Myall River

Floodplain Risk Management Study for Bulahdelah

Prepared for:
Great Lakes Council

August 2002

Flood Unit, Ecosystems Branch

LAND & WATER CONSERVATION

MYALL RIVER

FLOODPLAIN RISK MANAGEMENT STUDY

For BULAHDELAH

Prepared for:

GREAT LAKES COUNCIL

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EXECUTIVE SUMMARY

Bulahdelah is affected by flooding from both the Myall River and drainage paths transferring water from both east of the urban area and the urban area itself to the Myall River.

This study concentrates on flooding from the Myall River and its tributaries with a separate study being undertaken by Council dealing with local overland flooding/drainage issues.

The Myall River system has a catchment area of approximately 365km^2 at the Pacific Highway. The Crawford River, its major tributary, has a catchment area of 125km^2.

Flooding at Bulahdelah has not occurred for a number of years. The largest floods in available records occurred in 1897 and 1927. Smaller floods were recorded in 1947 and 1953 with less severe floods again occurring most recently in 1985 and 1987. Therefore the current knowledge of Bulahdelah residents of significant flooding is expected to be low.

Major floods can have a reasonable impact on Bulahdelah township resulting in significant property damage and the need for a number of dwellings to be evacuated. Flooding from the Myall River in the 1% annual exceedance probability (AEP) flood event will inundate around 45 houses and 7 non residential buildings. In an extreme event the peak flood level would be around 1.8m higher than the 1% AEP flood level with around 109 houses and 11 non residential buildings inundated. The potential flood damage in the 1% AEP event is estimated to be in the order of $1,700,000 with the annual average damage for the full range of floods expected to be in the order of $95,200. Therefore flooding can have significant implications to Bulahdelah.

This study has further investigated the extent of the flood problems from the Myall River and has assessed potential floodplain management measures aimed at dealing with the three types of flood risk, namely:

- existing flood risk which relates to existing development in the floodplain;
- future flood risk which relates to the risk to future development in the floodplain; and
- continuing flood risk is the flood risk remaining after management measures are implemented.

Each of these risks involves both danger to personal safety and property damage. This study highlights the need for a number of different measures to address these issues and types of flood risk.

The findings of the study and the potential management measures were presented to the community as part of the consultation undertaken as part of the project. There was very poor attendance at the community workshop and little feedback from the community consultation process overall and no clear community desires could be ascertained. The community was more interested in local drainage problems that occur regularly rather than riverine flooding which is more severe. This is probably due to both the regularity of the drainage problems and the long time frame since a major flood. A future major flood has the potential to significantly shift the communities focus onto riverine flooding.

This report recommends that the Council consider adopting the following management measures in its floodplain management plan.

- a voluntary house raising and voluntary purchase scheme is recommended to reduce existing flood risk.
- updating the Council's 1985 Flood Management Policy and associated development controls as outlined in this report to manage future flood risk.
- installation of a flood warning system with associated emergency management planning, community education and awareness will aid in addressing continuing flood risk.

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1.1 Floodplain Management in the Great Lakes Council Area

Council is responsible land use planning, including the management of flood prone land, within its local government area in accordance with the NSW Government's Flood Prone Land Policy.

To support effective floodplain management Council has formed a Floodplain Management Committee and is undertaking the floodplain management process in accordance with the NSW Government's Floodplain Management Manual. The process outlined in the manual aims at addressing the existing, continuing and future flood risks related to human occupation of the floodplain using a process of risk avoidance, minimisation and mitigation. This floodplain management study is the second of four steps in this process, described in the table below.

Table 1.1 Steps in the Floodplain Management Process

1	Flood Study	- Determines the nature and extent of the flood problem.
2	Floodplain Management Study	- Evaluates management options for the floodplain with respect to existing, future, and continuing flood risk.
3	Floodplain Management Plan	- Involves formal adoption by Council of a plan of management for the floodplain.
4	Implementation of the Plan	- May involves construction of flood mitigation works, where viable, to protect existing development and reduce existing flood risk. - Uses planning controls to ensure that future development is compatible with flood hazards in controlling future flood risk. Uses flood warnings to provide the community of information on potential flooding through the local emergency services. - Uses flood education and awareness to promote flood readiness to minimise continuing flood risk

This study is one of a number that are being undertaken by Council for different locations within its service area. This study concentrates on the impacts of the Myall River on Bulahdelah township. The floodplain management measures currently in place for Bulahdelah are discussed in Section 3.

1.2 Bulahdelah Floodplain Management Study

The Department of Land and Water Conservation (DLWC) was engaged by Council to undertake a floodplain management study for Bulahdelah to assess the impacts of the Myall River on the township.

The township of Bulahdelah is located about 96km north of Newcastle where the Pacific Highway crosses the Myall River (refer Figure 1). The Myall River at Bulahdelah has a history of flooding with the largest floods on record occurring in 1897 and 1927. Smaller floods were recorded in 1947 and 1953, and less severe floods occurred more recently in 1985 and 1987. The area of the study, shown in Figure 1, covers the floodplains of the Myall River and its main tributaries within the following limitations:

- Myall River from the Markwell Road bridge to downstream of the Pacific Highway bridge (5.2km);
- Frys Creek from upstream of the Markwell Road bridge to the Myall River (2.5km); and
- Crawford River from the confluence with Wild Cattle Creek to the Myall River (2.4km).

0 1km

SCALE

STUDY AREA
Figure 1

The main tributary of the Myall River, the Crawford River, enters 500m upstream of the Pacific Highway bridge. At this location the Myall and Crawford Rivers have catchment areas of about 240km^2 and 125km^2 respectively. Approximately 3km upstream of the Pacific Highway bridge, the Frys Creek tributary (catchment area 18 km^2) flows into the Myall River. From Bulahdelah the Myall River flows some 15 km to the Myall Lakes which drain to the ocean at Tea Gardens.

Bulahdelah is affected by flooding from both the Myall River and local overland flow from drainage paths transferring water from the urban area to the river. A separate study is being undertaken to examine the local overland flow/drainage issues in the township. This report deals only with flooding from the Myall River and its main tributaries, indicated above and builds upon previous work, including:

- the Bulahdelah Flood Appraisal, prepared for Great Lakes Council by NSW Public Works in October 1991 to assess flood behaviour for the Myall River floodplain in the vicinity of township; and
- the Frys Creek Flood Study was completed in July 1994 to assess flood behaviour in the lower reach of Frys Creek.

There has been no recent study of flood behaviour in the Crawford River.

Investigations indicate that approximately 52 buildings are affected by above floor flooding in Bulahdelah in a 1% AEP flood event which would cause in the order of $1,700,000 damage. The annual average damage (AAD) of the full range of floods would be in the order of $95,200 per annum.

To manage the flood risk posed to personal safety and property from the Myall River, Great Lakes Council through its Floodplain Management Committee, proposes to develop a Floodplain Management Plan for Bulahdelah. This plan is being developed in accordance with the NSW Government's Floodplain Management Manual, 2001. This study provides the basis for the development of the plan.

The plan and therefore this study deal with the management of both danger to personal safety and damage to property as related to the 3 types of flood risk, namely:

- existing flood risk is the risk vested in current development in the floodplain. This may need to be managed by floodplain mitigation options;
- future flood risk is related to new development within the floodplain. This risk is most effectively managed by the use of development controls; and
- continuing flood risk is the risk remaining after floodplain management and development controls are in place. Continuing flood risk needs to be managed by options such as flood warning, emergency management planning, public education and awareness.

Council has adopted the 1% annual exceedance probability (AEP) flood as the basis for setting flood planning levels (FPL) for control of new development in it's Flood Management Policy. This report reviews the flood situation at Bulahdelah and addresses the development and assessment of floodplain management options in the following sections:

Section 2	The Myall River Floodplain – describes existing floodplain conditions and flood behaviour;
Section 3	Existing Floodplain Management – describes current floodplain management practices;
Section 4	Emerging Issues at Bulahdelah – deals with the Pacific Highway upgrade and the local drainage;
Section 5	Future Options to Improve Floodplain Management – identifies and assesses appropriate floodplain management options from a social, economic and environmental viewpoint;
Section 6	Community Consultation – reports on the outcome of community consultation;
Section 7	Government Funding – indicates the current government funding programs;

Section 8 Conclusions and Recommendations;

Section 9 Glossary. Provides a definition of the terms used in this report;

Section 10 Acknowledgments; and

Section 11 References.

These sections of the report are supported by the following appendices:

Appendix A Flood Study Review – review of the previous investigations;

Appendix B Hydraulic and Hazard Categories – assessment of the flood hazards; and

Appendix C Flood Damages – assessment of flood damages.

2. THE MYALL RIVER FLOODPLAIN

2.1 PHYSICAL CHARACTERISTICS

The Myall River is a coastal river on the mid-north coast of New South Wales. It experiences a warm temperate climate with average annual rainfall of approximately 1300 millimetres per year. Highest rainfall is experienced from January to June with lower rainfall in late winter and early spring.

The Myall River rises in steep forested ranges south of Gloucester. It has a catchment area of 365km^2. The river drains into the Myall Lakes system before flowing into Port Stephens at Tea Gardens. River channel form has been characterised by DLWC in their stressed rivers assessment report for the Karuah River/Great Lakes catchment.

The channel form of the Myall River is typical of many New South Wales coastal rivers with steep headwaters gradually moving into a confined valley with a very narrow or no floodplain. Further downstream, the valley widens but the channel is still confined, the floodplain is discontinuous and the channel meanders. Bulahdelah is situated within the reach of the Myall River where the valley has widened sufficiently to result in a continuous floodplain. The floodplain is continuous until the Myall River drains into the Myall Lakes, a coastal lake system with tidal influence.

Bulahdelah is situated near the confluence of the Myall and Crawford Rivers, meaning that floodwater generated from either catchment have the potential to cause flooding.

2.1.1 Vegetation

Vegetation communities around the town itself have largely been cleared with only remnants remaining. Remnant communities are classified as dry open forest, wet open forest and swamp forest with species occurring typical of those found on the lower north coast. Tree species recorded in the area include rusty gum (*Angophora costata*), rough-barked apple (*A. floribunda*), red bloodwood (*Corymbia gummifera*), spotted gum (*C. maculata*), pink bloodwood (*C.intermedia*), thick-leaved white stringybark (*Eucalyptus carnea*), thin-leaved stringybark (*E. eugenioides*), white stringybark (*E. globoidea*), flooded gum (*E.grandis*), tallowwood (*E. micocorys*), blackbutt (*E. pilularis*), Sydney peppermint (*E. piperita*), small-fruited grey gum (*E. propinqua*), swamp mahogany (*E. robusta*), grey ironbark (*E. siderophloia*) and forest red gum (*E. tereticornis*).

It is likely that the area previously supported wet open forest and the majority of the floodplain was forested. A wetland protected under State Environmental Planning Policy no 14 – Coastal Wetlands exists downstream of the town of Bulahdelah on the Myall River floodplain. PPK (2000) report that this wetland is a shallow depression in the middle of grazing land.

Smaller wetland areas have been identified by PPK (2000) as occurring on the south-western outskirts of the township, as well as on both sides of the Myall River floodplain approximately 1km downstream of Bulahdelah.

A disturbed grassland habitat surrounds the town area. PPK (2000) noted that 5 threatened flora species have been recorded in the immediate vicinity of the town:

- *Eucalyptus fergusonnii* ssp. *fergussonii*, a tall tree species growing in wet sclerophyll forests or woodlands on sandy soils;
- *Angophora inopina*, a rough-barked tree species. A specimen found on the southern side of the confluence of the Myall and Crawford Rivers was tentatively identified as a cross between *A. inopina* and *A. floribunda*. For this reason, PPK considered *A. inopina* likely to occur in the area;

- *Asperula asthenes*, a small herb that grows in coastal areas in damp places often along river banks and water course. The NPWS ROTAP (Rare or Threatened Australian Plants) database records this species as occurring immediately south of the Myall and Crawford River confluence;
- *Syzygium paniculatum*, a shrub or small tree that grows in subtropical and littoral rainforests on sandy soil or stabilised dunes near the sea. The NPWS ROTAP (Rare or Threatened Australian Plants) database records this species as occurring immediately south of the Myall and Crawford River confluence;
- *Tetratheca juncea* is a small terrestrial herb with a restricted range from Lake Macquarie to Bulahdelah (Harden, 1992). This species has been previously recorded at two locations of the eastern outskirts of Bulahdelah.

None of the threatened flora species identified in the area are dependent of intermittent inundation from flood waters. However, a change in the hydrological regime of the floodplain through construction of flood mitigation works could disturb habitat requirements for species resulting in their extinction in the local area.

Threatened flora species could be affected through clearance of supporting habitat, for example clearance of canopy species could adversely affects light requirements for shrubs and other understorey species. Alternatively threatened flora species could be directly affected through clearing if they were located in an area where floodplain management works was proposed.

Several tree species found in the area are listed in Schedule 2 of State Environmental Planning Policy No. 44 - Koala Habitat and a koala habitat assessment would be required to determine whether any area to be cleared is *potential* or *core* koala habitat as defined in SEPP 44.

2.1.2 Fauna

PPK (2000) have reported threatened fauna recorded within the vicinity of Bulahdelah. There are 6 threatened fauna species found within the immediate environs of the township and a further 3 species recorded within the wider floodplain area. The species recorded within the township are:

- Squirrel glider (*Petaurus norfolcensis*), recorded near Jackson Street;
- Masked owl (*Tyto novaholandiae*), recorded near Jackson Street;
- Little bent-wing bat (*Miniopterus australis*), recorded near Meade Street on eastern side of Pacific Highway;
- Common bent-wing bat (*Miniopterus schreibersii*), recorded near Meade Street on eastern side of Pacific Highway;
- Glossy black cockatoo (*Calyptorhynchus lathami*) recorded near Meade Street on eastern side of Pacific Highway; and
- Black-necked stork (*Xenorhynchus asiaticus*), recorded near Myall River north of Lee Street.

Additional threatened fauna species found within the vicinity of the Bulahdelah township include:

- Koala (*Phascolarctos cinerus*), recorded on left bank of Crawford River approximately half a kilometre upstream of confluence of Myall and Crawford Rivers;
- Eastern little mastiff bat (*Mormopterus norfolkensis*), recorded near wetland area on right bank of Myall River approximately one kilometre downstream from Bulahdelah; and
- Wallum froglet (*Crinia tinnula*), recorded approximately half a kilometre north of Markwell Road and Lee Street intersection.

2.2 ABORIGINAL HERITAGE

Great Lakes State of the Environment Report for 1998/99 notes that according to the National Parks and Wildlife Service Aboriginal sites register, Great Lakes is rich in Aboriginal cultural values. A diverse range of sites have been recorded shire wide, including:

- Open camp sites;
- Bora/ceremonial;
- Scarred trees;
- Middens;
- Stone arrangements;
- Carved trees;
- Burials;
- Rock engraving;
- Axe grinding grooves; and
- Natural mythological (ritual) sites.

No specific information is available in relation to Aboriginal cultural heritage items within Bulahdelah itself. However, if any floodplain management works were proposed which disturbed the natural ground surface or required any clearing of vegetation, an archaeological survey would need to be undertaken.

2.3 BUILT ENVIRONMENT

The majority of the land zoned for urban development within the Myall River Floodplain has been developed. A significant proportion of the houses are greater than 20 years old with 45 houses inundated above floor level in the 1% AEP flood event, based upon a recent survey. The annual average damage (AAD) due to flooding with current development levels in Bulahdelah township is in the order of $111,000. Further details on the review of the flood study and damages are given in Appendices A and B.

Any future development is assumed to be in accordance with Council's development control requirements, including its Flood Management Policy. This policy sets the minimum floor levels a minimum of 0.5m above the 1% AEP flood level.

2.3.1 European Heritage

Schedule 2 of the Great Lakes Local Environmental Plan (LEP) indicates heritage items in the Council area. Five sites are indicated in the Bulahdelah region. There are 2 items in the study area which are of significance, both of which are regionally significant. These are the General Cemetery on Markwell Road and the former Courthouse in Crawford Street, on the south eastern side of the Pacific Highway. Both the Courthouse and the Cemetery are located outside the floodplain so no specific European Heritage sites would be directly affected by any floodplain management works proposed in this study.

2.3.2 Planning Controls

Great Lakes Council has in place a number of planning instruments and policies that control development within the study area. These include the:

- Great Lakes Local Environmental Plan, gazetted December 1996, last amended June 2000;
- Subdivision Development Control Plan, adopted September 1999;

- Residential Development Control Plan for Urban Areas, adopted September 1999;
- Exempt and Complying Development Control Plan, adopted August 1999; and
- Flood Management Policy, adopted on 10 December 1985.

The relationship of these planning measures to floodplain management is discussed in Section 3.

2.3.3 Available Flood Free Land

Land in the Bulahdelah township area to the east of the Pacific Highway and north of the bridge over the Myall River will not be affected by flooding from the Myall River in all events, including an extreme flood event. Hence the most suitable site(s) for evacuation of people and their possessions during floods will be located in this area. The existing plans for flood response are discussed in Section 3.

2.4 GREAT LAKES COUNCIL ENVIRONMENTAL PRIORITIES

Great Lakes Council's 1998/99 State of the Environment Report described progress made in relation to a series of high priority issues. High priority issues, first identified in 1994 are:

- determining the extent, flow, distribution, volume and quality of groundwater;
- lack of monitoring programs for a variety of surface and groundwater parameters;
- catchment management;
- mapping of stormwater outlets, drains and sewer overflows, including retention basins;
- mapping flood levels;
- vegetation loss;
- core habitat areas for bio-diversity;
- protection and management of wildlife corridors;
- rates of vegetation loss;
- contaminated sites, solid waste management; and
- acid sulfate soils.

This report assists in flood level mapping in the Bulahdelah area.

2.5 SOCIAL CHARACTER

Great Lakes Council area is made up of a number of distinctly separate communities, of which Bulahdelah is one.

The population of Great Lakes grew at a rate of greater than 2% per annum from 25,997 in 1991 to 28,609 in 1996. During this period the population of Bulahdelah rose at 0.38% per annum from 1092 to 1113.

Whilst the overall population of Bulahdelah was relatively static from 1991 to 1996, the age distribution of the population has changed. The population below 20 is relatively static, with the population from 20 to 59 decreased by 10% and the population above 60 rise by 20%.

These figures indicate that the population at Bulahdelah is relatively stable in number but is increasing in age.

2.6 FLOOD BEHAVIOUR

2.6.1 Assessment of Flood Behaviour

Bulahdelah is affected by flooding from both the Myall River and from local overland flow generated from the local catchments which drain through the urban area to the Myall River. This report deals only with flooding from the Myall River and its main tributaries and builds upon previous work including:

- Bulahdelah Flood Appraisal, by NSW Public Works, October 1991; and
- Frys Creek Flood Study, by NSW Public Works, July 1994.

There has been no recent study of flood behaviour in the Crawford River.

A review of these studies and associated additional works was undertaken as part of this study to model the flooding within the entire study area. Modelling in this study was based upon surveyed cross sections and calibrated against historical flood level information from the 1987 flood event. The calibrated model was to derive 1%, 2% and 5% AEP and extreme event flood levels for Bulahdelah.

2.6.2 Results of the Flood Analysis

Results of the flood analysis are discussed in detail in Appendix A and summarised below.

Flood contours and hazards and hydraulic for the 1% AEP flood event are provided in Figure 2. This figure indicates a range of flood levels from 5.6 to 6.1m AHD from upstream of the Pacific Highway to Lee Street at Bulahdelah. Peak average mainstream flow velocities vary from 3.1m/s in the vicinity of Lee Street to 1.3m/s upstream of the confluence of the Crawford River with velocities increasing as flow approaches the Pacific Highway. Peak average overbank velocities on the eastern side of the Myall River vary from 0.4 to 0.8m/s. The flood levels for the 1% and 2% AEP events appear to be similar to the 1897 and 1927 flood levels respectively in this vicinity.

Flood behaviour will be similar in an extreme event, with flood levels generally in the order of 1.8m higher than the 1% AEP flood event with flood extents (shown on Figure 2) marginally larger, but constrained by the rising ground levels around the floodplain.

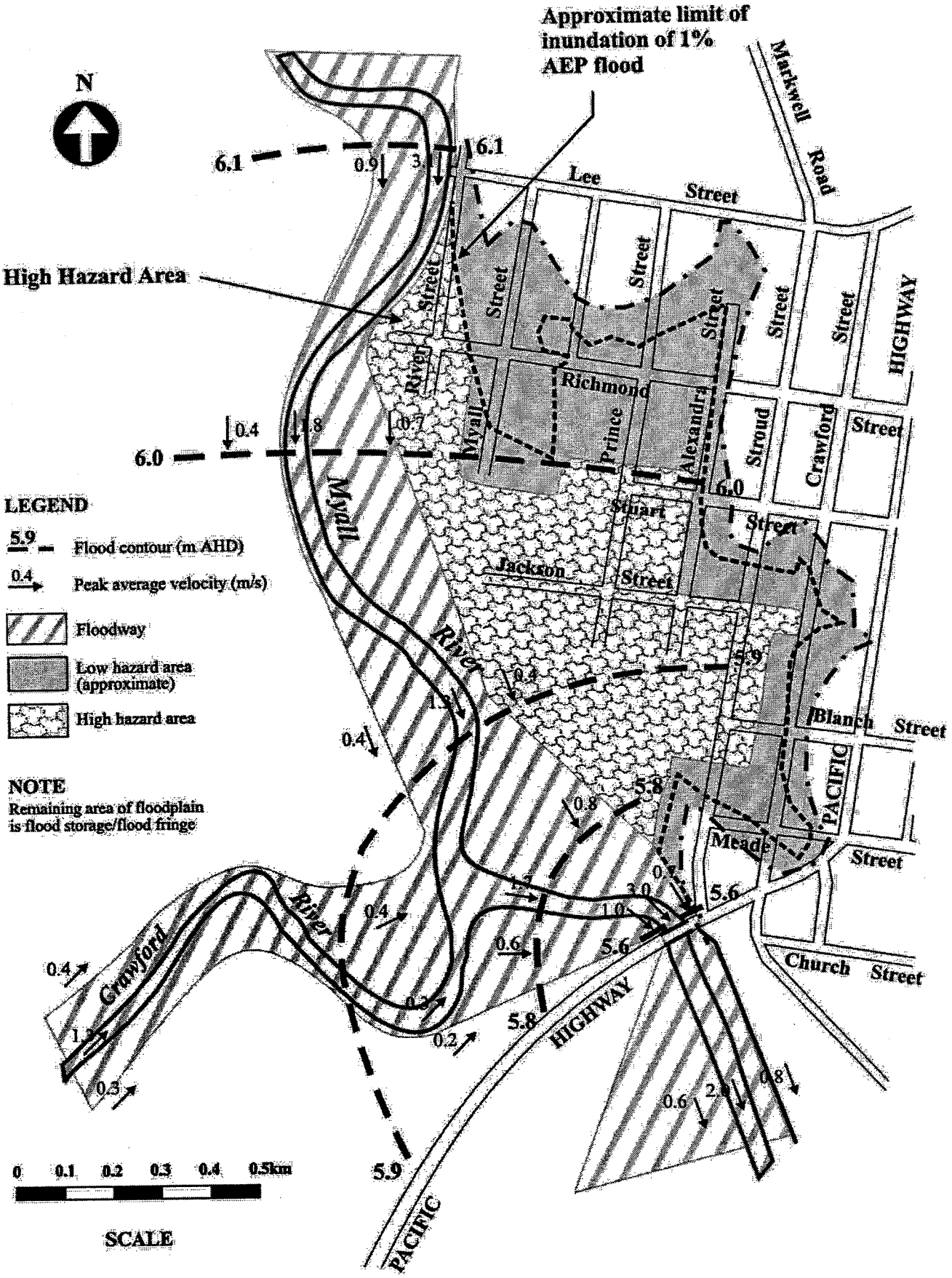
The derivation of flood hazards is discussed in Appendix B and considers flood depth and velocity and considers the short evacuation distances near the edge of the floodplain. The majority of the hazard is related to the depth of floodwaters, as the backwater flooding from the river would have low velocity. However, local runoff may result in higher velocities in major drainage flowpaths across the floodplain.

Hydraulic categories, which indicates that floodways, the area in which the majority of flood flow would occur, in confined to the vicinity of the river. The remainder of the area would be flood storage and flood fringe.

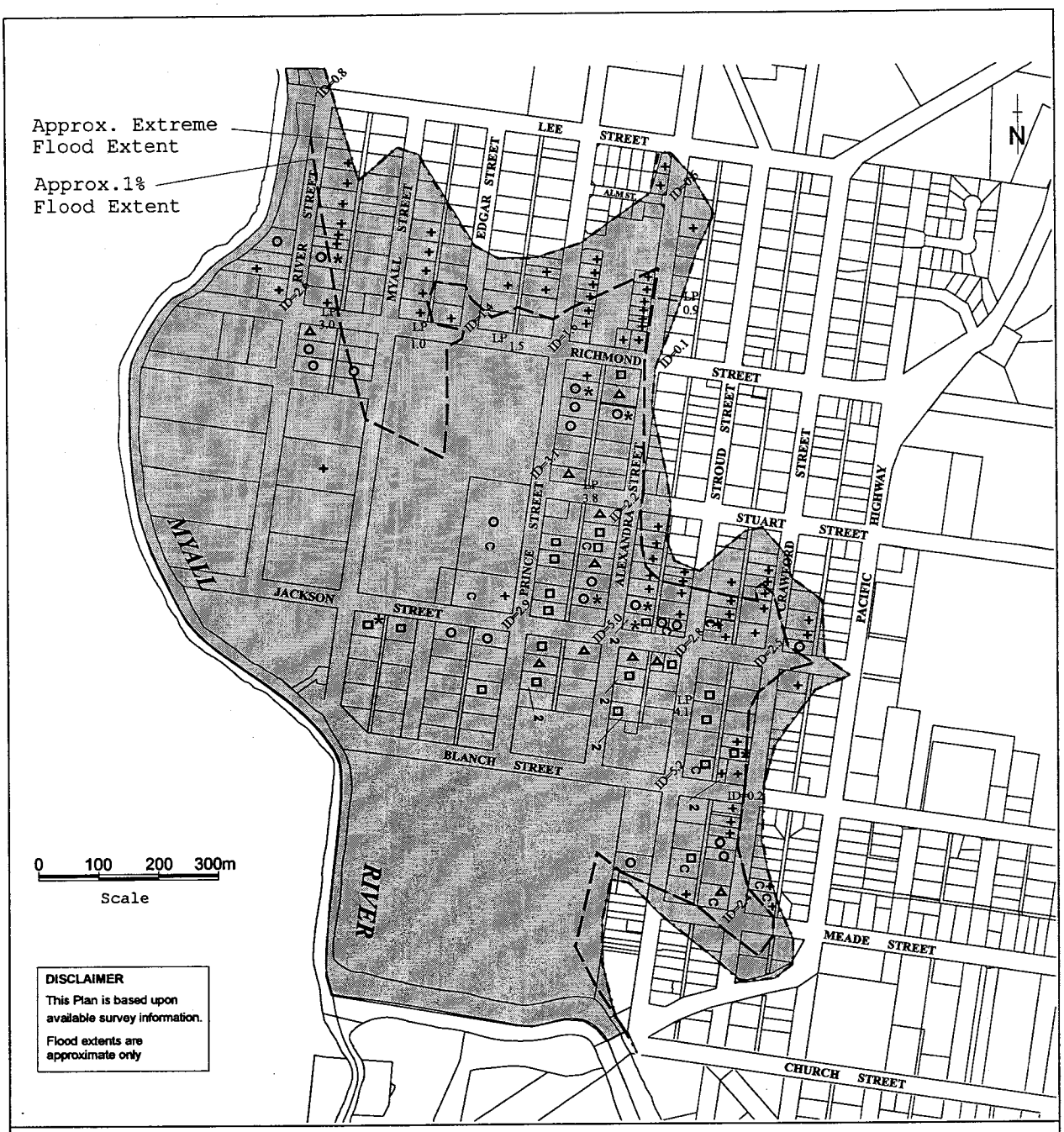
Figure 3 indicates the properties inundated above floor level in different flood events, based upon a recent survey. Figure indicates the approximate extents of the 1% AEP and extreme flood events within the township based upon available ground level information. This shows that a significant area west of Stroud Street and South of Richmond Street would be inundated in a 1% AEP flood event. This area is affected by backwater flooding rather than being a major conveyance area for river flood flows. Therefore the flow velocities are relatively low, though water can be quite deep.

Figure 3 also indicates approximate depths of water at intersections in an extreme event. Water depths in a 1% AEP event would generally be 1.6m lower than the extreme event. Local overland flooding may result in increased water depths across roads or in water across roads in other locations.

Flood levels for the 2%, 5% are provided in Appendix A, and Figure 4 provides an indication of the relative levels of floods in Bulahdelah township in relation to a house built at the Flood Planning Level.



APPROXIMATE FLOOD EXTENTS & 1% AEP HYDRAULIC & HAZARD CATEGORIES
Figure 2



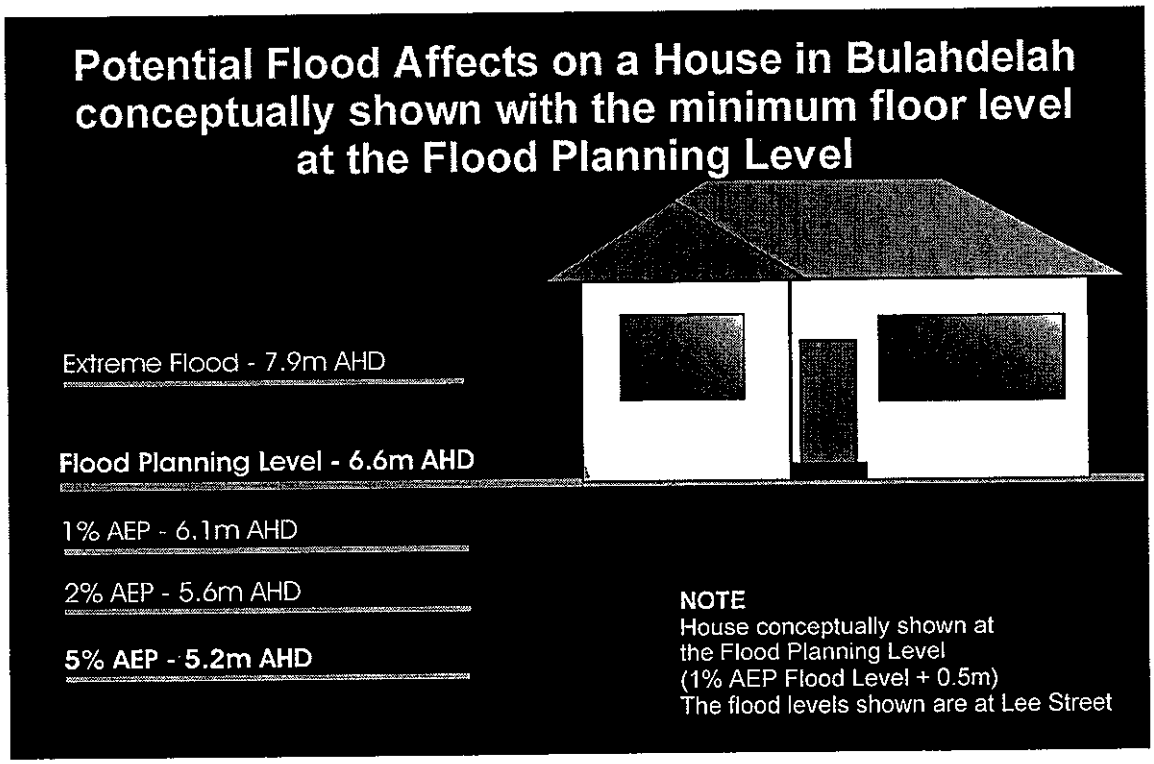
LEGEND

+	above 1% to Extreme Flood Level	◁	above 5% below 2%	*	Below 1% flood level and unsuitable for house raising
o	above 2% below 1%	□	below 5%	2	two storey - flooding relates to ground floor if built in
				C	Commercial/Industrial All others are residential
				ID=	Depth at intersection in Extreme Event
				LP	Depth at Low point in Extreme Event

MYALL RIVER FLOODPLAIN **MANAGEMENT STUDY AT BULAHDELAH**

PROPERTIES INUNDATED ABOVE FLOOR LEVE IN VARIOUS FLOOD EVENTS

Figure 3



RELATIVE LEVEL OF FLOODS AT BULAHDELAH

Figure 4

3. EXISTING FLOODPLAIN MANAGEMENT

Floodplain management at Bulahdelah currently involves a number of different measures aimed at addressing future and continuing flood risk. These measures involve development control using planning instruments and policies, as indicated in Section 2.3.2, and emergency response planning as identified in the Local Flood Plan for Great Lakes Council.

The role of the individual documents in floodplain management are discussed separately below.

3.1 GREAT LAKES LOCAL ENVIRONMENTAL PLAN 1996

The Local Environmental Plan (LEP), last amended in June 2000, indicates that the urban areas of Bulahdelah are zoned as Zone 2 Village with construction of dwellings compatible with this zoning. Areas within the floodplain outside the village are zoned as Zone 1(a) Rural with agricultural activities compatible with this zoning.

In relation to flooding, several provisions of the LEP are relevant. Clause 11 – Land Form Modification has the objective to control soil erosion, sedimentation and drainage impacts associated with land form modification. This clause indicates that filling or excavation is generally only permissible with the consent of Council. Consent may not be necessary, where in the opinion of Council the filling or excavation will not significantly affect the natural and existing built environments.

Clause 18 allows for the construction of 2 attached dwellings on a rural property with Clause 19 indicating that the minimum area of land upon which a dwelling can be built in a rural 1(a) zoning is 40 hectares unless a smaller parcel of land comprises the whole of the allotment.

Clause 25 – Waterways includes information on flood liable land. Flood liable land is not separately identified on an LEP map. This clause indicates that development on flood liable land requires Council consent and regard for Council's Flood Management Policy. Council may refuse development on flood liable land that, in Council's opinion, could significantly affect flood behaviour, increase flood hazard or damage, cause riverbank erosion, increase risk to human life, restrict the capacity of the floodway, or impose increased demand on agencies concerned with evacuation procedures.

Schedule 1 of the LEP indicates development not requiring consent. Section 11 enables Council or the Department of Land and Water Conservation to undertake flood mitigation works other than the erection or substantial modification of buildings and the formation or alteration of any access road without requiring development consent.

3.2 SUBDIVISION DEVELOPMENT CONTROL PLAN, SEPTEMBER 1999

This DCP contains provisions for subdivision planning. Section 1.3.5 indicates the need for a Statement of Environmental Effects to demonstrate consideration has been given to the environmental impact of the development and sets out measures taken to mitigate any likely adverse environmental impact. This statement would need to address the potential impact of development on flood levels. Therefore flooding is one of a number of issues that requires consideration when determining the suitability of a site for subdivision.

Section 2 deals with general requirements for subdivisions in all zones. Section 2.3, identifies the need to address site hazards at the development application stage. If flooding is identified as a site hazard, subdivision design should minimise the risk of inundation to urban development. Section 2.3.2, Controls and Design Principles, provides requirements for flooding which include:

- the extent of development and minimum floor levels are to be in accordance with the recommendation of Council's most recent flood risk assessment;
- subdivision layouts are to be based on a strategy for surface water drainage which minimises the incidence of nuisance flooding.

Section 2.7.2 Drainage Controls and Design Principles also indicates consideration needs to be given to the likely effects of flooding in determining an application. This appears to mean that local overland flooding (or drainage) needs consideration.

3.3 RESIDENTIAL DEVELOPMENT CONTROL PLAN FOR URBAN AREAS, SEPTEMBER 1999

This DCP does not contain specific provisions relating to flooding. It does however contain provisions that enable solid front fences or walls to be built to at least 1.2m height, and up to 1.8m height in certain circumstances. This may have implications for the free flow of water in flood liable areas.

Council's Local Approvals Policy of May 1996 states that fences (other than for swimming pools) are to be constructed so that they do not prevent the natural flow of stormwater drainage. This would be a suitable provision to extend to fences in flood liable areas.

3.4 EXEMPT & COMPLYING DEVELOPMENT CONTROL PLAN, AUGUST 1999

This DCP identifies types of and specifies the requirements for developments to be considered exempt and complying and outlines the procedures for obtaining certification of exempt development.

3.4.1 Exempt Development

Exempt development is very minor development which does not require Council approval provided it meets the requirements set out in this DCP.

Most categories of exempt development are unlikely to have an impact on the flooding in Bulahdelah, which is characterised by backwater flooding.

In rural areas Machinery/Hay Sheds and stables are allowable in rural land. However the requirement for these to be located a minimum of 40m from the top of bank of a stream, creek or watercourse would mean, in the context of flooding at Bulahdelah, that they would be outside floodway areas and therefore would have little impact on flood levels.

River and foreshore improvement works are permitted as long as their purpose is to repair damage caused by natural or human processes or activities to the river. These are exempt where a river care plan has been prepared on behalf of the local authority and a management plan for the public land has been prepared by or on behalf of the Public Authority managing the land. In addition, the approval of the NSW Fisheries and Department of Land and Water Conservation may also be required.

This would be applicable for any environmental improvements or enhancements being considered in the vicinity of the Myall River as part of this study.

3.4.2 Complying Development

Complying development is small scale low impact development which may be certified by an accredited private certifier or by Council if it meets the non-discretionary requirements set out in this DCP.

Development of land below the 1% AEP flood level is not considered to be complying development. Any filling of land below the 1% AEP level would require separate council consent. Therefore complying development is not applicable to the majority of flood liable land.

3.5 FLOOD MANAGEMENT POLICY

Council's Flood Management Policy was adopted on 10 December 1985, before the New South Wales Government's 1986 Floodplain Development Manual and the subsequent Floodplain Management Manual 2001. Council's policy aims at providing the community with the basis of Council's assessment of development on flood liable land, recognises the existing development and resources in flood liable areas and their value to the community, and encourages flood compatible development of flood liable land.

The policy does not require different floor height requirements for different land use categories but provides Council with the flexibility to allow for altered conditions in building extensions. The policy indicates that rezoning of flood liable land to uses incompatible with the flood situation will not be approved by Council.

The 1% AEP flood levels adopted for planning purposes in the Bulahdelah area are the levels given in the Bulahdelah Flood Appraisal and the Frys Creek Flood Study. There is little difference between the levels indicated in this report and those previously used for flood planning purposes.

There is an inconsistency in the application of minimum floor levels as discussed in Section 5.3. Other issues with the policy are discussed in Section 5.

3.6 FLOOD PLANNING LEVEL

Great Lakes has adopted the 1% AEP flood as the planning level flood for the Bulahdelah area. Thus the area of land below the 1% AEP flood level is subject to flood related development controls. Review of the planning level flood is discussed in Section 5.3.

3.7 FLOOD RESPONSE PLANNING

Flood response planning has been addressed by the Local Emergency Management Committee in a sub-plan of the Great Lakes Local Disaster Plan called the Great Lakes Local Flood Plan (draft September 1995).

The State Emergency Service (SES) has prepared a Local Flood Plan for the Great Lakes Council area. The plan covers preparedness measures, the conduct of response operations and the co-ordination of immediate recovery measures for flooding within the Council area, including Bulahdelah.

The plan includes a guide to the content of evacuation warning messages and identifies the Bulahdelah Central School in Meade Street as the site to be used as the evacuation centre. This site is located on flood free land on the east side of the Pacific Highway and is in close proximity to the inundated areas.

3.8 FLOOD WARNING

The Bureau of Meteorology does not issue flood warnings for watercourses within the Great Lakes Council area. However, in accordance with the Local Flood Plan the State Emergency Service (SES) personnel and the Bulahdelah Rescue Squad monitor developing floods on rivers, creeks and lakes, including the Myall River at Bulahdelah.

There were two gauges monitored on the Myall River near Bulahdelah. The first is an automatic gauge on the Pacific Highway bridge over the Myall River (AWRC No 209460) with river height information downloaded by facsimile using the computerised river watch (flood-to-fax) system maintained by the Department of Public Works and Services. The second gauge was at Markwell and was a manually read by the Bulahdelah Rescue Squad during flood events. This gauge was removed as part of the reconstruction of Markwell Bridge around 2 years ago. The local flood plan does not indicate any monitoring or existence of gauges on the Crawford River. Gauge monitoring results are provided along with advice on actual and anticipated flood severity to the Lower Hunter SES Division Headquarters for broadcast over local radio stations in SES Flood Bulletins.

Because of the infrequent nature of flooding and the limited monitoring facilities in the upstream Myall River and Crawford River catchments, there is little historical data on which flood forecasting and warning procedures can be based. This applies particularly with respect to identifying the need and maximising the available time for possible evacuation in a major flood.

4. EMERGING ISSUES IN BULAHDELAH

At this stage there is are two particular large scale issues that may impact upon floodplain management at Bulahdelah. These are the Pacific Highway Upgrade at Bulahdelah and major drainage.

4.1 Pacific Highway Upgrade

The assessment of options for the upgrade of the Pacific Highway at Bulahdelah has been completed following assessment of public comment received by the Roads and Traffic Authority (RTA) with the Eastern Bypass nominated at the preferred route. Detailed assessment of the impacts of options on flooding will be completed after modelling for this study is complete. However, a review of the findings of the preliminary investigations to date and associated recommendations for this option are given below.

PPK undertook preliminary investigations for the RTA to assess the upgrade options for the Pacific Highway at Bulahdelah. This did not involve any work in relation to sizing the structures associated with options.

The eastern bypass option will result in additional bridge structure(s) over the Myall River below the township. The new structure(s) may have an impact upon flooding at Bulahdelah unless appropriately designed. The report indicates that assessment would need to be made of the 1% AEP event to ensure that no increase in flood level occurs.

However, it is recommended that the assessment of impacts for the 5%, 2% and 1% AEP events to ensure that there are no flood level increases in the township in each of these design event. In addition a check should be made of the impacts on levels in an extreme event (3 x 1% AEP in peak and volume) to ensure that the increases in this event are not large and that flowpaths in a major event are not significantly altered. This will ensure that considerations are given to the range of events that can have a significant impact on Bulahdelah.

The eastern bypass option provides some additional benefits to Bulahdelah relating to reduction in catchment area to existing local drainage systems and the subsequent potential to reduce existing local drainage problems impacting upon the community. The impact on flooding from the Myall River will, however, be negligible and the assessment of these impacts is considered outside the scope of this study.

Overall, the floodplain management study assumes that the Pacific Highway upgrade at Bulahdelah will have no net impact upon flooding at Bulahdelah.

4.2 Major Drainage

The community consultation highlighted major drainage problems as a significant issue in Bulahdelah. Council has engaged a consultant to undertake works to assess major drainage problems and investigate solutions. Major drainage problems have been included in the 2001 Floodplain Management Manual but had not been included in the its predecessor, the 1986 Floodplain Development Manual.

The Bulahdelah Flood Risk Management Plan should highlight the importance of completing the drainage study and the need to update the plan considering appropriate management options (including development controls, mitigation works and flood awareness) as identified in the study. Some works may be eligible for subsidised funding, where it they are in a major drainage area. Funding is discussed in Section 7.

5. OPTIONS TO IMPROVE FLOODPLAIN MANAGEMENT

This section considers options to changes current floodplain management practices in Bulahdelah to address existing, continuing and future flood risk.

The objectives of floodplain management and the basis for assessment are discussed followed by the improvements that can be made to council's existing flood risk controls. The report then assesses floodplain management options and their effectiveness.

5.1 OBJECTIVES

The objectives of floodplain management are aimed at managing the danger to personal safety caused by flooding and managing the damage to property resulting from flooding. The management of these risks can be broken down into three areas:

- management of existing flood risk (the risk faced by existing development in the floodplain);
- management of future flood risk (the risk that would be faced by future development in the floodplain); and
- management of continuing flood risk (the risk remaining after adopted floodplain management options have been implemented).

Floodplain management options are available to manage these risks. These options can be broken down into the following three categories:

- property modification measures,
- response modification measures; and
- flood modification measures.

Examples of options available under these categories provided in Table 5.1

Table 5.1 Typical Floodplain Management Measures

Property Modification Measures	Response Modification Measures	Flood Modification Measures
Zoning and development control	Community awareness	Flood control dams & retarding basins
House raising	Community readiness	Levees and associated flood gates
Flood proofing of buildings	Flood prediction and warning	Bypass floodways
Voluntary purchase	Local flood plans	Channel improvements

Property modification measures aim at either altering existing development or placing controls on future development to minimise the potential danger to personal safety and the degree of damage due to flooding. Therefore property modification measures generally deal with existing or future flood risk.

Response modification measures make the community flood aware, developing an appropriate community response to flood events, and having local response agencies develop flood emergency response plans. These measures are generally used to deal with the continuing flood risk.

Flood modification measures, aim to modify the flood through the use of structural works. These measures are generally used to manage existing flood risk, though may also consider future flood risk. However, Commonwealth and State government funding would only be available for these works where they are designed to deal with existing flood risk.

5.2 BASIS FOR ASSESSMENT OF FLOODPLAIN MANAGEMENT MEASURES

Assessment of management options is undertaken relative to their effectiveness in meeting the objectives identified in Section 5.1 and the following additional criteria:

- environmental impact in relation to the affects of any proposed works;
- opportunities for environmental enhancement;
- affect on the community and the associated community support and acceptance;
- economic efficiency; and
- ability and capacity to implement measures.

5.3 REVIEW OF THE FLOOD PLANNING LEVEL

As indicated in Section 3.6, the 1% AEP flood event forms the basis of existing development control at Bulahdelah. In reviewing the Flood Planning Level the following have been considered:

- The ground level at the fringes of the floodplain increases steadily limiting any additional area of inundation due to a small rise in flood level. Therefore variation of the planning level flood (eg raise to the 0.5% AEP flood or lower to the 2% AEP flood) would not have a major effect on the area of land subject to flood related controls.
- There is land below the 1% AEP flood level that is available for development.
  - Development of the available land based upon the current controls related to the 1% AEP flood level, will not significantly increase flood damage, however, it will increase the amount of people in areas at risk of flooding;
  - Developing this land to a reduced flood planning level will be inconsistent with previous development control decisions. In addition it will increase the level of flood risk in Bulahdelah relative to adopting the current development controls; and
  - Developing with a higher flood planning level will have only a minimal effect on flood damage potential.
- The estimated 1% AEP flood levels in Bulahdelah are higher than recorded historical flood levels in the area. However on three occasions (in 1897, 1927 and 1947), the historical flood levels came to within 0.1 to 0.5m of the 1% AEP flood levels. Hence, the 1% AEP event is considered to provide a reasonable planning level flood relative to the experience of flooding in the area.
- There is scope for a flood warning system and associated improvements in emergency management planning (including evacuation) at Bulahdelah to limit the danger to personal safety in future development areas in floods greater than the 1% AEP flood.
- The flood behaviour in the extreme event is very similar to the 1% AEP Flood, though the flood levels are around 1.8m higher, the velocities slightly increased and the warning time shortened due to the quicker rise of the flood.
- The flood levels currently used for development control are very similar to those used to derive the Flood Planning Level. Council had previously adopted a set figure of 5.9m AHD for the 1% AEP flood level for Bulahdelah. This report recommended the use of a variation from 5.6m AHD (near the Pacific Highway Bridge) to 6.1m AHD (near Lee Street). This is unlikely to significantly impact upon existing development with the only potential impact in areas where the new flood level is higher than the previously applied level. If the new level was strictly applied to control the floor levels of extensions in this area it would impact upon the practicality of extensions. However, adopting a merit based approach to extensions (which is recommended), allowing them to be at the same level as the existing floor level, would negate this issue. In addition, given there is only a difference of 0.2m between the old and maximum new control this change should not significantly impact on streetscape issues.

In considering this information, there appears to be no valid reason to alter the current development control practice. Therefore it is recommended that development control remain linked to the 1% AEP flood event.

However, as indicated in Section 3.5, one particular inconsistency in the flood policy relates to land filled to or less than 0.2m above the 1% AEP flood level. If a property was 0.1m below the 1% AEP flood level the required minimum floor level would be 0.5m above the 1% AEP flood level. However, if the property was at or above the 1% AEP flood level only a minimum floor level of 0.3m above the ground would apply. This situation means that freeboard above the 1% AEP flood level to account for wave action, local hydraulic effects and other factors is not being consistently applied.

It is recommended that a flood planning level (FPL), of 0.5m above the 1% AEP flood, be adopted for development control. All land below this FPL would have a minimum floor level set at the FPL, removing this inconsistency. This has impacts upon Council's Flood Management Policy. Review of the policy is discussed below.

5.4 REVIEW OF THE FLOOD MANAGEMENT POLICY

Council's Flood Management Policy, adopted in December 1985, is described in Section 3.5. This policy aims at providing the community with the basis of Council's assessment of development on flood liable land, recognises the existing development and resources in flood liable areas and their value to the community, and encourages flood compatible development of flood liable land.

The policy requires revision to address the following issues:

- Revision of definitions to avoid confusion with the new Exempt and Complying Development DCP and to reflect current terminology in the floodplain management field.
- Council considers the hazard, hydraulic, land use and development categories when assessing developments. The hazard categorisation methodology recommended in the policy is preliminary only and should be over ridden by assessments in floodplain management studies for specific areas.
- Tables 1 to 6 of the Council's Policy are similar to those in the 1986 Floodplain Development Manual. This manual has been replaced with the Floodplain Management Manual (2001) which have revised tables that are to only be used in limited situations. In addition, special classifications for developments such as caravan and mobile home parks are included. Therefore the policy should limit the use of tables to areas where studies are yet to be undertaken and care should be taken in their use. Flood hazards for Bulahdelah for the 1% AEP flood event are indicated on Figure 2 and discussed in Section 2.6.
- The adoption of the 1% AEP plus 0.5m adopted freeboard as the Flood Planning Level for minimum floor levels for habitable development removes inconsistency in freeboard application. This criteria applies to all properties totally or partially below the FPL, ie, in the flood planning area.
- The basis for flood levels for development control in Bulahdelah should be the flood study review carried out as part of this management study and documented in Appendix A of this report.
- Appendix A of the flood policy relates to the NSW Government's Flood Prone Land Policy. This should be deleted as much of the background information is not relevant some 16 years after adopted of the policy and can refer to the Floodplain Management Manual: The Management of Flood Liable Land (2001).
- The policy also needs updating to make it consistent with the Floodplain Management Manual including the need to address issues such as major drainage, and flood awareness and education.
- The revised policy should be been renamed the Flood Risk Management Policy to be consistent with the Floodplain Management Manual.

- Emergency management in the extreme flood event should also be considered. This is particularly important in areas without direct evacuation routes to ground above the extreme flood levels. This is generally not an issue in Bulahdelah but may be for other areas of the Great Lakes Local Government Area.
- The policy should also outline information to be provided on Certificates under s149 of the Environmental Planning and Assessment Act (1979). This is discussed in Sections 3.2.4 and L6 of the NSW Government's Floodplain Management Manual with typical examples provided in Section L6.2 to L6.4.

5.5 CHANGES TO DEVELOPMENT CONTROLS

There are currently a range of planning and development provisions in place for flood liable land within the Great Lakes LGA. These provisions are contained in various documents (Policy, LEP, etc.).

There appears to be a case for centralising flood provisions in one document; eg a flood specific Development Control Plan (DCP), to cover all developed areas of the LGA, including Bulahdelah. This would facilitate Council's administration of floodplain management controls, as well as the community's understanding. In the interim the revision of Council's Flood Risk Management Policy, as discussed above, would improve the consistent control of development in Council's floodplains.

The LEP provisions are considered adequate in respect of flooding when used in conjunction with the relevant DCPs and the Flood Risk Management Policy.

5.6 CHANGES TO FLOOD RESPONSE PLANNING

A detailed evacuation plan should be prepared to establish evacuation procedures for Bulahdelah, including identification of preferred evacuation routes based on the flood hazard.

Figure 3 of this report indicates the potential flood extents, the properties likely to be affected above floor level in different flood events, and potential depths at intersections in an extreme event. The houses affected in more frequent events would generally need evacuation earlier in a flood event. The intersections with deeper inundation in the extreme event would generally be closed to traffic earlier in flood events, although location drainage paths may also impact on road closures. It is suggested that Council liaise with the SES in order to advance the development of a detailed local flood evacuation plan. The plan should recognise that floods greater than the 1% AEP event may occur. The local flood plan could use the information on Figure 3 of this report as the basis for considering evacuation logistics. Flooding early in a flood event is likely to impact on the following intersections:

- Stroud Street between Jackson Street and Meade Street,
- Jackson Street between Prince Street and Alexander Street, and
- Stuart Street between Prince Street and Alexander Street.

Some specific issues that should be addressed in the Local Flood Plan include:

- Annex A identifies the flood threat. A higher level of detail could be provided for the Myall River at Bulahdelah similar to the information on Wallis Lakes.
- Annex B indicates specific risk areas. Some additional information could be included for Bulahdelah relating to typical warning times, likely depths of water in some areas, evacuation routes and early road closures. In addition, the provision of depth indicators may improve safety in low points.
- Annex D provides a guide to the content of evacuation warning messages. Map 1 indicates that the Bulahdelah Rescue Squad (Volunteer Rescue Association) is designated as operating in Bulahdelah.

It would be useful if maps of townships indicating critical areas such as, evacuation routes and centres likely to be used for evacuation in significant flood events, were included. The plan for Bulahdelah township could be based upon Figure 3 in this report.

- The current flood warning procedures are informal and rely on empirical information and the decisions of individuals based upon general Bureau of Meteorology warnings. These warnings give no prediction of timing or specific severity to enable plans to be enacted. If a formal warning system were to be developed for Bulahdelah more detailed procedures for information dissemination would be required including the timing of information and expected warning triggers. The procedures would need to consider the differences in an extreme event resulting in faster rise of water, less evacuation time and longer flood duration.

5.7 PRELIMINARY OPTION ASSESSMENT

Preliminary assessment of the floodplain management options indicated in Table 5.1 was used to reduce the options to be considered in detail by examining their appropriateness and effectiveness. Preliminary assessment of options is discussed under the categories of property, response and flood modification measures.

5.7.1 Property Modification Measures

Potential property modification measures are indicated in Table 5.1. Their appropriateness to the flood situation at Bulahdelah and therefore the need for detailed assessment is discussed below. In general, property modification measures have little adverse impact on the environment but also offer little opportunity for environmental enhancement. However they do have implications in terms of economics and social issues and must be considered accordingly.

Zoning and development control can be used to control future flood risk and minimise the increase in potential flood damages and any additional danger to personal safety occurring due to increased development of the floodplain. These controls are already in place and are considered an appropriate management measure but could be improved by changes to the policy (Sections 5.3) and consolidation of measures into a single DCP (Section 5.4). This option is discussed further in Section 5.8.

Voluntary house raising is a management option used to reduce existing flood damages. Whilst its use is generally restricted to low hazard areas, in the case of Bulahdelah many of the houses proposed for raising are within a high hazard flood area. However, the hazard in these areas is due to the depth of flooding rather than the low flood velocities. Given the low velocities, the proposed flood warning system and procedures resulting in sufficient warning time and associated early evacuation, adequate community flood awareness and the relative short duration of flooding of the area, voluntary house raising is considered a viable option in this area. On this basis, there are some 37 existing dwellings affected by flooding above floor level that are suitable for raising. This option is considered viable and as such is discussed in detail in Section 5.8. However, it should be noted that voluntary house raising has little impact upon the danger to personal safety resulting from flooding.

Flood proofing of buildings usually relates to modifications to existing buildings or the use of particular construction materials in new buildings to reduce the structural damage likely to occur during a flood. Flood proofing of buildings does not address damage to contents or danger to personal safety resulting from flooding. Flood proofing is not as effective as voluntary house raising and therefore is not considered separately. It is necessary where filling to the FPL cannot be achieved or where Council provides some relaxation of minimum floor level requirements for minor extensions. Flood proofing provisions are incorporated into the draft flood risk management policy, included in Appendix D.

Voluntary purchase is generally appropriate in high hazard floodway areas and may be appropriate in high hazard flood storage areas where houses cannot be raised due to their construction. It removes both

the potential for flood damage and the danger to personal safety, by removing the people at risk and removing the need for others to rescue or assist in moving them. Voluntary purchase does, however, effectively limit land use to more flood compatible uses and should only be used where this is appropriate. There are 5 houses within the high hazard flood storage area and 3 within the low hazard flood storage area which are not suitable for raising and therefore voluntary purchase of some or all of these properties may be considered as part of an overall management scheme to reduce flood damages.

5.7.2 Response Modification Measures

Potential response modification measures are indicated in Table 5.1. Their appropriateness for use in Bulahdelah and therefore the need for detailed assessment is discussed below. In general, response modification measures have little adverse impact upon the social fabric of the community, have little impact on the environment, but offer little opportunity for environmental enhancement. However, they have a minor impact upon flood damages and therefore need to be considered in economic terms.

Community flood awareness involves the understanding that a flood problem exists and an understanding of what the community, as individuals, need to do in a flood event. This is desirable to reduce the danger to personal safety resulting from flooding. This will be considered in Section 5.8 in conjunction with community flood readiness, discussed below.

Community flood readiness is understanding and being ready to react appropriately in a flood event when informed by the relevant emergency response agency. This helps in reducing danger to personal safety resulting from flooding and may lead to reduced flood damages, where sufficient flood warning time is available to allow for the lifting or removal of house contents.

Flood prediction and warning are a valid floodplain management measure where the community is flood ready and the local emergency management committee has put in place appropriate plans to manage the communities response to a flood event and sufficient warning time is available. This option is considered in detail in Section 5.8.

Local flood plans are the plan developed by the local emergency management committee relating to how to respond to (and planning for recovery from) a flood event. They examine dissemination of warnings to the community and the roles and responsibilities of the different local authorities involved. These plans would include evacuation arrangements, where appropriate. The community is informed about these plans and any associated evacuation procedures as part of community awareness and readiness campaigns. The local flood plan prepared by the Local Emergency Management Committee for Great Lakes Shire, has been reviewed and recommendations for changes are discussed in Section 5.6. This forms part of the community flood readiness option in Section 5.8, as they are integrally linked.

5.7.3 Flood Modification Measures

Typical flood modification measures are listed in Table 5.1. Their appropriateness to the flood situation at Bulahdelah and therefore the need for detailed assessment is discussed below. Flood modification measures are likely to have adverse impacts upon the environment but may offer an opportunity for environmental enhancement. The options often have significant costs but can have significant benefits and therefore need to be considered in economic terms.

Experience indicates that flood control dams are generally not cost effective for flood damage reduction in cases comparable to Bulahdelah. This is because expensive embankment construction and a substantial storage area are required in order to effect a significant reduction in downstream peak 1% AEP discharges. Preliminary assessment of the Myall River and Crawford River catchments indicates that this situation would apply to Bulahdelah. An added problem in relation to Bulahdelah is the location of the confluence of the Myall and the Crawford Rivers just upstream of the township. Any structure on the Myall River needs to consider controls, or lack thereof, on the Crawford River. A flood control dam

is likely to have a significant environmental impact, affect reasonably large area of land, due to both for the dam wall and temporary upstream storage (during a flood event), and is likely to significantly increase upstream flood levels. Therefore a flood control dam is unlikely to be environmentally or economically viable and as such is not considered in detail.

Levees could be constructed to protect existing properties with low floor levels from inundation by floodwaters from the Myall River. They are a viable flood modification option and as such are discussed in Section 5.8. The height of the levees for control of the 1% AEP flood, the associated cost and land take and the impact on flood levels may prove prohibitive to this option.

Inundation is relatively deep in significant flood events and therefore there is little scope for cost effective reduction of 1% AEP flood levels by means of hydraulic modifications involving construction of additional flow paths (such as bypass floodways), to a level which would reduce inundation significantly. Therefore bypass floodways are not considered further.

The main channels of the Myall River and Crawford River are estimated to carry less than 40 per cent of the total flow under 1% AEP flood conditions at Bulahdelah. There would be scope to increase the proportion of channel flow to a small extent by means of works such as channel widening. The works would have to extend for a considerable distance downstream of Bulahdelah and even so, would only be expected to result in a minor reduction in 1% AEP flood levels. Channel works to modify the river capacity would have a significant environmental impact including flora, fauna and geomorphological issues and therefore channel improvement is not considered a viable alternative.

Another potential flood modification measure is an increase in the waterway area under the Pacific Highway. This may have some minor impact upon flood levels in the township, a maximum of 0.2m would be expected. However, with the significant depth of inundation within the township it is not expected to have a significant impact upon flood damages (the benefit cost ratio of less than 0.1) or significantly reduce the danger to personal safety. Therefore it is not considered a viable flood mitigation measures and as such has not been assessed further.

5.8 DETAILED OPTION ASSESSMENT

Following completion of the preliminary option assessment a list of options for detailed assessment was derived. This list includes:

- property modification measures including zoning and development control, and a combined examination of house raising, flood proofing and voluntary purchase;
- response modification measures including community flood readiness, flood prediction and warning, flood evacuation plans. These are often dealt with in local flood plans and community education and awareness; and
- a flood modification measure involving a levee system.

These measures are discussed individually below in relation to the criteria outlined in Section 5.2.

The State and Commonwealth Government may provide funding for undertaking some floodplain management measures as discussed in Section 7.

5.8.1 Property Modification Measures

Zoning and Development Control

Planning and development controls are important floodplain management measures in areas with ongoing development or re-development. Council indicates that development pressures in Bulahdelah are not high and Council has not identified any broad-scale land filling options.

Provisions relating to flooding are currently contained within a number of plans, policies and related documents of Council. Flood related planning and development controls should be centralised in one document; ie a Development Control Plan (DCP). The provisions of this DCP could cover all developed areas in the LGA including Forster, Tuncurry, Nabiac and Failford, as well as Bulahdelah.

Preparation of a flood-specific DCP would also provide an opportunity to update and add controls; eg specifying appropriate minimum floor levels according to land use, including design provisions to address privacy and drainage implications of filling to the flood level, appropriate fence construction methods, the impacts of waves in estuarine areas, and emergency response measures. These issues have been considered in Section 5.4.

In addition, the issue of further development at Bulahdelah needs to be considered. Whilst no development in the floodway areas identified on Figure 2 is recommended, the following recommendations are provided for the high hazard areas outside of the floodway which are also shown on Figure 2. The recommendations consider that installation of an appropriate flood warning system, instigation of an associated emergency management plan, and raising of community awareness will be undertaken. Without these components further restrictions on development would be recommended.

It is recommended that existing high hazard land not be subdivided further and development of properties in high hazard areas remain at the same density as current development, ie, generally single dwelling per lot.

Development or redevelopment of any of the existing sites needs to be cognisant of the flood situation, consider the flood planning level, and the potential flood and debris forces and evacuation issues. Certification of the structural adequacy for flood forces, including buoyancy, by a registered structural engineer, is recommended.

Where infill development is considered appropriate in high hazard areas closer to the river, but outside of the floodway, the following additional points need consideration. These are particularly relevant to properties to the west of River Street. Any development should meet the criteria outlined above and also be built away from the riverbank, toward River Street, the least hazardous area in these sites. Consideration should also be given to alignment any new development with existing development, where this is away from the river.

Voluntary House Raising, Voluntary Purchase and Flood Proofing

Voluntary house raising may be a practical measure to reduce the potential for flood damage to existing houses and their contents. It does not, however, address danger to personal safety. The survey identified 37 houses of timber or fibro-cement construction in the study area which would be inundated above their floor levels by the 1% AEP flood and which could be suitable for house raising. Of these 9 are in low hazard areas and 28 in high hazard areas.

Whilst voluntary house raising is generally restricted to low hazard areas, in the case of Bulahdelah the flood hazard is due to the depth of flooding rather than the low flood velocities. Given the low velocities, the proposed flood warning system and procedures resulting in sufficient warning time and associated early evacuation, adequate community flood awareness and the relative short duration of

flooding of the area, voluntary house raising is considered a viable option in this area. On this basis, there are some 37 existing dwellings affected by flooding above floor level that are suitable for raising.

The voluntary raising of these houses would have a negligible effect on flood behaviour nor would it be likely to have significant social impacts on the community, although streetscape issues may need to be considered.

The estimated cost of raising a fibro-cement or weatherboard house is around $30,000. The estimated cost of raising all suitable houses in the Bulahdelah area is $1,110,000. The economic benefit of raising these houses above the 1% AEP flood level, in terms of reduced flood damages, is estimated to be $1,035,000. Therefore the overall benefit-cost ratio of a voluntary house raising scheme would be about 0.93.

The benefit-cost ratios for individual houses will vary considerably with the regularity and depth of flooding. Table 5.2 indicates the benefits and costs for properties affected by above floor flooding in the 5%, 2% and 1% AEP events. The properties affected above floor level in these events are indicated in Figure 3. The houses below the 1% AEP flood level that cannot be raised are also highlighted.

This indicates that raising houses inundated in events up to and including the 5% AEP event has a benefit cost ratio of 1.87 providing an excellent damage reduction for the investment. Raising houses inundated in events between the 2% and 5% AEP has a benefit cost ratio of 0.58 whilst raising houses not affected by the 2% AEP event will have a benefit cost ratio of less than 0.2.

Table 5.2 Benefits/costs of House Raising dependant upon Regularity of above floor level flooding

Flooding Above Floor Level in AEP event	Indicative Cost	Benefit. Reduction in flood damages if houses raised to above 1% AEP level	Benefit to Cost Ratio
Between 2% & 1%	$420,000	$56,300	0.13
Between 5% & 2%	$240,000	$138,600	0.58
5% or more frequent	$450,000	$840,000	1.87

If voluntary house raising is adopted as a floodplain management measures the committee and council will need to consider the make up of the scheme and determine a procedure for it's implementation. Implementing the scheme could involve calling for expressions of interest from the affected public and offering funds to those interested in house raising in a priority order based upon depth of inundation. The council may also decide the scheme be limited to raising those houses affected by the 5% AEP or another appropriate flood event, where the economic return is higher.

Council also needs to consider floodplain management funding (discussed in Section 7) and particularly how the local component is funded. House raising schemes vary between councils with some Councils contributing toward the cost of damage reduction works in part or full and others not. The ability to implement the scheme may depend upon the option selected by Council and therefore the ability of the individual owners to contribute toward house raising. A part payment by Council may make house raising more affordable and implementation easier or more feasible.

Ensuring buildings being raised can withstand flood forces is an essential part of any house raising scheme. This may require special conditions in the Flood Risk Management Policy in relation to house raising and should incorporate the requirement for structural certification. A typical clause could be as follows:

House raising requires the raising of floor levels to a minimum of 0.5m above the 1% AEP flood level. In raising the house, all the materials used should be flood resistant and structurally sound in accordance with Council's Flood Risk Management Policy and considering the likely flow velocities in the floodplain. In determining design flood loadings consideration should be given to the additional loadings caused by flood debris. Information on flood levels and flow velocities in the area based upon current studies is available from Council. A certificate from a NPER registered Structural Engineer as to structural adequacy and appropriateness of material will be required prior to approval being given to raise the house.

As voluntary house raising does not deal with danger to personal safety it must be used in combination with an appropriate response modification measure. The local flood plan for Great Lakes deals with the flood situation at Bulahdelah. However, improvements could be made to this plan as discussed in Section 5.6.

In addition there is scope for flood warning and evacuation in Bulahdelah prior to the peak of a major flood event. If a high degree of flood awareness and readiness is maintained and an appropriate flood warning system is implemented, evacuation of properties could be achieved during the early stages of a flood in order to further reduce this risk.

Voluntary purchase of properties may be considered when it would be impractical or uneconomic to mitigate the effects of flooding in high hazard areas. The intent is to cease occupation of properties in high risk areas, in order to free both the residents and potential rescuers from danger to personal safety and to reduce damage costs in future floods. The inclusion of properties in such a scheme would be based on the level of hazard to each property such as remoteness from high ground and the combination of depth and velocity of floodwaters.

A voluntary purchase scheme at Bulahdelah would be much less effective in economic terms than voluntary house raising. For example, assuming an indicative purchase price of $120,000, giving the total scheme a cost of $960,000, the benefit would be $290,000 and the benefit-cost ratio would be 0.3.

Restricting purchase to those houses in high hazard areas would reduce the numbers to 5, the associated cost to $600,000, the benefit to $188,000 and therefore the benefit cost ratio would be 0.31, similar for the purchase of all non-raiseable properties with flood levels below the 1% AEP flood level.

However, restricting the voluntary purchase to the 3 properties below the 5% flood level (2 in the high hazard area), with flood depths of greater than 1m above floor level in the 1% AEP event has an indicative cost of $360,000, a benefit of $237,000, and a benefit-cost ratio of 0.66. It may be appropriate to consider these houses for voluntary purchase, if such a scheme were being considered.

5.8.2 Response Modification Measures

Community Flood Readiness

Ongoing education is necessary to ensure that the community in the floodplain has a high level of flood awareness (an accurate perception of the flood risk) and flood preparedness (knowledge of the appropriate course of action during a flood). Knowing what may occur and knowing what to do and being ready to do this is considered to be flood readiness. The flood preparedness message may be as simple as being aware of the need to react and listen to direction by the appropriate response agencies.

The most recent severe flood at Bulahdelah occurred in the 1950's. Given the time since the event and considering the arrival of new residents, and the tendency for the general level of flood awareness to diminish over time after floods in the absence of appropriate education campaigns the current level of

flood awareness is likely to be low. The Council in conjunction with the SES should conduct regular flood awareness campaigns, which could include measures such as:

- installation of permanent marks showing the levels reached by the largest historical floods;
- displays of plans indicating the flood situation;
- sending out regular information with rate notices; and
- SES displays and talks by SES officers to community groups.

Flood preparedness campaigns should educate the flood-affected community on issues such as:

- storage or removal of important items, memorabilia and treasured items as high as practicable and, at least, above the 1% AEP flood level;
- procedures for lifting and evacuation of possessions;
- provide an understanding of any warning system;
- indicating what is expected of individuals;
- indicate the roles of the various players in emergency management locally; and
- indicating where to evacuate to and who to report to once you arrive at the evacuation centre.

The estimated cost of an initial flood awareness and public education program would be between $5,000 and $10,000. The cost of ongoing activities to maintain flood readiness would be around $2,000 per annum.

Local Flood Plans

Improvements to the local flood plan will be necessary to make any flood warning system effective. It is suggested that Council liaise with the SES in order to advance the development of a detailed local flood evacuation plan. The plan should recognise that floods greater than the 1% AEP event may occur. Recommended improvements to the local flood plan are discussed in detail in Section 5.6.

Flood Warning and Predictions

As indicated in Section 3.8 the Bureau of Meteorology does not issue flood warnings for watercourses within the Great Lakes Council area. However, SES personnel and the Bulahdelah Rescue Squad monitor developing floods on rivers, creeks and lakes, including the Myall River at Bulahdelah including monitoring one gauge (Pacific Highway bridge over the Myall River). Information and advice on flood severity to the Lower Hunter SES Division Headquarters for broadcast over local radio stations in SES Flood Bulletins. Given the available information, the accuracy of predictions would have to be questioned.

Because of the infrequent nature of flooding and the limited monitoring facilities in the upstream catchments, there is little historical data on which flood forecasting and warning procedures can be based. This applies particularly with respect to identifying the need to evacuate and maximising the available time for possible evacuation in a major flood.

The critical storm on the catchment for the 1% AEP event is the 36 hour storm. Analysing this design storm indicates that there is typically 5 to 6 hours between the occurrence of the maximum rainfall intensity in the upstream catchment and the peak flood level at Bulahdelah due to catchment runoff. However shorter times can occur due to:

- shorter storms producing water levels of a similar magnitude;
- more severe storm intensities will result in water levels approaching critical levels for action and evacuation more quickly; and

- different spatial distributions may result in quicker flood level increases.

The potential warning time in most situations should be sufficient to warrant implementation of a flood warning system based on real-time monitoring of rainfall and river levels such as the "ALERT" system (Automated Local Evaluation in Real Time). The major components of an ALERT radio telemetry flood warning system for Bulahdelah would include:

- upgrade the Bulahdelah PWD Rain/River Gauge with ALERT Comms
- additional automatic rainfall/river height data collection station at Markwell on the Myall River upstream of Bulahdelah;
- 1 rain repeater station in the Upper Myall and one rain gauge in the Crawford River Catchment; and
- Software for Council's existing base station and contingencies.

Flood forecasting models would be required in order to provide predictions of flood heights using the data collected from the ALERT system together with meteorological forecasts. The hydrologic model (and possibly the hydraulic model) developed for the 1991 Flood Appraisal and upgraded for this study could be of assistance for this purpose. The models could be used to develop general relationships between catchment rainfall, river heights and flood levels at Bulahdelah. These relationships could then be readily applied during actual flood events.

The Bureau of Meteorology has completed a feasibility study for an ALERT based flood warning system for Bulahdelah which is with council. The capital cost of the system is estimated to be $63,000, with a maintenance cost of $5,000 per annum. The Council and State would need to contribute a total of $43,000, whilst the Bureau of Meteorology would contribute $20,000.

A comprehensive flood warning and evacuation system, supported by a flood awareness and public education program, would enable the potential flood damage to be reduced significantly. The system as outlined above would have an initial cost of $63,000 and a maintenance cost of $5,000 per annum. Based on an operating period of 20 years and a discount rate of 7% per annum, the present worth of total system cost is $115,000. It is estimated that the flood damages would be reduced by about 10 per cent (see Appendix A), leading to a present worth benefit of $195,000. Therefore the benefit-cost ratio of the system would be about 1.7.

In addition to the economic benefits the system would also provide the Bulahdelah Rescue Squad and SES with a better indication of the predicted flood level assisting them in concentrating their efforts on the properties likely to be affected.

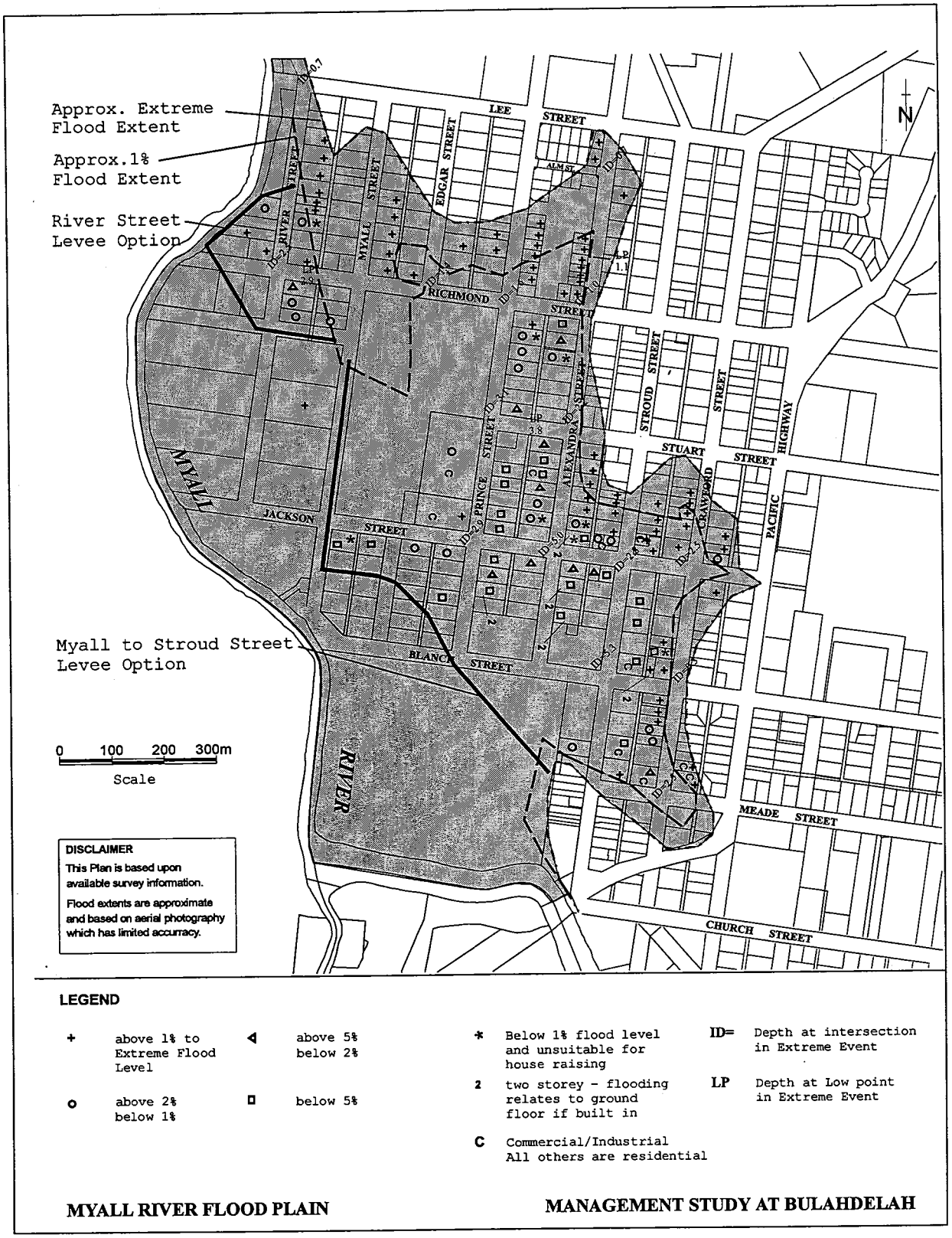
Overall, flood warning, with an appropriate response plan, enables a reduction of danger to personal safety due to flooding by providing a better indication of flood levels and more warning time for evacuation if used with a more formal flood response plan for Bulahdelah.

1.1.1 Flood Modification Measures

Levees

A number of levee options were considered with each allowing for 0.5m freeboard to crest level above the relevant design event. These were a 1% AEP levee for the River Street area and 1%, 2% and 5% AEP levees from Myall Street to Stroud Street. Indicative locations of these levees is shown on Figure 5.

The levees options were considered on the basis of earth levees with a 3m crest width and 1 in 4 side slopes.



POTENTIAL LEVEE OPTIONS FOR BULAHDELAH

Figure 5

The River Street levee only protects a small number of existing houses and provides a net present reduction in flood damages in the order of $36,000. Given the likely cost of in the vicinity of $600,000 for the 500m long levee this gives a benefit cost ratio of approximately 0.06. This levee is not viable, given that, it does not have a significant impact on flood damages, and there is little available space in River Street for the protection of houses in that area. Limited space would require a harder solution, such as a concrete levee, or the purchase of a number of properties to provide the space required for the levee significantly increasing the cost of the scheme. Both would increase the cost of the scheme.

The Myall to Stroud Street levee would protect a significant number of the houses inundated by flooding in the different design events. Different levels of protection were considered to assess benefits in relation to cost with results given in Table 5.3.

Table 5.3 Myall to Stroud Street Levee Options – Benefits relative to Costs

Level of Protection	Indicative Cost	Benefit. Reduction in flood damages	Benefit to Cost Ratio
1%	$2,400,000	$1,425,000	0.60
2%	$1,900,000	$1,120,000	0.59
5%	$1,500,000	$720,000	0.47

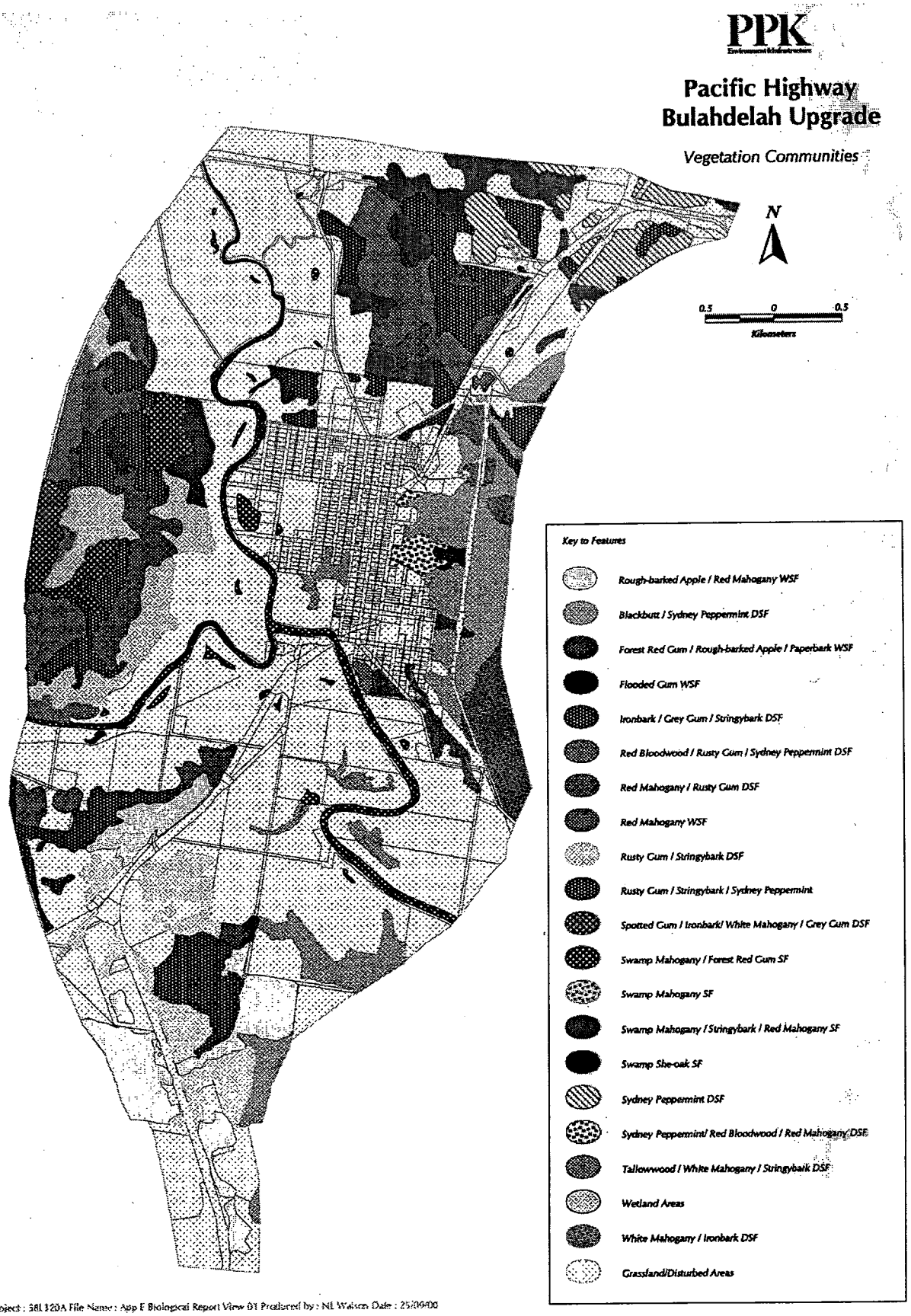
The 1% AEP levee would be around 950m long and would generally be in the order of 1.0 to 1.5m high. However, the height of the levee would approach 6m across the low point between Jackson and Stroud Streets. The levee would be around 4m higher than the centreline of Stroud Street. The high embankments may be visually intrusive and may reduce access to the river and therefore may not be readily accepted by the local community. Structures would be required through the levees to facilitate drainage of the local catchment areas behind the levees. The base width of the levee at the low point would be in the order of 50m meaning that drainage structures would be long and therefore expensive. Even with these structures local drainage problems may be exacerbated in the lower reaches of the catchment.

In addition, ancillary works such as detention basins and/or pumping may be required to protect against flooding from local runoff coincident with high river levels. These ancillary works have not been included in the estimates and allowances for drainage would need to be refined when these were sized.

In addition to the economic and social issues a levee may also have significant environmental impacts with the need to remove existing vegetation in the vicinity of the riverbank, particularly in the River Street area.

Two threatened fauna species have been recorded in the vicinity of the Myall and Jackson Street intersection. These species are the masked owl (*Tyto novaehollandiae*) and squirrel glider *(Petaurus norfolcensis*). The squirrel glider is an arboreal mammal dependent on mature trees with small hollows for den sites, foraging on plant exudates and arthropods in open forest and woodland communities. The masked owl is dependent on mature trees with large hollows for roost and or nest sites. This species is sensitive to a reduction in prey species associated with clearance of habitat.

The vegetation community identified by PPK (2000) (Figure 1 of the Biological report included as Figure 6 of this report) as occurring where a proposed levee would be situated between Jackson and Meade Street is characterised by very tall, mid-dense to dense blackbutt (*Eucalyptus pilularis*) and Sydney peppermint (*E. piperita*) with a sparse, tall to very tall mid-stratum with *Dodonaea triquetra, Allocasuarina torulosa* and *Melaleuca nodosa* and blady grass (*Imperata cylindrica*) mid-dense understorey. This community is generally not well-conserved and in other locations, has been known to provide suitable habitat for the threatened plant *Tetratheca juncea.* It may be possible to re-route a levee around this vegetation community. This re-routing would extend the levee by between 250 and 300m adding around $700,000 to the total cost of a 1% AEP levee reducing its benefit cost ratio further to around 0.61.



Project : 58L120A File Name : App F Biological Report View 01 Produced by : NL Watson Date : 25/09/02

Figure 6

Even with re-routing the levee, the constraints require any further consideration of a levee option to undergo a detailed feasibility study which would include the preparation of an eight part test as detailed in Section 5A of the *Environmental Planning and Assessment Act 1979* as amended by the *Threatened Species Conservation Act 1995* and *Fisheries Management Act 1997*. Given the known occurrence of threatened species in the area, an eight part test may recommend the preparation of a Species Impact Statement (SIS).

In addition, a more detailed examination of the quantities and costs involved in constructing the levee and associated infrastructure (such as sizing the drainage structure through the levee) would also need to be undertaken. Another drawback of levees was evidenced by the Nyngan flood of 1990. Levees do overtop in a flood event larger than they are designed to control. It is a case of **when** rather than if overtopping will occur. Communities behind levees often get a false sense of security that the levee provides complete protection and thus community flood awareness and readiness remains important, but may be more difficult, as the community perceives that the levee controls flooding.

In conclusion, flood modification measures are not as cost effective as house raising, in reduction of flood damages at Bulahdelah. They are likely to have adverse environmental impacts which would require further detailed investigation. The visual impacts of the levees are likely to be significantly adverse with the resulting disconnection of the community to the river in some areas.

5.9 FUTURE DEVELOPMENT OPTIONS

5.9.1 Description

Council has indicated that there are no significant development pressures in Bulahdelah. This is further evidenced by Australian Bureau of Statistics figures provided in the 1999 Great Lakes Community Profile which indicates a growth of 0.38% between 1991 and 1996 and a projected growth rate of around 1%. In addition there is an increase in population above 60 years of age and a decrease in population below 60 years of age. The existing land and appropriate development controls within Bulahdelah township should be sufficient to satisfy this growth rate.

However, Council has indicated that they are investigating the potential for rural residential development within a 15 kilometre radius of any town centre within the local government area, including Bulahdelah. Rural residential development within the catchment is unlikely, if filling is prevented within floodways and flood storage areas as controlled by adequate floodplain management, to significantly increasing flood flows or levels at Bulahdelah. Rural residential development should consider the flooding issues and be conditioned accordingly.

5.10 EFFECTIVENESS OF MEASURES IN FLOOD RISK CONTROL

This section examines the effectiveness of the floodplain management alternatives discussed in Section 5.9 on existing, continuing and future flood risk. Each of these risks contains two components that require consideration, namely, danger to personal safety and flood damage. Table 5.4 indicates the effectiveness of options in dealing with risk. The table indicates the need to undertake different floodplain management measures to deal with existing, future and continuing risk.

Existing flood risk can be mitigated by either construction of a levee(s) or house raising and voluntary purchase and to some degree by response modification measures. Future flood risk is best dealt with by zoning and development control, as is the case under Council's existing Flood Management Policy. Continuing flood risk can be reduced by improving community flood readiness and evacuation planning.

The addition of flood warnings and predictions will improve matters further.

Table 5.4 Effectiveness of Options in Dealing with Risk

	Existing Risk		Future Risk		Continuing Risk	
	Danger	**Damage**	**Danger**	**Damage**	**Danger**	**Damage**
Property Modification Measures						
Zoning and Development Control	-	-	High	High	-	-
House Raising	Low	High	-	-	-	-
Voluntary Purchase	High	High	-	-	-	-
Flood Proofing	-	Low	-	-	-	-
Response Modification Measures						
Community Flood Readiness	Low	Low	-	-	Medium	Medium
Local Flood Plans	Low	Low	-	-	Medium	Medium
Flood Predictions and Warnings	Medium	Low	-	-	High	High
Flood Modification Measures						
Levees	High	High	High	High	-	-

6. COMMUNITY CONSULTATION

Community consultation was undertaken at the draft study stage. This involved display of the draft report at the Tourist Information Centre in Bulahdelah and a public meeting on 28 May 2001.

Letters were delivered to all residents in the affected area inviting them to a meeting. Information/Questionnaire sheets were prepared and were provided to all attendees at the meeting. Extra newsletters were left in the rural transaction centre and at the Tourist Information Centre.

There were only 4 attendees at the Public Meeting. The attendees indicated that drainage was a more important issue in Bulahdelah and would have filled the hall.

A presentation on the findings was given at the public meeting and opinions were canvassed. There was no support for either the River or Myall to Stroud Street levee options due to both the cost and the visual impacts. There was also little support for voluntary purchase, flood proofing or house raising. There was some support for flood awareness, warning and planning including a flood warning system.

Several submissions were received as part of the community consultation. None particularly favoured any particular management options but made recommendations in relation to improving flood awareness and interest by marking power poles and writing to residents direct to ask their preferred option.

This could be considered to further canvass community sentiment prior to the adoption of a floodplain management plan for Bulahdelah.

7. GOVERNMENT FUNDING

7.1 FUNDING SOURCES

Funding for floodplain management is available through the State Government's Floodplain Management Program administered by the Department of Land and Water Conservation. Funding is only available for works protecting existing development residential development. Because of its low priority protection or modification works specifically directed at existing commercial and/or industrial development is generally ineligible for Government funding. There is considerable call for funding for floodplain mitigation works and therefore projects are ranked on a statewide basis considering the effectiveness of the mitigation option. Relative ranking is used to determine whether funding will be offered.

The Floodplain Management Program includes two sub-programs called the Commonwealth Assisted and State-Only Programs.

The Commonwealth Assisted Program is a partnership with the Commonwealth Government recently funded under it's Regional Flood Mitigation Program (RFMP) to approved floodplain management works. This program offers funding for works on $1 Commonwealth: $1 State: $1 Local basis. This program provides funds for the design and construction of works.

The State-Only Program provides State Government subsidy to fund approved floodplain management works. This program offers funding for works on $2 State: $1 Local basis. This program provides assistance for the construction of modification works and associated designs and studies into works.

Therefore both sub-programs require the local component to be one-third (33.3%) of the project cost.

7.2 THE LOCAL COMPONENT OF FUNDING

The local component (33.3%) of funding can be from any local source. In most instances the Council provides the local input through either its general rates or by the levy of a special rate for floodplain management measures.

Some councils have adopted schemes which require the individual to pay the whole one-third or part thereof for voluntary house raising where it is not required because of the impacts of other mitigation works on flood levels. A partial payment of the local component by Council may make this option more affordable and attractive to residents.

8. CONCLUSIONS AND RECOMMENDATIONS

Bulahdelah is affected by flooding from both the Myall River and local overland flooding from drainage paths. Flooding from the Myall River at Bulahdelah has not occurred for a number of years. The largest floods in available records at Bulahdelah occurred in 1897 and 1927. Smaller floods were recorded in 1947 and 1953 with less severe floods again occurring most recently in 1985 and 1987. Therefore the current knowledge of residents of Bulahdelah of significant flooding is low. This is reflected in the general low interest of the community found in consultation.

Major floods can have a reasonable impact and associated implications on Bulahdelah township. This can result in significant property damage and the need for a reasonable number of dwellings to be evacuated. Flooding from the Myall River in the 1% annual exceedance probability (AEP) flood event will inundate around 45 houses and 7 non residential properties above floor level. The potential flood damage in the 1% AEP event is estimated to be in the order of $1,700,000 with the annual average damage for the full range of floods expected to be in the order of $95,200.

The findings of the study and the potential management measures were presented to the community to canvass their opinion. There appeared to be little community interest in riverine flooding and no particular option for mitigation other than flood warning, awareness and planning was supported.

Notwithstanding this council needs to manage three types of flood risk. Each of flood risk involves a component related to danger to personal safety and property damage. The findings of the study indicate that a number of different measures are needed to address all types of flood risk, namely:

- existing flood risk which relates to existing development in the floodplain. This could be reduced by the adoption of a voluntary house raising scheme as outlined in Section 5.8 of the report. The raising of houses below the 5% flood level to 0.5m above the 1% flood level would have the most economic benefit with a return of around $5.60 for every local dollar expended (given a $2 State: $1 Local funding ratio). Raising of all floor levels would have a return of around $2.80 for every local dollar expended. Local funding could be from Council, property owners or a combination of both. In addition voluntary purchase of properties that are below the 5% event (depths of water > 1 metre in the 1% flood event) but unsuitable for raising raised should also be considered.
- future flood risk which relates to the risk to future development in the floodplain. This can be dealt with by recommended changes to Councils Flood Policy as outlined in Section 5.6. It is also recommended that Council consider including development constraints in a flood-related Development Control Plan over time.
- continuing flood risk is the risk remaining after management measures are implemented. To address this flood warning could be provided using a local alert system to warn the relevant emergency services. This system needs to be accompanied by appropriate community warning methods and community evacuation planning in the local flood plan. Recommendations are provided in relation to this plan in Section 5.6. This plan relies on community education and awareness of the problems. It is recommended that Council and the relevant emergency services groups combine to undertake regular education and awareness campaigns in the community.

Flood planning levels (FPLs) should be adopted as follows:

- The FPL for residential, commercial and industrial development in Bulahdelah should be the 1% AEP flood event plus the adopted freeboard of 0.5m.
- The FPL for flood awareness and emergency management should be the extreme flood level.

Council should consider adoption of the above recommendations and use these recommendations as the basis for the preparation of a floodplain management plan.

9. GLOSSARY

Following is a glossary of the terms used in this management study.

annual exceedance probability (AEP)	the chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a peak flood discharge of 500 m^3/s or larger occurring in any one year.
Australian Height Datum (AHD)	a common national surface level datum approximately corresponding to mean sea level.
average annual damage (AAD)	depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
development	is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act). **infill development**: refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. **new development**: refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. **redevelopment**: refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.
discharge	the rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
effective warning time	the time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.

emergency management	a range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
flood	relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood education, awareness & readiness	**flood education** seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves and their property in response to flood warnings and in a flood event. It invokes a state of flood readiness. **flood awareness** is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures. **flood readiness** is an ability to react within the effective warning time.
flood fringe areas	the remaining area of flood prone land after floodway and flood storage areas have been defined.
flood liable land	is synonymous with flood prone land (ie) land susceptible to flooding by the probable maximum flood (PMF) event.
flood mitigation standard	the average recurrence interval of the flood, selected as part of the floodplain management process that forms the basis for physical works to modify the impacts of flooding.
floodplain	area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain management options	the measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain management plan requires a detailed evaluation of floodplain management options.
floodplain management plan	a management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.
flood planning area	the area of land below the flood planning level and thus subject to flood related development controls.
flood planning levels (FPLs)	are the combinations of flood levels and freeboards selected for planning purposes, as determined in floodplain management studies and incorporated in floodplain

	management plans. The concept of flood planning levels supersedes the "standard flood event" of the first edition of this manual.
flood proofing	a combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	is land susceptible to flooding by the probable maximum flood event. Flood prone land is synonymous with flood liable land.
flood risk	potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. **existing flood risk:** the risk a community is exposed to as a result of its location on the floodplain. **future flood risk:** the risk a community may be exposed to as a result of new development on the floodplain. **continuing flood risk:** the risk a community is exposed to after floodplain management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
floodway areas	those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
freeboard	a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. It is usually expressed as the difference in height between the adopted flood planning level and the flood used to determine the flood planning level. Freeboard provides a factor of safety to compensate for uncertainties in the estimation of flood levels across the floodplain, such and wave action, localised hydraulic behaviour and impacts that are specific event related, such as levee and embankment settlement, and other effects such

	as "greenhouse" and climate change. Freeboard is included in the flood planning level.
habitable room	in a **residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom in an **industrial or commercial situation:** an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
hazard	a source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community.
hydraulics	term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
hydrograph	a graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
mainstream flooding	inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
mathematical/computer models	the mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
merit approach	the merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State's rivers and floodplains. The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into council plans, policy, and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain management plan, local floodplain management policy and EPIs.
minor, moderate and major flooding	both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood: **minor flooding:** causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge

	is the initial flood level at which landholders and townspeople begin to be flooded. **moderate flooding:** low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered. **major flooding:** appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.
modification measures	measures that modify either the flood, the property or the response to flooding.
peak discharge	the maximum discharge occurring during a flood event.
probable maximum flood (PMF)	the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with the PMF event should be addressed in a floodplain management study.
probable maximum precipitation	the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to the estimation of the probable maximum flood.
probability	a statistical measure of the expected chance of flooding (see annual exceedance probability).
risk	chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	the amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
stage	equivalent to "water level". Both are measured with reference to a specified datum.
stage hydrograph	a graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
water surface profile	a graph showing the flood stage at any given location along a watercourse at a particular time.

10. ACKNOWLEDGMENTS

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The study has been prepared by the Flood Unit of Ecosystems Branch in the Department of Land and Water Conservation with the assistance of Great Lakes Council and Council's Floodplain Management Committee.

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APPENDIX A - FLOOD STUDY REVIEW

A1 General

This study reviews the previous investigations undertaken within the study area as part of the floodplain management program.

A2 Previous Floodplain Management Program Investigations

Previous investigations of flooding in the study area as part of the floodplain management program are:

- Bulahdelah Flood Appraisal, by NSW Public Works, October 1991; and
- Frys Creek Flood Study, by NSW Public Works, July 1994.

These studies included hydrologic analyses to derive catchment runoff estimates and hydraulic analyses to derive design flood profiles along the Myall River and Frys Creek. The Watershed Bounded Network Model (WBNM) was used for hydrologic analysis and the MIKE-11 software package was used for hydraulic analysis.

The hydrologic analyses for the previous studies were based on current procedures and the design rainfall intensities in accordance with the 1987 edition of Australian Rainfall & Runoff. The Bureau of Meteorology indicated that no new design rainfall intensities are available for this catchment. Therefore the results of these analyses were considered to provide an appropriate basis for this floodplain management study.

The hydraulic model developed for the Bulahdelah Flood Appraisal extended only to the northern limits of the Bulahdelah township (at about Lee Street). A separate hydraulic model was developed in the Frys Creek Flood Study to cover the Myall River upstream of Bulahdelah (between Markwell Road and Lee Street) and Frys Creek. There was no hydraulic modelling of the Crawford River in the previous studies.

It was considered appropriate to develop a comprehensive hydraulic model of the total study area to meet the needs of this study.

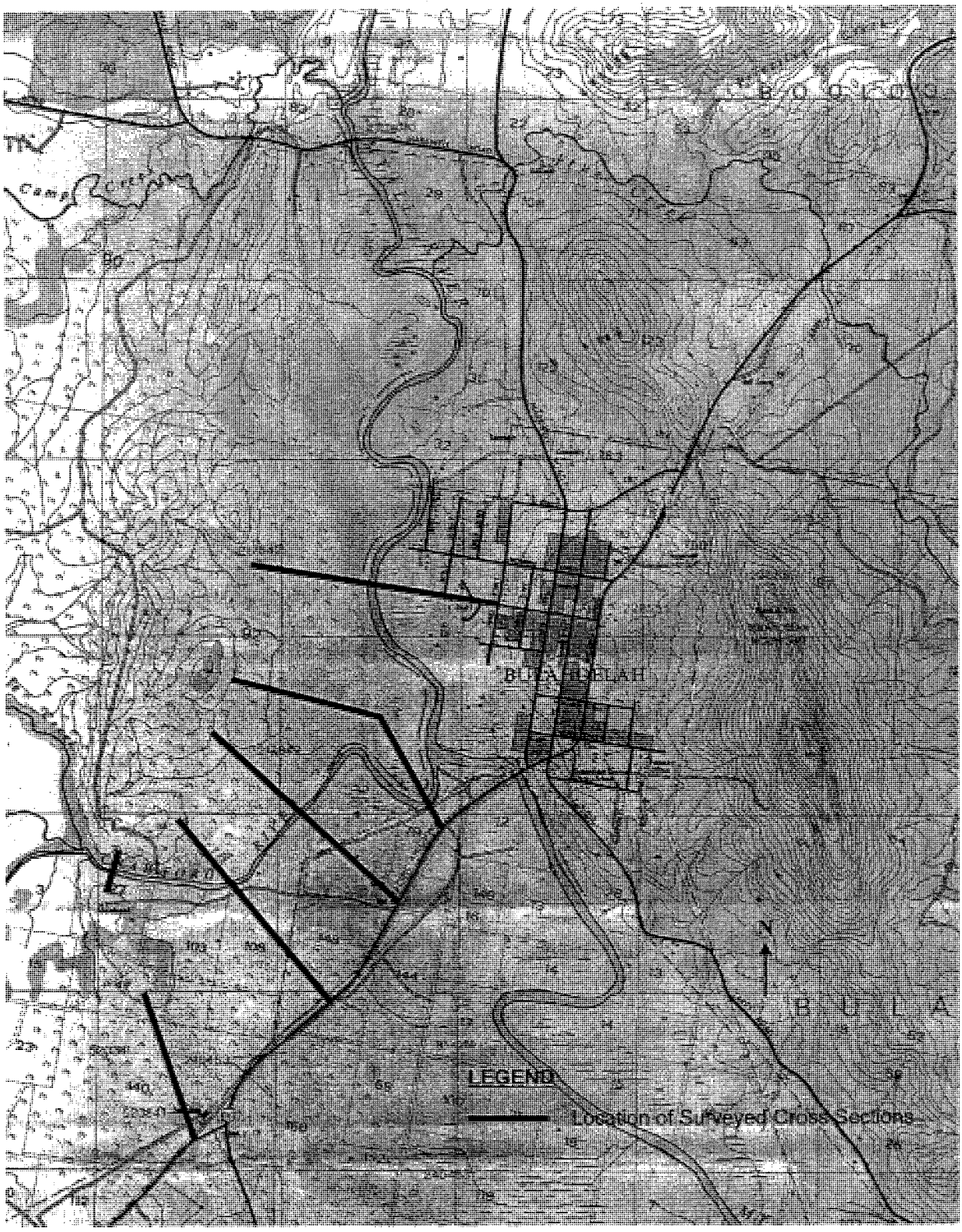
A3 Hydraulic Modelling

A3.1 Available Data

Available data pertinent to the development of the hydraulic model are documented in the previous study reports. They include topographic data, inflow hydrographs, downstream boundary conditions and historical flood levels. The principal sources of topographic data are:

- Survey cross-sections of the Myall River and Frys Creek obtained in conjunction with the previous studies; and
- Contour mapping of part of the Bulahdelah township area prepared in June 1974 (map scale 1:1000, contour interval 1 metre).

Four cross-sections of the Crawford River and one additional cross-section of the Myall River were obtained for this study. The survey was carried out by Great Lakes Surveys Pty Ltd in August 1997. The locations of the survey cross-sections are shown in Figure A.1.



0 1km
SCALE

1997 SURVEY CROSS SECTIONS
Figure A.1

A3.2 Methodology

Two alternative software packages were considered for the hydraulic model required for the Bulahdelah study area:

- MIKE-11 software package developed by the Danish Hydraulic Institute; and
- RMA-2 software package developed by Resource Management Associates, USA.

MIKE-11 is suitable for hydraulic modelling of one dimensional unsteady flow conditions and has been widely applied to rivers and floodplains throughout Australia. RMA-2 is well suited to simulation of the hydrodynamics of systems where two dimensional flow regimes exist.

A MIKE-11 model of the study area was formed by combining and refining the two existing MIKE-11 models together with extension of the modelled area to include the Crawford River. The model was calibrated to the November 1987 flood, which is the event with the best available rainfall and flood level records. Details of the MIKE-11 modelling are presented in Section A.5.

A RMA-2 model was also set up for the study area. The RMA-2 modelling was undertaken by the Water Research Laboratory of the University of New South Wales and is described in the associated report. This modelling is discussed in Section 2.6.

A4 Mike-11 Modelling

A4.1 Model Layout

The layout of cross sections for the MIKE-11 model within the defined study area is shown in Figure A.2. The model was extended about 6km downstream of the Pacific Highway to near the Muirs Creek confluence to provide a suitable downstream boundary.

Schematic layouts of the MIKE-11 model upstream and downstream of Lee Street are provided in Figures A.3 and A.4 respectively. Additional branches were included in the model to accommodate overflows during an extreme flood event. These branches provide for overflows from the Myall River to Frys Creek upstream of Bulahdelah and from the Crawford River across the Pacific Highway to the Myall River downstream of Bulahdelah.

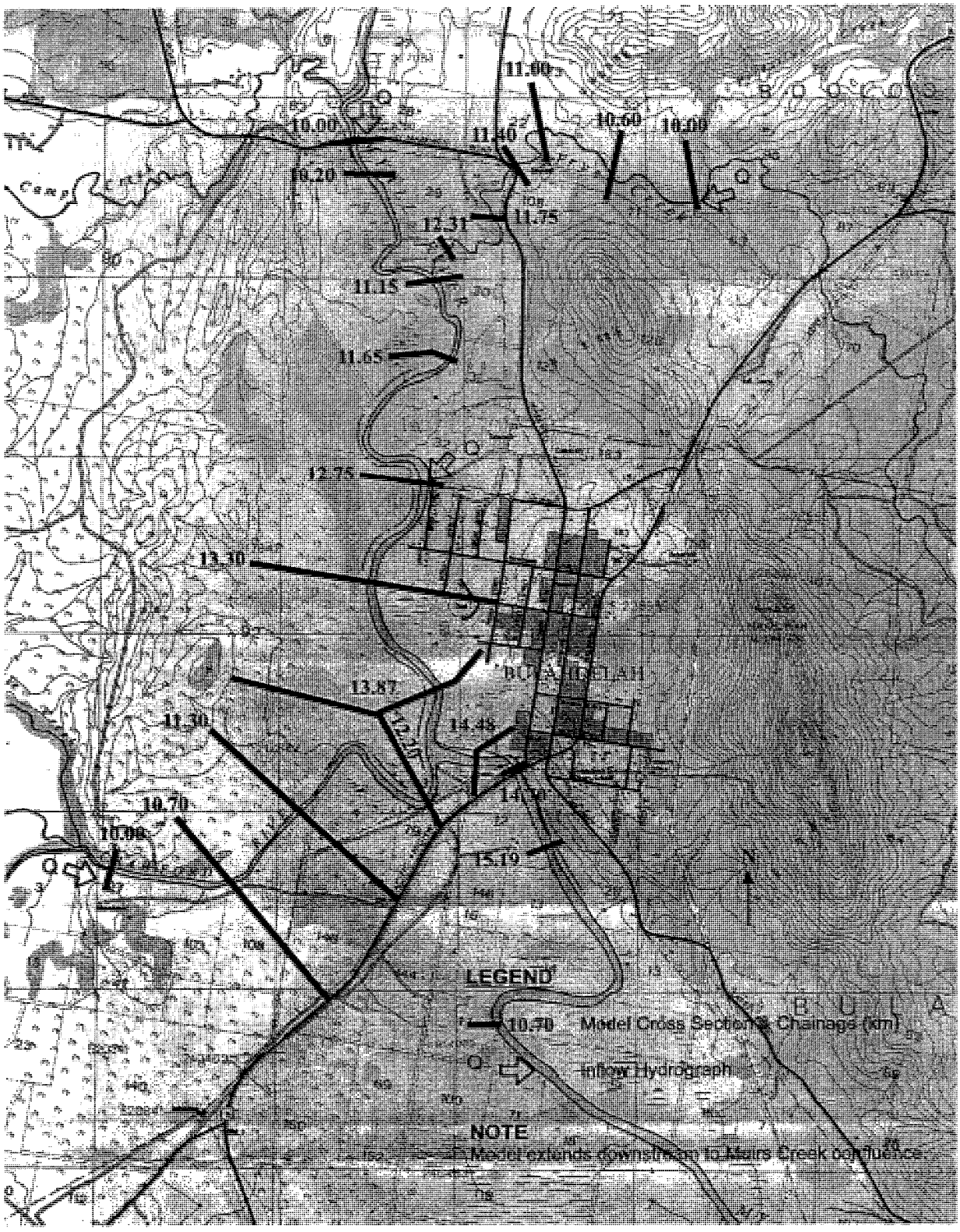
The adopted stage hydrographs at the downstream boundary were the same as those used in the 1991 Flood Appraisal, with peak levels of 2.9m AHD for the 1987 flood and 3.0m AHD for the design floods.

The model incorporates inflow hydrographs from four (4) catchment areas. These catchments, with estimated peak flows for the modelled events, are given in Table A.1.

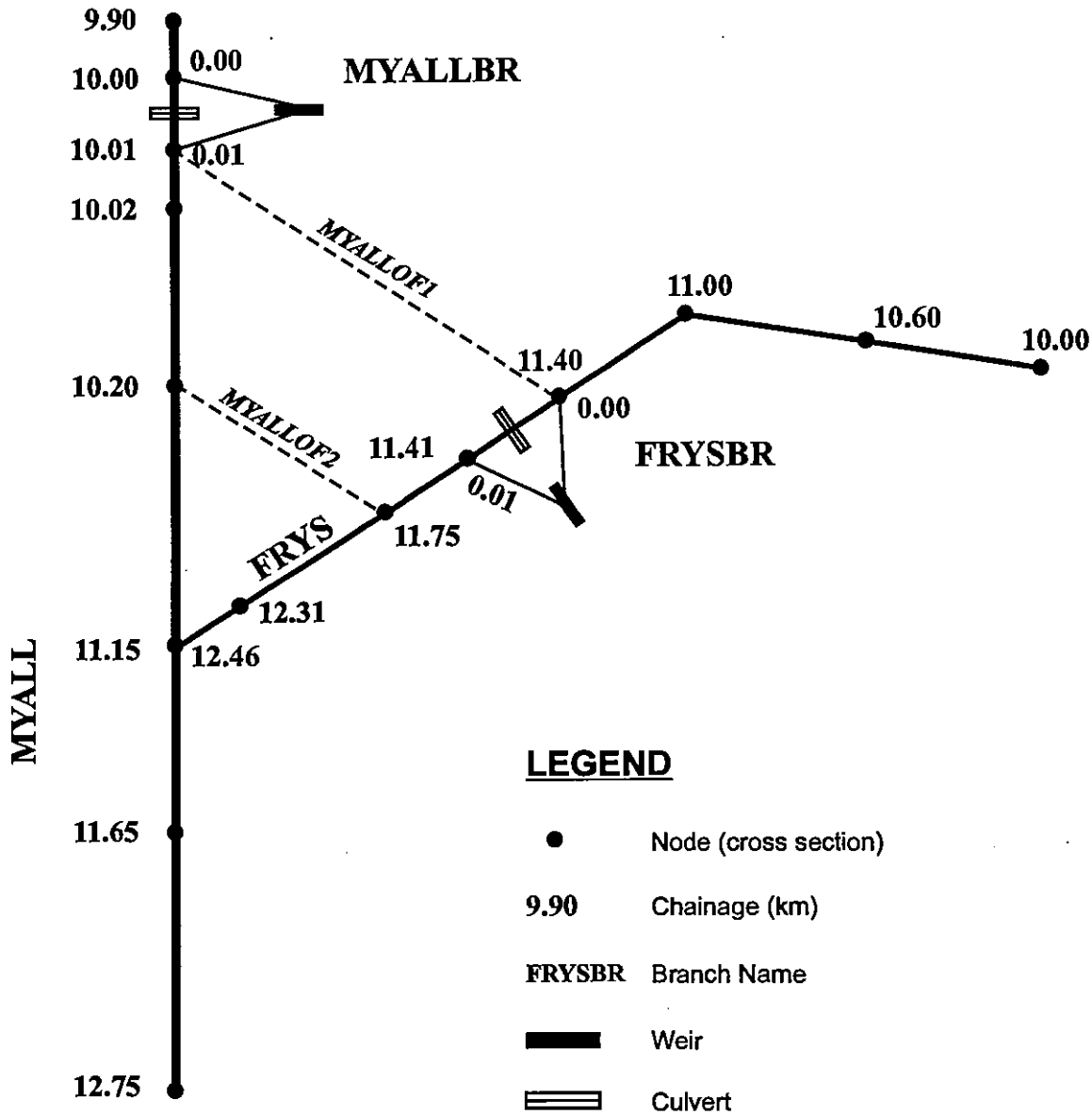
Table A.1 Peak Inflows to MIKE-11 Model

Catchment	Peak Flow (m^3/s)			
	Nov 1987	1% AEP	2% AEP	5% AEP
Myall River upstream of Frys Creek	325	1219	1011	840
Frys Creek	55	152	127	109
Local catchment between Frys Creek confluence & Pacific Highway	26	76	63	55
Crawford River	387	807	668	559

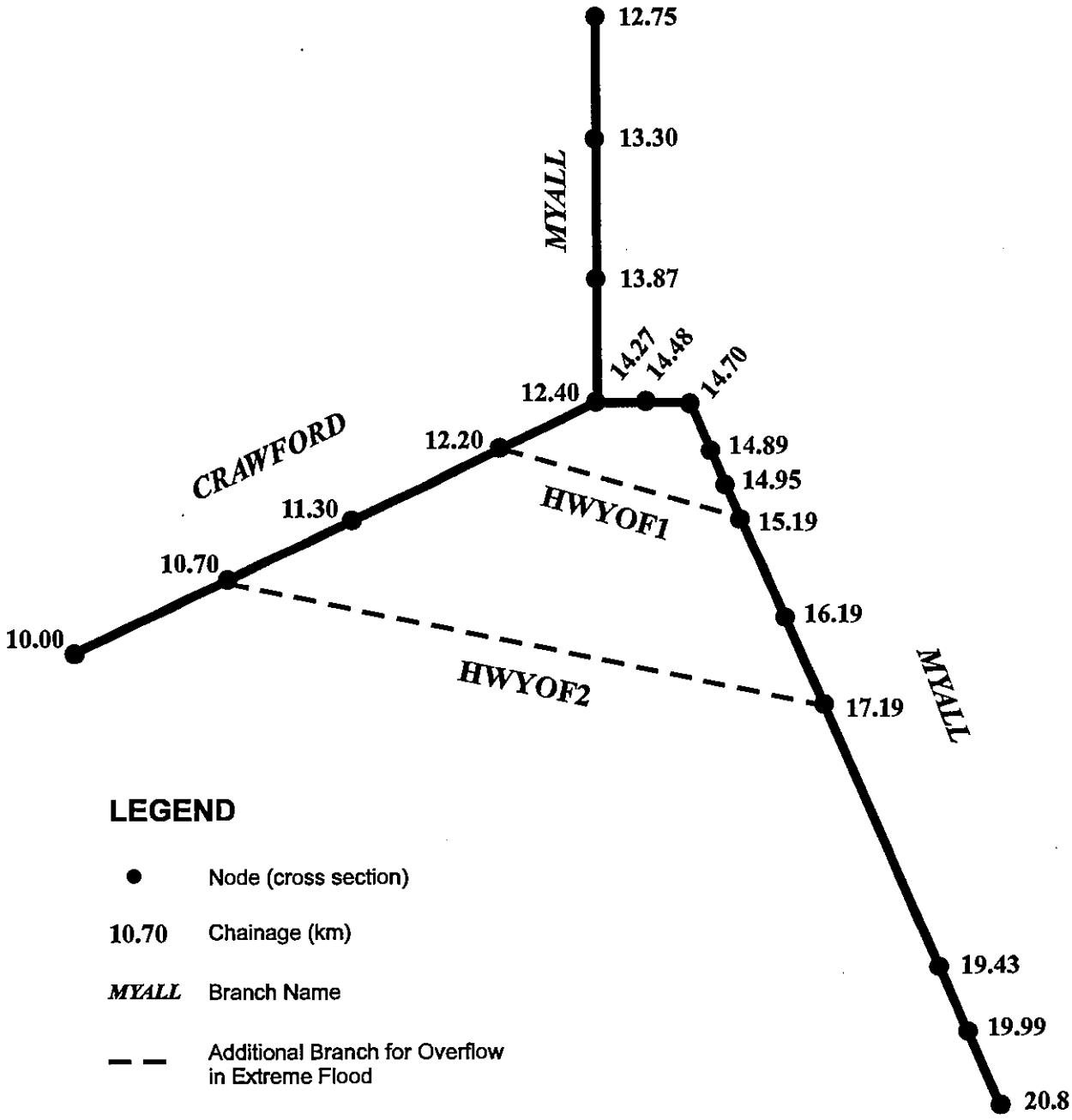
Notes:
1. Peak inflow estimates for the 1987 event shown in Table 1 are 25 per cent higher than WBNM estimates and were derived as part of the hydraulic model calibration.
2. Peak inflow estimates from the Crawford River catchment for the 1%, 2% and 5% AEP events are up to 7 per cent higher than the estimates contained in the 1991 Flood Appraisal, resulting from minor modification of the hydrologic model.



CROSS SECTIONS IN MIKE- 11 MODEL
Figure A.2



MODEL LAYOUT
Upstream of Lee Street
Figure A.3



MODEL LAYOUT
Downstream of Lee Street
Figure A.4

A4.2 Model Calibration

The MIKE-11 model was calibrated to the November 1987 flood. The calibration principally involved adjustment of the Manning "n" values for the watercourses and floodplain areas to achieve a reasonable reproduction of the recorded flood levels for that event. Variation of the estimated inflow hydrographs to the study area was also undertaken in recognition of the uncertainty in the runoff estimates. This uncertainty was largely due to the absence of pluviometers in the catchment at the time of this event.

The modelled flood profiles and recorded flood levels for the November 1987 event are shown in Figure A.5 for the Myall River and in Figure A.6 for Frys Creek and the Crawford River. Figure A.7 and A.8 show the 1% AEP flood contours and flow distribution respectively. The model calibration was achieved with inflows 25 per cent greater than the rainfall-runoff model estimates and Manning "n" values are given in Table A.2.

Table A.2 Adopted Mannings "n" Values

River	River Channel	Overbank Areas
Myall River	0.035 to 0.065	0.05 to 0.26
Frys Creek	0.04 to 0.05	0.04 to 0.10
Crawford River	0.04	0.06

The variation of inflow estimates was within an acceptable range and the Manning "n" values were considered reasonable for the existing conditions on the river and floodplain. Hence these "n" values were adopted for the modelling of design flood events.

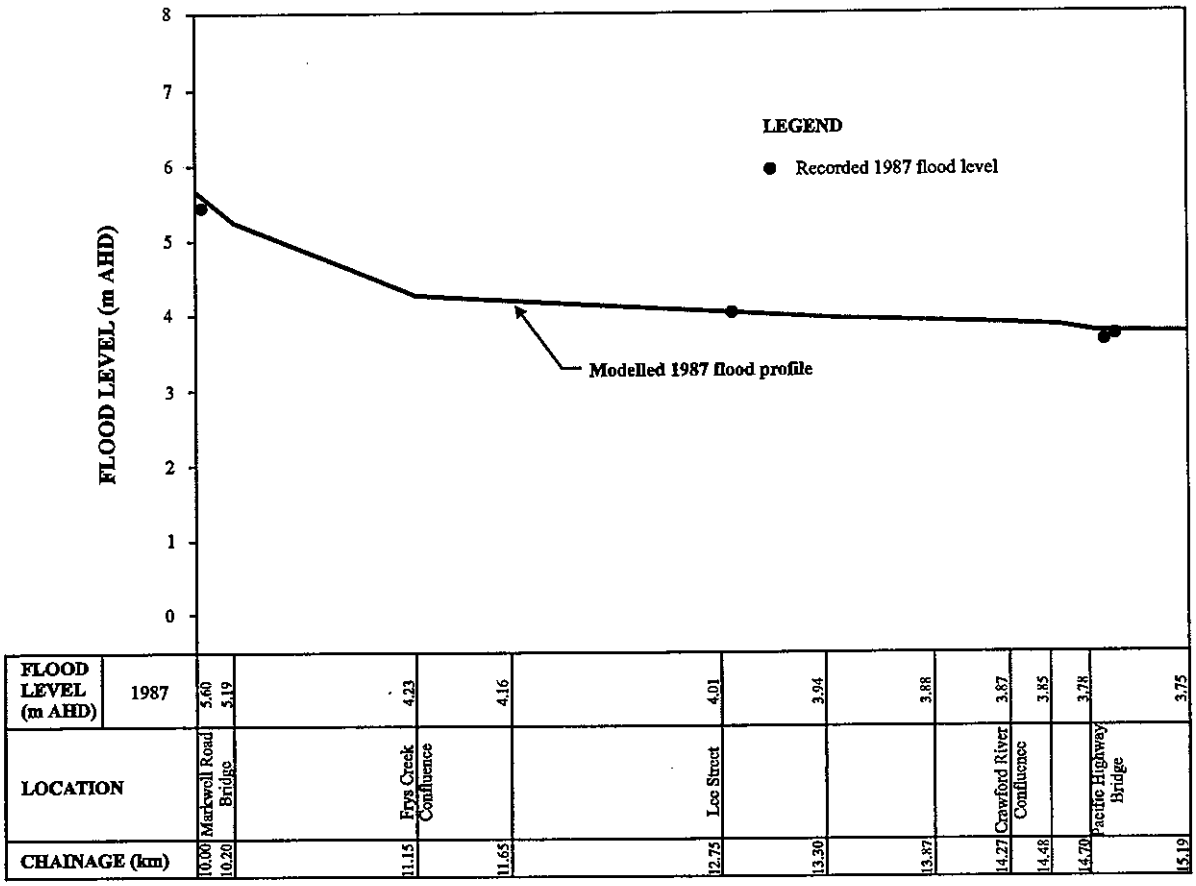
A4.3 Modelling of Design Events

The modelled flood profiles for the 1%, 2% and 5% AEP events are shown in Figures A.9 and A.10. The modelled 1% AEP flood levels are generally similar to the levels derived in the previous studies of the Myall River and Frys Creek. The estimates of 1% AEP flood level at most locations are within about 0.1m of the previous estimates.

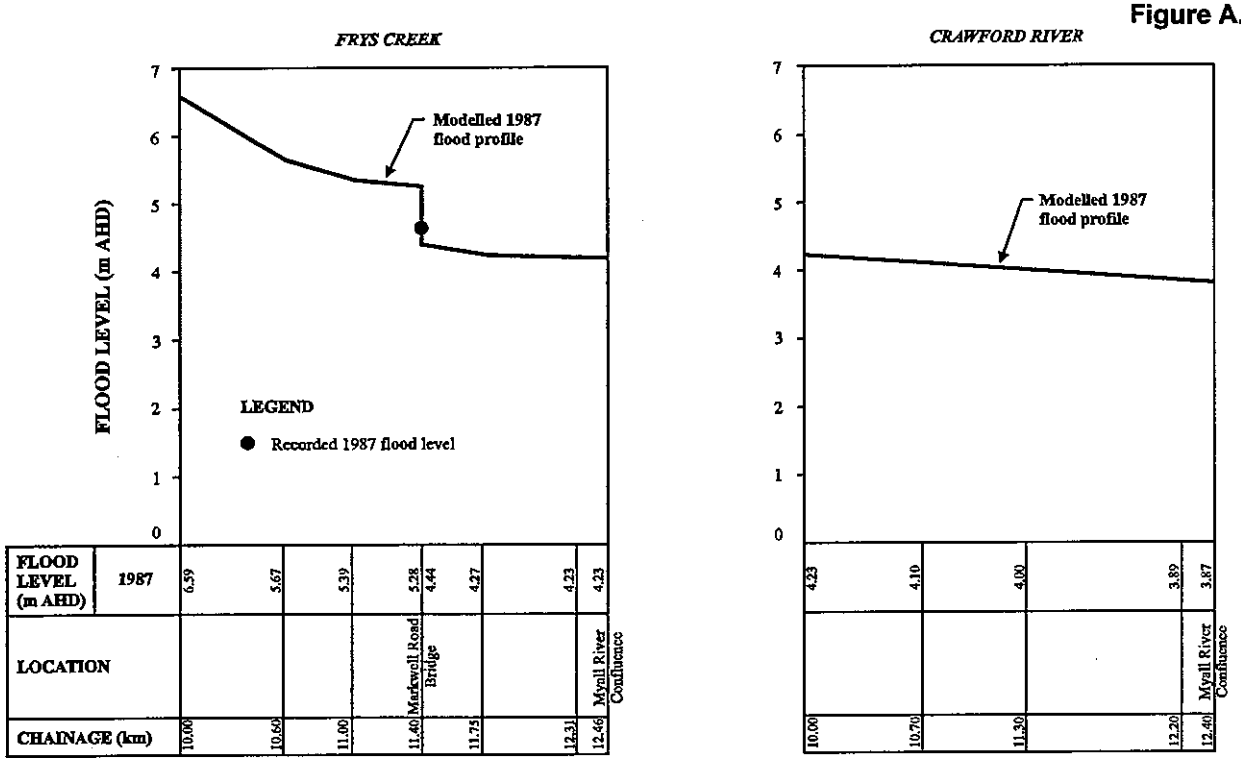
The model was also used to derive estimates of flood levels for an extreme flood event. For the purposes of this study, the extreme event was defined as an event with discharge of three (3) times the magnitude of the discharge for the 1% AEP event. The computed flood levels for the extreme event are also shown in Figures A.7 and A.8. The modelled flood levels for this event should be regarded as conservatively high because the model does not represent the likely full extent of overbank flow and floodplain storage under extreme conditions.

The 1% AEP and Extreme flood contours in the vicinity of Bulahdelah township, as derived from the MIKE-11 model results, are shown in Figure 2. The peak average velocities in the river channels and overbank areas are also indicated. The distribution of flood flow between the river channels and overbank areas for the 1% AEP flood event is shown in Figure A.11.

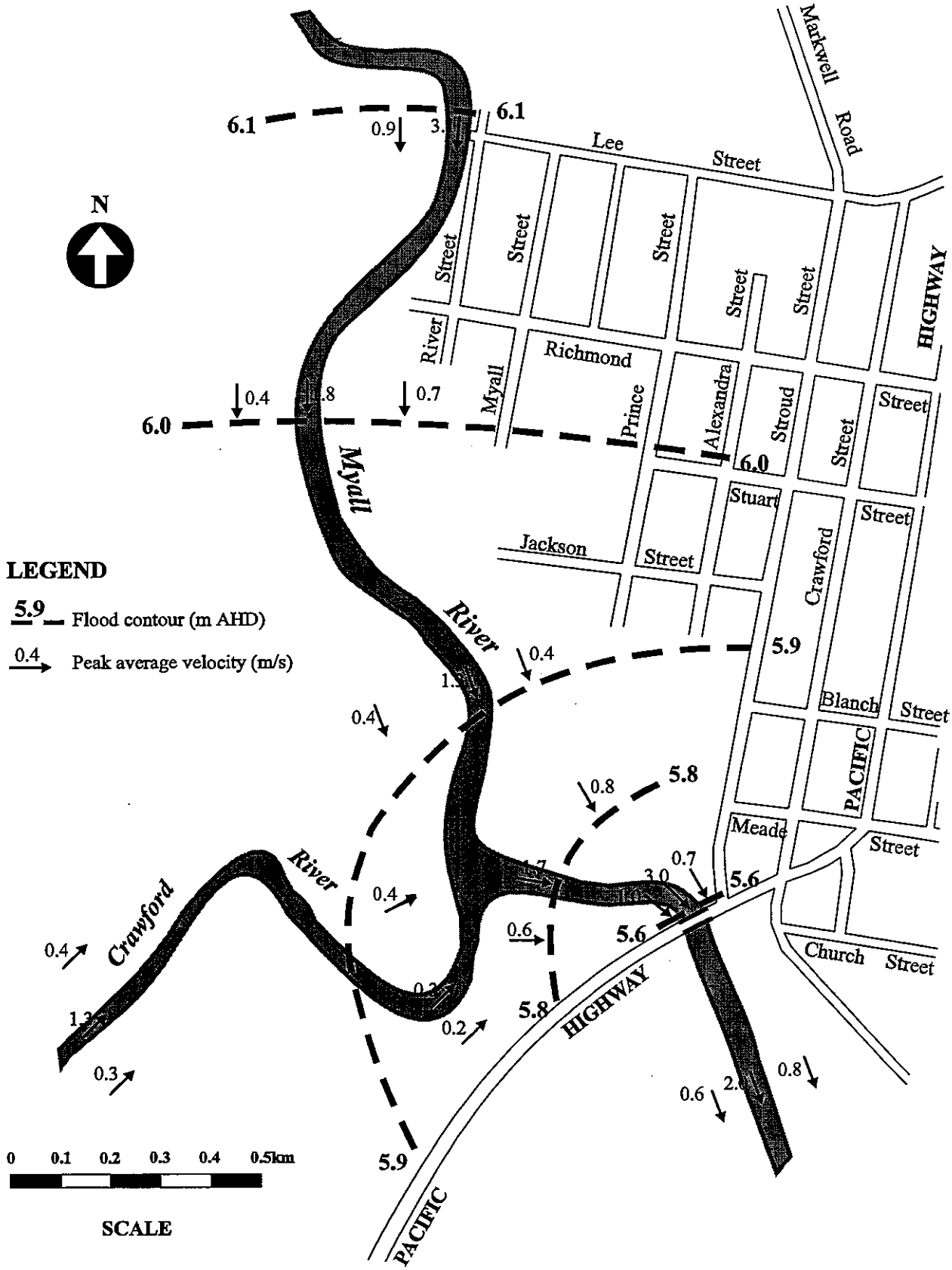
Table A.3 provides the design flood levels for all events at modelled cross sections.



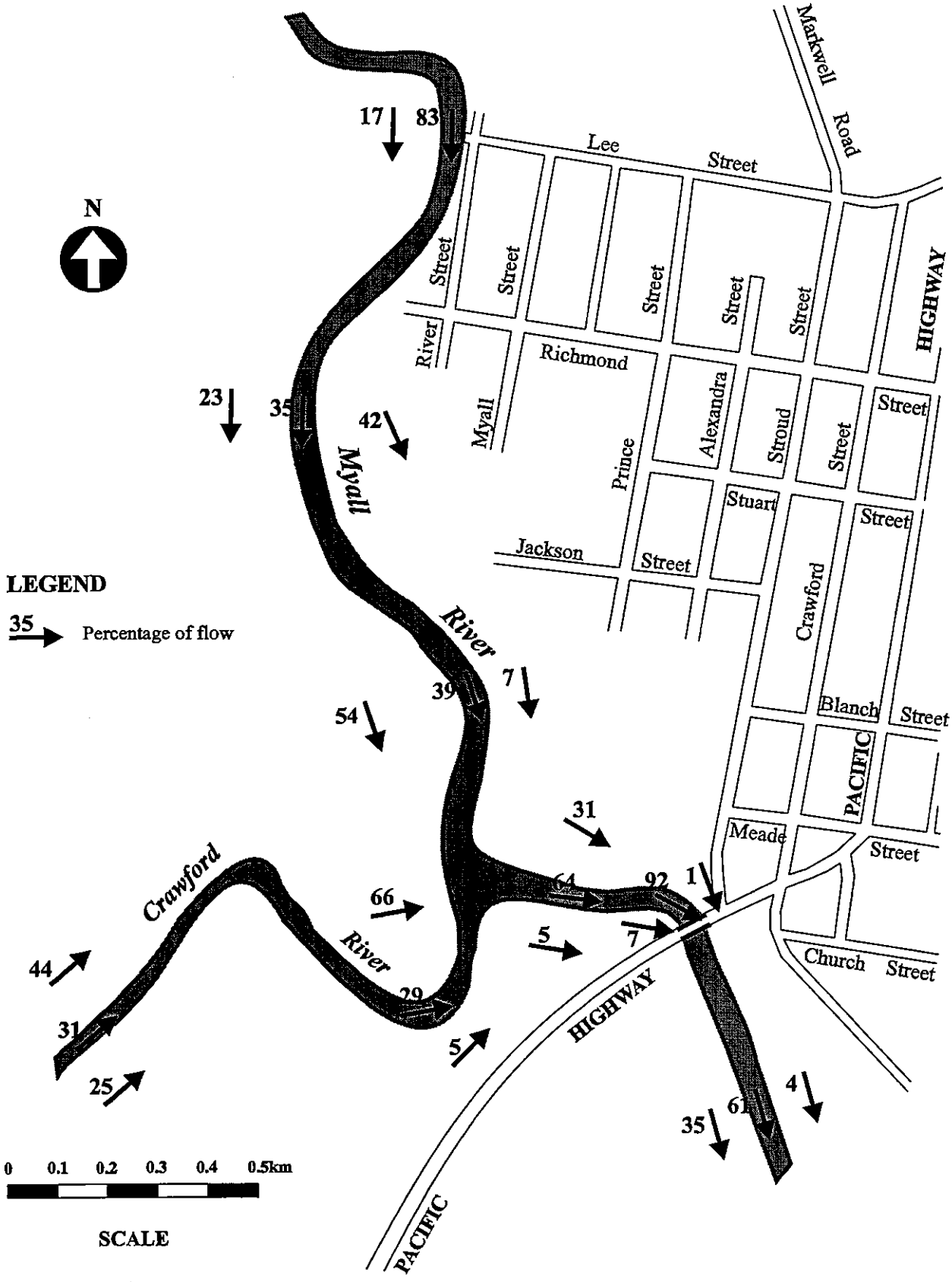
MYALL RIVER - 1987 FLOOD PROFILE
Figure A.5



FRYS CREEK AND CRAWFORD RIVER
1987 FLOOD PROFILES
Figure A.6



1% AEP FLOOD CONTOURS
Figure A.7



1% AEP FLOOD FLOW DISTRIBUTION
Figure A.8

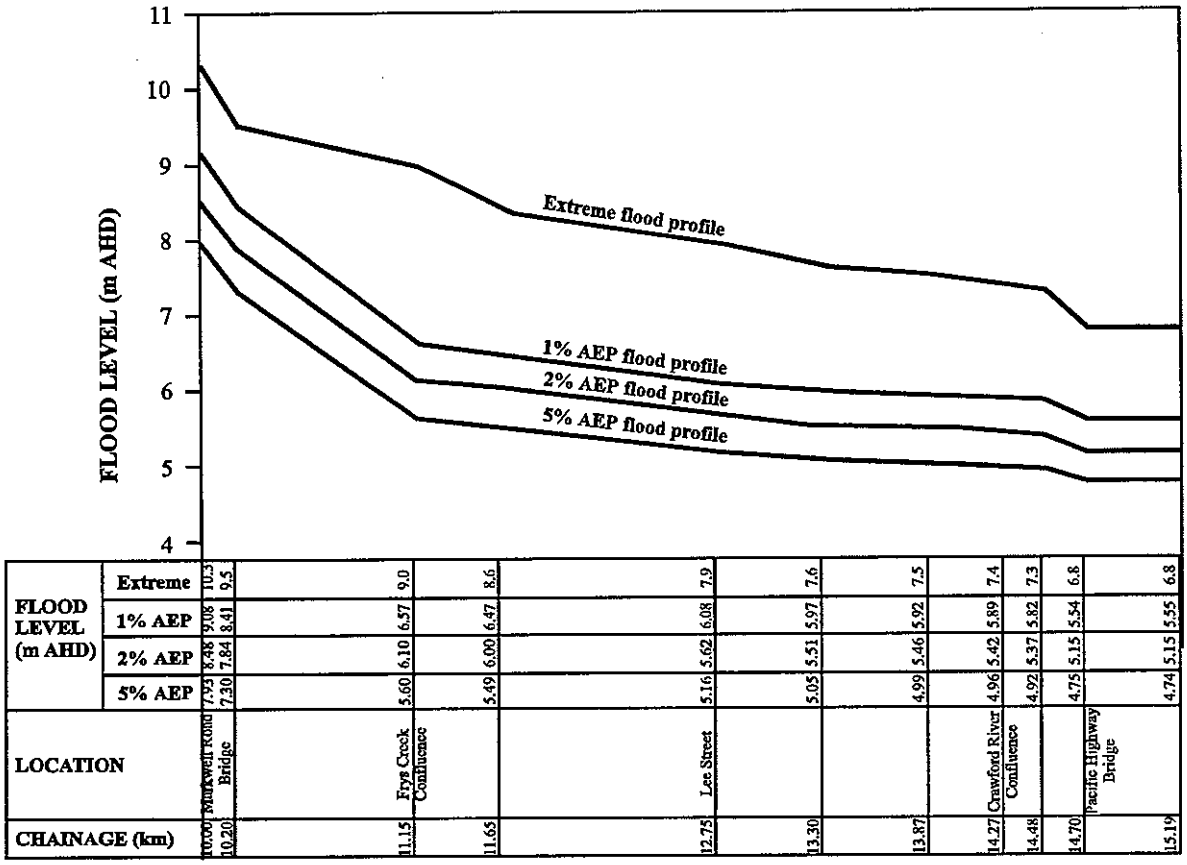
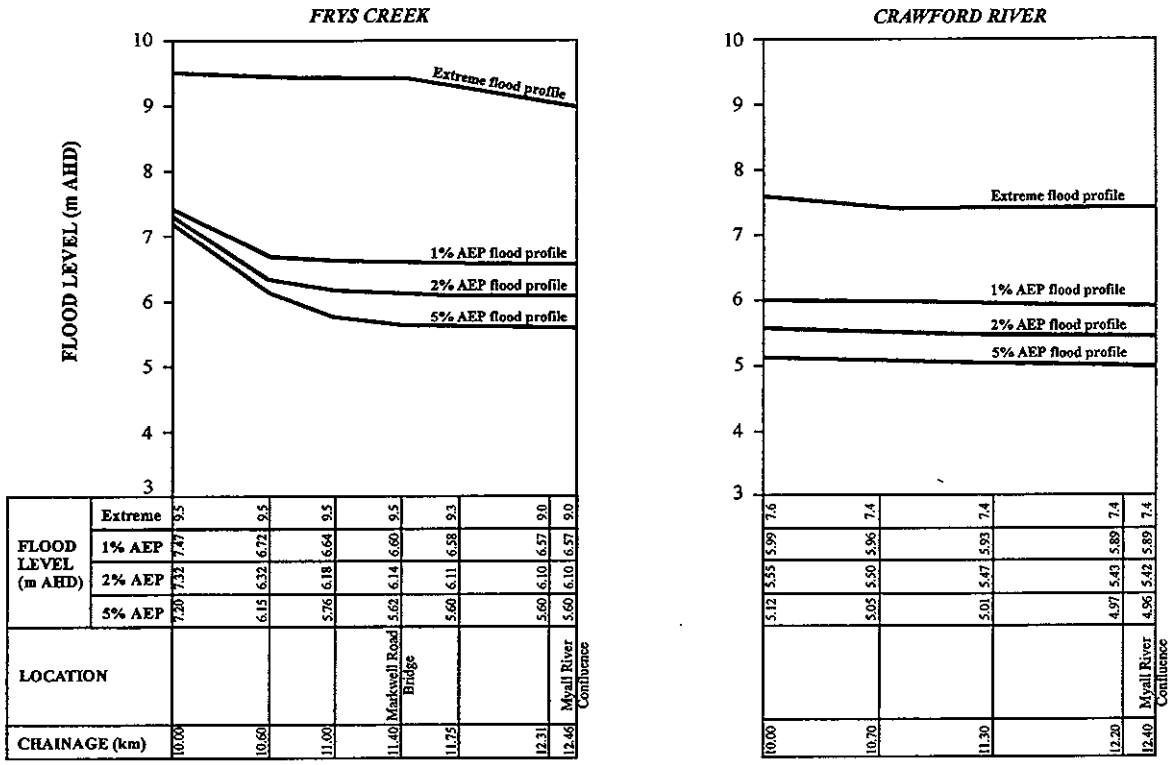
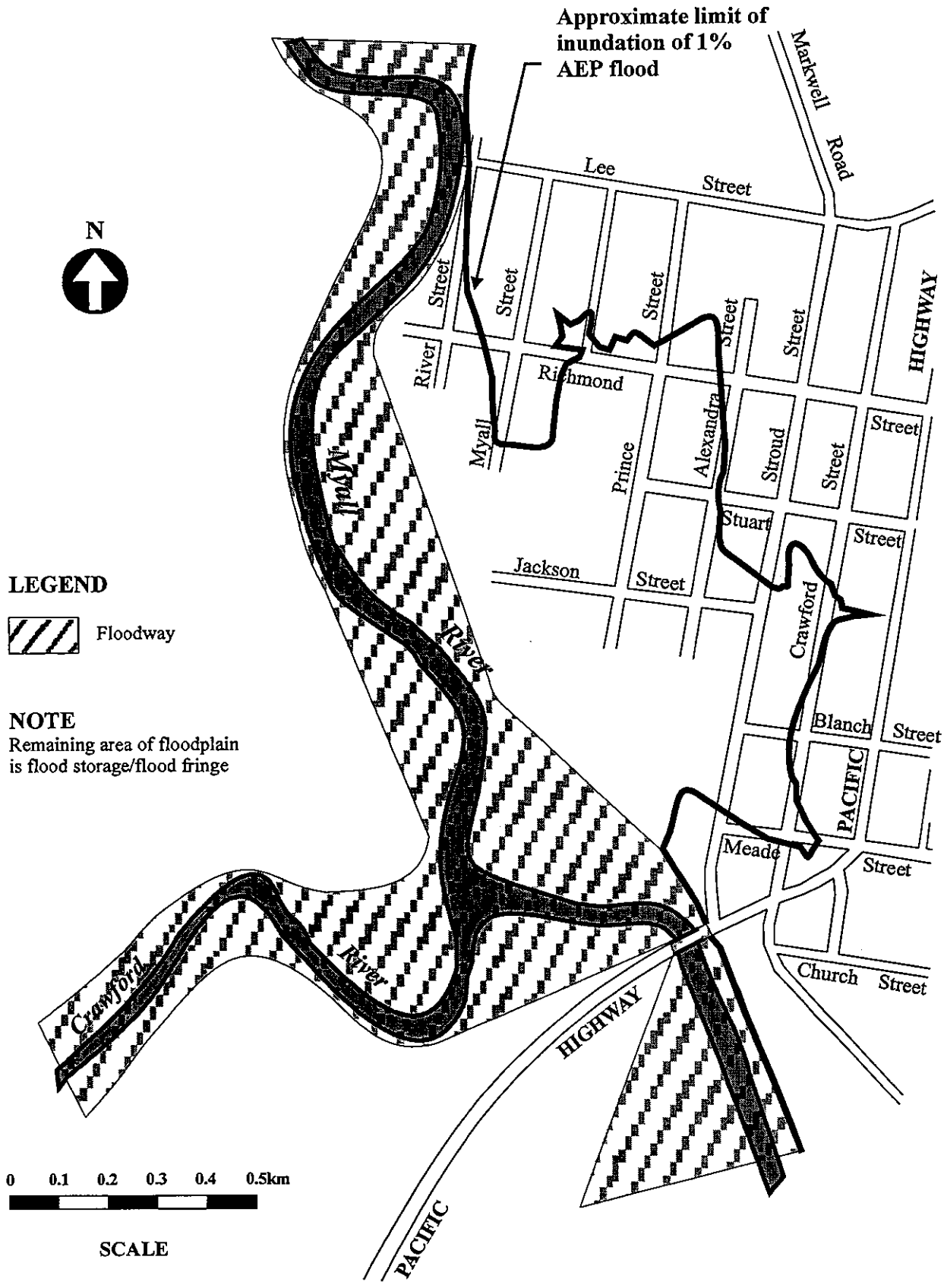


Figure A.9 MYALL RIVER - DESIGN FLOOD PROFILES



FRYS CREEK AND CRAWFORD RIVER DESIGN FLOOD PROFILES
Figure A.10



FLOODWAYS AT BULADELA IN 1% AEP FLOO
Figure A.1

Table A.3 Design Flood Levels at Cross Sections indicated on Figure A.2

Chainage km	Location Description	Extreme m AHD	1% AEP m AHD	2% AEP m AHD	5% AEP m AHD
Myall River					
M10.00	Markwell Road Bridge	10.3	9.08	8.48	7.93
M10.20		9.5	8.41	7.84	7.30
M11.15	Frys Creek Confluence	9.0	6.57	6.10	5.60
M11.65		8.6	6.47	6.00	5.49
M12.75	Lee Street	7.9	6.08	5.62	5.16
M13.30		7.6	5.97	5.51	5.05
M13.87		7.5	5.92	5.46	4.99
M14.27	Crawford River Confluence	7.4	5.89	5.42	4.96
M14.48		7.3	5.82	5.37	4.92
M14.70	Pacific Highway Bridge	6.8	5.54	5.15	4.75
M15.19		6.8	5.55	5.15	4.74
Frys Creek					
F10.00		9.5	7.47	7.32	7.20
F10.60		9.5	6.72	6.32	6.15
F11.00		9.5	6.64	6.18	5.76
F11.40	Markwell Road Bridge	9.5	6.60	6.14	5.62
F11.75		9.3	6.58	6.11	5.60
F12.31		9.0	6.57	6.10	5.60
F12.46	Myall River Confluence	9.0	6.57	6.10	5.60
Crawford River					
C10.00		7.6	5.99	5.55	5.12
C10.70		7.4	5.96	5.50	5.05
C11.30		7.4	5.93	5.47	5.01
C12.20		7.4	5.89	5.43	4.97
C12.40	Myall River Confluence	7.4	5.89	5.42	4.96

A5 RMA-2 Modelling

The RMA-2 model was set up and run for the 1987 flood and the 1% AEP flood as indicated in the report on the RMA-2 modelling. The 1% AEP flood profiles derived using RMA-2 were generally slightly higher than the profiles derived using MIKE-11. For example, in the vicinity of the confluence of the Myall River and Crawford River at Bulahdelah, the 1% AEP peak level estimate using RMA-2 was about 0.15m to 0.2m higher than the estimate using MIKE-11. The difference between the flood level estimates from the two models was about 0.3m along parts of Frys Creek through an area which is currently undeveloped.

A6 Discussion Of Modelling Results

Variations in design flood modelling results using different models tend to be greater in the absence of data from major historical floods for model calibration. This situation exists in the Bulahdelah area where the November 1987 flood was only a minor flood with limited recorded data. The potential advantages of RMA-2 over MIKE-11 in terms of modelling two dimensional flow effects are diminished to some extent where there is a paucity of data.

The 1% AEP flood level estimate at Bulahdelah from MIKE-11 is slightly higher than the recorded peak flood levels in the town in 1897 and 1927. The floods in these two years are considered to be the largest historical floods in the area. Therefore the 1% AEP flood level estimates from MIKE-11 appear to be reasonable.

The discrepancy between the RMA-2 level estimates and the MIKE-11 level estimates is within the freeboard of 0.5m recommended for planning purposes. The RMA-2 level estimates could be considered as upper bound estimates which are within the freeboard allowance.

It is proposed that the MIKE-11 estimates of the design flood levels, as shown in Figures A.7, A.8 and A.9, be adopted for this floodplain management study. As indicated in Section A4.3, these results are only slightly different from those currently being used by Council to control development and therefore the implications are not expected to be significant.

The RMA-2 model might still be retained to check the hydraulic impact of any structural floodplain management options or development options, where possible two dimensional flow effects were considered to be significant. The future modelling needs would be assessed in relation to the nature of the options to be tested.

Figure 3 indicates the properties inundated based upon the MIKE-11 modelling results and flood level survey conducted on behalf of Council in 2001.

APPENDIX B – HYDRAULIC AND HAZARD CATEGORIES

B1 Flooding

Assessment of existing Myall River flood conditions at Bulahdelah was undertaken for the 1% AEP event based on the guidelines provided in the Floodplain Management Manual (2001). This assessment considers a number of criteria including danger to personal safety, evacuation access, potential flood damages, flood depths and velocities, rate of rise of floodwaters, and the likely impacts of filling areas upon flood conditions.

Hydraulic classification of an area inundated by flooding depends upon the hydraulic conditions in this area and is discussed in Section B.2.

The hazard classification identifies the danger to personal safety from flooding. This is undertaken in a 2 step process. The first step is provisional hazard classification, based upon flood depth and velocity, as discussed in Section B.3. The second step is to consider mitigating or exacerbating circumstances which may impact upon the classification as discussed in Section B.4.

B2 Hydraulic Categories

There are three hydraulic categories of flood liable land:

- Floodways - areas where a significant volume of water flows during floods. Floodways are commonly identified as the areas where the product of depth (m) and velocity of flow (m/s) is greater than 1.0.
- Flood storage - areas that are important for the temporary storage of floodwaters during the passage of a flood. Complete filling of flood storage areas would generally cause significant increases in peak flood levels and/or peak discharges.
- Flood fringe - the remaining areas of land affected by flooding. Development in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.

The main channels of the Myall River, Crawford River and Frys Creek are floodways. The floodway areas extend beyond the banks of the main channels on to overbank areas where velocities and depths of inundation are high. The approximate extent of the floodway areas in the vicinity of Bulahdelah for the 1% AEP event is shown in Figure 2.

The remaining floodplain area at Bulahdelah is categorised generally as flood storage because complete filling of this area would cause significant increases in peak flood levels. However filling of parts of the area may be possible without significant adverse impacts on flooding. Such areas could be considered as flood fringe areas. However, any proposals to fill large areas of the floodplain should be modelled to determine their impacts upon other properties.

B3 Provisional Hazard Categories

The flood hazard is a measure of the risk to individuals and property resulting from the affects of flooding. The flood hazard applying to a particular area is dependent upon the following factors:

- depth and velocity of floodwaters;
- rate of rise of floodwaters;
- effective evacuation time;
- evacuation difficulties and access problems, including isolation of some areas as floodwaters rise;

- ability to effectively warn the community of the need to react in a flood event;
- duration of flooding;
- readiness of the community to respond to flood warnings; and
- type of development.

The first step in assessing flood hazard is to consider the depth and velocity of floodwaters as this provides a provisional determination of the flood hazard category based on the hydraulic conditions. The provisional hazard categories are then considered in relation to the other criteria indicated above and, where appropriate, categories may be altered due to these considerations.

The provisional hazard categories for the 1% AEP event in this study have been based on the diagram shown in Figure 2, which relates depth and velocity of floodwater to hazard.

In low hazard areas, people and their possessions would generally be evacuated from houses progressively as the floodwater level rises to the floor level. Able-bodied adults would have little difficulty in wading, and the damage potential and the risk to life and limb would be low.

In high hazard areas, the evacuation of flood affected people and their possessions may be difficult and potentially dangerous. There could be danger to personal safety, and social disruption and financial loss could be high.

The floodways in the Bulahdelah study area are provisionally categorised as high hazard due to the combination of velocity and depth of floodwater.

Most of the flood storage areas in the 1% AEP event are also provisionally categorised as high hazard because the depth of floodwater on the inundated property and/or on available evacuation routes will exceed 1 metre.

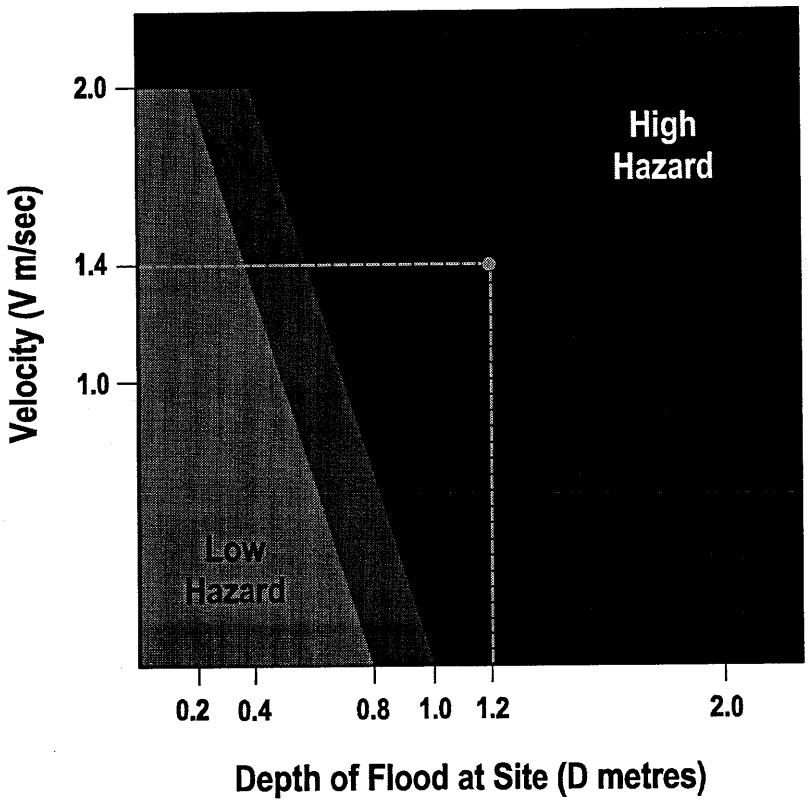
The low hazard areas under existing conditions are limited to areas near the limit of 1% AEP inundation where the velocity and depth of floodwater are comparatively low and where evacuation to higher ground can be accomplished readily. Figure B.1 shows the indicative location of provisional low hazard areas in the township of Bulahdelah.

B4 Revised Hazard Categories

There may be scope to reduce the flood hazard at Bulahdelah by provision of an effective flood warning and evacuation system.

The provision of higher level access routes can also assist in this area. In this regard the extension of Lee Street to River Road, even in its current gravel state, provides for improved evacuation access from the River Street area. In future development areas hazard may also be reduced by filling land and providing suitable evacuation routes.

Considering the factors listed in Section B.2 only appropriate flood warning and community flood readiness are likely to reduce the flood hazard. If these were in place areas where access routes are cut only in events greater than a 20 year AEP could be considered to provide reasonable security of access for early egress during a flood. The hazard categorisation of areas with this degree of access has been reduced from high to low. These areas are shown on Figure B.2.



NOTE:

The degree of hazard may be either :-

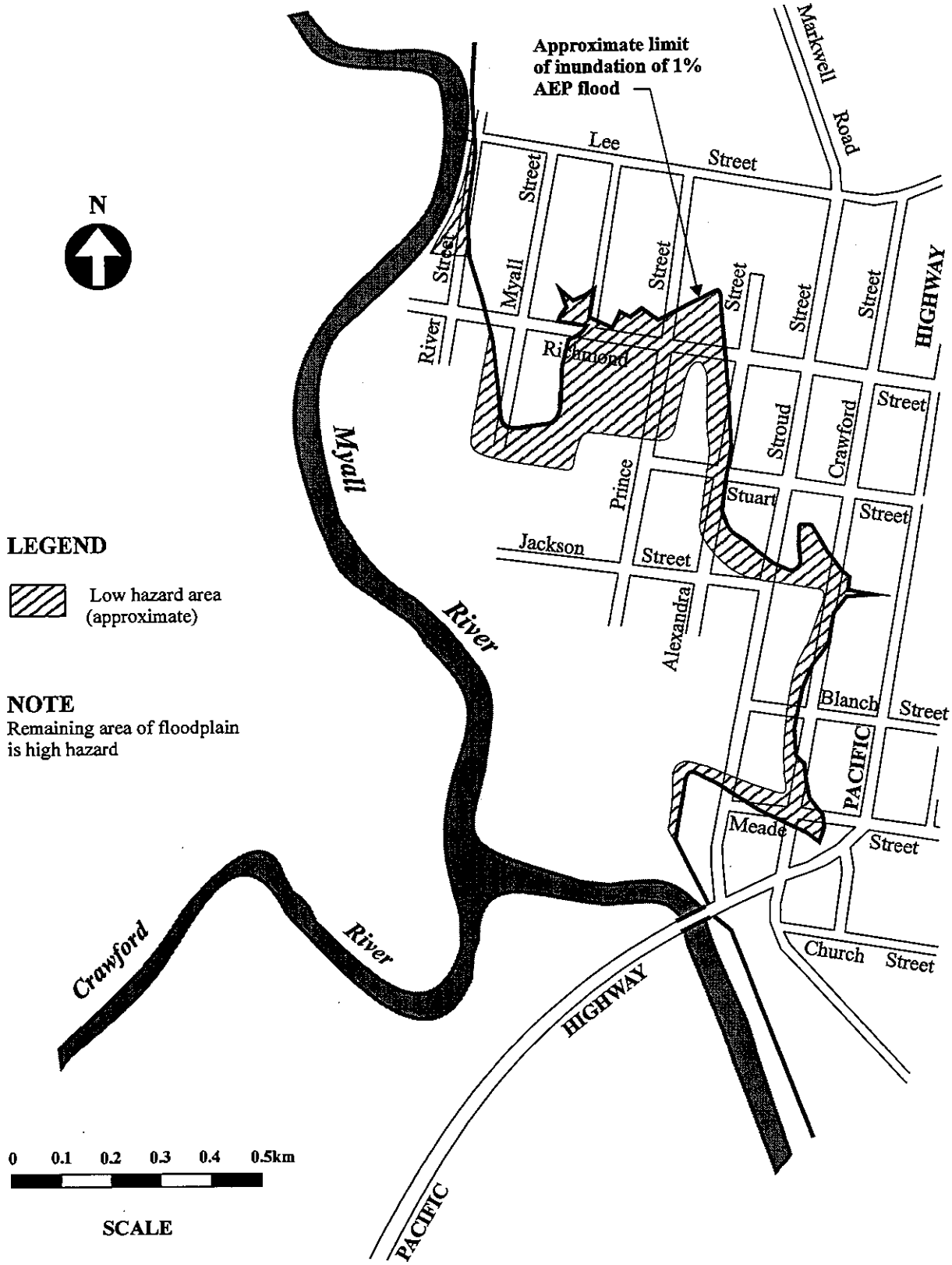
- reduced by the establishment of an effective flood evacuation procedure
- increased if evacuation difficulties exist

In the transition zone highlighted by the median colour, 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**

PROVISIONAL HAZARD CATEGORIES
Figure B.1



PROVISIONAL 1% AEP FLOOD HAZARD AT BULADELAH
Figure B.2

APPENDIX C - FLOOD DAMAGE ASSESSMENT

C1 General

Damages will be incurred to urban properties in the Bulahdelah area during major flood events. Flood damages can be divided into two major categories:

- Tangible damages, which are the financial costs of flooding and are quantified in dollar terms; and
- Intangible damages, which are the social costs of flooding and are reflected in increased levels of mental stress, physical illness, etc.

Tangible damages can be subdivided into two major sub-categories:

- Direct damage, which is the loss in value of property caused by direct contact with floodwaters; and
- Indirect damage, which is the loss in production or revenue, the loss of wages, additional accommodation and living expenses and any other extra outlays that occur as a consequence of the flood.

Potential damage refers to the damage that would be sustained if nothing was done to attempt to reduce this damage. The actual damage is always less than the potential damage. Even in the absence of flood warnings, people will attempt to save items by lifting them, by shifting cars, etc. Estimates of actual damage were derived for Bulahdelah assuming no official flood warnings.

C2 Depth-Damage Relationships

The damages are related primarily to the depth of inundation. Estimates of actual flood damage at Bulahdelah were derived using depth-damage relationships based on information provided in the User Manual for the computer program FLDAMAGE and adjusted for apparent changes in potential damages in recent times. This information takes account of damage data obtained from the most recent large floods in New South Wales including floods at Nyngan and Forbes in 1990, and Inverell in 1991.

The depth-damage relationship for inundation of properties above floor level includes the following components of direct and indirect damage:

- Internal damage, which refers to damage to the contents of the building on the property;
- Structural damage, which refers to damage sustained by the fabric of the building (eg foundations, floors and walls) and by permanent fixtures such as built-in cupboards;
- Clean-up costs, which refer to the cost of labour and materials required to clean out a flooded building; and
- Indirect financial costs such as the cost of alternative accommodation in the post flood recovery phase.

The adopted depth-damage relationship for residential buildings is given in Table C.1. Depth-damage relationships were also defined for external damage which refers to damage to items external to the main building such as motor vehicles, fences and gardens. The adopted relationship for residential properties is given in Table C.2.

Table C.1 Above Floor Damage Values for Residential Properties

Depth of Flooding Above Floor Level (m)	Estimated Damage ($)
0	1,800
0.1	9,400
0.2	13,600
0.25	24,600
0.4	29,800
0.6	35,200
0.9	40,200
1.2	42,000
1.6	43,600
2.0 or more	45,400

Table C.2 External Damage Values for Residential Properties

Depth of Flooding Above Ground Level (m)	Estimated Damage ($)
0	0
0.2	1,500
0.25	2,000
>4	3,700

C3 Estimation of Total Damages

Total damages were calculated for floods of extreme, 1%, 2% and 5% AEP using the peak flood level estimates, discussed in Appendix A. This information was used with a survey of developed properties in the Bulahdelah township area which are below or close to the 1% AEP flood level undertaken by Council in 1997. The survey included details of the structure (type, construction material, age, number of storeys and suitability for raising) as well as the floor level.

Properties which may experience external flooding but no internal flooding have not been identified. In addition properties not inundated by the 1% AEP flood, but which would be inundated in rarer floods have not been assessed. Hence the actual total damages throughout the Bulahdelah study area will exceed the computed damage values.

A curve of total damage versus probability was determined, assuming zero damage for the 10% AEP flood. The area under this curve represents average annual damage. The estimation of total damages and average annual damage was carried out for:

- Existing conditions
- Selected floodplain management options

For floodplain management options, the benefit is the reduction in damages compared with existing conditions. The present worth of benefits was calculated by multiplying the average annual benefit by a present worth factor of 15.8, based on a discount rate of 6% per annum and an analysis period of 50 years.

For the option involving the ALERT flood warning system, an analysis period of 20 years was considered to be more appropriate. The present worth factor for this period is 11.5. The estimated damages were calculated by adjustment of the depth-damage relationships assuming an available warning time of 5 hours. The adjustments were based on information contained in the FLDAMAGE User Manual. It is estimated that a comprehensive flood warning and evacuation system, supported by a public information and education program, would reduce average annual flood damage at Bulahdelah by approximately 30 per cent.

C4 Existing Conditions

It is estimated that about 52 developed properties will be inundated above floor level in the 1% AEP flood. These include 45 residential properties and 7 non-residential properties. The locations of the properties inundated above floor level are shown in Figure 4. In an extreme event the number of residential properties affected above flood level are likely to double, however exact details of the properties affected is an extreme event is not available due to limits on the current survey data.

Flood damages were estimated for the properties inundated above floor level in the 5%, 2% and 1% AEP and extreme flood events. The basis for the assessment of flood damages is outlined in Appendix A. The estimated total damages are as follows:

1% AEP flood damage	$1,700,000
average annual damage	$95,200

It should be noted that these estimates are for properties inundated above floor level. There are addition properties which will not experience above-floor inundation but which may suffer external damage; eg to car fences, etc. Hence the total damages throughout the study area may be higher than the above estimates.