



# Review of the Narrandera Floodplain Risk Management STUDY AND PLAN

March 2019  
MagiQ #408775



**NARRANDERA SHIRE COUNCIL**

**REVIEW OF THE NARRANDERA  
FLOODPLAIN RISK MANAGEMENT  
STUDY AND PLAN**

**MARCH 2019**

**VOLUME 1 – REPORT**

## **COPYRIGHT NOTICE**



This document, *Review of the Narrandera Floodplain Risk Management Study and Plan 2019*, is licensed under the [Creative Commons Attribution 4.0 Licence](https://creativecommons.org/licenses/by/4.0/), unless otherwise indicated.

**Please give attribution to:** © Narrandera Shire Council 2019

We also request that you observe and retain any notices that may accompany this material as part of the attribution.

### **Notice Identifying Other Material and/or Rights in this Publication:**

The author of this document has taken steps to both identify third-party material and secure permission for its reproduction and reuse. However, please note that where these third-party materials are not licensed under a Creative Commons licence, or similar terms of use, you should obtain permission from the rights holder to reuse their material beyond the ways you are permitted to use them under the [Copyright Act 1968](https://www.copyright.gov/). Please see the Table of References at the rear of this document for a list identifying other material and/or rights in this document.

### **Further Information**

For further information about the copyright in this document, please contact:

Narrandera Shire Council  
141 East Street, Narrandera  
[council@narrandera.nsw.gov.au](mailto:council@narrandera.nsw.gov.au)  
(02) 6959 5510

### **DISCLAIMER**

The [Creative Commons Attribution 4.0 Licence](https://creativecommons.org/licenses/by/4.0/) contains a Disclaimer of Warranties and Limitation of Liability. In addition: **This document (and its associated data or other collateral materials, if any, collectively referred to herein as the 'document') were produced by Lyall & Associates Consulting Water Engineers for Narrandera Shire Council only. The views expressed in the document are those of the author(s) alone, and do not necessarily represent the views of the Narrandera Shire Council. Reuse of this study or its associated data by anyone for any other purpose could result in error and/or loss. You should obtain professional advice before making decisions based upon the contents of this document.**

## FOREWORD

### NSW Government's Flood Policy

The NSW Government's Flood Prone Land 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 State through the following four sequential stages:

- |                                     |  |
|-------------------------------------|--|
| 1. Data Collection and Flood Study  | Collects flood related data and undertakes an investigation to determine 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 to ensure new development is compatible with the flood hazard. . Improvements to flood emergency management procedures. |

### Presentation of Study Results

The results of the flood study investigations commissioned by Narrandera Shire Council have been presented in four separate reports:

- *Narrandera Floodplain Risk Management Study* (SKM, 2009) (referred to herein as **FRMS 2009**)
- *Narrandera Floodplain Risk Management Plan* (SKM, 2009) (referred to herein as **FRMP 2009**)
- *Narrandera Flood Study Review and Levee Options Assessment* (L&A, 2015)
- **Review of Narrandera Floodplain Risk Management Study & Plan (this present report)** (referred to herein separately as **FRMS 2019** and **FRMP 2019**)

The studies have been prepared under the guidance of the Floodplain Risk Management Committee comprising representatives from Narrandera Shire Council, the Office of Environment and Heritage and the NSW State Emergency Service.

## ACKNOWLEDGEMENT

The studies have been prepared with financial assistance from the NSW Government through its Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the Office of Environment and Heritage.

## TABLE OF CONTENTS

	Page No.
<b>SUMMARY .....</b>	<b>S1</b>
<b>1 INTRODUCTION .....</b>	<b>1</b>
1.1 Study Background .....	1
1.2 Background Information .....	1
1.3 Overview of FRMS 2019 Report .....	1
1.4 Community Consultation .....	3
1.5 Flood Frequency and Terminology .....	4
<b>2 BASELINE FLOODING CONDITIONS .....</b>	<b>6</b>
2.1 Physical Setting .....	6
2.2 Drainage System .....	6
2.2.1 Murrumbidgee River Floodplain .....	6
2.2.2 Local Stormwater Drainage System .....	7
2.3 Recent Flood Experience .....	8
2.4 Design Flood Behaviour .....	11
2.4.1 Background .....	11
2.4.2 Design Flooding Patterns .....	12
2.5 Hydrologic Standard of Existing Road Network .....	14
2.6 Existing Flood Mitigation Measures .....	14
2.7 Economic Impacts of Flooding .....	16
2.8 Impact of Flooding on Vulnerable Development and Critical Infrastructure .....	20
2.9 Impact of a Partial Failure of the Southern Main Canal Embankment .....	20
2.10 Potential Impacts of Future Urbanisation .....	23
2.11 Potential Impacts of Climate Change .....	23
2.12 Flood Hazard and Hydraulic Categorisation of the Floodplain .....	24
2.12.1 General .....	24
2.12.2 Flood Hazard Categorisation .....	25
2.12.3 Hydraulic Categorisation of the Floodplain .....	27
2.13 Council's Existing Planning Instruments and Policies .....	28
2.13.1 General .....	28
2.13.2 Land Use Zoning – Narrandera Local Environmental Plan 2013 .....	28
2.13.3 Flood Provisions –Narrandera LEP 2013 .....	29
2.13.4 Flooding and Stormwater Controls –Narrandera DCP 2013 .....	29
2.14 Flood Warning and Flood Preparedness .....	31
2.15 Environmental Considerations .....	32
<b>3 POTENTIAL FLOODPLAIN MANAGEMENT MEASURES .....</b>	<b>33</b>
3.1 Range of Available Measures .....	33
3.2 Community Views .....	33
3.3 Outline of Chapter .....	35
3.4 Flood Modification Measures Assessed as Part of the Flood Study Review .....	36
3.4.1 General .....	36
3.4.2 New Town Levee Option .....	41
3.4.3 Southern Main Canal Embankment Upgrade Option .....	42

Cont'd Over

## TABLE OF CONTENTS (Cont'd)

	Page No.
3.4.4	Narrandera Airport Levee Replacement Option ..... 42
3.4.5	Irrigation Way Upgrade Option..... 43
3.4.6	New Airport Link Road (Paynters Siding Road) ..... 43
3.4.7	Weir Park Road Levee Option ..... 44
3.4.8	Narrandera Airport and Nallabooma Estate Ring Levee ..... 44
3.4.9	Water Supply Pumping Station Ring Levee ..... 44
3.4.10	Old Brewery Road Upgrade ..... 45
3.5	Flood Modification Measures Assessed as Part of the Present Study..... 45
3.5.1	General ..... 45
3.5.2	Town Siphon Works..... 45
3.5.3	Woolscour Road Siphon Works ..... 46
3.5.4	Narrandera Detention Basin Strategy..... 46
3.6	Property Modification Measures ..... 47
3.6.1	Controls over Future Development ..... 47
3.6.2	Rezoning of Land South of Main Canal ..... 55
3.6.3	Voluntary Purchase of Residential Properties ..... 55
3.6.4	Voluntary House Raising ..... 56
3.7	Response Modification Measures ..... 57
3.7.1	Improvements to Flood Warning System..... 57
3.7.2	Improved Emergency Planning and Response..... 58
3.7.3	Public Awareness Programs ..... 59
<b>4</b>	<b>SELECTION OF FLOODPLAIN MANAGEMENT MEASURES ..... 60</b>
4.1	Background ..... 60
4.2	Ranking of Options ..... 60
4.3	Summary..... 61
<b>5</b>	<b>FLOODPLAIN RISK MANAGEMENT PLAN 2019 ..... 63</b>
5.1	The Floodplain Risk Management Process ..... 63
5.2	Purpose of the Plan ..... 63
5.3	The Study Area ..... 63
5.4	Community Consultation ..... 64
5.5	Economic Impacts of Flooding ..... 64
5.6	Indicative Flood Extents..... 65
5.7	Structure of Floodplain Risk Management Study and Plan ..... 66
5.8	Planning and Development Controls ..... 67
5.8.1	Flood Policy..... 67
5.8.2	Revision to Narrandera LEP 2013..... 70
5.9	Improvements in Emergency Planning and Flood Awareness ..... 71
5.10	Flood Modification Works ..... 72
5.11	Combined Voluntary Purchase and House Raising Scheme..... 73
5.12	Implementation Program..... 73
<b>6</b>	<b>GLOSSARY OF TERMS..... 75</b>
<b>7</b>	<b>REFERENCES ..... 78</b>

## APPENDICES

- A Community Consultation
- B Hydrologic and Hydraulic Modelling
- C Flood Damages
- D Potential Flood Modification Measures (Bound in **Volume 2**)
- E Draft Flood Policy

## **LIST OF FIGURES (BOUND IN VOLUME 2)**

- 1.1 Location Plan
  
- 2.1 Existing Stormwater Drainage System at Narrandera (3 Sheets)
- 2.2 Alignment of Main Canal Embankments and Narrandera Airport Levee (2 Sheets)
- 2.3 Aerial Photograph Showing Historic Flooding at Narrandera – March 2012 Flood
- 2.4 Indicative Extent and Depths of Inundation – 1% AEP (4 Sheets)
- 2.5 Indicative Extent and Depths of Inundation – Extreme Flood (4 Sheets)
- 2.6 Longitudinal Section along Crest of Main Canal Embankments (2 Sheets)
- 2.7 Longitudinal Section along Crest of Narrandera Airport Levee
- 2.8 Time of Rise of Floodwaters
- 2.9 Indicative Extent of Inundation and Location of Vulnerable Development and Critical Infrastructure (3 Sheets)
- 2.10 Indicative Extent and Depths of Inundation – Partial Failure of Southern Main Canal Embankment - 1% AEP Murrumbidgee River Flooding Only (3 Sheets)
- 2.11 Impact of Partial Failure of Southern Main Canal Embankment on Flooding Behaviour – 1% AEP Murrumbidgee River Flooding Only (3 Sheets)
- 2.12 Potential Impact of Future Urbanisation on Flooding and Drainage Patterns – 1% AEP Local Catchment Flood (3 Sheets)
- 2.13 Potential Impact of Climate Change on Flooding and Drainage Patterns – 1% AEP (3 Sheets)
- 2.14 Flood Hazard and Hydraulic Categorisation of Floodplain – 1% AEP (3 Sheets)
- 2.15 Narrandera LEP 2013 Zoning
  
- 3.1 Assessed Flood Modification Measures
- 3.2 Typical Sections of Assessed Levee and Embankment Upgrade Options
- 3.3 Key Features of Detention Basin Strategy (Option 1)
- 3.4 Key Features of Detention Basin Strategy (Option 2)
- 3.5 Key Features of Detention Basin Strategy (Option 3)
- 3.6 Flood Emergency Response Planning Classifications – 1% AEP (3 Sheets)
- 3.7 Flood Emergency Response Planning Classifications – PMF (3 Sheets)



## ABBREVIATIONS

AEP	Annual Exceedance Probability (%)
AHD	Australian Height Datum
ARI	Average Recurrence Interval (years)
ARR	Australian Rainfall and Runoff (1987 Edition)
BoM	Bureau of Meteorology
Council	Narrandera Shire Council
DECC	Department of Environment and Climate Change
FDM	Floodplain Development Manual, 2005
FMC	Floodplain Management Committee
FPL	Flood Planning Level (1% AEP flood level + freeboard)
FPA	Flood Planning Area
FRMS	Floodplain Risk Management Study
FRMP	Floodplain Risk Management Plan
FRMS&P	Floodplain Risk Management Study and Plan
LEP	Local Environmental Plan
LiDAR	Light Detection and Ranging
MFL	Minimum Floor Level
MOF MFL	Major Overland Flow Minimum Floor Level
MSF MFL	Main Stream Flooding Minimum Floor Level
NSW SES	New South Wales State Emergency Service
OEH	Office of Environment and Heritage
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
VP	Voluntary Purchase

## SUMMARY

### S1 Study Objectives

Narrandera Shire Council commissioned the review of the *Narrandera Floodplain Risk Management Study* (SKM, 2009a) (**FRMS 2009**) and the *Narrandera Floodplain Risk Management Plan* (SKM, 2009b) (**FRMP 2009**) for the township of Narrandera. The overall objectives of the present study were to review the two aforementioned documents, define the nature of flooding which occurs in the urbanised parts of Narrandera during intense rainfall events, assess the impacts of flooding on the community, review existing Council policies as they relate to development of land in flood liable areas, consider options for the management of flood affected land and to develop a contemporaneous *Floodplain Risk Management Plan* (**FRMP 2019**) for the town 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.

The present study deals with both **Main Stream Flooding** from the Murrumbidgee River and **Major Overland Flow** which occurs in the urbanised parts of the town, as well as the presently undeveloped areas immediately to its north.

### S2 Study Activities

The activities undertaken as part of present study, details of which are documented in this *Floodplain Risk Management Study* (**FRMS 2019**) report included:

1. Undertaking a consultation program over the course of the study to ensure that residents and business owners in Narrandera were informed of the objectives, progress and outcomes over the course of the study (**Appendix A**).
2. Review of flooding patterns at Narrandera for flood events up to the Extreme Flood, as determined in the *Narrandera Flood Study Review and Levee Options Assessment* (Lyll & Associates, 2015), (denoted herein as the "**Flood Study Review**"), as well as developing a new set of flood models which were used to define the nature of Major Overland Flow at Narrandera. (**Chapter 2** and **Appendix B**).
3. Assess the impact a partial failure of the embankment which runs along the southern side of Murrumbidgee Irrigation's Main Canal (denoted herein as the "**Southern Main Canal Embankment**") would have on flooding behaviour.
4. Assessment of the economic impacts of flooding, including the numbers of affected properties and estimation of damages (**Chapter 2** and **Appendix C**).
5. Review of current flood related planning controls for Narrandera Shire and their compatibility with flooding conditions (**Chapter 2**).
6. Review of existing flood warning and preparedness (**Chapter 2**).

7. Strategic review of potential floodplain management works and measures aimed at reducing flood damages, including an economic assessment of the most promising measures and the preparation of a draft *Flood Policy* to guide future development in flood prone areas (**Chapter 3** and **Appendix D**).
8. Ranking of works and measures using a multi-objective scoring system which took into account economic, financial, environmental and planning considerations (**Chapter 4**).
9. Preparation of *FRMP 2019* for Narrandera (**Chapter 5**).

### **S3 Summary of Flood Impacts**

Flooding patterns in the vicinity of Narrandera are a complex interaction between several tributary and effluent systems of the Murrumbidgee River, principally Bundidgerry Creek, Old Man Creek, the Sandy Creek system (also known as Poison Water Holes Creek on the western side of the Narrandera – Tocumwal Railway to the south of Narrandera) and Gillenbah Creek. Each of these systems performs a dual function. During local storms they provide drainage from the floodplain to the Murrumbidgee River, while in flood times they form breakouts from the river into the local floodplain. The relative importance of these breakouts to the pattern of flows varies with the magnitude of the flood event.

Water levels in the river typically rise over a number of days, where they remain near their peak for a period of about a day before receding. Heavy rainfall over Narrandera can also cause major flooding, especially along a Major Overland Flow path that extends from Henry Mathieson Oval to the inlet of a large siphon which runs underneath Murrumbidgee Irrigation's Main Canal a short distance to the west of the Newell Highway crossing. **Figures 2.4** and **2.5** show the nature of both Main Stream Flooding and Major Overland Flow at Narrandera for 1% annual exceedance probability (**AEP**) and Extreme Flood events, respectively.

While existing development at Narrandera is generally located on high ground, there are fourteen residential properties that are located in the High Hazard Floodway zone on the Murrumbidgee River floodplain south of the Main Canal. There are also three dwellings that are located in a High Hazard Flood Storage area on the southern side of the Main Canal along Sudgeon Street.

#### **Damages Resulting from Main Stream Flooding**

At the 1% AEP level flooding, 49 individual residential type buildings would experience above-floor inundation. While sixteen commercial/industrial buildings would also be flooded above-floor level, no public buildings would experience above-floor inundation at the 1% AEP level of flooding. The total flood damage relating to property that is located on the Murrumbidgee River floodplain at Narrandera is \$6.79 Million, but could be as high as \$9.59 Million after taking into account freeboard provisions.

The average annual cost of flooding to the community as a whole for all floods up to 1% AEP in magnitude is estimated to be about \$330,000. On this basis, the *Present Worth Value* of damages at Narrandera resulting from all floods up to the magnitude of the 1% AEP at a seven per cent discount rate and 50 year economic life is \$4.4 Million, but could be as high as \$6.3 Million after taking into account freeboard provisions. This latter value represents the amount of capital spending which would be justified if a particular flood mitigation scheme prevented flooding for all properties that are located on the Murrumbidgee River floodplain up to the 1% AEP event.

While the *Flood Study Review* found that the partial failure of the earthen embankment which runs along the southern side of Murrumbidgee Irrigation's Main Canal (**Southern Main Canal Embankment**) would exacerbate flooding conditions in a number of residential and commercial properties, the *Present Worth Value* of damages resulting from a partial failure of the embankment for all floods up to the magnitude of the 1% AEP at a seven per cent discount rate and 50 year economic life is only \$290,000. This value represents the amount of capital spending which could be justified in upgrading the Southern Main Canal Embankment at Narrandera.

#### **Damages Resulting from Major Overland Flow**

At the 1% AEP level of flooding, 82 individual residential type buildings would experience above-floor inundation. While twenty-seven commercial/industrial buildings would also be flooded above-floor level, only two public buildings would experience above-floor inundation at the 1% AEP level of flooding. The total flood damage relating to property that is located on the northern (town) side of the Main Southern Canal Embankment is \$8.76 Million, but could as high as \$18.16 Million after taking into account freeboard provisions.

The *Present Worth Value* of damages at Narrandera resulting from all storms up to 1% AEP in intensity at a seven per cent discount rate and 50 year economic life is \$7.3 Million, but could be as high as \$17.3 Million after taking into account freeboard provisions. This latter value represents the amount of capital spending which would be justified if a particular flood mitigation scheme prevented flooding for all properties that are located on the northern (town) side of the Main Canal up to the 1% AEP event.

#### **S4 Flood Risk and Development Controls**

A draft *Flood Policy* has been prepared to guide future development in flood prone areas in Narrandera (refer **Appendix E**). The policy is based on the two types of flooding that are present at Narrandera: the deep and relatively slow rising flow in the Murrumbidgee River, and the shallow and slow moving flow in the Major Overland Flow paths. Controls over development are graded according to the flood risk. The delineation of flood risk zones is based on the proximity to flow paths, depths and velocities of flow, the rate of rise of floodwaters and ease of evacuation from the floodplain in the event of a flood emergency.

**Figure E1.1** in the *Flood Policy* is an extract from the *Flood Planning Map* relating to Narrandera and its immediate environs. The extent of the Flood Planning Area (**FPA**) (the area subject to flood related development controls) is shown in a solid red colour on the *Flood Planning Map* and has been defined as follows:

- In areas subject to Main Stream Flooding, the FPA is based on the traditional definition of the area inundated by the 1% AEP plus 500 mm freeboard.<sup>1</sup>
- In areas subject to Major Overland Flow, the FPA is defined as the extent of the High and Low Hazard Floodway zones, as well as areas where depths of inundation in a 1% AEP event exceed 100 mm.

The illustration in **Section 5.8.1** of *FRMP 2019* (refer **Chapter 5** of this report) demonstrates the derivation of the FPA in areas affected by Main Stream Flooding and Major Overland Flow. For areas outside the FPA shown on the *Flood Planning Map*, the FPA is defined as land which lies

---

<sup>1</sup> This includes the area which lies on the northern side of the Main Canal which would be subject to Main Stream Flooding should the Southern Main Canal Embankment fail during a 1% AEP flood event.

below the peak 1% AEP flood level plus 500 mm freeboard. An Outer Floodplain has also been defined comprising the additional land flooded between the extent of the FPA and the Extreme Flood, as shown on the *Flood Planning Map*.

Minimum Floor Level (**MFL**) requirements would be imposed on future development in properties that are identified as lying either partially or wholly within the extent of the FPA shown on the *Flood Planning Map*. The MFLs for all land use types affected by Main Stream Flooding is the level of the 1% AEP flood event plus 500 mm freeboard, while the MFLs for all land use types affected by Major Overland Flow is the level of the peak 1% AEP flood event plus 300 mm freeboard. The illustration in **Section 5.8.1** of *FRMP 2019* (refer **Chapter 5** of this report) demonstrates the application of the variable freeboard approach in the derivation of the MFL requirements in areas subject to Main Stream Flooding and Major Overland Flow.

## **S5 FRMP 2019**

The *Flood Study Review* assessed the technical and economic feasibility of the flood modification measures that formed part of *FRMP 2009*, as well as a number of alternative measures which were aimed at achieving the same flood mitigation objectives. The *Flood Study Review* concluded that a scheme involving the following components best achieved the flood mitigation objectives of *FRMP 2009*:

- the upgrade the Southern Main Canal Embankment where it runs from the Narrandera Regulator to Irrigation Way;
- the upgrade of a portion of the levee which protects the Narrandera Airport, as well as several lengths of additional levee in the vicinity of Nallabooma Estate, the longest of which would be located along Weir Park Road;
- a ring levee around the existing water supply pumping station which is located on the northern bank of the Murrumbidgee River a short distance upstream of the Newell Highway bridge crossing; and
- raising of Old Brewery Road between the Newell Highway and the aforementioned water supply pumping station.

The scheme, which was denoted the **Ultimate Flood Protection Scheme** in the *Flood Study Review*, was estimated to cost a total of \$10.2 Million and had a benefit cost ratio of 0.35. While the design and construction of the Ultimate Flood Protection Scheme does not form part of *FRMP 2019*, it does include a number of investigations which would assist in refining the scope of the scheme, including both its capital cost and the benefits that it would provide to the community.

*FRMP 2019* showing recommended flood management measures for Narrandera is presented in **Table S1**. They have been given a provisional priority ranking, confirmed by the Floodplain Risk Management Committee, according to a range of economic, social, environmental and other criteria set out in **Table 4.1** of the report.

*FRMP 2019* includes the following twelve measures:

- **Measure 1** - The application of the graded set of planning controls for future development that recognise the location of the development within the floodplain; to be applied through the draft *Flood Policy* for Narrandera, included in the report as **Appendix E**. Application of these controls by Council will ensure that future developments in flood liable areas at Narrandera are compatible with the flood risk.

- **Measure 2** – Updating of the wording in Clause 6.2 of the *Narrandera Local Environmental Plan 2013 (Narrandera LEP 2013)* titled *Flood planning*, the inclusion of a new clause 6.2A titled *Floodplain risk management* and the rezoning of land to the south of the Main Canal which is presently zoned *RU5 – Village* and lies within the Inner Floodplain (Hazard Category 1) flood zone to *E2 – Environmental Conservation* and a new zone centred on the Newell Highway at Gillenbah which would incorporate both new and existing development of a commercial nature. The changes to *Narrandera LEP 2013* will permit the adoption of the *Flood Policy* and ensure that future residential development is located in areas where there is an acceptable level of flood risk.
- **Measures 3 and 4** - Improvements in the NSW SES's emergency planning, including use of the flood related information contained in this study to assist with the update of the *Local Flood Plan* for Narrandera Shire. Information in this present report and in the *Flood Study Review* which would be of assistance to NSW SES in the update of the *Local Flood Plan* includes data on the nature and extent of flooding in Narrandera, times of rise of floodwaters, duration and depth of inundation at major road crossings for a range of flood events and properties affected by flooding.
- **Measure 5** - Commissioning of a detailed engineering study to assess the feasibility of upgrading the section of the Southern Main Canal Embankment which runs between the Narrandera Regulator and Irrigation Way. The feasibility study is to include a geotechnical investigation which will assess the structural integrity of the existing embankment and determine the scope of works which would be required to ensure that it will function as a formal flood protection levee during major floods on the Murrumbidgee River. The measure also includes a requirement to liaise with Murrumbidgee Irrigation to determine the operating protocols for the regulators at Narrandera, as this information will influence the decision on the scope of the Ultimate Flood Protection Scheme. Depending on the outcome of the detailed engineering study and **Measure 6**, Narrandera Shire Council is to proceed to concept design initially and then subject to the availability of Government Funding, detailed design and construction of the Ultimate Flood Protection Scheme.
- **Measure 6** - Commissioning of a crest level survey along the section of the Narrandera Airport Levee that was recently upgraded by Narrandera Shire Council. The measure also includes the commissioning of a geotechnical investigation to assess the level of compaction which was achieved when the fill material was placed along the upgraded section of levee. Depending on the outcome of the crest level survey, geotechnical investigation and **Measure 5**, Narrandera Shire Council is to proceed to concept design initially and then subject to the availability of Government Funding, detailed design and construction of the Ultimate Flood Protection Scheme.
- **Measure 7** - Commissioning of a detailed engineering study to assess the feasibility of constructing a ring levee around the water supply pumping station that is located on the northern bank of the Murrumbidgee River a short distance east (upstream) of the Newell Highway in combination with raising Old Brewery Road. The study would need to include a geotechnical investigation to assess the foundation requirements for the ring levee, as well as an assessment of whether raising Old Brewery Road would have an impact on flooding behaviour in existing development for events more frequent than 1% AEP. Depending on the outcome of the detailed engineering study, Narrandera Shire Council is to proceed to the detailed design and construction of the ring levee.

- **Measure 8** - Commissioning of a detailed engineering study to assess the feasibility of constructing two detention basins in the upper reaches of an 11 km<sup>2</sup> catchment runoff from which is the major cause of flood damages in the urbanised parts of Narrandera (denoted herein as “**Detention Basin Strategy (Option 2)**”). This would include a geotechnical investigation to assess the foundation conditions along the alignment of the basin embankments, as well as the preparation of a concept design of the works.
- **Measure 9** - Depending on the outcome of the feasibility study undertaken as part of Measure 8, Council apply for Government Funding to undertake the detailed design and construction of Detention Basin Strategy (Option 2).
- **Measure 10** – Design and construction of temporary flood storage works adjacent to the existing siphon which is located near Woolscour Road (denoted herein as the “**Woolscour Siphon Works (Option 3)**”).
- **Measure 11** – Preparation of a *Voluntary Purchase and House Raising Feasibility Study* for the fourteen residential properties that are located on the southern side of the Main Canal in the High Hazard Floodway zone (which are eligible for inclusion in a Voluntary Purchase Scheme) and the three dwellings that are located in a High Hazard Flood Storage area immediately south of the Main Canal along Sudgeon Street (which are eligible for inclusion in a Voluntary House Raising Scheme). Although subject to the agreement by the affected owners, this measure includes the cost of purchasing the fourteen properties and the raising of the three dwellings.

## **S6 Community Reaction to FRMP 2019**

A Community Workshop was held in Narrandera during the public exhibition of the draft document. While advertised via a media release, on the local radio, in the local newspaper and on Council’s Facebook page, the workshop was not well attended, with only two property owners directly affected by the recommendation to rezone land south of the Main Canal in attendance. While one of the owners objected to the rezoning of the land, the other favoured the idea along with the opportunity to participate in the recommended Voluntary Purchase scheme.

Following the Community Workshop, Council wrote to the owners of land which would be directly affected by the recommended rezoning. By the end of the public exhibition period, 47 written responses had been received by Council, noting that one submission related to issues associated with major overland flow in the urbanised parts of Narrandera and another 26 comprised a form letter which stated that while the signatories were not directly affected by the measure, they were concerned that the changes would adversely affect the community. The form letter also stated that the signatories were opposed to the recommended rezoning of the land, as well as the recommended Voluntary Purchase scheme.

The signatories of the remaining 20 submissions were not supportive of the recommendation to rezone the land south of the Main Canal as should it proceed it would in their view:

- impact existing right users if owners wanted to redevelop their dwellings, add extensions or rebuild;
- devalue the property; and
- significantly reduce the owner’s ability to continue using the land for farming purposes.

Several respondents also questioned why the new special commercial zone at Gillenbah would only comprise existing development of a specific nature. As this was not the intent of the recommended measure, the wording in *FRMP 2019* has been updated to reflect the actual intent which is to create a land use zone which is centred on the Newell Highway at Gillenbah and comprises both existing and new development of a commercial nature.

It should be noted that the draft *Flood Policy* set out in **Appendix E** of *FRMS 2019* and which forms part of **Measure 1** of *FRMP 2019* does not support residential development other than minor additions to existing dwellings in the area which is recommended to be rezoned. While rezoning of the land to *E2-Environmental Conservation* would prevent any new residential development (including minor additions to existing dwellings) from occurring, the implementation and enforcing of the prescriptive controls set out in the draft *Flood Policy* by Council would also greatly constrain the future development potential of the land in this area.

## **S7 Timing and Funding of FRMP Measures**

The total estimated cost to implement the preferred floodplain management strategy is **\$5.86 Million**, exclusive of Council and NSW SES Staff Costs. The timing of the measures will depend on Council's overall budgetary commitments and the availability of both Local and State Government funds.

Assistance for funding qualifying projects included in *FRMP 2019* may be available upon application under the Commonwealth and State funded floodplain management programs, currently administered by Office of Environment and Heritage.

## **S8 Council Action Plan**

1. Council finalises the *FRMS 2019* report and approves *FRMP 2019* according to the procedure recommended in **Section 5.13**.
2. Council and NSW SES commence work on the "non-structural" measures in the *FRMP (Measures 1 to 4)*.
3. Council applies for Government Funding for the investigation comprising **Measure 8** of the *FRMP*.
4. Council applies for Government Funding to undertake the detailed design and construction of Detention Basin Strategy (Option 2) (**Measure 9**).
5. Council applies for Government Funding for the investigations comprising **Measures 5 to 7** of the *FRMP*.
6. Council commissions a *Voluntary Purchase and House Raising Feasibility Study* which deals with the fourteen residential properties that are located to the south of Main Canal in the High Hazard Floodway zone (which are eligible for inclusion in a Voluntary Purchase Scheme) and the three properties that are located along Sudgeon Street immediately south of the Main Canal (which are eligible for inclusion in a Voluntary House Raising Scheme) (**Measure 11**). Depending on the outcome of the feasibility study and the availability of Government Funding, Narrandera Shire Council proceed with the acquisition/raising of the affected properties/dwellings.
7. Council commence the design of the Woolscour Siphon Works (Option 3) and when funds become available carry out the works (**Measure 10**).



**TABLE S1**  
**RECOMMENDED MEASURES FOR INCLUSION IN FLOODPLAIN RISK MANAGEMENT PLAN 2019**

Measure	Required Funding	Features of the Measure	Comment	Level of Importance	Works Funding Priority
1. Review flood related controls over future development in flood prone areas.	Council's staff costs	<ul style="list-style-type: none"> <li>Commence a review of planning related controls noting the recommendations of the FRMS 2019.</li> </ul>	This measure is designed to mitigate the flood risk to future development and has a high priority for inclusion in <i>FRMP 2019</i> . It does not require Government funding.	High	Not Applicable
2. Update of <i>Narrandera LEP 2013</i>	Council's staff costs	<ul style="list-style-type: none"> <li>Commence a review of Narrandera Local Environmental Plan noting the recommendations of the FRMS 2019.</li> </ul>	This measure is designed to mitigate the flood risk to future development and has a high priority for inclusion in <i>FRMP 2019</i> . It does not require Government funding.	High	Not Applicable
3. Ensure flood data in <i>FRMS 2019</i> are available to the NSW SES for improvement of flood emergency planning.	NSW SES costs	<ul style="list-style-type: none"> <li>NSW SES should update the <i>Narrandera Shire Local Flood Plan</i> using information on flooding patterns, times of rise of floodwaters and flood prone areas identified in the <i>Flood Study Review</i> and in <i>FRMS 2019</i>.</li> </ul>	This measure would improve emergency response procedures and has a high priority. It does not require Government funding.	High	Not Applicable
4. Implement flood awareness and education program for residents and business owners that are located on flood prone land.	Council staff costs	<ul style="list-style-type: none"> <li>Council to inform residents of the flood risk, based on the information presented in <i>FRMS 2019</i>. (e.g. displays of flood mapping at Council offices.</li> <li>Council to work with NSW SES to prepare flood awareness brochure for distribution with Rates notices.</li> </ul>	This measure would improve the flood awareness of the community and has a high priority. It does not require Government funding.	Medium	Not Applicable
5. Commissioning of investigation to assess requirements for upgrading the Southern Main Canal Embankment.	\$80,000	<ul style="list-style-type: none"> <li>A geotechnical investigation is to be carried out to assess the structural integrity of the existing embankment and to determine the upgrade requirements to ensure that it would function as a formal flood protection levee during a major flood on the Murrumbidgee River.</li> <li>Refine concept design prepared in <i>Flood Study Review</i></li> <li>Update cost estimate for the works.</li> <li>Further liaison is required with Murrumbidgee Irrigation to determine the operating protocols for the regulators at Narrandera, as well as their stage-discharge relationships.</li> <li>Depending on the outcome of the detailed engineering study and <b>Measure 6</b>, Narrandera Shire Council is to proceed to the concept design initially and then subject to the availability of Government Funding, detailed design and construction of the Ultimate Flood Protection Scheme.</li> </ul>	This measure would assist in the ongoing assessment of whether the Southern Main Canal Embankment is suitable to form part of a large-scale flood mitigation scheme at Narrandera.	High	3
6. Commissioning of a ground survey and geotechnical investigation for the recently upgraded section of the Narrandera Airport Levee.	Council costs	<ul style="list-style-type: none"> <li>As there are no details presently available on the crest height or the level of compaction which was achieved when placing the fill material along the recently upgraded section of the Narrandera Airport Levee it is recommended that a detailed ground survey and geotechnical investigation be commissioned by Council.</li> <li>Depending on the outcome of the crest level survey, geotechnical investigation and <b>Measure 5</b>, Narrandera Shire Council is to proceed to the concept design initially and then subject to the availability of Government Funding, detailed design and construction of the Ultimate Flood Protection Scheme.</li> </ul>	This measure would assist in the ongoing assessment of which sections of the Narrandera Airport Levee would need to be upgraded should the decision be made to construct a large-scale flood mitigation scheme at Narrandera.	High	5
7. Investigation and concept design of water supply pumping station ring levee and Old Brewery Road upgrade.	\$50,000	<ul style="list-style-type: none"> <li>Underground utilities search.</li> <li>Geotechnical investigation to assess foundation requirements for ring levee</li> <li>Hydraulic modelling to assess the impact raising Old Brewery Road would have on flooding behaviour for events more frequent than 1% AEP.</li> <li>Refine concept design prepared in <i>Flood Study Review</i> for Old Brewery Road upgrade.</li> <li>Cost-benefit analysis to confirm the economic feasibility of the schemes and establish priorities for implementation.</li> <li>Depending on the outcome of the detailed engineering study, Narrandera Shire Council is to proceed to the detailed design and construction of the ring levee.</li> </ul>	This measure would mitigate existing flooding problems. It would require Council and Government funding.	High	7

Cont'd Over

**TABLE S1 (Cont'd)**  
**RECOMMENDED MEASURES FOR INCLUSION IN FLOODPLAIN RISK MANAGEMENT PLAN 2019**

Measure	Required Funding	Features of the Measure	Comment	Level of Importance	Works Funding Priority
8. Investigation and concept design of Detention Basin Strategy (Option 2).	\$120,000	<ul style="list-style-type: none"> <li>Underground utilities search.</li> <li>Geotechnical investigation to assess foundation conditions and basin embankment requirements.</li> <li>Hydraulic modelling to confirm sizes of the key elements comprising Detention Basin Strategy (Option 2)</li> <li>Refine concept designs and cost estimates prepared in <i>FRMS 2019</i> to the Preliminary Design Stage.</li> <li>Cost-benefit analysis to confirm the economic feasibility of the schemes and establish priorities for implementation.</li> <li>Prepare a submission for Council and Government funding for detailed design and construction.</li> </ul>	This measure would mitigate existing flooding problems. It would require Council and Government funding.	High	1
9. Detailed design and construction of Detention Basin Strategy (Option 2).	\$2.48 Million	<ul style="list-style-type: none"> <li>Tasks involved are as follows:                             <ul style="list-style-type: none"> <li>Prepare detailed design and documentation for Detention Basin Strategy (Option 2).</li> <li>Prepare a submission for Council and Government funding.</li> <li>Construct drainage improvements.</li> </ul> </li> </ul>	This measure would mitigate existing flooding problems. It would require Council and Government funding. Note the required funding is an indicative present worth cost based on preliminary analyses undertaken in <i>FRMS 2019</i> .	High	2
10. Detailed design and construction of Woolscour Siphon Works (Option 3).	Council costs	<ul style="list-style-type: none"> <li>Prepare detailed design and documentation for Woolscour Siphon Works (Option 3).</li> <li>Construct drainage improvement works when funds become available.</li> </ul>	This measure would mitigate existing flooding problems. It would require Council to fully fund the work.	High	6
11. Commission <i>Voluntary Purchase and House Raising Feasibility Study</i> at an estimated cost of \$30,000 for fourteen residential properties that are located to the south of the Main Canal in the High Hazard Floodway zone and raise three dwellings that are located to the south of the Main Canal embankment along Sudgeon Street (Allocated amount of \$3.1 Million assumes all affected property owners opt into the two schemes)	\$3.13 Million	<ul style="list-style-type: none"> <li>Recommend existing dwellings be removed from the floodplain via the Voluntary Purchase scheme.</li> <li>The three dwellings are located in a hazard flood storage area where the depths of above-floor inundation exceeds 0.5 m in a 1% AEP flood event. While not economically justified, the three dwellings are located in a High Hazard Flood Storage area and should be raised 500 mm above the peak 1% AEP flood level to prevent damaging flooding from occurring on a relatively frequent basis.</li> </ul>	This measure would reduce the flood risk to occupiers of the floodplain, as well as removing existing residential development from the High Hazard Floodway zone. It would require Council and Government funding.	High	4
<b>Total Estimated Cost</b>	<b>\$5.86 Million</b>				

## 1 INTRODUCTION

### 1.1 Study Background

Narrandera Shire Council (**Council**) commissioned the *Review of the Narrandera Floodplain Risk Management Study* (SKM, 2009a) (**FRMS 2009**) and the *Narrandera Floodplain Risk Management Plan* (SKM, 2009b) (**FRMP 2009**) for the township of Narrandera in accordance with the New South Wales Government's Flood Prone Land Policy. This report sets out the findings of the review which utilises the flood models that were developed as part of the *Narrandera Flood Study Review and Levee Options Assessment* (Lyall & Associates, 2015) (**Flood Study Review**), as well as a new set of flood models that were used to define the nature of Major Overland Flow at Narrandera. **Figure 1.1** shows the location of Narrandera, which lies about 100 km to the west of Wagga Wagga on the northern limits of the Murrumbidgee River floodplain.

The present study (**FRMS 2019**) reviewed baseline flooding conditions, including an assessment of economic impacts and the feasibility of potential measures aimed at reducing the impact of flooding on both existing and future development. This process allowed the formulation of a contemporaneous *Floodplain Risk Management Plan* for Narrandera (**FRMP 2019**).

**FRMS 2019** deals with both **Main Stream Flooding** from the Murrumbidgee River and **Major Overland Flow** which occurs in the urbanised parts of the town, as well as the presently undeveloped areas immediately to its north.

### 1.2 Background Information

The following documents were used in the preparation of this report.

- *Floodplain Development Manual* (New South Wales Government (NSW Government, 2005)
- *Narrandera Flood Study* (SKM, 2000)
- *Narrandera Floodplain Risk Management Study* (SKM, 2009a) (**FRMS 2009**)
- *Narrandera Floodplain Risk Management Plan* (SKM, 2009b) (**FRMP 2009**)
- *Narrandera Levee Audit 2013* (NSW Public Works, 2013)
- *Narrandera Local Environmental Plan 2013*
- *Narrandera Development Control Plan 2013*
- *Narrandera Shire Flood Emergency Sub Plan* (NSW State Emergency Service, 2015)
- *Narrandera Flood Study Review and Levee Options Assessment* (Lyall & Associates, 2015) (**Flood Study Review**)

### 1.3 Overview of FRMS 2019 Report

The findings of the present study, as well as **FRMP 2019** are set out in this report. Contents of each Chapter of the report are briefly outlined below:

- **Chapter 2, Baseline Flooding Conditions.** This Chapter includes a description of the drainage system and a review of existing flood behaviour at Narrandera, for land subject to both Main Stream Flooding and Major Overland Flow, as derived by hydrologic models and hydraulic models that were developed as part of the *Flood Study Review*, as well as the present study (refer **Appendix B** for details). The Chapter also summarises the economic impacts of flooding on existing urban development, reviews Council's flood planning controls

and management measures and the NSW State Emergency Service's (**NSW SES's**) flood emergency planning. The Chapter also assesses the impacts of future urbanisation in the catchments, as envisaged by *Narrandera Local Environmental Plan 2013*.

- **Chapter 3, Potential Floodplain Management Measures.** This Chapter reviews the feasibility of floodplain management options for their possible inclusion in *FRMP 2019*. The list of measures considered is based on input from the Community Consultation process, which sought the views of residents and business owners in Narrandera on the range of measures which are set out in *FRMP 2009*, as well as other potential flood management measures which could be included in *FRMP 2019*. The measures are investigated at the strategic level of detail, including indicative cost estimates of the most promising measures and a benefit/cost analysis.
- **Chapter 4, Selection of Floodplain Management Measures.** This Chapter assesses the feasibility of potential floodplain management strategies using a multi-objective scoring procedure which was developed in consultation with the Floodplain Risk Management Committee (**FRMC**) and outlines the preferred strategy.
- **Chapter 5** presents *FRMP 2019* which comprises a number of structural and non-structural measures which are aimed at increasing the flood awareness of the community and ensuring that future development is undertaken in accordance with the local flood risk. A number of investigations are recommended, along with the design and construction of flood modification measures which are aimed at mitigating the impact of Major Overland Flow on existing development.
- **Chapter 6** contains a glossary of terms used in the study.
- **Chapter 7** contains a list of References.

Five technical appendices provide further information on the study results:

**Appendix A – Community Consultation** summarises residents' and business owners' views on potential flood management measures which could be incorporated in *FRMP 2019*.

**Appendix B – Hydrologic and Hydraulic Modelling** contains background to the development of hydrologic and hydraulic computer models that were developed in order to define the nature of Major Overland Flow at Narrandera.

**Appendix C – Flood Damages** is an assessment of the economic impacts of flooding to existing residential, commercial and industrial development, as well as public buildings in Narrandera. The damages have been assessed using the hydraulic models that were developed as part of the *Flood Study Review* and the present study, as well as the property database that was first developed as part of *FRMS 2009* and subsequently expanded as part of the *Flood Study Review* and the present study.

**Appendix D - Potential Flood Modification Measures** comprises a series of figures which show the impact a range of potential flood modifications measures would have on the behaviour of both Main Stream Flooding and Major Overland Flow at Narrandera. The figures comprising **Appendix D** are bound in Volume 2 of the report.

**Appendix E – Draft Flood Policy** presents guidelines for the control of future urban development in flood prone areas at Narrandera. The guidelines cater for both Main Stream Flooding of the river system, as well as Major Overland Flow resulting from surcharging of the trunk drainage systems in the overland flow paths draining the developed parts of Narrandera.

## 1.4 Community Consultation

Following the Inception Meeting of the FRMC which included Council, the Office of Environment and Heritage (OEH), NSW SES, NSW Public Works Advisory and community representatives, a *Community Newsletter* was prepared by the Consultants and distributed to residents and business owners in Narrandera. The *Community Newsletter* contained a *Community Questionnaire* seeking details from the community of flood experience and attitudes to the floodplain management measures which formed *FRMP 2009*, as well as a range of other potential floodplain management measures. Community responses are summarised in **Chapter 3** of the report, with supporting information in **Appendix A**.

The FRMC reviewed the potential flood management measures developed in **Chapter 3** and assessed the measures using the proposed scoring system of **Chapter 4**. The draft of *FRMS 2019* and the accompanying draft *FRMP 2019* were also reviewed by the FRMC and amended prior to public exhibition.

A Community Workshop that was advertised on the local radio, in the local newspaper and on Council's Facebook page was held in Narrandera during the public exhibition period. The workshop was attended by only two property owners, both of whom were directly affected by the recommendation to rezone land that is located to the south of the Main Canal from *RU5 – Village* to *E2 – Environmental Conservation*. While one of the property owners objected to the rezoning of the land, the other favoured the idea along with the opportunity to participate in the recommended Voluntary Purchase scheme.

Following the Community Workshop, Council wrote to the owners of properties that would be directly affected by the recommendation to rezone land south of the Main Canal. By the end of the public exhibition period, 47 written submissions had been received by Council, noting that one submission related to issues associated with major overland flow in the urbanised parts of Narrandera and another 26 comprised a form letter which stated that while the signatories were not directly affected by the measure, they were concerned that the changes would adversely affect the community. The form letter also states that the signatories are opposed to the recommended rezoning of the land, as well as the recommended Voluntary Purchase scheme.

The signatories of the remaining 20 submissions were not supportive of the recommendation to rezone the land from *RU5 – Village* to *E2 – Environmental Conservation* as should it proceed it would in their view:

- impact existing right users if owners wanted to redevelop their dwellings, add extensions or rebuild;
- devalue the property; and
- significantly reduce the owner's ability to continue using the land for farming purposes.

Several respondents also questioned why the new special commercial zone at Gillenbah would only comprise existing development. As this was not the intent of the recommended measure, the wording in the report has been updated to reflect the actual intent which is to create an area of land centred on the Newell Highway at Gillenbah where both existing and new development can be built of a commercial nature.

## 1.5 Flood Frequency and Terminology

In this report, the frequency of floods is referred to in terms of their Annual Exceedance Probability (**AEP**). The frequency of floods may also be referred to in terms of their Average Recurrence Interval (**ARI**). The approximate correspondence between these two systems is:

Annual Exceedance Probability (AEP) – %	Average Recurrence Interval (ARI) – years
0.2	500
0.5	200
1	100
10	10
20	5

The AEP of a flood represents the percentage chance of its being equalled or exceeded in any one year. Thus a 1% AEP flood, which is equivalent to a 100 year ARI, has a 1% chance of being equalled or exceeded in any one year and would be experienced, on the average, once in 100 years; similarly, a 20 year ARI flood has a 5% chance of exceedance, and so on.

In the *Flood Study Review*, flooding patterns on the Murrumbidgee River floodplain were assessed for design floods ranging between a 20% AEP event and the Extreme Flood, noting that the Extreme Flood was assumed to have a peak flow equal to 3 times the 1% AEP event. The definition of Major Overland Flow in the urban parts of Narrandera was also defined for storms with AEPs of between 20 and 0.2 per cent, as well as the Probable Maximum Flood, which was defined using procedures which are set out in the Bureau of Meteorology's (**BoM's**) *Bulletin 53* (BoM, 2003).

Note that in this report, reference is sometimes made to the Extreme Flood when referring collectively to flooding that results from both Main Stream Flooding and Major Overland Flow.

## 2 BASELINE FLOODING CONDITIONS

### 2.1 Physical Setting

Narrandera has a population of about 4,000 and is located on the Murrumbidgee River about 100 km to the west (downstream) of Wagga Wagga. A large irrigation canal which is owned by Murrumbidgee Irrigation and is named the Main Canal separates the township of Narrandera from the Murrumbidgee floodplain. The earth embankments which run along either side of the Main Canal (denoted herein as the “**Northern and Southern Main Canal Embankments**”) act to reduce the impact of Main Stream Flooding on parts of Narrandera.

While the majority of the town is situated on high ground, residential and commercial development is present on the Murrumbidgee River floodplain to the south of the Main Canal. These areas include the Nallabooma Estate, which is located near the Narrandera Airport, and Gillenbah which is located on the southern side of the Murrumbidgee River due south of the township.

There are about 145 residential buildings located on the Murrumbidgee River floodplain south of the Main Canal. Twenty-two of these are located at Gillenbah on the southern side of the Murrumbidgee River, while a further 50 are located in the vicinity of Narrandera Airport.<sup>2</sup> The remaining 73 are located between the Main Canal and the Murrumbidgee River in the vicinity of the Newell Highway and the dis-used Narrandera Tocumwal Railway corridors. A Caltex petrol station, the Newell Motor Inn, and the Narrandera Caravan Park are also located at Gillenbah.

The Narrandera Airport is located to the west of Narrandera and is owned and operated by Council. The airport is utilised by Rex Regional Express as part of its daily Sydney-Griffith-Narrandera service. An earthen ring levee has been constructed around the perimeter of the airport, further details on which are set out in **Section 2.5** (denoted herein as the “**Narrandera Airport Levee**”).

**Figure 2.1** (3 sheets) shows the layout of the drainage system in the vicinity of Narrandera, as well as the locations of dwellings that are located on the Murrumbidgee River side of the Main Canal, while **Figure 2.2** shows the alignment of the Northern and Southern Main Canal Embankments, as well as the Narrandera Airport Levee.

### 2.2 Drainage System

#### 2.2.1 Murrumbidgee River Floodplain

Flooding patterns in the vicinity of Narrandera are a complex interaction between several tributary and effluent systems of the Murrumbidgee River, principally Bundidgerry Creek, Old Man Creek, the Sandy Creek system (also known as Poison Water Holes Creek on the western side of the Narrandera – Tocumwal Railway to the south of Narrandera) and Gillenbah Creek. Each of these systems performs a dual function. During local storms they provide drainage from the floodplain to the Murrumbidgee River, while in flood times they form breakouts from the river into the local floodplain. The relative importance of these breakouts to the pattern of flows varies with the magnitude of the flood event.

Old Man Creek is a looped flood runner that leaves the southern bank of the Murrumbidgee River downstream of Wagga Wagga and re-joins approximately 17 km upstream of Narrandera. In times of flood, Old Man Creek fills due to breakouts and also due to high tailwater levels at its

---

<sup>2</sup> Note that 31 of the 50 buildings that are located in the vicinity of Narrandera Airport are located in Nallabooma Estate.



downstream end. During major floods, it breaks its banks and flows into the headwaters of Sandy Creek.

Sandy Creek is an ephemeral tributary of the Murrumbidgee River that has a small catchment centred on the village of Kywong. It is a receiver of breakouts from Old Man Creek and contributes to flows in Poison Waterholes Creek, which runs in a westerly direction to Narrandera before turning northwards to cross the Newell and Sturt Highways before flowing into the southern bank of the river.

Bundidgerry Creek is a northern branch of the Murrumbidgee River diverging from the river at Berembred Weir where water is extracted to supply the Main Canal. (The Main Canal upstream of Narrandera is also referred to as Bundidgerry Creek.) Until it was re-formed to perform the function of the Main Canal, Bundidgerry Creek re-joined the river to the south of the Narrandera township. Approximately 8 km upstream of Narrandera, the Bundidgerry regulator controls flow diverted into the Main Canal from the creek. In times of flood the canal is protected by diverting excess water at the regulator south into the floodplain.

In the vicinity of Narrandera, Gillenbah Creek is a looped flood runner that breaks out of the river approximately 2 km south of Narrandera and initially flows south, crossing the Sturt Highway before turning west and flowing across the Newell Highway and through the railway viaduct before turning north across the Sturt Highway and re-joining the river to the west of the township.

There are a number of stream gauges located along the Murrumbidgee River both upstream and downstream of Narrandera. These gauges, which are owned and operated by WaterNSW are used by various agencies to monitor water levels and flows in the river system for environmental, irrigation and flood flow purposes. A summary of the WaterNSW operated stream gauges in the vicinity of Narrandera is presented in **Table 2.1**.

**TABLE 2.1**  
**STREAM GAUGE DATA AT NARRANDERA<sup>(1,2)</sup>**

Station Number	Gauge Name	Period of Record
410001	Murrumbidgee River at Wagga Wagga	1894 to date
410005	Murrumbidgee River at Narrandera	1942 to date
410007	Yanco Creek at Offtake	1916 to date
410021	Murrumbidgee River at Darlington Point	1926 to date
410023	Murrumbidgee River at Downstream of Berembred Weir	1916 to date
410036	Murrumbidgee River at Downstream of Yanco Weir	1927 to date

1. Gauges listed in ascending gauge number order.
2. Refer **Figure 1.1** for location of stream gauges that are currently in operation.

### 2.2.2 Local Stormwater Drainage System

The layout of the stormwater drainage system at Narrandera is shown on **Figure 2.1** (3 sheets). The stormwater drainage system in the less urbanised parts of Narrandera generally comprises piped crossings at road intersections and at low points in roads. In the more urbanised parts of the town, the stormwater drainage system comprises numerous piped crossings at road intersections, as well as several trunk drainage lines.

Two pipes control local catchment runoff from behind the Northern Main Canal Embankment at Narrandera. The largest of the two comprises a 1800 mm diameter pipe which is located immediately to the west of the Newell Highway. The pipe extends beneath the Main Canal onto the Murrumbidgee River floodplain and functions as a siphon (denoted herein as the “**Town Siphon**”). The Town Siphon, the location of which is shown on **Figure 2.1**, sheet 3 controls a largely urbanised catchment of about 11 km<sup>2</sup> and has a penstock gate fitted to its outlet. During periods of heavy rain or when the penstock gate is closed, runoff is forced to pond behind the Northern Main Canal Embankment where it inundates the rear of several residential properties which are located along Larmer Street.

The second smaller pipe is 600 mm in diameter and is located immediately to the east of Woolscour Road. The pipe also functions as a siphon, with flow discharging to a channel which is located on the Murrumbidgee River side of the Main Canal (denoted herein as the “**Woolscour Road Siphon**”). The inlet of the Woolscour Road Siphon, the location of which is shown on **Figure 2.1**, sheet 3 has a penstock gate type arrangement fitted to it so as to prevent backwater flooding from occurring during periods of elevated water levels in the Main Canal.

While the catchment which generates flow in the Town Siphon has its headwaters to the north of the Junee Hay Railway, a continuous piped drainage system only commences in the vicinity of Narrandera High School on the southern side of the rail corridor. The enclosed section of the drainage system generally runs in a westerly direction where it runs through the central business district of Narrandera.

In the northern parts of Narrandera, new drainage lines have been constructed to control runoff from a new residentially developed area that is located along Boundary Road and Lettie Street, as well as in the Red Hill industrial area along Driscoll Road. Both of these drainage lines discharge into existing semi-natural drainage channels. A drainage line also conveys stormwater from the northern side of the Junee Hay Railway in the vicinity of Myrtle Street toward the south where it discharges into Cadell Street.

### 2.3 Recent Flood Experience

**Table 2.2** over sets out the peak heights that were recorded by the Murrumbidgee River at Narrandera stream gauge (GS 410005) (**Narrandera stream gauge**) during the ten largest floods to have been experienced at Narrandera since 1900. The following three historic floods for which flood data are available were used to calibrate the hydraulic models that were developed as part of the *Flood Study Review*:

- The September 1974 flood was typical of major flood events, originating from the catchment upstream of Wagga Wagga, with a three day travel time to Narrandera and an attenuation of the flood peak from 5,711 m<sup>3</sup>/s to 3,078 m<sup>3</sup>/s. Inspection of the daily rainfall records at stations in the catchment between these two centres indicated that contributions to flows in the Murrumbidgee River from the tributaries would have been quite small. This is confirmed by the shape of the single peaked discharge hydrograph at Narrandera, which rose sharply over a period of 24 hours, from around 500 m<sup>3</sup>/s to its 3,078 m<sup>3</sup>/s peak.<sup>3</sup>

---

<sup>3</sup> It is noted that the September 1974 flood pre-dated the construction of the three bridges on the Newell Highway south of the Main Canal crossing (1983 completion date). As a result, flooding patterns observed in the vicinity of the highway crossing during this historic flood would have been different to those observed during the March 2012 flood when the river peaked at about the same level on the Narrandera stream gauge.

**TABLE 2.2**  
**FLOOD HISTORY AND DESIGN FLOOD LEVELS<sup>(1,2,3,4,5)</sup>**  
**MURRUMBIDGEE RIVER AT NARRANDERA STREAM GAUGE**

Flood Event	Gauge Height (m)
Extreme Flood	11.47
0.2% AEP	10.10
0.5% AEP	9.62
1% AEP	9.28
2% AEP	9.10
September 1974	9.01
March 2012	9.00
June 1931	8.71
5% AEP	8.50
July 1900	8.31
Major Flood <sup>(5)</sup>	8.2
10% AEP	8.19
June 1925	8.18
April 1989	8.13
November 1975	8.08
December 2010	8.03
October 2016	8.01
July 1991	7.97
20% AEP	7.68
Moderate Flood <sup>(6)</sup>	7.3
Minor Flood <sup>(6)</sup>	6.7

1. Gauge zero = 137.391 m AHD
2. Only the ten highest recorded floods are included in the table.
3. Source of historic peak heights: WaterNSW online river data
4. Source of design flood levels: *Flood Study Review*
5. Peak design flood levels based on the hydraulic roughness values which were found to provide a good fit with flood levels recorded during the March 2012 event.
6. Source: Annex C of Narrandera Shire Local Flood Plan (NSW SES, 2012)

- The March 2012 flood had a peak stage at Wagga Wagga which was only 140 mm below that of the September 1974 flood, but a much lower peak discharge (3,631 m<sup>3</sup>/s versus 5,711 m<sup>3</sup>/s). This effect is considered to be due to the growth of riparian vegetation along the river over the intervening 38 years between the two events resulting in a change in the rating curve at the gauge. At Narrandera, the peak discharge according to WaterNSW's data was 3,043 m<sup>3</sup>/s in March 2012. However, the flow was gauged near the flood peak at 2,436 m<sup>3</sup>/s. (The latter discharge of 2,436 m<sup>3</sup>/s was adopted as the peak discharge for the aforementioned model calibration process.)

As the peak levels for the two floods at Narrandera were very similar (146.40 m AHD in September 1974 versus 146.39 m AHD in March 2012), it appears that the riparian vegetation build-up in the river caused both an attenuation in the peak discharge between Wagga Wagga and Narrandera (the peak attenuated from 3,631 m<sup>3</sup>/s to 2,436 m<sup>3</sup>/s between these two centres), as well as a change in the rating curve at Narrandera. Under present day conditions a higher flood level would be experienced for a given discharge than in former times. In the model calibration process that was undertaken as part of the *Flood Study Review* the result was a considerable increase in hydraulic roughness values being required to tune the hydraulic model to the March 2012 flood (and also the smaller December 2010 event) compared with values required for the September 1974 flood. The raising of the Newell Highway where it crosses the floodplain is also said to have had an impact on flooding patterns.

Another feature observed in the recorded hydrograph at Narrandera was the shape of the rising limb which in March 2012 showed a marked rise to a flow of about 750 m<sup>3</sup>/s in the days prior to the arrival of the upriver peak from Wagga Wagga. This effect was due to runoff from the tributaries resulting from heavy rainfall experienced over the rain day of the 4<sup>th</sup> March (i.e. the 24 hour period ending at 09:00 hours on 4<sup>th</sup> March).

**Figure 2.3** (3 sheets) is an aerial photograph showing the extent of flooding that was experienced at the peak of the March 2012 flood relative to existing buildings that are located on the southern side of the Main Canal. The extent to which local catchment runoff ponded behind the Northern Main Canal Embankment and the Narrandera Airport Levee can also be observed in the aerial photography.

- The December 2010 flood was a long duration event which originated from the catchment upstream of Wagga Wagga. River levels were prolonged at Narrandera near the peak for over a week. At Narrandera, this flood peaked about 900 mm below the other two events and there appears to have been little contribution from the tributaries. In addition, a greater proportion of the overall flow was conveyed in the channels of the drainage system between Wagga Wagga and Narrandera than for the other two events. The comparatively large 40 m grid size required to achieve practical run times of the TUFLOW model that was developed as part of the *Flood Study Review* restricted its ability to model the in-bank component of the flow. Accordingly, the model fit for December 2010 in the lower range of discharges experienced during this event was not as good as for the two larger floods.

Since the completion of the *Flood Study Review*, a significant flood event occurred in October 2016, when a peak height of 8.01 m was recorded on the Narrandera stream gauge. The flood closed the Newell and Sturt Highways and affected both residential and commercial development that is located to the south of the Main Canal and had an AEP of between 10 and 20 per cent.

**Annexure A** in **Appendix B** contains several plates showing flooding that was experienced in the urbanised parts of Narrandera north of the Main Canal during an intense storm that occurred in March 2010.

## 2.4 Design Flood Behaviour

### 2.4.1 Background

The *Flood Study Review* defined the nature of Main Stream Flooding on the Murrumbidgee River floodplain at Narrandera for floods ranging between 20 and 0.2% AEP, as well as the Extreme Flood. Two hydraulic models were developed as part of the *Flood Study Review*, a brief description of which is as follows:

- **Narrandera GPU TUFLOW Model**, which extends over a distance of 140 km from Wagga Wagga to a location about 4 km downstream of the commencement of the Main Canal at the Bundidgerry regulator. This model was used to route flood flows from Wagga Wagga to Narrandera and provided information on the distribution of flows in the Murrumbidgee River and its various flood runners approaching the town.
- **Narrandera Classic TUFLOW Model**, which overlaps the Narrandera GPU TUFLOW Model by about 15 km at its upstream end and extends downstream to a location about 10 km below the Tombullen Storage. Flows derived by the Narrandera GPU TUFLOW Model were applied to the upstream boundary of the Narrandera Classic TUFLOW Model.

A third hydraulic model was developed as part of the present study which was used to define the nature of Major Overland Flow at Narrandera (**Local Catchment TUFLOW Model**). **Appendix B** contains details on the development and testing of the Local Catchment TUFLOW Model, as well as a hydrologic model that was also developed as part of the present study (**Local Catchment Hydrologic Model**).

Extents of inundation resulting from both Main Stream Flooding and Major Overland Flow at Narrandera were defined from Light Detection and Ranging (**LiDAR**) survey data which were used to develop the hydraulic models of the drainage system. The extents of inundation shown in the present study are “indicative” reflecting the accuracy of the LiDAR survey data (95 per cent of the points lie within +/- 150 mm of the true elevation).

In order to create realistic results, anomalies caused by inaccuracies in the LiDAR survey data were removed. To do this, a filter was applied to remove depths of inundation over the natural surface less than 100 mm. This had the effect of removing the very shallow depths which are more prone to be artefacts of the model, but at the same time giving a reasonable representation of the various overland flow paths.

As far as flooding on the Murrumbidgee River is concerned, the filtering process did not have a significant effect on the representation of the areal extent of flooding. It is to be noted that while the flood level and velocity data derived from the analysis are consistent throughout the models, the flood extent diagrams should not be used to give a precise determination of depth of flood affectation in individual allotments.

The depth grids shown on the figures have also been trimmed to the building polygons, as experience has shown that property owners incorrectly associate depths of above-ground inundation at the location of buildings with depths of above-floor inundation.

## 2.4.2 Design Flooding Patterns

**Figures 2.4 and 2.5** (4 sheets each) show the nature of both Main Stream Flooding and Major Overland Flow at Narrandera for the 1% AEP and Extreme Flood events, respectively, while **Figures B3.3 to B3.9** in **Appendix B** show similar information for the 20, 10, 5, 2, 0.5 and 0.2% AEP storm events. **Figure 2.6** (2 sheets) is a longitudinal section along the Northern and Southern Main Canal Embankments showing their crest heights relative to design flood levels, while **Figure 2.7** shows similar information for the Narrandera Airport Levee. **Figure 2.8** shows the time of rise of floodwaters at key locations along the major roads which cross the Murrumbidgee River floodplain at Narrandera. **Table 2.2** provides a comparison between design and historic peak heights on the Narrandera stream gauge.

### Description of Main Stream Flooding

The key features of Main Stream Flooding behaviour at Narrandera for the assessed design flood events are as follows:

- **20% AEP** – Floodwater breaks out of the Murrumbidgee River immediately upstream and downstream of Council's water supply pumping station where it flows toward the two bridges which are located along the Newell Highway north of the main river crossing.

While the inbank area of Gillenbah Creek is not modelled accurately in the Narrandera Classic TUFLOW Model due to its 40 m square grid, floodwater is shown to leave the Murrumbidgee River at the confluence of the two watercourses where it discharges in a westerly direction crossing first the Sturt Highway, followed by the Newell Highway and then the Sturt Highway again before rejoining flow in the river.

- **10% AEP** – Floodwater inundates the Murrumbidgee River floodplain over a 2 km width generally to depths exceeding 1 m. Existing development located along the banks of the river and immediately west of the intersection of the Newell and Sturt Highways is impacted by floodwater to depths generally less than 1 m.
- **5% AEP** – Floodwater surcharges Weir Park Road where it extends a short distance to the north. Floodwater also surcharges Irrigation Way where it ponds up against the western side of the Narrandera Airport Levee. Nallabooma Estate is not affected by flooding. Freeboard to both the Southern Main Canal Embankment and Narrandera Airport Levee is less than 1 m at several locations.

Floodwaters break out of Gillenbah Creek along its southern bank and join flow in Poison Waterholes Creek on the eastern (upstream) side of the Newell Highway.

- **1% AEP** – Major breakouts of flow occur along the southern banks of both the Murrumbidgee River and Gillenbah Creek where floodwater joins flow in the Poison Waterholes Creek system. Parts of the Nallabooma Estate are inundated by floodwater generally to depths of less than 1 m.

While only minor overtopping of the Southern Main Canal Embankment would occur in a 1% AEP flood event, overtopping of the Narrandera Airport Levee would occur sufficient to result in the equalisation of water levels on either side of the embankment at the northern end of the airport.

- **0.5% AEP** – Flooding behaviour is generally similar to that described for the 1% AEP event, although floodwaters will surcharge the Southern Main Canal Embankment at an increased rate. The difference in the depth of inundation between the 1% and 0.5% AEP events is shown on the long sections (refer **Figures 2.6 and 2.7**).

While there would be increased overtopping of the Southern Main Canal Embankment, there is sufficient capacity in the Main Canal to prevent overtopping of the Northern Main Canal Embankment (this finding assumes that the upstream regulators are closed).

- **0.2% AEP** - Flooding behaviour is generally similar to that described for the 0.5% AEP event, although the rate at which floodwaters surcharge the Southern Main Canal Embankment would increase significantly given that water levels exceed the crest height of the embankment where it runs between the Narrandera Regulator and Irrigation Way (refer **Figure 2.6**, sheet 1). The difference in the depth of inundation between the 0.5% and 0.2% AEP events is similar to the difference between the 1% and 0.5% AEP events, as shown on **Figures 2.6 and 2.7**.
- **Extreme Flood Event** – While water levels are about 2 m higher when compared to peak 1% AEP flood levels (refer **Figures 2.6 and 2.7**), the extent of land inundated by floodwater does not increase substantially.

#### Description of Major Overland Flow

The rural land located to the north of the urbanised parts of Narrandera is characterised by undulating hills with a series of trapped low points. In a 20% AEP storm event, runoff ponds to depths greater than 300 mm at the location of the following trapped low points:

- On the eastern side of the Northern Main Canal Embankment to the north of Paynters Siding Road.
- Between the Junee-Hay Railway and Saw Mill Road.
- At the intersection of Saw Mill Road and Cliffords Road.
- In the rear of residential allotments on the western side of Bells Road.
- Narrandera Racecourse.
- On the northern (upslope) side of Barellan Road east of the Narrandera Racecourse.
- Between Barellan Road and the Newell Highway.

In the upper reaches of the catchment which drains to the Town Siphon, runoff is shown to pond on the northern (upslope) side of the Junee-Hay Railway causing a backwater to form across the Newell Highway which inundates the road to a depth of about 1 m in a 1% AEP storm event.

The Junee-Hay Railway line commences to overtop at this location in a 1% AEP storm event. Runoff that discharges across the rail corridor is conveyed in a grass-lined channel which runs along the western side of Henry Mathieson Oval before flowing in a westerly direction through the Narrandera High School. A piped drainage system extending to the west of the high school generally has sufficient capacity to convey flows up to about a 10% AEP storm event.

During storms with AEPs less than 10 per cent, a portion of the flow which discharges across the rail corridor north of Henry Mathieson Oval discharges through a large number of residential properties that are located to its west. The flow path that develops in this area extends south to Victoria Avenue, where it then turns west and runs toward Narrandera Park. Depths of overland flow along this overland flow path exceed 500 mm in a 1% AEP storm event at the following locations.

- Depths of overland flow exceed 800 mm in a number of properties that are located between Whitton Street and Victoria Avenue, resulting in 37 dwellings experiencing above-floor inundation.

- Floodwater ponds to depths approaching 700 mm in the trapped low point that is located on the western side of Arglye Street, causing above-floor inundation in six dwellings.
- Floodwater ponds to depths exceeding 1 m in the carpark that is located on the eastern side of East Street behind existing commercial development, causing above-floor inundation in 25 commercial buildings, three residential dwellings and one public building.
- Runoff that surcharges the concrete lined channel that is located on the southern (downstream) side of Twynam Street flows in a westerly direction where it ponds to a depth of 1.1 m in the trapped low point near the intersection of Audley Street and Adams Street.

Overland flow also impacts existing development in a 1% AEP storm event at the following locations:

- In existing residential development that is located between Crescent Street and King Street.
- At the location of the trapped low point which is located along Larmer Street between its intersection with Midgeon Street and Roberts Street.
- On the eastern side of River Street where it inundates one commercial property that is located near the intersection of Douglas Street.

## 2.5 Hydrologic Standard of Existing Road Network

**Figure 2.8** shows stage hydrographs at a number of locations along the major roads that traverse the Murrumbidgee River floodplain at Narrandera. All the major roads, including the Sturt and Newell Highways will be cut during floods larger than about 20% AEP, with the exception of access to Narrandera Airport and Nallabooma Estate via Irrigation Way which will be cut at the 2% AEP level of flooding.

Road access to Gillenbah from Narrandera is cut during flood events slightly larger than 5% AEP in magnitude, while in the area immediately south of the Main Canal access along Old Brewery Road will be cut more frequently than a 5% AEP flood. Access to the residential area which lies on the southern side of the Main Canal via Larmer Street will be cut during floods larger than 1% AEP in magnitude.

While major surcharge of the local stormwater drainage system in Narrandera does not occur for storms with intensities less than about 10% AEP, the Newell Highway will be inundated during storms as frequent as 20% AEP to the north of Henry Mathieson Oval.

## 2.6 Existing Flood Mitigation Measures

### 2.6.1.1 Main Canal Embankments

**Figure 2.2**, sheet 1 shows the alignment of the Northern and Southern Main Canal Embankments, while **Figure 2.6** shows their crest heights relative to the elevation of the adjacent floodplain, as well as design flood levels.

Both embankments were formed using material sourced during excavation for the Main Canal. Murrumbidgee Irrigation advised that details of the construction methodology of the Main Canal embankments are not known. A short section of the Southern Main Canal Embankment east (upstream) of the Newell Highway crossing was repaired by Murrumbidgee Irrigation following the March 2012 flood (refer **Figure 2.6**, sheet 1 for location). The repaired section of embankment corresponded with the location where floodwater was at the point of overtopping the crest during



the March 2012 flood. No details are available on the construction methodology which was adopted by Murrumbidgee Irrigation as part of the repair works. Council has also raised concerns regarding the quality of the material and also the degree of compaction which was used to make the repair.

A visual audit of the Southern Main Canal Embankment was undertaken by NSW Public Works (PW) in May 2013. The findings of the visual audit are documented in two reports (PW, 2013a and PW, 2013b). The visual audit identified a number of major defects in the embankment in regards its reliance to perform as a flood protection levee. These include:

- a large number of mature trees growing on the batters;
- surface erosion and slumping of the batters;
- rutting and longitudinal surface cracks along the crest of the embankment; and
- utilities extending through the embankment.

The visual audit also identified a number of actions that would need to be undertaken to address these issues, which included the removal (if permitted by relevant authorities) of the mature trees which are presently growing on the batters of the embankment.

#### 2.6.1.2 Narrandera Airport Levee

The Narrandera Airport Levee is about 6 km in length and is generally not greater than 1.0 - 1.5 m in height. **Figure 2.2**, sheet 2 shows the alignment of the Narrandera Airport Levee, while **Figure 2.7** is a long section showing the elevation of its crest relative to the adjacent floodplain levels, as well design flood levels.

In March 2012, flood levels were on the point of overtopping the ring levee in the vicinity of Ch 650 m, Ch 1,950 m and Ch 2,700 m and at other locations south of Ch 4,600 m. Sand bags were installed at several locations along the section of levee to prevent overtopping from occurring during the March 2012 flood. These locations generally corresponded with local access roads (temporary and permanent) which lead into the airport.

No information is available on the methodology or material which was used to construct the ring levee. Inspection of the LiDAR survey data shows the presence of a shallow depression which flanks both sides of the levee bank, indicating that it may have been partially or wholly constructed using local material sourced from the Murrumbidgee River floodplain.

A visual inspection of the Narrandera Airport Levee was undertaken by PW in May 2013. The findings of the visual audit are documented in a report entitled *Narrandera (Airport) Levee Audit 2013* (PW, 2013c). The report identified a number of major defects in the levee bank which included:

- large areas of bare earth due to the absence of protective vegetation;
- absence of closure mechanisms on the outlet of existing stormwater pipes;
- presence of trees and shrubs growing on the levee bank;
- erosion along the levee crest;
- presence of animal burrows and ants nests in the levee bank; and
- general lowering of the crest at the location of stormwater outlets.

The report identifies the actions which need to be undertaken to address these issues, including the immediate installation of closure mechanisms on the outlets of existing stormwater pipes.

Council has recently raised the section of the Narrandera Airport Levee where it runs alongside Irrigation Way using fill material which was provided by the NSW Roads and Maritime Services. No details are presently available on the finished crest level of the raised section of levee, or the level of compaction which achieved during the placement of the fill material.

### 2.6.1.3 Privately Owned Ring Levees and Fill Platforms

A privately owned ring levee has been constructed around the Narrandera Caravan Park which is located on the southern side of the Newell Highway at Gillenbah. Modelling undertaken as part of the *Flood Study Review* showed that the ring levee would be overtopped during floods larger than 20% AEP in magnitude. The adjacent Newell Motor Inn has been constructed on a fill platform, the elevation of which approximates the peak 1% AEP flood level.

### 2.6.1.4 Local Catchment Measures

A number of mitigation measures have been implemented by Council in recent years to reduce the impact of local catchment flooding on existing development. Recent works include new piped drainage systems along Boundary Road and Boundary Lane, and in the Red Hill industrial area along Driscoll Road.

Other recent changes includes the installation of concrete lids over some of the channels which run through the main commercial area of Narrandera. The trunk drainage system along Masons Lane which was once an open channel has now been covered with a concrete lid. While public safety was likely the main reason for the modification of the channel, its enclosure has had the effect of containing stormwater within the system and preventing the surcharge of the channel in Masons Lane.

Flood mitigation related works have also recently been completed adjacent to the inlet of the Town Siphon. This involved the installation of a spillway to the west of the Town Siphon which allows stormwater to discharge into the Main Canal at a lower level. A series of diversion banks and block walls have also been constructed which are aimed at diverting the flow which discharges to the Town Siphon toward the Main Canal when either the capacity of the pipe is exceeded or when the penstock gate is closed.

## 2.7 Economic Impacts of Flooding

The economic consequences of floods are discussed in **Appendix C**, which assesses flood damages to residential, commercial and industrial property and public buildings in areas affected by both Main Stream Flooding and Major Overland Flow. There is no data available on historic flood damages to the urban sectors 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 based on the publication *Floodplain Risk Management Guideline No. 4, 2007 (Guideline No. 4)* published by the Department of Environment and Climate Change (**DECCW**) (now OEH). Damages to industrial and commercial development, as well as public buildings were evaluated using data from previous floodplain management investigations in NSW.

It is to be noted that the principal objectives of the damages assessment were to gauge the severity of urban flooding likely to be experienced at Narrandera and also to provide data to allow the comparative economic benefits of various flood modification measures to be evaluated in **Chapter 3** of the report. As explained in **Appendix C**, it is not the intention to determine the depths of inundation or the damages accruing to *individual properties*, but rather to obtain a reasonable estimate of damages experienced over the extent of the urban area in the town for the various design flood events. The estimation of damages using *Guideline No. 4* (in lieu of site specific data determined by a loss adjustor) also allows a uniform approach to be adopted by

Government when assessing the relative merits of measures competing for financial assistance in flood prone centres in NSW.

The number of properties that would be affected by both Main Stream Flooding and Major Overland Flow, as well as the estimated damages which could occur for various flood recurrence intervals are summarised in **Tables 2.3** and **2.4** over the page, respectively.

Flood damages were assessed based on the design flood levels that were computed as part of the *Flood Study Review* in the case of Main Stream Flooding and the Local Catchment TUFLOW Model that was developed as part of the present study in the case of Major Overland Flow (denoted herein as the “*nominal flood levels case*”). Flood damages were also assessed based on a freeboard allowance which was added to the design flood level at each of the affected properties (denoted herein as the “*freeboard allowance case*”). In both cases, the assessed flood damages assume that the Southern Main Canal Embankment does not fail during a flood on the Murrumbidgee River.

### **Damages Resulting from Main Stream Flooding**

At the 1% AEP level flooding, 49 residential buildings would experience above-floor inundation. While sixteen commercial/industrial buildings would also be flooded above-floor level, no public buildings would experience above-floor inundation at the 1% AEP level of flooding. The total flood damage relating to property that is located on the Murrumbidgee River floodplain at Narrandera is \$6.79 Million for the nominal flood levels case, increasing to \$9.59 Million for the freeboard allowance case.

The *Present Worth Value* of damages at Narrandera resulting from all floods up to the magnitude of the 1% AEP at a seven per cent discount rate and 50 year economic life is \$4.4 Million for the nominal flood levels case, increasing to \$6.3 Million for the freeboard allowance case. This latter value represents the amount of capital spending which would be justified if a particular flood mitigation scheme prevented flooding for all properties that are located on the southern side of the Main Canal up to the 1% AEP event.

### **Damages Resulting from Major Overland Flow**

At the 1% AEP level of flooding, 144 residential properties that are located on the northern (town) side of the Main Canal would be flood affected (i.e. water has entered the allotment), within which 82 dwellings would experience above-floor inundation. While twenty-seven commercial/industrial buildings would also be flooded above-floor level, only two public buildings would experience above-floor inundation at the 1% AEP level of flooding. The total flood damage relating to property that is located on the northern (town) side of the Main Southern Canal Embankment is \$8.76 Million for the nominal flood levels case, increasing to \$18.16 Million for the freeboard allowance case.

The *Present Worth Value* of damages at Narrandera resulting from all storms up to 1% AEP in intensity at a seven per cent discount rate and 50 year economic life is \$7.3 Million for the nominal flood levels case, increasing to \$17.3 Million for the freeboard allowance case. This latter value represents the amount of capital spending which would be justified if a particular flood mitigation scheme prevented flooding for all properties that are located on the northern side of the Main Canal up to the 1% AEP event.

**TABLE 2.3**  
**FLOOD DAMAGES IN NARRANDERA RESULTING FROM MAIN STREAM FLOODING**

Category	Design Flood Event (%AEP)	Nominal Flood Levels			Nominal Flood Levels Plus Freeboard <sup>(1)</sup>		
		No of Allotments Flood Affected	No of Buildings Flooded Above Floor Level	Damages \$ Million	No of Allotments Flood Affected	No of Buildings Flooded Above Floor Level	Damages \$ Million
Residential	20	0	0	0	0	0	0.00
	10	16	8	0.76	17	11	1.01
	5	34	23	1.98	37	33	3.01
	1	55	49	5.80	61	59	8.19
	0.5	65	62	7.91	69	66	9.80
	0.2	89	82	11.23	95	91	13.74
	Extreme	178	166	25.32	187	181	29.22
Commercial	20	0	0	0	0	0	0
	10	15	11	0.31	15	14	0.39
	5	15	15	0.47	15	15	0.60
	1	16	16	0.99	16	16	1.40
	0.5	17	17	1.36	17	17	1.64
	0.2	20	20	1.89	20	20	2.37
	Extreme	23	23	3.83	23	23	4.48
Public	20	0	0	0	0	0	0
	10	0	0	0	0	0	0
	5	0	0	0	0	0	0
	1	0	0	0	0	0	0
	0.5	7	3	0.13	7	7	0.35
	0.2	8	8	0.52	8	8	0.86
	Extreme	8	8	1.54	8	8	1.96
Total	20	-	-	0	-	-	0
	10	-	-	1.07	-	-	1.40
	5	-	-	2.45	-	-	3.61
	1	-	-	6.79	-	-	9.59
	0.5	-	-	9.40	-	-	11.79
	0.2	-	-	13.64	-	-	16.97
	Extreme	-	-	30.69	-	-	35.66

1. Note: Freeboard allowance is 500 mm for 1% AEP and greater floods, 300 mm for 5% AEP and 200 mm for 10 and 20% AEP floods.

**TABLE 2.4**  
**FLOOD DAMAGES IN NARRANDERA RESULTING FROM MAJOR OVERLAND FLOW**

Category	Design Flood Event (%AEP)	Nominal Flood Levels			Nominal Flood Levels Plus Freeboard <sup>(1)</sup>		
		No of Allotments Flood Affected	No of Buildings Flooded Above Floor Level	Damages \$ Million	No of Allotments Flood Affected	No of Buildings Flooded Above Floor Level	Damages \$ Million
Residential	20	21	6	0.67	26	20	1.69
	10	45	15	1.55	53	42	3.60
	5	60	21	2.22	66	60	5.55
	1	144	82	7.41	154	152	15.27
	0.5	168	107	9.72	178	178	18.31
	0.2	192	137	12.65	205	204	21.60
	Extreme	531	431	51.87	542	537	68.26
Commercial	20	1	0	0.02	1	1	0.07
	10	1	0	0.02	2	2	0.11
	5	2	0	0.03	3	3	0.27
	1	30	27	1.29	30	30	2.74
	0.5	33	29	1.65	33	33	3.38
	0.2	40	30	2.20	41	41	4.35
	Extreme	112	104	17.76	114	114	24.07
Public	20	0	0	0	0	0	0
	10	0	0	0	0	0	0
	5	0	0	0	0	0	0
	1	2	2	0.06	2	2	0.15
	0.5	6	4	0.18	6	6	0.40
	0.2	6	6	0.27	6	6	0.50
	Extreme	16	13	2.32	16	16	3.27
Total	20	-	-	0.69	-	-	1.76
	10	-	-	1.57	-	-	3.71
	5	-	-	2.25	-	-	5.82
	1	-	-	8.76	-	-	18.16
	0.5	-	-	11.55	-	-	22.09
	0.2	-	-	15.12	-	-	26.45
	Extreme	-	-	71.95	-	-	95.60

1. Note: Freeboard allowance is 500 mm for 1% AEP and greater floods, 300 mm for 5% AEP and 200 mm for 10 and 20% AEP floods.

## 2.8 Impact of Flooding on Vulnerable Development and Critical Infrastructure

**Figure 2.9** (3 sheets) shows the location of vulnerable development and critical infrastructure relative to the extent of inundation for floods ranging between 20% AEP and the Extreme Flood, while **Table 2.5** over the page summarises the impact that flooding has on these types of development/infrastructure at Narrandera.<sup>4</sup>

While the Narrandera High School is impacted by Major Overland Flow during storms as frequent as 20% AEP, the flow path is principally located along the western boundary of the school grounds and the two playing ovals. No existing buildings within the school grounds are impacted by Major Overland Flow.

As mentioned, the ring levee that is located around the Narrandera Caravan Park in Gillenbah is overtopped during floods larger than 20% AEP in magnitude.

## 2.9 Impact of a Partial Failure of the Southern Main Canal Embankment

For flood levels greater than that of the Imminent Failure Flood (**IFF**), there is the potential for overtopping to occur which could lead to a partial failure of the embankment due to scour in the case of earth levees. The IFF is the threshold flood with a peak level which encroaches into the freeboard nominated for a levee when specifying its hydrologic level of protection. Freeboard is a factor of safety equal to the difference between the elevation of the levee crest and the peak flood level. A freeboard of 1 m has been adopted for the present study which is similar to the value which was recently recommended for the levee upgrade at Wagga Wagga (PW, 2010). Accordingly, floods which encroach into the 1 m freeboard allowance were assumed to cause the levee to fail.

Based on an adopted freeboard of 1 m, the IFF of the Southern Main Canal Embankment and the Narrandera Airport Levee is equivalent to about a 5% AEP flood.

The approach adopted for assessing the impact of a potential failure of the Southern Main Canal Embankment on the design flood envelopes was to run the TUFLOW model for floods greater than the IFF (i.e. floods greater than 5% AEP), with the elevation of a section of the Southern Main Canal lowered to half the depth of inundation along its southern side.<sup>5</sup> The Southern Main Canal Embankment was assumed to fail at three locations along its length, the locations of which are shown on **Figure 2.6**, sheet 1, noting that a levee failure analysis was not undertaken for the Northern Main Canal Embankment as significant overtopping at the low points in the embankment occurs following the failure of the Southern Main Canal Embankment.

**Figure 2.10** (3 sheets) shows the resulting depth of inundation on the northern side of the Main Canal assuming the Southern Main Canal Embankment was to fail at either of the three locations shown on **Figure 2.6**, sheet 1, while **Figure 2.11** (3 sheets) shows the impact that the failure of the embankment would have on flooding behaviour at the 1% AEP level of flooding

---

<sup>4</sup> Critical infrastructure has been split into two categories; community assets and emergency services.

<sup>5</sup> Note that a time based scour assessment was not undertaken given the long duration nature of flooding at Narrandera which would tend to set up steady state flow conditions in the Main Canal.

**TABLE 2.5**  
**IMPACT OF FLOODING ON VULNERABLE DEVELOPMENT AND CRITICAL INFRASTRUCTURE AT NARRANDERA**

Type	Development/Structure	Location Identifier <sup>(1)</sup>	20% AEP	10% AEP	5% AEP	1% AEP	0.5% AEP	0.2% AEP	Extreme Flood
Vulnerable Development	Educational Facility (Narrandera East Infants School)	EF1	O	O	O	O	O	O	O
	Educational Facility (St Joseph's Primary School)	EF2	O	O	O	O	O	O	O
	Educational Facility (Narrandera Public School)	EF3	O	O	O	O	O	O	O
	Educational Facility (Narrandera High School)	EF4	MOF	MOF	MOF	MOF	MOF	MOF	MOF
	Educational Facility (TAFE)	EF5	O	O	O	O	O	O	O
	Child Care Facility (Narrandera Pre-School Early Childhood Centre)	CC1	O	O	O	O	O	O	O
	Child Care Facility (TAFE's Children's Centre Child Care)	CC2	O	O	O	O	O	O	O
	Caravan Park / Camping Ground (Lake Tabot Tourist Park)	CP1	O	O	O	O	O	O	O
	Caravan Park / Camping Ground (Narrandera Caravan Park)	CP2	O	MSF	MSF	MSF	MSF	MSF	MSF
	Aged Care Facilities (Opal Narrandera)	AC1	O	O	O	O	O	O	MOF
	Aged Care Facilities (Teloca House Hostel)	AC2	O	O	O	MOF	MOF	MOF	MOF
	Aged Care Facilities (Uniting Pangarinda Village)	AC3	O	O	O	O	O	O	O
	Aged Care Facilities (Pangarinda Village)	AC4	O	O	O	O	O	O	MOF
	Health Care Centre (Narrandera Health Centre)	HC1	O	O	O	O	O	O	O
	Health Care Centre (Narrandera Community Health Care Centre)	HC2	O	O	O	O	O	O	O
Emergency Services	NSW SES Headquarters	-	O	O	O	MOF	MOF	MOF	MOF
	Police Station	-	O	O	O	MOF	MOF	MOF	MOF
	Fire & Rescue NSW Station	-	O	O	O	MOF	MOF	MOF	MOF
	Ambulance	-	O	O	O	O	O	O	MOF
	Evacuation Centre (Narrandera Showground Hall)	EC1	O	O	O	O	O	O	O
	Evacuation Centre (Narrandera High School)	EC2	MOF	MOF	MOF	MOF	MOF	MOF	MOF

**TABLE 2.5 (CONT'D)**  
**IMPACT OF FLOODING ON VULNERABLE DEVELOPMENT AND CRITICAL INFRASTRUCTURE AT NARRANDERA**

Type	Development/Structure	Location Identifier <sup>(1)</sup>	20% AEP	10% AEP	5% AEP	1% AEP	0.5% AEP	0.2% AEP	Extreme Flood
Community Assets	Telephone Exchange	-	O	O	O	MOF	MOF	MOF	MOF
	Electrical Sub Station	-	O	O	O	O	O	O	MSF/MOF
	Narrandera Airport	-	O	O	O	MSF	MSF	MSF	MSF
	Major Road Crossing (Gillenbah Creek at Stuart Highway)	MC1	O	MSF	MSF	MSF	MSF	MSF	MSF
	Major Road Crossing (Gillenbah Creek at Newell Highway)	MC2	O	MSF	MSF	MSF	MSF	MSF	MSF
	Major Road Crossing (Gillenbah Creek at Stuart Highway)	MC3	O	MSF	MSF	MSF	MSF	MSF	MSF
	Major Road Crossing (Karawatha Way)	MC4	O	MSF	MSF	MSF	MSF	MSF	MSF
	Major Road Crossing (Irrigation Way)	MC5	O	O	MSF	MSF	MSF	MSF	MSF
	Major Road Crossing (Paynters Siding Road)	MC6	O	O	O	MSF	MSF	MSF	MSF
	Major Road Crossing (Poison Waterhole Creek at Newell Highway)	MC7	O	O	O	MSF	MSF	MSF	MSF

1. Refer **Figure 2.9** (3 sheets) for location of vulnerable development and critical infrastructure

“O” = Infrastructure not impacted by flooding

“MSF” = Infrastructure impacted by Main Stream Flooding

“MOF” = Infrastructure impacted by Major Overland Flow



A partial failure of the Southern Main Canal Embankment during a 1% AEP flood event would result in the area which is bounded by the Northern Main Canal Embankment to the west, the dis-used Narrandera-Tocumwal Railway to the south, the June-Hay Railway to the east and high ground to the north generally being inundated to depths exceeding 1 m. Generally depths of inundation would be increased by up to 1 m when compared to conditions that result from local catchment runoff that would be generated by a 1% AEP local catchment storm event. Several residential and commercial properties would also experience above-floor inundation as a result of partial failure of the Southern Main Canal Embankment.

The peak 1% AEP flow discharging along the Main Canal north of Narrandera is limited to a maximum of about 41 m<sup>3</sup>/s due to constrictions imposed by rising ground to its east. This finding could potentially have implications on the assessment of flood risk in townships which are located along the Main Canal west of Narrandera such as Yanco and Leeton.

The impacts a partial failure of the Narrandera Airport Levee would have on flooding behaviour were not assessed as part of the present study as water levels on either side of the earth embankment presently equalise during a 1% AEP flood event.

## 2.10 Potential Impacts of Future Urbanisation

Future development has the potential to increase the rate and volume of runoff conveyed along the Major Overland Flow path that runs through the urbanised parts of Narrandera, as well as the depth to which stormwater ponds along the northern side of the Northern Main Canal Embankment.

An assessment of the potential impact future development at Narrandera would have on Major Overland Flow was undertaken as part of the present study. This involved increasing the fraction impervious in the Local Catchment Hydrologic Model to reflect an increase in hard stand areas and then running the Local Catchment TUFLOW Model to assess the change that could potentially occur to patterns of Major Overland Flow.<sup>6</sup>

**Figure 2.12** (3 sheets) shows the potential impact future urbanisation in Narrandera could have in the extent and depth of Major Overland Flow for a 1% AEP storm event. While depths of Major Overland Flow would typically be increased by up to 200 mm along the flow path which extends from Henry Mathieson Oval to the Town Siphon, increases of up to about 300 mm would occur in the major ponding area that is centred on Audley Street between its intersection with Narrandera Street and the Newell Highway.

The depth of ponding behind the Northern Main Canal Embankment immediately to the east of the Newell Highway would increase by more than 650 mm, while increases to the west of River Street would generally be no greater than 200 mm.

## 2.11 Potential Impacts of Climate Change

Consideration was given to the potential impacts of future climate change on design flood levels when considering the freeboard requirements for setting minimum floor levels for future development.

OEH's guideline titled *Practical Consideration of Climate Change, 2007* was used as the basis for examining climate change on flooding behaviour at Narrandera. The guideline recommends that

---

<sup>6</sup> A global 40% fraction impervious was applied to residential zoned areas, while a global 90% fraction impervious was applied to commercial and industrial zoned areas.

until further 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 which may apply near the end of the century. Under present day climatic conditions, increasing the 1% AEP design rainfall intensities by 10 per cent would produce about a 0.5% AEP flood; and increasing those rainfalls by 30 per cent would produce about a 0.2% AEP event.

For the purpose of the present investigation, the impact a 10% increase in design rainfall intensities would have on flooding behaviour was assessed by comparing the peak flood levels which were derived from the flood modelling for design events with AEPs of 1 and 0.5 per cent.

**Figure 2.13** (2 sheets) shows the afflux data (i.e. increase in peak flood levels compared with present day conditions for the 1% AEP event) derived from the hydraulic modelling that was undertaken as part of the *Flood Study Review* and the present study. The potential impact of 10% increase in rainfall intensity on patterns of Main Stream Flooding at Narrandera may be summarised as follows:

- The typical increase in peak 1% AEP flood levels on the Murrumbidgee River floodplain south of Narrandera and in the vicinity of the Narrandera Airport would generally be between 300 and 500 mm, sufficient to result in increased overtopping of the Southern Main Canal Embankments and the Narrandera Airport Levee.
- While there would be increased overtopping of the Southern Main Canal Embankment, there is sufficient capacity in the Main Canal to prevent overtopping of the Northern Main Canal Embankment (this finding assumes that the upstream regulators are closed).
- The extent of inundation along the length of the river does not widen significantly.

While depths of Major Overland Flow north of the Main Canal would typically be increased by up to 200 mm along the flow path which extends from Henry Mathieson Oval to the Town Siphon, increases of up to about 400 mm would occur in the major ponding area that is centred on Audley Street between its intersection with Narrungdera Street and the Newell Highway.

The depth of ponding behind the Northern Main Canal Embankment immediately to the east of the Newell Highway would increase by more than 600 mm, while increases to the west of River Street would generally be no greater than about 150 mm.

## 2.12 Flood Hazard and Hydraulic Categorisation of the Floodplain

### 2.12.1 General

According to Appendix L of *NSWG, 2005*, in order to achieve effective and responsible floodplain risk management, it is necessary to divide the floodplain into areas that reflect:

1. The impact of flooding on existing and future development and people. To examine this impact it is necessary to divide the floodplain into “*flood hazard*” categories, which are provisionally assessed on the basis of the velocity and depth of flow. This task was undertaken as part of the *Flood Study Review* where the floodplain was divided into *provisional low hazard* and *high hazard zones*. In this present report, a *final determination* of hazard was undertaken which involved consideration of a number of additional factors which are site specific to Narrandera. **Section 2.12.2** below provides details of the procedure adopted.

2. The impact of future development activity on flood behaviour. Development in active flow paths (i.e. “floodways”) has the potential to adversely re-direct flows towards adjacent properties. Examination of this impact requires the division of flood prone land into various “hydraulic categories” to assess those parts which are effective for the conveyance of flow, where development may affect local flooding patterns. Hydraulic categorisation of the floodplain was also undertaken as part of the *Flood Study Review* and was reviewed in this present investigation. **Section 2.12.3** below summarises the adopted procedure.

### 2.12.2 Flood Hazard Categorisation

As mentioned above, flood prone areas may be *provisionally* categorised into *Low Hazard* and *High Hazard* areas depending on the depth of inundation and flow velocity. A flood depth of 1 m in the absence of significant flow velocity represents the boundary between *Low Hazard* and *High Hazard* conditions. Similarly, a flow velocity of 2.0 m/s but with a small flood depth around 200 mm also represents the boundary between these two conditions. Interpolation may be used to assess the hazard for intermediate values of depth and velocity. 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:

1. Size of flood – major floods though rare can cause extensive damage and disruption.
2. Effective warning time – flood hazard and flood damage can be reduced by sandbagging entrances, raising contents above floor level and also by evacuation if adequate warning time is available.
3. Flood awareness of the population – flood awareness greatly influences the time taken by flood affected residents to respond effectively to flood warnings. The preparation and promotion by Council of Flood Studies and Floodplain Risk Management Studies and Plans increases flood awareness, as does the formulation and implementation of response plans by NSW SES (Local Flood Plans) for the evacuation of people and possessions.
4. 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.
5. 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. This duration is shorter in smaller, steeper catchments.
6. 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* (i.e. the hazard based on velocity and depth considerations only) is presented in **Table 2.6** over the page.

**TABLE 2.6**  
**INFLUENCE OF FLOOD RELATED PARAMETERS ON PROVISIONAL FLOOD HAZARD**

Parameter	Flood Characteristics	Influence on Provisional Hazard	
		Main Stream Flooding	Major Overland Flow
Size of flood	Main Stream Flooding is generally confined to the Murrumbidgee River floodplain, with only a relatively small number of properties subject to above-floor flooding. There are a large number of residential properties that would experience above-floor flooding due to Major Overland Flow in a 1% AEP storm.	+1	+1
Effective warning time	The flood wave takes several days to travel from Wagga Wagga to Narrandera. BoM and NSW SES also maintain an effective and proven Flood Warning System for the Murrumbidgee River at Narrandera. There is presently no formal weather warning service in place for Narrandera, indicating that there is potentially little or no warning time of potential inundation of property as a result of Major Overland Flow	-1	+1
Flood awareness	Flood awareness appears to be quite high due to the occurrence of the recent floods in December 2010, March 2012 and October 2016.	0	0
Rate of rise and velocity of floodwaters	Flooding rises to a peak over about a 24 hour period, which in conjunction with the Flood Warning System, would provide sufficient warning for residents to raise or remove contents and evacuate from the floodplain. While the rate of rise would be relatively quick, the resulting Major Overland Flow is relatively shallow and slow moving in nature.	-1	-1
Duration of flooding	Flooding resulting from medium to major events may be maintained for up to a week in the case of Main Stream Flooding. In the case of Major Overland Flow, water levels would have receded after about after a few hours.	0	-1
Evacuation problems	Evacuation to higher ground is maintained for all flood events on the northern side of the Murrumbidgee River. The relatively shallow and slow moving nature of Major Overland Flow in Narrandera would not prevent an able bodied person from wading out of a flood affected area.	+1	-1
<b>OVERALL SCORE</b>		<b>0</b>	<b>-1</b>

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

**Figure 2.14** (3 sheets) shows the division of the floodplain into high and low hazard areas following consideration of the factors set out in **Table 2.6**. While the *provisional flood hazard* classification has been adopted for the majority of the floodplain, the areas on the Murrumbidgee River floodplain, the true high hazard area on the Murrumbidgee River floodplain has been extended to include areas which are surrounded by a High Hazard Floodway and would be inundated during a 1% AEP flood event, as well as Low Hazard Floodways that would develop remote from the main body of the flow (refer **Section 2.12.13** for discussion on the definition of Floodways).

### 2.12.3 Hydraulic Categorisation of the Floodplain

According to the *NSWG, 2005*, the floodplain may be subdivided into the following zones:

- **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 re-distribution 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.

*Floodplain Risk Management Guideline No. 2 Floodway Definition*, offers guidance in relation to two alternative procedures for identifying floodways. They are:

- **Approach A.** Using a *qualitative approach* which is based on the judgement of an experienced hydraulic engineer. In assessing whether or not the area under consideration was a floodway, the qualitative approach would need to consider; whether obstruction would divert water to other existing flow paths; or would have a significant impact on upstream flood levels during major flood events; or would adversely re-direct flows towards existing development.
- **Approach B.** Using the hydraulic model, in this case TUFLOW, to define the floodway based on *quantitative experiments* where flows are restricted or the conveyance capacity of the flow path reduced, until there was a significant effect on upstream flood levels and/or a diversion of flows to existing or new flow paths.

One quantitative experimental procedure commonly used is to progressively encroach across either floodplain towards the channel until the designated flood level has increased by a significant amount (for example 0.1 m) above the existing (un-encroached) flood levels. This indicates the limits of the hydraulic floodway since any further encroachment will intrude into that part of the floodplain necessary for the free flow of flood waters – that is, into the floodway.

The *quantitative assessment* associated with **Approach B** is technically difficult to implement. Restricting the flow to achieve the 0.1 m increase in flood levels can result in contradictory results, especially in unsteady flow modelling, with the restriction actually causing reductions in computed levels in some areas due to changes in the distribution of flows along the main drainage line.

Accordingly the *qualitative approach* associated with **Approach A** was adopted, together with consideration of the portion of the floodplain which conveys approximately 80% of the total flow and also the findings of *Howells et al, 2004* who defined the floodway based on velocity of flow and depth. Howells et al suggested the following criteria for defining those areas which operate as a “floodway” in a 1% AEP event:

- Velocity x Depth greater than 0.15 m<sup>2</sup>/s **and** Velocity greater than 0.25 m/s; or
- Velocity greater than 1 m/s.

Flood storage areas are identified as those areas which do not operate as floodways in a 1% AEP event but where the depth of inundation exceeds 0.3 m and 1 m in areas subject to Major Overland Flow and Main Stream Flooding, respectively. The remainder of the flood affected area was classified as flood fringe.

**Figure 2.14** (3 sheets) shows the division of the floodplain into floodway, flood storage and flood fringe areas at the 1% AEP level of flooding. While the majority of the flood affected area on the Murrumbidgee River floodplain functions as a High Hazard Floodway, the area to the north of Weir Park Road in the vicinity of the Narrandera Airport is largely Low Hazard Flood Fringe.

Areas affected by Major Overland Flow north of the Main Canal are largely classified as Low Hazard Flood Storage or Flood Fringe, with the exception of the relatively deep ponding area which forms along the northern side of the Junee Hay Railway immediately east of the Barellan Road.

## 2.13 Council’s Existing Planning Instruments and Policies

### 2.13.1 General

The *Narrandera Local Environmental Plan, 2013 (Narrandera LEP 2013)* is the principal statutory planning document used by Council for controlling development by defining zoning provisions, establishing permissibility of land use and regulating the extent of development in the town.

The *Narrandera Development Control Plan 2013 (Narrandera DCP 2013)* supplements *Narrandera LEP 2013* by providing general information and detailed guidelines and controls which relate to the decision making process.

### 2.13.2 Land Use Zoning – Narrandera Local Environmental Plan 2013

**Figure 2.15** shows the zonings incorporated in *Narrandera LEP 2013* at Narrandera. Most of the urban area of Narrandera is zoned *RU5-Village*, which includes the area on the southern side of the Main Canal, extending south as far as Gillenbah. Nallabooma Estate is zoned *R5-Large Lot Residential*. Within Narrandera there are some areas zoned *IN1-General Industrial* and *IN2-Light Industrial*. The urban area also includes land zoned *SP2-Infrastructure* and *RE1-Public Recreation*. In the rural areas surrounding Narrandera, the majority of the land is zoned *RU4-Primary Production Small Lots* or *RU1-Primary Production*. There are also large areas of land zoned *E1-National Parks and Nature Reserve*, *E2-Environmental Conservation* and *E4-Environmental Living*. The inbank area of the Murrumbidgee River, as well as Lake Talbot are zoned *W2-Recreational Waterways*.

### 2.13.3 Flood Provisions –Narrandera LEP 2013

Clause 6.2 of *Narrandera LEP 2013* entitled “Flood Planning” outlines its objectives in regard to development of land that is identified as “Flood planning area’ on the *Flood Planning Map* and other land that is at or below the FPL. It is similar to the standard Flood Planning Clause used in recently adopted LEPs in other NSW country centres and applies to land at or below the FPL.

The FPL referred to is the 1:100 ARI (or 1% AEP) flood plus an allowance for freeboard of 500 mm. The area encompassed by the FPL (i.e. the Flood Planning Area (**FPA**)) denotes the area subject to flood related development controls, such as locating development outside high hazard areas and setting minimum floor levels for future residential development. It is now standard practice for the residential FPL to be based on the 1% AEP flood plus an appropriate freeboard unless exceptional circumstances apply.

Whilst appropriate for Main Stream Flooding, the present clause 6.2 would result in a large part of the urban areas of Narrandera which are affected by shallow overland flow being subject to flood affectation notification on Planning Certificates issued under S10.7 of the EP&A Act. It would also result in flood related development controls being applied to land which is presently rural in nature where the flood risk is very low.

For the *Flood Planning Map* to be modified, a formal amendment would need to be made to *Narrandera LEP 2013*, which would take considerable time. It is therefore recommended that the *Flood Planning Map* not be attached to *Narrandera LEP 2013*, as this way it can be updated without the need to update the LEP. Recommended amendments to the wording of clause 6.2 are set out in **Section 3.6.1.4** of the report.

*Narrandera LEP 2013* would need to be supported by the *Flood Policy* in **Appendix E** which sets out specific requirements for development in flood liable areas based on the flood extent and hazard mapping for Narrandera. While not too dissimilar, this *Flood Policy* would replace the flood related planning controls that are currently set out in *Narrandera DCP 2013*. **Figure E1.1** in **Appendix E** is an extract from the *Flood Planning Map* referred to in clause 6.2 and relates to Narrandera.

It is also recommended that a new floodplain risk management clause be include in *Narrandera LEP 2013*. The objectives of the new clause are as follows:

- in relation to development with particular evacuation or emergency response issues (e.g. schools, group homes, residential care facilities, hospitals, etc.) to enable evacuation of land which lies above the FPL; and
- to protect the operational capacity of emergency response facilities and critical infrastructure during extreme flood events.

The new clause would apply to land which lies between the FPL and the level of the Extreme Flood, but would not apply to land at or below the FPL. Suggested wording in relation to this new clause is given in **Section 3.6.1.4**.

### 2.13.4 Flooding and Stormwater Controls –Narrandera DCP 2013

Part E Chapter 10 of *Narrandera DCP 2013* under the main heading “Flood Liable Land” sets out the controls that apply to development on the floodplain. The objective of the chapter is to ‘place development controls on the further development of flood liable land’.

The chapter includes mapping which shows the division of the floodplain into floodway, flood storage and flood fringe, definitions of different types of development, and tables specifying the suitability and controls applicable to differing types of development within the different areas of the floodplain (i.e. if the development is located in floodway, flood storage or flood fringe).

The flood controls at Narrandera differ according to the area the development is located in. Separate flood control tables are specified for the Gillenbah Precinct, Nallabooma Estate and the remainder of the floodplain. The different development controls reflect the differing development aims and nature of flooding within these three areas.

Within the Gillenbah Precinct, critical and sensitive uses, as well as industrial development is classified as not suitable. Residential, commercial and recreational/agricultural type developments are permitted in this area but are subject to controls. For these three permitted types of development, all development is required to demonstrate it is structurally sound and built of materials compatible with flooding, as well as having an evacuation route above the Extreme Flood accompanied by an evacuation plan. All development is also required to not increase flood impacts elsewhere through loss of floodplain storage or altered flood levels or velocities. Residential development in this area must have a flood level set above the 1% AEP flood level plus 0.5 m freeboard. This differs from commercial and recreational/agricultural type development which is permitted to have a habitable flood level above the 5% AEP flood level plus 0.5 m freeboard. However, goods must be stored above the 1% AEP flood level.

Within the Nallabooma Estate, only residential type development is permitted subject to controls. All other types of development are deemed not suitable for this area. Any residential development in this area is subject to similar controls laid out for the Gillenbah Precinct, namely regarding structural soundness, building materials, evacuation, flood impacts on other properties, and a minimum floor level (set at the 1% AEP flood level plus 0.5 m freeboard).

Over the rest of the floodplain, critical land uses are listed as not suitable. Sensitive land uses in floodway and flood storage are not suitable, however in flood fringe areas sensitive land uses may occur provided that the floor level is set at no lower than the Extreme Flood and that it complies with other controls relating to construction, evacuation and impacts, similar to those that applied to the Gillenbah Precinct and the Nallabooma Estate. Residential development may occur in floodway, flood storage or flood fringe areas, given that the development complies with the same controls which apply to residential development in the Gillenbah Precinct and the Nallabooma Estate. Recreation/agricultural development is permitted in all areas of the floodplain provided that all floor levels are no lower than the 5% AEP flood level and that goods are stored above the 1% AEP flood level. Industrial development and other development which does not fit into any other category is not permitted in floodway areas, however is permitted flood storage and flood fringe. Industrial development in these areas must have habitable floor levels no lower than the 5% AEP flood level, and goods must be stored above the 1% AEP flood level.

Appendix 1 in Part E of the Narrandera DCP 2013 includes additional information which supplements Chapter 10. This includes descriptions on historic flooding, local areas impacted by flooding, flood protection measures, a flood development control matrix, and design levels and river cross sections.



## 2.14 Flood Warning and Flood Preparedness

The NSW SES is nominated as the principal combat and response agency for flood emergencies in NSW. NSW SES is responsible for the issuing of relevant warnings (in collaboration with BoM), as well as ensuring that the community is aware of the flood threat and how to mitigate its impact. BoM operates a flood warning system which provides predictions of gauge heights along the Murrumbidgee River, including at Narrandera.

The *Narrandera Shire Local Flood Plan*, 2015 (herein referred to as the **Local Flood Plan**) published by NSW SES covers preparedness measures, the conduct of response operations and the coordination of immediate recovery measures for all levels of flooding within the Narrandera Shire LGA. The *Local Flood Plan* is administered by the Narrandera NSW SES Local Controller who controls flood operations within the Narrandera Shire LGA.

The *Local Flood Plan* covers the Narrandera Shire LGA, which includes the towns of Narrandera and Barellan, as well as the villages of Binya, Grong Grong and Kamarah. It also covers the surrounding rural land. The *Local Flood Plan* is divided into the following parts:

- **Introduction**; this section of the *Local Flood Plan* identifies the responsibilities of the NSW SES Local Controller and NSW SES members and supporting services such as the Police, BoM, Ambulance, Country Energy, Fire Brigades, Department of Community Services, Council, etc. The *Local Flood Plan* identifies the importance for NSW SES and Council to coordinate the development and implementation of a public education program to advise the population of the flood risk.
- **Preparedness**; this section deals with activities required to ensure the *Local Flood Plan* functions during the occurrence of the flood emergency.
- **Response**. The NSW SES maintains a Local Operations Centre at 19-21 Twynam Street, Narrandera. The Narrandera Shire Emergency Operations Centre is located at the same address.

Response operations will commence: on receipt of a Preliminary Flood Warning, Flood Warning, Flood Watch, Severe Thunderstorm Warning or a Severe Weather Warning for flash flooding from BoM; on receipt of a dam failure alert; or when other evidence leads to an expectation of flooding within the Shire. Sources of Flood Intelligence identified will include BoM, NSW SES Region headquarters and Council.

Flood warnings are issued by BoM for Narrandera Shire based on recorded rainfall and stream gauge data. The response strategies to be employed by NSW SES and Council are listed in Section 3.4 of the *Local Flood Plan* and include information provision and warning, property protection, evacuation, rescue, and resupply.

- **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 *Local Flood Plan*.

Annexes A and B of the 2012 version of the *Local Flood Plan* describe the flood threat and impact that flooding has on the community in the Narrandera Shire area, respectively. Annex C of the document lists the stream gauges that are monitored in the area, with the 'Minor', 'Moderate' and 'Major' flood levels on the Narrandera stream gauge given as 6.7 m, 7.3 m and 8.2 m, respectively. **Table 2.2** provides a comparison of the 'Minor', 'Moderate' and 'Major' flood levels set out in Annex C with the gauge heights reached by the largest ten historic flood events, as well as design floods of between 20% AEP and the Extreme Flood.

## 2.15 Environmental Considerations

The river and creek systems at Narrandera are largely in their natural state where they run to the south of the township. Consideration would need to be given to the impact any upgrade of the Southern Main Canal Embankment would have on existing vegetation as its footprint would increase as a result of an increase in the elevation of its crest. **Section 3.4.3** of this report sets out the requirements for the upgrade of the existing embankment.

Based on the zoning map in *Narrandera LEP 2013*, there are a number of areas in the vicinity of Narrandera which are zoned as *E1-National Parks and Nature Reserves* and *E2-Environmental Conservation*. While any floodplain management measures undertaken in these areas would have to comply with the aims of the *Narrandera LEP 2013*, any proposed management measures in adjacent zones (in particular structural flood modification measures) should consider the impacts the proposed works may have in these areas. In a similar way, impacts on areas zoned *RE1-Public Recreation* and *W2-Recreational Waterways* (i.e. Lake Talbot and the surrounding areas) should be minimised or ensure that they will not interfere with the stated aims of these zones.

Clause 6.6 of *Narrandera LEP 2013* entitled “Riparian land and watercourses” relates to land which is defined as “Watercourse” on the relevant LEP map, or land that is within 40 metres of the top of bank of an identified watercourse. Among other restrictions specified by this clause, development in this area must consider whether there will be a resulting impact on the water quality and flows within the watercourse.

Clause 6.7 of *Narrandera LEP 2013* entitled “Wetlands” aims to ensure that wetlands are preserved and protected from the impacts of development. This clause is applicable to Narrandera as there are several regions on the floodplain in the vicinity of the town which are identified as “Wetland” on the relevant LEP map. The clause calls for consideration of any impact to the flora and fauna in the wetland, to the habitat of fauna or to the surface water characteristics of the land, including water quality and natural water flows.

Clauses 6.9 and 6.10 of *Narrandera LEP 2013* entitled “Development on river front areas” and “Development on riverbeds and banks”, respectively apply to development on river front areas and on riverbeds and banks. The objectives of these clauses can be summarised as to manage and maintain the water quality and environmental health of both the Murrumbidgee River and the riverine corridor. In general terms, these clauses restrict any development in the Murrumbidgee River, on its banks, or in river front areas unless it can be shown that the development will not have a negative effect on water quality, erosion, flow patterns or the river environment.

### 3 POTENTIAL FLOODPLAIN MANAGEMENT MEASURES

#### 3.1 Range of Available Measures

A variety of floodplain management measures can be implemented to reduce flood damages. They may be divided into three categories, as follows:

**Flood modification** measures change 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, detention basins, channel improvements and upgrades of piped drainage systems in urban areas. Such measures are also known as “structural” options as they involve the construction of engineering works.

**Property modification** measures reduce risk to properties through appropriate land use zoning, specifying minimum floor levels for new developments, voluntary purchase of residential property in high hazard areas, or raising existing residences in the less hazardous areas. Such options are largely planning (i.e. “non-structural”) 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 to individual properties.

**Response modification** measures change the response of flood affected communities to the flood risk by increasing flood awareness, implementation of flood warning and broadcast systems and the development of emergency response plans for property evacuation. These options are entirely non-structural.

#### 3.2 Community Views

Comments on potential flood management measures were sought from the Narrandera community by way of the *Community Questionnaire* which was distributed at the commencement of the present study. The responses are summarised in **Appendix A** of this report. Question 15 in the *Community Questionnaire* outlined a range of potential flood management measures that were included in *FRMP 2009*, while Question 16 listed a range of additional potential flood mitigation measures for possible inclusion in *FRMP 2019*. The responses in Questions 15 and 16 are shown on **Tables 3.1** and **3.2**, respectively over the page. The measures are discussed in more detail in later sections of this Chapter.

The Community favoured the following measures which were included in *FRMP 2009*:

- Construction of a ring levee around the water supply pumping station.
- Update the *Local Flood Plan* to include recent flood level information in the Flood Warning System for Narrandera.
- Preparation of flood evacuation plans for dwellings with multiple occupancy, including motels and caravan parks.
- Upgrade of the Southern Main Canal Embankment.
- Upgrade of the Narrandera Airport Levee.

The Community also favoured the following additional measures:

- Improvement to the stormwater system within the town area.
- Provision of a Planning Certificate to purchasers in flood prone areas, stating that the property is flood affected.

- Improvement to flood warning and evacuation procedures both before and during a flood.
- Specify additional controls on future development in flood-liable areas.

Other measures suggested by individual respondents but not itemised in the *Community Questionnaire* include:

- Increasing the height of the Newell Highway between the Southern Main Canal Embankment and the Sturt Highway, including the installation of continuous box culverts beneath the upgraded section of road.
- Improvements to Irrigation Way to the west of the town to ensure access is maintained between Narrandera and Leeton during flood events.
- Improvements to the Newell Highway to the east of the town to prevent isolation during flood events.
- Maintaining an up-to-date database of road closures on Council's website during flood events.
- Increasing the number of empty sandbags permanently stored at Narrandera to allow for early dissemination to community.

**TABLE 3.1  
COMMUNITY VIEWS ON FLOOD MANAGEMENT MEASURES  
INCORPORATED IN FRMP 2009**

Flood Management Measure		Classification <sup>(1)</sup>	Respondent's Views	
			Yes	No
a)	PM1 – Rezoning of land at Gillenbah.	PM	31	17
b)	PM2 – Update Local Environmental Plan and Development Control Plan documents.	PM	31	12
c)	PM3 – Flood proofing future development in Gillenbah which are located within the floodway.	PM	23	23
d)	RM1 – Updates to existing Narrandera Local Flood Plan to include recent flood level information in Flood Warning system.	RM	50	4
e)	RM2 – Program of flood education to raise awareness amongst the local community allow residents to be 'flood ready'.	RM	35	16
f)	RM3 – Preparation of flood evacuation plans for dwellings with multiple occupancy, including motels and caravan parks.	RM	43	12
g)	FM1 – Upgrade the Southern Main Canal Embankment.	FM	41	13
h)	FM2 – Upgrade of Narrandera Airport Levee.	FM	43	9
i)	FM3 – Construction of a levee around the Nallabooma Estate.	FM	34	18
j)	FM4 – Construction of a ring levee around the Water Supply Pumping Station.	FM	52	4

1. FM = Flood Modification Option PM = Property Modification Option RM = Response Modification Option

**TABLE 3.2**  
**COMMUNITY VIEWS ON OTHER POTENTIAL FLOOD MANAGEMENT MEASURES**

Flood Management Measure		Classification <sup>(1)</sup>	Respondent's Views	
			Yes	No
a)	Management of riparian vegetation to provide flood mitigation, stability, aesthetic and habitat benefits.	FM	24	19
b)	Widening of watercourses.	FM	21	24
c)	Removal of floodplain obstructions.	FM	30	15
d)	Improve the stormwater system within the town area.	FM	48	5
e)	Voluntary scheme to purchase residential property in high hazard areas.	PM	23	22
f)	Provide funding or subsidies to raise houses above major flood level in low hazard areas.	PM	18	26
g)	Specify additional controls on future development in flood-liaable areas (e.g. controls on extent of filling)	PM	37	7
h)	Improve flood warning and evacuation procedures both before and during a flood.	RM	42	9
i)	Provide a Planning Certificate to purchasers in flood prone areas, stating that the property is flood affected.	PM	45	4

1. FM = Flood Modification Option PM = Property Modification Option RM = Response Modification Option

### 3.3 Outline of Chapter

A number of the measures set out in **Tables 3.1** and **3.2** were examined at the strategic level of detail in **Chapter 3** and where appropriate, tested for feasibility on a range of assessment criteria in **Chapter 4**. Following consideration of the results by the FRMC, selected measures were included in *FRMP 2019* which is set out in **Chapter 5**.

The potential flood modification measures which were investigated as part of the *Flood Study Review* included the upgrade of the Southern Main Canal Embankment, the upgrade of the Narrandera Airport Levee, construction of a levee around Nallabooma Estate, and construction of a ring levee around the water supply pumping station. An indicative cost estimate was prepared and an economic (benefit/cost) analysis undertaken to determine if the upgrade of the levees could be justified on economic grounds. In addition, potential flood modification measures that were investigated as part of the present study included the construction of up to two detention basins in the headwaters of the catchment which discharges to the Town Siphon, as well as minor stormwater upgrade works that are currently being investigated by Council along the northern side of the Northern Main Canal Embankment immediately west of River Street. The flood mitigation benefits of the works that were recently constructed by Council adjacent to the inlet of the Town Siphon have also been tested.

In the economic analysis, the damages prevented by a flood mitigation scheme represent its benefits. The damages were computed for present day and post-scheme conditions for a range of floods up to the Extreme Flood. By integrating the area beneath the damages – frequency curve up to the “design standard” of the measure, the long term “*average annual*” value of benefits were calculated (by subtraction of post-scheme from present day damages). These

average annual benefits were then converted to an equivalent *present worth value* for each of the three discount rates nominated by NSW Treasury Guidelines for the economic analysis of public works (i.e. 4, 7 and 11 per cent), over an economic life of 50 years. These present worth values of benefits were then divided by the capital costs of the schemes to give benefit/cost ratios for the three discount rates. **Table 3.3** over summarises the present worth value of the various flood modification schemes that were assessed as part of both the *Flood Study Review* and the present study, along with their estimated capital costs and benefit cost ratios.

**Figure 3.1** shows the location of the flood modification measures that were assessed as part of both the *Flood Study Review* and the present study, while **Figure 3.2** shows typical sections of the measures that were assessed on the Murrumbidgee River floodplain. Figures contained in **Appendix D** of this report show the impact several of the assessed flood modification measures would have on both Main Stream Flooding and Major Overland Flow at Narrandera.

The property modification measures considered as part of *FRMP 2009* included rezoning land at Gillenbah, updating the then current LEP and DCP, and flood proofing future development in Gillenbah which are located in the floodway area. Additional property modification measures considered as part of the present study include controls over future development, voluntary purchase of residential properties and house raising.

Response modification measures considered in the *FRMP 2009* included a program of flood education to raise awareness amongst the local community to be 'flood ready', and preparation of flood evacuation plans for dwelling with multiple occupancy such as motels and caravan parks. Improvements to the flood warning system and evacuation procedures based on the information contained in this report have been considered as part of the present study.

### 3.4 Flood Modification Measures Assessed as Part of the Flood Study Review

#### 3.4.1 General

The *Flood Study Review* assessed the technical and economic feasibility of the flood modification measures that formed part of *FRMP 2009*, as well as a number of alternative measures which were aimed at achieving the same flood mitigation objectives. The followings sections of the report provide an overview of the flood modification measures that were assessed as part of the *Flood Study Review*, noting that the report concluded that a scheme involving the following components best achieved the flood mitigation objectives of *FRMP 2009*:

- Southern Main Canal Embankment Upgrade - Narrandera Regulator to Irrigation Way.
- Narrandera Airport and Nallabooma Estate Ring Levee.
- Water Supply Pumping Station Ring Levee.
- Old Brewery Road Upgrade.

The scheme, which was denoted the **Ultimate Flood Protection Scheme**, was estimated to cost a total of \$10.2 Million and have a benefit cost ratio of 0.35. **Table 3.4** summarises the advantages and disadvantages of the flood modification measures that were assessed as part of the *Flood Study Review*, including the Ultimate Flood Protection Scheme, while **Figure D1.1** in **Appendix D** shows the impact that the Ultimate Flood Protection Scheme would have on flooding behaviour at the 1% AEP level of flooding.

**TABLE 3.3**  
**BENEFIT COST RATIOS FOR ASSESSED FLOOD PROTECTION MEASURES**

Mechanism of Flooding	Type of Measure	Flood Modification Measure <sup>(1)</sup>	Present Worth Value of Benefits (Damages Prevented) <sup>(2)</sup> (\$ Million)	Estimated Cost of Measure (\$ Million)	Benefit/Cost Ratio	
Main Stream Flooding	Levee Upgrade	New Town Levee (Bundidgerry Regulator to Ch 16,200 m)	\$0.44	\$29.0	0.02	
		New Town Levee (Narrandera Regulator to Ch 16,200 m)	\$0.44	\$12.5	0.04	
		New Town Levee (Narrandera Regulator to Irrigation Way)	\$0.27	\$10.0	0.03	
		Southern Main Canal Embankment Upgrade (Bundidgerry Regulator to Ch 16,200 m)	\$0.44	\$3.8	0.12	
		Southern Main Canal Embankment Upgrade (Narrandera Regulator to Ch 16,200 m)	\$0.44	\$2.7	0.16	
		Southern Main Canal Embankment Upgrade (Narrandera Regulator to Irrigation Way)	\$0.27	\$2.4	0.11	
		Narrandera Airport Levee Replacement (1.0 m Freeboard)	\$3.00	\$6.4	0.47	
		Narrandera Airport Levee Replacement (0.7 m Freeboard)	\$3.00	\$5.4	0.56	
		Weir Park Road Levee <sup>(3)</sup>	\$0.27	\$1.1	0.25	
		Narrandera Airport and Nallabooma Estate Ring Levee	\$3.27	\$6.8	0.48	
	Water Supply Pump Station Ring Levee	\$0.01	\$0.2	0.04		
	Road Upgrade	Irrigation Way Upgrade	Not Assessed-			
		New Airport Link Road (Paynters Siding Road) <sup>(3)</sup>	Negative <sup>(4)</sup>	\$5.1	NA	
Old Brewery Road Upgrade <sup>(5)</sup>		\$0.01	\$1.0	0.01		
Levee and Road Upgrade	Ultimate Flood Protection Scheme	\$3.54	\$10.2	0.35		
Major Overland Flow	Detention Basin	Basin Strategy Option 1	\$3.2	\$2.1	1.52	
		Basin Strategy Option 2	\$3.5	\$2.6	1.35	
		Basin Strategy Option 3	\$3.7	\$3.0	1.23	

1. Unless otherwise stated, each levee protection option incorporates a freeboard of 1 m.
2. Based on flood damages which are based on a freeboard allowance, with the exception of Basin Strategy Options 1, 2 and 3
3. Includes the costs and benefits of building the Narrandera Airport Levee Replacement Option.
4. While not quantified, this option would result in an increase in the *Present Worth Value* of damages due to the increase in depths of inundation in a number of residential properties.
5. Includes the costs and benefits of building the Water Supply Pumping Station Ring Levee.
6. Not assessed due to its major impact on flooding behaviour in Nallabooma Estate

**TABLE 3.4**  
**ADVANTAGES AND DISADVANTAGES OF FLOOD PROTECTION MEASURES ASSESSED AS PART OF THE FLOOD STUDY REVIEW**

Flood Protection Measure	Advantages	Disadvantages	Comments
New Town Levee (Bundidgerry Regulator to Ch 16,200 m)	<ul style="list-style-type: none"> <li>Levee independent of the Southern Main Canal Embankment which is located on land owned by Murrumbidgee Irrigation.</li> </ul>	<ul style="list-style-type: none"> <li>Most expensive option.</li> <li>Cannot be justified on economic grounds.</li> <li>Significant environmental impacts relating to land clearing requirements and infilling of existing flood runner.</li> <li>Would likely require the purchase of land, the cost of which has not been factored into the cost estimate.</li> <li>Third-party related impacts.</li> </ul>	<ul style="list-style-type: none"> <li>While technically feasible, this option cannot be justified on economic and environmental grounds.</li> <li>Recommend that it not be considered for detailed design.</li> </ul>
New Town Levee (Narrandera Regulator to Ch 16,200 m)	<ul style="list-style-type: none"> <li>Same as for full length option and also cheaper.</li> </ul>	<ul style="list-style-type: none"> <li>Same as for full length option.</li> <li>Requires the height of the Narrandera Regulator to be raised.</li> </ul>	<ul style="list-style-type: none"> <li>While technically feasible, this option cannot be justified on economic and environmental grounds.</li> <li>Recommend that it not be considered for detailed design.</li> </ul>
New Town Levee (Narrandera Regulator to Irrigation Way)	<ul style="list-style-type: none"> <li>Same as for full length option but also cheapest of Town Levee options.</li> </ul>	<ul style="list-style-type: none"> <li>Same as for full length option.</li> <li>Requires the height of the Narrandera Regulator to be raised.</li> <li>Does not prevent overtopping of Southern Main Canal Embankment north of Irrigation Way.</li> </ul>	<ul style="list-style-type: none"> <li>While technically feasible, this option cannot be justified on economic and environmental grounds.</li> <li>Recommend that it not be considered for detailed design.</li> </ul>
Southern Main Canal Embankment Upgrade (Bundidgerry Regulator to Ch 16,200 m)	<ul style="list-style-type: none"> <li>More cost effective than Town Levee option.</li> <li>Increases the design standard of the Southern Main Canal Embankment at Narrandera to 1% AEP.</li> <li>Reduction in environmental impacts when compared to Town Levee option.</li> </ul>	<ul style="list-style-type: none"> <li>Cannot be justified on economic grounds.</li> <li>Requires agreement with Murrumbidgee Irrigation.</li> <li>Costs may increase if the condition of the existing embankment is found to be unsuitable.</li> <li>Third-party related impacts.</li> </ul>	<ul style="list-style-type: none"> <li>While technically feasible, this option is not recommended. Rather, one of the shorter upgrade options offers more cost effective means of protecting existing development located on the northern side of the Main Canal.</li> </ul>
Southern Main Canal Embankment Upgrade (Narrandera Regulator to Ch 16,200 m)	<ul style="list-style-type: none"> <li>Same as for full length option and also cheaper.</li> </ul>	<ul style="list-style-type: none"> <li>Same as for full length option.</li> <li>Requires the height of the Narrandera Regulator to be raised.</li> </ul>	<ul style="list-style-type: none"> <li>In the absence of other measures, this option offers the most cost effective and greatest level of protection for existing development located on the northern side of the Main Canal.</li> </ul>
Southern Main Canal Embankment Upgrade (Narrandera Regulator to Irrigation Way)	<ul style="list-style-type: none"> <li>Same as for full length option but also cheapest of upgrade options.</li> <li>Could form part of an integrated scheme which protects existing development at Narrandera from riverine flooding (for example, the Ultimate Flood Protection Scheme).</li> </ul>	<ul style="list-style-type: none"> <li>Same as for full length option.</li> <li>Requires the height of the Narrandera Regulator to be raised.</li> <li>Does not prevent overtopping of Southern Main Canal Embankment north of Irrigation Way.</li> </ul>	<ul style="list-style-type: none"> <li>This option should be considered in combination with say the Narrandera Airport and Nallabooma Estate Ring Levee option, since the latter will prevent overtopping of the Southern Main Canal Embankment north of Irrigation Way.</li> </ul>
Narrandera Airport Levee Replacement (1.0 m Freeboard)	<ul style="list-style-type: none"> <li>Protects existing infrastructure within the airport for all floods up to the 1% AEP.</li> </ul>	<ul style="list-style-type: none"> <li>Cannot be justified on economic grounds.</li> <li>Expensive relatively to the <i>Present Worth Value</i> of damages saved (Current assessment does not include the costs associated with repairs to the runway resulting from prolonged inundation by floodwater).</li> <li>Third-party related impacts.</li> </ul>	<ul style="list-style-type: none"> <li>While not justified on economic grounds, benefits associated with keeping the airport operational during a flood event may result in this option being recommended for detailed design (decision to proceed needs to be made by others). However, consideration should be given to adopting a reduced freeboard of say 0.7 m (see below).</li> </ul>
Narrandera Airport Levee Replacement (0.7 m Freeboard)	<ul style="list-style-type: none"> <li>Reduced freeboard saves \$1 Million in the cost of replacing the existing ring levee.</li> </ul>	<ul style="list-style-type: none"> <li>Cannot be justified on economic grounds.</li> <li>Expensive relatively to the <i>Present Worth Value</i> of damages saved (Current assessment does not include the costs associated with repairs to the runway resulting from prolonged inundation by floodwater).</li> <li>Reduced freeboard to peak 1% AEP flood levels.</li> <li>Third-party related impacts.</li> </ul>	<ul style="list-style-type: none"> <li>This option provides a high level of protection to airport infrastructure at a more reasonable cost when compared to the 1 m freeboard option.</li> </ul>

Cont'd Over



**TABLE 3.4 (Cont'd)**  
**ADVANTAGES AND DISADVANTAGES OF FLOOD PROTECTION MEASURES ASSESSED AS PART OF THE FLOOD STUDY REVIEW**

Flood Protection Measure	Advantages	Disadvantages	Comments
Irrigation Way Upgrade	<ul style="list-style-type: none"> <li>Road works confined to existing road reserve.</li> <li>Increases hydrologic standard of section of Irrigation Way between the Southern Main Canal Embankment and the airport to 1% AEP.</li> </ul>	<ul style="list-style-type: none"> <li>Significant impact on flooding behaviour in existing development.</li> <li>Section of Irrigation Way which runs between the dis-used Narrandera Tocumwal Railway line and the Main Canal may still be affected by flooding in the event of overtopping or failure of the Southern Main Canal Embankment.</li> </ul>	<ul style="list-style-type: none"> <li>While technically feasible, this option is not recommended due to its impact on flooding behaviour in existing development.</li> </ul>
New Airport Link Road (Paynters Siding Road)	<ul style="list-style-type: none"> <li>Increases hydrologic standard of section of Irrigation Way between the Southern Main Canal Embankment and the airport to 1% AEP.</li> </ul>	<ul style="list-style-type: none"> <li>Expensive.</li> <li>Cannot be justified on economic grounds.</li> <li>While of low probability, access issues may still be a problem on northern side of Main Canal during periods when heavy rainfall coincides with elevated water levels in the river.</li> <li>Third-party related impacts.</li> </ul>	<ul style="list-style-type: none"> <li>While technically feasible, this option is not recommended due to its cost and also the residual access issues.</li> </ul>
Weir Park Road Levee	<ul style="list-style-type: none"> <li>Increases hydrologic standard of section of Irrigation Way between the Southern Main Canal Embankment and the airport to 1% AEP.</li> <li>Has added benefit of reducing flood damages in existing residential development located to the south of the airport principally within the Nallabooma Estate.</li> </ul>	<ul style="list-style-type: none"> <li>Cannot be justified on economic grounds.</li> <li>Sections of embankment located on privately owned land requiring easements to be created to facilitate access and maintenance.</li> <li>Does not provide the required freeboard to allow Council to remove Section 10.7 flood notifications from existing residential development located to the south of the airport principally within the Nallabooma Estate.</li> <li>Results in an increase in peak flood levels in existing development for floods larger than 5% AEP.</li> <li>While of low probability, access issues may still be a problem on northern side of Main Canal during periods when heavy rainfall coincides with elevated water levels in the river.</li> <li>Third-party related impacts.</li> </ul>	<ul style="list-style-type: none"> <li>While this option has merit and should be considered for detailed design, Council should also consider expanding this option into the Narrandera Airport and Nallabooma Estate Ring Levee option (refer below) if the decision is made to upgrade the airport levee.</li> <li>Further investigations need to be undertaken to assess whether additional measures are required to mitigate third-party related impacts.</li> </ul>
Narrandera Airport and Nallabooma Estate Ring Levee	<ul style="list-style-type: none"> <li>Provides 1% AEP level of protection to both the airport and existing development to its south.</li> <li>Increases hydrologic standard of section of Irrigation Way between the Southern Main Canal Embankment and the airport to 1% AEP.</li> <li>Would allow Section 10.7 flood notifications to be removed from allotments which are protected by the ring levee.</li> <li>Not that much more expensive than the Narrandera Airport Ring Levee option, but offers significantly more protection to existing development.</li> </ul>	<ul style="list-style-type: none"> <li>Cannot be justified on economic grounds.</li> <li>Sections of embankment located on privately owned land requiring easements to be created to facilitate access and maintenance.</li> <li>Results in an increase in peak flood levels in existing development for floods larger than 5% AEP.</li> <li>While of low probability, access issues may still be a problem on northern side of Main Canal during periods when heavy rainfall coincides with elevated water levels in the river.</li> <li>Third-party related impacts.</li> </ul>	<ul style="list-style-type: none"> <li>While not cheap, this option has merit and could be considered for detailed design.</li> <li>Further investigations need to be undertaken to assess whether additional measures are required to mitigate third-party related impacts.</li> </ul>
Water Supply Pumping Station Ring Levee	<ul style="list-style-type: none"> <li>Provides 1% AEP level of protection to water supply pumping station.</li> </ul>	<ul style="list-style-type: none"> <li>Geotechnical investigations may find that there is the possibility of groundwater intrusion to protected area during a flood event requiring the implementing of expensive measures such as sheet piling (not presently costed).</li> </ul>	<ul style="list-style-type: none"> <li>This option has merit and should be considered for detailed design.</li> </ul>

Cont'd Over

**TABLE 3.4 (Cont'd)**  
**ADVANTAGES AND DISADVANTAGES OF FLOOD PROTECTION MEASURES ASSESSED AS PART OF THE FLOOD STUDY REVIEW**

Flood Protection Measure	Advantages	Disadvantages	Comments
Old Brewery Road Upgrade	<ul style="list-style-type: none"> <li>• Increases hydrologic standard of Old Brewery Road to 1% AEP.</li> <li>• Social benefits as it removes the need for Council staff to use boats to access the pump station during a flood event.</li> </ul>	<ul style="list-style-type: none"> <li>• None</li> </ul>	<ul style="list-style-type: none"> <li>• This option has merit and should be considered for detailed design.</li> </ul>
Ultimate Flood Protection Scheme	<ul style="list-style-type: none"> <li>• Same advantages as listed above for individual measures comprising the scheme.</li> <li>• Maximises the number of properties which would be protected from riverine type flooding for events up to 1% AEP.</li> <li>• Improves access to both the Narrandera Airport and residential development located to its south during a flood event.</li> </ul>	<ul style="list-style-type: none"> <li>• Same disadvantages as listed above for individual measures comprising the scheme.</li> <li>• Expensive.</li> <li>• Third-party related impacts.</li> </ul>	<ul style="list-style-type: none"> <li>• While expensive, this option meets the objectives of <i>FRMP 2009</i>. That is, it provides 1% AEP level of protection to the Narrandera Airport, the water supply pumping station and existing development located to the north of the Main Canal and to the south of the airport.</li> <li>• This option could be considered for detailed design subject to funding and resolution of land ownership/easement requirements.</li> <li>• Further investigations would also need to be undertaken to:               <ul style="list-style-type: none"> <li>○ assess whether additional measures are required to mitigate third-party related impacts; and</li> <li>○ assess whether the section of the Southern Main Canal Embankment which runs between the Narrandera Regulator and Irrigation Way is suitable to form the basis of a formal flood protection levee.</li> </ul> </li> </ul>

One of the major constraints associated with the implementation of the Ultimate Flood Protection Scheme is that the Main Canal is in the ownership of Murrumbidgee Irrigation who does not have responsibility for floodplain risk management and/or flood operations within its charter. Council will therefore need to consult further with Murrumbidgee Irrigation regarding how the Southern Main Canal Embankment could be upgraded to act as a formal flood protection measure, with Council taking responsibility for its upgrade and ongoing maintenance.

While the cost of the upgrade of the Narrandera Regulator could be funded through the NSW Government's floodplain management program, it is recommended that the scheme not rely on the operation of the gates for flood mitigation purposes, for the above stated reason that Murrumbidgee Irrigation does not have responsibility for floodplain risk management and/or flood operations in its charter. This will require an assessment to be undertaken of the discharge characteristics of the regulator gates in their fully open position to ensure existing development is not at risk of flooding should they remain open during a major flood event.

*FRMP 2019* includes a recommendation to undertake a feasibility study for upgrading the section of the Southern Main Canal Embankment which runs between the Narrandera Regulator and Irrigation Way. The feasibility study is to include a geotechnical investigation which will assess the structural integrity of the existing embankment and determine the scope of works which would be required to ensure that it will function as a formal flood protection levee during major floods on the Murrumbidgee River.

### **3.4.2 New Town Levee Option**

There are presently no geotechnical data available to guide the decision on the approach to upgrading the Southern Main Canal Embankment. One approach would be to remove the existing bank and replace it with suitable engineered material to the design level and occupying the same cross-section. An alternative approach would be to construct a new earth embankment on the river side of the existing bank on land not owned by Murrumbidgee Irrigation. As the levee would be several metres in height, a large area would need to be cleared of vegetation in order to facilitate its construction. Construction of the levee would also result in the filling of the flood runner which runs along the toe of the existing bank west (downstream) of the Narrandera Regulator.

For costing purposes, three alternative levee alignments were assessed. These comprised:

- The construction of a new earth embankment which would extend from the Bundidgerry Regulator to a location opposite Narrandera Airport at about Ch 16,200 m. This option would provide the required level of protection to development located on the northern side of the Main Canal.
- The construction of a new earth embankment which would extend from the Narrandera Regulator to a location opposite Narrandera Airport at about Ch 16,200 m. While this option would also provide the required level of protection to development located on the northern side of the Main Canal, it would require the height of the Narrandera Regulator to be raised to prevent it being overtopped by floodwater. The current gate arrangement would also allow a portion of the flow conveyed in the canal to bypass the regulator. An investigation would need to be undertaken to determine whether the rate at which floodwater could discharge to the downstream reach of canal is sufficient to cause flooding of property located on the northern side of the Northern Main Canal Embankment.
- The construction of a new earth embankment which would extend from the Narrandera Regulator to the location where Irrigation Way crosses the Main Canal. As the available

freeboard to the crest of the Southern Main Canal Embankment west (downstream) of Irrigation Way is less than 1 m, it is necessary to assume that this section of bank could fail during a 1% AEP flood event. It is noted that the peak 1% AEP flood level on the river side of the bank is RL 144.7 m AHD and that this level lies above the floor level of only four dwellings and one commercial building that are located on the northern side of the Main Canal (i.e. this represents the maximum damage which would occur should a section of the embankment fail downstream of the Irrigation Way crossing of the Main Canal).

**Figure D1.2 in Appendix D** shows the impact the construction of an earth embankment on the river side of the Southern Main Canal Embankment between the Bundidgerry Regulator and a location opposite Narrandera Airport would have on flooding behaviour at the 1% AEP level of flooding. Increases in peak 1% AEP flood levels of greater than 20 mm would occur in the vicinity of several dwellings that are located downstream of the disused Narrandera-Tocumwal Railway, while increases of greater than 50 mm would occur in the vicinity of several residential dwellings which are located downstream of Irrigation Way.

Given the large costs associated with the construction of all three levee options and the impact they would have on the riparian and floodplain vegetation, the construction of a new embankment along the river side of the Southern Main Canal Embankment is not recommended.

### 3.4.3 Southern Main Canal Embankment Upgrade Option

This option involves raising sections of the Southern Main Canal Embankment so as to achieve the required 1 m freeboard to peak 1% AEP flood levels. **Figure D1.3 in Appendix D** is a long section along the Southern Main Canal Embankment showing the sections of the existing bank which would need to be raised in order to achieve the 1 m freeboard requirement.

In order to raise the crest level of the existing embankment it would be necessary to clear and grub the crest and southern (river side) face of the embankment and also an area adjacent to its toe. It is noted that the removal of the vegetation and the top 300 mm of material would address a number of concerns raised by PW during its visual audit of the embankment in 2013.

Concept designs for the same three lengths of levee which were assessed for the New Town Levee (refer **Section 3.4.2**) were developed, the costs of which are given in **Table 3.3**. By inspection of **Figure D1.4 in Appendix D**, the upgrade of the Southern Main Canal Embankment will not have a significant impact on peak 1% AEP flood levels on the Murrumbidgee River floodplain.

While a geotechnical investigation will be required to assess the suitability of the Southern Main Canal Embankment to be used as a formal flood protection levee, its upgrade is recommended in favour of the construction of a new town levee. The need to raise the embankment east (upstream) of the Narrandera Regulator will depend on the outcomes of discussions with Murrumbidgee Irrigation and after consideration of the upgrade requirements for the regulator.

### 3.4.4 Narrandera Airport Levee Replacement Option

**Figure D1.5 in Appendix D** shows that the existing ring levee effectively has less than 1 m of freeboard to peak 1% AEP flood levels along its full length. Given the relatively low height of the existing bank (i.e. between 1-1.5 m), the most cost effective approach to upgrading the levee would be to remove it and replace it with suitable engineered material to the design level. The cost of upgrading the ring levee to achieve the 1 m freeboard requirement is estimated at \$6.4 Million.

Given that the upgraded levee would protect only the runway and a limited number of commercial buildings (i.e. no residential dwellings), a cost estimate was prepared for a levee which incorporated a reduced freeboard of 0.7 m. The adoption of the reduced freeboard resulted in the cost of the upgrade reducing to about \$5.4 Million (i.e. a saving of \$1 Million).

**Figure D1.6** in **Appendix D** shows the impact the upgrade of the Narrandera Airport Levee would have on flooding behaviour at the 1% AEP level of flooding. In addition to increasing peak flood levels in a number of rural residential properties, the levee would also result in a minor increase in the rate at which floodwater would overtop the Southern Main Canal Embankment at around Ch 20,000 m.

As previously mentioned, Council has recently placed fill material along the section of the Narrandera Airport Levee which runs along the northern side of Irrigation Way. As no details are available on the crest height of the newly upgraded section of levee or the level of compaction which was achieved when placing the fill material, a recommendation has been included in *FRMP 2019* for Council to commission a crest level survey and to undertake geotechnical testing to ascertain compaction levels along its length.

### 3.4.5 Irrigation Way Upgrade Option

This option would involve raising the section of Irrigation Way which runs between the Main Canal and the Narrandera Airport to increase its level of flood immunity to greater than 1% AEP. **Figure D1.7** in **Appendix D** shows the impact the raising of Irrigation Way in combination with upgrading the Narrandera Airport Levee would have on flooding behaviour at the 1% AEP level of flooding. Due to its orientation, it is not possible to provide sufficient waterway area beneath the road embankment to mitigate the blocking effects the raised section of road would have on flooding behaviour. Given the significant impacts this option has on flooding behaviour in a large number of residential properties it was not investigated further.

### 3.4.6 New Airport Link Road (Paynters Siding Road)

This option would involve the construction of a new road linking Paynters Siding Road on the northern side of the Main Canal with Narrandera Airport. While the new road would have a minimum hydrologic standard of 1% AEP, it is noted that Paynters Siding Road was inundated by local catchment runoff which ponded behind the Northern Main Canal Embankment during the March 2012 flood. Council advised that access into Narrandera is possible via a circuitous route to the north, but that this road is unsealed and that it could be susceptible to damage during prolonged or heavy rainfall events.

As part of the new road works it would be necessary to construct a new road bridge across the Main Canal and also install a large viaduct structure which for modelling purposes comprised 35 off 3000 mm wide by 900 mm high reinforced concrete box culverts.

**Figure D1.8** in **Appendix D** shows that the new road in combination with upgrading the Narrandera Airport Levee would increase peak 1% AEP flood levels in a number of residential properties.<sup>7</sup>

Given its impact on flooding behaviour, its large cost and also the access issues which could arise during coincident prolonged or heavy rainfall, this option was not considered further.

---

<sup>7</sup> It is noted that the increase in peak flood levels downstream of the new road is a function of the new ring levee around Narrandera Airport.

### 3.4.7 Weir Park Road Levee Option

This option involves the construction of a new earth embankment which would run between the Southern Main Canal Embankment and high ground which is located at the western end of Weir Park Road. The total length of the levee would be about 1.8 km.

**Figure D1.9** in **Appendix D** shows the impact the construction of the Weir Park Road Levee in combination with upgrading the Narrandera Airport Levee would have on flooding behaviour at the 1% AEP level of flooding. Construction of the Weir Park Road Levee would prevent the break out of flow which occurs across Weir Park Road for floods larger than about 5% AEP. This would in turn remove flooding from a large number of properties located in Nallabooma Estate and also provide flood free access to Narrandera Airport via Irrigation Way for floods up to 1% AEP.<sup>8</sup>

Increases in peak 1% AEP flood levels of greater than 10 mm are shown to occur in the vicinity of the Park Hill, Goonahra, Goonerah and Gillenbah Station homesteads. A review of the property database provided by Council shows that there would be greater than 500 mm freeboard to the floor level of the Park Hill homestead and an adjacent dwelling following construction of the Weir Park Road Levee. No floor level information is available for the other homesteads. Should Council decide to proceed with the Weir Park Levee option, then it would be necessary to survey the floor level of these residences, including the height of any protective ring levee to determine whether the increase in peak flood levels will reduce the available freeboard to less than 500 mm.

The key issue with this option is that it does not provide the necessary freeboard to allow Council to remove Section 10.7 flood notifications from individual allotments. The reason for this is that there are several low points which are present in the high ground to the west of the levee where the freeboard is less than 1 m. Floodwater is also shown to back up along Irrigation Way and around the eastern side of the Narrandera Airport Levee in a 1% AEP flood event.

### 3.4.8 Narrandera Airport and Nallabooma Estate Ring Levee

This option involves the construction of a series of earth embankments which would provide the required 1% AEP level of protection to the Narrandera Airport and also existing development which is located to its south. The Weir Park Road Levee and also the northern portion of the Narrandera Airport Levee Replacement option would form part of the scheme, as would a levee bank along the line of the New Airport Link Road (Paynters Siding Road) option described above. A short section of levee bank incorporating a gated low flow pipe would also be required across Irrigation Way near the south-west corner of the Narrandera Airport Levee.

**Figure D1.10** in **Appendix D** shows that similar to the Weir Park Road Levee option, peak 1% AEP flood levels would be increased across the full width of the floodplain. Due to the shielding effects of the ring levee, peak 1% AEP flood levels would be reduced along the Southern Main Canal Embankment north of the airport sufficient to prevent it from being overtopped, albeit with negligible freeboard.

### 3.4.9 Water Supply Pumping Station Ring Levee

Council presently pump treated bore water which is stored in a large balance tank which is located on the northern bank of the Murrumbidgee River upstream of the Newell Highway

---

<sup>8</sup> This assumes that the Southern Main Canal Embankment does not fail during a major flood event, as otherwise the section of Irrigation Way which runs from the disused Narrandera-Tocumwal Railway to the Main Canal would be inundated.

crossing to a series of reservoirs. Access to the adjacent pump station is gained via Old Brewery Road which has been built at the level of the floodplain. Two pumps are located in a dry well, the base of which is set several metres below the slab level of the building. Council advised that it would cost about \$100,000 to replace the two pumps were they to be damaged by floodwater.

During the March 2012 flood, floodwater reached to within a few centimetres of the floor slab of the pumping station. Water was also observed to discharge to the dry well through at least one large crack which is present in one of its side walls.

Due to the topography of the area and the presence of adjacent ancillary infrastructure it would be necessary to construct a reinforced concrete block wall around the perimeter of the pumping station in order to protect it from flooding. Advice would be required from a geotechnical engineer as to the foundation treatment to be adopted for the wall given the potential for water to percolate beneath it and either cause its failure and/or flooding of the dry well. Repairs to the side wall of the dry well should also be undertaken to prevent the ingress of water during a flood event.

Due to uncertainties associated with ground conditions in the area, the scope of works associated with a ring levee around the water supply pumping station could not be assessed. It is recommended that a feasibility study be undertaken which is to include a geotechnical investigation to determine the foundation treatment for the ring levee. This measure has been included in *FRMP 2019*.

#### **3.4.10 Old Brewery Road Upgrade**

Access to the aforementioned water supply pumping station is presently cut once the Murrumbidgee River breaks its banks during a flood. During the March 2012 flood, Council staff gained access to the pumping station via boat and were forced to reside overnight at the pump station to observe rising flood levels and to sandbag the entrances to the building.

The costs associated with raising Old Brewery Road to improve its level of flood immunity to greater than 1% AEP was assessed at about \$800,000. As the road runs parallel with the path floodwater takes after it breaks the northern bank of the river and flows towards the Newell Highway, the *Flood Study Review* found that raising it would not have an impact on peak 1% AEP flood levels (refer **Figure D1.11** in **Appendix D**).

### **3.5 Flood Modification Measures Assessed as Part of the Present Study**

#### **3.5.1 General**

As the *Flood Study Review* assessed the merits of implementing a range of flood modification measures that were aimed at mitigating the impact of Main Stream Flooding on existing development, it was necessary to assess a number of additional measures that are aimed at mitigating the impact of Major Overland Flow on existing development that is located on the northern side of the Main Canal in the urbanised parts of Narrandera.

The following sections of the report provide a description of the flood modification measures that were assessed as part of the present study, as well as the benefits that they would provide in terms of reducing the impact of Major Overland Flow on existing development.

#### **3.5.2 Town Siphon Works**

As mentioned in **Section 2.6.1.4**, Council has recently completed flood modification works adjacent to the inlet of the Town Siphon. This involved the installation of a spillway to the west of

the Town Siphon which allows stormwater to discharge to the Main Canal at a lower level than was previously the case. A series of diversion banks and block walls have also been constructed which are aimed at diverting the flow which discharges to the Town Siphon toward the Main Canal when either the capacity of the pipe is exceeded or when the penstock gate is closed.

**Figure D1.12** in **Appendix D** shows that the works will have a beneficial effect in terms of reducing the impact of flooding in existing residential development that is located on the northern side of the Main Canal adjacent to the inlet of the Town Siphon. While there are no additional measures which could be implemented at this location to further reduce flooding, the construction of one or more detention basins in the upper reaches of the catchment which drains to the Town Siphon will further enhance the flood mitigating benefits of these works (refer **Section 3.5.4** for details).

### 3.5.3 Woolscour Road Siphon Works

Council has developed three options for flood modification works in the vicinity of the Woolscour Road Siphon. Option 1 would involve the construction of a temporary flood storage area on the western side of River Street, immediately north of the Main Canal, while Option 2 would involve the installation of a new 1800 mm diameter siphon beneath the Main Canal in combination with upstream and downstream channel works. Option 3 would be similar to Option 1, but include a second temporary flood storage area on the eastern side of River Street immediately south of the Junee Hay Railway line.

**Figure D1.13** in **Appendix D** shows that while the works comprising Option 1 would reduce depths of ponding on the northern side of the Main Canal by up to 0.2 m, they would not prevent floodwater from surrounding the existing dwelling that is located on the eastern side of Woolscour Road. **Figure D1.14** in **Appendix D** shows that the works comprising Option 2 would have a limited benefit in terms of reducing the depth and extent of inundation when compared to Option 1.

While not modelled in TUFLOW, Option 3 has the potential to mitigate the impact of flooding on existing residential and commercial development that is located along the eastern side of River Street between the rail corridor and Irrigation Way. While the works associated with Option 3 would reduce the impact that major overland flow has on existing development, the resulting benefits would not be sufficient to attract external funding given its limited benefits. However, the works associated with Option 3 have been included in *FRMP 2019*, the construction of which is to be funded by Council.

### 3.5.4 Narrandera Detention Basin Strategy

The majority of flood damages in the urban parts of Narrandera north of the Main Canal occur along the Major Overland Flow path that extends from Henry Mathieson Oval to the inlet of the Town Siphon. The implementation of a detention basin strategy which is aimed at temporarily storing runoff which is generated by the catchment which contributes to flow along this overland flow path would be a cost effective means of reducing the flood damages in Narrandera when compared to the cost of upgrading the existing stormwater drainage system where it runs through town.

The benefits that three alternative detention basins strategies would have on flooding behaviour in the urbanised parts of Narrandera were assessed as part of the present study, the key features of which are as follows:



- **Detention Basin Strategy (Option 1)**, which involves the construction of a detention basin on the northern side of the Newell Highway on Crown Land that is zoned *E2-Environmental Conservation*, in combination with changes in the elevation of Whitton Street to ensure floodwater discharges to Henry Mathieson Oval rather than toward the Major Overland Flow path that presently runs through existing residential development that is located to its west. An embankment would also need to be constructed along the western boundary of Henry Mathieson Oval to prevent floodwater from discharging toward the aforementioned flow path. **Figure 3.3** shows the key features of Detention Basin Strategy (Option 1), while **Figure D1.15** in **Appendix D** shows the impact that its implementation would have on flooding behaviour for a 1% AEP storm event.
- **Detention Basin Strategy (Option 2)**, which would be identical to Detention Basin Strategy (Option 1), but also include a second detention basin that would be formed by constructing an earth embankment partially around the perimeter of Henry Mathieson Oval in combination with the installation of a new 1200 mm diameter pipe beneath Lethbridge Drive. **Figure 3.4** shows the key features of the Detention Basin Strategy (Option 2), while **Figure D1.16** in **Appendix D** shows the impact that its implementation would have on flooding behaviour for a 1% AEP storm event.
- **Detention Basins Strategy (Option 3)**, which would be identical to Detention Basin Strategy (Option 1), but also include the construction of a second detention basin on the eastern oval in Narrandera High School. **Figure 3.5** shows the key features of to Detention Basin Strategy (Option 3), while **Figure D1.17** in **Appendix D** shows the impact that its implementation would have on flooding behaviour for a 1% AEP storm event.

By inspection of **Figure D1.15**, **D1.16** and **D1.17**, all three detention basin options would provide a significant benefit in terms of reducing the impact of flooding on existing development that is located along the Major Overland Flow which extends from Henry Mathieson Oval to the Town Siphon.

As set out in **Table 3.3**, all three options would save over \$3 Million in flood damages for all storm events up to 1% AEP in intensity and have a benefit cost ratio of greater than 1, meaning they can all be justified on economic grounds. While Detention Basin Strategy (Option 1) has the highest benefit cost ratio, Detention Basin Strategy (Option 2), while slightly more expensive would reduce the present worth value of flood damages in Narrandera by an additional \$0.3 Million. Detention Basin Strategy (Option 3) is not preferred as it would result in hazardous depths of ponding in the Narrandera High School. Based on the above findings, the works comprising Detention Basin Strategy (Option 2) have been included in *FRMP 2019*.

By inspection of **Figure D1.18** there would be a significant reduction in the number of properties that would lie either partially or wholly within the extent of the FPA under post-Detention Basin Strategy (Option 2) conditions.

### **3.6 Property Modification Measures**

#### **3.6.1 Controls over Future Development**

##### **3.6.1.1 Considerations for Setting Flood Planning Level**

Selection of the 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 outside the FPA (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 FPL will subject land that is rarely flooded to unwarranted controls.

Councils are responsible for determining the appropriate FPLs within their local government area. *Narrandera LEP 2013* nominates the “1:100 ARI (average recurrence interval) flood event plus 0.5 m freeboard” as the FPL. However, the LEP does not presently distinguish between the two flood producing mechanisms at Narrandera; namely Main Stream Flooding on the Murrumbidgee River floodplain and the slow moving and shallow Major Overland Flow from the local catchments that drain the area north of the Main Canal.

### 3.6.1.2 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% AEP 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 10.7 planning certificates, a revised ministerial direction (Direction 15 – now Direction 4.3 issued of 1 July 2009) regarding flood prone land (issued under Section 9.1 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 NSWG, 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 1% AEP 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 or outside the FPA.

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, developments for aged care and schools.
- 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.

### 3.6.1.3 Proposed Planning Controls for Narrandera

The draft *Flood Policy (Appendix E)* used the concepts of *flood hazard* and *hydraulic categorisation* outlined in the previous sections to develop flood related controls for future development in Narrandera. The *Flood Policy* caters for the two types of flooding in Narrandera:

- **Main Stream Flooding** resulting from flows that surcharge the Murrumbidgee River. These flows may be several metres deep in the channels and relatively slow moving with velocities up to 1 m/s.

- **Major Overland Flow** is present along several flow paths that run through the urbanised parts of Narrandera. It is also present in the undeveloped areas which border the town principally to its north. Flows on the Major Overland Flow paths would typically be less than 300 mm deep, travelling over the surface at velocities less than 0.5 m/s.

Considerable reduction in the number of properties in Major Overland Flow areas classified as “flood affected” would result by the adoption of a threshold depth of inundation under 1% AEP conditions of 100 mm as the criterion for flood affectation, compared with the traditional approach. Properties with depths of inundation 100 mm or greater, or in a floodway (i.e. traversed by significant overland flows) would be considered to be flood affected and lie within the FPA. Properties with depths of inundation under 1% AEP conditions of less than 100 mm would be classified as “Local Drainage” and, as such would be subject to controls such as the Building Code of Australia (**BCA**) requirements, rather than attracting a flood affectation notice. This approach is supported by NSWG, 2005 and would not adversely impact on Council’s duty of care in regard to management of flood prone lands. The proposed categorisation of the floodplain, terminology and controls are shown on **Table 3.5**.

**TABLE 3.5  
PROPOSED CATEGORISATION OF THE FLOODPLAIN**

Category (FDM, 2005)	Proposed Terminology used to define inundation in <i>FRMS 2019 and FRMP 2019</i>	Are Development Controls Required?	Is Section 10.7 Notification Warranted?
Main Stream Flooding	“Main Stream Flooding”	Yes	Yes
Local Overland Flooding - Local Drainage - Major Drainage	“Local Drainage” “Major Overland Flow”	No (ref. footnote 1). Yes (ref. footnote 2).	No (ref footnote 1) Yes (ref footnote 3)

**Footnotes**

1. Inundation in Local Drainage areas is accommodated by the minimum floor level requirement of 100 mm above finished surface level contained in the BCA and does not warrant a flood affectation notice in S10.7 Planning Certificates.
2. These are the deeper flooded areas with higher flow velocities. Development controls are specified in the draft *Flood Policy* of **Appendix E**.
3. Depth and velocity of inundation in Major Overland Flow areas are sufficient to warrant a flood affectation notice in S10.7 Planning Certificates. Inundation is classified as “flooding”.

**Figure E1.1** in **Appendix E** is an extract from the *Flood Planning Map* at Narrandera. The figure includes areas subject to both Main Stream Flooding and Major Overland Flow in the town. The extent of the FPA (the area subject to flood related development controls) is shown in a solid red colour in **Figure E1.1** and has been defined as follows:

- In areas subject to Main Stream Flooding, the FPA is based on the traditional definition of the area inundated by the 1% AEP plus 500 mm freeboard.<sup>9</sup>
- In areas subject to Major Overland Flow, the FPA is defined as the extent of the High and Low Hazard Floodway zones, as well as areas where depths of inundation in a 1% AEP event exceed 100 mm.

The illustration in **Section 5.8.1** of *FRMP 2019* (refer **Chapter 5** of this report) demonstrates the derivation of the FPA in areas affected by Main Stream Flooding and Major Overland Flow.

<sup>9</sup> This includes the area which lies on the northern side of the Main Canal which would be subject to Main Stream Flooding should the Southern Main Canal Embankment fail during a 1% AEP flood event.

It is proposed that properties intersected by the extent of the FPA would be subject to S10.7 flood affectation notification and planning controls graded according to flood hazard (dependent on depth of inundation and flow velocity). NSWG, 2005 suggests wording on S10.7 (2) Planning Certificates along the following lines:

*“Council considers the land in question to be within the Flood Planning Area and therefore subject to flood related development controls. Information relating to this flood risk may be obtained from Council. Restrictions on development in relation to flooding apply to this land as set out in Council’s Flood Policy which is available for inspection at Council offices or website.”*

**Annexures 2.1 and 2.2 in Appendix E** set out the graded set of flood related planning controls which have been developed for Narrandera. **Annexure 2.1** deals with areas subject to Main Stream Flooding, while **Annexure 2.2** deals with areas subject to Major Overland Flow. **Figure E1.2 in Appendix E** is the *Development Controls Matrix Map* for Narrandera showing the areas over which both **Annexures 2.1 and 2.2** apply.

Minimum floor level (**MFL**) requirements would be imposed on future development of properties that are identified as lying either partially or wholly within the extent of the FPA shown on the *Flood Planning Map*. The MFLs for all land use types affected by Main Stream Flooding is the level of the 1% AEP flood event plus 500 mm freeboard, while the MFLs for all land use types affected by Major Overland Flow is the level of the 1% AEP flood event plus 300 mm freeboard. For areas outside the FPA shown on the *Flood Planning Map*, the MFL for all land use types is the level of the 1% AEP flood event plus 500 mm freeboard.

The illustration in **Section 5.8.1 of FRMP 2019** (refer **Chapter 5** of this report) demonstrates the application of the variable freeboard approach in the derivation of the MFL requirements in areas affected by Main Stream Flooding and Major Overland Flow.

**Figure E1.3 in Appendix E** is the *Flood Hazard Map* for Narrandera which shows the subdivision of the floodplain into a number of categories which have been used as the basis for developing the graded set of planning controls.

The floodplain has been divided into the following four categories in areas that are affected by Main Stream Flooding:

- The **Inner Floodplain (Hazard Category 1)** zone (shown as a solid red colour) comprises areas where factors such as the depth and velocity of flow, time of rise, isolation on Low Flood Islands and evacuation problems mean that the land is unsuitable for most types of development. It principally comprises High and Low Hazard Floodway areas. Erection of buildings and carrying out of work; use of land, subdivision of land and demolition subject to State Environmental Planning Policies and Local Environmental Plan provisions are not permitted in this zone.
- The **Inner Floodplain (Hazard Category 2)** zone (shown as a solid yellow colour) comprises High and Low Flood Storage areas, as well as areas where isolation on Low Flood Islands and evacuation problems mean development other than Essential Community Facilities, Critical Utilities, Schools and Flood Vulnerable development is permitted provided it is capable of withstanding hydraulic forces and sited on the allotment to minimise adverse redirections of flow toward adjacent properties. Council may require a *Flood Risk Report* if it considers that the proposal has the potential to significantly affect flooding behaviour in adjacent properties.

- The **Intermediate Floodplain** zone (shown as a solid blue colour) is the remaining land lying outside the extent of the Inner Floodplain zones, but within the FPA (defined as land which lies below the 1% annual exceedance probability (AEP) flood level plus 500 mm freeboard). Within this zone, there would only be the requirement for MFL's to be set at the 1% AEP flood levels plus 500 mm. Land use permissibility would be as specified by State Environmental Planning Policies or the Local Environmental Plan.
- The **Outer Floodplain** zone is the area outside the Intermediate Floodplain where the depth of inundation will exceed 100 mm in the Extreme Flood (shown as a solid cyan colour). This area is outside the extent of the FPA and hence controls on residential, commercial and industrial development do not apply. However, Essential Community Facilities, Critical Utilities and Flood Vulnerable development is not permitted in this zone.

The floodplain has been divided into the following two additional categories in areas that are affected by Major Overland Flow:

- The **High Hazard Floodway** (shown as solid orange) zone identifies areas where significant overland flow of a high hazard nature occur in Narrandera. These are presently limited to a few reaches of incised drainage channel that are located on the western limits of the town.
- The **Low Hazard Floodway / Flood Storage** zone (shown as a solid green colour) identifies the areas where significant overland flow or excessive depths of ponding of a low hazard nature occur in Narrandera.<sup>10</sup> Council may permit residential, commercial and industrial development on this part of the floodplain, provided it is capable of withstanding hydraulic forces and is sited within the allotment to minimise adverse re-direction of flow towards adjacent properties. There would also be the requirement for MFLs to be set at the 1% AEP flood levels plus 300 mm on this part of the floodplain, as well as restrictions on site filling to prevent blockage of flows. Similar controls exist for commercial and industrial development. Council may require a *Flood Risk Report* for development proposals in this area (typically for larger scale commercial or industrial developments).

The **Intermediate Floodplain** zone in areas subject to Major Overland Flow is the remaining land lying outside the extent of the Floodway and Flood Storage areas where the depth of inundation during a 1% AEP storm event depths will exceed 100 mm, while the **Outer Floodplain** zone represents the area outside the aforementioned areas where the depth of inundation will exceed 100 mm during the PMF. Flood related planning controls in these two areas are similar to those that apply to development in areas subject to Main Stream Flooding, with the following exceptions:

- the adoption of a reduced freeboard of 300 mm for defining MFLs in the **Intermediate Floodplain**; and
- the potential for Essential Community Facilities, Critical Utilities and Flood Vulnerable Residential type development to take place in both the **Intermediate Floodplain** and **Outer Floodplain** subject to compliance with the flood related development controls set out in **Annexure 2.2** of the *Flood Policy*.

---

<sup>10</sup> Note that in order to maintain connectivity between the areas of deeper flow, the Floodway zone has been extended in some areas to include areas where the depth of flow is less than 150 mm.

### 3.6.1.4 Revision of Narrandera LEP 2013 by Council

To implement the recommended approach set out in *FRMS 2019* and *FRMP 2019*, clause 6.2 of *Narrandera LEP 2013* would require minor amendments, namely in regards the wording of sub clause (2) and deletion of clause (5). It is recommended that the following clause replaces the existing clause 6.2 of *Narrandera LEP 2013*:

#### 6.2 Flood planning

- (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 on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change,
  - (c) to avoid significant adverse impacts on flood behaviour and the environment.
- (2) This clause applies to land at or below the flood planning level.
- (3) Development consent must not be granted for 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) is not 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 Floodplain Development Manual, unless it is otherwise defined in this Plan.

In order to support the proposed changes to clause 6.2 of *Narrandera LEP 2013*, it will be necessary to include the following definitions in the Dictionary:

- **Flood planning level** means the level of a 1% AEP (annual exceedance probability) flood event plus 0.5 metre freeboard, or other freeboard as determined by any floodplain risk management plan adopted by the Council in accordance with the Floodplain Development Manual.
- **Floodplain Development Manual** means Floodplain Development Manual (ISBN 0 7347 5476 0) published by the NSW Government in April 2005.

It is also recommended that a new floodplain risk management clause be added to *Narrandera LEP 2013* as follows:

**Floodplain risk management**

- (1) The objectives of this clause are as follows:
  - (a) in relation to development with particular evacuation or emergency response issues, to enable evacuation of land subject to flooding in events exceeding the flood planning level,
  - (b) to protect the operational capacity of emergency response facilities and critical infrastructure during extreme flood events.
- (2) This clause applies to land which lies between the flood planning level and the level of the probable maximum or extreme flood, but does not apply to land at or below the flood planning level.
- (3) Development consent must not be granted to development for the following purposes on land to which this clause applies unless the consent authority is satisfied that the development will not, in flood events exceeding the flood planning level, affect the safe occupation of, and evacuation from, the land:
  - (a) amusement centre
  - (b) camping ground
  - (c) caravan park
  - (d) child care centre
  - (e) commercial premises (including business premises and retail premises)
  - (f) community facility
  - (g) correctional centre
  - (h) eco-tourist facility
  - (i) educational establishment (including schools and tertiary institutions)
  - (j) emergency services facility
  - (k) entertainment facility
  - (l) extractive industry
  - (m) function centre
  - (n) health services facility
  - (o) industry
  - (p) mining
  - (q) place of public worship
  - (r) residential accommodation (including seniors housing)

- (s) respite day care centre
  - (t) tourist and visitor accommodation
  - (u) waste or resource management facility
- (4) A word or expression used in this clause has the same meaning as it has in the Floodplain Development Manual, unless it is otherwise defined in this Plan.

In order to support the inclusion of the new clause in *Narrandera LEP 2013*, it will be necessary to include the following definitions in the Dictionary:

- **probable maximum or extreme flood** means the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation.

The steps involved in Council's amending *Narrandera LEP 2013* following the finalisation and adoption of the *FRMS&P* are:

1. Council Planning Staff consider the conclusions of *FRMS 2019* and suggested amendments to *Narrandera LEP 2013*.
2. Council resolves to amend *Narrandera LEP 2013* in accordance with *FRMP 2019*.
3. Council prepares a Planning Proposal in accordance with NSW Planning and Environment Guidelines. Planning Proposal submitted to NSW Planning and Environment in accordance with section 3.33 of the EP&A Act, 1979.
4. Planning Proposal considered by NSW Planning and Environment and determination made in accordance with section 3.34 of the EP&A Act, 1979 as follows:
  - (a) whether the matter should proceed (with or without variation),
  - (b) whether the matter should be resubmitted for any reason (including for further studies or other information, or for the revision of the planning proposal),
  - (c) community consultation required before consideration is given to the making of the proposed instrument (the community consultation requirements),
  - (d) any consultation required with State or Commonwealth public authorities that will or may be adversely affected by the proposed instrument,
  - (e) whether a public hearing is to be held into the matter by the Planning Assessment Commission or other specified person or body,
  - (f) the times within which the various stages of the procedure for the making of the proposed instrument are to be completed.
5. Planning Proposal exhibited for public comment.
6. Planning Proposal reviewed following public submissions and submissions from relevant State and Commonwealth authorities.
7. Final Local Environmental Plan with proposed amendments drafted.
8. Amending Local Environmental Plan made by the Minister and gazetted.



### 3.6.2 Rezoning of Land South of Main Canal

In addition to the above changes to the wording in *Narrandera LEP 2013*, it is recommended that the land that is presently zoned *RU5-Village* that is located to the south of the Main Canal and is categorised as Inner Floodplain (Hazard Category 1) be rezoned to *E2-Environmental Conservation* so as not to permit future development in this area.

While the stated objectives of the *E2-Environmental Conservation* zone in *Narrandera LEP 2013* are to protect, manage and restore areas of high ecological, scientific, cultural or aesthetic values and to prevent development that could destroy, damage or otherwise have an adverse effect on those values, it also meets the objectives of *FRMP 2019* which is to prohibit new residential and commercial type development while allowing (subject to consent) development such as extensive agriculture and recreation areas. The rezoning of the land would also not remove Existing Use Rights for development which was lawfully commenced at the time of the change.

The exception to the above recommended rezoning is the commercial hub at Gillenbah that includes existing development such as the Caltex Service Station and the Newell Motor Inn. This area should be rezoned as a special use area, with only commercial type development permitted.

The rezoning of the *RU5-Village* area should include the acquisition of the thirteen residential properties whose dwellings are located in a High Hazard Floodway zone and as such would qualify for inclusion in the NSW Government's Voluntary Purchase scheme (refer below for further details).

### 3.6.3 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 re-developed and re-zoned for public open space or some other flood compatible use. Further criteria applied by NSW Government agencies in assessing eligibility for funding is that:

- the property must be in a high hazard floodway area, 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; and
- the dwelling was erected prior to 1986, the date the first Floodplain Development Manual was released by the NSW Government.

Under a Voluntary Purchase (**VP**) scheme the owner is notified that the body controlling the scheme, Council in the present case, 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.

Prior to progressing to the purchase of a property, it would first be necessary to undertake a *Voluntary Purchase Feasibility Study*, especially if Council intends to apply for NSW Government grant funding. The study is to include discussions with each eligible and agreeable property owner, as well as a detailed assessment of each property to determine a priority order and costing for each.

The hydraulic calculations described in **Chapter 2** show that there are fourteen<sup>11</sup> residential properties whose dwellings are located in the High Hazard Floodway zone on the Murrumbidgee River floodplain south of the Main Canal. **Table 3.6** over the page is an economic analysis of a VP scheme involving the fourteen dwellings assuming an average purchase price of \$200,000 per property. While the inclusion of the fourteen properties in the NSW Government's VP scheme cannot be justified on economic grounds, their purchase would remove habitable development from the High Hazard Floodway zone. Based on the social benefits that this would provide, the undertaking of a *Voluntary Purchase Feasibility Study* and the subsequent purchase of these properties (subject to agreement by the affected property owners) has been included in *FRMP 2019*.

**TABLE 3.6**  
**ECONOMIC ANALYSIS – VOLUNTARY PURCHASE SCHEME FOR NARRANDERA**

Discount Rate %	4	7	10
Present Worth Value of Benefits (Damages Prevented) \$ Million	2.58	1.66	1.08
Cost of scheme \$ Million	2.80	2.80	2.80
Benefit/Cost Ratio	0.92	0.59	0.39

### 3.6.4 Voluntary House Raising

The term “house raising” 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 MFL. 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.

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 the adopted *FRMP*.
- 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:

---

<sup>11</sup> One property is located on the southern bank of the Murrumbidgee River immediately downstream of the disused Narrandera-Tocumwal Railway on land zoned *RU4-Primary Production Small Lots*.

- 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.

Prior to progressing to the raising of a dwelling, it would first be necessary to undertake a *Voluntary House Raising Feasibility Study*, especially if Council intends to apply for NSW Government grant funding. The study is to include discussions with each eligible and agreeable property owner, as well as a detailed assessment of each property to determine a priority order and costing for each.

The current cost to raise a medium sized (150 m<sup>2</sup>) house is about \$100,000 based on recent experience in other centres.

There are presently three dwellings that are located in a High Hazard Flood Storage area on the Murrumbidgee River floodplain south of the Main Canal that would be above-floor inundated in a 1% AEP flood event. All three dwellings are located on the western side of Sudgeon Street, immediately south of the existing crossing of the Main Canal. **Table 3.7** is an economic analysis of a house raising strategy at Narrandera for the three discount rates. While the strategy is not economically feasible, there would be merit in including these three properties in a house raisings scheme, especially given the high hazard nature of the area. Based on the social benefits that this would provide, the undertaking of a *Voluntary House Raising Feasibility Study* and the raising of the three dwellings (subject to agreement by the affected property owners) has been included in *FRMP 2019*.

**TABLE 3.7**  
**ECONOMIC ANALYSIS – RAISING FLOORS OF THREE TIMBER FRAMED RESIDENCES TO 1% AEP LEVEL PLUS FREEBOARD**

Discount Rate %	4	7	10
Present Worth Value of Benefits (Damages Prevented) \$ Million	0.22	0.14	0.09
Cost of scheme \$ Million	0.30	0.30	0.30
Benefit/Cost Ratio	0.72	0.46	0.30

### 3.7 Response Modification Measures

#### 3.7.1 Improvements to Flood Warning System

Improvements to the flood warning and response procedures were strongly favoured by the community during the consultation process. An effective flood warning system has three key components, i.e. a flood forecasting system, a flood warning broadcast system and a response/evacuation plan. All systems need to be underpinned by an appropriate public flood awareness program.

As mentioned in **Section 2.14**, BoM currently operates a well-established and proven flood warning system which provides predictions of gauge heights along the Murrumbidgee River, including at Narrandera. BoM's system is based on the conversion of rainfalls recorded at telemetered gauges within the catchments to predicted peak flood levels at the gauges, which are updated and conveyed to NSW SES Local Units during a flood emergency.

As the flood wave typically takes several days to travel between Wagga Wagga and Narrandera, there is sufficient time for NSW SES to warn occupiers of the floodplain south of the Main Canal to take action. While it is not necessary to install any additional stream gauges to improve the flood warning system at Narrandera, it is recommended that the *Flood Intelligence Card* for the Narrandera stream gauge be updated using information contained in this report.

### 3.7.2 Improved Emergency Planning and Response

As mentioned in **Section 2.14**, the *Local Flood Plan* provides detailed information regarding the preparedness measures, conduct of response operations and coordination of immediate recovery measures for all levels of flooding. The NSW SES should ensure the *Local Flood Plan* is updated to include any maps that were developed as part of the present study that complement the information already present in the document. NSW SES should also ensure information contained in this report on the impacts of both Main Stream Flooding and Major Overland Flow on urban development, as well as recommendations regarding community education is used to update the document. The *Local Flood Plan* should include the following information:

**1 – The Flood Threat** includes the following sub-sections:

**1.1 Land Forms and River Systems** – ref. **Sections 2.1** and **2.2** of the report for information on these topics.

**1.4 Characteristics of Flooding** – Indicative extents of inundation for the 1% AEP and Extreme Flood events are shown on **Figures 2.4** and **2.5**, while **Figure 2.8** shows the typical times of rise of floodwaters at key locations along the major roads that traverse the Murrumbidgee River floodplain south of the Main Canal. **Table 2.5** summarises the impact flooding has on vulnerable development and critical infrastructure at Narrandera. The location of vulnerable development and critical infrastructure relative to the flood extents are shown on **Figure 2.9**.

**1.5 Flood History** – Recent flood experience at Narrandera is discussed in **Section 2.3** of the report, while aerial photography showing the extent of flooding experienced near the peak of the March 2012 flood is shown on **Figure 2.3**.

**1.6 Flood Mitigation Systems** – ref. **Section 2.6** of the report which provides a detailed description of the Northern and Southern Main Canal Embankments, the Narrandera Airport Levee and two privately owned measures that protect existing commercial development at Gillenbah. **Figures 2.6** and **2.7** are longitudinal sections along the Main Canal embankments and the Narrandera Airport Levee. **Figure 2.11** shows the impact of partial failure of the Southern Main Canal Embankment would have on flooding behaviour

**1.7 Extreme Flood Events** – The Extreme Flood (Main Stream Flooding) and PMF (Major Overland Flow) were modelled and the indicative above-ground and above-floor depths of inundation presented in this report (**Figure 2.5**).

### **2 – Effects on the Community**

Information on the properties affected by the 1% AEP design flood are included in this report (**Figure 2.4**). As floor level data used in this assessment were largely estimated from the LiDAR survey and “drive by” survey they are indicative only. While fit for use in estimating the economic impacts of design floods, the data should not be used to provide specific details of the degree of flood affectation of individual properties.

**Figure 2.8** shows stage hydrographs at key locations along the roads that traverse the Murrumbidgee River floodplain south of the Main Canal, the locations of which are shown on **Figure 2.9**. The flood related information is given for design flood with AEPs ranging between 20 and 1 per cent.

**Figure 2.9** shows the location of vulnerable development and critical infrastructure relative to floods with AEPs of 5 and 1 per cent, as well as the Extreme Flood. Refer **Section 2.8** and **Table 2.5** for details of affected infrastructure.

**Figures 3.6** and **3.7** show the flood emergency response planning classifications for the 1% AEP and Extreme Flood events, respectively based on the definitions set out in the *Floodplain Risk Management Guideline – Flood Emergency Response Classification of Communities* (DECC, 2007).

While the majority of the Murrumbidgee River floodplain south of the Main Canal at Narrandera is classified as High Hydraulic Hazard Flooding, only the following areas in the urbanised parts of Narrandera on the northern side of the Main Canal are classified as high hazard in nature:

- Along the section of Newell Highway which is inundated to the north of the Junee Hay Railway, east of its intersection with Barellan Road.
- On the southern side of the Junee Hay Railway immediately north of Henry Mathieson Oval.
- In Bolton Street west of its intersection with Jonsen Street.
- In Audley Street between its intersection with Jellinbah and Adams streets.
- Along the northern side of the Northern Main Canal Embankment in the vicinity of the Town Siphon.

### 3.7.3 Public Awareness Programs

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. The improvements to flood warning arrangements described above, as well as the process of disseminating this information to the community, would represent a major opportunity for increasing flood awareness in Narrandera.

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

- displays at Council offices using the information contained in the present study and photographs of historic flooding in the area; and
- talks by NSW SES officers with participation by Council and longstanding residents with first-hand experience of flooding in the area.

Council and NSW SES should also liaise with the owners of the Newell Motor Inn and the Narrandera Caravan Park at Gillenbah to ensure that they have contemporaneous flood evacuation plans which include information contained in this report.

## 4 SELECTION OF FLOODPLAIN MANAGEMENT MEASURES

### 4.1 Background

NSWG, 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 Floodplain Risk Management 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 NSW Government's requirements for floodplain management as set out in NSWG, 2005 and other relevant policies. A further consideration is that some elements of the Floodplain Risk Management 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 the preparation of the Floodplain Risk Management Plan 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 (e.g. NSWG, 2005 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 *FRMP 2019* 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 *FRMP 2019*.

Each option is given a score according to how well the option meets the considerations discussed 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 suggested scoring matrix for the options reviewed in **Chapter 3** at Narrandera. This scoring has been used as the basis for prioritising the components of *FRMP 2019*. **The proposed scoring and weighting shown in Table 4.1 were reviewed by the FRMC as part of the process of finalising the overall FRMP.**

### 4.3 Summary

**Table 4.1** indicates that there are good reasons to consider including the following elements into *FRMP 2019*:

- Implement Detention Basin Strategy (Option 2).
- Implement Woolscour Siphon Works (Option 3).
- Planning Controls via a Flood Policy for future development in Narrandera, in addition to the rezoning of land to the south of the Main Canal which is presently zoned *RU5 – Village* and lies in the High Hazard Floodway zone to *E2 – Environmental Conservation*.
- Incorporation of the catchment specific information on flooding impacts contained in this Study in NSW SES Response Planning and Flood Awareness documentation for the study area.
- Voluntary purchase of the fourteen residential properties that are located to the south of the Main Canal in the High Hazard Floodway zone.
- Voluntary raising of the three residential dwellings that are located in a High Hazard Flood Storage area along Sudgeon Street to the 1% AEP flood level plus 500 mm freeboard.

**TABLE 4.1**  
**ASSESSMENT OF POTENTIAL FLOODPLAIN MANAGEMENT MEASURES FOR INCLUSION IN THE FLOODPLAIN RISK MANAGEMENT PLAN**

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
<b>Flood Modification</b>										
Ultimate Flood Protection Scheme	+2	+1	+1	+2	-1	-2	-2	0	+1	+3
Woolscour Siphon Works (Option 1)	+1	+2	+2	+1	0	-1	+1	0	0	+6
Woolscour Siphon Works (Option 2)	0	+2	+1	0	-1	-2	-1	0	0	-1
Woolscour Siphon Works (Option 3)	+2	+2	+2	+1	0	-1	+1	0	0	+7
Detention Basin Strategy (Option 1)	+2	+2	+2	+2	-1	+2	+2	0	+1	+12
Detention Basin Strategy (Option 2)	+2	+2	+2	+2	0	+2	+2	0	+1	+13
Detention Basin Strategy (Option 3)	+2	+1	+2	+2	0	+2	+2	0	0	+11
<b>Property Modification</b>										
Controls over Future Development (via draft Flood Policy);	+2	+2	+2	+2	0	0	0	+1	+2	+11
Rezoning of land south of the Main Canal	+2	+1	+2	+2	0	0	0	+1	+2	+10
Voluntary Purchase of Residential Property	+2	0	+2	+2	+2	-1	0	+2	+2	+11
Voluntary House Raising in High Hazard Flood Storage Areas	+1	0	+2	+2	0	-1	0	0	+1	+5
<b>Response Modification</b>										
Improvements to Flood Warning System	+2	+2	+1	+1	0	+2	+2	+1	+1	+12
Improved Emergency Planning and Response	+2	+2	+1	+1	0	+1	+1	+1	+1	+10
Public Awareness Programs	+1	+2	0	+1	0	+1	0	+1	+2	+8



## 5 FLOODPLAIN RISK MANAGEMENT PLAN 2019

### 5.1 The Floodplain Risk Management Process

The *Floodplain Risk Management Study 2019 (FRMS 2019)* and the *Floodplain Risk Management Plan 2019 (FRMP 2019)* have been prepared for Narrandera as part of a Government program to mitigate the impacts of major floods and reduce the hazards in the floodplain. *FRMP 2019* which is set out in this Chapter 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 *FRMP 2019* were the collection of flood data and the review of previous studies which included the *Narrandera Floodplain Risk Management Study (SKM, 2009a) (FRMS 2009)*, the *Narrandera Floodplain Risk Management Plan (SKM, 2009b) (FRMP 2009)* and the *Narrandera Flood Study Review and Levee Options Assessment (Lyll & Associates, 2015) (Flood Study Review)*.

The *Flood Study Review* was the formal starting process of reviewing contemporaneous management measures for flood liable land and represented a detailed technical investigation of flood behaviour on the Murrumbidgee River floodplain at Narrandera.

*FRMS 2019* deals with both **Main Stream Flooding** from the Murrumbidgee River and **Major Overland Flow** which occurs in the urbanised parts of the town, as well as the presently undeveloped areas immediately to its north. In order to define the nature of Major Overland Flow at Narrandera it was necessary to develop a new set of flood models as part of *FRMS 2019*.

### 5.2 Purpose of the Plan

The overall objectives of *FRMS 2019* were to assess the impacts of flooding, review policies and options for management of flood affected land and to develop *FRMP 2019* 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 *FRMP 2019*.
- Proposes amendments to Council's existing policies to ensure that the future development of flood affected land at Narrandera is undertaken so as to be compatible with the flood hazard and risk.
- Ensures *FRMP 2019* is consistent with NSW SES's local emergency response planning procedures.
- Ensures that *FRMP 2019* has the support of the community.

### 5.3 The Study Area

The study area for *FRMP 2019* comprises the town of Narrandera and its immediate environs. *FRMP 2019* applies in areas affected by the two flood producing mechanisms that occur at the town: Main Stream Flooding on the Murrumbidgee River and the shallower and slower moving Major Overland Flow through the urbanised parts of town, as well as the presently undeveloped areas immediately to its north.

The solution to problems resulting from surcharges of the minor stormwater drainage systems in individual allotments remote from the Major Overland Flow paths or in the local street system, which may occur during localised storms, is outside the scope of the present investigation.

#### 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 residents and business owners at Narrandera allowed the wider community to gain an understanding of the issues being addressed as part of the study;
- the public exhibition of the draft FRMS2019 and FRMP2019;
- the holding of a Community Workshop during the public exhibition period;
- the direct mail-out of letters to the owners of land which would be affected by the recommended rezoning of land south of the Main Canal; and
- meetings of the Floodplain Risk Management Committee (**FRMC**) to discuss results as they became available.

While the Community Workshop was not well attended, 47 written submissions were received by Council during the exhibition period, all but one of which related to the recommendation to rezone the land south of the Main Canal (the one other submission related to the impacts of major overland flow in the urbanised parts of Narrandera). Twenty six of the submissions comprised a form letter, the signatories to which, while not directly affected by the recommended rezoning, were opposed to it due to its potential to adversely affect the community. The signatories of the other 20 written submissions who were directly affected by the recommended rezoning were also opposed to the measure as they believed that it would:

- impact existing right users if owners wanted to redevelop their dwellings, add extensions or rebuild;
- devalue the property; and
- significantly reduce the owner's ability to continue using the land for farming purposes.

#### 5.5 Economic Impacts of Flooding

**Tables 5.1** and **5.2** over the page show the number of properties that would be flooded to above-floor level and the damages experienced for the various classes of property in Narrandera as a result of Main Stream Flooding and Major Overland Flow, respectively. Damages in Narrandera for a range of design flood events are evaluated in **Appendix C** of *FRMS 2019*.

By inspection of the values given in **Tables 5.1** and **5.2**, flood damages at Narrandera resulting from Major Overland Flow are greater than for Main Stream Flooding. Flood damages in the urbanised parts of Narrandera are principally a result of a Major Overland Flow path which forms between Henry Mathieson Oval and the inlet of an existing siphon that runs beneath Murrumbidgee Irrigation's Main Canal immediately west of the Newell Highway (**Town Siphon**).

**TABLE 5.1  
ECONOMIC IMPACTS OF FLOODING AT NARRANDERA  
RESULTING FROM MAIN STREAM FLOODING**

Design Flood Event (% AEP)	Properties Flooded Above-Floor Level						Total Flood Damages
	Residential		Commercial/Industrial		Public		
	No.	\$ Million	No.	\$ Million	No.	\$ Million	\$ Million
20	0	0	0	0	0	0	0
10	8	0.76	11	0.31	0	0	1.07
5	23	1.98	15	0.47	0	0	2.45
1	49	5.80	16	0.99	0	0	6.79
0.5	62	7.91	17	1.36	3	0.13	9.40
0.2	82	11.23	20	1.89	8	0.52	13.64
Extreme	166	25.32	23	3.83	8	1.54	30.69

**TABLE 5.2  
ECONOMIC IMPACTS OF FLOODING AT NARRANDERA  
RESULTING FROM MAJOR OVERLAND FLOW**

Design Flood Event (% AEP)	Properties Flooded Above-Floor Level						Total Flood Damages
	Residential		Commercial/Industrial		Public		
	No.	\$ Million	No.	\$ Million	No.	\$ Million	\$ Million
20	6	0.67	0	0.02	0	0	0.69
10	15	1.55	0	0.02	0	0	1.57
5	21	2.22	0	0.03	0	0	2.25
1	82	7.41	27	1.29	2	0.06	8.76
0.5	107	9.72	29	1.65	4	0.18	11.55
0.2	137	12.65	30	2.20	6	0.27	15.12
Extreme	431	51.87	104	17.76	13	2.32	71.95

## 5.6 Indicative Flood Extents

**Figure 2.4** shows the indicate extent of both Main Stream Flooding and Major Overland Flow at Narrandera for a flood event that has an Annual Exceedance Probability (**AEP**) of 1 per cent.

The 1% AEP design flood has been adopted as the “planning flood” for the purposes of specifying flood related controls over future development. The extent of flooding is indicative only, being based on hydrologic and hydraulic models that were developed as part of both the *Flood Study Review* and *FRMS 2019*. The floor levels of a large number of properties were estimated from a “drive by” survey. Consequently the results should not be used to identify the degree of flood affectation or otherwise of individual properties, for which a site specific survey would be required.

This level of accuracy in the flood mapping is supported by the NSW Office of Environment and Heritage, as the costs associated with undertaking of detailed ground survey in each flood affected property lies outside the scope of the NSW Government's Floodplain Management Program. Under the program, it is Council's responsibility to identify the flood risk within the floodplain and prepare maps showing indicative flood extents (i.e. the mapping presented in this report), 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/her allotment.

To allow Council to assess individual development proposals for the purposes of the draft *Flood Policy* (ref. **Section 5.8** below), a detailed site survey would be required to allow the extent of flooding and the flood hazard to be evaluated using the results of *FRMS 2019*. For this reason, proponents will be required to submit a detailed survey plan of the site for which development is proposed.

## 5.7 Structure of Floodplain Risk Management Study and Plan

*FRMS 2019* and *FRMP 2019* are supported by Appendices which provide additional details of the investigations. A summary of *FRMP 2019* proposed for the study area along with broad funding requirements for the recommended measures are shown in **Table S1** at the commencement of the *FRMS 2019* report. These measures comprise a program of engineering investigations and capital works, preparation of planning documentation by Council, improvements to the flood warning system and community education on flooding by Council and NSW SES to improve flood awareness and response. The measures will over time achieve the objectives of reducing the flood risk to existing and future development for the full range of floods.

*FRMP 2019* is based on the following mix of measures which have been given a provisional priority ranking according to a range of economic, social, environmental and other criteria set out in **Table 4.1** of the report:

- **Measure 1** – Planning and development controls for future development in flood prone areas.
- **Measure 2** – Update wording in Narrandera Local Environmental Plan 2013, as well as rezone land at Gillenbah.
- **Measure 3** – Improvements in flood emergency response planning.
- **Measure 4** – Increase public awareness of the risks of flooding in the community.
- **Measure 5** – Commission a detailed engineering study to assess the feasibility of upgrading the Southern Main Canal Embankment between the Narrandera Regulator and Irrigation Way.
- **Measure 6** – Commission an investigation to assess the crest height and the compaction levels of the earth fill which was recently placed along the section of the Narrandera Airport Levee which runs alongside Irrigation Way.
- **Measure 7** – Commission a detailed engineering study to assess the feasibility of constructing a ring levee around the water supply pumping station in combination with raising Old Brewery Road.
- **Measure 8** – Commission a detailed engineering study to assess the feasibility of constructing Detention Basin Strategy (Option 2)
- **Measure 9** – Design and construction of Detention Basin Strategy (Option 2)

- **Measure 10** – Design and construction of Wooolsour Siphon Works (Option 3)
- **Measure 11** – Include fourteen properties that are located in the High Hazard Floodway area south of the Main Canal in the NSW Government's Voluntary Purchase Scheme and three existing dwellings that are located in the High Hazard Flood Storage area along Sudgeon Street immediately south of the Main Canal in the NSW Government's Voluntary House Raising Scheme.

## 5.8 Planning and Development Controls

The results of *FRMS 2019* indicate that an important measure for Narrandera Shire Council to adopt in the floodplain would be strong floodplain management planning applied consistently by all branches of Council.

### 5.8.1 Flood Policy

The *Flood Policy* proposed for Narrandera (**Appendix E**) used the concepts of *flood hazard* and *hydraulic categorisation* outlined in **Section 2.12** of the report to develop flood related controls for future development in flood prone land. The *Flood Policy* caters for two types of flooding in Narrandera:

- **Main Stream Flooding** resulting from flows that surcharge the Murrumbidgee River. These flows may be several metres deep in the channels and relatively slow moving with velocities up to 1 m/s.
- **Major Overland Flow** is present along several flow paths that run through the urbanised parts of Narrandera. It is also present in the undeveloped areas which border the town principally to its north. Flows on the Major Overland Flow paths would typically be less than 300 mm deep, travelling over the surface at velocities less than 0.5 m/s.

To implement the recommended approach set out in *FRMP 2019*, clause 6.2 of the *Narrandera Local Environmental Plan 2013 (Narrandera LEP 2013)* would require minor amendment. A new clause aimed at addressing potential flood evacuation issues in parts of Narrandera would also need to be inserted into *Narrandera LEP 2013* (ref. **Section 5.8.2** below).

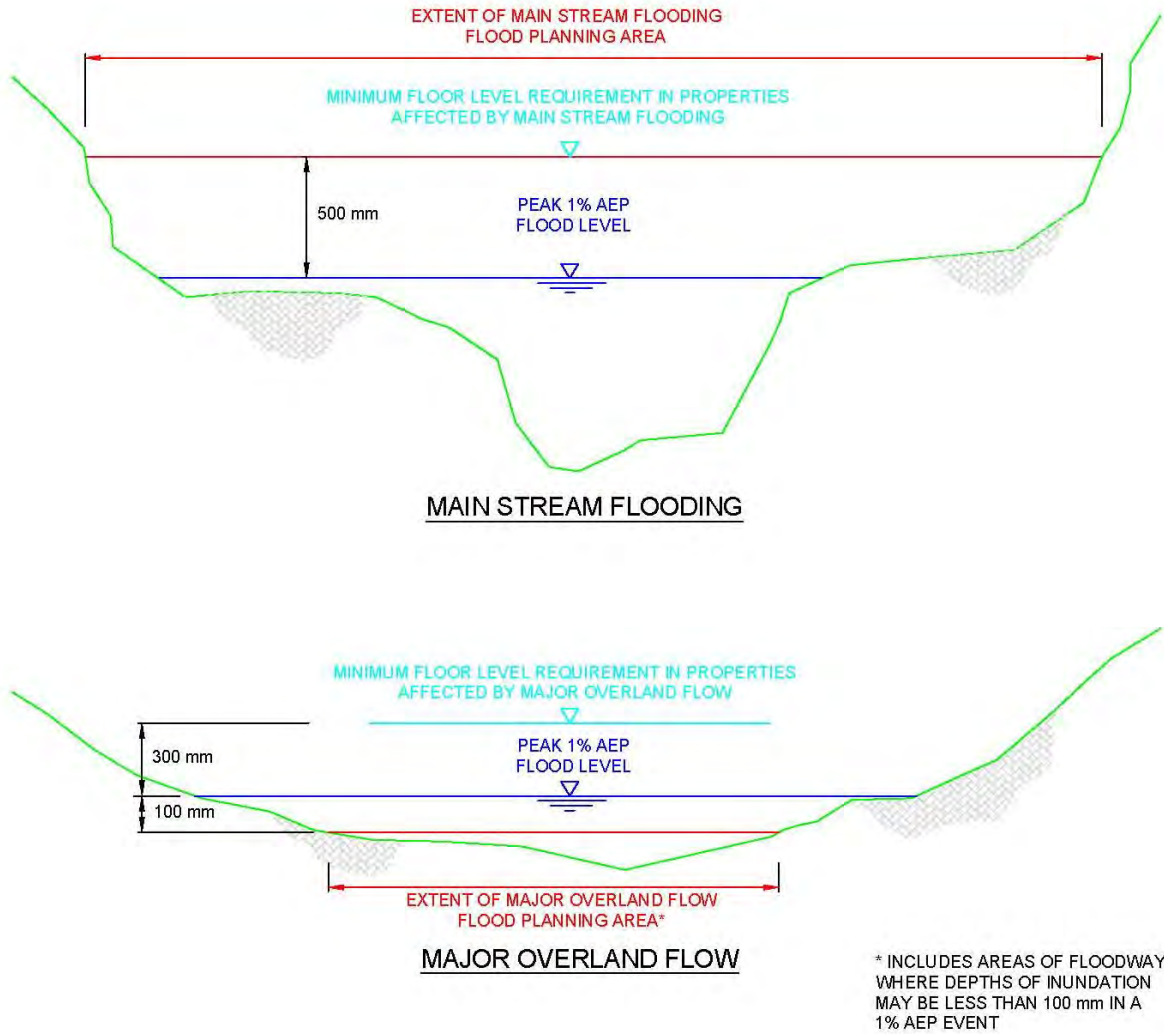
**Figure E1.1** in the *Flood Policy* is an extract from the *Flood Planning Map* relating to the urbanised parts of Narrandera. The extent of the Flood Planning Area (**FPA**) (the area subject to flood related development controls) is shown in a solid red colour on the *Flood Planning Map* and has been defined as follows:

- In areas subject to Main Stream Flooding, the FPA is based on the traditional definition of the area inundated by the 1% AEP plus 500 mm freeboard.<sup>12</sup>
- In areas subject to Major Overland Flow, the FPA is defined as the extent of the High and Low Hazard Floodway zones, as well as areas where depths of inundation in a 1% AEP event exceed 100 mm.

The illustration over the page demonstrates the derivation of the FPA in areas subject to Main Stream Flooding and Major Overland Flow.

---

<sup>12</sup> This includes the area which lies on the northern side of the Main Canal which would be subject to Main Stream Flooding should the Southern Main Canal Embankment fail during a 1% AEP flood event.



TYPE OF FLOODING	LAND BELOW THIS LEVEL DEFINED AS FLOOD PLANNING AREA	MINIMUM FLOOR LEVEL (MFL) REQUIREMENT
MAIN STREAM FLOODING	Peak 1% AEP Flood Level Plus (+) 500mm	Peak 1% AEP Flood Level Plus (+) 500mm
MAJOR OVERLAND FLOW	Peak 1% AEP Flood Level Minus (-) 100mm*	Peak 1% AEP Flood Level Plus (+) 300mm

*Illustration showing the approach that has been used to derive the extent of the Flood Planning Area and the Minimum Floor Levels (MFL) requirements in areas affected by Main Stream Flooding and Major Overland Flow at Narrandera*

It is proposed that properties intersected by the extent of the FPA would be subject to S10.7 flood affectation notification and planning controls graded according to flood hazard. **Annexures 2.1 and 2.2** in the *Flood Policy* set out the graded set of flood related planning controls which have been developed for Narrandera. **Annexure 2.1** deals with areas subject to Main Stream Flooding, while **Annexure 2.2** deals with areas affected by Major Overland Flow. **Figure E1.2** in the *Flood Policy* is the *Development Controls Matrix Map* and shows the area over which both **Annexures 2.1 and 2.2** apply.

Minimum floor level (**MFL**) requirements would be imposed on future development in properties that are identified as lying either partially or wholly within the extent of the FPA shown on the *Flood Planning Map*. The MFLs for all land use types affected by Main Stream Flooding is the level of the 1% AEP flood event plus 500 mm freeboard, while the MFLs for all land use types affected by Major Overland Flow is the level of the 1% AEP flood event plus 300 mm freeboard. For areas outside the FPA shown on the *Flood Planning Map*, the MFL for all land use types is the level of the 1% AEP flood event plus 500 mm freeboard. The illustration over the page demonstrates the application of the variable freeboard approach in the derivation of the MFL requirements in areas subject to Main Stream Flooding and Major Overland Flow.

**Figure E1.3** in the *Flood Policy* is the *Flood Hazard Map*. The figure shows the subdivision of the floodplain into a number of categories which have been used as the basis for developing the graded set of planning controls.

The floodplain has been divided into the following four categories in areas that are affected by Main Stream Flooding:

- The **Inner Floodplain (Hazard Category 1)** zone (shown as a solid red colour) comprises areas where factors such as the depth and velocity of flow, time of rise, isolation on Low Flood Islands and evacuation problems mean that the land is unsuitable for most types of development. It principally comprises High and Low Hazard Floodway areas. Erection of buildings and carrying out of work; use of land, subdivision of land and demolition subject to State Environmental Planning Policies and Local Environmental Plan provisions are not permitted in this zone.
- The **Inner Floodplain (Hazard Category 2)** zone (shown as a solid yellow colour) comprises High and Low Flood Storage areas, as well as areas where isolation on Low Flood Islands and evacuation problems mean development other than Essential Community Facilities, Critical Utilities, Schools and Flood Vulnerable development is permitted provided it is capable of withstanding hydraulic forces and sited on the allotment to minimise adverse redirections of flow toward adjacent properties. Council may require a *Flood Risk Report* if it considers that the proposal has the potential to significantly affect flooding behaviour in adjacent properties.
- The **Intermediate Floodplain** zone (shown as a solid blue colour) is the remaining land lying outside the extent of the Inner Floodplain zones, but within the FPA (defined as land which lies below the 1% annual exceedance probability (AEP) flood level plus 500 mm freeboard). Within this zone, there would only be the requirement for MFL's to be set at the 1% AEP flood levels plus 500 mm. Land use permissibility would be as specified by State Environmental Planning Policies or the Local Environmental Plan.
- The **Outer Floodplain** zone is the area outside the Intermediate Floodplain where the depth of inundation will exceed 100 mm in the Extreme Flood (shown as a solid cyan colour). This area is outside the extent of the FPA and hence controls on residential, commercial and industrial development do not apply. However, Essential Community Facilities, Critical Utilities and Flood Vulnerable development is not permitted in this zone.

The floodplain has been divided into the following two additional flood hazard zones in areas that are affected by Major Overland Flow:

- The **High Hazard Floodway** zone (shown as solid orange) identifies areas where significant overland flow of a high hazard nature occur in Narrandera. These are presently limited to a few reaches of incised drainage channel that are located on the western limits of the town.
- The **Low Hazard Floodway / Flood Storage** zone (shown as a solid green colour) identifies the areas where significant overland flow or excessive depths of ponding of a low hazard nature occur in Narrandera.<sup>13</sup> Council may permit residential, commercial and industrial development on this part of the floodplain, provided it is capable of withstanding hydraulic forces and is sited within the allotment to minimise adverse re-direction of flow towards adjacent properties. There would also be the requirement for MFLs to be set at the 1% AEP flood levels plus 300 mm on this part of the floodplain, as well as restrictions on site filling to prevent blockage of flows. Similar controls exist for commercial and industrial development. Council may require a *Flood Risk Report* for development proposals in this area (typically for larger scale commercial or industrial developments).

The **Intermediate Floodplain** zone in areas subject to Major Overland Flow is the remaining land lying outside the extent of the Floodway and Flood Storage areas where the depth of inundation during a 1% AEP storm event depths will exceed 100 mm, while the **Outer Floodplain** represents the area outside the aforementioned areas where the depth of inundation will exceed 100 mm during the PMF. Flood related planning controls in these two areas are similar to those that apply to development in areas subject to Main Stream Flooding, with the following exceptions:

- the adoption of a reduced freeboard of 300 mm for defining MFLs in the **Intermediate Floodplain** zone; and
- the potential for Essential Community Facilities, Critical Utilities and Flood Vulnerable Residential type development to take place in both the **Intermediate Floodplain** and **Outer Floodplain** zones subject to compliance with the flood related development controls set out in **Annexure 2.2** of the Flood Policy.

### 5.8.2 Revision to Narrandera LEP 2013

Clause 6.2 of *Narrandera LEP 2013* entitled “Flood Planning” outlines its objectives in regard to development of flood prone land. It is similar to the standard Flood Planning Clause used in recently adopted LEPs in other NSW country centres and applies to land beneath the Flood Planning Level (**FPL**). The FPL referred to is the 1% AEP flood plus an allowance for freeboard of 500 mm. The area encompassed by the FPL is known as the FPA and denotes the area subject to flood related development controls, such as locating development outside high hazard areas and setting minimum floor levels for future residential development.

Whilst appropriate for Main Stream Flooding, the present clause 6.2 would have resulted in a large part of the urban area which is affected by shallow overland flow being subject to flood affectation notification on Planning Certificates issued under S10.7 of the EP&A act.

---

<sup>13</sup> Note that in order to maintain connectivity between the areas of deeper flow, the Floodway zone has been extended in some areas to include areas where the depth of flow is less than 150 mm.



To implement the *Flood Policy* set out in **Appendix E**, clause 6.2 of *Narrandera LEP 2013* would require minor amendment. Suggested amendments are given in **Section 3.6.1.4**. **Figure E1.1** in **Appendix E** is an extract from the *Flood Planning Map* referred to in clause 6.2.

It is also recommended that a new floodplain risk management clause be include in the *Narrandera LEP 2013*. The objectives of the new clause are as follows:

- in relation to development with particular evacuation or emergency response issues (e.g. group homes, residential care facilities, hospitals, etc.) to enable evacuation of land subject to flooding in events exceeding the flood planning level; and
- to protect the operational capacity of emergency response facilities and critical infrastructure during extreme flood events.

The new clause would apply to land identified as Outer Floodplain (i.e. land which lies between the FPA and the Extreme Flood in the case of Main Stream Flooding and the PMF in the case of Major Overland Flow). Suggested wording in relation to this new clause is given in **Section 3.6.1.4**.

In addition to the above changes to the wording in *Narrandera LEP 2013*, it is recommended that land to the south of the Main Canal that is presently zoned *RU5 – Village* and lies within the High Hazard (Category 1) flood zone (refer **Figure E1.3** (3 sheets) in **Appendix E** for extent) be rezoned *E2 – Environmental Conservation*. As part of the rezoning process should seek to acquire the fourteen existing dwellings that are located in the High Hazard Floodway (refer **Measure 11**). A new commercial zone should also be created in Gillenbah to permit existing development such as the Caltex Service Station, Newell Motor Inn and the Narrandera Caravan Park to continue to operate, but with restrictions placed on their future use.

## 5.9 Improvements in Emergency Planning and Flood Awareness

Two measures are proposed in *FRMP 2019* to improve flood emergency planning and maintain awareness in the community of the threat posed by floods:

**Measure 3** involves the update by NSW SES of the *Narrandera Shire Local Flood Plan* using information on flooding patterns, times of rise of floodwaters and flood prone areas identified in this report. Figures have been prepared showing indicative extents of flooding, high hazard areas, expected rates of rise of floodwaters in low points along the major roads and locations where flooding problems would be expected. **Section 3.7.2** references the locations of key data within this report.

Council should also take advantage of the information on flooding presented in this report, including the flood mapping, to inform occupiers of the floodplains of the flood risk (included as **Measure 4** of the *FRMP 2019*). This information could be included in a *Flood Information Brochure* to be prepared by Council with the assistance of NSW SES containing both general and site specific data and 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. *FRMP 2019* should be publicised and exhibited in Council offices and at community gathering places to make residents aware of the measures being proposed.

## 5.10 Flood Modification Works

While existing development at Narrandera is generally located on high ground, both *FRMS 2009* and the *Flood Study Review* assessed the merits of implementing a range of measures on the Murrumbidgee River floodplain which is aimed at reducing the impact of flooding on existing development, including Narrandera Airport. The *Flood Study Review* concluded that a scheme involving the following components best achieved the flood mitigation objectives of *FRMP 2009*:

- Southern Main Canal Embankment Upgrade - Narrandera Regulator to Irrigation Way.
- Narrandera Airport and Nallabooma Estate Ring Levee.
- Water Supply Pumping Station Ring Levee.
- Old Brewery Road Upgrade.

The scheme, which was denoted the **Ultimate Flood Protection Scheme**, was estimated to cost a total of \$10.2 Million and have a benefit cost ratio of 0.35.

One of the major constraints associated with the implementation of the Ultimate Flood Protection Scheme is that the Main Canal is in the ownership of Murrumbidgee Irrigation who does not have responsibility for floodplain risk management and/or flood operations within its charter. Council will therefore need to consult further with Murrumbidgee Irrigation regarding how the Southern Main Canal Embankment could be upgraded to act as a formal flood protection measure, with Council taking responsibility for its upgrade and ongoing maintenance.

While the cost of the upgrade of the Narrandera Regulator could be funded through the NSW Government's floodplain management program, it is recommended that the scheme not rely on the operation of the gates for flood mitigation purposes, for the above stated reason that Murrumbidgee Irrigation does not have responsibility for floodplain risk management and/or flood operations within their charter. This will require an assessment to be undertaken of the discharge characteristics of the regulator gates in their fully open position to ensure existing development is not at risk of flooding should they remain open during a major flood event.

**Measure 5** of *FRMP 2019* involves the commissioning of a detailed engineering study to assess the feasibility of upgrading the section of the Southern Main Canal Embankment between the Narrandera Regulator and Irrigation Way. The feasibility study is to include a geotechnical investigation which will assess the structural integrity of the existing embankment and determine the scope of works which would be required to ensure that it will function as a formal flood protection levee during major floods on the Murrumbidgee River. **Measure 5** includes a requirement to liaise with Murrumbidgee Irrigation to determine the operating protocols for the regulators at Narrandera, as these data will influence the decision on the scope of the Ultimate Flood Protection Scheme. Depending on the outcome of the detailed engineering study and **Measure 6**, Narrandera Shire Council is to proceed to concept design initially and then subject to the availability of Government Funding, detailed design and construction of the Ultimate Flood Protection Scheme.

**Measure 6** of *FRMP 2019* involves the commissioning of a crest level survey along the section of the Narrandera Airport Levee that was recently upgraded by Narrandera Shire Council. **Measure 6** also includes the commissioning of a geotechnical investigation to assess the level of compaction which was achieved when the fill material was placed along the upgraded section of levee. Depending on the outcome of the crest level survey, geotechnical investigation and **Measure 5**, Narrandera Shire Council is to proceed to concept design initially and then subject to the availability of Government Funding, detailed design and construction of the Ultimate Flood Protection Scheme.

**Measure 7** of *FRMP 2019* involves the commissioning of a detailed engineering study to assess the feasibility of constructing a ring levee around the water supply pumping station that is located on the northern bank of the Murrumbidgee River a short distance east (upstream) of the Newell Highway in combination with raising Old Brewery Road. The study would need to include a geotechnical investigation to assess the foundation requirements for the ring levee, as well as an assessment of whether raising Old Brewery Road would have an impact on flooding behaviour in existing development for events more frequent than 1% AEP. Depending on the outcome of the detailed engineering study, Narrandera Shire Council is to proceed to the detailed design and construction of the ring levee.

**Measure 8** of *FRMP 2019* involves the commissioning of a detailed engineering study to assess the feasibility of constructing Detention Basin Strategy (Option 2). This would include a geotechnical investigation to assess the foundation conditions along the alignment of the basin embankments, as well as the preparation of a concept design of the works.

**Measure 9** of *FRMP 2019* involves the design and construction of Detention Basin Strategy (Option 2).

**Measure 10** of *FRMP 2019* involves the design and construction of Woolscour Siphon Works (Option 3).

#### **5.11 Combined Voluntary Purchase and House Raising Scheme**

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

The review undertaken in *FRMS 2019* showed that while the implementation of a Voluntary Purchase scheme at Narrandera was not economically viable, it could be justified on social grounds given there are fourteen dwellings located in High Hazard Floodway zone south of the Main Canal.

Similarly, while the analysis undertaken in *FRMS 2019* showed that the implementation of a voluntary house raising program at Narrandera is not economically viable, it could be justified on social grounds given there are three dwellings that are located in a High Hazard Flood Storage area on the Murrumbidgee River floodplain. Based on this finding, it is recommended that the three properties which are all located on Sudgeon Street immediately south of the Main Canal be included in the NSW Government's Voluntary House Raising Scheme.

In order to access grant funding from the NSW Government it would be necessary for Council to commission a *Voluntary Purchase and House Raising Feasibility Study*. The study is to include discussions with each eligible and agreeable property owner, as well as a detailed assessment of each property to determine a priority order and costing for each. The preparation of the study, as well as the acquisition of the fourteen properties and the raising of the three dwellings (subject to the agreement by the affected property owners) forms **Measure 11** of *FRMP 2019*.

#### **5.12 Implementation Program**

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

1. Floodplain Risk 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 *FRMS 2019* and the proposed works and measures to be included in *FRMP 2019* as set out in **Table S1**); exhibit the draft *FRMS 2019* and *FRMP 2019* and seek community comment.
2. Consider public comment, modify the document if and as required, and submit to Council.
3. Council adopts *FRMP 2019* and submits an application for funding assistance. Assistance for funding qualifying projects included in *FRMP 2019* may be available upon application under the Commonwealth and State funded floodplain management programs currently administered by the NSW Office of Environment and Heritage.
4. Assistance for funding qualifying projects included in *FRMP 2019* may be available upon application under the Commonwealth and State funded floodplain management programs, currently administered by the NSW Office of Environment and Heritage.
5. As funds become available from Government agencies and/or Council's own resources, implement the measures in accordance with the established priorities.

*FRMP 2019* 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 *FRMP 2019*. In any event, a thorough review every five years is warranted to ensure the ongoing relevance of *FRMP 2019*.

## 6 GLOSSARY OF TERMS

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

TERM	DEFINITION
<b>Annual Exceedance Probability (AEP)</b>	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, for a flood magnitude having five per cent AEP, there is a five per cent probability that there would be floods of greater magnitude each year.
<b>Australian Height Datum (AHD)</b>	A common national surface level datum corresponding approximately to mean sea level.
<b>Flood Affected Properties</b>	Properties that are either encompassed or intersected by the <b>Flood Planning Area (FPA)</b> .
<b>Floodplain</b>	Area of land which is subject to inundation by floods up to and including the Probable Maximum Flood (PMF) event, that is, flood prone land.
<b>Flood Planning Area</b>	The area of land that is shown to be in the Flood Planning Area on the <i>Flood Planning Map</i> .
<b>Flood Planning Map</b>	The <i>Flood Planning Map</i> referred to in the Narrandera Local Environmental Plan 2013, extracts of which are shown on <b>Figure E1.1</b> .
<b>Flood Planning Level (FPL) (General Definition)</b>	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.
<b>Flood Planning Level (FPL)</b>	For land within the Flood Planning Area subject to Main Stream Flooding in Narrandera, the Flood Planning Level (FPL) is the level of the 1% AEP flood event <u>plus</u> 500 mm.  In areas subject to Major Overland Flow, the FPL is the level of the 1% AEP flood event <u>minus</u> 100 mm.  For areas outside the Flood Planning Area shown on the <i>Flood Planning Map</i> , the FPL is the level of the 1% AEP flood event <u>plus</u> 500 mm.
<b>Flood Prone/Flood Liable Land</b>	Land susceptible to flooding by the PMF. Flood Prone land is synonymous with Flood Liable land.
<b>Floodway</b>	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.
<b>Flood Storage Area</b>	Those parts of the floodplain that may be important for the temporary storage of floodwaters during the passage of a flood. Loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation.
<b>Freeboard</b>	Provides reasonable certainty that the risk exposure selected in deciding a particular flood chosen as the basis for the FPL and MFL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the FPL and MFL.

TERM	DEFINITION
<b>Habitable Room</b>	<p>In a residential situation: a living or working area, such as a lounge room, dining room, kitchen, bedroom or workroom.</p> <p>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.</p>
<b>Inner Floodplain (Hazard Category 1)</b>	Comprises areas where factors such as the depth and velocity of flow, time of rise, isolation and evacuation difficulties mean that the land is unsuitable for most types of development. It includes areas of High and Low Hazard Floodway. Erection of a buildings and carrying out of work not permitted; use of land, subdivision of land and demolition subject to State Environmental Planning Policies and Local Environmental Plan provisions.
<b>Inner Floodplain (Hazard Category 2)</b>	Comprises areas of High and Low Hazard Flood Storage areas, as well as areas where isolation on Low Flood Islands and evacuation problems where development other than Essential Community Facilities, Critical Utilities and Flood Vulnerable Residential Development may be permitted provided it is capable of withstanding hydraulic forces and sited on the allotment to minimise adverse redirections of flow towards adjacent properties. Council may require a <i>Flood Risk Report</i> if it considers that the proposal has the potential to significantly affect flooding behaviour in adjacent properties.
<b>Intermediate Floodplain</b>	<p>For Main Stream Flooding, is the remaining land lying outside the extent of the Inner Floodplain zones, but within the FPA (defined as land which lies below the 1% annual exceedance probability (AEP) flood level plus 500 mm freeboard).</p> <p>For Major Overland Flow, it is the land outside the High Hazard Floodway and Low Hazard Floodway / Flood Storage zones where the depth of inundation during the 1% AEP storm event is greater than 100 mm.</p>
<b>Local Drainage</b>	Land on an overland flow path where the depth of inundation during the 1% AEP storm event is less than 100 mm.
<b>Main Stream Flooding</b>	The inundation of normally dry land occurring when water overflows the natural or artificial banks of a major stream; for the study area, the main stream is the Murrumbidgee River.
<b>Major Overland Flow</b>	Where the depth of overland flow during the 1% AEP storm event is greater than 100 mm.
<b>Minimum Floor Level (MFL) (General Definition)</b>	The combinations of flood levels and freeboards selected for setting the Minimum Floor Levels (MFLs) of future development located in properties subject to flood related planning controls.
<b>Main Stream Flooding Minimum Floor Level (MSF MFL)</b>	<p>For properties subject to Main Stream Flooding, the MSF MFL is the level of the 1% AEP flood event plus 500 mm freeboard.</p> <p>Note that for areas outside the Flood Planning Area shown on the Flood Planning Map, the MSF MFL is the level of the 1% AEP flood event plus 500 mm freeboard.</p>

TERM	DEFINITION
<b>Major Overland Flow Minimum Floor Level (MOF MFL)</b>	<p>For properties subject to Major Overland Flow, the MOF MFL is the level of the 1% AEP flood event plus 300 mm freeboard.</p> <p>Note that for areas outside the Flood Planning Area shown on the <i>Flood Planning Map</i>, the MOF MFL is the level of the 1% AEP flood event plus 500 mm freeboard.</p>
<b>Outer Floodplain</b>	<p>This is defined as the land between the FPA and the extent of the PMF.</p> <p>For Main Stream Flooding it is the area that lies outside the Intermediate Floodplain where depths of inundation will exceed 100 mm during the Extreme Flood.</p> <p>For Major Overland Flow, it is the area that lies outside the High Hazard Floodway, Low hazard Floodway / Flood Storage and Intermediate Floodplain zones where depths of inundation will exceed 100 mm during the PMF.</p>
<b>Probable Maximum Flood (PMF)</b>	<p>The largest flood that could conceivably occur at a particular location. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain.</p> <p>For the study area, the extent of the PMF has been trimmed to include depths greater than 100 mm.</p>

## 7 REFERENCES

Bureau of Meteorology (2003). ***“The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method”***.

Department of Environment, Climate Change and Water, NSW (2007) ***“Floodplain Risk Management Guideline – Flood Emergency Response Classification of Communities”***.

Department of Environment, Climate Change and Water, NSW (2007) ***“Floodplain Risk Management Guideline – Practical Considerations of Climate Change”***.

Department of Environment, Climate Change and Water, NSW (2008) ***“Floodplain Risk Management Guideline No 4. Residential Flood Damage Calculation”***.

Howells et al, (2004) ***“Defining the Floodway - Can One Size Fit All?”*** FMA NSW Annual Conference, Coffs Harbour, February 2004.

Lyll & Associates (2015) ***“Narrandera Flood Study Review and Levee Options Assessment”***.

Narrandera Shire Council (2013) ***“Narrandera Development Control Plan 2013”***.

NSW SES (2015) ***“Narrandera Shire Flood Emergency Sub Plan”***.

New South Wales Government (2005) ***“Floodplain Development Manual: the Management of Flood Liable Land”***.

PW (Public Works), 2010. ***“Wagga Wagga Levee Upgrade Flood Freeboard”***.

PW (Public Works), 2013a. ***“Narrandera (East) Levee Audit 2013”***

PW (Public Works), 2013b. ***“Narrandera (West) Levee Audit 2013”***

PW (Public Works), 2013c. ***“Narrandera (Airport) Levee Audit 2013”***

SKM (2000) ***“Narrandera Flood Study”***

SKM (2007) ***“Review of Narrandera Flood Study”***

SKM (2009a) ***“Narrandera Floodplain Risk Management Study”***

SKM (2009b) ***“Narrandera Floodplain Risk Management Plan”***

The Institution of Engineers, Australia (1987) ***“Australian Rainfall and Runoff – A Guide to Flood Estimation”***, Volumes 1 and 2.

WMA (WMAwater), (2014). ***“Wagga Wagga Detailed Flood Model Revision”***, Draft Final Report



**APPENDIX A**

**COMMUNITY CONSULTATION**

## TABLE OF CONTENTS

	Page No.
<b>A1. INTRODUCTION .....</b>	<b>A-1</b>
A2.1 General .....	A-2
A2.2 Experiences of Flooding .....	A-2
<b>A3 POTENTIAL FLOOD MANAGEMENT MEASURES.....</b>	<b>A-5</b>
<b>A4 INPUT TO THE STUDY AND FEEDBACK FROM THE COMMUNITY.....</b>	<b>A-6</b>
<b>A5 SUMMARY.....</b>	<b>A-7</b>
A5.1 Issues .....	A-7
A5.2 Flood Management Measures .....	A-7

## ATTACHMENTS

<b>ATTACHMENT 1</b>	Community Newsletter and Questionnaire
<b>ATTACHMENT 2</b>	Responses to Community Questionnaire

## A1. INTRODUCTION

At the commencement of *FRMS 2019*, the Consultants prepared a *Community Newsletter* and a *Community Questionnaire*, both of which were distributed by Council to the residents and business owners in Narrandera that are affected by the 1% AEP Murrumbidgee River flood as defined in L&A, 2015. An online version of the *Questionnaire* was also available on Council's website. A copy of the *Community Newsletter* and *Questionnaire* is contained in **Attachment 1**.

A media release was also prepared that introduced the project and encouraged the community to provide input to the study by responding to the *Community Questionnaire*.

The purpose of the *Community Newsletter* was to set the scene on flooding conditions at Narrandera, provide a summary of the findings of SKM, 2009 and introduce the objectives of the present study so that the community would be better able to respond to the *Community Questionnaire* and contribute to the study process.

The *Community Newsletter* contained the following information:

- Plan showing the extent of the study area and the plan location of the floodplain management measures which form the *FRMP 2009*.
- A summary of the abovementioned measures, including the priority assigned to each and its estimated cost.
- A statement of the objectives of *FRMS 2019* and *FRMP 2019*; namely to assist Council in refining strategic plans for mitigating and managing the effects of existing, future and continuing flood risk.

The *Community Questionnaire* was structured with the objectives of:

- Obtaining local information on flood experience and behaviour at residents' and business owners' properties.
- Determining residents' and business owners' attitudes to controls over future development in flood liable areas.
- Re-appraising community views on the floodplain management measures which form the *FRMP 2009*, as well as other possible options which could be considered for further investigation in the present study.
- Obtaining feedback on any other flood related issues and concerns which the residents and business owners cared to raise.

This **Appendix** to *FRMS 2019* discusses the responses to the 18 questions that were included in the *Community Questionnaire* and the comments made by respondents.

**Chapter A2** deals with the residents' and business owners' experience with historic flooding, as well as determining their views on the relative importance of classes of development over which flood-related controls should be imposed by Council.

**Chapter A3** identifies residents' and business owners' views on the suitability of the various options which could be considered in more detail in *FRMS 2019*.

**Chapter A4** discusses the best methods by which the community could provide feedback to the consultants over the course of the study.

**Chapter A5** summarises the findings of the community consultation process.

## A2 RESIDENT PROFILE AND FLOOD AWARENESS

### A2.1 General

Residents were requested to complete the *Community Questionnaire* and return it to the Consultants by 15 November 2017. The deadline was extended to include any submissions that were received after this date. The Consultants received 64 responses in total out of the approximately 280 that had been distributed.

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

### A2.2 Experiences of Flooding

The first seven questions of the *Community Questionnaire* canvassed resident information such as length of time at the property, the type of property (e.g. 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. Questions 8 – 10 gauged the extent of physical and non-physical damage as a result of the worst flood experienced. Question 11 enquires as to how respondents received flood warnings (if at all).

Of the sixty-four responses, sixty-two were residents and fourteen were business owners (**Question 2**).<sup>1</sup> One respondent owned property in Narrandera, but resided elsewhere. Twenty-six respondents had lived in Narrandera for between 5 and 20 years and twenty-eight for more than 20 years (**Question 3**).

The majority of respondents occupied a single dwelling (fifty-seven), while three occupied a unit/flat, eight owned vacant land, one owned an industrial unit, two owned shopfronts and one owned a community building (**Question 4**). Seventeen respondents identified that they owned “other” types of properties which included, farms (nine), rural residential buildings (three), two heritage listed buildings, a breeding facility, a church and a motel.

Forty-seven respondents reported that they had information about flooding on their property (**Question 5**), forty-five of whom cited their own experience and twenty-seven of whom reported having photographs of flooding. Six respondents reported to have flood levels provided to them by Council and three had information provided to them by NSW SES. Of the six respondents who reported “other” available information at the property, four had recorded flood marks, one had information that was provided by the previous owner and one had invoices for repairs made to the property following damaging flooding.<sup>2</sup>

In response to **Question 6**, forty-two respondents reported that they had experienced flooding on their property either as a result of main stream flooding (twenty-three) or shallow overland flow (twenty-six)<sup>3</sup>. Of those, twenty reported flooding on their property in October 2010, forty in March 2012 and twenty-two in October 2016. Four respondents reported flooding on their property in September 1974, whilst two reported shallow overland flow enters their property during any significant rainfall event.

---

<sup>1</sup> Note that thirteen of the respondents were both a resident and business owner in Narrandera.

<sup>2</sup> Note that the responses are not mutually exclusive; several respondents selected more than one option.

<sup>3</sup> Note that seven of the respondents have experience both main stream flooding and shallow overland flow.

Of the ten respondents that advised that they had experienced above-floor inundation at their property (**Question 7**), eight were flooded in March 2012 flood, two in December 2010 and one each in September 1974 and October 2016<sup>4</sup>.

While sixteen respondents did not experience damage to their property during the largest flood event (**Question 8**), a number of respondent reported that flooding had previously caused damage to garden/yards (thirty-one), garage/sheds (fourteen), electrical equipment (nine), stock (six) vehicles (five), and other items such as fences (seven), feed (three), crops (two), driveways (two) and septic tanks (two). Eight respondents reported internal damage to carpet and/or furniture, while another eight reported external building damage.

In response to **Question 9**, eight respondents have experienced a loss of business/trade as a result of flooding, whilst a further twenty-six have experienced restricted access to their workplace during flood events. Twenty of the respondents experienced higher insurance premiums as a result of flooding and two have considered moving (**Question 9**).

In response to **Question 10**, fifteen respondents reported that they hadn't incurred any damages as a result of flooding, while eighteen incurred damage to their property of less than \$5,000. Seven respondents incurred damages greater than \$20,000, the largest of which was \$300,000.

Considering the provision of flood warnings to the population of Narrandera (**Question 11**), thirty-eight respondents said they received warning from their own observations, twenty-nine by either the police or NSW SES, twenty-three by radio, nineteen by neighbours or relatives and fourteen by TV. Six respondents claimed they had no warning at all. These results are characteristic of when there is significant warning time available as the flood wave travels down a major river system.

### **A2.3 Controls over Development in Flood Prone Areas**

The respondents were also asked to rank from 1 to 4 the classes of development which they consider should receive protection from flooding (**Question 12**). Rank 1 was the most important and rank 4 the least.

The classes in decreasing order of importance to respondents, ranged from vulnerable residential (e.g. aged persons accommodation), residential property, essential community facilities (e.g. schools, evacuation centres) and lastly, commercial/business.

These results gave a guide to the Consultants as to the appropriate location of future development of the various classes within the floodplain. For example, on the basis of community views, vulnerable residential would receive the highest level of protection by locating future development of this nature outside the floodplain.

In **Question 13**, respondents were asked what notifications Council should give about the flood affectation of individual properties. The community was strongly in favour of advising existing residents and prospective purchasers of the known potential flood threat, with only one resident not in favour of providing flood related notifications.

---

<sup>4</sup> Note that one respondents experienced above-floor inundation in three of the most recent floods (i.e. December 2010, March 2012 and October 2016).

Respondents were also asked in **Question 14** about the level of control Council should place on new development to minimise flood-related risks. The equal most popular responses were to advise of the flood risks, but allow the individual the choice as to whether they develop or not provided they take steps to minimise the potential flood risks, and to place restrictions on developments to reduce the potential for flood damage (e.g. minimum floor level controls or the use of compatible building materials). The next most favoured response was to prohibit new development only in those locations which would be extremely hazardous to persons or property during floods. Three respondents felt that Council should prohibit all development on land with any potential to flood.

### A3 POTENTIAL FLOOD MANAGEMENT MEASURES

The respondents were asked their opinion on the floodplain management measures that formed part of *FRMP 2009*, which are re-appraised as part of the present investigation, by ticking a “yes” or “no” to the ten options identified in **Question 15**.

The respondents were generally in favour of the measures that formed *FRMP 2009*, with the exception of flood proofing future development in Gillenbah which are located in the floodway (PM3), which evenly divided the community’s opinion. The most popular options were updating the existing Narrandera Local Flood Plan (RM1) and the construction of a ring levee around the Water Supply Pumping Station (FM4). Updating the Main Canal southern embankment (FM1) and existing Aerodrome levee (FM2) also received strong support.

The respondents were also asked for their opinion on nine additional potential flood management measures which could be evaluated in *FRMS 2019* in **Question 16**.

The options comprised a range of *structural flood management measures* (e.g. programs by Council to manage vegetation in the creek system to maintain hydraulic capacity; improving the stormwater system; widening of watercourses; removal of floodplain obstructions), as well as various *non-structural management measures* (e.g. voluntary purchase of residential properties in high hazard areas; raising floor levels of houses in low hazard areas; additional flood related controls over new developments in flood liable land; improvements to flood warning and evacuation procedures; flood advice certificates). The options were not mutually exclusive, as *FRMP 2019* could, in theory, include all of the options set out in the *Community Questionnaire*, or indeed, other measures nominated by the respondents or the FRMC.

The measures which received strong support from the community were the improvement of the stormwater system in the town, specifying additional controls on future development in flood-labile areas, improvement of flood warning and evacuation procedures and the provision of a Planning Certificate to purchasers of flood prone areas. The respondents were evenly divided over the remaining five measures.

Other measures suggested by individual respondents but not itemised in the *Questionnaire* include:

- Increasing the height of the Newell Highway between the southern Main Canal embankment and the Sturt Highway, including the installation of continuous box culverts beneath the upgraded section of road.
- Improvements to Irrigation Way to the west of the town to ensure access is maintained between Narrandera and Leeton during flood events.
- Improvements to the Newell Highway to the east of the town to prevent isolation during flood events.
- Maintaining an up-to-date database of road closures on Council’s website during flood events.
- Increasing the number of empty sandbags permanently stored at Narrandera to allow for early dissemination to community.

#### **A4 INPUT TO THE STUDY AND FEEDBACK FROM THE COMMUNITY**

In **Question 17**, residents were asked for their view on the best methods of providing input to the Study and feedback to the Consultants over the course of the investigation. Articles in the local newspaper was the most popular method, followed by communication via Council's website and the FRMC. Other suggestions raised by respondents suggested a letter drop (similar to the *Community Newsletter* and *Community Questionnaire* distributed as part of the present investigation) and announcements on local radio as methods of community engagement.



## **A5 SUMMARY**

Sixty-four responses were received to the *Community Questionnaire* which was distributed by Council to residents and business owners in Narrandera. The responses amounted to about twenty per cent of the total distributed. Of those that responded to the *Questionnaire*, forty-two respondents reported that they had experienced flooding on their property either as a result of main stream flooding (twenty-three) or shallow overland flow (twenty-six), in flood events that occurred in September 1974, December 2010, March 2012 and October 2016.

Ten respondents advised that they had experienced above-floor inundation at their property, while fifty respondents reported incurring damage to vehicles, garden/yards, garage/sheds, electrical equipment, stock, fences, crops, driveways and septic tanks on their properties. Eight respondents to the *Questionnaire* have experienced a loss of business/trade, twenty-six have experienced restricted access to their workplace and twenty experienced higher insurance premiums as a result of recent flooding.

Fifteen residents reported that they hadn't incurred any damages as a result of flooding, while eighteen incurred damage to their property of less than \$5,000. Seven respondents incurred damages greater than \$20,000, the largest of which was \$300,000

### **A5.1 Issues**

The issues identified by the responses to the *Community Questionnaire* support the objectives of the study as nominated in the attached *Community Newsletter*, and the activities nominated in the Study Brief. No new issues were identified in regard to Main Stream Flooding and Major Overland Flow.

### **A5.2 Flood Management Measures**

The respondents were generally in favour of the ten floodplain management measures that formed the *FRMP 2009*, with the exception of flood proofing future development in Gillenbah which are located in the floodway (PM3), which evenly divided the community's opinion. The most popular options were updating the existing Narrandera Local Flood Plan (RM1) and the construction of a ring levee around the Water Supply Pumping Station (FM4). Updating the Main Canal southern embankment (FM1) and existing Aerodrome levee (FM2) also received strong support.

Of the additional *structural measures* which could be incorporated in *FRMP 2019* developed as part of the present investigation, the most popular was the improvement of the stormwater system in the town. Specifying additional controls on future development in flood-labile areas, improvement of flood warning and evacuation procedures and the provision of a Planning Certificate to purchasers of flood prone areas appeared to be the most popular of the additional potential *non-structural measures* set out in the *Community Questionnaire*.

**ATTACHMENT 1**

**COMMUNITY NEWSLETTER  
AND QUESTIONNAIRE**

## To Residents and Business Owners of Narrandera:

Narrandera Shire Council has engaged consultants to undertake a review of the *Narrandera Floodplain Risk Management Study and Plan* which was prepared for the township in 2009. The purpose of the review is to assist Council in refining strategic plans for mitigating and managing the effects of existing flood risk (associated with existing development on flood prone land), future flood risk (associated with any new development on flood prone land) and continuing flood risk (the risk remaining in both existing and future development areas after floodplain risk management measures are implemented).

The review is jointly funded by Council and the NSW Office of Environment & Heritage and aims to build community resilience towards flooding through informing better planning of development, emergency management and community awareness. Council has established a Floodplain Risk Management Committee which is comprised of relevant council members, state government agencies and community representatives.

The review will utilise the results of the recently completed *Narrandera Flood Study Review and Levee Options Assessment* which was completed in 2015. The work to be carried out as part of the review will also include the identification of the various major overland flow paths and ponding areas which develop in parts of Narrandera during intense rainfall events. **Figure 1** attached shows the indicative extent of the 1 in 100 year flood on the Murrumbidgee River, as well as the extent of flood prone land (as defined by the extent of the Extreme Flood) at Narrandera under present day conditions.

A brief summary of the floodplain management measures which form the *Narrandera Floodplain Risk Management Plan* (2009), including their estimated cost is provided over, while an electronic copy of the *Narrandera Floodplain Risk Management Study and Plan* (2009) and *Narrandera Flood Study Review and Levee Options Assessment* (2015) can be found on Council's website at [www.narrandera.nsw.gov.au](http://www.narrandera.nsw.gov.au) (simply type the word "flood" into the search engine which is located on the Home page).

## Have Your Say on Floodplain Management

An important first step in the review process is to re-appraise what flood related issues are important to the community. The attached **questionnaire** has been provided to residents and businesses to assist the Consultants in gathering this important information. The questionnaire may also be completed online via Council's website at [www.narrandera.nsw.gov.au](http://www.narrandera.nsw.gov.au). All information provided will remain confidential and for use in this study only. Please return the completed questionnaire in the reply paid envelope provided by **Wednesday 15 November 2017**.

Contact: Narrandera Shire Council

Fred Hammer | Manager of Projects & Assets

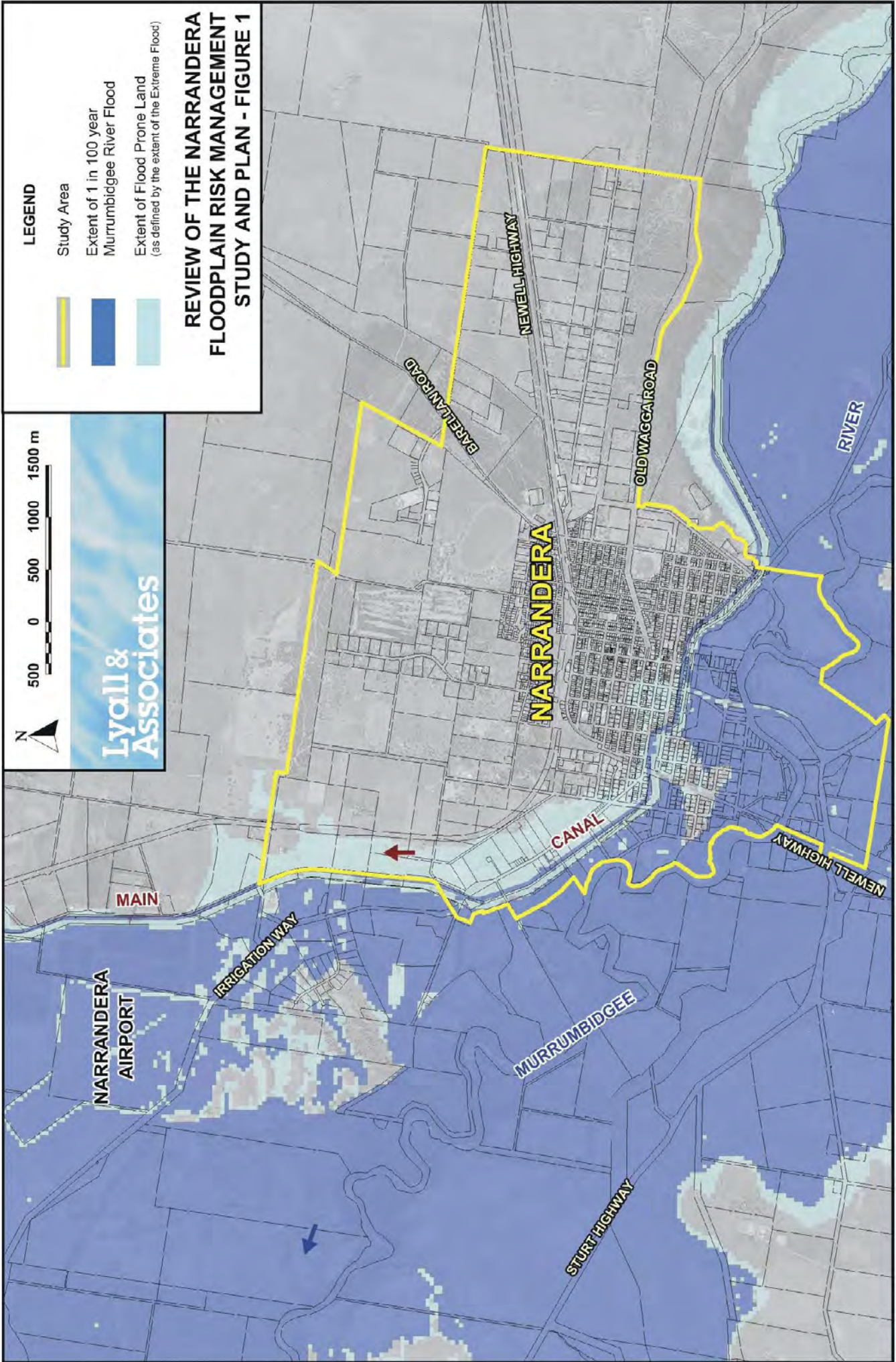
Phone: (02) 6959 5568

Email: [fred.hammer@narrandera.nsw.gov.au](mailto:fred.hammer@narrandera.nsw.gov.au)




**Floodplain Management Measures Forming the  
Narrandera Floodplain Risk Management Plan (2009)**

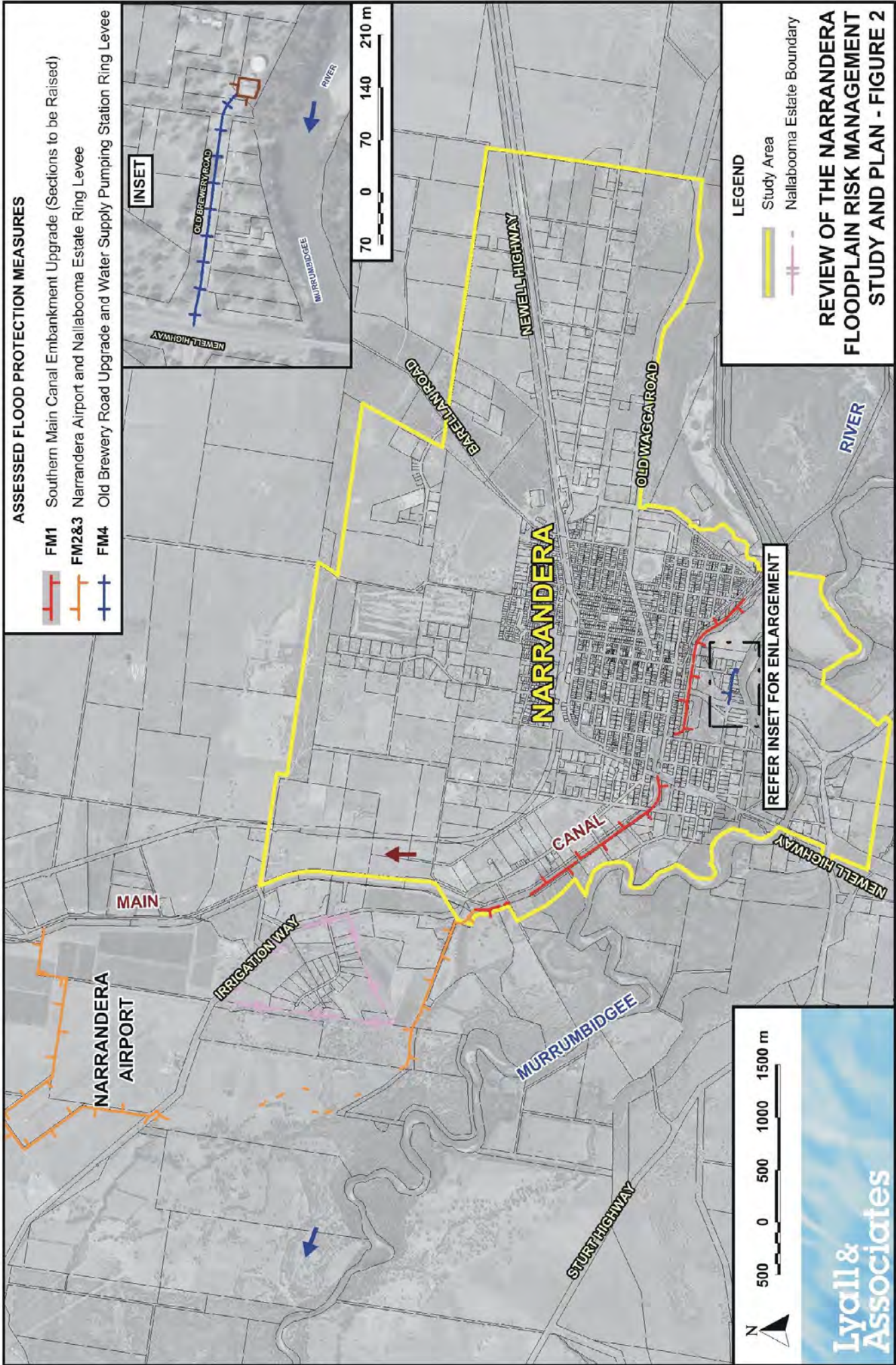
Option	Estimate Cost <sup>(1)</sup>	Priority Assigned to Implementation of Measure
PM1 – Rezoning of land at Gillenbah to allow commercial development and restrict further residential development to existing lots only.	Council Cost	Medium
PM2 – Update Local Environmental Plan and Development Control Plan documents to include minimum Flood Planning Levels for different types of development and land zones.	Council Cost	Medium
PM3 – Flood proofing future development in Gillenbah which are located within the floodway.	Council Cost	High
RM1 – Updates to existing Narrandera Local Flood Plan to include recent flood level information in Flood Warning system.	NSW SES Cost	High
RM2 – Program of flood education to raise awareness amongst the local community and provide information to allow residents to be 'flood ready'.	Council Cost	High
RM3 – Preparation of flood evacuation plans for dwellings with multiple occupancy, including motels and caravan parks.	Property/Business Owner Cost	High
FM1 – Upgrade the Main Canal southern embankment to provide a 1 in 100 year standard of protection plus 1.0 metre freeboard. <sup>(1,2)</sup>	\$2.4 Million	Medium
FM2 – Upgrade of existing Aerodrome levee to provide a 1 in 100 year standard of protection plus 1.0 metre freeboard and new 500 metre levee. <sup>(1,2)</sup>	\$6.8 Million	Medium
FM3 – Construction of a levee around the Nallabooma Estate to a 1 in 100 year standard of protection plus 1.0 metre freeboard. <sup>(1,2)</sup>	Cost of works included in FM2	Medium
FM4 – Construction of a ring levee around the Water Supply Pumping Station to protect water supply against flooding in the Extreme Flood (includes the raising of Old Brewery Road). <sup>(1,2)</sup>	\$1.0 Million	High
<b>Total Cost of Implementing Flood Mitigation Measures FM1, FM2, FM3 and FM4<sup>(1,2)</sup></b>	<b>\$10.2 Million</b>	

1. Scope of floodplain management measure refined as part of *Narrandera Flood Study Review and Levee Options Assessment* (2015). Refer **Figure 2** attached for location and plan extent of each measure.
2. Following the adoption of the revised Plan, Narrandera Shire Council can seek funding from the NSW State Government under its Floodplain Management Program to cover the majority of the cost of implementing the recommended set of measures.





**ASSESSED FLOOD PROTECTION MEASURES**

-  **FM1** Southern Main Canal Embankment Upgrade (Sections to be Raised)
-  **FM2&3** Narrandera Airport and Nallabooma Estate Ring Levee
-  **FM4** Old Brewery Road Upgrade and Water Supply Pumping Station Ring Levee



**LEGEND**

-  Study Area
-  Nallabooma Estate Boundary

**REVIEW OF THE NARRANDERA FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN - FIGURE 2**

REFER INSET FOR ENLARGEMENT

## Community Questionnaire

This Questionnaire is part of the *Review of the Narrandera Floodplain Risk Management Study and Plan*, which is currently being undertaken by Narrandera Shire Council with the financial and technical support of the NSW Office of Environment & Heritage. Your responses to the questionnaire will help us determine the flood issues that are important to you.

Please return your completed Questionnaire in the reply paid envelope provided by **Wednesday 15 November 2017**. No postage stamp is required. If you have misplaced the supplied envelope or wish to send an additional submission the address is:

Lyall & Associates Consulting Water Engineers  
Reply Paid 85163  
NORTH SYDNEY NSW 2060

1. Your name (optional): \_\_\_\_\_

Address: \_\_\_\_\_

### About your property

2. Please tick as appropriate:

- I am a resident
- I am a business owner
- Other (please specify \_\_\_\_\_)

3. How long have you been at this address?

- 1 year to 5 years
- 5 years to 20 years
- More than 20 years (... years)

4. What is your property?

- House
- Villa/Townhouse
- Unit/Flat/Apartment
- Vacant land
- Industrial unit in larger complex
- Stand alone warehouse or factory
- Shop
- Community building
- Other (\_\_\_\_\_)

### Your flood experience

*(If flooding has affected your property – Go to Q5*

*If not, but flooding has affected you in other ways – Go to Q9*

*If you have not been affected by flooding – Go to Q12)*

5. Do you have any information about flooding at the property?

- Yes
- No

If yes, what information do you have?

- Own experience
- Flood levels from Council
- Information from State Emergency Service (SES)
- Photographs
- Other (\_\_\_\_\_)

6. Have you ever experienced flooding, either as a result of the river breaking its banks or due to shallow overland flow through the property?

- Yes - River break out
- Yes - Shallow overland flow
- No

If yes, which floods?

- December 2010
- March 2012
- October 2016
- Other (\_\_\_\_\_)

7. In the biggest flood you have experienced, was the property flooded above floor level of the main building?

- No  Yes

If yes, what was the depth of water over the floor?

\_\_\_\_\_

What year? \_\_\_\_\_

8. During the biggest flood, what was damaged by floodwaters?

(Tick one or more boxes)

- No damage occurred
- Vehicles
- Garden, yard, paddocks
- Garage, shed
- Electrical equipment, machinery, tools
- Stock and other goods
- Carpet, furniture, fittings and/or office equipment
- Your premises (paint, structurally, etc)
- Other part of your property

Please specify \_\_\_\_\_

9. As a result of the biggest flood, did you experience any problems during or after the flood?

(Tick one or more boxes)

- No problems experienced
- Loss of business / trade
- Restricted access / can't get to work
- Higher insurance premiums
- Considered selling/moving

10. During the biggest flood, what was the approximate cost to you (at the time) from the damage caused by the flood?

\$ \_\_\_\_\_

11. In this biggest flood, did you receive any warning, and if so, from where?

(Tick one or more boxes)

- No warning whatsoever
- TV
- Radio
- Own observations
- Police
- State Emergency Service (SES)
- Neighbours, relatives or friends
- Other (\_\_\_\_\_)

### Your attitudes to Council's development controls

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

Development Type	Rank
Commercial/Business	
Residential	
Vulnerable residential development (e.g. aged persons accommodation)	
Essential community facilities (e.g. schools, evacuation centres)	

13. What notifications do you consider Council should give about the potential flood affectation of individual properties?

(Tick one or more boxes)

- Advise every resident and property owner on a regular basis of the known potential flood threat
- Advise only those who enquire to Council about the known potential flood threat
- Advise prospective purchasers of property of the known potential flood threat.
- Provide no notifications
- Other (\_\_\_\_\_)

14. What level of control do you consider Council should place on new development to minimise flood-related risks?

(Tick only one box)

(In addition to being favoured by the Community, these options would also need to comply with legislation)

- Prohibit all new development on land with any potential to flood
- Prohibit all new development only in those locations that would be extremely hazardous to persons or property due to the depth and/or velocity of floodwaters, or evacuation difficulties
- Place restrictions on developments which reduce the potential for flood damage (e.g. minimum floor level controls or the use of flood compatible building materials)
- Advise of the flood risks, but allow the individual a choice as to whether they develop or not, provided steps are taken to minimise potential flood risks
- Provide no advice regarding the potential flood risks or measures that could minimise those risks



## Your opinions on floodplain risk management measures

15. **The Narrandera Floodplain Risk Management Study Plan (2009) included a number of measures which were aimed at minimising the effects of flooding in Narrandera. Do you consider that these options should be included in the refined Plan?**

For each of the options listed, please indicate "yes" or "no" to indicate if you favour the option. Please leave blank if undecided.

Option	Yes	No
PM1 – Rezoning of land at Gillenbah to allow commercial development and restrict further residential development to existing lots only.		
PM2 – Update Local Environmental Plan and Development Control Plan documents to include minimum Flood Planning Levels for different types of development and land zones.		
PM3 – Flood proofing future development in Gillenbah which is located within the floodway.		
RM1 – Updates to existing Narrandera Local Flood Plan to include recent flood level information in Flood Warning system.		
RM2 – Program of flood education to raise awareness amongst the local community and provide information to allow residents to be 'flood ready'.		
RM3 – Preparation of flood evacuation plans for dwellings with multiple occupancy, including motels and caravan parks.		
FM1 – Upgrade the Main Canal southern embankment to provide a 1 in 100 year standard of protection plus 1.0 metre freeboard. <sup>(1)</sup>		
FM2 – Upgrade of existing Aerodrome levee to provide a 1 in 100 year standard of protection plus 1.0 metre freeboard and new 500 metre levee. <sup>(1)</sup>		
FM3 – Construction of a levee around the Nallabooma Estate to a 1 in 100 year standard of protection plus 1.0 metre freeboard. <sup>(1)</sup>		
FM4 – Construction of a ring levee around the Water Supply Pumping Station to protect water supply against flooding in the Extreme Flood (includes the raising of Old Brewery Road). <sup>(1)</sup>		

1. Scope of floodplain management measure refined as part of *Narrandera Flood Study Review and Levee Options Assessment* (2015). Refer **Figure 2** attached for location and plan extent of each measure.

16. **Below is a list of other possible options that may be looked at to try to minimise the effects of flooding in the study area.**

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 indicate "yes" or "no" to indicate if you favour the option. Please leave blank if undecided.

Option	Yes	No
Management of riparian vegetation to provide flood mitigation, stability, aesthetic and habitat benefits.		
Widening of watercourses.		
Removal of floodplain obstructions.		
Improve the stormwater system within the town area.		
Voluntary scheme to purchase residential property in high hazard areas.		
Provide funding or subsidies to raise houses above major flood level in low hazard areas.		
Specify additional controls on future development in flood-liable areas (e.g. controls on extent of filling)		
Improve flood warning and evacuation procedures both before and during a flood.		
Provide a Planning Certificate to purchasers in flood prone areas, stating that the property is flood affected.		

### Other Information

17. **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?** (Tick one or more boxes)

- Council's website
- Articles in local newspaper
- Through Council's Floodplain Management Committee
- Other (please specify) \_\_\_\_\_

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

Name: \_\_\_\_\_

Address: \_\_\_\_\_

Phone: \_\_\_\_\_

Best time to call is \_\_\_\_\_

Fax No: \_\_\_\_\_

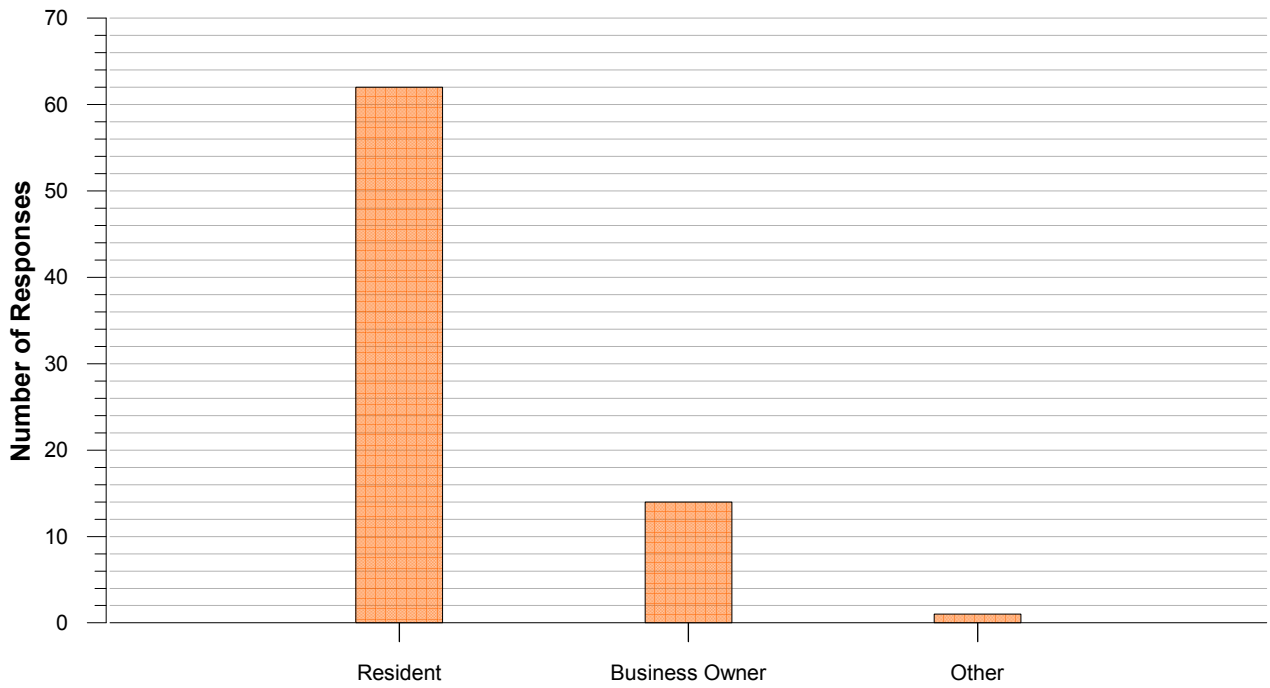
Email: \_\_\_\_\_



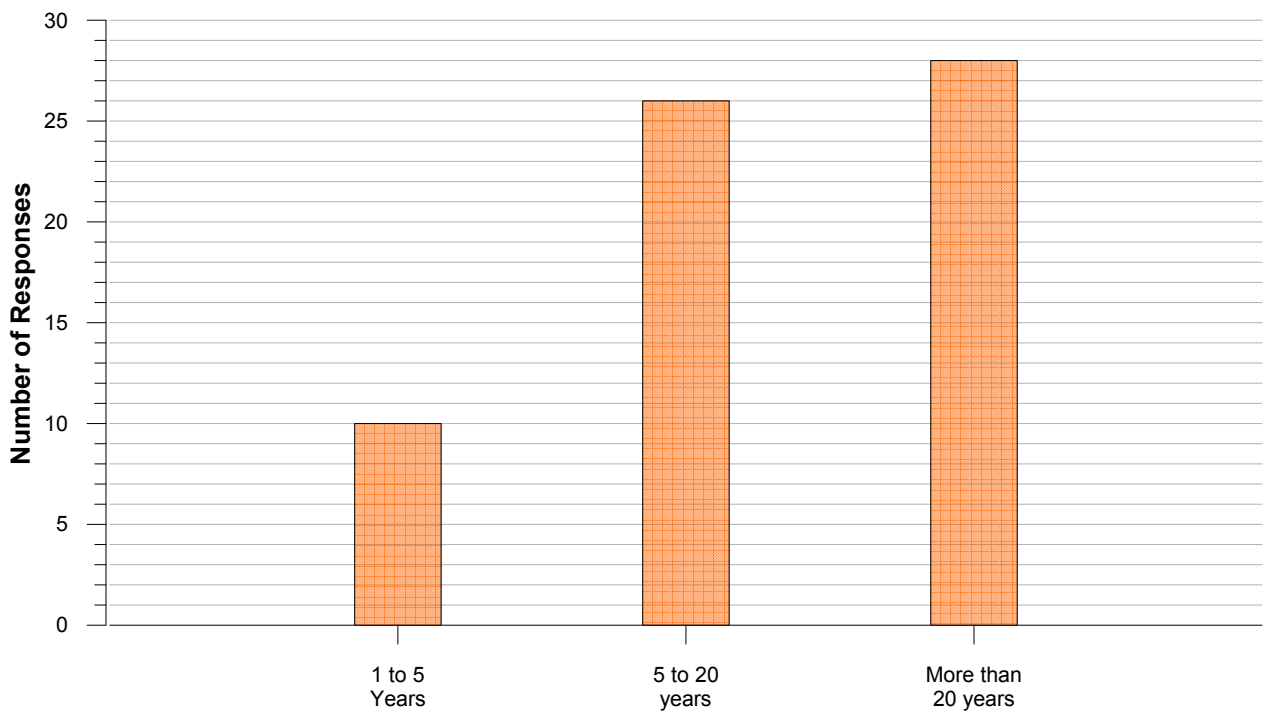
**ATTACHMENT 2**

**RESPONSES TO COMMUNITY QUESTIONNAIRE**

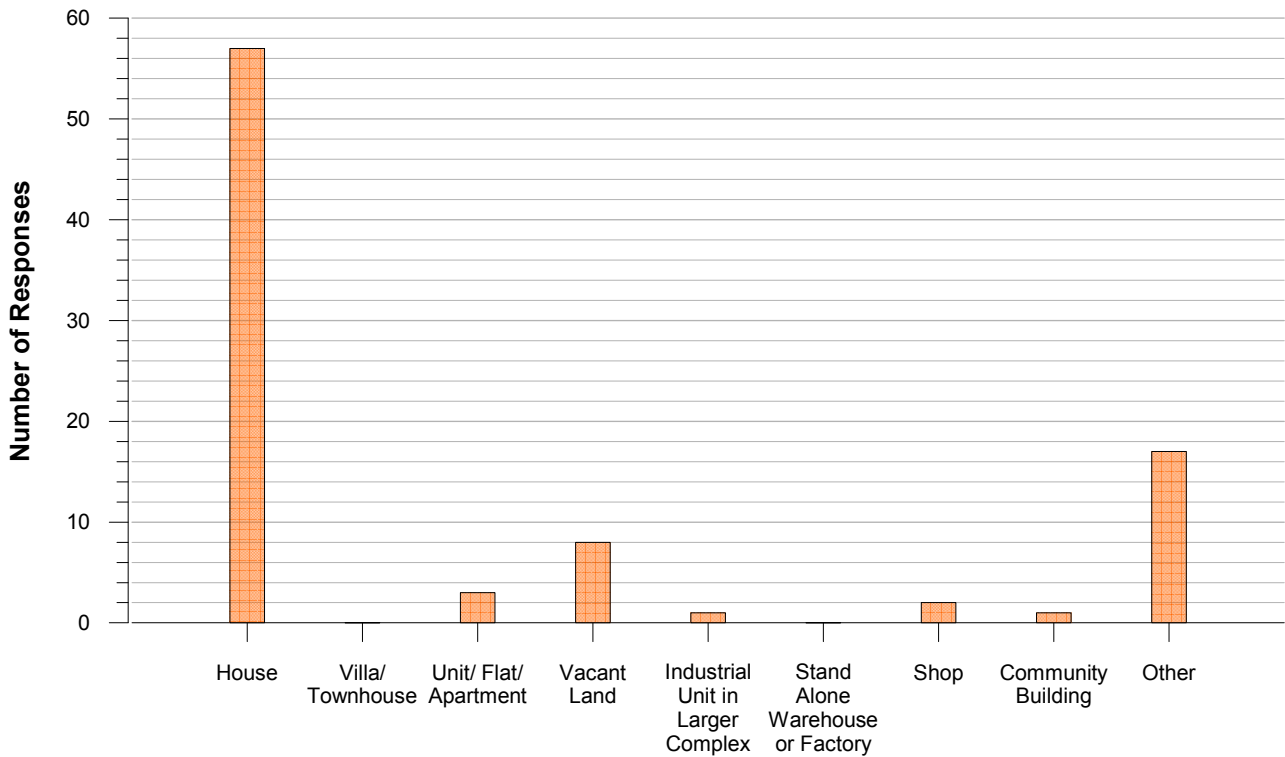
### Q2. Residential Status



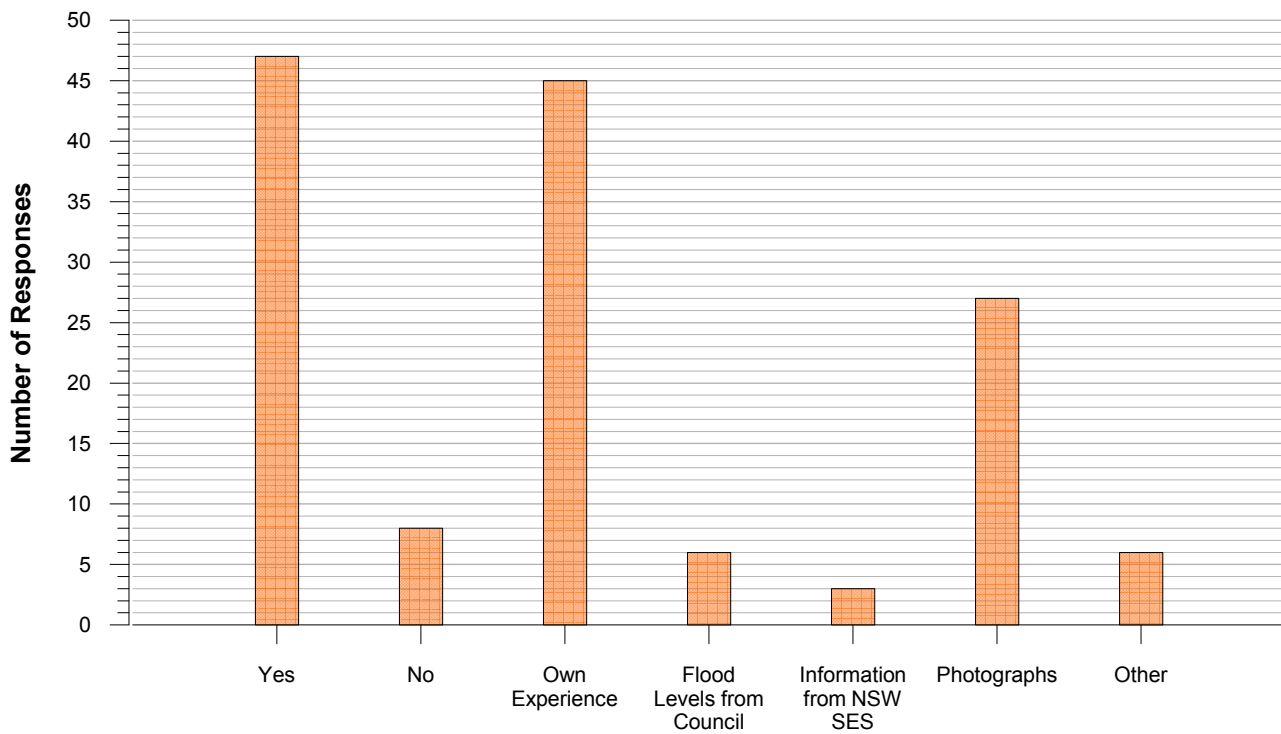
### Q3. How long have you owned or lived at this address?



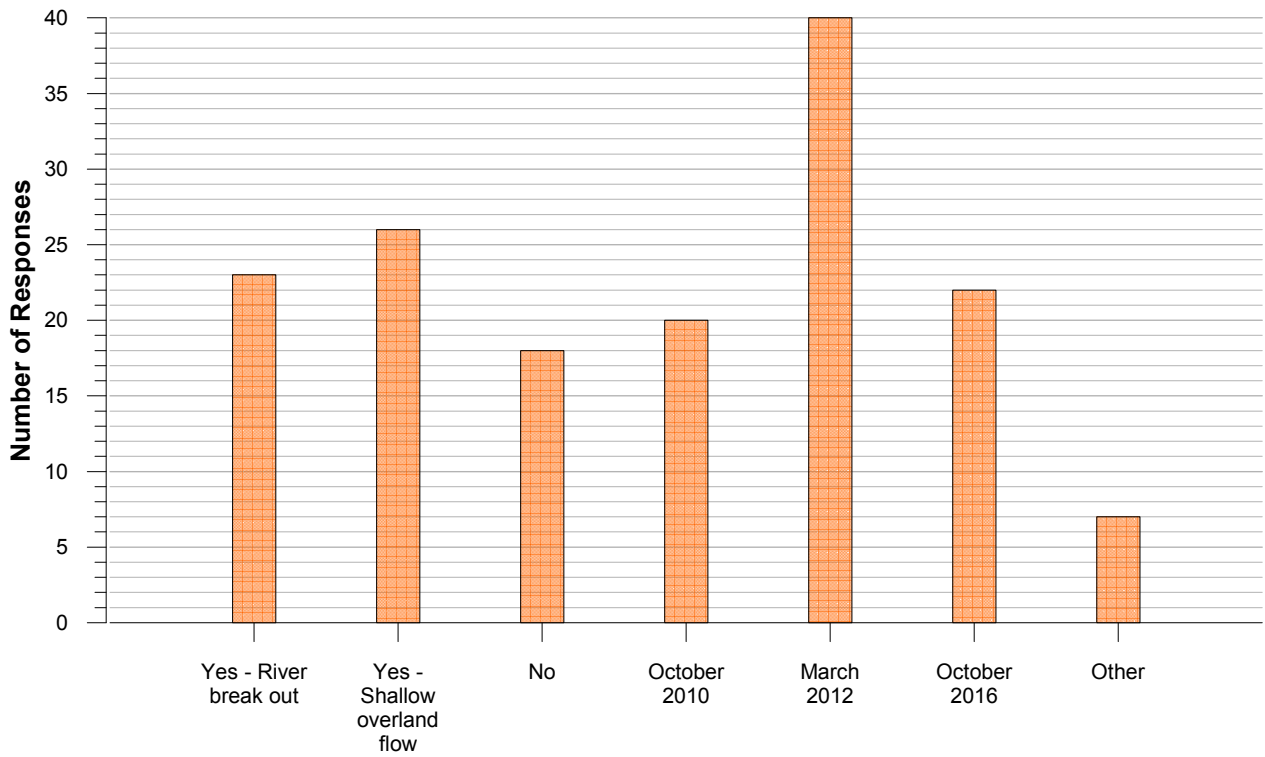
#### Q4. Type of Property



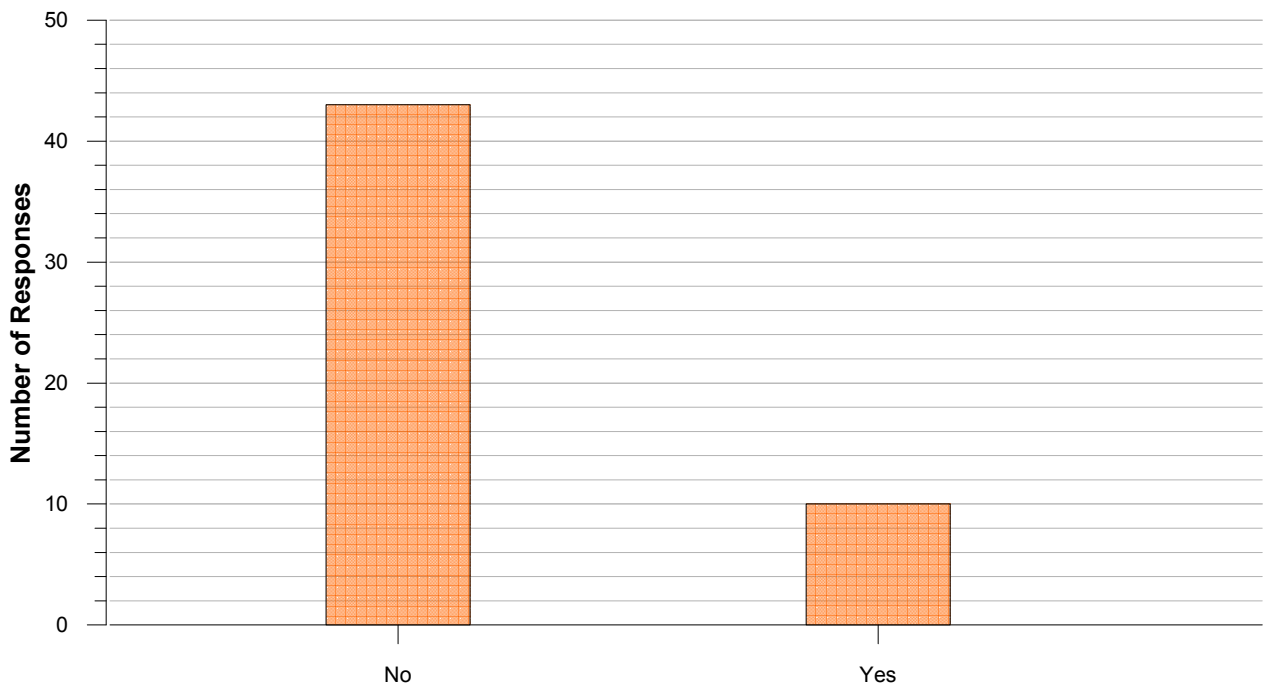
#### Q5. Do you have any information about flooding at your property?



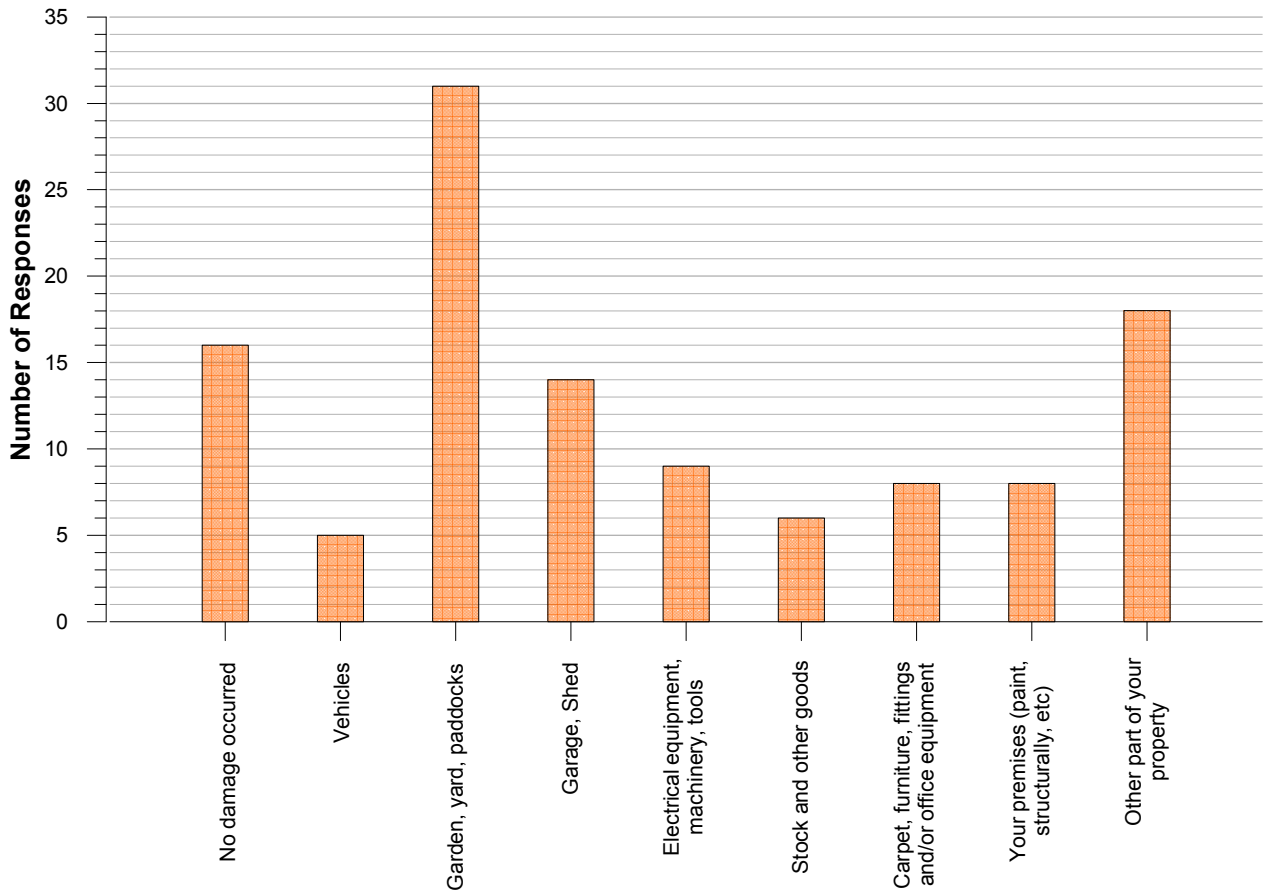
**Q6. Have you experienced flooding?**



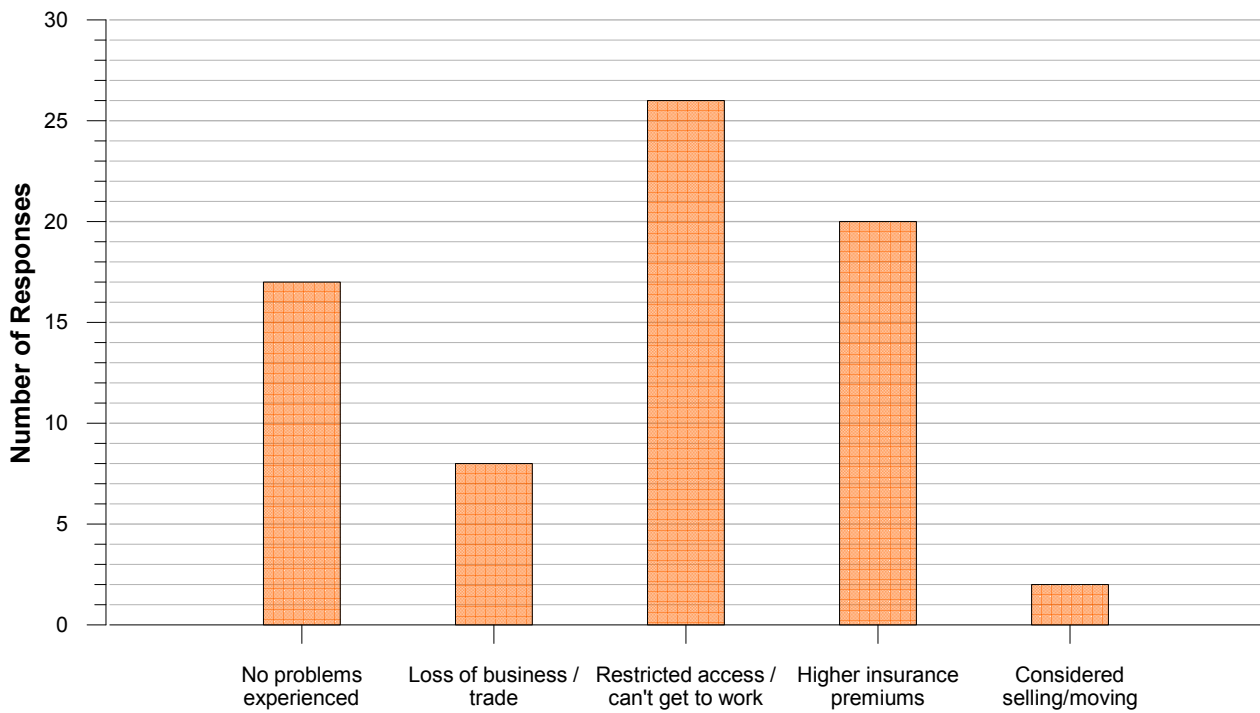
**Q7. Was the main building of your property flooded above floor level?**



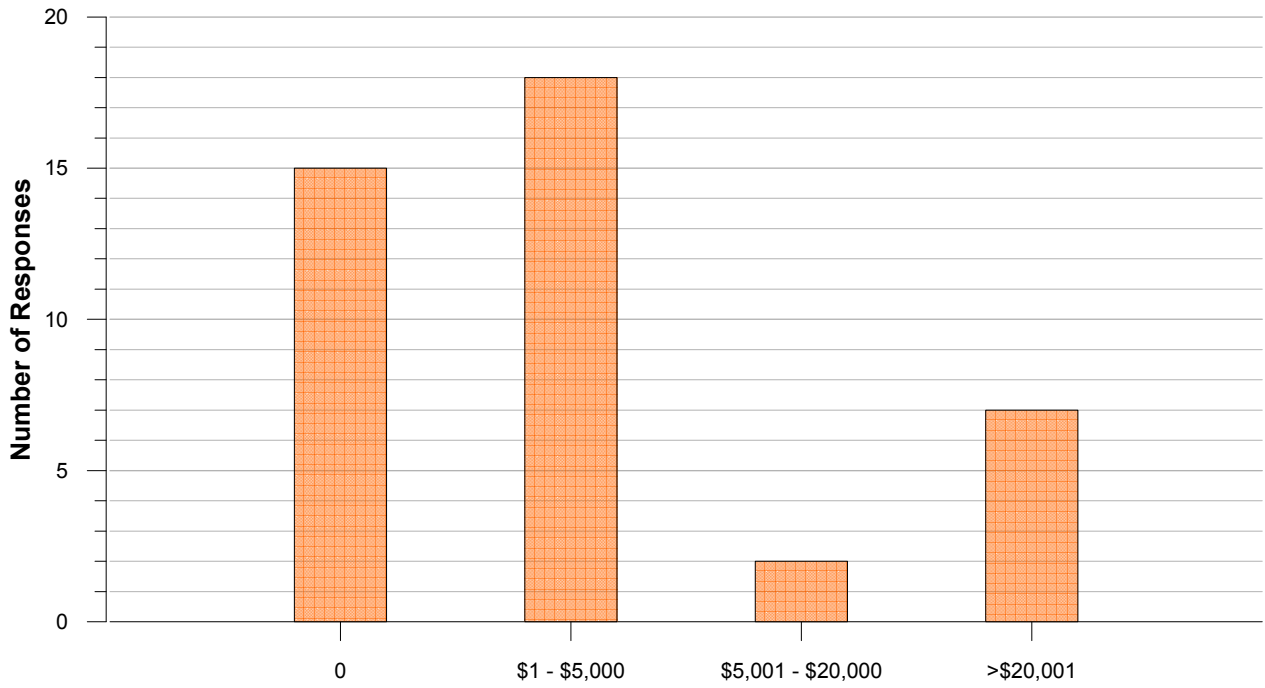
### Q8. What was damaged by floodwaters?



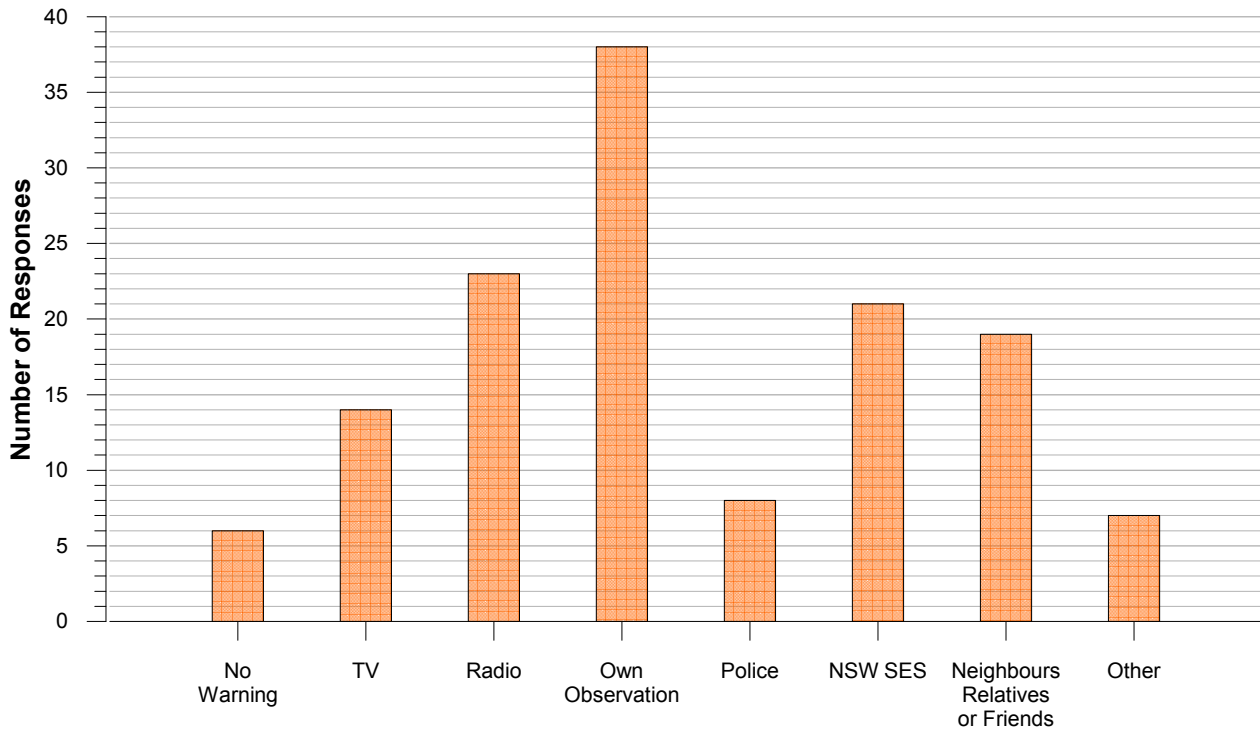
### Q9. Did you experience any problems due to flooding?



### Q10. What was the cost of damage?

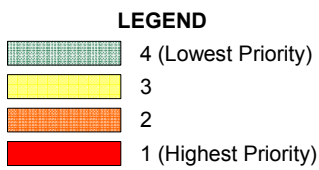
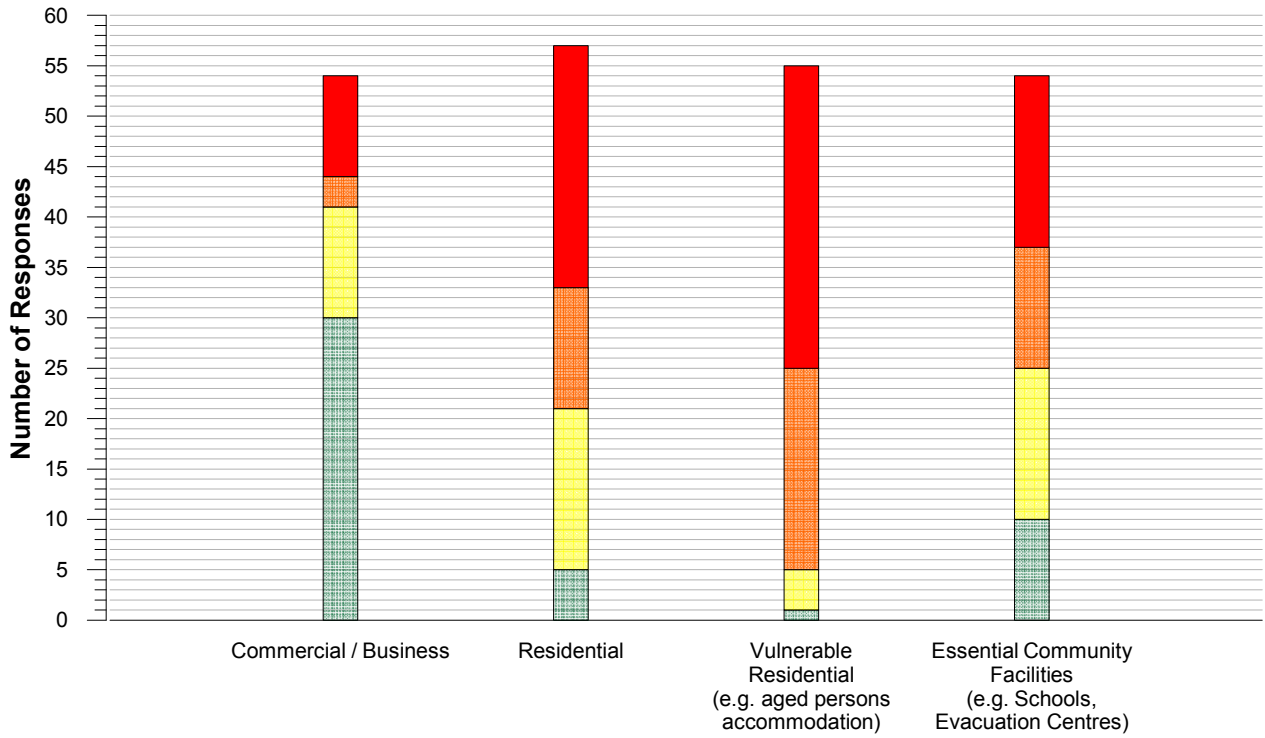


### Q11. Where did the Flood Warning Come From?

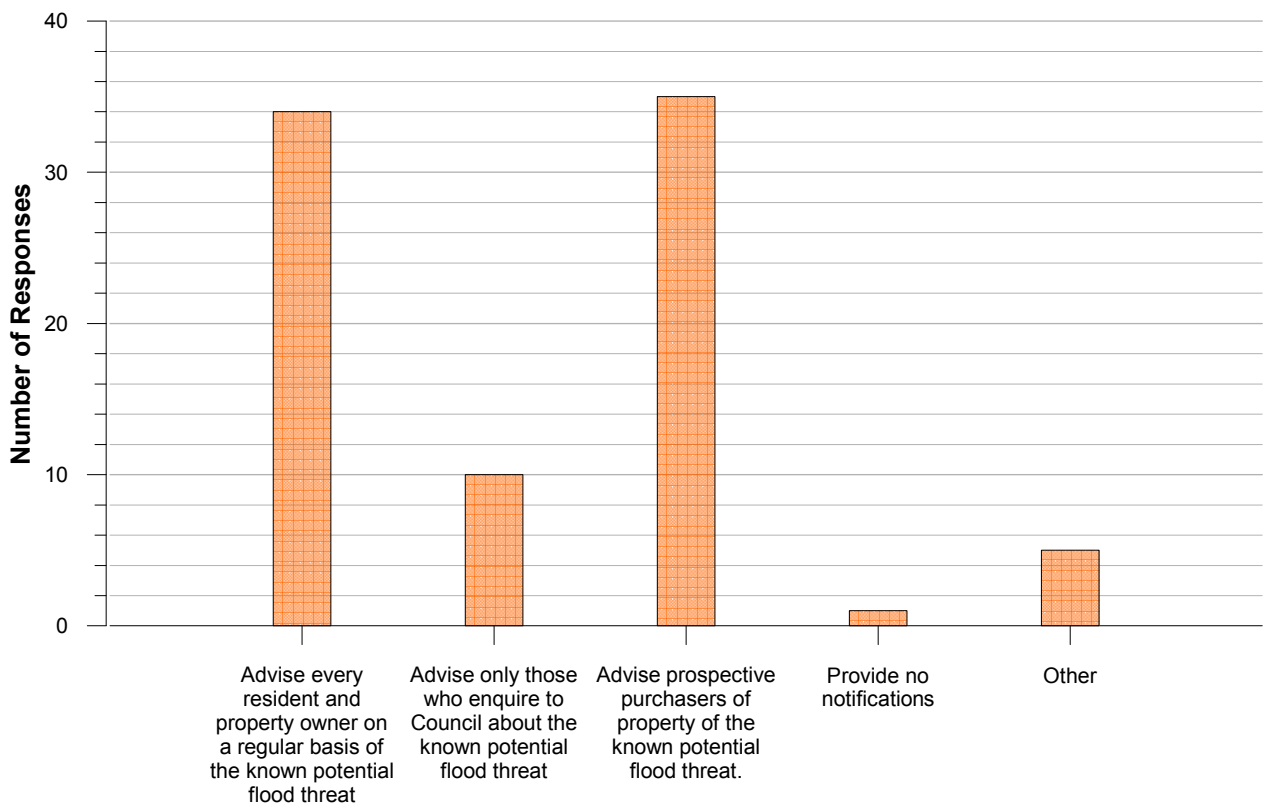




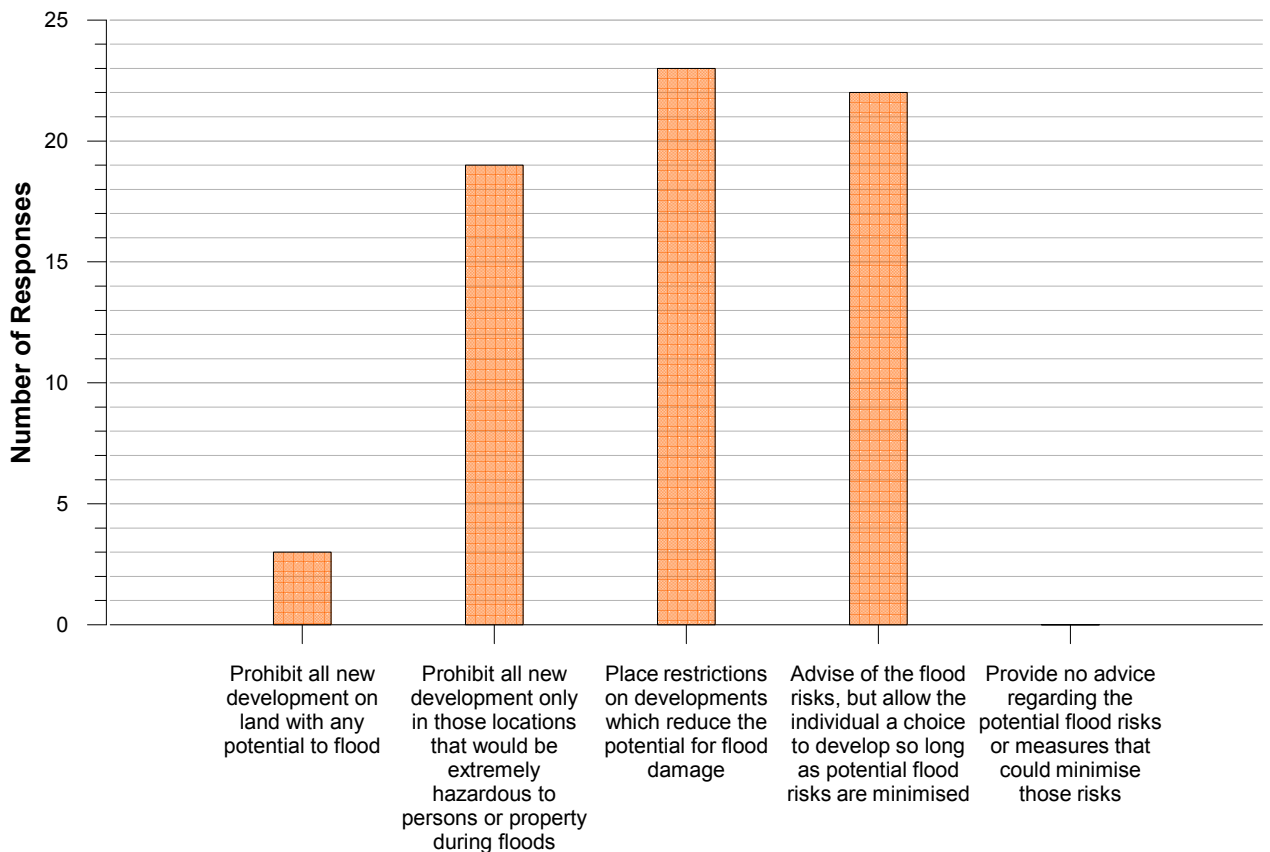
**Q12. Ranking of development types by importance to protect from floods**



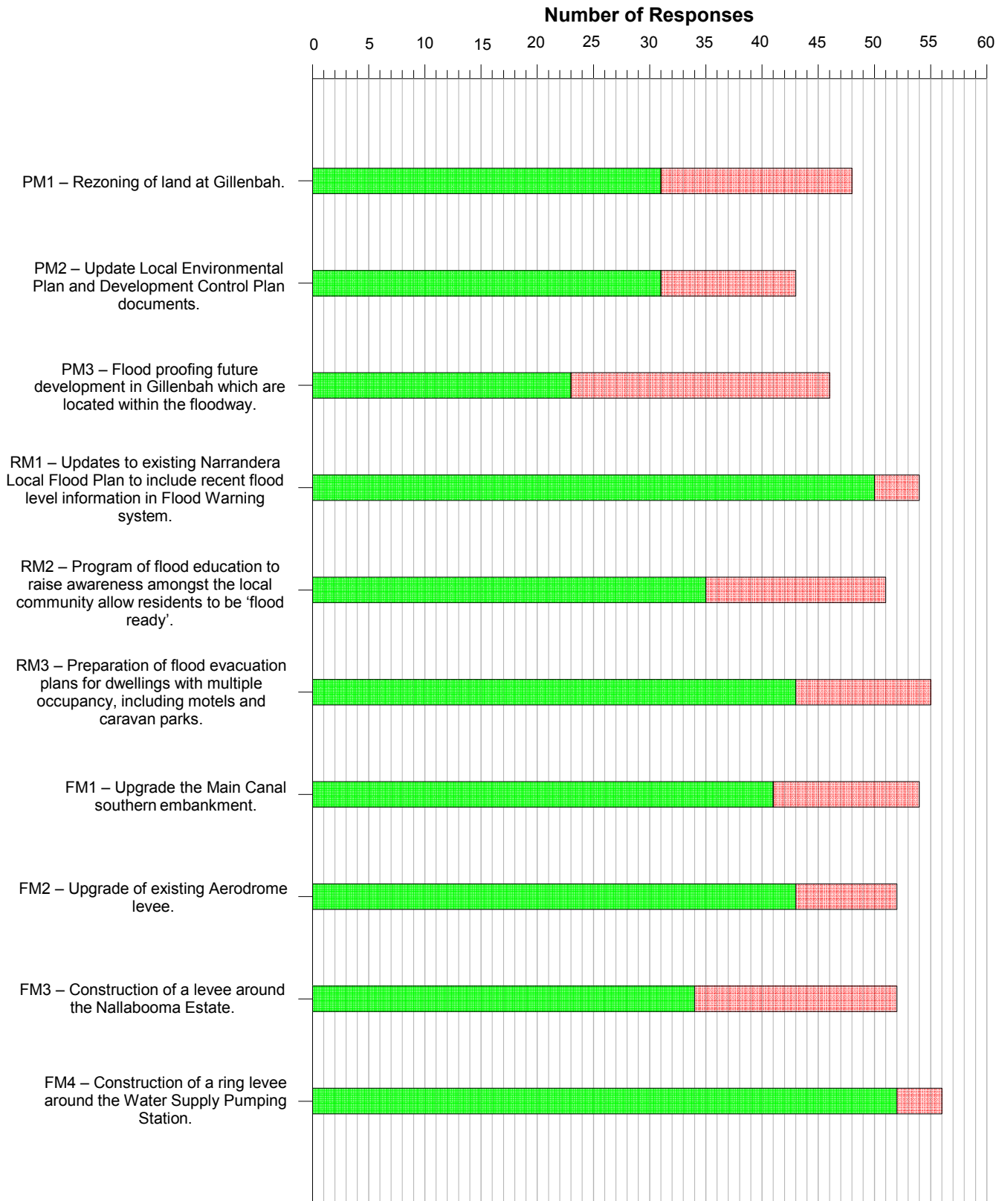
**Q13. What notifications should Council give about the potential flood affectation of properties?**



**Q14. What level of control should Council place on new development to minimise flood-related risks?**



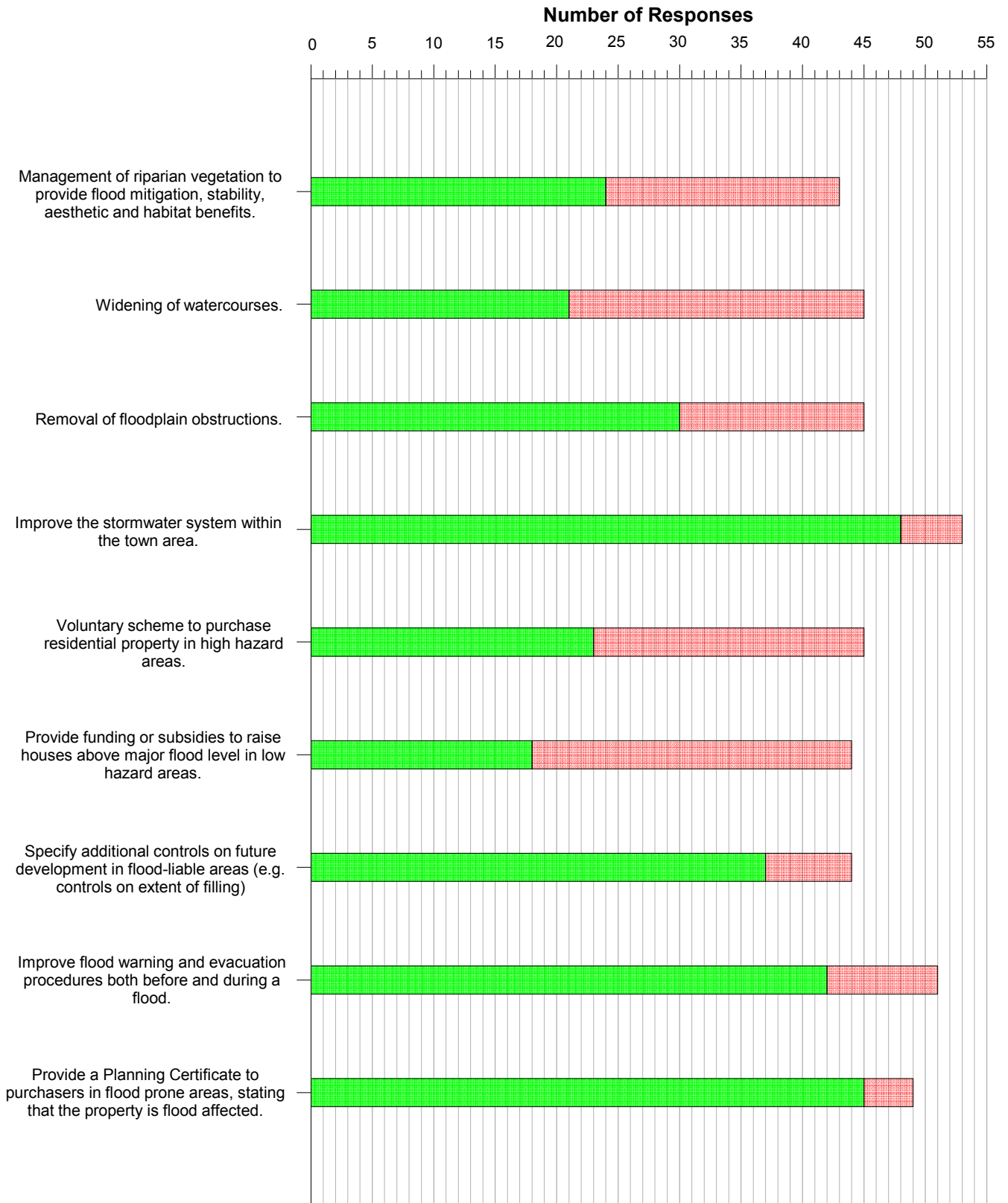
### Q15. Possible Flood Management Options



**LEGEND**

Yes No

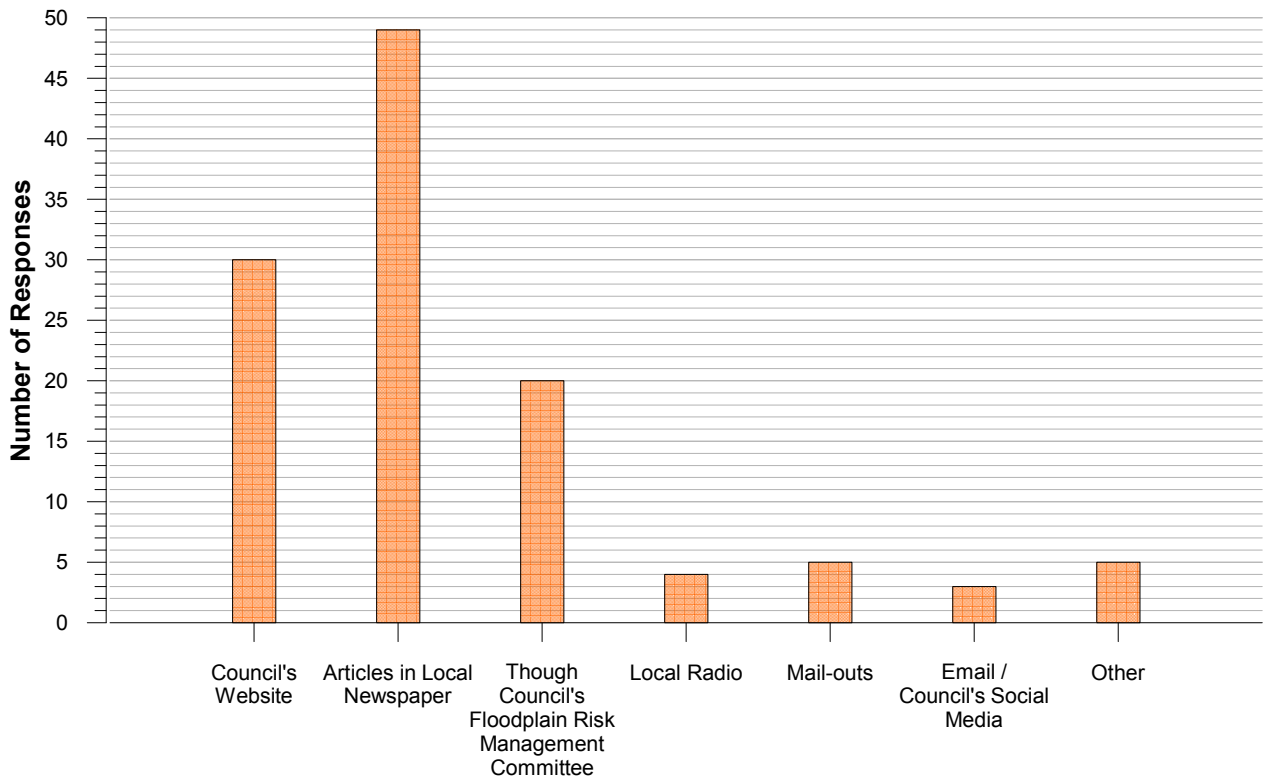
## Q16. Other Possible Methods to Minimise Effects of Flooding



**LEGEND**



**Q17. Best methods to get input and feedback from the local community**



## **APPENDIX B**

### **HYDROLOGIC AND HYDRAULIC MODELLING**

## TABLE OF CONTENTS

	Page No.
<b>B1. INTRODUCTION AND SCOPE.....</b>	<b>B-1</b>
<b>B2. HYDROLOGIC MODEL DEVELOPMENT.....</b>	<b>B-2</b>
B2.1 Hydrologic Modelling Approach .....	B-2
B2.2 Hydrologic Model Layout .....	B-2
B2.3 Design Rainfall .....	B-2
B2.3.1 Rainfall Intensity .....	B-2
B2.3.2 Areal Reduction Factors .....	B-2
B2.3.3 Temporal Patterns .....	B-2
B2.3.4 Probable Maximum Precipitation.....	B-3
B2.4 Design Rainfall Losses .....	B-3
B2.5 Hydrologic Model Tuning .....	B-4
B2.5 Derivation of Design Discharges .....	B-6
<b>B3. HYDRAULIC MODEL DEVELOPMENT .....</b>	<b>B-7</b>
B3.1 TUFLOW Modelling Approach .....	B-7
B3.2 TUFLOW Model Setup.....	B-7
B3.3 Model Boundary Conditions .....	B-8
B3.4 Model Roughness.....	B-8
B3.5 TUFLOW Model Results .....	B-9
B3.5.1 Presentation of Results.....	B-9
B3.6 Sensitivity Studies .....	B-10
B3.6.1 General .....	B-10
B3.6.1 Sensitivity to Hydraulic Roughness .....	B-10
B3.6.2 Sensitivity to Partial Blockage of Hydraulic Structures .....	B-10
<b>B5. REFERENCES .....</b>	<b>B-11</b>

## ANNEXURES

- A Plates Showing Historic Flooding in Narrandera

## **FIGURES (BOUND IN VOLUME 2)**

- B2.1 Local Catchment Hydrologic Model Layout
- B3.1 Local Catchment TUFLOW Model Layout (3 Sheets)
- B3.2 TUFLOW Schematisation of Floodplain
- B3.3 TUFLOW Model Results – 20% AEP (3 Sheets)
- B3.4 TUFLOW Model Results – 10% AEP (3 Sheets)
- B3.5 TUFLOW Model Results – 5% AEP (3 Sheets)
- B3.6 TUFLOW Model Results – 1% AEP (3 Sheets)
- B3.7 TUFLOW Model Results – 0.5% AEP (3 Sheets)
- B3.8 TUFLOW Model Results – 0.2% AEP (3 Sheets)
- B3.9 TUFLOW Model Results – Extreme Flood (3 Sheets)
- B3.10 Sensitivity of Local Catchment Flood Behaviour to 20% Increase in Hydraulic Roughness Values – 1% AEP (3 Sheets)
- B3.11 Sensitivity of Local Catchment Flood Behaviour to Partial Blockage of All Hydraulic Structures – 1% AEP (3 Sheets)
- B3.12 Sensitivity of Local Catchment Flood Behaviour to Partial Blockage of Siphons Only – 1% AEP (3 Sheets)



## B1. INTRODUCTION AND SCOPE

The Appendix deals with the development of hydrologic and hydraulic models that were used to define the nature of Major Overland Flow in the urbanised and rural parts of Narrandera that lie to the north of the Main Canal. A two-staged approach to flood modelling was adopted which involved the running in series of:

1. The hydrologic model of the town based on the RAFTS and ILSAX rainfall-runoff modelling approaches within the DRAINS software (**Local Catchment Hydrologic Model**).
2. The hydraulic model of the town based on the TUFLOW software (**Local Catchment TUFLOW Model**). The Local Catchment TUFLOW Model incorporated the areas of Nallabooma Estate and South Narrandera, the hydrology for which was based on the direct rainfall on grid approach.<sup>1</sup>

The DRAINS model computed discharge hydrographs which were then applied to the TUFLOW hydraulic model at relevant sub-catchment outlets.

The TUFLOW model used a two-dimensional (in plan), grid-based representation of the natural surface based on the available LiDAR survey data, as well as piped drainage data provided by Council which was supplemented by field measurements. The TUFLOW model results were used to define patterns of overland flow for storms ranging between 20 and 0.2% AEP, as well as the PMF.

---

<sup>1</sup> Note that the major overland flow was not defined at Gillenbah as Main Stream Flooding is the dominant mechanism for flooding in this area.

## **B2. HYDROLOGIC MODEL DEVELOPMENT**

### **B2.1 Hydrologic Modelling Approach**

The present investigation required the use of hydrologic models that are capable of representing the rainfall-runoff processes that occur within the rural areas which border Narrandera, as well as those in the urbanised parts of the township.

The hydrologic response of the rural and urban parts of Narrandera that are located to the north of the Main Canal was simulated using the RAFTS and ILSAX sub-models in the DRAINS software, respectively, while the hydrologic response of the areas which lie to the south of the Main Canal (i.e. Nallabooma Estate and South Narrandera) were simulated using the direct rainfall on grid approach in the TUFLOW software.

### **B2.2 Hydrologic Model Layout**

**Figure B2.1** shows the sub-catchment areas that were modelled using the RAFTS and ILSAX sub-models in DRAINS, as well as the area over which the direct rainfall on grid approach was applied. The outlets of the sub-catchments in the headwaters of the study area were linked and the lag times between each assumed to be equal to the distance along the main drainage line divided by an assumed flow velocity of 0.5 m/s.

Percentages of impervious area were assessed using the available aerial photography and cadastre boundary data. Sub-catchment slopes used for input to the RAFTS component of the hydrologic model were derived using the vectored average slope approach. The available LiDAR derived contour data was used as the basis for computing the slope for both methods.

### **B2.3 Design Rainfall**

#### **B2.3.1 Rainfall Intensity**

The procedures used to obtain temporally and spatially accurate and consistent Intensity-Frequency-Duration (**IFD**) design rainfall curves for the assessment of flooding at Narrandera are presented in the recently release edition of Australian Rainfall and Runoff (GA, 2016). Design storms for frequencies of 20, 10, 5 and 1% AEP were derived for storm durations ranging between 30 minutes and seven days. The IFD dataset was downloaded from BoM's *2016 Rainfall IFD Data System*.

#### **B2.3.2 Areal Reduction Factors**

The rainfalls derived using the processes outlined in GA, 2016 are applicable strictly to a point. In the case of a catchment of over tens of square kilometres area, it is not realistic to assume that the same rainfall intensity can be maintained. An Areal Reduction Factor (**ARF**) is typically applied to obtain an intensity that is applicable over the entire catchment.

However, as the catchments contributing to flow in the local drainage system at Narrandera are relatively small, the reduction in rainfall intensity would be quite small. Accordingly, no reduction in design point rainfalls was made for this present study (i.e. an ARF of 1.0 was adopted).

#### **B2.3.3 Temporal Patterns**

GA, 2016 prescribes the analysis of 10 temporal patterns per storm duration for various zones in Australia. These patterns are used in the conversion of a design rainfall depth with a specific AEP into a design flood of the same frequency. The patterns may be used for AEP's down to

0.2 per cent where the design rainfall data is extrapolated for storm events with an AEP less than 1 per cent.

The temporal pattern ensembles that are applicable to catchments for Frequent (more frequent than 14.4% AEP), Intermediate (between 3.2 and 14.4% AEP) and Rare (rarer than 3.2% AEP) storm events were obtained from the ARR Data Hub,<sup>2</sup> while those for the very rare events were taken from BoM's update of *Bulletin 53* (BoM, 2003).

### B2.3.4 Probable Maximum Precipitation

Estimates of PMP were made using the Generalised Short Duration Method (**GSDM**) as described in BoM's update of *Bulletin 53* (BoM, 2003). This method is appropriate for estimating extreme rainfall depths for catchments up to 1000 km<sup>2</sup> in area and storm durations up to 6 hours. Therefore the method is appropriate for use for the local catchments at Narrandera.

The steps involved in assessing PMP for the local catchments at Narrandera are briefly as follows:

- Calculate PMP for a given duration and catchment area using depth-duration-area envelope curves derived from the highest recorded US and Australian rainfalls.
- Adjust the PMP estimate according to the percentages of the catchment which are meteorologically rough and smooth, and also according to elevation adjustment and moisture adjustment factors.
- Assess the design spatial distribution of rainfall using the distribution for convective storms based on US and world data, but modified in the light of Australian experience.
- Derive storm hyetographs using the temporal distribution contained in *Bulletin 53* (BoM, 2003), which is based on pluviographic traces recorded in major Australian storms.

## B2.4 Design Rainfall Losses

The ARR Data Hub is generally used to derive the initial, continuing and pre-burst loss values to be applied in flood hydrograph estimation. **Table B2.1** sets out the ARR Data Hub recommend Storm and Continuing Loss values for application at Narrandera that were derived using the predicted loss equations that have been developed as part of GA, 2016.

**TABLE B2.1**  
**DESIGN STORM AND CONTINUING LOSS VALUES**

Source	Catchment	Storm Loss (mm)	Continuing Losses (mm/hr)
ARR Data Hub	-	22	0.2
GA, 2016 <sup>(1)</sup>	Region 2 Minimum	20.0	1.6
	Region 2 Maximum	60.0	10.4
	Region 2 Median	37.5	2.7

1. Taken from Table 5.3.5 and 5.3.6 in Chapter 3 of Book 5 of GA, 2016.

<sup>2</sup> It is noted that the temporal pattern data set for the *Murray Basin* region is suitable for use at Narrandera.

The loss prediction equations that were developed as part of GA, 2016 (refer Chapter 3 of Book 5) are split into four regions across Australia; Regions 1 and 3 representing the summer- and winter-dominant regions in the north and the south of the country, Region 4 representing catchments in the south-west of Western Australia, and Region 2, where Narrandera is located, representing the remainder of the country. The loss prediction equations for Region 2 were derived using data at nine gauged catchments within the region, the closest of which is located about 370 km to the east of Narrandera on the east coast of the continent.

The Storm and Pre-Burst Loss values extracted from the ARR Data Hub have been adopted for the present study as they are consistent with the range presented in GA, 2016 for Region 2.

As the Continuing Loss value recommended for use at Narrandera is significantly lower than the minimum value used to derive the loss prediction equations for Region 2, a value of 2.5 mm/hr has been adopted for the present study.

As DRAINS uses the Hortonian loss modelling approach which does not require the user to input a continuing loss rate, the following set of parameters were adopted for generating flows in the urbanised parts of Narrandera:

- Paved area depression storage = 2 mm
- Grassed area depression storage = 10 mm
- Soil Type = 3.0
- AMC = 3.0

## B2.5 Hydrologic Model Tuning

There were no historic data on flows experienced along the Major Overland Flow paths in Narrandera to allow the hydrologic model to be calibrated. The procedure adopted for the testing of the hydrologic model therefore involved an iterative process sometimes referred to as “tuning”. The process usually involves adjusting the hydrologic parameters until the peak flows generated by the model gave a good match to those derived using the Regional Flood Frequency Estimation (RFFE) Model, procedures for which are set out in GA, 2016.<sup>3</sup> **Table B2.2** over provides a comparison between the peak flows derived using the RFFE and those derived from the Local Catchment Hydrologic Model using the following hydrologic parameters:

- PERN value of 0.04
- BX = 1.2
- Storm Loss = 22 mm
- Continuing Loss = 2.5 mm/hr

---

<sup>3</sup> Note that the RFFE is suitable for design peak flow estimation in rural catchments only.

**TABLE B2.2**  
**COMPARISON OF DESIGN PEAK FLOWS<sup>(1)</sup>**

AEP (%)	Nar_01 [Catchment Area = 4.8 km <sup>2</sup> ]			Nar_02 [Catchment Area = 0.4 km <sup>2</sup> ]			Nar_03 [Catchment Area = 4.3 km <sup>2</sup> ]			Nar_04 [Catchment Area = 0.4 km <sup>2</sup> ]			Nar_05 [Catchment Area = 0.3 km <sup>2</sup> ]		
	RFFE	Local Catchment Hydrologic Model <sup>(2)</sup>	Difference <sup>(3)</sup> (m)	RFFE	Local Catchment Hydrologic Model <sup>(2)</sup>	Difference <sup>(3)</sup> (m)	RFFE	Local Catchment Hydrologic Model <sup>(2)</sup>	Difference <sup>(3)</sup> (m)	RFFE	Local Catchment Hydrologic Model <sup>(2)</sup>	Difference <sup>(3)</sup> (m)	RFFE	Local Catchment Hydrologic Model <sup>(2)</sup>	Difference <sup>(3)</sup> (m)
20	3.8	3.5	-0.3	0.9	0.5	-0.4	2.8	3.5	0.7	0.9	0.4	-0.5	0.7	0.4	-0.3
10	5.5	5.6	0.1	1.2	0.9	-0.3	4.0	5.6	1.6	1.3	0.6	-0.7	1.0	0.6	-0.4
5	7.5	7.7	0.2	1.7	1.3	-0.4	5.4	7.5	2.1	1.8	0.8	-1.0	1.3	0.9	-0.4
2	10.5	11.6	1.1	2.4	1.9	-0.5	7.6	11.4	3.8	2.6	1.2	-1.4	1.9	1.3	-0.6
1	13.4	14.4	1.0	3.0	2.3	-0.7	9.6	13.8	4.2	3.3	1.4	-1.9	2.4	1.6	-0.8

1. Refer **Figure B2.1** for location of peak flow comparison.
2. Refer **Section B2.4** for Storm and Continuing Loss values that were applied to the Local Catchment Hydrologic Model.
3. A positive value indicates that the peak flow derived by the Local Catchment Hydrologic Model is higher, and conversely a negative value indicates that the peak flow derived by the Local Catchment Hydrologic Model is lower than those derived by the RFFE.

**Table B2.2** shows that the Local Catchment Hydrologic Model generally provided a good match with the peak flows derived using the RFFE with the exception of location Nar\_01 which represents the 4.3 km<sup>2</sup> catchment draining directly to Lake Talbot. It was not possible to gain a match between the two methods as the catchment to the north of the lake is very steep (grades greater than 15%) which is considered distinctly different from the range found in a “typical” catchment at Narrandera for which the RFFE is better suited.

## **B2.5 Derivation of Design Discharges**

The hydrologic model was run with the adopted parameters (refer **Sections B.2.3** and **B2.4** for details) to obtain design discharge hydrographs for AEP’s ranging between 20 and 0.2% AEP, together with the PMF for input to the TUFLOW hydraulic model.

### **B3. HYDRAULIC MODEL DEVELOPMENT**

#### **B3.1 TUFLOW Modelling Approach**

TUFLOW is a true two-dimensional hydraulic model which does not rely on a prior knowledge of the pattern of flood flows in order to set up the various fluvial and weir type linkages which describe the passage of a flood wave through the system. The basic equations of TUFLOW involve all of the terms of the St Venant equations of unsteady flow. Consequently, the model is "fully dynamic" and once tuned will provide an accurate representation of existing flood behaviour in terms of depth, velocity and distribution of flow. TUFLOW solves the equations of flow at each point of a rectangular grid system which represent overland flow on the floodplain and along streets. The choice of grid point spacing depends on the need to accurately represent features on the floodplain which influence hydraulic behaviour and flow patterns (e.g. buildings, streets, changes in channel and floodplain dimensions, hydraulic structures which influence flow patterns, etc.).

Pipe drainage and channel systems can be modelled as one-dimensional elements embedded in the larger two-dimensional domain which typically represents the wider floodplain. Flows are able to move between the one and two-dimensional elements of the model depending on the capacity characteristics of the drainage system being modelled.

#### **B3.2 TUFLOW Model Setup**

**Figure B3.1** shows the layout of the various components which comprise the Local Catchment TUFLOW Model. A 4 m grid spacing was found to provide the appropriate balance between the need to define features along the Major Overland Flow Paths versus model run times. Grid data were derived from the LiDAR survey of the floodplain, with ridge and gully lines added to the model where the grid spacing was considered too coarse to accurately represent important topographic features.

The footprints of a large number of individual buildings located along the overland flow paths in the two-dimensional model domain were digitised and assigned an artificially high hydraulic roughness value which accounted for their blocking effect on flow while maintaining storage in the model. Individual allotments along the overland flow paths where development is present were also digitised and assigned an artificially high hydraulic roughness value (although not as high as for individual buildings) to account for the reduction in conveyance capacity which will result from fences and other obstructions stored on these properties.

Details of the piped drainage system were incorporated into the TUFLOW model based on information contained in Council's asset database where available and supplemented by field measurements. Limited information was available on pipe invert levels. Therefore an assumed cover of 700 mm was adopted for those drainage elements where invert levels or depth measurements were not available. Adjustments were made to the assumed invert levels where this approach resulted in a negatively graded reach of pipe or culvert.

Several types of pits are identified on **Figure B3.1**, including junction pits which have a closed lid and inlet pits which are capable of accepting overland flow. Council's asset database contained some information in regard to inlet pit types and dimensions which was supplemented with visual inspections to derive inlet capacity relationships for incorporation in the TUFLOW model.

Pit losses throughout the various piped drainage networks were modelled using the Engelund approach in TUFLOW. This approach provides an automatic method for determining time-varying energy loss coefficients at pipe junctions that are recalculated each time step based on a range of variables including the inlet/outlet flow distribution, the depth of water within the pit, expansion and contraction of flow through the pit, and the horizontal deflection and vertical drop across the pit.

**Table B3.1** summarises the pit and pipe data that were incorporated into the TUFLOW model.

**TABLE B3.1  
SUMMARY OF MODELLED DRAINAGE STRUCTURES**

Element	Number	Length (m)
Pipes	419	13,060
Box Culverts	123	2,420
Inlet Pits	304	-
Junction Pits	52	-
Headwalls	361	-

### B3.3 Model Boundary Conditions

The locations where discharge hydrographs derived by the Local Catchment Hydrologic Model were applied to the Local Catchment TUFLOW Model are shown on **Figure B3.1**. These comprise both point-source inflows at selected locations along the existing piped drainage systems, and distributed inflows via “Rain Boundaries”.

The location of point source inflows coincide with the location of inlet pits where runoff can presently enter the piped drainage system, and generally correspond with the downstream limit of each sub-catchment modelled in DRAINS.

The Rain Boundaries act to “inject” flow into the two-dimensional domain of the Local Catchment TUFLOW Model, firstly at a point which has the lowest elevation, and then progressively over the extent of the Rain Boundary as the grid in the two-dimensional model domain becomes wet as a result of overland flow.

The downstream boundaries of the model comprised “free discharge” outlets, where TUFLOW derived normal depth calculations were used to define hydraulic conditions at the outlet.

### B3.4 Model Roughness

The main physical parameter for TUFLOW is the hydraulic roughness. Hydraulic roughness is required for each of the various types of surfaces comprising the overland flow paths. In addition to the energy lost by bed friction, obstructions to flow also dissipate energy by forcing water to change direction and velocity and by forming eddies. Hydraulic modelling traditionally represents all of these effects via the surface roughness parameter known as “Mannings n”.



There are no historic flood level data available to assist with the tuning of the model for roughness. In areas where there were limited historic flood level data available to assist with the tuning of the model for roughness, roughness was estimated from site inspection, past experience and values contained in the engineering literature.

**Table B3.2** presents the “best estimate” of hydraulic roughness values adopted for design purposes. These values gave reasonable correspondence with observed flood behaviour. The adoption of a value of 0.02 for the surfaces of roads, along with an adequate description of their widths and centreline and kerb elevations, allowed a reasonably accurate assessment of their conveyance capacity to be made. Similarly, the high value of roughness adopted for buildings recognised that they completely blocked the flow but were capable of storing water when flooded.

**TABLE B3.2**  
**“BEST ESTIMATE” OF HYDRAULIC ROUGHNESS VALUES**  
**ADOPTED FOR TUFLOW MODELLING**

Surface Treatment	Mannings n Value
Asphalt or concrete road surface	0.02
Grass or lawns	0.045
Vegetated area	0.08
Allotment	0.10
Main Canal	0.03
Buildings	10

**Figure B3.2** is a typical example of flow patterns derived from the above roughness values. This example applies for the 1% AEP design storm event and shows flows through existing development in the overland flow path between Rupert Street and Grosvenor Street.

The left hand side of the figure shows the roads and inter-allotment areas, as well as the outlines of buildings, which have been individually digitised in the model. The right hand side shows the resulting flow path in the form of scaled velocity vectors and the depths of inundation. The buildings with their high values of hydraulic roughness block the passage of flow, although the model recognises that they store floodwater when inundated and therefore correctly accounts for flood storage. The flow is conveyed via the road reserves and through the open parts of the allotments. Similar information to that shown on **Figure B3.2** may be presented at any location within the model domain (which is shown on **Figure B3.1**, sheet 1) and will be of assistance to Council in assessing individual flooding problems in the urbanised parts of Narrandera.

### **B3.5 TUFLOW Model Results**

#### **B3.5.1 Presentation of Results**

**Figures 2.2** and **2.3** (4 sheets each) of the Main Report show the nature of both Main Stream Flooding and Major Overland Flow at Narrandera for the 1% AEP and Extreme Flood events, respectively, while **Figures B3.3** to **B3.9** show similar information for the 20, 10, 5, 2, 0.5 and 0.2% AEP storm events.

**Section 2.4.2** of the Main Report contains a discussion on the nature of Major Overland Flow in Narrandera.

## **B3.6 Sensitivity Studies**

### **B3.6.1 General**

The sensitivity of the hydraulic model was tested to variations in model parameters such as hydraulic roughness and the partial blockage of existing piped drainage system at Narrandera. The main purpose of these studies was to give some guidance on the freeboard to be adopted when setting floor levels of development in flood prone areas.

#### **B3.6.1 Sensitivity to Hydraulic Roughness**

**Figure B3.10** shows the difference in peak flood levels (i.e. the “afflux”) for the 1% AEP flood event resulting from an assumed 20% increase in hydraulic roughness compared to values adopted for design flood estimation (refer values set out in **Table B3.2**). This figure also identifies areas where land is rendered flood free, or where additional areas of land are flooded. The typical increase in peak flood level in areas affected by major overland flow is in the range 10 to 50 mm.

#### **B3.6.2 Sensitivity to Partial Blockage of Hydraulic Structures**

The mechanism and geometrical characteristics of blockages in the piped system are difficult to quantify and would no doubt be different for each storm event. Realistic scenarios would be limited to one or two pipes becoming partially blocked during a storm event. However, for the purposes of the present study, analyses were carried out with the cross sectional areas of all pipes and conduits reduced for storm events with varying AEP's. The following blockage scenarios were assessed:

- 50% blockage of all conduits.
- 100% blockage of the Town and Woolscour Road Siphons.

This represents a case which is well beyond a blockage scenario which could reasonably be expected to occur and is presented for illustrative purposes.

**Figure B3.11** shows the afflux for the 1% AEP 12 hour duration storm resulting from a 50 per cent blockage of the existing stormwater drainage system. Peak flood levels would be increased by a maximum 80 mm along the Major Overland Flow Path that extends downstream of Henry Mathieson Oval to the Town Siphon, and by up to 640 mm in the trapped low points which lie adjacent to it. A partial blockage of the culverts beneath the Junee-Hay Railway would also increase peak 1% AEP flood levels in the rural parts of the study area by up to 700 mm.

**Figure B3.12** shows the afflux for the 1% AEP 12 hour duration storm resulting from closure of the penstock flood gates on the Town and Woolscour Road Siphons. On the upstream side of the Town Siphon peak flood levels would increase by up to 90 mm and 640 mm on the eastern and western side of the Newell Highway, respectively. Closure of the penstock flood gate fitted to the inlet of the Woolscour Road Siphon would increase peak 1% AEP flood levels in the vicinity of Woolscour Road by about 50 mm.

## **B5. REFERENCES**

BoM (Bureau of Meteorology), 2003. ***“The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method”***.

Geoscience Australia (2016). ***“Australian Rainfall and Runoff – A Guide to Flood Estimation”***

**ANNEXURE A**

**PLATES SHOWING HISTORIC FLOODING IN NARRANDERA**

**MARCH 2010 STORM EVENT**



**Plate B1.1** – 7/03/2010 16:29 hours - Looking north along Charles Street south of Kiesling Lane (Source: Council)



**Plate B1.2** – 7/03/2010 16:29 hours - Looking north along Charles Street intersection of Kiesling Lane (Source: Council)



**Plate B1.3** – 7/03/2010 16:29 hours – Major Overland Flow in Kiesling Lane (Source: Council)



**Plate B1.4** – 7/03/2010 16:30 hours – Looking east along Kiesling Lane, open drain (Source: Council)



**Plate B1.5** – 7/03/2010 16:31 hours - Looking north along Charles Street south of Kiesling Lane (Source: Council)



**Plate B1.6** – 7/03/2010 16:33 hours – Looking north along Bolton Street (Source: Council)

**MARCH 2010 STORM EVENT**



**Plate B1.7** – 7/03/2010 16:39 hours - Looking west along silt basin (Source: Council)



**Plate B1.8** – 7/03/2010 16:39 hours - Looking north along open drain, silt basin (Source: Council)



**Plate B1.9** – 7/03/2010 16:43 hours – Looking west along Irrigation Way (Source: Council)



**Plate B1.10** – 7/03/2010 16:44 hours – Looking south along Sugden Street from Irrigation way (Source: Council)



**Plate B1.11** – 7/03/2010 16:45 hours - Looking east along Woolscour Road (Source: Council)



**Plate B1.12** – 7/03/2010 16:45 hours – Looking east along Woolscour Road, north of canal (Source: Council)

**APPENDIX C**

**FLOOD DAMAGES**

## TABLE OF CONTENTS

	Page No.
<b>C1. INTRODUCTION AND SCOPE.....</b>	<b>C-1</b>
C1.1 Introduction .....	C-1
C1.2 Scope of Investigation .....	C-1
C1.3 Terminology .....	C-1
<b>C2. DESCRIPTION OF APPROACH.....</b>	<b>C-2</b>
<b>C3. SOURCES OF DATA .....</b>	<b>C-4</b>
C3.1 General .....	C-4
C3.2 Property Data .....	C-4
C3.3 Flood Levels Used in the Analysis .....	C-5
<b>C4. RESIDENTIAL DAMAGES .....</b>	<b>C-6</b>
C4.1 Damage Functions .....	C-6
C4.2 Total Residential Damages .....	C-8
<b>C5. COMMERCIAL AND INDUSTRIAL DAMAGES .....</b>	<b>C-10</b>
C5.1 Direct Commercial and Industrial Damages .....	C-10
C5.2 Indirect Commercial and Industrial Damages .....	C-11
C5.3 Total Commercial and Industrial Damages .....	C-11
<b>C6. DAMAGES TO PUBLIC BUILDINGS.....</b>	<b>C-13</b>
C6.1 Direct Damages – Public Buildings .....	C-13
C6.2 Indirect Damages – Public Buildings .....	C-13
C6.3 Total Damages – Public Buildings.....	C-13
<b>C7. DAMAGES TO INFRASTRUCTURE AND COMMUNITY ASSETS .....</b>	<b>C-15</b>
C7.1 Qualitative Assessment .....	C-15
C7.2 Quantitative Assessment .....	C-15
C7.2.1 Town Water Supply .....	C-15
C7.2.2 Airport Infrastructure.....	C-16
<b>C8. SUMMARY OF TANGIBLE DAMAGES .....</b>	<b>C-17</b>
C8.1 Tangible Damages .....	C-17
C8.2 Definition of Terms .....	C-17
B8.3 Average Annual Damages .....	C-17
C8.3 Present Worth of Damages at Narrandera .....	C-18
<b>C9. REFERENCES AND BIBLIOGRAPHY .....</b>	<b>C-21</b>



**FIGURES**  
**(BOUND IN VOLUME 2)**

- C8.1 Damage - Frequency Curves and Cumulative Flooded Properties versus Depth of Inundation Diagram – 1% AEP Murrumbidgee River Flood (Nominal Flood Levels Case)
- C8.2 Damage - Frequency Curves and Cumulative Flooded Properties versus Depth of Inundation Diagram – 1% AEP Murrumbidgee River Flood (Freeboard Allowance Case)
- C8.3 Damage - Frequency Curves and Cumulative Flooded Properties versus Depth of Inundation Diagram – 1% AEP Local Catchment Flood (Nominal Flood Levels Case)
- C8.4 Damage - Frequency Curves and Cumulative Flooded Properties versus Depth of Inundation Diagram – 1% AEP Local Catchment Flood (Freeboard Allowance Case)

## **C1. INTRODUCTION AND SCOPE**

### **C1.1 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.

### **C1.2 Scope of Investigation**

In the following sections, tangible damages to residential, commercial and industrial properties and public buildings have been estimated resulting from flooding at Narrandera. Intangible damages have not been quantified. The threshold floods at which damages may commence to infrastructure and community assets have also been estimated, mainly from site inspection and interpretation of flood level data. However, there are no data available to allow a quantitative assessment of damages to be made to this category.

### **C1.3 Terminology**

Definitions of the terms used in this Appendix are presented in **Section C8** which also summarises the value of Tangible Flood Damages.

## C2. 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 hydraulic modelling, 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 floor elevation at each property.

Council provided a copy of the property database which was compiled as part of SKM, 2009. A review of the information provided by Council identified a number of existing buildings which were not included in the property database. A comparison of the ground and floor level information in the property database with the LiDAR survey data also indicated that the levels had been estimated from available contour maps rather than from detailed ground survey. The missing buildings were therefore added to the property database and the floor level information updated by adding the height of floor above a representative natural surface within the allotment (as estimated by visual inspection) to the natural surface elevation determined from the LiDAR survey data. The type of structure and potential for property damage were also assessed during the visual inspection. A similar approach was adopted for properties that are affected by Major Overland Flow.

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 DECC. Damage curves for other categories of development (commercial and industrial, public buildings) 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 levels as computed by the hydraulic model are not subject to localised influences;
- the estimation of property floor levels by visual inspection rather than by formal field survey;
- the use of "average" stage-damage relationships, rather than a unique relationship for each property;
- the uncertainties associated with assessing appropriate factors 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.

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

### C3. SOURCES OF DATA

#### C3.1 General

To estimate *Average 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 is not possible at Narrandera as specific damage surveys were not conducted following the recent floods in October 2010 and March 2012.
- 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 present study. As mentioned, the *DECC Guideline No 4, 2007* procedure was adopted for the assessment of residential damages. The approach 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 in the study area. The data collected during site inspection in the flood liable areas assisted in providing the necessary adjustments. Commercial and industrial damages were assessed via reference to recent floodplain management investigations of a similar nature to the present study (L&A, 2010).

#### C3.2 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 type of structure
- representative natural surface level of the allotment
- floor level of the residence

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
- natural surface level
- 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 of the PMF in the case of Major Overland Flow and the Extreme Flood in the case of Main Stream Flooding were included in the database. The total number of residential, commercial, industrial and public properties is shown in **Table C3.1**.

**TABLE C3.1  
NUMBER OF PROPERTIES INCLUDED IN DAMAGES DATABASE**

Development Type	Number of Properties	
	Main Stream Flooding	Major Overland Flow
Residential	174	1,192
Commercial / Industrial	17	154
Public	7	24
<b>Total</b>	<b>198</b>	<b>1,270</b>

### **C3.3 Flood Levels Used in the Analysis**

Flood damages relating to Main Stream Flooding were computed for the design flood levels determined from the hydraulic models that were developed as part of L&A, 2014, while the those relating to Major Overland Flow were determined from the Narrandera TUFLOW Model that was developed as part of the present study. The design flood levels assume that the drainage system is operating at optimum capacity. They do not allow for any increase in levels resulting from uncertainties in the accuracy of design flood flows, local effects on the floodplain or wave action. These factors are usually taken into account by adding a factor of safety (freeboard) to the nominal flood level when assessing the “level of protection” against flooding of a particular property.

A particular level of protection could not be ascribed to a development unless it was protected against the design flood level of a particular return period plus the freeboard allowance. For this reason, flood damages were also carried out with the design flood levels increased by a freeboard allowance. Freeboard is related to the velocity of flow, which is itself dependent on the bed slope and hydraulic roughness of the drainage system. Flow velocities tend to increase with peak flow and therefore increasing the freeboard with increase in flood return period could be justified. For the present analysis, a 500 mm freeboard allowance was adopted for assessing damages for floods equal to or larger than 1% AEP in magnitude, reducing to 300 mm for the 5% AEP event and 200 mm for the 10 and 20% AEP events.

## C4. RESIDENTIAL DAMAGES

### C4.1 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 (BoM and NSW SES).

Flooding on the Murrumbidgee River generally has a time of rise of floodwaters of at least a day. There is also a well-tested flood warning system operated by the Bureau of Meteorology and specific flood response procedures are incorporated in the Local Flood Plan developed by NSW SES. Consequently, there would be considerable time in advance of a flood event in which to warn residents and for them to take action to mitigate flood losses. Provided warning is 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 in the case of Narrandera extend for several days.

Flooding along the major overland flow paths is “flash flooding” in nature with a time of rise typically limited to less than a few hours. The duration of peak flooding is similarly quite short. There is no “flash flooding” flood warning system in operation at Narrandera. Furthermore, no specific response procedures have been developed by NSW SES for flooding along the major overland flow paths. Consequently, there would be very limited time in advance of a flood event in which to warn residents and for them to take action to mitigate flood losses.

**Table C4.1** over sets out the parameters and resulting factors that were adopted for converting potential to actual damages after taking into account the differences between the rate of rise and duration of inundation of Main Stream Flooding and Major Overland Flow.

**TABLE C4.1  
DAMAGE ADJUSTMENT FACTORS/PARAMETERS FOR RESIDENTIAL DEVELOPMENT  
SUBJECT TO MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW**

Property Damage	Parameter/Factor	Main Stream Flooding	Major Overland Flow
Building	Typical Duration of Immersion (hours)	48	1
	Building Damage Repair Limitation Factor	1.0	0.85
	Total Building Adjustment Factor	2.77	2.36
Contents	Contents Damage Repair Limitation Factor	0.9	0.75
	Level of Flood Awareness	High	Low
	Effective Warning Time	24 <sup>(1)</sup>	0
	Typical Table/Bench Height (TTBH) (m)	0.9	0.9
	Total Contents Adjustment Factor (Above-Floor Depth ≤ TTBH)	0.70	1.32
	Total Contents Adjustment Factor (Above-Floor Depth > TTBH)	1.58	1.32

1. Maximum value permitted in damages spreadsheet.

**Table C4.2** shows total flood damages estimated for the three classes of residential property using the procedures identified in *Guideline No. 4*, for typical depths of above-floor inundation of 0.3 m and 1.0 m. A typical ground floor area of 240 m<sup>2</sup> was adopted for the assessment. The values in **Table C4.2** allow for damages to buildings and contents, as well as external damages and provision for alternative accommodation.

**TABLE C4.2  
DAMAGES TO RESIDENTIAL PROPERTIES**

Type of Residential Construction	0.3 m Depth of Inundation Above Floor Level		1.0 m Depth of Inundation Above Floor Level	
	Main Stream Flooding	Major Overland Flow	Main Stream Flooding	Major Overland Flow
Single Storey Slab on Ground	\$67,433	\$77,368	\$121,940	\$103,882
Single Storey High Set	\$101,947	\$87,257	\$138,586	\$118,030
Double Storey	\$47,203	\$54,158	\$85,358	\$72,717

Note: These values allow for damages to buildings and contents, as well as external damages and provision for alternative accommodation.



## C4.2 Total Residential Damages

**Tables C4.3** and **C4.4** at the end of this Chapter summarise residential damages at Narrandera for Main Stream Flooding and Major Overland Flow, respectively.

For nominal flood levels, damages of \$5.80 Million are predicted in the residential sector for the 1% AEP Murrumbidgee River flood, increasing to \$25.32 Million at the Extreme Flood level. Allowing for an increase in nominal flood levels of up to 500 mm for freeboard, residential damages increase to \$8.19 Million for the 1% AEP flood and \$29.22 Million for the Extreme Flood. **Figures C8.1** and **C8.2** respectively show corresponding Murrumbidgee River damages for the nominal flood level and freeboard allowance cases.

For nominal flood levels, damages of \$7.41 Million are predicted in the residential sector for the 1% AEP local catchment flood, increasing to \$51.87 Million at the PMF level. Allowing for an increase in nominal flood levels of up to 500 mm for freeboard, residential damages increase to \$15.27 Million for the 1% AEP flood and \$68.26 Million for the PMF. **Figures C8.3** and **C8.4** respectively show corresponding Murrumbidgee River damages for the nominal flood level and freeboard allowance cases.

The location of residential properties that would experience above-floor inundation for the 1% AEP and Extreme Flood events are shown on **Figures 2.4** and **2.5** of the Main Report, respectively. Also shown on these figures is the indicative depth of inundation that would be experienced in the affected properties for the 1% AEP and Extreme Flood events.

**TABLE C4.3**  
**RESIDENTIAL FLOOD DAMAGES**  
**MAIN STREAM FLOODING**

Design Flood Event (%AEP)	Nominal Flood Levels			Nominal Flood Levels Plus Freeboard <sup>(1)</sup>		
	No of Allotments Flood Affected	No of Buildings Flooded Above Floor Level	Damages \$ Million	No of Allotments Flood Affected	No of Buildings Flooded Above Floor Level	Damages \$ Million
20	0	0	0	0	0	0.00
10	16	8	0.76	17	11	1.01
5	34	23	1.98	37	33	3.01
1	55	49	5.80	61	59	8.19
0.5	65	62	7.91	69	66	9.80
0.2	89	82	11.23	95	91	13.74
Extreme	178	166	25.32	187	181	29.22

**TABLE C4.4  
RESIDENTIAL FLOOD DAMAGES  
MAJOR OVERLAND FLOW**

Design Flood Event (%AEP)	Nominal Flood Levels			Nominal Flood Levels Plus Freeboard <sup>(1)</sup>		
	No of Allotments Flood Affected	No of Buildings Flooded Above Floor Level	Damages \$ Million	No of Allotments Flood Affected	No of Buildings Flooded Above Floor Level	Damages \$ Million
20	21	6	0.67	26	20	1.69
10	45	15	1.55	53	42	3.60
5	60	21	2.22	66	60	5.55
1	144	82	7.41	154	152	15.27
0.5	168	107	9.72	178	178	18.31
0.2	192	137	12.65	205	204	21.60
Extreme	531	431	51.87	542	537	68.26

## C5. COMMERCIAL AND INDUSTRIAL DAMAGES

### C5.1 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; and
- 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 tend to seriously underestimate true damage costs (*DECC Guideline No 4, 2007*). OEH 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 Narrandera study.

On the basis of previous investigations 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 <sup>2</sup>	(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 <sup>2</sup>	(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 <sup>2</sup>	(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 Narrandera study, the above potential damages were converted to actual damages using a multiplier which ranged between 0.5 and 0.8 depending on the depth of inundation above the floor. While the majority of the commercial – industrial properties that are subject to Main Stream Flooding are inundated to depths exceeding 1 m (refer **Figure C8.1**), it would be expected that business owners would be able to take significant action to mitigate damages by removing stock and equipment from the premises given the long warning time which is available of an impending flood event. Consequently, the multiplier of 0.5 was adopted to convert potential to actual damages for depths of inundation up to 1.2 m, increasing to 0.8 for greater depths.

## **C5.2 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<sup>2</sup> of floor area of each flooded property was also included.

## **C5.3 Total Commercial and Industrial Damages**

**Tables C5.1** and **C5.2** at the end of this Chapter summarise commercial/industrial damages at Narrandera for Main Stream Flooding and Major Overland Flow, respectively.

In the case of Main Stream Flooding, damages of \$0.99 Million are predicted in the commercial and industrial sector based on nominal flood levels for the 1% AEP flood, increasing to \$3.83 Million at the Extreme Flood level. Allowing for an increase in nominal flood levels of up to 500 mm for freeboard, commercial and industrial damages increase to \$1.40 Million for the 1% AEP flood and \$4.48 Million for the Extreme Flood. **Figures C8.1** and **C8.2** respectively show corresponding Murrumbidgee River damages for the nominal flood level and freeboard allowance cases.

In the case of Major Overland Flow, damages of \$1.29 Million are predicted in the commercial and industrial sector based on nominal flood levels for the 1% AEP flood, increasing to \$17.76 Million at the PMF level. Allowing for an increase in nominal flood levels of up to 500 mm

for freeboard, commercial and industrial damages increase to \$2.74 Million for the 1% AEP flood and \$24.07 Million for the PMF. **Figures C8.3** and **C8.4** respectively show corresponding Murrumbidgee River damages for the nominal flood level and freeboard allowance cases.

The location of commercial and industrial properties that would experience above-floor inundation for the 1% AEP and Extreme Flood events are shown on **Figures 2.4** and **2.5** of the Main Report, respectively. Also shown on these figures is the indicative depth of inundation that would be experienced in the affected properties for the 1% AEP and Extreme Flood events.

**TABLE C5.1  
COMMERCIAL AND INDUSTRIAL FLOOD DAMAGES  
MAIN STREAM FLOODING**

Design Flood Event (%AEP)	Nominal Flood Levels			Nominal Flood Levels Plus Freeboard <sup>(1)</sup>		
	No of Allotments Flood Affected	No of Buildings Flooded Above Floor Level	Damages \$ Million	No of Allotments Flood Affected	No of Buildings Flooded Above Floor Level	Damages \$ Million
20	0	0	0	0	0	0
10	15	11	0.31	15	14	0.39
5	15	15	0.47	15	15	0.60
1	16	16	0.99	16	16	1.40
0.5	17	17	1.36	17	17	1.64
0.2	20	20	1.89	20	20	2.37
Extreme	23	23	3.83	23	23	4.48

**TABLE C5.2  
COMMERCIAL AND INDUSTRIAL FLOOD DAMAGES  
MAJOR OVERLAND FLOW**

Design Flood Event (%AEP)	Nominal Flood Levels			Nominal Flood Levels Plus Freeboard <sup>(1)</sup>		
	No of Allotments Flood Affected	No of Buildings Flooded Above Floor Level	Damages \$ Million	No of Allotments Flood Affected	No of Buildings Flooded Above Floor Level	Damages \$ Million
20	1	0	0.02	1	1	0.07
10	1	0	0.02	2	2	0.11
5	2	0	0.03	3	3	0.27
1	30	27	1.29	30	30	2.74
0.5	33	29	1.65	33	33	3.38
0.2	40	30	2.20	41	41	4.35
Extreme	112	104	17.76	114	114	24.07

## C6. DAMAGES TO PUBLIC BUILDINGS

### C6.1 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 <sup>2</sup>	
Medium value	\$420/m <sup>2</sup>	(eg. council buildings, SES HQ, fire station)
High value	\$650/m <sup>2</sup>	(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.

### C6.2 Indirect Damages – Public Buildings

A value of \$15/m<sup>2</sup> 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.

### C6.3 Total Damages – Public Buildings

**Tables C6.1** and **C6.2** at the end of this Chapter summarise damages to public buildings at Narrandera for Main Stream Flooding and Major Overland Flow, respectively.

Eight public buildings are located on the Murrumbidgee River floodplain south of the Southern main Canal Embankment, none of which would be flooded as a result of Main Stream Flooding at the 1% AEP level. During an Extreme Flood all eight properties would experience above-floor inundation, with the damages increasing from \$1.54 Million for the nominal flood levels case to \$1.96 Million for the freeboard allowance case.

Of the sixteen public buildings that would be affected by Major Overland Flow for the nominal flood level case, two would experience above-floor inundation in a 1% AEP storm, increasing to 13 during a PMF event. Damages due to Major Overland Flow based on the nominal flood levels would increase from \$0.06 Million at the 1% AEP level to \$2.32 Million at the PMF level. While the addition of freeboard to the nominal flood levels would not increase the number of public buildings that would experience above-floor inundation during a 1% AEP flood, all sixteen flood affected properties would be above-floor inundated during a PMF.

The location of the two public buildings that would experience above-floor inundation due to Major Overland Flow for the 1% AEP and Extreme Flood events are shown on **Figures 2.4** and **2.5** of the Main Report, respectively. Also shown on these figures is the indicative depth of inundation that would be experienced in the two buildings for the 1% AEP and Extreme Flood events.

**TABLE C6.1  
PUBLIC FLOOD DAMAGES  
MAIN STREAM FLOODING**

Design Flood Event (%AEP)	Nominal Flood Levels			Nominal Flood Levels Plus Freeboard <sup>(1)</sup>		
	No of Allotments Flood Affected	No of Buildings Flooded Above Floor Level	Damages \$ Million	No of Allotments Flood Affected	No of Buildings Flooded Above Floor Level	Damages \$ Million
20	0	0	0	0	0	0
10	0	0	0	0	0	0
5	0	0	0	0	0	0
1	0	0	0	0	0	0
0.5	7	3	0.13	7	7	0.35
0.2	8	8	0.52	8	8	0.86
Extreme	8	8	1.54	8	8	1.96

**TABLE C6.2  
PUBLIC FLOOD DAMAGES  
MAJOR OVERLAND FLOW**

Design Flood Event (%AEP)	Nominal Flood Levels			Nominal Flood Levels Plus Freeboard <sup>(1)</sup>		
	No of Allotments Flood Affected	No of Buildings Flooded Above Floor Level	Damages \$ Million	No of Allotments Flood Affected	No of Buildings Flooded Above Floor Level	Damages \$ Million
20	0	0	0	0	0	0
10	0	0	0	0	0	0
5	0	0	0	0	0	0
1	2	2	0.06	2	2	0.15
0.5	6	4	0.18	6	6	0.40
0.2	6	6	0.27	6	6	0.50
Extreme	16	13	2.32	16	16	3.27

## C7. DAMAGES TO INFRASTRUCTURE AND COMMUNITY ASSETS

### C7.1 Qualitative Assessment

While infrastructure such as electrical and telephone supply and sewerage supply systems would not be prone to damaging flooding up to the 1% AEP level, assets such as local roads, parks and other recreational amenities would suffer damages. Some damage would also be incurred to the Main Canal Embankments, airport infrastructure and the water supply pumping station at the 1% AEP level. A qualitative matrix of the effects of flooding on these categories is presented in **Table C7.1**, while the findings of a quantitative analysis based on data provided by Council are presented in **Section C7.2**.

**TABLE C7.1**  
**QUALITATIVE EFFECTS OF FLOODING ON**  
**INFRASTRUCTURE AND COMMUNITY ASSETS**  
**AT NARRANDERA<sup>(1)</sup>**

Damage Sector	Historic Flood Events		Design Flood Event (% AEP)			
	October 2010	March 2012	20	5	1	Extreme
Electricity	N	N	0	0	0	X
Telephone	N	S	0	X	X	X
Roads	S	S	X	X	X	X
Bridges	N	N	0	0	0	X
Sewerage	N	N	0	0	0	X
Water Supply	N	N	0	0	0	X
Parks and Gardens	N	S	0	0	X	X
Levees	N	N	0	0	X	X
Airport Infrastructure	N	N	0	0	X	X

1. Assuming no major levee failure.

**Legend:** N = No significant damages incurred.

S = Some damages incurred.

0 = No significant damages likely to be incurred.

X = Some damages likely to be incurred.

### C7.2 Quantitative Assessment

#### C7.2.1 Town Water Supply

During the March 2012 flood, floodwaters reached to within a few centimetres of the floor slab of the pumping station which is located on the northern bank of the Murrumbidgee River a short distance east (upstream) of the New England Highway. As the peak 1% AEP flood level adjacent to the pumping station is about 250 mm higher than the maximum water level reached during the March 2012 flood, it can be expected that the dry well which contains the two relatively large pumps will be submerged during an event of this return period.



Council advised that the replacement cost of the two pumps were they to be damaged by floodwater would be about \$100,000. While the present worth value of the damage incurred to the pumps is relatively small (i.e. because flood damages only commence at about the 1% AEP level), the intangible costs associated with the disruption caused to the town's water supply would be relatively large.

### C7.2.2 Airport Infrastructure

As well as causing damage to the existing ring levee and buildings (7 off), an overtopping event would also likely cause damage to infrastructure such the runaway and taxiway, carpark areas and internal access road. **Table C7.2** gives a breakdown of the estimated costs associated with repairing existing infrastructure at the airport, details of which were provided by Council.<sup>1</sup>

**TABLE C7.2  
ESTIMATED REPAIR COSTS TO AIRPORT INFRASTRUCTURE**

Description	Unit	Rate	Quantity	Amount
Repairs to runway and taxiways (sealed areas) <sup>(1)</sup>	m <sup>2</sup>	\$35.67	65,200	\$2,325,684
Repairs to runway and taxiways (gravel areas) <sup>(1)</sup>	m <sup>2</sup>	\$16.67	89,400	\$1,490,298
Repairs to carpark area, Knight Drive and access roads to hangers (gravel areas) <sup>(2)</sup>	m <sup>2</sup>	\$16.67	6,800	\$113,356
Line marking (carpark area only)	Item	\$2,000.00	1	\$2,000
Replace runway lighting	Item	\$400,000	1	\$400,000
<b>TOTAL</b>				<b>\$4,331,338</b>

1. This allows for rehabilitation (i.e. profiler to mix down to about 250 mm), supply and lay new material, apply two off single-chip seal to sealed areas, rehabilitate gravel runway, taxiway and shoulders on sealed runway & taxiway.
2. This allows for re-profiling to 100 mm depth, supply and place new gravel, seal with one off single-chip seal.

Assuming the ring levee was to partially fail during floods greater than about 5% AEP (i.e. greater than the assessed IFF for the levee), then the present worth value of damages to airport infrastructure is estimated to be about \$3 Million.<sup>2,3</sup>

Current figures indicate that REX has a turnover of about 12,000 passengers alighting at Narrandera Airport annually. Depending on the period over which the airport would be closed following an overtopping event, a proportion of these passengers would need to fly out of Griffith or Wagga Wagga Airports. Narrandera Airport is also used by emergency services organisations during major flood events in the valley. While its closure due to flooding would impose an added constraint on such services, Griffith Airport is located only 85 km to the north east, and Wagga Wagga Airport about 100 km to the east of Narrandera.

<sup>1</sup> Does not include the costs associated with damage to the commercial buildings (7 off), amounts for which have been incorporated in the commercial and industrial flood damages assessment.

<sup>2</sup> Includes present worth value of damages incurred to the commercial buildings (7 off), which is about \$10,000.

<sup>3</sup> This value assumes damages commence at the 5% AEP level of flooding, which is the IFF for the Narrandera Airport Levee.

## **C8 SUMMARY OF TANGIBLE DAMAGES**

### **C8.1 Tangible Damages**

Flood damages under existing conditions have been computed for a range of flood frequencies from 20% AEP to the PMF in the case of Major Overland Flow and the Extreme Flood in the case of Main Stream Flooding.

The flood damages resulting from Main Stream Flooding for each flood event are given in **Table CS1**, while **Figures C8.1** and **C8.2** respectively show the corresponding damage - frequency curves for the three property categories: residential, commercial/industrial and public for the nominal flood levels and freeboard allowance cases. By inspection of **Figure C8.1** and **Table CS1**, the 10% AEP is the “threshold” flood magnitude at which significant damages are experienced at Narrandera.

The flood damages resulting from Major Overland Flow for each flood event are given in **Table CS2**, while **Figures C8.3** and **C8.4** respectively show the corresponding damage - frequency curves for the three property categories: residential, commercial/industrial and public for the nominal flood levels and freeboard allowance cases. By inspection of **Figure C8.3** and **Table CS1**, the 20% AEP is the “threshold” flood magnitude at which significant damages are experienced at Narrandera.

### **C8.2 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. Tables B8.1 and B8.2

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.

A flood management scheme which has a design 1% AEP 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 and converted to the Present Worth value via the discount rate.

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 Average Annual Damages**

The *Average Annual Damages* at Narrandera for Murrumbidgee River and local catchment flood events are shown in **Tables B8.1** and **B8.2** at the end of this chapter, respectively. Note that values have been quoted to two decimal places to highlight the relatively small recurring damages in the town.

### **C8.3 Present Worth of Damages at Narrandera**

The *Present Worth Value* of damages likely to be experienced in the study area for all flood events, a 50 year economic life and discount rates of 4, 7 and 10 per cent are shown on **Tables C8.3** and **C8.4** at the end of this chapter.

From **Table C8.3**, for a discount rate of 7% pa, the *Present Worth Value* of damages for all Murrumbidgee River floods up to the 1% AEP flood is about \$4.4 Million for the nominal flood levels case, increasing to \$6.3 Million for the freeboard allowance case.

From **Table C8.4**, for the 7% discount rate, the *Present Worth Value* of damages for all local catchment floods up to the 1% AEP flood is about \$7.3 Million for the nominal flood levels case, increasing to \$17.3 Million for the freeboard allowance case.

Based on the above findings, one or more schemes costing up to \$6.3 Million in the case of Main Stream Flooding and \$17.3 Million in the case of Major Overland Flow could be economically justified if they eliminated damages for all flood events up to the 1% AEP level.<sup>4</sup> 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.

---

<sup>4</sup> Note that OEHL will permit the use of the freeboard allowance case when assessing the economic feasibility of flood modification measures in NSW.

**TABLE C8.1  
AVERAGE ANNUAL DAMAGES - \$ MILLION  
MAIN STREAM FLOODING**

Design Flood Event (%AEP)	Nominal Flood Levels				Nominal Flood Levels Plus Freeboard			
	Residential	Commercial	Public	Total	Residential	Commercial	Public	Total
20	0	0	0	0	0	0	0	0
10	0.04	0.02	0	0.06	0.05	0.02	0	0.07
5	0.11	0.03	0	0.14	0.15	0.04	0	0.19
1	0.26	0.06	0	0.32	0.38	0.08	0	0.46
0.5	0.30	0.07	0	0.37	0.42	0.09	0	0.51
0.2	0.33	0.07	0	0.40	0.46	0.10	0	0.56
Extreme	0.36	0.08	0	0.44	0.50	0.10	0.01	0.61

**TABLE C8.2  
AVERAGE ANNUAL DAMAGES - \$ MILLION  
MAJOR OVERLAND FLOW**

Design Flood Event (%AEP)	Nominal Flood Levels				Nominal Flood Levels Plus Freeboard			
	Residential	Commercial	Public	Total	Residential	Commercial	Public	Total
20	0.10	0	0	0.10	0.25	0.01	0	0.26
10	0.21	0	0	0.21	0.52	0.02	0	0.54
5	0.31	0	0	0.31	0.75	0.03	0	0.78
1	0.50	0.03	0	0.53	1.16	0.09	0	1.25
0.5	0.54	0.04	0	0.58	1.25	0.10	0	1.35
0.2	0.57	0.04	0	0.61	1.31	0.12	0.01	1.44
PMF	0.64	0.06	0	0.70	1.39	0.14	0.01	1.54

**TABLE C8.3**  
**PRESENT WORTH VALUE OF DAMAGES AT NARRANDERA**  
**MAIN STREAM FLOODING**

Case	Discount Rate	Nominal Flood Levels	Nominal Flood Levels Plus Freeboard
	%	\$ Million	\$ Million
All floods up to 1% AEP	4	6.9	9.9
	7	4.4	6.3
	10	2.9	4.1
All floods up to Extreme Flood	4	9.5	13.1
	7	6.1	8.4
	10	4.0	5.5

**TABLE B8.4**  
**PRESENT WORTH VALUE OF DAMAGES AT NARRANDERA**  
**MAJOR OVERLAND FLOW**

Case	Discount Rate	Nominal Flood Levels	Nominal Flood Levels Plus Freeboard
	%	\$ Million	\$ Million
All floods up to 1% AEP	4	11.4	26.9
	7	7.3	17.3
	10	4.8	11.3
All floods up to PMF	4	15.1	33.1
	7	9.7	21.3
	10	6.3	13.9

## C9. REFERENCES AND BIBLIOGRAPHY

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

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

L&A (Lyll and Associates Consulting Water Engineers), 2010 ***"Conargo Floodplain Risk Management Study and Plan"***. Report prepared for Conargo Shire Council and DECCW.

L&A (Lyll and Associates Consulting Water Engineers), 2015. ***"Narrandera Flood Study Review and Levee Options Assessment"***. Report prepared for Narrandera Shire Council and OEH.

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

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

SKM (Sinclair Knight Merz), 2009. ***"Narrandera Floodplain Risk Management Study Report"***, Final Report

WS (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.

WS (Water Studies), 1992. ***"Forbes Flood Damage Survey, August 1990 Flood"***.

**APPENDIX D**

**POTENTIAL FLOOD MODIFICATION MEASURES  
(BOUND IN VOLUME 2)**

**APPENDIX E**

**DRAFT FLOOD POLICY**



## TABLE OF CONTENTS

	Page No.
<b>E1. INTRODUCTION .....</b>	<b>E-1</b>
E1.1 What does the Policy do? .....	E-1
E1.2 Objectives .....	E-2
E1.3 Will the Policy affect my Property?.....	E-2
E1.4 How to use this Policy .....	E-2
E1.5 Other Documents Which May Need to be Read in Conjunction with this Policy .	E-3
<b>E2. WHAT ARE THE CRITERIA FOR DETERMINING APPLICATIONS? .....</b>	<b>E-4</b>
E2.1 General .....	E-4
E2.2 Division of the Floodplain into Hazard Zones .....	E-4
E2.3 Main Stream Flooding.....	E-4
E2.4 Major Overland Flow.....	E-5
E2.6 Local Drainage .....	E-6
E2.7 Land Use Categories and Minimum Floor Level Requirements .....	E-6
E2.8 Assessing Commercial and Industrial Development Proposals.....	E-6
E2.9 Critical Utilities and Essential Services .....	E-7
E2.10 Flood Vulnerable Residential Development.....	E-7
E2.11 Minor Additions (Residential) .....	E-7
E2.12 Checking of Completed Finished Floor Height .....	E-8
E2.13 Fencing .....	E-8
E2.14 Other Uses and Works .....	E-8
E2.15 Land Filling and Obstructions to Flow .....	E-8
E2.16 Flood Related Information to be Submitted to Council.....	E-9
E2.16.1 Survey Details – Existing Site and Proposed Development .....	E-9
E2.16.2 Evaluation of Development Proposals.....	E-9
E2.16.3 Flood Risk Report – Inner Floodplain (Hazard Category 2), High Hazard Floodway and Low Hazard Floodway / Flood Storage Zones .....	E-9
<b>E3. GLOSSARY OF TERMS.....</b>	<b>E-11</b>
<b>E4. REFERENCES .....</b>	<b>E-14</b>

## ANNEXURES

**ANNEXURE 1** – Land Use Categories

**ANNEXURES 2.1** and **2.2** – Development Controls Matrices

**ANNEXURE 3A** – General Building Matters

**ANNEXURE 3B** – Flood Compatible Materials

**ANNEXURE 4** – Development Application Requirements

**FIGURES  
(BOUND IN VOLUME 2)**

- E1.1 Extract of Flood Planning Map at Narrandera
- E1.2 Narrandera Development Controls Matrix Map
- E1.3 Narrandera Flood Hazard Map

## ABBREVIATIONS

AHD	Australian Height Datum
AEP	Annual Exceedance Probability (%)
Council	Narrandera Shire Council
EP&A	Environmental Planning and Assessment
FPL	Flood Planning Level (1% AEP flood level + freeboard)
FPA	Flood Planning Area (area inundated at the FPL)
FRMS&DP	Floodplain Risk Management Study and Draft Plan
LEP	Local Environmental Plan
MFL	Minimum Floor Level (1% AEP flood level + freeboard)
MOF MFL	Major Overland Flow Minimum Floor Level (1% AEP flood level plus 300 mm freeboard)
MSF MFL	Main Stream Flooding Minimum Floor Level (1% AEP flood level plus 500 mm freeboard)
NSW SES	New South Wales State Emergency Service
PMF	Probable Maximum Flood

## E1. INTRODUCTION

This Flood Policy has been prepared to provide specific controls to guide development of land in flood prone areas in Narrandera.

The Flood Policy incorporates the findings of the *Review of the Narrandera Floodplain Risk Management Study and Plan, 2019* and the procedures set out in the NSW Floodplain Development Manual (NSWG, 2005).

The *Review of the Narrandera Floodplain Risk Management Study and Plan, 2019* identified the occurrence of two types of flooding in Narrandera:

- **Main Stream Flooding** resulting from flows that surcharge the Murrumbidgee River. These flows may be several metres deep in the channels and relatively slow moving with velocities up to 1 m/s.
- **Major Overland Flow** is present along several flow paths that run through the urbanised parts of Narrandera. It is also present in the undeveloped areas which border the town principally to its north. Flows on the Major Overland Flow paths would typically be less than 300 mm deep, travelling over the surface at velocities less than 0.5 m/s.

The Flood Policy takes into account the “*Guideline on Development Controls on Low Flood Risk Areas*” and Ministerial Direction No 4.3 issued by the then Department of Planning on 1 July 2009. As a consequence, residential areas within the extent of the **Flood Planning Area (FPA)** shown on the **Flood Planning Map** are subject to flood related development controls in this Flood Policy. **Figure E1.1** is an extract from the Flood Planning Map showing the extent of the FPA at Narrandera. Within the FPA, the controls over residential development reflect the nature of the flood risk. The division of the floodplain into hazard areas is shown on the **Flood Hazard Map** for Narrandera (refer **Figures E1.3**).

The Policy recognises the need for controls over commercial and industrial development within the FPA to balance the flood risk against the requirement for continuing the long term viability of this sector in the town. The Policy also recognises that the safety of people and associated emergency response planning need to be considered and imposes restrictions on vulnerable development (for example education and aged care facilities) and critical emergency response and recovery facilities and infrastructure (evacuation centres, hospitals and utilities).

### E1.1 What does the Policy do?

The Flood Policy provides information to assist people who want to develop or use land affected by potential flooding in Narrandera. 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;
- subdividing land.

## E1.2 Objectives

The objectives of this Flood 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 the Narrandera Local Environmental Plan 2013 (Narrandera LEP 2013) and the findings of the *Review of the Narrandera Floodplain Risk Management Study and Draft Plan, 2019*.
- (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 Narrandera.
- (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 strategies adopted by the NSW State Emergency Service (**NSW SES**) and does not impose additional burdens on, or risk to its personnel during flood emergencies.

Definitions of flood related terms used herein are provided in the **Glossary** in **Section E3** of this document.

## E1.3 Will the Policy affect my Property?

The Policy applies to all development permitted with the consent of Council on land:

- i) to which the Narrandera LEP 2013 applies,
- ii) that lies within the extent of the FPA, as shown in **Figure E1.1**;
- iii) land that lies at or below the **Flood Planning Level (FPL)**; and
- iv) that lies on the floodplain but outside the extent of the FPA (refer area identified as "Outer Floodplain" in **Figure E1.1**).

## E1.4 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 Narrandera. 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 E1.1**.
- ii) Determine which Development Controls Matrix applies to the development from **Figure E1.2** (i.e. either Main Stream Flooding or Major Overland Flow)
- iii) Determine the flood hazard zone(s) that applies to the development from **Figures E1.3**.
- iv) Identify the category of the development from **Annexure 1: Land Use Category**.

- v) Determine the flood level at the site using information contained in the *Review of the Narrandera Floodplain Risk Management Study and Plan, 2019*, as well as the appropriate freeboard for defining the Minimum Floor Level (MFL) and flood related development controls for the category of development from **Figures E1.3** and **Annexure 2: Development Controls Matrices**.
- vi) Confirm that the development conforms with the controls 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 Narrandera and the controls over development imposed by this Policy are available by discussion with and upon written application to Council.

#### **E1.5 Other Documents Which May Need to be Read in Conjunction with this Policy**

- New South Wales Government (NSWG) Floodplain Development Manual (NSWG, 2005); and associated Guideline on Development Controls on Low Flood Risk Areas; and Ministerial Direction No. 4.3, 1 July 2009;
- Narrandera LEP 2013;
- *Narrandera Flood Study Review and Levee Options Assessment* (Lyll & Associates, 2015);
- *Review of the Narrandera Floodplain Risk Management Study and Plan* (Lyll & Associates, 2019); and
- Relevant Council policies, development control plans and specifications.

## E2. WHAT ARE THE CRITERIA FOR DETERMINING APPLICATIONS?

### E2.1 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, levels of potential flood inundation and flood hazard.

The controls applicable to proposed development depend upon:

- The type of development.
- The part(s) of the floodplain where the development is located.
- Peak flood levels at the site of the development.

### E2.2 Division of the Floodplain into Hazard Zones

**Figure E1.3** shows the division of the floodplain at Narrandera into a number of flood hazard zones in areas subject to Main Stream Flooding and Major Overland Flow.

### E2.3 Main Stream Flooding

In the areas subject to Main Stream Flooding:

The **Inner Floodplain (Hazard Category 1)** zone (shown as a solid red colour) comprises areas where factors such as the depth and velocity of flow, time of rise, isolation on Low Flood Islands and evacuation problems mean that the land is unsuitable for most types of development. It principally comprises High and Low Hazard Floodway areas. Erection of buildings and carrying out of work; use of land, subdivision of land and demolition subject to State Environmental Planning Policies and Local Environmental Plan provisions are not permitted in this zone.

The **Inner Floodplain (Hazard Category 2)** zone (shown as a solid yellow colour) comprises High and Low Flood Storage areas, as well as areas where isolation on Low Flood Islands and evacuation problems mean development other than Essential Community Facilities, Critical Utilities, Schools and Flood Vulnerable development is permitted provided it is capable of withstanding hydraulic forces and sited on the allotment to minimise adverse redirections of flow toward adjacent properties. Council may require a *Flood Risk Report* if it considers that the proposal has the potential to significantly affect flooding behaviour in adjacent properties.

The **Intermediate Floodplain** zone (shown as a solid blue colour) is the remaining land lying outside the extent of the Inner Floodplain zones, but within the FPA (defined as land which lies below the 1% annual exceedance probability (AEP) flood level plus 500 mm freeboard). Within this zone, there would only be the requirement for MFL's to be set at the 1% AEP flood levels plus 500 mm. Land use permissibility would be as specified by State Environmental Planning Policies or the Local Environmental Plan.

The **Outer Floodplain** zone is the area outside the Intermediate Floodplain where the depth of inundation will exceed 100 mm in the Extreme Flood (shown as a solid cyan colour). This area is outside the extent of the FPA and hence controls on residential, commercial and industrial development do not apply. However, Essential Community Facilities, Critical Utilities and Flood Vulnerable development is not permitted in this zone.

#### **E2.4 Major Overland Flow**

Major Overland Flow is present along several flow paths that run through the developed parts of Narrandera. It is also present in the undeveloped areas which border the town. Flows on the Major Overland Flow paths would typically be up to a maximum of 300 mm deep in a 1% AEP storm event, travelling over the surface at velocities less than 0.5 m/s.<sup>1</sup> These characteristics result in the flow typically being of a low hazard nature.

In the areas subject to Major Overland Flow:

The **High Hazard Floodway** zone (shown as solid orange) identifies areas where significant overland flow of a high hazard nature occur in Narrandera. These are presently limited to a few reaches of incised drainage channel that are located on the western limits of the town.

The **Low Hazard Floodway / Flood Storage** zone (shown as a solid green colour) identifies the areas where significant overland flow or excessive depths of ponding of a low hazard nature occur in Narrandera.<sup>2</sup> Council may permit residential, commercial and industrial development in this zone, provided it is capable of withstanding hydraulic forces and is sited within the allotment to minimise adverse re-direction of flow towards adjacent properties. There would also be the requirement for MFL's to be set at the 1% AEP flood levels plus 300 mm in this zone, as well as restrictions on site filling to prevent blockage of flows (ref. **Section E2.15**). Similar controls exist for commercial and industrial development. Council may require a *Flood Risk Report* for development proposals in this zone (typically for larger scale commercial or industrial developments).

The **Intermediate Floodplain** zone is defined by the area outside the High Hazard Floodway and Low Hazard Floodway / Flood Storage zones where depths of flow would exceed 100 mm in a 1% AEP storm event (shown as a solid blue colour). Within this zone, there would only be the requirement for MFL's to be set at the 1% AEP flood levels plus 300 mm. Land use permissibility would be as specified by State Environmental Planning Policies or the Local Environmental Plan.

The **Outer Floodplain** is the area outside the Intermediate Floodplain zone where depths of flow would exceed 100 mm in a PMF event (shown as a solid cyan colour). This area is outside the extent of the FPA and hence controls on residential, commercial and industrial development would not apply. While Essential Community Facilities, Critical Utilities and Flood Vulnerable Residential development would be permitted in this zone, the flood related development controls identified in **Annexure 2.2** would apply to these types of development.

---

<sup>1</sup> Note that pockets of deeper Major Overland Flow are present in parts of Narrandera. These areas are typically associated with stormwater ponding behind road and railway embankments, as well as in localised depressions within private property.

<sup>2</sup> Note that in order to maintain connectivity between the areas of deeper flow, the Floodway zone has been extended in some areas to include areas where the depth of flow is less than 150 mm.



## E2.6 Local Drainage

At the lower end of the scale, drainage problems are typically caused by direct surface runoff, surcharges and overflows from low points in kerbs, or overflows from the smaller pipes in the stormwater drainage system. They typically involve depths of inundation up to 300 mm. In the Floodplain Development Manual (NSWG, 2005), these situations are categorised as **Local Drainage**.

NSWG, 2005 recognises that Local Drainage problems are not always amenable to rigorous analysis and therefore Council is **not** obliged to convey information on Planning Certificates under Section 149 of the EP&A Act. Local Drainage problems involve shallow depths of inundation with generally little danger to personal safety. Problems due to property inundation generally arise because of deficiencies in stormwater management controls or building practice where floor levels are near finished ground levels.

In Narrandera, the threshold between Major Overland Flow and Local Drainage has been reduced to 100 mm in recognition that depths of flow greater than this value could result in above-floor inundation if appropriate controls are not imposed on new development.

## E2.7 Land Use Categories and Minimum Floor Level Requirements

Eight land use categories have been adopted. The specific land use in each category is listed in **Annexure 1**. The MFL's for the various land use types are:

- For new residential development, the MFL is the peak 1% AEP flood level at the particular development site, plus an allowance for freeboard. Within the Main Stream Flooding FPA, the freeboard is 500 mm. For residential allotments in the FPA of the Major Overland Flow paths, the freeboard is 300 mm.
- For commercial and industrial development the MFL is the peak 1% AEP flood level plus freeboard. Within the Main Stream Flooding FPA, the freeboard is 500 mm. For allotments in the FPA of the Major Overland Flow paths, the freeboard is 300 mm. Council may at its discretion allow variation to this MFL, subject to local conditions (refer **Section E2.8**).
- For Essential Community Facilities, Critical Utilities and Flood Vulnerable Residential Development (nursing homes, aged care facilities and the like), the MFL is the peak 1% AEP flood level plus freeboard. While development of this type is not permitted on the Murrumbidgee River floodplain (defined as the extent of the Outer Floodplain for Main Stream Flooding), for allotments where development of this type is permitted (i.e. in areas that lie outside the High Hazard Floodway and Low Hazard Floodway / Flood Storage areas associated with Major Overland Flow), the freeboard is 300 mm. 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 a PMF (refer **Sections E2.9** and **E2.10**).

## E2.8 Assessing Commercial and Industrial Development Proposals

The *Flood Policy* nominates the same MFL 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 storage of goods at a minimum level equal to the MFL. This area should be at least 20% of the gross floor area, or as determined by Council.

## E2.9 Critical Utilities and Essential Services

In areas affected by Major Overland Flow, the *Flood Policy* nominates the same MFL as for residential development. It also recognises that 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 MFL. Development proposals are to ensure that valuable equipment necessary for the operation of the facility is located at or above the PMF, or otherwise protected from extreme flooding. Council will also require development proposals to provide safe and reliable access to facilities during major flooding.

## E2.10 Flood Vulnerable Residential Development

The *Flood Policy* nominates the same MFL for Flood Vulnerable Residential Development (which includes nursing homes, aged care facilities and the like) as for residential development. The applicant is also to ensure that valuable equipment necessary for the operation of the facility is located above the MFL (*at a level determined by Council*). Council will also require development proposals to provide safe and reliable access during major flooding.

## E2.11 Minor Additions (Residential)

Council has nominated the floor levels of minor additions to residences to be no lower than the MFL. However, where it can be demonstrated by the applicant that this is not practicable, Council at its discretion may allow a reduction in minimum floor levels, provided that the level is at least 300 mm above natural ground level, or as otherwise determined by Council so as to be above the level of frequent flooding.

The Policy **does not favour** the replacement of dwellings in the **Inner Floodplain (Hazard Category 1)** zone because of the potential increase in risk to life and limb resulting from developments in floodway areas where velocities are significant and because of potential increases in the economic impacts of flooding.

Council, at its discretion and depending on the merits of the situation, may allow the raising or replacement of an existing dwelling, subject to the provision by the Applicant of supporting documentation prepared by a suitably qualified engineer which demonstrates to Council's satisfaction that:

- a) The structure will be stable against the forces of buoyancy and velocity of flow and suitably flood proofed by the use of flood resistant materials to the peak 1% AEP flood level plus an allowance of 500 mm.
- b) The development will have no significant adverse impact on local flooding patterns and adjacent development.
- c) Minimum floor level requirements are satisfied (1% AEP plus 500 mm freeboard).

To ensure that these objectives are met, the building should be constructed on piers with the underside of the floor above the 1% AEP flood level. No site filling is permissible and obstruction to flow by piers and other supporting structures are to be minimised.

A Flood Risk Report is required in support of the Application, with the scope of reporting set out in **Section E2.16.3**.

Prior to approving any proposed replacement, Council will consult with NSW SES to confirm that the development does not adversely impact on emergency management procedures set out the Narrandera Shire Local Flood Plan. Any dwelling raised or replaced would not be eligible for future inclusion in Council's Voluntary Purchase Scheme.

### **E2.12 Checking of Completed Finished Floor Height**

After the building has been built to the relevant MFL, Council officers will check compliance with this requirement at the relevant inspection stage. The applicant is to provide a benchmark on the site, levelled to Australian Height Datum (**AHD**). Alternatively, Council officers may require surveyor's certification as the finished floor height(s).

### **E2.13 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 Inner Floodplain (Hazard Categories 1 and 2), High Hazard Floodway and Low Hazard Floodway / Flood Storage zones 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.

### **E2.14 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.

### **E2.15 Land Filling and Obstructions to Flow**

No filling or alteration of the land surface is permissible in the Inner Floodplain (Hazard Category 1) and High Hazard Floodway zones due to the potential for filling or obstructions to flow to adversely re-direct flows. Any minor extensions or repairs 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 to be above the 1% AEP flood level.

Council may permit building pads for residential blocks in the Inner Floodplain (Hazard Category 2) and Low Hazard Floodway / Flood Storage zones, provided it is satisfied that the proposal will not significantly obstruct or adversely re-direct flows towards adjacent developments. In order not to significantly obstruct flows, Council may require 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 1% AEP flood level. Sub-surface drainage of building pads is required.

## **E2.16 Flood Related Information to be Submitted to Council**

### **E2.16.1 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 the Flood Planning Map. The Survey Plan will enable Council to assess the extent and depth 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;
- 1% AEP flood level(s) over the site (to be provided by Council); and flood extents; and
- 0.2 metre natural surface contour intervals across the entire property (existing and proposed). Note: All levels must be relative to AHD.

**Annexure 4** outlines requirements for survey data required by Council.

### **E2.16.2 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 the proposal does not increase the flood hazard to existing and future occupiers of the floodplain (see Section E2.16.3).**

**Council will make its evaluation and confirm requirements regarding the proposed site development, based on the Survey Plan and accompanying data on the proposed development (see Annexure 4); and according to the conformance of the proposal with the performance requirements of the Development Controls Matrices – Annexures 2.1 and 2.2 and Chapter E2.**

### **E2.16.3 Flood Risk Report – Inner Floodplain (Hazard Category 2), High Hazard Floodway and Low Hazard Floodway / Flood Storage Zones**

#### **A. Scope of Work – General**

Council will require a *Flood Risk Report* for any (minor) residential development located in the High Hazard Floodway zone. Depending on its nature and scale, Council may also require a *Flood Risk Report* for a development situated in the Inner Floodplain (Hazard Category 2) and Low Hazard Floodway / Flood Storage zones where lesser but still significant flow velocities may be expected and/or where depths of inundation may be significant and a partial filling may restrict flow.

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 MFL for the particular category of development (MFL to be determined 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 1% AEP 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 1% AEP flood. These measures shall include but are not limited to the following:
  - Types of materials to be used, up to the MFL 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 MFL.
- f) All electrical connections must be located above the MFL. 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 are to be flood compatible to a minimum level equivalent to the MFL (**Annexure 3B**).

**B. Additional Items (Commercial and Industrial Development)**

- h) For commercial and industrial development (in the Inner Floodplain (Hazard Category 2) and Low Hazard Floodway / Flood Storage zones), include flood warning signs/depth indicators for areas that may be inundated, such as open car parking areas.

### E3. GLOSSARY OF TERMS

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

TERM	DEFINITION
<b>Annual Exceedance Probability (AEP)</b>	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, for a flood magnitude having five per cent AEP, there is a five per cent probability that there would be floods of greater magnitude each year.
<b>Australian Height Datum (AHD)</b>	A common national surface level datum corresponding approximately to mean sea level.
<b>Flood Affected Properties</b>	Properties that are either encompassed or intersected by the <b>Flood Planning Area (FPA)</b> .
<b>Floodplain</b>	Area of land which is subject to inundation by floods up to and including the Probable Maximum Flood (PMF) event, that is, flood prone land.
<b>Flood Planning Area</b>	The area of land that is shown to be in the Flood Planning Area on the <i>Flood Planning Map</i> .
<b>Flood Planning Map</b>	The <i>Flood Planning Map</i> referred to in the Narrandera Local Environmental Plan 2013, extracts of which are shown on <b>Figure E1.1</b> .
<b>Flood Planning Level (FPL) (General Definition)</b>	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.
<b>Flood Planning Level (FPL)</b>	For land within the Flood Planning Area subject to Main Stream Flooding in Narrandera, the Flood Planning Level (FPL) is the level of the 1% AEP flood event <u>plus</u> 500 mm.  In areas subject to Major Overland Flow, the FPL is the level of the 1% AEP flood event <u>minus</u> 100 mm.  For areas outside the Flood Planning Area shown on the <i>Flood Planning Map</i> , the FPL is the level of the 1% AEP flood event <u>plus</u> 500 mm.
<b>Flood Prone/Flood Liable Land</b>	Land susceptible to flooding by the PMF. Flood Prone land is synonymous with Flood Liable land.
<b>Floodway</b>	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.
<b>Flood Storage Area</b>	Those parts of the floodplain that may be important for the temporary storage of floodwaters during the passage of a flood. Loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation.
<b>Freeboard</b>	Provides reasonable certainty that the risk exposure selected in deciding a particular flood chosen as the basis for the FPL and MFL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the FPL and MFL.

TERM	DEFINITION
<b>Habitable Room</b>	<p>In a residential situation: a living or working area, such as a lounge room, dining room, kitchen, bedroom or workroom.</p> <p>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.</p>
<b>Inner Floodplain (Hazard Category 1)</b>	Comprises areas where factors such as the depth and velocity of flow, time of rise, isolation and evacuation difficulties mean that the land is unsuitable for most types of development. It includes areas of High and Low Hazard Floodway. Erection of a buildings and carrying out of work not permitted; use of land, subdivision of land and demolition subject to State Environmental Planning Policies and Local Environmental Plan provisions.
<b>Inner Floodplain (Hazard Category 2)</b>	Comprises areas of High and Low Hazard Flood Storage areas, as well as areas where isolation on Low Flood Islands and evacuation problems where development other than Essential Community Facilities, Critical Utilities and Flood Vulnerable Residential Development may be permitted provided it is capable of withstanding hydraulic forces and sited on the allotment to minimise adverse redirections of flow towards adjacent properties. Council may require a <i>Flood Risk Report</i> if it considers that the proposal has the potential to significantly affect flooding behaviour in adjacent properties.
<b>Intermediate Floodplain</b>	<p>For Main Stream Flooding, is the remaining land lying outside the extent of the Inner Floodplain zones, but within the FPA (defined as land which lies below the 1% annual exceedance probability (AEP) flood level plus 500 mm freeboard).</p> <p>For Major Overland Flow, it is the land outside the High Hazard Floodway and Low Hazard Floodway / Flood Storage zones where the depth of inundation during the 1% AEP storm event is greater than 100 mm.</p>
<b>Local Drainage</b>	Land on an overland flow path where the depth of inundation during the 1% AEP storm event is less than 100 mm.
<b>Main Stream Flooding</b>	The inundation of normally dry land occurring when water overflows the natural or artificial banks of a major stream; for the study area, the main stream is the Murrumbidgee River.
<b>Major Overland Flow</b>	Where the depth of overland flow during the 1% AEP storm event is greater than 100 mm.
<b>Minimum Floor Level (MFL) (General Definition)</b>	The combinations of flood levels and freeboards selected for setting the Minimum Floor Levels (MFL's) of future development located in properties subject to flood related planning controls.
<b>Main Stream Flooding Minimum Floor Level (MSF MFL)</b>	<p>For properties subject to Main Stream Flooding, the MSF MFL is the level of the 1% AEP flood event plus 500 mm freeboard.</p> <p>Note that for areas outside the Flood Planning Area shown on the Flood Planning Map, the MSF MFL is the level of the 1% AEP flood event plus 500 mm freeboard.</p>

TERM	DEFINITION
<b>Major Overland Flow Minimum Floor Level (MOF MFL)</b>	<p>For properties subject to Major Overland Flow, the MOF MFL is the level of the 1% AEP flood event plus 300 mm freeboard.</p> <p>Note that for areas outside the Flood Planning Area shown on the <i>Flood Planning Map</i>, the MOF MFL is the level of the 1% AEP flood event plus 500 mm freeboard.</p>
<b>Outer Floodplain</b>	<p>This is defined as the land between the FPA and the extent of the PMF.</p> <p>For Main Stream Flooding it is the area that lies outside the Intermediate Floodplain where depths of inundation will exceed 100 mm during the Extreme Flood.</p> <p>For Major Overland Flow, it is the area that lies outside the High Hazard Floodway, Low hazard Floodway / Flood Storage and Intermediate Floodplain zones where depths of inundation will exceed 100 mm during the PMF.</p>
<b>Probable Maximum Flood (PMF)</b>	<p>The largest flood that could conceivably occur at a particular location. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain.</p> <p>For the study area, the extent of the PMF has been trimmed to include depths greater than 100 mm.</p>



#### **E4. REFERENCES**

Lyall and Associates (2015) ***“Narrandera Flood Study Review and Levee Options Assessment”***.

Lyall and Associates (2019) ***“Review of the Narrandera Floodplain Risk Management Study and Plan”***.

New South Wales Government (2005) ***“Floodplain Development Manual – The Management of Flood Liable Land”***.

**ANNEXURE 1  
LAND USE CATEGORIES**

<b>Essential Community Facilities</b>	<b>Critical Utilities and Uses</b>	<b>Flood Vulnerable Residential</b>	<b>Residential</b>	<b>Business, Commercial/Industrial &amp; Rural Industry</b>	<b>Non-Urban and Outbuildings</b>	<b>Residential Subdivision</b>	<b>Minor Additions (Residential)</b>
Development that may provide an important contribution to the notification and evacuation of the community during flood events; Hospitals; Institutions; Child care centres; 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;	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 <sup>2</sup> area.	Subdivision of land involving the creation of new allotments for residential purposes; Earthworks or filling operations covering 100 m <sup>2</sup> or more than 0.3 m deep.	An addition to an existing dwelling of not more than 30 m <sup>2</sup> (habitable floor area)

**ANNEXURE 2.1  
DEVELOPMENT CONTROLS MATRIX - MAIN STREAM FLOODING**

	Outer Floodplain							Intermediate Floodplain							Inner Floodplain (Hazard Category 2)						Inner Floodplain (Hazard Category 1)												
	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)	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
Building Components											1	1		1	1				1	1		1	1									1	
Structural Soundness											1	1		1	1				1	1		1	1									1	
Flood Affection																			1	1	1	1	1							1		1	
Evacuation / Access																			1	1	1	1	1										
Management and Design												3		1	5				6	3,6	2,6	1,6	5							2,6		5,6	

 Not Relevant       Unsuitable Land Use

Main Stream Flooding applies for inundation of land bordering the Murrumbidgee River.

The Intermediate Floodplain is defined by the area between the two Inner Floodplain zones and the Flood Planning Area (FPA). The Outer Floodplain is the area that lies outside the Intermediate Floodplain zone where the depth of inundation will exceed 100 mm during the Extreme Flood.

See Notes over page:

**ANNEXURE 2.1 (CONT'D)**  
**DEVELOPMENT CONTROLS MATRIX - MAIN STREAM FLOODING**

**Floor Level**

1. Floor levels to be equal to or greater than the Main Stream Flooding Minimum Floor Level (MSF MFL) (1% AEP flood level plus 500 mm freeboard).

**Building Components**

1. All structures to have flood compatible building components below the MSF MFL.

**Structural Soundness**

1. Structure to be designed to withstand the forces of floodwater, debris and buoyancy up to the MSF MFL.

**Flood Affection in Adjacent Areas**

1. A Flood Risk Report may be required to demonstrate that the development will not increase flood hazard (see Item 7 Management and Design below).

**Note:** When assessing Flood Affection 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 1% AEP 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. No external storage of materials which may cause pollution or be potentially hazardous during Extreme Flood.
3. Where it is not practicable to provide floor levels to the MSF MFL, applicant is to provide an area to store goods at that level.
4. Applicant is to provide an area to store valuable equipment above the MSF MFL (level to be advised by Council) – see **Section E2.8**.
5. Where it is not practicable to provide floor levels to the MSF MFL, Council may allow a reduction for minor additions to habitable areas – see **Section E2.11**.
6. Flood Risk Report may be required prior to development of this nature in this area – see **Sections E2.16.2** and **E2.16.3**.

**NOTE: THESE NOTES ARE TO BE READ IN CONJUNCTION WITH REMAINDER OF THE FLOOD POLICY, IN PARTICULAR CHAPTER E2.**

**ANNEXURE 2.2**  
**DEVELOPMENT CONTROLS MATRIX – MAJOR OVERLAND FLOW**

	Outer Floodplain								Intermediate Floodplain							Low Hazard Floodway / Flood Storage						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)	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	2	2	2	2	2		2	2	2	2	2	2		2	2					1	1		1	1								1
Building Components	2	2						2	2	1	1	1		1	1				1	1		1	1								1	
Structural Soundness	2	2						2	2	1	1	1		1	1				1	1		1	1								1	
Flood Affection																			1	1									1		1	
Evacuation / Access	1	1	1					1	1	1																						
Management and Design	2,3	2,3	5					2,3	2,3	5		4		1	6				7	4,7		1,7	6						3,7		6,7	

 Not Relevant

 Unsuitable Land Use

Major Overland Flow applies for inundation of land along the various flow paths which are present in the developed parts of Narrandera, as well as along those that border the town.

The Intermediate Floodplain is defined by the area which lies outside the High Hazard Floodway and Low Hazard Floodway / Flood Storage zones where the depth of overland flow will exceed 100 mm during a 1% AEP storm event. The Outer Floodplain is the area which lies outside the High Hazard Floodway, Low Hazard Floodway / Flood Storage and Intermediate Floodplain zones where the depth of overland flow will exceed 100 mm during the Probable Maximum Flood.

See Notes over page:

**ANNEXURE 2.2 (CONT'D)**  
**DEVELOPMENT CONTROLS MATRIX - MAJOR OVERLAND FLOW**

**Floor Level**

1. Floor levels to be equal to or greater than the Major Overland Flow Minimum Floor Level (MOF MFL) (1% AEP flood level plus 300 mm freeboard).
2. Floor levels to be equal to or greater than the MOF MFL (1% AEP flood level plus 300 mm freeboard) or 300 mm above natural surface levels, whichever is the higher.

**Building Components**

1. All structures to have flood compatible building components below MOF MFL.
2. All structures to have flood compatible building components below PMF flood level (where PMF level is higher than MOF MFL).

**Structural Soundness**

1. Structure to be designed to withstand the forces of floodwater, debris and buoyancy up to MOF MFL.
2. Structure to be designed to withstand forces of floodwater, debris and buoyancy up to PMF flood (where PMF level is higher than MOF MFL).

**Flood Affection in Adjacent Areas**

1. Residential development may be “deemed to comply” provided it conforms with the requirements of **Section E2.15**. A Flood Risk Report may be required to demonstrate that the development will not increase flood hazard (see Item 7 Management and Design below).

**Note:** When assessing Flood Affection the following must be considered:

- iii. Loss of conveyance capacity in the floodway or areas where there is significant flow velocity.
- iv. 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 1% AEP 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 PMF.
3. No external storage of materials which may cause pollution or be potentially hazardous during PMF.
4. Where it is not practicable to provide floor levels to MOF MFL, applicant is to provide an area to store goods at that level.
5. Applicant is to provide an area to store valuable equipment above MOF MFL (level to be advised by Council) – see **Section E2.8**.
6. Where it is not practicable to provide floor levels to MOF MFL, Council may allow a reduction for minor additions to habitable areas – see **Section E2.11**.
7. Flood Risk Report may be required prior to development of this nature in this area – see **Sections E2.16.2** and **E2.16.3**.

**NOTE: THESE NOTES ARE TO BE READ IN CONJUNCTION WITH REMAINDER OF THE FLOOD POLICY, IN PARTICULAR CHAPTER E2.**

## 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 MFL. 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 MFL. 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 MFL. 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 MFL 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 MFL. 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 MFL.

##### **iii) Ducting**

All ductwork located below the MFL 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 MFL 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**

<b>Building Component</b>	<b>Flood Compatible Material</b>	<b>Building Component</b>	<b>Flood Compatible Material</b>
<b>Flooring and Sub Floor Structure</b>	<ul style="list-style-type: none"> <li>Concrete slab-on-ground monolith construction. Note: clay filling is not permitted beneath slab-on-ground construction which could be inundated.</li> <li>Pier and beam construction or</li> <li>Suspended reinforced concrete slab</li> </ul>	<b>Doors</b>	<ul style="list-style-type: none"> <li>Solid panel with waterproof adhesives</li> <li>Flush door with marine ply filled with closed cell foam</li> <li>Painted material construction</li> <li>Aluminium or galvanised steel frame</li> </ul>
<b>Floor Covering</b>	<ul style="list-style-type: none"> <li>Clay tiles</li> <li>Concrete, precast or in situ</li> <li>Concrete tiles</li> <li>Epoxy formed-in-place</li> <li>Mastic flooring, formed-in-place</li> <li>Rubber sheets or tiles with chemical set adhesive</li> <li>Silicone floors formed-in-place</li> <li>Vinyl sheets or tiles with chemical-set adhesive</li> <li>Ceramic tiles, fixed with mortar or chemical set adhesive</li> <li>Asphalt tiles, fixed with water resistant adhesive</li> <li>Removable rubber-backed carpet</li> </ul>	<b>Wall and Ceiling Linings</b>	<ul style="list-style-type: none"> <li>Brick, face or glazed</li> <li>Clay tile glazed in waterproof mortar</li> <li>Concrete</li> <li>Concrete block</li> <li>Steel with waterproof applications</li> <li>Stone natural solid or veneer, waterproof grout</li> <li>Glass blocks</li> <li>Glass</li> <li>Plastic sheeting or wall with waterproof adhesive</li> </ul>
<b>Wall Structure</b>	Solid brickwork, blockwork, reinforced, concrete or mass concrete	<b>Insulation</b>	<ul style="list-style-type: none"> <li>Foam or closed cell types</li> </ul>
<b>Windows</b>	Aluminium frame with stainless steel or brass rollers	<b>Nails, Bolts, Hinges and Fittings</b>	<ul style="list-style-type: none"> <li>Galvanised</li> <li>Removable pin hinges</li> </ul>



## ANNEXURE 4 DEVELOPMENT APPLICATION REQUIREMENTS

### Step 1

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

- Is located on *Flood Prone Land* (Based on initial assessment of the extent of flood affectation and flood levels (refer from **Section E1.4** for details)).
- Is permissible in the Flood Hazard zone and determine the MFL for the particular category of land use.
- Note: an existing site survey (see **Section E2.16.1** 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 Australian Height Datum around the perimeter of the proposed building; and
  - b) The existing or proposed floor levels to Australian Height Datum.
- 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.