaces on issues relating to the Floodplain Management Study occur with respect to the following:

- **Flood warning and Emergency Management** — Bureau of Meteorology, NSW Police Service, Council and SES.
- **Planning controls** — Department of Urban Affairs & Planning, Council. The regional planning powers of the Department and its overview of zoning matters is important in any rezoning.
- **Funding** — Commonwealth Government, DLWC, Council - any request for funds to implement the recommendations of this report will be submitted through DLWC with assistance sought from the Commonwealth.
- **Floodplain crossings** — The Roads and Traffic Authority owns bridge and approach embankment works on the floodplain and will be interested in any recommendation concerning these works.
- **Welfare Management** — Department of Community Services, a range of Service Groups, Council, SES, Police. The complex arrangements under the State Emergency Management Organisation structure create numerous interfaces in the delivery of welfare services.
- **Floodplain Management Committee** — The Floodplain Management Committee assists Council in the development and implementation of a Floodplain Management Plan for the area under its jurisdiction. Membership includes a balanced mix of elected, administrative and community representatives, together with technical experts.

2.11 Community Concerns and Public Consultation

Flooding in the Pages River raises the following social implications for life in Murrurundi and Blandford:

- The business district of Murrurundi is severely affected by floods commencing at 50 year ARI. The social implications resulting from restricted access to services are apparent. As a result of the January 1996 flood some businesses took a number of weeks to re-establish themselves.
- The New England Highway was flooded at the Arnolds Bridge and high velocity flows were experienced along Mayne Street.

2.12 Transport Links

There are several road and rail crossings of the floodplains of the Pages River and its tributaries in Murrurundi Shire. Their hydraulic performance is summarised in Appendix B.

Within the township of Murrurundi roads are generally flood free for minor and medium river flooding. During times of major flooding, the New England Highway is inundated by up to 300 mm from floodwaters surcharging the Pages River between Boyd Street and Arnolds Bridge. On the eastern side of the river, surcharging of the levee fronting Adelaide Street leads to the inundation of the Highway leading through the CBD. Surcharging of the road drainage within the town will occur for the lesser events due to the insufficient capacity of local road culverts.

Between the townships of Murrurundi and Blandford the New England Highway is surcharged in the vicinity of Benhams Bridge when the river breaks its left bank for medium flood events.

At the township of Blandford, Warlands Creek breaks its right bank during minor flood events. Floodwaters flow into Norvill Park where the road to Timor is severed. During medium flood events the volume of water surcharging Warlands Creek is sufficient to cause the surcharging of the Highway. The duration of inundation, up to 5 hours, leads to its closure by the Council. Additionally, floodwaters surcharging the right bank of Warlands Creek traverse the network of local streets as shallow sheet flow.

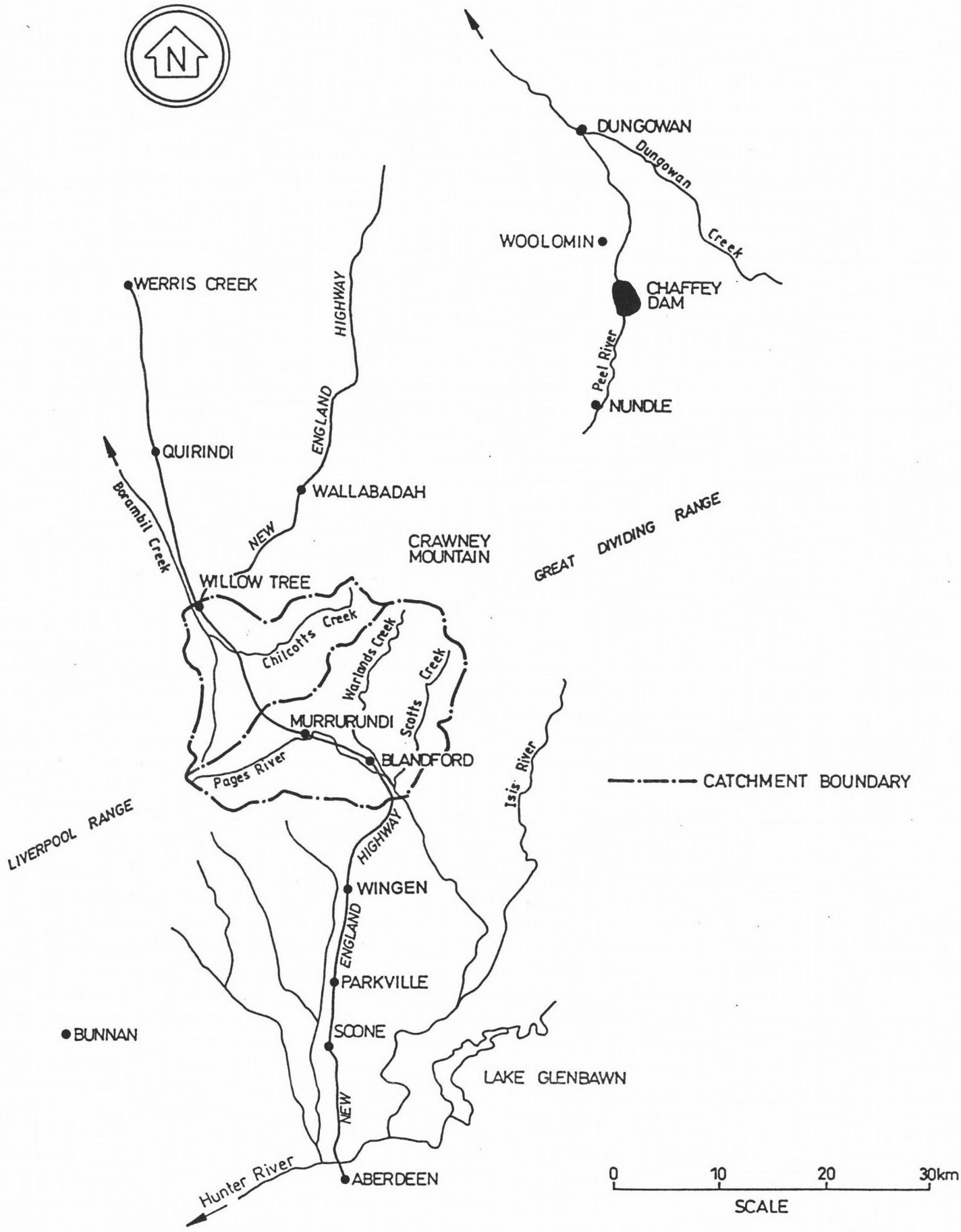
On the western side of the ranges, Borambil Creek breaks its right bank upstream of Hams Bridge and floodwaters traverse the floodplain before surcharging Merriwa Road in the vicinity of the Public School. A causeway is situated at Oaklyn Road where it crosses Borambil Creek and is inundated during minor flood events.

2.13 National Trust and Heritage Buildings

There are a number of flood affected properties which are National Trust buildings or listed as heritage items on the Murrurundi LEP. Most important are Bridge House, White Hart Hotel and Dooleys Store which are all located in Mayne Street. Bridge House is situated on the right bank of the Pages River and was constructed of local bricks with a shingle roof in 1856. An addition to

the residence at the rear of the building was flooded in the January 1996 flood. Dooleys Store is located on higher ground next to Bridge House and was not flooded. The present store was erected in 1905.

White Hart Hotel, which is situated opposite Adelaide Street was originally a wooden building built as an inn in 1842 and enlarged in 1857 and 1901-06. A second storey was added in 1936. It is situated in the path of overflows of the existing levee and was flooded in the January 1996 flood.

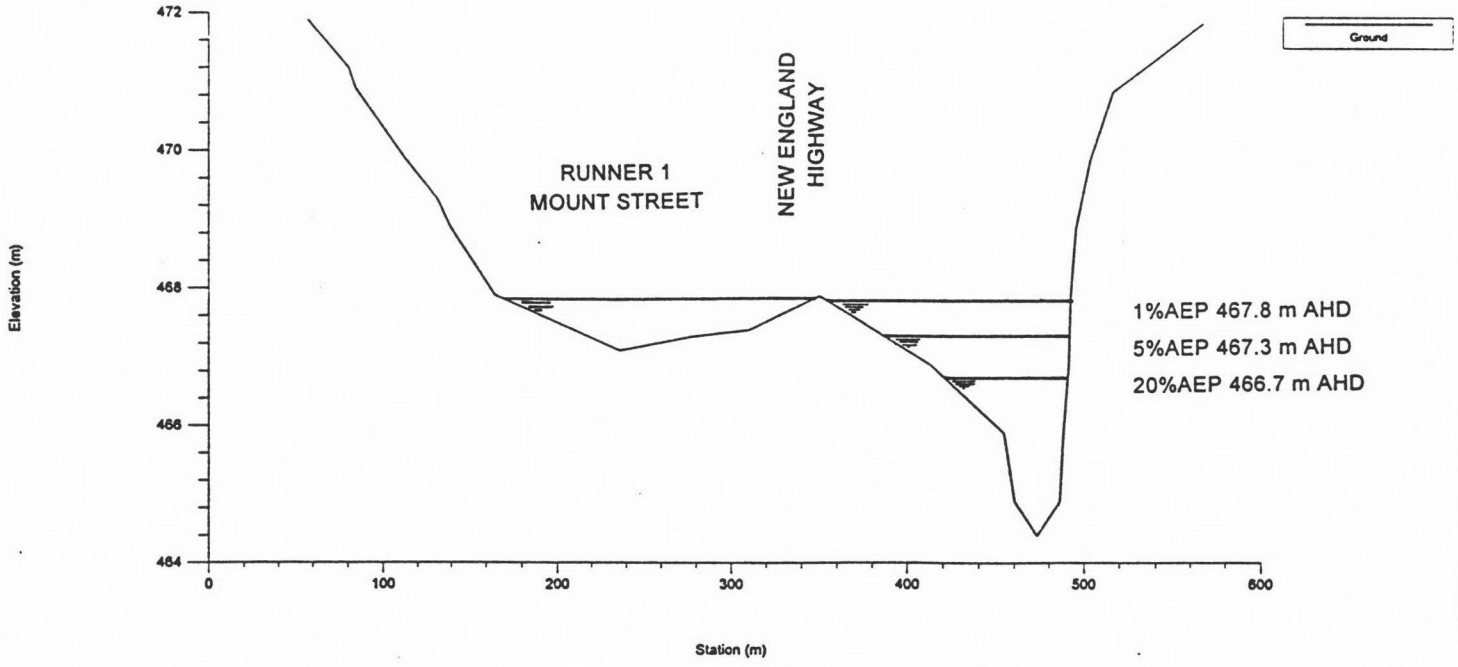


MURRURUNDI, BLANDFORD & WILLOW TREE FLOODPLAIN MANAGEMENT STUDY

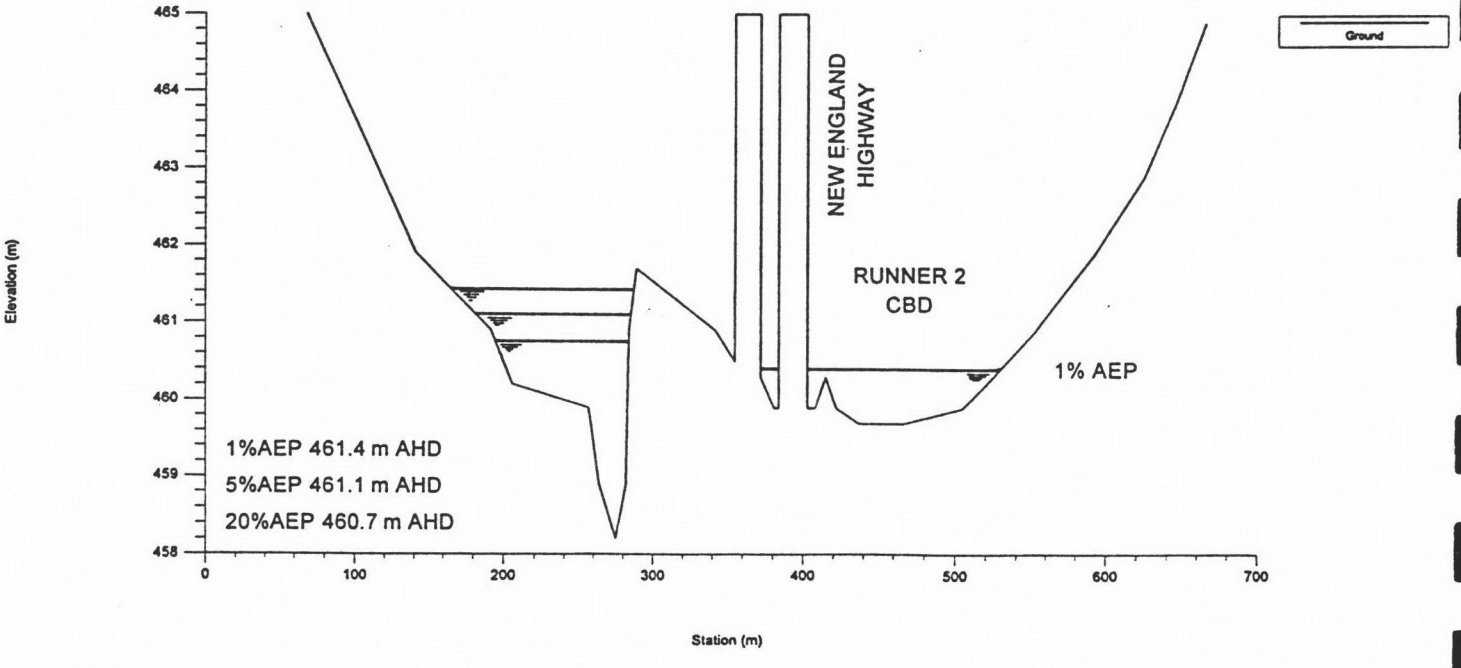
Figure 2.1

Location Plan

Pages River @ Mount Street



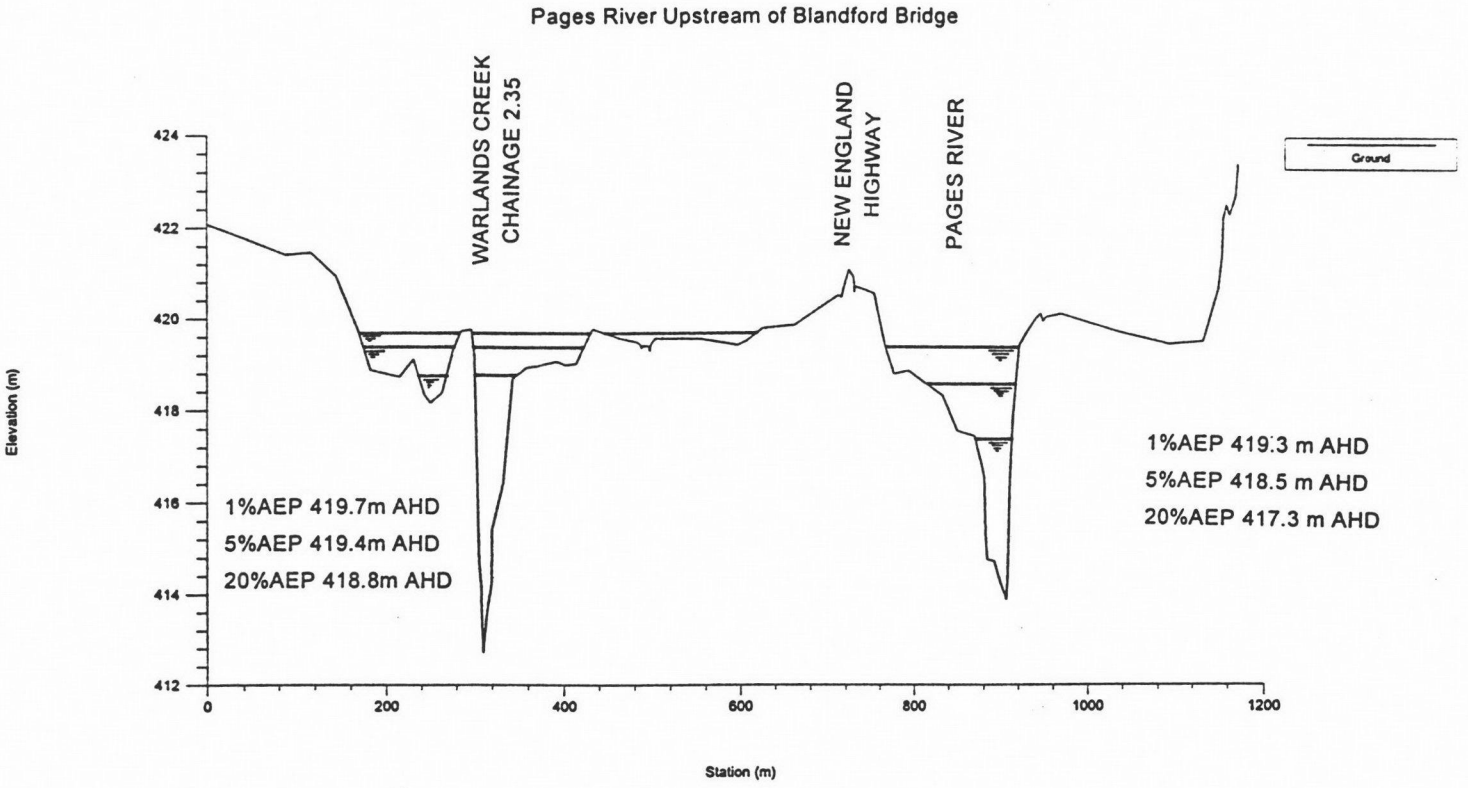
Pages River @ Wades Lane

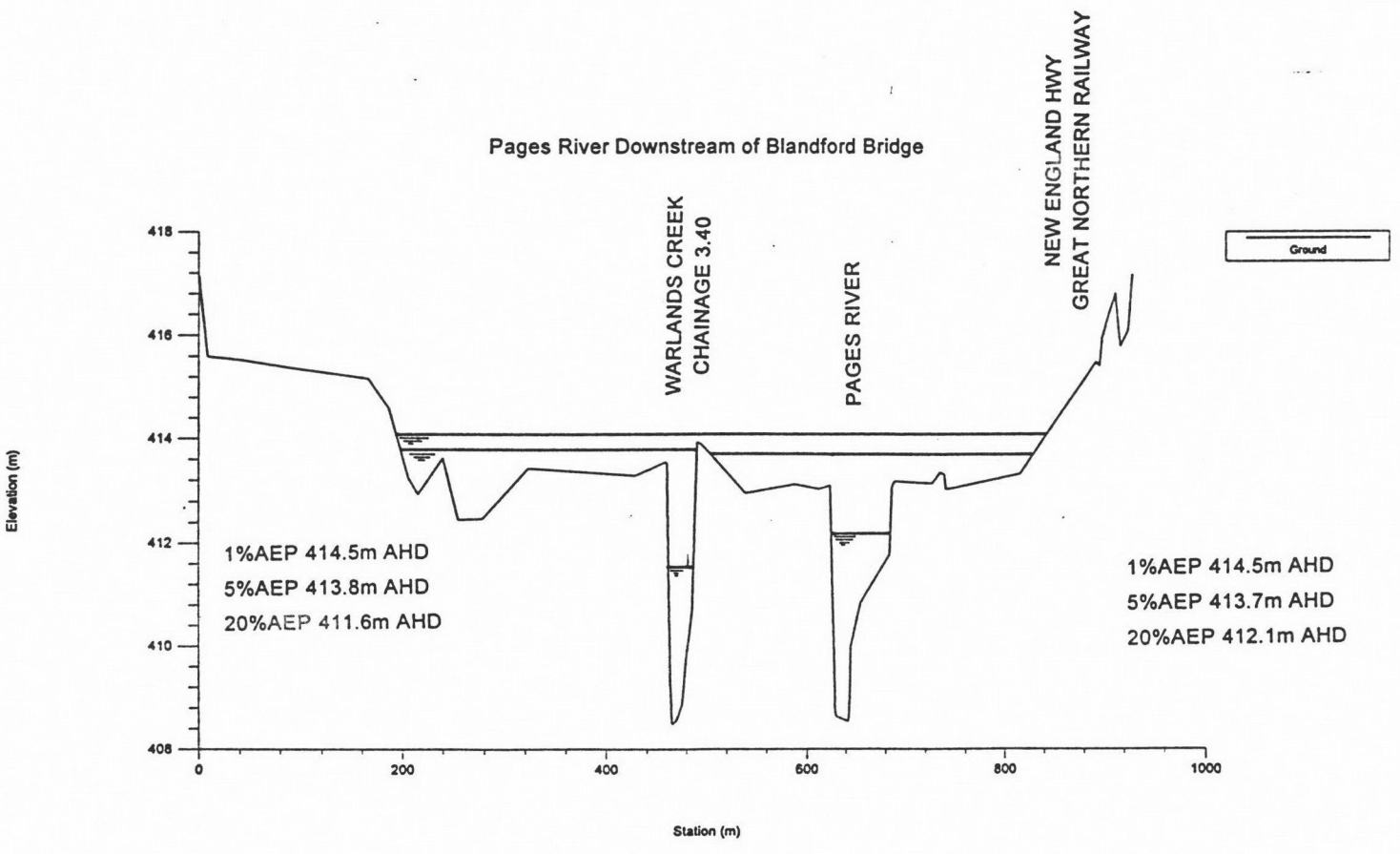


MURRURUNDI, BLANDFORD & WILLOW TREE FLOODPLAIN MANAGEMENT STUDY

Figure 2.5

Typical Cross Sections
Murrurundi

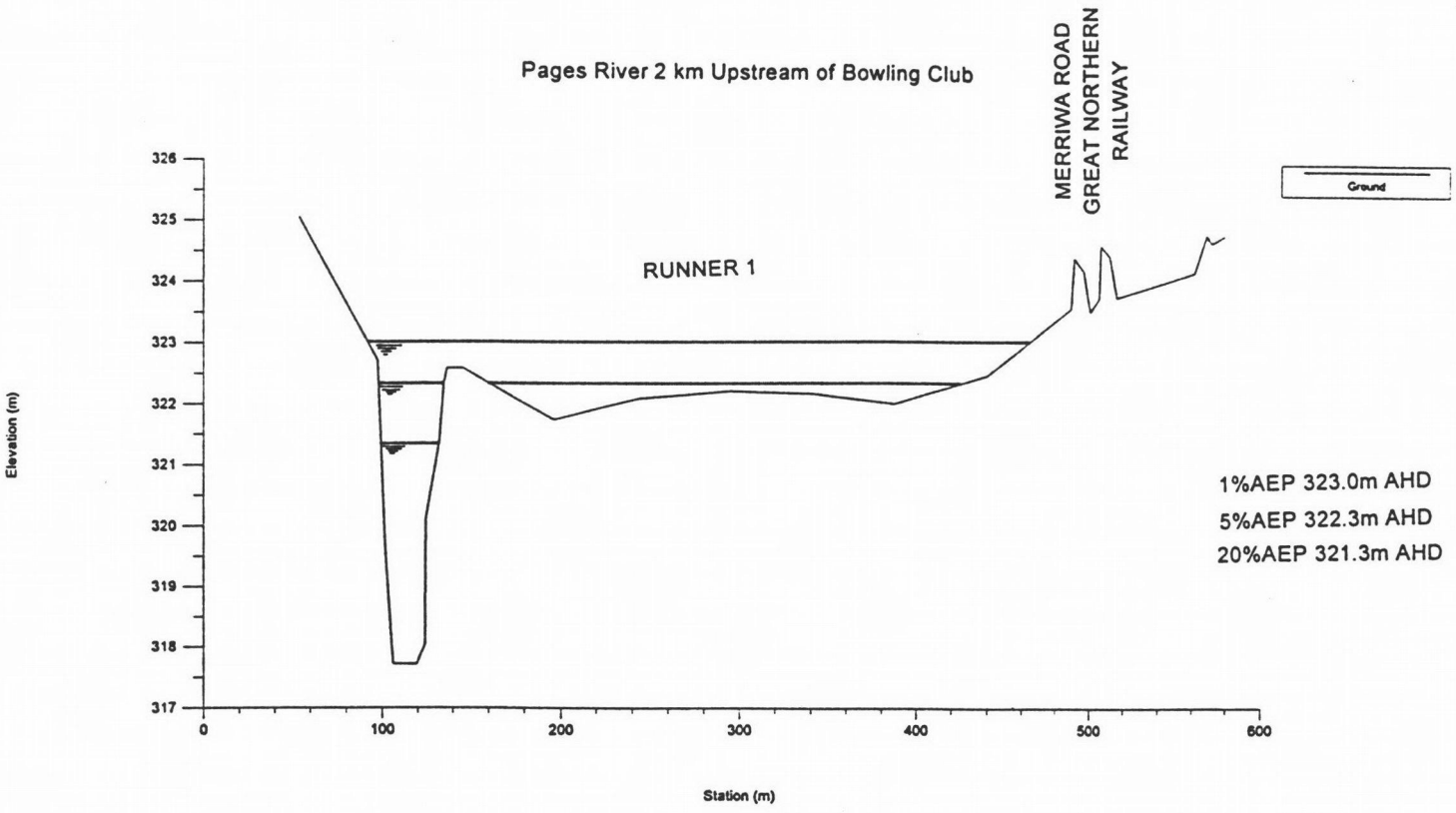


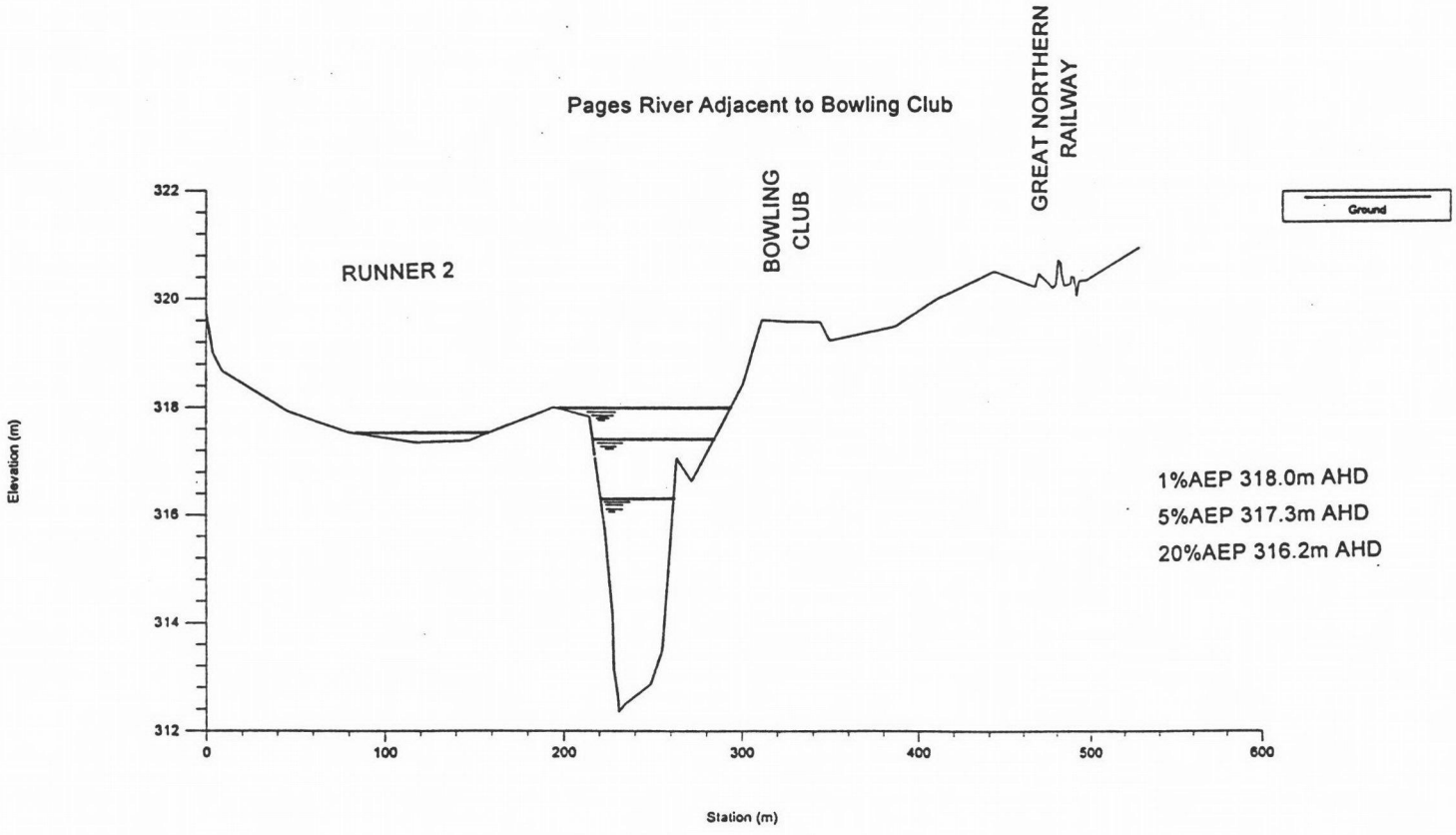


MURRURUNDI, BLANDFORD & WILLOW TREE FLOODPLAIN MANAGEMENT STUDY

Figure 2.6

Typical Cross Sections
Blandford

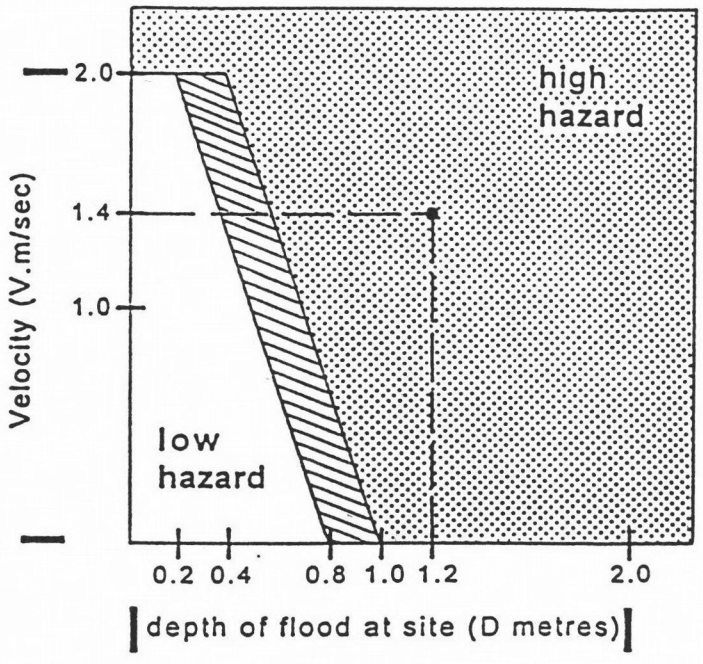




MURRURUNDI, BLANDFORD & WILLOW TREE FLOODPLAIN MANAGEMENT STUDY

Figure 2.7

Typical Cross Sections
Willow Tree



NOTE:
The degree of hazard may be either -

- reduced by the establishment of an effective flood evacuation procedure.
- increased if evacuation difficulties exist.

Within ▨ area the degree of hazard is dependent on site conditions and the nature of the proposed development.

EXAMPLE
If the depth of flood water is 1.2m
and the velocity of floodwater is 1.4m/sec

then the provisional flood hazard is high

(Source: NSW Floodplain Development Manual)

MURRURUNDI, BLANDFORD & WILLOW TREE FLOODPLAIN MANAGEMENT STUDY

Figure 2.8

Provisional Hazard Categories

3. EXISTING FLOODPLAIN MANAGEMENT MEASURES

3.1 General

To date no comprehensive flood management measures have been undertaken in the study area. Some bank stabilisation measures were undertaken in the Pages River by the DLWC (then Water Conservation and Irrigation Commission) in the 1950's. These works comprised groynes and tree plantings and appear to have been reasonably successful in arresting bank erosion.

The levee along the right bank of the Pages River upstream of Arnolds Bridge was originally constructed following the February 1955 flood and was successful in preventing breakouts until the flood of January 1996 when it was overtopped and breached. Council reinstated the levee following the flood which occurred in October 1996.

At Blandford, there is evidence of attempts to raise the right bank of Warlands Creek upstream of the Barsham Bridge to prevent overbank flow which surcharges the New England Highway and flows through the grounds of the school. One local resident in Clarke Street has constructed a private levee to protect his residence from overflows of Warlands Creek downstream of the bridge.

At Willow Tree, a levee has been constructed to protect the public school from overflows of Borambil Creek. This levee mainly acts as a diversion bank to deflect breakouts from the creek towards Merriwa Road. It has not been continued along the frontage of Merriwa Road and consequently the school allotment is subject to backwater flooding.

4. FLOODPLAIN MANAGEMENT OPTIONS

4.1 Overview of Available Measures

There are a variety of floodplain management measures which could be implemented to reduce flood damages. When considering the range of available measures it is useful to adopt the classification system shown in Figure 4.1 (based on AWRC, 1992) which distinguishes three categories:

Property modification to reduce risk to properties through measures such as land use zoning, minimum floor level requirements, or house raising. Such options are aimed at ensuring that the use of floodplains and the design of buildings are consistent with flood risk. These measures comprise a mixture of "non-structural" measures such as planning controls and "structural" options which involve construction works.

Response modification by changing the response of flood prone communities to the flood risk through increasing flood awareness, by the installation of flood warning systems and by the development of emergency management plans for property evacuation. These options are wholly non-structural.

Flood modification by changing the behaviour of floods in terms of flow velocity, depth or the duration of flooding in order to reduce flood impacts. Such "structural" options usually involve the construction of engineering works such as levees to keep water out, flood control dams to reduce flows or channel improvements to speed up the flow of water.

A number of mitigation measures are reviewed in the following sections which follow the hierarchy of options shown in Figure 4.1. Figures 4.2 and 4.3 show the locations of the various structural measures assessed in Sections 4.8 - 4.9 below.

4.2 Planning Controls

4.2.1 General

The merit based approach to floodplain management in NSW was introduced in 1984 as an essential platform within the NSW Flood Prone Lands Policy. This approach, which is described in detail in the Floodplain Development Manual (1986), involves consideration of local social, economic and environmental factors in selecting appropriate flood related planning controls rather than adopting a State wide standard.

The manual states:

> *"Selection of the flood standard for an area is an important and fundamental decision as the standard is the reference point for the preparation of floodplain management plans. In effect it determines the area of land that should be subject to flood related development controls and building controls. The merit approach is inherent in the selection of the flood standard. It involves balancing social, economic and ecological considerations against the consequences of flooding, with a view to minimising the potential for property damage and the risk to life and limb. If the adopted standard is too low, new development in areas above the flood standard (particularly where the difference in level is not great) may be inundated relatively frequently and damage to associated public services will be greater. Alternatively, adoption of an excessively high standard will subject land that is rarely flooded to unwarranted controls."*

The process envisaged at the time the Manual was prepared was that the flood level corresponding to the adopted flood standard (later termed the "designated flood") would define the area of land which should be subject to flood related planning controls. The exact nature of these controls could vary depending on the land use (eg residential, commercial or industrial) to which they referred as well as the flood hazard at a particular location. Typically the adopted flood standard was also adopted as the basis for setting the planning controls. Thus, in a situation in which the 100 year ARI flood had been adopted as the designated flood, minimum floor levels for residential buildings were, typically, defined relative to that flood.

In recent years it has been recognised that all flood prone land needs to be considered and greater emphasis has been placed on defining the appropriate standards to be applied to different land uses. This change reflects a recognition that different land uses might warrant different levels of protection. For instance, a much higher level of flood protection would normally be warranted for essential services such as a hospital than, say, an industrial building. Current practice retains the merit based approach but focuses on defining appropriate planning flood levels for different land uses which reflect the needs of the local community. Central to this approach is the recognition that there is a gradation of flood risk which decreases towards the boundary of the extent of the probable maximum flood (PMF). Within the boundary of this flood prone land, a range of different land uses are possible. For each land use, the social, economic and environmental factors need to be assessed separately and this may lead to different planning flood levels being adopted for different land uses.

The adoption of a planning flood level for any particular land use has wide implications, especially in planning matters. The adopted level will provide a basis for setting allowable floor levels for development. In addition, flood hazard zones will identify locations where future development will and will not be allowed. Therefore the selection of the planning flood level for different land uses should be given considerable attention and the 100 year ARI flood should not be adopted by default.

As discussed above, responsible floodplain management involves applying appropriate controls to different land uses on the floodplain. This usually ranges from very strict controls on land near the creek graduating to less restrictive controls away from the creek. On the outer floodplain, there may be no formal controls and the residual flood risk will need to be managed by other means, principally by emergency management.

Council has a duty of care which requires it to take a responsible development decision in recognition of any potential hazard of which it should be aware. However, Council is indemnified in respect of floodplain management provided it follows the principles and procedures set down in the Floodplain Management Manual. By undertaking this Floodplain Management Study, giving due consideration to adopting planning flood levels and implementing a Floodplain Management Plan, Council will have taken steps to demonstrate due diligence.

This section of the report sets out the factors that influence the selection of planning flood levels and recommends the appropriate standards for Murrurundi, Blandford and Willow Tree. The selection of appropriate planning flood levels for different land uses is a decision which must be made with a view to the long term future. The decision to set a particular level as the basis for control of development and building on the floodplain will only take effect as new buildings and developments are proposed or as existing buildings are redeveloped. Whilst it is often difficult for a community to envisage a radical change from the current pattern of development within the town, it is necessary to look to the long term future in order to develop policies which will reduce the impact of floods on the community. The key to sensible floodplain management is to balance the need to reduce the impact of flooding against the social, economic and environmental factors of importance to the community.

While considering appropriate planning flood levels for adoption, it must be recognised that the associated controls will only apply to new developments, redevelopment or extensions to existing properties. The adopted controls must, therefore look to the future and must set appropriate standards for the long term development of the town. Adoption of a particular planning flood level will have no effect on the existing building stock, and will only take effect as the current stock is redeveloped or upgraded.

4.2.2 Considerations

The key factors in selecting appropriate planning flood levels are:

- Topography
- Current zoning and Council policies
- Flood history and community perception
- Flood frequency-damages relationship
- Future development/available land
- Economic, environmental and social impact
- Implications of a flood greater than the planning level
- Flood warning, evacuation, response issues

In Murrurundi , Blandford and Willow Tree there are a number of land use classes which need to be considered in terms of setting appropriate planning flood levels:

- Residential (including residential buildings on rural land)
- Commercial and industrial
- Essential services and uses which require special consideration such as schools.

Tables 4.1 to 4.3 summarise the main issues which need to be taken into account in determining appropriate planning controls for the three townships.

Table 4.1 Planning Flood Level Considerations for Murrurundi

Issue	Considerations	Range of Planning Flood Level (years ARI)		
		Residential	**Commercial/ Industrial**	**Essential Services**
Is there a characteristic of the local topography which points to a particular planning level for any land use?	• Flows mainly contained within vicinity of channel up to 20 year ARI. Damages low at this level. • Stream is steep and comparatively large increases in discharge results in comparatively small increases in level (400-600 mm increase between 20 and 100 year ARI). • Surcharge of right bank upstream of Arnolds Bridge occurs at 50 year ARI, with Mayne Street becoming a high hazard floodway. • Surcharges of left bank upstream of Arnolds Bridge and flow over NE Highway into floodrunner at 100 year ARI. High hazard conditions in floodrunner and on left bank of Pages River near Arnolds Bridge. • From a topographic perspective, there is no reason to differentiate between the appropriate planning levels for commercial and industrial premises from residential.	100 Restrict development in floodways	50-100 Place conditions on development in floodway	>100
Is there a characteristic of the zoning in the area, the pattern of development or Council's current policies that points to a particular planning flood level?	• Land within the floodplain at Murrurundi has been zoned Village/Urban and has largely been developed. The zoning does not differentiate between residential and commercial/industrial land uses. • No floodplain land has been zoned open-space. Policies do not recognise the hazardous nature of floodways. • No plans currently exist to illustrate the extent of flood liable land referred to in the 1993 LEP.	>50	>50	>100
Does the flood history in Murrurundi suggest a particular planning flood level? This involves a consideration of the magnitude and frequency of historic floods, as well as the "flood awareness" of the population.	• The recent floods of January and October 1996 caused damaging flooding in the township. These events had ARIs of approximately 100 and 50 years in Murrurundi township. • Both floods are within the recent experience of the community. • Extent of flooding and flood levels for the recent flood events are known by residents. • The community has only a limited understanding that floods larger than the 1996 floods could occur, or that the extreme flood could be about 2-3 m higher than the January 1996 flood.	>50	>50	>100

Table 4.1 (continued - 1) Planning Flood Level Considerations For Murrurundi

Issue	Considerations	Range of Planning Flood Level (years ARI)		
		Residential	Commercial/ industrial	Essential Services
Does the nature or rate of increase of flood damages vary greatly within the feasible range of planning levels?	• Commercial damages begin at about the 50 year ARI flood level. • There is only 200-300 mm difference between the 50 and 100 year ARI floods, but this leads to an 80% increase in the average annual damages. • Potential commercial damages are 1.5 to 1.8 times residential damages for floods up to 200 year ARI level. • For commercial properties, 100 year ARI planning flood level would require new or redeveloped shops to have floor levels up to 1.2 m above the street level (adopting 500 mm freeboard). • Any redevelopment of businesses on higher land would completely alter the character of the town. • Commercial damages could be reduced by requiring storage area above the planning flood level, or floodproofing	100	100 Require flood proofing or raised storage areas	>100
Will the choice of planning flood level affect future trends in flood damages, either adversely or beneficially?	• Commercial damages and hazard in CBD area will increase if planning levels are set too low. • Increase in flood hazard if residential development permitted in floodway areas.	100	>50	>100
Will the selection of a particular planning flood level encourage a complacent attitude towards flooding which will result in markedly adverse effects when a larger flood eventually occurs?	• A flood greater than the planning level will eventually occur unless the extreme flood is adopted. • If a medium flood (eg 20 year ARI) was adopted this could result in a large amount of additional unwise development. Significant damages commence at around the 50 year ARI (there is already substantial existing development in the floodplain between this level and the 100 year ARI flood extent). The occurrence of a similar or larger flood could therefore have a substantial impact. • If a major flood (eg 100 year ARI) was adopted there may develop a sense of complacency amongst those occupying new developments above that level. The occurrence of a flood greater than this can and will occur and would result in increased damages. • Unless the PMF was adopted, the adopted planning flood level would need to be implemented in conjunction with measures to provide information and procedures to cope with larger floods.	>20	>20	>100

Table 4.1 (continued - 2) Planning Flood Level Considerations For Murrurundi

Issue	Considerations	Range of Planning Flood Level (years ARI)		
		Residential	Commercial /Industrial	Essential Services
Is there a range of planning flood levels which would have a marked economic or social impact? Does the riverine or built environment suffer or benefit from the selection of a particular planning level?	• A very restrictive planning flood level would increase development costs. Too low a standard encourages unwise development and increases flood damages. • Could be significant economic and social impact of adopting a high level for commercial buildings. • Controls for redevelopment could be less stringent than for new development. • Relocating the business centre, even in the long term, would radically alter the character of the town, and would not be favoured by the business community or the residents. • Social impacts likely with any long term removal or restriction of residential development in the floodplain. • A number of residences in the vicinity of Arnolds Bridge face sufficiently hazardous flood conditions to warrant strict control on future development. • Choice of planning flood level would have negligible impact on the riverine or riparian environment.	>20 Restrict development in floodways	>20 Require flood proofing or raised storage areas	>100
Will the choice of a planning flood level affect flood warning, evacuation, response issues?	• Unless the PMF is chosen as the planning level, flooding in excess of the planning level will occur and will need to be managed by other means, principally by emergency management. • The planning level should be chosen with the risks to emergency management personnel and feasibility of evacuation in mind. • It would be wise to prevent development in areas which are likely to become isolated and would be hazardous for evacuations to be effected from. • Where development is in areas where there is adequate flood warning time, suitable and non-hazardous evacuations routes and where the damages resulting from flooding are relatively low, these may be suitable for exclusion from controls associated with the planning flood level. • Commercial property owners are aware of flood impacts and will tend to respond to early flood warnings.	>50	>20	>100

Table 4.2 Planning Flood Level Considerations for Blandford

Issue	Considerations	Range of Planning Flood Level (years ARI)		
		Residential	Commercial/ Industrial	Essential Services
Is there a characteristic of the local topography which points to a particular planning level for any land use?	• Flows mainly contained within vicinity of channels of Warlands Creek and Pages River up to 20 year ARI. Significant surcharges and overland flows occur at 50 Year ARI. • Considerable overland flow from Warlands Creek to Pages River at 100 year ARI, causing closure of NE Highway and flow through grounds of Public School. • Some flooding along Debenham Street, but most of built-up section of Blandford in low hazard area at 100 year.	<100	<100	>100
Is there a characteristic of the zoning in the area, the pattern of development or Council's current policies that points to a particular planning flood level?	• Land within the floodplain at Blandford has been zoned Village/Urban and has largely been developed. The zoning does not differentiate between residential and commercial/industrial land uses. • No floodplain land has been zoned open-space. Policies do not recognise the hazardous nature of floodways. • No plans currently exist to illustrate the extent of flood liable referred to in the 1993 LEP.	>50	>50	>100
Does the flood history in Blandford suggest a particular planning flood level? This involves a consideration of the magnitude and frequency of historic floods, as well as the "flood awareness" of the population.	• The recent floods of January 1996 caused nuisance flooding in the township. This event had an ARI of approximately 50 years at Blandford. • Extent of flooding for the January 1996 flood and flood levels are known by residents. • The community has only a limited understanding that floods larger than the January 1996 flood could occur, or that the extreme flood could be about 3-4 m higher than the January 1996 flood.	>50	>50	>100

Table 4.2 (continued - 1) Planning Flood Level Considerations for Blandford

Issue	Considerations	Range of Planning Flood Level (years ARI)		
		Residential	Commercial /Industrial	Essential Services
Does the nature or rate of increase of flood damages vary greatly within the feasible range of planning levels?	• Damages begin at about the 20 year ARI flood level but are only significant at 50 year ARI. Damages are mostly residential. • Average annual damages are not large at 100 year ARI and do not greatly increase between 100 and 200 year ARI.	100	100 Require raised storage areas	>100
Will the choice of planning flood level affect future trends in flood damages, either adversely or beneficially?	• Increase in flood hazard if residential development permitted in floodway areas.	100	>50	>100
Will the selection of a particular planning flood level encourage a complacent attitude towards flooding which will result in markedly adverse effects when a larger flood eventually occurs?	• A flood greater than the planning level will eventually occur unless the extreme flood is adopted. • If a medium flood (eg 20 year ARI) was adopted this could result in a large amount of additional unwise development . (Most of the existing development in the floodplain is between the 20 year and the 100 year ARI flood extent). The occurrence of a similar or larger flood could therefore have a substantial impact on future development. • If a major flood (eg 100 year ARI) was adopted there may develop a sense of complacency amongst those occupying new developments above that level. The occurrence of a flood greater than this can and will occur and would result in increased damages. • Unless the PMF was adopted, the adopted planning flood level would need to be implemented in conjunction with measures to provide information and procedures to cope with larger floods.	>20	>20	>100

Table 4.2 (continued - 2) Planning Flood Level Considerations for Blandford

Issue	Considerations	Range of Planning Flood Level (years ARI)		
		Residential	**Commercial /Industrial**	**Essential Services**
Is there a range of planning flood levels which would have a marked economic or social impact? Does the riverine or built environment suffer or benefit from the selection of a particular planning level?	• A very restrictive planning flood level would increase development costs. Too low a standard encourages unwise development and increases flood damages. • Controls for redevelopment could be less stringent than for new development. • Social impacts likely with any long term removal or restriction of residential development in the floodplain. • Few residences face sufficiently hazardous flood conditions to warrant strict control on future development. • Choice of planning flood level would have negligible impact on the riverine or riparian environment.	>20 Restrict development in floodways	>20 Require raised storage areas	>100
Will the choice of a planning flood level affect flood warning, evacuation, response issues?	• Unless the PMF is chosen as the planning level, flooding in excess of the planning level will occur and will need to be managed by other means, principally by emergency management. • The planning level should be chosen with the risks to emergency management personnel and feasibility of evacuation in mind. • It would be wise to prevent development in areas which are likely to become isolated and would be hazardous for evacuations to be effected from. • Where development is in areas where there is adequate flood warning time, suitable and non-hazardous evacuations routes and where the damages resulting from flooding are relatively low, these may be suitable for exclusion from controls associated with the planning flood level.	>50	>20	>100

Table 4.3 Planning Flood Level Considerations for Willow Tree

Issue	Considerations	Range of Planning Flood Level (years ARI)		
		Residential	Commercial/ Industrial	Essential Services
Is there a characteristic of the local topography which points to a particular planning level for any land use?	• Flows contained within channel at 5 year ARI, except for high hazard area between Public School and Borambil Creek, where surcharging of Merriwa Road occurs. • At 20 year ARI, most of floodplain between Recreation Road and Borambil Creek is inundated and is a high hazard area. • Extensive inundation of Merriwa Road at 100 year ARI, but no flood affectation north of Recreation Road. • Most of the town is located on high ground north of railway line and only affected by extreme flood events.	100 Restrict development in floodways	<100	>100
Is there a characteristic of the zoning in the area, the pattern of development or Council's current policies that points to a particular planning flood level?	• Land within the floodplain at Willow Tree has been zoned Village/Urban and has largely been developed. The zoning does not differentiate between residential and commercial/industrial land uses. • No floodplain land has been zoned open-space. Policies do not recognise the hazardous nature of floodways. • No plans currently exist to illustrate the extent of flood liable referred to in the 1993 LEP.	>50	>50	>100
Does the flood history in Willow Tree suggest a particular planning flood level? This involves a consideration of the magnitude and frequency of historic floods, as well as the "flood awareness" of the population.	• The 1949 flood is within the lifetime of only a few residents and the effects, would not be recalled by many members of the community. The 1996 floods were only small events at Willow Tree. • Extent of flooding has not been mapped and consequently flood levels for historic floods are not known by residents. • The community has only a limited understanding that floods larger than the 1949 flood could occur, or that the extreme flood could be about 3-4 m higher than historic flood events.	>50	>50	>100

Table 4.3 (continued - 1) Planning Flood Level Considerations for Willow Tree

Issue	Considerations	Range of Planning Flood Level (years ARI)		
		Residential	Commercial /Industrial	Essential Services
Does the nature or rate of increase of flood damages vary greatly within the feasible range of planning levels?	• Flood damages begin for floods in excess of 200 year ARI flood level. • For commercial properties, 100 year ARI planning flood level would not impose significant restraints on redevelopment. • Any redevelopment of businesses on flood-free land would completely alter the character of the town and is not warranted. • Commercial damages could be reduced by requiring storage area above the planning flood level.	100	100 Require flood proofing or raise storage areas	>100
Will the choice of planning flood level affect future trends in flood damages, either adversely or beneficially?	• Increase in flood hazard if residential development permitted in floodway areas.	100	>50	>100
Will the selection of a particular planning flood level encourage a complacent attitude towards flooding which will result in markedly adverse effects when a larger flood eventually occurs?	• A flood greater than the planning level will eventually occur unless the extreme flood is adopted. • If a medium flood (eg 20 year ARI) was adopted this could result in a large amount of additional unwise development. There is currently little development in the floodplain between this level and the 100 year ARI flood extent). The occurrence of a larger flood could therefore have a substantial impact. • If a major flood (eg 100 year ARI) was adopted there may develop a sense of complacency amongst those occupying new developments above that level. The occurrence of a flood greater than this can and will occur and would result in increased damages. • Unless the PMF was adopted, the adopted planning flood level would need to be implemented in conjunction with measures to provide information and procedures to cope with larger floods.	>20	>20	>100

Table 4.3 (continued - 2) Planning Flood Level Considerations for Willow Tree

Issue	Considerations	Range of Planning Flood Level (years ARI)		
		Residential	**Commercial /Industrial**	**Essential Services**
Is there a range of planning flood levels which would have a marked economic or social impact? Does the riverine or built environment suffer or benefit from the selection of a particular planning level?	• A very restrictive planning flood level would increase development costs. Too low a standard encourages unwise development and increases flood damages. • Controls for redevelopment could be less stringent than for new development. • Social impacts likely with any long term removal or restriction of residential development in the floodplain. • A number of residences (Merriwa Road) face sufficiently hazardous flood conditions to warrant control on future development. • Choice of planning flood level would have negligible impact on the riverine or riparian environment.	>20 Restrict development in floodways	>20 Require raised storage areas	>100
Will the choice of a planning flood level affect flood warning, evacuation, response issues?	• Unless the PMF is chosen as the planning level, flooding in excess of the planning level will occur and will need to be managed by other means, principally by emergency management. • The planning level should be chosen with the risks to emergency management personnel and feasibility of evacuation in mind. • It would be wise to prevent development in areas which are likely to become isolated and would be hazardous for evacuations to be effected from. • Where development is in areas where there is adequate flood warning time, suitable and non-hazardous evacuations routes and where the damages resulting from flooding are relatively low, these may be suitable for exclusion from controls associated with the planning flood level.	>50	>20	>100

4.2.3 Freeboard

It is common to apply a "freeboard" above the planning flood level to cater for uncertainties in the estimation of flood discharges and levels, the variation of flood levels across the floodplain and for wave effects. In effect, freeboard acts as a "factor of safety" to ensure that full protection is provided against the planning flood level. Freeboard should not be relied on to provide protection against flood larger than the planning flood. Any added protection is a bonus, not a guarantee.

4.2.4 Fences and Filling

Fences are a common feature of any urban area and provide privacy and security for the householder. However in flood prone areas fences, particularly solid paling or sheet metal structures, can:

- divert the natural flow of water;
- increase water levels upstream;
- cause a wave of water when they collapse.

Although these problems are more apparent with solid fences, wire mesh fences are also prone to blocking with debris and causing similar problems.

Filling or mounding of the ground can also cause flow patterns to alter.

For the study area, the main areas where fences or filling are likely to exacerbate flooding problems are the floodways and the high hazard areas close to the Pages River, Warlands Creek and Borambil Creek. It would be appropriate to consider controls on fencing and filling to ensure that flood flows are not impeded.

4.3 Voluntary Purchase Schemes

Removal of housing from high hazard floodway areas in the floodplain is often a cost effective means of correcting previous decisions to build in such areas and can be a good option for such areas when other management measures are not acceptable. The voluntary purchase of residential property in hazardous areas has been part of subsidised floodplain management programs in NSW for over 20 years. After purchase, land is subsequently cleared and the site redeveloped and rezoned for public open space or some other flood compatible use.

A further criterion applied by State Government agencies is that the property must be in a high hazard area such as a floodway, that is, in the path of flowing floodwaters where the depth and velocity are such that life could be threatened, damage of property is likely and evacuation difficult. Prior to adopting a voluntary purchase scheme, Council will need to gauge community support as the success of the scheme will depend on the co-operation of affected residents. If such support is not forthcoming then the scheme will not be effective as a management measure.

Where a property is considered to qualify for a voluntary purchase scheme the owner is notified that the body controlling the scheme, in this case Murrurundi Shire Council, is prepared to purchase the property when the owner is ready to sell. There is no compulsion whatsoever to sell at any time. The price is determined by independent valuers and the Valuer General, and by negotiation between Council and the owners. Valuations are not reduced due to the flood affected nature of the site.

The Floodplain Development Manual indicates that all properties with the high hazard flood zone could be candidates for inclusion in a voluntary purchase scheme. Any proposal by Council to pursue a voluntary purchase scheme must be handled in a sensitive manner as the proposals could have a significant impact on the individuals concerned. For this reason, details of the recommended priority for a voluntary purchase scheme are usually considered only in conditions of strict confidentiality by the Floodplain Management Committee and Council.

An assessment of residential development eligible for a voluntary purchase scheme within each township was made and the results are outlined below.

Murrurundi

There are four residential properties in the vicinity of Arnolds Bridge which lie within the high hazard floodway area and were considered for the scheme. Valuations of the individual properties have not been carried out, but from the drive by survey undertaken for this study (Appendix B), the indicative cost of a voluntary purchase scheme for these four properties was assessed at around $360,000. Assuming that this cost would be spread evenly over a 20 year period, the net present value of the scheme (for a 7% discount rate) would be $190,000. However, the present worth of benefits, determined from the damages assessment, amount to only $13,000. While the scheme is not justifiable on economic grounds, voluntary purchase schemes are generally implemented on social grounds rather than purely economic justification.

Blandford

There is one residential property situated in a high hazard floodway zone within Blandford. The house of concern was severely flooded in the January 1996 event and is presently in a run-down state and vacant. The house has been constructed in a major flowpath for waters surcharging the banks of Warlands Creek and its purchase and rezoning is strongly recommended.

Willow Tree

No residential properties within the township of Willow Tree would be eligible for a voluntary purchase scheme.

4.4 Flood Proofing

This term refers to procedures undertaken, usually on a property by property basis, to protect structures from damage by floodwaters. The most common process is to raise the affected house so that the floor level is above (usually 0.5 m above) the planning flood level. For weatherboard and similar buildings this can be achieved by jacking up the house, constructing new supports, stairways and balconies and reconnecting services. Alternatively, where the house contains high ceilings, floor levels can be raised within rooms without actually raising the house. It is usually not practical to raise brick or masonry houses.

Other procedures to flood proof properties include the construction of levees or diversion banks to deflect floodwaters away from residences. These banks could take the form of grass covered mounding or low block walls. Each situation needs to be evaluated individually and a site plan prepared showing the required works. The effect of the proposed works must also be evaluated in terms of the cumulative effect of a number of such proposals. Runoff from within protected areas must be catered for by temporary storage or drainage to downstream areas. On occasions, micro-pump out systems have been used to dispose of internal drainage.

Waterproofing the outer skins of buildings and providing floodgates/shutters on doorways and windows have also been used. This method is usually only applied to brick or masonry structures, is not common and is not usually very aesthetically pleasing. Another technique is to replace flood-damageable materials with materials that are flood compatible, or which at least suffer less damage than other materials.

The State and Federal Governments have agreed that flood mitigation funds will be available for house raising, subject to the same economic evaluation and subsidy arrangements that apply to other structural and non-structural flood mitigation measures. State Government subsidy of $10,000 is available for house raising to owners of homes where habitable floors are just below designated flood level. Such properties would not normally qualify for a house raising scheme on economic grounds.

In accepting schemes for eligibility the Government has laid down the following conditions:

- house raising should be part of an adopted Floodplain Management Plan
- the scheme should be administered by the local authority.

The Government also requires that Councils carry out ongoing monitoring in areas where subsidised voluntary house raising has occurred to ensure that redevelopment does not occur to re-establish habitable areas below the design floor level. In addition, it is expected that Councils will provide documentation during the conveyancing process so that subsequent owners are made aware of restrictions on development below the design floor level.

Council's principal role in subsidised voluntary house raising would be to:

- define a habitable floor level, which it will have already done in exercising controls over new house building in the area,
- guarantee a payment to the builder after satisfactory completion of the agreed work

- monitor the area of voluntary house raising to ensure that redevelopment does not occur to re-establish habitable areas below the design floor level.

Most of the contractors who specialise in house raising are not interested in the building aspects of the work and it is therefore likely that two contractors would be involved. The current cost to raise a medium sized (150 square metres) house is between $25,000 and $35,000 based on recent experience in Murwillumbah, Grafton and Fairfield.

An assessment of residential development eligible for a house raising within each township was made and the results are outlined below.

Murrurundi

Apart from the four buildings located within floodways which have been considered highest priority for voluntary purchase, there are 20 residential, 29 commercial and three public buildings which would be damaged in a 100 year ARI flood. (Flood protection or flood-proofing of commercial buildings is generally not eligible for public funding subsidy but would considerably reduce damages resulting from the shallow inundation which is typical of flood events.)

Of the 20 residential buildings, 10 are suitable for house raising. Assuming a cost of $35,000 per home for raising and reconnection of services, the total cost of a scheme to raise these houses would be $350,000. Assuming the raising of houses was undertaken at one time, rather than in a staged process as would be more likely, the present worth of benefits would amount to $11,000 (for a 7% discount rate). Implementation of a formal house raising scheme for Murrurundi is clearly not justified economically.

As previously mentioned, $10,000 is available as a subsidy for house raising and not subject to economic evaluation. However, the landowner has to fund the remaining cost. Experience with this arrangement in other flood prone locations suggests that the subsidy would not be attractive for residents in Murrurundi or the other two townships.

Blandford

There are two residential properties flooded at the 100 year ARI on the banks of Warlands Creek, one of which was recommended for voluntary purchase. Results of the hydraulic modelling show that the depth of inundation within the remaining property is minimal and the cost required to raise the floor is not justified. Flood proofing of doorways would be a more cost-effective solution.

Willow Tree

There are no residential properties within the township of Willow Tree which are flooded at the 100 year ARI event, therefore house raising is not a practical measure.

Summary

The above assessment indicates that implementation of a strategy for house raising is not economically justified. In the case of Murrurundi, a total of 10 houses are suitable for house raising, eight of which are located in or around the CBD area. The cost of raising these houses is around $350,000 and the present worth of benefits is only $11,000. Experience suggests that there would be few residents willing to fund the balance of the cost of house raising over and above the $10,000 subsidy available from State Government. The cost of rebuilding the Adelaide Street levee has been assessed at around $110,000. Removal of bed material in the vicinity of Arnold bridge will enable the waterway to function at capacity, and will cost an additional $250,000 (see Section 4.8 following). This scheme will alleviate a large portion of the damages to both residential, commercial and public properties and is a more economically viable solution.

4.5 Flood Warning and Response

The existing flood warning and response system in Murrurundi Shire is reviewed in Appendix D and summarised below.

In the Shire of Murrurundi, the division of responsibility is such that the Murrurundi SES Local Controller has responsibility for flood management in Murrurundi and Blandford, while the Quirindi Local Controller covers Willow Tree.

A draft Flood Sub-Plan has been prepared for the area east of the Liverpool Ranges which defines the nature of the flood threat including flood producing mechanisms, locations of road closures and areas inundated in Murrurundi and Blandford and sets out procedures undertaken by the Local Controller with respect to flood warnings and response. A draft Quirindi Local Flood Plan has been prepared which covers the headwaters of the Namoi system, including Willow Tree.

While the general pattern of flooding in the townships has been identified from historic flooding, the results of the Flood Study along with floor levels of flood affected properties will allow more precise identification of areas at risk from the full range of flood events likely to trigger flood response procedures in the three townships. This information should be incorporated in the Flood Plans.

BOM currently issue a Flood Alert (formerly known as a Confidential Flood Advice) as an alerting mechanism for the SES. These advises are of a qualitative nature only. There is no formal flood prediction system in operation for the three townships. Due to their small size and steepness, flooding on the catchments is of a "flash flooding" nature with only around 1-2 hours between the occurrence of heavy rainfall and the resulting flood peak. Implementation of a flood forecasting system based on the ALERT system is not likely to be effective for the three townships, although it may be useful in downstream flood affected locations where the response time of the catchments is longer.

However, in the case of the three townships, there is little time to carry out evacuations and the best that could probably be achieved is an announcement over local radio stations that flooding is imminent.

Some formalisation and expansion of the network of local river and rain watchers, along with training and strengthening of communications, is considered appropriate to maximise the available warning time and the effectiveness of the system.

The formalisation of designated sandbag storage areas is recommended which can be easily accessible to SES personnel and the general public.

Along the Pages River, the surcharging of the New England Highway may cause difficulties in respect to emergency response to the townships of Murrurundi and Blandford. It is recommended that the Murrurundi Flood Plan include back up personnel able to assist in the event of SES personnel being unavailable. It is essential that SES and backup personnel are

adequately trained and sufficient qualified people are available to disseminate advice and provide assistance.

4.6 Flood Awareness Program

The majority of the residents in Murrurundi Shire have a high degree of consciousness of the threat of flooding. This is because of the occurrence of significant recent floods in the townships of Murrurundi and Blandford.

However, a continuing awareness program must still be put in place to inform new residents of the nature of flood risk and maintain the level of awareness of old residents. An effective flood awareness scheme will require an ongoing commitment from Council.

Murrurundi, Blandford and Willow Tree would benefit from an ongoing flood education program sponsored by Council which develops and maintains a working knowledge of the flood threat to the townships. This program should put the flood danger into perspective for those residents and businesses in the flood prone areas. The education program should promote at least the following elements:

- An awareness of the extent of and hazard associated with a range of floods up to the 100 year ARI flood. A pre-requisite is the provision of flood mapping. Accurate definition of flooding is difficult to achieve in Blandford and Willow Tree, as the present standard of topographic mapping is poor.

- Flood advice on S.149 certificates issued by Council when property is bought. These certificates should contain clear advice and consistent requirements for floor levels for new dwellings.

- A knowledge of the characteristics of flooding among the affected property owners. These characteristics should include information on the frequency of flooding and the depths at various locations. This information could be included in a flood information booklet containing both general and site specific data and distributed with the rate notices. Flood height markers at a number of key locations around the town can also provide a useful reminder to residents.

- An awareness of the effects of an occurrence of a flood greater than the planning flood level. Considerable care must be taken to inform residents that a flood greater than historic flood levels or the planning level can, and will, occur at some time in the future.

- The Floodplain Management Plan developed as a result of this study should be publicised and exhibited in Council offices, libraries and similar locations to make residents aware of the measures being proposed.

- An ongoing awareness of flooding and flood impacts. In the lower Hunter Valley, flood awareness in the community has been raised by holding commemorative events to mark the anniversary of particularly noteworthy floods (eg 1955 flood).

4.7 Flood Data Collection

Council has collected a significant body of data relating to the January 1996 flood and subsequent floods.

It is important that information on future flooding is captured and collated, to allow development of the Flood Plan any flood warning system implemented in the future.

Council should file and index all flood related information in a "Compendium of Data" which should be upgraded after each significant flood event. The data would include the following items and could be incorporated in a GIS such as Mapinfo or equivalent:

- daily rainfalls and pluviographic traces (processed to give tabulated rainfall depths) throughout the catchment,
- stage hydrographs recorded at the Blandford stream gauge and at relevant upstream locations,
- observations made during a reconnaissance survey to collect and level flood marks, establish flooding patterns, conduct interviews with affected residents, etc,
- flood damage data,
- SES and BOM post flood reports,
- maps showing the extents of flooding,
- hydrographic survey of the main river system based on updating the cross sectional survey undertaken for the Flood Study.

A plan should be prepared in collaboration with the SES to collect these data in future flood events. The plan should include the officers responsible, type and timing of observations required and the mechanism of recording the data.

4.8 Levees

4.8.1 General

Levees are an effective means of protecting flood affected properties up to the design flood level provided account is taken of potential re-distribution of flood flows, the requirements for disposal of internal drainage from the protected area and the possibility of overtopping the levee in floods greater than the design event.

Levees are usually constructed of compacted soil won from local sources and carefully placed to strict engineering standards. The Department of Land & Water Conservation (DLWC) and NSW Public Works and Services (DPW&S) have issued criteria to provide a preliminary guide to a local authority in preparing specifications for levees which include the following recommendations:

- design and construction supervision to be undertaken by a professional engineer,
- crest width should be sufficient to allow the passage of vehicles,
- a freeboard for the crest level above the design flood,

- geotechnical investigation required to determine side slopes, assess material suitability and foundation conditions.

Levees constructed with public funds must meet the current design and construction requirements set down by the DLWC and DPW&S and usually constitute a designated development which requires that an EIS must be submitted in support for an application for development consent.

Concrete block walls are often used in situations where urbanisation abuts the river and there is insufficient land available for earth banks. Block walls must be provided with reinforced concrete footings of sufficient width to withstand overturning during flood events.

4.8.2 Murrurundi Town Levee

WC&IC prepared a concept design for a levee to protect Murrurundi in the 1970's. The levee extended along the right bank as far as Brook Street. It followed the line of the then existing levee upstream of Arnolds Bridge. However, it is not known whether it was intended to replace that structure or incorporate it into the proposed scheme. No information is available regarding the height of the proposed levee. Consequently the following discussions on this concept is of a general nature only and is based on the levee scheme denoted LM1 (Table 4.8).

There are several factors which militate against the WC&IC town levee scheme:

- Unless it was constructed to the level of the PMF there would be a chance of its being surcharged, particularly upstream of Arnolds Bridge. In this eventuality, overflows would be conveyed along Mayne Street, as occurred in January 1996. Flow would not be able to return to the river, due to the blocking effect of the levee downstream of the bridge.

- If the levee were to be constructed to the level of the PMF, there would be an increase in flood levels along the length of the levee together with a re-direction of flow towards the left bank. Flooding on that side of the river would be exacerbated with potentially serious consequences for existing development on the upstream side of Arnolds Bridge.

- There do not appear to be any opportunities for storing runoff from the local catchments on the landward side of the levee or from surcharge of the existing levee, pending return of flow to the river after the flood has receded. Consequently, considerable ponding would be experienced on the landward side which could result in flood levels in protected areas being not greatly lowered compared with present day conditions.

Conclusion: A major town levee scheme is rejected on technical grounds and would not be economically justified given the relatively small damages experienced in the township.

4.8.3 Adelaide Street Levee

Several opportunities exist for minor levee schemes. Re-building the existing levee upstream of Arnolds Bridge to ensure its safety in the event of a major flood is a very effective measure, as it would prevent Mayne Street acting as a floodway. This levee is denoted LM2 on Figure 4.2. The existing levee ties in to the elevated bridge abutment on Mayne Street and extends for a distance of approximately 80 m upstream. There are no records detailing the date of the levee, the nature of its construction or who built it (local knowledge indicates that the levee may have been in place since the 1950s). Given the scouring of the levee in the recent floods, it appears that construction materials consist of loosely compacted river gravel, building materials and soil.

In January 1996 the levee was the site of surcharging from the Pages River. Water flowed into the CBD area and caused damage to properties. Reports of the flood indicate that the levee was both overtopped and breached by floodwaters. A flood breached the levee again in October 1996, after which some reinstatement work was carried out by Council. It is understood that the crest level of the reinstated levee was not significantly altered.

It is considered that the reconstruction of the levee as an engineered structure would benefit the town given that in the past two floods, the levee has sustained structural damage and allowed floodwaters to enter the CBD. There are concerns that raising the levee significantly above existing levels to obtain a greater level of protection will adversely affect properties on the left bank of the Pages River and downstream of Arnolds Bridge. However, even if the levee was not raised, its replacement by a structure capable of withstanding some overtopping would reduce the probability of a sudden surge of water into the township due to scour.

Hydraulic modelling undertaken for the Flood Study indicated that a flow of around 30 m^3/s surcharges the existing levee for the 100 year ARI event. This flow represents around 7% of the total discharge immediately upstream of the bridge.

Hydraulic modelling was undertaken for this present investigation to assess the effects on flood levels in the Pages River of raising the levee to exclude the 100 year ARI flood without overtopping. Results of the modelling showed that flood levels would be raised by between 100 to 200 mm adjacent to the levee for the 100 yr ARI event. Effects on flood levels reduced rapidly upstream and were negligible adjacent to Pages Street, approximately 350 m upstream of Arnolds Bridge. Modelling indicated that flows which surcharge the New England Highway upstream of Arnolds Bridge under existing conditions were not significantly increased due to the rise in flood levels.

The increase in flood levels upstream of the bridge would result in an increase of 200 mm in the depth of inundation in two properties adjacent to the river bank which are currently flooded at the 100 year ARI. As well, one additional property currently not flooded, would experience shallow inundation over the floor. In practice, levees are usually constructed with a freeboard on the design flood level to allow for settlement, wave action and uncertainties in the estimation of design flood levels. The freeboard commonly ranges between 500 and 1000 mm. In the present case, provision of such a freeboard would exacerbate flooding on the left bank in the event of floods which result in peak levels which are higher than the nominal 100 year ARI design levels, but which are below the level of the crest. The relief which would be provided by surcharging of

the existing levee would no longer be available for those floods and consequently peak levels in the river would be raised compared with present day conditions. If this scheme were adopted, it would be advisable to adopt a crest level approximating that of the existing levee ie around the 50 year ARI flood level.

Due to the increased flow contained within the river by the levee, flood levels downstream of the bridge would be raised by around 100 mm for a distance of approximately 400 m. An increase in the "leakage" of floodwaters from the river into Mayne Street would occur. Flow would enter the street between the properties fronting the road.

Conclusion: The existing levee needs to be rebuilt as a properly engineered structure. Due to the potential exacerbation of flooding on the left bank, construction of the levee significantly above existing crest level would probably not be favoured. The existing levee has around a 50 years ARI level of protection and consequently, if rebuilt to the same level, would need to be armoured to withstand overtopping in the event of flows greater than the design flood. The cost of the new 50 year ARI levee is estimated at $110,000. The present worth value of benefits is assessed as $70,000. It would be advisable to also remove the bed material obstructing the bridge waterway as this would reduce flood levels and provide a level of protection equal to 100 year ARI with freeboard. The additional cost of removing the bed material is assessed as $250,000 – see Section 4.9.1.1, where this scheme is denoted CM1.

4.8.4 Minor Levee downstream of Arnolds Bridge

Another potential scheme is to extend the Adelaide Street levee described above along the right bank downstream of Arnolds Bridge to protect Bridge House and possibly several other adjacent properties during major events. Downstream of the bridge, floodwaters frequently surcharge the relatively low right bank of the Pages River. During major flood events floodwaters traverse the rear of the properties in this vicinity at depths around 2 m and velocities reaching 2 m/s. Floodwaters run between the properties fronting Mayne Street and flow down the road, rejoining the Pages River downstream of Brook Street. A scheme, which would prevent the inundation of the right bank, is shown as LM3 on Figure 4.2. Scheme LM3 includes rebuilding the existing levee and removing the bed material at Arnolds Bridge (scheme CM1) plus constructing the levee downstream of the bridge.

The proposed levee is connected to the elevated abutment of Arnolds Bridge at its upstream end and extends downstream to Wades Lane, a distance of around 370 m. It may be necessary to extend the levee past Wades Lane to prevent floodwaters entering a natural depression to the south, which may direct water back towards the township.

For the 100 year ARI peak flood levels along the length of the levee downstream of Arnolds Bridge reduce from RL464.4 m AHD to RL461.4 m AHD at Wades Lane. Allowing for 500 mm freeboard, the levee immediately downstream of the bridge would need to be approximately 2.8 m in height reducing to a small bank of nominal height at Wades Lane.

The presence of buildings close to the river would require vertical block walls to be incorporated into the levee design in two locations. If the levee were constructed of compacted earth fill it would have a large footprint. Assuming a crest width of 2 m and 1 (vertical) on 4 (horizontal) side slopes, its maximum extent would be 25 m. Constructing the levee in concrete block walls in constricted areas reduces this requirement.

A low spot exists behind the levee alignment on the northern side of Mayne Street, adjacent to Adelaide Street. A common problem with levee schemes is the difficulty experienced in draining local runoff which ponds behind the levee. With this scheme, a pipe would need to be laid which would run parallel with the levee on its landward side and extend downstream of Brook Street, to allow positive drainage to the river during major flood events.

For preliminary planning, this scheme has been sized to provide a nominal 100 year ARI level of protection. Larger flood events must be taken into consideration when designing a levee as overtopping can cause a failure of the levee bank. A spillway section would therefore need to be incorporated just upstream of the bridge, which would allow filling behind the levee prior to major overtopping. No spillway would be necessary at the downstream end as floodwaters could escape overland towards Brook Street before rejoining the river flow.

Hydraulic modelling of this scheme was undertaken in conjunction with the raised levee upstream of Adelaide Street. This scheme would prevent flooding of the CBD area for major flood events up to 100 year ARI.

A preliminary costing was undertaken for the levee scheme which gave a total cost of around $750,000 exclusive of the cost of voluntary purchase of property on the left bank which may be adversely affected. This scheme eliminates damages up to the 100 year ARI, the present worth value of which is around $140,000.

Conclusion: Scheme LM3 has technical difficulties in regard to the control and temporary storage of local catchment runoff and in the event of surcharges of the levee upstream of Arnolds Bridge. It is not economically justified.

4.8.5 Blandford Town Levee

Warlands Creek frequently surcharges its right bank upstream of Barsham Bridge. Floodwaters traverse the right floodplain and pond behind the New England Highway at Norvill Park. The highway is elevated above the natural terrain by around 600 mm at this location. Floodwaters escape from the park by either:

1) running along the northern side of the highway and rejoining Warlands Creek flows adjacent to Blandford school, or

2) ponding to a depth which will allow surcharging of the highway. Floodwaters which surcharge the highway flow overland through the school grounds to the Pages River upstream of Blandford Bridge

Additionally, flooding occurs within the village area of town to the north of Blandford Bridge. During major flood events, flooding is experienced due mainly to shallow sheet flow which traverses the street system. This sheet flow originates at the northern extent of the village area in the vicinity of Hayles and Debenham Streets. As mentioned, floodwaters also flow down the highway from Norvill Park.

During the January 1996 event, flows on Warlands Creek surcharged the highway in the vicinity of Norvill Park and resulted in closure of the road. Water also traversed the street system and caused nuisance flooding.

A levee scheme which diverts floodwaters around the township is shown in Figure 4.3 and is denoted scheme LB1.

Detailed ground level information is not available. Therefore the estimates of the required levee extent and height are indicative only. Based on available data, the levee would need to be between 1–1.5 m in height to have a 100 year ARI design standard and have a length of around 1400 m. Timor Road would need to be raised to cross the levee near the New England Highway, but should remain at grade on the northern side to allow the passage of floodwaters.

The cost of the levee scheme was estimated at $520,000. Benefits gained by the levee are the protection given to the Blandford School and the New England Highway against overland flow from Warlands Creek.

Clearly, such a major levee scheme cannot be justified economically solely on the grounds of damages prevented to the township. Overland flows leaving Warlands Creek would be directed towards the township and may actually result in an increase in the flood hazard, as flood levels for the 100 year ARI would be raised by around 100 mm. The New England Highway is a major trunk road and reduction in the incidence of flooding would have some economic benefits. However, as the duration of closure is limited to several hours during relatively infrequent flood events, improving access in not likely to warrant such a large expenditure.

Conclusion: Scheme LB1 is not economically justified and the additional flows directed towards Blandford by the levee may result in an increase in flood hazard.

4.8.6 Warlands Creek Levee

From site inspection, previous attempts have been made to prevent breakouts from the right bank of Warlands Creek upstream of Barsham Bridge, by raising the bank level with a low levee bank.

Hydraulic modelling was undertaken for a raised levee scheme generally following the line of the existing levee, which would contain all flows up to the 100 yr ARI within the banks of Warlands Creek. This scheme is denoted LB2 on Figure 4.3. Initially, the creek bank in the vicinity of Barsham Bridge was raised as it is the site of extensive breakouts during major flooding. The levee was modelled in conjunction with an increase in bridge waterway area from 105 m^2 to 140

m^2, which was affected by the inclusion of an additional span of 10 m width by 3.5 m height on the left bank of the creek.

Results of the modelling show that the bridge forms a constriction to the flow and the increase in waterway area would not significantly reduce the flood levels upstream of the bridge. The levee upstream of the bridge would need to be around 3.5 m in height. The increase in flood levels due to the resulting increase in flow through the bridge would cause overtopping of the bridge deck by around 0.5 m. Road levels would need to be raised to prevent the escape of flows at the bridge.

Conclusion: Due to the extent of works required for this option, not only at Barsham Bridge but further downstream, levee scheme LB2 does not warrant further investigation and will not be considered further.

4.8.7 Willow Tree School Levee

Surcharging of Borambil Creek upstream of Hams Bridge and the subsequent inundation of a low lying area immediately to the south of the school occurs for minor flood events.

A levee has been constructed along the southern fence line of the school in an attempt to deflect floodwaters away from the school and back towards Borambil Creek. The levee is approximately 200 m in length and around 1 m in height. At Merriwa Road, the levee slopes to natural surface to allows drainage of flows from the school grounds to the low lying area to the south.

In the January 1996 event, the levee was both overtopped and outflanked by the floodwaters in the vicinity of Merriwa Road.

To prevent floodwaters from entering the school grounds the existing levee would need to be raised by around 1.4 m. An additional length of levee would need to be constructed along Merriwa Road to prevent outflanking. Ground levels along Merriwa Road do not allow for the levee to tie into high ground, but flood levels downstream of Merriwa Road reduce rapidly. Extending the levee about 130 m to the north along Merriwa Road should prevent outflanking. The height of the new section of levee would vary between 1.4 – 2.4 m.

A cost analysis was undertaken with the cost of the levee estimated at around $150,000.

Conclusion: This scheme cannot be justified on economic grounds. The January 1996 flood approximated a 100 year ARI event and did not result in above-floor inundation even though the school grounds were flood affected. The duration of the flood event is limited to several hours.

4.9 Channel Works

General

The hydraulic capacity of a river may be increased by widening, deepening or straightening the channel and by clearing the banks and bed of obstructions. The scope of such improvements can vary from minor works such as de-snagging and bank clearing, which do not increase the waterway area but reduce hydraulic roughness, to major channel excavations.

Careful attention to design is required to ensure stability of the channel is maintained, and scour or sediment build up is minimised. A degree of sinuosity is usually provided in the channel route for aesthetic reasons. The potential for channel improvements to increase downstream flood peaks also needs to be evaluated using an unsteady flow hydraulic model.

Erosion problems in the upper reaches of the Pages River were first brought to notice after the major flood of October 1949 during which general overbank flow occurred threatening the New England Highway adjacent to and upstream of Arnolds Bridge.

During the early 1950s river improvement works in the form of stone groynes and timber training walls were constructed at isolated locations to arrest the problem of bank erosion in this area and these works, although damaged by later floods are still providing some degree of protection.

The Pages River exhibits the typical behaviour of streams flowing through recent alluvial deposits, that of meander development, and at many locations layers of shingle underlying the friable loams make the Pages River susceptible to bank erosion. Once developed the eroding meanders tend to migrate downstream and develop in magnitude.

At the bends in a stream faster currents are experienced adjacent to the outside or concave bend and these seek out any weakness where erosion can commence. During high flows, the increased water velocity at the outside of the bends rapidly extend the erosion of the friable banks and at the same time the slower water velocities on the inside of the meanders cause the heavier material eroded from banks further upstream to be deposited forming banks of coarse, barren material.

The bed of the Pages River over the reach covered by this study consists almost entirely of coarse shingle and small boulders mainly derived from the extensive basaltic rocks in the River's upper catchment in the Liverpool Range. This material forms the bed-load of the River and is deposited in shoals in the river bed after each fresh. The shoaling tendency is increased by the reduction in the transporting power of the river due to loss of competence as it enters the relatively flat alluvial plain upstream of the township. The resulting deposits of shingle and boulders generally become consolidated and require higher flows to shift them than the flows occurring when they were formed. During the extended periods of low flow which occur in the Pages, vegetation becomes established, thereby increasing the resistance of the deposits to removal by subsequent freshes and floods. The overall result is that a shingle carrying river flowing through alluvial flats has a high tendency to erode its banks due to the constant diversion its channel by shoals of shingle and boulders. This is very evident in this section of the Pages

River where there are many actively eroding banks and numerous locations where large areas of valuable land have been lost and replaced by barren shingle and gravel deposits.

At a few isolated locations, bank protection works were installed at those sites where excessive widening occurred and losses of land were likely to occur. This entailed selection of a suitable alignment for the stream, relocation of the excavated channel within the selected alignment and construction of a low platform between the new alignment and the eroding bank with the gravel excavated from the new channel. A grid of wire mesh fences, supported on steel cables anchored to steel piles was constructed on the platform to provide protection for willow plantings installed in conformity with the selected alignment. All work was restricted to the confines of the channel.

The channel improvement measures described in the following sections have been designated so as not to adversely affect existing bank protection works.

4.9.1 Increased Waterway Area at Arnolds Bridge

Arnolds Bridge has three 15 m spans and is a reinforced concrete deck and pier structure with a waterway area of approximately 130 m^2. During major flooding, floodwaters are constricted by the 45 m wide opening. The 100 year ARI discharge at the bridge is 380 m^3/s and the velocity of flow through the waterway reaches around 3 m/s.

4.9.1.1 Removal of River Bed Material

Survey undertaken for the Flood Study indicates that of the three 15 m spans, only the centre span operates at its full potential waterway area due to the build up of river bed material within the end spans. Removal of this material will increase the available waterway area from 130 m^2 to around 240 m^2. This scheme has been denoted CM1. It includes the rebuilding of the existing levee upstream of Arnolds Bridge (Adelaide Street levee) which is shown as Levee LM2 on Figure 4.2.

The removal of the bed material would require re-contouring of the river banks in the vicinity of the bridge. Protection works on the upstream and downstream sides of the bridge would be required. These works would consist of rock gabions to provide stability to the banks and prevent erosion during floods.

Hydraulic modelling indicated that a reduction of peak flood levels could be achieved in the vicinity of the bridge, with the effects extending approximately 500 m upstream. The reduction in levels adjacent to the Adelaide Street levee (in conjunction with a re-built levee) would increase the level of security offered to the CBD. The increase in waterway area allows the rate of passage of flood flows beneath the bridge to increase which in turn leads to a minor increase in flood levels downstream. Table 4.4 summarises the results for the 100 year ARI flood.

A preliminary cost estimate was undertaken which indicated works totalling around $360,000 would be required. They comprise $110,000 for the levee and $250,000 for channel excavation and gabion retaining walls. The channel works in conjunction with levee substantially reduce

damages up to and including the 100 yr ARI event. The present worth of value benefits amounts to $100,000.

TABLE 4.4
HYDRAULIC EFFECTS OF REBUILDING ADELAIDE ST. LEVEE AND REMOVAL OF BED MATERIAL IN VICINITY OF ARNOLDS BRIDGE (SCHEME CM1)

Location	Reduction in 100 year ARI Peak Levels (m)
Upstream of Mount Street	0.0
Mount Street to Arnolds Bridge	0.0 – 1.2
Arnolds Bridge to Wades Lane	0.1 (increase)
Downstream of Wades Lane	0.0

Conclusion: As shown above, the removal of bed material from the bridge opening has a localised effect on flood levels. The bridge works lead to a decrease in flood levels adjacent to the Adelaide Street levee and if undertaken in conjunction with re-building that levee (as Scheme CM1) will offer a higher level of security to the CBD area. Maintenance of the scheme is required to prevent build up of gravel and shingle in the channel.
A feasibility study would need to be carried out to ascertain the effects the removal of material may have on the structural integrity of the existing bridge and preliminary design prepared to allow refinement of the cost estimate.

4.9.1.2 Additional Bridge Span

The existing bridge waterway area could be increased by incorporating an additional span of 15 m length at the western approach to the bridge, which would increase the waterway area to 240 m^2. This option would probably require the purchase of two properties on the upstream side on the bridge. Downstream of the bridge, the Wilson Memorial Park fronts the western approach and some acquisition of open space land would be required.

Incorporating the additional span would also require the Pages River to be widened in the vicinity of the bridge. For preliminary planning, an excavated channel of 40 m base width was adopted which extended for a distance of approximately 300 m upstream of the bridge, with a gradual reduction in base width continuing further upstream to Mount Street. This scheme is denoted CM2 on Figure 4.2. The excavated channel has the same invert as the existing channel. Downstream of the bridge the channel has a transition to accommodate the wider bridge opening. The total volume of excavation required was estimated at around 50,000 m^3.

Hydraulic modelling gave a reduction in peak flood levels which extended as far upstream as Murulla Street. Downstream of the bridge water levels were slightly increased. Table 4.5 summarises the results for the 100 year ARI flood.

TABLE 4.5
HYDRAULIC EFFECTS OF
ENLARGEMENT OF ARNOLDS BRIDGE WATERWAY
AND MINOR CHANNEL EXCAVATION
(SCHEME CM2)

Location	Reduction in 100 year ARI Peak Levels (m)
Upstream of Murulla Street	0.0
Murulla Street to Mount Street	0.0 – 0.4
Mount Street to Arnolds Bridge	0.4 – 1.5
Arnolds Bridge to Wades Lane	0.1 (increase)
Downstream of Wades Lane	0.0

Upstream of the bridge, the maximum reduction in water surface elevation would be experienced adjacent to Pages Street. This reduction would be due to the large increase in the conveyance capacity of the river resulting from implementing the works. The existing surcharging of the left bank of the Pages River for the 100 year ARI event would be eliminated between Murulla Street and the bridge. Surcharging of the left bank between Boyd and Murulla Street would still occur. The reduction in levels would also eliminate surcharging at the Adelaide Street levee.

The increase in waterway area at the bridge and the resulting containment of flows within the channel would have the effect of allowing larger flow rates to pass beneath the bridge. For the 100 year ARI event the discharge passing through the bridge increases from 380 m^3/s to 430 m^3/s. This would have the effect of raising flood levels downstream of the bridge by around 100 mm. These effects would be experienced downstream to approximately Wades Lane.

A preliminary estimate of the cost of this scheme, including bridge widening and channel excavation is $1.3 M. Damages would be prevented up to around the 80 year ARI and the present worth of benefits amounts to about $100,000.

Conclusion: Scheme CM2 cannot be justified on economic grounds. Resumption of two properties on the left bank is required. Maintenance of the scheme is required to prevent build up of gravel and shingle in the channel.

4.9.2 Major Channel Excavation

4.9.2.1 Channel Lowering

Following the review of the responses to the Community Questionnaire, a commonly held view within the community is that the invert of the Pages River has risen in recent years. During river freshes and floods the river appears to have deposited silt and shingle to depths of around 1 m. (This estimate was supplied by long term residents).

An hydraulic analysis was undertaken for a major scheme where the river invert was excavated to a depth of 1 m between Boyd Street and Brook Street, a distance of around 2.4 km. The excavation would be undertaken in conjunction with the removal of bed material at Arnolds Bridge similar to Scheme CM1 (Section 4.9.1.1). The volume of excavation required was assessed at around 56,000 m^2. This scheme has been denoted CM3.

A preliminary estimate of the cost of this scheme is around $1.5 M, which does not include any riverbank stabilisation works which may be required at specific locations other than Arnolds Bridge. Damages would be prevented up to the 100 year ARI and the present worth of benefits amounts to about $140,000.

TABLE 4.6
HYDRAULIC EFFECTS OF MAJOR CHANNEL EXCAVATION INVOLVING LOWERING THE PAGES RIVER INVERT AND REMOVAL OF BED MATERIAL AT ARNOLDS BRIDGE (SCHEME CM3)

Location	Reduction in 100 year ARI Peak Levels (m)
Upstream of Boyd Street	0.0
Boyd Street to Arnolds Bridge	0.3 – 1.8
Arnolds Bridge to Brook Street	0.4 – 0.6
Downstream of Brook Street	0.0

Conclusion: Scheme CM3 results in considerable reduction in flood levels but cannot be justified on economic grounds and would require maintenance to control build up of gravel.

4.9.2.2 Additional Bridge Span and Channel Widening

This scheme (Scheme CM4) comprised channel excavation extending from the Mount Street pedestrian bridge, through Arnolds Bridge and continuing to a point approximately 200 m downstream of Brook Street, a total distance of around 1800 m.

Excavation of the channel would consist of the following:

- enlargement of the river bed to a width ranging between 35 and 40 m upstream of the bridge and 20 m downstream;
- maintaining the existing channel invert level;
- side slopes ranging between 1 (vertical) on 4 and 1 (horizontal) on 6. The existing river banks are not significantly disturbed;
- maintaining the existing sinuous alignment of the channel.

The above works would require around 85,000 m^3 of material to be removed from the river channel.

Channel improvements by themselves would not be a cost-effective measure, due to the restrictions on flow imposed by Arnolds Bridge waterway. Accordingly, this scheme also includes the increase in the existing waterway area of the bridge by the inclusion of an additional bridge span, as detailed in Section 4.9.1.2 for Scheme CM2.

Hydraulic modelling was undertaken for this scheme. From Table 4.7 it can be seen that the excavation and bridge enlargement would achieve a large reduction in flood levels, especially in the reach of river immediately upstream of the bridge.

TABLE 4.7
HYDRAULIC EFFECTS OF
ENLARGEMENT OF ARNOLDS BRIDGE WATERWAY
AND MAJOR CHANNEL EXCAVATION
(SCHEME CM4)

Location	Reduction in 100 year ARI Peak Levels (m)
Upstream of Murulla Street	0.0
Murulla Street to Mount Street	0.4 – 0.9
Mount Street to Arnolds Bridge	0.6 – 1.8
Arnolds Bridge to Wades Lane	0.6 – 1.1
Downstream of Wades Lane	0.0

A preliminary estimate of the cost of this scheme is $2 M. Damages would be prevented up to the 100 year ARI and the present worth of benefits amounts to about $140,000.

Extensive channel works on the Pages River would probably not be acceptable on environmental grounds. Additionally, historical evidence indicates that the river is continually depositing alluvial material. Consequently maintenance of the channel excavation works would be required.

Conclusion: Scheme CM4 controls flooding up to the 100 year ARI but cannot be justified on economic grounds. Resumption of two properties on the left bank is required. Maintenance is required to control build up of gravel as per previous scheme.

4.10 Flood Mitigation Dams

Flood mitigation dams, or dams which have a significant flood storage component, (eg Burrendong Dam on the Macquarie River and Glenbawn Dam on the Hunter River), can significantly reduce downstream peak flood levels. In the case of Burrendong Dam, for example, flood levels are reduced in the towns below the dam to a point downstream of Dubbo. At Dubbo, the dam reduces the highest recorded flood from an 80 year ARI flood event to a much rarer flood occurring on average every 500 years, and is a vital component of the floodplain management planning for the town.

Major dams are extremely expensive and can only be justified in economic terms if, like Burrendong Dam, they also serve irrigation and town water supply uses.

There are no dam sites on the Pages River and Borambil Creek and in any case, the magnitude of flood mitigation benefits is insufficient for storages to be economically justified. Consequently implementation of flood mitigation dams is not a feasible measure.

4.11 Summary

Details of the schemes are summarised in Tables 4.8 to 4.10. The following points are to be noted:

The schemes generally have a nominal design frequency no greater than 100 years ARI. Consequently, the potential benefits in present worth terms are no greater than $140,000 for Murrurundi and $50,000 at Blandford. Willow Tree is not significantly affected by flooding more frequent than 200 year ARI.

Consequently, given the relatively small magnitude of damages in the towns it is not possible to justify major works purely on economic grounds. One scheme worthy of consideration, however, is the replacement of the existing levee on the right bank of the Pages River upstream of Arnolds Bridge with a properly engineered structure of the same crest elevation, in conjunction with removal of bed material in the vicinity of the bridge waterway. This scheme is denoted CM1 and would provide a 100 year ARI level of protection to the CBD area. The estimated cost is $360,000.

Structural measures in other areas of Murrurundi or in the other two townships do not appear justified. Flood management measures appropriate to those townships are confined to the non-structural category such as land use controls and other planning measures.

TABLE 4.8
STRUCTURAL FLOOD MANAGEMENT MEASURES AT MURRURUNDI

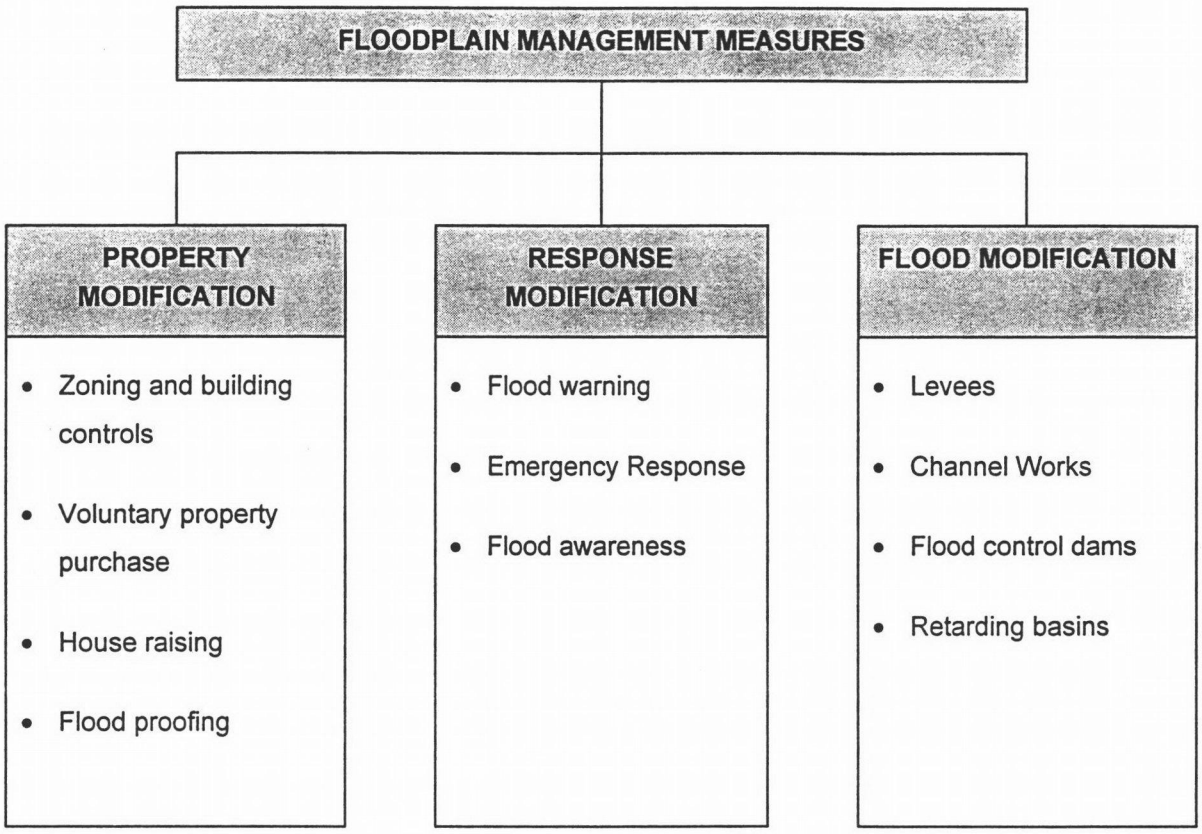
Scheme	Details	Cost $	Benefits $	Comments
LM1	Murrurundi Town Levee	Not Costed	140,000 (maximum)	Technically difficult and not economically justified.
LM2	Adelaide Street Levee (Rebuild existing Levee)	110,000	70,000	Replace existing levee with upgraded levee with crest at elevation of existing levee crest (50 year ARI)
CM1	Remove bed material at Arnolds Bridge and re-build existing levee	360,000	100,000	Adelaide Street level rebuilt to level of existing levee, but channel excavation provides 100 year ARI security against overtopping
LM3	Scheme comprises CM1 plus levee downstream of Arnolds Bridge	750,000	140,000	Scheme has a nominal design standard of 100 year ARI and protects Bridge House area
CM2	Additional bridge span at Arnolds Bridge and minor channel excavation	1.3 M	100,000	Additional 15m span on left bank and excavate channel for 400m upstream
CM3	Removal of bed material at Arnolds Bridge and extensive channel excavation involving lowering of Pages River invert	1.5 M	140,000	Lower channel invert over 2.4 km from Boyd Street to Brook Street. No additional span at Arnolds Bridge
CM4	Additional bridge span at Arnolds Bridge and major channel excavation	2 M	140,000	Enlarge channel over 1.3 km from Mount Street to 200m downstream of Brook Street and provide additional 15m span on left bank

TABLE 4.9
STRUCTURAL FLOOD MANAGEMENT MEASURES AT BLANDFORD

Scheme	Details	Cost $	Benefits $	Comments
LB1	Blandford Town Levee	520,000	50,000	Levee scheme prevents overland flow through school and surcharging of NE Highway. It is not economically justified.
LB2	Warlands Creek Levee	Not Costed	Not significant	Extensive levee required along right bank plus enlargement of bridge waterway. Could increase flood hazard downstream in Blandford.

TABLE 4.10
STRUCTURAL FLOOD MANAGEMENT MEASURES AT WILLOW TREE

Scheme	Details	Cost $	Benefits $	Comments
LW1	Willow Tree School Levee	520,000	Not significant	This scheme is an extension and raising of the existing levee. It is not economically justified.
-	Channel Improvements	Not costed	-	Not appropriate, as the township is not significantly flood affected for floods up to 200 year ARI



MURRURUNDI, BLANDFORD & WILLOW TREE FLOODPLAIN MANAGEMENT STUDY

Figure 4.1

Floodplain Management Measures

SCALE

0 100 200 400 600m

LEGEND

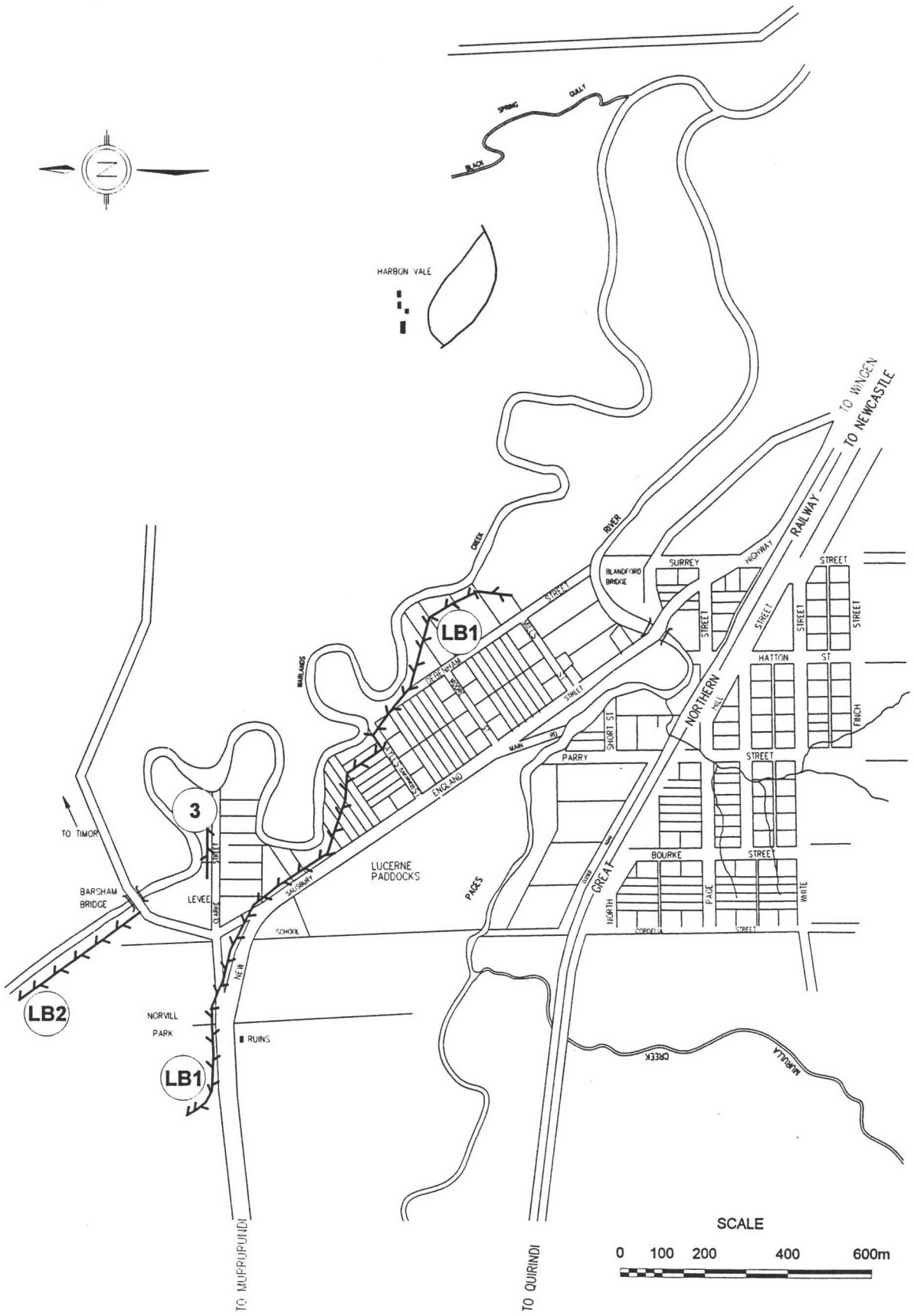
- LM2 — Adelaide St Levee
- LM3 — Levee Scheme (Including Adelaide St. Levee)
- CM2 — Extent of Minor Channel Works
- CM4 — Extent of Major Channel Works

MURRURUNDI, BLANDFORD AND WILLOW TREE FLOODPLAIN MANAGEMENT STUDY

Figure 4.2

Possible Flood Mitigation Measures
Murrurundi Township

NX518/WORK/FIGURES/BLAND



LEGEND

- LB1 — Blandford Town Levee
- LB2 — Warlands Creek Levee
- 3 — Existing Levee

MURRURUNDI, BLANDFORD AND WILLOW TREE FLOODPLAIN MANAGEMENT STUDY

Figure 4.3

Possible Flood Mitigation Measures
Blandford Township

5. SELECTION OF FLOODPLAIN MANAGEMENT MEASURES

5.1 Background

As noted in Section 4.2, the Floodplain Development Manual requires a Council to develop a Floodplain Management Plan based on balancing the merits of social, economic and economic considerations which are relevant to the community. It is important that, in developing an overall plan, Council has before it an analysis of the issues to be considered in making choices, even where some of them appear trivial for the particular circumstances. This chapter sets out a range of factors which need to be taken into consideration when selecting the mix of works (eg. levees, channel improvements) and measures (eg. land use, zoning, flood warning) that should be included in the overall Floodplain Management Plan.

Each community will have different priorities and, therefore, each needs to establish its own set of considerations used to assess the merits of different options. The considerations adopted by a community must, however, recognise the State Government requirements for floodplain management as set out in the Floodplain Development Manual and other relevant policies. A further consideration is that some elements of the Plan may be eligible for subsidy from State and Federal Government sources and the requirements for such funding must, therefore, be taken into account. Typically, State and Federal Government funding is given on the basis of merit as judged by a range of criteria:

- Degree of flood hazard and number of properties affected;
- Damage caused by flooding and the benefit/cost ratio of proposals;
- The importance given to strategic planning in the overall Plan;
- Compatibility of proposals with TCM and other government policies;
- Community involvement in plan preparation;
- Availability of local funding for proposed works.

The issues which need to be considered in developing a Floodplain Management Plan typically fall under the following broad headings:

- Community Expectations and Social Impacts;
- Natural Resource Management and Environmental Impact;
- Economic and Financial Feasibility;
- Technical Merit.

The next section of this chapter presents a summary of appropriate planning controls for the three townships which form the basis for any Floodplain Management Plan. The subsequent sections of the report present a review of a range of considerations under the four headings listed above. An analysis is then presented which assesses the performance of the available options against the factors to be considered.

5.2 Planning Controls

Section 4.2 presented an analysis of the issues to be considered in selecting the appropriate planning controls to be applied to the Murrurundi Shire area. As noted previously, the final choice of appropriate planning flood levels must be on qualitative rather than quantitative grounds. In keeping with the merit based approach advocated in the Floodplain Development Manual, such decisions must be based on balancing the economic, social and environmental factors applying to each community and to the different land uses within the area. The majority of the commercial area of Murrurundi is affected by the 100 year ARI flood. It would be difficult to support a planning flood level which limits future development in this area. It would be easier to support a level equivalent to a more frequent event, such as the 20 year flood. If such a level were adopted, however, the damages and impact when a rarer event occurs would be significant.

The pattern of development in the town and the impact of flooding discussed in Chapter 2 suggest that a graded set of controls would be appropriate. In principle these controls would:

- Encourage the use of floodways for open space activities such as sports fields and parks or for agriculture;
- Seek to remove those dwellings that are subject to highly hazardous conditions during a flood which make rescue difficult;
- Encourage commercial development in a manner which reduces flood damages by providing storage space above the planning flood level;
- Placing floor level controls on all residential buildings within the floodplain.

It was necessary for the Floodplain Management Committee to review the technical information presented in this report and consider the matters listed in Tables 4.1 to 4.3, particularly issues of equity. The recommended area of land to which planning controls could logically apply is the floodplain area lying within the area zoned Village. This area approximately corresponds to the area which would be inundated by the Probable Maximum Flood and is shown on Figures 2.2 to 2.4 denoted "indicative extent of floodplain". The following graded planning controls could apply within this area:

5.2.1 Residential Buildings

Flood related controls and measures should be:

Floodway and high hazard areas:

(i) No new dwellings, or extensions to existing dwellings allowed. Repairs only allowed.

(ii) Replacement only allowed with consent of Council.

(iii) Implementation of a voluntary purchase scheme for most severely affected residences

Floodplain

(i) Minimum floor levels to be at least 500 mm above the 100 year ARI flood level for that land.

(ii) The minimum floor level for a rural building is to be at or greater than the 100 year ARI flood level for that land.

Council should also develop a building code for buildings within the floodplain area which would include:

- Recommended building materials for use up to 500 mm above the 100 year flood level,
- Requirements for sub-soil drainage under the building where slab on ground construction is used.

5.2.2 Commercial Development

Recommended controls on commercial development are:

Floodway and high hazard areas:

(i) Redevelopment permitted only with the consent of Council.

(ii) Minimum floor level equal to the 100 year ARI flood level for the area.

(iii) Any new construction to include flood compatible materials up 500 mm above the 100 year ARI flood level.

(iv) The building must also contain provision for all stock to be lifted to elevated shelving, a loft or mezzanine floor situated 500 mm above the 100 year ARI flood level.

Floodplain

(i) Redevelopment permitted only with the consent of Council.

(ii) Minimum floor level equal to the 100 year ARI flood level for the area.

(iii) Any new construction to include flood compatible materials up 500 mm above the 100 year ARI flood level.

(iv) The building must also contain provision for all stock to be lifted to elevated shelving, a loft or mezzanine floor 500 mm above the 100 year ARI flood level.

5.2.3 Essential Services

A higher planning flood level is justified for essential services. Any future relocation of the police, ambulance, fire fighting or SES should, if possible, be undertaken on land which lies outside the floodplain.

5.2.4 Essential Utilities

Essential utilities such as electricity, telephone, water supply and sewerage should be capable of continued functioning under any flood conditions. All power supply sub-stations and the telephone exchange should be located above the extreme flood level. Sewage pumping stations should, preferably be capable of operation in any flood conditions, but if this is not feasible they should be capable of being restarted immediately the flood level has receded.

5.3 Community Expectations and Social Impacts

Community expectations are an important consideration in selecting appropriate floodplain management measures. These expectations may encompass a range of issues which are not directly economic or environmental in character such as:

- Community acceptance and expectations,
- Public safety and welfare,
- Compatibility with planning objectives, including future development limits,
- Administrative and political issues.

5.3.1 Community Acceptance

Flood related works and measures can have a range of effects on the community and individuals. These effects, if strongly negative, are often enough to deter the implementation of a proposal which might otherwise have significant merit. The issues impacting upon acceptance of a proposed measure are likely to include:

- Potential for individual financial loss/gain;
- Disruption to daily life during and after floods;
- Perception of fair play;
- Public safety and welfare.

Consultation with the community in the course of this study indicates that floods are considered to be a "fact of life" in the townships and there is not strong community support for proposals which would radically alter the character of the town. Large scale relocation of the most flood affected properties or the construction of major levee schemes to protect Blandford or the business centre of Murrurundi would not be favoured. While the community may be concerned about the impact on house values of any alteration to the planning rules, Council is obliged to make decisions on behalf of the whole community and to consider the interests of future generations.

5.3.2 Strategic Planning Objectives

Murrurundi Shire Council has developed a set of planning policies for future development which reflects the long term goals of the community. These policies are embodied in the Local Environmental Plan which has been reviewed in Chapter 2 and for which a number of suggested amendments are detailed in Appendix E. Planning controls will be a key element of the Floodplain Management Plan for the three townships. The recommended amendments are designed to ensure that the LEP and other Council policies and instruments relating to land use on the floodplain are consistent with the Floodplain Development Manual (1986) and current government thinking.

Proposals for other works and measures to be included in the Floodplain Management Plan must be assessed for consistency with Council's overall planning policy relating to floodplain management.

5.3.3 Administrative/Political Issues

Effective floodplain management involves the coordinated action of the community, Council and state government agencies. Clearly, any recommendation contained in the Floodplain Management Plan will have more chance of success if it fits within current administrative structures and allocation of responsibilities. On the other hand, should an alteration to the administrative system be clearly beneficial to the Plan, it should be so stated and the implications accepted.

The majority of the parties with responsibilities for floodplain management and emergency response in the event of a flood are represented on the Floodplain Management Committee and have been consulted in the course of this study. None of the options presented in Chapter 4 involves any radical changes to the existing administrative structures and responsibilities.

5.4 Natural Resource Management and Environmental Impact

5.4.1 Total Catchment Management

Total Catchment Management (TCM) involves the coordinated and sustainable use and management of land, water, vegetation and other natural resources on a catchment basis. It allows for a co-operative forum where decisions may be made at both the community and government level. This is typically achieved through a Catchment Management Committee which consists of both community and government representatives.

The Pages River catchment is located within the Hunter Valley Catchment Management Trust area. The Trust has recently undertaken bank stabilisation works at Professional Row. The goals established for TCM are:

- To encourage best management practices for land, vegetation and water so that they remain in good condition;
- To increase community awareness about the benefits that can be gained from managing natural resources properly;
- To make it easier for the community to get accurate and relevant information which will then allow them to actively participate in projects that will rehabilitate and protect land from further degradation;
- To ensure that native plants and animals are conserved in a region that is extensively developed for agriculture;
- To enable the cultural heritage, recreational and attractive values of the Catchment to be maintained;
- To ensure that governments and catchment communities cooperate effectively.

Aspects of a Floodplain Management Plan which could have implications for TCM include any proposals for flood mitigation storages, major levees or large scale channel enlargement works. As outlined in Sections 4.8 to 4.10, such works are not economically viable and are therefore unlikely to be an issue, although re-building the Adelaide Street levee and excavation in the channel to restore the Arnolds Bridge waterway to its full hydraulic capacity, could be justified on social grounds. Any activities undertaken to manage riparian vegetation in a way which maintains hydraulic capacity would be consistent with TCM objectives provided they were planned to enhance habitat values as well.

5.4.2 Other Relevant Government Policies

The NSW Government has developed a number of polices which are of direct relevance to floodplain management. The first of these are the policies enshrined in the Floodplain Development Manual which forms the basis for the formulation of Floodplain Management Plans. The second is the State Rivers and Estuaries Policy (NSW Water Resources Council, 1993) which is the umbrella policy statement for subsidiary policies including the Wetlands Policy; the Stream Management Policy; and the Riparian Zone Policy. Of these, the proposed Riparian Zone Policy is most pertinent to the management of the floodplains in the Murrurundi Shire area. The policy suggests that the overall objective should be to manage the riparian zones of NSW in ways which:

- Slow, halt or reverse the overall rate of degradation;
- Ensure the long term sustainability of essential biophysical functions;
- Maintains the beneficial use of these resources.

For the purposes of floodplain management, the riparian zone may be taken as the area above the low flow level to the inner edge of the floodplain. In practice, the riparian zone merges into the floodplain and any management policies or actions should not stop at artificially defined boundaries. Any activities to manage the riparian zone within the study area would be consistent with this policy by improving:

- Stream stability
- Ecology and habitat
- Buffer strip functioning
- Scenic amenity
- Recreational amenity

5.4.3 Environmental Impact

Few floodplain management measures could be considered seriously if the impact on the environment was extremely adverse. On the other hand, there are often opportunities for environmental enhancement in association with floodplain management works or measures. The most likely activity to have environmental impacts would be channel improvements in the Pages River. Maintenance of channel stability would be the primary issue.

5.5 Economic and Financial Feasibility

5.5.1 Economic Feasibility

There is a range of procedures available to judge the economic worth of making an investment in floodplain management works and measures. The most common is the benefit/cost ratio (B/C) which has been used in this study. On a purely theoretical basis, no investment should be made in a measure if the benefits do not exceed the costs. However, many public projects are undertaken where this is not the case because the intangible benefits, which are not able to be quantified, are considered important. Not all of the measures applicable to the study area lend themselves to meaningful B/C analysis.

The benefits of floodplain management measures largely occur as savings in damages to existing properties or developments, and the savings in damages achieved by preventing flood sensitive developments occurring in the future. The costs are primarily the capital and operating costs of proposed measures.

The results of the economic analysis for some of the measures assessed in Chapter 4 are summarised in Table 5.1. Benefits and costs are presented for three discount rates: 7% (best estimate), 11% (high) and 4% (low), in accordance with the NSW Government Treasury Guidelines. Tables 5.2 and 5.3 summarise the numbers of properties at Murrurundi and Blandford respectively which would be flooded with the implementation of the various schemes compared to the existing (do nothing) situation.

The data in Tables 5.1 and 5.2 shows that:

- None of the flood modification measures (ie structural) are economically justified, that is, has a benefit/cost ratio greater than one. The option with the highest ratio is re-building the Adelaide Street levee (Levee LM2).. At a 7% discount rate, the benefit/cost ratio for this measure alone is about 0.64. This scheme will give a 50 year ARI level of protection against overtopping.

- Removal of bed material at Arnolds Bridge plus re-building Levee LM2, i.e. Scheme CMI, has a benefit/cost ration of 0.28. This scheme will give a 100 year ARI level of protection.

- Continuing the levee downstream of Arnolds Bridge and removing bed material from the bridge waterway had a benefit/cost of 0.19.

- Other structural measures examined which included various channel improvement and levee schemes are economically not attractive.

Other measures which were considered included flood mitigation dams, voluntary purchase schemes, house raising schemes, and other non-structural methods such as flood preparedness, flood awareness and planning measures. Of these, only the non-structural measures are considered justified.

5.5.2 Financial Feasibility

Measures proposed for the Floodplain Management Plan for Murrurundi Shire must be capable of being funded over the proposed period of implementation. The sources of funding are traditionally:

- Council
- NSW Government
- Commonwealth Government

In the past, contributions from these three sources were such that, where the costs were attributable to approved floodplain management activities, Council would bear 20% of the overall cost with the balance being equally shared by NSW and Commonwealth Governments. However, the Commonwealth Government has indicated its intention to withdraw from funding flood mitigation projects. Therefore, the historic levels of Government contribution cannot be guaranteed.

The limitations on Council funding will be related to the magnitude of Council income in any one year, its borrowing capacity and existing commitments. The total allocation and sources of funds will vary in any one year and are dependent on special grants. In any one year, the funds available for floodplain management measures will be dependent on Council priorities but it appears that Council would have the capacity to allocate only $15,000 to $20,000 in a typical year.

TABLE 5.1
ECONOMIC ANALYSIS OF POTENTIAL FLOOD MANAGEMENT MEASURES

Scheme	Discount Rate								
	4%			7%			11%		
	$ x 10^3 Benefits	$ x 10^3 Costs	B/C	$ x 10^3 Benefits	$ x 10^3 Costs	B/C	$ x 10^3 Benefits	$ x 10^3 Costs	$ x 10^3 B/C
Voluntary Purchase – Murrurundi	18	250	0.07	13	190	0.07	9	140	0.06
Flood Proofing by House Raising – Murrurundi	16	350	0.05	11	350	0.03	8	350	0.02
Re-build Adelaide Street Levee (Levee LM2)	98	110	0.89	70	110	0.64	49	110	0.45
Remove bed material at Arnolds Bridge and re-build Adelaide St. Levee (Scheme CM1)	140	360	0.39	100	360	0.28	70	360	0.20
Continue Levee LM2 d/s of Arnolds Bridge and remove bed material at bridge (Scheme LM3)	195	750	0.26	140	750	0.19	98	750	0.13
Additional span at Arnolds Bridge and minor channel excavation (Scheme CM2)	139	1,300	0.11	100	1,300	0.08	70	1,300	0.05
Remove bed material at Arnolds Bridge and lower channel invert (Scheme CM3)	195	1,500	0.13	140	1,500	0.10	98	1,500	0.07
Additional span at Arnolds Bridge and major channel excavation (Scheme CM4)	195	2,000	0.10	140	2,000	0.07	98	2,000	0.05
Blandford Town Levee (Scheme LB1)	70	520	0.13	50	520	0.10	35	520	0.07
Willow Tree School Levee			-	Not significant	520	-			

TABLE 5.2
NUMBER OF PROPERTIES FLOODED WITH THE IMPLEMENTATION OF VARIOUS FLOOD MANAGEMENT MEASURES
MURRURUNDI

Option	50 year ARI Event				100 year ARI Event			
	Residential	Commercial	Public	Total	Residential	Commercial	Public	Total
Existing	**14**	**21**	**0**	**35**	**24**	**29**	**3**	**56**
Murrurundi Town Levee (Levee LM1)	2	0	0	2	7	1	0	8
Re-build Adelaide Street Levee (Scheme LM2)	3	0	0	3	24	29	3	56
Remove bed material at Arnolds Bridge and re-build Adelaide St. Levee (Scheme CM1)	0	0	0	0	5	1	0	6
Continue Levee LM2 downstream of Arnolds Bridge and remove bed material at bridge (Scheme LM3)	3	0	0	3	24	29	3	56
Additional span at Arnolds Bridge and minor channel excavation (Scheme CM2)	0	0	0	0	1	0	0	1
Remove bed material at Arnolds Bridge and lower invert of Pages River by 1 m (Scheme CM3)	0	0	0	0	0	0	0	0
Remove bed material at Arnolds Bridge and major channel excavation (Scheme CM4)	0	0	0	0	0	0	0	0
Voluntary Purchase Scheme	10	21	0	31	20	29	3	52
Flood Proofing by House Raising	9	21	0	30	14	29	3	46

TABLE 5.3
NUMBER OF PROPERTIES FLOODED WITH THE IMPLEMENTATION OF VARIOUS FLOOD MANAGEMENT MEASURES
BLANDFORD

Option	50 year ARI Event				100 year ARI Event			
	Residential	Commercial	Public	Total	Residential	Commercial	Public	Total
Existing	**1**	**0**	**2**	**3**	**2**	**0**	**2**	**4**
Blandford Town Levee (Scheme LB1)	1	0	0	1	1	0	0	1
Voluntary Purchase Scheme	0	0	2	2	1	0	2	3
Flood Proofing doorways	1	0	2	3	1	0	2	3

Any State Government contribution is limited by the allocation to flood mitigation programs on an annual basis. The commencement/completion of flood mitigation projects would depend on the availability of Council's funds and/or limited Government funding. Flood mitigation projects can take anywhere from 5 to 15 years to complete because of funding considerations. Since Council has many demands for drainage/and road works, the financial feasibility is likely to be a significant constraint to the rate at which works can be undertaken.

Because of limitations on possible allocation of future Government funding to Murrurundi Shire, Council should give serious consideration to alternative sources of funding for projects related to flood management. Alternative sources such as "Rivercare" programs should be actively investigated.

5.6 Technical Merit

5.6.1 Engineering Feasibility

Floodplain management works, as distinct from measures, must be readily constructible and free of major engineering constraints to become an acceptable element of any plan. Maintenance requirements should also be considered in this assessment.

5.6.2 Performance in Exceedance Floods

Section 5.2 outlines proposals for floor levels of future residential development to be set at the 100 year ARI flood level plus 500 mm.

However, any proposed floodplain management measures must also be assessed assuming that at some future time they will be exposed to floods which exceed the planning flood level. It is imperative that, should an extreme flood occur, the works and measures under consideration do not expose the community to unacceptable risks far beyond those experienced without the work or measure.

A key consideration for extreme floods must be the provision of escape routes which allow for evacuation as a flood develops. The most important requirement for this is that islands surrounded by deeper floodwater should be avoided.

5.7 Ranking of Options

The considerations discussed above must be assessed in terms of their relative importance to the Murrurundi Shire community as well as the likelihood of attracting government subsidy. Although multi-objective assessment methods are now well accepted by Government for selecting from a range of options, the decision to provide state funds is still linked closely to economic and financial factors. The Floodplain Management Committee and the Community, however, have expectations which give more weight to social, environmental and planning issues.

Throughout the preparation of this report there has been close consultation with Council's Floodplain Management Committee which contains representatives of the community, Council and relevant Government agencies. Based on these consultations, and taking account of current government policies, a suggested approach to assessing the merits of various options is to use a subjective scoring system. The chief merits of such a system are that it allows comparisons to be made between alternatives using a common "currency". In addition it makes the assessment of alternatives "transparent" (ie all important factors are included in the analysis). The system does not, however, provide an absolute "right" answer as to what should be included in the plan and what should be left out. Rather, it provides a method by which the Council can re-examine its options and, if necessary, debate the relative scoring and weight given to aspects of the plan.

The assessment system involves three steps:

1. Each issue to be considered for assessing the merits of various proposals is given a weighting according to how important each is for the town. A suggested classification is:

   "Essential" - (weight = 1.0)
   - Gains community acceptance
   - Meets planning objectives
   - Positive or minimal environmental impacts

   "Desirable" - (weight = 0.5)
   - Economically justified
   - Financially feasible
   - Does not increase damage or risk in extreme floods

   "Considerations" - (weight = 0.25)
   - Consistent with Government policies
   - Consistent with TCM objectives
   - Consistent with current administrative arrangements and responsibilities

2. Each option is given a score according to how well the option meets the considerations discussed in Sections 5.2 - 5.5. In order to keep the scoring simple the following system is proposed:

+2	Option rates very highly
+1	Option rates well
0	Option is neutral
-1	Option rates poorly
-2	Option rates very poorly.

3. The score for each option is multiplied by the relevant weighting for the issue under consideration and the weighted scores are added to get a total for each option.

Based on considerations outlined in this chapter, Table 5.4 presents a scoring matrix for the options reviewed in Chapter 4. This scoring has been used as the basis for prioritising the components of the draft Floodplain Management Plan. It must be emphasised, however, that the scoring shown in Table 5.5 is not "absolute" and ***Council should carefully review the proposed scoring and weighting as part of the process of finalising the overall Floodplain Management Plan***.

Table 5.4 indicates that there are good reasons to consider including the following elements into the Floodplain Management Plan:

TABLE 5.4
FLOODPLAIN MANAGEMENT OPTIONS ASSESSMENT

Option	Essential (weight=1.0)			Desirable (weight=0.5)			Considerations (weight=0.25)			Weighted Score
	Community Acceptance	Planning Objectives	Environ. Impacts	Economic Justification	Financial Feasibility	Extreme Flood	Government Policies	TCM Objectives	Administrative Arrangement	
Property Modification										
Zoning and Building Controls	1	1	1	1	1	1	2	1	1	5.5
Voluntary purchase scheme	1	1	1	0	0	1	2	1	1	4.5
Flood proofing selected buildings	0	1	1	0	0	0	1	0	0	2.25
Response Modification										
Flood Warning	0	1	0	0	0	0	1	0	1	1.5
Emergency response plan	0	1	0	1	1	0	1	0	1	2.5
Flood awareness program	0	1	0	1	1	0	1	0	1	2.5
Flood data collection	0	1	0	1	1	0	1	0	1	2.5
Flood Modification										
Re-build Adelaide Street Levee and remove bed material at Arnolds Bridge	2	1	1	0	-1	-1	1	0	0	3
Enlarge waterway area at Arnold's Bridge with new span	1	0	0	-2	-2	-1	0	0	0	-1.5
Enlarge waterway plus major channel excavation	1	0	-1	-2	-2	-1	0	0	0	-2.5
Blandford Town Levee	0	0	0	-2	-2	-2	0	0	0	-3

6. THE DRAFT FLOODPLAIN MANAGEMENT PLAN

The following sections set out the recommended elements of the draft Floodplain Management Plan for Murrurundi Shire based on the Floodplain Management Options Assessment presented in Section 5, and provides information on funding and implementation. A summary of the draft Floodplain Management Plan proposed for the study area is shown on Table 6.3 (at the end of this chapter). The draft Plan relies on property controls (planning controls), structural works (levee and removal of bed material at Arnolds Bridge), flood warning and response, flood awareness and preparedness.

6.1 Property Modification Measures

6.1.1 Zoning and Floor Levels

The results of the Floodplain Management Study indicate that an important measure for Council to adopt in Murrurundi would be strong floodplain management planning applied consistently by all branches of Council. It is recommended that:

- The floodplain within the existing area zoned "village" should be adopted as the area to which flood related planning controls will apply. This area approximately corresponds to the area which would be inundated by the Probable Maximum Flood. Different planning controls should apply to residential and commercial development in different precincts of the three townships within this area as set out in Tables 6.1 and 6.2.

- The floodway and high hazard areas associated with the 100 year ARI flood should be adopted for the purposes of defining the floodway areas.

TABLE 6.1
PROPOSED RESIDENTIAL PLANNING CONTROLS

Floodway:	(i)	No new dwellings, or extensions to existing dwellings allowed. Repairs only allowed.
	(ii)	Replacement only allowed with consent of Council.
	(iii)	Investigation and possible implementation of a voluntary purchase scheme for most severely affected residences
Floodplain	(i)	Minimum floor levels to be at least 500 mm above the 100 year ARI flood level for that land.
	(ii)	The minimum floor level for a rural building is to be at or greater than the 100 year ARI flood level for that land.

TABLE 6.2
PROPOSED COMMERCIAL PLANNING CONTROLS

Floodway:	(i)	Redevelopment permitted only with the consent of Council.
	(ii)	Minimum floor level equal to the 100 year ARI flood level for the area. Measures to flood proof building against ingress of floodwaters up to 500 mm above 100 year ARI flood level to be encouraged.
	(iii)	Any new construction to include flood compatible materials up to 500 mm above the 100 year ARI flood level.
	(iv)	The building must also contain provision for all stock to be lifted to elevated shelving, a loft or mezzanine floor situated 500 mm above the 100 year ARI flood level.
Floodplain	(i)	Redevelopment permitted only with the consent of Council.
	(ii)	Minimum floor level equal to the 100 year ARI flood level for the area.
	(iii)	Any new construction to include flood compatible materials up to 500 mm above the 100 year ARI flood level.
	(iv)	The building must also contain provision for all stock to be lifted to elevated shelving, a loft or mezzanine floor 500 mm above the 100 year ARI flood level.

- To implement the recommended planning controls Council should resolve to prepare an amendment to the Murrurundi LEP 1993 to provide for the inclusion of a new Environmental Protection 7(f) "Floodway" zone. A draft amending LEP is contained in Appendix E and further discussion of this topic is set out in Section 6.5.

- Council should also resolve to exhibit the Floodplain Management Plan as a Development Control Plan in support of the proposed amendment to the Murrurundi LEP, 1993. The Floodplain Management Plan would be based on this draft Floodplain Management Plan and contain the required planning controls such as those set out in Tables 6.1 and 6.2.

- The residual flood risk should be reduced to the maximum practical extent by encouraging future redevelopment of community assets and essential services on land above the Probable Maximum Flood extent.

6.1.2 Flood Mapping

The plans showing the extent of flooding (Figures 2.2 to 2.4) should be upgraded and used as a basis for implementing flood related planning controls. It is to be noted that the best available topographic mapping for Blandford and Willow Tree is at 1:25,000 scale with 10 m contour interval and is not adequate for defining flood extent to the degree of accuracy required. Council

has available a database of floor levels of flood liable buildings in Murrurundi, Blandford and Willow Tree. This information should be used as the basis for flood related advice for individual properties.

6.1.3 Voluntary Purchase Scheme

Removal of housing is a means of correcting previous decisions to allow buildings in high hazard areas in the floodplain. The voluntary purchase of residential property in hazardous areas has been part of subsidised floodplain management programs in NSW for over 10 years.

Where a property is considered to qualify for a voluntary purchase scheme, the owner is notified that the body controlling the scheme (usually but not always Council) is prepared to purchase the property when the owner is ready to sell. There is no compulsion whatsoever to sell at any time. The price is determined by independent valuers and the Valuer General, and by negotiations between Council and the owners. Valuations are based on an equivalent residence which is not affected by flooding.

The timing of any agreed purchase is at the discretion of the landowner. Once the property is purchased, buildings are usually demolished. The land must then be used for flood compatible activities and is usually rezoned for open space.

A limited voluntary purchase scheme could be adopted for houses exposed to the most hazardous conditions. As part of this study, a database summarising information on residential properties located in high hazard areas has been prepared. Approximately 10 residential properties are located in the high hazard floodway areas, four of which are considered sufficiently flood affected to warrant inclusion in a voluntary purchase scheme.

Council will need to reach consensus about the criteria to be applied in setting priorities for listing properties on a voluntary purchase program. The process for finalising the houses to be placed on the list would then involve the following steps:

- As part of the process of Council's formal adoption of the Floodplain Management Plan for the area, seek agreement in principle to establish a voluntary purchase program and determine the criteria to be applied in placing residences on the program. Such criteria would normally be based on factors such as severity of flooding, hazard and isolation.

- Analysis should then be undertaken by Council to determine the flood levels and flood hazard applicable to a particular residence using procedures specified in the Floodplain Development Manual, which are to be used in conjunction with the Flood Maps. This procedure is to confirm that voluntary purchase is in fact appropriate.

- Seek funding subsidies from State and Federal Government.

- Review and revise the candidate list of properties to be placed on the voluntary purchase scheme using the criteria adopted by Council in adopting the Floodplain Management Plan.

- Make personal approach to each resident concerned to explain the nature of the voluntary purchase program.

- Issue formal letters to residents concerned.

6.1.4 House Raising

House raising is economically unattractive for Murrurundi Shire. Subsidised house raising should only be considered on hardship grounds in individual cases.

6.1.5 Filling

Filling has the effect of reducing flow area and diverting flows onto neighbouring properties. When evaluating the effects of filling proposals in individual allotments, consideration should also be given to the effect filling in adjacent allotments would have on flooding. That is, the cumulative flooding impacts associated with such filling should be evaluated. Restrictions on filling should be more severe in the floodway which by definition is an area where a significant proportion of the flood flow is concentrated and velocities are higher. However, some restrictions may also be warranted outside the confines of the floodway to reduce adverse effects resulting from loss of floodplain storage or velocity effects resulting from floods greater than the designated 100 year ARI event. The recommended policy should be generally:

Floodway	No filling or alteration of the land surface which could adversely affect the pattern of flood flows
Floodplain	Building pads up to 1 m high be permitted for residential blocks subject to the above restriction of no adverse effect on flood flows. (Note: All slab on ground construction within floodprone areas should include at least 100 mm of sand with agricultural drainage pipe to promote drainage from under the slab).

6.2 Flood Warning and Response

6.2.1 Flood Warning

As part of the Flood Study, water surface levels have been computed for the 5, 20, 50 and 100 ARI floods, as well as the PMF. The floor levels of properties potentially affected by flooding have also been surveyed. Consequently there is sufficient information available to identify areas at risk from flooding for the full range of flood events likely to trigger flood response procedures in the three townships.

The Local Flood Plans should be further developed by SES so as to produce a graded response plan involving:

- Ranking the threatened houses according to their hazard situation, taking account of depth and velocity of floodwaters, and means of access, as a flood develops.

- Preparing a detailed response plan which focuses on initial evacuations from the most hazardous locations, followed by further evacuations in descending exposure to hazardous conditions.

- Preparing a plan for traffic management which takes account of the sequence of road flooding as a flood develops. This plan would aim to:

  - maximise opportunities for the community to evacuate,
  - prevent unnecessary traffic through the affected area,
  - ensure access for SES operations.

Implementation of the Flood Intelligence Card system, as recommended in Flood Warning: an Australian Guide (published by Emergency Management Australia, 1995) would be an appropriate activity in connection with developing this graded response plan. The Blandford and Willow Tree Public Schools both are susceptible to flooding. Particular attention should be given to warning the respective Principals of imminent flooding and evacuation planning.

Other improvements to the system could include improving communications between gauge readers, the SES and the local community both when a flood situation is developing and then during the flood, as discussed in Appendix D. The SES needs to consult the local community on their requirements for information and improved communications and how these requirements can be fulfilled.

6.2.2 Flood Awareness

A number of measures are recommended to maintain awareness in the community of the threat posed by floods:

- Clear flood advice should be contained on S.149 certificates issued by Council when property is bought. These certificates should contain clear advice and consistent requirements for floor levels for a new dwellings.

- Council should continue to promote a knowledge of the characteristics of flooding among the affected property owners. These characteristics should include information on the frequency of flooding and the depths at various locations. This information could be included in a flood information booklet containing both general and site specific data and distributed with the rate notices. The community must also be made aware that a flood greater than historic levels or the planning level can, and will, occur at some time in the future. The need for a flood response and preparedness plan to address such an occurrence must be clearly explained

- Flood height markers should be erected at a number of key locations around the town to remind the community of historic and predicted flood levels for the 100 year ARI flood and an extreme flood.

- The Floodplain Management Plan should be publicised and exhibited in Council offices and at community gathering places to make residents aware of the measures being proposed.

- The community need to be reminded periodically of the extent and impacts of flooding. For instance, in the Hunter Valley, flood awareness in the community has been raised by holding commemorative events to mark the anniversary of particularly noteworthy floods (eg 1955 flood).

6.3 Flood Management Measures

6.3.1 Engineering Works

Measures such as major levees, large scale channel improvements or flood mitigation dams on the Pages River or Borambil Creek catchments would be neither effective in reducing the flood risk, economically justifiable nor would they be socially acceptable and are therefore not recommended.

Re-building the existing levee which runs along the right bank upstream of Arnolds Bridge is recommended to protect the Murrurundi CBD area. The elevation of the crest of the new levee should approximate that of the existing one to ensure that development on the left bank is not adversely affected by raised flood levels and re-direction of flows. Removal of bed material in the vicinity of the bridge will allow the waterway to function at its full hydraulic capacity and will provide additional freeboard for the levee. While these measures cannot be justified on a strict economic basis, they will significantly reduce the flood risk in Murrurundi. After the removal of the bed material, the re-built levee will not be overtopped in the event of a 100 year ARI flood.

6.4 Funding

Broad funding requirements for the recommended measures to be included in the Draft Floodplain Management Plan are given in Table 6.3 below. These measures will achieve the objectives of reducing the flood risk to existing and future development for the full range of floods.

6.5 Implementation Program

The steps in progressing the floodplain management process from this point onwards are:

- Floodplain Management Committee to consider and adopt recommendations of this study. In particular, the Committee should review the basis for ranking floodplain management measures (as set out in Table 5.4) and the proposed aspects to be included in the proposed plan as set out in earlier sections of this Chapter.

- Council considers the Floodplain Management Committee's recommendations,

- Exhibit the draft Plan and Study Report and seek community comment,

- Consider public comment, modify the Plan if and as required, and submit the final Plan to Council,

- Council adopt the Plan and submit an application for funding assistance to DLWC and other agencies as appropriate,

- As funds become available from DLWC, other state government agencies and/or Council's own resources, implement the measures in accordance with the established priorities.

It is recommended that the most appropriate method of ensuring that the findings of the Murrurundi, Blandford and Willow Tree Floodplain Management Plan are implemented is for Council to resolve, pursuant to section 54 of the Environmental Planning and Assessment (EPA) Act, 1979, to prepare an amendment to the Murrurundi LEP, 1993 to provide for the inclusion of a new Environmental Protection 7(f) Floodway zone which will control development within the floodway and high hazard areas. A draft amending LEP is contained in Appendix E. The provisions of this draft LEP should be incorporated into any other changes which Council considers warranted as per the discussion in Appendix E.

To allow Council to further control development in the floodway and high hazard areas, and indeed in the floodplain, it is recommended that once a Floodplain Management Plan has been prepared by Council based on this Floodplain Management Study Report, Council resolve, pursuant to section 72 of the EPA Act, 1979, to exhibit the Murrurundi, Blandford and Willow Tree Floodplain Management Plan as a Development Control Plan in support of the proposed amendment to the Murrurundi LEP, 1993. The DCP would contain recommended graded planning controls within the different areas of the floodplain as set out in Tables 6.1 and 6.2.

The Plan should be regarded as a dynamic instrument requiring review and modification over time. The catalysts for change could include new flood events and experiences, legislative change, alterations in the availability of funding, reviews of the shire planning strategies and importantly, the outcome of some of the studies proposed in this report as part of the Plan. In any event, a thorough review every five years is warranted to ensure the ongoing relevance of the Plan.

MURRURUNDI, BLANDFORD AND WILLOW TREE

FLOODPLAIN MANAGEMENT STUDY

PRELIMINARY DRAFT

APPENDIX E

PLANNING AND LAND USE CONTROLS

November 1997

Job No.: NX518	Date: 13 November, 1997	Principal: BWL
File: J:\nx518\docs\appende.doc	Rev No.: 1.0	Reviewer: SAB

TABLE OF CONTENTS

FIGURES

E.1 INTRODUCTION

Murrurundi Shire Council has resolved to prepare Floodplain Management Plans (FMPs) for the Murrurundi, Blandford and Willow Tree town areas. As part of the preparation of those FMPs there is a requirement that the existing planning controls which relate to those areas be reviewed, and suggestions made regarding the means by which those controls could be amended and/or supplemented with regard to land which is potentially impacted by flood waters.

This report provides Council with a summary of the land use planning controls which currently apply to flood liable land in the Shire, and provides a series of options for the consideration of Council for amendment of the existing controls.

E.2 EXISTING LAND USE PLANNING CONTROLS

Land use within the Murrurundi Shire is generally regulated by the Murrurundi Local Environmental Plan (LEP), 1993. Advice from Council is that there are no Development Control Plans accompanying the Local Environmental Plan.

The Murrurundi LEP, 1993 contains some references to the management of development on flood liable land. Clauses which refer to either flooding or flood liable land are:

Clause 5 (1) - Interpretation

The following definition is contained within Clause 5:

> *"**flood liable land**" means the land within the township of Murrurundi or the village of Blandford or Willow Tree or elsewhere which is affected by flood as indicated on the map;"*

A review of the map indicates that there are no areas within the Shire notated as being flood liable land.

Clause 6 - Model Provisions

This clause adopts the Environmental Planning and Assessment Model Provisions, 1980 except for, inter alia, Clause 34 which essentially states that a person shall not erect a building or carry out work on land within a flood prone area without the consent of Council. This clause is of little relevance in Murrurundi Shire because, except for agriculture in the rural zones, all development in the Shire requires the consent of Council. As such, the exclusion of Clause 34 is justified.

Clause 19 - Flood Liable Land

This clause, despite the need for development consent for all development other than agriculture in any zone within the Shire, provides for the requirement of Clause 34 of the Environmental Planning and Assessment Model Provisions, 1980 that no development on flood liable (prone) land shall be undertaken without the consent of Council. Clause 19 states that:

> *"19 Notwithstanding any other provision of this plan, the Council shall not grant consent to the carrying out of any development on flood liable land, unless it has made an assessment of:-*
>
> *(a) the effect of the proposed development on the flow of flood waters on that land or land in its immediate vicinity;*
>
> *(b) the safety of the proposed development in the time of flood;*
>
> *(c) whether the proposed development involves any risk to life, human safety or private property in time of flood;*
>
> *(d) whether the floor level of any dwelling-house or other habitable building on the land will be at least 500 millimetres above the highest known flood in the vicinity; and*
>
> *(e) whether adequate measures have been or will be taken to offset the likely effects of flooding on the development."*

E.3 COMMENTARY ON EXISTING LAND USE PLANNING CONTROLS

Apart from the above-mentioned areas within the Murrurundi LEP, 1993, there is no control on development on flood liable land within the Shire of Murrurundi.

The following comments are made in order that Council can consider ways in which it can strengthen the existing provisions of the Murrurundi LEP, 1993 to account for the effect of flooding on development within the Murrurundi Shire and indeed the effect of development on the flood regime.

Part 1 - Preliminary

The Murrurundi LEP, 1993 is an aims and objectives based planning instrument. Clause 2 details the general aims and objectives of the plan, with the specific objectives of each zone contained in the Table to Clause 9 of the LEP.

There is no aim or objective of the plan for the control of development on flood liable land. It is recommended that such and objective be included in Clause 2 of the LEP. A possible objective is:

> *"2. (1) (c) to reduce the incidence of damages and hazard in areas subject to flooding by restricting development on flood liable land."*

Clause 5 of the LEP defines "flood liable land" as:

> ***"flood liable land"** means the land within the township of Murrurundi or the village of Blandford or Willow Tree or elsewhere which is affected by flood as indicated on the map;"*

As indicated above, the map shows no land within the Shire as being flood liable, and as such the definition has little value in the control of development within the Shire.

Council commissioned Flood Studies in Murrurundi, Blandford and Willow Tree which were submitted in draft form by Lyall and Macoun Consulting Engineers (LMCE, 1997). Those studies have identified areas which are subject to flooding and assessed the flood hazard in accordance with the NSW Government *"Floodplain Development Manual" (PWD, 1986)*. As such, Council now has information on the flood regime within those townships to enable it to resolve that certain sections of each township fall within the definition of "flood liable land".

It is recommended that Council resolve to prepare mapping which delineates the flood liable land. In doing so, it is also recommended that Council consider an amendment to the definition of flood liable land contained within the LEP. At present, the definition requires the land classified as flood liable to be denoted on the map, i.e. the LEP Map.

As Council will appreciate, the map attached to the LEP forms part of the legislation of NSW and any amendment to that map requires an amendment to the legislation. To effect such a change, an amending LEP must be prepared, exhibited and then made by the Minister for Urban Affairs and Planning.

It is apparent that the land which is considered to be flood liable may alter in the light of further flood experience and refinement of the analysis of flood patterns and hazards. It is recommended that Council adopt a means of noting flood liable land in graphic format which allows revision and refinement in future.

It is recommended, rather than have the flood mapping tied to the LEP map, that there be a separate series of maps held by Council which delineate land which has been determined as flood liable. Such an

approach will allow Council to make reference to those maps in the definition of flood liable land contained in the LEP, while at the same time allowing Council to amend its flood mapping without the need for a formal amendment to the LEP. This approach would also allow Council to prepare additional maps for rural areas of the Shire should Council consider that flood related planning controls be appropriate for dwellings and certain types of rural industries (eg. intensive animal housing) In this regard, a suggested amendment to the definition of flood liable land is:

> *"**flood liable land** means land identified by the Council as being liable to flooding and indicated as flood liable land on a map marked "Flood Liable Land Map".*

Part 2 - General Provisions

The Table to Clause 9 of the LEP contains the objectives of each zone in the LEP. None of the zones within the LEP contain a specific objective for the control of development on flood liable land.

If Council adopts the Flood Study results as being the basis for the delineation of flood liable land, and subsequently amends the LEP as indicated above, then it is recommended that Council also considers an amendment to the objectives of each of the three zones which apply to the Shire to provide further re-enforcement of Council's concern for the control of development in the flood liable areas of the Shire.

A possible objective for inserting into the Table for each zone is:

> *"To ensure that development of land which is flood liable is carried out in a manner appropriate to the flood hazard."*

Part 3 - Special Provisions

Clause 19 of the LEP contains a standard clause which controls development on flood liable land. Whilst this clause has merit, it is considered that it can be strengthened to provide greater control on such development. It is recommended that Council consider an amendment to that clause as follows:

> ***Flood liable land***
>
> *19. (1) Notwithstanding any other provision of this plan, the Council shall not grant consent to the carrying out of development or works for any purpose on flood liable land without the consent of Council.*
>
> *(2) The Council shall not grant consent to the carrying out of development or works for any purpose on land that is flood liable unless it is satisfied that:*
>
> *(a) the development or work would not unduly restrict the flow characteristics of flood waters; and*

(b) the development or work would not unduly increase the level of flooding on land in the vicinity; and

(c) the structural characteristics of any building or work, the subject of the application, are capable of withstanding flooding; and

(d) any proposed building is adequately flood proofed.

(3) The Council shall not grant consent required by this clause unless it has taken into consideration:

(a) the cumulative effect of the development or work on flood behaviour; and

(b) the risk of pollution to the waterways caused by the development or work; and

(c) the availability of flood free access to the development or work.

(4) The Council may require the floor level of habitable rooms of a building to be erected at a height which is sufficient, in its opinion, to obviate the frequent flooding of the building or work."

It is considered that the above replacement clause will allow more control over development on flood liable land while at the same time allowing more flexibility with regard to floor levels of buildings.

Section 149 Certificates Under the Environmental Planning and Assessment Act, 1979

Advice from Council is that Annexure Item 3 to all s.149 Certificates issued by Council simply quotes the existing Clause 19 of the LEP. As indicated above, there is no flood liable land identified on the LEP Map, and as such the s.149 Certificate has little or no effect in this regard.

It is recommended that Council amend the Annexure to the s.149 Certificates in accordance with the above-recommended amendments to the LEP.

E.4 PLANNING OPTIONS

In addition to the above recommendations for the general controls within the LEP, there are other means by which Council can further strengthen its planning controls over flood liable land.

E.4.1 Flood Plain Management Plan/Development Control Plan

The Floodplain Management Plans being prepared for Council will provide for a set of specific development and flood protection guidelines which will assist in the control of development on flood liable land.

It is recommended that a series of graded controls apply to land which is flood liable depending upon the flood hazard which is identified for a particular parcel of land and the proposed use of that land. These graded controls could, and should, form the basis of a Development Control Plan for each township.

Having regard to the limited resources available to Council, it is recommended that the completed Floodplain Management Plan for each township be adopted by Council as a Development Control Plan. This will allow Council to have more specific controls on development and indeed provide for a dynamic approach to development control in flood liable areas.

The adoption of the FMPs as DCPs may require a further amendment to the LEP to provide for the creation of those DCPs. In this regard, a further proposed objective of the LEP could be:

> *"2 (1) (d)* *to provide a basis for development control plans to supplement the broad controls of this plan with more detailed provisions for regulating the carrying out of development."*

E.4.2. Environmental Protection Zone

The preceding sections of this report have discussed measures which should be implemented by Council to provide for a more effective LEP as far as the control of development on flood liable land is concerned.

It is recommended that Council also consider further strengthening controls on land which is identified in the Flood Study as being "floodway" and/or "high hazard". This could be achieved by a further amendment to the LEP 1993 to include a new zone – Environmental 7(f) floodway.

A draft amending LEP is attached for the consideration of Council (Attachment A). It is recommended that, as part of the preparation and exhibition of the draft LEP, Council also exhibit the Floodplain Management Plan (FMP) for each township as a Development Control Plan. The provisions of this draft LEP should also be incorporated into any other changes contained within this report which Council considers warranted. The exhibition of that FMP as a DCP will provide detailed environmental planning controls for both the newly created 7(f) (Environmental Protection - Floodway) Zone and other flood liable land within the Shire.

Figures E.1 and E.2 are plans of Murrurundi and Blandford respectively, which show the approximate extent of flooding for the 100 year ARI, the high hazard areas for that flood and existing land use zoning. The high hazard areas which are suitable for inclusion in the 7(f) (Environmental Protection-Floodway) Zone have been identified.

It is to be noted that the standard of contour mapping in Blandford and Willow Tree is poor, being restricted to 1:25000 scale topographic maps with 10 m contours. The flood information shown on these plans is based on the (limited) number of cross sections of the floodplain which were surveyed for the Flood Study. There is no reliable connection to Australian Height Datum (AHD) in the township of Willow Tree and therefore the hydraulic analysis and presentation of results were undertaken to an arbitrary datum. Connection of the arbitrary datum to AHD and additional survey to better define the extent of flooding are recommended for the two townships.

In the case of Murrurundi, 1:1000 scale sewer maps with 1 m contour spacing are available which are considered to provide a reasonable base for presenting flood information, although some additional work may be required to identify the flood extent.

E.5 SUMMARY

This appendix has identified a number of measures which should be taken to strengthen the flood related planning controls available to council. In essence these include:

1) Council should resolve to prepare an amendment to the LEP 1993 to:

- Add an objective related to control of development on flood liable land (Clause 2(1)(c))
- Add a further objective (2(1)(d)) which would allow Council to adopt the Floodplain Management Plan for each township as a Development Control Plan
- Amend the definition of "flood liable land" (Clause 5) to refer to a separate series of maps which are not tied to the LEP map. This will allow Council to amend such maps in the light of future flood experience without the need for a formal amendment of the LEP.

- Amend the objectives for three zones to include mention of flooding considerations in the Table to Clause 9.

- Strengthen Clause 19 to provide greater control of development on flood liable land.

2) As part of the preparation and exhibition of the draft LEP, Council should also exhibit the Floodplain Management Plan for each township as a Development Control Plan.

3) Council should also consider strengthening planning controls on land which is identified as "floodway" or "high hazard" by further amending the LEP 1993 to include a new zone – Environmental Protection 7(f) Floodway.

The area which would be affected by this proposal is shown on Figures E1 and E2

It is to be recognised that all existing, "lawful" development within the proposed 7(f) zone which would be prohibited by the amending LEP would, upon gazettal of the amending LEP, be "non-conforming uses" and as such will have "existing use rights" pursuant to the Environmental Planning and Assessment Act, 1979. It is also to be understood that significant development "rights" will be removed from vacant land within the newly created 7(f) zone.

It is recommended that Council implement a voluntary purchase scheme for land within the 7(f) zone as part of the rezoning of that land. Such a scheme will provide for compensation to landowners.

ATTACHMENT A – DRAFT AMENDMENT
ENVIRONMENTAL PLANNING AND ASSESSMENT ACT 1979

MURRURUNDI LOCAL ENVIRONMENTAL PLAN 1993
(AMENDMENT No.XX)

I, the Minister for Urban Affairs and Planning, in pursuance of section 70 of the Environmental Planning and Assessment Act 1979, make the local environmental plan set out hereunder. (file number)

CRAIG KNOWLES MP
Minister for Urban Affairs and Planning

Sydney, xxx

Name of plan

1. This plan is called the Murrurundi Local Environmental Plan 1993 (Amendment No.xx).

Aims, objectives etc.

2. The aim of this plan is to provide for control of development on flood liable land identified as floodway.

Land to which the plan applies

3. This plan applies to the land shown edged black on the map marked "Murrurundi Local Environmental Plan 1993 (Amendment No.xx)" deposited in the office of the Murrurundi Shire Council.

Relationship to other environmental planning instruments

4. This plan amends Murrurundi Local Environmental Plan 1993 in the manner set out in Clause 5.

Amendment of Murrurundi Shire Local Environmental Plan 1993

5. Murrurundi Shire Local Environmental Plan 1993 is amended:

   (i) by inserting into Clause 5 after the definition of "flood liable land" the following definitions:

"**floodway**" means an area that carries a significant discharge of water during a flood, and even if only partially blocked, would cause significant redistribution of flow or a significant increase in flood levels.

(ii) by inserting into the definition of "the map" in Clause 5 the following:

Murrurundi Local Environmental Plan 1993 (Amendment No.xx)

(iii) by inserting into Clause 8 the following:

Zone No.7(f) (Environmental Protection - Floodway) - edged black and lettered "7(f)"

(iv) by inserting into the Table to Clause 9 the following:

Zone No. 7(f) (Environmental Protection - Floodway)

1. Objective of zone

The objective of this zone is to provide for the proper management of the floodway as identified in accordance with the Floodplain Development Manual, 1986.

2. Without development consent

Nil.

3. Only with development consent

Agriculture (other than intensive livestock keeping establishments and which does not involve the clearing of trees); camp and caravan sites; landscaping; recreation areas; subdivision; utility installations (other than gas generating works).

4. Prohibited

Any purpose other than a purpose included in item 3.

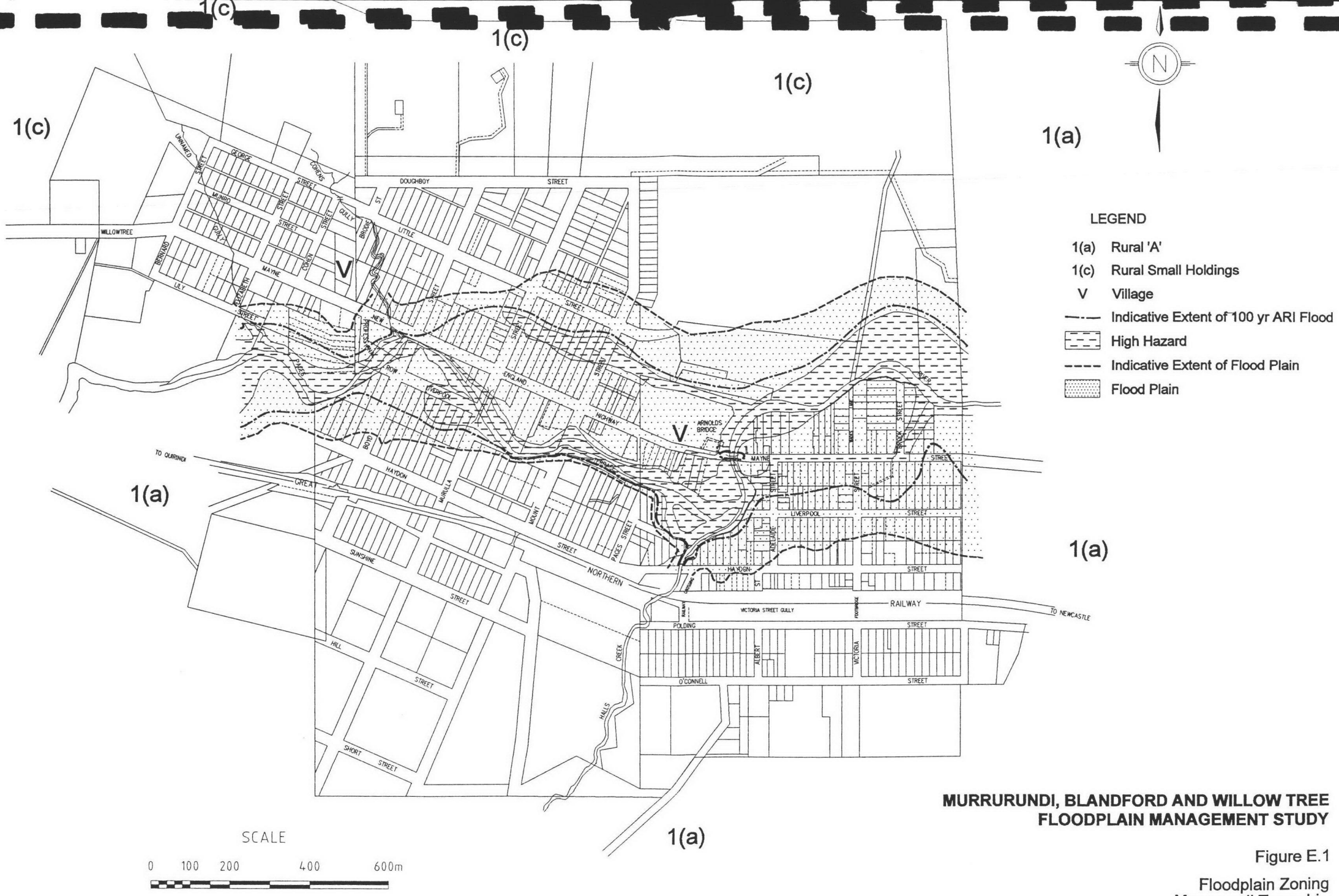
(v) by inserting at the end of Clause 20 the following:

20A. (1) The Council may vary the boundary between zone 7(f) and an adjoining zone.

(2) In determining a zone boundary under subclause (1), the Council shall not determine that zone boundary

until it has had regard to a report prepared by an appropriately qualified Engineer which assesses the likely impact of the variation of the zone boundary on both the flood regime and flooding of any development which may be permissible on the land following any variation to the zone boundary.

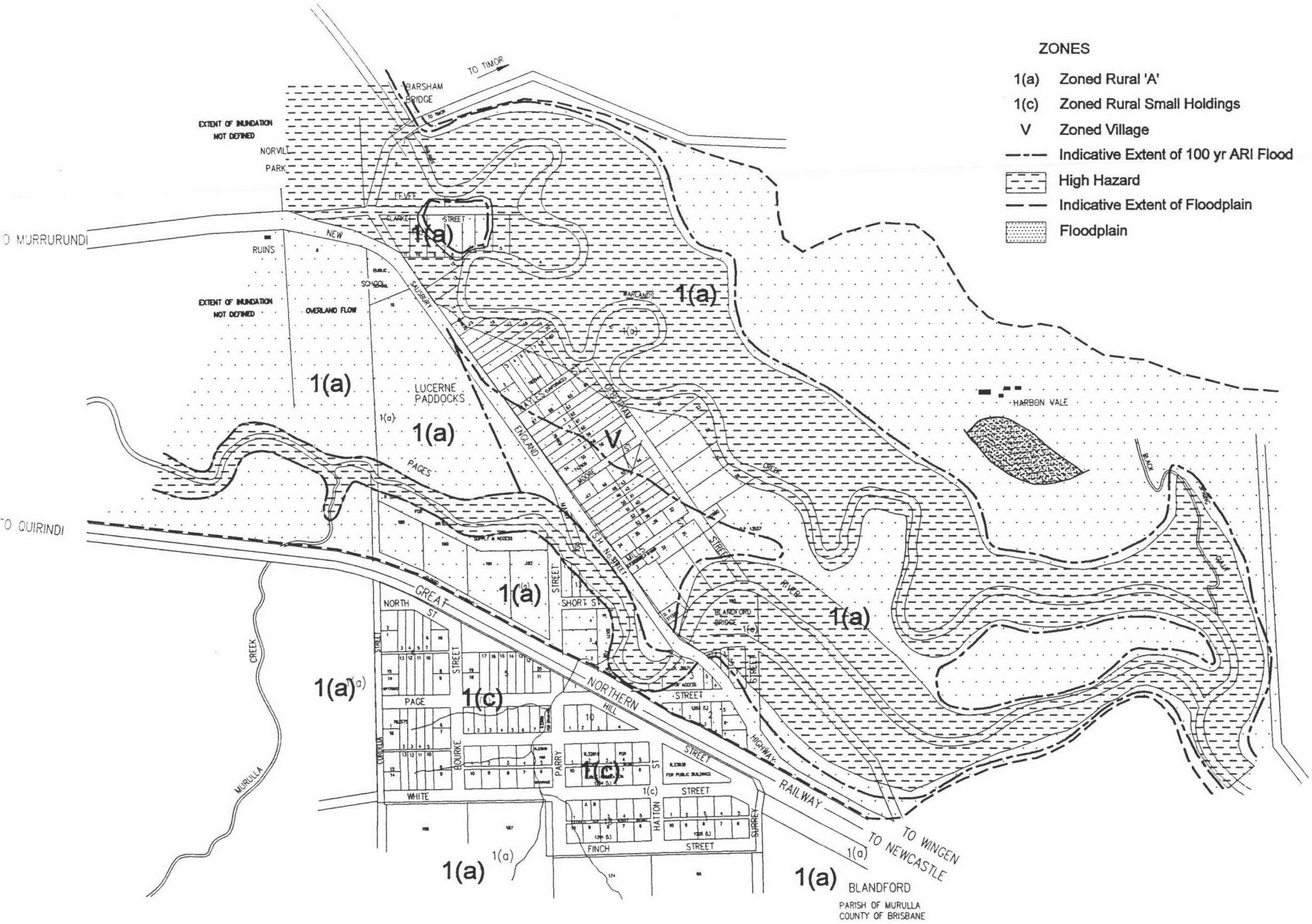
(3) In determining a zone boundary under subclause (2), the Council shall also have regard to clause 19 of this plan.



MURRURUNDI, BLANDFORD AND WILLOW TREE FLOODPLAIN MANAGEMENT STUDY

Figure E.1

Floodplain Zoning
Murrurundi Township



MURRURUNDI, BLANDFORD AND WILLOW TREE FLOODPLAIN MANAGEMENT STUDY

Figure E.2

Floodplain Zoning
Blandford Township

LEGEND

1(a) Zoned Rural 'A'

1(c) Zoned Rural Small Holdings

V Zoned Village

Indicative Extent of 100 yr ARI Flood

High Hazard

Indicative Extent of Floodplain

Floodplain

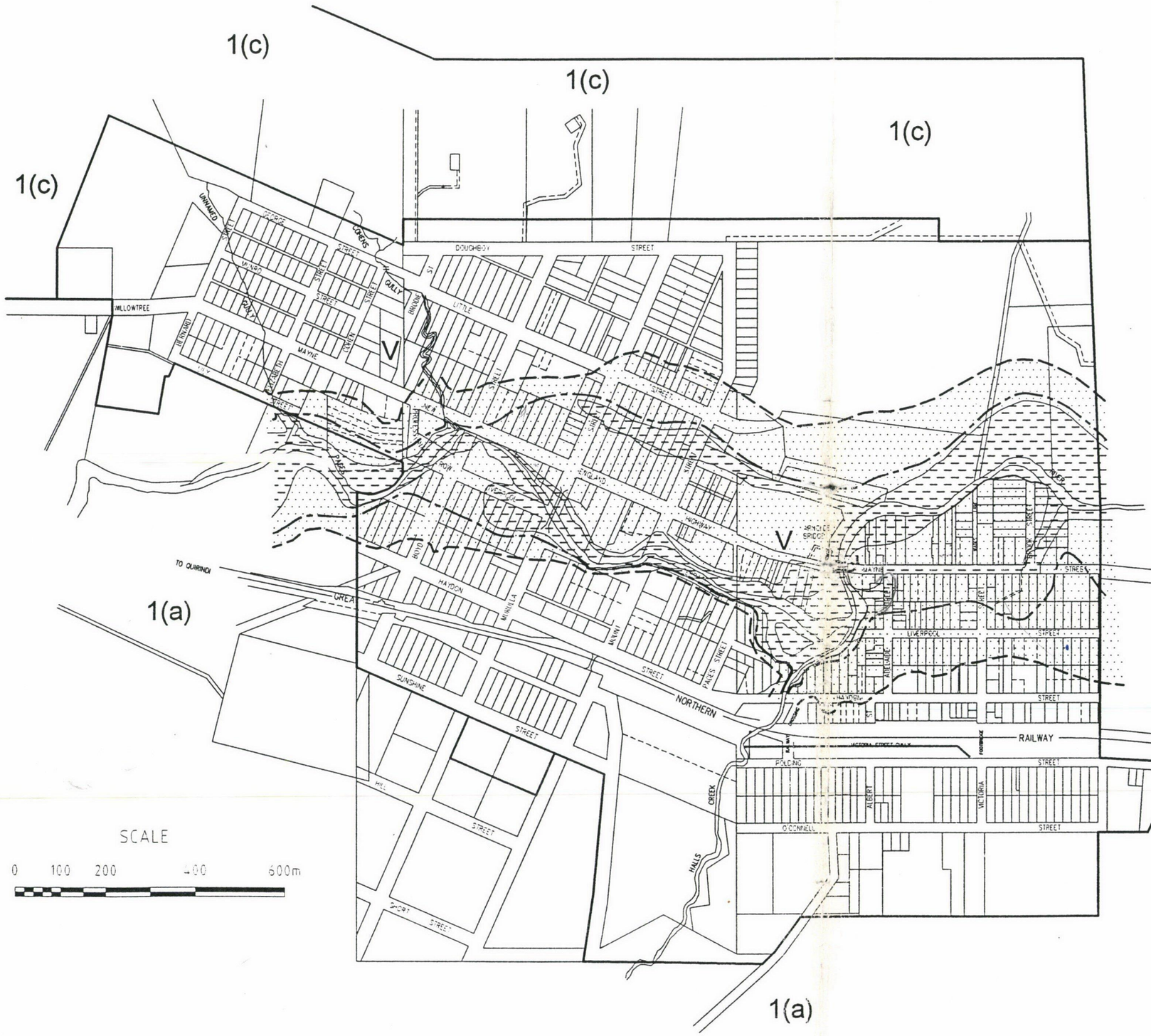
SCALE

0 100 200 400 600m

MURRURUNDI, BLANDFORD AND WILLOW TREE FLOODPLAIN MANAGEMENT STUDY

Figure 2.3

Floodplain Zoning
Blandford Townsh



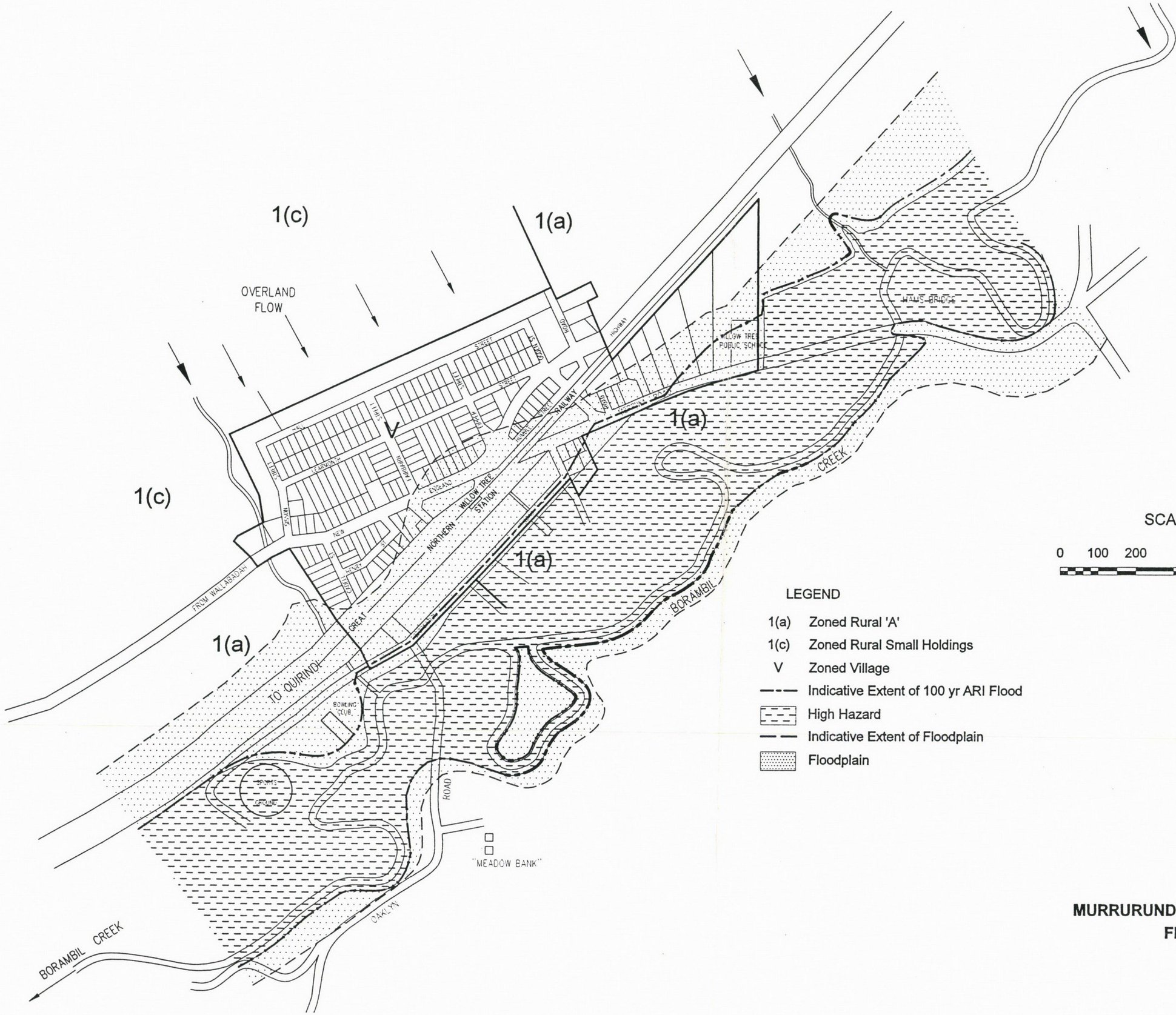
LEGEND

- 1(a) Zoned Rural 'A'
- 1(c) Zoned Rural Small Holdings
- V Zoned Village
- Indicative Extent of 100 yr ARI Flood
- High Hazard
- Indicative Extent of Floodplain
- Floodplain

MURRURUNDI, BLANDFORD AND WILLOW TREE FLOODPLAIN MANAGEMENT STUDY

Figure 2.2

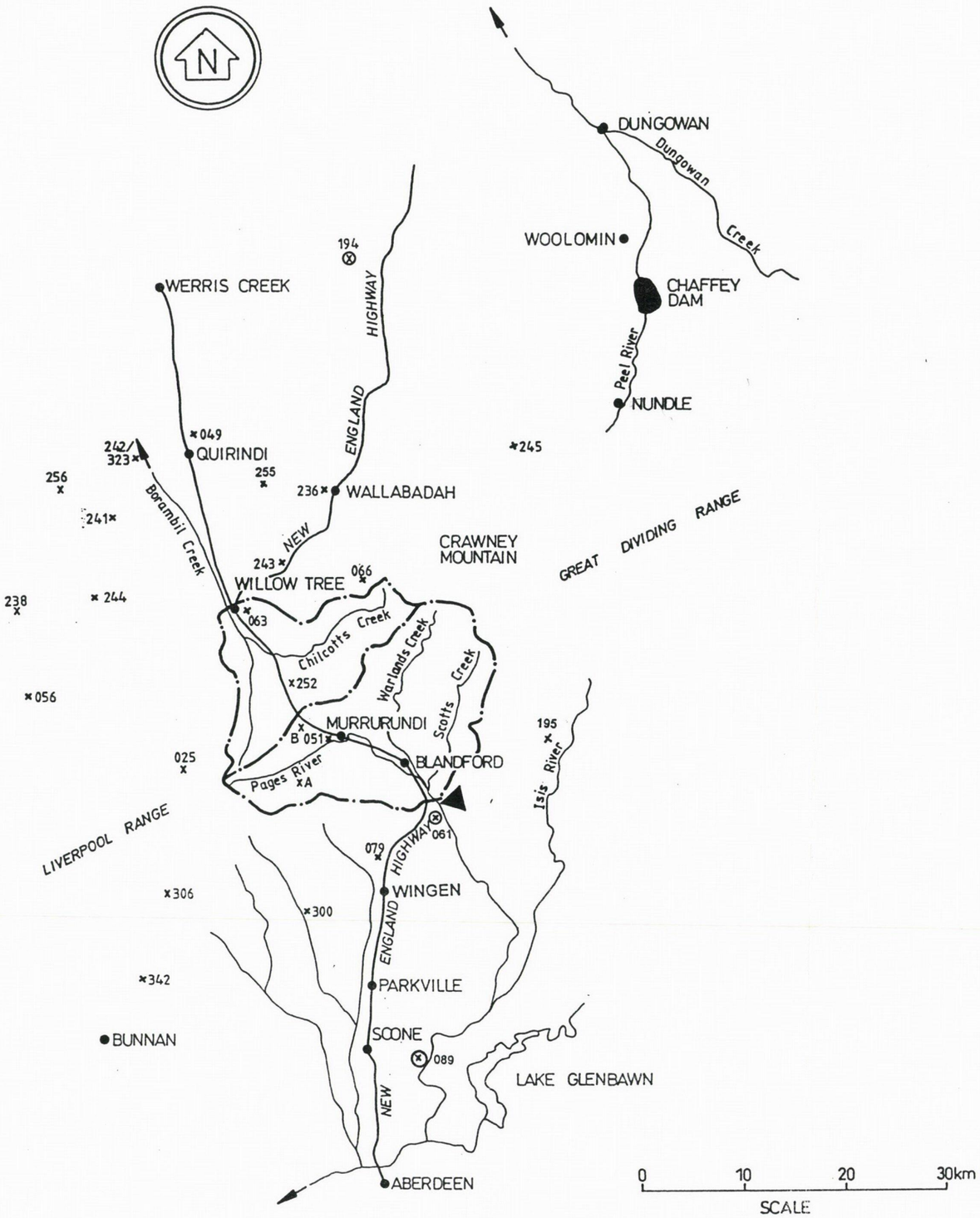
Floodplain Zoning
Murrurundi Township



MURRURUNDI, BLANDFORD AND WILLOW TREE FLOODPLAIN MANAGEMENT STUDY

Figure 2.4

Floodplain Zoning
Willow Tree Township



LEGEND

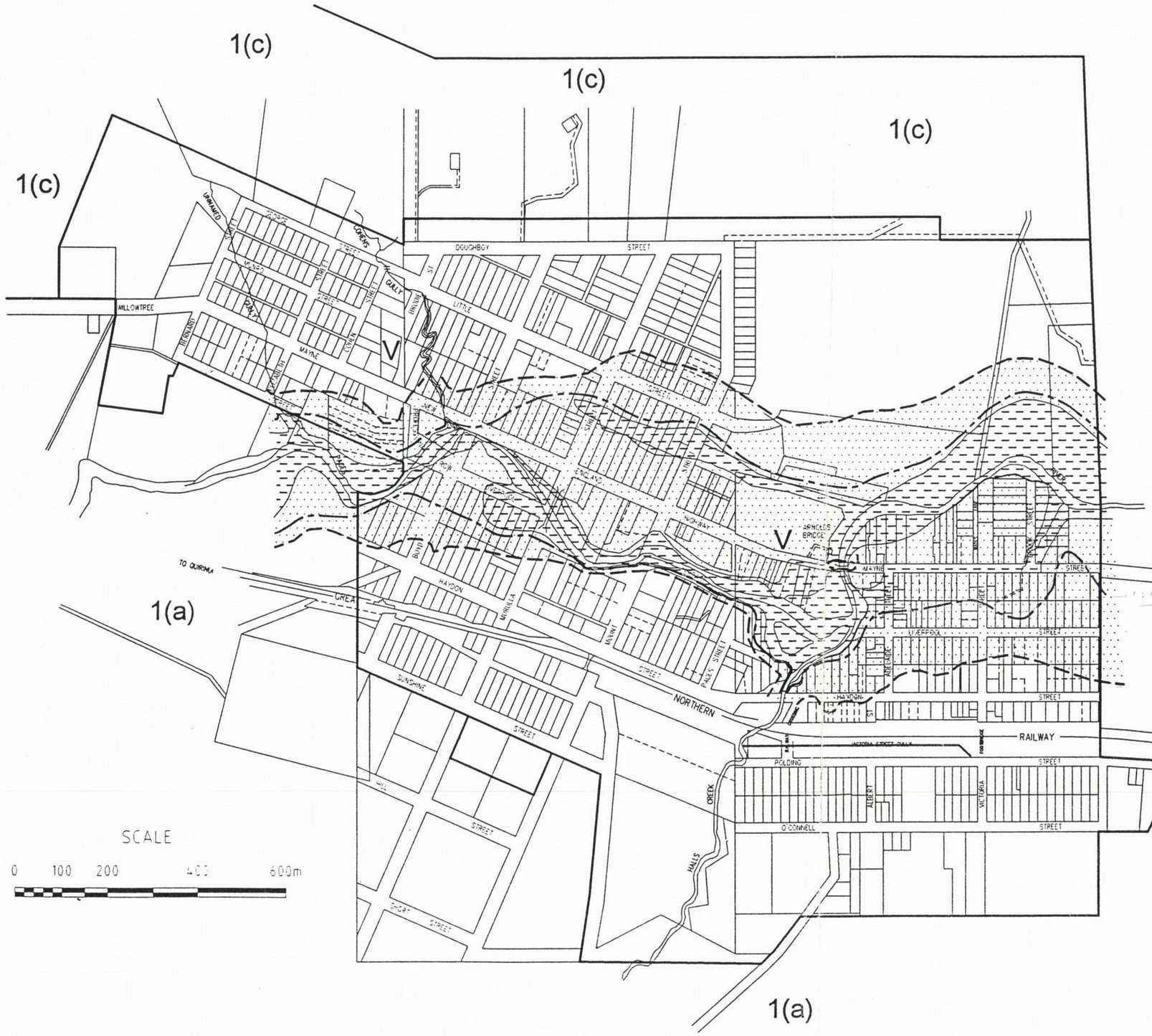
- × DAILY RAINFALL STATION
- ⊗ PLUVIOGRAPHIC RAINFALL STATION
- ◀ PAGES RIVER AT BLANDFORD STREAM GAUGING STATION
- —·—·— CATCHMENT BOUNDARY

Station	Lat.	Long.	Location
BOM Daily Rainfall Stations			
055025	31.79	150.67	Willow Tree (Highlands)
055049	31.51	150.68	Quirindi Post Office
055056	31.73	150.51	Willow Tree (Green Hills)
055063	31.65	150.73	Willow Tree Post Office
055066	31.62	150.86	Wallabadah (Woodton)
055236	31.53	150.83	Wallabadah (Seychelles)
055238	31.65	150.50	Pine Ridge (Boondari)
055241	31.57	150.60	Quirindi (Kooyong)
055242	31.52	150.63	Braefield (Hunday)
055243	31.61	150.78	Willow Tree (Pertala)
055244	31.64	150.57	Willow Tree (Cooinda)
055245	31.50	151.03	Nundle (Keeva)
055252	31.72	150.79	Willow Tree (Temi)
055255	31.53	150.76	Quirindi (Springvale)
055256	31.55	150.55	Quirindi (Red Braes)
055323	31.52	150.63	Quirindi (Hunday)
061051	31.77	150.84	Murrurundi Post Office
061079	31.87	150.88	Wingen (Murrulla)
061195	31.77	151.07	Murrurundi (Timor)
061300	31.92	150.80	Parkville (Aroona)
061306	31.90	150.67	Kars Springs (Woodlands)
061342	31.98	150.63	Bunnan (The Cuan)
BOM Pluviographic Rainfall Stations			
055194	31.34	150.85	Gowrie North
061089	32.06	150.93	Scone Soil Conservation Service
210061	31.81	150.93	Blandford Gauging Station
Private Gauges of Local Residents Daily Rainfalls			
A	31.78	150.79	Wykcham Park (Mr Paton)
B	31.76	150.81	Glenalvon (Mr Arnott)

MURRURUNDI, BLANDFORD & WILLOW TREE FLOODPLAIN MANAGEMENT STUDY

Figure D.1

Rainfall and Stream Gauging Stations



N

LEGEND

1(a)	Zoned Rural 'A'
1(c)	Zoned Rural Small Holdings
V	Zoned Village
----	Indicative Extent of 100 yr ARI Flood
	High Hazard
— —	Indicative Extent of Floodplain
	Floodplain

MURRURUNDI, BLANDFORD AND WILLOW TREE FLOODPLAIN MANAGEMENT STUDY

Figure E.1

Floodplain Zoning
Murrurundi Township

LEGEND

1(a) Zoned Rural 'A'

1(c) Zoned Rural Small Holdings

V Zoned Village

Indicative Extent of 100 yr ARI Flood

High Hazard

Indicative Extent of Floodplain

Floodplain

N

SCALE

0 100 200 400 600m

MURRURUNDI, BLANDFORD AND WILLOW TREE FLOODPLAIN MANAGEMENT STUDY

Figure E.2

Floodplain Zoning
Blandford Township