WARRUMBUNGLE SHIRE COUNCIL

TERIDGERIE CREEK AT BARADINE FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

DRAFT STUDY REPORT

MAY 2012

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FOREWORD

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

Under the Policy, the management of flood liable land remains the responsibility of local government. The State subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist councils in the discharge of their floodplain management responsibilities.

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

1.	Flood Study	Determines the nature and extent of flooding.
2.	Floodplain Risk Management Study	Evaluates management options for the floodplain in respect of both existing and proposed development.
3.	Floodplain Risk Management Plan	Involves formal adoption by Council of a plan of management for the floodplain.
4.	Implementation of the Plan	Construction of flood mitigation works to protect existing development; use of Local Environmental Plans and flood related controls to that ensure new development is compatible with the flood hazard.

ACKNOWLEDGEMENT

This *Floodplain Risk Management Study and draft Plan* has been prepared for Warrumbungle Shire Council with the financial and technical support of the Office of Environment and Heritage, Department of Premier and Cabinet (formerly Department of Environment, Climate Change and Water - DECCW) and follows the *Teridgerie Creek at Baradine Flood Study, 2012* (denoted the *Flood Study, 2012* herein) which defined the pattern of flooding in the study area.

The study was undertaken under the direction of the Baradine Floodplain Management Committee, comprising Office of Environment and Heritage, Warrumbungle Shire Council, Community and Government Agency representatives.

ABBREVIATIONS

AEP	Annual Exceedance Probability (%)
AHD	Australian Height Datum
ARI	Average Recurrence Interval (years)
ARR	Australian Rainfall and Runoff, 1998 Edition
BOM	Bureau of Meteorology
DECCW	Department of Environment, Climate Change and Water
OEH	Office of Environment and Heritage (formerly DECCW)
SES	State Emergency Service

NOTE ON FLOOD FREQUENCY

The frequency of floods is generally referred to in terms of their Annual Exceedance Probability (AEP) or Average Recurrence Interval (ARI). For example, for a flood magnitude having 5% AEP, there is a 5% probability that there will be floods of equal or greater magnitude each year. As another example, for a flood having 20 year ARI there will be floods of equal or greater magnitude once in 20 years on average. The approximate correspondence between these two systems is:

ANNUAL EXCEEDANCE PROBABILITY (AEP) %	AVERAGE RECURRENCE INTERVAL (ARI) YEARS
0.5	200
1	100
5	20
20	5

In this report, the severity of flooding is referred to in terms of Average Recurrence Interval. Reference is also made in the report to the Extreme Flood, which is defined as the limiting value of floods that could reasonably be expected to occur. The Extreme Flood was assumed to have a peak discharge equal to three times that of the 100 year ARI flood and a recurrence interval of 1 in 10,000 years. It was used for the purposes of assessing the economic impacts of flooding at Baradine and to assist SES with development of flood emergency management procedures.

SUMMARY

S1 Study Objectives

Warrumbungle Shire Council commissioned the preparation of the *Floodplain Risk Management Study* and *Plan* for Teridgerie Creek at Baradine. The overall objectives of the *Floodplain Risk Management Study (FRMS)* were to assess the impacts of flooding, review existing Council policies as they relate to development of land in flood liable areas bordering Teridgerie Creek, consider options for management of flood affected land and to develop a draft *Floodplain Risk Management Plan (FRMP)* which:

i) Proposes modifications to existing Council policies to ensure that the development of flood affected land is undertaken so as to be compatible with the flood hazard and risk.

ii) Proposes Flood Planning Levels for the various land uses in the Floodplain.

iii) Sets out the recommended program of works and measures aimed at reducing over time, the social, environmental and economic impacts of flooding.

iv) Provides a program for implementation of the proposed works and measures.

S2 Study Activities

The activities undertaken in this *Floodplain Risk Management Study* (*FRMS)* included:

- Review of flooding patterns on Teridgerie Creek at Baradine for flood events up to the Extreme Flood (**Chapter 2**).
- Undertaking a consultation program over the course of the study to ensure that the Teridgerie Creek community was informed of the objectives, progress and outcomes of the study (**Appendix C**).
- Assessment of the economic impacts of flooding, including the numbers of affected properties and estimation of damages (**Chapter 2** and **Appendix B**).
- Review of current flood related planning controls for Baradine and their compatibility with flooding conditions on Teridgerie Creek catchment (**Chapter 2**).
- Strategic assessment of potential floodplain management measures aimed at reducing flood damages, including a preliminary economic assessment of measures (**Chapter 3**).
- Ranking of measures using a multi - objective scoring system which took into account economic, financial, environmental, social and planning considerations (**Chapter 4**).
- Preparation of a draft *FRMP* for Teridgerie Creek (**Chapter 5**).

S3 Summary of Flood Impacts

The study focusses on the Teridgerie Creek floodplain from a location about 1.6 km south of Walker Street near the Ashby property and continuing downstream to Worrigal Street (Coonamble Road), a distance of about 3.4 km along the main arm of the creek. The catchment area of Teridgerie Creek at Ashby is 10.5 km^2, increasing to 14 km^2 at Walker Street. Teridgerie Creek also receives runoff from an additional area of 2.5 km^2 from the developed part of town on the eastern side of the disused Wallerawang to Gwabegar railway and other local sub-catchments, giving a total catchment area of 16.5 km^2 at Worrigal Street. **Figure 1.1** shows the catchment contributing flows to Teridgerie Creek.

Baradine has experienced significant flooding, most recently on 22 December 2007 when flows on Teridgerie Creek outflanked the levee system and entered the eastern part of town via backflooding through the culverts in the railway embankment. The *Flood Study, 2012* which defined the pattern of flooding in the study area estimated the 2007 flood to have a return period between 5 and 20 years. Larger historic floods are reported to have entered the eastern part of town by overtopping Walker Street and the railway embankment. Flooding on Teridgerie Creek is "flash flooding" in nature, with flood levels peaking several hours after the commencement of heavy rainfall. **Figure 2.1** shows indicative extents of inundation for design floods ranging between 5 and 100 years ARI, as well as for the Extreme Flood.

Damaging flooding would commence in existing residential development in the event of a 5 year ARI flood, with the numbers of flood affected properties progressively increasing as shown in **Table S.1**. Above-floor flooding would occur in 59 residences at the 100 year ARI level of flooding, when predicted flood damages to residential property would be about $3.11 Million (**Table 2.3**) and depths of inundation up to 0.8 m would be experienced. Predicted damages to all categories of development in Baradine (residential, commercial and public buildings) would amount to $ 3.54 Million.

TABLE S.1
NUMBER OF PROPERTIES FLOODED
BY TERIDGERIE CREEK AT BARADINE

Flood Event Years ARI	No. of Properties Flooded Above Floor Level		
	Residential	Commercial/ Industrial	Public Buildings
5	8	1	-
20	38	5	3
100	59	5	3
Extreme Flood	75	7	8

Note: These properties would experience flooding above floor level. Flood liable properties (100 year ARI) are shown on **Figure B8.3** of **Appendix B**.

S4 Flood Hazard and Draft Flood Policy

Based on the results of the *Flood Study, 2012* a draft *Flood Policy* has been developed in **Appendix A** of the report to guide future development in flood prone areas of Baradine. The policy recognises that controls over development should depend on the flood hazard, which varies across the floodplain according to the depth and velocity of flow and whether the development is located in an area where significant flows occur (i.e. a floodway).

Other relevant factors influencing proposed controls over development include the rate of rise of floodwaters and ease of egress of residents from the floodplain in the event of a flood emergency. To administer the *Flood Policy* the floodplain has been divided into a number of hazard zones. The significance of these hazard zones to the proposed flood related controls over future development is summarised in **Section 3.8** of the report.

S5 The Floodplain Risk Management Plan

The draft *FRMP* showing recommended flood management measures for the Teridgerie Creek floodplain is presented in **Table S.2**. The draft *FRMP* includes three non-structural management measures which could be implemented by Council with the assistance of SES, using existing data and without requiring Government funding. These measures have been given a **Priority 1** assessment and are considered to be an essential part of the *FRMP*. The measures are as follows:

- **Measure 1** - The application of a graded set of planning controls for future residential development that vary according to the location of the development in the floodplain. Application of these controls by Council via the proposed *Flood Policy* will ensure that future development in the catchment is compatible with the flood risk.
- **Measures 2** and **3** - Improvements in the SES's emergency management planning for the catchment, including incorporation of the flood related information contained in the *Flood Study, 2012* and this present study into the next edition of the *Warrumbungle Shire Local Flood Plan*, and preparation by SES of a "FloodSafe Brochure" identifying the nature and extent of flooding, time of rise of floodwaters and other flood related information for the benefit of residents.

All of the other measures require Council and Government funding. Their priorities depend on the results of feasibility studies which are also part of the draft *FRMP.* They have been given a provisional priority ranking by the Floodplain Management Committee according to a range of economic, social, environmental and other criteria set out in **Table 4.1** of the report. The priorities would be confirmed by the results of the respective feasibility study. The measures are as follows:

- **Measure 4** - Development in the feasibility study of the design concept for a 2.4 km long levee along the eastern floodplain of Teridgerie Creek (denoted Scheme 1 in **Chapter 3** of the report). The scheme will replace the existing system of un-coordinated levees. It could also include the diversion of flows to the Baradine Creek catchment at a location near the Ashby property upstream of Walker Street, which would reduce the height of levees required to protect the town. (The combined levee/diversion scheme is denoted Scheme 2). The investigation would involve refining the concept design and cost estimates developed in **Chapter 3** of this report and would also include survey and engineering analysis. Additional technical investigation of the schemes would be required than is practicable in this study, which is strategic in nature. The investigation is required to confirm the engineering feasibility and economic merit of the schemes and provide documentation to a standard necessary to support an application for Government funding for the project.
- **Measure 5** - Depending on the results of the above feasibility study and agreement on the provision of funding, preparation of detailed design and documentation of either the levee (Scheme 1) or the combined diversion/levee scheme (Scheme 2), followed by its construction as funding becomes available.
- **Measures 6** and **7** – Based on the results of this *FRMS* the combined diversion/levee (Scheme 2) is the preferred method of protecting Baradine from flooding and has been given a **Priority 1** ranking. However, in the event that the feasibility study for the scheme (i.e. **Measure 4**) does not confirm its viability, the creation of a floodway/riparian corridor on Teridgerie Creek could be considered as an alternative flood mitigation measure. A design concept and cost estimate for such a scheme has been prepared in **Chapter 3** of the report as Scheme 4, which would need to be refined in a feasibility study requiring additional survey and engineering analysis. These investigations (**Measure 6**) would be required to confirm the engineering feasibility and economic merit of the floodway/riparian corridor and provide documentation to a standard necessary to support an application for Government funding for

the project. If justified, the construction of the floodway/riparian corridor (**Measure 7**) could then proceed as funding becomes available. **Measures 6** and **7** have been given a **Priority 2** ranking.

- **Measure 8** - Further Investigation of the feasibility of a Flash Flood Warning System for the catchment and development of the scheme if justified. This scheme could be adopted to provide advance warning of flooding on the Teridgerie Creek catchment in the event that neither of the structural schemes (**Measure 5** or **Measure 7**) proceeds in a reasonable timeframe. The Flash Flood Warning System would not affect the pattern of flooding in the study area, but with the assistance of **Measures 2** and **3** would allow residents to reduce damages to contents and safely evacuate prior to the arrival of floodwaters. It has been given a **Priority 3** ranking.

S6 Timing and Funding

The total estimated cost to implement the preferred floodplain management strategy (the non-structural measures plus the feasibility study of the diversion/levee scheme, followed by detailed design and construction) is $3.7 Million, exclusive of Council and SES Staff Costs for the non-structural measures. The timing of implementing the scheme will depend on Council's overall budgetary commitments and the availability of Council and Government funds.

Assistance for funding qualifying projects included in the *FRMP* may be available upon application under the Commonwealth and State funded floodplain management programs, currently administered by OEH.

S7 The Need for Better Survey Information

It would assist Council with the operation of the *Flood Policy* and the preparation of designs for any of the flood mitigation schemes identified in the report, if natural surface levels on the floodplain of Teridgerie Creek could be identified with greater accuracy than is presently possible with the available 0.5 m contour mapping, which is based on conversion to SI units of an imperial units plan of the 1940's and the limited cross sectional survey used to prepare the hydraulic model of the creek in the *Flood Study, 2012*.

This could be achieved at comparatively modest cost by undertaking an Airborne Laser Scanning survey of the study area (possibly extended at minor cost to the whole of Warrumbungle Shire Council area), which would achieve accuracies in defining natural surface levels in the range 150 - 200 mm. This would be a major improvement on the accuracy of existing mapping sources and would also assist Council in the planning and design of other engineering and town planning disciplines (roads, stormwater management, strategy studies and the like). However, the cost of the survey would be outside the scope of the NSW Government's floodplain program and would therefore need to be borne by Council.

TABLE S.2
RECOMMENDED MEASURES FOR INCLUSION IN
DRAFT FLOODPLAIN RISK MANAGEMENT PLAN

Measure	Required Funding	Features of the Measure	Priority
1. Implement controls over future development in urban areas of Baradine affected by flooding from Teridgerie Creek, based on the draft *Flood Policy* of **Appendix A**, as amended by Council.	Council's staff costs	▪ Control residential development in floodplain as summarised in the draft *Flood Policy* (ref. **Section 3.8** and **Appendix A**). ▪ Graded set of flood controls based on location within the Flood Planning Area, defined as land inundated by the 100 year ARI flood plus 500 mm freeboard and therefore subject to flood related development controls. ▪ Floodplain divided into zones: High Hazard Floodway, Overland Flow Zone, Intermediate Floodplain. ▪ Council's evaluation of development proposals to use data presented in *Flood Study, 2012* and in this *FRMS, 2012.*	**Priority 1**: this measure has a high priority for inclusion in the *FRMP*. It does not require Government funding.
2. Ensure flood data in *this Floodplain Risk Management Study and Plan* are available to SES for inclusion in flood response procedures.	SES costs	▪ SES's Warrumbungle Shire *Local Flood Plan* to be updated using information on patterns of flooding shown in *Flood Study, 2012*. Locations of flood prone development are incorporated in the *FRMS* and shown in **Figure B8.3** of **Appendix B**.	**Priority 1**: this measure would improve SES's emergency management procedures and has a high priority. It does not require Government funding.
3. Implement flood awareness and education program for residents bordering the creek.	SES, Council staff costs	▪ Council and SES to prepare *FloodSafe Brochure* to inform residents of the flood risk, based on the information presented in the *FRMS*.	**Priority 1**: this measure would reduce flood losses and has a high priority. It does not require Government funding.
4. Feasibility Study of a flood protection levee along the eastern side of Teridgerie Creek, with consideration of diversion of flows to Baradine Creek (alternative Schemes 1 or 2).	$150,000	▪ Detailed survey along routes of levee and flow diversion structures. ▪ Prepare concept design; refine initial costing and economic analysis presented in this *FRMS*. ▪ Undertake environmental studies and Community Consultation, as well as liaison with Agencies to gain regulatory approval. ▪ Prepare a submission for Council and Government funding of the construction.	**Priority 1**: this measure is the first step in providing the diversion/levee scheme and has a high priority in view of the economic impacts resulting from flooding in Baradine. It requires Council and Government funding.
5. Preparation of detailed design and construction of the levee/diversion scheme (dependent on the results of the Measure 4 feasibility study)	$3.55 Million	▪ Liaison with landowners for land acquisition or easements. ▪ Prepare detailed design and documentation of scheme (indicative cost applies for diversion to Baradine Creek catchment plus levees) . ▪ Works are to be implemented by Council when funding available. ▪ Annual maintenance costs are included (1% of capital cost adopted in economic analysis of **Table 3.4**).	**Priority 1**: this measure would depend on a favourable outcome from the above Feasibility Study and on the availability of Council and Government funding.
6. Feasibility Study of a floodway/riparian corridor along Teridgerie Creek (Scheme 4).	$120,000	▪ Detailed survey along corridor route. ▪ Prepare concept design; refine initial costing and economic analysis presented in this *FRMS*. ▪ Undertake environmental studies and liaison with Agencies to gain regulatory approval and Community Consultation. ▪ Prepare a submission for Council and Government funding of the construction.	**Priority 2**: this measure is an alternative to the diversion/levee scheme should the feasibility study (Measure 4) show that it is not viable. It requires Council and Government funding.
7. Preparation of detailed design and construction of the floodway/riparian corridor scheme	$6.9 Million	▪ Liaison with landowners for land acquisition and easements. ▪ Prepare detailed design and documentation of scheme (indicative cost applies for riparian corridor plus levees). ▪ Works are to be implemented by Council when funding available. ▪ Annual maintenance costs are included (1% of capital cost adopted in economic analysis of **Table 3.6**).	**Priority 2**: this measure would depend on a favourable outcome from the Feasibility Study and the availability of Council and Government funding.
8. Implementation of Flash Flood Warning System	$200,000	▪ Cost is the capital cost only and allows for instrumentation, software, training and public flood awareness program. ▪ Allow an additional annual cost of $15,000 for maintenance of the system (Council costs).	**Priority 3**: this measure could be considered if the feasibility studies for the above structural measures show that none is viable. Implementation and maintenance of this measure would require Council and Government funding.
Total Estimated Cost (Preferred Strategy)	**$3.7 Million**	**Note: the currently preferred strategy comprises Measures 1 to 5.**	

1 INTRODUCTION

1.1 Study Background

The town of Baradine is located on the north-west slopes of NSW, 45 km north of Coonabarabran and 500 km north-west of Sydney. The population of the town is around 600. The layout of the urban area is a grid pattern of streets running in a north-south and east-west direction. The eastern boundary of the urban area is defined by Baradine Creek which is located within the Namoi River Valley. Teridgerie Creek is situated on the western side of the urban area and is located within the Castlereagh River Valley. (The creek running through Baradine is actually an un-named tributary of the Teridgerie Creek system, but has been given the name Teridgerie Creek for the purposes of this study.)

Figure 1.1 shows the Teridgerie Creek catchment and the study area, the focus of which is the floodplain downstream of Ashby and extending to Worrigal Street (Coonamble Road). Historic flooding has resulted in damage to residential properties on the floodplain. A major storm occurred on 22 December 2007 which would have escaped into the residential area but for prompt action by SES and residents in blocking gaps in the levee at Namoi Street and Lachlan Street (see also **Figure 2.1** for street locations). High flood levels in Teridgerie Creek coincident with local stormwater runoff generated from the urban catchment on the eastern side of the railway inhibited the discharge of flows through the railway culverts to the creek. Considerable ponding was experienced in the urban area on the eastern side of the culverts.

The recently completed *Flood Study, 2012* assessed main stream flooding patterns and was the first part of the NSW Government's Floodplain Risk Management process, which aims to reduce the impact of flooding and flood liability for flood prone land in the catchment. The *Floodplain Risk Management Study (FRMS)* and *draft Plan (FRMP)* for the catchment (this present report) represented the next phase of the Government's management process.

The first step in the *FRMS* process was the collection of flood data via a Community Questionnaire which was distributed by Council to residents bordering Teridgerie Creek. Based on the knowledge of flooding patterns determined in the flood study and the survey of the floor levels of properties located within the floodplain, the economic impacts of flooding were assessed. Measures aimed at managing the flood risk for existing development and reducing the risk for future development, were then formulated and their feasibility assessed.

The potential flood management measures were ranked by the Floodplain Management Committee according to a scoring system based on economic, social and environmental criteria. Based on these results a draft *FRMP* was then prepared under the guidance of the Committee.

1.2 Overview of Report

This report sets out the findings of the *FRMS* and presents the draft *FRMP*.

Chapter 2 of the Report contains information on baseline flooding conditions on the floodplain. It includes a review of Council's existing planning policies as they relate to flood affected land, assessment of the impacts of flooding on the community, a review of SES's flood warning and emergency management arrangements and a consideration of environmental factors which could influence the works and measures recommended for inclusion in the draft *FRMP*.

Chapter 3 is a review of possible floodplain management measures which could be included in the *FRMP*. Community views obtained from the Questionnaire are summarised, leading to a list of potential flood management measures which are then tested for their feasibility.

Chapter 4 details the selection of the floodplain management measures for the *FRMP*. Floodplain management strategies comprising various combinations of measures are assessed according to a multi-objective scoring system and a preferred strategy is outlined.

Chapter 5 presents the draft *FRMP.*

Chapter 6 contains a list of References.

The Study is supported by **Appendices** which provide additional details of the investigations undertaken for the preparation of the Study and Plan.

Appendix A –Draft Flood Policy presents a policy aimed at guiding future development in areas of Baradine affected by flooding from Teridgerie Creek.

Appendix B - Flood Damages is an assessment of the economic impacts of flooding on urban development in Baradine.

Appendix C – Community Newsletter and Responses to Questionnaire summarises residents' views on potential flood management measures.

1.3 Community Consultation

Following the Inception Meeting of the Floodplain Management Committee which included Council, Community, DECCW (now Office of Environment and Heritage) and other Government agency representatives, a Community Newsletter was prepared by the Consultants and distributed to residents by Council. The Newsletter contained a Questionnaire seeking details from the community of flood experience and attitudes to potential floodplain management options. Community responses are summarised in **Chapter 3** and **Appendix C**.

Subsequently, the Committee reviewed the results of the flood study as well as the potential flood management measures developed in **Chapter 3** and assessed the measures using the scoring system of **Chapter 4**. The *draft FRMS* and accompanying *draft FRMP* were reviewed and amended by the Committee prior to public exhibition.

N

250 0 250 500 750 m

Scale: 1:25,000

TERIDGERIE CREEK
FLOOPLAIN RISK MANAGEMENT STUDY

Figure 1.1

LOCATION PLAN

2 BASELINE FLOODING CONDITIONS

2.1 Catchment Description

Figure 1.1 is a location plan showing the extent of the Terididgerie Creek catchment. The catchment area of Teridgerie Creek at Worrigal Street (Coonamble Road) is around 16.5 km^2. The catchment boundary in the rural area upstream of town is difficult to define due to the indistinct nature of the drainage paths and the forested terrain. The area of the catchment contributing flow to the urban area downstream of Walker Street may be dependent upon the nature of land use occurring at the time of storm event and the season of the year.

The disused Wallerawang to Gwabegar railway runs in a north to south direction through the centre of town. Stormwater runoff from the eastern side of town discharges westwards to Teridgerie Creek via twelve 750 mm diameter Armco pipes set in the low railway embankment. Inundation and damage to properties in the urban area of Baradine on both sides of the railway are caused by flooding from Teridgerie Creek, exacerbated by the ponding of stormwater runoff on its eastern side during high water levels in the creek.

Floodwaters from several historic floods on Teridgerie Creek have caused inundation and damage to property. Most recently, flood events that caused damage occurred on the 22 December 2007, 24 February 2004 and 20 November 2000. In each of these events houses were reported to be inundated and several others required emergency sandbagging. During major flood events, vehicle access to the western side of Baradine was formerly prevented for up to 20 hours. However, recent upgrading of the Walker Street crossing has improved access, although the crossing was subject to shallow overtopping in a flood which occurred in February 2010 shortly after its upgrading. During major flooding access across Walker Street would be prevented for up to 5 hours.

In the December 2007 flood event, floodwaters from Teridgerie Creek escaped outside the eastern levee bank, entering the urban area on the eastern side of the railway line via backwatering through the culverts. More severe historic flooding is reported to have flooded town via overtopping the railway. The *Flood Study, 2012* estimated the return period of the 22 December 2007 flood to be between 5 and 20 years ARI. More severe historic flooding is reported to have flooded the eastern part of town by overtopping Walker Street and flowing in a northerly and north-westerly direction over the railway embankment before returning to Teridgerie Creek. The extent of historic flooding shown in the SES's *Warrumbungle Shire Local Flood Plan* (see **Appendix C**) agrees with the indicative extent of inundation diagram compiled as part of the flood study (ref. **Figure 2.1** herein).

Property owners living near the waterway have taken steps over years to protect their property. There are levees running along the eastern side of the creek from a location upstream of Walker Street to Macquarie Street. However, the levees denoted *Levee 4* and *Levee 3* on **Figure 2.1**, are not continuous, as there are gaps at several cross streets which must be manually blocked prior to the arrival of floods. Residents have constructed localised levees, for example *Levee 1,* and some have raised the levels of their houses. After each flood event, property protection measures have been put in place, mainly of an ad hoc nature.

The potential adverse impacts of the levees on flooding patterns have caused concern and are one of the reasons for undertaking the present study. The levee system is described in detail in the *Flood Study, 2012*.

2.2 Characteristics of Flooding

2.2.1 Main Stream Flooding

Figure 2.1 shows the areas likely to be inundated by the 5, 20 and 100 year ARI design floods, as well as the Extreme Flood. The flood extents were estimated in the *Flood Study, 2012* from the creek cross sections used to develop the hydraulic model of Teridgerie Creek, supplemented by natural surface levels in residential properties determined during the course of the property survey used to assess flood damages (**Appendix B**).

As mentioned, the levees shown on **Figure 2.1** are not continuous over several of the road crossings, requiring closure by temporary earth banking or sandbagging prior to the arrival of the flood peak. The levees are also of uncertain standard of construction and the photographic records of their performance during the significant floods of December 2007 and February 2010 led to the conclusion that they were not likely to withstand a major flood, either because of scouring in the event of their overtopping or by piping and seepage failures. Consequently, the hydraulic modelling in the flood study was undertaken on the basis that the levees bordering Teridgerie Creek did not restrain the floodwaters from inundating the floodplain.

The extents of inundation shown on **Figure 2.1** are indicative only due to limitations in the accuracy of the available survey data and should not be used to assess the flood affectation or otherwise of individual properties. A site survey would be required to assess the degree of flood affectation of individual properties.

Because of the small size of the catchment, flooding is of a “flash flooding” nature and is usually of short duration. Times of rise of floodwaters for design flood events are shown in the flood study. For 100 year ARI design storms, floodwaters would rise to a peak between two and three hours after the commencement of heavy rainfall. This is in contrast to observed behaviour during the December 2007 flood when floodwaters rose more slowly and were of longer duration. Rainfalls experienced during that historic storm were less intense and of longer duration than the synthesised storms used for design flood analysis, which contain shorter bursts of more intense rainfall.

Flow velocities in the channel for the design storms range between 1 and 1.5 m/s, with lower velocities on the floodplain averaging about 0.3 m/s. Depths of flow in the channel for the 100 year ARI flood reach a maximum of 2 m in the vicinity of Worrigal Street, reducing to about 1.5 m between that location and Walker Street. Upstream of Walker Street the depth in the channel averages about 1.2 m.

2.2.2 Local Catchment Flooding

The local stormwater catchment encompasses an area on the eastern side of the railway approximately bounded by Walker Street to the south, Narren Street to the east and extends northwards to Wellington Street. This catchment generates a peak discharge at the railway culverts of about 5 m^3/s from the 100 year ARI storm.

In the absence of high flows in the creek, the railway culvert, comprising 12x750 mm diameter Armco pipes, has sufficient capacity to discharge the local stormwater runoff without excessive ponding on its upstream side. However, high flows in Teridgerie Creek impede the discharge of runoff and could result in a reversal of the flow into the eastern side of the railway. Council constructed a relief drain to

alleviate the back-flooding which occurred from the direction of Teridgerie Creek in the 22 December 2007 flood. The drain runs northwards along the eastern side of the railway from the railway culverts, crossing Wellington Lachlan and Macquarie Streets and discharging towards Baradine Creek. However, the capacity of the drain is limited by the sizes of the pipes at the street crossings, which range between 450 and 600 mm diameter. During major flooding, the relief drain surcharges, with shallow, slow moving overland flow heading in a north and north-easterly direction along the eastern side of the railway towards Baradine Creek.

Details of the operation of the stormwater system are discussed in **Section 3.3** in connection with a possible replacement of the existing levees bordering Teridgerie Creek. As noted therein, because construction of the levee would require either blocking the railway culverts or providing them with flood gates to prevent back flooding into town, upgrading the relief drain would be required to discharge stormwater from the protected area on the eastern side of the railway.

2.3 Flood Hazard Zones and Floodway Areas

Prior to formulating policies for development in flood prone areas, it is the usual practice to sub-divide the floodplain into zones of varying flood hazard, as well as examining the effectiveness of various areas of the floodplain in a hydraulic sense. As noted below the principal parameters used to assess *provisional* flood hazard are depth and velocity of flow, but there are additional parameters to be considered before making a final evaluation. It is also recognised that flood levels and the passage of the floodwave are dependent on the hydraulic conveyance capacity of the channel as well as the ability of the overbanks to temporarily store flood waters. Determination of these features is known as hydraulic categorisation of the floodplain. Definition of flood hazard and hydraulic categorisation are discussed below.

2.3.1 Flood Hazard

In the *Flood Study, 2012*, provisional flood hazard categories were assigned to flood affected areas in accordance with the procedures outlined in the *Floodplain Development Manual, 2005*. Flood prone areas were provisionally categorised into *Low Hazard* and *High Hazard* areas depending on the depth of inundation and flow velocity.

However, flood hazards categorised on the basis of depth and velocity only are *provisional*. They do not reflect the effects of other factors that influence hazard. These other factors include:

- Size of flood – major floods though rare can cause extensive damage and disruption.
- Effective warning time – flood hazard and flood damage can be reduced by evacuation if adequate warning time is available.
- Flood awareness of the population – flood awareness greatly influences the time taken by flood affected residents to respond effectively to flood warnings. The formulation and implementation of response plans for the evacuation of people and possessions promote flood awareness.
- Rate of rise of floodwaters – situations where floodwaters rise rapidly are potentially more dangerous and cause more damage than situations in which flood levels increase slowly.
- Duration of flooding – the duration of flooding (or length of time a community is cut off) can have a significant impact on costs associated with flooding. The duration is shorter in smaller, steeper catchments.

- Evacuation problems and access routes – the availability of effective access routes from flood prone areas directly influences flood hazard and potential damage reduction measures.

Provisional hazard categories may be reduced or increased after consideration of the above factors in arriving at a final determination. A qualitative assessment of the influence of the above factors on the *provisional* flood hazard on Teridgerie Creek is presented in **Table 2.1**. Factors identified in **Table 2.1** which would increase the flood hazard are balanced by considerations reducing the hazard. Consequently, there would be no reason to adjust the provisional flood hazard and the determination of hazard in the floodplains could be based on depth and velocity alone.

TABLE 2.1
INFLUENCE OF FLOOD RELATED PARAMETERS
ON PROVISIONAL FLOOD HAZARD IN TERIDGERIE CREEK FLOODPLAIN

Parameter	Influence on Provisional Hazard	Flood Characteristics
Size of flood	0	Apart from the immediate vicinity of the creek, flooding is comparatively shallow, with no sudden increases in depth of flow or alternative flow paths developing with increasing severity of flooding.
Effective warning time	1	The warning time is short and presently limited to about three to six hours, which would tend to increase the provisional flood hazard.
Flood awareness	-1	Flood awareness appears to be quite high due to the occurrence of several major storms over the past ten years including the major flood of December 2007 which was well remembered by residents in their responses to the Questionnaire.
Rate of rise and velocity of floodwaters	1	Flooding is of a "flash flooding" nature, with the stream rising substantially within three hours of the commencement of heavy rainfall. This would tend to increase the flood hazard, although the hazard could be reduced by education the community about flood risk.
Duration of flooding	– 1	The duration of the flood peak is quite short, around two hours for the design storms shown in the *Flood Study, 2012*).
Evacuation problems	– 1	There is easy evacuation from the residential area out of the flooded area to higher ground. Evacuees would not need to travel more than 200 m through rising ground to flood free land.

Legend 0 = neutral impact on provisional hazard
1 = tendency to increase provisional hazard
– 1 = tendency to reduce provisional hazard

2.3.2 Hydraulic Categorisation

It is usual practice to divide the floodplain into the following hydraulic zones:

- Floodway;
- Flood Storage
- Flood Fringe

Floodways are those areas where a significant volume of water flows during floods and are often aligned with obvious natural channels. They are areas that, even if partially blocked, would cause a significant increase in flood level and/or a significant redistribution of flow, which may in turn adversely affect other areas. They are often, but not necessarily, areas with deeper flow or areas where higher velocities occur.

Flood Storage areas are those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. If the capacity of a flood storage area is substantially reduced by, for example, the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased. Substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.

Flood Fringe is the remaining area of land affected by flooding, after floodway and flood storage areas have been defined. Development in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.

In determining appropriate hydraulic categories, it is important that the *cumulative* impact of progressive development be evaluated, particularly with respect to floodway and flood storage areas. Whilst the impact of individual developments may be small, the *cumulative* effect of the ultimate development of the area can be significant and may result in unacceptable increases in flood levels and flood velocities elsewhere in the floodplain. Teridgerie Creek is a small catchment which does not have an extensive floodplain. Displacement of flood storage would not result in significant downstream effects on downstream flows. Consequently, for the hydraulic categorisation, the floodplain could be divided into two principal components: *floodway* and *flood fringe*.

The *floodway* zone could be further sub-divided into a *floodway* on the western side of the railway, which follows the central thread of the stream and which would convey most of the flow, together with an additional zone where flows may be significant but at lesser depths and velocities. That latter zone has been denoted the *overland flow* zone and includes the portion of the eastern floodplain where, during major flooding, flows cross the railway embankment and return to the creek from the eastern part of town, as well as the area on the eastern side of the railway where overland flows surcharging the relief drain head northwards towards Baradine Creek. The remainder of the floodplain represents the *flood fringe.*

The flood hazard and hydraulic categorisation data described above have been used for the purposes of developing the *Flood Policy* for guiding future development in flood prone areas bordering the creek system. The area of the floodplain encompassing the *Flood Planning Area* has been sub-divided into three zones as shown on **Figure 2.2**. They comprise the "*High Hazard Floodway"* the "*Overland Flow Zone*" and the *"Intermediate Floodplain"*. Use of these categories in the proposed *Flood Policy* is outlined in **Section 3.8** and **Appendix A**.

2.4 Impacts of Climate Change

CSIRO undertook investigations for the NSW Government (Hennessy et al, 2004) which indicated that whilst the region will become drier on average due to climate change, the frequency and intensity of climate extremes such as storms, floods and droughts will increase. That is, large flood producing storms will occur more often and be greater in magnitude. The investigations suggest that until 2030, there will be an increase in the 40 year ARI 24 hour rainfall of +3 per cent and an increase of +10 per cent by 2070.

DECCW (now OEH) recommends that its guideline *Practical Consideration of Climate Change, 2007* be used as the basis for examining climate change in projects undertaken under the State Floodplain Management program and the *Floodplain Development Manual, 2005*. The guideline recommends that until more work is completed in relation to the climate change impacts on rainfall intensities, sensitivity analyses should be undertaken based on increases in rainfall intensities ranging between 10 and 30 per cent. On current projections the increase in rainfalls within the service life of developments or flood management measures is likely to be around 10 per cent, with the higher value of 30 per cent representing an upper limit.

As shown in the flood study, an increase of 10 per cent in rainfall intensities would result in an increase in peak flows of 14 per cent. This increase in flows would result in an increase in flood levels averaging 60 to 80 mm along Teridgerie Creek. The 30 per cent increase in rainfalls would result in an increase of no more than 150 mm in flood levels. Therefore the future effects of climate change, as far as peak flood levels are concerned, could be accommodated within the 500 mm of freeboard which is usually applied to the best estimate of flood levels, with a reasonable margin remaining for other uncertainties such as local hydraulic effects and wave action.

The impact of climate change on *flooding patterns* in Teridgerie Creek in the event of major flooding may be summarised as:

- A gradual widening of the extent of inundation along the length of the main arm of Teridgerie Creek.
- A small increase in flow velocities within the inundated area running along the main arm, but no sudden increase in the provisional flood hazard due to increased flood depths and flow velocities.
- No islands or new flow paths would be created. Flow would continue to follow its existing course along the creek.
- There may be a small reduction in the time of rise of the floodwaters. Teridgerie Creek is flash flooding with only a few hours of warning time available to residents. Effective flood warning may not be achievable even with the benefit of future technical improvements in systems. Therefore on-going community education of the nature of flooding via Council and SES is required to limit risks to people and property.

2.5 Economic Impacts of Flooding

The economic consequences of floods are discussed in detail in **Appendix B**, which assesses flood damages to property in the floodplain, which are mainly of a residential nature. There are no data

available on historic flood damages to the residential sector in the study area. Accordingly it was necessary to use data on damages experienced as a result of historic flooding in other urban centres.

The residential flood damages were assessed using techniques developed and tested in numerous urban and rural flood situations in NSW and based on the recent publication *Floodplain Guideline Number 4, 2007* published by DECCW. **Figure B8.3** of **Appendix B** identifies properties which would be subject to above-floor inundation in the event of the 100 year ARI flood. This diagram has been prepared after comparison of peak design flood levels derived with the floor levels obtained during the property survey used to estimate flood damages. The numbers of properties flooded above floor level are listed on **Table 2.2**.

Significant flood damages would be experienced at the 5 year ARI level. A total of 8 residential properties would experience flooding above floor level. At the 100 year ARI, a total of 59 residences would experience flooding above floor level with the greatest depth being 800 mm. In the event of an Extreme Flood, 75 residences would be flooded above floor level.

TABLE 2.2
NUMBER OF PROPERTIES
FLOODED AT BARADINE

Flood Event Year ARI	No. of Properties Flooded Above Floor Level		
	Residential	Commercial/ Industrial	Public Buildings
5	8	1	-
20	38	5	3
100	59	5	3
Extreme Flood	75	7	8

Note: These properties would experience above-floor flooding. Flood liable properties (100 year ARI) are shown on **Figure B8.3** of **Appendix B**.

Table 2.3 shows the damages experienced for each class of property

TABLE 2.3
PREDICTED FLOOD DAMAGES
AT BARADINE

Average Recurrence Interval Year ARI	Flood Damages to Each Category ($ x 10^6)			Total Damages ($ x 10^6)
	Residential	Commercial	Public	
5	0.57	0.03	-	0.60
20	2.05	0.22	0.03	2.30
100	3.11	0.37	0.06	3.54
Extreme Flood	4.65	0.88	0.24	5.76

2.6 Existing Flood Modification Measures (Structural Works)

There are no structural flood management measures currently in place for the Teridgerie Creek catchment apart from the informal system of levees and the relief drain on the eastern side of the railway. As mentioned, the levees which are of uncertain construction would be overtopped and outflanked during major flooding by breakouts from the creek further upstream. Apart from *Levee 2,* which is grassed and appears to be of a better standard of compaction, it is likely that the levees would fail by scour, internal erosion, or a combination of both mechanisms.

2.7 Council's Existing Planning Instruments and Policies

The *"Shire of Coonabarabran Local Environmental Plan, 1990"* is used by Warrumbungle Shire Council to manage development in Baradine. Coolah and Coonabarabran amalgamated to form Warrumbungle Shire in 2004 and retained their respective LEP's.

2.7.1 Land Use Zoning

The urban area of Baradine is zoned Village 2(v).

2.7.2 Flood Provisions of the Shire of Coonabarabran LEP, 1990

Flood related clauses are contained in Clause 25 of the LEP and are presented below:

(1) A person shall not erect a building or carry out a work for any purpose on flood prone land except with the consent of Council.

(2) The Council shall not grant consent to the erection of a building or the carrying out of a work on flood liable land or on land within a floodway if in the opinion of Council the carrying out of the development is likely:

- *(a) to impede the flow of flood waters on that land or adjacent land,*
- *(b) to imperil the safety of persons on that land or adjacent land in the event of those lands being inundated with flood waters,*
- *(c) to aggravate the consequences of flood waters flowing on that land with regard to erosion, siltation and the destruction of vegetation, or*
- *(d) to have an adverse effect on the water table of that land or adjacent land.ct of the building or work on flood behaviour.*

2.7.3 Flood- Related Clauses in Updated LEP

Warrumbungle Shire Council is currently in the process of updating its LEP in common with other LGA's in NSW. DOP and DECCW (now OEH) have carried out extensive negotiations regarding the generic wording of flood related clauses to be included in new versions of LEP's in NSW.

The *provisionally* agreed (and subject to change) generic wording for new LEP's is shown below:

" 7.3 Flood planning [local d07]

(1) The objectives of this clause are as follows:

(a) to minimise the flood risk to life and property associated with the use of land;

(b) to allow development compatible with the land's flood hazard, taking into account projected sea level rise;

(c) to avoid significant adverse impacts on flood behaviour and the environment.

(2) This clause applies to:

(a) land that is shown as "Flood Planning Area" on the Flood Planning Map, and

(b) other land at or below the flood planning level.

Drafting direction
Councils know of some areas that flood and those areas are mapped as "flood planning area", but there are other areas where accurate mapping is not possible. Consequently, the wording of this sub-clause captures the land that can be accurately mapped and the land that cannot. Such unmapped land includes the "flood planning area" (as defined in the Floodplain Development Manual) up to the "flood planning level".

(3) Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:

(a) is compatible with the flood hazard of the land; and

(b) will not significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and

(c) incorporates appropriate measures to manage risk to life from flood, and

(d) will not significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and

(e) will not be likely to result in unsustainable social and economic costs to the community as a consequence of flooding.

(4) A word or expression used in this clause has the same meaning as it has in the NSW Government's Floodplain Development Manual published in 2005, unless it is otherwise defined in this clause.

(5) In this clause:

***flood planning level** means the level of a 1:100 ARI (average recurrent interval) flood event plus [insert number 0.xx] metres freeboard.*

Flood Planning Map means the [Name] Local Environmental Plan 2012 Flood Planning Map. "

The ***flood planning level*** referred to above is the 100 year ARI flood plus an allowance for freeboard, which is usually set at 500 mm. It is the minimum level set for future residential development. The area encompassed by the *FPL* is known as the *Flood Planning Area* and denotes the area subject to flood related development controls. It is now standard practice for the residential *FPL* to be based on the 100 year ARI flood plus freeboard unless exceptional circumstances apply (see **Section 3.8.2** for further discussion).

This wording recognises recent amendments to government policy that for residential land use, the area to be subject to flood-related development controls will be limited to land inundated by the 100 year ARI flood plus an allowance for freeboard.

Under the arrangements agreed to by DOP and DECCW (now OEH), flood related development controls for other categories of development for which a higher level of protection may be required (e.g. hospitals, aged persons accommodation, critical utilities, etc), may be covered by Flood Policy DCP's.

2.7.4 Section 149 Certificates

Warrumbungle Shire Council currently requires minimum floor levels for residential property, to be based on the "100 year ARI flood level plus 500 mm freeboard". Council presently bases the area of Baradine subject to flood related controls on the SES flood map which is shown in the Community Questionnaire in **Appendix C** of this study. Minimum floor levels are based on historic floods. Pending the adoption of the *Flood Study, 2012* and this *FRMS*, Council is not able to provide specific information on flooding.

The proposed updating of Council's LEP will necessarily require an updating of the flood related wording in Council's S149 (2) Certificates, because Clause 25 will probably be amended to conform with the above wording agreed to by DOP and DECCW (**Section 2.7.3**). It is not possible at this time to propose amended wording, in view of the fact that the currently agreed wording for the LEP is provisional.

However it is suggested that the new wording of S149 (2) certificates could be simplified along the following lines:

"Based on flood investigations and mapping in Council's possession, this property may lie within the extent of the residential Flood Planning Area (land encompassed by the 100 year ARI flood level plus 500 mm) and is therefore subject to flood related development controls, which are set out in Council's Flood Policy and the Teridgerie Creek at Baradine Floodplain Risk Management Study, 2012. Further information may be obtained by enquiries of Council."

2.7.5 Council's Flood Policy

Council does not currently have a formal flood policy. A draft policy is attached to this present study as **Appendix A**. The draft *Flood Policy*, which is summarised in **Section 3.8.4** of the report, structures the criteria to be adopted for assessing proposals which are potentially affected by flooding in recognition that different controls are applicable to different land uses and degrees of potential flood inundation and hazard.

The draft *Flood Policy* conforms with the requirements of the Circular issued by the Department of Planning on 31 January 2007 which contained a package of information clarifying flood related controls on land located above the 100 year ARI flood level (i.e. land which is infrequently flooded).

The Flood Policy would be consistent with the suggested amendments to the LEP above. The Policy is supported by the results of the *Flood Study, 2012*, which defined flood levels, flood extents and the hydraulic and hazard categorisation of the floodplain.

In keeping with modern flood policy, the draft *Flood Policy* structures the criteria to be adopted for assessing proposals which are potentially affected by flooding in recognition that different controls are applicable to different land uses and levels of potential flood inundation and hazard.

The types of controls identified in the draft *Flood Policy* have been graded relative to the severity and frequency of potential floods, having regard to the location within the floodplain. As discussed in **Section 3.8.4** it is proposed to divide the floodplain into zones, extending from the zone of highest hazard within and bordering the creek channel (denoted the "*High Hazard Floodway*") to the outside limits of the flooded area.

2.8 Flood Warning and Flood Preparedness

2.8.1 Warrumbungle Shire Local Flood Plan

The State Emergency Service is nominated as the principal combat and response agency for flood emergencies in NSW. The SES is responsible for the issuing of relevant warnings (in collaboration with the Bureau of Meteorology), as well as ensuring that the community is aware of the flood threat and how to mitigate its impact.

SES typically prepares a *Local Flood Plan* for flood prone urban centres which is used to manage flood emergencies. The *Warrumbungle Shire Local Flood Plan, July 2006 Edition* covers preparedness measures, the conduct of response operations and the coordination of immediate recovery measures for all levels of flooding within the area and is administered by the SES Local Controller who controls flood operations within the Warrumbungle Shire Council area, which is located within the Namoi SES Division.

The *Local Flood Plan* is divided into the following parts:

- ***Preparedness***, the *Local Flood Plan* typically devotes considerable attention to flood alert and emergency response procedures to be followed in the event of imminent flooding.

- ***Response***. The Warrumbungle SES maintains an operation centre at the Local SES Headquarters in Baradine. The SES also monitors the potential problem areas such as low points on roads, bridges, creeks and flood runners. These locations should be identified in the Plan.

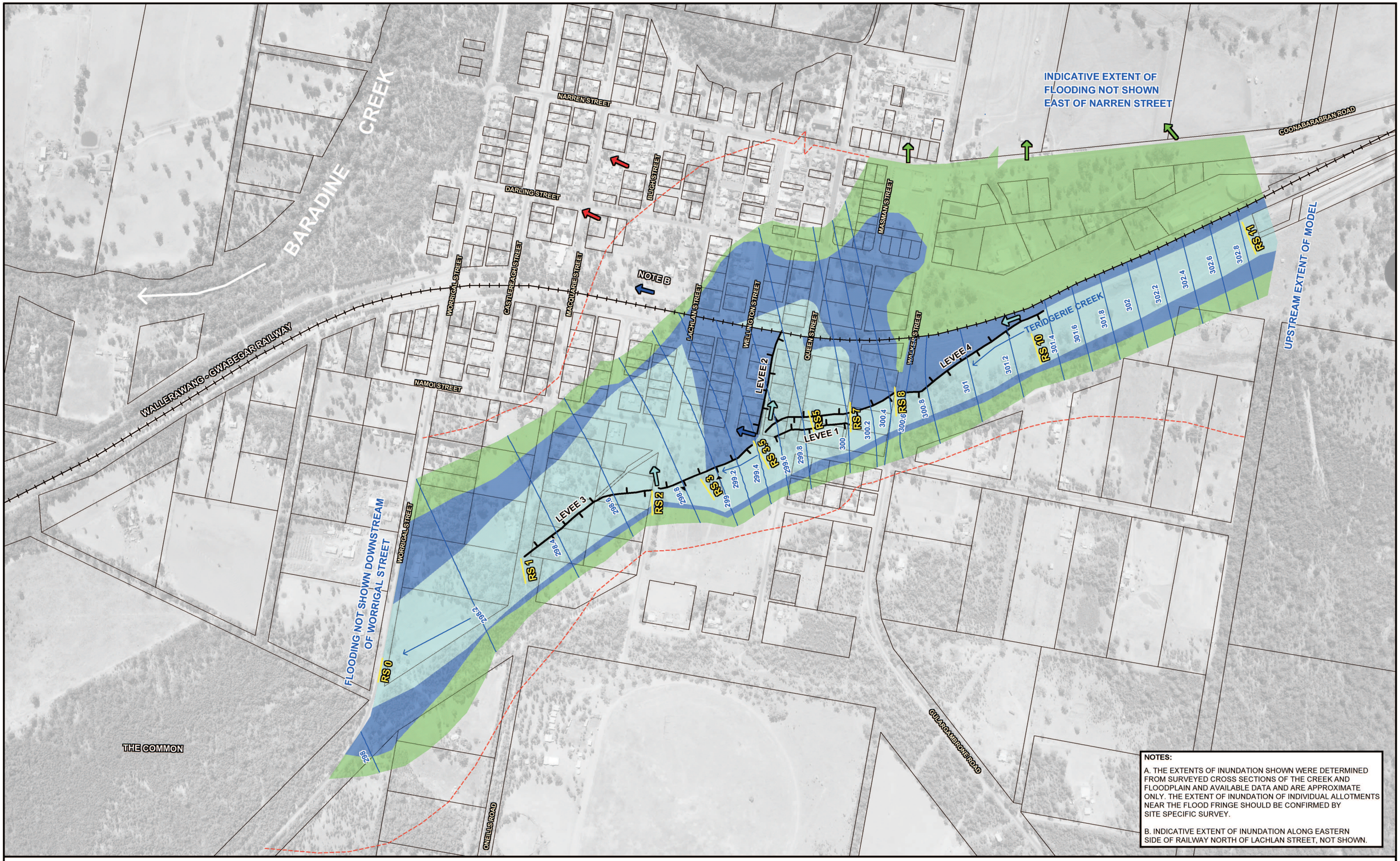
- ***Recovery,*** involving measures to ensure the long term welfare for people who have been evacuated, recovery operations to restore services and clean up and de-briefing of emergency management personnel to review the effectiveness of the Plan.

2.8.2 Incorporation of Flood Data in the Local Flood Plan

Annex A – The Local Flood Threat and *Annex B – Effects of Flooding on the Community* could be updated in the next edition of the *Warrumbungle Shire Local Flood Plan* to include information on the impacts of flooding on urban development bordering Teridgerie Creek at Baradine. The following information which is contained in the *Flood Study, 2012* and this present report will be of assistance in this regard:

- Indicative extents of inundation during major floods (repeated as **Figure 2.1** in this report).
- Typical times of rise of floodwaters.
- Locations of residential properties inundated by floodwaters of various recurrence intervals and depths of above floor flooding (**Figure B8.3**).
- Inundation of local access roads.
- Information on the operation of the local stormwater system (see **Chapter 3**).

The *Warrumbungle Shire Local Flood Plan* should also recognise that the flooding which occurs within the Teridgerie Creek urban area is of a "flash flooding" nature with floodwaters rising to a peak several hours after the onset of heavy rainfall.



NOTES:

A. THE EXTENTS OF INUNDATION SHOWN WERE DETERMINED FROM SURVEYED CROSS SECTIONS OF THE CREEK AND FLOODPLAIN AND AVAILABLE DATA AND ARE APPROXIMATE ONLY. THE EXTENT OF INUNDATION OF INDIVIDUAL ALLOTMENTS NEAR THE FLOOD FRINGE SHOULD BE CONFIRMED BY SITE SPECIFIC SURVEY.

B. INDICATIVE EXTENT OF INUNDATION ALONG EASTERN SIDE OF RAILWAY NORTH OF LACHLAN STREET, NOT SHOWN.

N

80 0 80 160 240 m

Scale: 1:8,000

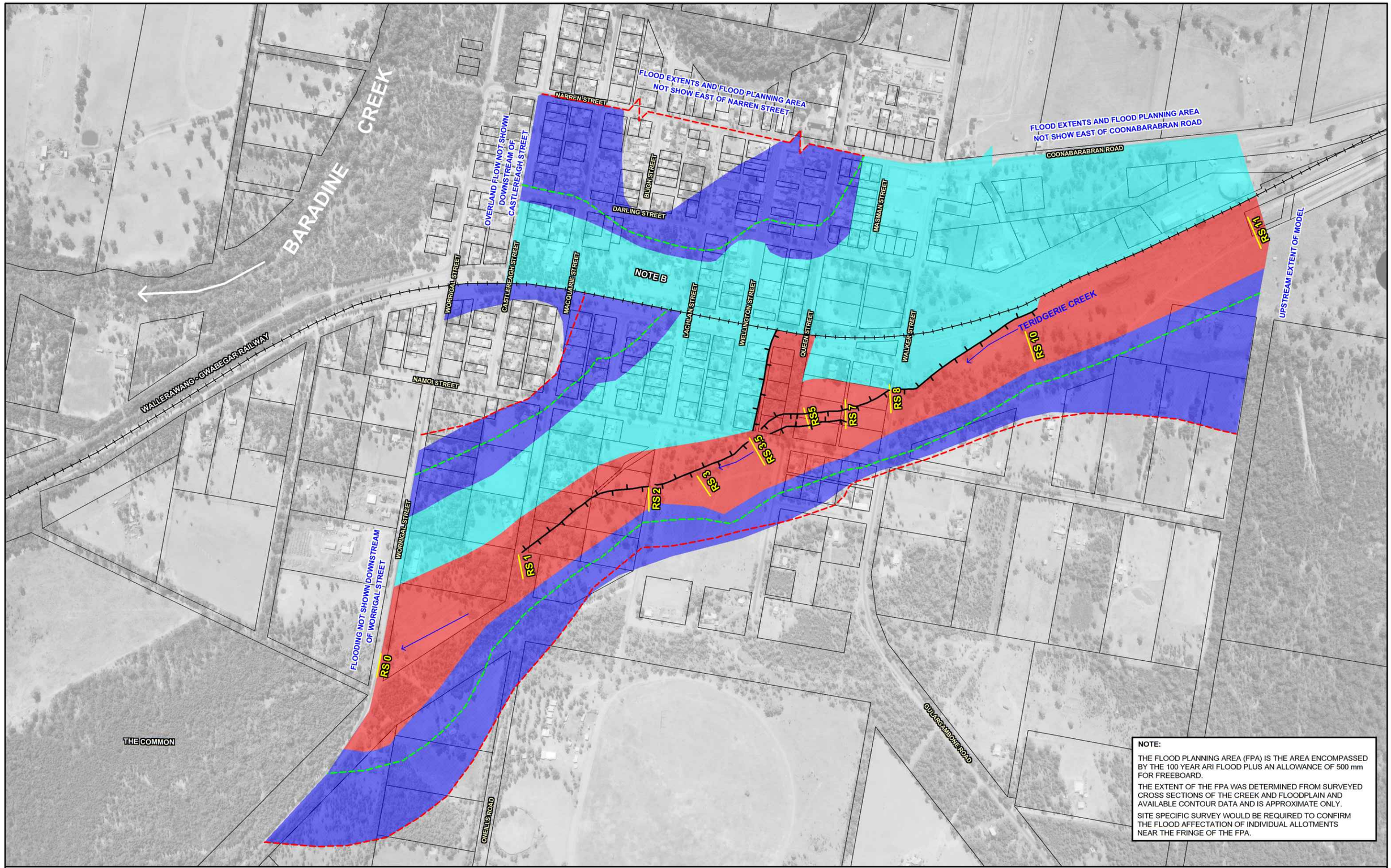
LEGEND

- Area Inundated by 5 Year ARI Flood
- Additional Area Inundated by 20 Year ARI Flood
- Additional Area Inundated by 100 Year ARI Flood
- Approximate Extent of Extreme Flood
- 298.2 Water Surface Level Contour (100 Year ARI)
- Escape of Flow From Creek/Levee System at 5 Year ARI Flood
- Escape of Flow From Creek/Levee System at 20 Year ARI Flood
- Escape of Flow From Creek/Levee System at 100 Year ARI Flood
- Escape of Flow From Creek/Levee System at Extreme Flood
- RS 0 River Station

TERIDGERIE CREEK
FLOODPLAIN RISK MANAGEMENT STUDY

Figure 2.1

INDICATIVE EXTENTS OF INUNDATION
5, 20, 100 YEAR ARI AND EXTREME FLOOD



NOTE:

THE FLOOD PLANNING AREA (FPA) IS THE AREA ENCOMPASSED BY THE 100 YEAR ARI FLOOD PLUS AN ALLOWANCE OF 500 mm FOR FREEBOARD.

THE EXTENT OF THE FPA WAS DETERMINED FROM SURVEYED CROSS SECTIONS OF THE CREEK AND FLOODPLAIN AND AVAILABLE CONTOUR DATA AND IS APPROXIMATE ONLY.

SITE SPECIFIC SURVEY WOULD BE REQUIRED TO CONFIRM THE FLOOD AFFECTATION OF INDIVIDUAL ALLOTMENTS NEAR THE FRINGE OF THE FPA.

N

80 0 80 160 240 m

Scale: 1:8,000

LEGEND

- Indicative Extent of 100 Year ARI Flood
- Indicative Extent of Extreme Flood
- RS 0 River Station
- High Hazard Floodway
- Overland Flow Zone
- Intermediate Floodplain (Indicative Extent of Flood Planning Area)

TERIDGERIE CREEK AT BARADINE
FLOODPLAIN RISK MANAGEMENT STUDY

Figure 2.2

FLOODWAY - FLOOD PLANNING AREA

3 POTENTIAL FLOODPLAIN MANAGEMENT MEASURES

3.1 Range of Available Measures

A variety of floodplain management measures can be implemented to reduce flood damages, as follows:

Flood modification refers to changing the behaviour of floods in regard to discharges and water surface levels to reduce flood risk. This can be done by the construction of levees, retarding basins and channel improvements. Such measures are also known as "structural" options as they involve the construction of engineering works.

Property modification refers to reducing risk to properties through measures such as land use zoning, minimum floor level requirements, or house raising. Such options are largely planning measures, as they are aimed at ensuring that the use of floodplains and the design of buildings are consistent with flood risk. Property modification measures could comprise a mix of structural and non-structural methods of damage minimisation.

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

3.2 Community Views

Comments on potential flood management measures were sought from the local community by way of the Questionnaire distributed at the commencement of the study. The responses are summarised in **Appendix C.** Question 9 in the Questionnaire outlined a range of potential flood management options. The responses are shown on **Table 3.1**, together with initial comments on the feasibility of the measures, which are discussed in more detail in later sections of this Chapter. The Community favoured the following measures:

- Management of vegetation in Teridgerie Creek to maximise hydraulic capacity.
- Enlarging the channel to increase hydraulic capacity.
- Construction of the levee along the eastern side of the creek to protect residential development.
- Controls over future development in flood liable areas.
- Improved flood warning procedures.
- Improved evacuation and emergency assistance plans.
- Community education to promote flood awareness in the community.
- Provision of Flood advice certificates for properties located within the Flood Planning Area.

The Flood Modification measures, as well as Property Modification and Response Modification measures included in the Questionnaire are examined at the strategic level of detail in this Chapter of the report and tested for feasibility on a range of assessment criteria in **Chapter 4.**

Flood Modification Measures considered include replacement of the existing flood protection levees, diversion of flows from the upper reaches of Teridgerie Creek to Baradine Creek and improvements to the hydraulic capacity of the stream.

They have been incorporated into four schemes, components of which have been shown on **Figure 3.1** and discussed individually in later sections of this Chapter.

- **Scheme 1** involves replacement of the existing levees running along the eastern side of Teridgerie Creek by a new levee, together with the closure of the railway culverts and the upgrading of Council's relief drain to cater for stormwater runoff from the urban part of town on the eastern side of the railway embankment.

- **Scheme 2** includes the diversion of flow to the Baradine Creek catchment at a location near the Ashby property, together with the upgrade of the levees in town to contain residual flows generated by the sub-catchments of Teridgerie Creek catchment downstream of the diversion. If all of the flow at Ashby were diverted, flood levels in town may be sufficiently lowered to allow the discharge of town stormwater via the railway culverts to Teridgerie Creek. The upgrading of the relief drain may not then be required.

- **Scheme 3** involves vegetation management in The Common area to reduce upstream flood levels.

- **Scheme 4** is a major increase in the hydraulic capacity of Teridgerie Creek by the creation of a riparian corridor from Walker Street to Worrigal Street, together with levees to contain flows, closure of the railway culverts and the upgrade of the relief drain.

Following consideration by the Floodplain Management Committee of the results of the investigation of the above schemes, favoured schemes were included as recommended Measures in the draft *FRMP* in **Chapter 5**.

TABLE 3.1
COMMUNITY VIEWS ON POTENTIAL FLOOD MANAGEMENT MEASURES FOR BARADINE

Flood Management Measure		Classific-ation	Respondents' Views		Comments
			Yes	No	
a)	Maintenance programs to manage vegetation in the creek.	FM	54	2	This option is strongly favoured by the Community and is reviewed in **Section 3.5**. The community considered that clearing of vegetation in the area known as The Common, located on the downstream side of Worrigal Street, would increase the hydraulic capacity of the waterway and reduce flood levels in the urban area of Baradine.
b)	Enlarge the Creek Channel	FM	30	12	This option is strongly favoured by the Community. The feasibility of this option is reviewed in **Section 3.5**. The existing hydraulic capacity of the culverts beneath Walker Street is also assessed.
c)	Construct permanent levees to contain floodwaters.	FM	39	3	This option is strongly favoured by the Community. The feasibility of reconstruction and completion of the existing levee along the eastern side of the creek to contain floodwaters is considered in **Sections 3.3**. and **3.4**.
d)	Voluntary purchase of residential property within 100 year ARI flood extent.	PM	9	27	The community is strongly against this option, which is often adopted to remove residential property in high hazard areas of the floodplain. This option is reviewed in **Section 3.9**.
e)	Provide funding or subsidies to raise houses above 100 year ARI flood level.	PM	18	22	Community opinion is evenly divided on this option. House raising is applicable to timber framed residences only, usually located in low hazard zones. This option is reviewed in **Section 3.10**.
f)	Controls on future development in flood-liable areas. (eg controls on location in the floodplain, minimum floor levels. etc.)	PM	38	3	Controls over development in flood prone land are very strongly supported by the community and would be an essential part of the *FRMP*. This issue is covered in the suggested development controls in **Section 3.8**.

Legend: FM = Flood Modification Option PM = Property Modification Option RM = Response Modification Option

TABLE 3.1
COMMUNITY VIEWS ON POTENTIAL FLOOD MANAGEMENT MEASURES FOR BARADINE
(Continued)

Flood Management Measure		Classification	No of Respondents		Comments
			Yes	No	
g)	Improve flood warning and flood response procedures	RM	36	5	There is presently no formal flood warning system for the creek, where flooding is of a "flash flooding" nature, with sudden rises in water levels after the onset of heavy rainfall. Improvements in flood warning procedures are strongly supported by the community and are considered in **Section 3.11**.
h)	Improve evacuation and emergency assistance plans	RM	26	9	Emergency management in Baradine is the responsibility of the SES. SES respond to a flood emergency based on experiences gained during recent flood events. Improvements to procedures would be strongly favoured by the community and are discussed in **Section 3.12**.
i)	Community education, participation and flood awareness programs	RM	33	8	Promotion of awareness of the flood risk would be strongly favoured among the community. This option is reviewed in **Section 3.11**.
j)	Provide a certificate to all residents stating whether their property is flood affected and to what extent	RM	38	7	Provision of information on the flood affection of properties is strongly favoured by the community. This is currently achieved by notation of flood affectation of allotments on Section 149 Certificates. This option is reviewed in **Section 3.8.**

Legend: FM = Flood Modification Option PM = Property Modification Option RM = Response Modification Option

3.3 Flood Modification Measures – Flood Protection Levee (Scheme 1)

3.3.1 General

Levees are an effective means of protecting flood affected properties up to the chosen design flood level. In designing a levee, it is necessary to take account of potential adverse re-direction of flood flows, the requirements for disposal of internal drainage from the protected area and the consequences of overtopping the levee in floods greater than the design event.

A major difficulty with urban levee schemes is the provision of facilities for the collection, temporary storage and disposal of stormwater runoff derived from the local sub-catchments within the protected area. In some situations, evacuation of runoff by pumping over the levee has been adopted where there is insufficient area available to store runoff for later disposal by gravity as the flood recedes. In other situations separate provisions are made for the collection and transfer of stormwater runoff along the protected side of the levee, downstream to a location where the flood gradient in the main stream allows its conveyance back to the main stream by gravity.

3.3.2 Potential for Levees along Teridgerie Creek

An upgraded levee which follows the route of the existing levees along the eastern floodplain would constrict major flood flows and raise flood levels excessively, exacerbating flooding in properties on the western floodplain in the area between Queen Street and Walker Street. Hydraulic modelling showed that increases in the 100 year ARI flood level of up to 500 mm could be expected. Upgrading the levee along a new route further to the east is required, which would provide a larger waterway area to convey major flood events.

Figure 3.2 shows a possible route and heights of an upgraded levee aimed at providing a 100 year ARI level of flood protection to properties upstream of Worrigal Street. This scheme is denoted Scheme 1. Two residential properties on the northern side of Worrigal Street which are flooded at the 100 year ARI would not be protected by the scheme and would require individual earth bunds to achieve protection. There is also a residential property on the western side of the creek which is on the point of being flooded above floor level which may require a similar individual treatment.

It is to be noted that the route is indicative only and has been presented in the report for illustrative purposes and to allow a preliminary cost-benefit analysis to be carried out. A feasibility study incorporating extensive consultation with residents to arrive at a route for the levee which meets hydraulic requirements and Community expectations would be required to refine the investigations undertaken in this study. For preliminary planning purposes, the levee was assumed to commence at Worrigal Street and continue upstream (southwards) a distance of 2.4 km to a location near the silos at River Station 11 (cross section L) of the hydraulic model used to assess flooding conditions in the *Flood Study, 2012*. This location is about 900 m south of Walker Street. Continuation of the levee upstream of Walker Street is required to prevent escapes of flow from Teridgerie Creek which may overtop the existing levee and railway embankment, cross Walker Street between the railway and Narren Street and enter the eastern part of town.

The levee scheme would include the following works:

- Demolition and removal of the existing sections of the levees along the east bank, which are of an uncertain standard of construction and rebuilding the levees along a new alignment with crest levels which achieve 0.5 m freeboard on the 100 year ARI flood. The

levee would need to continue in an easterly direction along the southern side of Worrigal Street for a distance of 300 m to tie into high ground. Provision would need to be made for the disposal of runoff from the protected area behind the levee, which would collect at the low point at its north-east corner. The work would also include replacement or raising of the existing levee which runs eastwards from Namoi Street to join the railway embankment (denoted *Levee 2* in the **Figure 2.1***)*.

- Raising a short 50 m section of the railway embankment at the location of the railway culverts and either blocking or removing the culverts, or fitting them with flood gates to prevent back-flooding into town from Teridgerie Creek.

- Upgrading the relief drain running northwards along the eastern side of the railway to cater for local stormwater runoff from the town area which presently is discharged to Teridgerie Creek via the railway culverts. At present the capacity of this drain is limited by the small sizes of the pipes at the road crossings of Wellington, Lachlan and Macquarie Streets.

- Locally raising road levels at Walker Street on the eastern side of the existing culverts to provide continuity of the levee and ensure that Teridgerie Creek flows do not escape into town on the eastern side of the railway.

- Locally raising road levels at the gaps in the present levee system at Macquarie, Lachlan and Namoi Streets to provide continuity of the levee.

Town stormwater would be discharged along the route of Council's relief drain running along the eastern side of the railway embankment. Improvements to the drain would be required to discharge local catchment flows of up to 5 m^3/s under 100 year ARI conditions. The relief drain would continue northwards to Worrigal Street. At the proposed discharge point, it appears from existing survey that the storm water runoff may be safely discharged with the prevailing grade towards Baradine Creek. **Section 3.3.3** describes the concept design for the upgraded relief drain.

Hydraulic modelling of the levee proposal showed that 100 year ARI flood levels in Teridgerie Creek would still be increased by up to 300 mm due to the constriction imposed by the provisional levee route shown on **Figure 3.2**. The constriction is most evident at the Namoi Street crossing, where the width of flow approaching the causeway reduces to around 90 m. At Namoi Street, it may be necessary to lower road levels at the creek crossing in order to reduce flood levels and mitigate flooding in the residential properties on the western side of the creek. Alternatively, a short section of levee may be required to protect property on the western side of the creek between Queen Street and Walker Street.

For the purposes of this analysis it was assumed that the crest of the levee would be 0.5 m above the level of the 100 year ARI flood (freeboard) under post-levee conditions. The freeboard is a factor of safety which allows for wave action, uncertainties in the assessment of 100 year ARI flood levels, construction tolerances and potential settlement of the levee. Survey information along the route of the levee is sparse, with information on natural surface levels being confined to the cross sections of the creek incorporated in the hydraulic model of the floodplain developed for the flood studies, as well as Council's contour plan. Based on these sources of data, the height of the levee would range between 1.3 m near Worrigal Street, increasing to 1.6 m north of Walker Street and averaging 1 m along the line of the existing levee south of that street.

To achieve design crest levels along the north-south section of levee between Namoi Street and the railway (existing *Levee 2* of **Figure 2.1**), the existing levee crest would need to be raised by up to 1 m. It has been assumed for costing purposes that the existing *Levee 2* will be demolished and replaced by a new levee. However, this levee appears to be of more robust construction than the remaining sections and therefore, depending on the type of material comprising the levee and its standard of compaction, it may be possible to incorporate the existing levee in the new works. This is subject to confirmation by geotechnical testing at the design stage, as the engineering properties and compaction of the fill material are presently unknown.

3.3.3 Provisions for Discharge of Stormwater

The provision of facilities for the temporary detention and release of runoff from the protected areas whilst creek levels are maintained will be an important issue in planning for the levee. During major floods, elevated water levels will be maintained in the creek for a period of up to four hours. In the absence of improvements to the relief drain, stormwater flows from the eastern part of town would have to be stored, pending drainage to the creek as floodwaters recede.

To prevent back-flooding from the creek when water levels are near their peak, the existing 750 mm diameter Armco pipes comprising the railway culvert (if retained) would need to be flap- gated. Volumes of around 20,000 to 25,000 m^3 would have to be stored in a dedicated storage area behind the railway embankment. There are no sites capable of being developed to accommodate such a large volume, supporting the proposal for disposal of local storm water runoff via an upgraded relief drain.

Hydraulic analysis was carried out using the HEC-RAS model developed in the *Flood Study, 2012* to give initial sizes of culverts and channel dimensions for the upgraded relief drain. **Figure 3.3** shows the resulting water surface profile and typical cross sections for the drain (the levels in this discussion have the same datum as was used for the *Flood Study, 2012*). A grassed channel is proposed. However, to maximise hydraulic capacity a comparatively low hydraulic roughness of 0.035 was adopted which will require regular and continuing maintenance to be replicated in the field. The existing pipes beneath the crossings which range between 450 and 600 mm diameter would be replaced by wide and shallow box culverts.

Channel dimensions are controlled by the presence of the railway embankment on the western side and property boundaries to the east. The maximum bed gradient which could be achieved is about 0.14 per cent and the depth of flow is limited to about 500 mm. Between Worrigal Street and Macquarie Street there is sufficient room available to provide a 20 m bed width for the channel. Upstream of Lachlan Street the width is limited to between 8 and 10 m. As the height of culverts is limited to between 600 and 750 mm, twin culverts each of 4200 mm width have been adopted at each road crossing for preliminary planning.

Flows up to 100 year ARI are generally contained within the extent of the drain except upstream of Lachlan Street where there is a small surcharge into the eastern overbank. At the detailed design stage, consideration may have to be given to providing a lined channel over portion of the route to achieve additional capacity, or adjusting property boundaries to achieve a larger waterway area.

3.3.4 Indicative Cost of Levee (Scheme 1)

The indicative capital cost estimate for the levee is $3.55 Million, with details given in **Appendix D**. Annual maintenance costs amounting to 1 per cent of the capital cost have been converted to a

present worth value and added to the above capital cost to obtain an indicative total cost of the scheme of $3.92 Million, which has been used in the economic analysis below.

The costing information has been developed using existing sources of survey data. This is appropriate for a strategy study such as the present *FRMS*, where the principal objective is to evaluate projects on a comparative basis. However, in order to gain Government funding, it would be necessary to refine the analysis and costing using more detailed survey and cost data. Community Consultation and Government approvals would also be required for the upgraded levee. A feasibility study is proposed as a project for inclusion in the draft *Floodplain Risk Management Plan* for Teridgerie Creek (as **Measure 4** of **Table S.2**). Feasibility studies, together with the costs of preparation of detailed designs quality for Government funding, along with construction costs of the works.

3.3.5 Economic Assessment of Levee (Scheme 1)

Table 3.2 shows the results of the economic analysis of a levee scheme which has the objective of mitigating damages up to the 100 year ARI. The analysis has been carried out for the three discount rates nominated by NSW Treasury Guidelines for the economic analysis of public works.

Significant surcharging of the channel of Teridgerie Creek occurs at the 5 year ARI, with damaging flooding in the residential properties bordering the creek. From the economic assessment of flooding presented in **Appendix B**, the *present worth value* of damages for all floods up to the 100 year ARI magnitude is $4.46 Million for a 7 per cent discount rate and over an economic life of 20 years. In an economic analysis, the damages prevented by a flood mitigation scheme represent its benefits.

Therefore, provided damages up to the 100 year ARI level of flooding were eliminated by the proposed scheme, expenditure of the above amount for the levee could be economically justified. The total cost including capital and annual maintenance costs is about $3.92 Million for the 7 per cent discount rate. The benefit/cost ratio of the channel improvements scheme at the 7 per cent discount rate is therefore 1.1.

TABLE 3.2
ECONOMIC ANALYSIS OF LEVEE (SCHEME 1)
ON TERIDGERIE CREEK

Discount Rate %	4	7	10
Present Worth Value of Benefits* (Damages Prevented) $ x 10^6	5.72	4.46	3.58
Cost of scheme (capital and annual maintenance costs) $ x 10^6	4.03	3.92	3.85
Benefit/Cost Ratio	1.4	1.1	0.9

Note: * **Section 8.3 of Appendix B** includes a definition of terms used in the economic assessment of flood impacts

3.4 Diversion of Flows to Baradine Creek (Scheme 2)

3.4.1 General

Figure 3.4 shows the possible route and heights of an upgraded levee aimed at providing a 100 year ARI level of flood protection in conjunction with the diversion of flows from the upper reaches of Teridgerie Creek to the Baradine Creek catchment. This scheme is denoted Scheme 2. Because of the reduction in flows that would be achieved by the diversion, it may be possible to move the levee closer to the creek at its downstream end near Worrigal Street without restricting flows and hence reduce its impact on residential allotments located within its footprint. Considerable reductions in the height of the levee would be achieved by the diversion. Under post-diversion conditions, hydraulic modelling showed that 100 year ARI flood levels would generally be reduced to present day 5 year ARI levels along the extent of the levee.

As it is presently possible to discharge runoff from the urban part of town on the eastern side of the railway to Teridgerie Creek via the Armco culverts under 5 year ARI conditions, then it follows that upgrading of Council's relief drain may not be required with the diversion. Whether or not upgrading is required will be determined in the feasibility study for the scheme included as recommended Measure 4 in the *FRMP* (**Table S.2**). Measure 4 will incorporate extensive consultation with residents to arrive at an agreed location of the diversion structures and a route for the levee which meets hydraulic requirements and Community expectations.

3.4.2 Elements of the Diversion Structure

Figure 3.5 shows key features of the diversion structures to be located on public lands near the Ashby property. The dimensions and locations of the various elements of the scheme are preliminary only and will be refined in the feasibility study The diversion would comprise the following elements:

- A bank across Teridgerie Creek which would create a storage area upstream and divert flood flows across the catchment boundary into the catchment of the Bugaldie Creek tributary. A low flow pipe would be located in the creek bed which would drain the storage area created by the diversion bank after floods, but its capacity would be limited to only 2 to 5 m^3/s to minimise peak flows continuing to Baradine. The diversion of flow would commence once the storage level rose to RL 304.18 m, corresponding with the lowest level of the catchment boundary and about 1 m above the creek bed. Under 100 year ARI conditions the peak discharge on Teridgerie Creek at the diversion bank would be 96 m^3/s and the peak storage level would rise to RL 305 m, compared with a flood level on the creek of RL 304.3 m under present day conditions. Natural surface levels at the Ashby building located at the western end of the bank are around RL 306.2 m, giving over 1 m of freeboard against inundation under 100 year ARI conditions. Hydraulic modelling based on surveyed cross sections of the floodplain and using the HEC-RAS software showed that the backwater influence of the storage would be restricted to the public lands on which the diversion banks are located and there would be no difference between present day and post-diversion flood levels in the cultivated land upstream.

- The diversion bank would continue across the catchment boundary to the railway line, turning 90 degrees and continuing southwards along its western (upstream) side and across the Bugaldie Creek tributary to tie into high ground on its southern side. Because of the magnitude of peak discharge to be diverted (about 126 m^3/s under 100 year ARI conditions from the combined catchments of Teridgerie Creek and the tributary) it would be necessary to

remove the existing six 1250 mm diameter Armco culverts in the railway line and replace them with a formal control structure, as they have insufficient capacity to convey the flow. A concrete structure set in the diversion bank would control flows. For preliminary planning purposes a structure 40 m wide was adopted which would function as a broad crested weir with crest level set at RL 301.5 m. The control structure would convey the combined 100 year ARI discharge from the two catchments at a storage level of RL 303.5 m.

- The proposed diversion will result in greater depths of inundation over the Coonabarabran Road and larger flows on the Bugaldie Creek tributary than presently occur. **Table 3.3** shows peak flows and depths on flooding over the road under present day and post-diversion conditions. It is based on the results of hydraulic modeling using the HEC-RAS software and surveyed cross sections of the Bugaldie Creek tributary. Under 100 year ARI conditions the depth of overtopping would increase from 0.78 m to 1.45 m. Flows over the road would be maintained for up to 6 hours. These conditions apply for the 180 minutes design storm duration which was critical for maximisation of flows and levels in the *Flood Study, 2012*. The impacts of the changes in flooding conditions in terms of the structural integrity and serviceability of the Coonabarabran Road and emergency management procedures at the crossing will need to be addressed in the feasibility study of the diversion project. It will also be necessary to consider impacts on the stability of the channel of the Bugaldie Creek tributary due to the increase in flows resulting from the diversion.

TABLE 3.3
IMPACTS OF FLOW DIVERSION ON
FLOODING AT COONABARABRAN ROAD

Average Recurrence Interval ARI - Years	Pre-Diversion		Post-Diversion	
	Peak Discharge (m^3/s)	Depth of Flow Over Road (m)	Peak Discharge (m^3/s)	Depth of Flow Over Road (m)
5	6	0.39	25	0.73
20	14	0.57	62	1.05
100	29	0.78	126	1.45

3.4.3 Economic Assessment of Diversion (Scheme 2)

The supplementary levees required along Teridgerie Creek in the town would be less expensive than for the Scheme 1 and would compensate for the costs associated with the diversion works. Indicative capital costs are:

- Diversion Works $1.56 Million
- Supplementary Levees $1.65 Million
- Total Capital Cost $3.21 Million

Table 3.4 is an economic analysis of the diversion scheme, allowing 1% annual maintenance cost, as previously. The benefit/cost ratio of the diversion scheme is higher than for the levee scheme in isolation (Scheme 1), as lower levees are required. The cost of upgrading Council's relief drain on the eastern side of the railway in town has been omitted in this initial economic analysis. However the scheme will still be economically viable even in the event that the more detailed analyses undertaken in the feasibility study shows that the upgrading is required.

TABLE 3.4
ECONOMIC ANALYSIS OF
FLOW DIVERSION/LEVEE (SCHEME 2)

Discount Rate %	4	7	10
Present Worth Value of Benefits (Damages Prevented) \$ x 10^6	5.72	4.46	3.58
Cost of scheme (capital and annual maintenance costs) \$ x 10^6	3.65	3.55	3.48
Benefit/Cost Ratio	1.6	1.3	1.0

3.5 Flood Modification Measures – Increase Hydraulic Capacity of Creek

3.5.1 Introductory Remarks

The hydraulic capacity of a stream may be increased by widening, deepening or straightening the channel, clearing the banks of obstructions and reducing the tree and vegetation cover on the floodplain. The scope of such improvements can vary from minor "vegetation management" schemes which do not increase the waterway area but reduce hydraulic roughness, to major channel excavations. Careful attention to design is required to ensure stability of the channel is maintained and scour or sediment build-up is minimised. The potential for channel improvements to increase downstream flood peaks also needs to be considered. In general, channel improvements need to be carried out over a substantial stream length to have any significant effect on flood levels. Proposals also need to conform with Government Policies in regard to retention of native vegetation, maintenance of fish habitat and other environmental considerations.

In regard to Council's adopting reductions in flood levels achieved by vegetation management, for planning purposes, OEH's view is that any modelled reductions in flood levels are not guaranteed due to difficulties in assessing hydraulic roughness conditions and doubts about future maintenance and should be regarded only as a "bonus". They should not be used by Council to support any reductions in the ***Flood Planning Levels (FPL's)***, which would continue to be based on prior conditions. OEH has confirmed that there are considerable legislative hurdles to be negotiated before permission would be received to undertake any such works.

OEH is in the process of preparing a Floodplain Guideline on Vegetation Management which will confirm the above. Whilst the new Guideline may not be issued prior to the finalisation of this investigation, its principles would still apply.

Several alternative proposals for increasing the capacity of Teridgerie Creek are evaluated in the following sections of the report. They comprise:

- The management of vegetation in The Common area downstream of Worrigal Street, aimed at reducing upstream flood levels.
- Construction of a grassed floodway upstream of Worrigal Street, involving a large increase in waterway area to contain flows up to the 100 year ARI.
- Creation of a floodway/riparian corridor upstream of Worrigal Street, involving a modest excavation in the creek and overbanks with compensatory planting on the floodplain. Supplementary levees would be required to contain floodwaters to the extent of the corridor.

3.5.2 Vegetation Management in The Common (Scheme 3)

As noted above, it may be difficult to gain Government approval for this measure. However, for the sake of completeness, hydraulic modelling was undertaken to assess the potential reductions in peak flood levels achieved by clearing the stream and reducing the height and thickness of vegetation in overbank areas of The Common downstream of Worrigal Street. With this proposal, the waterway area would not be increased by excavation. The lowering of flood levels would be achieved by a reduction in the resistance to flow (that is, a reduction in the "hydraulic roughness" of the natural surfaces in contact with the floodwaters). For modelling purposes, it was assumed that the vegetation management works would continue for a distance of 600 m downstream of Worrigal Street and extend across the floodplain over a width of several hundred metres.

Hydraulic roughness is defined by a parameter known as "Mannings n". An "n" value of 0.2 was adopted for the present day roughness of the floodplain in The Common area in the *Flood Study, 2012*. For the purposes of assessing the impacts of vegetation management, it was assumed that the roughness could be reduced to a value of 0.08 (subject to regular maintenance). Peak flood levels on Teridgerie Creek under existing conditions and under post-vegetation management conditions for the 20 and 100 year ARI floods are shown on **Table 3.5**.

As shown on the table, the impacts of vegetation management reduce progressively with distance upstream of Worrigal Street, where a reduction of about 300 mm in flood levels could be achieved for the 100 year ARI flood. At Macquarie Street, the reduction would only be 100 mm and further upstream at Lachlan Street, there would be no practical reduction in levels. At the 100 year ARI level there are nine residential properties in the floodplain between Worrigal Street and Lachlan Street which are presently subject to shallow above-floor inundation and which would no longer be flooded by the above reductions in peak water level.

Vegetation management in The Common would therefore have some localised benefits in reducing flood levels. However, given the legislative difficulties associated with gaining approval, the need for ongoing maintenance to remain effective, OEH's reservations regarding adoption of reductions in flood levels and the fact that any flood benefits are localised, vegetation management does not appear to be an effective mitigation measure for major floods and has not been recommended for inclusion in the draft *FRMP*.

TABLE 3.5
PEAK FLOOD LEVELS ON TERIDGERIE CREEK
EXISTING CONDITIONS AND AFTER VEGETATION MANAGEMENT (SCHEME 3)

Teridgerie Creek		20 year ARI			100 year ARI		
Street	Model RS	Existing (m)	Post-Veg Manage (m)	Reduction (mm)	Existing (m)	Post -Veg. Manage (m)	Reduction (mm)
Worrigal	0	297.75	297.49	260	298.08	297.77	310
Macquarie	1	297.99	297.93	60	298.28	298.18	100
Lachlan	2	298.53	298.53	0	298.73	298.73	0
Namoi	3	298.31	298.31	0	298.56	298.56	0

3.5.3 Grassed Floodway

In former times, particularly in urbanising areas, the hydraulic capacity of natural streams was commonly increased by large scale engineered channel works. For example, in order to convey 100 year ARI flows on Teridgerie Creek, a grassed floodway about 75 m wide with 1 on 4 side slopes would be required. This configuration would convey the flow at a depth of 1.2 m and a velocity of 1.2 m/s. To provide 500 mm freeboard for wave action and other local effects, the average depth of excavation would be about 1.7 m. The proposal would adversely affect the traffickability of the local access roads, which would have to be substantially lowered to allow continuity of the invert of the floodway.

The grassed trapezoidal floodway concept does not fit with the rural appearance of the Teridgerie Creek floodplain and would not be supported by OEH and the Catchment Management Authority.

3.5.4 Floodway/Riparian Corridor on Teridgerie Creek (Scheme 4)

Over the last 20 years there has been a move away from achieving increased hydraulic capacity by relatively straight, engineered grassed floodways, to designs more in keeping with the appearance and morphology of natural streams. The Department of Water and Energy (DWE), now OEH, has noted that construction in the bed of streams or within 40 m of the banks would be regulated by the Water Management Act, 2000 and that approval for works would be required. It is likely that a grassed floodway concept would not be supported, for environmental reasons. Modern practice is to consider creeks as functioning as riparian corridors and recognise that they form a transitional zone between terrestrial and aquatic environments, performing a range of important environmental functions, in addition to conveying flood flows. A concept for a riparian corridor combining these features is developed below.

As noted in *DWE's Guidelines for Riparian Corridors, 2008* the functions are:

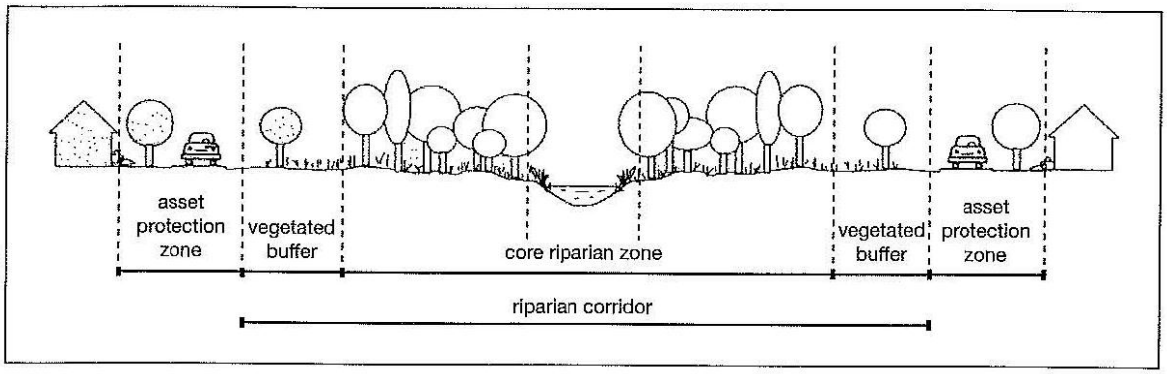
- Provide bed and bank stability and reduce channel and bank erosion.
- Protect water quality by trapping sediment nutrients and other contaminants.
- Provide a diversity of habitat for terrestrial riparian and aquatic flora and fauna species.
- Allow for the conveyance of flood flows and control their direction.
- Provide an interface between developments and waterways.

As shown on the schematic cross section Figure 1 below, extracted from DWE, 2008 a riparian corridor would typically comprises three zones:

- The core riparian zone (CRZ) contained within and adjacent to the channel.
- A vegetated buffer protecting the CRZ from weed invasion.
- An asset protection zone protecting houses from bushfire damage.

Teridgerie Creek is a typical ephemeral stream with long dry periods and intermittent surface runoff events and occasional significant flood flows such as occurred on 22 December 2007. There is also the potential for the occurrence of major flood events considerably greater than that event. In view of the proximity of development on the eastern floodplain, mitigation of flooding would be a more important objective of the development of the riparian corridor than on other streams which do not have urban flooding problems. In order to achieve a flood mitigation objective, the overall hydraulic capacity of the waterway would need to be substantially increased. The following section of the report deals with the potential for a floodway/riparian corridor on Teridgerie Creek over the 2.2 km reach upstream of Worrigal Street.

Figure 1. Riparian corridor zones.



As the vegetated zones on the floodplain associated with a riparian corridor on Teridgerie Creek may result in an increase in hydraulic roughness compared with the existing grass cover on the floodplain, there will need to be a substantial compensatory increase in the area of the channel. Consideration would need to be given to limiting the density of planting in the area bordering the channel to ensure that flood levels for the events which surcharge the channel are reduced, compared with present day conditions. It would be desirable to vary the bed gradient and also provide a sinuous channel (in plan) more in keeping with natural streams, with occasional sections of transverse rock banking across the invert for the creation of ponds and control of bed scour.

Hydraulic modelling was carried out of a riparian corridor involving the above features. The objective was, if possible, to contain the extent of flooding up to the 100 year ARI event to the confines of the floodway without the need for levees. It was not proposed to increase the number of culverts elements at Walker Street. During significant floods the roadway would be overtopped, as occurs at present. However, the road on its eastern side would need to be raised to prevent the escape of flows into the town as presently occurs in the event of major flooding. Improvements to the hydraulic capacity of the creek would need to be continued upstream of Walker Street to ensure that major floods do not surcharge the railway embankment in an uncontrolled fashion and result in sudden failure due to scour or seepage. The proposed channel works would involve a minor excavation of the channel and overbanks. The inverts of the channel and the lowest points of the road crossings at Worrigal,

Macquarie and Lachlan Streets would be maintained; but elsewhere along the creek, natural surface levels would be reduced over the footprint of the corridor.

Under present day conditions there is a restriction in the flow to a width of about 90 m at Namoi Street, due to the presence of existing east-west running *Levee 2* on the right bank and the residential development on the left bank. The level of the causeway would be lowered by about 400 mm over a 90 m width to reduce the constriction and increase the waterway area at that location. The modelling showed that the 100 year ARI flood levels between Worrigal Street and Walker Street would be reduced by an average of about 300 mm which is not sufficient to eliminate damaging flooding for that return period without substantial supplementary levees on the eastern overbank. **Figure 3.6** shows the footprint of the floodway/riparian corridor and the supplementary levees (**Scheme 4**) which, as for the proposals considered in previous sections, would have to be moved to the east to remove the constriction imposed by existing *Levee 4.* The diversion of flows out of the Teridgerie Creek catchment into the Baradine Creek catchment, which was previously introduced in the levee proposal could also be incorporated in **Scheme 4**, as it would reduce the scale of works required.

3.5.6 Indicative Cost of Floodway/Riparian Corridor (Scheme 4)

Indicative costs of this scheme are shown below. The cost of the supplementary levee component includes an allowance for purchasing the land occupied by the levee footprint. However, the cost of purchasing the land occupied by the floodway/riparian corridor (about 37 ha) has not been included in the costing:

- Floodway/Riparian Corridor $3.92 Million
- Supplementary Levees $2.38 Million
- Total Capital Cost $6.30 Million

3.5.7 Economic Assessment of Floodway/Riparian Corridor (Scheme 4)

Table 3.6 shows the results of the economic analysis. Although the scheme would protect the residential area against main stream flash flooding up to the 100 year ARI and would have considerable social benefits in terms of a reduction in flood risk to residents, it is considerably more expensive than either of the levee proposals and is probably beyond Council's financial resources.

TABLE 3.6
ECONOMIC ANALYSIS OF FLOODWAY/RIPARIAN CORRIDOR
ON TERIDGERIE CREEK PLUS SUPPLEMENTARY LEVEES (SCHEME 4)

Discount Rate %	4	7	10
Present Worth Value of Benefits (Damages Prevented) $ x 10^6	5.72	4.46	3.58
Cost of scheme (capital and annual maintenance costs) $ x 10^6	7.1	6.9	6.8
Benefit/Cost Ratio	0.8	0.7	0.5

3.6 Environmental Constraints of Levee Upgrade

By comparison of the data in **Tables 3.2**, **3.4** and **3.6**, levee Schemes 1 and 2 are more economically attractive than the floodway/riparian corridor Scheme 4. The creation of the visually attractive riparian corridor may score highly on the multi-objective scoring system of **Chapter 4** of the report on both environmental grounds and conforming with Government policies and is also likely to be viewed favourably as meeting community objectives.

On the other hand the levee scheme, although scoring well in terms of meeting flood mitigation objectives may not be viewed as favourably by the community because of visual impact and the proximity of the levee to existing development. At present there is a clear visual and physical linkage between the creek and the residential community on the eastern floodplain. Construction of a levee closer than the present levee to residential development may impact on this linkage, even though the maximum height of the levee is only 1.6 m. The diversion of flows to Baradine Creek would reduce the height and footprint required for the levees and may be viewed more favourably by residents. Extensive Consultation with the community during the feasibility study will be required to resolve this potential issue.

3.7 Flood Modification Measures - Construction of Detention Basins

Detention basins provide a temporary storage of floodwaters additional to that contained in the natural floodplain, which can reduce the flood peak in downstream reaches of the creek. "Offline" basins, remote from the streams, with intake and outlet channels to and from the stream, are preferred over embankments constructed across the channel to maintain the continuity of the creek system.

However, an offline basin is not feasible on Teridgerie Creek due to the limited extent of the floodplain and the nature of existing land use. The basin should also be located in the middle or lower reaches of the catchment, sufficiently close to the area intended to be protected, that its attenuating effects over flood peaks is not negated by downstream tributary inflows. Typically the basin should command in excess of 60 to 70 percent of the total catchment at the damage centre. An on-line basin could in theory be constructed across the channel and its overbanks upstream of Walker Street. The catchment area at this site amounts to 14 km^2, about 70 per cent of the 16.5 km^2 at Worrigal Street.
Another requirement is that the basin be of sufficient size to store a significant percentage of runoff from the design storm. Basins attenuate the flood peak (i.e. reduce the downstream peak rate of runoff) by temporarily storing the incoming discharge hydrograph and releasing it at a controlled rate.

Flows up to the 100 year ARI would usually be controlled by low level pipes. A portion of the embankment crest in the vicinity of the channel would be depressed and armoured with reno-mattress or equivalent to act as a spillway for the conveyance of higher flows. (Alternatively an armoured by-wash spillway in one of the abutments could provided.) Small basins are quickly overwhelmed the incoming flood waters with the result that the level of stored water quickly rises to the level of the emergency by-wash spillway. Because the spillway is able to pass a large rate of flow, with little rise in level, the rate of outflow rapidly rises to the rate of inflow, negating the purpose of the basin.For a basin on Teridgerie Creek, the objective would be to reduce the 100 year ARI inflow discharge from 96 m^3/s to an outflow of no more than 24 m^3/s, in order to reduce flows to no greater than the pre-basin 5 year ARI peak, which may be conveyed within the floodplain with a relatively minor supplementary levee system.

Under 100 year ARI conditions, the total volume of runoff entering the basin for storms of duration likely to maximise flows on Teridgerie Creek would be around 1.4×10^6 m^3, of which 0.9×10^6 m^3 is in

that part of the hydrograph above the rate of 24 m^3/s and would need to be stored, with the remainder below 24 m^3/s released through the low level outlets. Containment of this volume would require a rectangular storage area of 800 m by 800 m at an average depth of 1.4 m. Although there is no survey available upstream of Walker Street apart from the two cross sections of the hydraulic model, it appears that there are no storage sites capable of storing the required volume and a suitable storage site would have to be excavated in the floodplain.

The requirements for storage indicate that detention basins would not be a cost-effective flood management measure for Teridgerie Creek and should not be included in the list of management measures for the draft *Floodplain Risk Management Plan*.

3.8 Property Modification Measures – Development Controls

3.8.1 Considerations for Setting Flood Planning Level

Selection of the **Flood Planning Level** (*FPL*) for an area is an important and fundamental decision as the standard is the reference point for the preparation of floodplain management plans. It is based on adoption of the peak level reached by a particular flood plus an appropriate allowance for freeboard. It involves balancing social, economic and ecological considerations against the consequences of flooding, with a view to minimising the potential for property damage and the risk to life and limb. If the adopted *FPL* is too low, new development in areas above the *FPL* (particularly where the difference in level is not great) may be inundated relatively frequently and damage to associated public services will be greater. Alternatively, adoption of an excessively high flood planning level will subject land that is rarely flooded to unwarranted controls.

Councils are responsible for determining the appropriate *FPL*'s within their local government area. Whilst the flood used to determine the residential *FPL* is a decision of the Council, the FPM, 2005 highlights that *FPL*'s for typical residential development would generally be based around the 100 year ARI flood, plus an appropriate freeboard (typically 500 mm).

3.8.2 Current Government Policy

The circular issued by the Department of Planning on 31 January 2007 contained a package of changes clarifying flood related development controls to be applied on land in low flood risk areas (land above the 1 in 100 year flood). The package included an amendment to the Environmental Planning and Assessment Regulation 2000 in relation to the questions about flooding to be answered in Section 149 planning certificates, a revised ministerial direction (Direction 15) regarding flood prone land (issued under Section 117 of the EP&A Act, 1979) and a new Guideline concerning flood-related development controls in low flood risk areas.

The Circular advised that Councils will need to follow both the Floodplain Development Manual, 2005 as well as the Guideline to gain the legal protection given by Section 733 of the Local Government Act.

The Department of Planning Guideline confirmed that **unless exceptional circumstances applied, councils should adopt the 100 year ARI flood (1 in 100 year flood) with appropriate freeboard as the *FPL* for residential development**. In proposing a case for exceptional circumstances, a Council would need to demonstrate that a different *FPL* was required for the management of residential development due to local flood behaviour, flood history, associated flood hazards or a particular historic flood. Unless there were exceptional circumstances, Council should not impose

flood-related development controls on residential development on land with a low probability of flooding, that is land above the residential *FPL*.

Nevertheless, the safety of people and associated emergency response management needs to be considered in low flood risk areas, which may result in:

- Restrictions on types of development which are particularly vulnerable to emergency response, for example, nursing homes and developments for aged care.
- Restrictions on critical emergency response and recovery facilities and infrastructure. These aim to ensure that these facilities and the infrastructure can fulfil their emergency response and recovery functions during and after a flood event. Examples include evacuation centres and routes, hospitals and major utility facilities.

3.8.3 Proposed Flood Planning Levels

Consideration of the data supports retaining the 100 year ARI flood plus a freeboard allowance of 500 mm for floor levels of residential development, along with a graded set of controls depending on the location of the development within the area flooded by that event.

3.8.4 Proposed Draft Flood Policy

The flood prone land (as defined by the Extreme Flood) is divided into areas of varying flood risk using the hydraulic and hazard categorisation data derived in the *Flood Study, 2012*. In the draft *Flood Policy* presented in **Appendix A**, it was proposed that the flood prone land be divided into planning zones. (The diagram showing the proposed flood hazard zones is reproduced as **Figure 2.2**):

- **"*High Hazard Floodway*"** this is the most flood affected land and the area where the highest flow velocities would be expected at the 100 year ARI flood. This zone should be kept clear of future development, although **minor additions** to existing residences and small outbuildings may be permitted by Council, subject to conformance with the controls demonstrating that the flood risk is not increased to existing and proposed developments.
- **"*Overland Flow Zone"***. In this zone, there may be overland flows through residential and commercial allotments, but low hazard conditions will generally occur due to the shallow depth and low velocities. All land uses would be permitted in this zone, but the development would need to be capable of withstanding hydraulic forces and sited within the allotment to minimise adverse re-directions of flow towards adjacent properties.
- **"*Intermediate Floodplain*"** is the remaining land lying within the ***Flood Planning Area*** (land inundated by the 100 year ARI flood levels plus 500 mm). Within this area, there would only be the requirement for minimum residential floor levels to be set at 100 year ARI flood levels plus 500 mm. All land uses would be permitted in this zone. However, Essential Community Facilities, Critical Utilities and Flood Vulnerable development such as housing for aged and disabled persons would be subject to additional controls.

'No controls would apply for residential development outside the ***Flood Planning Area***. However, because the flood extents and hazard zones have been mapped using available contour mapping, Council would check proposed floor levels of developments up to the Extreme Flood extent to ensure that they are no lower than the ***FPL***.

3.9 Property Modification Measures - Voluntary Purchase of Residential Properties

Removal of housing from high hazard floodway areas in the floodplain is generally accepted as a cost effective means of correcting previous decisions to build in such areas. The voluntary purchase of residential property in hazardous areas has been part of subsidised floodplain management programs in NSW for over 20 years. After purchase, land is subsequently cleared and the site redeveloped and rezoned for public open space or some other flood compatible use. A further criterion applied by State Government agencies in assessing eligibility for funding is that the property must be in a high hazard area such as floodway, that is, in the path of flowing floodwaters where the depth and velocity at the peak of the flood are such that life could be threatened, damage of property is likely and evacuation difficult.

Under a voluntary purchase (VP) scheme the owner is notified that the body controlling the scheme, Council in the case of Teridgerie Creek, is prepared to purchase the property when the owner is ready to sell. There is no compulsion whatsoever to sell at any time. The price is determined by independent valuers and the Valuer General, and by negotiation between Council and the owners. Valuations are not reduced due to the flood affected nature of the site.

Table 3.7 shows locations of the maximum depths of inundation for the six properties subject to the greatest depths of inundation at the 20 year and 100 year ARI flood magnitudes. For the purposes of illustration, an economic analysis was carried out for a VP scheme which would involve the purchase of these properties. **Table 3.8** shows the results of the economic analysis. The benefits of the scheme comprise the present worth value of the flood damages for the residential two properties which would be saved by their purchase. For the analysis the costs were based on an average purchase cost of $300,000 per property, typical of recent sale prices in the area.

TABLE 3.7
DETAILS OF SIX RESIDENCES SUBJECT TO DEEPEST ABOVE-FLOOR INUNDATION

Location	Flooded by 100 Year ARI Flood		Flooded by 20 Year ARI Flood	
	No. of Residences in Sample	Max Depth of Inundation – m	No of Residences in Sample	Max Depth of Inundation – m
Worrigal Street	2	0.7	2	0.4
Macquarie Street	1	0.7	1	0.5
Wellington Street (western side of railway)	1	0.7	1	0.4
d/s Walker Street (east side of creek)	2	0.8	2	0.6
Total	**6**	**0.8**	**6**	**0.6**

TABLE 3.8
ECONOMIC ANALYSIS OF VOLUNTARY
PURCHASE SCHEME FOR SIX DEEPEST FLOODED PROPERTIES

Discount Rate %	4	7	10
Present Worth Value of Benefits (Damages Prevented) $ x 10^6	0.99	0.77	0.62
Cost of Scheme $ x 10^6	1.80	1.80	1.80
Benefit/Cost Ratio	0.6	0.4	0.3

It is clear from the above analysis that a voluntary purchase scheme would not be justified on economic grounds and was not favoured by the community in their responses to the Questionnaire.

A VP scheme is, however, sometimes implemented to clear properties located in the higher hazard areas on social grounds even though the scheme is not economically feasible. Although the area is subject to "flash flooding" with little warning time, flooding in the street system is relatively shallow, of short duration and there is ready access to high ground. Hydraulic calculations described in **Chapter 2** showed that strictly speaking, only one of the residences was located in a high hazard area. Although the implementation of a VP scheme was not considered justified, it has been included for evaluation in the multi-objective assessment of **Chapter 4**.

3.10 Property Modification Measures - Raising Floor Levels of Residential Properties

This term refers to procedures undertaken, usually on a property by property basis, to protect structures from damage by floodwaters. The most common process is to raise the affected house by a convenient amount so that the floor level is at or above the *FPL*. For weatherboard and similar buildings this can be achieved by jacking up the house, constructing new supports, stairways and balconies and reconnecting services. Alternatively, where the house contains high ceilings, floor levels can be raised within rooms without actually raising the house. It is usually not practical to raise brick or masonry houses. Most of the costs associated with this measure relate to the disconnection and reconnection of services. Accordingly, houses may be raised a considerable elevation without incurring large incremental costs.

The State and Federal Governments have agreed that flood mitigation funds will be available for house raising, subject to the same economic evaluation and subsidy arrangements that apply to other structural and non-structural flood mitigation measures. In accepting schemes for eligibility, the Government has laid down the following conditions:

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

The Government also requires that Councils carry out ongoing monitoring in areas where subsidised voluntary house raising has occurred to ensure that redevelopment does not occur to re-establish habitable areas below the design floor level. In addition, it is expected that Councils will provide

documentation during the conveyancing process so that subsequent owners are made aware of restrictions on development below the design floor level.

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

- Define a habitable floor level, which it will have already done in exercising controls over new house building in the area.
- Guarantee a payment to the builder after satisfactory completion of the agreed work.
- Monitor the area of voluntary house raising to ensure that redevelopment does not occur to re-establish habitable areas below the design floor level.

The current cost to raise a medium sized (150 square metres) house is between $60,000 and $75,000 based on recent experience in other centres. For the purposes of the economic analysis, a cost of $70,000 was adopted.

Table 3.9 is an economic analysis of a house raising strategy of those properties examined in the VP analysis of **Table 3.7** which are of timber frame construction and therefore could be raised. The benefits of the scheme comprise the present worth value of the flood damages for the residential properties which would be saved by their raising. If the houses were raised to at least the 100 year ARI flood level plus an appropriate freeboard then the scheme's benefits would comprise the damages up to that flood.

TABLE 3.9
ECONOMIC ANALYSIS OF RAISING FLOORS
OF SIX TIMBER FRAMED RESIDENCES SUBJECT TO
DEEPEST ABOVE-FLOOR INUNDATION

Discount Rate %	**4**	**7**	**10**
Present Worth Value of Benefits (Damages Saved) $ x 10^6	0.63	0.49	0.39
Cost of Scheme $ x 10^6	0.42	0.42	0.42
Benefit/Cost Ratio	1.5	1.2	0.9

This strategy is economically feasible for the study area. The community were evenly balanced in their responses to the Questionnaire. It has been retained for evaluation in the multi-objective assessment of **Chapter 4**.

3.11 Response Modification Measures - Flood Forecasting, Warning and Evacuation Plans

3.11.1 Flash Flood Warning Systems

Flood forecasting and warning can be an effective flood management measure if there is sufficient warning time for the community to react to the warning. An effective flood warning system has three key components, i.e. a flood forecasting system, a flood warning broadcast system and an evacuation plan.

Flood response to rainfall on the Teridgerie Creek catchments is relatively short and is expected to be between around three to four hours (i.e. from the commencement of heavy rainfall to the occurrence of the flood peak in the lower reaches of the creek near the Oxley Highway – ref. **Figure 2.2**).

A workshop was sponsored by Bureau of Meteorology in 2007 to develop guidelines for the NSW Flood Warning Consultative Committee to co-ordinate funding proposals for local flash flood warning systems. Three levels of local flash flood warning system were identified:

- **General System** – relies on existing warning services provided by the Bureau of Meteorology for severe weather and thunderstorms as well as Flood Watches. These services are typically issued on a regional basis, or for a larger catchment than Teridgerie Creek. These warnings can be augmented by real time information from local weather radars, automatic weather stations and existing rainfall and river gauges. They do not involve additional rainfall or river gauge instrumentation in the catchment. **Indicative cost:** Initial cost zero to $20,000 and annual costs of $1,000 to $7,000 for a public awareness program.
- **Intermediate System** – General system plus additional rain and river gauges within the targeted flash flood catchment to help local emergency personnel to assist the community through improved evaluation and management of the flash flood threat. **Indicative cost:** Initial cost **$**60,000 and annual costs of $10,000 to $15,000 for a public awareness program and maintenance of instrumentation.
- **Total Warning System** – Intermediate system plus a targeted warning dissemination system to people located on the high flood hazard sites where evacuation may be necessary. **Indicative cost:** Initial cost $100,000 to $300,000 and annual costs of $10,000 to $15,000 for a public awareness program and maintenance of instrumentation.

While all systems need to be underpinned by an appropriate public flood awareness program, the **Total Warning System** would require a more comprehensive and recurrent public flood awareness campaign.

Provisionally, the **Total Warning System** is recommended for further consideration in the *FRMP* for Teridgerie Creek. It would be based on the "READY", "SET", "GO" warning phases as follows:

- READY – flooding is possible in a general area; monitoring of weather is required.
- SET – flooding is more likely in a specific area; prepare to act.
- GO – flooding is very likely in a specific area; Action required.

The advantages of the **Total Warning System** over the two lesser systems are:

- Enhanced reduction in risk to life and property from flash flooding through precautionary actions triggered by general warnings, as per the **General System** (i.e. READY and SET phases), and targeted Bureau of Meteorology Flash Flood Warnings based on the predicted exceedance of flash flood thresholds (GO phase), being directly communicated to the affected community.
- Reduction (compared with the **Intermediate System**) in risk to life and property from flash flooding by better local emergency response and management, through the Bureau providing forecasts for the exceedence of flood thresholds for the area.

The six components of the **Total Warning System** are:

1. **Predictions**
   - Bureau of Meteorology warnings and information from radar, AWS and rain and river gauges as per the **Intermediate System** used to trigger "READY" and "SET" phases.
   - Targeted Flash Flood Warnings issued by the Bureau of Meteorology for the exceedence of Flash Flood Thresholds based upon information from the *FRMS* for the area to trigger the "GO" phase. Depending on the information from flood modelling, predictions may be issued for flood/no flood scenarios or for levels of flooding resulting from floods of various probabilities of occurrence.
2. **Interpretation**
   - Areas likely to be flooded determined from **flood maps**, from the flood modelling results or studies for the area, and from SES flood intelligence.
3. **Warning message Construction**
   - Pre-determined flash flood warning messages for the specific areas.
4. **Communication**
   - Warnings broadcast by media and available on the BOM website.
   - Warnings directly communicated to the affected area either automatically or manually, depending on the size of the catchment, population size and available SES resources.
5. **Response**
   - Pro-active community and SES response underpinned by local recurrent public flood awareness/education program.
6. **Review**
   - Performance of the system after each major flood.
   - Regular review of the readiness and maintenance of system components such as gauges, communications, public education and planning.

Funding to establish local flash flood warning systems has traditionally been made available on the basis of no Council contribution to the initial capital cost in recognition of the high maintenance costs which Council would have to meet. The costs of maintaining the system would include such items as rain and river gauges, warning communication systems and ongoing public awareness/education programs. The maintenance obligations would need to be identified and included in any initial funding grant. Upon installation of the local flash flood warning system, the SES Local Flood Plan for the area could be used to document the operation and maintenance specifications of the system, including the public education/awareness components.

3.11.2 Flash Flood Warning System – Discussion

Assuming an initial capital cost of $200,000 and annual cost of $10,000 for maintenance, the total cost of the Total Warning System at the 7 per cent discount rate would be about $358,000 over an

economic life of 20 years. It would need to reduce damages to contents by about 50 per cent to be economically feasible. This may not be achievable and therefore the system would have to be justified on social and other non-economic grounds.

Further, if the structural mitigation schemes (Schemes 1, 2 or 4) were constructed in a reasonable timeframe then it may be difficult to justify implementation of the system as those schemes would provide protection to the 100 year ARI level of flooding.

Nevertheless, improvements to the flood warning and flood response procedures (of which implementation of a flash flood warning system could form an important component) were very strongly favoured by the community and would score well on the multi-objective assessment of **Chapter 4**. The committee should therefore give careful consideration to including this option.

3.12 Response Modification Measures - Public Awareness Programs

3.12.1 General Comments

Community awareness and appreciation of the existing flood hazards in the floodplain would promote proper land use and development in flood affected areas. A well informed community would be more receptive to requirements for flood proofing of buildings and general building and development controls imposed by Council. One aspect of a community's preparedness for flooding is the "flood awareness" of individuals. This includes awareness of the flood threat in their area and how to protect themselves against it. It is fair to assume that the level of awareness drops as individuals' memories of previous experience dim with time.

Means by which community awareness of flood risks can be maintained or may be increased include:

1. Sending out regular information with rates notices. The information contained in this present study could be edited and used by Council and SES to prepare a *Flood Information Brochure* for Teridgerie Creek.
2. Displays at Council offices using the information contained in the present study and photographs of historic flooding in the area.
3. Talks by SES officers with participation by Council and longstanding residents with first hand experience of flooding in the area.

3.12.2 Flood Information Brochure

The *Flood Information Brochure* (also known as a "FloodSafe" brochure) which could also form a component of the education process associated with the Flash Flood Warning system should contain information on:

- What steps for residents to take in advance to protect themselves from flooding.
- Developing procedures for lifting contents above flood level and evacuating property.
- An Evacuation Plan for the area showing the best routes for egress from the floodplain.
- Evacuation routes would have to be developed in the light of further analyses by Council to assess streets which are vulnerable to surcharges from the local stormwater system. Council could undertake additional analyses using their recently developed DRAIND model of the system to provide this information.

The benefits of a regular flood-preparedness campaign would extend to more than just reducing monetary losses. The campaign would also have social benefits by improving people's feeling of control, since they would have a better idea of how to respond to a flood emergency. Given the recent history of flooding in the area and the Community's high state of flood awareness evidenced in responses to the Questionnaire, it would not appear difficult to generate the interest and co-operation required.

3.13 Summary

This Chapter has reviewed a number of potential floodplain management measures. Preliminary analysis of the flood modification measures (i.e. involving the construction of engineering works) has been undertaken and indicative cost estimates prepared on the basis of available survey data. The findings are summarised in **Table 3.10** and outlined below.

- The upgrading of the flood protection levees along the eastern side of the creek could be considered, possibly in conjunction with the upstream diversion of flows to Baradine Creek. Further investigation would be required to confirm its feasibility.

- Improvements to increase the conveyance capacity of the creek associated with the implementation of a riparian corridor are supported by the Community and are worth considering further by the Committee for inclusion in the draft *FRMP*.

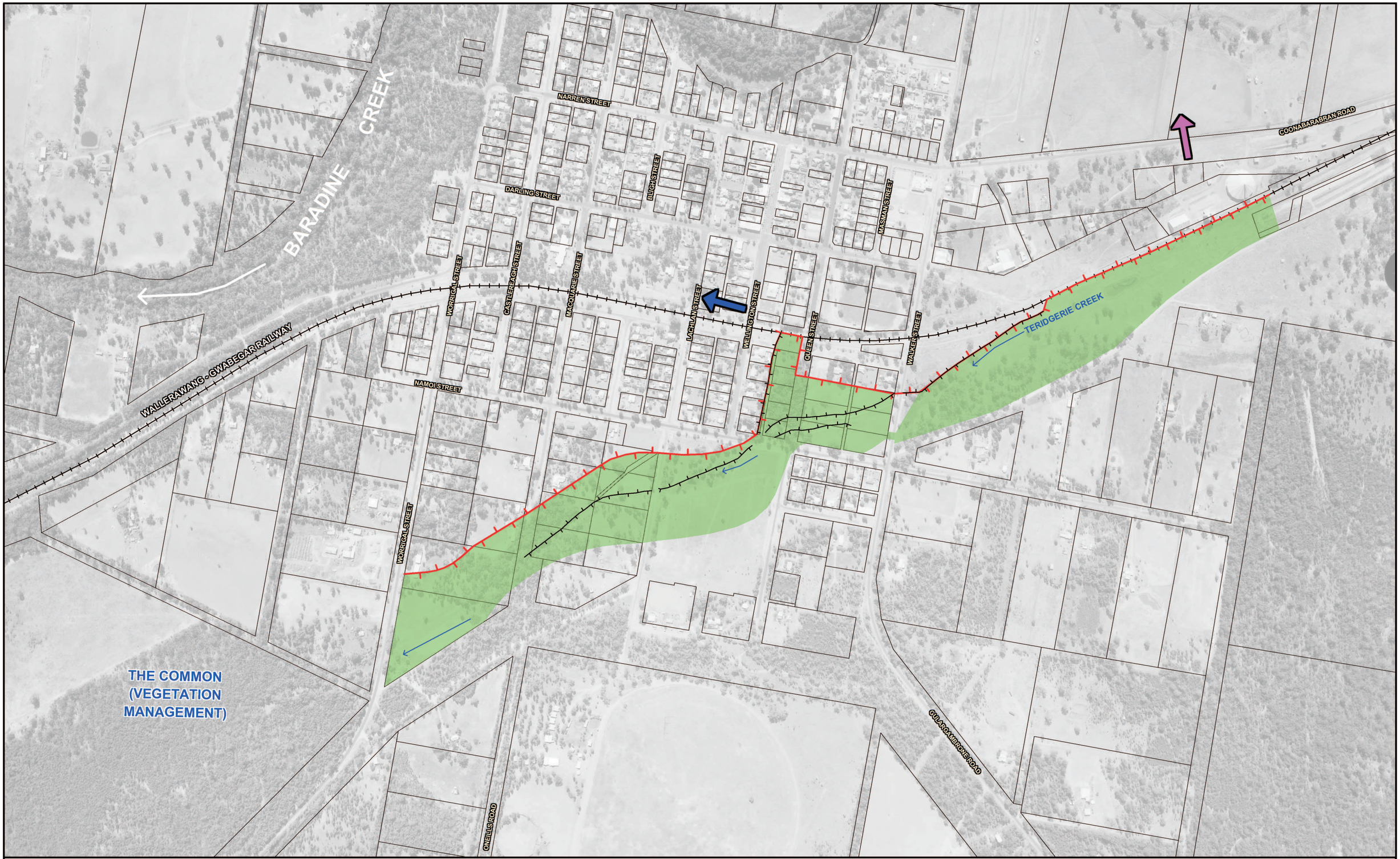
- Planning controls separately or in combination with the above measures are an essential component of the *FRMP*. A draft Flood Policy for Baradine is attached as **Appendix A.**

- Response modification measures which are supported comprise incorporation of flood improved flood awareness via the preparation of a Flood Information Brochure and incorporation of flood data included in this *FRMS* in SES's Local Flood Plan.

- Further consideration of a *Flash Flood Warning System* for Teridgerie Creek catchment may be justified if the diversion/levee or floodway/riparian corridor schemes do not proceed in a reasonable timeframe.

TABLE 3.10
REVIEW OF POTENTIAL FLOOD MANAGEMENT MEASURES

Scheme	Comments
Construct Diversion/Flood Protection Levees	It is technically feasible to construct a levee to the 100 year ARI level plus freeboard. However, levees in isolation would require an upgrade of the relief drain on the eastern side of the railway embankment to capture and dispose of local stormwater. The upstream diversion of flows to the Baradine Creek catchment would reduce the height of levees required in town and may eliminate the need for an upgrade of the relief drain. Either scheme should be considered for inclusion in the *FRMP* and tested in a future feasibility study.
Floodway/Riparian Corridor	This measure would be a dual purpose project providing environmental and flood mitigation benefits. A riparian corridor on Teridgerie Creek is considered worthy of further consideration for inclusion in the *FRMP*. However it is considerably more expensive than the levee alternatives and is probably beyond Council's capacity to fund.
Construct Detention Basins	There are no natural storage areas of sufficient size in the middle reaches of Teridgerie Creek to mitigate downstream flood peaks. Construction of an effective detention basin would require considerable land acquisition and excavation. Detention basins are not considered to be a feasible flood management measure for inclusion in the *FRMP*.
Voluntary Purchase of Residential Property	This measure is sometimes employed to remove residential development from high risk areas of the floodplain. Implementation of a voluntary purchase scheme for the Teridgerie Creek catchment is not economically justified. In view of the relatively shallow and short duration of flooding which would be experienced in these residences and the ready access to high ground from the flood affected areas, the scheme would probably not be justified on social grounds.
House Raising	This measure is sometimes employed to raise residential development in medium and low hazard areas of the floodplain. Implementation of a house raising scheme for Teridgerie Creek is not economically warranted. In view of the relatively shallow and short duration of flooding which would be experienced in these residences, the scheme could not be justified on social grounds.
Planning Controls (Flood Policy)	This is a low cost and essential component of the *FRMP* and will over time reduce damages. A draft *Flood Policy* recommending a graded set of controls for development, which depend on the nature of the development and its location within the floodplain is attached as **Appendix A**.
Flood Warning and Forecasting	It is not technically feasible to provide extended warning times with a conventional flood warning system. A Flash Flood Warning System along the lines of the system outlined in **Section 3.10** would reduce the present day flood risk. However, if the levee scheme proceeds, the flood risk would be reduced and a formal Flash Flood Warning system may not be required. SES and other emergency management authorities should use the flood information contained in this *FRMS* to update their procedures for flood response and evacuation, pending construction of the improved channel/riparian corridor.
Flood Awareness	Continuation of Council's policy of notifying flood affectation on S149 Certificates for properties impacted by floods up to 100 year ARI is supported. The affectation notices could be removed with the implementation of the levee scheme. Flood awareness would be increased by the Council and SES collaborating to prepare a FloodSafe Brochure for areas of Baradine affected by flooding from Teridgerie Creek.



LEGEND

- Upgraded Levee
- Upgraded Relief Drain
- Floodway/Riparian Corridor
- Diversion to Baradine Creek
- Existing Levees (to be Demolished)

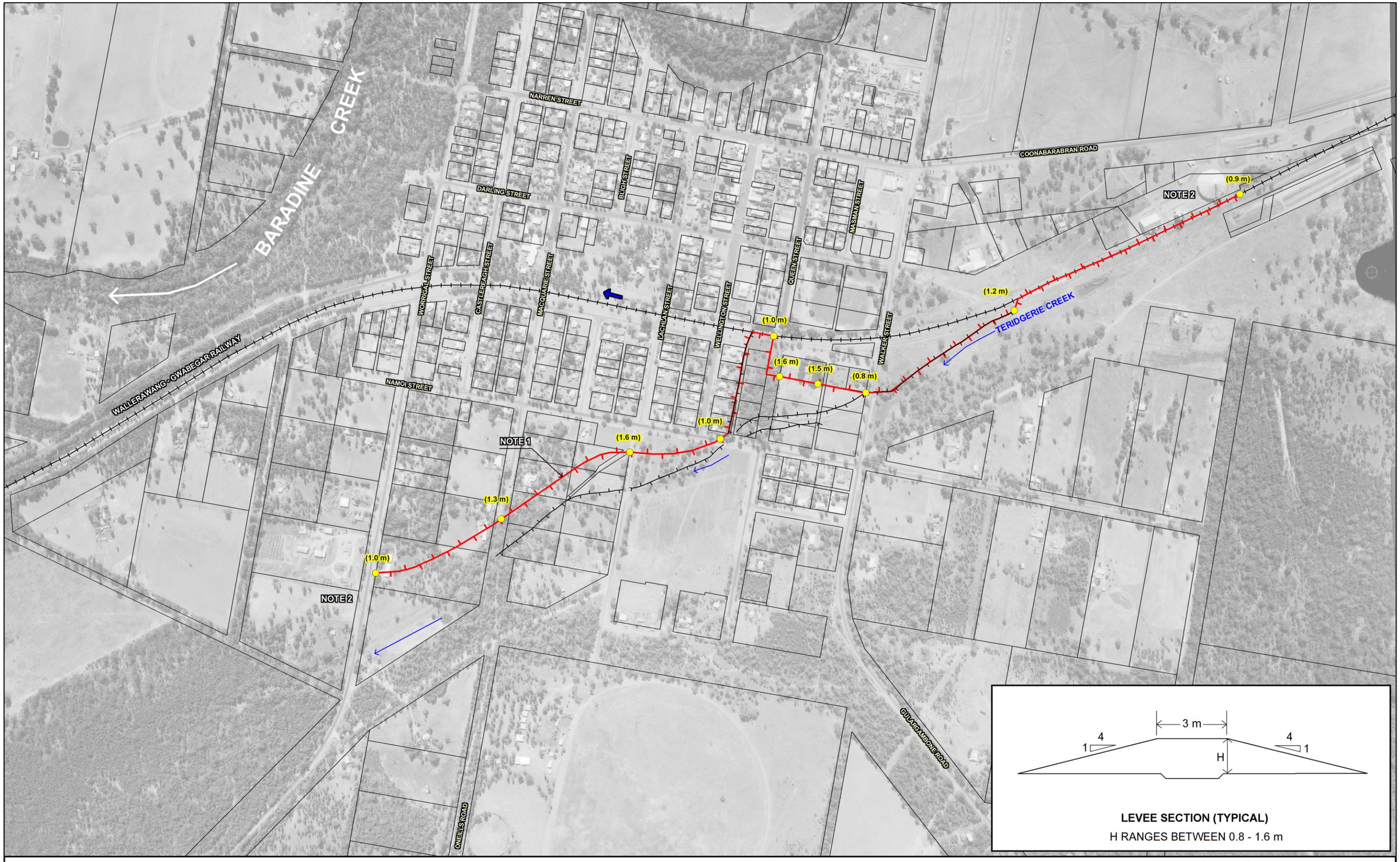
80 0 80 160 240 m

Scale: 1:8,000

TERIDGERIE CREEK
FLOODPLAIN RISK MANAGEMENT STUDY

Figure 3.1

POTENTIAL FLOOD MITIGATION SCHEMES



80 0 80 160 240 m

Scale: 1:8,000

N

NOTES

1. ROUTE OF UPGRADED LEVEE IS INDICATIVE ONLY. ROUTE TO BE CONFIRMED IN FUTURE FEASIBILITY STUDY AND IN CONSULTATION WITH COMMUNITY.
2. EXTENTS OF LEVEE ARE PRELIMINARY ONLY.

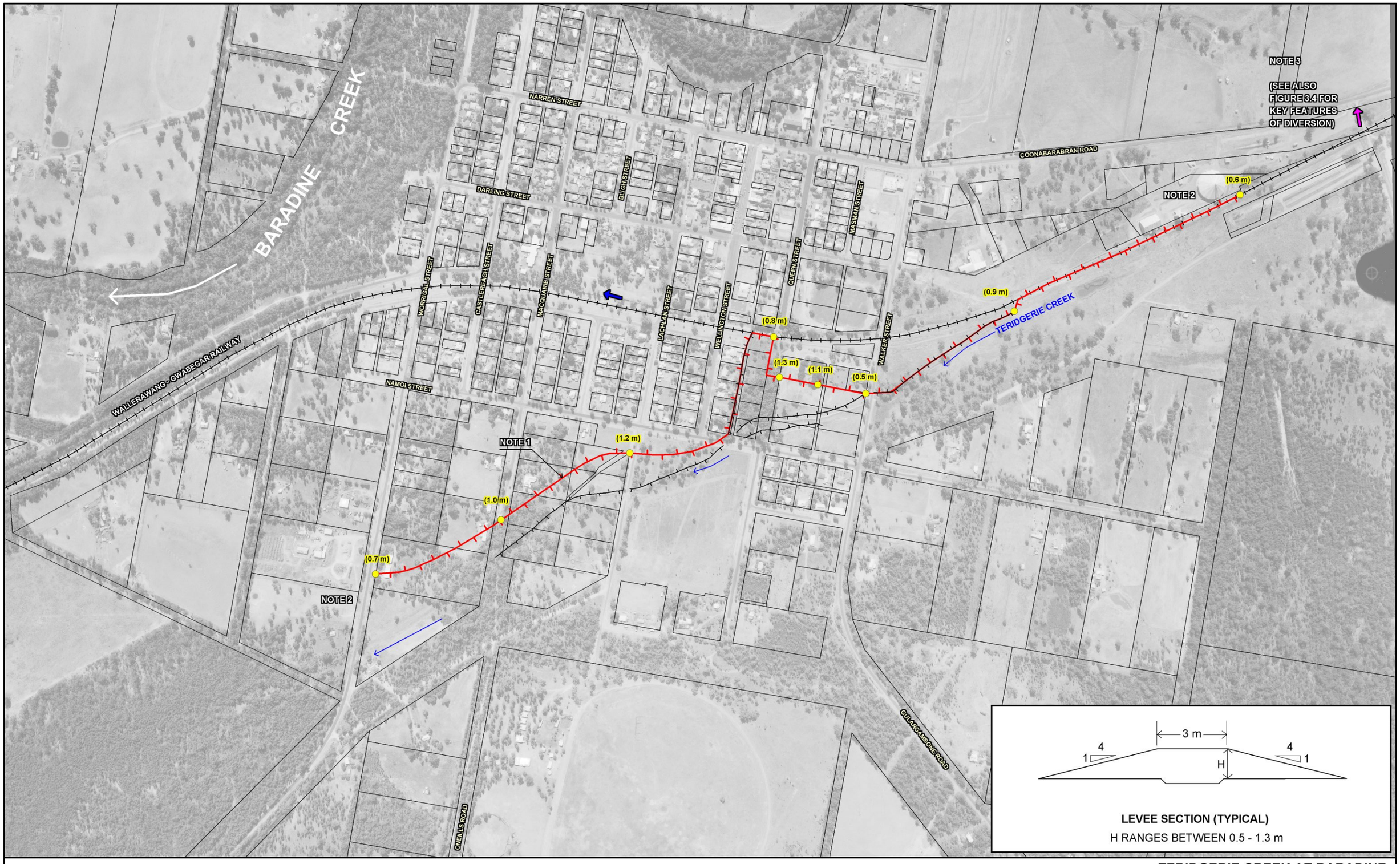
LEGEND

- Upgraded Levee Alignment (Note 1)
- (1.6 m) Upgraded Levee Height (m)
- Upgraded Relief Drain
- Existing Levees (to be Demolished)

TERIDGERIE CREEK AT BARADINE FLOODPLAIN RISK MANAGEMENT STUDY

Figure 3.2

FLOOD MODIFICATION SCHEME 1
UPGRADED LEVEES



80 0 80 160 240 m

Scale: 1:8,000

NOTES

1. ROUTE OF UPGRADED LEVEE IS INDICATIVE ONLY. ROUTE TO BE CONFIRMED IN FUTURE FEASIBILITY STUDY AND IN CONSULTATION WITH COMMUNITY.
2. EXTENTS OF LEVEE ARE PRELIMINARY ONLY.
3. LOCATION OF POTENTIAL DIVERSION IS INDICATIVE ONLY. LOCATION AND STRUCTURES TO BE CONFIRMED IN FUTURE FEASIBILITY STUDY AND IN CONSULTATION WITH COMMUNITY.

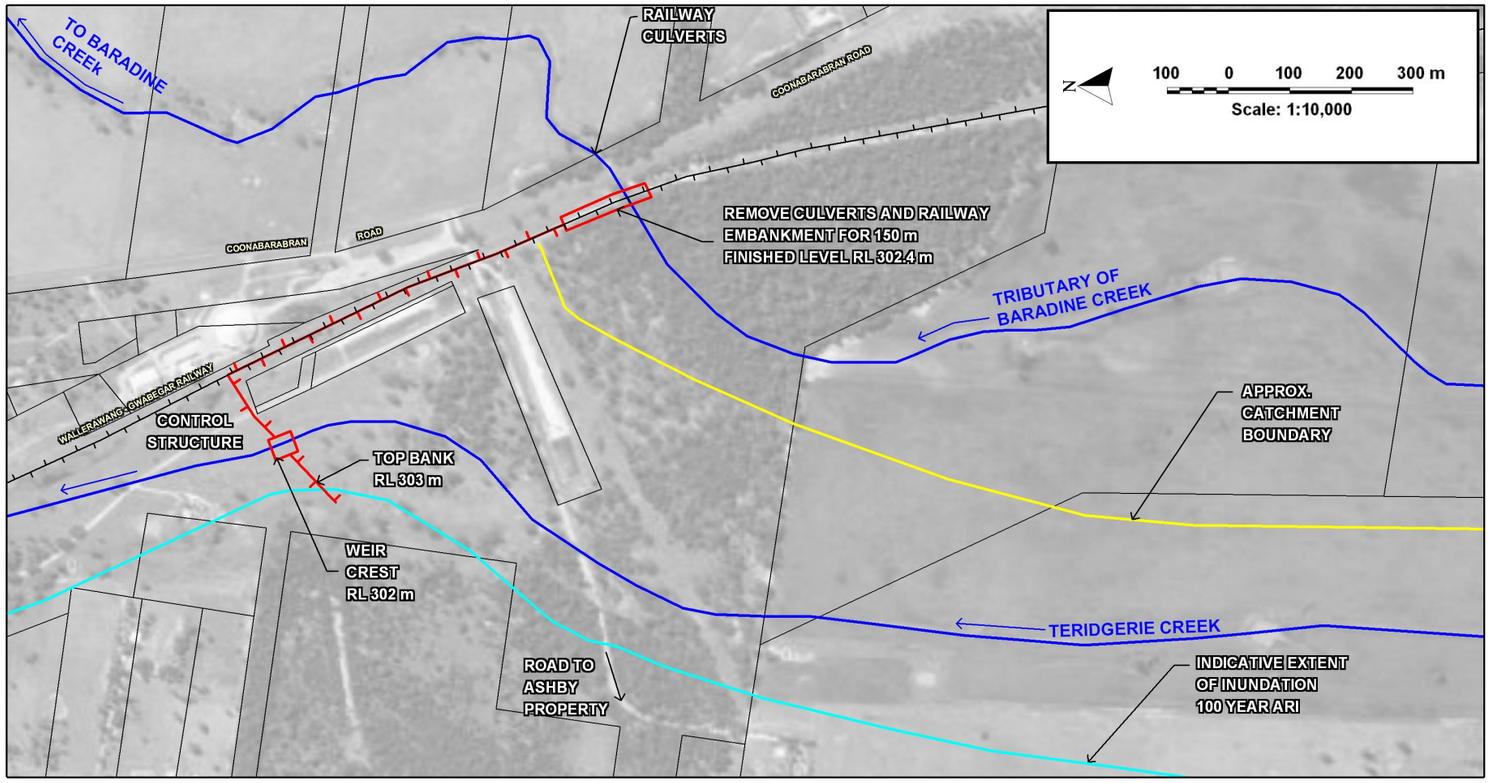
LEGEND

- Upgraded Levee Alignment (Note 1)
- (1.2 m) Upgraded Levee Height (m)
- Upgraded Relief Drain
- Existing Levees (to be Demolished)
- Diversion to Baradine Creek (Note 3)

TERIDGERIE CREEK AT BARADINE
FLOODPLAIN RISK MANAGEMENT STUDY

Figure 3.3

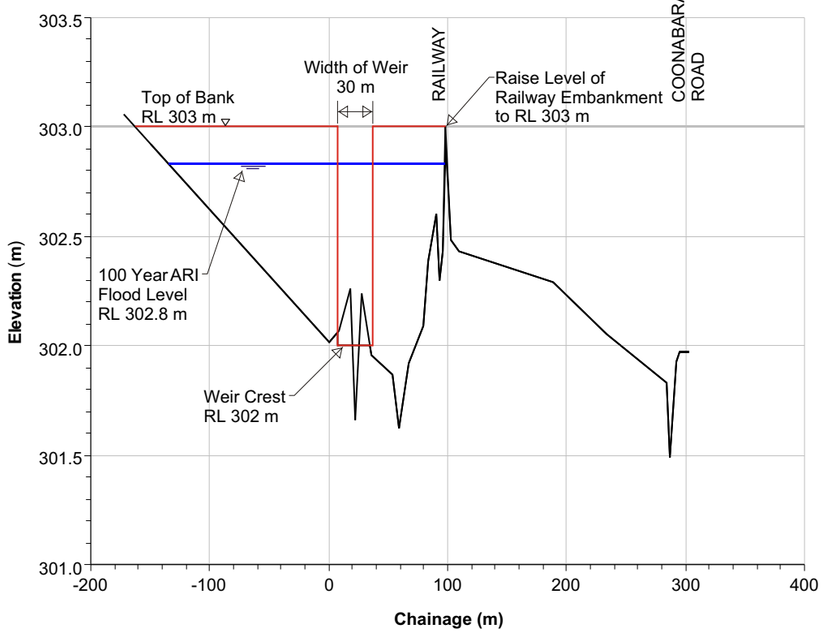
FLOOD MODIFICATION SCHEME 2
UPGRADED LEVEES AND
DIVERSION TO BARADINE CREEK



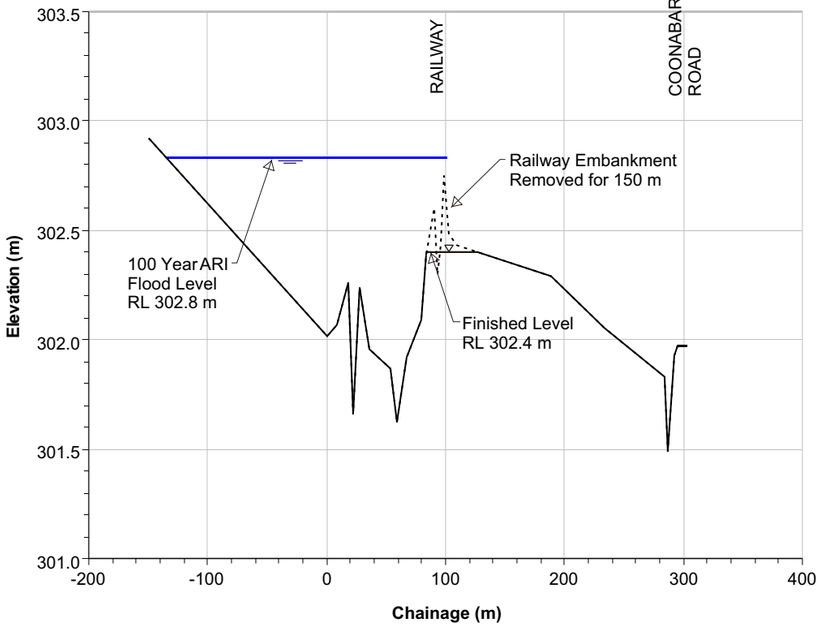
PLAN

NOTES:

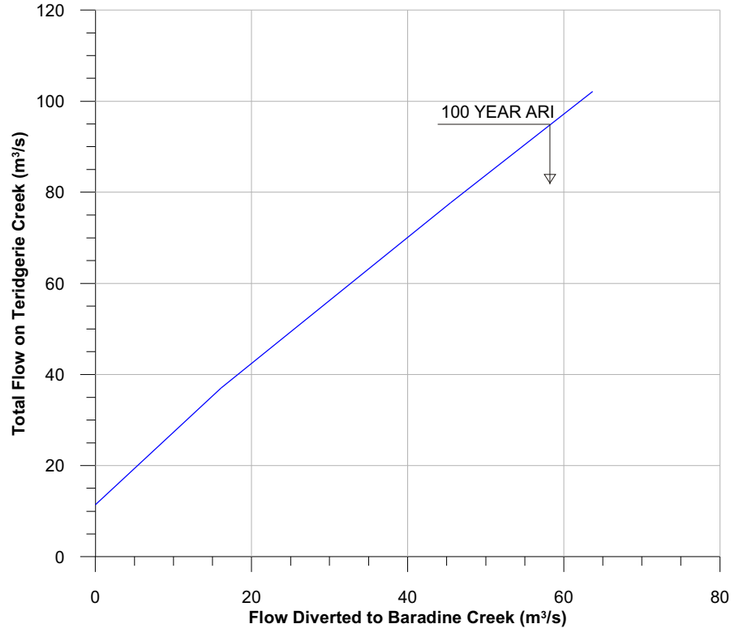
1. LEVELS SHOWN ARE TO THE SAME DATUM AS FLOOD STUDY, 2011
2. LOCATIONS OF CONTROL STRUCTURE AND DIVERSION TO BARADINE CREEK ARE INDICATIVE ONLY AND SUBJECT TO VARIATION IN FUTURE FEASIBILITY STUDY



SECTION AT CONTROL STRUCTURE



SECTION UPSTREAM OF CONTROL STRUCTURE

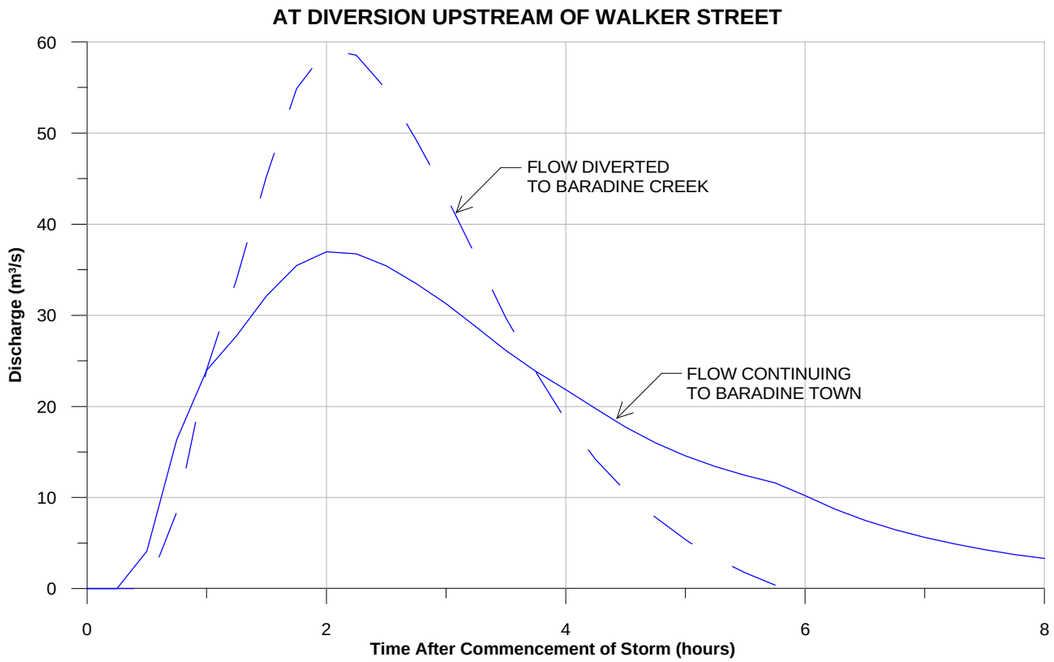


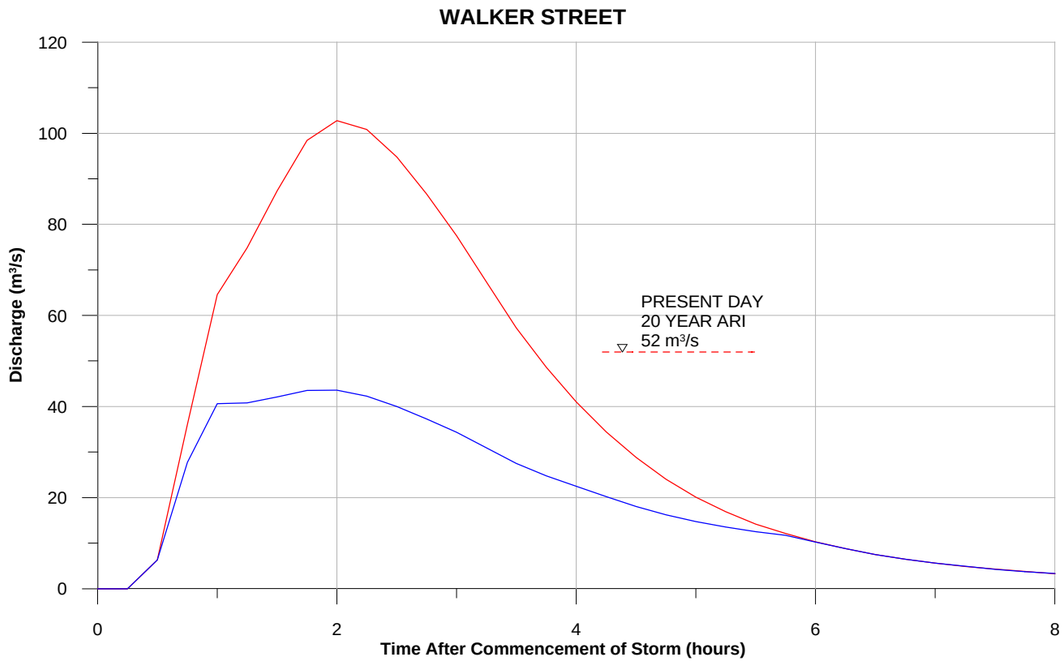
FLOW DIVERSION CURVE

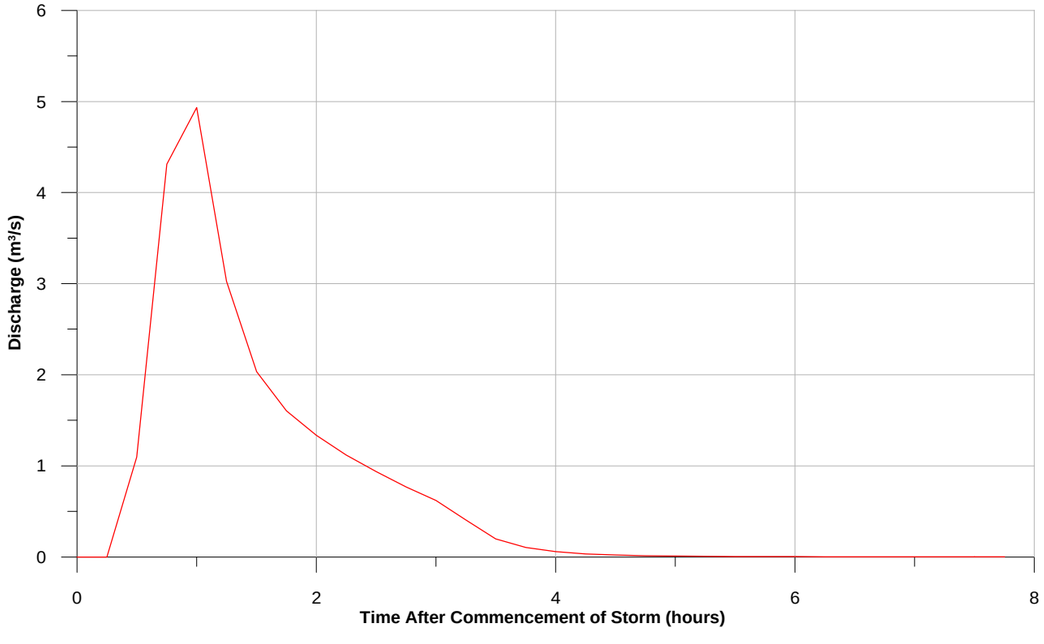
TERIDGERIE CREEK AT BARADINE
FLOODPLAIN RISK MANAGEMENT STUDY

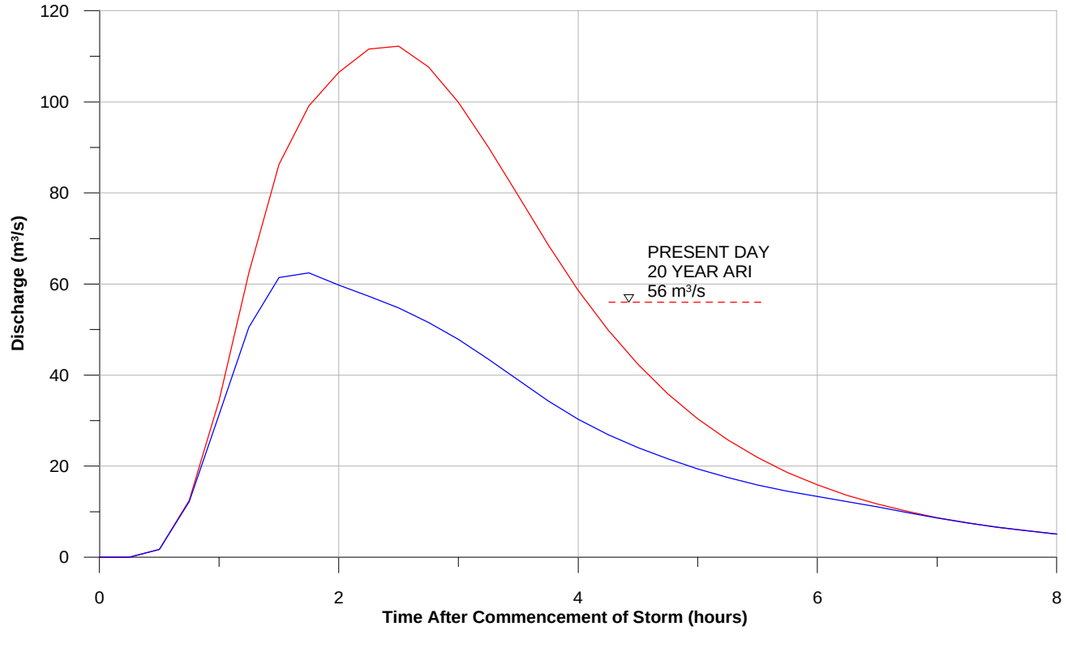
Figure 3.4

KEY FEATURES OF DIVERSION TO BARADINE CREEK SCHEME 2









NOTE

HYDROGRAPHS APPLY FOR STORM
OF 180 MINUTES DURATION.

TERIDGERIE CREEK

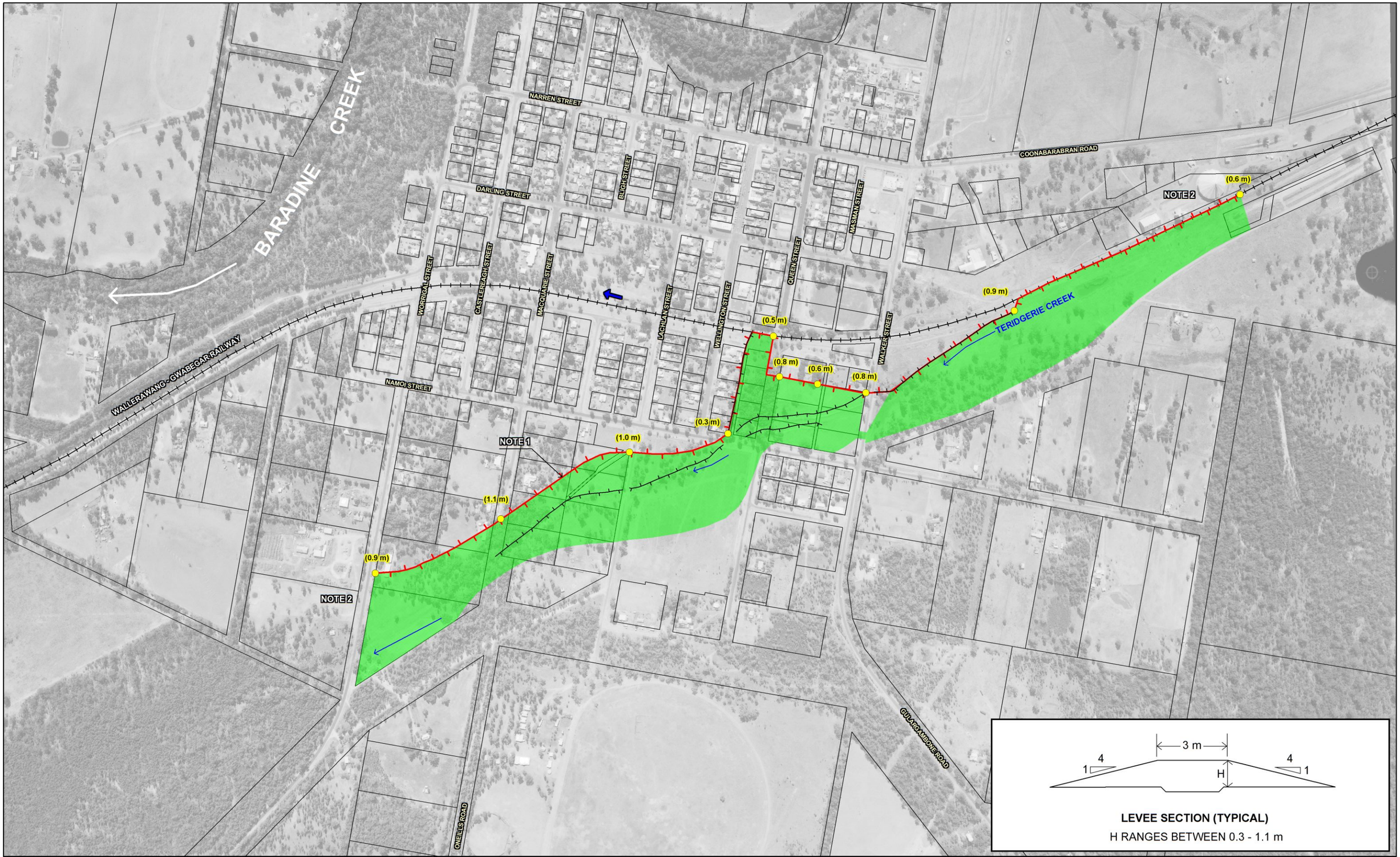
PRESENT DAY

POST - DIVERSION

TERIDGERIE CREEK AT BARADINE
FLOODPLAIN RISK MANAGEMENT STUDY

Figure 3.5

FLOWS ON TERIDGERIE CREEK
POST - DIVERSION TO BARADINE CREEK - 100 YEAR ARI



80 0 80 160 240 m

Scale: 1:8,000

NOTES

1. ROUTE OF UPGRADED LEVEE IS INDICATIVE ONLY. ROUTE TO BE CONFIRMED IN FUTURE FEASIBILITY STUDY AND IN CONSULTATION WITH COMMUNITY.
2. EXTENTS OF LEVEE ARE PRELIMINARY ONLY.

LEGEND

- Upgraded Levee Alignment (Note 1)
- (1.1 m) Upgraded Levee Height (m)
- Upgraded Relief Drain
- Existing Levees (to be Demolished)
- Floodway/Riparian Corridor

TERIDGERIE CREEK AT BARADINE FLOODPLAIN RISK MANAGEMENT STUDY

Figure 3.6

FLOOD MODIFICATION SCHEME 4
UPGRADED LEVEES AND
RIPARIAN CORRIDOR

4 SELECTION OF FLOODPLAIN MANAGEMENT MEASURES

4.1 Background

The *Floodplain Development Manual, 2005* requires a Council to develop a *Floodplain Risk Management Plan* based on balancing the merits of social, economic and environmental considerations which are relevant to the community. This chapter sets out a range of factors which need to be taken into consideration when selecting the mix of works and measures that should be included in the overall *Plan*.

The community will have different priorities and, therefore, each needs to establish its own set of considerations used to assess the merits of different options. The considerations adopted by a community must, however, recognise the State Government's requirements for floodplain management as set out in the *Floodplain Development Manual, 2005* and other relevant policies. A further consideration is that some elements of the *Plan* may be eligible for subsidy from State and Federal Government sources and the requirements for such funding must, therefore, be taken into account.

Typically, State and Federal Government funding is given on the basis of merit, as judged by a range of criteria:

- The magnitude of damage to property caused by flooding and the effectiveness of the option in mitigating damage and reducing the flood risk to the community.
- Community involvement in *Plan* preparation and acceptance of the option.
- The technical feasibility of the option (relevant to structural works).
- Conformance of the option with Council's planning objectives.
- Impacts of the option on the environment.
- The economic justification, as measured by the benefit/cost ratio of the option.
- The financial feasibility as gauged by Council's ability to meet its commitment to fund its part of the cost.
- The performance of the option in the event of a flood greater than the design event.
- Conformance of the option with Government Policies (eg *FDM, 2005*, Rivers and Estuaries Policy and Catchment Management objectives).

4.2 Ranking of Options

A suggested approach to assessing the merits of various options is to use a subjective scoring system. The chief merits of such a system are that it allows comparisons to be made between alternatives using a common "currency". In addition it makes the assessment of alternatives "transparent" (i.e. all important factors are included in the analysis). The system does not, however, provide an absolute "right" answer as to what should be included in the plan and what should be left out. Rather, it provides a method by which the Council can re-examine its options and if necessary, debate the relative scoring given to aspects of the plan.

Each option is given a score according to how well the option meets the criteria identified in **Section 4.1** above. In order to keep the scoring simple the following system is proposed:

+2 Option rates very highly

+1 Option rates well

0 Option is neutral

-1 Option rates poorly

-2 Option rates very poorly

The scores are added to get a total for each option.

Based on considerations outlined in this chapter, **Table 4.1** presents a scoring matrix for the options reviewed in **Chapter 3**. This scoring has been used as the basis for prioritising the components of the draft *Floodplain Risk Management Plan*. The proposed scoring and weighting shown in **Table 4.1** was reviewed by the Committee as part of the process of finalising the draft Plan. This process allowed their consolidated views to be included in the report. Similarly the draft Plan shown in **Chapter 5** was based on the collective views of the Committee.

4.3 Summary

Table 4.1 indicated that there are good reasons to consider including the following elements into the draft *FRMP*:

- Planning Controls via Council's existing Flood Policy for Warrumbungle.
- Incorporation of the Catchment Specific information on flooding impacts contained in this Study in SES Emergency Management Procedures and Flood Awareness documentation for the study area.
- Diversion/Upgrade Flood Protection Levees (as an alternative mitigation measure to the floodway/riparian corridor below).
- Channel Improvement/Riparian Corridor on Teridgerie Creek to provide flood mitigation and environmental benefits.
- Flash Flood Warning System (in the event that neither of the structural mitigation measures proceeds).

Property modification measures such as voluntary purchase of residential property or house raising schemes were not considered justified.

TABLE 4.1
TERIDGERIE CREEK
ASSESSMENT OF FLOODPLAIN MANAGEMENT OPTIONS

Option	Impact on Flooding/ Reduction in Flood Risk	Community Acceptance	Technical Feasibility	Planning Objectives	Environ. Impacts	Economic Justification	Financial Feasibility	Extreme Flood	Government Policies and TCM Objectives	Score
Flood Modification										
Diversion/Upgrade flood protection Levees along east bank	+2	+2	+1	+2	0	+2	+1	0	+1	+11
Floodway/Riparian Corridor	+2	+2	+1	+1	+1	-1	-2	0	+2	+6
Property Modification										
Flood Related Controls over future development (via Council Flood Policy)	+2	+2	0	+2	0	+2	0	0	+2	+10
House Raising in Low Hazard Areas	+1	0	0	+1	0	+1	+1	0	+1	+5
Voluntary Purchase of Residential Property	0	-1	0	+1	0	-1	-1	+1	+1	0
Response Modification										
Improvements in Flood Warning and Response	+1	+2	0	+1	0	+1	+1	+1	+1	+8
Community Education and Flood Awareness	+2	+2	0	+1	0	+1	0	+1	+2	+9
Certificate of Flood Affectation of property	+2	+2	0	+2	0	+1	0	+1	+2	+10

5 DRAFT FLOODPLAIN RISK MANAGEMENT PLAN

5.1 The Floodplain Risk Management Process

A draft *Floodplain Risk Management Plan* (*FRMP*) has been prepared for Teridgerie Creek at Baradine as part of a Government program to mitigate the impacts of major floods and reduce the hazards in the floodplain. The *FRMP* has been prepared as part of the Floodplain Risk Management Process in accordance with NSW Government's Flood Prone Land Policy.

The first steps in the process of preparing the *FRMP* were the collection of data and the review of the *Flood Study, 2012*. That Flood Study was the formal starting process of defining management measures for flood liable land and represented a detailed technical investigation of flood behaviour in the catchment.

5.2 Purpose of the Plan

The overall objectives of the *FRMS* and *FRMP* were to assess the impacts of flooding, review policies and options for management of flood affected land and to develop an *FRMP* which:

- Sets out the recommended program of works and measures aimed at reducing over time, the social, environmental and economic impacts of flooding and establishes a program and funding mechanism for the *FRMP*.
- Proposes amendments to Council's existing policies to ensure that the future development of flood affected land on Teridgerie Creek at Baradine is undertaken so as to be compatible with the flood hazard and risk.
- Ensures the *FRMP* is consistent with local emergency management planning.
- Ensures that the *FRMP* has the support of the community.

5.3 The Study Area

This *FRMP* deals with the floodplain of the Teridgerie Creek at Baradine, which has a total catchment area of 16.5 km^2 at the downstream end of town at Worrigal Street. For the purposes of this *FRMP* the study focusses of the residential area in the 2 km long floodplain of the creek between Walker Street and Worrigal Street.

5.4 Community Consultation

The Community Consultation process provided valuable direction over the course of the investigations, bringing together views from key Council staff, other departments and agencies, and importantly, the views of the community gained through:

- The delivery of a Community Newsletter and Questionnaire to property occupiers located in the floodplain, as well as inclusion of the documentation on Council's web site to allow the wider community to gain an understanding of the issues being addressed as part of the study.
- Meetings of the Floodplain Management Committee to discuss results as they became available.
- Exhibition of the draft Study Report to give the community the opportunity to comment on the study findings and the draft *FRMP.*

5.5 Structure of Floodplain Risk Management Study and Plan

The *FRMS* and *draft FRMP* are supported by Appendices which provide additional details of the investigations undertaken during the investigation. A summary of the *draft FRMP* proposed for the study area is shown in **Table S.2** at the commencement of this report. In order of priority the *draft FRMP* is based on:

- Planning and development controls for future development in flood prone areas,
- Improvements to existing flood preparedness and awareness in the Teridgerie Creek community.
- Upgrading the existing levees on the eastern floodplain of Teridgerie Creek, possibly in conjunction with the diversion of flood flows to the adjacent Baradine Creek catchment to reduce flooding in the town .

A priority list of alternative measures which could mitigate existing flooding conditions in the event that the levee scheme does not proceed is also presented in **Table S.2**.

5.6 Flooding Pattern and Impact

5.6.1 Flood Pattern

Figure 2.1 shows the indicative extents of flooding for the 5, 20 and 100 year ARI and the Extreme Flood. **Figure B8.3** of **Appendix B** shows properties which would be flooded above floor level in the event of a 100 year ARI flood. The extent of flooding and inundation of flood affected properties is indicative only, being based on available survey data. It should not be used to identify the flood affectation of individual properties, for which a site specific survey would be required.

5.6.2 Impacts of Flooding

Table 5.1 shows the number of properties which would be flooded to above floor level and the damages experienced for the various classes of property in Baradine.

TABLE 5.1
ECONOMIC IMPACTS OF FLOODING
AT BARADINE

Flood Event ARI	No. of Properties Flooded and Flood Damages						Total Flood Damages
	Residential		Commercial /Industrial		Public Buildings		
	No.	$ x 10^6	No.	$ x 10^6	No.	$ x 10^6	$ x 10^6
5	8	0.57	1	0.03	0	-	0.60
20	38	2.05	5	0.22	3	0.03	2.30
100	59	3.11	5	0.37	3	0.06	3.54
Extreme	75	4.65	7	0.88	8	0.24	5.76

5.7 Flood Modification Measures

5.7.1 Flood Protection Levee and Diversion

The construction of a 2.4 km flood protection levee along the left bank of the creek is supported by the Community and is worth inclusion in the draft *FRMP*. Further investigation with the benefit of additional survey information would be required to confirm its feasibility. The levee would be up to 1.6 m in height. Diversion of flows to the Baradine Creek catchment would reduce the maximum height of the levee to 1.1 m.

Further hydrologic analysis with the benefit of additional survey information, the preparation of concept designs and refinement of the cost estimate would be required to prepare a submission for Council/Government funding and has been included as a recommended measure in the draft *FRMP*, as the first step in the implementation of the project.

5.7.2 Channel Improvement/ Riparian Corridor Scheme

Improvements to increase the conveyance capacity of the creek associated with the implementation of a floodway/riparian corridor are supported by the Community. The channel improvement /riparian corridor would extend over about a 2.4 km reach upstream of Worrigal Street. However, preliminary costing based on existing sources of survey data showed that this scheme was considerably more expensive than the diversion/levee scheme and may be beyond Council's capacity to fund.

5.8 Property Modification Measures

The results of the *FRMS* indicate that an important measure for Warrumbungle Shire Council to adopt in the floodplain would be strong floodplain management planning applied consistently by all branches of Council. A draft *Flood Policy* is attached as **Appendix A** of the report.

The building and development controls set out in the *draft Flood Policy* involve the imposition of measures aimed at flood proofing future developments in flood affected areas. They include the specification of:

- Minimum habitable floor levels for development (including appropriate freeboard provision);
- Appropriate flood compatible building materials.

The floodplain of Teridgerie Creek has been divided into various zones according to the level of the flood risk. The approximate extents of the various **Flood Risk Zones** are shown in **Figure 2.2** and comprise:

- **"*High Hazard Floodway*"** this is the most flood affected land and the area where the highest flow velocities would be expected at the 100 year ARI flood. This zone should be kept clear of future development, although **minor additions** to existing residences and small outbuildings may be permitted by Council, subject to conformance with the controls demonstrating that the flood risk is not increased to existing and proposed developments.
- ***"Overland Flow Zone"***. In this zone, there may be overland flows through residential and commercial allotments, but low hazard conditions will generally occur due to the shallow depth and low velocities. All land uses would be permitted in this zone, but the development would need to be capable of withstanding hydraulic forces and sited within the allotment to minimise adverse re-directions of flow towards adjacent properties.

- ***"Intermediate Floodplain"*** is the remaining land lying within the ***Flood Planning Area*** (land inundated by the 100 year ARI flood levels plus 500 mm). Within this area, there would only be the requirement for minimum residential floor levels to be set at 100 year ARI flood levels plus 500 mm. All land uses would be permitted in this zone. However, Essential Community Facilities, Critical Utilities and Flood Vulnerable development such as housing for aged and disabled persons would be subject to additional controls.

*'*No controls would apply for residential development outside the ***Flood Planning Area***. However, because the flood extents and hazard zones have been mapped using available contour mapping, Council would check proposed floor levels of developments up to the Extreme Flood extent to ensure that they are no lower than the ***FPL***.

Flood Planning Levels

The ***Flood Planning Level*** (*FPL*) is the minimum floor level for the various categories of development. For new residential, commercial and industrial development the proposed *FPL* is the peak 100 year ARI flood level at the particular development site, as defined in the *Flood Study, 2012,* plus an allowance of 500 mm freeboard. Council may give consideration to allowing lower floor levels for commercial and industrial developments, in situations where application of the *FPL* may result in a floor level which is so high as to conflict with the streetscape. However, in such cases, a mezzanine area at the *FPL* would be required for the temporary storage of goods during periods of flooding.

The draft *Flood Policy* adopts the 100 year ARI flood level plus 500 mm as the *FPL* for Essential Community Facilities and Critical Utilities, with the additional requirement that these classes of development are to be designed to be able to continue to function in the event of the Extreme Flood. The policy recommends the residential *FPL* be applied for Flood Vulnerable Residential Development However, the applicant is to ensure that valuable equipment necessary for the operation of the facility is located at or above the *FPL* (and preferably at the Extreme Flood level), either permanently or via relocation to a temporary storage area of an area suitable for this purpose.

The draft *Flood Policy* is based on the recognition that individual developments should not be evaluated in isolation, but rather, should be considered in a strategic sense as if it were one of several developments in the area. Whilst individual developments in isolation may not have a measurable impact on flooding, the cumulative impacts of ongoing development could be significant. New buildings, or additions to existing buildings would be subjected to these building controls with the long term objective of having all buildings in the area ultimately flood proofed. Controls need to be imposed on a merit basis, balancing restrictive development conditions with the impact of development on flood behaviour in the floodplain.

5.9 Indicative Flood Extents

The plans showing the extents of flooding and flooded properties (**Figure 2.1**) are indicative only, being based on available 0.5 m contour mapping and limited cross sections of the creeks and their floodplains. This level of accuracy in the flood mapping is supported by OEH, as the costs associated with undertaking detailed ground survey in each flood affected property presently lies outside the scope of the NSW Government's floodplain program.

Under the program, it is Council's responsibility to identify the flood risk within the floodplain and prepare maps showing indicative flood extents, with the onus being on the property owner to carry out sufficient survey to allow a more accurate picture of flood affection to be described in his allotment.

To allow Council to assess individual development proposals, a detailed site survey would be required to allow the extent of flooding and the flood hazard to be evaluated using the results of the *Flood Study, 2012*. For this reason, applicants will be required to submit a detailed survey plan of the site for which development is proposed.

It would, however, assist Council with the operation of the draft *Flood Policy* if the extent and depths of inundation in flood prone areas bordering the creeks could be identified with greater accuracy than is presently possible. This could be achieved at comparatively modest cost by undertaking an Airborne Laser Survey of the study area (possibly extended at minimal cost to the whole of the Warrumbungle Council LGA), which would achieve accuracies in defining natural surface levels in the range 150-200 mm.

This would be a major improvement on the accuracy of existing mapping sources and would also assist Council in the planning and design of other engineering and town planning disciplines (roads, stormwater management, strategy studies and the like). However, as mentioned the cost of the survey would be outside the scope of the NSW Government's floodplain program and would therefore be borne by Council.

5.10 Voluntary Purchase of Residential Property

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

The review undertaken in the *FRMS* showed that implementation of a Government sponsored voluntary purchase scheme was not economically viable and could not be justified on social grounds.

5.11 Raising Floor Levels of Residential Property

The analysis undertaken in the *FRMS* showed that the implementation of a voluntary house raising program was economically viable and could be included in the *FRMP*.

5.12 Response Modification Measures

5.12.1 Flood Warning and Response

The floor levels of properties potentially affected by flooding have been surveyed, or estimated from available topographic survey. Plans have been prepared as part of this present study, showing the indicative extent of flooding, high hazard areas and the locations of flooded properties. Plans showing the expected rate of rise of floodwaters have also been prepared. Consequently there is information available to identify areas at risk from flooding for the full range of flood events likely to trigger flood response procedures (Note, however, that this information could be refined with the ALS survey mentioned at the conclusion of **Section 5.9**).
The next edition of SES's *Warrumbungle Shire Local Flood Plan* should take advantage of information on flooding included in this study and the *Flood Study, 2012* to improve emergency management procedures, in particular:

- Indicative extents of inundation during major floods (see **Figure 2.1** in this report).
- Typical times of rise of floodwaters.

- Locations of residential properties inundated by floodwaters of various recurrence intervals and depths of above floor flooding (**Figure B8.3**).
- Information on the operation of the local stormwater system (see **Chapter 3**).

This will allow SES to:

- Rank the threatened houses according to their hazard situation, taking account of depth and velocity of floodwaters, and means of access, as a flood develops.
- Prepare a detailed response plan which focusses on initial evacuations from the most hazardous locations, followed by further evacuations in descending exposure to hazardous conditions.
- Prepare a plan for traffic management, which takes account of the sequence of road flooding as a flood develops. This plan would aim to:
  - maximise opportunities for the community to evacuate,
  - prevent unnecessary traffic through the affected area,
  - ensure access for SES operations.

5.12.2 Flood Awareness

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

- The proposed amendments to the draft *Flood Policy* should be considered, amended as required and adopted by Council.
- Council should continue to promote knowledge of the characteristics of flooding among the affected property owners. These characteristics should include information on the frequency of flooding and the depths at various locations. Council and SES should incorporate this information and the data derived from **Section 5.12.1** above in a FloodSafe Brochure to inform residents of the flood risk, which could be distributed with the rate notices. The community should also be made aware that a flood greater than historic levels or the planning level can, and will, occur at some time in the future. The need for a flood response and preparedness plan to address such an occurrence should be clearly explained.
- The *FRMP* should be publicised and exhibited in Council offices and at community gathering places to make residents aware of the measures being proposed.

5.12.3 Flash Flood Warning System

In the event that neither of the two structural flood mitigation measures (diversion/flood protection levee or channel improvement/riparian corridor) proceeds in a reasonable timeframe, a *Flash Flood Warning* system as outlined in **Section 3.11** could be considered. A study would be required to confirm its feasibility prior to its implementation. Both the feasibility study and implementation of the system would qualify for Government funding assistance.

5.13 Recommended Measures and Funding

Broad funding requirements for the recommended measures to be included in the *draft FRMP* are given in **Table S.2**. These measures comprise a program of engineering investigations and capital works, preparation of planning documentation by Council, and community education on

flooding by SES to improve flood awareness and response. They will over time, achieve the objectives of reducing the flood risk to existing and future development for the full range of floods.

5.14 Implementation Program

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

- Floodplain Management Committee to consider and adopt recommendations of this study. In particular, the Committee should review the basis for ranking floodplain management measures (as set out in **Table 4.1** of the *FRMS* and the proposed works and measures to be included in the draft *FRMP* as set out in **Table S.2**).
- Exhibit the *draft FRMS* and *FRMP* and seek community comment.
- Consider public comment, modify the document if and as required, and submit to Council. In addition to Council comments, two responses were received from the community.
- Council adopts the *FRMP* and submits an application for funding assistance from the Floodplain Management Program administered by OEH and/or the Natural Disaster Mitigation Program administered by the State Emergency Management Committee and other agencies.
- As funds become available from OEH, other Government agencies and/or Council's own resources, implement the measures in accordance with the established priorities.

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

6 DEFINITIONS

Note: For expanded list of definitions, refer to Glossary contained within the NSW Government's *Floodplain Development Manual, 2005*.

TERM	DEFINITION
Annual Exceedance Probability (AEP)	The per cent probability of occurrence of a flood equal to or greater than a particular magnitude. For example, the 100 year ARI flood has a 1% chance (i.e a one-in-100 chance) of being equalled or exceeded in any one year.
Extreme Flood	A flood with a peak discharge equal to three times that of the 100 year ARI event and used in this study to define the upper limit of flooding that could reasonably be expected to occur at a particular location.
Floodplain	The area inundated by the **Extreme Flood**
Flood Planning Level (*FPL*)	Flood levels selected for planning purposes, as determined in the *Teridgerie Creek at Baradine Flood Study, 2012* and referenced in the *Floodplain Risk Management Study, 2012* and associated *Floodplain Risk Management Plan*. For residential development in the floodplain, it is the flood level derived from the 100 year ARI flood event, plus the addition of a 500 mm Freeboard. Essential Community Facilities (eg. schools, hospitals), Critical Infrastructure and Flood Vulnerable Development (eg housing for Aged Persons and people with disabilities) should be excluded from the floodplain or at least have minimum floor levels equal to that of the Extreme Flood.
Flood Prone/Liable Land	Land susceptible to flooding up to the Extreme Flood.
Floodway	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	The factor of safety usually expressed as a height above the peak level of the flood used for planning purposes. Freeboard allows for factors such as wave action, localised hydraulic effects, greenhouse and climatic change, as well as accuracy of flood modelling data. The default value for freeboard is 500 mm unless a site specific freeboard to take account of localised effects is agreed to by Council.

TERM	DEFINITION
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.

7 REFERENCES

Lyall and Associates Consulting Water Engineers, 2012. *"Teridgerie Creek at Baradine Flood Study"*.

New South Wales Government, 2005. *"Floodplain Development Manual: the Management of Flood Liable Land"*.

Warrumbungle Shire Council, *"Baradine Local Environmental Plan, 1990"*.

SES, July 2006, *"Warrumbungle Shire Local Flood Plan".*

WARRUMBUNGLE SHIRE COUNCIL

TERIDGERIE CREEK AT BARADINE FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

APPENDIX A

DRAFT FLOOD POLICY

MAY 2012

Job No: DI283	Date: May 2012	Principal: BWL
File: Teridgerie Creek Appendix A.doc	Rev No: 4.0	Author: BWL

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1 INTRODUCTION

This *Flood Policy* was prepared to provide specific controls to guide development of land in flood prone areas bordering the Teridgerie Creek system at Baradine.

The *Flood Policy* incorporates the findings of the *Teridgerie Creek at Baradine Floodplain Risk Management Study and Plan, 2012* and the procedures set out in the NSW *Floodplain Development Manual, 2005*.

The *Flood Policy* also takes into account the "*Guideline on Development Controls on Low Flood Risk Areas*" and associated Ministerial Direction No 15 issued by the Department of Planning in January 2007. As a consequence, residential areas above the ***Flood Planning Level*** (100 year ARI flood level plus a 500 mm allowance for freeboard) are not subject to flood related development controls. Within the extent of the ***Flood Planning Area*** *(*land inundated at the ***Flood Planning Level****)*, controls over residential development reflect the nature of the flood risk.

The *Policy* recognises the need for controls over commercial and industrial development to balance the flood risk against the requirement for continuing the long term viability of this sector of Baradine.

The *Policy* also recognises that the safety of people and associated emergency response management need to be considered and imposes restrictions on vulnerable development (for example aged care facilities) and critical emergency response and recovery facilities and infrastructure (evacuation centres, hospitals and utilities).

1.1 What does the Policy do?

The *Policy* provides information and guidelines to assist people who want to develop or use land affected by potential flooding in Baradine. Development may include, among other things:

- dwelling construction, including additions to existing dwellings;
- filling land to provide building platforms above flood level;
- commercial and industrial development;.
- sub-dividing land.

1.2 Objectives

The objectives of this *Policy* are:

(a) To provide detailed flood related development controls for the assessment of applications on land affected by floods in accordance with the provisions of Shire of Coonabarabran *LEP 1990* (and as amended in future editions) and the findings of the *Teridgerie Creek at Baradine Floodplain Risk Management Study and Plan, 2012*.

(b) To alert the community to the hazard and extent of land affected by floods.

(c) To inform the community of Council's policy in relation to the use and development of land affected by the potential floods in Baradine.

(d) To reduce the risk to human life and damage to property caused by flooding through controlling development on land affected by floods.

(e) To ensure new development is consistent with the flood response strategy set out in the Warrumbungle Shire *Baradine Local Flood Plan*, published by the State Emergency Service (SES) and does not impose additional burdens on, or risk to, SES personnel during flood emergencies.

Definitions of flood related terms used herein are provided in the **Glossary** in **Section 3** of this document

1.3 Will the Plan affect my Property?

The *Policy* applies to all development permissible with the consent of Council on land that:

i) is zoned *2(v)* under Shire of Coonabarabran *LEP* and as subsequently amended; and

ii) lies within the extent of the ***Flood Planning Area*** (***FPA***) of Teridgerie Creek, as shown in **Figure A1.1**.

1.4 How To Use This Policy

The *Policy* provides criteria which Council will use for the determination of development applications in areas within the extent of the ***FPA*** in Baradine. The criteria recognise that different controls apply to different land uses and levels of potential flood inundation or hazard.

The procedure Council will apply for determining the specific controls applying to proposed development within the ***FPA*** is set out below. Upon enquiry by a prospective applicant, Council will make an initial assessment of the flood affectation and flood levels at the site using the following procedure:

i) Determine which part of the floodplain the development is located in from **Figure A1.1**.

ii) Identify the category of the development from **Annexure 1: Land Use Category**.

iii) Determine the appropriate ***Flood Planning Level*** and flood related conditions for the category of development from **Figure A1.1** and **Annexure 2: Development Controls Matrix**.

iv) Determine the flood level at the site using flood contour data shown in **Figure A1.1** and information contained in the *Teridgerie Creek at Baradine Floodplain Risk Management Study and Plan, 2012* and confirm that the development conforms with the controls set out in **Annexure 2**.

With the benefit of this initial information from Council, the Applicant will prepare the Documentation to support the development application according to **Annexures 2** and **4**.

A survey plan showing natural surface levels over the site will be required as part of the Development Application Documentation. Provision of this plan by the applicant at the initial enquiry stage will assist Council in providing flood related information relevant to the site.

Further information on flooding in Baradine and the controls over development imposed by this Policy are available by discussion with and upon written application to Council.

1.5 Other Documents Which May Need to be Read in Conjunction with this Plan

- *Shire of Coonabarabran LEP 1990*, and as subsequently amended;
- *Teridgerie Creek at Baradine Floodplain Risk Management Study and Plan, 2012*;
- *Teridgerie Creek at Baradine Flood Study, 2012*;
- NSW Government *Floodplain Development Manual, 2005*; associated *Guideline on Development Controls on Low Flood Risk Areas*; and *Ministerial Direction No. 15, January 2007.*
- Relevant Council policies, development control plans and specifications;

BARADINE CREEK

WALLERAWANG - GWABEGAR RAILWAY

NARREN STREET

FLOOD EXTENTS AND FLOOD PLANNING AREA NOT SHOW EAST OF NARREN STREET

OVERLAND FLOW NOT SHOWN DOWNSTREAM OF CASTLEREAGH STREET

BLIGH STREET

DARLING STREET

MASMAN STREET

FLOOD EXTENTS AND FLOOD PLANNING AREA NOT SHOW EAST OF COONABARABRAN ROAD

COONABARABRAN ROAD

UPSTREAM EXTENT OF MODEL

WORRIGAL STREET

CASTLEREAGH STREET

MACQUARIE STREET

NOTE B

LACHLAN STREET

WELLINGTON STREET

QUEEN STREET

WALKER STREET

TERIDGERIE CREEK

NAMOI STREET

RS 11

RS 10

RS 8

RS 7

RS 5

RS 4

RS 3.5

RS 3

RS 2

RS 1

RS 0

FLOODING NOT SHOWN DOWNSTREAM OF WORRIGAL STREET

WORRIGAL STREET

THE COMMON

ONEILLS ROAD

GULARGAMBONE ROAD

NOTE:

THE FLOOD PLANNING AREA (FPA) IS THE AREA ENCOMPASSED BY THE 100 YEAR ARI FLOOD PLUS AN ALLOWANCE OF 500 mm FOR FREEBOARD.

THE EXTENT OF THE FPA WAS DETERMINED FROM SURVEYED CROSS SECTIONS OF THE CREEK AND FLOODPLAIN AND AVAILABLE CONTOUR DATA AND IS APPROXIMATE ONLY.

SITE SPECIFIC SURVEY WOULD BE REQUIRED TO CONFIRM THE FLOOD AFFECTATION OF INDIVIDUAL ALLOTMENTS NEAR THE FRINGE OF THE FPA.

N

80 0 80 160 240 m

Scale: 1:8,000

LEGEND

- Indicative Extent of 100 Year ARI Flood
- Indicative Extent of Extreme Flood
- RS 0 River Station
- High Hazard Floodway
- Overland Flow Zone
- Intermediate Floodplain (Indicative Extent of Flood Planning Area)

TERIDGERIE CREEK AT BARADINE
FLOODPLAIN RISK MANAGEMENT STUDY

Figure A1.1

FLOODWAY - FLOOD PLANNING AREA

2 WHAT ARE THE CRITERIA FOR DETERMINING APPLICATIONS?

2.1 General

Development controls on flood prone land are set out in **Annexure 2** of this *Flood Policy*. The controls recognise that different controls are applicable to different land uses, the location within the floodplain and levels of potential flood inundation and flood hazard.

The controls applicable to proposed development depend upon:

- The type of development.
- The **Flood Hazard** zone where the development is located.
- Peak Flood Levels at the site of the development.

2.2 Land Use Categories and Flood Planning Levels

Eight land use categories have been adopted. The specific land uses, in each category are listed in **Annexure 1**.

The ***Flood Planning Level* (*FPL*)** is the minimum floor level for the land uses:

- For new residential development in Baradine, the ***FPL*** is the peak 100 year ARI flood level at the particular development site, plus an allowance of 500 mm for freeboard.
- For commercial and industrial development the ***FPL*** is the peak 100 year ARI flood level plus an allowance of 500 mm for freeboard. Council may at its discretion allow an amendment to this ***FPL***, subject to local conditions (refer **Section 2.4**).
- Essential Community Facilities and Critical Utilities require a higher level of flood protection. The ***FPL*** is the 100 year ARI flood plus 500 mm freeboard. In addition, these uses are to be designed to be able to continue to function and suffer minimal damage to structure and valuable contents in the event of an Extreme Flood (refer **Section 2.5**).
- For Flood Vulnerable Residential Development (nursing homes, aged care facilities and the like) the **FPL** is the peak 100 year ARI flood level plus an allowance of 500 mm for freeboard. Council will require an area at a higher level (to be nominated by Council) for the temporary storage of valuable equipment and will also require the applicant to demonstrate that there is safe access to the site in the event of a flood emergency (refer **Section 2.6**).

2.3 Division of the Floodplain into Flood Hazard Zones

The types of controls have been graded relative to the severity and frequency of potential floods, having regard to the following Flood Hazard Zones within the floodplain (refer **Figure A1.1**):

- **"*High Hazard Floodway*"** this is the most flood affected land and the area where the highest flow velocities would be expected at the 100 year ARI flood. This zone should be kept clear of future development, although **minor additions** to existing residences and small outbuildings may be permitted by Council, subject to conformance with the controls specified in **Annexure 2** and the provision of a satisfactory Flood Risk Report demonstrating that the development is capable of withstanding hydraulic forces and is

sited to minimise adverse re-directions of flow to adjacent properties. Site filling in this zone is to be avoided (ref. **Section 2.11**).

- **"*Overland Flow Zone"***. In this zone, there may be overland flows through residential and commercial allotments, but low hazard conditions will generally occur due to the shallow depth and low velocities. All land uses would be permitted in this zone, but the development would need to be capable of withstanding hydraulic forces and sited within the allotment to minimise adverse re-directions of flow towards adjacent properties. Council may require a Flood Risk Report for commercial and industrial development proposals in this zone (typically for larger scale developments) if it considers that the proposal has the potential to significantly re-direct flows towards adjacent properties. There are restrictions on site filling in this zone (ref. **Section 2.11**).
- **"*Intermediate Floodplain*"** is the remaining land lying within the ***Flood Planning Area*** (land inundated by the 100 year ARI flood levels plus 500 mm). Within this area, there would only be the requirement for minimum residential floor levels to be set at 100 year ARI flood levels plus 500 mm. All land uses would be permitted in this zone. However, as noted in **Section 2.2** above, Essential Community Facilities, Critical Utilities and Flood Vulnerable development such as housing for aged and disabled persons would be subject to additional controls, which are identified in subsequent sections and in **Annexure 2**.

No controls would apply for residential development outside the ***Flood Planning Area***. However, because the flood extents and hazard zones have been mapped using available contour mapping, Council would check proposed floor levels of developments up to the Extreme Flood extent to ensure that they are no lower than the ***FPL***.

2.4 Assessing Commercial and Industrial Development Proposals

The *Flood Policy* nominates the same ***FPL*** as for residential development. However, where it is not practicable to achieve this level, Council may approve a lesser level commensurate with the local streetscape. In this eventuality, the applicant is to provide an area within the development for the temporary storage of goods at a minimum level equal to the ***FPL***. This area should be at least 20% of the gross floor area, or as nominated by Council.

2.5 Critical Utilities and Essential Services

Whilst the *Flood Policy* nominates the same ***FPL*** for these categories of development as for residential development, critical utilities and essential services necessary for emergency management need to be designed to be capable of operating during extreme flood events and constructed of flood resistant materials so as to suffer minimal damages at a higher level of flooding than the ***FPL***. Development proposals are to ensure that valuable equipment necessary for the operation of the facility is located at or above the Extreme Flood, either permanently or via relocation to a temporary storage area suitable for this purpose, or otherwise protected from extreme flooding. Council will also require development proposals to provide safe and reliable access to facilities during major flooding.

2.6 Vulnerable Residential Development

The *Flood Policy* nominates the residential ***FPL*** for Flood Vulnerable Residential Development (which includes nursing homes, aged care facilities and the like). However, the applicant is to ensure that valuable equipment necessary for the operation of the facility is located at or above the ***FPL***, either permanently or via relocation to a temporary storage area suitable for this purpose. Council will also

require development proposals to provide safe and reliable access to developments to the ***FPL*** during major flooding.

2.7 Minor Additions (Residential)

Council has nominated the floor levels of minor additions to residences to be no lower than the ***FPL***. However, where it can be demonstrated by the applicant that this is not practicable, Council at its discretion may allow a reduction provided that the level is at least 500 mm above natural surface level or as otherwise nominated by Council so as to be above the level of frequent flooding.

2.8 Checking of Completed Finished Floor Height

After the building has been built to the relevant ***FPL***, Council officers will check compliance with this requirement at the relevant inspection stage. The applicant is to provide a benchmark on the site connected to a datum to be nominated by Council.

2.9 Fencing

Any proposed fencing is to be shown on the plans accompanying a development application to allow Council to assess the likely effect of such fencing on flood behaviour.

In the ***High Hazard Floodway*** or ***Overland Flow Zone,*** where flow velocities may be significant, fences which minimise obstructions to flow are to be adopted. Where impermeable fences such as Colorbond, galvanised metal, timber or brush are proposed, fencing panels should be either:

a) removable so that panels can be laid flat; or

b) horizontally hinged where a portion of at least 1 m high is capable of swinging open to allow floodwater to pass. Trees/landscaping and other structures are not to impede the ability of a hinged fence to open.

2.10 Other Uses and Works

All other development, building or other works within any of the categories that require Council's consent will be considered on their merits. In consideration of such applications, Council must determine that the proposed development is in compliance with the objectives of this Policy.

2.11 Land Filling

No filling or alteration of the land surface is permissible in the ***High Hazard Floodway*** due to the potential for filling or obstructions to flow to adversely re-direct flows. Any minor extensions, repairs or re-developments permitted by Council should be located on piers to minimise obstructions to the passage of flow, with the underside of any structure supporting the buildings above the 100 year ARI flood level.

Building pads up to 1 m high may be permitted for residential blocks in the ***Overland Flow Zone***. However, the fill and other obstructions are not to extend across more than 50% of the width of the allotment at right angles to the direction of flow. In order not to significantly obstruct flows, Council may require at least part of the development to be located on piers to minimise obstructions to the

passage of flow, with the underside of any structure supporting the buildings to be above the 100 year ARI flood level. Sub-surface drainage of building pads is required.

2.12 Flood Related Information to be Submitted to Council

2.12.1 Survey Details – Existing Site and Proposed Development

A Survey Plan prepared by a Registered Surveyor is required to be lodged with the Development Application for properties located on flood affected land as shown on **Figure A1.1**. The Survey Plan will enable Council to assess extents and depths of inundation over the site (at existing natural surface levels) and must indicate the following:

- The location of existing building or structures;
- The floor levels and ceiling heights of all existing buildings or structures to be retained;
- Existing and/or proposed drainage easements and watercourses or other means of conveying flood flows that are relevant to the flood characteristics of the site;
- 100 year ARI **Flood Level(s)** over the site (to be provided by Council); and flood extents;
- 0.2 metre natural surface contour intervals across the entire property (existing and proposed). Note: All levels must be relative to the Datum used for the flood levels used in the *Teridgerie Creek at Baradine Flood Study, 2012,* or as nominated by Council.

Annexure 4 outlines requirements for survey data required by Council for the proposed development.

2.12.2 Evaluation of Development Proposals

The Applicant will need to demonstrate, using Council supplied flood information, that:

1. The development conforms with the requirements of this Policy for the particular Flood Hazard zone in which it is located.

2. Depending on the nature and extent of the development and its location within the floodplain, Council may request the Applicant to prepare a Flood Risk Report to demonstrate that its construction does not increase the flood hazard to existing and future occupiers of the floodplain (see Section 2.12.3).

Council will make its evaluation and confirm requirements regarding the proposed site development, based on the Existing Site Survey Plan and accompanying survey data on the proposed development (see Annexure 4) and provision of information set out in the Development Controls Matrix – Annexure 2 and Chapter 2.

2.12.3 Flood Risk Report – *High Hazard Floodway and Overland Flow Zone*

A. Scope of Work – General

Council will require a **Flood Risk Report** for any (minor) residential development located in the ***High Hazard Floodway***. Depending on its nature and scale, Council may also require a **Flood Risk Report** for a development situated in the ***Overland Flow Zone***, where lesser but still significant flow velocities may be expected. Typically such a report may be required for a large commercial or

industrial development which Council considers has the potential to adversely re-direct flows. This report is to be prepared by a suitably qualified Consulting Engineer and must address the following:

a) Confirm the ***Flood Planning Level*** for the particular category of development through enquiries of Council.

b) Specify proposed floor levels (and existing floor levels where they are to be retained) of habitable and non-habitable structures.

c) Include a site-specific flood assessment that may require flood modelling to demonstrate that there will be no adverse impact on surrounding properties as a result of the development, up to the 100 year ARI flood.

d) Propose measures to minimise risk to personal safety of occupants and the risk of property damage, addressing the flood impacts on the site of the 100 year ARI flood. These measures shall include but are not limited to the following:

- Types of materials to be used, up to the ***Flood Planning Level*** to ensure the structural integrity for immersion and impact of velocity and debris.
- Waterproofing methods, including but not limited to electrical equipment, wiring, fuel lines or any other service pipes and connections.

e) Confirm the structural adequacy of the development, taking into account the following:

- all piers and all other parts of the structure which are subject to the force of flowing waters or debris have been designed to resist the stresses thereby induced.
- all forces transmitted by supports to the ground can be adequately withstood by the foundations and ground conditions existing on the site.
- the structure will be able to withstand stream flow pressure, force exerted by debris, and buoyancy and sliding forces caused by the full range of flooding up to the 100 year ARI.

f) all electrical connections to be located above the 100 year ARI flood level plus 500 mm. Council will also require all electrical circuit connections to be automatically isolated in the event of flood waters having the potential to gain access to exposed electrical circuits, either internal or external of the building (see also **Annexure 3A**).

g) all materials used in the construction to be flood compatible to a minimum level equivalent to a 100 year ARI flood level plus 500 mm (**Annexure 3B**).

B. <u>Additional Items (Commercial and Industrial Development)</u>

h) For commercial and industrial developments (in the ***Overland Flow Zone)***, include flood warning signs/depth indicators for areas that may be inundated, such as open car parking areas.

3 DESCRIPTION OF TERMS

Note: For expanded list of definitions, refer to Glossary contained within the NSW Government Floodplain Development Manual, 2005.

TERM	DEFINITION
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 (see average recurrence interval).
Average Recurrence Interval (ARI)	The average return period between the occurrence of a particular flood event. For example, a 100 year ARI flood has an average recurrence interval of 100 years.
Australian Height Datum (AHD)	A common national surface level datum corresponding approximately to mean sea level. There is no AHD in Baradine. Consequently, for administration of this policy the same datum as was used in the *Teridgerie Creek at Baradine Flood Study, 2012* will apply.
Flood Affected Properties	Properties that are either encompassed or intersected by the **Flood Planning Level (FPL)**.
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.
Flood Planning Level (FPL) (General Definition)	The combinations of flood levels and freeboards selected for planning purposes, as determined in floodplain risk management studies and incorporated in floodplain risk management plans.
Flood Planning Level (for Baradine)	Flood levels selected for planning purposes, as determined in the *Teridgerie Creek at Baradine Floodplain Risk Management Study and Plan, 2012*. For residential development in the floodplain, it is the 100 year ARI flood level at the particular site, plus the addition of a Freeboard of 500 mm. For commercial and industrial development it is the 100 year ARI flood level plus 500 mm Freeboard, unless otherwise allowed by Council and with the requirement for a temporary storage area at the **FPL**. For essential community facilities, essential services and vulnerable residential development it is the 100 year ARI flood level plus 500 mm Freeboard with additional requirements for storage and safe access/evacuation as nominated in the Policy.
Extreme Flood	For the purposes of this policy the Extreme Flood is a flood with a peak discharge equal to three times that of the 100 year ARI flood and is used to define the extent of flood prone land that is, the floodplain. Generally, it is not physically or economically possible to provide complete protection against this event. The definition of the floodplain is used to assist SES with managing the flood emergency.
Flood Prone/Flood Liable Land	Land susceptible to flooding by the Extreme Flood. Flood Prone land is synonymous with Flood Liable land.
Floodway (General Definition)	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.

TERM	DEFINITION
High Hazard Floodway (for Baradine)	**T**his is the most flood affected land and the area where the highest flow velocities would be expected at the 100 year ARI flood. This zone should be kept clear of future development.
Overland Flow Zone (for Baradine)	This is flood affected land where lesser but still significant flow velocities may be experienced. Developments in this area would need to be capable of withstanding hydraulic forces and would also need to be sited to minimise adverse re-directions of flow to adjacent properties. The local impacts on flooding of any proposals for filling would need to be assessed.
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 as 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, 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.
Intermediate Floodplain	It encompasses the zone between the Floodway or Overland Flow Zone and the line defining the indicative extent of flooding resulting from the occurrence of the 100 year ARI flood plus 500 mm. In this zone there would still be a significant risk of flood damages, but these damages may be minimised by the application of appropriate development controls.

ANNEXURE 1
LAND USE CATEGORIES

Essential Community Facilities	Critical Utilities and Uses	Flood Vulnerable Residential	Residential	Business & Commercial/Industrial	Non-Urban and Outbuildings	Subdivision and Filling	Minor Additions (Residential)
Building that may provide an important contribution to the notification and evacuation of the community during flood events; Hospitals; Institutions; Educational establishments.	Telecommunication facilities; Public Utility Installation that may cause pollution of waterways during flooding, or if affected during flood events would significantly affect the ability of the community to return to normal activities after the flood events. Hazardous industry; Hazardous storage establishments.	Group home; Housing for aged or disabled persons; and Units for aged persons.	Dwelling; Residential flat building; Home industry; Boarding house; Professional consulting rooms; Public utility undertakings (other than critical utilities); Utility installation (other than critical utilities); Child care centre; Caravan Park.	Bulk Store; Bus depot; Bus station; Car repair stations; Club; Commercial premises (other than where referred to elsewhere); General store; Health care professional; Hotel; Intensive livestock keeping; Junkyard; Liquid fuel depot; Motel; Motor showroom; Place of Assembly (other than essential community facilities; Place of public worship; Public building (other than essential community facilities); Recreation facility; Refreshment room; Road transport terminal; Rural industry; Service station; Shop; Tourist facilities; Warehouse.	Retail nursery; Recreation area; Roadside stall; Outbuildings (Sheds, Garages) up to 40 m^2 area.	Subdivision of land involving the creation of new allotments for residential purposes; Earthworks or filling operations covering 100 m^2 or more than 0.3 m deep.	An addition to an existing dwelling of not more than 30 m^2 (habitable floor area)

ANNEXURE 2

DEVELOPMENT CONTROLS MATRIX

Consideration	Intermediate Floodplain								Overland Flow Zone								High Hazard Floodway							
	Essential Community Facilities	Critical Utilities and Uses	Flood Vulnerable Residential	Residential	Business & Commercial/Industrial	Non-Urban and Outbuildings	Residential Sub-Division	Minor Additions (Residential)	Essential Community Facilities	Critical Utilities and Uses	Flood Vulnerable Residential	Residential	Business & Commercial/Industrial	Non-Urban and Outbuildings	Residential Sub-Division	Minor Additions (Residential)	Essential Community Facilities	Critical Utilities and Uses	Flood Vulnerable Residential	Residential	Business & Commercial/Industrial	Non-Urban and Outbuildings	Residential Sub-Division	Minor Additions (Residential)
Floor Level	1	1	1	1	1		1	1	1	1	1	1	1		1	1								1
Building Components	2	2	1	1	1		1	1	2	2	1	1	1		1	1								1
Structural Soundness	2	2	1	1	1		1	1	2	2	1	1	1		1	1								1
Flood Affectation									1	1	1	1	1		1	1						1		1
Evacuation / Access	1	1	1						1	1	1													
Management and Design	2,3	2,3	5		4			6	2,3,7	2,3,7	5,7	6	4,7		1,7	6						3,8		6,8

Not Relevant Unsuitable Land Use

See Notes over page:

Floor Level

1. Floor levels to be equal to or greater than the ***FPL*** (100 year ARI food level plus 500 mm freeboard).

Building Components

1. All structures to have flood compatible building components below 100 year ARI flood level plus 500 mm freeboard.
2. All structures to have flood compatible building components below Extreme Flood level (where Extreme Flood level is higher than FPL).

Structural Soundness

1. Structure to be designed to withstand the forces of floodwater, debris and buoyancy up to 100 year ARI flood plus 500 mm freeboard.
2. Structure to be designed to withstand forces of floodwater, debris and buoyancy up to Extreme Flood (where Extreme Flood level is higher than FPL).

Flood Affection in Adjacent Areas

1. Residential development will be "deemed to comply" provided it conforms with the requirements of **Section 2.11**. A Flood Risk Report may be required for other categories of development in Floodway or Overland Flow Zones to demonstrate that the development will not increase flood hazard (see Item 8 Management and Design below).
   Note: When assessing Flood Affectation the following must be considered:
   i. Loss of conveyance capacity in the floodway or areas where there is significant flow velocity.
   ii. Changes in flood levels and flow velocities caused by the alteration of conveyance of floodwaters.

Evacuation/ Access

1. Reliable access for pedestrians or vehicles required in the event of 100 year ARI flood.

Management and Design

1. Applicant to demonstrate that potential developments as a consequence of a subdivision proposal can be undertaken in accordance with this Policy and the Plan.
2. Applicant to demonstrate that facility is able to continue to function in event of Extreme Flood.
3. No external storage of materials which may cause pollution or be potentially hazardous during Extreme Flood.
4. Where it is not practicable to provide floor levels to 100 year ARI plus 500 mm freeboard, applicant is to provide an area to store goods at that level.
5. Applicant is to provide an area to store valuable equipment above 100 year ARI plus 500 mm freeboard – see **Section 2.6**.
6. Where it is not practicable to provide floor levels to 100 year ARI plus 500 mm freeboard, Council may allow a reduction for minor additions to habitable areas – see **Section 2.7.**
7. Flood Risk Report may be required prior to development of this nature in this area – see **Sections 2.12.2** and **2.12.3.**
8. Flood Risk Report will be required prior to development in **High Hazard Floodway** – see **Sections 2.12.2** and **2.12.3.**

NOTE: THESE NOTES ARE TO BE READ IN CONJUNCTION WITH REMAINDER OF THE FLOOD POLICY, IN PARTICULAR CHAPTER 2.

ANNEXURE 3A
GENERAL BUILDING MATTERS

Electrical and Mechanical Equipment

For dwellings constructed on land to which this policy applies, the electrical and mechanical materials, equipment and installation should conform to the following requirements.

Main Power Supply

Subject to the approval of the relevant authority the incoming main commercial power service equipment, including all metering equipment, shall be located above the FPL. Means shall be available to easily isolate the dwelling from the main power supply.

Wiring

All wiring, power outlets, switches, etc, should be, to the maximum extent possible, located above the FPL. All electrical wiring installed below this level should be suitable for continuous underwater immersion and should contain no fibrous components. Earth leakage circuit breakers (core balance relays) must be installed. Only submersible type splices should be used below the FPL. All conduits located below the relevant designated flood level should be so installed that they will be self-draining if subjected to flooding.

Equipment

All equipment installed below or partially below the FPL should be capable of disconnection by a single plug and socket assembly.

Reconnection

Should any electrical device and/or part of the wiring be flooded it should be thoroughly cleaned or replaced and checked by an approved electrical contractor before reconnection.

Heating and Air Conditioning Systems

Where viable, heating and air conditioning systems should be installed in areas and spaces of the house above the FPL. When this is not feasible, every precaution should be taken to minimise the damage caused by submersion according to the following guidelines:

i) Fuel

Heating systems using gas or oil as a fuel should have a manually operated valve located in the fuel supply line to enable fuel cut-off.

ii) Installation

The heating equipment and fuel storage tanks should be mounted on and securely anchored to a foundation pad of sufficient mass to overcome buoyancy and prevent movement that could damage the fuel supply line. All storage tanks should be vented to the FPL.

iii) Ducting

All ductwork located below the FPL should be provided with openings for drainage and cleaning. Self-draining may be achieved by constructing the ductwork on a suitable grade. Where ductwork must pass through a watertight wall or floor below the relevant flood level, a closure assembly operated from above the FPL should protect the ductwork.

Sewer

All sewer connections to properties in flood prone areas are to be fitted with reflux valves.

ANNEXURE 3B

FLOOD COMPATIBLE MATERIALS

Building Component	Flood Compatible Material	Building Component	Flood Compatible Material
Flooring and Sub Floor Structure	• Concrete slab-on-ground monolith construction. Note: clay filling is not permitted beneath slabo-on-ground construction which could be inundated. • Pier and beam construction or • Suspended reinforced concrete slab	**Doors**	• Solid panel with waterproof adhesives • Flush door with marine ply filled with closed cell foam • Painted material construction • Aluminium or galvanised steel frame
Floor Covering	• Clay tiles • Concrete, precast or in situ • Concrete tiles • Epoxy formed-in-place • Mastic flooring, formed-in-place • Rubber sheets or tiles with chemical set adhesive • Silicone floors formed-in-place • Vinyl sheets or tiles with chemical-set adhesive • Ceramic tiles, fixed with mortar or chemical set adhesive • Asphalt tiles, fixed with water resistant adhesive • Removable rubber-backed carpet	**Wall and Ceiling Linings**	• Brick, face or glazed • Clay tile glazed in waterproof mortar • Concrete • Concrete block • Steel with waterproof applications • Stone natural solid or veneer, waterproof grout • Glass blocks • Glass • Plastic sheeting or wall with waterproof adhesive
Wall Structure	Solid brickwork, blockwork, reinforced, concrete or mass concrete	**Insulation**	• Foam or closed cell types
Windows	Aluminium frame with stainless steel or brass rollers	**Nails, Bolts, Hinges and Fittings**	• Galvanised • Removable pin hinges

ANNEXURE 4
DEVELOPMENT APPLICATION REQUIREMENTS

Step 1

Check with Council staff to see whether or not the proposal:

- Is located on Flood Prone Land
- Is permissible in the Flood Risk zone and determine the FPL for the particular category of land use.
- Note: an existing site survey (see **Section 2.12.1** of the Policy) is to accompany development proposals to confirm the flood affectation of the allotment and its location within the flood risk zoning system.

Step 2

Plans – A Development Application should include the following plans showing the nature of the proposed development and its extent within the allotment:

- A locality plan identifying the location of the property.
- Plan of the existing site layout including the site dimensions (in metric), site area, contours (0.20 m intervals), existing trees, other natural features, existing structures, north point, location of building on adjoining properties (if development involves a building), floor plans located on a site plan, roof plan, elevations and sections of the proposed building, finished levels of floors, paving and landscaped areas, vehicular access and parking.
- Plans should indicate:
  a) The existing ground levels to the same datum as used for the *Teridgerie Creek at Baradine Flood Study, 2012* around the perimeter of the proposed building; and
  b) The existing or proposed floor levels.
- Minor additions to an existing dwelling must be accompanied by documentation from a registered surveyor confirming existing floor levels.
- In the case of subdivision, four (4) copies of the proposed site layout showing the number of lots to be created (numbered as proposed lot 1, 2, 3 etc), the proposed areas of each lot in square metres, a north point, nearest roads and the like.

Council require plans presented on A3 sheets as a minimum
A scale of 1:200 is recommended for site plans

Extent of Cut and Fill – All areas subject to cut and fill require the depths of both to be shown as well as the measures proposed to retain both. Applications shall be accompanied by a survey plan (with existing and finished contours at 0.20 m intervals) showing relative levels to Australian height datum.

Vegetation Clearing – Landscaping details including a description of trees to be removed existing and proposed planting, retaining walls, detention basins, fences and paving.

Stormwater Drainage – Any existing and all proposed stormwater drainage to be indicated on the site plan.

WARRUMBUNGLE SHIRE COUNCIL

TERIDGERIE CREEK AT BARADINE FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

APPENDIX B

FLOOD DAMAGES

DRAFT

MAY 2012

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B8.1 Damage - Frequency Curve

B8.2 Histogram of Flooded Residential Properties – 100 Year ARI

B8.3 Flooded Properties 100 Year ARI

SYNOPSIS

Estimation of flood damages to urban development in flood prone areas bordering Teridgerie Creek at Baradine was carried out to assess the impact of flooding on the community. The objectives were to assist the Floodplain Management Committee in confirming the Flood Planning Level and allow an economic assessment of various flood management measures to be carried out. Damages were assessed for floods ranging between the 5 Year ARI and Extreme Flood events.

There were no data available on historic flood damages at Baradine. The analysis was carried out using the flood damages model attached to *"Floodplain Risk Management Guideline No 4. Residential Flood Damages",* which was prepared by DECCW (now OEH) to allow a consistent assessment across NSW for the comparison of flood management projects. For *Guideline No 4*, damage assessments which had been undertaken after major flooding in urban centres were adjusted and used to estimate damages likely to be experienced to typical residential development in NSW. Data for the flood damages model comprised the depths of inundation over the floodplain, as well as information on the unit values of damages to residential property. The depths of inundation were determined from the results of the hydraulic modelling described in the *Flood Study, 2011* and from surveyed floor levels. The estimated damages, which could occur for various floods, are summarised in **Table S1** below (values rounded to two decimal places). Sub-division of urban flood damages is usually based on the three categories: "Residential", "Commercial" and "Public Buildings". Development affected by flooding from Teridgerie Creek is mainly of a residential nature and hence this category is the major contributor to flood damages.

Residential damages versus flood frequency are shown graphically on **Figure B8.1**. Under 5 year ARI conditions, the floors of 8 residences would be inundated. In the event of a 100 year ARI flood 59 properties would be similarly flooded. Under Extreme Flood conditions the number of residences flooded above floor level would increase to 75. The Extreme Flood is assumed to have a peak discharge equal to three times that of the 100 year ARI flood and is an extremely rare flood. For the purposes of assessing *average annual flood damages* it was assumed to have a return period of 1 in 10^5 years. **Figure B8.2** shows the depths of inundation above surveyed floor level for the 100 year ARI flood in histogram format. Depths of inundation range between zero and 800 mm, with a median value of 300 mm. **Figure B8.3** shows the locations of flooded properties.

TABLE S1
FLOOD DAMAGES AT BARADINE

Average Recurrence Interval Year ARI	Flood Damages to Each Category ($ x 10^6)			Total Damage ($ x 10^6)
	Residential	Commercial	Public	
5	0.57	0.03	-	0.60
20	2.05	0.22	0.03	2.30
100	3.11	0.37	0.06	3.54
Extreme Flood	4.65	0.88	0.24	5.76

B1. INTRODUCTION AND SCOPE

B1.1 Introduction

Damages from flooding belong to two categories:

- **Tangible Damages**
- **Intangible Damages**

Tangible damages are defined as those to which monetary values may be assigned, and may be subdivided into direct and indirect damages. Direct damages are those caused by physical contact of floodwater with damageable property. They include damages to commercial and residential building structures and contents as well as damages to infrastructure services such as electricity and water supply. Indirect damages result from the interruption of community activities, including traffic flows, trade, industrial production, costs to relief agencies, evacuation of people and contents and clean up after the flood.

Generally, tangible damages are estimated in dollar values using survey procedures, interpretation of data from actual floods and research of government files.

The various factors included in the **intangible damage** category may be significant. However, these effects are difficult to quantify due to lack of data and the absence of an accepted method. Such factors may include:

- inconvenience
- isolation
- disruption of family and social activities
- anxiety, pain and suffering, trauma
- physical ill-health
- psychological ill-health.

B1.2 Scope of Investigation

In the following sections, damages to residential, commercial and industrial properties and public buildings have been estimated due to flooding from Teridgerie Creek at Baradine. Damages to community assets have also been assessed where data were available.

B1.3 Terminology

Definitions of the terms used in this Appendix are presented in **Section 8** which also summarises the value of Tangible Flood Damages.

B2. DESCRIPTION OF APPROACH

The damage caused by a flood to a particular property is a function of the depth of flooding above floor level and the value of the property and its contents. The warning time available for residents to take action to lift property above floor level also influences damages actually experienced. A spreadsheet model which had been developed for previous investigations of this nature was used to estimate damages on a property by property basis according to the type of development, the location of the property and the depth of inundation.

Using the results of the *Flood Study, 2011*, a peak flood elevation for each event was interpolated at each property. The interpolated property flood levels were input to the spreadsheet model which also contained property characteristics and depth-damage relationships. The depth of flooding was computed as the difference between the interpolated flood level and the surveyed floor elevation at each property.

The depth-damage curves for residential damages were determined using procedures described in *"Floodplain Management Guideline No 4. Residential Flood Damage Calculation"*, *2007* published by DECCW. Damage curves for commercial and industrial developments were derived from previous floodplain management investigations.

It should be understood that this approach is not intended to identify individual properties liable to flood damages and the values of damages in individual properties, even though it appears to be capable of doing so. The reason for this caveat lies in the various assumptions used in the procedure, the main ones being:

- the assumption that computed water levels and topographic data used to define flood extents are exact and without any error;
- the assumption that the water surfaces between hydraulic model cross sections are adequately represented by interpolation and are not subject to localised influences;
- the use of "average" stage-damage relationships, rather than a relationship for each property;
- the uncertainty associated with assessing an appropriate factor to convert potential damages to actual flood damages experienced for each property after residents have taken action to mitigate damages to contents.

The consequence of these assumptions is that some individual properties may be inappropriately classified as flood liable, while others may be excluded. Nevertheless, when applied over a broad area these effects would tend to cancel, and the resulting estimates of overall damages, would be expected to be reasonably accurate.

The information contained in the spreadsheets used to prepare the estimates of flood damages for the catchments should not therefore be used to provide information on the above-floor inundation of individual properties.

B3. SOURCES OF DATA

B3.1 General

To estimate A*verage Annual Flood Damages* for a specific area it is necessary to estimate the damages for several floods of different magnitudes, i.e. of different frequencies, and then to integrate the area beneath the damage – frequency curve over the whole range of frequencies. To do this it is necessary to have data on the damages sustained by all types of property over the likely range of inundation. There are several ways of doing this:

- The ideal way would be to conduct specific damage surveys in the aftermath of a range of floods, preferably immediately after each. An example approaching this ideal is the case of Nyngan where surveys were conducted in May 1990 following the disastrous flood of a month earlier (DWR, 1990). This approach would not be practicable in the present case due to the absence of recent major flooding on Teridgerie Creek.

- The second best way is for experienced loss adjusters to conduct a survey to estimate likely losses that would arise due to various depths of inundation. This approach is used from time to time, but it can add significantly to the cost of a floodplain management study (LMJ, 1985). It was not used for the present investigation.

- The third way is to use generalised data such as that published by CRES (Centre for Resource & Economic Studies, Canberra) and used in the Floodplain Management Study for Forbes (SKM, 1994). These kinds of data are considered to be suitable for generalised studies, such as broad regional studies. They are not considered to be suitable for use in specific areas, unless none of the other approaches can be satisfactorily applied.

- The fourth way is to adapt or transpose, data from other flood liable areas. This was the approach used for the Baradine study. For the assessment of residential damages the *DECCW Guideline No 4, 2007* procedure was adopted, which was based on data collected following major flooding in Katherine in 1998, with adjustments to account for changes in values due to inflation, and after taking into account the nature of development and flooding patterns at Baradine. The data collected during site inspection in the flood liable areas of Teridgerie Creek assisted in providing the necessary adjustments. Commercial and industrial damages were assessed via reference to recent floodplain management investigations (LACE, 2009).

B3.2 Property Data

The properties were divided into three categories: residential, commercial/industrial and public buildings.

For residential properties, the data used in the damages estimation included:

– the location/address of each property
– an assessment of the construction type

- a description of any external buildings/structures
- floor level of the residence

The residential descriptions were used to classify the properties into three categories which relate to the magnitude of likely flood damages (**Table B4.1**).

For commercial/industrial properties, the Property Survey obtained information regarding:

- the location of each property
- the nature of each enterprise
- an estimation of the floor area
- floor level

The property descriptions were used to classify the commercial developments into categories (i.e. high, medium or low value properties) which relate to the magnitude of likely flood damages.

Properties lying within the extent the flood map for Baradine attached to the SES's Local Flood Plan were included in the database.

B4. RESIDENTIAL DAMAGES

B4.1 Damage Functions

The procedures identified in *DECCW Guideline No 4, 2007* allow for the preparation of a depth versus damage relationship which incorporates structural damage to the building, damage to internals and contents, external damages and clean up costs. In addition, there is the facility for including allowance for accommodation costs and loss of rent. Separate curves are computed for three residential categories:

- Single storey slab on ground construction
- Single storey elevated floor
- Two storey residence

The level of flood awareness and available warning time are taken into account by factors which are used to reduce "potential" damages to contents to "actual" damages. "Potential" damages represent losses likely to be experienced if no action were taken by residents to mitigate impacts. A reduction in the potential damages to "actual" damages is usually made to allow for property evacuation and raising valuables above floor level, which would reduce the damages actually experienced. The ability of residents to take action to reduce flood losses is mainly limited to reductions in damages to contents, as damages to the structure and clean up costs are not usually capable of significant mitigation.

The reduction in damages to contents is site specific, being dependent on a number of factors related to the time of rise of floodwaters, the recent flood history and flood awareness of residents and emergency planning by the various Government Agencies (Bureau of Meteorology and State Emergency Service).

Teridgerie Creek is a "flash flooding" catchment with a likely time of rise of floodwaters of less than six hours There is no catchment specific flood warning system operated by the Bureau of Meteorology. Consequently, there would be limited time in advance of a flood event in which to warn residents and for them to take action to mitigate flood losses.

Provided warning were available, house contents may be raised above flood level to about 0.9 m, which corresponds with the height of a typical table/bench height. The spreadsheet provides two factors, one for above and one for below the typical bench height. The reduction in damages is also dependent on the likely duration of inundation of contents, which on Teridgerie Creek would be limited to no more than an hour for most flooded properties. The "Total Contents Adjustment Factor" which converts potential damages to actual damages to contents was 0.87 for depths of inundation up to 0.9 m and 0.94 for greater depths.

Table B4.1 below shows total flood damages estimated for the three classes of residential property using the procedures identified in *Guideline No 4*. A typical ground floor area of 135 m^2 was adopted, representative of house floor areas in Baradine.

TABLE B4.1
DAMAGES TO RESIDENTIAL PROPERTIES

Type of Residential Construction	0.5 m Depth of Inundation Above Floor Level	1m Depth of Inundation Above Floor Level
Single Storey Slab on Ground	$42,976	$53,976
Single Storey High Set	$49,759	$60,567

Note: These values include allowances for structural, contents and clean up costs. External costs, which are incurred when allotments are inundated, are added separately in the following tables.

B4.2 Total Residential Damages

Table B4.2 summarises residential damages for a range of floods. The damage estimates were carried out for floods between the 5 Year ARI and the Extreme Flood, which were modelled hydraulically in the *Flood Study, 2011*.

TABLE B4.2
RESIDENTIAL DAMAGES AT BARADINE

Flood Event Year ARI	No. of Flooded Residences*	Flood Damages $ x 10^6
5	8	0.57
20	38	2.05
100	59	3.11
Extreme Flood	75	4.65

B5. COMMERCIAL AND INDUSTRIAL DAMAGES

B5.1 Direct Commercial and Industrial Damages

The method used to calculate damages requires each property to be categorised in terms of the following:

- damage category
- floor area
- floor elevation.

The damage category assigned to each enterprise may vary between "low", "medium" or "high", depending on the nature of the enterprise and the likely effects of flooding. Damages also depend on the floor area.

It has recently been recognised following the 1998 flood in Katherine that previous investigations using stage damage curves contained in proprietary software tends to seriously underestimate true damage costs (*DECCW Guideline No 4, 2007*). DECCW are currently researching appropriate damage functions which could be adopted in the estimation of commercial and industrial categories as they have already done with residential damages. However, these data were not available for the Teridgerie Creek study.

On the basis of previous investigations (LACE, 2009) the following typical damage rates are considered appropriate for potential external and internal damages and clean up costs for both commercial and industrial properties They are indexed to a depth of inundation of 2 metres. At floor level and 1.2 m inundation, zero and 70% of these values respectively were assumed to occur:

Low value enterprise	$\$280/m^2$	(e.g. Commercial: small shops, cafes, joinery, public halls. Industrial: auto workshop with concrete floor and minimal goods at floor level, Council or Government Depots, storage areas.)
Medium value enterprise	$\$420/m^2$	(e.g. Commercial: food shops, hardware, banks, professional offices, retail enterprises, with furniture/fixtures at floor level which would suffer damage if inundated. Industrial: warehouses, equipment hire.)
High value enterprise	$\$650/m^2$	(e.g. Commercial : electrical shops, clothing stores, bookshops, newsagents, restaurants, schools, showrooms and retailers with goods and furniture, or other high value items at ground or lower floor level. Industrial: service stations, vehicle showrooms, smash repairs.)

The factor for converting potential to actual damages depends on a range of variables such as the available warning time, flood awareness and the depth of inundation. Given sufficient warning time a well prepared business will be able to temporarily lift property above floor level. However, unless property is actually moved to flood free areas, floods which result in a large depth of inundation, will cause considerable damage to stock and contents.

For the present study, the above potential damages were converted to actual damages using a multiplier which ranged between 0.3 and 0.7 depending on the depth of inundation above the floor. The factors also took into consideration the absence of recent damaging flooding in the commercial sector of Baradine.

B5.2 Indirect Commercial and Industrial Damages

Indirect commercial and industrial damages comprise costs of removal of goods and storage, loss of trading profit and loss of business confidence.

Disruption to trade takes the following forms:

- The loss through isolation at the time of the flood when water is in the business premises or separating clients and customers. The total loss of trade is influenced by the opportunity for trade to divert to an alternative source. There may be significant local loss but due to the trade transfer this may be considerably reduced at the regional or state level.

- In the case of major flooding, a downturn in business can occur within the flood affected region due to the cancellation of contracts and loss of business confidence. This is in addition to the actual loss of trading caused by closure of the business by flooding.

Loss of trading profit is a difficult value to assess and the magnitude of damages can vary depending on whether the assessment is made at the local, regional or national level. Differences between regional and national economic effects arise because of transfers between the sectors, such as taxes, and subsidies such as flood relief returned to the region. Some investigations have lumped this loss with indirect damages and have adopted total damage as a percentage of the direct damage. In other cases, loss of profit has been related to the gross margin of the business, i.e. turnover less average wages. The former approach has been adopted in this present study. Indirect damages have been taken as 50% of direct actual damages. A clean up cost of \$15/m^2 has also been adopted.

B5.3 Total Commercial and Industrial Damages

Table B5.1 summarises estimated commercial and industrial damages.

TABLE B5.1
COMMERCIAL AND INDUSTRIAL DAMAGES AT BARADINE

Flood Event Year ARI	Number of Properties with Floors Inundated	Damages \$ x 10^6
5	1	0.03
20	5	0.22
100	5	0.37
Extreme	7	0.88

B6. DAMAGES TO PUBLIC BUILDINGS

B6.1 Direct Damages – Public Buildings

Included under this heading are government buildings, churches, swimming pools and parks. Damages were estimated individually on an areal basis according to the perceived value of the property. Potential internal damages were indexed to a depth of above floor inundation of 2 m as shown below. At floor level and 1.2 m depth of inundation, zero and 70% of these values respectively were assumed to occur.

Low value	$\$280/m^2$	
Medium value	$\$420/m^2$	(eg. council buildings, SES HQ, fire station)
High value	$\$650/m^2$	(eg. schools)

These values were obtained from the Nyngan Study (DWR, 1990) as well as commercial data presented in the Forbes Water Studies report (WS, 1992). External and structural damages were taken as 4 and 10% of internal damages respectively.

B6.2 Indirect Damages – Public Buildings

A value of $\$15/m^2$ was adopted for the clean-up of each property. This value is based on results presented in the Nyngan Study and adjusted for inflation. Total "welfare and disaster" relief costs were assessed as 50% of the actual direct costs.

B6.3 Total Damages – Public Buildings

Table 6.1 summarises expected damages to public buildings.

TABLE B6.1
DAMAGES TO PUBLIC BUILDINGS AT BARADINE

Flood Event Year ARI	Number of Properties with Floors Inundated	Damages \$ x 10^6
5	-	-
20	3	0.03
100	3	0.06
Extreme	8	0.24

B7. DAMAGES TO INFRASTRUCTURE AND COMMUNITY ASSETS

Infrastructure in Baradine, such as electrical and telephone supply, sewerage and water supply systems, and road network, are potentially prone to damaging flooding. Community assets such as parks and other recreational amenities could also suffer damages. No data are available on damages experienced during historic flood events. However, a qualitative matrix of the effects of flooding on these categories is presented in **Table B7.1**.

TABLE B7.1
QUALITATIVE EFFECTS OF FLOODING ON INFRASTRUCTURE AND COMMUNITY ASSETS AT BARADINE

Damage Sector	Flood Event ARI				
	5	20	50	100	Extreme Flood
Electricity	0	0	0	X	X
Telephone	0	0	0	X	X
Roads	X	X	X	X	X
Bridges	0	0	0	X	X
Sewerage	0	0	0	0	0
Water Supply	X	X	X	X	X
Parks and Gardens	X	X	X	X	X

Notes: 0 = No significant damages likely to be incurred.
X = Some damages likely to be incurred.

B8 SUMMARY OF TANGIBLE DAMAGES

B8.1 Tangible Damages

Flood damages under existing conditions have been computed for a range of flood frequencies from 5 year ARI to the Extreme Flood.

The total damages for each flood event are shown on **Table B8.1**. Cumulative average annual damages were assessed and are also shown. A 1 in 100,000 year return period was assigned to the Extreme Flood. **Figure B8.1** shows the residential damage - frequency curve. **Figure B8.2** is a histogram of the depths of residential above floor inundation for the 100 year ARI flood. **Figure B8.3** shows properties flooded by the 100 year ARI event.

TABLE B8.1
TOTAL DAMAGES AT BARADINE

Flood Event Year ARI	No. of Properties with Floors Inundated			Total Damages $ x 10^6	Cumulative AAD $ x 10^6
	Residential	Commercial/ Industrial	Public		
5	8	1	-	0.60	0.09
20	38	5	3	2.30	0.31
100	59	5	3	3.54	0.42
Extreme Flood	75	7	8	5.76	0.47

B8.2 Definition of Terms

Average Annual Damages (also termed "expected damages") are determined by integrating the area under the damage-frequency curve. They represent the time stream of annual damages, which would be expected to occur on a year by year basis over a long duration.

Using an appropriate discount rate, average annual damages may be expressed as an equivalent "*Present Worth Value"* of damages and used in the economic analysis of potential flood management measures.

Cumulative Annual Average Damages may be referenced to a particular flood frequency. They represent the average damages which would be expected on an annual basis for all flood events up to and including that nominated frequency and are estimated by computing the area beneath the damages versus frequency curve.

For example, the cumulative average annual value of damages on Teridgerie Creek for all floods up to the 100 year ARI level is $420,000 (**Table B8.1**). A flood management scheme which has a design 100 year ARI level of protection, by definition, will eliminate damages up to this level of flooding. If the scheme has no mitigating effect on larger floods, then these damages represent the benefits of the scheme expressed on an average annual basis.

Under current NSW Treasury guidelines, economic analyses are carried out assuming a 20 year economic life for projects and discount rates of 7% pa. (best estimate) and 10% and 4% pa. (sensitivity analyses).

B8.3 Present Worth of Damages at Baradine

The *Present Worth Values* of damages likely to be experienced in the study area for all flood events up to the 100 year ARI, a 20 year economic life and discount rates of 4, 7 and 10 per cent are shown on **Table B8.2**. Corresponding values for all floods up to the Extreme Flood are shown on **Table B8.3**.

For a discount rate of 7% pa, the *Present Worth Value* of damages for all flood events up to the Extreme Flood is about $4.95 Million for a 20 year economic life. Therefore a scheme costing up to $4.95 Million could be economically justified if it eliminated damages for all flood events up to this level. Similarly, a scheme providing a 100 year ARI level of protection could be economically justified if it cost up to $4.46 Million.

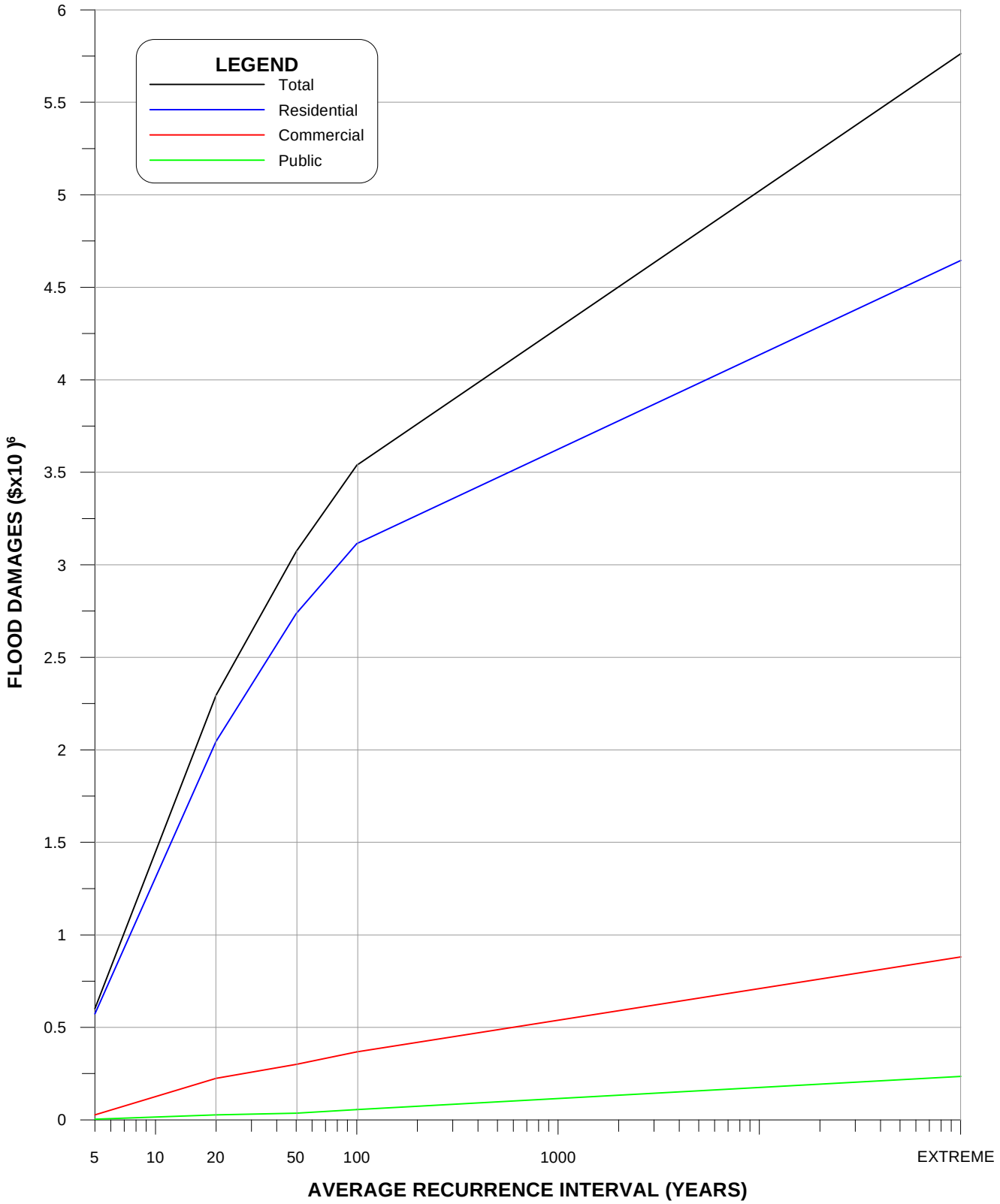
More expensive schemes would have a benefit/cost ratio less than 1, but may still be justified according to a multi-objective approach which considers other criteria in addition to economic feasibility. Flood management measures are considered on a multi-objective basis in the Main Report.

TABLE B8.2
PRESENT WORTH OF DAMAGES AT BARADINE
ALL FLOODS UP TO 100 YEAR
ECONOMIC LIFE OF 20 YEARS
$ X 10^6

Discount Rate – per cent		
4	**7**	**10**
5.72	4.46	3.58

TABLE B8.3
PRESENT WORTH OF DAMAGES AT BARADINE
ALL FLOODS UP TO EXTREME FLOOD
ECONOMIC LIFE OF 20 YEARS
$ X 10^6

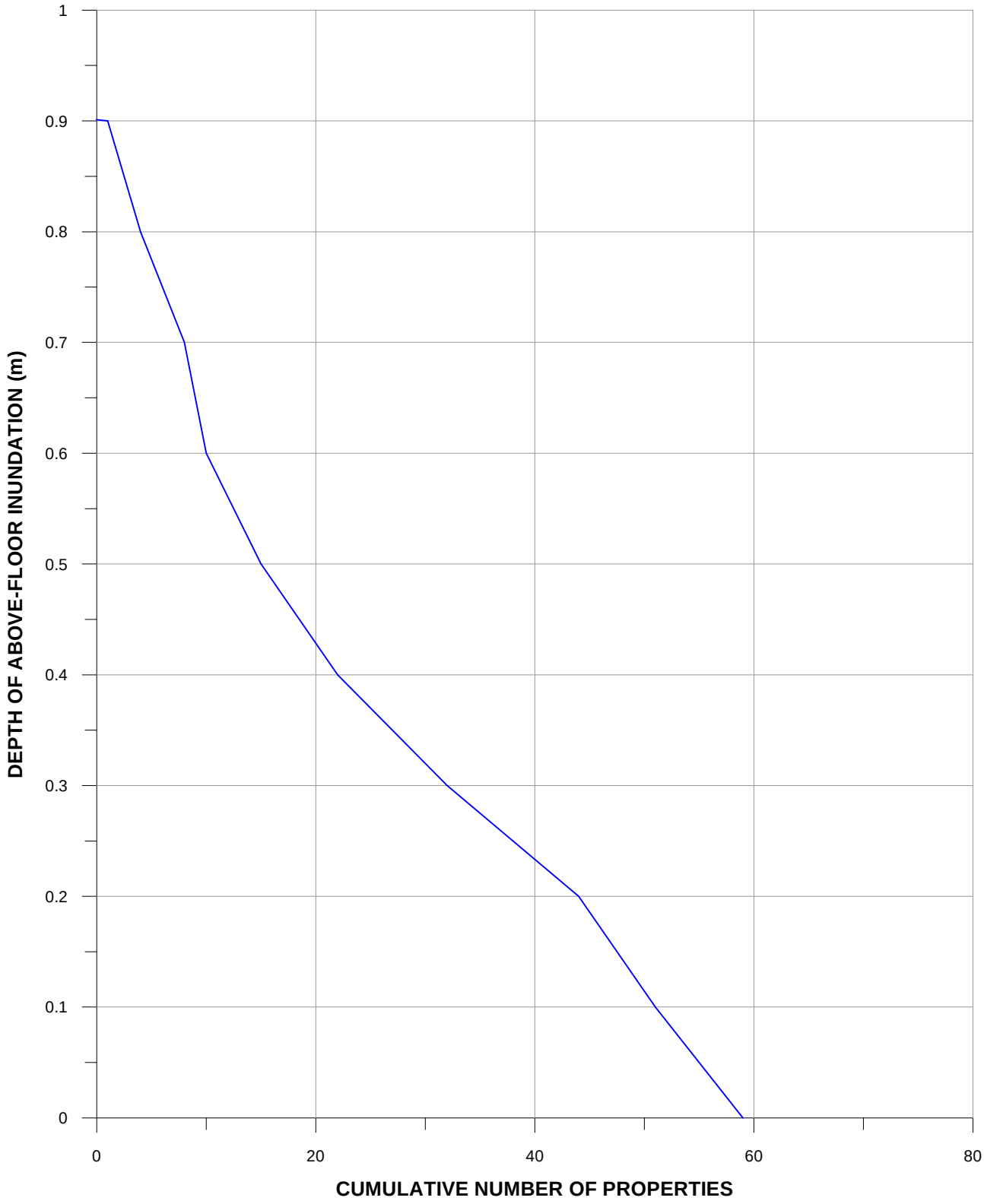
Discount Rate – per cent		
4	**7**	**10**
6.35	4.95	3.98



TERIDGERIE CREEK AT BARADINE
FLOODPLAIN RISK MANAGEMENT STUDY

Figure B8.1

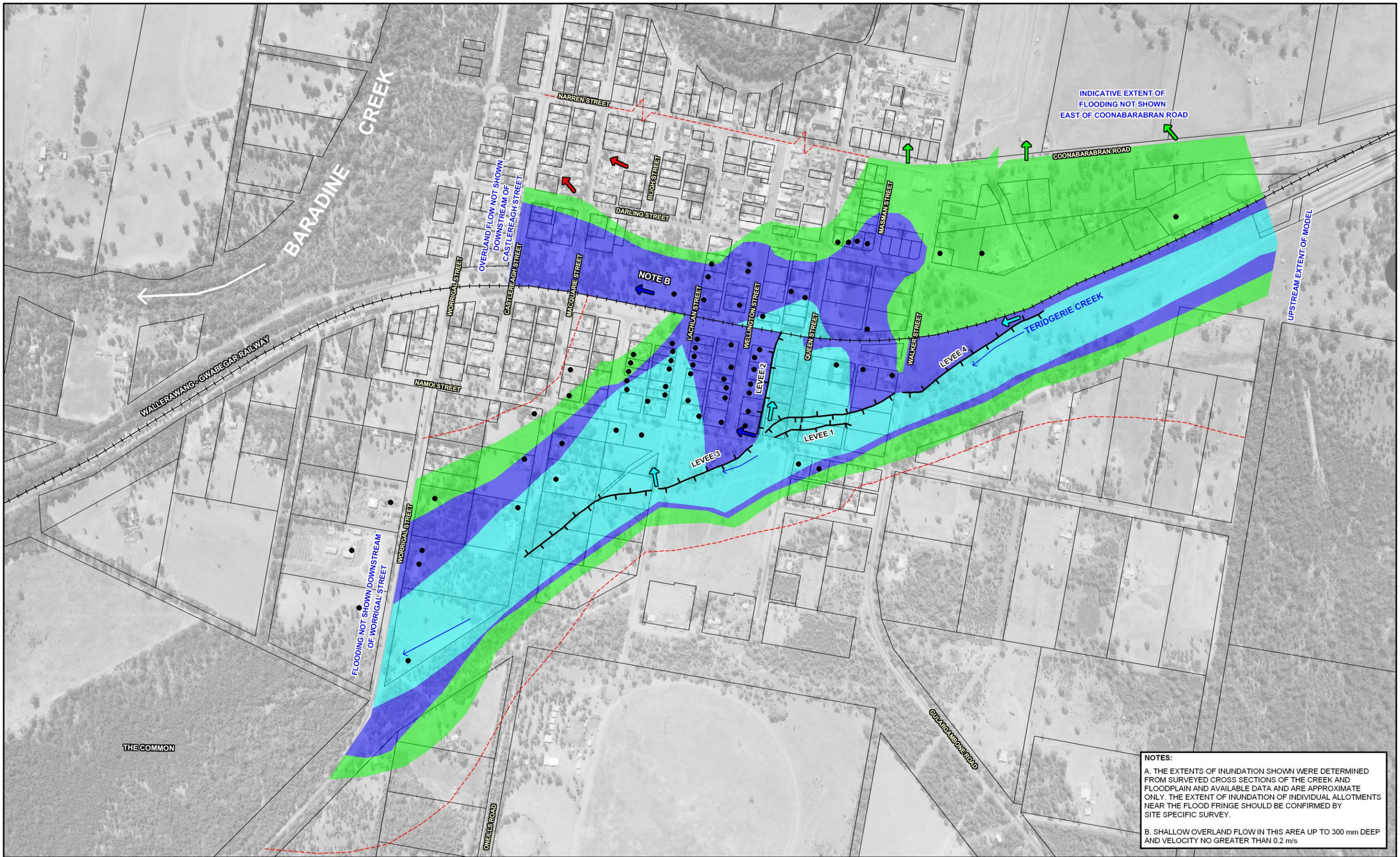
DAMAGE - FREQUENCY CURVE



TERIDGERIE CREEK AT BARADINE
FLOODPLAIN RISK MANAGEMENT STUDY

Figure B8.2

HISTOGRAM OF FLOODED RESIDENTIAL PROPERTIES - 100 YR ARI



NOTES:

A. THE EXTENTS OF INUNDATION SHOWN WERE DETERMINED FROM SURVEYED CROSS SECTIONS OF THE CREEK AND FLOODPLAIN AND AVAILABLE DATA AND ARE APPROXIMATE ONLY. THE EXTENT OF INUNDATION OF INDIVIDUAL ALLOTMENTS NEAR THE FLOOD FRINGE SHOULD BE CONFIRMED BY SITE SPECIFIC SURVEY.

B. SHALLOW OVERLAND FLOW IN THIS AREA UP TO 300 mm DEEP AND VELOCITY NO GREATER THAN 0.2 m/s

N

80 0 80 160 240 m

Scale: 1:8,000

LEGEND

- Area Inundated by 5 Year ARI Flood
- Additional Area Inundated by 20 Year ARI Flood
- Additional Area Inundated by 100 Year ARI Flood
- Approximate Extent of Extreme Flood
- Properties Inundated Above Floor Level by 100 Year ARI Flood
- Escape of Flow From Creek/Levee System at 5 Year ARI Flood
- Escape of Flow From Creek/Levee System at 20 Year ARI Flood
- Escape of Flow From Creek/Levee System at 100 Year ARI Flood
- Escape of Flow From Creek/Levee System at Extreme Flood

TERIDGERIE CREEK AT BARADINE
FLOODPLAIN RISK MANAGEMENT STUDY

Figure B8.3

FLOOD PROPERTIES 100 YEAR ARI

B9. REFERENCES AND BIBLIOGRAPHY

Lyall and Associates Consulting Water Engineers (2009) *"Conargo Floodplain Risk Management Study and Plan"*. Report prepared for Conargo Shire Council and DECCW.

Department of Environment and Climate Change, NSW (2007) *"Floodplain Management Guideline No 4. Residential Flood Damages"*.

Department of Water Resources, NSW (1990) *"Nyngan April 1990 Flood Investigation".*

Lyall, Macoun and Joy, Willing and Partners Pty Ltd (1985) *"Camden Floodplain Management Study"*. Report for Water Resources Commission and Camden Municipal Council.

Sinclair Knight Merz (1994) *"Forbes Floodplain Management Report and Draft Floodplain Management Plan, Volume 1"*. Report prepared for Department of Land and Water Conservation.

Water Studies (1986) *"The Sydney Floods of August 1986"*, Volume I Residential Flood Damage Survey, Report prepared for CRCE Water Studies Pty Ltd for the NSW PWD.

Water Studies (1992) *"Forbes Flood Damage Survey, August 1990 Flood"*. Report prepared for Department of Water Resources.

WARRUMBUNGLE SHIRE COUNCIL

TERIDGERIE CREEK
FLOODPLAIN RISK MANAGEMENT
STUDY AND PLAN

APPENDIX C

COMMUNITY QUESTIONNAIRE
AND RESPONSES

DECEMBER 2010

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ATTACHMENTS

1. Community Questionnaire

2. Responses to Community Questionnaire

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C1. INTRODUCTION

At the commencement of the *Teridgerie Creek Floodplain Risk Management Study,* the Consultants prepared a Community Questionnaire which was distributed by Council to residents bordering the creek system and also placed on Council's Website (refer to **Attachment 1**).

The Questionnaire contained the following information:

- A Plan of the creek system in Baradine.
- The objectives of the *Floodplain Risk Management Study*, namely the assessment of options for reducing the impacts of flooding on existing development and the preparation of Flood Policy guidelines for future development, in accordance with best floodplain management principles.

The Questionnaire was structured with the objectives of:

- Obtaining local information on flood experience and behaviour at residents' properties.
- Determining residents' attitudes to controls over development in flood liable areas in Baradine.
- Inviting community views on possible flood management options which could be considered for inclusion in the *Floodplain Risk Management Plan*.
- Obtaining feedback on any other flood related issues and concerns which the residents cared to raise.

This **Appendix** discusses the responses to the 10 questions included in the Questionnaire and comments made by respondents.

Section C2 deals with the residents' experience with historic flooding; determining residents' views on the relative importance of classes of development over which flood-related controls should be imposed by Council; and whether residents are aware of the controls Council currently places on development in flood prone areas.

Section C3 identifies potential measures which could be incorporated in the *Floodplain Risk Management Plan* for Teridgerie Creek and summarises residents' views on their inclusion.

Section C4 discusses the best methods by which the community could provide feedback to the consultants over the course of the study.

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C2 RESIDENT PROFILE AND FLOOD AWARENESS

C2.1 General

The Consultants received 57 responses to the Questionnaire as of the cutoff date, 26 November 2010. Fourteen respondents (optionally) provided their addresses, which allowed the Consultants to cross reference information they provided about flooding on their properties to the property survey which the Consultants will use to assess the economic impacts of flooding.

To provide basic data for the property survey, Council commissioned the survey of natural surface levels and floor levels of residential properties bordering the creek system. The objective was to survey all properties lying within the extent of the *Flood Planning Level* (*FPL*). (The *FPL* at a particular location equals the peak 100 year flood level plus an allowance of 500 mm for freeboard. The area encompassed by the *FPL* is known as the *Flood Planning Area* and is the area within which flood related controls over development usually apply).

The Consultants have collated the responses, which are shown in graphical format (**Attachment 2**).

C2.2 Experiences of Flooding

The first six questions canvassed resident information such as length of time at the property, the type of property (eg house, unit/flat), whether the respondent had any experience of flooding and if so which particular flood and whether they had experienced above-floor inundation. Twenty six respondents had lived in the study area for between 5 and 20 years and 20 for more than 20 years (**Question 1**). Almost all respondents occupied a house.

Eighteen respondents reported that they had experienced flooding on their property, with 11 nominating flooding as a result of the December 2007 flood, 8 reporting flooding in February 2004 and 6 in November 2000 (**Question 4**). Several residents reported flooding in 2010 and in the wet years of the 1970's. Only one resident advised that they had experienced above-floor inundation in the largest flood which they had experienced (**Question 5**).

As far as the source of flood warnings to the Baradine population is concerned (**Question 6**), 13 residents advised that they had received no warnings of imminent flooding; two residents advised being warned by TV or radio; 14 by their own observations, 5 by neighbours and 2 by SES. One resident received a warning from the police.

These results are characteristic of situations where flooding is of a "flash flooding" nature with little warning time being available for the dissemination of warnings by the authorities.

C2.3 Controls over Development in Flood Prone Areas

The residents were also asked to rank from 1 to 4 the classes of development which they consider should receive protection from flooding (**Question 7**). Rank 1 was the most important and rank 4 the least. These rankings were added for each response to achieve a total score for the survey. The lowest score identified the most important class overall for the residents of Baradine.

The residents considered that vulnerable residential development (aged persons' accommodation) and essential community facilities (eg schools, evacuation centres) warranted the highest priority for protection, followed by residential property and lastly, commercial/business development.

The residents were asked whether or not they were aware of Council's controls over new development in flood prone areas (**Question 8**). A total of five respondents replied yes, and 48 advised that they were not aware of these controls. Based on historic flooding patterns, Council have adopted a Flood Planning Level equal to the 100 year ARI flood level plus an allowance of 500 mm freeboard when setting minimum floor levels for new development.

C3 POTENTIAL FLOOD MANAGEMENT MEASURES

The respondents were also asked for their opinion on potential flood management measures which could be included in the Floodplain Risk Management Plan, by ticking a “yes” or “no” to the 10 options provided in **Question 9**.

The options comprised a range of structural measures (e.g. programs by Council to manage vegetation in the creek system to maintain hydraulic capacity; channel enlargements to increase capacity; levees to contain floodwaters); as well as non-structural measures (e.g. voluntary purchase of residential properties in high hazard areas; raising floor levels of houses in low hazard areas; flood related controls over new developments; improvements to flood warning and evacuation procedures; community education on flooding; and flood advice certificates). The options were not mutually exclusive, as the Management Plan adopted could, in theory, include all of the options set out in the Questionnaire, or indeed, other measures to be nominated by the respondents or the Floodplain Management Committee.

The most popular measure was maintenance of the hydraulic capacity of the creek system by the management of vegetation in the channels and the removal of debris following storm events. Another favoured structural measure was enlarging the creek channel to increase capacity. The construction of levees to contain floodwaters within the creek was also strongly favoured.

Flood-related development controls and Council’s provision of advice regarding flood affectation of existing properties to prospective purchasers (e.g. via Section 149 Certificates); improved flood warning procedures and evacuation and emergency plans; community education and flood awareness programs were also strongly favoured by the respondents.

Respondents were strongly against the implementation of a residential Voluntary Purchase scheme (to be administered by Council and designed by Government to allow residents on a wholly voluntary basis to vacate high hazard areas in the floodplain). A lukewarm response was given to the provision of subsidies for raising the floor levels of existing residential properties located in less hazardous zones of the floodplain.

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C4 INPUT TO THE STUDY AND FEEDBACK FROM THE COMMUNITY

At **Question 10** residents were asked for their view on the best methods of their providing input to the Study and feedback to the Consultants over the course of the investigation. Articles in the local newspaper and communication via through Council's Floodplain Management Committee were the two most popular methods.

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C5 FLOODING ISSUES RAISED BY RESPONDENTS

The *Teridgerie Creek Floodplain Risk Management Study and Plan* covers main stream flooding issues resulting from surcharges of the creek channels when catchment-wide major storms occur. Issues resulting from overflows of the minor pipes in the township's stormwater system due to localised storms are, strictly speaking, outside the scope of the present investigation.

Main stream flooding and surcharges of the piped stormwater system both occur as a result of intense rainfalls on the respective catchments and are therefore, likely to be closely correlated. Consequently, when considering main stream measures which could be incorporated in the Plan, the Consultants will give consideration to companion measures which could be incorporated to improve the performance of the local stormwater system.

A popular flood mitigation measure was to upgrade the existing levees protecting the township. Site inspection during the property survey indicated that the levees are un-coordinated and may be of doubtful structural integrity. A difficulty associated with levee schemes is the capture and disposal of local stormwater runoff generated in the protected area behind the levee. Unless appropriate measures are incorporated in the design, it is possible that the levees may exacerbate flooding problems in the protected areas.

A Councillor and former resident of Baradine provided sketches of several levee schemes in his detailed response. Their feasibility will be assessed during the study.

Several respondents proposed fitting the culverts beneath the railway embankment with flap gates to prevent backflooding from Teridgerie Creek. The railway culverts were designed to discharge runoff derived from the local stormwater catchments on the eastern side of the railway. However, during major flooding on the Teridgerie Creek catchment, backflooding occurs into the township. Council recently upgraded the drainage system to convey these flows northwards along the eastern side of the railway to link with Baradine Creek. The Consultants will consider blocking the railway culverts to prevent the backflooding with further upgrades of the drainage system (if required) to convey the town stormwater towards Baradine Creek.

Several respondents noted that the restrictions on flow imposed by the dense vegetation in the Common area (near Worrigal Street) caused a back up of flooding in the township area. They suggested clearing out this area to reduce upstream flood levels. This measure will be considered in the Study, however it should be appreciated that extensive clearing of vegetation in NSW is subject to legislative controls and may not be supported on environmental grounds. In addition DECCW view any modelled reduction in levels achieved by stream clearing to be a "bonus" and not to be relied upon to achieve a reduction in the flood planning levels. This is due to the fact that a formal and continuing program of maintenance would be required to ensure that the reduction in levels is maintained over time.

One respondent reported difficulties faced by residents at the flooded crossing of the creek at Namoi Street and suggested that it should be upgraded to provide flood free access. Whilst this measure will also be considered in the study, it should be noted that the upgrading would be an expensive exercise.

Conversely one respondent considered that lowering the roadway at the crossing would reduce upstream flood levels and would be beneficial.

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C6 SUMMARY

Fifty seven responses were received to the Community Questionnaire distributed by Council. The responses amounted to about 20 per cent of the total distributed. The responses indicated a considerable interest by the Baradine community in the study. However there was little information of a quantitative nature on historic flood levels, although the residents specifically nominated several recent floods occurring in the 2000's which had flooded their properties. Only one resident reported that he had been flooded above floor level.

C6.1 Issues

The issues identified by respondents in their responses to the Questionnaire support the proposed objectives of the Study and the activities nominated in the Study Brief. No new issues were identified in regard to main stream flooding which is the primary subject of the Study. Several residents suggested structural flood mitigation measures which will be of assistance to the Consultants in the development of the Plan.

C6.2 Flood Management Measures

The non-structural flood management measures such as planing controls over new development in flood liable areas, as well as improvements to flood warning and emergency management measures appear to be the most popular of the potential measures set out in the Questionnaire.

Of the structural measures, management of vegetation and clearing the creek of debris following flood events, construction of detention basins to reduce downstream peak flood flows and enlargement of the channel to increase hydraulic capacity were the most popular. There do not appear to be any new measures raised by the respondents in their responses to **Question 10**.

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Attachment 1
Typical Response to a Community Questionnaire

SS

Teridgerie Creek at Baradine Floodplain Risk Management Study and Plan

NSW GOVERNMENT Environment, Climate Change & Water

warrumbungle SHIRE COUNCIL

Community Questionnaire

This questionnaire is part of the Flood and Floodplain Risk Management Study for Teridgerie Creek at Baradine. The primary objectives of the Study will be to assess options for reducing the impacts of flooding on existing urban development in the town and to prepare guidelines for future development in accordance with best floodplain management principles. The study is being undertaken by Consultants on behalf of Warrumbungle Shire Council and the Department of Environment, Climate Change and Water. Your response to this questionnaire will help us determine the flood issues that are important to you.

This questionnaire will be picked up from you within the next seven (7) days. If we miss you would you please post your response in the attached reply paid envelope by 19 November 2010.

Floodwaters traverse Namoi Street during December 2007 Flood.

About your property

1. **How long have you owned or lived at this address?**
   (Please circle one of the following.)
   a. 1 year to 5 years
   (b.) 5 years to 20 years
   c. More than 20 years (..... years)

2. **What is your property?**
   (Please circle one of the following.)
   a. House
   b. Villa/Townhouse
   c. Unit/Flat/Apartment
   d. Vacant land
   e. Other (house + 4hectares)

Please turn over to continue questionnaire

Your flood experience

(If you have experienced a flood, please answer Questions 3 to 6, otherwise go to Question 7)

3. Do you have any information about flooding at the property?
(Please circle one or more of the following.)

(a.) Yes b. No

* **If Yes, what information do you have?**

(a.) Own experience
b. Flood levels from Council
c. Council planning certificate
d. Information from SES
(e.) Photographs
f. Other (_____)

4. Have you ever experienced flooding at the property?
(Please circle one or more of the following.)

a. (Yes) b. No

* **If yes, which floods?**

(a.) 22 December 2007
b. 24 February 2004
c. 20 November 2000
d. Other (eg. 1956, 1970's, 2010)
(_____)

5. In the biggest flood you have experienced, was the property flooded above floor level of the main residence?
(Please circle one of the following.)

a. Yes b. (No)

* **If Yes, what was the depth of water over the floor?** _____

What year? _____

6. In this biggest flood, did you receive any warning, and if so, from where?
(Please circle one or more of the following.)

(a.) No warning whatsoever
b. TV
c. Radio
d. Own observations
e. Police
f. State Emergency Service (SES)
g. Neighbours, relatives or friends
h. Other (_____)

7. Please <u>rank the following development types</u> according to which you think are the most important to protect from floods (1=highest priority to 4=least priority)

a. Commercial/Business ☐ 4
b. Residential ☐ 2
c. Vulnerable residential development (eg. aged persons accommodation) ☐ 1
d. Essential community facilities (eg. hospital, school, evacuation centre) ☐ 3

8. Are you aware of the controls Warrumbungle Council currently places on development in flood prone areas?
(Please circle one of the following.)

a. (Yes) b. No

Comment: _____

Your opinions on flood mitigation measures

9. Below is a list of possible options that may be looked at to try to minimise the effects of flooding from Teridgerie Creek.

This list is not in any order of importance and there may be other options that you think should be considered.
(For each of the options listed, please tick "yes" or "no" to indicate if you favour the option. Please leave blank if undecided.)

		<u>Yes</u>	<u>No</u>
a.	Maintenance programs to clear creek of vegetation and debris impeding flows.	☑	☐
b.	Enlarge the creek channel.	☐	☑
c.	Construct permanent, engineered levees to contain floodwaters	☑	☐
d.	Voluntary scheme to purchase residential property in high hazard areas.	☐	☑
e.	Provide subsidies to raise houses above major flood level in low hazard areas.	☐	☑
f.	Specify controls over future development in flood-liable area (eg. controls on extent of filling, minimum floor levels, etc)	☑	☐
g.	Improve flood warning procedures both before and during a flood.	☑	☐
h.	Improve evacuation and emergency assistance plans.	☐	☑
i.	Community education, participation and flood awareness programs.	☐	☑
j.	Provide a certificate to purchasers in flood prone areas stating that the property is flood affected and to what extent.	☑	☐
k.	Any other options? (nominate below)	☐	☐

Comment: _____

Other Information

10. What do you think is the best way for us to get input and feedback from the local community about the results and proposals from this study?
(Please circle one or more of the following.)

a. Council's website
b. Articles in local newspaper
c. Open days or drop-in days
d. Through Council's Floodplain Risk Management Committee
e. Other (Surveys (Independant of Council))

11. If you wish us to contact you so you can provide further information, please provide your details below:

Name: _____

Address: _____

_____

Phone (Home) _____

Best time to call is _____

Fax No. _____

Email: _____

Who can I contact for further information?

Warrumbungle Shire Council
Mr Kevin Tighe
Phone: 6849 2000

Local Contacts

Mr Mitchell Evans	6843 1001
Mr Richard Crawley	6843 1765
Mr Barry Johnston	0427 003 923
Cr Kerry Campbell	6843 1145
Cr Denis Todd	6843 1831

Lyall & Associates
Consulting Water Engineers
Mr Scott Button
Phone: 9929 4466

Reply Paid 78855
NORTH SYDNEY NSW 2060

Copies of this questionnaire can be obtained from:

www.warrumbungle.nsw.gov.au

Comments

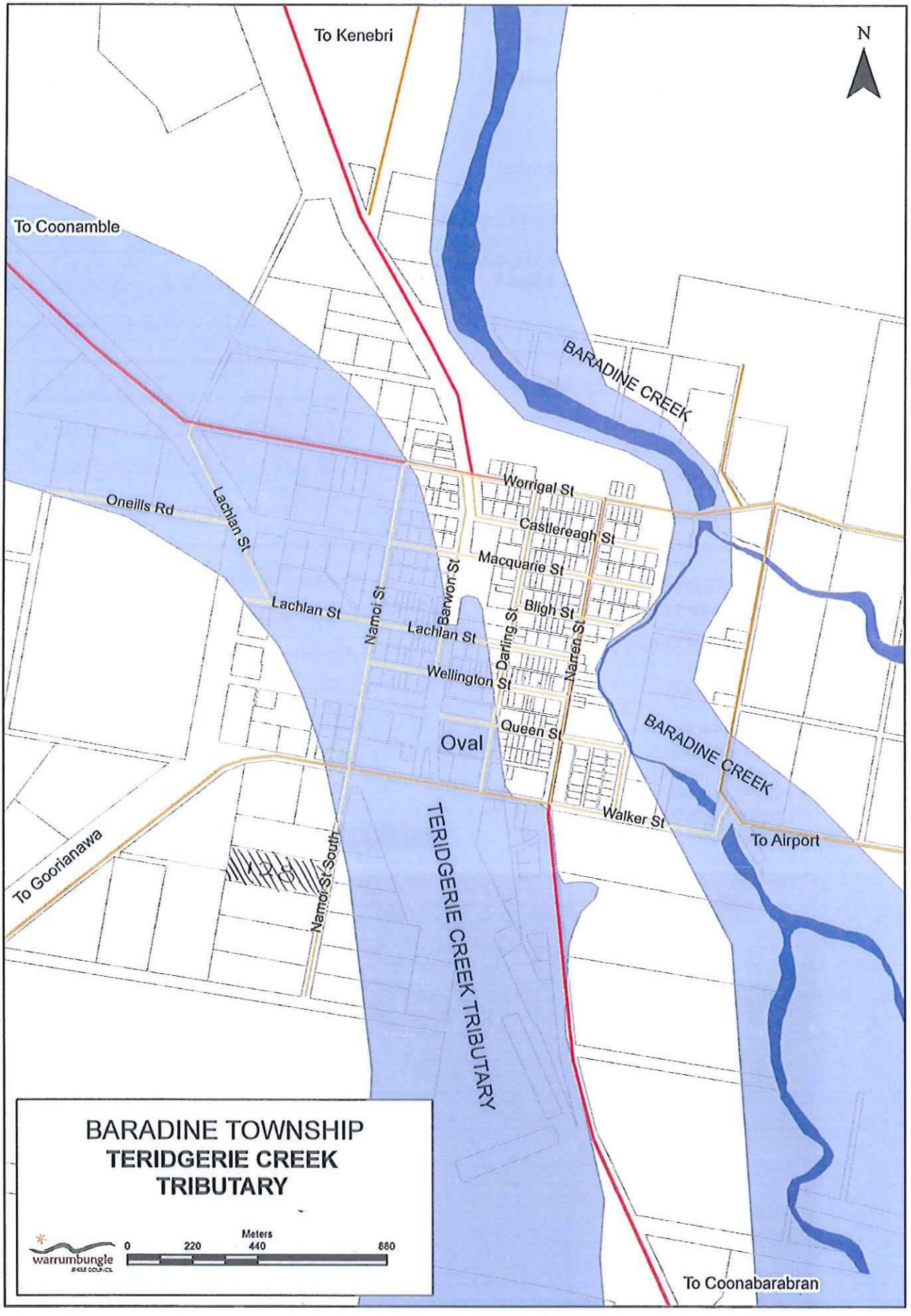
My property location marked on map overleaf.

I live alone with my 4 children under 7 years old.

Access to town/hospital is imperative to me, the improvements made on Walker St need to be duplicated on the Namoi St/Tributary intersection.

Thank you for your participation in this study

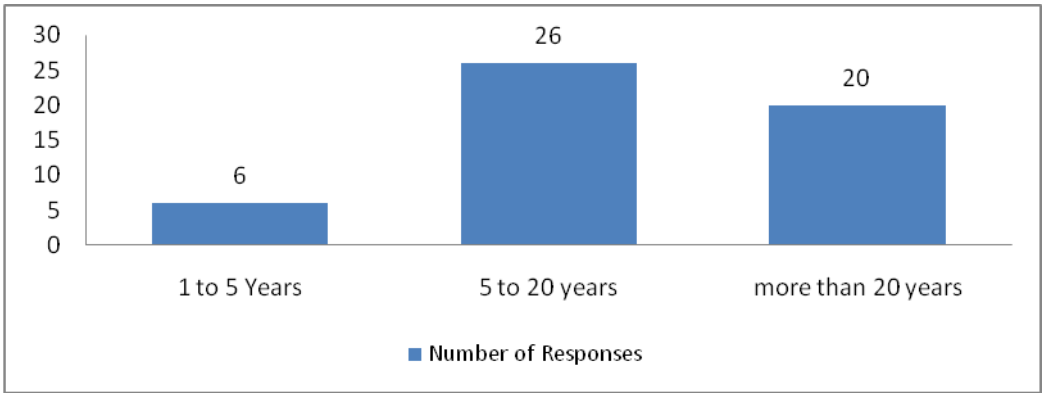
A house in Wellington Street outside the Teridgerie Creek waterway – just 50mm from inundation of floor.


To Kenebri
N
To Coonamble
BARADINE CREEK
Worrigal St
Castlereagh St
Macquarie St
Bligh St
Oneills Rd
Lachlan St
Namoi St
Barwon St
Darling St
Narren St
Wellington St
Queen St
Oval
BARADINE CREEK
Walker St
To Airport
To Goorianawa
Namoi St South
TERIDGERIE CREEK TRIBUTARY
To Coonabarabran
BARADINE TOWNSHIP
TERIDGERIE CREEK
TRIBUTARY
warrumbungle
Meters
0
220
440
880

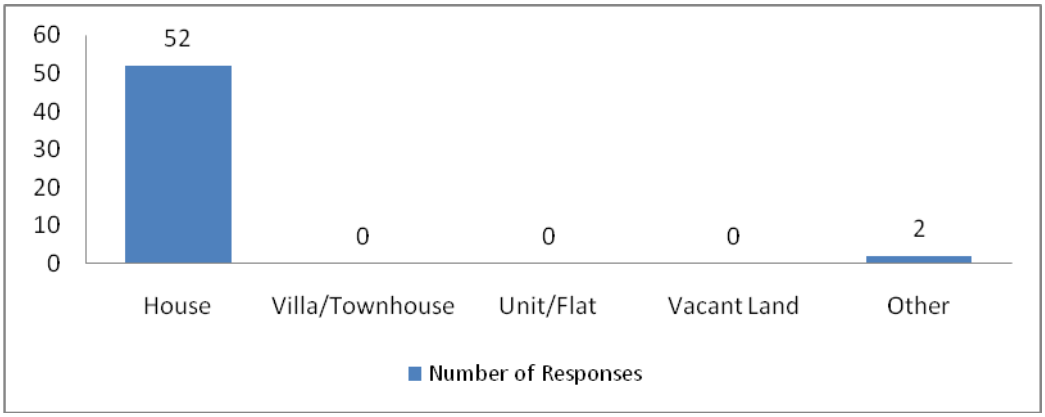
Attachment 2
Responses to Community Questionnaire

ABOUT YOUR PROPERTY

Question 1 – Time at this Address?

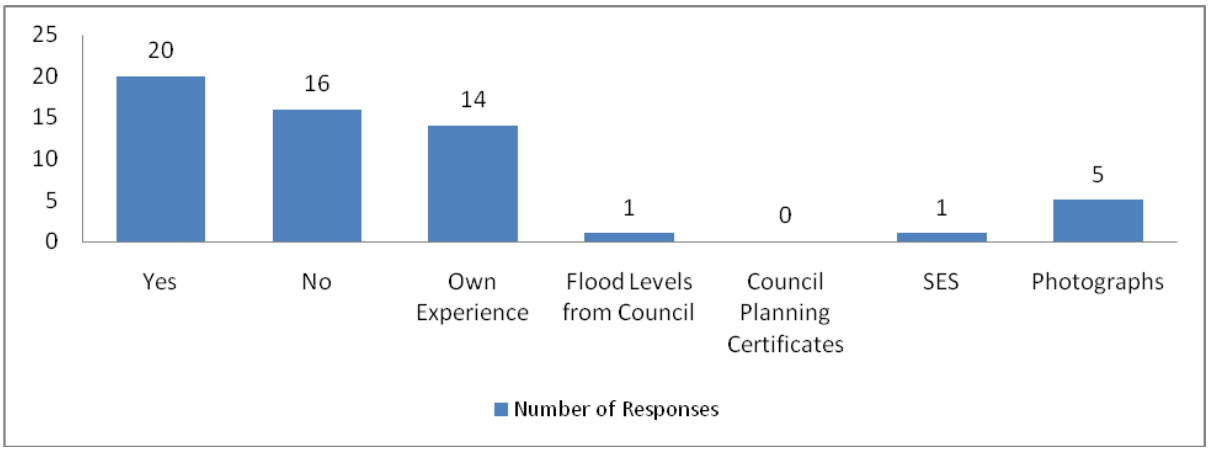


Question 2 – Type of Property?

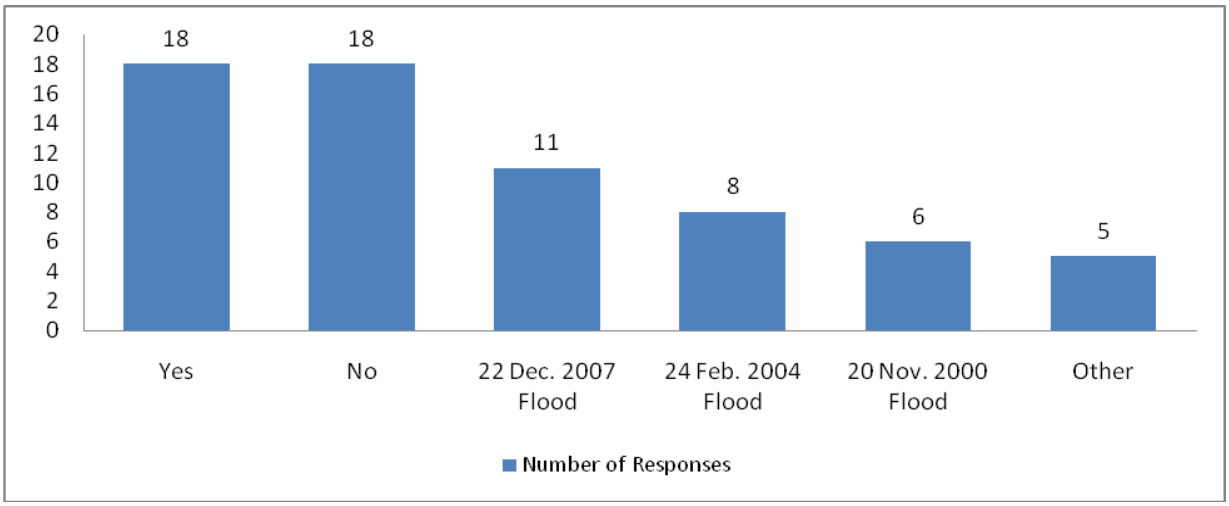


YOUR FLOOD EXPERIENCE

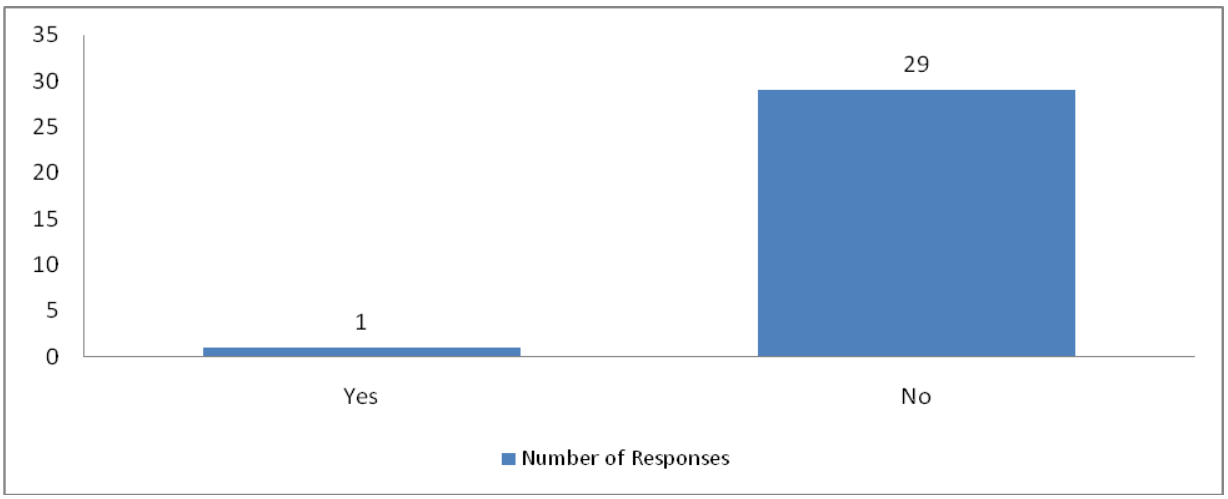
Question 3 – Any Information About Flooding at the Property?



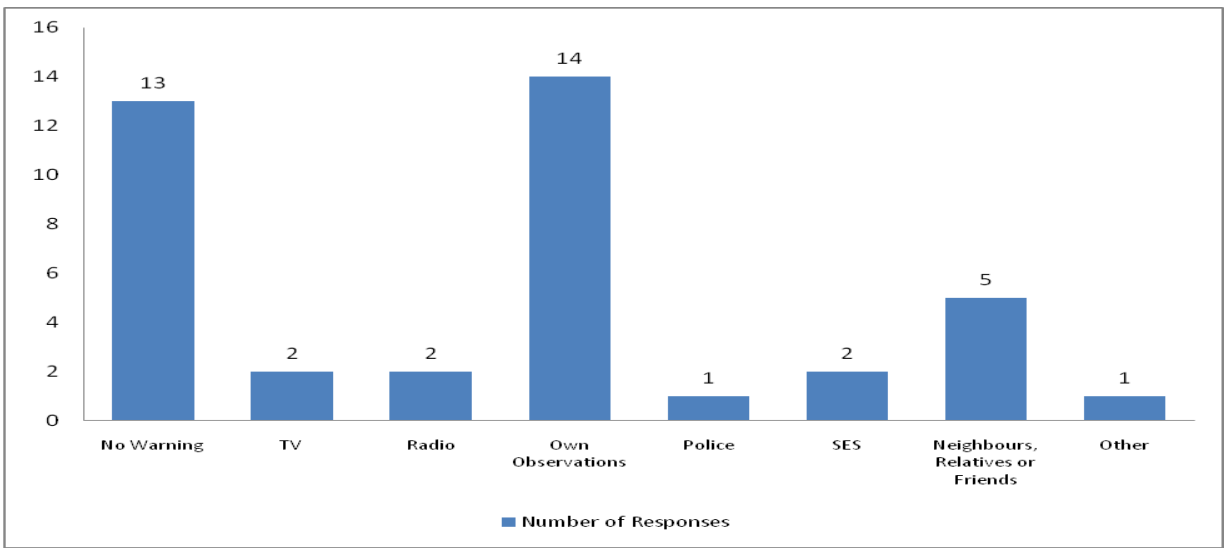
Question 4 – Flood Experienced on Property?



Question 5 – Flooding Above Floor Level?

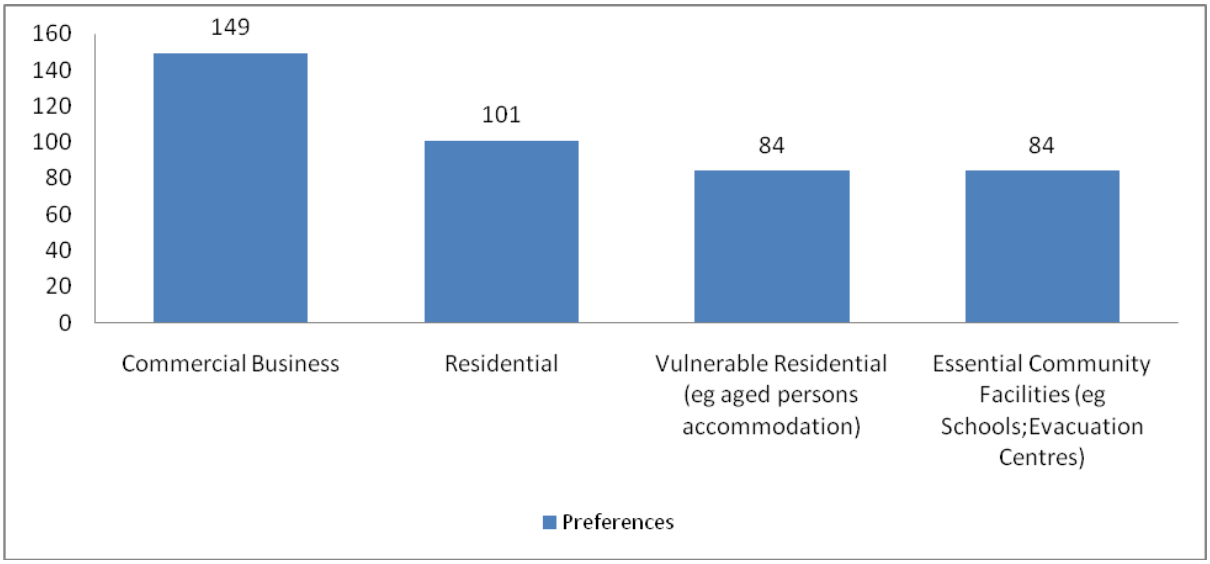


Question 6 – Where Did the Flood Warning Come From?

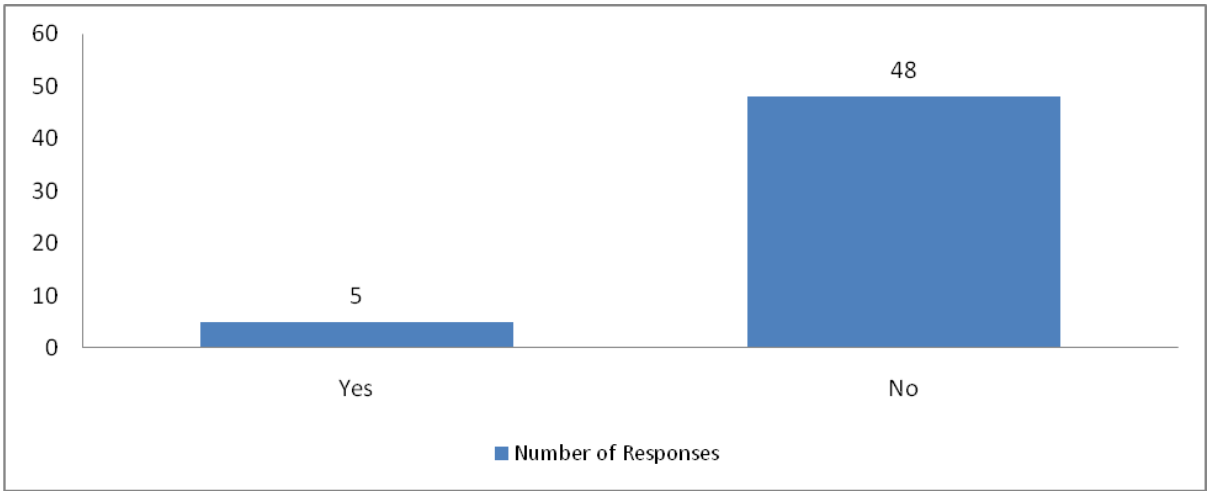


YOUR ATTITUDE TO FLOOD RELATED DEVELOPMENT CONTROLS

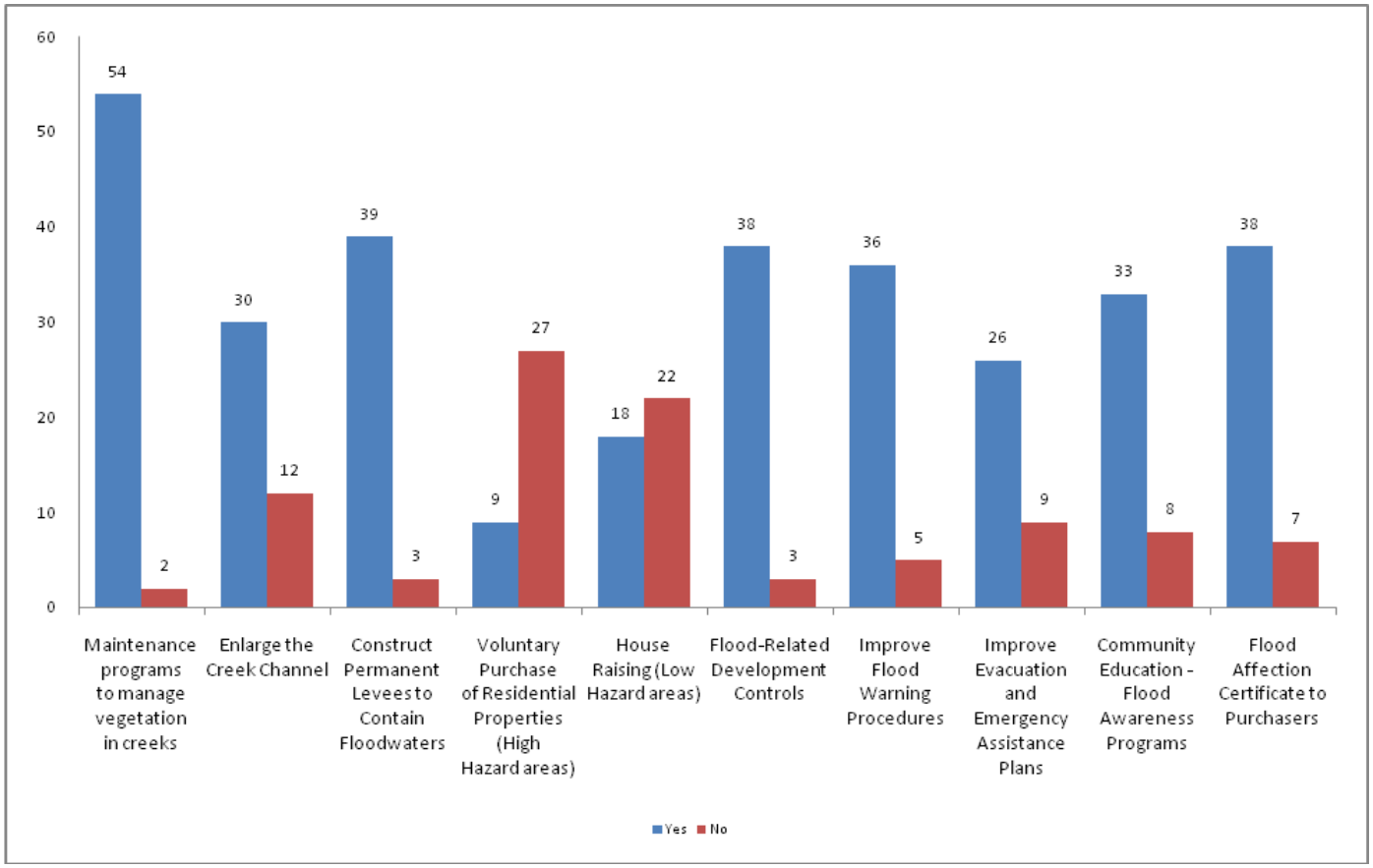
Question 7 – Ranking Development for Protection
(Note: lowest score= most important)



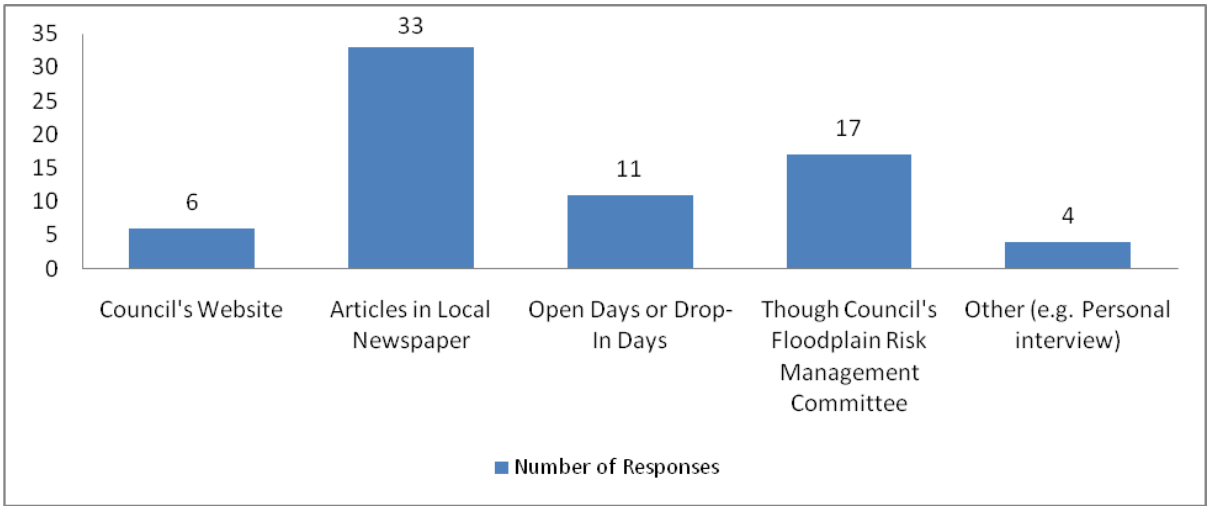
Question 8 – Aware of Advice Currently Provided by Council Regarding Flooding?



Question 9 – Possible Flood Management Options



Question 10 – Best Methods to get Input and Feedback from the Local Community



WARRUMBUNGLE SHIRE COUNCIL

TERIDGERIE CREEK AT BARADINE FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

APPENDIX D

COST DETAILS FLOOD MITIGATION SCHEMES

MAY 2012

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1 LEVEE UPGRADE – SCHEME 1

The indicative capital cost estimate for the levee is given in **Table D1.1**. Annual maintenance costs amounting to 1 per cent of the capital cost have been converted to a present worth value and added to the above capital cost to obtain an indicative total cost of the scheme, which has been used in the economic analysis of **Chapter 3** of the **Main Report**.

The costing has been developed using existing sources of survey data. This is appropriate for a strategy study such as the present *FRMS*, where the principal objective is to evaluate projects on a comparative basis. However, in order to gain Government funding, it would be necessary to refine the analysis and costing using more detailed survey and cost data. A concept design study is proposed as a project for inclusion in the draft *FRMP* in the **Main Report**.

TABLE D1.1
PRELIMINARY ESTIMATE CAPITAL COST
LEVEE UPGRADE – SCHEME 1

Item	Cost $
Purchase land over levee footprint	420,000
Preliminaries (Establishment, Geotechnical Testing, Sediment Control)	20,000
Remove existing levees and reinstate surfaces	44,000
Clear and grub levee footprint and stockpile	27,000
Roll and compact levee foundation	160,000
Supply and compact impervious fill for levee embankment	1,040,000
Excavate from stockpile and spread topsoil over all excavated surfaces	30,000
Grass seed levee batters	165,000
Upgrade relief drain along eastern side of railway embankment to discharge town stormwater	265,000
Supplementary levee on western side of Teridgerie Creek at Namoi Street	100,000
Raise levels and re-instate road surfaces at street crossings (Lachlan, Macquarie, Namoi and Walker Streets) to provide continuity of levee	250,000
Survey, investigation and design (12.5%)	307,000
Un-estimated items and contingencies (25%)	690,000
TOTAL CAPITAL COST	**$3.55 M**

2 DIVERSION TO BARADINE CREEK – SCHEME 2

Table D2.1 provides an indicative capital cost of the cost of the diversion structure which would be located upstream of Walker Street. **Table D2.2** provides similar costing for supplementary levees which would be required to contain residual un-diverted flows in the town.

TABLE D2.1
PRELIMINARY ESTIMATE CAPITAL COST
DIVERSION TO BUGALDIE CREEK TRIBUTARY– SCHEME 2
DIVERSION BANK AND CONTROL STRUCTURE NEAR ASHBY

Item	Cost $
Sediment Control over duration of project	15,000
Remove culverts in railway embankment Bugaldie Creek Tributary and prepare foundation for concrete control structure	10,000
Supply and cast concrete for control structure	187,000
Supply and install reno mattress protection upstream and downstream of control structure	180,000
Supplementary banking to direct approaching flow to control structure	70,000
Remove and dispose of vegetation beneath diversion bank Teridgerie Creek and Bugaldie Creek Tributary	16,000
Excavate to remove topsoil (150 mm) over diversion bank footprint and stockpile for later spreading over levee batters	13,000
Roll and compact diversion bank foundation	78,000
Supply and compact suitable impervious fill to form diversion bank	470,000
Excavate from stockpile and spread topsoil over faces of banks	15,000
Grass seed batters	54,000
Survey, investigation and design (12.5%)	138,000
Un-estimated items and contingencies (25%)	311,500
TOTAL CAPITAL COST	**$1.56 M**

TABLE D2.2
PRELIMINARY ESTIMATE CAPITAL COST
DIVERSION TO BARADINE CREEK – SCHEME 2
COST OF SUPPLEMENTARY LEVEES IN BARADINE TOWN

Item	Cost $
Purchase land over levee footprint	220,000
Preliminaries (Establishment, Geotechnical Testing, Sediment Control)	15,000
Remove existing levees and reinstate surfaces	23,000
Clear and grub levee footprint and stockpile	19,000
Roll and compact levee foundation	110,000
Supply and compact impervious fill for levee embankment	496,000
Excavate from stockpile and spread topsoil over all excavated surfaces	21,000
Grass seed levee batters	112,000
Upgrade relief drain along eastern side of railway embankment to discharge town stormwater	Not Reqd.
Supplementary levee on western side of Teridgerie Creek at Namoi Street	180,000
Raise levels and re-instate road surfaces at street crossings (Lachlan, Macquarie, Namoi and Walker Streets) to provide continuity of levee	80,000
Survey, investigation and design (12.5%)	147,000
Un-estimated items and contingencies (25%)	331,000
TOTAL CAPITAL COST	**$1.65 M**

3 FLOODWAY/RIPARIAN CORRIDOR – SCHEME 4

Table D3.1 provides an indicative capital cost of the capital cost of the floodway/riparian corridor Scheme 4 and **Table D3.2** is a preliminary costing of levees required to contain flows.

TABLE D3.1
PRELIMINARY ESTIMATE CAPITAL COST
FLOODWAY/RIPARIAN CORRIDOR – SCHEME 4

Item	Cost $
Preliminaries (Establishment, Geotechnical Testing, Sediment Control)	20,000
Remove and dispose of vegetation over surface of floodway	394,000
Strip and Store Topsoil for later re-use on excavated surfaces	319,000
Excavate to lower levels in the floodplain over 2.4 km reach upstream of Worrigal Street; spread spoil on floodplain	735,000
Spread stored topsoil over excavated surfaces	345,000
Grass seed channel invert	450,000
Supply and place rock in channel invert to form rock pools and control scour	90,000
Riparian Zone plantings along channel overbanks (50 m each side)	394,000
Reinstate road crossings (Worrigal, Macquarie, Lachlan, Namoi and Walker Streets)	50,000
Survey, investigation and design (12.5%)	343,000
Un-estimated items and contingencies (25%)	785,000
TOTAL CAPITAL COST	**$3.92 M**

TABLE D3.2
PRELIMINARY ESTIMATE CAPITAL COST
FLOODWAY/RIPARIAN CORRIDOR – SCHEME 4
COST OF SUPPLEMENTARY LEVEES

Item	Cost $
Purchase land over levee footprint	245,000
Preliminaries (Establishment, Geotechnical Testing, Sediment Control)	20,000
Remove existing levees and reinstate surfaces	26,000
Clear and grub levee footprint and stockpile	21,000
Roll and compact levee foundation	123,000
Supply and compact impervious fill for levee embankment	560,000
Excavate from stockpile and spread topsoil over all excavated surfaces	23,000
Grass seed levee batters	125,000
Upgrade relief drain along eastern side of railway embankment to discharge town stormwater	200,000
Supplementary levee on western side of Teridgerie Creek at Namoi Street	100,000
Raise levels and re-instate road surfaces at street crossings (Lachlan, Macquarie, Namoi and Walker Streets) to provide continuity of levee	250,000
Survey, investigation and design (12.5%)	212,000
Un-estimated items and contingencies (25%)	476,000
TOTAL CAPITAL COST	**$2.38 M**