City of Wagga Wagga

WAGGA WAGGA REVISED MURRUMBIDGEE RIVER

FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

FINAL REPORT

wma water

APRIL 2018

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Project Wagga Wagga Revised Murrumbidgee River Floodplain Risk Management Study and Plan	**Project Number** 116017
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3	FRMS – Public Exhibition Draft Report for FRMAC Review (CG/EA)	Wagga Wagga City Council, NSW OEH	Jul 2017
2	FRMS – Stage 2 Report (CG/SY)	Wagga Wagga City Council, NSW OEH	Apr 2017
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Front cover photo: http://www.abc.net.au/news/2012-03-06/state-of-emergency-declared-in-wagga-wagga/3871866

EXECUTIVE SUMMARY

The Wagga Wagga Revised Floodplain Risk Management Study, which follows on from the Detailed Flood Model Revision for the area completed in 2014 (Reference 2), has been undertaken in accordance with the NSW Government's Flood Prone Land Policy. This FRMS represents a revision to the Management Study completed in 2009 (Reference 3), and revisits several options assessed in 2009 using updated data improved flood modelling techniques. A full assessment of the existing flood risk in the catchment has been carried out, including flood hazard across the study area, overfloor flooding of residential, commercial and industrial properties, identification of known flooding issues and hotspots, and emergency response during a flood event. Various measures aimed at managing this flood risk were assessed for their efficacy across a range of criteria, which allows options to be recommended as part of the Revised Floodplain Risk Management Plan for the area.

Flood Prone Land Policy Framework

The NSW Government Flood Prone Land Policy supported by the Floodplain Development Manual provides a framework for the assessment and management of flood risk across the state. Specifically, the Floodplain Development Manual guides Councils in the development and implementation of detailed local floodplain risk management plans in order to plan for and manage flood risk. The Floodplain Development Manual outlines the process and the roles and responsibilities of the various stakeholders involved in the process.

Council (both elected members and Council staff) are primarily responsible for managing flood prone land through the implementation of floodplain risk management strategies. The Floodplain Risk Management Advisory Committee assists Council in the development and implementation of these strategies by providing a forum for discussion of the differing viewpoints within the study area, identifying management options and considering and making recommendations to Council on appropriate measures and controls with the primary objective of achieving an equitable result for the study area. The committee is the driving force behind the study and may be required to vote to determine the majority opinion if consensus cannot be reached.

State Government agencies provide funding and technical support to assist Council and the committee in developing a robust Floodplain Risk Management Plan. In most cases a specialist consultant is engaged by Council to undertake the required technical investigations and assessment. The committee directs the consultant through this investigation and receives this information from the consultants to assist with their deliberations.

WMAwater has undertaken the investigation and assessment for this Wagga Wagga Revised Floodplain Risk Management Study under the guidance and direction of the Floodplain Risk Management Advisory Committee.

Background

Wagga Wagga is located in the Riverina region of NSW, and is subject to flooding from the Murrumbidgee River. The Murrumbidgee River traverses the floodplain from east to west and is a major tributary to the Murray System draining some 100,000 km^2. The catchment area of the Murrumbidgee River at Wagga Wagga is approximately 26,400 km^2. The City of Wagga Wagga is the largest inland city in NSW and is the regional centre of the Riverina district. The City is the regional focus for major commercial, retail and business centre activities, with many secondary and service industries supporting primary industry. The majority of the floodplain is comprised of *RU1 Primary Production* with usage primarily devoted to grazing and cropping endeavours. Numerous farm houses are scattered throughout the area. Higher density residential areas are positioned off the floodplain or behind the levees, with North Wagga zoned as *RU5 Village* and residential development behind the CBD Levee typically zoned as *R1 General Residential, R3 Medium Density Residential, B3 Commercial and B5 Business Development*.

Existing Flood Environment

Wagga Wagga has experienced riverine flooding on numerous occasions requiring large scale evacuations and causing considerable damage, loss of property, loss of revenue, disruption of services, disruption of lifestyle and significant inconvenience. Since early settlement, Wagga has experienced numerous large floods, with four events (1852, 1853, 1870 and 1891) in the 1800's equalling or exceeding 10.5 m at the Hampden bridge gauge. Following significant flooding in the 1950's the CBD Levee was constructed to provide flood protection to the township of Wagga. At the time of writing, the CBD Levee was being upgraded to a 1% AEP level of protection. There are a number other levees on the floodplain, including one encircling North Wagga and providing a level of protection of approximately an 12% AEP event, one at Gumly Gumly protecting for flood breakouts north of Lamprey Avenue (up to a 10% AEP level of protection), and the Riverina Water Country Council (RWCC) which protects Wagga Wagga's potable water supply.

Wagga Wagga is made up of several geographic floodplain communities, and the flood characteristics differ between each of these. The main differences are the flood hazard (i.e. flood depths and velocities) in and around each area, and the ability for residents to safely access flood free land. These inherent differences mean that flood risk mitigation must be approached differently for each community, to achieve the best outcome for residents appropriate to the flood behaviour in that area.

Economic Impact of Flooding

A flood damages assessment was carried out for the inundation of residential and commercial properties in the area. The assessment was based on surveyed and estimated flood levels for over 4000 properties in the Study Area. The annual average damages for residential and commercial/industrial properties was found to be $5.58M.

Flood Risk Management Options

This Floodplain Risk Management Study process under the direction of the Floodplain Risk Management Advisory Committee has identified and assessed a range of risk management measures that would help mitigate flooding to reduce existing and future flood damages. The options were assessed using a multicriteria analysis, which considered not only flood impacts, but also construction feasibility, economic merits and the alleviation or exacerbation of property damages, risk to life and pressure on the SES. These measures have been grouped into the following general categories:

Flood modification measures modify the flood's physical behaviour (depth, velocity) by undertaking structural works in particular areas of the floodplain. Among the flood modification options considered are levees for North Wagga, Oura and Gumly Gumly, and several community proposed options including large scale excavations of Malebo Gap, beneath Gobbagombalin Bridge and a bypass floodway north of North Wagga. Vegetation management can be used as a means of flood modification by reducing the hydraulic roughness in riparian areas.

Property modification measures modify the existing land use or buildings as well as development controls for future development. These measures primarily involve updating policies and regulations which relate to development on the floodplain. Property Modification Options including Voluntary Purchase and Voluntary House Raising were assessed, as well as a broad range of planning measures that aim to reduce flood risk to life, to proposed development and to the wider floodplain.

Response modification measures are aimed at changing and enhancing the community's response to the potential hazards of flooding. This is achieved by educating the property owners and the wider community about flooding, its behaviour and potential damages, so that they can make better informed decisions. The Response Modification Options considered in this FRMS are generally to 'continue and improve' Wagga Wagga's current flood emergency management systems and practices.

Recommended Options

The outcomes of the analysis undertaken in this Floodplain Risk Management Study are presented in this report and from that information the Floodplain Risk Management Advisory Committee has made recommendations which include property modification (for example, planning controls, voluntary house raising), flood modification (for example, levee, vegetation management) and response modification (for example, community education, flood emergency management planning), and detailed in Table 1 and Table 2 overleaf. The Draft Floodplain Risk Management Study and Plan was placed on public exhibition to allow the broader community and stakeholders to provide feedback on the recommendations. The Floodplain Risk Management Advisory Committee considered submissions received and made any appropriate changes required. The submissions and changes are detailed in Appendix M.

Table 1 Recommended Floodplain Risk Management Measures

Ref	Option	Description	Benefits	Concerns	Priority
PR1	Feasibility study to investigate a Voluntary House Raising & Voluntary Purchase Scheme in Wagga Wagga Study Area. The feasibility study is to be investigated in conjunction with Option L4B (see below)*.	Residential properties located outside leveed areas may be eligible for voluntary house raising which aims to reduce property damages to residential dwellings, or voluntary purchase, which aims to remove residents from high hazard areas and prevent future development of the purchased lot.Feasibility study is to include economic appraisal of both options, eligibility criteria for participation, identification of construction constraints and extensive community consultation to determine likely participation rates.	The frequency of overfloor inundation (and hence property damage) is significantly reduced by raising the dwelling above the Flood Planning Level. This option can provide benefits to many dwellings across the floodplain without impacting others. Voluntary purchase reduces the number of residents in high hazard areas and can improve conveyance by removing dwellings and rezoning lots to prevent future development.	Suitability for house raising depends on building footings (slab on ground not appropriate), which may limit participation.Some residents may not want stairs due to health and mobility issues.Economic viability of this scheme would be directly linked with participation rates.Raised houses could encourage residents to 'shelter in place' during floods, however isolation and long durations of floods put them at high risk. Significant ongoing education efforts will be required to ensure any evacuation orders are heeded.	High*
L4B	Feasibility Study to investigate North Wagga Levee Upgrade to 5% AEP level of protection including upgrade to Hampden Avenue to equivalent level (as embankment and conveyance improvements through Wilks Park. Feasibility study is to be conducted in conjunction with Option PR1 (see above)*.	Undertake a study to further investigate and determine the feasibility of raising the North Wagga Levee to a 5% AEP level of protection, and raising Hampden Avenue to an equivalent level with some excavation of Wilks Park to improve conveyance and offset upstream flood impacts. The feasibility study is to include EIS for the park excavation, geotechnical assessment of existing levee, site-by-site assessment of third party impacts and extensive community consultation.	Moderate reduction in frequency of inundation and property damages in North Wagga and minor benefits upstream due to increased flow conveyance beneath the newly excavated Wilks Bridge.	Significant concerns regarding risk to life of residents inside levee: ongoing education required to ensure residents fully understand the level of protection the levee would offer. Raising the levee has external adverse flood impacts on a number of properties which require further investigation. The upgrade involves additional excavation beneath Wilks Park Bridge which is likely to have associated environmental impacts. Other concerns include the high capital cost and the need for ongoing maintenance.	High*
VMP	Update the recently completed Vegetation Management Plan to consider new state biodiversity legislation instruments, then draft Standard Operation Procedures for selected recommended activities.	The recently completed VMP was written in accordance with new biodiversity legislation, however implementation guides and instruments were not available at the time of writing. Following completion, Council is to select recommended activities to progress, and draft Standard Operating Procedures for these items.	Controlled vegetation management ensures that in the long term, vegetation does not roughen the riparian zone excessively, and to protect areas of ecological value (especially habitat for native fauna).	There is a perception that broadscale clearing may occur, however vegetation management activities will be targeted and controlled. Vegetation management will not explicitly reduce flood affectation, however will ensure that over time flood behaviour is not worsened by increased riparian roughness due to increased vegetation density.	High
RE1	Improve Flood Warning System	Various measures to continue and improve on Wagga Wagga's existing flood warning systems, both to enhance flood forecasting and dissemination of information to the public, including investigation of "DipStik" to be installed at Oura to provide water level alerts.	Improved warning systems will better increase the accuracy and timeliness of flood predictions and improve the communication methods to deliver accurate and persuasive messages during flooding.	BOM is responsible for issuing Flood Watch and Flood Warnings.	High
RE2	Flood Emergency Management Planning	Review and update current Council and SES emergency flood response documents, drawing from latest modelling and recent floods.	Improved flood planning reduces flood risk to life and property, assisting residents of flood prone areas better prepare themselves and their property for flooding.	There are a number of documents to be updated and coordinated.	High
RE3	Community Flood Education	Ongoing community engagement is key to maintaining flood awareness, which can wane as time between flood events increases.	A flood aware community is generally better prepared for flooding, more responsive to evacuation orders and more resilient in recovery.	Levee upgrades can cause increased complacency in residents, which needs to be gently targeted with ongoing flood education campaigns.	High
A1	Future consideration of increasing conveyance beneath Wiradjuri Bridge by extending span and/or excavating beneath the bridge.	Future Option: use planned upgrades to Wiradjuri Bridge (maintenance/ traffic capacity upgrade etc.) as an opportunity to improve flood conveyance between North and South Wagga.	Increasing flow conveyance reduces flood levels across the floodplain upstream of Wiradjuri Bridge and reduces flood damages in the CBD, Wagga Floodplain and parts of North Wagga.	There may be adverse impacts downstream of the bridge, high capital costs and ongoing maintenance costs. Would have to be undertaken in conjunction with other bridge works.	Low
R1	Improved Access to Oura	Long term, staged upgrades to raise Oura Road (or other route) above the 1% AEP flood level.	Flood free access east-west across Wagga Wagga to Oura is beneficial not only to residents of Oura but to communities across the Riverina.	This road intersects several major flow paths and would require significant culverts/ bridge sections. Costs would be significant.	Low
R2	Improved Access to Gumly Gumly	Long term, staged upgrades to raise or divert the Sturt Highway (or other route) above the 1% AEP flood level between East Wagga and Gumly Gumly.	Flood free access east-west across Wagga Wagga to Oura is beneficial not only to residents of Gumly Gumly but to communities across the Riverina.	This road intersects several major flow paths and would require significant culverts/ bridge sections. Costs would be significant. Sturt Highway is owned by RMS.	Low

*Feasibility studies are to be undertaken in conjunction to determine a) if options are feasible, and if so, b) the preferred of the two options.

Table 2 Recommended Floodplain Risk Management Planning Measures

Ref	Option		Description	Benefits	Concerns	Priority
PL1	General Changes	Move Flood Planning Area mapping into the Wagga Wagga DCP, whilst retaining the definition of the Flood Planning Area and Flood Planning Level in the LEP.	A general definition of both FPL and FPA is to remain in LEP, with details and FPA mapping provided in the DCP for ease of updating following the completion of future studies.	By keeping the FPA mapping in the DCP, Council would not be required to prepare a Planning Proposal each time the FPA map is updated (e.g. with completion of future flood studies).	This amendment to the LEP would require Council to submit a planning proposal.	High
PL2		Reformat DCP to Matrix style document	The Development Control Plan (DCP) is currently a long, wordy and cumbersome document. Reverting to a matrix style format will make it easier for Council and the public to apply and understand.	Matrix style with controls dependent on hydraulic categorisation and hydraulic hazard will be clearer and simpler to interpret. Controls specific to each precinct are not necessary.	There may be resistance to moving away from precinct-centric controls, however the proposed format would be more equitable and clearer about which controls apply to a proposed development.	High
PL3	Controls to reduce risk to life	Add clause to LEP to control critical facilities and vulnerable land uses between the FPA and PMF extent.	This clause empowers Council to apply appropriate flood related controls to critical facilities within the PMF extent that fall outside the FPA (which are not subject to the DCP).	Critical facilities including schools, aged care facilities, childcare facilities outside of the FPA are not currently subject to development controls, however are vulnerable to flood risk in events greater than the 1% AEP. This clause will require development of critical facilities to consider and prepare for flooding during the development application stage.	This amendment to the LEP would require Council to submit a planning proposal, which could be lodged in conjunction with Option PL1.	High
PL4		Requirement of Site Specific Flood Emergency Plans	Certain types of developments will be required to provide site specific emergency flood plans to demonstrate how occupants and stock will be kept safe during and after flood events.	Preparation of a plan increases the flood awareness of the business owner and reduces risk to life of staff or occupants by improving evacuation efficiency and preparedness. Increased awareness can also reduce property damages by preparing the site for flooding.	There may be resistance from developers, as preparation of a site-specific flood plan may be considered onerous to prospective developers.	High
PL5		Flood Risk Info on s149 Planning Certificates	Increase depth of flood information to be provided on s149(2) and (5) certificates to identify the property's flood hazard, hydraulic category and whether or not flood related development controls apply.	The more informed a home owner is, the greater the understanding of their flood risk. During a flood event this information can help prepare residents to evacuate and reduces the number of residents that elect to take shelter in high hazard areas.	None - s149 certificates already contain basic information, Council to provide further detail from current FRMS results.	High
PL6	Controls to reduce risk to proposed development	Controls to set Minimum Floor Levels	The Flood Planning Level (FPL) for a variety of types of development is set at a design flood event level plus a freeboard.	Incidences of overfloor inundation can be reduced for new developments by ensuring their floor levels are set at the FPL (as a minimum).	FPL and FPA to be updated based on results from this FRMS and applied appropriately to various types of development.	High
PL7		Controls to set Minimum Flood Proofing Levels	Flood proofing to the FPL is to be required for certain types of development to reduce flood damages.	Implementation of a minimum flood proofing level can lead to reduced flood damages. Wet or dry flood proofing could be allowed at the developer's discretion.	FPL and FPA to be updated based on results from this FRMS and applied appropriately to various types of development.	High
PL8		Controls to ensure appropriate building design and materials	Certain developments are to be certified by an engineer to ensure they can withstand flooding forces, buoyancy and debris.	Developments in higher hazard areas or the floodway may be subject to fast flowing or deep floodwaters, and buoyant debris. This control will ensure such buildings are constructed suitably to withstand such forces and reduce damages and hazard.	There may be resistance from developers, as engineering certification may be considered onerous to prospective developers.	High
PL9	Controls to Reduce Risk to the Wider Floodplain	Controls to Manage Offsite Impacts: Flood Impact Assessment	A flood impact assessment can be used to demonstrate that a proposed development will not have any adverse flood impacts elsewhere in the floodplain (e.g. on a neighbouring property).	Developments in higher hazard areas or the floodway may cause adverse flood impacts to other properties and contribute to impacts of cumulative development. This control requires developments of a certain size to submit an impact assessment to demonstrate no offsite flood impacts occur.	There may be resistance from developers, as a flood impact assessment may be considered onerous to prospective developers.	High
PL10		Appropriate Dwelling Design	Redevelopment of existing dwellings should be undertaken so as to improve flood risk where possible, and development controls can be used to achieve improvement over time.	The proposed controls seek to reduce the flood impacts of a replaced dwelling by, for example, locating it on the part of the lot with the lowest hazard, orienting the dwelling to cause least obstruction of flow, requiring minimum floor levels above the FPL, and using open piers to allow flow beneath the property.	There may be limited scope to change the siting of the dwelling or resistance to having open space beneath houses.	High

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AAD	Average Annual Damages
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ALS	Airborne Laser Scanning
ARI	Average Recurrence Interval
ARR	Australian Rainfall & Runoff
BC	Benefit Cost
BCA	Building Code of Australia
BOM	Bureau of Meteorology
CBD	Central Business District
CMA	Central Mapping Authority
DCP	Development Control Plan
DECC	Department of Environment and Climate Change
DNR	Department of Natural Resources
DPE	Department of Planning and Environment (NSW)
DRM	Digital Rainfall Method
DTM	Digital Terrain Model
EPI	Environmental Planning Instrument
EP&A	Environmental Planning and Assessment Act
EY	Exceedances per Year
FDM	Floodplain Development Manual (Reference 1)
FERP	Flood Emergency Response Planning
FFA	Flood Frequency Analysis
FIA	Flood Impact Assessment
FIC	Flood Intelligence Card
FPA	Flood Planning Area
FPL	Flood Planning Level
FRMAC	Floodplain Risk Management Advisory Committee
FRMS	Floodplain Risk Management Study
GIS	Geographic Information System
GPS	Global Positioning System
HyFS	Hydrological Forecasting System
IFD	Intensity, Frequency and Duration of Rainfall
LEP	Local Environmental Plan
LFP	Local Flood Plan
LGA	Local Government Area
LLS	Local Land Services Act
mAHD	meters above Australian Height Datum
NSW	New South Wales
OEH	Office of Environment and Heritage (NSW)
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
RAAF	Royal Australian Air Force
RWCC	Riverina Water County Council

SEPP	State Environmental Planning Policy
SFP	State Flood Plan
SES	State Emergency Service
SOP	Standard Operating Procedure
SRMT	Shuttle Radar Mission Topography
TUFLOW	one-dimensional (1D) and two-dimensional (2D) flood and tide simulation software program (hydraulic computer model)
VHR	Voluntary House Raising
VMP	Vegetation Management Plan
VP	Voluntary Purchase
WBNM	Watershed Bounded Network Model (hydrologic computer model)
WLT	Warning Lead Time
WSUD	Water Sensitive Urban Design
WWCC	Wagga Wagga City Council

TERMINOLOGY USED IN REPORT

Australian Rainfall and Runoff have produced a set of draft guidelines for appropriate terminology when referring to the probability of floods. In the past, AEP has generally been used for those events with greater than 10% probability of occurring in any one year, and ARI used for events more frequent than this. However, the ARI terminology is to be replaced with a new term, EY. The terminology is explained below.

Annual Exceedance Probability (AEP) is expressed using percentage probability. It expresses the probability that an event of a certain size or larger will occur in any one year, thus a 1% AEP event has a 1% chance of being equalled or exceeded in any one year. For events smaller than the 10% AEP event however, an annualised exceedance probability can be misleading, especially where strong seasonality is experienced. Consequently, events more frequent than the 10% AEP event are expressed as X Exceedances per Year (EY). Statistically a 0.5 EY event is not the same as a 50% AEP event, and likewise an event with a 20% AEP is not the same as a 0.2 EY event. For example an event of 0.5 EY is an event which would, on average, occur every two years. A 2 EY event is equivalent to a design event with a 6 month average recurrence interval where there is no seasonality, or an event that is likely to occur twice in one year.
While AEP has long been used for larger events, the use of EY is to replace the use of ARI, which has previously been used in smaller magnitude events. The use of ARI, the Average Recurrence Interval, which indicates the long term average number of years between events, is now discouraged. It can incorrectly lead people to believe that because a 100-year ARI (1% AEP) event occurred last year it will not happen for another 99 years. For example there are several instances of 1% AEP events occurring within a short period, for example the 1949 and 1950 events at Kempsey.

Where the % AEP of an event becomes very small, for example in events greater than the 0.02 % AEP, the ARR draft terminology suggest the use of 1 in X AEP so a 0.02 % AEP event would be the same as a 1 in 5,000 AEP.

The PMF is a term also used in describing floods. This is the Probable Maximum Flood that is likely to occur. It is related to the PMP, the Probable Maximum Precipitation.

This report has adopted the approach of the ARR draft terminology guidelines and uses % AEP for all events greater than the 10% AEP and EY for all events smaller and more frequent than this.

EY	AEP (%)	AEP (1 in x)	ARI	Use
6	99.75	1.002	0.17	WSUD
4	98.17	1.02	0.25	
3	95.02	1.05	0.33	
2	86.47	1.16	0.50	
1	63.21	1.58	1.00	
0.69	50.00	2	1.44	Stormwater/pit and pipe design
0.5	39.35	2.54	2.00	
0.22	20.00	5	4.48	
0.2	18.13	5.52	5.00	
0.11	10.00	10	9.49	
0.05	5.00	20	20	Flooding
0.02	2.00	50	50	
0.01	1.00	100	100	
0.005	0.50	200	200	
0.002	0.20	500	500	
0.001	0.10	1000	1000	
0.0005	0.05	2000	2000	Limit CRC FORGE*
0.0002	0.02	5000	5000	Extreme risk /Dams
PMF	**1 x 10^{-5} AEP - 1 x 10^{-7} AEP**			

A copy of the draft terminology is available at: http://www.arr.org.au/arr-guideline/draft-chapters/

* *CRC-FORGE (Cooperative Research Centre – Focussed Rainfall Growth Estimation)*

FOREWORD

The NSW State Government's Flood Prone Land Policy provides a framework to ensure the sustainable use of floodplain environments. The Policy is specifically structured to provide solutions to existing flooding problems in rural and urban areas. In addition, the Policy provides a means of ensuring that any 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 Government subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist councils in the discharge of their floodplain management responsibilities. The Federal Government may also provide subsidies in some circumstances.

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

1. Flood Study

- Determine the nature and extent of the flood problem.

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.

The Wagga Wagga Revised Murrumbidgee River Floodplain Risk Management Study & Plan (Wagga Wagga FRMS&P) presented herein constitutes the second and third stages of the NSW Floodplain Risk Management Process for the Murrumbidgee River floodplain at Wagga Wagga and follows on from the Detailed Flood Model Revision Project (WMAwater 2014). It reviews and revises the previously adopted 2009 Wagga Wagga FRMS&P, and extends the study area. WMAwater have been engaged by Wagga Wagga City Council (Council) to prepare this FRMS&P under the guidance of the Floodplain Risk Management Advisory Committee (FRMAC).

This report has 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.

1. INTRODUCTION

This Study has been prepared by WMAwater on behalf of Wagga Wagga City Council (Council). This FRMS&P utilises updated topographical data and more sophisticated modelling techniques to revise the Wagga Wagga FRMS&P (Reference 3) completed by WMAwater in 2009, and follows the Wagga Wagga Detailed Flood Model Revision Project (Reference 2, WMAwater 2014) which is referred to as the 'Flood Study' throughout this report for ease of reference. The Flood Study defined design flood behaviour for the 1% and 5% AEP events on the Murrumbidgee River floodplain at Wagga Wagga under existing conditions and supersedes the 2004 Wagga Wagga Flood Study (Reference 4) and 2010 Murrumbidgee River Model Conversion Project (Reference 5). Work undertaken in the Flood Study has been expanded upon in this FRMS&P to further understand and determine the nature and extent of the flood risk at Wagga Wagga.

The Study is comprised of two phases:

1. The Wagga Wagga Revised Murrumbidgee River Floodplain Risk Management Study; and
2. The Wagga Wagga Revised Murrumbidgee River Floodplain Risk Management Draft Plan.

1.1. Study Objectives

The primary objective of this study is to provide Council with a revised FRMS&P for the Murrumbidgee River floodplain which considers the recommendations of the Wagga Wagga FRMS 2009 (Reference 3), identifies current floodplain risk using the most recent modelling, and investigates and recommends appropriate risk management strategies.

The Study includes consideration of a range of options to effectively manage existing, future and continuing flood risks along the floodplain. The outcomes from the Revised FRMS&P will also assist the SES in updating the Local Flood Plan to include risk management advice for the Murrumbidgee River floodplain at Wagga Wagga.

Council has identified five key outcomes of the current project, being;

1. A community informed and engaged in the Floodplain Risk Management Planning process;
2. A vegetation management plan;
3. A strategy to manage the cumulative effects of development on the floodplain;
4. Identification and quantification of flood hazards (hydraulic and hazard categorisation); and
5. Development of preferred mitigation options to concept design stage.

In addition to the above listed key outcomes, various other study objectives are presented in the following sections.

1.1.1. Flood Study Revision Objectives

The objective of this component of the current study is to review and ensure the suitability of the Flood Study hydrologic/hydraulic modelling system and to further define and understand design flood behaviour. The updated design flood results form the basis of works undertaken as part of the Revised FRMS&P. Specifically, the following objectives have been examined in Section 4.3:

- Validation/review of the existing hydrologic/hydraulic modelling system;
- Modelling of a full range of potential flood events including the 0.2EY, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP events and the Probable Maximum Flood (PMF);
- A flood damages assessment for all properties within the study area;
- Flood hazard mapping (1% AEP and 5% AEP events);
- Hydraulic categorisation mapping (1% AEP and 5% AEP events);
- Definition of the Flood Planning Area for both pre and post upgrade of the CBD Levee; and
- Emergency Response Planning (ERP) Classification mapping.

1.1.2. Floodplain Risk Management Study Objectives

The objective of the Floodplain Risk Management Study component of the current study is to investigate a range of flood mitigation works and measures to address the existing, future and continuing flood problems, in accordance with the NSW Government's Flood Prone Land Policy. This includes:

- Investigate solutions for management of flood hazard within the study area to reduce risk to people and property and for forward thinking strategies to incorporate into Council's strategic planning. These measures should ensure future development is controlled in a manner consistent with the flood hazard and risk. The adverse impacts (planning, environmental, social, economic or flooding) in the floodplain should be considered and whether they can be minimalised;
- Provide guidelines for potential new release areas, proposed rezoning and subdivisions; including lot sizes, allowable fill, building and development controls;
- Examine ways in which the river and floodplain environment may be enhanced without having a detrimental effect on flooding and existing development;
- Investigate a 1% AEP level of protection for North Wagga Wagga including possible support from State agencies and eligibility for funding under the NSW Floodplain Management Program;
- Preparation of a vegetation management plan;
- Consider the cumulative impact of multiple developments on the floodplain and the management of vegetation on the floodplain;
- Consider an asset management program highlighting assets to protect during flood (e.g. sewerage and water supply assets), assets to use during flood (e.g. evacuation centres and critical access routes) and prioritised asset activity post flooding (e.g. return to operation of sewerage, water supply and electricity).

1.1.3. Floodplain Risk Management Draft Plan Objectives

The Floodplain Risk Management Draft Plan makes a range of recommendations relating to flood mitigation works and measures that address the existing, future and continuing flood problems, in accordance with the NSW Government's Flood Prone Land Policy. The recommended works and measures presented in the Plan are aimed to establish a program for implementation of the FRMS&P and the delivery of the plan including priorities, indicative estimates of cost, staging, funding opportunities, responsibilities, constraints and monitoring.

For feasible floodplain management options, sufficient information is provided to assist Council in applying for funding from the NSW State Government's Floodplain Management Program. Information provided may include the number of properties protected by an option, concept design drawings and cost benefit analysis. Typically a greater depth of information is provided for options shortlisted by the Floodplain Risk Management Advisory Committee (FRMAC).

1.1.4. Review of the 2009 Wagga Wagga Floodplain Risk Management Plan

A key component of providing Council with a revised FRMS&P is the review of the existing plan of action for the management of flood risk in the study area; in this case the 2009 FRMS&P (Reference 3). As with the current study, the 2009 study comprised of a FRMS followed by a FRMP. The 2009 FRMP provided Plan is presented in Table 3 below with each option prioritised as either High, Medium or Low. The current status of each option recommended in the Plan has been reviewed with this information forming the basis of the current study. Review of the 2009 Study also revealed the options that were assessed and not recommended, and options that were not considered at all. This information has been used to shape the options investigated further in this report.

Table 3: Summary of the 2009 Plan and Option Status

Recommended Measure	Priority	Description	Status
F1 - Main City and North Wagga Levee upgrade	High	Community consultation plan based on the NSW PWD concept designs completed. Project has moved onto detailed design for a 1% AEP level of protection for the CBD Levee. Further investigation of suitable protection for North Wagga Levee is being undertaken as part of this FRMS&P.	Construction Phase
F4 – Vegetation Management Plan	High	Vegetation modelling done was as part of the 2D model conversion project (see Section 3.4. Accordingly, a detailed Vegetation Management Plan is part of the scope of the current FRMS&P revision.	The Vegetation Management Plan is being drafted as part of this current FRMS&P.

Recommended Measure	Priority	Description	Status
P3 – Adopt Appropriate Flood Planning Levels	High	Engineering needs to consult with Planning to ensure that the revised flood planning levels contained in the latest modelling are being used to determine development applications. The use of WaterRide for S149 certificates also needs to be more widely utilised.	Implemented
P4 – Review and update Council's current flood policy	High	Subsequent to completion of the 2009 FRMP, Council updated the DCP (2010) which included a draft flood policy. The 2010 DCP requires revision and recommendations in regards to this are made in this report.	Requires Revision
P5 – Adopt a consistent freeboard of 0.5 m above the design flood level	High	The Flood Planning Level is based on the latest adopted flood study, utilising WaterRide software. The FPL should be based on model results provided in this FRMS.	Implemented
P6 – Review and update Section 149 Certificates	High	S149 Certificates are now based on the most recently adopted Flood Studies and WaterRide software.	Implemented
P8 – Review and update LEP	High	Engineering consults with Planning to ensure the latest modelling results are being used for updates to the Local Environment Plan. Current LEP was published in 2010. Requires revision with current study FPA.	Requires revision
P9 – Adopt and implement updated development controls for flood prone land	High	Engineering consults with Planning to ensure the latest modelling results are being used for updates of Development Controls.	Implemented
R1 – Continue to improve public access to flood warning information	High	SES has become more proactive in this regard over the last decade and both Council and SES seek to ensure information is shared. The statutory role of disseminating flood warning information rests with SES.	Implementation underway – SES has commenced a study into the Local Flood Plans and warning.
R2 – Review and update local flood plan	High	The SES has a carriage of Local Flood Plans and is currently updating the Wagga Wagga Local Flood Plan and Flood Intelligence Card.	Underway – temporary pause while the LFP study is conducted.

Recommended Measure	Priority	Description	Status
R4 – Develop and implement a flood education program	High	Over approximately the last 5 years Council has undertaken extensive community consultation. The SES is also involved in this consultation as well as having their own program of preparing and distributing guideline documents on preparing and managing flood response.	Underway – ongoing community engagement.
R5 – Obtain more detailed topographic information	High	Complete.	Implemented
F2 & F3 – Remove Eastern Industrial Levee from Councils Planning	Medium	Complete.	Implemented
P1 – Allow house raising for suitable properties	Medium	This has been encouraged and proposals to raise floor levels of existing premises above the 1% AEP level are generally approved.	Implemented
P7 – Notify existing property owners of current S149 Planning Certificate details	Medium	Residents are advised upon purchasing property. There is no current program to individually advise existing residents of the possible impacts.	Implemented
R3 – Monitor changes to the floodplain	Medium	Illegal activities in the floodplain are still an issue, but the community is now much more aware and assists Council in managing such instances. Further works needs to be undertaken in this area.	Requires further work
P2 – Allow flood proofing	Low	Council is sympathetic to flood proofing of existing residences and will consider all such proposals	Implemented

Review of the 2009 FRMP indicates that of the 19 actionable items presented in Table 3, only four (Options F4, P4, P8 and R3) have not yet been fully implemented. These options are a key focus for the current study and are listed below with further details in the referenced sections:

- Option F4 – A Vegetation Management Plan is currently being prepared. The draft report is included in Appendix H and summarised in Section 9.4;
- Option P4 – Post the 2009 FRMP, Council updated the Wagga 2010 DCP to include recommended flood policy changes. However, with recent modelling updates, further revision of Council's flood policy is required. Recommended updates to Council's flood related development control plan are examined in 9.7;
- Option P8 – Review and update of Council's LEP was completed post the 2009 FRMP with the release of the Wagga 2010 LEP. As per Option P4, the 2010 LEP requires revision. This is examined in Section 9.7.2.1; and

- Option R3 – preliminary consultation with local community members indicated that illegal activities on the floodplain are a significant issue and that Council needs to work towards stricter management and enforcement of these activities. This is examined in Section 9.7.5.1.

2. BACKGROUND

2.1. Study Area

Wagga Wagga is located in the Riverina region of NSW. The study area (depicted in Figure 1) is subject to flooding from the Murrumbidgee River. The Murrumbidgee River traverses the floodplain from east to west and is a major tributary to the Murray System draining some 100,000 km^2. The catchment area of the Murrumbidgee River at Wagga Wagga is approximately 26,400 km^2.

The majority of the Murrumbidgee River floodplain in this area is used for agricultural purposes with most urban and industrial developments concentrated in Central Wagga Wagga and North Wagga. Other significant commercial/industrial areas are located on the southern floodplain and east of Wagga Wagga along the Sturt Highway (Hammond Avenue). Recent population growth has mainly been centred in the southern and elevated areas of Wagga Wagga. Other significant residential centres away from the riverine floodplain comprise Kooringal, Estella, Boorooma, Gobbagombalin, Lake Albert, Tatton, Turvey Park, Mt Austin, Glenfield, Tolland, Bourkelands and Lloyd.

Wagga Wagga is situated at the boundary of two very differing geographical regions. The sharp relief of the Great Dividing Range (in the upper catchment) flattens to form the Riverina Plain.

The model domain covers the Murrumbidgee River floodplain and this region is represented by the model extent shown in Figure 1. The modelled reach includes the area 5 km upstream of Oura which is located approximately 15 km east of Wagga Wagga (upstream) and runs downstream of the Malebo Gap some 9 km to the west (downstream) of Wagga Wagga. The total river length modelled is approximately 63 km.

Throughout this report, the study area is described as eight precincts. In some instances, these precincts may be aggregates of numerous smaller communities, however have been consolidated due to similarities is location, flood behaviour and risk. The location and delineation of these precincts are presented in Figure 2A-2C and are listed below in Table 4.

Table 4: Floodplain Precincts

Community	Description
Wagga CBD	all regions provided with some level of protection by the Wagga CBD Levee
East Wagga	area on the southern floodplain between Wagga CBD and Gumly
North Wagga	land protected by the North Wagga Levees (including Mill/East Streets)
West Wagga	all regions on the floodplain not protected by the levees to the west of North Wagga
Gumly Gumly	Gumly Gumly community to the north of Sturt Highway
Oura	Oura community
Wagga Floodplain	areas on the floodplain between North Wagga and Eunony Bridge Road
Eunony	areas on the floodplain between Eunony Bridge Road and Oura

2.2. Land Use

The City of Wagga Wagga is the largest inland city in NSW and is the regional centre of the Riverina district. The City is the regional focus for major commercial, retail and business centre activities, with many secondary and service industries supporting primary industry. Figure 3A-3C presents the 2010 Wagga Wagga Local Environmental Plan (2010 LEP) land use mapping. The existing land use can influence and guide the types of measures that are recommend flood risk in the study area.

The majority of the floodplain is comprised of *RU1 Primary Production* with usage primarily devoted to grazing and cropping endeavours. Numerous farm houses are scattered throughout the area. Higher density residential areas are positioned off the floodplain or behind the levees, with North Wagga zoned as *RU5 Village* and residential development behind the CBD Levee typically zoned as *R1 General Residential, R3 Medium Density Residential, B3 Commercial Core and B5 Business Development*.

Whilst the majority of business and industrial uses are positioned behind the CBD Levee, a significant industrial/business precinct exists in East Wagga bordering Hammond Avenue. Typical land use in this region is *IN1 General Industrial* and *B6 Enterprise Corridor.*

2.3. Demographic Overview

Understanding the social characteristics of the area can help ensure that the right risk management practices are adopted. The Census data can provide useful information on categories including dwelling and tenure type, languages spoken, age of population and movement of people into and from the area. Information has been extracted for the 2011 Census. In 2011, The Wagga Wagga LGA had a population of over 59,000 living in 25,000 private dwellings. The Australian Bureau of Statistics estimates that there were more than 63,000 residents living in the Wagga Wagga LGA in 2015.

Of interest is the data on population movement in recent years. Generally residents who have lived in an area for a longer time will have a better understanding of flooding issues in their area than those who have recently moved to the area. Within the last five years 35% of the population has moved to the Wagga Wagga area and in the year prior to the 2011 census 14% of the population moved to the area. This means that the majority of the current population would have experienced one or both of the recent flood events (2010, 2012) and therefore likely have good flood awareness of flood risk in the region.

It is useful to consider the tenure of housing. Those living in properties which they own are more likely to be aware of the flood risks and have measures in place to reduce them (where possible). Rental properties are likely to have a higher turnover of people living in them compared to privately owned properties and therefore those people in rental properties may be less aware of the flood risk. In Wagga Wagga 17% houses are rented.

The languages spoken by the population are also useful to consider as this can have implications in regard to the provision of flood information to the public. In Wagga Wagga less than 5% of the population speak a language other than English at home.

The age distribution of a population is important to consider as this can affect the ease and speed of emergency response. Within the study area there are almost 3,800 residents over the age of 75. Elderly people are often more frail and unable to respond as quickly to flood emergencies, without some assistance.

The family composition within a residence can affect awareness and response during a flood emergency. In Wagga Wagga there are more than 5,500 lone person households in the LGA, who are at greater risk of being unaware of evacuation warnings. There are also more than 2,600 single parent families, which typically means a low adult-to-child ratio within the household and therefore can make evacuation more difficult.

Table 5 below shows some of the above characteristics of Wagga Wagga LGA compared to the NSW average.
a
Table 5: Characteristics of the Wagga Wagga LGA (Australian Bureau of Statistics, 2011)

	Wagga Wagga LGA	NSW
Population Age:		
0 – 14 years	21.1%	19.2%
15 - 64 years	65.6%	66.1%
> 65 years	13.2%	14.7%
Average people per dwelling	2.5	2.6
Own/mortgage property	64.1%	66.6%
Rent property	17.2%	30.1%
Moved into area:		
- within last year	14%	-
- within last five years	35%	-
No cars at dwelling	7.4%	10.9%
Speak only English at home	95.9%	72.5%

2.4. Local Environment

The environment surrounding Wagga Wagga is highly modified from its original state. Early settlement of the area saw extensive clearing of native vegetation for farming and grazing and, eventually, development of the urban infrastructure.

Dry land salinity, in both urban and rural settings, is likely to continue to be a problem in the future, despite significant efforts to tackle the problem. Ongoing pressures include over-watering, water leakage and insufficient deep-rooted perennial vegetation.

In rural areas, the productive farming land faces a range of environmental pressures including dryland salinity, soil acidity, soil erosion, soil structural decline and weed invasion.

At least 35 species of plants and animals in the LGA that are threatened, with most relying on intact native vegetation for their survival.

Water quality in the Murrumbidgee River at Wagga Wagga is generally poor to fair with the main attributes measured being nutrients, turbidity and salinity.

2.5. Available Data

2.5.1. Floor Level Database

A key outcome of the current study is a flood damages assessment (Section 7). To complete this aspect of the study, floor level estimates are required to undertake a broad assessment of flood affectation. While the assessment uses floor level data for individual properties, the results are not an indicator of individual flood risk exposure but part of a regional assessment of flood risk exposure. A summary of available and required floor level estimates is provided below:

1. **North Wagga Properties -** floor level survey for 174 properties provided with a level of protection by the North Wagga Levees was undertaken in 2008 as part of the 2009 FRMS&P. This information requires review due to potential changes since 2008.

2. **Properties Outside the Levees -** Approximately 500 properties situated outside of the North Wagga and CBD Levees do not have any detailed floor level estimates.

3. **Wagga City Properties -** +3,000 properties situated inside of the CBD Levee that have the potential to become flood affected in events larger than the 1% AEP do not have any available floor level estimates.

Ideally, floor level survey for all flood affected properties within the study area would be undertaken, however this would lead to exorbitant costs for Council. Accordingly, WMAwater undertook the following works to update Council's floor level database:

1. **North Wagga Properties –** The accuracy of the 2008 survey data was examined to identify any changes to existing properties, or addition of new properties, post the 2008 survey. This data set was updated to 2016 conditions.

2. **Properties Outside the Levees –** properties situated on the Murrumbidgee River floodplain at Wagga were estimated through visual inspection of height above ground and using the highly accurate LiDAR data.

3. **Wagga City Properties –** Due to the large number of properties that require floor level estimates within the CBD Levee, a sample population was examined to determine the average floor level height from ground for properties within the levee. This information was then combined with LiDAR data to estimate floor levels for all properties.

WMAwater have used these estimation techniques for numerous other studies and find that the accuracy of this method is reasonable and consistent with the purposes of a flood damages assessment. The level of accuracy is considered suitable for two reasons. Firstly, the estimation of property damage due to flooding is inherently difficult to estimate, given the large variation in building types, their contents, the duration of flooding and other factors, and so the accuracy of floor heights should be in line with this accuracy. Secondly, the economic damages assessment is only intended to be used as an estimate of the Study Area-wide flood affectation, and not on a per-property basis. It should be noted that due to the nature of floor level estimations, damages results are not an indicator of individual flood risk exposure, but part of a regional assessment of flood risk exposure.

3. PREVIOUS INVESTIGATIONS

The Murrumbidgee River at Wagga Wagga has been the subject of much investigation, especially since the flood of 1974. In the last decade or so however, the technology with which studies can be undertaken, and data available, has improved dramatically. This section briefly describes the investigations undertaken since 2004 (in chronological order) on flood behaviour in the Study Area.

3.1. Murrumbidgee River Wagga Wagga Flood Study, WMAwater, 2004 (Reference 4).

The Murrumbidgee River Wagga Wagga Flood Study was completed in 2004 (2004 Flood Study) and used a 1D RUBICON model and flows derived via Flood Frequency Analysis (FFA) to determine design flood extents and levels. The 2004 study revised previous flood related studies at Wagga Wagga to incorporate the following:

- more technologically advanced hydraulic models became available,
- significant developments/alterations to the floodplain have been made such as the construction/raising of the North Wagga Wagga levee,
- earlier studies did not consider larger floods such as the PMF or overtopping of the Main Town levee.

A summary of the design results from the 2004 Flood Study are presented in Table 6.

Instead of the PMF, an extreme event was approximated by increasing the 1% AEP flow by a factor of 5 to produce a flow at Wagga Wagga of around 34,000 m^3/s (Reference 4). This approach was later replaced in the 2014 Wagga Wagga Detailed Model Revision (Reference 2) which defined the PMF flow using outputs of The Burrinjuck Flood Mapping Study, described in Section 4.2.2.5.

Table 6: 2004 Flood Study – design flows and gauge levels

Event	Discharge (m^3/s)	Stage (m)
0.2EY	1,300	8.6
10% AEP	2,000	9.3
5% AEP	3,000	9.9
2% AEP	4,900	10.8
1% AEP	6,900	11.4
0.2% AEP	14,900	12.6

Note: Hampden Bridge gauge zero = 170.05 mAHD

3.2. Wagga Wagga Floodplain Risk Management Study, WMAwater 2009 (Reference 3)

This report conducted a review of the 2004 Flood Study (Reference 4) which identified a discrepancy in levels of the CBD levee upstream of the Hampden Bridge and led to commissioning of a new survey to incorporate updated topographic data into the RUBICON hydraulic model. Further to this, a draft guideline for the assessment of flood levels and impacts associated with leveed towns had been developed by the former Department of Natural Resources (DNR) which required the model to be updated. Prior to this guideline development, previous modelling work had assumed that a levee remains completely intact for the full range of design events, including those well above the design level of protection of the levee. This is not a realistic scenario, and the guideline asserted that once the design height of the levee has been exceeded the levee is assumed to have failed, at least partially. This assumption was applied in the 2009 FRMS, and has been applied to all subsequent modelling including the Wagga Wagga Detailed Flood Model Revision (2014) (Reference 2) and this current FRMS.

With these model updates in place, the 2009 FRMS examined flooding issues resulting from the Murrumbidgee River in the vicinity of Wagga Wagga City and immediate surrounds. The primary objectives of the Study were to identify, assess and optimise measures aimed at reducing the impact of flooding on both existing and future development, and to make recommendations for the future management of the area. The recommended options arising from this Study are recorded in Section 1.1.4, along with an indication of how they have progressed since the report was released.

Survey of floor levels for a set of properties (174) situated within the floodplain were obtained by Council for use in the study. The remainder of floor levels (some 3000) were estimated. A flood damages assessment was undertaken, and determined that greater than 2300 properties were affected with overfloor inundation in the 1% AEP event. The average annual damages estimate was $2.1 Million.

3.3. Wagga Wagga Floodplain Risk Management Plan, WMAwater, 2009

The FRMP follows on from the FRMS and provides a prioritised plan of action for the management of flood risk in the study area. A review of the 2009 Plan and further details of this report are presented in Section 1.1.4.

The study assessed a range of management measures, including flood modification measures such as levees, property modification and response modifications. 18 options were recommended in the Plan, and these are listed below.

- **Flood Modification Measures:**
  - F1 – Investigate feasibility of raising CBD Levee
  - F2 & F3 – Remove the eastern industrial levee proposal from Council's long term planning and continue with Council's current 5% AEP level filling policy.
  - F4 – Implement vegetation management plan for Parkan Pregan and overbank areas.

- **Property Modification Measures:**
  - P1 – Allow house raising for suitable properties
  - P2 – Allow flood proofing
  - P3 – Adopt appropriate flood planning level
  - P4 – review and update Council's current flood policy
  - P5 – adopt a consistent freeboard of 0.5m above the design flood level
  - P6 – Review and update Section 149 Certificates
  - P7 – Notify existing property owners of current S149 certificate details
  - P8 – Review and update LEP
  - P9 – Adopt & implement updated development controls for flood prone land

- **Response Modification Measures:**
  - R1 – Continue to improve public access to flood warning information
  - R2 – Review and update local flood plan
  - R3 – Monitor changes to the floodplain
  - R4 – Develop and implement a flood education program
  - R5 – Obtain more detailed topographic information

3.4. Wagga Wagga Murrumbidgee River Model Conversion Project, WMAwater, 2010.

The Rubicon model established in the 2004 Flood Study and modified as part of the 2009 FRMS was converted to a 2D model (TUFLOW) and new design flood extents and levels were calculated.

The majority of the data for the construction of the 2D model was derived from ALS data prepared by Fugro Spatial Solutions and captured in 2008. Details on structures were extracted from the existing RUBICON model. A key inclusion was the alignment and elevation of the Main and North Wagga levees based on data utilised in the 2004 Flood Study.

The model was calibrated and validated to 1974, 1975 and 1976 events. The model was used to develop design flood information for the 10%, 5%, 2% and 1% AEP events as well as the PMF.

Results from the Flood Study (WMAwater, 2014) (Section 4.1) supersede the results from the Wagga Wagga Murrumbidgee River Model Conversion Project (WMAwater, 2010).

3.5. Wagga Wagga Levee Upgrade – Flood Freeboard Report, NSW Public Works, 2010.

NSW Public Works undertook an assessment of freeboard requirements for the proposed Wagga Wagga levee upgrade works. The freeboard allowances contribute to the overall design levee levels for the CBD and North Wagga Levees. Consideration of factors including; wave action; local water surge; uncertainties in flood levels; settlement; defects and climate change were all accounted for in a joint probability framework.

Based on the assessment to proposed levee freeboards are as follows:

- CBD Levee – 0.9 m
- North Wagga – 0.75 m

3.6. Murrumbidgee River Flooding – Flood Data Collection – December 2010.

WMAwater were engaged by the SES in order to collect flood data associate with the December 2010 event. This study provided 25 peak flood level marks for the 2010 event which were used to validate the flood model developed as part of the Flood Study (WMAwater, 2014).

3.7. Wagga Wagga Major Overland Flow Flood Study, WMAwater, 2011.

The main recognised mechanism for flooding in Wagga Wagga is the Murrumbidgee River. Flooding can also be caused by local rainfall however and numerous areas of Wagga Wagga, including commercial and residential areas, are liable to flooding following intense local rainfall. The project defined existing case design flood behaviour for major overland flow branches throughout the study area.

The study area was broken into four model domains for the City (Glenfield Drain, Silvalite Reserve, various CBD bound flow paths), East (Marshalls and Crooked Creeks), Lake Albert (Stringybark Creek etc) and North (Duke's Creek). The model was verified to the February 5th, 2010 local rainfall event and was able to replicate observed behaviour.

3.8. Wagga Wagga Levee Upgrade – Concept Design Report, NSW Public Works, 2011.

One of the high priority recommendations from the 2009 FRMP was to investigate the feasibility of raising the Main City (CBD) and North Wagga levees. The Wagga Wagga Levee Upgrade report presents the recommended concept design derived in 2011. The recommended designs were based on varying design flood levels, the 1% AEP for the Main Levee and 5% for the North Wagga Levee. Embankment type levees were deemed the most economic and the upgrades would follow the existing alignment and generally be located on only one face of the levee to minimise impacts and costs. The estimated cost for the upgrades was $17.5 million.

The levee concept designs from this study were superseded post the completion of the Flood Study (WMAwater, 2014).

3.9. Impact Modelling of roadworks between Parken Pregan and Wiradjuri Bridges, 2011.

Hampden Avenue links Wagga Wagga CBD and North Wagga via Wiradjuri Bridge. During moderate flooding (events greater than 5% AEP) flood waters flow over Hampden Avenue preventing egress from North Wagga to Wagga CBD. This occurs prior to the overtopping of the Wagga City and North Wagga levees.

During the recent December 2010 flood event Council built a temporary earthen levee on either side of Hampden Avenue. The main purpose of this was to maintain the road link between Wagga CBD and North Wagga so as to aid in evacuation and emergency response.

Following the event Council observed that maintaining access to North Wagga via Hampden Avenue was of sufficient benefit that making the levee arrangement permanent was of interest. Of concern, however, were the potential impacts on flood levels upstream of Hampden Avenue, and accordingly, Council requested an impact assessment be carried out. The impact assessment was carried out using the Wagga Wagga Model Conversion Project (WMAwater, 2010).

Results from this impact assessment determined the following:

- For a flood event with a peak flood level of 9.8 m (~2010 event magnitude) the following impacts were noted:
    - Immediately upstream of Hampden Avenue flood levels increase up to 0.14 m;
    - Most of the area affected by the proposed works lie within Parken Pregan Lagoon with increased flood levels of up to 0.05 m;
    - Increase in flood level of up to 0.05 m at a few properties upstream of the proposed roadworks; and
    - Peak velocity through Parken Pregan Bridge increases by 0.2 m/s.
- Peak flood impacts for the 1% AEP event were found to be less than 0.05 m and contained entirely within the lagoon area.

3.10. Wagga Wagga Local Government Area – Murrumbidgee River Flood Modelling, WMAwater, 2012.

This study defined design flood levels for the entire local government area (areas impacted by riverine flooding only). A 2D model of Murrumbidgee River and surrounding floodplain was built using TUFLOW, with a 40m grid size. The model was calibrated to the 1974 event, which demonstrated a reasonable match – 95% of all points were found to lie within the standard flood planning level freeboard of 500 mm.

The model was then used to generate the 1% AEP design extent and flood levels. The results were also compared to the model results from the 2010 study, which was generally favourable. Results from the Flood Study (WMAwater, 2014) (Section 4.1) supersede the results from the Wagga Wagga Local Government Area – Murrumbidgee River Flood Modelling, (WMAwater, 2012).

3.11. Murrumbidgee River Flooding – Flood Intelligence Collection – March 2012.

WMAwater were engaged by the SES in order to collect flood data associate with the March 2012 flood on the Murrumbidgee River from Jugiong to Hay. Flood intelligence describes flood behaviour and the consequence flooding has for the community. It enables the SES to determine the likely impacts (or consequences) of flooding, and what actions should be undertaken by response agencies. This study provided 58 peak flood level marks for the 2012 event which were used to calibrate the flood model developed as part of the Flood Study (WMAwater, 2014).

3.12. Riverina Water County Council, Levee Works, Flood Impact Assessment – July 2014

Riverina Water County Council (RWCC) own and operate a water treatment facility on the northern side of Hammond Avenue (right bank of Marshalls Creek and left bank of the Murrumbidgee River floodplain).

This study was aimed to assess the flood impacts associated with raising the existing 5% AEP levee to afford protection from a 1% AEP event. Due to the RWCC close proximity to Marshalls Creek, flood impacts for the following scenarios were examined:

- Marshalls Creek alone;
- Murrumbidgee River alone; and
- Marshalls Creek and the Murrumbidgee River together

The analysis indicated that impacts from the proposed levee design are within the typically accepted tolerance range of 0.01 m providing justification for the proposed works. Furthermore, from a floodplain risk management point of view, the proposed levee is desirable as it helps secure a major potable water supply source for Wagga Wagga.

3.13. Wagga Wagga Levee Upgrade – Detailed Design Report, NSW Public Works, 2015.

NSW Public Works were engaged by Council to undertake the detailed design, investigate options for North Wagga, and undertake an economic appraisal for each of the various options, as well as the project as a whole. The options investigated for the North Wagga levee were:

- No modification to the existing levee design level;
- Raising the levee to afford protection for 5% AEP;
- Raising the levee to afford protection for 1% AEP; and
- Removal of the North Wagga levee.

The outcome of the economic appraisal favours the upgrade of the North Wagga Wagga levee to a 1% AEP level of protection. However, there are numerous other considerations which will be addressed in the current study to investigate what is the best option for North Wagga from a flood risk mitigation perspective as per the NSW Government Floodplain Development Manual.

3.14. Flood Impact Assessment for Proposed Harness Racing Track at North Wagga, 2017.

WMAwater undertook a flood impact assessment on behalf of Harness Racing NSW for the proposed horse racetrack and associated infrastructure in North Wagga. The location of the track and infrastructure is bounded by Hampden Avenue, Cooramin Street and Wright Street, an area zoned as Rural Primary Production (RU1) as per Council LEP 2010. The proposed track is situated on the Murrumbidgee River floodplain and has the potential to impact on flood behaviour.

The assessment of riverine impacts indicated that in a 10% AEP flood event the proposed racetrack and infrastructure cause a maximum peak flood level increase of 0.02 m in open areas adjacent to the racetrack precinct. In 5%, 2% and 1% AEP flood events the maximum increase in peak flood level is 0.01 m at adjacent properties. Again, this impact is only observed in open land.

The assessment also considered the flood impacts of the development on the local Dukes Creek catchment. These impacts will be discussed in the Wagga Wagga Major Overland Flow Floodplain Risk Management Study and Plan.

4. CURRENT FLOODPLAIN RISK MANAGEMENT PROCESS

As described in the Foreword, the NSW Government's Flood Prone Land Policy is structured in four sequential stages that are subject to periodic revision as new data becomes available or substantial development of the floodplain has occurred. The Wagga Wagga Detailed Flood Model Revision Report, undertaken by WMAwater in 2014, serves as the 'Flood Study' Stage for the current Revised Floodplain Risk Management Study and Plan. The findings of the 2014 study are described below, followed by the elements of the model that have been changed for this current study.

4.1. Wagga Wagga Detailed Flood Model Revision Report, WMAwater, August 2014

Since the 2009 Floodplain Risk Management Study, Council has been involved in an ongoing project to upgrade the Wagga Wagga levees. The 2012 flood event and the apparent decline in the River's conveyance, gave cause to reinvestigate the design protection provided by the proposed revised levees. As such, WMAwater were commissioned to undertake revised flood modelling and hydrologic analysis. In particular, design flood modelling of the 5% and 1% AEP events were required.

Bathymetric survey for 66 km's of the river was obtained. The model was calibrated successfully to the 2012 event for flow gauging, flow and stage hydrographs at Hampden Bridge, and 58 peak flood levels. The model was validated against the 2010 event successfully.

The study also investigated why the stage/discharge relationship has changed. The work indicated that the change in stage/discharge relationship can plausibly be attributed to a range of factors including changes in vegetation density and changes to the shape of the river and overbank topography as a result of flood events and development on the floodplain. This was verified by successfully matching hydraulic model results to 1974 flood observations by adjusting infrastructure to 1974 conditions and by modifying vegetation as per 1971 aerial photography. These works led to the conclusion that the change in stage/discharge relationship at Wagga is substantially due to vegetation changes on the floodplain that have occurred over time. A change in effective roughness of approximately 20% has led to the stage/discharge relationship changing such that a given flow now produces relatively higher flood levels. For example a flow of 3,000 m^3/s previously produced a height of 9.9 m, the same flow is now estimated to produce a height of 10.1 m. These works led the NSW Department of Primary Industries Water (DPIwater) to revise the high flow rating at Wagga Wagga.

A summary of the Flood Study design flood discharge and stage are provided Table 7.

Table 7: 2014 Detailed Flood Study – design flows and gauge levels

ARI	Discharge (m^3/s)	Stage (m)
5% AEP	3,000	10.1
1% AEP	5,100	11.3

Note: Hampden Bridge gauge zero = 170.05 mAHD

The vegetation management activities described in Appendix H and summarised in Section 9.4 aim to control vegetation density so as to not increase the hydraulic roughness of the riparian zone, and hence prevent the worsening of flood behaviour in the future. The vegetation management plan is not intended to return the extent and density of vegetation to that of the early 1970s.

The hydrology and hydraulic modelling undertaken as part of the Detailed Flood Model Revision (WMAwater, 2014) study forms the basis of the current study Flood Study revision. This model has been reviewed as described below.

4.2. Hydrology Review

4.2.1. Introduction

There are two basic approaches to undertaking design flood analysis:

- The rainfall runoff routing approach; and
- The flood frequency approach (also called FFA).

Both approaches have advantages and disadvantages however for Murrumbidgee River design flows at Wagga Wagga the balance was very much in favour of using the flood frequency approach.

The flood frequency approach is generally preferred over the rainfall/runoff routing approach where the length and quality of the observed record and accuracy of the rating curve are considered adequate. In addition, large complex upstream catchments will lead to less reliable design flow estimates when using rainfall/runoff routing methods.

4.2.2. Flood Frequency Analysis

4.2.2.1. Overview

FFA uses the record of past flooding at a site to determine the design event discharge. By fitting a probability distribution to a series of historical floods, the AEP of a given discharge can be determined. The two principles underlying the analysis are that previous floods will re-occur with the same frequency in the future and that the flood record is an accurate representation of the general flooding behaviour, i.e. of adequate sample size.

4.2.2.2. Adopted Data Set and Probability Distribution

The FFA was undertaken as part of the Wagga Wagga Detailed Flood Model Revision and used an annual maximum series obtained for the Hampden Bridge gauge at Wagga Wagga (No. 410001).

FFA was performed on the highest recorded value of discharge for each year of record at the Hampden gauge at Wagga Wagga. Using a series of annual maximums lowers the risk of two successive peaks being dependent, and is recommended by Australian Rainfall and Runoff (ARR 2012). The annual series used is presented in the Flood Study (WMAwater, 2014).

The annual series data set can be separated into two periods, the continuous data period (1892 – 2012) and the period prior to 1892 (1838 – 1891). The details of these two sets are described in the Flood Study (WMAwater, 2014). Data for the period prior to 1892 has been incorporated into the analysis as censored data using Bayesian techniques. It was determined that two of the four major events that occurred prior to the continuous record were larger than the 1925 flood, which formed the threshold for censored events.

4.2.2.3. Hydrology Review Conclusions

The FFA methods used in the Flood Study (WMAwater, 2014) have been reviewed and are considered best practise. The employed methodology is consistent with that used in flood studies for the towns of Gundagai and Yass situated upstream in the Murrumbidgee River catchment.

4.2.2.4. Hydrology Results – Design Flows

The frequency plot at Wagga Wagga is displayed in the Flood Study (WMAwater, 2014) with design flows tabulated in Table 8 below. The frequency plot and results table display both the Log Pearson III parameter fit probability and the expected probability which accounts for sample bias. The expected probability distribution is preferred for determining flows for design events. Fitting a probability distribution to this record produced the revised 1% AEP estimate of 5,100 m^3/s at the Hampden Bridge Gauge, which is slightly smaller than the 1974 flood event (5,200 m^3/s). This flow is scaled up for input at the inflow boundary (some 35.6 km upstream) to account for attenuation through the town.

Table 8: Wagga Wagga Design Flow Estimates

Event*	Flow (m^3/s)		90% Confidence Limits	
	LP3 Parameter Fit Probability	Expected Probability	Flow (m^3/s)	Flow (m^3/s)
20%	1,000**	1,200**	900	1,500
10%	1,800	2,000	1,500	2,400
5%	2,700	2,900	2,200	3,600
2%	4,000	4,100	3,200	5,500
1%	5,100	5,100	3,900	7,400
0.5%	6,300	6,300	4,500	9,700
0.2%	7,900	8,200	5,100	14,000
PMF	28,400***	28,400***	-	-

* Event probability is displayed as AEP. Please see the Terminology Section at the beginning of this report for conversion to ARI.
** The 20% AEP event flow has been determine using methods consistent with ARR87. The annual series recurrence interval was transformed to a partial series recurrence interval with the flows determined from the respective probability distributions.
*** See Section 4.2.2.5 for explanation of the Murrumbidgee River PMF estimate.

The design flows presented in Table 8 have been applied by scaling the 1974 flood hydrograph shape for use in design flood modelling.

4.2.2.5. Wagga PMF Flow

The Burrinjuck Flood Mapping study (2004, Reference 6) provides PMF flow estimates and associated hydrographs downstream of Burrinjuck Dam. A flow of 28,400 m^3/s was determined for Wagga which has been applied to the hydraulic model as a time varying hydrograph extracted from the Reference 6 study.

Prior to this study, the PMF was simulated by estimating an “extreme event”, approximated by increasing the 1% AEP flow by a factor of 5 to produce a PMF flow at Wagga Wagga of around 34,000 m^3/s (Reference 4).

4.3. Hydraulic Model Review

4.3.1. Introduction

The Flood Study (WMAwater, 2014) performed hydraulic modelling using TUFLOW. The TUFLOW modelling package includes a finite difference numerical model for the solution of the depth averaged shallow water flow equations in two dimensions. The model is capable of dynamically simulating complex flow regimes such as those experienced on the floodplain at Wagga Wagga.

The hydraulic model extent stretches from approximately 5 km upstream of Oura to 9 km downstream of Malebo Gap giving a total river reach of approximately 63 km with a model extent of approximately 220 km^2.

The grid size utilised in the model build process is 20 m by 20 m. The model grid size was adopted following consideration of the extent of the modelling area, the required time step to satisfy the Courant criterion (relates to model stability), adequate resolution of the in-bank capacity and the resulting model run times involved.

4.3.2. Hydraulic Model Calibration/Validation

Model calibration was performed on the March 2012 flood and model validation on the December 2010 event. A variety of data was available for the calibration exercise including:

- Matching gauged flows performed by the DPIwater;
- Matching the stage hydrograph level recorded at the Hampden Bridge gauge over the course of the event;
- Matching peak flood levels obtained post both events; and
- Matching modelled extents to observed flood extents obtained via aerial imagery.

The overall calibration/validation results are considered to be good to excellent in regards to the four calibration data sets listed above and are discussed in Sections 4.3.2.1 and 4.3.2.2. The results from the calibration/validation runs imply that a high degree of confidence can be had in the Wagga Wagga design flood level estimates, particularly for the 1% AEP event.

The 1974 event model run results are described in Section 4.3.2.3. These results were used to better understand the change in stage/discharge relationship described in Section 5.2.

4.3.2.1. Calibration Summary – March 2012 Event

Comparison of modelled flows to gauged flows for the 2012 event found good agreement with the difference between modelled and observed flows being less than 1%.

The observed stage hydrograph at the Hampden Bridge gauge was matched well by the model results. The modelled flood level and timing was found to accurately represent observed conditions with a difference of 0.03 m at the peak.

The maximum difference in peak flood level between that modelled and observed is an under estimate of 0.2 m at one point and an over estimate of 0.2 m at another (i.e. the modelled level is 0.2 m lower and 0.2 m higher than that observed), however a mean absolute error of approximately 0.07 m was achieved. This calibration is based on comparison of modelled and surveyed peak flood levels at 50 locations. Variation between observed and modelled levels was not positively or negatively biased, i.e. variance was due to minor localised effects, not overall model behaviour.

A review of the spatial variance in the difference between observed peak flood levels to modelled levels revealed that for the 2012 event the model on average accurately reproduces observed flood behaviour throughout the model domain. Flood marks with large differences between modelled and observed levels tend to be scattered and are often surrounded by flood marks which have calibrated accurately.

4.3.2.2. Validation Summary – December 2010 Event

Comparison of modelled flows to gauged flows for the 2010 event found good agreement with the difference between modelled and observed flows being less than 2%.

The observed stage hydrograph at the Hampden Bridge gauge was matched well by the model results. The modelled flood level and timing was found to accurately represent observed conditions with a difference of 0.04 m at the peak.

The maximum difference in peak flood level between that modelled and observed is an under estimate of 0.3 m at one point and an over estimate of 0.3 m at another (i.e. the modelled level is 0.3 m lower and 0.3 m higher than that observed), however a mean absolute error of approximately 0.15 m was achieved. This calibration is based on comparison of modelled and surveyed peak flood levels at 19 locations. Variation between observed and modelled levels was not positively or negatively biased, i.e. variance was due to minor localised effects, not overall model behaviour.

4.3.2.3. 1974 Model Results

Comparison of modelled flows upstream of the Railway Bridge were found to accurately represent the gauged flow (at a gauge height of 10.357 m) with only 3% difference between modelled and observed.

The observed stage hydrographs at the Hampden Bridge gauge were compared to modelled flood levels. The modelled flood level and timing was found to accurately represent observed conditions with a difference of 0.03 m at the peak.

A comparison of modelled and surveyed peak flood levels at 90 locations indicated that mean absolute error of approximately 0.13 m was achieved. Variation between observed and modelled levels was not positively or negatively biased, i.e. variance was due to minor localised effects, not overall model behaviour.

4.4. Summary of Model Revisions

A number of changes have been made to the model since the Flood Study (Reference 2). These are summarised below:

- Addition of Wagga CBD Levee spillways at Kooringal Road and Wiradjuri Walking Track;
- North Wagga Levee at its existing level (previously modelled as 5% AEP design height);
- Addition of Marshalls Creek inflow;
- Addition of bridge over Marshalls Creek;
- Refinement of existing Gumly Levee;
- Addition of unofficial levees (west of North Wagga along Murrumbidgee River);
- Addition of ad-hoc levees constructed before the 2012 event along Hampden Avenue between Wiradjuri Bridge and North Wagga;
- Addition of RWCC Proposed Levee (1% AEP Level of Protection) west of East Wagga Industrial Area; and
- Levee breach scenarios for design events greater than design level of protection.

4.5. Design Results

The Flood Study (WMAwater, 2014) investigated the 5% and 1% AEP events. A requirement of the current study was modelling of a full range of design events (0.2EY, 10%, 5%, 2%, 1%, 0.5%, 0.2% AEP events and the PMF). At the completion of the project, Council will be provided with all design flood results for interpretation via GIS programs. However, for display purposes, a set of maps (Figure 4a – c to Figure 11a - c) have been produced to display flood affected regions for the various design events.

It should be noted that as described in Section 5.9.2, the CBD Levee has been raised to provide protection for the 1% AEP event using available detailed design plans provided by NSW Public Works. These works include proposed spillway designs. Other levees including the RWCC levee and informal levees along Hampden Avenue were included in the modelling using available survey and/or design drawings. Additionally, inundation patterns and/or peak flood levels shown for design events are based on best available estimates of flood behaviour within the catchment. Inundation from creek and particularly local overland flow paths have not been examined as part of this study.

Levees have been modelled to ensure design spillways become active for events that exceed the level of protection.

Table 9 displays the peak flood heights and flows at the Hampden Bridge gauge for the range of design flood events.

Table 9: Hampden Bridge Gauge – Design Peak Flood Heights and Flows

Event*	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
Peak Gauge Height (m)	9.1	9.7	10.1	10.8	11.3	11.8	12.3	16.1
Event Peak Flow (m^3/s)	1,200	2,000	2,900	4,100	5,100	6,300	8,200	28,400
Event Peak Flow (ML/day)	104,000	173,000	251,000	354,000	441,000	544,000	708,000	2,454,000

*Event probability is displayed as AEP. Please see the Terminology Section at the beginning of this report for conversion to ARI.

5. EXISTING FLOOD ENVIRONMENT AND RISK

5.1. Flood History

Since early settlement, Wagga has experienced numerous large floods, with four events (1852, 1853, 1870 and 1891) in the 1800's equalling or exceeding 10.5 m at the Hampden bridge gauge. Following significant flooding in the 1950's the CBD Levee was constructed to provide flood protection to the township of Wagga. Since the start of the 20th century, only March 2012 and August 1974 floods have exceeded 10.5 m at Wagga, with the levee affording adequate flood protection to stop inundation of the southern and main part of town for both flood events (and also for numerous other small events, including October 2016 which reached 8.95 m at the Hampden Bridge Gauge).

Table 10 displays events that exceed 9 m on the Hampden Bridge gauge with the flood of record (in terms of stage) occurring in July 1853 with a gauge height of 10.9 m. More recently, flood events in 2012, 2010 and 1974 caused significant inundation of property.

Table 10: Events Over 9 m at Wagga

Year	Month	Stage (m)
1853	July	10.9
1974	Aug	10.74
1852	June	10.67
1870	April	10.67
2012	Mar	10.60
1891	June	10.46
1925	May	10.11
1950	Mar	10.06
1900	Jul	9.96
1952	Jun	9.70
2010	Dec	9.70
1991	Jul	9.61
1931	Jun	9.60
1956	Jul	9.60
1975	Oct	9.58
1989	Apr	9.38
1976	Oct	9.38
1934	Oct	9.20
1922	Aug	9.17
1894	Apr	9.14
1959	Oct	9.07

Hampden Bridge Gauge Zero: 170.05 mAHD

5.2. Existing Flood Behaviour

Wagga Wagga has experienced riverine flooding on numerous occasions causing evacuation, considerable damage, loss of property, loss of revenue, disruption of services, disruption of lifestyle and significant inconvenience. These events have shaped the past and will continue to shape the future development of the city and the region.

After a 19-year period from 1991 without major or moderate Murrumbidgee River floods, and not even a minor flood between 1996 and 2010 (Diagram 1) the December 2010 event put flooding back on Wagga Wagga's agenda.

The most recent floods were in December 2010 (9.67 m, 10% AEP), March 2012 (10.60 m, ~2.85% AEP and October 2016 (8.95 m, <10% AEP event).

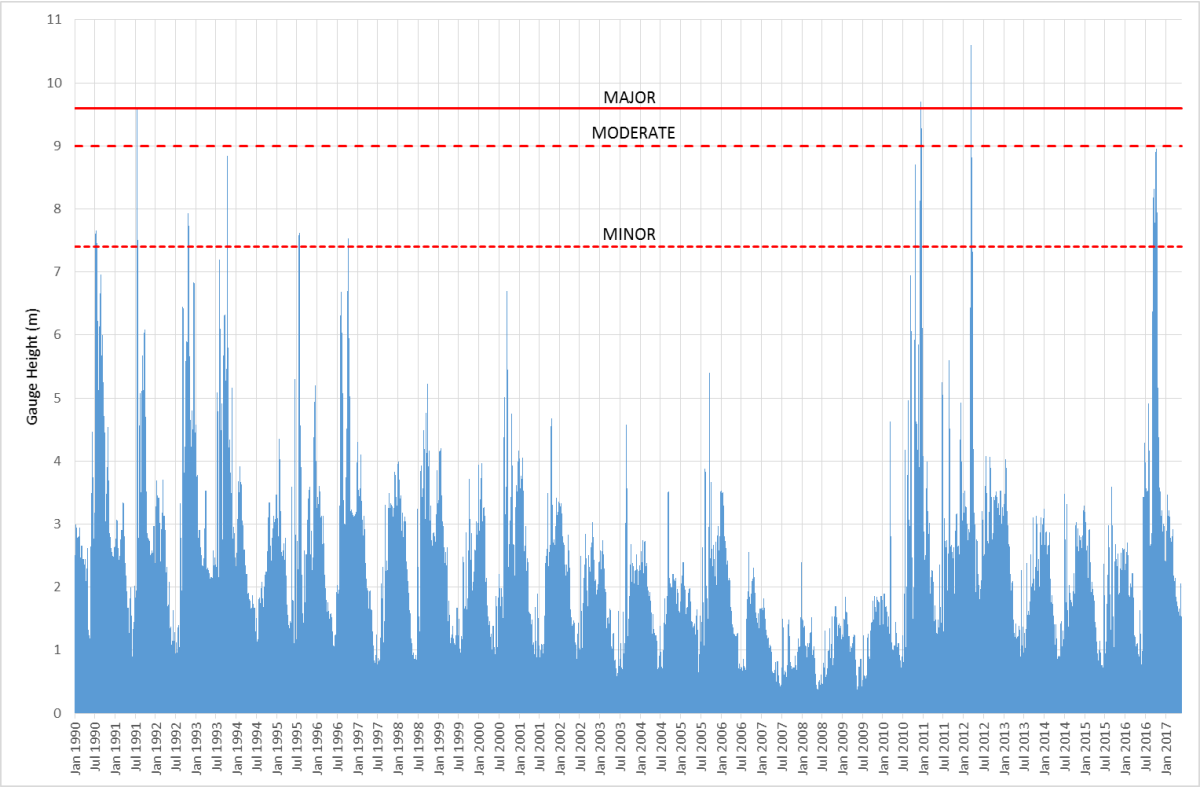


Diagram 1: Maximum Monthly Flood Peaks, Wagga Wagga gauge, Jan 1990 – Oct 2016

The magnitude of the volume of floodwaters generated by the catchment means that it is impossible to significantly reduce the peak flood flows, even with the construction of major dams such as Burrinjuck, Blowering and Tantangara in the Snowy Mountains. The main means of protecting the city from inundation has been the construction of levee banks (see Section 5.9.1) together with Council controls imposed on new development.

The rate of rise of floodwaters is related to the catchment size and influenced by the catchment slope, soil types and land use. In Wagga Wagga the rise is delayed, taking a relatively long time as the expansive storage areas of the overall floodplain are filled. The rate of rise can vary significantly between events, for example in 1974, the river rose from a flow of 1000 m^3/s at the Hampden Bridge Gauge to 5000 m^3/s in 6.5 hours, however in 2012 the same increase took less than 3 hours. Generally the duration of flooding in Wagga Wagga is extensive and while the peak may subside after a number of days, inundation in some areas may last several weeks.

In March 2012 the Murrumbidgee River flooded. Homes, businesses and land were inundated from Jugiong to Darlington Point. On the 5th of March higher than expected flood level readings at Eringoarrah forced a revision of the 10.6 m flood expected to arrive at Hampden Bridge on March 6th. The revised estimate of 10.9 m (higher than the levee design height) meant that evacuation of the entire CBD was required. An estimate of the number of people evacuated from the Wagga Wagga region is approximately 9,000, with the vast majority of these coming from the southern floodplain. The flood peaked at 10.6 m at the gauge, just below the design height of the Wagga CBD levee at the time.

North Wagga was also evacuated, however, given North Wagga levee's design height is at approximately 9.95 m on the Hampden Bridge gauge, water overtopped the levee and inundated approximately 190 homes.

Following both the December 2010 and the March 2012 events, the then NSW Department of Primary Industries Water (DPIwater) gaugings led to a revision of the rating table for the Hampden Bridge gauge (amongst other Murrumbidgee River gauges). The revision of the rating is quite substantial with approximately 25% less flow required to achieve a similar level to that predicted by the previous stage-discharge rating relationship and observed during past events. This was demonstrated by the 2012 flood, in which the peak flood level resulted from 311 GL/day whilst the previous rating (based on 1974 flood etc.) indicated that approximately 400 GL/day would be required to achieve such a stage height. The revision of the Hampden Bridge gauge rating has a substantial impact on the flood protection afforded to Wagga Wagga by the current levees. WaterNSW is now the responsible organisation for performing gaugings and updating rating tables in NSW.

As well as the 2010 and 2012 events, Wagga suffered more recently with a large rainfall event in late 2016. The river level peaked in October with a maximum gauge reading of 8.95 m at the Hampden Bridge gauge. Wagga Beach Caravan Park was evacuated as well as areas of Edward Street in the CBD. Neither the North Wagga or Wagga CBD levees were overtopped during this event meaning largescale evacuation could be avoided. The 2016 event is smaller than the design 20% AEP event, which peaks at 9.1 m at the Hampden Bridge Gauge.

Flooding in Wagga Wagga is also caused by a number of major overland flow paths, which interact with riverine flood runners. This mechanism has not been considered in this study, however the recommendations provided herein should be applied in conjunction with results from the Wagga Wagga Major Overland Flow Floodplain Risk Management Study, which is being undertaken concurrently by Council.

5.3. Hydraulic Categorisation

Hydraulic categorisation of the floodplain is used in the development of the Floodplain Risk Management Plan. The *Floodplain Development Manual* (Reference 1) describes flood prone land as belonging to one of the following three hydraulic categories (refer definition in Appendix A):

- Floodway,
- Flood Storage, and
- Flood Fringe.

Floodways are those areas where a significant volume of water flows during floods and are often aligned with obvious natural channels. They are areas that, even if only partially blocked, would cause a significant increase in flood levels and/or a significant redistribution of flood 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.

Appendix D details the methods used to determine the floodway at Wagga. Once the floodway was defined the remainder of the floodplain outside the floodway becomes either flood storage or flood fringe. In this study Flood Storage was initially defined as the land outside the Floodway where the depth is greater than 0.5 m and Flood Fringe is where the depth is less than 0.5 m. The initial definitions are then assessed using what is known as encroachment analysis. That is, for a particular floodway, the flood storage area was blocked out to approximate development, and if the reduction in conveyance resulted in an increase of greater than 0.1 m on existing flood levels, parameters were adjusted to increase the floodway area.

There is no ‘one size fits all’ method of defining a floodway with the applied approach requiring specific tailoring to suit a study area. The goal is to produce floodway extents that match flow behaviour so that the areas which need to be retained for flow are identified whilst other parts of the flood extent can be developed as appropriate.

Hydraulic categorisation of the 1% and 5% AEP events is presented in Figure 12 and Figure 13. The analysis indicates that much of the floodplain is classified as floodway in the 1% AEP event. Notably, the towns of North Wagga, Gumly Gumly and Oura are also largely classified as floodway.

Figure 12 also presents the 2009 FRMS floodway extent as purple lines for comparison to the current study floodway results. The floodways are similar in extent in the areas near the CBD Levee and the opposing bank, however do differ upstream and downstream of Wagga CBD. In particular:

- the entire area of East Wagga was previously classified as floodway, however the current study identifies a defined floodway flowing south of Copland Street, leaving much of the urban areas of East Wagga outside of the floodway extent; and
- Downstream of the Gobbagombalin Bridge, the current study floodway is significantly larger than the 2009 FRMS floodway extent. This is due to a lack of survey data available at the time of the 2009 FRMS and the associated reduced resolution of the model results.

The current study hydraulic categories supersede, and are to be used in preference, to the 2009 FRMS results.

5.4. Hydraulic Hazard Classification

The risk to life and potential damages to buildings during floods varies both in time and place across the floodplain. In order to provide an understanding of the effects of a proposed development on flood behaviour and the effects of flooding on development and people, the floodplain can be sub-divided based on hydraulic and hazard categories.

Hydraulic hazard classification plays an important role in informing floodplain risk management in an area. Previously, hazard classifications were binary – either Low or High Hazard as described in the Manual. In addition, hazard classifications were reviewed to consider a range of criteria that may impact the prevailing risk including, size of the flood, rate of rise, duration of flooding, effective warning time, flood awareness, effective flood access, evacuation problems, and type of development. Current practice is to consider a range of mapping including hydraulic hazard, hydraulic categorisation, and evacuation constraints to gain a picture of the flood risk. In addition, in recent years there have been a number of developments in the classification of hazard. Managing the floodplain: a guide to best practice in flood risk management in Australia (Australian Government, 2013) provides revised hazard classifications which add clarity to the hazard categories and what they mean in practice. The classification is divided into 6 categories, listed in Table 11, which indicate the restrictions on people, buildings and vehicles.

Table 11: Hazard Categories

Category	Constraint to people/vehicles	Building Constraints
H1	*No constraints*	*No constraints*
H2	Unsafe for small vehicles	*No constraints*
H3	Unsafe for all vehicles, children and the elderly	*No constraints*
H4	Unsafe for all people and all vehicles	*No constraints*
H5	Unsafe for all people and all vehicles	Buildings required special engineering design and construction
H6	Unsafe for people or vehicles	All building types considered vulnerable to failure

The criteria and threshold values for each of the hazard categories are presented in Diagram 2.

Diagram 2: Hazard Classifications

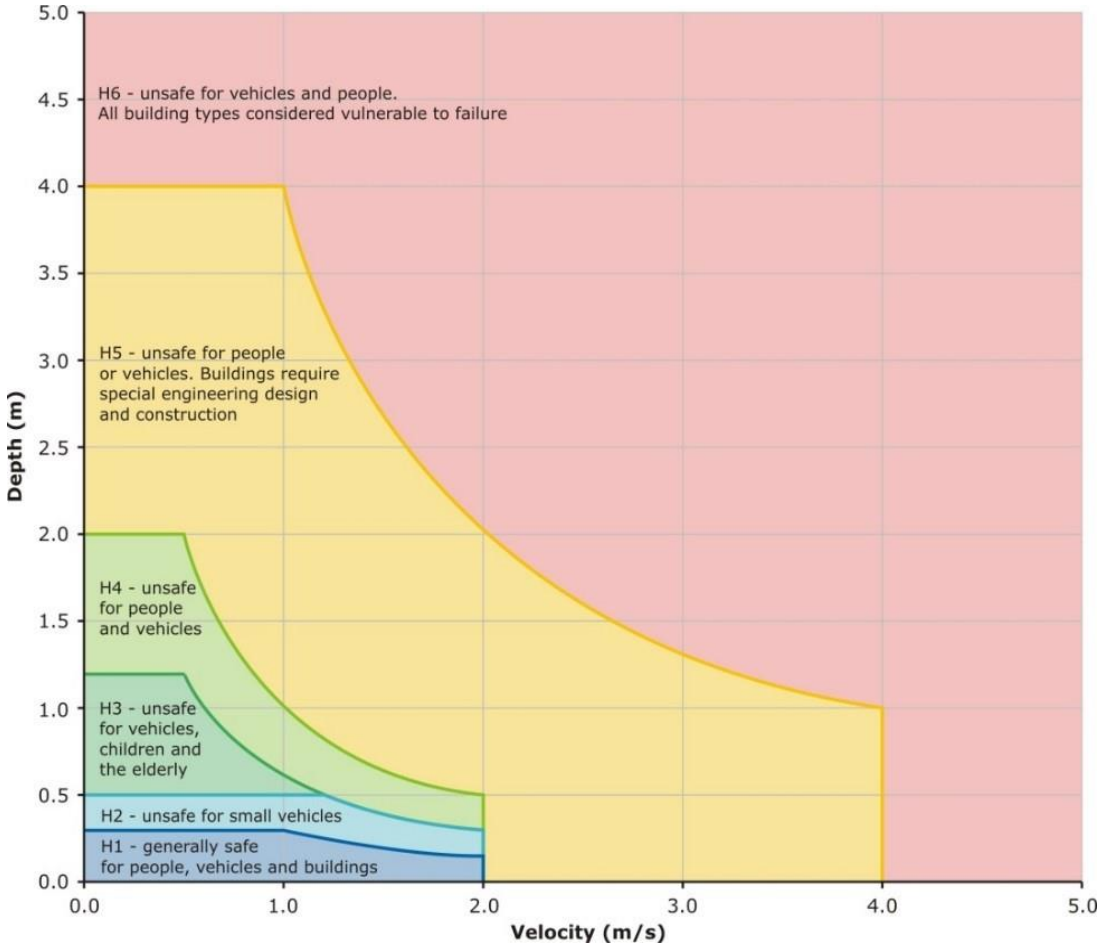


Figure 14 and Figure 15 present the hazard classifications based on the H1-H6 delineations for the 1% AEP and 5% AEP events respectively. Under this classification for a 1% AEP event much of the floodplain is classified as H5 which is considered unsafe for people or vehicles and buildings require special engineering design and construction. Areas in Gumly Gumly and

East Wagga have typically lower flood hazard ranging from H1 – H4. A more detailed discussion of flood hazard is presented in Section 5.7 for the various floodplain communities.

5.5. Evacuation Constraints

To assist in the planning and implementation of response strategies, the NSW SES in conjunction with OEH has developed guidelines to classify communities according to the impact that flooding has upon them. These Emergency Response Planning (ERP) classifications (Reference 7) consider flood affected communities as those in which the normal functioning of services is altered, either directly or indirectly, because a flood results in the need for external assistance. This impact relates directly to the operational issues of evacuation, resupply and rescue. Based on the guidelines, communities are classified as either; Flood Islands; Road Access Areas; Overland Escape Routes; Trapped Perimeter Areas or Indirectly Affected. The ERP classification can identify the type and scale of information needed by the NSW SES to assist in emergency response planning (refer to Table 12). Section 5.5.1 provides a description of each of the ERP Classification definitions.

Table 12: Emergency Response Planning Classifications of Communities

Classification	Response Required		
	Resupply	**Rescue/Medivac**	**Evacuation**
High flood island	Yes	Possibly	Possibly
Low flood island	No	Yes	Yes
Area with rising road access	No	Possibly	Yes
Area with overland escape routes	No	Possibly	Yes
Low trapped perimeter	No	Yes	Yes
High trapped perimeter	Yes	Possibly	Possibly
Indirectly affected areas	Possibly	Possibly	Possibly

Key considerations for flood emergency response planning in these areas include:

- Cutting of external access isolating an area;
- Key internal roads being cut;
- Transport infrastructure being shut down or unable to operate at maximum efficiency;
- Flooding of any key response infrastructure such as hospitals, evacuation centres, emergency services sites;
- Risk of flooding to key public utilities such as gas, power, sewerage; and
- The extent of the area flooded.

Figure 16 and Figure 17 presents the ERP classifications for the floodplain near Wagga for the 1% AEP and PMF events respectively. This has been determined by examining design flood results up to and including the PMF. These figures show that the majority of the floodplain is classified as ‘Low Flood Island’ which has restricted flood access. A more detailed discussion of ERP classifications is presented in Section 5.7 for the various floodplain communities.

5.5.1. ERP Classification Definitions

The Emergency Response Planning (ERP) classifications, defined below, have been reproduced directly from Reference 7.

5.5.1.1. Flood Islands

These are inhabited or potentially habitable areas of high ground within a floodplain linked to the flood-free valley sides by a road across the floodplain and with no alternative overland access. The road can be cut by floodwater, closing the only evacuation route and creating an island. After closure of the road the only access to the area is by boat or by aircraft. Flood islands are classified according to what can happen after the evacuation route is cut as follows:

High Flood Island - The flood island includes enough land higher than the limit of flooding (i.e. above the PMF) to cope with the number of people in the area. During a flood event the area is surrounded by floodwater and property may be inundated. However, there is an opportunity for people to retreat to higher ground above the PMF within the island and therefore the direct risk to life is limited. The area will require resupply by boat or air if not evacuated before the road is cut. If it will not be possible to provide adequate support during the period of isolation, evacuation will have to take place before isolation occurs.

Low Flood Island - The flood island is lower than the limit of flooding (i.e. below the PMF) or does not have enough land above the limit of flooding to cope with the number of people in the area. During a flood event the area is isolated by floodwater and property will be inundated. If floodwater continues to rise after it is isolated, the island will eventually be completely covered. People left stranded on the island may drown and property will be inundated.

5.5.1.2. Trapped Perimeter Areas

These would generally be inhabited or potentially habitable areas at the fringe of the floodplain where the only practical road or overland access is through flood prone land and unavailable during a flood event. The ability to retreat to higher ground does not exist due to topography or impassable structures. Trapped perimeter areas are classified according to what can happen after the evacuation route is cut as follows.

High Trapped Perimeter Area - The inhabited or potentially inhabited area includes enough land to cope with the number of people in the area that is higher than the limit of flooding (i.e. above the PMF). During a flood event the area is isolated by floodwater and property and may be inundated. However, there is an opportunity for people to retreat to higher ground above the PMF within the area and therefore the direct risk to life is limited. The area will require resupply by boat or air if not evacuated before the road is cut. If it will not be possible to provide adequate support during the period of isolation, evacuation will have to take place before isolation occurs.

Low Trapped Perimeter Area - The inhabited or potentially inhabited area is lower than the limit of flooding (i.e. below the PMF) or does not have enough land above the limit of flooding to cope with the number of people in the area. During a flood event the area is isolated by floodwater and property may be inundated. If floodwater continues to rise after it is isolated, the area will eventually be completely covered. People trapped on the island may drown.

5.5.1.3. Areas Able to be Evacuated

These are inhabited areas on flood prone ridges jutting into the floodplain or on the valley side that are able to be evacuated. However, their categorisation depends upon the type of evacuation access available, as follows:

Areas with Overland Escape Route - are those areas where access roads to flood free land cross lower lying flood prone land. Evacuation can take place by road only until access roads are closed by floodwater. Escape from rising floodwater is possible but by walking overland to higher ground. Anyone not able to walk out must be reached by using boats and aircraft. If people cannot get out before inundation, rescue will most likely be from rooftops.

Areas with Rising Road Access - are those areas where access roads rising steadily uphill and away from the rising floodwaters. The community cannot be completely isolated before inundation reaches its maximum extent, even in the PMF. Evacuation can take place by vehicle or on foot along the road as floodwater advances. People should not be trapped unless they delay their evacuation from their homes. For example people living in two storey homes may initially decide to stay but reconsider after water surrounds them.

5.5.1.4. Indirectly Affected Areas

Areas which are outside the limit of flooding and therefore will not be inundated nor will they lose road access. However, they may be indirectly affected as a result of flood damaged infrastructure or due to the loss of transport links, electricity supply, water supply, sewage or telecommunications services and they may therefore require resupply or in the worst case, evacuation.

5.5.1.5. Overland Refuge Areas

Areas that other areas of the floodplain may be evacuated to, at least temporarily, but which are isolated from the edge of the floodplain by floodwaters and are therefore effectively flood islands or trapped perimeter areas. They should be categorised accordingly and these categories used to determine their vulnerability.

5.6. Summary of Existing Property Flood Affectation

Floor level estimates (Section 2.5.1) and design results were used to identify flood affectation for individual properties and to determine what AEP is responsible for over floor flooding in the first instance.

5.6.1. Residential and Non Residential Property Flood Affectation

Table 13 details the total number of properties flooded in each design event for the Murrumbidgee River floodplain at Wagga Wagga and Table 14 presents the above floor flood liability of various floodplain precincts within the Study Area.

Table 13: Number of Flood Prone Residential Properties

Event	Residential Properties		Non Residential Properties	
	No. Properties Affected	No. Flooded Above Floor Level	No. Properties Affected	No. Flooded Above Floor Level
10% AEP	45	30	12	11
5% AEP	257	190	50	44
2% AEP	353	301	112	103
1% AEP	395	347	202	192
0.5% AEP	1737	1564	665	606
0.2% AEP	2671	2619	1065	1042
PMF	3393	3380	1351	1348

NOTE: Properties affected are those where there is flooding above ground level within the property boundary (ie the lot). This does not necessarily mean that any buildings on the property are flooded or that the entire lot is inundated.

Table 14 indicates that the large majority (2,893 or 86%) of properties flooded above floor in the PMF are situated in Wagga CBD behind the CBD Levee. For events smaller than the 1% AEP, North Wagga has the largest degree of above floor liability with 158 properties flooded in the 5% AEP and 198 properties flooded in the 1% AEP. The townships of Gumly Gumly and Oura also have significant flood liability during more frequent events with 35 and 31 properties flooded above floor level in the 1% AEP event respectively.

Table 14: Residential Properties Flooded Above Floor Level – by Precinct*

Event	Wagga CBD	East Wagga	North Wagga	West Wagga	Gumly	Oura	Wagga Floodplain	Eunony	Total
10% AEP	0	1	12	10	2	0	5	0	**30**
5% AEP	0	2	158	18	4	0	7	1	**190**
2% AEP	0	19	198	25	15	28	12	4	**301**
1% AEP	0	34	198	29	35	31	15	5	**347**
0.5% AEP	1177	40	202	32	56	33	17	7	**1564**
0.2% AEP	2206	45	203	39	60	38	19	9	**2619**
PMF	2893	74	203	56	65	44	25	20	**3380**

* Region delineation presented in Figure 2.

Table 15 indicates that 1,348 non-residential properties are flooded above floor level in the PMF, with the large majority (1,069 or 74%) of these situated in Wagga CBD behind the CBD Levee. For events smaller than the 1% AEP, East Wagga has the largest degree of above floor liability with 70 properties flooded in the 2% AEP and 155 properties flooded in the 1% AEP.

Table 15: Non-Residential Properties Flooded Above Floor Level – by Region*

Event	Wagga CBD	East Wagga	North Wagga	West Wagga	Gumly	Oura	Wagga Floodplain	Eunony	Total
10% AEP	0	4	0	4	0	0	3	0	11
5% AEP	0	15	16	5	1	2	4	1	44
2% AEP	0	70	17	7	1	3	4	1	103
1% AEP	0	155	17	8	3	3	4	2	192
0.5% AEP	360	205	17	9	6	3	4	2	606
0.2% AEP	781	215	17	12	7	3	4	3	1042
PMF	1069	220	17	22	7	3	6	4	1348

* Region delineation presented in Figure 2.

5.7. Summary of Community Flood Risk

Summaries of the flood risk associated with Murrumbidgee River flooding for the various floodplain communities described in Section 2 and reproduced in Table 16 below, are provided in the following sections.

Table 16: Floodplain Communities

Community	Description
Oura	Oura community
Gumly Gumly	Gumly Gumly community to the north of Sturt Highway
North Wagga	land protected by the North Wagga Levee (including Mill/East Streets)
Wagga Floodplain	areas on the floodplain between North Wagga and Eunony Bridge Road
West Wagga	all regions on the floodplain to the west of North Wagga
Wagga CBD	all regions protected by the Wagga CBD Levee
East Wagga	area on the southern floodplain between Wagga CBD and Gumly
Eunony	areas on the floodplain between Eunony Bridge Road and Oura

Table 17 further summaries the communities' flood risk in tabular form for the 5% AEP, 1% AEP and PMF events. The number of properties flooded above floor and the maximum depth of flooding above floor, provide an indication of the degree of flood risk. For example the Eunony community has relatively limited flood risk in the 5% AEP event if residents stay in their homes as only one property is flooded to a maximum flood depth above floor of 0.1 m. On the other hand, the Wagga Floodplain community has ten properties that are flooded above floor in the 5% AEP event to a maximum depth of 2.4 m which would pose a significant risk to life.

5.7.1. Oura

Oura is a village of about 64 dwellings, located on the northern Murrumbidgee River floodplain about 15-16 km (as the crow flies) upstream of the Wagga Wagga gauge. The village abuts high land, which for most of the village provides Rising Road Access to flood-free land, even though during larger floods Oura is likely to be isolated from Wagga Wagga to the west and possibly also from Wantabadgery and Junee to the east.
In the August 1974 flood, the Local Flood Plan records that a large proportion of the village was flooded, with buildings in Short, Mitchell, Adams, Oura, Wagga Wagga, Davidson and Barney Streets affected.

In the March 2012 flood, about seven houses were reported to be flooded over floor, with several others flooded to just below floor level. Several households had to evacuate hurriedly in the middle of the night to higher land. One issue identified was that the local evacuation centre designated in the Local Flood Plan (the Presbyterian Church) could not be accessed.

The flood modelling and exposure database suggests that it is in floods rarer than the 5% AEP event that significant effects begin to occur, with 28 houses likely to flood above floor level in the 2% AEP event and 31 houses flooded in the 1% AEP event. Flood depths above floor level of up to 1.3 m are experienced in the 1% AEP flood (Table 17).

Of the 64 dwellings, 44 are estimated to be flooded above floor in the PMF, with 20 homes not flooded.

During a flood, several dwellings located on the southwest side of Wagga Wagga Street can be isolated during events as small as the 5% AEP, before being inundated, representing a more dangerous Low Flood Island setting. During the 5% AEP event a flow path along Wagga Wagga Street, with fast flowing, deep water cuts the only available evacuation routes to higher ground for these residential properties. This flood characteristic is classified as a floodway (see Section 5.3) extending northwest along Wagga Wagga Street in both the 1% AEP and PMF events. This floodway region encompasses a large number of houses with the remainder of the town mostly classified as flood storage or situated beyond the PMF extent.

Residential properties on the floodplain are classified as H6 hazard in the PMF and H3 – H5 hazard in the 1% AEP event (presented in Figure 15 and Figure 14 respectively).

5.7.2. Gumly Gumly

For the purposes of this analysis, Gumly Gumly is defined as the area between East Wagga and Forest Hill, north of the Sturt Highway and south of the Murrumbidgee River. It is a relatively flat area. A few depressions (possibly abandoned river courses) cross the floodplain and during rising floods cut access to portions of the sector. These include the area around Gumly Common, which is cut at the Graham Avenue culvert at about 8.2 m on the Wagga Wagga gauge, isolating six dwellings, and the entire area north of low points on Pioneer Avenue and the western end of Gumly Road, cut at about 8.5 m on the Wagga Wagga gauge, isolating about 43 dwellings. In severe floods, virtually the entire area north of these low-points can be flooded subsequent to loss of access, so the Emergency Response Classification is properly categorised as a dangerous Low Flood Island setting. Towards Sturt Highway, there may be more opportunity for uninterrupted evacuation, though the Sturt Highway can be cut at East Wagga near Marshalls Creek.

During a 1% AEP flood event, 35 properties are flooded above floor level to a maximum depth of 1.3 m (see Table 17). As mentioned above, many of these homes are isolated prior to the flood peak, sometimes by several days. The majority of properties are situated in areas of H1 to H3 hazard flooding during the 1% AEP event.

Gumly village is protected from some flooding by a levee. The design of height of the levee is 9.6 m (on the Wagga Wagga gauge) plus 0.15 to 0.3 metres of freeboard. This levee failed during the March 2012 flood event.

In the March 2012 flood, about four houses were reported to be flooded to serious depths over floor, with three others flooded to almost floor level. The SES issued an Evacuation Order for Gumly, and it is estimated that just under half the population evacuated. Family members insisted that their elderly relatives evacuated. However, the overall, relatively low level of compliance with the Evacuation Order points to the community's self-sufficiency and confidence in assessing and managing floods itself.

Figure 15 indicates, the consequences for Gumly Gumly in a low probability flood such as the PMF would be extreme – the depths would be such that houses would be washed away, and lives would be at great peril. Previous flood events do not provide context for an event of this magnitude, and if evacuation prior to the loss of road routes was poor, remaining residents would require rescue by boat or helicopter, in dangerous conditions. In a PMF, the modelled rate-of-rise[1] from about 10.0 m to 13.0 m on the gauge is modelled at about 1.0 m/hr, which could make it difficult for emergency responders to respond in a timely fashion given the likelihood for many concurrent time-sensitive requests for assistance.

[1] Note: the rate-of-rise is based on modelling work undertaken as part of the Burrinjuck Flood Mapping Study (Reference 6) (see Section 4.2.2.5) and could differ during an actual event.

5.7.3. North Wagga

North Wagga levee provides protection to 203 dwellings, though recent flood modelling suggests that the levee commences to overtop at about the 8 year ARI flood (~12% AEP) (See Section 5.9.1.2). Some credible reports exist of the levee being observed to overtop near the Black Swan Hotel below 9.6 m on the Wagga Wagga gauge during the March 2012 flood, which is 0.3 m below the current design height. In this event, the vast majority of houses within the protected area were flooded, to depths of up to 2 metres.

In the 5% AEP event, 156 houses are estimated to flood above floor level, to a maximum depth of 1.6 m (Table 17). The frequency and severity of flooding explains why North Wagga contributes so significantly to the overall annual flood damages for the study area.

The North Wagga Levee also represents a serious risk to life due to the isolation faced by residents during flood events. There is some uncertainty about the integrity and maintenance of the 'temporary' levees constructed along Hampden Avenue, which forms the evacuation route to Wagga Wagga (and if necessary, thence to Estella). Even with these informal levees are disregarded, North Wagga (behind the levee) becomes a High Flood Island from about 9.0 m on the Wagga Wagga gauge – about a 0.2EY event – and a Low Flood Island from about 9.6 m on the gauge when the levees begin to overtop – about an 8 year ARI event (~12% AEP). People failing to evacuate prior to inundation of the evacuation route will at least be isolated – for 2 - 3 days. This occurred in the December 2010 flood. But if floodwaters overtop the levee, they could be forced to retreat to refuge areas (e.g. spectator mounds at the oval) or rooftops, and require rescue.

Hydraulic hazard maps show that in a 1% AEP event, significant areas within North Wagga (within the levee) would be at H5 hazard conditions, which poses a danger to buildings, though for the most part the hazard at buildings is a little less. In a PMF, however, the entire area would be subject to extremely dangerous H6 conditions.

5.7.4. Wagga Floodplain

The Wagga Floodplain region encompasses the area to the north of Wagga CBD on the Murrumbidgee River floodplain not including North Wagga. It is a sparsely populated region occupied mostly for the purposes of primary production. Approximately 30 properties in the region, residential and non-residential, are flooded affected in the PMF event.

Ten houses are flooded above floor in the 5% AEP event which is a large proportion for an event of such magnitude given the small population (Table 17). Flood depths above floor level exceed 2 m in some instances indicating a high degree of flood liability.

There are several houses in the Wagga Floodplain region which have high set floors and despite areas of their property flooding in smaller events, inundation over floor is prevented up to the 1% AEP event. Although this offers benefits in terms of damages it can often create a reluctance to evacuate in residents, which can be dangerous if flood waters exceed predictions.

Planning controls applied following the 1974 flood required floor levels for all new development to be set at the 1974 level plus freeboard – the 1974 event was assumed to equate to a 1% AEP event at the time. Over time, this level of protection has decreased as the 1% AEP design level has changed. The peak flow during the 1974 event was approximately 5,200 m^3/s, which produced a peak at the gauge of 10.74 m. The 1% AEP peak design flow is estimated to be 5,100 m^3/s producing a peak level of 11.3 m at the gauge. Design flood changes can be attributed to a number of factors discussed in Section 4.4.

A large area of the Wagga Floodplain has been classified as low flood island for emergency response planning in both the 1% AEP and PMF events. The region becomes isolated during relatively small events with Hale Street, Hampden Road and Oura Road all being inundated up to 0.5 m in the 20% AEP event. There is also a small northern perimeter classified as having overland escape routes or rising road access.

Almost total inundation of the region occurs by the 5% AEP event with an elevated flood island near Hale Street and Hinkler Street. Excluding this flood island, the region is classified as floodway in both the 1% AEP and PMF events. The majority of the Wagga Floodplain has also been classified as H5 hazard during the 1% AEP event and is unsafe for people and vehicles. In the PMF event this hazard classification is upgraded to H6 meaning the area is unsuitable for people, vehicles or buildings.

5.7.5. West Wagga

West Wagga (as specified for this study) is a large, sparsely populated floodplain community. It is mostly characterised by large properties for primary production. The Wagga sewage treatment plant is located within West Wagga, to the northwest of Wagga CBD (see Section 5.8.1.3).

The majority of West Wagga is classified as a Low Flood Island as two anabranches isolate areas to the north and south of the Murrumbidgee River. Areas not classed as Low Flood Island are typically classified as Rising Road Access. Key access roads such as River Road and Edward Street West are cut at 7.4 m and 7.6 m respectively on the Hampden Bridge gauge isolating properties in events as small as a 3 year ARI. Old Narrandera Road is cut in events exceeding the 5% AEP.

There is a total of approximately 80 properties, both residential and non-residential, which are flooded over floor in the PMF event. During a 1% AEP event, 30 properties are flooded above floor level by depths exceeding 3 m (Table 17), indicating a high degree of flood hazard for residents who do not evacuate. The Low Flood Island setting further increases hazard as residents who do not evacuate early cannot self-evacuate later on.

Hydraulic hazard classifications identify the majority of West Wagga as H5 level hazard during the 1% AEP. In the PMF event the entire West Wagga region is H6 hazard (see Section 5.4).

5.7.6. Wagga CBD

The Wagga Central Business District (Wagga CBD) is afforded protection by the CBD Levee which is currently being raised to provide protection for floods up to a 1% AEP event. However, even with the increased flood protection associated with raising the levee, a residual risk is still present for larger flood events. It must be noted that the levee does not provide flood protection for overland flow flooding that can occur behind the levee.

During a PMF event 4,700 residential and non-residential buildings, are predicted to be flooded above floor level in the Wagga CBD. Properties north of the Sturt Highway are situated in a Low Flood Island Emergency Response Precinct (ERP) classification (see Section 5.5), with areas to the south of this road generally classified as Rising Road Access thus allowing vehicular evacuation. The vast majority of the floodplain within the Wagga CBD is classified as H6 hazard (see Section 5.4) during the PMF which would mean the majority of buildings are vulnerable to failure. Flood depths above floor level exceed 8 m during a PMF event (Table 17).

Significant flood affectation would also occur during the 0.5% and 0.2% AEP events with 1,500 and 2,400 residential and non-residential buildings flooded above floor in these events.

In addition to significant property flood affectation, various vital infrastructure and critical and vulnerable land uses are also subject to flooding in events larger than the 1% AEP within the Wagga CBD (see Section 5.8).

Total evacuation of the Wagga CBD is required should a peak flood exceeding the levee's design height be predicted. Sufficient warning time should be available for people's evacuation, however as seen in the March 2012 event, changes in floodplain behaviour can causes issues with flood forecasting and prediction.

Table 17: Community Risk Summary

Community *	5% AEP design flood				1% AEP design flood				PMF				Emergency Response Classification*
	Residential		Non-residential		Residential		Non-residential		Residential		Non-residential		
	Flooded over floor	Max depth over floor	Flooded over floor	Max depth over floor	Flooded over floor	Max depth over floor	Flooded over floor	Max depth over floor	Flooded over floor	Max depth over floor	Flooded over floor	Max depth over floor	
Wagga CBD	0	-	0	-	0	-	0	-	2,894	7.8	1,069	9.6	High Flood Island; Low Flood Island (>10.7m)
East Wagga	2	0.6	13	0.6	34	1.7	154	2.0	73	6.5	219	6.8	Mostly Low Flood Island; Some Rising Road Access or Overland Escape Route
North Wagga	156	1.6	16	1.0	198	2.7	17	2.3	203	7.5	17	7.1	High Flood Island (>9.0m); Low Flood Island (>9.6m)
West Wagga	19	2.1	5	2.0	30	3.3	8	2.0	57	8.3	22	8.0	Mostly Low Flood Island Some Rising Road Access or Overland Escape Route

Community *	5% AEP design flood				1% AEP design flood				PMF				Emergency Response Classification*
	Residential		Non-residential		Residential		Non-residential		Residential		Non-residential		
	Flooded over floor	Max depth over floor	Flooded over floor	Max depth over floor	Flooded over floor	Max depth over floor	Flooded over floor	Max depth over floor	Flooded over floor	Max depth over floor	Flooded over floor	Max depth over floor	
Gumly Gumly	4	0.6	1	0.1	35	1.3	3	1.1	65	5.6	7	5.2	Mostly Low Flood Island; Some Overland Escape Route near Sturt Hwy
Oura	0	-	2	0.5	31	1.3	3	1.7	44	6.5	3	6.8	Mostly Rising Road Access; Low Flood Island west of Wagga Wagga St
Wagga Floodplain	10	2.2	6	2.4	18	3.4	7	3.5	26	8.2	7	8.3	Mostly Low Flood Island; Some Rising Road Access or Overland Escape Route
Eunony	1	0.1	1	0.4	5	1.1	2	1.6	20	8.2	4	8.3	Mostly Low Flood Island
TOTAL	192		43		351		193		3,382		1,347		

* Region delineation presented in Figure 2. See Section 5.5 for further details on Emergency Response Classifications.

5.7.7. East Wagga

East Wagga is a predominantly industrial/commercial hub situated on the southern bank of the Murrumbidgee between Marshalls Creek and Kooringal Road. A defining characteristic of this region is the large number of businesses and relatively small number of residential properties. Council's planning policy requires that non-residential floor levels are built above the 5% AEP level plus a freeboard which reduces flood affectation for smaller events, however in the 1% AEP 149 non-residential and 34 residential properties are flooded above floor level by depths of up to 2 m (see Table 17).

Residential properties south of Hammond Avenue are typically elevated enough to provide some refuge from floodwaters during smaller flood events. The inverse impact of this feature is that these properties can become isolated on a Low Flood Island in rarer events (see Section 5.5). For example, in March 2012 floodwaters cut access along Hammond Avenue and Copland Street for more than two days. Hammond Avenue is completely inundated during the 2% AEP event which would severely hinder egress.

Flood hazard in East Wagga is typically classified as H3 to H4 during the 1% AEP event, and H6 in the PMF event (see Section 5.4).

5.7.8. Eunony

Eunony (as specified for this study) is a large, sparsely populated floodplain community. Numerous homes are situated above the 1% AEP flood level on higher land but are isolated by high hazard flood waters during the 1% AEP event. During the 1% AEP event 5 properties are flooded above floor to a maximum depth of 1.1 m and flood hazard ranges from not flood affected to H5 category hazard (see Section 5.4).

24 residential and non-residential properties are flooded over floor level in the PMF event. The maximum depth above floor exceeds 8 m during the PMF event and all properties are affected by H6 category hazard.

Key access roads, such as Oura and Eunony Bridge Roads, which provide vital evacuation routes for Eunony are flooded by depths exceeding 0.5 m during the 20% AEP event. As such Eunony is largely classified as a Low Flood Island (see Section 5.5), with 15 properties situated in this classification.

5.8. Public Infrastructure and Other Land Uses

Susceptible public sector (non-building) flood liabilities include; recreational/tourist facilities; water and sewerage supply; gas supply; telephone supply; electricity supply including transmission poles/lines, sub-stations and underground cables; rail; roads and bridges including traffic lights/signs and emergency services. Public sector flood affectation can contribute significantly to flood risk and should be considered.

5.8.1.1. Electricity

Essential Energy was contacted about potential flood risk to electrical infrastructure, however did not provide a response.

5.8.1.2. Water Supply

Wagga's potable water is supplied by Riverina Water Country Council (RWCC). RWCC own and operate three water treatment facilities that are presented in Table 18 along with their approximate capacity and flood liability.

Table 18: RWCC Water Treatment Facilities

Location	Capacity	Flood Liability (AEP)	Flood Liability (Hampden Bridge Gauge height)
Hammond Avenue near Marshalls Creek	~ 80 ML/day	Currently ~5% AEP. Existing ring levee is proposed for upgrade to provide 1% AEP protection. Due for completion 2018 financial year.	Currently 10.1 m Upgrade to provide protection to 11.3 m
West Wagga at Olympic Highway / McNickle Road	~ 25 ML/day	Not flood affected until events larger than the 0.2% AEP. Flooded by 2 m depth in the PMF.	Not flood affected until events greater than 0.2% AEP. Flooded by 2 m when gauge height is at 16.1m
North Wagga off East Street	~ 10 ML/day	Currently ~ 10% AEP.	Currently 9.7 m

The flood liability of these facilities is important for consideration as they cannot treat water once they have become flooded. Once flooded, it would take approximately one week for the facilities to become operational. Additionally, interruption to electricity supply would make these facilities non-operational.

All water treatment facilities currently pump into storage tanks so that they can be gravity fed into the town's water supply. The storage tanks only contain enough water to service Wagga for approximately one day.

This analysis indicates that if the Hammond Avenue facility were to become inundated, the water supply at Wagga would be significantly affected for an extended period. This should be considered as part of Wagga's Local Flood Plan.

5.8.1.3. Sewerage

Wagga Wagga is currently serviced by three sewage treatment plants, all operated by Wagga Wagga City Council and located within close proximity to the CBD. Narrung Street Sewage Treatment Plant is the largest plant in the area and is located just 2 km north of the city centre. It treats both domestic and industrial sewage housing various ponds and tanks as well as sludge lagoons for biological digestion. This facility poses a serious risk of contamination to the surrounding region during flooding as floodwater can lead to effluent overflow from tanks and ponds. It is affected by the 20% AEP event with flood depths of approximately 1.5 m.

Further, the Kooringal and Forest Hill Sewage Treatment Plants are both located 7 - 8 km to the east of the city. They treat mostly domestic as well as light industrial sewage, containing similar tanks and lagoons to the Narrung Street facility. The Forest Hill Plant also services the RAAF base. Similar to the Narrung Street facility these plants both present serious contamination risks to the local area during flood events. Kooringal is unaffected by the PMF event but may be subject to significant overland flow. Areas of the Forest Hill plant are first affected by the 20% AEP event.

5.8.1.4. Schools

North Wagga Public School
54 Hampden Ave, Wagga Wagga NSW 2650
North Wagga Public school is afforded the protection of the North Wagga levee for events up to and including the 10% AEP. For events larger than this, the North Wagga levee is overtopped and the school property is significantly affected by the 5% AEP event. During the PMF, the school is flooded to a depth of approximately 6 m.

Wagga Wagga Public School
Gurwood St, Wagga Wagga NSW 2650
Wagga Wagga Public School is first affected by the 0.2% AEP event with relatively minor flooding in the school grounds during this event. The school becomes isolated once the CBD Levee is overtopped. The school property and buildings are completely inundated during the PMF event to a depth of approximately 2.5 m.

St Joseph's Primary School
Johnston St, Wagga Wagga NSW 2650
The grounds of St Joseph's Primary School are first affected by the 0.2% AEP event with some of the school buildings also flooded over floor level. The school becomes isolated once the CBD Levee is overtopped. The school is inundated by the PMF event to a depth of approximately 5 m.

South Wagga Public School

140 Edward St, Wagga Wagga NSW 2650

South Wagga Public School is flood affected by events approaching the magnitude of the PMF event. During the PMF, the school buildings are flooded over floor to a depth of approximately 2.5 m.

Wagga Wagga Christian College

401 Kooringal Rd, Kooringal NSW 2650

Wagga Wagga Christian College grounds are first affected by the 1% AEP event over a small area along the northernmost property boundary with flood depths of up to 1.5 m. During the 0.5% AEP event the oval and grounds to the north of the school buildings become inundated to a depth of 1 m. School buildings are also first flooded over floor level during the 0.2% AEP event to depths of 0.5 m. During the PMF the school is inundated with depths up to 4 m. Kooringal Road, near the entrance of the school, remains unaffected during all events meaning that the school does not become isolated and evacuation is possible.

5.8.1.5. Childcare Centres

Table 19 presents a risk summary for all childcare centres in the study area. Note that the details provided in Table 19 pertain to flood behaviour post the CBD Levee upgrade and current emergency response protocol should be followed until the levee upgrade is complete.

Table 19: Childcare Centres Risk Summary

Name	Address	First Flooded Ground/ Floor	ERP Class	Description
Central Wagga Childcare Centre	58 Evans Street, Wagga Wagga	0.5% AEP / 0.5% AEP	LFI	Floods to a level of 1.5 m during the 0.5% AEP. Becomes completely inundated to approximately 2 m during the PMF event.
Goodstart Early Learning Wagga Wagga (Morgan)	184 Morgan Street, Wagga Wagga	0.2% AEP / 0.2% AEP	RRA	Access blocked during 0.5% AEP event with 1 m depths on Morgan Street. Completely inundated to depths of 5 m during the PMF event.
Goodstart Early Learning - Wagga Wagga (Station)	6/10 Station Place, Wagga Wagga	PMF / PMF	RRA	Flooded to depth of 2.5 m during the PMF event.
Goodstart Early Learning	6 Kenneally Street, Kooringal	Not Affected	-	-
Possums Playground Occasional Child Care Inc.	7 Forsyth Street, Wagga Wagga	0.5% AEP / 0.5% AEP	LFI	Surrounding roads become inundated during the 0.5% AEP event isolating the centre. This event also floods the centre over floor level to minor depths. Flooded to approximately 6.5 m during the PMF event.
St Luke's Preschool	70 Docker Street, Wagga Wagga	0.2% AEP, PMF	RRA	Areas of the property first flooded during 0.5% AEP event to minor depths of 0.25 m and access via Shaw and Docker Streets is blocked by floodwater. Flooded over floor to 5 m depth during PMF event.
St Mary's Rainbow Preschool	2 George Street, Wagga Wagga	5% AEP / 5% AEP	LFI	Becomes isolated during the 5% AEP event with depths up to 1 m on George and William Street. Completely inundated to 7 m during PMF event.
Goodstart Early Learning Wagga Wagga (Lake)	270/274 Lake Albert Road, Wagga Wagga	Not affected	-	-
Wagga Wagga Early Years Learning Centre	57 Fernleigh Road, Wagga Wagga	Not Affected	-	-
Pe4k Childcare Wagga	117 Ashmont Avenue, Wagga Wagga	PMF / PMF	RRA	Entire property inundated to depths of approximately 5 m during PMF event and access via Sturt Highway and Ashmont Avenue cut.
Kings Kids Early Learning Centre	555 Kooringal Road, Wagga Wagga	Not Affected	-	-
KU Kangaroo Preschool	11 Marloo Crescent, Wagga Wagga	Not Affected	-	-
KU Kingfisher Preschool	Bolger Avenue, Wagga Wagga	Not Affected	-	-
Note: this list is based on Wagga CBD levee upgrade scenario				

Name	Address	First Flooded Ground/ Floor	ERP Class	Description
KU Koala Preschool	61 Murray Street, Wagga Wagga	0.2% AEP/PMF	RRA	Access restricted during the 0.2% AEP as Murray Street, Morgan Street and Oates Avenue are flooded to depths of approximately 0.5 m. Entire property inundated to depths of 5 m during PMF event.
KU Kookaburra Preschool	82 Coleman Street, Wagga Wagga	Not Affected	-	-
Shaw Street Children's Centre	6 Kent Crescent, Wagga Wagga	0.5% AEP / 0.5% AEP	LFI	Inundated up to 1 m during the 0.5% AEP event with Shaw Street and S Parade inundated to similar depths preventing access. Entire property flooded up to 6m during PMF event.
Angel's Paradise Adaptive Montessori	33 Cootamundra Boulevard, Gobbagombalin	Not Affected	-	-
Spring Kidz Early Learning Centre	10 Burrundulla Road, Wagga Wagga	Not Affected	-	-
Wiradjri Aboriginal Community Child Care Centre Corp.	155 Docker Street, Wagga Wagga	PMF / PMF	LFI	Entire property flooded up to 6 m depths during PMF event. Access via Docker Street restricted during 0.2% AEP event with road inundated to 1 m depth.
Amy Hurd Early Learning Centre	2 Kulgoa Street, Kooringal	Not Affected	-	-
Note: this list is based on Wagga CBD levee upgrade scenario				

5.8.1.6. Aged Care Facilities

Table 20 presents a risk summary for all aged care facilities in the study area. Note that the details provided in Table 20 pertain to flood behaviour post the CBD Levee upgrade and current emergency response protocol should be followed until the levee is upgrade is complete.

Table 20: Aged Care Facility Risk Summary

Name	Address	First Flooded Ground/ Floor	ERP Class	Description
The Haven Community	156 Bourke Street, Wagga Wagga	Not Affected	-	-
The Remembrance Village	50-56A McKell Avenue, Mount Austin	Not Affected	-	-
BaptistCare Caloola Centre	Plumpton Road, Wagga Wagga	Not Affected	-	-
Riverina Gums Retirement Village	44 Dalman Parkway, Wagga Wagga	Not Affected	-	-
BaptistCare Watermark	14-20 Church Street, Wagga Wagga	20% AEP / 0.2%AEP	LFI	This village is situated in very close proximity to the river and suffers flood minor affectation in small events before the levee overtops. It becomes isolated in the 0.2% AEP event as surrounding main roads, Tarcutta and Johnston Street, are inundated. In the PMF event the entire village is flooded to approximately 5m depth.
Gumleigh Chauncy Lodge Retirement Village, Gumleigh Gardens – UPA Riverina and Gumleigh Gardens Hostel	21-23 Albury Street, Wagga Wagga and 29-35 Shaw Street, Wagga Wagga	0.5% AEP / 0.5% AEP	LFI	Surrounding roads including Albury Street, Shaw Street, Bolton Street and Docker Street become inundated up to 1m depth in the 0.5% AEP event isolating the property. Areas of the facility are also flooded over floor in this event. The entire area is flooded to 6 m depth during the PMF event.
Wagga Gardens	52 – 54 Travers Street, Wagga Wagga	0.5% AEP / 0.5% AEP	LFI	The northern boundary of the property and the northern buildings become inundated during the 0.5% AEP event. During the PMF event the entire facility is inundated to depths of 6m.
Rosebank Retirement Village	12 Thomas Street, Wagga Wagga	0.5% AEP / 0.5% AEP	LFI	The majority of the grounds and buildings are flooded during the 0.5% AEP event to approximately 1.5 m depth. The entire village is inundated to approximately 7 m depth during the PMF event.
Abbeyfield Australia	29 Wiradjuri Crescent, Wagga Wagga	0.5% AEP / 0.5% AEP	LFI	Surrounding roads become inundated during the 0.5% AEP event isolating the retirement village. Many houses also flood over floor during this event. During the PMF event, the entire village is flooded to approximately 9 m depths.
Note: this list is based on Wagga CBD levee upgrade scenario				

5.8.1.7. Hospitals

Wagga Wagga Rural Referral Hospital (previously Wagga Wagga Base Hospital)
Wagga Wagga Base Hospital is the main public hospital facility which services the wider Murrumbidgee Region. It has a capacity of up to 500 beds and includes an emergency department. The majority of the hospital grounds first become inundated by events approaching the magnitude of the PMF, with flood depths of up to 4 m experienced. The hospital is also flooded above floor level during a PMF event. It is also noted that the hospital becomes completely isolated during this event with all surrounding roads covered to a depth of 2 – 4 m.

Calvary Riverina Hospital
Located to the south-west of Wagga Wagga city centre, Calvary Riverina Hospital is a large private facility which services the surrounding region. It provides a wide range of services including both overnight and day surgery, Maternity and Women's Health Services and a Critical Care Unit. Calvary Riverina Hospital is not flooded above floor by Murrumbidgee River flood events, however areas of the grounds and carparks are impacted by depths of up to 1m during the PMF event. Access and evacuation is restricted as Hardy Avenue, Emblen Street, Meurant Avenue and Lewisham Avenue are inundated by up to 4 m in places.

5.8.1.8. Emergency Services

Wagga Wagga Fire Station
Wagga Wagga's Fire Station is located in close proximity to the city centre opposite the southern boundary of the Wollundry Lagoon. For floods up to the 1% AEP event, the station is protected by the levee. During the 0.5% AEP event the front grounds of the property are flooded to minor depths and access to the station is cut off as The Esplanade, Thorne Street and Tompson Street experienced flood depths of up to 0.5 m experienced at these roads. The station first floods over floor in the 0.2% AEP event and is completely inundated to 5 m depth during the PMF event.

Rural Fire Service
The Wagga Wagga Rural Fire Service is not affected by Murrumbidgee River flooding.

Wagga Wagga Police Station
Wagga Wagga Police Station is un-affected in events up to the 1% AEP event due to the protection afforded by the levee. During the 0.2% AEP event the station is flooded over floor to approximately 1m depth. The station becomes isolated during this event as Tarcutta and Johnston Street are flooded by depths exceeding 1 m.

5.8.1.9. Operations Centres

The Regional SES Unit for Murrumbidgee is located at 206 Fernleigh Road, Wagga Wagga. This unit is responsible for servicing Wagga Wagga and the greater Murrumbidgee area.

The Wagga Wagga SES Unit is situated above the level of the Murrumbidgee River PMF. Access to the Unit may be restricted during large flood events due to road closures.

5.9. Existing Floodplain Management

5.9.1. Existing Levees

Since the mid 1800's, when the scale of the flood problem became known, local residents constructed levee banks on the floodplain and placed buildings on higher ground. These levees have since been formalised with the Wagga CBD Levee protecting Wagga Wagga city and the North Wagga Levee protecting North Wagga.

5.9.1.1. Wagga CBD Levee

Following the 1956 floods, Council decided to construct the Wagga CBD Levee to protect development located on the southern floodplain. This levee has undergone numerous upgrades since its initial construction.

The Wagga CBD Levee follows the Murrumbidgee River from near Kooringal Road in the east to the Olympic Highway in the west and has a length of approximately 9.6 km. The levee currently has a nominal design height of 10.74 m which is the level of the 1974 event at the Hampden Bridge gauge, with an additional freeboard of 1.0 m above the design level. It should be noted that the height of the levee is not uniform so as to provide adequate protection taking into account the gradient of the flood upstream and downstream. The levee currently provides protection for events up to the 2% AEP flood.

To increase flood protection, the CBD Levee is in the process of being upgraded to provide flood protection for events up to and including the 1% AEP event. The revised design flood height for the levee is 11.3 m. A design flood height of 11.3 m is merely an indication of the Hampden Bridge gauge height for which the levee is designed to protect. In actuality, there is a significant flood slope along the levee which is associated with a levee design height ranging between 182.3 mAHD in the upstream to 179.2 mAHD in the downstream. The design profile of the levee was determined by the Flood Study (Reference 2) and is presented in Figure 22 of that report. The NSW Public Works Flood Freeboard Report (2010) determined that a freeboard of 0.9 m should be added to the design height of the levee to provide adequate protection. By adding 0.9 m to the design height the levee crest level can be determined.

There are two spillways on the CBD Levee which have slightly lower freeboard and allow for the controlled overtopping of the levee in events greater than its design level of protection.

Levees are design to fail in a controlled manner once their design height is exceeded in order to avoid catastrophic failure of the levee. The spillways are located at Kooringal Rd (near Copland Street) in the upstream, and along the Wiradjuri Walking Track in the downstream reach of the levee.

It is important to note that all analysis undertaken in this report, unless otherwise stated, assumes that the CBD Levee has been upgraded to provide 1% AEP level of protection. Modelling has been undertaken to incorporate available levee and spillway design information provided by NSW Public Works. At the time of writing the construction of the levee had begun.

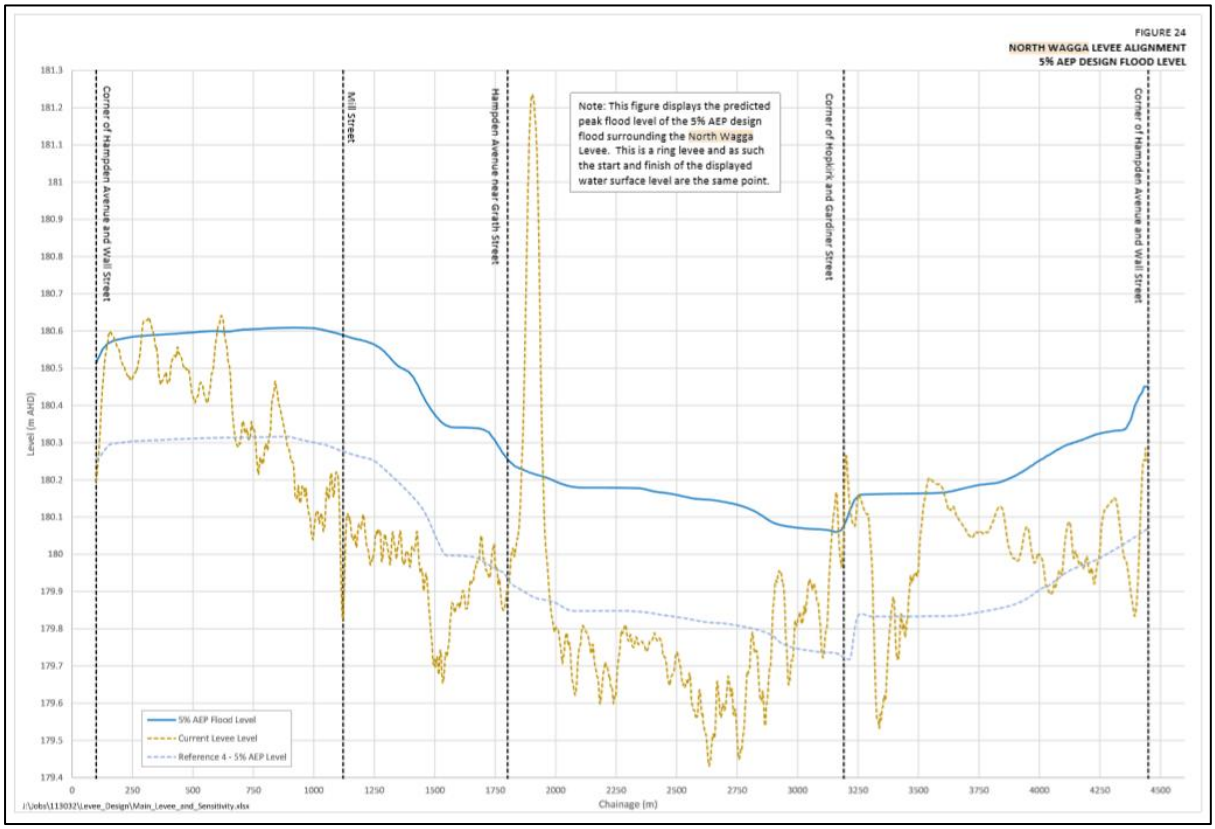
5.9.1.2. North Wagga Levee

Temporary levees have been constructed around the village of North Wagga Wagga since at least the mid-1930's. These levees were formalised as more permanent structures in 1990, and designed to be between 0.5 m and 1 m below the 1974 flood level. The ring levee surrounds North Wagga and has a total length of approximately 4.3km, with a spillway located along Hopkirk Street. In addition to the main North Wagga levee a smaller separate levee also provides protection to houses along Mill and East Streets. At the time, this was understood to provide protection of approximately a 5% AEP (20 year ARI) event. It was acknowledged in the 2009 FRMS (Reference 3, pg 34) that some sections of the levee are lower than this and would require sandbagging during flood events. It is also worth noting that the 2009 FRMS (Reference 3, pg 34) suggests that the 0.3 m freeboard is unlikely to be suitable for ensuring a 5% AEP level of protection.

In 2010, a major upgrade of the modelling tool was undertaken with the conversion to a 2D hydraulic model (Reference 5). This allowed for detailed localised assessment and mapping of flood behaviour across the full model domain as opposed to point information, that had previously been available. This report identified that the North Wagga levee would be overtopped in a 5% AEP (20 y ARI) event, that is, its level of protection was below a 20 y ARI. During the 2012 flood event the levee was reportedly overtopped near the Black Swan Hotel at approximately 9.6m on the gauge, confirming a lower level of protection.

Following the events in 2010 and 2012, it was apparent that far less flow was required to achieve a similar peak level to previous events. For example, the peak flood levels of 1974 and 2012 are comparable but the 2012 event was gauged at approximately 3,600 m^3/s (311 GL/day) at Wagga compared to the 5,200 m^3/s (450 GL/day) estimated for the 1974 flood. A detailed investigation was undertaken as part of the 2014 report (Reference 2) which concluded that a number of factors had contributed to a reduction in the conveyance of the channel. These factors include riparian vegetation, debris, and a change in channel shape. The outcome was a shift in the established relationship between height and flow. The 5% AEP flood level at Hampden Bridge shifted from 9.9 m to 10.1 m, with a larger increase on the floodplain near North Wagga of up to 0.3 m. Diagram 3 below is reproduced from the 2014 report and compares the 2010 5% AEP flood level and the 2014 5% AEP flood level with the North Wagga levee crest height.

Diagram 3 Comparison of 2010 5% AEP and 2014 5% AEP flood level with the North Wagga levee crest height (Reference 2)



Finally, current best practice for determining appropriate levee freeboard requires consideration of a range of factors including wave action, water surge, flood level uncertainties, settlement, defects and climate change. This assessment was undertaken by Public Works in November 2010, and determined the appropriate freeboard for the North Wagga levee to be 0.75 m (as opposed to 0.3 m which had been assumed previously).

These factors place the current level of protection at approximately an 8 y ARI (12% AEP). In addition to the main North Wagga levee a smaller separate levee also provides protection to houses along Mill and East Streets, however its protection level is limited to river levels of 9.6 m at the gauge (Reference 2).

The main city levee upgrade does not alter the current level of protection of the North Wagga levee.

The North Wagga levee and spillway has been modelled at its current height for existing conditions.

5.9.1.3. Other levees in the Study Area

There are several other official levees on the floodplain at Wagga, most notably:

- The Gumly Gumly levee which is situated east of Gumly Road and protects for flood breakouts from an oxbow north of Lamprey Avenue for events up to approximately the 10% AEP. This levee was construction in 1992; and
- The Riverina Water Country Council (RWCC) levee which is currently being raised to provide protection for events up to and including the 1% AEP event. This levee provides protection for Wagga's potable water (see Section 5.8.1.2).

Other unofficial levees on the floodplain have been included as topographic features within the model, and include levees around several quarries upstream and downstream of the town. This also includes the ad-hoc levees constructed prior to the 2012 event along Hampden Avenue between North Wagga and Wiradjuri Bridge.

5.9.2. Consideration of 'Current' Levee Conditions in the Current Study

The levees described in the previous sections afford varying levels of protection with some of these levees proposed for upgrade in the near future. With impending levee works, assumptions have been made to ensure that the current study results are not antiquated in the coming years once the proposed levee works are complete.

The North Wagga Levee has been modelled at its current height, however the Wagga CBD has been modelled at its upgraded height. For the purposes of the damages assessment, OEH advises levees should be 'artificially breached' in events greater than the design level of protection to ensure spillways become active. This approach is described in detail in Section 7.

Table 21: Study Assumed Levee Conditions – Afforded Level of Protection

Levee	Current Level of Protection	Proposed Level of Protection	Comment
Wagga CBD	~2% AEP	1% AEP	At the time of writing, the construction of the Main City levee upgrade had commenced. State and Federal Government funding is available for the project and it is estimated that the project will be complete by end of 2018. For the current study it has been assumed that the construction of the CBD Levee is complete. This assumption has been made to ensure model results are valid post the CBD levee upgrade to ensure the study and its findings are suitable for use in the long term. This assumption should be noted so that current emergency management protocols are not impacted prior to the completion of the CBD levee upgrade project.
North Wagga	~12% AEP	To be determined as part of this study	Upgrade of the North Wagga levee to an appropriate level of protection is considered in detail as part of the current study. As yet the suitable design height of this level has not been determined. Details are presented in Section 9.3.3
Gumly	~10% AEP	n/a	No works are currently proposed for the Gumly levee. Due to damage caused by overtopping failure during the March 2012 flood this levee has been recently repaired. Upgrade of this levee has been examined as an option in Section 9.3.2.1.
RWCC	~5% AEP	1% AEP	The RWCC levee upgrade is currently under construction to provide protection for events up to the 1% AEP flood. For the current study it has been assumed that the RWCC levee upgrade is complete to assure longevity of the current study results.

5.9.3. Audit of Levees

Following the Nyngan floods in 1990 the NSW State Government undertook an audit of levees in NSW regional towns. An audit of Wagga Wagga levee was undertaken, as well as review of the North Wagga Wagga levee.

Both levees were found to be constructed of grey/brown to black clays which have high shrinkage potential. Fill density tests were undertaken and found adequate compaction in the upper levels and marginally adequate compaction at the lower levels. Stability factors were a concern at the following locations and warranted further investigation:

- south of Hampden Bridge to Sturt Street,
- south of Morrow Street,
- at the railway line, and
- at Flowerdale Lagoon.

The audit recommended that the levee be repaired and upgraded to the August 1974 level plus 1 m. The audit also recommended that the North Wagga levee should maintain the level of protection to which it had been designed (1 in 20y ARI).

Since the completion of the audit some remedial works have been undertaken. These include;

- the area surrounding Wagga Beach,
- a section near Flowerdale Lagoon, and
- some sections of the North Wagga Wagga levee have had additional fill placed.

A visual audit of the levee was undertaken in 2007 (Reference 27). The audit identified a number of areas along the CBD Levee where erosion was evident. A number of areas were also highlighted due to minimal vegetation cover and their potential for erosion. Vertical cracks were documented in the concrete sections of the levee. The audit also identified a section adjacent to Flowerdale Lagoon which had been constructed in October 2006. This section has evidence of cracking and holes. The audit identified that no documentation or testing of this section was available.

The audit identified a number of sections along the North Wagga Wagga levee which were also displaying evidence of erosion. Minimal vegetation cover and the existence of trees within the bank may be contributing to the erosion.

The audit found that the levees are generally maintained and are in a satisfactory condition. The audit states that visually there does not appear to be any area of concerns although a number of areas warrant attention and are listed in the audit document.

5.9.4. Current Flood Warning Systems

The forecasting responsibility for floods at Wagga Wagga is the statutory responsibility of the Bureau of Meteorology. However, after many events in the 1970s through to the 1990s and following discussion with the Bureau of Meteorology it was decided that there should be some local input too, delivered through the Murrumbidgee Region of the NSW State Emergency Service (SES), who also stay in close contact with Council's Infrastructure staff. Wagga Wagga City Council also prepared a Flood Operations Manual (Reference 4), including a chapter on flood forecasting that was last updated in early 2012. This contains much historic information and a method for estimating flood heights at Wagga Wagga.

The SES has the responsibility for issuing Evacuation Warnings and Evacuation Orders if required.

A review of the operations of the flood warning system at Wagga Wagga for the December 2010 and March 2012 floods has been conducted. The flood warnings, evacuation warnings and evacuation orders issued for these events are listed in Appendix K.

One measure of the quality of flood warnings is to compare the predicted peak height to the observed peak height. The target accuracy for the Wagga Wagga gauge (AWRC No. 410001) is that 70% of peak forecasts are within ± 0.3m (Reference 12). In December 2010, the peak was slightly over predicted (10.0m predicted, 9.70m observed). Similarly, in March 2012, the peak was slightly over predicted (10.9m predicted, 10.60m observed). Although within the target accuracy range, a 0.3m difference can have very significant implications for evacuation decisions. In particular, the Wagga CBD levee's design height was set to 10.7m on the gauge at the time of the March 2012 event, so a prediction of 10.9m required the major task of evacuating the area in the interests of reducing risk to life, with significant costs both for the evacuation and to affected businesses unable to operate for a day or so. But achieving better accuracies is by no means straightforward. In the case of the March 2012 event, the Murrumbidgee River gauge at Eringoarrah was higher than the August 1974 flood there, which prompted an upwards revision of the prediction for Wagga Wagga located downstream. As it was, the 2012 flood was about 0.14m lower than the 1974 flood at Wagga.

Another measure is to assess whether the target warning lead times for different trigger heights at the Wagga Wagga gauge – as set out in Reference 12 – were achieved. For the December 2010 flood, the target warning lead times for minor, moderate and major flooding were all easily met (Table 22). Also, more than one full day was available between the issuance of the Evacuation Order for North Wagga and the loss of the evacuation route (Diagram 4). Interviews indicate that residents made use of this time to undertake significant property protection either through lifting property onto improvised scaffolds or relocating property away from the floodplain. As it was, the floodwater did not quite overtop the North Wagga levee.

For the March 2012 flood, the target warning lead times for minor and moderate flooding were met, but that for major flooding was not (Table 22). Since the SES relies upon flood warnings for triggering evacuation decisions, there was considerably less evacuation time available for residents of North Wagga to evacuate. An assessment of time required using the *SES Flood Evacuation Capacity Assessment Guideline* (Reference 11) suggests that North Wagga could be evacuated within only 3.7 hours (excluding time for SES crews to doorknock properties, including Warning Acceptance Factor, Warning Lag Factor, Travel Time and Traffic Safety Factor).

Diagram 5 shows that only about three hours was available between the time when the Evacuation Order was issued and the time when the evacuation route was expected to be first inundated based on prior flood intelligence, though about eight hours was available up to the time when the evacuation route was expected to be cut (when flooded by 0.3 m) based on prior intelligence. In fact, informal levee works along Hampden Avenue are believed to have kept the evacuation route clear of floodwater until about 7.30am on 5 March, which could have extended the available time for evacuation. But the SES had told residents that they had only five hours to evacuate, and it is reported that once residents evacuated, they were not permitted to return to undertake property protection. This was a source of upset in the North Wagga community (see Table 23). Note that the 0.3 m road closure depth was nominally

assumed for the purpose of this analysis, but depths less than 0.3 m can be dangerous to drivers. Small passenger vehicles can become buoyant in depths of 0.3 m (in low velocity water), and can be washed away in 0.1 m depths if the velocity is 3.0 m/s (Reference 29).

Another measure of the quality of flood warnings is in the particular wording of the messages. In both events, 'peak' predictions were evidently issued too soon, since they were subsequently replaced by 'reach' predictions and the important caveats 'further rises possible if spill from major dams increase' (Dec 2010) or 'Further rises possible over the next few days from forecast rain' (Mar 2012). In the case of the March 2012 flood, as late as 8 am on Saturday 3 March, the relevant warning was, 'Peak near 9.0 metres Sunday morning [04/03/12] with minor flooding'. It may have been that this warning influenced the stand-in Incident Controller who allegedly told residents of North Wagga on the Saturday that they would be isolated but not flooded, which was another grievance for the North Wagga community (see Table 23).

Other community feedback from the March 2012 flood operation is reported in Table 23. Representatives of Gumly Gumly and North Wagga outside the levee expressed general satisfaction with flood information available from the Bureau, though an untimely software update reportedly meant that real-time water levels were not updated for several hours during the September 2016 floods.

Diagram 4: December 2010 Flood Hydrograph with Selected Flood Warnings, Evacuation Warnings and Evacuation Orders

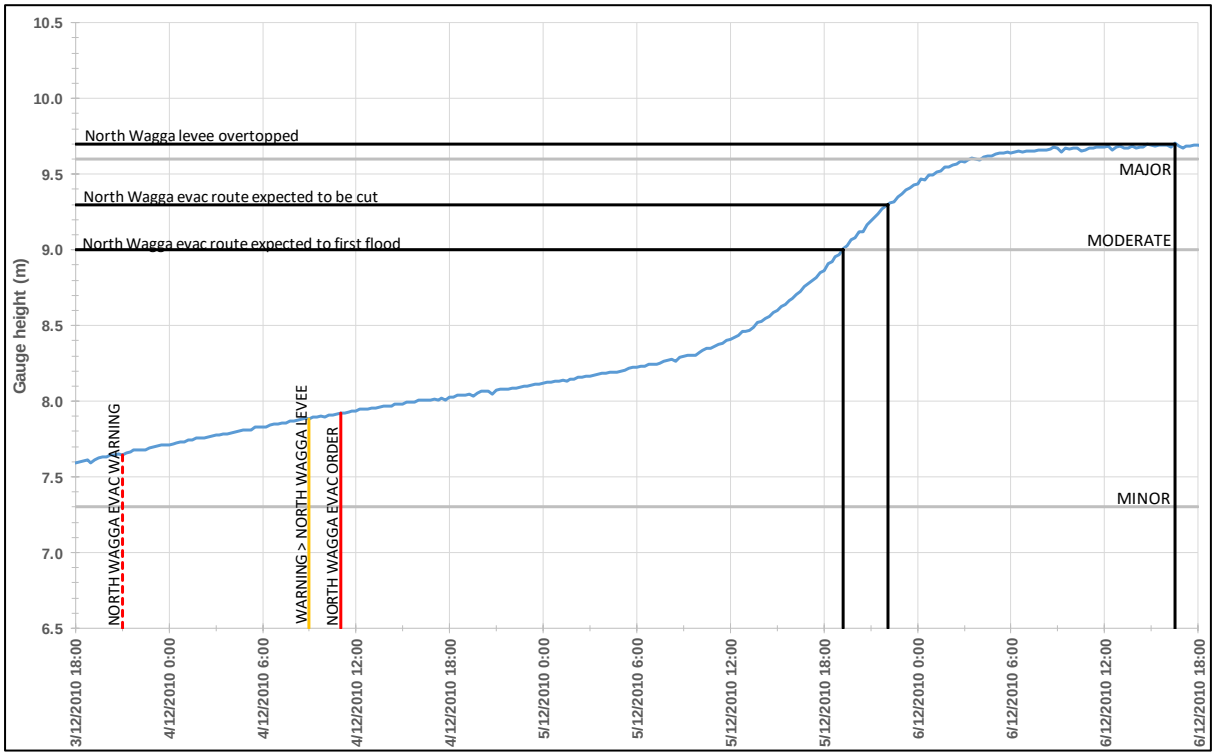


Diagram 5: March 2012 Flood Hydrograph with Selected Flood Warnings, Evacuation Warnings and Evacuation Orders

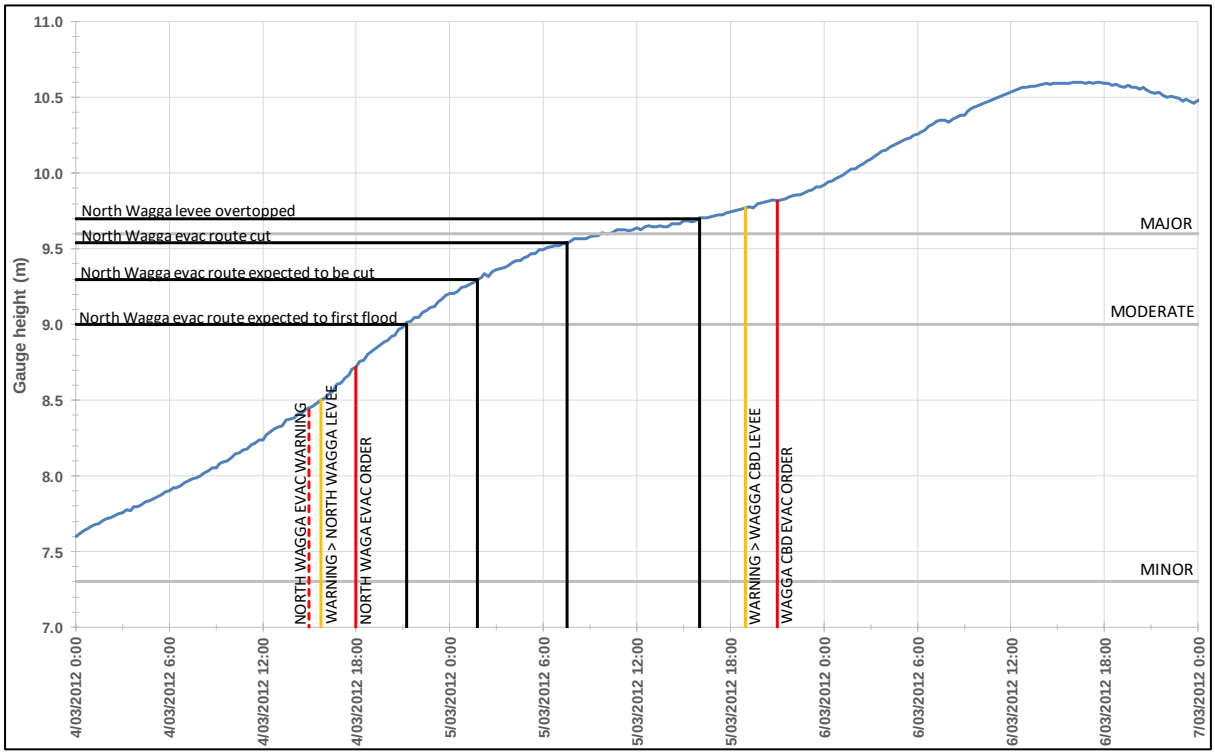


Table 22: Assessment of flood warning lead times, Dec 2010 and Mar 2012 floods

Target Warning Lead Time (WLT)	Actual WLT Dec 2010 flood		Actual WLT Mar 2012 flood	
12 hours for 7.3m (minor flood)	48 hours	☑	50 hours	☑
24 hours for 9.0m (moderate flood)	60 hours	☑	37 hours	☑
30 hours for >9.6m (major flood)	42 hours	☑	18 hours	☒

Table 23: Community feedback on March 2012 flood operation

Location	Feedback
Oura	• Community was surprised by March 2012 flood, which was first time many people had seen river break banks • People had prepared better for December 2010 flood, but that experience caused some complacency in March 2012 • People evacuated in middle of night onto higher land; there was no access to the church • Community desires a local flood warning trigger, which can then be disseminated through existing RFS telephone tree • Real need for a local emergency management centre to control operations, serve as evacuation centre, act as supply station for sandbagging etc; Oura Progress Association has purchased disused Presbyterian Church
Gumly Gumly	• Flood warning good – from internet, social media, word of mouth, SES door knock, SMS when Evacuation Order issued (but receipt of an SMS intended for Murray Region undermined confidence) • Probably just under half evacuated including most elderly who community persuaded to go • Competition for sandbags was difficult • RFS fire trucks were useful as floodwaters rose • Gumly is relatively self-sufficient community – use a tractor and a boat to maintain access with the island formed when Graham Avenue cut.
East Wagga	• Evacuation was judged by some proprietors as an unnecessary cost to business • Roads need to be reopened sooner to allow access to non-flooded businesses as soon as road clear
North Wagga (outside levee)	• Most residents use www.bom.gov.au website to view river levels and predictions and calculate rate-of-rise • Many residents remained at their homesteads since many are on higher land, are farms with animals, and due to security concerns; in relation to Evacuation Orders, there should be a different standard for properties outside the levee • Apply common sense protocols for allowing people to go into town to get supplies or to work and to return; issue pass-outs

Location	Feedback
North Wagga (inside levee)	• Greater care is required to communicate *accurate* information: on Saturday 3rd March residents were (allegedly) advised by SES that North Wagga would definitely *not* be flooded and to prepare for a week's isolation, but on Sunday 4th only five hours' warning was given to evacuate, which was insufficient to save most possessions • Frustration at not being permitted to save more property when time was available prior to loss of evacuation route • Provision of areas for storage of relocated personal property would be welcome
Wagga Wagga (inside levee)	• Some opposition to Evacuation Order

Sources: Post-2012 Flood SES questionnaire, Post-2012 Flood Oral History Project, interviews

5.9.5. Flood Emergency Management Planning

The NSW State Emergency Service (SES) is the legislated combat agency for floods in NSW and is responsible for the control of flood operations. This role is undergirded by detailed flood planning. The SES maintains the Wagga Wagga Local Flood Plan (Reference 13) and a Flood Intelligence Card for the Wagga Wagga gauge (Reference 14). These planning documents are reviewed here, and the appropriateness of the minor/moderate/major flood classifications is reassessed.

Council also plays a key role in emergency response and has a Flood Operations Manual (Reference 15) including a detailed Flood Emergency Plan listing actions to be undertaken or consequences at 0.1 m intervals, such as closing floodgates. It also has important information on stormwater pumping works.

Based on entries in the Flood Intelligence Card, the setting of the 'minor' flood classification to 7.30m appears to be about right, since it is associated with flooding of a public road. It is noted that as of May 2014, the SES knew of 22 properties affected by flooding less than the minor flood level. It is a subjective judgment whether these effects constitute 'significant' effects. The historic judgment of the SES has been that they do not, and so the flood heights that cause these lesser effects are regarded as below the minor flood category.

Based on entries in the Flood Intelligence Card, the setting of the 'moderate' flood classification to 9.00m also appears to be justified, since it is associated with flooding of a main road, Sturt Highway west of Wagga (although the FIC indicates that this intelligence needs to be confirmed). Since, at least historically (i.e. prior to construction of the informal levee along Hampden Avenue, which delays the inundation of the access/evacuation route), North Wagga would be isolated at this height, it is also prudent to require the longer warning time that a 'moderate' classification demands.

The threshold of 9.60 m for 'major' flooding also appears to be about right, since it is at about this height that overtopping of Gumly and North Wagga levees is anticipated, with flooding of 'appreciable urban areas'.

Table 24: Flood categories

Category	Generic definition	Current height	ARI at height
Minor	Flooding which causes inconvenience such as closing of minor roads and the submergence of low-level bridges. The lower limit of this class of flooding is the initial flood level at which landholders and/or townspeople begin to be affected in a significant manner that requires the issuing of a public flood warning by the Australian Government Bureau of Meteorology.	7.30	~3-4y?
Moderate	Flooding which inundates low-lying areas, requiring removal of stock and/or evacuation of some houses. Main traffic routes may be flooded.	9.00	~5y
Major	Flooding which causes inundation of extensive rural areas, with properties, villages and towns isolated and/or appreciable urban areas flooded.	9.60	~8y

5.9.6. Local Flood Plan

The current Local Flood Plan for Wagga Wagga was endorsed in 2006. The SES are currently updating and revising the flood plan and flood intelligence cards for the area, however, at the time of this study, were not complete.

The Local Flood Plan covers *"preparedness measures, the conduct of response operations and the coordination of immediate recovery measures from flooding within the Wagga Wagga City Council area. It covers operations for all levels of flooding within the Council area."*

Annex A provides details of the flood risk in Wagga Wagga, whilst Annex B profiles the community at risk. Included in this is a list of the roads which are subject to closure during flooding within the Wagga Wagga City Council area. These being:

a) Collingullie to Lockhart Rd

b) Sturt Hwy, at Sandy Creek and between Wagga Wagga and Forest Hill

c) Hampden Ave, between Wiradjuri Bridge and Cartwrights Hill

d) Old Narrandera Rd (Wagga Wagga to Narrandera), from North Wagga to Dukes Creek Bridge and other locations to the west.

e) Wagga Wagga – Oura Road, from North Wagga to Paterson Rd and at other locations to the east.

f) Collingullie – Coolamon Road, at Mundowie Bridge.

g) Eunony Bridge Rd (Sturt Hwy to Wagga Wagga – Oura Rd) along virtually its entire length.

h) Boorooma St (Old Narrandera Rd to Davidson St).

i) Edward St West / McNickle Rd (Sturt Hwy to Roach Rd).

j) Olympic Way at Uranquinty.

5.10. Management of Future Flood Risk

The Floodplain Risk Management Study examines not only the current flood risk, but takes into account flood management into the future by considering elements such as climate change, future development areas and the impacts of cumulative development across the floodplain.

5.10.1. Climate Change

Human-induced climate change is expected to have (and to be having) an effect on rainfall intensities, and should therefore be incorporated in the assessment of design flood behaviour in a particular area. However, there is uncertainty over the ways in which climate change will manifest itself in Australia. In the case of flood estimation, there is uncertainty over how much rainfall intensities will increase by (in the long term), and how changes in other variables (e.g. evaporation and temperature) will influence runoff.

The impact of climate change on flood behaviour in the study area has been assessed by comparing the 1% AEP flood levels to those of the 0.5% AEP event. This comparison allows the sensitivity of the 1% AEP flood levels to the possible long term influences of climate change to be identified. This increases the estimated discharge from 5,115 m^3/s (4,534,300 Ml/d) to 6,300 m^3/s (5,585,100 Ml/d). This increase represents slightly more than 20% which is considered an overly conservative estimate based on current predictions.

Table 25: Climate Change Impact - 1% AEP vs 0.5% AEP Comparison

Location	1% AEP Level (mAHD)	Increase in Level under 0.5% AEP Event (m)
Oura Rd / Barney St / Wagga Wagga St	187.8	0.5
Barney St / MacIntyre St	187.8	0.5
Oura Rd / Parkins Rd	185.1	0.3
Killpatrick Ave / Graham Ave	183.0	0.3
Graham Ave / Gumly Rd	183.3	0.3
Eunony Bridge	182.5	0.3
Hale St / Mingara St	181.6	0.5
Railway Bridge Near Whittle St	181.7	0.5
Hampden Ave / Mill St	181.4	0.5
Scott St / Edward St	179.1	0.4
Gobbagombalin Bridge	179.8	0.4
Roach Rd / McNickle RD	179.0	0.4
Sturt Hwy / Cloughs RD	174.6	0.2
Windmill Rd/ Bavin Rd	183.3	0.4
Tasman Rd / Schiller St	182.9	0.27

The table shows the increase in flood levels will be between 0.2 and 0.5 m. The largest difference is near in the floodplain upstream of North Wagga where a breakout from an oxbow on the main channel has a greater impact with increasing flood level. The smallest difference is downstream of the town with an increase of 0.19 m on the Sturt Highway near Cloughs Rd. These variations are within the freeboard allowance of levee design and applied flood planning level.

5.10.2. Future Development

Wagga Wagga City Council has flagged a number of zones in the LGA for potential future residential and commercial development. These areas generally lie on or beyond the fringe of the Murrumbidgee River Floodplain and do not constitute major concerns for future flood behaviour, however one area in East Wagga is subject to more severe flood behaviour. The prescribed locations are shown with respect to the hydraulic categorisation of the floodplain in Figure G1. The areas to the west of North Wagga and in East Wagga are located partially in the Floodway. This same area is partially classified as Hydraulic Hazard H5: Unsafe for people or vehicles, and buildings would require special engineering design and construction (shown in Figure G2). Any future development in this location particularly should not be undertaken without considering the flood risk.

It should also be noted that while the other proposed zones lie outside the riverine floodplain, they are likely to be affected by overland flow flooding. The same areas will be examined in the Wagga Wagga Major Overland Flow Floodplain Risk Management Study.

5.10.3. Cumulative Development

A key outcome of the Floodplain Risk Management Process is to develop strategies to reduce flood risk across the floodplain into the future. A key principle of the Floodplain Development Manual (Reference 1) is to achieve this outcome by not allowing development (including dwellings, commercial premises or agricultural infrastructure) in the floodway. For reference, the floodway is defined in Section 5.3 and depicted in Figures 12 and 13. It describes the part of the floodplain that conveys the majority of flow, and where any obstruction is likely to reduce conveyance and result in impacts elsewhere. The floodway in Wagga Wagga is extensive and already highly developed in parts, with residential precincts, individual dwellings and agricultural infrastructure, limiting the practicality of applying a blanket ban on all development. As such, concessional controls that allow for appropriate utilisation of the floodway are required within the Study Area.

A key control that ensures a development is suitable is to require a flood impact assessment. This can be quite an onerous and expensive task, requiring the proponent to engage a flood consultant to model the proposed development and demonstrate that there are no offsite flood impacts. Assessing flood impacts in this way alone also leads to concerns about the cumulative impact of multiple developments. To reduce this burden and to address the cumulative development concerns, controls can instead be structured to allow development up to a certain size before requiring a flood impact assessment. One method used to determine this threshold is to assess a cumulative development scenario for multiple developments to ensure that the flood impacts are acceptable. That is, if a particular development were repeated across the floodplain, it would not unduly increase peak flood levels or worsen the existing flood hazard.

Section 9.7.5 discusses appropriate recommendations to ensure that flood behaviour is not worsened over time due to the cumulative effects of ongoing development. Specific controls will be developed by Council and exhibited as part of their revised Development Control Plan.

6. PLANNING AND POLICY REVIEW

6.1. National Provisions - Building Code of Australia

The Building Code of Australia (BCA) is a uniform set of technical provisions for the design and construction of buildings and other structures throughout Australia. The goals of the BCA are to enable the achievement and maintenance of acceptable standards of structural sufficiency, safety, health and amenity for the benefit of the community now and in the future.

The BCA contains requirements to ensure new buildings and structures and, subject to State and Territory legislation, alterations and additions to existing buildings located in flood hazard areas do not collapse during a flood when subjected to flood actions resulting from the defined flood event.

The BCA provides additional requirements for buildings in flood hazard areas consistent with the objectives of the BCA which primarily aim to protect the lives of occupants of those buildings in events up to and including the defined flood event.

Flood hazard areas are identified by the relevant State/Territory or Local Government authority. The BCA is produced and maintained by the Australian Building Codes Board and given legal effect through the *Building Act 1975,* which in turn is given legal effect by building regulatory legislation in each State and Territory. Any provision of the BCA may be overridden by, or subject to, State or Territory legislation. The BCA must, therefore, be read in conjunction with that legislation.

6.2. State Provisions

It is important to understand the state legislation that overarches all local legislation to enable appropriate floodplain risk management measures to be proposed that are in keeping with both state and local statutory requirements. This section discusses the state legislation that influences planning in relation to flood risk at the local government level.

6.2.1. NSW Environmental Planning and Assessment Act 1979

The NSW Environmental Planning and Assessment Act 1979 (EP&A Act) provides the framework for regulating and protecting the environment and controlling development.

6.2.2. Ministerial Direction 4.3

The NSW Environmental Planning and Assessment Act 1979 (EP&A Act) provides the framework for regulating and protecting the environment and controlling development. Pursuant to Section 117(2) of the EP&A Act, the Minister has directed that Councils have the responsibility to facilitate the implementation of the NSW Government's Flood Prone Land Policy. Specifically, Direction 4.3 states:

Objectives

(1) The objectives of this direction are:

(a) to ensure that development of flood prone land is consistent with the NSW Government's Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005, and

(b) to ensure that the provisions of an LEP on flood prone land is commensurate with flood hazard and includes consideration of the potential flood impacts both on and off the subject land.

Clause (3) of Direction 4.3 states:

(3) This direction applies when a relevant planning authority prepares a planning proposal that creates, removes or alters a zone or a provision that affects flood prone land.

Clauses (4)-(9) of Direction 4.3 state:

(4) A planning proposal must include provisions that give effect to and are consistent with the NSW Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005 (including the Guideline on Development Controls on Low Flood Risk Areas).

(5) A planning proposal must not rezone land within the flood planning areas from Special Use, Special Purpose, Recreation, Rural or Environmental Protection Zones to a Residential, Business, Industrial, Special Use or Special Purpose Zone.

(6) A planning proposal must not contain provisions that apply to the flood planning areas which:

(a) permit development in floodway areas,
(b) permit development that will result in significant flood impacts to other properties,
(c) permit a significant increase in the development of that land,
(d) are likely to result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services, or
(e) permit development to be carried out without development consent except for the purposes of agriculture (not including dams, drainage canals, levees, buildings or structures in floodways or high hazard areas), roads or exempt development.

(7) A planning proposal must not impose flood related development controls above the residential flood planning level for residential development on land, unless a relevant planning authority provides adequate justification for those controls to the satisfaction of the Director-General (or an officer of the Department nominated by the Director-General).

(8) For the purposes of a planning proposal, a relevant planning authority must not determine a flood planning level that is inconsistent with the Floodplain Development Manual 2005 (including the Guideline on Development Controls on Low Flood Risk Areas) unless a relevant planning authority provides adequate justification for the proposed departure from that Manual to the satisfaction of the Director-General (or an officer of the Department nominated by the Director-General).

(9) A planning proposal may be inconsistent with this direction only if the relevant planning authority can satisfy the Director-General (or an officer of the Department nominated by the Director-General) that:

(a) the planning proposal is in accordance with a floodplain risk management plan prepared in accordance with the principles and guidelines of the Floodplain Development Manual 2005, or
(b) the provisions of the planning proposal that are inconsistent are of minor significance.

6.2.3. NSW Flood Prone Land Policy

The primary objectives of the NSW Government's Flood Prone Land Policy are:

(a) to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone land, and

(b) to reduce public and private losses resulting from floods whilst utilising ecologically positive methods wherever possible.

The NSW Floodplain Development Manual 2005 (the Manual), relates to the development of flood prone land for the purposes of Section 733 of the Local Government Act 1993 and incorporates the NSW Flood Prone Land Policy.

The Manual outlines a merits approach based on floodplain management. At the strategic level, this allows for the consideration of social, economic, cultural, ecological and flooding issues to determine strategies for the management of flood risk.

The Manual recognises differences between urban and rural floodplain issues. Although it maintains that the same overall floodplain management approach should apply to both, it recognises that a different emphasis is required to address issues particular to a rural floodplain. These issues include:

- The large area of land under investigation;
- The complexity of flood behaviour;
- The impacts of protection works for valuable crops on flood behaviour;
- The period of inundation;
- The uncertainties associated with flood related data, and
- The environmental values associated with flood dependent ecosystems on a rural floodplain.

6.2.4. Planning Circular PS 07-003

Planning Circular PS 07-003 (31 January 2007) provides advice on a package of changes concerning flood-related development controls for land above the 1-in-100 year flood and up to the Probable Maximum Flood (PMF).

Councils can make an application to the Department of Planning and Environment for exceptional circumstances for the inclusion of a Floodplain Risk Management Clause in its Local Environmental Plan (LEP), as per Planning Circular PS 07-003. This can be useful for areas where there are significant increases in flood risk associated with increased flood magnitude above the 1% AEP event. Some Councils, where this is an issue, choose to prohibit critical and vulnerable land uses below the PMF. This is discussed further in Section 6.3.1 and 9.7.3.1.

The Wagga Local Environmental Plan 2010 contains a Flood Planning clause allowing for flood related development controls to be applied up to the Flood Planning Level which is defined as:

> *... the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metres freeboard.*
>
> The full clause is listed in Section 6.3.1.

6.2.5. Section 149 Planning Certificates

Section 149 of the EP&A Act states:

> *(1) A person may, on payment of the prescribed fee, apply to a council for a certificate under this section (a planning certificate) with respect to any land within the area of the council.*
>
> *(2) On application made to it under subsection (1), the council shall, as soon as practicable, issue a planning certificate specifying such matters relating to the land to which the certificate relates as may be prescribed (whether arising under or connected with this or any other Act or otherwise).*
>
> *(3) (Repealed)*
>
> *(4) The regulations may provide that information to be furnished in a planning certificate shall be set out in the prescribed form and manner.*

The Environmental Planning and Assessment Regulation 2000 prescribes the matters which must be included in a s.149 Planning Certificate, including whether a parcel of land is subject to controls relating to flooding.

Schedule 4 of the Regulations gives requirement for inclusions on s149 certificates under Section 149(2) of the Act. In particular Schedule 4, 7A refers to flood related development control information and requires that Council include whether or not development on the land or part of the land is subject to flood related development controls.

Section 149 (5) is a more detailed certificate and could for instance include “notes” on flood risk. Wagga Wagga City Council currently issues S 149(2) certificates containing details as required by the legislation in relation to flood related development controls. Types of additional information that may be included on the 149(5) certificate have been recommended in Section 9.7.3.3.

6.2.6. State Environmental Planning Policy (Exempt and Complying Development Codes (2008))

The aims of State Environmental Planning Policy (Exempt and Complying Development) 2008 are:

This Policy aims to provide streamlined assessment processes for development that complies with specified development standards by:

(a) providing exempt and complying development codes that have State-wide application, and
(b) identifying, in the exempt development codes, types of development that are of minimal environmental impact that may be carried out without the need for development consent, and

(c) identifying, in the complying development codes, types of complying development that may be carried out in accordance with a complying development certificate as defined in the Act, and

(d) enabling the progressive extension of the types of development in this Policy, and

(e) providing transitional arrangements for the introduction of the State-wide codes, including the amendment of other environmental planning instruments.

The policy includes a number of restrictions on flood control lots, which are lots where flood related development controls apply. The restrictions do not allow development in areas classified as flood storage, floodway, flow path, high hazard or high risk areas.

6.2.7. General Housing Code

Part 3 of the SEPP relates to the *"General Housing Code"*.

Division 1 of Part 3 of the SEPP, which comprises clauses 3.1-3.6 of the SEPP, relates to:

Development that is complying development under this code

Clause 3.1 states:

3.1 Land to which code applies

This code applies to development that is specified in clauses 3.2-3.5 on any lot in Zone R1, R2, R3, R4 or RU5 that:

(a) has an area of at least 200 m^2, and

(b) has a width, measured at the building line fronting a primary road, of at least 6m.

Clause 3.2 of the SEPP states:

3.2 New single storey and two storey dwelling houses

The erection of a new single storey or two storey dwelling house is development specified for this code.

Clauses 3.3-3.5 generally relate to single and two storey dwelling houses and ancillary development.

Division 2 of Part 3 of the SEPP contains:

Development standards for this code

Subdivision 9 contains:

Development standards for particular land

Subdivision 9 contains Clause 3.36C of the SEPP which relates to development standards for the General Housing Code on *"flood control lots"*. A *"flood control lot"* is defined in the SEPP as:

> ***flood control lot*** *means a lot to which flood related development controls apply in respect of development for the purposes of industrial buildings, commercial premises, dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (other than development for the purposes of group homes or seniors housing).*
>
> ***Note.*** *This information is a prescribed matter for the purpose of a certificate under section 149 (2) of the Act.*

As such, a *"flood control lot"* is a lot where the Council has provided for flood related development controls, which are all lots with notation on a s.149 Planning Certificate that flood related development controls apply. This is generally land which falls within the *"Flood Planning Area"*.

Clause 3.36C states:

> ***3.36C Development standards for flood control lots***
>
> *(1) This clause applies:*
>
> *(a) to all development specified for this code that is to be carried out on a flood control lot, and*
> *(b) in addition to all other development standards specified for this code.*
>
> *(2) The development must not be on any part of a flood control lot unless that part of the lot has been certified, for the purposes of the issue of the relevant complying development certificate, by the council or a professional engineer who specialises in hydraulic engineering as not being any of the following:*
>
> *(a) a flood storage area,*
> *(b) a floodway area,*
> *(c) a flow path,*
> *(d) a high hazard area,*
> *(e) a high risk area.*
>
> *(3) The development must, to the extent it is within a flood planning area:*
>
> *(a) have all habitable rooms no lower than the floor levels set by the council for that lot, and*
>
> *(b) have the part of the development at or below the flood planning level constructed of flood compatible material, and*
>
> *(c) be able to withstand the forces of floodwater, debris and buoyancy up to the flood planning level (or if on-site refuge is proposed, the probable maximum flood level), and*

(d) not increase flood affectation elsewhere in the floodplain, and

(e) have reliable access for pedestrians and vehicles from the development, at a minimum level equal to the lowest habitable floor level of the development, to a safe refuge, and

(f) have open car parking spaces or carports that are no lower than the 20-year flood level, and

(g) have driveways between car parking spaces and the connecting public roadway that will not be inundated by a depth of water greater than 0.3m during a 1:100 ARI (average recurrent interval) flood event.

(4) A standard specified in subclause (3) (c) or (d) is satisfied if a joint report by a professional engineer who specialises in hydraulic engineering and a professional engineer who specialises in civil engineering confirms that the development:

(a) can withstand the forces of floodwater, debris and buoyancy up to the flood planning level (or if on-site refuge is proposed, the probable maximum flood level), or

(b) will not increase flood affectation elsewhere in the floodplain.

(5) If a word or expression used in this clause is defined in the Floodplain Development Manual, the word or expression has the same meaning as it has in that Manual unless it is otherwise defined in this clause.

(6) In this clause:

***flood compatible material** means building materials and surface finishes capable of withstanding prolonged immersion in water.*

***Floodplain Development Manual** means the Floodplain Development Manual (ISBN 0 7347 5476 0) published by the NSW Government in April 2005.*

***flow path** means a flow path identified in the council's flood study or floodplain risk management study carried out in accordance with the Floodplain Development Manual.*

***high hazard area** means a high hazard area identified in the council's flood study or floodplain risk management study carried out in accordance with the Floodplain Development Manual.*

***high risk area** means a high risk area identified in the council's flood study or floodplain risk management study carried out in accordance with the Floodplain Development Manual.*

6.2.8. Rural Housing Code

Part 3A of the SEPP contains the *"Rural Housing Code"*.

Division 1 of Part 3A of the SEPP defines:

Development that is complying development under this code

Clauses 3A.1 and 3A.2 state:

3A.1 Land to which code applies

This code applies to development that is specified in clauses 3A.2-3A.5 on lots in Zones RU1, RU2, RU3, RU4, RU6 and R5.

3A.2 New single storey and two storey dwelling houses

(1) The erection of a new single storey or two storey dwelling house is development specified for this code if the development is erected on a lot:

(a) in Zone RU1, RU2, RU4 or RU6 that has an area of at least 4,000m^2, or

(b) in Zone R5.

(2) This clause does not apply if the size of the lot is less than the minimum lot size for the erection of a dwelling house under the environmental planning instrument applying to the lot.

Clause 3A.38 contains:

Development standards for flood control lots

The development standards contained in clause 3A.38 are the same as those contained in clause 3.36 as detailed above.

6.2.9. Summary of State Legislative and Planning Policies

From the above discussion of both the General Housing Code and the Rural Housing Code, it is clear that, unless a lot affected by flooding is included as a *"flood control lot"*, a s.149 notification is not required and, as a result, planning controls relating to flooding do not apply and a Complying Certificate can be granted without having regard to any Council flood controls. This scenario has considerable implications with regard to Council deciding whether a lot which is flood affected is included in the Flood Planning Area.

6.3. Local Provisions

Appropriate planning restrictions, ensuring that development is compatible with flood risk, can significantly reduce flood damages.

Environmental Planning Instruments (EPIs) such as LEPs guide land use and development by zoning all land, identifying appropriate land uses allowed in each zone, and controlling development through other planning standards and Development Control Plans (DCPs).

LEPs are made under the EP&A Act. In 2006, the NSW Government initiated the Standard Instrument LEP program and produced a new standard format which all LEPs should conform to. Wagga LEP 2010 was prepared under the Standard Instrument LEP program.

LEPs are used as tools to guide new development away from high flood risk locations and ensure that new development does not increase flood risk elsewhere. LEPs can also be used to develop appropriate evacuation and disaster management plans to better reduce flood risks to the existing population.

Councils also use Development Control Policies to control development on flood prone land.

Wagga Wagga's LEP and DCP are discussed below and later have been reviewed in regards to flood risk management to identify where improvements might be made (see Section 9.7).

6.3.1. Wagga Wagga Local Environment Plan 2010 (WLEP 2010)

Wagga City Council's LEP was adopted in 2010 and was prepared under the Standard Instrument LEP program. Clause 7.2 of WLEP 2010 relates to flood planning and states:

7.2 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:

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

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

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

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

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

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

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

(e) 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 NSW Government's Floodplain Development Manual published in April 2005, unless it is otherwise defined in this clause.

(5) In this clause:

***flood planning level** means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metres freeboard.*

***Flood Planning Map** means the Wagga Wagga Local Environment Plan 2010 Flood Planning Map*

Editorial note. When this Plan was made there was no Flood Planning Map.

6.3.2. Wagga Wagga Development Control Plan 2010 (WDCP 2010).

Section 4.2 of WDCP 2010 is titled "Flooding" and applies to land that is identified as flood prone. The DCP notes that the section *"is based on the terminology and recommendations of the Wagga Wagga Floodplain Risk Management Study 2009".* The DCP is based around the flood risk precincts, identified in the FRMS, reproduced below

Flood risk precinct	Levee	Flood risk
Central Wagga	Protected by levee	Low
Central Wagga	Not protected by levee	High
North Wagga	Protected by levee	High
Gumly/Oura/Collingullie	N/A	High
Rural floodplain	N/A	Low
Rural floodplain	N/A	High
Eastern Industrial	N/A	Medium

The stated objectives of the flood related development controls are:

O1 Minimise the public and private costs of flood damage.
O2 Minimise the risk of life during floods by encouraging construction and development that is "flood proofed" and compatible with the flood risk of the area.
O3 Ensure that development and construction are compatible with the flood hazard.
O4 Require compatibility with the Floodplain Development Manual 2005 as relevant.

The DCP then stipulates objectives, controls or conditions for each precinct, tailored to development use and specified flood risk (low, medium or high). Controls may relate to floor levels, structural soundness, management and design, flood affectation, and evacuation.

7. ECONOMIC IMPACT OF FLOODING

Flood damages due to the Murrumbidgee River have been assessed as part of this study. This analysis has not considered overland flow flooding which can also cause significant flooding issues and damage in Wagga Wagga. The damages as a result of major overland flow would be considered as part of the Wagga Wagga Major Overland Flow Floodplain Risk Management Study being undertaken concurrently by Council.

7.1. Tangible Flood Damages

Tangible flood damages are comprised of two basic categories; direct and indirect damages. Direct damages are caused by floodwaters wetting goods and possessions thereby damaging them and resulting in either costs to replace or repair or in a reduction to their value. Direct damages are further classified as either internal (damage to the contents of a building including carpets, furniture), structural (referring to the structural fabric of a building such as foundations, walls, floors, windows) or external (damage to all items outside the building such as cars, garages). Indirect damages are the additional financial losses caused by the flood for example the cost of temporary accommodation, loss of wages by employees etc.

Given the variability of flooding, and property and content values, the total likely damages in any given flood event is useful to get an indication of the magnitude of the flood problem, however it is of little value for absolute economic evaluation. However, damages estimates are useful when studying and comparing the economic effectiveness of proposed mitigation options. Understanding the total damages prevented over the life of the option in relation to current damages, or to an alternative option, can assist in the decision making process.

The damages were calculated using a number of height-damage curves derived from OEH Guidelines (Reference 18) which relate the depth of water above the floor with tangible damages. These curves included points for the following events: PMF, 0.5%, 1%, 2%, 5%, 10% and 20% AEP events. Each component of tangible damages is allocated a maximum value and a maximum depth at which this value occurs. Any flood depths greater than this allocated value do not incur additional damages as it is assumed that, by this level, all potential damages have already occurred.

7.1.1. Treatment of Levees

As various regions in Wagga Wagga are protected by levee systems, these need to be considered when calculating damages. In accordance with OEH advice, a properly constructed and maintained levee is considered to only offer protection against floods up to the magnitude of the design flood. For events larger than the design flood, the levee may be deemed to have failed, and therefore inundation of the protected area should be assumed. The purpose of this approach is to provide a conservative estimation of possible damages.

The failure of the Wagga CBD levee in events greater than the 1% AEP event was modelled by removing the freeboard from the spillways (400 mm) and lowering the remaining crest height by the same amount, leaving a freeboard of 500 mm compared to the original 900 mm freeboard allowance. This approach is in accordance with OEH guidelines for levees with officially designed spillways, and acts to ensure the spillways are activated in events greater than the levee's design level of protection.

The North Wagga Levee was originally designed with a level of protection of what was understood to be a 5% AEP at the time of construction, with a 0.3 m freeboard allowance. Since this time, freeboard assessments have shown that 0.3 m is insufficient, and a freeboard of 0.75 m is recommended. This later finding means that the North Wagga Levee does not currently provide at 5% AEP level of protection. Further to this, several factors have resulted in the increase of design flood levels since the original construction, including revision of the Hampden Bridge Gauge rating curve, increase in vegetation, development on the floodplain, and construction of the Wagga CBD. The North Wagga levee currently is considered to have a design level of protection of ~ 8 year ARI. For consistency with the OEH Guidelines for levees that do not have a formal spillway design, the existing North Wagga Levee is artificially breached in events greater than and including the 5% AEP event. The breach is modelled by reducing a 100 m section on each side of the levee (upstream and downstream) to a level halfway between natural surface and the existing level of protection to allow controlled failure to occur. It was not deemed necessary to also breach the levee in the 10% AEP event as the levee is not overtopped in this design event.

For options that involve the upgrade of North Wagga Levee (to the 1% AEP level in Option L3, and 5% AEP level in Option L4), the same approach described for the CBD levee was applied, as the upgrades would include formal spillway designs.

The design flood information also assumes that each design flood event will not be affected by wind and wave setup, wave action, and other factors considered in the levee system's freeboard. Apart from levee settlement or other degradation, the freeboard factors can act to make the flood level either higher or lower. For example, wind setup can cause the design flood to be either higher or lower than predicted as it comes up against the levee, depending on the wind setup. Assuming all factors would act to raise the flood level, which is the equivalent of removing the levee freeboard when making the flood damages calculations, would overestimate the effect of flooding for a particular design event, and therefore has not been included in this assessment.

7.1.2. Treatment of Floor Levels

The current OEH position is that levee freeboard (and hence floor level freeboard) can provide some economic benefit. This was proposed by Chris Stanton (Reference 28) and argues that from an economic perspective the probability of failure at the safe operating level and/ or design flood level is zero and at the crest (which includes freeboard) 1.0. The relationship between the two points however is unknown, and would be related to the potential for a levee breach occurring or, in the case of floor levels, freeboard factors contributing to increase the design flood level. Stanton assumed a straight line between the two points on the flood damage curve.

In Wagga Wagga, removing 0.5 m freeboard from floor levels is considered overly conservative and would increase flood damages by 24%. This increase in the estimation of average annual damages may by extension overestimate the benefits available with the implementation of mitigation options. In light of this, no freeboard has been subtracted from surveyed or estimated floor levels for the purposes of the flood damages assessment.

7.1.3. Damages Assessment Results

Damages were calculated for residential and commercial\industrial properties separately and the process and results are described in the following sections. The combined results are provided in Table 26. This flood damages estimate does not include the cost of restoring or maintaining public services and infrastructure. It should be noted that damages calculations do not take into account flood damages to any basements or cellars, hence where properties have basements damages can be underestimated. On a study-area wide basis these exclusions are considered reasonable.

The database compiled for undertaking damages calculations including floor level information and design flood levels will be provided to Council as part of the handover information for this project. Note that the terminology used refers to a property or lot being the land within the ownership boundary. Flooding of a property does not necessarily mean flooding above floor level of a building on that property/lot.

Table 26: Estimated Combined (Residential and Commercial/Industrial) Flood Damages for Wagga Wagga Study Area

Event	No. Properties Affected[1]	No. Flooded Above Floor Level[2]	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
10% AEP	57	41	$ 3,391,500	3	$ 145,200
5% AEP	307	234	$ 21,811,500	11	$ 184,900
2% AEP	465	404	$ 44,473,400	17	$ 226,600
1% AEP	597	539	$ 65,274,700	10	$ 237,300
0.5% AEP	2,402	2,170	$ 237,319,800	14	$ 228,200
0.2% AEP	3,736	3,661	$ 508,812,900	20	$ 314,700
PMF	4744	4728	$ 861,669,800	25	$ 424,300
Average Annual Damages (AAD)			**$ 5,581,900**		**$ 2,600**

[1]*'No. Properties Affected': there is flooding above ground level within the property boundary (i.e the lot)*
[2]*'No. Flooded above floor level': there is flooding above the surveyed or estimated floor level of the house.*

As described above, OEH recommends modelling a levee-breach scenario in events greater than the levee's design level of protection. Therefore the number of properties affected is much greater than one would expect under a no-failure scenario. The jump in flood affectation is shown clearly between the 1% AEP event and the 0.5% AEP event reflects this, as properties previously protected by the levee are susceptible to inundation in the 0.5% AEP event. The number of affected properties increases from 597 to 2,402, and over-floor flooding from 539 to 2,170. This means that approximately 75% of properties affected in the 0.5% AEP are not affected in the 1% AEP event, let alone more frequent events. It is important to note that while the damages figure is highly conservative, it still shows the relative effects of different sized events, and provides a basis for comparing proposed mitigation options and calculating B/C ratios. A breakdown of the over-floor flood affectation of properties by floodplain community is provided in Table 27.

Table 27 Over-floor flood affectation by floodplain community (combined residential and non residential)

Event	Wagga CBD	East Wagga	North Wagga	West Wagga	Gumly	Oura	Wagga Floodplain	Eunony	Total
10% AEP	0	5	12	14	2	0	8	0	41
5% AEP	0	17	174	23	5	2	11	2	234
2% AEP	0	89	215	32	16	31	16	5	404
1% AEP	0	189	215	37	38	34	19	7	539
0.5% AEP	1537	245	219	41	62	36	21	9	2170
0.2% AEP	2987	260	220	51	67	41	23	12	3661
PMF	3962	294	220	78	72	47	31	24	4728

The following sections provide a more detailed overview of the assessment for residential and commercial/industrial damages.

7.1.3.1. Residential Properties

Residential properties suffer damages from flooding in a number of ways. Direct damages include loss of property contents and/or damage to the structure of the property. Indirect damage costs can be incurred when property occupiers live elsewhere while repairs are being made. For this analysis, a floor level database was used using the methods outlined in Section 2.5.1.

In assessing various mitigation measures it is important to compare them using a suitable metric. By applying a monetary value to property damages and then comparing damage estimates for the existing situation with assumed mitigation work (approximately costed) a benefit/cost (B/C) ratio can be calculated which is readily comparable. A flood damages assessment was undertaken for all residential properties flooded in the PMF event in order to identify flood damages for a range of design events. A summary of the assessment is provided in the following sections with full details included in Appendix C.

Table 28 shows the damages for a range of design events and the Annual Average Damage (AAD). This forms the base case scenario against which damages from a number of mitigation measures can be assessed.

Table 28: Potential Residential Damages for Murrumbidgee River near Wagga

Event	No. Properties Affected[1]	No. Flooded Above Floor Level[2]	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
10% AEP	45	30	$ 2,248,600	3	$ 50,000
5% AEP	257	190	$ 15,599,200	13	$ 60,700
2% AEP	353	301	$ 27,966,700	19	$ 79,200
1% AEP	395	347	$ 35,508,800	9	$ 89,900
0.5% AEP	1737	1564	$ 138,706,400	13	$ 79,900
0.2% AEP	2671	2619	$ 288,897,800	19	$ 108,200
PMF	3393	3380	$ 479,359,300	23	$ 141,300
Average Annual Damages (AAD)			**$ 3,370,900**		**$ 1,000**

[1]*'No. Properties Affected': there is flooding above ground level within the property boundary (i.e the lot)*
[2]*'No. Flooded above floor level': there is flooding above the surveyed or estimated floor level of the house.*

Approximately a third of the AAD can be attributed to events from the 2% AEP and smaller. A significant contributor to the AAD from these smaller events is North Wagga, the flooding of which contributes to 39.9% of the total AAD (see Table 29). This is the largest contributor to AAD of any of the floodplain villages, and only contributing slightly less than Wagga CBD despite having 17 times fewer dwellings. This large portion of the AAD is a result of the more frequently occurring damages in North Wagga.

Table 29: Residential Contribution to AAD - by Region

Region	AAD	% of Total AAD
Wagga CBD	$1,392,100	41.3
East Wagga	$90,700	2.7
North Wagga	$1,346,000	39.9
West Wagga	$230,700	6.8
Gumly	$97,000	2.9
Oura	$91,600	2.7
Wagga Floodplain	$103,900	3.1
Eunony	$18,700	0.6
Total	**$3,370,900**	**100**

7.1.3.2. Non-Residential - Commercial, Industrial and Agricultural Activities

Commercial/industrial properties are affected either directly by flood damage or indirectly by loss of business due to restricted customer and/or employee access. Costs vary significantly dependent on the type of commercial activity;

- Type of business – stock based or not, costs of damages to goods;
- Duration of flooding – affects how long a business may be closed for not just whether the business itself is closed, but when access to it is restored;
- Ability to move stock or assets before onset of flooding - some large machinery will not be able to moved and in other instances there may be insufficient warning time to move stock to dry locations; and
- Ability to transfer business to a temporary location.

The magnitude of flood damages to agricultural activities can be largely dependent on the depth and duration of flooding. Longer duration flooding can damage crops and ground leading to loss of harvest or suitable grazing lands. Although grazing animals such as sheep and cattle, may be able to be moved, this would often be to less suitable grazing land.

An description of the methods used to assess non-residential damages is provided in Appendix C.

Table 28 shows the potential damages for a range of design events and the Annual Average Damage (AAD). This forms the base case scenario against which damages from a number of mitigation measures can be assessed.

Table 30: Potential Non-Residential Damages for Murrumbidgee River near Wagga

Event	No. Properties Affected	No. Flooded Above Floor Level	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
10% AEP	12	11	$ 1,142,900	3	$ 95,200
5% AEP	50	44	$ 6,212,300	8	$ 124,200
2% AEP	112	103	$ 16,506,700	15	$ 147,400
1% AEP	202	192	$ 29,765,900	10	$ 147,400
0.5% AEP	665	606	$ 98,613,400	15	$ 148,300
0.2% AEP	1065	1042	$ 219,915,100	22	$ 206,500
PMF	1351	1348	$ 382,310,500	27	$ 283,000
Average Annual Damages (AAD)			**$ 2,211,100**		**$ 1,600**

[1]'No. Properties Affected': there is flooding above ground level within the property boundary (i.e. the lot)
[2]'No. Flooded above floor level': there is flooding above the surveyed or estimated floor level of the house.

A significant contributor to the AAD is East Wagga, the flooding of which contributes to 34% of the total AAD (see Table 29). This is predominately due to over floor flooding in events smaller than the 1% AEP, high density of non-residential dwellings and current floor level policy requiring a minimum floor level of the 5% AEP design event. The largest contributor to non-residential AAD of any of the floodplain communities is the Wagga CBD, however the associated flood damages only occur once the design height of the CBD Levee is exceeded.

Table 31: Non-Residential Contribution to AAD - by Region

Region	AAD	% of Total AAD
Wagga CBD	$955,300	43
East Wagga	$755,300	34
North Wagga	$237,100	11
West Wagga	$117,000	5
Gumly	$18,600	1
Oura	$33,700	2
Wagga Floodplain	$78,300	4
Eunony	$15,800	1
Total	**$2,211,100**	**100**

7.2. Intangible Flood Damages

The intangible damages associated with flooding, by their nature, are inherently more difficult to estimate in monetary terms. In addition to the tangible damages discussed previously, additional costs/damages are incurred by residents affected by flooding, such as stress, risk/loss to life, injury, loss of sentimental items etc. It is not possible to put a monetary value on the intangible damages as they are likely to vary dramatically between each flood (from a negligible amount to several hundred times greater than the tangible damages) and depend on a range of factors such as the size of flood, the individuals affected, and community preparedness. Furthermore, the flood damages assessment is intended to be used consistently across the state and at present there is no guideline for the estimation of intangible damages. However, it is still important that the consideration of intangible damages is included when considering the impacts of flooding on a community.

Post flood damages surveys have linked flooding to stress, ill-health and trauma for the residents. For example the loss of memorabilia, pets, insurance papers and other items without fixed costs and of sentimental value may cause stress and subsequent ill-health. In addition flooding may affect personal relationships and lead to stress in domestic and work situations. In addition to the stress caused during an event (from concern over property damage, risk to life for the individuals or their family, clean up etc.) many residents who have experienced a major flood are fearful of the occurrence of another flood event and the associated damage. The extent of the stress depends on the individual and although the majority of flood victims recover, these effects can lead to a reduction in quality of life for the flood victims.

Section 9.8 investigates several response modification options and community awareness that aim to reduce anxiety and unnecessary stress caused by not having a good understanding of flood risk in Wagga Wagga. An example of such anxiety could be that residents believe flooding can happen very quickly and dramatically (as in other catchments), whereas previous events and modelling has shown there is a relatively slow rate of rise and a longer warning time for flooding in Wagga Wagga. Providing better information about this could help residents handle stress and have more confidence in their own safety and preparedness.

8. STAKEHOLDER CONSULTATION

Community consultation is an important element of the floodplain risk management process facilitating community engagement and ultimate acceptance of the overall project.

8.1. Post-2012 Flood SES Questionnaire

The NSW State Emergency Service (SES) issued a questionnaire following the March 2012 floods in south west NSW. While chiefly intended to collect flood data to update flood intelligence (e.g. Local Flood Plans) and to inform Flood Studies, the questionnaire also included questions about temporary protection (sandbagging), evacuation responses and alternative accommodation, which are useful for the current study. Some respondents also used the opportunity to include unsolicited information on the effectiveness of the March 2012 flood operation. Approximately 150 responses were received from within the study area. These have been reviewed as part of the current study.

8.2. Post-2012 Oral History Project

In the months following the March 2012 flood, Wagga Wagga City Library and State Library of NSW sponsored the recording of 25 interviews for an oral history project. The interviews include perspectives from WWCC, SES and affected communities especially North Wagga. Insights from these interviews have been drawn upon for this work.

8.3. Flood Futures Program

Council conducted extensive consultation in 2015 around proposals to raise the main city (CBD) and North Wagga levees, the former to provide protection to the 1% AEP flood, and the latter to provide protection to the 5% AEP flood. This consultation is summarised in documents available at http://yoursaywagga.com.au/floodfutures/documents, and has been considered as part of the current study.

8.4. Floodplain Risk Management Advisory Committee

The Wagga Wagga FRMAC comprises a number of representatives from the local community, including residents, members of Council, OEH and Department of Planning and Environment (DPE) representatives and the SES.

8.5. Stakeholder Engagement

Consultation with key stakeholders is an important element of the floodplain risk management process ultimately facilitating community engagement and acceptance of the overall project. Engagement with key stakeholders from the early stages (August and September 2016) of the current study has been undertaken for the following community groups and government agencies:

- Oura Progress Association
- Gumly Gumly community representative
- Wagga Floodplain Residents Protection Association
- North Wagga Residents Association
- WWCC – current and former personnel
- SES – current and former personnel
- Bureau of Meteorology

Consultation included phone conversations, emails and one-on-one meetings with the relevant groups. A summary of this initial consultation is presented in Appendix B. The key findings of consultation within the various community groups are:

- *That floodplain management and the current study need to be undertaken in an equitable fashion which benefits people living in areas both protected and not protected by the levees. Various floodplain communities acknowledge the benefits of raising the CBD levee, however think that raising the North Wagga levee is inequitable by placing more value on the North Wagga community than other communities on the floodplain.*
- *That a long-term strategic plan be implemented to reduce damages associated with flooding at Wagga by allowing future development in areas away from the floodplain and encouraging current floodplain developments to leave the floodplain.*
- *That Community perception is that the flood model is incorrect. More work is required to build confidence in the flood model results to appease community perception.*
- *Community consultation and engagement is paramount for the success and acceptance of the current Floodplain Risk Management Study.*

In addition to the above listed key stakeholders, consultation with the following stakeholders and agencies has also been undertaken:

- Council's Planners and Engineers;
- Office of Environment and Heritage;
- NSW State Emergency Service;
- Bureau of Meteorology;
- Murray-Darling Basin Authority;
- Department of Primary Industries;
- Local Land Services;
- Essential Energy;
- Riverina Water County Council;
- Department of Primary Industries;
- Roads and Maritime Services; and
- Australian Rail Track Corporation.

These stakeholders and agencies have been contacted for input into the current study. Where applicable, the provided information has been incorporated into this FRMS&P.

8.6. Public Exhibition of the Draft Final FRMS and FRMP

Public exhibition of the Draft Wagga Wagga Revised Murrumbidgee River FRMS and FRMP is required by the Local Government Act (1993, Section 402). This section stipulates that Council must exhibit the draft plan for public comment for a period of at least 28 days, and that submissions must be considered by the council before the plan is endorsed or amended.

The Draft Report was endorsed for public exhibition at the Council meeting on the 23rd October 2017. The Public Exhibition period commenced on the 24th October and was originally scheduled to finish on the 21st November 2017. Following requests from the community, the exhibition period was extended for another two weeks, closing on the 6th December 2017.

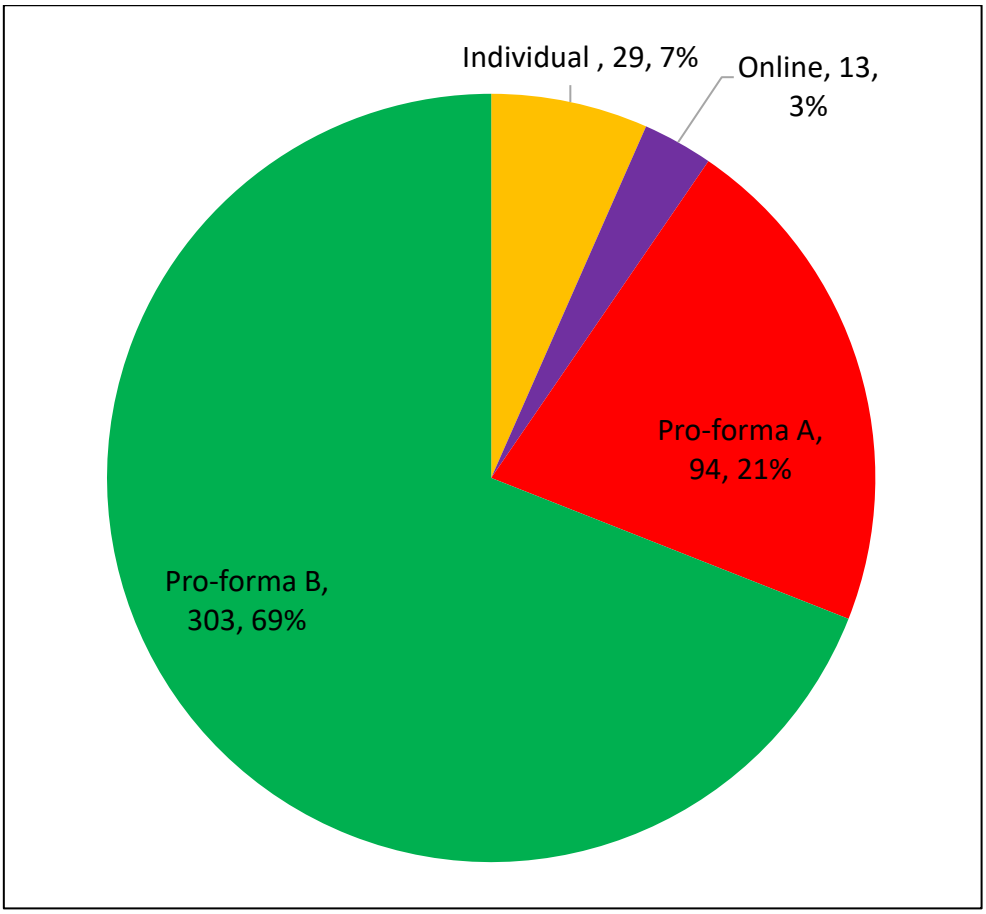
Digital copies of the report were available on the Council website. Nine drop-in sessions were held across the study area, attended by Council and WMAwater staff. The following drop-in sessions were held:

- Gumly Hall, 1/11/17
- Oura Hall, 2/11/17
- Council meeting room, 8/11/17
- Sturt Mall, 9/11/17
- Market Place Shopping Centre, 10/11/17
- Market Place Shopping Centre, 11/11/17
- North Wagga Hall, 14/11/17
- Council Chambers, 15/11/17
- Council Chambers, 30/11/17

8.6.1. Submissions

Residents could make submissions either by writing a letter or email directly to Council, or submitting an online form via the Council 'Have your Say' website. A large number of submissions were in the form of a pre-written proforma signed by individuals. The total number and break down of submission types is shown in Chart 1.

Chart 1 Types of Submissions received during the Public Exhibition Period



8.6.2. Responses to Submissions

All submissions were read and logged by Council and WMAwater. Submissions were categorised into key issues so that responses could be prepared. Due to the sheer number of submissions received, and the fact that many respondents did not provide contact details, it is not possible to personally acknowledge or respond to every submission. Instead, the key issues identified, and responses to each issue have been provided in Appendix M. This appendix also notes any changes to the report that have arisen due to submissions. Specific changes to the report have been documented in Table 1 at the end of Appendix M. The FRMAC reviewed this Appendix in detail prior to changes being made to the report.

9. FLOODPLAIN RISK MANAGEMENT MEASURES

9.1. Background

Floodplain risk management measures are actions which can be undertaken in both the short and long term which manage the risk of flooding. Measures range from flood modification measures such as levees and retarding basins, to response measures such as emergency response planning and property modification measures such as house raising or development controls. These types are described in the following section. The section also describes the management measures that were assessed in detail for the Study Area.

9.1.1. Categories of Floodplain Risk Management Measures

The 2005 NSW Government's Floodplain Development Manual (Reference 1) separates risk management measures into three broad categories.

Flood modification measures modify the physical behaviour of a flood including depth, velocity and redirection of flow paths. Typical measures include flood mitigation dams, retarding basins, channel improvements, levees or defined floodways. Pit and pipe improvement and even pumps may be considered where practical.

Property modification measures modify the existing land use and development controls for future development. This is generally accomplished through such means as flood proofing, house raising or sealing entrances, strategic planning such as land use zoning, building regulations such as flood-related development controls, or voluntary purchase/voluntary house raising.

Response modification measures modify the response of the community to flood hazard by educating flood affected property owners about the nature of flooding so that they can make better informed decisions. Examples of such measures include provision of flood warning and emergency services, improved information, awareness and education of the community and provision of flood insurance.

Table 32 provides a summary of typical floodplain risk management measures that have been assessed for the current study. It should be noted that many of these management measures are not appropriate for Wagga Wagga and have not been considered further.

Table 32: Flood Risk Management Measures

Flood Modification	Property Modification	Response Modification
Levees (Lv)	Land zoning	Community awareness
Temporary Defences (TD)	Voluntary purchase	Flood warning
Channel Construction (CC)	Building & development controls	Evacuation planning
Channel Modification (CM)	Flood proofing	Evacuation access
Major Structure Modification (MSM)	House raising	Flood plan / recovery plan
Drainage Network Modification (DNM)	Flood access	
Drainage Maintenance (DM)		
Retarding Basins (RB)		

Flood Modification Measures are investigated for individual floodplain communities in Section 9.3 with Study-Area wide options in 9.4. Property Modification Measures are presented in Section 9.6 and planning and future development control measures are discussed in Section 9.7. Response Modification Measures are discussed in Section 9.8.

9.1.2. Assessment Criteria

There are a number of factors to be considered when deciding whether or not to implement a flood mitigation option. Cost-benefit ratios (BC ratios) do not reflect the range of factors to be considered (e.g. social, environmental, technical), and therefore do not provide a full picture of an option's feasibility. Therefore, in addition to cost-benefit analysis, the Floodplain Development Manual (Reference 1) recommends undertaking a multi-criteria analysis to assess each option against a range of criteria (see examples of criteria listed below).

This report uses a multi-criteria matrix to assess each option, assigning scores to each of the listed criteria. An option that has a negative score would not be considered viable, while positive scores indicate that there are more pros than cons, and that the option could be considered further. The scoring system for the above criteria is provided alongside the assessment results in Table 99. All criteria are given a score between -3 and +3, with the exception of Risk to Life and Impacts on NSW SES which is scored between -6 and +6. Risk to Life is scored higher than the other criteria as reducing Risk to Life is considered to be the most important outcome of the current study as well as the FDM (Reference 1). Tangible costs and damages are also used as the basis of B/C analysis for some measures. A score has been allocated and endorsed by the FRMAC, and Community Acceptance scores were assigned following the public exhibition period. The NSW SES supports the implementation of mitigation options that reduce risk to life and property. NSW SES acknowledge however that some mitigation options may increase emergency management challenges which need to be managed.

The criteria assigned a value in the assessment matrix are:

- Impact on flood behaviour (reduction in flood level, hazard or hydraulic categorisation) over the range of flood events;
- Number of properties impacted by measure;
- Technical feasibility (design considerations, construction constraints, long-term performance);
- Community acceptance and social impacts;
- Economic merits (capital and recurring costs versus reduction in flood damages);
- Environmental and ecological benefits;
- Impacts on the NSW State Emergency Service; and
- Risk to life.

9.2. Overview of Flood Modification Types Investigated

This section provides a brief description of the types of flood modification options assessed in the various floodplain communities. There are other types of mitigation options that have not been considered further, and these are described in Section 9.4.6.

9.2.1. Levees

Levees are barriers between the watercourse and developed areas that prevent the ingress of floodwater up to a design height. Levees usually take the form of earth embankments but can also be constructed of concrete walls or steel sheet piles where there is limited space or other constraints. Flood gates, flap valves and pumps are often associated with levees to prevent backing up of drainage systems in the area protected by a levee and/or to remove ponding of local water behind the levee. These types of infrastructure are vital for the effectiveness of the levees.

Once constructed, levee systems need to be inspected on a regular basis for erosion or failure. Although a levee can keep out flood waters, flooding can occur within the levee due to local runoff being unable to drain, or during an event that exceeds its design height. The failure of a levee can cause catastrophic flooding in events even below its design level of protection. In addition, as the levee causes a displacement of water from one area of the floodplain to another they should be carefully designed using hydraulic modelling techniques so as to ensure the levee does not increase flood risk to an adjacent area or internally in a larger event.

The crest height of a levee is set at a level that equals the height of the design flood event for which is designed to protect against plus an allowance for freeboard. The freeboard allows for: settlement of the structure overtime, variations in flood levels due to the behaviour of the flood event, wave action from passing vehicles or watercraft and effects of wind. A full freeboard assessment for each of the levees investigated in this section is outside of the scope of the current study. Accordingly, freeboard allowances have been assumed based on the freeboard analysis undertaken for the Wagga Wagga Levee Upgrade Flood Freeboard study (Reference 8). A lower freeboard is used at the spillways. A spillway is a lower portion of the

levee which allows for controlled overtopping of the levee to ensure the structure is not damaged by being subject to floods larger than the design level of protection.

It should be noted that levees can be socially divisive. There are often differing opinions regarding the equity of protection between communities inside and outside levees, and residents generally do not want to pay higher rates to subsidise a levee that does not protect them personally. There may also be concerns that raising or constructing levees could lead to decreases in property values outside of the levee, and an increase in capital losses for these properties.

At the time of writing, the upgrade of the Wagga CBD (Main City) levee was well underway following being recommended in the 2009 Study. Modelling in this FRMS assumes the CBD levee upgrade is complete.

Four levee alignments have been considered which are summarised below with full details in the ensuing sections:

- Option L1, Oura Levee (Section 9.3.1.1);
- Option L2, Gumly Gumly Levee (Section 9.3.2.1);
- Option L3 (A, B & C), North Wagga Levee raised to the 1% AEP design event (Section 9.3.3); and
- Option L4 (A, B & C), North Wagga Levee raised to the 5% AEP design event (Section (9.3.3);
- Option L5: Removal of existing North Wagga Levee (Section 9.3.3.7); and
- Option L6: Opening of existing North Wagga Levee (Section 9.3.3.8).

Levees are constructed for the protection of property, and reduction of property damages. They do not fully remove risk to life, and in fact can exacerbate it if the area is classified as a low or high flood island, in which residents can become isolated if they do not evacuate at an appropriate time. It should be noted that with the construction of a levee, many residents feel it is safer to stay in their homes longer, which may not be the case depending on key access routes. This attitude can greatly increase pressure on the SES during an event if the floodwaters cut access routes to a leveed area, and even more so if the levee is breached while residents are still at home.

9.2.2. Channel Modifications

Channel modifications may include increasing the size of a channel, straightening, concrete lining, removal of obstructing structures, dredging and vegetation clearing. In some instances increasing native vegetation density in the channel upstream can reduce peak levels downstream by slowing flows and making better use of flood storage. On the other hand, straightening and channelling the flow can improve flooding by removing flood waters from an area more efficiently. However, such measures may also increase flood levels in adjacent or downstream locations, and consideration must be given to the scale of works, environmental impacts and the availability of an appropriate location to deposit excavated material.

Channel modification works were not considered in the 2009 FRMS (Reference 3) as it was expected that given the size of the Murrumbidgee River any improvement works would have negligible benefits and were likely to have significant environmental disadvantages. Despite generally concurring with this assessment, the current report investigates two options raised during community consultation; these address views about the perceived value of widening constrictions at Malebo Gap and Gobbagombalin Bridge in Section 9.3.5.1 and 9.3.5.2 respectively.

Channel modifications can have significant impacts on the environment and ecological systems. The proposed options incorporating major excavations would significantly alter the geomorphology and the natural ecosystem surrounding the excavation site. The relocation of the excavated soil can adversely affect ecosystems if not disposed of properly. Furthermore, the excavation could cause unforeseeable alterations to the flow of the Murrumbidgee River and cause new flood behaviours upstream of the site. Consequently, the options defined as major excavations are considered to be a 'major disbenefit' to the environment.

9.2.3. Bypass Floodways

Floodways are lower overbank areas which can carry significant flow volumes in times of flood and occur naturally on some floodplains. In some instances, on smaller streams, an artificial floodway can be created in an environmentally sensitive manner to achieve a reduction in upstream flood levels. The 2009 Study (Reference 3) did not consider bypass floodways, citing that given the size of the Murrumbidgee River floodplain, and the volume of water involved, artificial floodways were not considered to be a viable management measure. Feedback from community consultation conducted in 2016 however suggested that residents would like to see a flowpath around the north of North Wagga assessed. This has been investigated in Section 9.3.4.2.

9.2.4. Major Structure Modification

Hydraulic controls such as bridges or major culverts on significant waterways can affect upstream flood levels due to backwatering effects. By increasing hydraulic conveyance, flood levels upstream of a structure can be decreased. Generally the most effective way of increasing hydraulic conveyance is by increasing a structure's cross sectional area (normal to the flow direction). This is often done by lengthening a bridge to span part of the floodplain, raising the deck level or increasing the size of culverts. Such an option is considered for Hampden Avenue, assessed in Section 9.3.4.1. Option CM2, excavation under Gobbagombalin Bridge, also would involve major structure modification as the bridge footings would need to be redesigned to accommodate the proposed excavation.

9.2.5. Road Raising

Depending on the topography of an area, floods can leave communities isolated by overtopping access routes (see Section 5.5). Raising roads to provide flood free access to such areas is commonly investigated in the floodplain risk management process as it can reduce evacuation time and improve accessibility as the flood progresses. However, raised roads can act like levees and increase flood levels unless culverts or overland bridge spans are used appropriately. An initial assessment of raising Oura Road (Section 9.3.1.2) and Sturt Highway (Section 9.3.2.2) has been undertaken.

9.3. Options for Floodplain Communities

As discussed in Section 5.7, there are a number of distinct Floodplain Communities in Wagga Wagga that experience flood risk or flooding in a specific and individual manner, and each community has different response systems and levels of flood resilience. For this reason, flood risk mitigation options investigated are grouped by the Floodplain Community which they most directly affect. The options considered are summarised in Table 33 and an overview is shown in Figure E1. The results of the assessment are presented as the following:

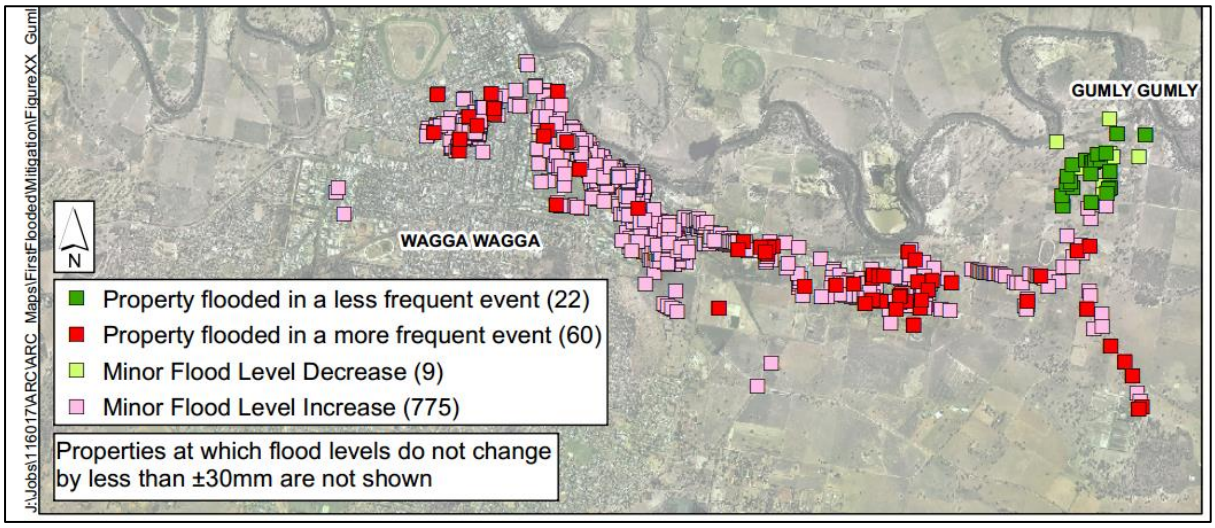
a) **Property Affectation Results:** shows the number of properties affected by flooding externally and above floor level in each design event, and how these results compare to the design base case;

b) **Property Damages by Community:** Shows how the Annual Average Damages is affected by the implementation option in each floodplain community as described in Section 5.7

c) **Property Damages Figures:** These figures show the over floor property affectation associated with the implementation of the option. An example is shown in Diagram 6, in which:

- **Dark green squares:** The property would be flooded in a less frequent event if the option were implemented (compared to the existing situation);
- **Dark red squares:** Property would be flooded in a more frequent event if the option were implemented (compared to the existing situation);
- **Light green squares:** Flood levels at the property would decrease, but not change the frequency at which the property is flooded; and
- **Light red squares:** Flood levels at the property would increase, but not change the frequency at which the property is flooded.

Diagram 6 Property Affectation Example Figure



d) Economic Assessment: The economic assessment lists the capital cost, overall reduction in Annual Average Damages and the resulting B/C ratio. Details on each of these elements is provided in Appendix F.

e) Discussion of Other Concerns: This section is used to raise any other concerns associated with the option, including construction feasibility and constraints, alleviation or exacerbation of the flood risk precinct classification (and subsequently pressure on SES and risk to life), community education needs and environmental issues.

A broad range of flood modification options were assessed. These are listed in Table 33 and described and assessed in the subsequent sections.

Table 33 Flood modification mitigation options assessed

Floodplain Community	Option	Mitigation Options Considered	Report Reference
Oura	L1	Oura Levee	9.3.1.1
	R1	Oura Road Raising	9.3.1.2
Gumly Gumly	L2	Gumly Gumly Levee	9.3.2.1
	R2	Raising Sturt Highway	9.3.2.2
North Wagga	L3 (A-C)	North Wagga Levee Upgrade (1% AEP Event Design)	9.3.3.1
	L4 (A-C)	North Wagga Levee Upgrade (5% AEP Event Design)	9.3.3.4
	L5	Removal of North Wagga Levee	9.3.3.7
	L6	Opening of North Wagga Levee	9.3.3.8
Wagga Floodplain	A1	Increase Conveyance beneath Wiradjuri Bridge	9.3.4.1
	BF1	North Wagga Floodplain Bypass Floodway	9.3.4.2
West Wagga	CM1	Excavation of Malebo Gap	9.3.5.1
	CM2	Excavation beneath Gobbagombalin Bridge	9.3.5.2
Study Area	VM(A-D)	Vegetation Management	9.4

9.3.1. Oura

9.3.1.1. Option L1: Oura Levee

Option Description

Option L1 examined the implementation of a levee at Oura. The examined levee is 2,300 m in length and runs approximately parallel and to the south of Wagga Wagga Street, Oura. The modelled alignment is presented in Figure E1. A typical levee section and a preliminary costing are provided in Appendix F. Preliminary consultation with Oura community members (see Appendix B) identified a desire for examination of the feasibility of a levee to protect the Oura Community. At present, 31 properties are subject to over-floor inundation in the 2% AEP event, and 36 in the 1% AEP event. As described in Section 5.7.1, flooding of residential properties in Oura first occurs for events larger than the 10% AEP flood. A levee has been investigated to mitigate for floods larger than the 1% AEP. The freeboard requirements for this levee have not been assessed but have been assumed to be similar to those defined in Reference 8 for the CBD and North Wagga levees, between 0.75 m and 0.9 m.

Modelled Impacts

The earthfill embankment levee construction was modelled by raising the existing ground level along the alignment by up to 3 m in parts to provide protection from the 1% AEP event. The 1% AEP results are presented in Figure E2 and show widespread minor increases in flood levels (up to 0.05 m) extending approximately 2 km upstream and to the south of Oura, while removing all flood affectation behind the levee and reducing flood levels by up to 0.05 m downstream of the levee. There are negligible external impacts in the 5% AEP event and the flooding is excluded from Oura, as shown in Figure E3.

Change in Property Flood Affectation

Table 34 indicates the number of properties affected both externally and internally (over floor level) in each design event tested as part of this Study.

Table 34 Option L1: Property Affectation

Event	Total Properties Affected Externally		Total Properties Affected Over floor level			
	Existing Case	Option Implemented	Existing Case	Option Implemented	Floor Level Difference	% Floor Level Difference
10% AEP	57	56	41	40	1	2.4%
5% AEP	307	293	234	231	3	1.3%
2% AEP	465	427	404	372	32	7.9%
1% AEP	597	556	539	503	36	6.7%
0.5% AEP	2402	2402	2170	2170	0	0.0%
0.2% AEP	3736	3736	3661	3661	0	0.0%
PMF	4744	4744	4728	4728	0	0.0%

*Positive numbers indicate NET reduction in number of properties flooded above floor

Property affectation is removed from 32 properties across the floodplain (31 in Oura) in the 2% AEP event and reduced for 36 properties in the 1% AEP event (34 in Oura). The levee has no impact on internal or external property damages in events greater than the 1% AEP event. Diagram 7 indicates how properties flooded over floor are affected by implementation of the option across the full range of design events, and shows that property flood affectation downstream of Oura does not change by more than 30 mm. These effects are reflected in Table 35 which shows the property damages by Floodplain Community, and indicates very minor differences across all communities other than Oura itself. There are no benefits across the floodplain for events including and greater than 0.5% AEP. One property just upstream of the proposed levee is adversely impacted and now flooded over floor in the 0.5% AEP event, although this may be managed by refining the levee alignment.

Diagram 7 Option L1: Change in internal property affectation due to option implementation

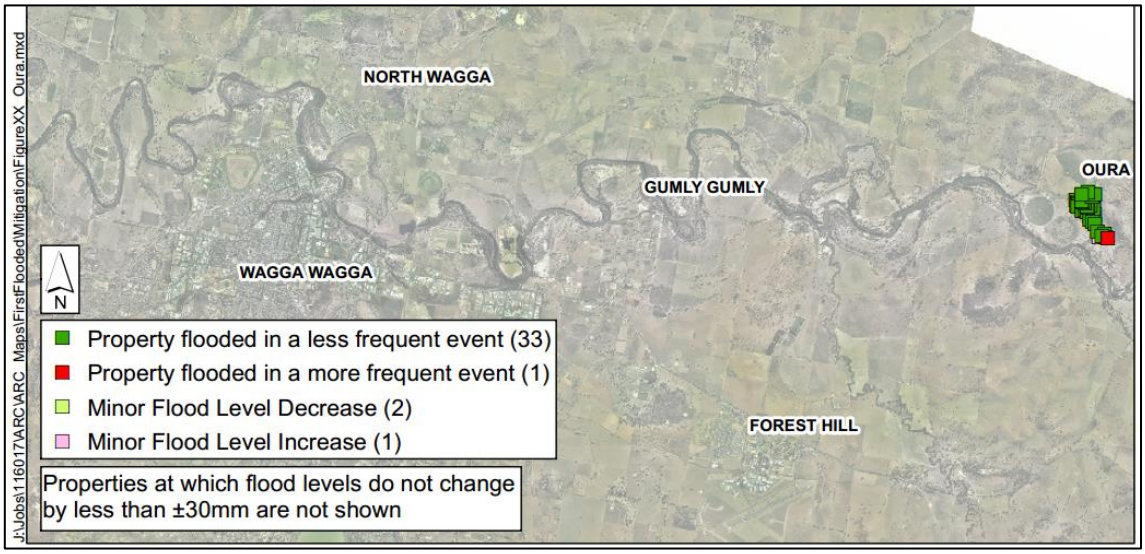


Table 35 Option L1: Property Damages by Community

Community	AAD (Existing Case)	AAD (Option Implemented)	Difference*	% Difference
Wagga CBD	$2,347,400	$2,347,000	$400	0.0%
East Wagga	$846,000	$844,800	$1,200	0.1%
North Wagga	$1,583,100	$1,583,100	$0	0.0%
West Wagga	$347,800	$347,800	$0	0.0%
Gumly	$115,600	$115,600	$0	0.0%
Oura	$125,200	$36,600	$88,600	70.8%
Wagga Floodplain	$182,200	$180,800	$1,400	0.8%
Eunony	$34,600	$34,600	$0	0.0%
Total AAD	**$5,581,900**	**$5,490,300**	**$91,600**	**1.6%**

*Positive numbers indicate reduction in total AAD with implementation of the option

Construction of a 1% AEP levee to protect Oura would reduce damages locally by 71%, reducing Oura's AAD from $125,200 to $36,600. However, the levee has a minimal impact on the overall floodplain Annual Average Damages, reducing the total by only 1.6%. This minor reduction leads to a low BC ratio, as shown in Table 36, which indicates that Option L1 is not economically feasible as the benefits are limited to a small number of properties compared to the high capital cost of design and construction.

Table 36 Option L1: Economic Assesment

Capital Cost	$3,083,200
Reduction in Total AAD	$92,000
Reduction in Total AAD	1.6%
BC Ratio	0.42

Other Concerns

Complacency and Reluctance to Evacuate

The levee would reduce the incidence of flooding thus reducing required SES attendance for events up to the design height of the levee. However, the construction of a levee could encourage residents to stay in their homes during flood events which may increase demand on SES should the levee be overtopped. Being an open levee (as opposed to an enclosed ring levee) there are fewer issues to note in regards to access/egress, evacuation and risk to life compared to a ring levee, and Oura generally has good access to land above the floodplain. The Oura community has rising road access to the north and the Presbyterian Church is currently being negotiated for use as an evacuation centre, however the upgrade of two currently unsealed roads (Adams Street and Jarvis Street) would be required to secure the access route during wet weather.

Residual Flood Risk Education

This option would require input into educating the community about the residual flood risk that would remain. While the proposed option would protect the community up to and including the 1% AEP event, risk of inundation would still exist for larger events. Without understanding these risks, communities often feel a false sense of security with such a large levee in place. Additionally, education regarding the ways in which levees can fail is important to ensure that residents understand that there is still a risk of flooding with a levee in place.

Construction Practicality and Internal Flooding

The catchment area behind the levee is approximately 1.5 km^2. Internal drainage issues are expected to be relatively minor, however will need to be considered with construction of a levee. Drainage can be managed through the implementation of suitable gates or non-return valves to minimise flooding within the levee. Land acquisition may also be required to obtain suitable easement for the proposed alignment, which may be substantial to accommodate the proposed footprint.

Mobility of Elderly Citizens

Successful evacuation requires sufficient warning time, prepared residents and ample assistance for those less mobile, such as the aged residents. According to the Australian Bureau of Statistics (Reference 26), the overall percentage of persons aged over 60 in Oura is 21.9% compared to the 21.8% in NSW. Any community with elderly residents is vulnerable to evacuation difficulties, as can be seen in Lismore during the flood in March 2017 (Photo 1). Note that concerns regarding the age and mobility of residents apply to all types of flood mitigation options, however constructing a levee may lead to residents becoming reluctant to evacuate, or shelter in place for longer, leading to more assistance required when evacuation does occur.

Conclusion

Based on the outcomes of the above assessment and consideration of concerns, the following scores have been assigned to Option L1 in the multi-criteria assessment, noting that Community Acceptance scores have been allocated based on feedback received during the Public Exhibition period.

Table 37 Option L1: Multi-Criteria Assessment Results

Ref	Option	Impact on Flood Behaviour	Impact on Property Damage	Technical Feasibility	Community Acceptance	Economic Merits	Environmental/ Ecological Benefits	Impact on SES	Risk to Life*	Total Score
L1	Oura 1% AEP Levee	-1	0	0	1	-2	-1	-1	-2	-6

* A detailed breakdown of the factors contributing to the risk to life score is presented in Table 101.

Option L1 Summary of Recommendations

☒ The FRMAC does not recommend further consideration of a levee up to the 1% AEP protection level for Oura, as it has been shown to have limited flood benefits for a small number of residents compared to capital costs. This imbalance leads to a low BC ratio of 0.42 indicating that the option is not economically viable.

9.3.1.2. Option R1: Oura Road Raised to 1% AEP Level

Option Description

This option assesses raising Oura Road between Hampden Avenue (North Wagga) and the northern side of Oura. This is intended to provide flood free access between Oura and Wagga Wagga, and is likely to be a long term project. Upgrades to Sturt Highway (discussed in Section 9.3.2.2) could combine to provide east-west flood free access across Wagga Wagga, Oura and Gumly Gumly. Currently, Oura Road is first cut near Bomen Lagoon, when the river reaches 9.16 m at the Hampden Bridge Gauge. Access to Wagga Wagga is required for Oura residents to continue working and to reach the various services available there. This option was considered in 2009 (Reference 3) and has been revisited for assessment under current conditions. A preliminary long section is provided in Appendix F.

Modelled Impacts

For this initial assessment, the roads have been modelled to be upgraded using a standard earth fill embankment construction raised above the 1% AEP peak flood level, with several culverts and overland bridges to reduce the levee effect of the road. The bridge sections are marked in green on the 1% AEP impact map provided in Figure E4. This allows initial viability of the road to be determined. As expected there are significant widespread impacts. These impacts simply indicate that further thought is required into the type of construction, appropriate location of culverts and overland bridges (such as the recently completed Kempsey Bypass on the NSW Mid North Coast) to minimise increases in flood levels.

Other Concerns

The improvement of flood free access is of great benefit to SES and residents during flood events, extending the window of safe evacuation greatly. However, this may cause some residents to take longer to evacuate and increase pressure on SES if they do not leave their homes in time to reach flood free land. This is only a minor concern for residents of Oura as there is access to flood free land to the north, and use of the Presbyterian Church as an evacuation centre is currently being negotiated. It should be noted that SES assistance to Oura is problematic due to road closures between Wagga Wagga and Oura, as a result the Junee Unit may be required to attend if available.

The main concern however is the cost of construction. As it is difficult to quantify the benefits (in terms of risk to life/ ease of evacuation), a cost benefit analysis would not be favourable. Large scale projects such as this (and the other road raising options assessed) require much greater investigation into the feasibility and benefits than this report allows for. It is envisaged that work would be staged and subject to available funding as it arises.

Alternate Routes

During the public exhibition period, a small number of submissions identified existing roads (or potential easements for roads) north of the floodplain that could be utilised to achieve the outcome of providing flood free access from the CBD to Oura. This recommendation has therefore been updated to allow for the consideration of alternate routes.

Conclusion

Based on the outcomes of the above assessment and consideration of concerns, the following scores have been assigned to Option R1 in the multi-criteria assessment, noting that Community Acceptance scores have been allocated based on feedback received during the Public Exhibition period.

Table 38 Option R1: Multi-Criteria Assessment Results

Ref	Option	Impact on Flood Behaviour	Impact on Property Damage	Technical Feasibility	Community Acceptance	Economic Merits	Environmental/ Ecological Benefits	Impact on SES	Risk to Life*	Total Score
R1	Oura Road Raising	-1	-1	-1	3	0	1	3	2	6

* A detailed breakdown of the factors contributing to the risk to life score is presented in Table 101.

Option R1: Summary of Recommendations

☑ With appropriate construction and route selection, improved road access could be achieved without the significant flood impacts shown in this assessment. The option should be tabled for future investigation due to the benefits in terms of evacuation safety and flood free access between all parts of Wagga Wagga.

9.3.2. Gumly Gumly

9.3.2.1. Option L2: Gumly Gumly Levee

Option Description

Option L2 investigated the construction of a levee to protect residences in Gumly Gumly from inundation for flood events up to and including the 1% AEP event as an improvement on the current levee, which protects from flood breakouts from an oxbow north of Lamprey Avenue for events up to approximately the 10% AEP. At present, road flooding and property inundation first occurs during events from the 0.2EY and larger (see Section 5.7.1). A ring levee has been examined, with an approximate length of 3,400 m and average crest height 1.1 m above ground, and encloses an area of 0.57 km^2. No formal freeboard estimate has been made at this stage, but is assumed to be similar to the Dept. of Public Works estimate for the Wagga Main City (CBD) Levee and North Wagga levee. The levee has been designed to not cut major flood runners or flow paths to minimise impacts, and accordingly cannot protect all properties in Gumly. The modelled alignment is presented in Figure E1, and a typical levee section and a preliminary costing is provided in Appendix F.

Modelled Impacts

Option L2 mitigates flooding within the township of Gumly Gumly for events up to the 1% AEP. A flood impact map for the 1% AEP event is presented in Figure E5. Flood level impacts of up to 0.1 m extend upstream to Braehour Road. Impacts of the levee in the 5% AEP event are shown in Figure E6 and are comparatively minor. Flooding is prevented within the ring levee, and increases upstream are in the order of 0.05 m.

Change in Property Flood Affectation

Table 39 indicates the number of properties affected both externally and internally (over floor level) in each design event tested as part of this Study. In events greater than and including the 2% AEP, properties in East Wagga are negatively impacted by the levee and experience over-floor flooding in earlier events than they otherwise would. This results in a net negative outcome.

Table 39 Option L2: Property Affectation

Event	Total Properties Affected Externally		Total Properties Affected Over floor level			
	Existing Case	Option Implemented	Existing Case	Option Implemented	Floor Level Difference	% Floor Level Difference
10% AEP	57	56	41	40	1	2.4%
5% AEP	307	302	234	232	2	0.9%
2% AEP	465	464	404	412	-8	-2.0%
1% AEP	597	590	539	542	-3	-0.6%
0.5% AEP	2402	2441	2170	2203	-33	-1.5%
0.2% AEP	3736	3736	3661	3662	-1	0.0%
PMF	4744	4744	4728	4728	0	0.0%

*Positive numbers indicate NET reduction in number of properties flooded above floor

While the Option L2 levee provides flood protection for a number of properties within the Gumly Gumly levee for events up to and including the 1% AEP, properties situated outside of the levee are newly flooded or flooded in a more frequent event, causing a net increase in property damages. Diagram 8 indicates how properties flooded over floor are affected by implementation of the option across the full range of design events, and shows that the Gumly Levee worsens flooding for a large number of properties downstream of Gumly Gumly, especially through East Wagga and the CBD. These effects are reflected in Table 40 which shows the property damages by Floodplain Community.

Diagram 8 Option L2: Change in internal property affectation due to option implementation

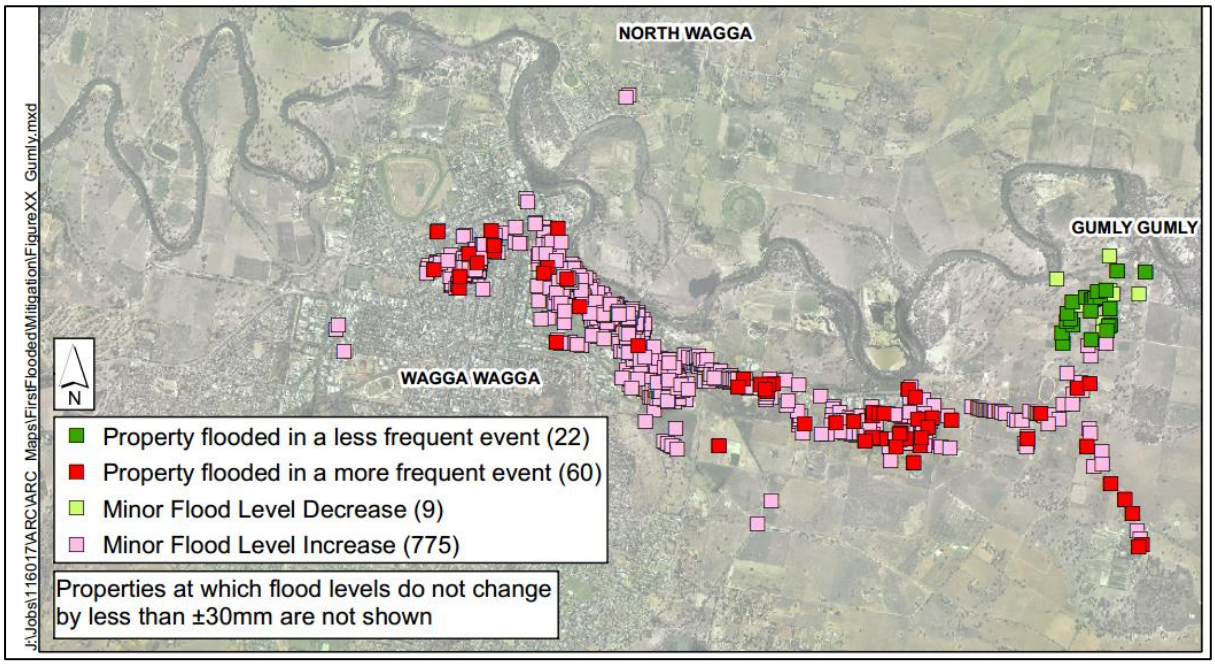


Table 40 Option L2: Property Damages by Community

Community	AAD (Existing Case)	AAD (Option Implemented)	Difference	% Difference
Wagga CBD	$2,347,400	$2,368,800	-$21,400	-0.9%
East Wagga	$846,000	$902,200	-$56,200	-6.6%
North Wagga	$1,583,100	$1,582,700	$400	0.0%
West Wagga	$347,800	$347,700	$100	0.0%
Gumly	$115,600	$93,100	$22,500	19.5%
Oura	$125,200	$125,200	$0	0.0%
Wagga Floodplain	$182,200	$180,700	$1,500	0.8%
Eunony	$34,600	$33,700	$900	2.6%
Total AAD	**$5,581,900**	**$5,634,100**	**-$52,200**	**-0.9%**

*Positive numbers indicate NET reduction in number of properties flooded above floor

Construction of a 1% AEP levee to protect Gumly Gumly would reduce damages locally by 19.5%, reducing Gumly Gumly's AAD from $115,200 to $93,100. Due to the alignment of the levee having to avoid key flowpaths, the levee does not protect all of Gumly Gumly, hence resulting in a less comprehensive damages reduction than the Oura levee afforded to Oura (see Section 9.3.1.1). Furthermore, the levee has adverse impact on the overall Annual Average Damages, increasing the total by 0.9%. This increase leads to a negative BC ratio, as shown in Table 41, which indicates that Option L2 is not economically feasible.

Table 41 Option L2: Economic Assesment

Capital Cost	$4,096,000
Reduction in Total AAD	-$52,000
Reduction in Total AAD	-0.9%
BC Ratio	<0

Other Concerns

There are a range of construction issues associated with a levee upgrade in Gumly Gumly. Acquisition of levee easements (or corridors for widening the existing levee) would be necessary which would require negotiation with local land holders. The condition of the existing informal levee is not well understood, and the suitability for it to be build upon will be key to the total cost of the project.

Access and Egress

Furthermore, Option L2 levee could exacerbate the dangerous Low Flood Island ERP category at Gumly Gumly (see Section 5.5). This would increase the Impact on SES and Risk to Life criteria. It is likely that for Option L2 to be feasible, a bridge or raised road structure would be required to provide rising road access for events up to the design height of the levee, which varies from 1.3 m to 2 m above natural surface. This height is substantial and would impact on the visual amenity for Gumly Gumly residents. The bridge would need to be located to the south of the investigated ring levee and provide access across the floodplain runner situated to the south of Gumly Road, to Sturt Highway/ Hammond Avenue. The construction of such a structure would significantly increase the cost of this Option. An upgrade to the Sturt Highway to provide this access is investigated in the subsequent section.

Complacency and Reluctance to Evacuate

As with all levees, implementation of this option may act to encourage residents to stay in their homes during flood events which would drastically increase pressures on the SES, should the levee be overtopped or fail, or residents decide to leave at a later point.

Residual Flood Risk Education

This option requires input into educating the community about the residual flood risk that would remain. While the proposed option would protect the community up to and including the 1% AEP event, risk of inundation would still exist for larger events. Without understanding these risks, communities often feel a false sense of security with such a large levee in place. Additionally, education regarding the ways in which levees can fail is important to ensure that residents understand that there is still a risk of flooding with a levee in place.

Mobility of Elderly Citizens

Successful evacuation requires sufficient warning time, prepared residents and ample assistance for those less mobile, such as the aged residents. According to the Australian Bureau of Statistics (Reference 26), the overall percentage of persons aged over 60 in Gumly Gumly is 29.2% compared to 21.8% in NSW. Any community with elderly residents is vulnerable to evacuation difficulties, as can be seen in Lismore during the flood in March 2017 (Photo 1). Note that concerns regarding the age and mobility of residents apply to all types of flood mitigation options, however increasing the levee's level of protection may lead to residents becoming reluctant to evacuate, or shelter in place for longer, leading to more assistance required when evacuation does occur.

Conclusion

Based on the outcomes of the above assessment and consideration of concerns, the following scores have been assigned to Option L2 in the multi-criteria assessment, noting that Community Acceptance scores have been allocated based on feedback received during the Public Exhibition period.

Table 42 Option L2: Multi-Criteria Assessment Results

Ref	Option	Impact on Flood Behaviour	Impact on Property Damage	Technical Feasibility	Community Acceptance	Economic Merits	Environmental/ Ecological Benefits	Impact on SES	Risk to Life*	Total Score
L2	Gumly Gumly 1% AEP Levee	-2	-2	-2	-1	-3	-1	-2	-4	-17

* A detailed breakdown of the factors contributing to the risk to life score is presented in Table 101.

Option L2 Summary of Recommendations

☒ The construction of a ring levee would worsen peak levels elsewhere in the floodplain impacting dwellings and exacerbate the potential for isolation of the encircled residents. The option results in an increase in AAD. In addition, without an accompanying road upgrade the option is not deemed acceptable in terms of the impact on SES and risk to life. This makes this option more financially unviable and is not recommended.

9.3.2.2. Option R2: Raising Sturt Hwy to 1% AEP Level

Option Description

The area around Gumly Common is cut at the Graham Avenue culvert at about 8.2 m on the Wagga Wagga gauge, isolating six dwellings, and the entire area north of low points on Pioneer Avenue and the western end of Gumly Road, cut at about 8.5 m on the Wagga Wagga gauge, isolating about 43 dwellings. Furthermore, the Sturt Highway can be cut at East Wagga near Marshalls Creek. This option investigates raising 6.8 km of the Sturt Highway between Elizabeth Avenue and Marshalls Creek to provide improved access for residents of East Wagga and Gumly Gumly. While it is acknowledged that the Sturt Highway is owned and managed by RMS it has been investigated as part of this study to determine if there is merit in proceeding further. This option is similar to the East Wagga Levee option considered in 2009 (Reference 3) and has been revisited for assessment under current conditions. The intent of this road is not to act as a levee, and its construction would require a number of culverts and bridge sections to ensure flowpaths are not obstructed. A preliminary long section is provided in Appendix F.

Modelled Impacts

For this initial assessment, the roads have been modelled to be upgraded using a standard earth fill embankment construction raised above the 1% AEP peak flood level, with several culverts and overland bridges to reduce the levee effect of the road. The bridge sections are marked in green on the 1% AEP impact map provided in Figure E7. This allows initial viability of the road to be determined. As expected there are significant widespread impacts. These impacts simply indicate that further thought is required into the type of construction and appropriate location of culverts and overland bridges (such as the recently completed Kempsey Bypass on the NSW Mid North Coast) to minimise increases in flood levels.

Other Concerns and Benefits

It is envisaged that the costs associated with raising the Sturt Highway would be significant and greatly reduce the feasibility of the project, but that the option would provide regional benefit. An alternate alignment to the south may be preferable to attempting to raise the road above the riverine floodplain, however overland flow coming from the hills to the south would also need to be considered.

Opportunities

During the public exhibition period, one submission identified an opportunity to consider an east-west flood free route in conjunction with other infrastructure improvements, for example the southern route proposed in the WWCC Integrated Transport Strategy 2040. In light of this, the recommendation will be revised to allow for consideration of alternate routes that will contribute to the same outcome, that is, flood free access between the Wagga Wagga CBD and Gumly Gumly (and beyond).

Conclusion

Based on the outcomes of the above assessment and consideration of concerns, the following scores have been assigned to Option R2 in the multi-criteria assessment, noting that

Community Acceptance scores have been allocated based on feedback received during the Public Exhibition period.

Table 43 Option R2: Multi-Criteria Assessment Results

Ref	Option	Impact on Flood Behaviour	Impact on Property Damage	Technical Feasibility	Community Acceptance	Economic Merits	Environmental/ Ecological Benefits	Impact on SES	Risk to Life*	Total Score
R2	Sturt Hwy Raised (RMS)	2	0	1	3	0	2	3	2	13

* A detailed breakdown of the factors contributing to the risk to life score is presented in Table 101.

Option R2 Summary of Recommendations

☑ With appropriate construction, the raising of Sturt Highway could be implemented without the significant flood impacts shown in this assessment. While the cost is likely to be prohibitive, the option should be tabled for future investigation by Council and NSW Government due to the benefits in terms of evacuation safety and flood free access between all parts of Wagga Wagga and regionally.

Alternatively, other infrastructure projects may provide an opportunity to develop flood free access between Wagga Wagga and Gumly Gumly. Routes other than the existing Sturt Highway therefore should also be considered.

9.3.3. North Wagga

Background

Consideration of changes to the North Wagga levee was a key aspect investigated in the 2009 FRMS&P (Reference 3). The 2009 FRMS&P considered in detail issues of equity, risk and impact, cost benefit, the history of the current design level of protection and the benefit a higher levee would actually achieve. The recommendation was that it is not appropriate to raise the levee but that the relative level of protection should be maintained. The level of protection is approximately 12% AEP and is described in detail in Section 5.9.1.2. With recent floods in 2010 and 2012 and the CBD levee upgrade proceeding, the North Wagga levee has again become an issue for consideration and as such, a number of options have been assessed as potential mitigation measures as part of this FRMS. There are a number of concerns however associated with a ring levee located in a floodway that must be considered before proceeding with further assessment of any proposed individual options. The major concerns align with criteria in the multi-criteria assessment (Section 10), against which all floodplain risk management options are assessed. The following sections outlines a range of concerns that are common to any proposed levee option for North Wagga. Concerns regarding each levee variation considered are included in the following relevant sections. Due to the characteristics of flood behaviour in North Wagga, flood risk management for this area must be approached differently to the CBD.

Flood Characteristics of North Wagga

Flood Impacts

Given North Wagga Village's position in the floodway, upstream impacts on other properties is a key concern of any levee upgrade. While a levee may protect a large number of properties within North Wagga in events smaller than its design level of protection, it would do so at the expense of properties upstream of North Wagga in the floodplain due to the reduced floodway conveyance. In events greater than the design level of protection the levee still acts as an obstruction, worsening flood behaviour in the upstream floodplain and within the (upgraded) CBD leveed area in events which exceed the CBD levee design height. Should the impact be found to be significant on existing infrastructure, there may be a need to offset these impacts with compensatory works. This would also increase the costs of the overall project and reduce economic viability. The flood impacts of each option considered are detailed in the following sections.

Drainage Following a Flood Event

In flood events that overtop the North Wagga levee, floodwaters can be impounded by the ring levee bank for many days or weeks. Accounts from residents of North Wagga have noted the village becoming like a swamp following the 2012 event, as the contaminated floodwaters could not drain until the river flood level had dropped, which did not occur for some time. In this situation, residents are unable to return to their homes and 'get on with their lives' until well after much of the remainder of Wagga Wagga. The extended periods of isolation that occur emphasise how critical evacuation is, as residents who may elect to stay could be cut

off from services for weeks and be exposed to the associated health risks. Regardless of if a levee upgrade is recommended for North Wagga, the existing capacity of the flood pumps is likely to require investigation and potential improvement.

Risk to Life: Access and Egress

Emergency Response Planning (ERP) classifications (Section 5.5, Reference 7) consider flood affected communities as those in which the normal functioning of services is altered, either directly or indirectly, because a flood results in the need for external assistance. This impact relates directly to the operational issues of evacuation, resupply and rescue. Based on the guidelines, communities are classified as either; Flood Islands; Road Access Areas; Overland Escape Routes; Trapped Perimeter Areas or Indirectly Affected. North Wagga is classified as a 'Low Flood Island', which means it is lower than the limit of flooding (i.e. the PMF). During a flood event the area is isolated by floodwater and property will be inundated. If floodwater continues to rise after isolation, the island will eventually be completely submerged by up to 3 m in the 0.5% AEP event. In this sized event, flood free ground to the north is over 2 km away, and Hampden Avenue is inundated with depths up to 4.8 m in parts making access impossible. People left stranded on the 'island' are likely to need rescuing (placing others in danger), or may drown as property becomes inundated. Some of this risk can be offset by ensuring egress routes remain available for as long as possible.

There are currently significant access and egress issues associated with Low Flood Island ERP classification, which would be exacerbated by raising the levee. At present, road access is cut for events larger than the 0.2EY event (disregarding informal levees) and property inundation first occurs once the levee is overtopped during events of approximately a 12% AEP. As for the Gumly levee option, raising the North Wagga Levee to the 1% AEP level without constructing an associated egress route, increases the isolation risk of the community inside the levee, thus increasing the reliance on SES and subsequently risk to life.

Furthermore, construction of a higher levee would mean that the frequency between floods that enter the leveed area would be significantly reduced. This may lead to residents having a higher degree of complacency about their flood risk, and an unwillingness or reluctance to evacuate when ordered to. This attitude can increase significantly following events in which residents are ordered to evacuate, and the predicted peak flood level turns out to be much lower. Ignoring evacuation orders drastically increases pressures on the SES, should the levee be overtopped or fail, or residents decide to leave at a later point.

The cost of construction of upgrading Hampden Avenue to the same level as an upgraded levee would be substantial and would reduce the financial viability of any upgrade option. Options L3B, L3C, L4B and L4C consider levee upgrades with an associated upgrade to Hampden Avenue between Wall Street and Wiradjuri Bridge, as well as Mill Street between Hampden Avenue and East Street. This route is the most direct link to the CBD and is likely to be the most cost effective upgrade option. An alternative route could be along Hampden Avenue to the north via Cartwrights Hill, then to the west and south to the CBD via Gobbagombalin Bridge. This route however is substantially longer and as much of its length

is exposed to flooding, an upgrade to this route would be significantly more costly and cause impacts elsewhere on the floodplain. This alternate route has not been considered in the subsequent sections, but has been mapped and provided in Appendix L. Any levee upgrade would also require substantial upgrade to Mill Street between East Street and Hampden Avenue. Located over a major flood runner, this road would require significant culverts or bridge sections to allow flow conveyance.

Construction Practicality and Cost Estimates

The additional levee height of an upgrade presents a number of challenges including construction practicality and land acquisition requirements. For a level of protection of 1% AEP, the levee would need to be raised by 2 m in some parts, and for a 5% AEP level of protection the height would increase by up to 0.9 m in parts. If earth embankment construction is selected, minimum batter slope requirements will result in a significant levee footprint (extra 5m wide for 5% AEP level of protection, or 13 m wider for a 1% AEP levee. This additional footprint width may encroach on private property or public recreation areas, resulting in a number of difficulties and costs for the project to acquire the easement and proceed. Alternative construction methods (concrete walls, sheet pile walls) may increase costs and impact on public acceptance.

The condition of the levee will determine if the upgrade requires razing the existing levee and starting from scratch, or if the existing levee is structurally sound enough to build upon. There would be significant costs involved with demolition of the existing levee and building from natural surface level if this is required. There are likely to be ongoing costs relating to community education and engagement, as the risk to life for residents behind a ring levee is inherently worsened. Community education and compensatory works for affected residents outside the leveed areas have not been included in preliminary cost estimates.

Community Acceptance and Social Issues

The community response to this option was assessed in detail during the public exhibition phase. As described in Appendix M, the North Wagga levee is a controversial topic, with varying attitudes from residents especially in North Wagga and the Floodplain upstream of North Wagga. The primary aim of this FRMS is to reduce flood risk for the entire Wagga Wagga floodplain. There were also concerns that upgrading the North Wagga levee would increase pressure on Council to increase development density inside North Wagga, which would be in conflict with Clause 7.1 of the Wagga Wagga LEP 2010 and may reduce the ‘village feel’ of the area, which may not be popular with residents. It is important to note that if the North Wagga Levee were to be raised it is recommended that development density controls remain in place. This would assist in not increasing the number of residents subject to flood risk.

Any levee option would require significant input into educating the community about the residual flood risk of the protected area, as levees can fail and risk of inundation would still exist for larger events. Without understanding these risks or the true capacity of the levee, communities often feel a false sense of security with a large levee in place.

Mobility of Elderly Citizens and the Risks of Growing Populations

Successful evacuation requires sufficient warning time, prepared residents and ample assistance for those less mobile, such as the aged residents. According to the Australian Bureau of Statistics (Reference 26), the overall percentage of persons aged over 60 in North Wagga has been fairly constant over the last three censuses (at 13.2% in 2016 compared to 19.6% in the Wagga Wagga City), while the younger population (especially "young workforce" aged 25-34 is on the rise, increasing from 9.8% in 2006 compared to 12.7% in the city, to 16.8% in 2016 compared to 14.0% in the city. However, any community with elderly residents is vulnerable to evacuation difficulties, as can be seen in Lismore during the flood in March 2017 (Photo 1). Note that concerns regarding the age and mobility of residents apply to all types of flood mitigation options, however increasing the levee's level of protection may lead to residents becoming reluctant to evacuate, or shelter in place for longer, leading to more assistance required when evacuation does occur.

Furthermore, the growing population in the North Wagga region (1,118 in 2011 to 1,793 in 2016) increases the number of persons living in a high hazard area, and necessarily increases the number of residents who will be required to evacuate. This leads to more evacuation traffic, and evacuation taking longer and therefore requiring an earlier issuance of evacuation orders.

It is noted that North Wagga residents demonstrated a high level of evacuation compliance in 2010 (~80%) and 2012 (~97%) (Appendix J), compared to other flood affected towns in NSW. This high rate is attributed to the flood awareness and engagement of North Wagga residents, the close succession of two flood events which may have led to a stronger living memory of flooding, and the authority and trust in the local SES Region Controller. These factors require significant ongoing effort to be sustained, especially with a moderate rate of resident turnover and growth, and potentially many years between flood events. Such elements of human behaviour are not typically relied upon when making strategic infrastructure decisions as the risk-to-life elements still exist, however nor should they be overlooked in the decision-making process.

Photo 1 Evacuations from Lismore, March 2017

Assessed Options

The 2009 FRMS had recommended consideration of maintaining the existing level of protection of the North Wagga levee in light of proposed works for the CBD. During subsequent community consultation in 2012-2015, requests to upgrade the levee to a 1% AEP level of protection were received and some investigation was undertaken. In order to receive funding through the NSW Floodplain Management Program, such an upgrade would need to be assessed and recommended as part of a thorough FRMS report. For these reasons, this FRMS has assessed options for levee upgrade for North Wagga. In an effort to reduce the risk to life issues associated with a levee located in a floodway, these options have also been assessed with access upgrades to Hampden Avenue. To complete the suite of options considered in the Wagga Wagga Flood Futures program (Reference 25) the removal of the existing North Wagga Levee and an option to open up the levee by lowering a 'spillway' at the upstream and downstream faces to allow passage of floodwaters in more frequent events have been assessed.

Table 44 Levee Options assessed for North Wagga

Option ID	Levee Level of Protection	Option Description	Report Ref
L3(A)	1% AEP	Levee Upgrade (1% AEP level of protection (LOP)) Only	9.3.3.1
L3(B)	1% AEP	Levee Upgrade (1% AEP LOP) with Hampden Avenue upgraded (as embankment)	9.3.3.2
L3(C)	1% AEP	Levee Upgrade (1% AEP LOP) with Hampden Avenue upgraded (as overland bridge)	9.3.3.3
L4(A)	5% AEP	Levee Upgrade (5% AEP LOP) Only	9.3.3.4
L4(B)	5% AEP	Levee Upgrade (5% AEP LOP) with Hampden Avenue upgraded (as embankment)	9.3.3.5
L4(C)	5% AEP	Levee Upgrade (5% AEP LOP) with Hampden Avenue upgraded (as overland bridge)	9.3.3.6
L5	N/A	Removal of North Wagga Levee	9.3.3.7
L6	20% AEP	Opening of North Wagga Levee (lowering spillways to 20% AEP LOP)	9.3.3.8

9.3.3.1. Option L3(A): North Wagga Levee Upgrade (1% AEP Event Design)

Option Description

Option L3(A) investigates raising the existing North Wagga ring levee to provide flood protection for events up to and including the 1% AEP flood. This option includes the raising of the smaller separate levee along Mill and East Streets. These levees have an approximate combined length of 4,300 m, and an increase in existing levee crest height of ~2.0 m (inclusive of 0.7 m freeboard, as per Reference 8) would be required. At present, road access is cut for events larger than the 0.2EY event (disregarding informal levees) and property inundation first occurs once the levee is overtopped during events of approximately a 12% AEP.

Modelled Impacts

Option L3(A) prevents flooding within the township of North Wagga as well as properties along Mill and East Streets for events up to and including the 1% AEP flood. A flood impact map for the 1% AEP event is presented in Figure E8. Flood impacts associated with Option L3 outside of the levee were found to be significant in the 1% AEP event with increases in flood level found to exceed 0.1 m, extending beyond East Wagga. In the 5% AEP event, the levee causes upstream increases to a lesser extent, however flooding in an area of East Wagga is increased by up to 0.3 m and the extent of inundation increased.

Change in Property Flood Affectation

Table 45 indicates the net number of properties affected both externally and internally (over floor level) in each design event tested as part of this Study. In the 5% AEP event for example, 175 properties are positively affected, however 5 properties in East Wagga would now be flooded over floor in the 5% AEP event (previously not flooded over floor), resulting in a net difference of 170 properties. In the 1% AEP event, 9 properties in East Wagga, 1 in Gumly Gumly and 1 in Eunony are also flooded above floor when they were previously not affected.

Table 45 Option L3(A): Property Affectation

Event	Total Properties Affected Externally		Total Properties Affected Over floor level			
	Existing Case	Option Implemented	Existing Case	Option Implemented	Floor Level Difference	% Floor Level Difference
10% AEP	57	41	41	28	13	31.7%
5% AEP	307	105	234	64	170	72.6%
2% AEP	465	249	404	190	214	53.0%
1% AEP	597	393	539	335	204	37.8%
0.5% AEP	2402	2535	2170	2312	-142	-6.5%
0.2% AEP	3736	3754	3661	3689	-28	-0.8%
PMF	4744	4745	4728	4729	-1	0.0%

*Positive numbers indicate NET reduction in number of properties flooded above floor

While the Option L3(A) levee provides flood protection for a significant number of properties within North Wagga for events up to and including the 1% AEP, a large number of properties situated outside of the levee (and some inside) are newly flooded or flooded in a more frequent event. Diagram 9 indicates how properties flooded over floor are affected by implementation of the option across the full range of design events, and shows that the North Wagga Levee benefits properties inside the levee, however it significantly worsens flooding for a large number of properties across the floodplain, East Wagga and the CBD. Even within the proposed North Wagga levee, 29 properties experience greater inundation with implementation of the levee, plus 19 properties in the Mill St Area due to worsened flooding in events greater than the 1% AEP event. These effects are reflected in Table 46 which shows the property damages by Floodplain Community.

Diagram 9 Option L3(A): Change in internal property affectation due to option implementation

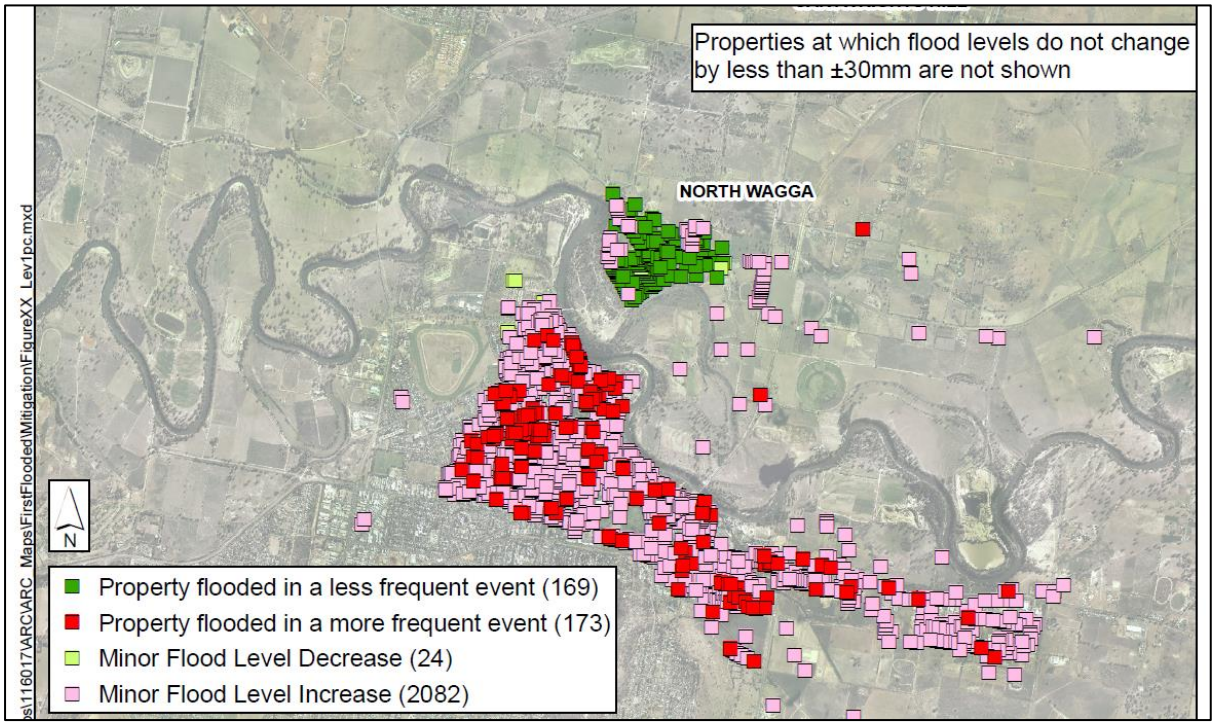


Table 46 Option L3(A): Property Damages by Community

Community	AAD (Existing Case)	AAD (Option Implemented)	Difference	% Difference
Wagga CBD	$2,347,400	$2,458,200	-$110,800	-4.7%
East Wagga	$846,000	$882,000	-$36,000	-4.3%
North Wagga	$1,583,100	$234,600	$1,348,500	85.2%
West Wagga	$347,800	$347,700	$100	0.0%
Gumly	$115,600	$116,800	-$1,200	-1.0%
Oura	$125,200	$125,200	$0	0.0%
Wagga Floodplain	$182,200	$182,800	-$600	-0.3%
Eunony	$34,600	$34,900	-$300	-0.9%
Total AAD	**$5,581,900**	**$4,382,200**	**$1,199,700**	**21.5%**

*Positive numbers indicate NET reduction in number of properties flooded above floor

Construction of a 1% AEP levee to protect North Wagga would reduce damages locally by 85.2%, reducing North Wagga's AAD from $1,583,100 to $234,600. This is a significant reduction, which results in a reduction of the total Annual Average Damages by approximately $1.2M or 21.5%, even with the negative impacts across the floodplain. This reduction leads to a high BC ratio, as shown in Table 47 which indicates that Option L3(A) is economically feasible. It is important to note that economic feasibility is not the only aspect that determines the overall viability of an option, as described below in the 'Other Concerns' section below and those concerns described in Section 9.3.3.

Table 47 Option L3(A): Economic Assesment

Capital Cost	$10,615,600
Reduction in Total AAD	$1,200,000
Reduction in Total AAD	21.5%
BC Ratio	1.65

Other Concerns

The key concerns regarding increasing the level of protection around North Wagga are described in 9.3.3 and centre around the inadequate access and egress for residents. The main issue is that North Wagga's access roads would be cut, and the whole area surrounded by flood waters long before the levee is even close to being overtopped. Unfortunately residents' perception of their own safety can be overestimated, even with significant community education efforts, and result in residents delaying or ignoring evacuation orders. Even the most compliant communities are at risk of not being able to evacuate due to insufficient warning time or an unexpected increase in the rate of rise of flood waters. A higher levee would serve to exacerbate the Low Flood Island emergency response classification of North Wagga as the area would still be isolated by floodwaters then submerged in events greater than a 1% AEP. A further complication is North Wagga's ageing population which would further increase evacuation time due to impaired mobility and assistance required.

Conclusion

Based on the outcomes of the above assessment and consideration of concerns, the following scores have been assigned to Option L3(A) in the multi-criteria assessment, noting that Community Acceptance scores have been allocated based on feedback received during the Public Exhibition period.

Table 48 Option L3(A): Multi-Criteria Assessment Results

Ref	Option	Impact on Flood Behaviour	Impact on Property Damage	Technical Feasibility	Community Acceptance	Economic Merits	Environmental/ Ecological Benefits	Impact on SES	Risk to Life*	Total Score
L3A	1% AEP North Wagga Levee Upgrade	-3	-3	-2	2	3	-1	-3	-6	-13

* A detailed breakdown of the factors contributing to the risk to life score is presented in Table 101.

Option L3(A) Summary of Recommendations

☒ The construction of a 1% AEP level ring levee would cause unacceptable adverse flood impacts on other properties across the floodplain and unacceptable changes to the risk to life imposed on residents inside the levee. Construction of a 1% AEP Levee without an adequate access route upgrade would significantly increase the risk to life of residents in North Wagga and accordingly increase the demand on SES during flood events. Further to this, the levee's high capital cost, construction difficulty, the need to acquire easements for a substantial footprint and the impact on visual amenity contribute to this option not being recommended for further investigation.

9.3.3.2. Option L3(B): North Wagga Levee Upgrade (1% AEP Event Design) with Hampden Ave as Embankment

Description

Option L3(B) assesses the same levee option as L3(A), that is, raising the North Wagga Levee to a 1% AEP level of protection, however it also incorporates a significant upgrade to Hampden Avenue. In this option Hampden Avenue is raised using an embankment style construction from Wiradjuri Bridge through to Wilks Park Bridge, and the Wilks Park Bridge section is extended and excavated to allow increased conveyance. An upgrade to Mill Street would also be necessary, however this has not been modelled at this stage.

Modelled Impacts

Option L3(B) has the effect of removing flood affectation inside North Wagga in events up to and including the 1% AEP event, however in the 1% AEP event causes an increase in upstream flood levels of up to 0.2 m across the floodplain, as shown in Figure E10. The impacts in the 5% AEP event are a direct result of the increased conveyance beneath Wilks Park Bridge and are shown in Figure E11. This figure shows a decrease in flood levels on the upstream side of the levee and the floodplain to the north as more flow is allowed through the Wilks Park flowpath. The effect of this is an increase in peak flood levels of over 0.3 m directly downstream of Hampden Avenue.

Change in Property Flood Affectation

Table 49 indicates the number of properties affected both externally and internally (over floor level) in each design event tested as part of this Study. While there are a significant number of properties benefited in events up to the 1% AEP, several properties in East Wagga and one property in the West Wagga region are negatively impacted. In the 0.5% AEP event 89 properties in the CBD would be flooded above floor (previously only flooded above floor in events greater than or equal to the 0.2% AEP).

Table 49 Option L3(B): Property Affectation

Event	Total Properties Affected Externally		Total Properties Affected Over floor level			
	Existing Case	Option Implemented	Existing Case	Option Implemented	Floor Level Difference	% Floor Level Difference
10% AEP	57	42	41	27	14	34.1%
5% AEP	307	92	234	55	179	76.5%
2% AEP	465	247	404	189	215	53.2%
1% AEP	597	384	539	326	213	39.5%
0.5% AEP	2402	2491	2170	2261	-91	-4.2%
0.2% AEP	3736	3757	3661	3690	-29	-0.8%
PMF	4743	4744	4727	4728	-1	0.0%

*Positive numbers indicate NET reduction in number of properties flooded above floor

While the Option L3(B) levee provides flood protection for a significant number of properties within North Wagga for events up to and including the 1% AEP, external and internal flood affectation is increased for properties situated outside of the levee. Diagram 10 indicates how properties flooded over floor are affected by implementation of the option across the full range of design events, and shows that the North Wagga Levee benefits properties inside the levee, however it significantly worsens flooding for a large number of properties across the floodplain, East Wagga and the CBD. These effects are reflected in Table 50 which shows the property damages by Floodplain Community. It should be noted that this option also worsens flood affectation for 46 properties within North Wagga itself and the Mill St area due to the both the changed flow regime downstream of Hampden Avenue as a result of the increased flow conveyance through Wilks Park, and the impact of the levee as an obstruction to flow.

Diagram 10 Option L3(B): Change in internal property affectation due to option implementation

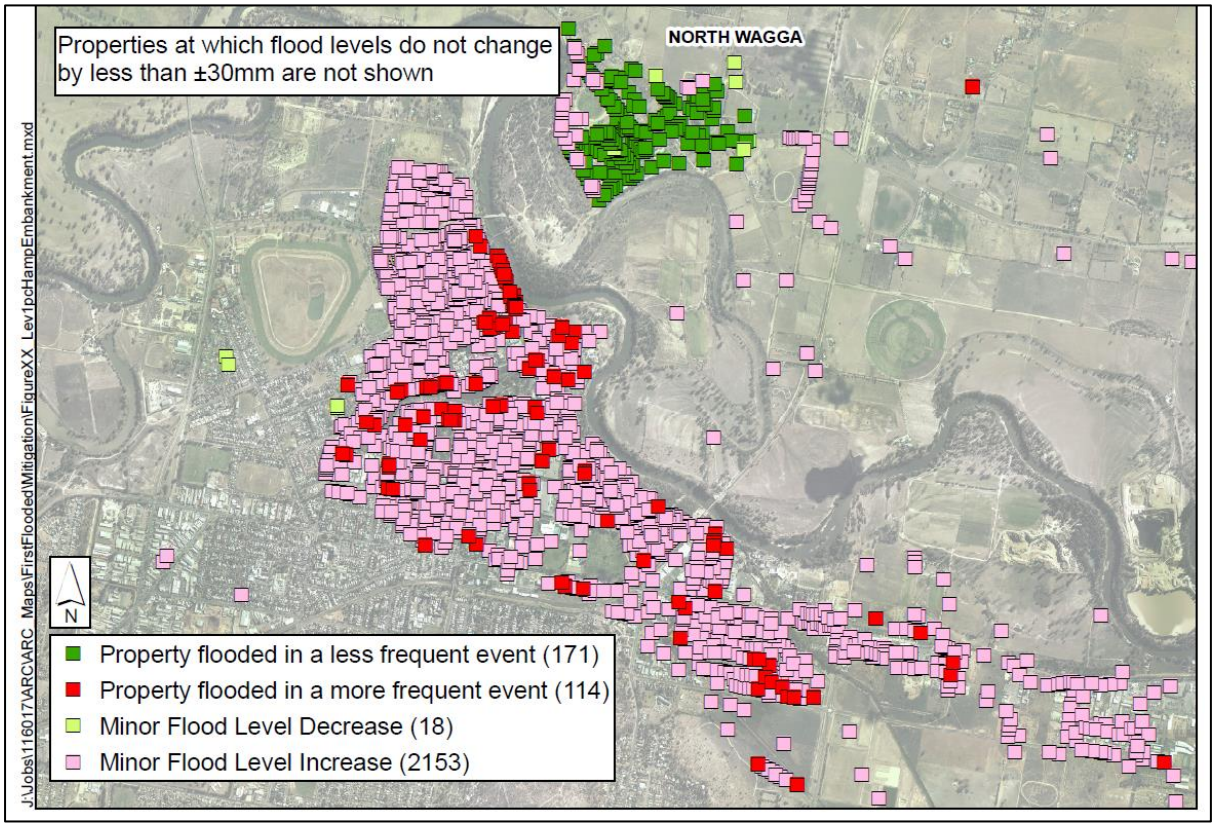


Table 50 Option L3(B): Property Damages by Community

Community	AAD (Existing Case)	AAD (Option Implemented)	Difference	% Difference
Wagga CBD	$2,347,400	$2,421,100	-$73,700	-3.1%
East Wagga	$846,000	$837,600	$8,400	1.0%
North Wagga	$1,583,100	$234,100	$1,349,000	85.2%
West Wagga	$347,800	$349,600	-$1,800	-0.5%
Gumly	$115,600	$116,400	-$800	-0.7%
Oura	$125,200	$125,200	$0	0.0%
Wagga Floodplain	$182,200	$179,100	$3,100	1.7%
Eunony	$34,600	$34,600	$0	0.0%
Total AAD	**$5,581,900**	**$4,297,700**	**$1,284,200**	**23.0%**

*Positive numbers indicate NET reduction in number of properties flooded above floor

Construction of a 1% AEP levee and embankment-style road upgrade to protect North Wagga would reduce damages locally by 85.2%, reducing North Wagga's AAD from $1,583,100 to $234,100. This is a significant reduction, which results in a reduction of the total Annual Average Damages by approximately $1.28M or 23.0%, despite the external floodplain impacts. This reduction leads to a high BC ratio, as shown in Table 51 which indicates that Option L3(B) is economically feasible despite the significant capital costs involved. A detailed costing is provided in Appendix F. At this stage the upgrade to Mill Street has not been included. It is important to note that economic feasibility is not the only aspect that determines the overall viability of an option, as described below in the 'Other Concerns' section below and those concerns described in Section 9.3.3.

Table 51 Option L3(B): Economic Assesment

Capital Cost	$15,388,400
Reduction in Total AAD	$1,285,000
Reduction in Total AAD	23.0%
BC Ratio	1.22

Other Concerns

As for Option L3(A) and as described in Section 9.3.3, concerns remain about the education of the community to ensure residents fully understand the level of protection offered by the levee upgrade, and their responsibility in regards to timely evacuation. While this option has less risk than Option L3(A) as it allows more time for residents to evacuate before access is restricted, this may indeed cause residents to *take* more time, and not heed evacuation orders from the SES.

The option involves substantial excavation beneath Wilks Park Bridge to improve flow conveyance, however this would have significant environmental impacts as it would require significant reduction in vegetation with high ecological value. Excavation also needs to consider bank stability and unpredictable changes in flow behaviour caused by major channel modification works, including sediment transfer, scouring and formation of new breakouts and flowpaths.

Conclusion

Based on the outcomes of the above assessment and consideration of concerns, the following scores have been assigned to Option L3(B) in the multi-criteria assessment, noting that Community Acceptance scores have been allocated based on feedback received during the Public Exhibition period.

Table 52 Option L3(B) Multi-criteria assessment scores

Ref	Option	Impact on Flood Behaviour	Impact on Property Damage	Technical Feasibility	Community Acceptance	Economic Merits	Environmental/ Ecological Benefits	Impact on SES	Risk to Life*	Total Score
L3B	1% AEP North Wagga Levee Upgrade with Hampden Ave Embankment	-2	-2	-3	2	1	-2	-2	-3	-11

* A detailed breakdown of the factors contributing to the risk to life score is presented in Table 101.

Option L3(B) Summary of Recommendations

☒ The construction of a 1% AEP level ring levee with upgrade to Hampden Avenue has unacceptable adverse flood impacts on other properties across the floodplain and presents a number of unacceptable risks. Construction of a 1% AEP Levee with the access route upgrade still requires significant education to ensure residents heed evacuation orders in a timely manner. Other factors to be considered include the environmental impacts involved with the excavation of Wilks Park and associated vegetation clearing, construction feasibility, high capital cost (and ongoing maintenance) and impacts on visual amenity. As a result, this option is not recommended.

9.3.3.3. Option L3(C): North Wagga Levee Upgrade (1% AEP Event Design) with Hampden Ave as Overland Bridge

Description

This option is functionally the same as Option L3(B), however in Option L3(C) the 1% AEP North Wagga Levee is paired with an upgrade to Hampden Avenue using an overland bridge construction to reduce the upstream flood impacts caused by Hampden Avenue itself. In this option the existing Hampden Avenue road embankment is removed and significant excavation is undertaken beneath the current Wilks Park Bridge. An upgrade to Mill Street would also be necessary, however this has not been modelled at this stage.

Modelled Impacts

Similarly to Option L3(B), the increased levee causes upstream impacts in the order of 0.1 m in the 1% AEP event as shown on Figure E12. In the 5% AEP event however, the significant excavation of Wilks Park and removal of all obstructions caused by Hampden Avenue does reduce flood levels in the immediate upstream vicinity (See Figure E13), though these are balanced by flood level increases downstream of the bridge. It should be noted that the overland bridge was modelled to cause zero obstruction, though in reality the piers would cause some obstruction to flow and would present a design challenge.

Change in Property Flood Affectation

Table 53 indicates the number of properties affected both externally and internally (over floor level) in each design event tested as part of this Study. While there are a significant number of properties benefited in events up to the 1% AEP, several properties in East Wagga and one property in the West Wagga region are negatively impacted. In the 0.5% AEP event 68 properties in the CBD would be flooded above floor (previously only flooded above floor in events greater than or equal to the 0.2% AEP).

Table 53 Option L3(C): Property Affectation

Event	Total Properties Affected Externally		Total Properties Affected Over floor level			
	Existing Case	Option Implemented	Existing Case	Option Implemented	Floor Level Difference	% Floor Level Difference
10% AEP	57	42	41	27	14	34.1%
5% AEP	307	91	234	54	180	76.9%
2% AEP	465	247	404	189	215	53.2%
1% AEP	597	383	539	326	213	39.5%
0.5% AEP	2402	2470	2170	2240	-70	-3.2%
0.2% AEP	3736	3755	3661	3685	-24	-0.7%
PMF	4744	4744	4728	4728	0	0.0%

*Positive numbers indicate NET reduction in number of properties flooded above floor

While the Option L3(C) levee provides flood protection for a significant number of properties within North Wagga for events up to and including the 1% AEP, both under and over floor flood affectation is increased for properties situated outside of the levee, especially for events greater than the 1% AEP event. Diagram 11 indicates how properties flooded over floor are affected by implementation of the option across the full range of design events, and shows that the North Wagga Levee benefits properties inside the levee, however it significantly worsens flooding for a large number of properties across the floodplain, East Wagga and the CBD. These effects are reflected in Table 50 which shows the property damages by Floodplain Community. It should be noted that this option also worsens flood affectation for 53 properties within North Wagga itself and the Mill St area due to the both the changed flow regime downstream of Hampden Avenue as a result of the increased flow conveyance through Wilks Park, and the impact of the levee as an obstruction to flow.

Diagram 11 Option L3(C): Change in internal property affectation due to option implementation

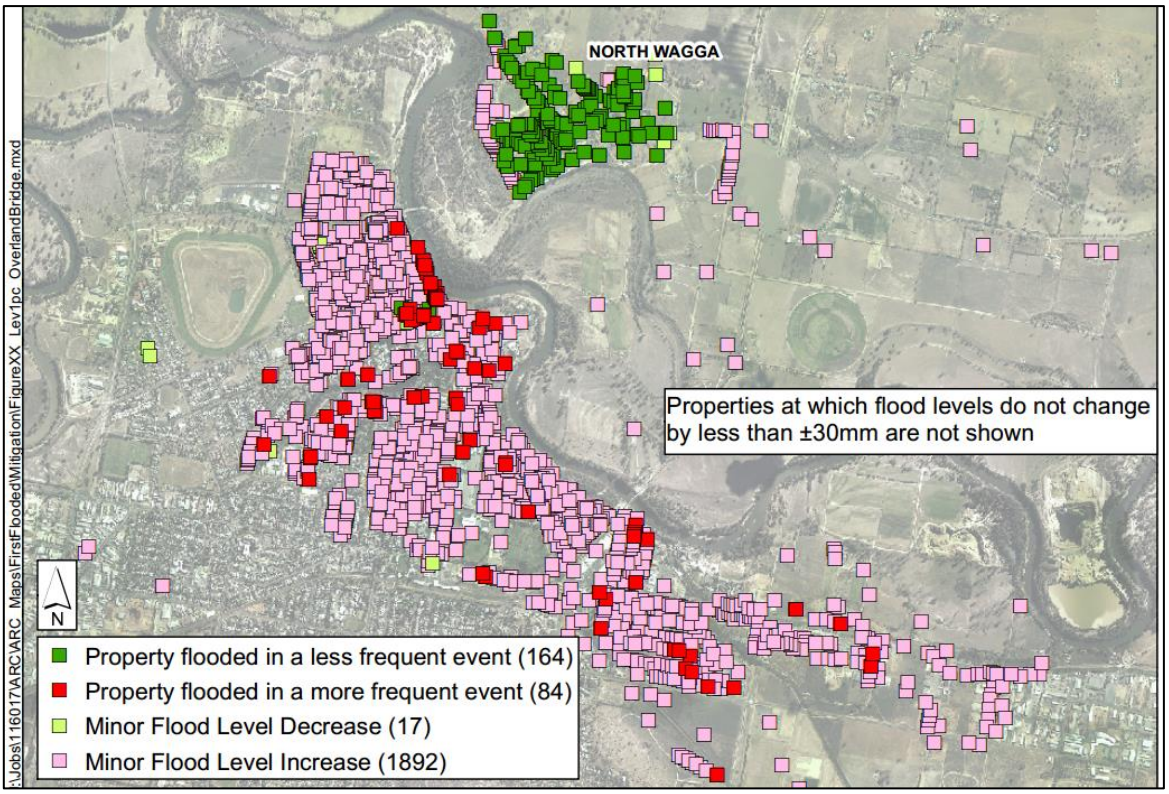


Table 54 Option L3(C): Property Damages by Community

Community	AAD (Existing Case)	AAD (Option Implemented)	Difference	% Difference
Wagga CBD	$2,347,400	$2,404,300	-$56,900	-2.4%
East Wagga	$846,000	$833,900	$12,100	1.4%
North Wagga	$1,583,100	$234,100	$1,349,000	85.2%
West Wagga	$347,800	$349,700	-$1,900	-0.5%
Gumly	$115,600	$116,400	-$800	-0.7%
Oura	$125,200	$125,200	$0	0.0%
Wagga Floodplain	$182,200	$178,900	$3,300	1.8%
Eunony	$34,600	$34,600	$0	0.0%
Total AAD	**$5,581,900**	**$4,277,100**	**$1,304,800**	**23.4%**

*Positive numbers indicate NET reduction in number of properties flooded above floor

Construction of a 1% AEP levee and overland bridge-style road upgrade to protect North Wagga would reduce damages locally by 85.2%, reducing North Wagga's AAD from $1,583,100 to $234,100. This is a significant reduction even with the adverse impacts across the floodplain, which results in a reduction of the total Annual Average Damages by approximately $1.3M or 23.4%. However the option would require significant capital investment, resulting in a low BC ratio, as shown in Table 55 which indicates that Option L3(C) is not economically feasible. A detailed costing is provided in Appendix F. At this stage the upgrade to Mill Street has not been included.

Table 55 Option L3(C): Economic Assesment

Capital Cost	$43,154,300
Reduction in Total AAD	$1,305,000
Reduction in Total AAD	23.4%
BC Ratio	0.45

Other Concerns

The key concerns regarding increasing the level of protection around North Wagga are described in 9.3.3. Despite the significant reductions in flood affectation within North Wagga, a levee at this height would increase flood levels outside the levee and exacerbate the isolation of residents within the levee. A levee protecting North Wagga up to and including the 1% AEP event is not considered feasible as it results in significant adverse impacts in the areas upstream. Although an upgrade would reduce overall flood damages in Wagga Wagga, the affluxes in flood levels caused in other regions would somehow need to be mitigated in the levee design process. Additionally, the option could put greater pressure on the SES during a flood event, and subsequently increase risk to life as residents may feel they do not need to heed evacuation instructions.

The option involves substantial excavation beneath Wilks Park Bridge to improve flow conveyance, however this would have significant environmental impacts as it would require significant reduction in vegetation with high ecological value. Excavation also needs to consider bank stability and unpredictable changes in flow behaviour caused by major channel modification works, including sediment transfer, scouring and formation of new breakouts and flowpaths.

Conclusion

Based on the outcomes of the above assessment and consideration of concerns, the following scores have been assigned to Option L3(C) in the multi-criteria assessment, noting that Community Acceptance scores have been allocated based on feedback received during the Public Exhibition period.

Table 56 Option L3(C): Multi-Criteria Assessment Results

Ref	Option	Impact on Flood Behaviour	Impact on Property Damage	Technical Feasibility	Community Acceptance	Economic Merits	Environmental/ Ecological Benefits	Impact on SES	Risk to Life*	Total Score
L3C	1% AEP North Wagga Levee Upgrade with Hampden Ave Overland Bridge	-1	-2	-3	2	-2	-2	-2	-3	-13

* A detailed breakdown of the factors contributing to the risk to life score is presented in Table 101.

Option L3(C) Summary of Recommendations

☒ The construction of a 1% AEP level ring levee with upgrade to Hampden Avenue has unacceptable adverse flood impacts on other properties across the floodplain and presents a number of unacceptable risks. Construction of a 1% AEP Levee with the access route upgrade still requires significant education to ensure residents heed evacuation orders in a timely manner. Other factors to be considered include the environmental impacts involved with the excavation of Wilks Park and associated vegetation clearing, construction feasibility, high capital cost (and ongoing maintenance) and impacts on visual amenity. As a result, this option is not recommended.

9.3.3.4. Option L4(A): North Wagga Levee Upgrade (5% AEP Event Design)

Description

Option L4(A) assesses a levee for North Wagga that has a 5% AEP level of protection and no associated road upgrade to Hampden Avenue. While this is an upgrade to the existing level of protection provided by the levee, it would not provide ensured protection against events of similar size to the 2012 event. This option includes the raising of the smaller separate levee along Mill and East Streets. The levees have an approximate combined length of 4,300 m, and an increase in existing levee crest height of ~0.9 m (inclusive of 0.7 m freeboard, as per Reference 8) would be required. At present, road access is currently cut for events larger than the 0.2EY event (disregarding informal levees) and property inundation first occurs once the levee is overtopped during events with an approximate 12% AEP.

Modelled Impacts

Raising the North Wagga levee to a 5% AEP level of protection does not prevent inundation of North Wagga in greater events, and in fact worsens flooding inside North Wagga in the 1% AEP event (see Figure E14). It also causes minor upstream flood level increases in the order of 0.05 m as far upstream as the East Wagga commercial area. Impacts in the 5% AEP event are shown in Figure E15 and indicate the protection provided to North Wagga, though again at the expense of the area directly upstream of the levee in the floodplain which experiences flood level increases of up to 0.05 m.

Change in Property Flood Affectation

Table 57 indicates the number of properties affected both externally and internally (over floor level) in each design event tested as part of this Study. While there are a significant number of properties benefited in events up to the 1% AEP, several properties in East Wagga are negatively impacted. In the 0.5% AEP event 13 properties in the CBD would be flooded above floor (previously only flooded above floor in events greater than or equal to the 0.2% AEP).

Table 57 Option L4(A): Property Affectation

Event	Total Properties Affected Externally		Total Properties Affected Over floor level			
	Existing Case	Option Implemented	Existing Case	Option Implemented	Floor Level Difference	% Floor Level Difference
10% AEP	57	41	41	28	13	31.7%
5% AEP	307	105	234	64	170	72.6%
2% AEP	465	466	404	404	0	0.0%
1% AEP	597	597	539	537	2	0.4%
0.5% AEP	2402	2418	2170	2184	-14	-0.6%
0.2% AEP	3736	3739	3661	3666	-5	-0.1%
PMF	4744	4744	4728	4728	0	0.0%

*Positive numbers indicate NET reduction in number of properties flooded above floor

While the Option L4(A) levee provides flood protection for a significant number of properties within North Wagga for events up to and including the 5% AEP, a number properties situated outside of the levee are newly flooded or flooded in a more frequent event. Diagram 9 indicates how properties flooded over floor are affected by implementation of the option across the full range of design events, and shows that the North Wagga Levee benefits properties inside the levee, however it worsens flooding for a large number of properties across the floodplain, East Wagga and the CBD. Even within North Wagga and the Mill Street areas, 27 properties experience greater overfloor inundation in events greater than the levee's level of protection. These effects are reflected in Table 58 which shows the property damages by Floodplain Community.

Diagram 12 Option L4(A): Change in internal property affectation due to option implementation

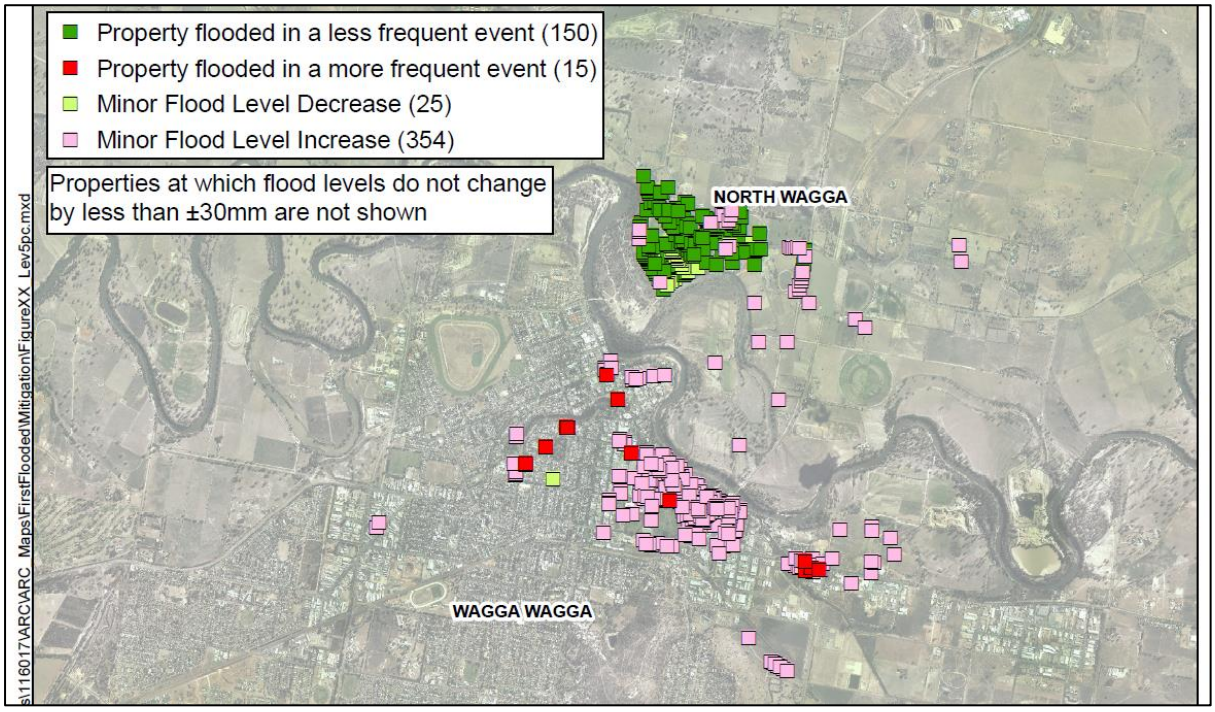


Table 58 Option L4(A): Property Damages by Community

Community	AAD (Existing Case)	AAD (Option Implemented)	Difference	% Difference
Wagga CBD	$2,347,400	$2,360,300	-$12,900	-0.5%
East Wagga	$846,000	$866,000	-$20,000	-2.4%
North Wagga	$1,583,100	$901,800	$681,300	43.0%
West Wagga	$347,800	$347,800	$0	0.0%
Gumly	$115,600	$116,200	-$600	-0.5%
Oura	$125,200	$125,200	$0	0.0%
Wagga Floodplain	$182,200	$181,400	$800	0.4%
Eunony	$34,600	$34,600	$0	0.0%
Total AAD	**$5,581,900**	**$4,933,300**	**$648,600**	**11.6%**

*Positive numbers indicate NET reduction in number of properties flooded above floor

Construction of a 5% AEP levee to protect North Wagga would reduce damages locally by 43.0%, reducing North Wagga's AAD from $1,583,100 to $901,800. This is a significant reduction despite the number of properties adversely impacted, which results in a reduction of the total Annual Average Damages by approximately $648,000 or 11.6%. This significant reduction leads to a high BC ratio, as shown in Table 59 which indicates that Option L4(A) is economically feasible. It is important to note that economic feasibility is not the only aspect that determines the overall viability of an option, as described below in the 'Other Concerns' section below and those concerns described in Section 9.3.3.

Table 59 Option L4(A): Economic Assesment

Capital Cost	$4,808,300
Reduction in Total AAD	$648,000
Reduction in Total AAD	11.6%
BC Ratio	1.93

Other Concerns

The key concerns regarding increasing the level of protection around North Wagga are described in 9.3.3 and centre around the inadequate access and egress for residents. The main issue is that North Wagga's access roads would be cut, and the whole area surrounded by flood waters before the levee is overtopped, which it would still be in events of a similar size to 2012. Unfortunately residents' perception of their own safety can be overestimated, (particularly with the 0.9 m increase in levee height), even with significant community education efforts, and result in residents delaying or ignoring evacuation orders. Even the most compliant communities are at risk of not being able to evacuate due to insufficient warning time or an unexpected increase in the rate of rise of flood waters. A higher levee would serve to exacerbate the 'Low Flood Island' emergency response classification of North Wagga, as the area would still be isolated by floodwaters then submerged. A further complication is North Wagga's ageing population which would further increase evacuation time due to impaired mobility and assistance required.

Conclusion

Based on the outcomes of the above assessment and consideration of concerns, the following scores have been assigned to Option L4(A) in the multi-criteria assessment. noting that Community Acceptance scores have been allocated based on feedback received during the Public Exhibition period.

Table 60 Option L4(A): Multi-Criteria Assessment Results

Ref	Option	Impact on Flood Behaviour	Impact on Property Damage	Technical Feasibility	Community Acceptance	Economic Merits	Environmental/ Ecological Benefits	Impact on SES	Risk to Life*	Total Score
L4A	5% AEP North Wagga Levee Upgrade	-1	-2	-2	-1	3	-1	-3	-3	-10

* A detailed breakdown of the factors contributing to the risk to life score is presented in Table 101.

Option L4(A) Summary of Recommendations

☒ The construction of a 5% AEP level ring levee would cause unacceptable adverse flood impacts on other properties across the floodplain and presents a number of unacceptable risks. Construction of a 5% AEP Levee without an adequate access route upgrade would significantly increase the risk to life of residents in North Wagga and accordingly increase the demand on SES during flood events. Further to this, the levee's high capital cost, construction difficulty, the need to acquire easements for a substantial footprint and the impact on visual amenity contribute to this option not being recommended for further investigation.

9.3.3.5. Option L4(B): North Wagga Levee Upgrade (5% AEP Event Design) with Hampden Ave as Embankment

Description

This option examines an upgrade to North Wagga Levee to a level of protection of 5% AEP, with an associated upgrade to Hampden Avenue. Due to the Low Flood Island ERP classification, potential delays to evacuate and the subsequent risk to life, the upgrade of the North Wagga Levee cannot be considered without an upgrade of the access route (i.e. Hampden Avenue towards the CBD to a level consistent with the level of protection of the proposed levee). An upgrade to Mill Street would also be necessary, however this section of road has not been modelled at this stage.

Option L4(B) assesses the same levee option as L4(A), that is, raising the North Wagga Levee to a 5% AEP level of protection, however it also incorporates a significant upgrade to Hampden Avenue. In this option Hampden Avenue is raised using an embankment style construction from Hampden Bridge through to Wilks Park Bridge, and the Wilks Park Bridge section is extended and excavated to allow increased conveyance to offset flood level impacts that are caused by the levee.

Modelled Impacts

Option L4(B) has the effect of removing flood affectation inside North Wagga in events up to and including the 5% AEP event, and in the 1% AEP event causes only minor upstream flood impacts largely due to the Wilks Park excavation as shown in Figure E16. The impacts in the 5% AEP event are also a direct result of the increased conveyance beneath Wilks Park Bridge and are shown in Figure E17. This figure shows a decrease in flood levels on the upstream side of the levee and the floodplain to the north as more flow is allowed through the Wilks Park flowpath. The effect of this is an increase in peak flood levels of up 0.2 m directly downstream of Hampden Avenue. The environmental feasibility of undertaking this excavation is paramount to the impacts on properties outside of the proposed levee and road upgrades.

Change in Property Flood Affectation

Table 61 indicates the net number of properties affected both externally and internally (over floor level) in each design event tested as part of this Study. While there are a significant number of properties benefited in events up to the 5% AEP, one property in the West Wagga region is negatively impacted, and would be inundated overfloor in the 10% AEP event compared to the 5% AEP event in the existing case. With option implementation, there are ‘winners and losers’ that are represented in Diagram 13, however are not individually represented in Table 61 which only shows the net increase/decrease in property affectation. It should be noted that the low number of negatively affected properties upstream of North Wagga is attributed to the excavation of Wilks Park that has been modelled. If this excavation is not undertaken, the flood impacts in this area are significantly worsened. The environmental impacts of undertaking this excavation should be determined as a primary aim of the feasibility study prior to proceeding further with this option.

Table 61 Option L4(B): Property Affectation

Event	Total Properties Affected Externally		Total Properties Affected Over floor level			
	Existing Case	Option Implemented	Existing Case	Option Implemented	Floor Level Difference	% Floor Level Difference
10% AEP	57	42	41	27	14	34.1%
5% AEP	307	92	234	55	179	76.5%
2% AEP	465	463	404	402	2	0.5%
1% AEP	597	595	539	537	2	0.4%
0.5% AEP	2402	2400	2170	2168	2	0.1%
0.2% AEP	3736	3734	3661	3659	2	0.1%
PMF	4744	4744	4728	4728	0	0.0%

*Positive numbers indicate NET reduction in number of properties flooded above floor.

Diagram 13 indicates how properties flooded over floor are affected by implementation of the option across the full range of design flood events. These effects are reflected in Table 62 which shows the property damages by Floodplain Community. It should be noted that this option worsens flood affectation during large events for 34 properties within North Wagga itself due to the changed flow regime downstream of Hampden Avenue as a result of the increased flow conveyance through Wilks Park and obstruction caused by the levees.

Diagram 13 Option L4(B): Change in internal property affectation due to option implementation

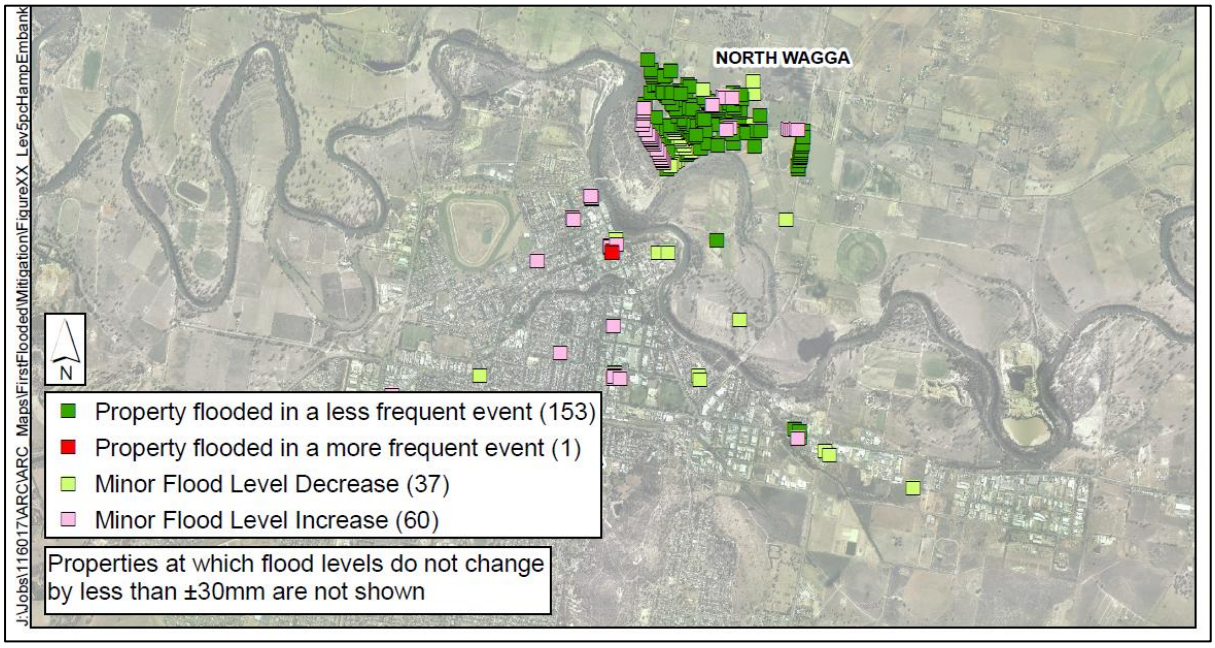


Table 62 Option L4(B): Property Damages by Community

Community	AAD (Existing Case)	AAD (Option Implemented)	Difference	% Difference
Wagga CBD	$2,347,400	$2,346,700	$700	0.0%
East Wagga	$846,000	$823,600	$22,400	2.6%
North Wagga	$1,583,100	$900,200	$682,900	43.1%
West Wagga	$347,800	$349,600	-$1,800	-0.5%
Gumly	$115,600	$115,600	$0	0.0%
Oura	$125,200	$125,200	$0	0.0%
Wagga Floodplain	$182,200	$178,300	$3,900	2.1%
Eunony	$34,600	$34,600	$0	0.0%
Total AAD	**$5,581,900**	**$4,873,800**	**$708,100**	**12.7%**

*Positive numbers indicate NET reduction in number of properties flooded above floor

Construction of a 5% AEP levee and embankment-style road upgrade to protect North Wagga would reduce damages locally by 43.1%, reducing North Wagga's AAD from $1,583,100 to $900,200. This is a significant reduction, which results in a reduction of Wagga Wagga's total Annual Average Damages by approximately $708,100 or 12.7%. This reduction leads to a BC ratio greater than 1, as shown in Table 63 which indicates that Option L4(B) is economically feasible despite the significant capital costs involved. A detailed costing is provided in Appendix F. At this stage the access upgrade to Mill Street has not been included. Furthermore, it should be noted that this costing does not include community engagement and ongoing education activities, nor does it include any compensatory works to residents adversely impacted. Despite the high BC ratio, it is important to note that economic feasibility is not the only aspect that determines the overall viability of an option, as described below and Section 9.3.3.

Table 63 Option L4(B): Economic Assesment

Capital Cost	$7,489,000
Reduction in Total AAD	$708,000
Reduction in Total AAD	12.7%
BC Ratio	1.37

Concern: Impact on Flood Behaviour

Raising the levee and Hampden Avenue as an embankment worsens upstream flood impacts as a result of it obstructing floodwaters. The option has been modelled with excavation beneath the Wilks Park bridge to offset such impacts. If the proposed excavation is not undertaken, upstream impacts are worsened significantly. The proposed feasibility study should as a priority determine if this excavation is possible and environmentally sound. If not, for Option L4(B) to proceed further detailed assessment of third party impacts and identification of suitable types of compensatory works would be required.

Concern: Construction Practicalities and Costs

An initial estimate of the capital cost of this option is over $7.5M, and this is likely to increase as challenges arise and other costs are included, such as the upgrade of Mill Street between

East Street and Hampden Avenue. The visual levee audit (see Section 5.9.3) undertaken in 2007 identified a number of sections along the North Wagga levee which were displaying evidence of erosion, which can possibly be attributed to the minimal vegetation and effects of trees with roots through the bank. The proposed feasibility study should ascertain the condition of the existing levee and determine if it is suitable to provide the foundation for the proposed levee upgrade.

Concern: Access and Isolation

Despite the access route upgrades to Hampden Avenue and Mill Street, risk to life still exists for residents living within an area classified as a Low Flood Island, that is, areas that are initially isolated by floodwaters then submerged. A North Wagga Levee with a 5% AEP level of protection would still be overtopped in larger events (for example the 2012 event, which reached 10.6 m at the Hampden Bridge Gauge). While this option allows more time for residents to evacuate before access is restricted, this may indeed cause residents to *take* more time, and not heed evacuation orders from the SES. Ongoing community education will be necessary to ensure residents are aware of the importance of timely response to evacuation orders.

Concern: Appreciation of the Levee's Level of Protection

Significant community education would be required to ensure residents understand the level of protection of the upgraded levee, and that it is not equal to the Wagga CBD levee. A recent example of a misconception of a levee's level of protection is in the Lismore 2017 event, in which SES rescued over 400 residents during the night despite there having been extensive investment in flood awareness activities (such as annual business breakfasts). One key issue noted by SES staff was that despite extensive education, many residents believed the levee had a much greater level of protection than it actually did. Community preparedness is likely to change over time, and even if the current community is highly flood aware, this awareness may decline as time passes without floods, and as residents move in and out of the area. In addition, a levee upgrade would significantly reduce the frequency of flood waters entering the leveed areas, which may increase complacency of residents.

North Wagga's evacuation compliance has been exemplary in the past, with 97% of residents evacuating when (or before) instructed to do so by the SES, indicating that the current community has a strong understanding of their flood risk and high level of trust in the authority of the local SES controller. Ongoing community engagement will help ensure these attitudes continue in the future.

Concern: Community Awareness of Residual Flood Risk

Further to fully understanding the true level of protection offered by the levee upgrade, if the levee were to fail by any mechanism, the resulting velocities and depths of floodwaters flowing into North Wagga may be greater than if the existing levee were to fail in the same way, depending on the depth of water being held back by the levee at the time of failure. This can have dire consequences if residents have not yet evacuated – either due to needing

assistance, having reduced mobility, receiving insufficient warning time, or simply perceiving their own safety to be assured by the now upgraded levee.

Conclusion

Based on the outcomes of the above assessment and consideration of concerns, the following scores have been assigned to Option L4(B) in the multi-criteria assessment, noting that Community Acceptance scores have been allocated based on feedback received during the Public Exhibition period.

Table 64 Option L4(B): Multi-Criteria Assessment Results

Ref	Option	Impact on Flood Behaviour	Impact on Property Damage	Technical Feasibility	Community Acceptance	Economic Merits	Environmental/ Ecological Benefits	Impact on SES	Risk to Life*	Total Score
L4B	5% AEP North Wagga Levee Upgrade with Hampden Ave Upgrade and Conveyance Improvements through Wilks Park	1	-1	-3	-1	2	-2	-1	-2	-7

* A detailed breakdown of the factors contributing to the risk to life score is presented in Table 101.

The outcomes of the assessment have resulted in an overall multi-criteria score of -8, which indicates that the option is not considered viable. Following a number of workshops to discuss the assessment outcomes, the FRMAC felt that further assessment was required to confirm these outcomes and the FRMAC voted to proceed this option to feasibility stage.

The feasibility study should address the range of other concerns arising from this option, including, but not limited to, the environmental feasibility of excavation of the Wilks Park floodway, condition of the existing levee bank, third party impacts to residents of the Wagga Floodplain and community engagement requirements to ensure residents within the levees have a strong understanding of their residual flood risk. Key elements to be addressed in the feasibility study are set out in Table 65, noting that this is not an exhaustive list.

Table 65 Key items to be investigated in the proposed North Wagga Levee Feasibility Study

Social	Construction & Implementation
• Appetite for levee upgrade (residents inside and outside levee to be interviewed) • Preference for VHR & VP Scheme instead; • Expectations of residents; • Visual impact concerns.	• Environmental impacts of Wilks Park Excavation • Procurement of local materials/ contractors; • Space constraints for increased footprint and easement allowances; • Interim access routes and detours so residents can access their properties during road upgrade; and • Internal drainage pumps/gates
Financial	**Other**
• Capital and ongoing costs of constructing and maintaining levee • Cost of environmental assessment for the Wilks Park Excavation • Cost of compensatory works • Cost of Hampden Avenue upgrade • Time & resources for planning and assessment; • Benefits/ Damage reduction.	• Residual Flood Risk: Significant community education required to promote awareness of: ○ Levee will be overtopped in events greater than a 5% AEP ○ Levees can fail in a number of ways, at any time ○ Dangers of sheltering in place instead of evacuating (isolation, long duration of inundation • Third party impacts

It is proposed that this feasibility study be undertaken in parallel with a feasibility study for Option PR1: a Voluntary House Raising and Voluntary Purchase Scheme for the Study Area. As described in 9.6.1, the Scheme would provide a greater degree of flood risk reduction to residents both inside and outside of North Wagga, and could be a potential alternative to a levee upgrade.

Option L4(B) Summary of Recommendations

The completion of a feasibility study for a North Wagga Levee with a 5% AEP level of protection WITH an equivalent upgrade to Hampden Avenue and conveyance improvements through Wilks Park between North Wagga and the CBD is recommended.

☑ The feasibility study would involve identifying the environmental constraints of excavating Wilks Park to offset flood impacts, assessing the condition of the existing levee, detailed floor survey and site by site assessment of negatively affected properties to determine individual flood impacts and subsequently, eligibility for and suitable types of compensatory works. Further to this, the study would also be required to consider ongoing community education issues and engagement programs. Consideration must also be given to internal drainage infrastructure.

The feasibility study should be undertaken in conjunction with Option PR1, which will assess the feasibility of a Voluntary House Raising and Voluntary Purchase Scheme in eligible areas of the Wagga Wagga Study Area. This option is described in detail in Section 9.6.1.

9.3.3.6. Option L4(C): North Wagga Levee Upgrade (5% AEP Event Design) with Hampden Ave as Overland Bridge

Description

Due to the Low Flood Island ERP classification, reluctance to evacuate and the subsequent risk to life, the upgrade of the North Wagga Levee cannot be considered without an upgrade of the access route to a level consistent with the level of protection of the proposed levee. As with the 1% AEP upgrade this option is subsequently considered with two road upgrade scenarios to provide flood free access at the 5% AEP.

Option L4(C) assesses the same levee option as L4(B), however the upgrade to Hampden Avenue is achieved using an overland bridge style construction from Hampden Bridge through to Wilks Park Bridge that involves removing the existing road embankment and excavating the flow path beneath the existing Wilks Park Bridge to increase flow conveyance. An upgrade to Mill Street would also be necessary, however this has not been modelled at this stage.

Modelled Impacts

Option L4(C) has the effect of removing flood affectation inside North Wagga in events up to and including the 5% AEP event, and in the 1% AEP event causes only minor upstream flood impacts largely due to the Wilks Park excavation and removal of the current Hampden Avenue road embankment as shown in Figure E18. Flood levels are increased however in a region at the downstream side of North Wagga due to the increased flow through Wilks Park. The impacts in the 5% AEP event are too a direct result of the increased conveyance beneath Wilks Park Bridge and are shown in Figure E19. This figure shows a decrease in flood levels on the upstream side of the levee and the floodplain to the north and south east as more flow is allowed through the Wilks Park flowpath. The effect of this is an increase in peak flood levels of up 0.2 m directly downstream of Hampden Avenue.

Change in Property Flood Affectation

Table 61 indicates the number of properties affected both externally and internally (over floor level) in each design event tested as part of this Study. The Option L4(C) levee provides flood protection for a significant number of properties within North Wagga for events up to and including the 5% AEP, and generally reduces external and internal flood affectation for properties situated outside of the levee, however one property in the West Wagga region is negatively impacted, and would be inundated overfloor in the 10% AEP event compared to the 5% AEP event in the existing case. This is shown in Diagram 14, which indicates how properties flooded over floor are affected by implementation of the option across the full range of design events. These effects are reflected in Table 66 which shows the property damages by Floodplain Community. It should be noted that this option also worsens flood affectation for 27 properties within North Wagga and the Mill Street area itself due to the changed flow regime downstream of Hampden Avenue as a result of the increased flow conveyance through Wilks Park and obstruction caused by the levee.

Table 66 Option L4(C): Property Affectation

Event	Total Properties Affected Externally		Total Properties Affected Over floor level			
	Existing Case	Option Implemented	Existing Case	Option Implemented	Floor Level Difference	% Floor Level Difference
10% AEP	57	43	40	28	12	30.0%
5% AEP	307	108	232	69	163	70.3%
2% AEP	465	464	404	401	3	0.7%
1% AEP	597	593	539	536	3	0.6%
0.5% AEP	2276	2250	2046	2018	28	1.4%
0.2% AEP	3599	3544	3487	3439	48	1.4%
PMF	4743	4743	4727	4727	0	0.0%

*Positive numbers indicate NET reduction in number of properties flooded above floor

Diagram 14 Option L4(C): Change in internal property affectation due to option implementation

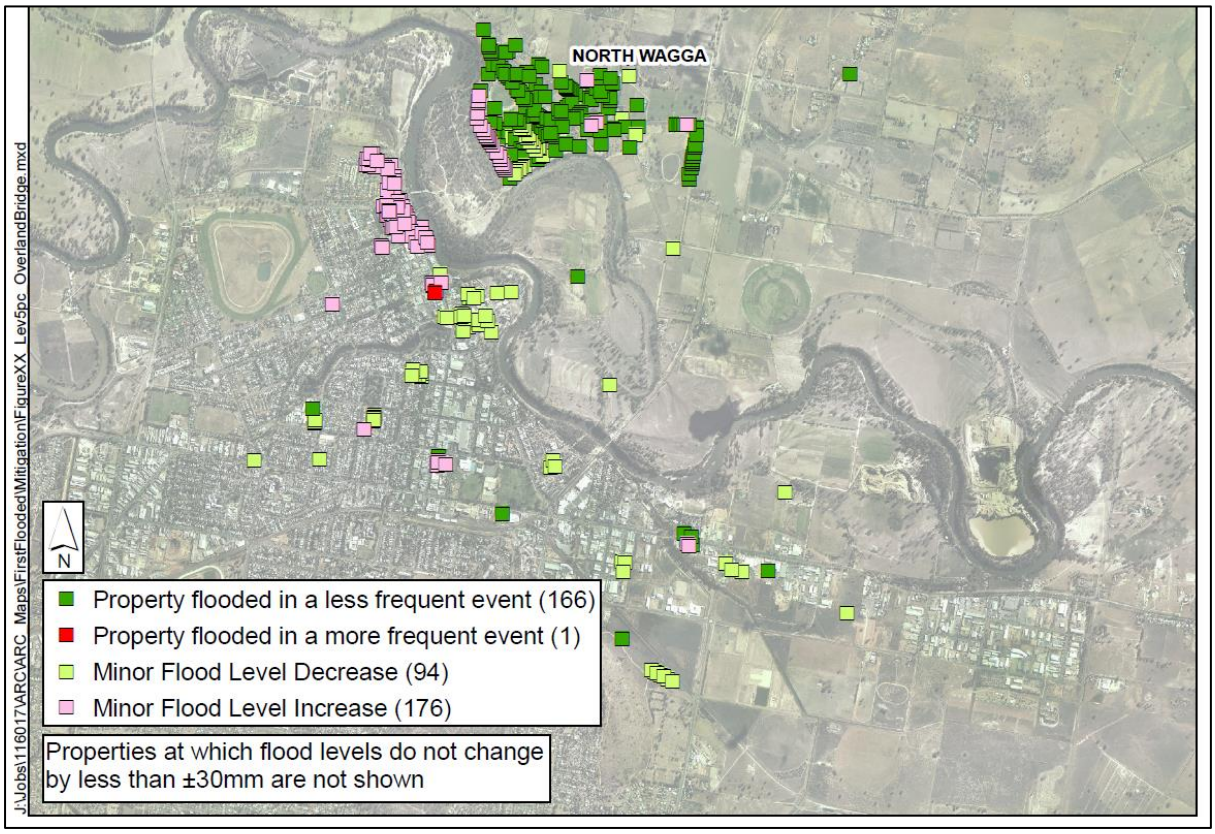


Table 67 Option L4(C): Property Damages by Community

Community	AAD (Existing Case)	AAD (Option Implemented)	Difference	% Difference
Wagga CBD	$2,347,400	$2,175,200	$172,200	7.3%
East Wagga	$846,000	$784,300	$61,700	7.3%
North Wagga	$1,583,100	$983,800	$599,300	37.9%
West Wagga	$347,800	$347,600	$200	0.1%
Gumly	$115,600	$114,100	$1,500	1.3%
Oura	$125,200	$125,200	$0	0.0%
Wagga Floodplain	$182,200	$213,600	-$31,400	-17.2%
Eunony	$34,600	$34,600	$0	0.0%
Total AAD	**$5,581,900**	**$4,778,400**	**$803,500**	**14.4%**

*Positive numbers indicate NET reduction in number of properties flooded above floor

Construction of a 5% AEP levee and overland bridge-style road upgrade to protect North Wagga would reduce damages locally by 37.9%, reducing North Wagga's AAD from $1,583,100 to $983,800. This is a significant reduction, which along with widespread benefits caused by the increased flow conveyance, results in a reduction of the total Annual Average Damages by approximately $803,500 or 14.4%. However the option would require significant capital investment, resulting in a low BC ratio, as shown in Table 68 which indicates that Option L4(C) is not economically feasible. A detailed costing is provided in Appendix F. At this stage the upgrade to Mill Street has not been included.

Table 68 Option L4(C): Economic Assesment

Capital Cost	$23,000,300
Reduction in Total AAD	$680,000
Reduction in Total AAD	12.2%
BC Ratio	0.43

Other Concerns

The key concerns regarding increasing the level of protection around North Wagga are described in 9.3.3. Despite the significant reductions in flood affectation within North Wagga, a levee at this height would not protect properties in North Wagga from an event greater than a 5% AEP event (for example the 2012 event). There would need to be significant community education to understand that the levee is likely to still be overtopped (or indeed could fail), and that residents will need to be ready to evacuate. The upgrade to Hampden Avenue would increase the window of opportunity for this evacuation to take place, however this may also act to make residents complacent about heeding evacuation orders immediately and result in increased risk to life and pressure on the SES.

Conclusion

Based on the outcomes of the above assessment and consideration of concerns, the following scores have been assigned to Option L4(C) in the multi-criteria assessment, noting that Community Acceptance scores have been allocated based on feedback received during the Public Exhibition period.

Table 69 Option L4(C): Multi-Criteria Assessment Results

Ref	Option	Impact on Flood Behaviour	Impact on Property Damage	Technical Feasibility	Community Acceptance	Economic Merits	Environmental/ Ecological Benefits	Impact on SES	Risk to Life*	Total Score
L4C	5% AEP North Wagga Levee Upgrade with Hampden Ave Overland Bridge	2	0	-3	-1	-2	-2	-1	-2	-9

* A detailed breakdown of the factors contributing to the risk to life score is presented in Table 101.

Option L4(C) Summary of Recommendations

☒ Construction of a levee with a 5% AEP level of protection is not economically viable due to the high capital costs of replacing Hampden Avenue with an overland bridge to meet access/egress requirements. Other factors to be considered include the environmental impacts involved with the excavation of Wilks Park and associated vegetation clearing, construction feasibility, and impacts on visual amenity. As a result, this option is not recommended.

9.3.3.7. Option L5: Removal of North Wagga Levee

Option Description

This option assesses the removal of the existing North Wagga Levee. As an option in isolation it is not expected to be feasible as it would increase the flood damages and have a significant excavation cost, however has been investigated simply for completeness as it was listed as an option in the Options for North Wagga Flood Futures program (Reference 25). Coupling this option with other strategies such as a Voluntary House Raising and Voluntary House Purchase Scheme (discussed in Section 9.6.1) would offset some of the negative impacts on flood damages, particularly in North Wagga.

Modelled Impacts

Removing the North Wagga Levee essentially removes a key obstruction from the floodway in Wagga Wagga, which in the 1% AEP event results in widespread minor reductions in flood levels of up to 0.05 m upstream of the levee and across the floodplain (Figure E20). There is little difference to flood levels within Wagga itself in the 1% AEP, as the levee would have always been significantly overtopped in this size event. The 5% AEP event sees more dramatic results, with widespread significant reductions in flood levels upstream of the levee across the width of the floodplain and into East Wagga, however flood levels at the immediate downstream side of the (now removed) levee increase by up to 0.2 m, which would not typically be considered acceptable. Interestingly, the removal of the levee reduces flood affection at the rear (downstream) end of North Wagga by up to 0.1 m in parts. These impacts are shown on Figure E21.

Change in Property Flood Affectation

Table 70 indicates the number of properties affected both externally and internally (over floor level) in each design event tested as part of this Study.

Table 70 Option L5 Property Affectation

Event	Total Properties Affected Externally		Total Properties Affected Over floor level			
	Existing Case	Option Implemented	Existing Case	Option Implemented	Floor Level Difference	% Floor Level Difference
10% AEP	57	204	41	132	-91	-222.0%
5% AEP	307	297	234	232	2	0.9%
2% AEP	465	464	404	403	1	0.2%
1% AEP	597	595	539	538	1	0.2%
0.5% AEP	2402	2383	2170	2146	24	1.1%
0.2% AEP	3736	3726	3661	3649	12	0.3%
PMF	4744	4743	4728	4727	1	0.0%

*Positive numbers indicate NET reduction in number of properties flooded above floor

Removing the North Wagga Levee only has a net negative outcome in events smaller than the current capacity of the levee (~12% AEP), as seen in the row indicating property affectation in the 10% AEP event in Table 70. Removing the levee however reduces flood affectation across much of the remainder of the floodplain as can be seen in Diagram 15. There are a small number of properties downstream of North Wagga that would be adversely impacted by removal of the levee. These results are reflected in Table 71 which shows the breakdown of Annual Average Damages by Floodplain Community.

Diagram 15 Option L5: Change in internal property affectation due to option implementation

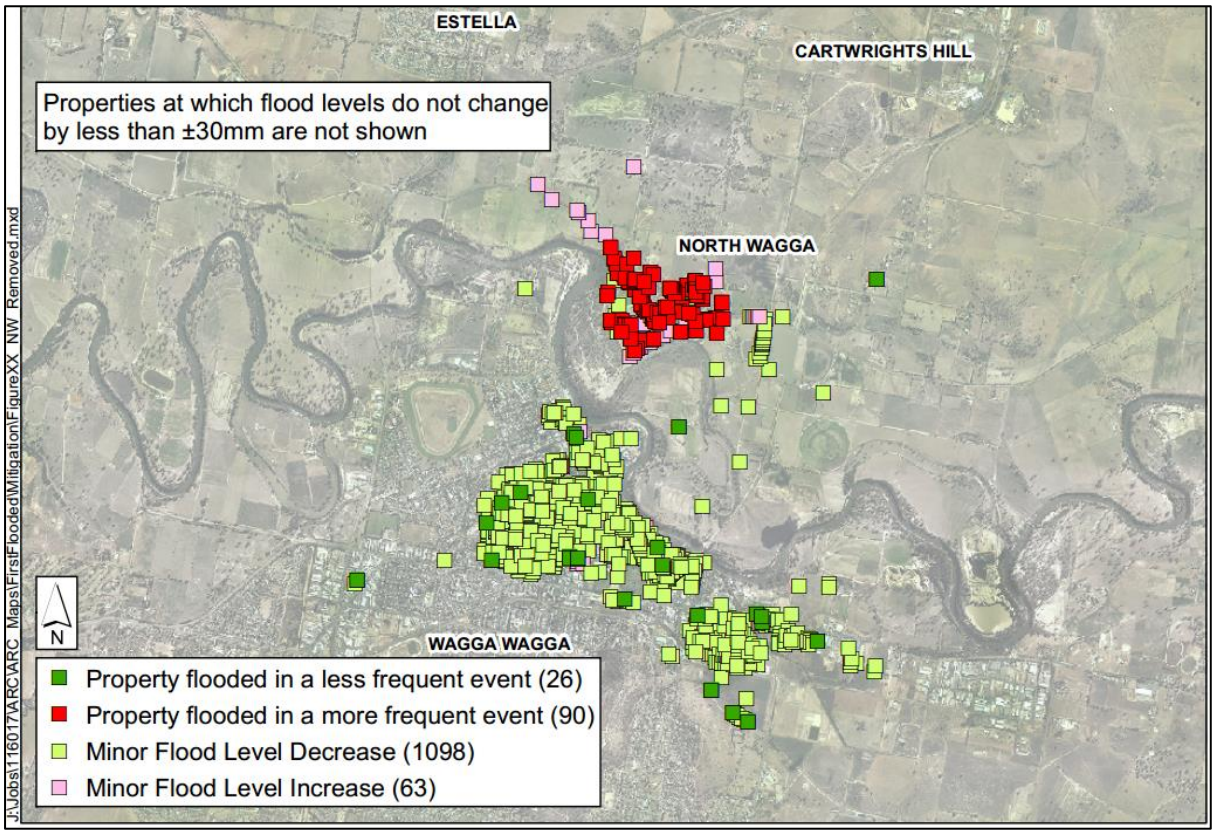


Table 71 Option L5: Property Damages by Community

Community	AAD (Existing Case)	AAD (Option Implemented)	Difference	% Difference
Wagga CBD	$2,347,400	$2,327,300	$20,100	0.86%
East Wagga	$846,000	$804,100	$41,900	4.95%
North Wagga	$1,583,100	$2,100,700	-$517,600	-32.70%
West Wagga	$347,800	$349,500	-$1,700	-0.49%
Gumly	$115,600	$115,100	$500	0.43%
Oura	$125,200	$125,200	$0	0.00%
Wagga Floodplain	$182,200	$215,400	-$33,200	-18.22%
Eunony	$34,600	$34,600	$0	0.00%
Total AAD	**$5,581,900**	**$6,071,900**	**-$490,000**	**-8.78%**

*Positive numbers indicate NET reduction in number of properties flooded above floor

Removal of the existing North Wagga Levee would increase damages within North Wagga by 32.7%, increasing North Wagga's AAD from $1,583,100 to $2,100,700. Furthermore, West Wagga and the Wagga Floodplain would also experience increases in their damages, though to a lesser extent. While East Wagga and the CBD enjoy reduced flood levels, the extent is not significant enough to outweigh the disbenefits to North Wagga, West Wagga and the Wagga Floodplain, and results in an increase in the overall Annual Average Damages by approximately $490,000 or 8.78%. This increase leads to a negative BC ratio, as shown in Table 72 which indicates that Option L5 alone is not economically feasible.

Table 72 Option L5 Economic Assesment

Capital Cost	$395,000[1]
Reduction in Total AAD	-$490,000[2]
Reduction in Total AAD	-8.8%
BC Ratio	<0

[1] Estimated by Flood Futures (Reference 25)

[2] Removal of North Wagga Levee Increases Total AAD

Other Concerns

Removing North Wagga Levee alone significantly worsens flood affectation inside and downstream of North Wagga. In this option, access routes out of North Wagga would be cut at the same level (although slightly later), and residents would have had to evacuate by this time even with the levee still in place. However residents who chose not to evacuate would have their properties (and indeed the streets of North Wagga) inundated earlier than if the levee were in place.

Noting that the increase in the overall flood damages is mainly due to overfloor inundation worsened in North Wagga and some properties downstream, if there were widespread raising of houses throughout these areas, this option might be considered to be favourable for the whole floodplain. A Voluntary House Raising and Voluntary House Purchase Scheme (discussed in Section 9.6.1) could offset the negative impacts on overfloor inundation as a result of the levee removal while allowing flood level reductions over the broader floodplain. However considering the removal of the levee alone would significantly increase the damages in North Wagga making it not economically feasible. It is also likely that this option would be highly unpopular with residents of North Wagga, and significant community education would be required to both explain the works and inform residents of their new responsibilities and flood liability.

Conclusion

Based on the outcomes of the above assessment and consideration of concerns, the following scores have been assigned to Option L5 in the multi-criteria assessment, noting that Community Acceptance scores have been allocated based on feedback received during the Public Exhibition period.

Table 73 Option L5: Multi-Criteria Assessment Results

Ref	Option	Impact on Flood Behaviour	Impact on Property Damage	Technical Feasibility	Community Acceptance	Economic Merits	Environmental/ Ecological Benefits	Impact on SES	Risk to Life*	Total Score
L5	Removal of North Wagga Levee	-3	-3	-2	-2	-3	-2	-2	-2	-19

* A detailed breakdown of the factors contributing to the risk to life score is presented in Table 101.

Option L5 Summary of Recommendations

☒ The removal of the North Wagga Levee would cause significant increase in property damages throughout North Wagga and, to a lesser extent, the West Wagga and Floodplain communities. It is likely to be very unpopular with residents of North Wagga and residents downstream, and would require significant education and consultation. As a result this option is not recommended.

9.3.3.8. Option L6: Opening North Wagga Levee

Option Description

This option assesses effectively 'opening' the currently enclosed North Wagga ring levee, by excavating an upstream and downstream spillway to the level of the 0.2EY. This option is investigated to assess if there are any benefits available to North Wagga and the northern floodplain by allowing floodwaters to escape North Wagga rather than being impounded by the existing levee.

Modelled Impacts

The minor adjustment to the levee makes no difference to peak flood levels in the 1% AEP event, as shown in Figure E22. However, the impacts in the 5% AEP event are more notable and show peak flood levels increased at the upstream (eastern) side of North Wagga, for very little benefit elsewhere. The flood impacts for the 5% AEP event are shown in Figure E23.

Change in Property Flood Affectation

Table 74 indicates the number of properties affected both externally and internally (over floor level) in each design event tested as part of this Study. The 97 properties now inundated in the 10% AEP event are all located within North Wagga. The areas benefited however include East Wagga and the Wagga Floodplain.

Table 74 Option L6 Property Affectation

Event	Total Properties Affected Externally		Total Properties Affected Over floor level			
	Existing Case	Option Implemented	Existing Case	Option Implemented	Floor Level Difference	% Floor Level Difference
10% AEP	57	181	41	138	-97	-236.6%
5% AEP	307	301	234	231	3	1.3%
2% AEP	465	463	404	403	1	0.2%
1% AEP	597	595	539	537	2	0.4%
0.5% AEP	2402	2401	2170	2170	0	0.0%
0.2% AEP	3736	3736	3661	3661	0	0.0%
PMF	4744	4744	4728	4728	0	0.0%

*Positive numbers indicate NET reduction in number of properties flooded above floor

Opening up the North Wagga Levee has a net negative outcome in events smaller than the current capacity of the levee (~12% AEP), as seen in the row indicating property affectation in the 10% AEP event in Table 74. In larger events however, opening up the levee mildly reduces over-floor property inundation for a small number of properties, as can be seen in Diagram 16. Properties in the floodplain both upstream and downstream of North Wagga are also negatively impacted by the new flow behaviour, as can be seen in Table 75, which shows the breakdown of Annual Average Damages by Floodplain Community.

Diagram 16 Option L6: Change in internal property affectation due to option implementation

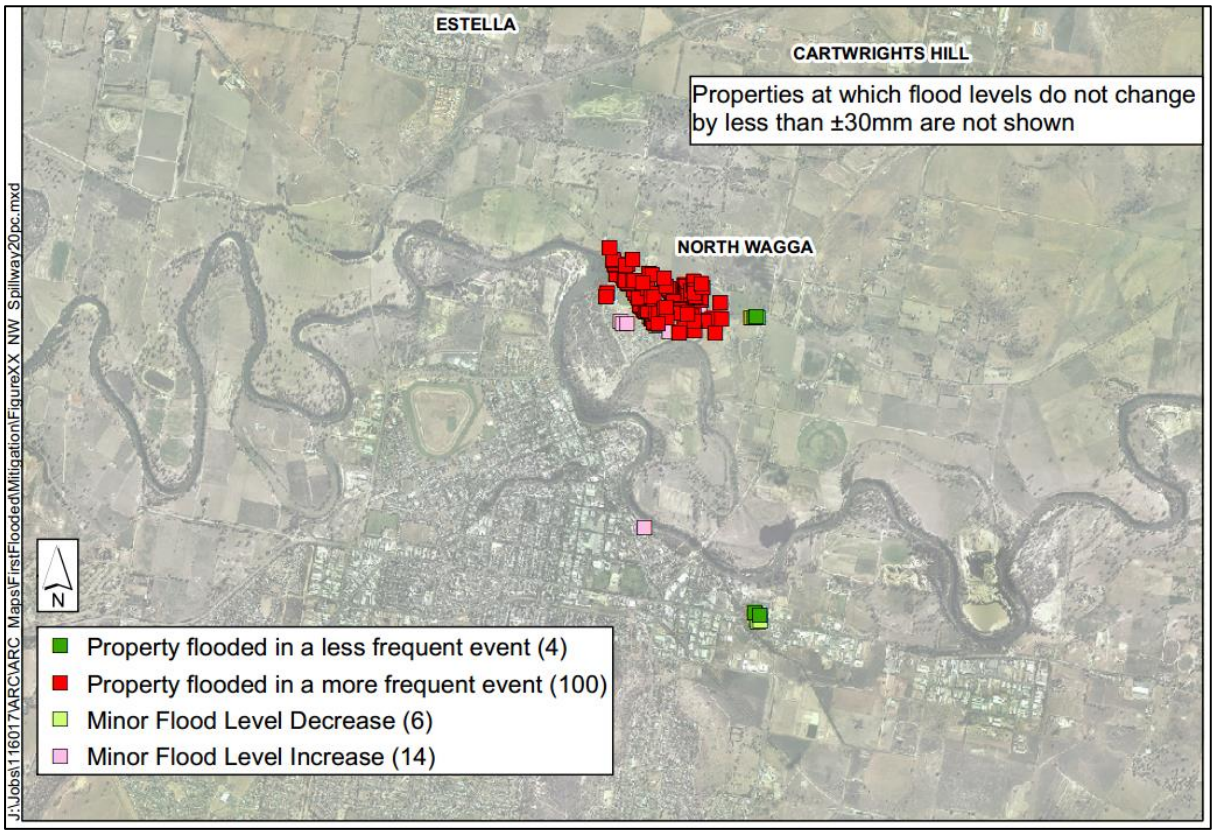


Table 75 Option L6: Property Damages by Community

Community	AAD (Existing Case)	AAD (Option Implemented)	Difference	% Difference
Wagga CBD	$2,347,400	$2,346,900	$500	0.02%
East Wagga	$846,000	$833,100	$12,900	1.52%
North Wagga	$1,583,100	$2,160,800	-$577,700	-36.49%
West Wagga	$347,800	$347,900	-$100	-0.03%
Gumly	$115,600	$115,600	$0	0.00%
Oura	$125,200	$125,200	$0	0.00%
Wagga Floodplain	$182,200	$181,300	$900	0.49%
Eunony	$34,600	$34,600	$0	0.00%
Total AAD	**$5,581,900**	**$6,145,400**	**-$563,500**	**-10.10%**

*Positive numbers indicate NET reduction in number of properties flooded above floor

Opening up the existing North Wagga Levee would increase damages within North Wagga by 36.49%, increasing North Wagga's AAD from $1,583,100 to $2,160,800. Furthermore, West Wagga would experience increases to its damages, though to a lesser extent (0.03%). While East Wagga and the CBD enjoy reduced flood damages, the extent is not significant enough to outweigh the disbenefits to North Wagga and West Wagga, resulting in an increase in the overall Annual Average Damages by approximately $563,500 or 10.10% This increase leads to a negative BC ratio, as shown in Table 76 which indicates that Option L6 is not economically feasible.

Table 76 Option L6 Economic Assesment

Capital Cost	$359,000[1]
Reduction in Total AAD	-$563,000[2]
Reduction in Total AAD	-10.10%
BC Ratio	<0

[1] Estimated by Flood Futures (Reference 25)

[2] Removal of North Wagga Levee Increases Total AAD

Other Concerns

The main concern with this option is that it significantly worsens flood affectation in North Wagga during small events, without providing notable benefits to the rest of the floodplain. In small events residents would have less time to evacuate or prepare their homes for inundation as water would overtop the new spillways much earlier. There would need to be significant community education to ensure all residents are aware of the reduced capacity of the levee. It is envisaged that this option would be highly unpopular with residents of North Wagga and the Wagga Floodplain.

Conclusion

Based on the outcomes of the above assessment and consideration of concerns, the following scores have been assigned to Option L6 in the multi-criteria assessment, noting that Community Acceptance scores have been allocated based on feedback received during the Public Exhibition period.

Table 77 Option L6: Multi-Criteria Assessment Results

Ref	Option	Impact on Flood Behaviour	Impact on Property Damage	Technical Feasibility	Community Acceptance	Economic Merits	Environmental/ Ecological Benefits	Impact on SES	Risk to Life*	Total Score
L6	Opening of North Wagga Levee	-3	-3	-1	-1	-3	-1	-2	-2	-16

* A detailed breakdown of the factors contributing to the risk to life score is presented in Table 101.

Option L6 Summary of Recommendations

☒ The opening of the North Wagga Levee would cause significant increase in property damages throughout North Wagga and, to a lesser extent, the West Wagga and Floodplain communities for no substantial benefit elsewhere. As a result this option is not recommended.

9.3.4. Wagga Floodplain

9.3.4.1. Option A1: Increase Conveyance beneath Wiradjuri Bridge

Option Description

Hampden Avenue connects North Wagga on the Murrumbidgee's northern floodplain to Wagga Wagga on the southern banks via Wiradjuri Bridge. Between Wall Street in North Wagga and the bridge over the river, Hampden Avenue is founded on an embankment raised up to 1.5 m above the natural ground level. This option investigates extending the span of the bridge to remove a portion of the Hampden Avenue road embankment that acts to obstruct flows, and lowering the embankment to match the surrounding natural ground level. Future upgrades to the bridge for normal maintenance purposes or expansion for increased traffic capacity may provide an opportunity to extend the bridge span and undertake excavation beneath the bridge to improve flood conveyance and reduce flood levels. In addition to this, upgrades to Hampden Avenue itself (for example as part of a levee upgrade) may also present an opportunity to improve flow conveyance by extending the span of Wiradjuri Bridge.

Modelled Flood Impacts

It should be noted that the modelled scenario simulated removing the entirety of Hampden Avenue between Wiradjuri Bridge and Wall Street, replacing it with an overland bridge. In reality, the excavation and bridge span is unlikely to so extensive, however this modelling approach is a good basis to gauge the extent of flood benefits that could be available.

The flood impacts for Option A1 are presented in Figure E26 and Figure E27 for the 1% AEP and 5% AEP event respectively. There are minor flood level reductions of 0.03 m on average in the Murrumbidgee floodplain between North Wagga and East Wagga. There is a localised area of increased flood levels downstream of the existing bridge of less than 0.05 m.

There are minor reductions as a result of this option however there is limited benefit to properties and over floor inundation and one previously flood -free property in West Wagga would be inundated over floor in the 10% AEP event.

Change in Property Flood Affectation

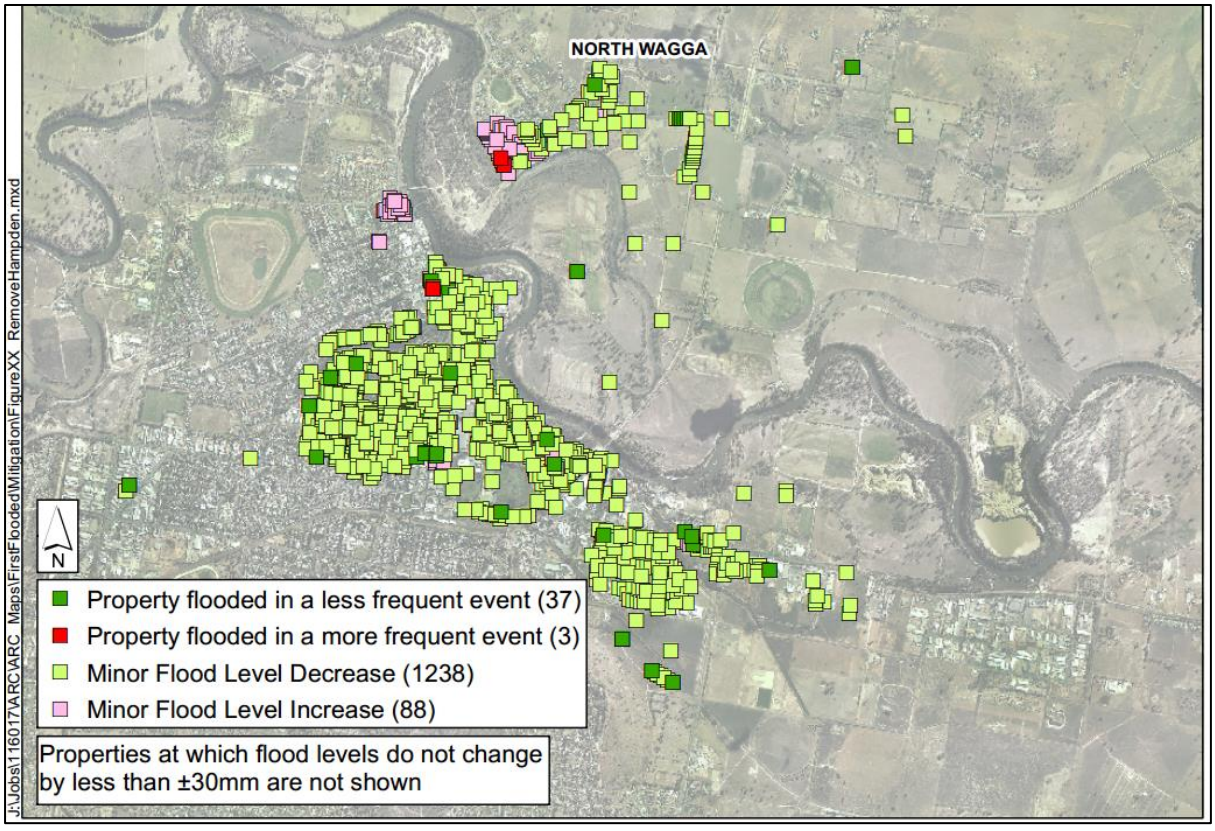
Table 78 indicates the number of properties affected both externally and internally (over floor level) in each design event tested as part of this Study. Not captured in this table is the fact that a property in West Wagga would first be subject to over floor flooding in the 10% AEP event with the implementation of this option, rather than in the 5% AEP.

Table 78 Option A1: Property Affectation

Event	Total Properties Affected Externally		Total Properties Affected Over floor level			
	Existing Case	Option Implemented	Existing Case	Option Implemented	Floor Level Difference	% Floor Level Difference
10% AEP	57	51	41	36	5	12.2%
5% AEP	307	297	234	228	6	2.6%
2% AEP	465	464	404	403	1	0.2%
1% AEP	597	595	539	538	1	0.2%
0.5% AEP	2402	2382	2170	2145	25	1.2%
0.2% AEP	3736	3723	3661	3644	17	0.5%
PMF	4744	4743	4728	4727	1	0.0%

*Positive numbers indicate NET reduction in number of properties flooded above floor

Diagram 17 Option A1: Change in internal property affectation due to option implementation



Due to its position in the floodway, removing the obstruction caused by Hampden Avenue reduces flood levels upstream and to the south for a broad range of events. This can be seen in the change in property affectation shown in Diagram 17 above and in Table 79 which provides the breakdown of Annual Average Damages by Floodplain Community.

Table 79 Option A1: Property Damages by Community

Community	AAD (Existing Case)	AAD (Option Implemented)	Difference	% Difference
Wagga CBD	$2,347,400	$2,327,300	$20,100	0.86%
East Wagga	$846,000	$810,400	$35,600	4.21%
North Wagga	$1,583,100	$1,557,600	$25,500	1.61%
West Wagga	$347,800	$349,700	-$1,900	-0.55%
Gumly	$115,600	$115,100	$500	0.43%
Oura	$125,200	$125,200	$0	0.00%
Wagga Floodplain	$182,200	$214,200	-$32,000	-17.56%
Eunony	$34,600	$34,600	$0	0.00%
Total AAD	**$5,581,900**	**$5,534,100**	**$47,800**	**0.86%**

*Positive numbers indicate NET reduction in number of properties flooded above floor

As shown in Table 79 the conversion of Hampden Avenue into an overland bridge has minimal benefits for most areas in Wagga Wagga (up to 4.21% reduction in East Wagga), and due to increased flood affectation in the Wagga Floodplain (17.56%), only reduces the overall Annual Average Damages by 0.86%. The significant capital cost is not balanced by this minor reduction, resulting in a very low BC ratio as noted in Table 80, indicating the option is not economically feasible.

Table 80 Option A1: Economic Assesment

Capital Cost	$27,115,600
Reduction in Total AAD	$48,000
Reduction in Total AAD	0.86%
BC Ratio	0.03

Other Concerns

The modelled option did not only remove the existing road embankment, but also modelled significant excavation beneath what would be the new bridge in the order of 256,200 m^3. This scale of excavation would have significant environmental impacts and also require a dedicated spoil location out of the floodplain.

The implementation of this option is currently not justified economically. In the future however, if there are planned upgrades to Wiradjuri Bridge, say for traffic capacity enhancements or structural maintenance/ replacement, extending the bridge span, excavating banks and removing some of the road for the purposes of flood conveyance should be considered.

Conclusion

Based on the outcomes of the above assessment and consideration of concerns, the following scores have been assigned to Option A1 in the multi-criteria assessment, noting that Community Acceptance scores have been allocated based on feedback received during the Public Exhibition period.

Table 81 Option A1: Multi-Criteria Assessment Results

Ref	Option	Impact on Flood Behaviour	Impact on Property Damage	Technical Feasibility	Community Acceptance	Economic Merits	Environmental/ Ecological Benefits	Impact on SES	Risk to Life*	Total Score
A1	Future Option: Increase Conveyance beneath Wiradjuri Bridge	3	1	-3	2	-3	-3	3	1	1

* A detailed breakdown of the factors contributing to the risk to life score is presented in Table 101.

Option A1 Summary of Recommendations

☑ The conversion of Hampden Avenue to an overland bridge is not economically feasible in its current form, however if in the future Wiradjuri Bridge is being upgraded (for example for structural or traffic capacity reasons), opportunities for increasing flood conveyance should be considered.

9.3.4.2. Option BF1: North Wagga Floodplain Bypass Floodway

Option Description

This option examines the potential flood benefits caused by the excavation of a new bypass floodway to the north of North Wagga. Bypass Floodways were not considered in the 2009 Study (Reference 3) citing that given the size of the Murrumbidgee River floodplain, and the volume of water involved, artificial floodways were not considered to be a viable management measure. This option was specifically raised during community consultation and so has been investigated in this report. The option involves the excavation of a 20 m wide channel 4-5 m deep, approximately 406,000 m^3 of cut (enough to fill ~162 Olympic swimming pools). The channel is 5.6 km long, and runs from an existing low point east of Byrnes Road to the Murrumbidgee River at Boorooma Street. Concept Designs of a typical floodway section are provided in Appendix F.

Modelled Impacts

Even with such large scale excavation, the flood benefits of this option are relatively minor, with widespread reductions of up to 0.05 m extending to downstream of Gumly in both the 5% and 1% AEP events. The impacts are shown on Figures E18 and E19. While impacts are relatively minor due to the scale of works relative to the total flow across the Murrumbidgee floodplain, this option prevents inundation of buildings across East Wagga (5), North Wagga (18) and the Wagga Floodplain (1) in the 5% AEP event. Over flood inundation is prevented for 17 and 12 buildings in the Wagga CBD during the 0.5% AEP and 0.2% AEP, respectively.

Flood Damages Assessment

A flood damages assessment for the North Wagga Floodplain Bypass Floodway has been undertaken, with results shown in Table 82. No properties are caused to be inundated overfloor in an earlier event with implementation of this option.

Table 82 Option BF1: Property Affectation

Event	Total Properties Affected Externally		Total Properties Affected Over floor level			
	Existing Case	Option Implemented	Existing Case	Option Implemented	Floor Level Difference	% Floor Level Difference
10% AEP	57	47	41	32	9	22.0%
5% AEP	307	300	234	227	7	3.0%
2% AEP	465	462	404	402	2	0.5%
1% AEP	597	593	539	536	3	0.6%
0.5% AEP	2402	2387	2170	2146	24	1.1%
0.2% AEP	3736	3727	3661	3648	13	0.4%
PMF	4744	4743	4728	4727	1	0.0%

*Positive numbers indicate NET reduction in number of properties flooded above floor

Table 83 Option BF1: Property Damages by Community

Community	AAD (Existing Case)	AAD (Option Implemented)	Difference	% Difference
Wagga CBD	$2,347,400	$2,325,400	$22,000	0.94%
East Wagga	$846,000	$822,700	$23,300	2.75%
North Wagga	$1,583,100	$1,513,900	$69,200	4.37%
West Wagga	$347,800	$344,800	$3,000	0.86%
Gumly	$115,600	$114,500	$1,100	0.95%
Oura	$125,200	$125,200	$0	0.00%
Wagga Floodplain	$182,200	$179,100	$3,100	1.70%
Eunony	$34,600	$34,600	$0	0.00%
Total AAD	**$5,581,900**	**$5,460,200**	**$121,700**	**2.18%**

*Positive numbers indicate NET reduction in number of properties flooded above floor

As shown in Table 83 the bypass floodway has slight benefits for most areas in Wagga Wagga, however only reduces the overall Annual Average Damages by 2.19%. The significant capital cost however is not balanced by this minor reduction, resulting in a very low BC ratio as noted in Table 84 indicating the option is not economically feasible.

Table 84 Option BF1: Economic Assesment

Capital Cost	$8,478,200
Reduction in Total AAD	$122,000
Reduction in Total AAD	2.19%
BC Ratio	0.21

Other Concerns

The modelled option requires an enormous amount of excavation for very little benefit, which would have a significant cost and environmental impacts attached to it. This spoil would then need to be deposited outside the floodplain to ensure there are no adverse flood impacts. Social and community impacts would also be significant, as the channel would require the acquisition of land, increasing flood risk to the properties adjacent, drainage to ensure it does not pond water (to depths which would require fencing for public safety).

Conclusion

Based on the outcomes of the above assessment and consideration of concerns, the following scores have been assigned to Option BF1 in the multi-criteria assessment, noting that Community Acceptance scores have been allocated based on feedback received during the Public Exhibition period.

Table 85 Option BF1: Multi-Criteria Assessment Results

Ref	Option	Impact on Flood Behaviour	Impact on Property Damage	Technical Feasibility	Community Acceptance	Economic Merits	Environmental/ Ecological Benefits	Impact on SES	Risk to Life*	Total Score
BF1	North Wagga Bypass Floodway	1	1	-3	0	-3	-3	-2	-2	-11

* A detailed breakdown of the factors contributing to the risk to life score is presented in Table 101.

Option BF1 Summary of Recommendations

☒ The scale of flooding in the Murrumbidgee across Wagga Wagga is simply too large to be substantially affected by the excavation of one new flood bypass channel. Add to this the cost of construction and complications with public safety and environmental approvals, this option is not recommended for further investigation.

9.3.4.3. Other Considerations for the Wagga Floodplain

The residents of the Wagga Floodplain are more exposed to changes in flood levels due to mitigation works across the floodplain as their area is not protected by a levee. Accordingly, if mitigation flood modification options are implemented, a key consideration must be to the third-party impacts inflicted on properties across the Wagga Floodplain. If unacceptable impacts are found to occur, residents may be eligible for compensatory measures such as house raising, stock mounds or property-specific levees.

Additionally, over time the flood risk across the Wagga Floodplain will be lessened with the application of flood related development controls which are discussed in detail in Section 9.7. These controls will apply to developments of certain types and sizes, and seek to reduce flood risk to life (of occupants) and to prevent neighbouring works from impacting on existing property and infrastructure.

9.3.5. West Wagga

9.3.5.1. Option CM1: Excavation of Malebo Gap

Option Description

'Malebo Gap' is a constriction point on the Murrumbidgee River in West Wagga, about 20 km downstream of Hampden Bridge. Many Wagga residents believe the widening of such bottlenecks would be a fast, cost-effective way to prevent a flooding catastrophe. To address such claims the excavation of an area of 0.13 km^2 (about 23 football fields) was modelled at Malebo Gap, and positioned so as to link the river proper with an oxbow to the south, on the left bank. This area was lowered to 169.5 mAHD, which is approximately 3 m below existing natural surface and equates to a volume of approximately 395,000 m^3, enough earth to fill 158 Olympic swimming pools. Concept Designs of typical excavation sections are provided in Appendix F.

Modelled Impacts

As expected, the modelled excavation significantly reduces upstream peak flood levels, however the benefits are largely for the floodplain west of the Wagga CBD (downstream of Gobbagombalin Bridge). In events up to the 1% AEP event, the North Wagga and Wagga CBD are unaffected by the large scale excavation (Figure E28). In the 5% AEP event (Figure E29) there is a reduction in flood level of up to 0.1 m. Due to the sparse development in the areas of reduced flood level there is limited impact on over floor inundation.

Change in Property Flood Affectation

Table 86 indicates the number of properties affected both externally and internally (over floor level) in each design event tested as part of this Study. No properties are caused to be inundated overfloor in an earlier event with implementation of this option.

Table 86 Option CM1: Property Affectation

Event	Total Properties Affected Externally		Total Properties Affected Over floor level			
	Existing Case	Option Implemented	Existing Case	Option Implemented	Floor Level Difference	% Floor Level Difference
10% AEP	57	56	41	40	1	2.4%
5% AEP	307	303	234	233	1	0.4%
2% AEP	465	448	404	398	6	1.5%
1% AEP	597	570	539	524	15	2.8%
0.5% AEP	2402	2267	2170	2071	99	4.6%
0.2% AEP	3736	3661	3661	3598	63	1.7%
PMF	4744	4733	4728	4714	14	0.3%

*Positive numbers indicate NET reduction in number of properties flooded above floor

Table 87 Option CM1: Property Damages by Community

Community	AAD (Existing Case)	AAD (Option Implemented)	Difference	% Difference
Wagga CBD	$2,347,400	$2,281,300	$66,100	2.82%
East Wagga	$846,000	$844,400	$1,600	0.19%
North Wagga	$1,583,100	$1,582,700	$400	0.03%
West Wagga	$347,800	$345,700	$2,100	0.60%
Gumly	$115,600	$102,800	$12,800	11.07%
Oura	$125,200	$125,200	$0	0.00%
Wagga Floodplain	$182,200	$180,800	$1,400	0.77%
Eunony	$34,600	$34,600	$0	0.00%
Total AAD	**$5,581,900**	**$5,497,500**	**$84,400**	**1.51%**

*Positive numbers indicate NET reduction in number of properties flooded above floor

Analysis of the property damages by each Floodplain Community has shown that Gumly Gumly would experience a reduction in damages of 11.07%, largely due to events greater than the 1% AEP event, however the excavation option only reduces the overall annual average damages by 1.51%, as shown in Table 87. This leads to a low BC ratio of 0.19 as shown in Table 88.

Table 88 Option CM1: Economic Assesment

Capital Cost	$6,522,400
Reduction in Total AAD	$84,400
Reduction in Total AAD	1.52
BC Ratio	0.19

Other Concerns

As described above, this option requires a significant amount of excavation with a substantial cost involved as well as spoiling material at an appropriate location away from the floodplain so as not to inadvertently worsen flooding elsewhere. Furthermore, large scale works to river banks can have serious implications for the river's geomorphology, and may trigger the creation of new flowpaths or changes in flow behaviour, with potential for increased velocities (and hence erosion/scour) elsewhere. Changes to the geomorphology also affect habitats, and it is unlikely the works would be approved based on the potential negative environmental and ecological impacts they would cause.

Conclusion

Based on the outcomes of the above assessment and consideration of concerns, the following scores have been assigned to Option CM1 in the multi-criteria assessment, noting that Community Acceptance scores have been allocated based on feedback received during the Public Exhibition period.

Table 89 Option CM1: Multi-Criteria Assessment Results

Ref	Option	Impact on Flood Behaviour	Impact on Property Damage	Technical Feasibility	Community Acceptance	Economic Merits	Environmental/ Ecological Benefits	Impact on SES	Risk to Life*	Total Score
CM1	Malebo Gap Excavation	1	1	-3	1	-3	-3	0	0	-6

* A detailed breakdown of the factors contributing to the risk to life score is presented in Table 101.

Option CM1 Summary of Recommendations

☒ Intuitively, the widening of tight river passages is one way to reduce upstream flood levels. The modelling confirms these community-held expectations, though the impacts are not widespread. However, the option is not recommended due to the sheer scale of excavation, need for suitable spoil site and the likely negative impacts on the river's health. Excavation to a lesser extent would mean the option would not provide substantial benefits, and even as it is, reductions in flood levels are generally limited to the floodplain west of the CBD, meaning the reduction in flood damages is minor. As a result, the option is not recommended.

9.3.5.2. Option CM2: Excavation beneath Gobbagombalin Bridge

Option Description

As with Option CM1, this is a community-led investigation that responds to ideas about excavating the constriction point at the Gobbagombalin 'Gobba' Bridge to allow improved flow and reduce upstream flood levels. The option was modelled by lowering two areas along the banks of the river (about 600 m in length) to 170 mAHD, representing a lowering of up to 6 m in parts, and a volume of approximately 340,000 m^2 (enough to fill 135 Olympic swimming pools). Concept Designs of typical excavation sections and preliminary costings are provided in Appendix F.

Modelled Impacts

Excavation of the river bank beneath Gobbagombalin Bridge provides a significant reduction in peak levels immediately upstream of the bridge (up to 0.2 m), and up to 0.05 m across North Wagga until just upstream of the railway in the 1% AEP event. These impacts are shown on Figure E30. The impacts in the 5% AEP event, shown in Figure E31, show flood level reductions up to 0.2 m immediately upstream of Gobba Bridge, and lesser reductions through North Wagga to Hampden Avenue. There are minimal impacts across the floodplain upstream of Hampden Avenue. The minor increases in flood levels downstream of the works are limited to approximately 0.05 m. The results have shown that this option does not significantly improve over floor inundation of affected buildings and accordingly has very little impact on the overall Annual Average Damages as described below.

Change in Property Flood Affectation

Table 90 indicates the number of properties affected both externally and internally (over floor level) in each design event tested as part of this Study. No properties are caused to be inundated overfloor in an earlier event with implementation of this option.

Table 90 Option CM2: Property Affectation

Event	Total Properties Affected Externally		Total Properties Affected Over floor level			
	Existing Case	Option Implemented	Existing Case	Option Implemented	Floor Level Difference	% Floor Level Difference
10% AEP	57	55	41	38	3	7.3%
5% AEP	307	231	234	231	3	1.3%
2% AEP	465	397	404	397	7	1.7%
1% AEP	597	524	539	524	15	2.8%
0.5% AEP	2402	2162	2170	2162	8	0.4%
0.2% AEP	3736	3641	3661	3641	20	0.5%
PMF	4744	4727	4728	4727	1	0.0%

*Positive numbers indicate NET reduction in number of properties flooded above floor

Table 91 Option CM2: Property Damages by Community

Community	AAD (Existing Case)	AAD (Option Implemented)	Difference	% Difference
Wagga CBD	$2,347,400	$2,326,100	$21,300	0.91%
East Wagga	$846,000	$831,800	$14,200	1.68%
North Wagga	$1,583,100	$1,557,500	$25,600	1.62%
West Wagga	$347,800	$343,200	$4,600	1.32%
Gumly	$115,600	$102,500	$13,100	11.33%
Oura	$125,200	$125,200	$0	0.00%
Wagga Floodplain	$182,200	$180,400	$1,800	0.99%
Eunony	$34,600	$34,600	$0	0.00%
Total AAD	**$5,581,900**	**$5,501,300**	**$80,600**	**1.44%**

*Positive numbers indicate NET reduction in number of properties flooded above floor

Analysis of the property damages by each Floodplain Community has shown that Gumly Gumly would experience a reduction in damages of 11.33%, largely due to events greater than the 1% AEP event, however the excavation option only reduces the overall annual average damages by 1.44%, as shown in Table 91. This leads to a low BC ratio of 0.21 as shown in Table 92.

Table 92 Option CM2: Economic Assesment

Capital Cost	$5,650,200
Reduction in Total AAD	$81,000
Reduction in Total AAD	1.45%
BC Ratio	0.21

Other Concerns

The concerns with this option are largely the same as Option CM2: Excavation of Malebo Gap. These are centred around the large scale excavation, which has implications for river geomorphology and will affect flow rates, levels and velocities of the river all year round, not just during flood events. Such works would be subject to approval regarding the environmental and ecological impacts caused by the dramatic change in the river cross section at this location. In addition the existing bridge structure is unlikely to have been designed for this type of large scale excavation which may lead to instability of the structure.

Conclusion

Based on the outcomes of the above assessment and consideration of concerns, the following scores have been assigned to Option CM2 in the multi-criteria assessment. Note that Community acceptance scores have been updated based on feedback received during the Public Exhibition period.

Table 93 Option CM2: Multi-Criteria Assessment Results

Ref	Option	Impact on Flood Behaviour	Impact on Property Damage	Technical Feasibility	Community Acceptance	Economic Merits	Environmental/ Ecological Benefits	Impact on SES	Risk to Life*	Total Score
CM2	Gobbagombalin Bridge Excavation	1	1	-3	0	-3	-3	0	0	-7

* A detailed breakdown of the factors contributing to the risk to life score is presented in Table 101.

Option CM1 Summary of Recommendations

☒ The modelling shows that there are only minor benefits to the community-held expectations regarding excavation beneath Gobbagombalin Bridge. The option is not recommended due to the sheer scale of excavation, need for suitable spoil site and the likely negative impacts on the river's health. There are also concerns regarding the structural stability of the bridge if there were to be excavation around the existing piers. For these reasons this option is not recommended.

9.3.6. Wagga CBD

The upgrade of the Wagga CBD Levee to a design height of the 1% AEP (plus freeboard) was the main outcome from the 2009 Study. At the time of writing, the upgrade process was well underway and construction was due to start in October 2017. With this in mind, no further flood modification options have been assessed for this area, however the road raising option for the Sturt Highway will improve connectivity between Gumly Gumly, the East Wagga Industrial Area and the Wagga CBD.

Study-area wide options including vegetation management, property modifications, planning and development controls and response modification measures will have benefits for the Wagga CBD.

9.3.7. East Wagga

While no specific flood modification options have been assessed for East Wagga, landholders in the floodplain at East Wagga would benefit from the Sturt Highway road raising option which aims to provide flood free access in the 1% AEP event. In addition a number of measures across the floodplain result in benefits to property inundation in East Wagga.

Furthermore, study-area wide options including vegetation management, property modifications, planning and development controls and response modification measures will have benefits for East Wagga.

Note that an Eastern Industrial Levee was investigated in the 2009 study. The Study concluded:

"Due to the significant flood risk at Gumly Gumly (and in other areas) associated with the protection of east Wagga, as well as the impacts on flood evacuation for the area, any protection by a levee is considered to be unacceptable. There are no real compensatory measures that will adequately reduce the hydraulic impacts at Gumly Gumly.

Council's current filling policy will produce a similar beneficial outcome for landholders within the eastern industrial area while limiting impact upstream at Gumly Gumly and still allowing for broad scale economic benefits through the protection of the eastern industrial area."

These development controls are still in place, and are discussed further in Section 9.7.

9.3.8. Eunony

While no specific flood modification options have been assessed for Eunony, residents in the floodplain at Eunony would benefit from the Oura Road raising option which aims to provide flood free access in the 1% AEP event. Study-area wide options including vegetation management, property modifications, planning and development controls and response modification measures will have benefits for Eunony.

9.4. Option VMP: Vegetation Management Plan

9.4.1. Background

Vegetation management refers to the planning and implementation of the activities involved in managing native and exotic plant species within a particular area. Activities may include removal of weeds or debris, thinning of shrub layers or targeting a particularly problematic noxious plant species. In a flooding context, vegetation management may aim to improve flood behaviour, however in a broader context it may bring about a range of ecological values, for example the improvement of habitats for native fauna or bushfire hazard reduction. While there are many benefits available, the current legislative context imposes a number of constraints on vegetation management, especially in riparian areas.

With these constraints in place, the process involved in moving towards implementation of activities is therefore complex, and starts with the development of a Vegetation Management Plan (VMP). A VMP is a high level document designed to provide specific advice to Council. Following this, targeted investigations can be undertaken to develop Standard Operating Procedures (SOPs) for the activities recommended in the VMP. Council may wish to engage a consultant to assist in the development of SOPs. Approval from authorities including NSW Office of Water and Local Land Services is required before implementation of the actions outlined in the SOPs can occur. SOPs should cover both the initial implementation and ongoing maintenance of any activities, and consider a range of issues that may arise in relation to the activity, for example the appropriate use of chemicals near waterways or bank stability during clearing activities.

The Wagga Wagga Floodplain Risk Management Study and Plan completed in 2009 (Reference 3) recommended the completion of a Vegetation Management Plan on the Murrumbidgee River Floodplain. Further, the Wagga Wagga Detailed Model Revision (2014, Reference 2) indicated that the flood behaviour may be sensitive to changes in vegetation density. These studies have found that over the last few decades, the amount of vegetation along the banks of the Murrumbidgee River has significantly increased and has potentially changed the flood behaviour in the Wagga Wagga LGA. As such, a VMP has been undertaken parallel to this study, and the report produced by Waratah Eco Works can be found in Appendix H. The report identified a number of specific vegetation management activities that are designed to ensure flood behaviour is not worsened in the future as a result of increased vegetation density.

It is acknowledged that many residents in the floodplain regard vegetation management in the form of wide-scale clearing as a 'cure all' that will significantly reduce flooding, especially across the North Wagga floodplain. As discussed in the appended VMP, the scale of clearing that would be required to achieve even modest flood level benefits is immense, and would not be approved of or be appropriate considering current ecological legislation. Furthermore, the purpose of vegetation management is not to necessarily improve existing flood behaviour, but to manage new growth and weed/sapling density so as to not worsen flood behaviour in the future.

9.4.2. Methodology

The VMP begins by setting the federal, state and local planning context within which any vegetation management activities would occur, and provides a brief description of relevant legislative documents. In August 2017, some legislation pertinent to vegetation management was repealed (Threatened Species Conservation Act 1995; Native Vegetation Act 2003). The VMP has been prepared in line with new legislation (Biodiversity Conservation Act 2016; Local Land Services Amendment Bill 2016), however at the time of writing not all instruments and implementation documents had been released. As such, the VMP should be updated when these instruments become available.

In preparing the VMP, the consultant carried out a desktop data review and a site visit, including a trip along the Murrumbidgee River from Oura to just upstream of Wiradjuri Bridge. Findings from the site visit led to the identification of opportunities for vegetation management, and hydraulic modelling of potential sites for vegetation reduction and intensification to determine if significant changes to flood behaviour within the Study Area were possible. Existing and planned vegetation density can be represented in flood modelling using the hydraulic roughness parameter known as 'Manning's n'. The n value is determined by a number of factors that affect the resistance of channels and floodplains, including but not limited to vegetation. The modelling showed that even with significant clearing (which would not be appropriate within the current legislative context), only minor reductions in flood levels were achieved. Despite the minor flood benefits that may occur, activities to reduce and manage the density of exotic species were recommended to both ensure flood behaviour is not worsened due to unmanaged densification of vegetation and for the complementary ecological values that can be achieved. The recommendations arising from the VMP are outlined below and detailed in Appendix H.

9.4.3. Recommendations arising from the Vegetation Management Plan

The actions summarised below will contribute to the maintenance of riparian vegetation to ensure that significant increases in roughness do not occur over time. The below options should be considered in more detail, and Standard Operating Procedures drafted for those actions selected as viable options.

9.4.3.1. Targeted Willow Treatment

Downstream of Eunony Bridge, dense pockets of willows occur sporadically on the riverbank. Coordinated willow treatment should involve the following:

- identifying aims and objectives;
- stakeholder engagement;
- willow mapping;
- identification of suitable treatment methods for willows;
- catchment-wide recommendations and priorities;
- identification of sources of funding; and
- production of tender documentation for engaging contractors to undertake willow control works.

9.4.3.2. Treatment of Weeds in Riparian Areas

A coordinated approach to the management of weeds in areas where grazing and mowing are excluded is required. Left unchecked, increasing densities in the following areas will lead to increased roughness levels and potentially changes to flood behaviour. Priority areas include North Wagga Flats, Wilks Park, Wiradjuri Reserve and the islands and vegetation on the meander opposite Marrambidya Wetland. Control efforts should identify need for primary (initial) weed control works, and secondary (follow up) works that should continue for the long-term.

9.4.3.3. Reduction in Debris

There are high densities of timber debris associated with the 2010 and 2012 flood events, and although in areas it may cause localised increased flood levels by obstructing flow, this debris contributes significantly to habitat values for a variety of native fauna species. As such, careful consideration is required to identify areas in which debris could be reduced while having the least impact on habitat values.

9.4.3.4. Reduction in Shrub and Canopy Regeneration Layer Density

The plan sets out the understanding that widely separated round trunks have a lower impact than dense undergrowth on hydraulic roughness or flood flow friction loss. To reduce the hydraulic roughness level in areas close to Wagga Wagga city, a reduction in the density of the shrub layer is required. The selective thinning of these areas of regenerating canopy would reduce roughness levels. The modelling outlined in Options VM(A), VM(B) and VM(AB) (See Appendix H) has simulated such reduction in roughness. The modelling showed that minor improvements in flood behaviour may be available, however the purpose of this option is aimed at identifying these areas and ensuring there is not significant increase in density and obstruction over time.

9.4.4. Flood Damages Assessment

A flood damages assessment for the listed recommendations has not been undertaken, as the purpose of vegetation management is not to reduce current flood damages, but to ensure that in the future, flood behaviour and the resulting damage to property is made no worse by the uncontrolled densification of exotic saplings/ weedy undergrowth in riparian areas.

9.4.5. Other Issues for Consideration

The Standard Operating Procedures developed in the next stage of the vegetation management process must consider a number of issues regarding the implementation of a sustainable and successful vegetation management plan. A discussion of these issues is provided in the following section.

9.4.5.1. Ongoing Maintenance

Ongoing maintenance is imperative to the success of any vegetation management plan, and is often not undertaken to the degree required to achieve the objectives of the plan. Councils are eligible for funding through the Floodplain Management Program to assist with the initial drafting of a vegetation management plan, however the long-term maintenance must be carried out at Council's own expense, which often leads to it being omitted from annual scheduling and budgeting. Furthermore, ongoing maintenance across the entire catchment is necessary to ensure efforts in one Council area are not negated by upstream or downstream vegetation densification.

9.4.5.2. Consideration of Impacts on Native Fauna

The potential impacts of vegetation management activities on threatened species need to be considered. In the near future, impacts on native vegetation and threatened species will need to meet the requirements of the Biodiversity Conservation Act 2016 and the modified Local Lands Services Act 2013. Riverina LLS should be contacted to determine the management actions that are associated with the Property Vegetation Plans within the area covered by the FRMS&P. Further to these requirements, due diligence in accordance with the Due Diligence Code of Practice for the Protection of Aboriginal Objects in New South Wales would need to be undertaken before works were commenced.

9.4.5.3. Cooperation of Various Jurisdictions

It should be noted that the Vegetation Management Plan identifies actions that extend beyond land owned or managed by Wagga Wagga City Council, which may make implementation complicated. Coordination between responsible parties will be necessary to ensure the activities are effective.

9.4.5.4. Riparian Bank Stability

Any debris reduction, sapling clearing or weed management activities should also consider river bank stability and vehicle hygiene prior to implementation. Vegetation often plays a key role in preventing or reducing erosion and maintaining bank stability. The identification of banks and areas vulnerable to erosion or instability will be key to designing safe and sustainable vegetation removal procedures.

9.4.5.5. New Biodiversity Legislation

The Vegetation Management Plan (VMP) has been written to be consistent with new state biodiversity legislation (Biodiversity Conservation Act 2016) and the Local Land Services Amendment Bill 2016, however at the time of writing, associated instruments had not been implemented. It is recommended that Council update the Vegetation Management Plan to be consistent with these instruments as they become available. Council may wish to engage a consultant to undertake this work.

9.4.6. Summary

A number of vegetation management activities have been identified as suitable for the Murrumbidgee River riparian areas through Wagga Wagga, and are detailed in Appendix H. While the vegetation management activities do not significantly improve flood behaviour, if left unchecked it is expected that exotic species are likely to increase in density and thereby increase roughness and hence potentially worsen flood behaviour. Further to the prevention of increased roughness, the VMP notes the ecological value of reducing the density of exotics and removing weeds.

To progress the Vegetation Management Plan, it is recommended that the VMP is updated as new legislative instruments become available, and to then draft Standard Operating Procedures to detail the methods by which the recommended activities are to be safely undertaken in accordance with the requirements of legislation.

Conclusion

Based on the outcomes of the above assessment and consideration of concerns, the following scores have been assigned to Option VMP in the multi-criteria assessment. Note that community acceptance scores have been updated based on feedback received during the Public Exhibition period.

Table 94 Option VMP: Multi-Criteria Assessment Results

Ref	Option	Impact on Flood Behaviour	Impact on Property Damage	Technical Feasibility	Community Acceptance	Economic Merits	Environmental/ Ecological Benefits	Impact on SES	Risk to Life*	Total Score
VMP	Vegetation Management Plan	1	0	3	1	0	3	0	0	8

* A detailed breakdown of the factors contributing to the risk to life score is presented in Table 101.

Vegetation Management: Recommended Activities

☑ Update Vegetation Management Plan based on new legislative instruments.

☑ Develop Standard Operating Procedures for the recommended vegetation management activities, including:

- Targeted Willow Treatment
- Treatment of Weeds in Riparian Areas
- Reduction in Debris
- Reduction in Shrub and Canopy Regeneration Layer Density

Council may wish to engage a consultant to assist with the above recommendations.

9.5. Flood Modification Options Not Considered Further

9.5.1. Temporary Flood Barriers

DESCRIPTION

Temporary flood barriers include demountable defences, wall systems and sandbagging which is deployed before the onset of flooding.

DISCUSSION

Demountable defences can be used to protect large areas and are often used as a means to assist in current mitigation measures rather than as sole protection measures. For example they are best used to fill in gaps in levees or raising them as the risk of levee overtopping develops. The effectiveness of these measures relies on sufficient warning time and the ability of a workforce to install. They are more likely to be used for mainstream fluvial flooding from rivers which have sufficient warning time and are not a suitable technique for overland flooding.

SUMMARY

In Wagga Wagga, demountable defences are not suitable to be used to reduce flood risk and inundation of dwellings, due to the lack of suitable locations for their placement and insufficient available warning time. They may be used Oura or Gumly Gumly to temporarily provide flood free access by preventing roads being overtopped. It should be noted that temporary flood barriers are proposed to be used across numerous roadways in the upgraded CBD levee.

9.5.2. Retarding/Detention Basins

Retarding basins are often used in developing catchments. These measures are appropriate for use in controlling flooding in small catchments, to retard flow in the upstream reaches of large catchments, or to mitigate the effects of increased runoff caused by development. Retarding basins store runoff temporarily and then release it at a reduced rate. Although they do not reduce the total volume of runoff significantly, they do reduce the rate at which runoff occurs, thus reducing downstream flood levels. They also typically include a spillway on the embankment wall, which is a slightly lower section that allows controlled overtopping if the basin capacity is exceeded. Retarding basins are sometimes used in conjunction with large scale development to allow for communal mitigation of increases to runoff. They can also be used in general urban drainage systems for example, some Councils use playing fields for retention of flows during flood events.

Retarding basins are used to treat much smaller flow rates than that experienced in Wagga Wagga due to riverine flooding. Generally speaking, a very large retarding basin may be able to mitigate a flow in the order of 100 m^3/s. As the 1% AEP peak flow in Wagga Wagga is over 5,000 m^3/s, this makes them not applicable to the Study Area.

9.5.3. Flood Mitigation Dams

Dams and reservoirs are capable of providing flood mitigation by detaining and retarding discharge on the upper part of a catchment. As with retarding basins, a dam located upstream of an area may be able to capture some or all of the runoff volume in a flood event, significantly reducing the peak discharge downstream. The ability of the dam to reduce the downstream flooding depends on the available storage volume in the dam prior to the event occurring, as well as its outlet structures and their ability to pass or retain large volumes of runoff. In turn, the available storage is highly dependent on the dam's primary purpose. For example, a dam used for water supply purposes will retain as much runoff as possible during each year, which may mean the dam is full when a flood occurs.

Some dams and weirs upstream of Wagga Wagga have secondary uses as flood mitigation dams, including Burrinjuck, Blowering and Tantangara in the Snowy Mountains. These dams' primary use is for water supply and flood mitigation is only sometimes possible. If a flood-producing rainfall occurs when one of the dams is full, it will pass the full flow to the downstream area, and not reduce the flood peak. The variability of possible flood-producing rainfall events and the very large catchment area mean there is little certainty about what effect the dams will have in future flood events.

The magnitude of the volume of floodwaters generated by the catchment means that it is impossible to significantly reduce the peak flood flows, even with the construction of major dams listed above. The construction of a dam for flood mitigation purposes at Wagga Wagga is not appropriate for the scale of flood risk. Furthermore, the reliability of dams used for flood mitigation is less than that of other mitigation works or measures. To maximise the reduction in flood peak, the dam must always have a large part of its storage reserved for potential inflows, which requires constant discharge of inflows and is at odds with the other dam uses (i.e. water supply). There are also often significant environmental impacts which cannot be justified given the scale of risk.

9.6. Property Modification Measures

Property modification measures refer to the modifications to existing development such as the voluntary raising of floor levels or voluntary purchase of a dwelling for the purpose of reducing or removing flood risk. Flood proofing can also be considered as a method to reduce flood damages to existing and future development. This section discusses the use of these measures to reduce flood risk to residential properties within the Study Area.

Property modification also refers to development controls on property and community infrastructure for future development. Section 9.7 assesses changes to development controls and planning policies to ensure that future development is compatible with the flood risk, does not endanger its occupants and does not adversely impact other properties in the floodplain.

9.6.1. Option PR1: Voluntary House Raising and Voluntary House Purchase Scheme in the Study Area

INTRODUCTION

A Voluntary House Raising and Voluntary Purchase Scheme for the entire Study Area has been suggested for consideration as a potential alternative to upgrading the levee around North Wagga. This scheme would be available to a wider region of the floodplain, and provide residents inside and outside North Wagga an opportunity to reduce their flood risk. Where appropriate, residents would be able to choose to raise their house to (or above) the Flood Planning Level (1% AEP + 0.5m, described in Section 9.7.1.2), or, to sell the dwelling to Council, who would demolish the dwelling and rezone the lot to prevent future development. The following section provides a high-level overview of the benefits and concerns of this scheme, however ultimately recommends that a detailed feasibility study be undertaken to determine if the scheme would be possible in the Study Area and if eligible residents would participate. It should be noted that this scheme would only apply to residential development due to constraints on funding availability.

Note that participation in this scheme would be completely optional for property owners, with no obligation to proceed.

DESCRIPTION

Voluntary house raising has been widely used throughout NSW to eliminate or significantly reduce flooding over habitable floors particularly in lower hazard areas of the floodplain, albeit in limited overall numbers. Voluntary house raising (VHR) seeks to reduce the frequency of exposure to flood damage of the house and its contents by raising an existing dwelling above the FPL, and accordingly reduce the frequency of household disruption and associated trauma and anxiety. House raising is most suitable for non-brick single storey buildings on piers, however the addition of a second story to houses that cannot be raised would also be suitable, as long as the ground level were not used as a habitable area. For some types of dwellings, a Voluntary Purchase Scheme could be more appropriate (see below).

VHR is typically eligible for funding based on eligibility criteria set out in the OEH Guidelines for Voluntary House Raising Schemes (Reference 20), however this guideline notes that houses in high hazard areas are not eligible, as the overarching goal is to completely remove residents from high hazard areas. The proposed scheme is therefore a special case, as it acknowledges the unlikelihood of removing all dwellings and is proposed as an alternative to a situation where residents would remain in high hazard floodway areas. Furthermore, by raising such dwellings above the FPL, the scheme would provide a greater reduction in damages than a levee around North Wagga with a 5% AEP level of protection. For redevelopment of dwellings, planning controls relating to minimum floor level requirements will negate the need for future raising of properties. Such controls are described in Section 9.7.4.1.

Voluntary Purchase (VP) Schemes are a long-term option to remove residential properties from hazardous areas. VP gives residents the option to sell their house to Council, which would then demolish the dwelling and place a restriction on the lot to prevent dwellings being built there in the future. This is a potential option for residents in high hazard areas whose dwellings cannot be raised or would prefer to move out of the area, and will be subject to a range of criteria. Removal of properties not only removes people from high hazard areas, but restores the natural hydraulic capacity of the floodplain, the storage volume and waterway area. Government funding for voluntary purchase schemes is typically made available for properties that comply with funding criteria outlined in Reference 21, however as this VHR & VP Scheme is a special case, properties that do not meet all the criteria will not necessarily be excluded from the Scheme. The eligibility criteria would be determined through the feasibility study process.

Wagga Wagga has a successful history of using Voluntary Purchase to remove a number of dwellings in the late 1980s-90s, especially from the North Wagga Village. Upwards of $50,000 in funding (from Federal and State Government as well as Council) was granted to purchase several dwellings and reduce the risk to life and improve the hydraulic conveyance of the North Wagga region. This has resulted in a number of policies in North Wagga, in particular limiting the number of dwellings. The LEP and these Council policies would require updating if this Scheme is implemented.

DISCUSSION

The VHR & VP Scheme is intended to be investigated as an alternative to upgrading the North Wagga Levee to a 5% AEP level of protection (Option L4(B), Section 9.3.3.5). This section raises some of the key benefits and concerns associated with this scheme, noting that some concerns of Option L4(B) would be resolved through the VHR & VP Scheme.

Benefit: Reduced Frequency of Inundation

The key benefit of the Scheme is that raised houses will be inundated less frequently, significantly reducing property damages. While Option L4(B) would offer protection to a 5% AEP level, VHR would raises houses well above the 1% AEP level. Statistically, the probability of experiencing at least one 5% AEP event in a lifetime (70 year period) is 97%, and experiencing at least two 5% AEP events in a 70 year period is 86.4%. Conversely, the

probability of experiencing at least one 1% AEP event is only 50.3%, and the probability of experiencing at least two is 15.6% (Table K1, Reference 1). Voluntary house raising would significantly reduce the incidences of inundation dwellings would be subject to, and hence better reduce the associated trauma and recovery period from property damage following flood events.

Benefit: Improved Flood Behaviour

Another major benefit of VHR is that there would be significantly less upstream impact on flood levels and behaviour than that of a levee. As discussed in Section 9.3.3.5, raising the North Wagga Levee to 5% AEP causes a number of properties upstream of the proposed levee (and some properties inside) to experience worsened flood behaviour, and even more so if the proposed excavation beneath Wilks Park Bridge is not completed. VHR & VP does not involve the construction of a new obstruction in the floodway, and conversely can actually reduce blockage in the floodway if ground floor levels are opened/ houses are converted to pier/ stilt construction. This would be further improved if works to minimise the impact of the North Wagga levee are undertaken in conjunction this option. The benefits of the removal or opening of the North Wagga Levee are discussed in Sections 9.3.3.7 and 9.3.3.8, respectively. Voluntary Purchase would remove dwellings from high hazard areas, creating localised reductions in flood levels where obstructions are removed, supported by policy changes which would ensure redevelopment and subsequent obstruction cannot occur.

Benefit: Flood Protection without the visual impact of a levee

Residents of the Wagga Floodplain and North Wagga with consistent viewing opportunities (i.e. from dwellings), or whose interest is specifically focussed on the landscape, are likely to have a higher sensitivity to visual impacts, such as earthen embankments or concrete-wall levees. The scale or magnitude of visual effects is related to the short viewing distance (i.e. view blocked by a levee), scale of the change in the view (current levee raised up to 1 m to reach the 5% AEP level of protection (Option L4B)) and introduction of elements which are uncharacteristic to the existing landscape features. The importance of visual impact should be considered as one of the social issues investigated in the proposed feasibility study, as the VHR & VP Scheme would not impose the same changes in visual amenity as a levee would. Various architects are currently working to improve the visual amenity of houses that have been raised to avoid flooding, with one example focusing specifically in heritage areas in Maitland (Reference 30).

Benefit: Community Acceptance and Social Issues

Consultation with the FRMAC and community during the Public Exhibition period indicated that a VHR & VP Scheme would be welcomed by residents, as it would provide a higher degree of flood risk reduction as property damages would be prevented in events up to and including the 1% AEP event, compared to the 5% AEP in Option L4B. The other major advantage is that the option to raise or sell a dwelling could be taken up by a broader range of residents both inside and outside the North Wagga area, improving the perception of equity for all floodplain residents and offering a greater overall reduction in property damages. Some residents needed assurance that the program would be *voluntary*, as their initial impressions

were that the scheme would be imposed upon them by Council. This is not the case, and has highlighted the importance of community education and clear communication needed to ensure residents fully understand the option. Appendix M contains specific feedback from the public exhibition period relating to the Voluntary House Raising and Voluntary Purchase Schemes.

Benefit: House Valuation

The OEH Guideline for voluntary purchase sets out how a VP scheme should be undertaken and how properties should be valued. Valuations are to assume there are no flood related development constraints applied to the property. The aim of this is to allow those who take up voluntary purchase to be able to buy a similar property in a location not subject to flood risk, acknowledging that flood risk and subsequent flood related constraints may have an impact on property value.

Excerpt from OEH guideline:

"The council should obtain a valuation in accordance with the Valuer General requirements to provide a range that is considered fair and equitable in relation to market value. This provides a basis for determining the maximum value that is eligible for subsidy. The valuation should assume no VP scheme is in place, consider the requirements for minimum floor levels due to flooding, but disregard any flood-related development constraints that may apply on that land due to its flood hazard. The valuation should be undertaken by a registered land and house valuer." – NSW OEH Guideline for Voluntary Purchase (Reference 21).

Concern: Time to Implement and Funding Process

Typically, VHR & VP Schemes are implemented over a long period, sometimes decades, as funding is limited and eligible properties across the state are competing for the same funding pool. In Lockhart for example, VP is occurring at a rate of one property per year. However, by entering into a combined VHR & VP Scheme as a standalone project, the Scheme may be eligible for funding via a different channel, which would lead to a much more efficient process that could occur over a reduced time period. In the proposed Scheme, a pool of funding could be made available to all eligible properties within the Study Area, and actioning VP or VHR for these properties would be ranked only against each other (not all dwellings in the state), prioritised on flood risk and depth of inundation. The criteria for prioritisation would be determined as part of the proposed feasibility study.

The FRMAC discussed the possibility of linking the Scheme to the dwelling itself, so that if the property were to change hands during the project timeframe, new owners would have the opportunity to take up the scheme. This arrangement would require investigation during the feasibility study.

Concern: Construction Practicality

House raising would be typically limited to residential dwellings able to be lifted from their footings onto taller piers, which excludes any houses of slab-on-ground construction. This VHR & VP Scheme would also include an alternative option to construct a second story on top of the existing dwelling, and convert the first story to a non-habitable area. While this does not remove the floodway obstruction as traditional VHR would, it still raises possessions above the FPL and reduces the frequency of flood damage. The proposed feasibility study should include an audit of all houses in the Flood Planning Area and determine criteria for eligibility for raising, then identify the number of eligible properties. For houses not eligible, voluntary purchase may be considered as a preferred alternative option. Whilst construction practicality is a key concern, the VHR & VP Scheme would not face the same issues relating to land and easement acquisition that an increased levee footprint (for example Option L4B) would require.

Concern: Accessibility for Residents

House raising schemes generally fund installation of front and back door steps and associated safety rails, however ageing residents or those with health and/or mobility issues may prefer not to live upstairs. Views pertaining to this issue should be canvassed during the feasibility study, along with potential solutions such as the installation of elevators or stair-chair lifts and the appetite for overcoming this difficulty. It is noted however that as new families move into the area there may be a future appetite for participation in the voluntary house raising program, and if not, voluntary purchase may be a preferred alternative.

Concern: Community Appreciation of Residual Flood Risk and Evacuation Orders

A greater degree of in-home safety may be perceived by residents whose floor levels are above the FPL, however due to the duration of flooding, and isolation from medical and other services, evacuation of the North Wagga and Floodplain areas would still be necessary. Successful evacuation requires sufficient warning time, prepared residents and ample assistance for those less mobile, such as the aged residents. Raising houses above the FPL is intended to reduce property damages, not reduce risk to life, which would remain high for these areas. Public consultation and education is required to ensure this is well understood by residents. Compared to living behind a high levee however, residents may have a better view of the river and approaching floodwaters, and as a result have a greater awareness of impending evacuation requirements.

Conclusion

Based on the outcomes of the above assessment and consideration of concerns, the following scores have been assigned to Option PR1 in the multi-criteria assessment. Note that community acceptance scores have been updated based on feedback received during the Public Exhibition period. See Table 100 for the scoring of Voluntary House Raising and Voluntary Purchase separately.

Table 95 Option PR1: Multi-Criteria Assessment Results

Ref	Option	Impact on Flood Behaviour	Impact on Property Damage	Technical Feasibility	Community Acceptance	Economic Merits	Environmental/ Ecological Benefits	Impact on SES	Risk to Life*	Total Score
PR1	Combined Voluntary House Raising and Voluntary Purchase Scheme	3	3	-2	2	0	2	1	2	11

* A detailed breakdown of the factors contributing to the risk to life score is presented in Table 101.

RECOMMENDATION

It is recommended that Wagga Wagga City Council undertake a feasibility study to investigate the application of a Voluntary House Raising and Voluntary Purchase (VHR & VP) Scheme in the Wagga Wagga Study Area defined in this report (See Figure 1). This feasibility study is to be undertaken in conjunction with Option L4(B) with a view to determine which of the two options is a) feasible and b) if both are feasible, which option is more viable in terms of reducing flood risk exposure in Wagga Wagga.

The VHR & VP Scheme Feasibility Study should investigate a broad range of issues including, but not limited to the above discussion points and the following items:

Table 96 Key items to be investigated in the proposed Feasibility Study

Social	Construction & Implementation
• Appetite for Scheme/ likelihood of participation; • Preference for levee option L4B instead; • Expectations of residents; • Number of properties eligible; • Prioritisation of eligible dwellings; • Visual impact concerns.	• Procurement of local materials/ contractors; • Types of dwellings eligible for raising; • Method of raising – piers/ second story; • Interim accommodation or assistance to residents during house raising.
Financial	**Other**
• Costs to raise a house; • Retrospective subsidy available for those who have already raised their houses above the FPL; • Co-contribution from OEH, Council, residents; • Time & resources for planning and assessment; • Benefits/ Property Damage reduction.	• Flood immunity of key access routes and if road upgrades should be considered; • Community education regarding responsibility to evacuate; • Rules for appropriate use of ground floor (if not pier construction); • Overall timeframe of scheme and future participation; • Consideration of participation by subsequent property owners; • Residual flood risk and dangers of sheltering in place instead of evacuating (isolation, long duration of inundation

SUMMARY

There is a large number of dwellings in the Wagga Wagga Study Area subject to high hazard flood conditions. A combined Voluntary House Raising and Voluntary Purchase scheme would, over time, either raise dwellings above the FPL or remove eligible dwellings from the area to remove residents from high hazard areas, thereby reducing instances of over-floor flooding and hence damages. The Scheme could be an alternative to Option L4B, which involves a feasibility study to assess upgrading the North Wagga Levee to the 5% AEP Level with associated access upgrade, and the two feasibility studies should be undertaken in conjunction to determine if both options are feasible, and if so, which is more viable for reducing flood risk exposure in Wagga Wagga.

9.6.2. Option PR2: Flood Proofing

DESCRIPTION

Flood proofing is often divided into two categories; wet proofing and dry proofing. Wet proofing assumes that water will enter a building and aims to minimise damages and/or reduce recovery times by choice of materials which are resistant to flood waters and facilitates drainage and ventilation after flooding. Dry proofing aims to totally exclude flood waters from entering a building and is best incorporated into a structure at the construction phase.

Temporary flood barrier measures such as sandbagging and flood barriers can be a cheaper option than retrofitting to existing properties and can be useful in areas where there is frequent shallow flooding. Sandbagging, often used in conjunction with plastic sheeting, can provide a buffer for dealing with flooding in smaller areas and at individual properties. Whilst sandbags and plastic sheeting seldom prevent the ingress of floodwaters entirely, they can substantially decrease the depth of over floor flooding and decrease foulness of floodwaters, thus aiding the clean-up process. This is particularly useful at sites outside of town where contamination from leaked septic tanks can be an issue.

DISCUSSION

Flood proofing requirements are typically more suited to commercial properties, though there are some examples of residential application particularly for wet proofing. Retro fitting permanent flood proofing measures can be difficult and permanent flood proofing is best achieved during construction. Temporary flood proofing can be achieved during flooding although relies on someone to put up flood gates or similar and therefore effective flood warning times and the time of flooding can affect their efficiency.

Floor levels of new buildings, both residential and commercial, can be controlled by Council's DCP. New commercial buildings can alternatively be required to be flood proofed to the Flood Planning Level (FPL) when constructed which would include consideration of suitable materials, electrical and other services installation and efficient sealing of any possible entrances for water. Council would make these requirements through the DCP. It is recommended that planning controls allow some flexibility for either dry or wet flood proofing

to be used, and for temporary flood gate options to also be included in building design for low risk non-habitable development. This has been discussed further in Section 9.7.4.1.

SUMMARY

Permanent flood proofing is a good solution to reducing flood risk to commercial and industrial properties and should be encouraged for all new development of this type, particularly where floor levels may be low. Consideration of appropriate construction materials is still needed for those residential developments where floor levels will be raised above the 1% AEP flood level but structures can still become inundated below the floor level. This could be implemented using appropriate development controls as described in Section 9.7.4.1.

Temporary flood proofing techniques may be deployed although warning time and available resources (especially labour) is essential to their effectiveness. They should be considered as a secondary option to more permanent measures being implemented.

Property Modification Recommendations

☑ **Voluntary House Raising & Voluntary Purchase:** A feasibility study should be conducted to investigate a VHR & VP Scheme for residential dwellings within the Study Area, to be undertaken in conjunction with the Option L4(B) feasibility study to determine if the options are practical, and if so, which option is more viable in terms of reducing flood risk exposure in Wagga Wagga. At a minimum, the feasibility study should investigate concerns listed in Table 96.

☑ **Flood Proofing**
Flood proofing of commercial properties can reduce damages significantly. Refer to Section 9.7.4.1. for discussion of the ways in which planning controls may be used to implement flood proofing for new development.

9.7. Planning and Future Development Control Measures

Appropriate planning restrictions which ensure that development is compatible with flood risk can significantly reduce flood damages. Planning instruments can be used as tools to:

- Reduce risk to life;
- Reduce damage to the proposed development itself; and
- Reduce damage to the broader floodplain and existing development.

In this section, 'development' is as defined in the Environmental Planning Assessment Act 1979, and includes buildings of all types, infrastructure, levees, roads, etc. The Floodplain Development Manual (Reference 1) describes the following types of development:

- **Infill development:** refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land.
- **New development:** refers to development of a completely different nature to that associated with the former land use. E.g. the urban subdivision of an area previously used for rural purposes. New developments typically require extensions of existing urban services such as roads, water supply, sewerage and electricity.
- **Redevelopment:** refers to rebuilding in an area. E.g. as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require major extensions to urban services.

This section contains recommendations that require amendments to the following Council Policies in order to reduce risk to the aspects listed above, as well as a general recommendation to improve the usability of the current control policies:

- Wagga Wagga LEP 2010
- Land Use Planning
- Flood Planning Levels
- Flood Planning Area
- Wagga Wagga DCP 2010

Two workshops were held with Council planners (2nd June 2017, 20th June 2017). Council has expressed concern with a number of aspects regarding these documents, such as:

- The current DCP is long and cumbersome which makes it difficult to interpret and apply for both planners and developers;
- The clauses are not explicitly controls, and are therefore difficult to apply. Explicit controls would be preferable to conditions or aims;
- There is concern regarding development of critical facilities between the FPA and PMF especially once the Wagga CBD levee is upgraded; and
- Important mapping is missing from the LEP which prevents planners from accessing the region breakdown map.

The proposed amendments in the following section seek to address these gaps and make the planning and assessment process easier and more efficient.

9.7.1. Definitions

9.7.1.1. Critical Facilities

Critical facilities are those properties that, if flooded, would result in severe consequences to public health and safety. Critical facilities in a town might include fire, ambulance and police stations, hospitals and nursing homes, schools and childcare centres, water and electricity supply installations, interstate highways, bus stations and chemical plants. Various controls may be used to ensure these facilities have a reduced flood risk, for example by being located above the PMF level. Other controls may include requiring critical infrastructure such as generators are located above the PMF level, or that facilities must have closure policies that are triggered when flood warnings are issued.

9.7.1.2. Flood Planning Level

DESCRIPTION

Flood Planning Levels (FPLs) are an important tool in floodplain risk management. Appendix K of the Floodplain Development Manual (the Manual, Reference 1) provides a comprehensive guide to the purpose and determination of FPLs. The FPL is derived from a combination of a flood event and a freeboard and can provide a development control measure for managing future flood risk and setting minimum levels for floodplain mitigation works. This section discusses FPLs for development planning purposes only, however it should be noted that different amounts of freeboard are usually appropriate for mitigation works such as levees.

The Manual states that, in general, the FPL for a standard residential development would be the 1% AEP event plus a freeboard which is typically 0.5 m.

The purpose of the freeboard is to provide reasonable certainty that the reduced flood risk exposure provided by selection of a particular flood as the basis of an FPL, is actually provided given the following factors:

- Uncertainty in estimating flood levels;
- Differences in water level because of local factors;
- Increases due to wave action, and
- The cumulative effect of subsequent infill development.

Typically, the FPL is used to define the minimum level at which habitable or commercial/industrial floor levels should be constructed, or to which permanent flood proofing of industrial and commercial buildings should be undertaken (As discussed in Section 9.7.4.1).

DISCUSSION

Depending on the nature of the development and the level of flood risk, individual FPLs can be adopted for a local area within a greater floodplain area and varied based on either the design flood event selected or the choice of freeboard. For example in areas prone only to shallow overland flow flooding and not riverine flooding, application of the 0.5 m freeboard can be excessive. Selecting the appropriate FPL for a particular floodplain involves trading off the social and economic benefits of a reduction in the frequency, inconvenience, damage and risk to life caused by flooding against the social, economic and environmental costs of restricting land use in flood prone areas and of implementing management measures.

The FPL can also be varied depending on the land use, and the vulnerability of the building/development to flooding. For example, residential development could be considered more vulnerable due to people being present, whilst commercial development could be considered less vulnerable, or it could be accepted that policies and controls are more effectively applied at commercial properties. For developments more vulnerable to flooding (hospitals, schools, electricity sub-stations, seniors housing and the like), the FPL can be varied based on the selection of the design flood event. Ideally, consideration should be given to events rarer than the 1% AEP when determining their FPL and either consider the PMF or situating those developments outside the floodplain where possible. In situations where this may be inconsistent with other strategies, other controls can be used to support flood risk minimisation.

SUMMARY

The FPL should be used to set finished floor level requirements for residential development. Less vulnerable uses such as industrial and commercial developments could be subject to lower floor level requirements (such as 5% AEP + 0.5 m) but it is recommended that they should be subject to flood proofing to the FPL where floor levels are lower. An FPL of 1% AEP plus 0.5 m is considered appropriate for such developments in Wagga Wagga, based on the results of modelling presented in this report. More vulnerable developments and critical infrastructure should be subject to more stringent requirements if possible.

9.7.1.3. Flood Planning Area

The Flood Planning Area (FPA) is an area to which flood planning controls are applied. A FPA map is a required outcome of the FRMS&P and is recommended to be included in the DCP rather than the LEP for reasons discussed in Section 9.7.2.1.

Typically, and as per the Manual, the FPA will be based on the flood extent formed by the 1% AEP mainstream flooding event plus 0.5 m freeboard, and therefore, extend further than the extent of the 1% AEP event. Planning controls may, therefore, be applied to development which is not flooded in a 1% AEP event.

The FPA as defined by the Manual (1% AEP plus typically 0.5 m freeboard) is suitable for areas of mainstream flooding. Revisions have been made to the flood modelling of the Murrumbidgee River at Wagga Wagga as part of this FRMS which require the FPA map to be revised. The changes are discussed in greater detail in Section 4.3 and involve several revisions to Wagga Wagga's official and unofficial levees, most notably the upgrade of the CBD Levee to a 1% AEP level of protection.

This section recommends that Council updates the FPA based on modelling results from this FRMS. The FPA has been provided in Figure 18 for post-levee upgrade conditions for riverine flooding only. The Major Overland Flow FPA will be defined by the MOFFRMS (project underway at the time of writing) for those catchment areas. There will be some overlap in the riverine and overland flow FPAs and both should be used as appropriate.

9.7.2. General Changes to Planning Policy Structure

9.7.2.1. Option PL1: Move Flood Planning Area mapping into the Wagga Wagga DCP, whilst retaining the definition of the Flood Planning Area and Flood Planning Level in the LEP

Council addresses development in the Flood Planning Area (defined in Section 9.7.1.3) in Clause 7.2 of LEP 2010 which applies to:

(a) land that is shown as Flood Planning Area on the Flood Planning Map, and
(b) other land at or below the flood planning level.

It is becoming increasingly common for flood maps to be excluded from LEPs, largely because any modification to flood mapping contained within an LEP requires the preparation of a Planning Proposal. This is a time consuming (12-18 months) and often inappropriate way to control development of land affected by flooding, especially as flood mapping is updated periodically with the completion of studies and revision studies.

In order to remedy this situation, it is recommended that LEP 2010 be amended to reflect current thinking with regard to flood mapping and that Clause 7.2 of LEP 2010 be modified to remove reference to the Flood Planning Area Map and replace it with reference to land at or below the Flood Planning Level, that is a definition of the flood planning area. This also allows for any variation in the flood planning level for other catchments in the LGA, such as those subject to major overland flow. This approach will allow significantly more flexibility to the planning of development in flood affected areas.

It is also recommended that Council include a definition of Flood Planning Level in the Dictionary to LEP 2010 as follows:

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.*

9.7.2.2. Option PL2: Adoption of matrix-style Development Control Plan

A Development Control Plan (DCP) is a document that supports the requirements of the LEP and provides a guide for development. Chapter 4.2 of the Wagga Wagga DCP 2010 provides guidance in relation to the development of flood liable land. Regardless of the support for changes to Clause 7.2 of LEP 2010 discussed in Section 9.7.2.1, it is necessary to amend Section 4.2 of DCP 2010.

One clear and concise method of providing information on development controls to those seeking to develop flood affected land is to provide a matrix. The advantage of using a matrix is that all controls are contained in a central location and there is no requirement to comprehend a lengthy and often confusing document. It is proposed that Wagga Wagga restructure its existing DCP for Flooding Risk by having controls that vary depending on:

- The sensitivity of a land use to flooding;
- Severity of flood hazard at the site (H1-H6 as defined in Section 5.4); and
- Hydraulic category at the site (Floodway, Flood Storage or Flood Fringe as defined in Section 5.3.

It is considered that these factors are sufficient in determining relevant controls, and that having individual control policies for each 'flood risk precinct' (floodplain community) as is currently used, may lead to confusion (regarding uncertainty of precinct delineations), duplication of controls and an overly long and cumbersome document. Using the above filters (land use, flood hazard and hydraulic category classification) is what differentiates the proposed matrix from that adopted out of the 2009 report, which relied on not explicitly defined 'flood risk precincts' to establish applicable development controls.

The steps required to use the proposed DCP structure would be based on those in other LGAs, and are set out below:

Step 1: Identify the Flood Hazard Category: This pertains to the location of the proposed development site, and the hazard classification at that site as determined in this Study. The hazard categories are H1 – H6 as shown on Figure 14 and defined in Table 97. Corresponding GIS layers are provided to Council in this Study for this purpose.

Table 97 Flood Hazard Categories

Category	Constraint to people/vehicles
H1	*No restrictions*
H2	Unsafe for small vehicles
H3	Unsafe for vehicles, children and the elderly
H4	Unsafe for people and vehicles
H5	Unsafe for people and vehicles. Buildings require special engineering design and construction.
H6	Unsafe for people, vehicles or buildings

Step 2: Identify the Land Use Risk Category: This pertains to the proposed use of the land, classified as one of the criteria listed below, and requires defining at the start of the DCP.

Examples of Land Use Risk Categories:

- Critical Uses & Facilities (e.g. Community facility which may provide an important contribution to the notification or evacuation of the community during flood events, or public utilities (power, telecommunications, liquid fuel depots);
- Vulnerable Uses & Facilities (e.g. schools, hospitals or residential care facilities);
- Subdivision;
- Residential;
- Commercial & Industrial;
- Tourist Related Development; and
- Recreation.

Step 3: Identify the Relevant Controls: The format of this step is crucial to ease of interpretation. A matrix style table, for example this excerpt from the Liverpool City Council DCP 2008 (Diagram 18), is recommended:

Diagram 18: Excerpt from Liverpool City Council DCP 2008: Matrix

Flood Risk Category	Land Use Risk Category	Planning Controls							
		Floor Level	Building Components	Structural Soundness	Flood Effects	Car Parking & Driveway Access	Evacuation	Management & Design	Fencing
Low Flood Risk	Critical Uses & Facilities								
	Sensitive Uses & Facilities	12	4	4	2, 4, 5	2, 3, 6, 7, 8	2, 6, 8	4, 5	
	Subdivision				2, 4, 5			1, 6	
	Residential (++)	2, 6	3	3		2, 3, 6, 7, 8	2, 6		
	Commercial & Industrial	2, 6	3	3	2, 4, 5	2, 3, 6, 7, 8	1, 6	2, 3, 5	
	Tourist Related Development	1, 6, 15	3	3	2, 4, 5	2, 3, 6, 7, 8	2, 6	2, 3, 5	
	Recreation & Non-Urban	1, 9, 15	3	3		1, 5, 7, 8	6, 8	2, 3, 5	
	Concessional Development	14	3	3		1, 3, 5, 7, 8, 9	2, 6	2, 3, 5	
Medium Flood Risk	Critical Uses & Facilities								
	Sensitive Uses & Facilities								
	Subdivision				1, 4, 5			1	1, 2, 3
	Residential	2, 6, 15	3	1	2, 4, 5	2, 3, 6, 7, 8	2, 6		1, 2, 3
	Commercial & Industrial	2, 6, 15	3	1	2, 4, 5	2, 3, 6, 7, 8	1, 6	2, 3, 5	1, 2, 3
	Tourist Related Development	1, 6, 15	3	1	2, 4, 5	2, 3, 6, 7, 8	2, 6	2, 3, 5	1, 2, 3
	Recreation & Non-Urban	1, 9, 15	3	1	2, 4, 5	1, 5, 7, 8	6, 8	2, 3, 5	1, 2, 3
	Concessional Development	1, 14, 15	3	1	2, 4, 5	1, 3, 5, 7, 8, 9	2, 8	2, 3, 5	1, 2, 3
High Flood Risk	Critical Uses & Facilities								
	Sensitive Uses & Facilities								
	Subdivision								
	Residential								
	Commercial & Industrial								
	Tourist Related Development								
	Recreation & Non-Urban	1, 9, 15	3	1	1, 4, 5	1, 5, 7, 8	6, 8	2, 3, 5	1, 2, 3
	Concessional Development	1, 14, 15	3	1	1, 4, 5	1, 3, 5, 7, 8, 9	2, 6	2, 3, 5	1, 2, 3

Key:

Not Relevant

Unsuitable Land Use

1, 2, 3 — Control reference number relevant to the particular planning consideration. (see Table 6)

(++) Attached dwellings, Dwelling houses, dual occupancies, multi unit dwelling housing, residential flat buildings (not including development for the purpose of group homes or seniors housing), Secondary dwellings and Semi-detached dwellings are exempt from these controls.

Note: Hydraulic hazard and categorisations would be used in place of 'Flood Risk' in the above example.

Step 4: Explanation of Development Controls: It is proposed that Wagga Wagga City Council consolidates its existing controls, and rephrase any 'conditions' as controls as required for ease of reference. An example of the Explanation of Development Controls is shown in Diagram 19.

Diagram 19 Excerpt from Liverpool DCP 2008

Table 6 Explanation of Development Controls

Ref No	Controls
Floor level	
1	All floor levels to be as high as practical but not less than the 20% AEP flood level.
2	Non habitable floor levels to be as high as practical but no less than the 5% AEP flood level.
3	Non-habitable floor levels to be not less than the 1% AEP flood.
4	The level of Non-habitable and general Industrial floor areas to be as high as practical but not less than the 2% AEP flood. Where this is impractical for single lot developments within an existing developed area, the floor shall be as high as practical but no less than the 5% AEP flood.
5	Habitable floor levels to be equal to or greater than the 1% AEP flood level plus 300mm freeboard.
6	Habitable floor levels to be equal to or greater than the 1% AEP flood level plus 500mm freeboard.
7	Habitable floor levels to be no lower than the 1% AEP flood plus 500mm freeboard unless justified by site specific assessment.
8	Habitable and general commercial floor levels to be as high as practical but no lower than the 1% AEP flood plus 500mm freeboard unless justified by site specific assessment.
9	The level of habitable floor areas to be equal to or greater than the 1% AEP flood level plus 500mm freeboard. If this level is impractical a lower floor level may be considered provided the floor level is as high as possible but no less than the 5% AEP flood level.
10	All floor levels to be equal to or greater than the 1% AEP flood level plus 300mm freeboard. Freeboard may be reduced if justified by site specific assessment.
11	All floor levels to be no lower than the 1% AEP flood plus 500mm freeboard. Freeboard may be reduced if justified by site specific assessment.
12	All floor levels to be equal to or greater than the PMF level. If this level is impractical a lower floor level may be considered provided the floor level is as high as possible but no less than the 1% AEP flood level plus 500mm freeboard.

Wording of controls is important as they form the basis of decisions for permitting or rejecting development proposals within the LGA. Poorly worded or vague clauses can be challenged by a proponent and cause general confusion for both developers and the Council staff trying to assess development applications. Review of Wagga Wagga City Council's current Development Control Plan found that it contains phrases that are intended to be controls, but are in fact worded as 'objectives' or 'conditions', which cannot be applied to individual development applications nor defended legally.

Furthermore, the LEP is a statutory document, while the DCP is not. Provisions in the DCP therefore may be more likely to be subject to pressure from developers and will need to be phrased so as to withstand being challenged. The restructuring of the DCP into a matrix format provides the ideal opportunity for Council to review the existing controls and reword any that are not appropriate.

9.7.3. Controls to Reduce Risk to Life

Council's various control policies can act to reduce flood risk to human life. Subsequent sections examine controls that reduce risk to property and the damages associated with flooding. The exact phrasing of controls will be determined by Councils during revision of the DCP, however the intent of this section is to describe types of controls that will endeavour to achieve the objectives set out below.

9.7.3.1. Option PL3: Controlling Critical and Vulnerable Land Uses between the FPA and PMF

Further to the clause revision recommended in Section 9.7.2.1, it is imperative that the Council also consider modifying the LEP to impose controls for certain land uses located between the Flood Planning Area and the Probable Maximum Flood. This would allow Council to apply appropriate controls to critical facilities and sensitive land uses within the PMF extent, that would otherwise not be subject to flood related development controls as they fall outside the FPA. According to the Manual (Section A6.1, Reference 1) critical facilities might include fire, ambulance and police stations, water and electricity supply installations, interstate highways, bus/train stations and chemical plants, while 'vulnerable land uses' refer to those with vulnerable occupants such as hospitals, nursing homes or schools.

Following completion of the CBD levee upgrade, the FPA will not include land protected by the levee. The proposed FPA is shown in Figure 18. This means the large area behind the levee will not be subject to flood related development controls set out in the DCP under the current LEP clauses, however will still be subject to flood risk in events greater than the 1% AEP event. By modifying the LEP to control critical facilities and vulnerable uses in this zone, Council will have a way of ensuring such developments consider their flood risk and address it appropriately.

9.7.3.2. Option PL4: Requirement for Site Specific Flood Emergency Plans

The safety of employees or residents in buildings in high hazard areas can be improved by having a site specific flood emergency plan. This is a document that would be required to be provided to Council with submission of a Development Application. The Flood Emergency Plan could include the following, for example:

- Relevant ground and flood levels of the site relative to the local gauge;
- Preparation: Moving stock to higher shelves/ floors when flood warning is received;
- Business Closure: If appropriate, businesses could close in event of flood to reduce number of persons on site; and
- Evacuation Plan: Identifying safe access routes and time required for occupants/employees to safely leave the premises well before roads are overtopped.

Council already has a number of 'conditions' to address evacuation requirements for a range of development types. The specific evacuation needs for particular types of development such as aged, disabled and child care facilities, mobile homes and caravan parks, isolated houses, schools, hospitals and community centres must be considered by Council. Amending the LEP to include a provision for developments between the FPA and PMF (See Section 9.7.3.1) will allow Council to enforce the requirement of site specific emergency management and evacuation plans from critical facilities and vulnerable land uses outside of the FPA.

The NSW SES provides resources to assist business owners to develop their own flood plans and improve their flood awareness and preparedness. Resources are available on the NSW SES FloodSafe website (http://www.floodsafe.com.au). This website has a range of useful information regarding floods, including tools to help households and businesses develop a Home Emergency Plan and Business FloodSafe Toolkit, NSW SES Local Flood Plans and other information on how NSW SES plans for floods.

It should be noted however that the NSW SES is opposed to the use of private evacuation plans as a condition of development consent. The NSW SES does not have the statutory authority to endorse private Evacuation Plans nor does it have the resources to review and comment on private plans written at the individual development level.

9.7.3.3. Option PL5: Inclusion of Flood Risk Information on s149 (2) & (5) Planning Certificates

Section 149 Planning Certificates are issued in accordance with the Environmental Planning & Assessment Act 1979. They contain information on how a property may be used and the restrictions on development that apply. A person may request a 149 certificate at any time to obtain information about his or her own property, but generally a 149 certificate will be requested when a property is to be redeveloped or sold. When land is bought or sold the Conveyancing Act 1919 requires that a Section 149 Planning Certificate be attached to the Contract for Sale.

Schedule 4 of the Environmental Planning and Assessment Regulations 2000 gives requirement for inclusions on s149 Planning Certificates under Section 149(2) of the Act. In particular Schedule 4, Clause 7A refers to flood related development control information and requires that Council include whether or not development on the land or part of the land is subject to flood related development controls.

Section 149 (5) provides for a more detailed Planning Certificate and could for instance include "notes" on flood risk such as whether the property is above or below the FPL, details of other events including the PMF, percentage of lot affected, potential flood heights and hazard categories. Where only parts of lots are flood affected the 149 Planning Certificate may notify either the percentage area of a lot that is affected and/or only include lots that are 15% affected or greater.

Currently Council provides information related to flood related development controls on 149(2) Planning Certificates for properties within the FPA as defined in the recent Flood Study (Reference 2). This is based on a FPL of the 1% AEP flood level + 0.5 m freeboard, the extent of which will change significantly based on updated model results which includes the upgraded CBD Levee, as described in Section 9.7.4.1 of this report. The Section 149 (5) currently does not provide additional details related to flooding.

More sophisticated data and mapping produced in this study will assist in the dissemination of accurate and site-specific information to the community. A GIS based map can provide useful information to a property owner and simplify the identification of issues by a Council staff member. Section 17.2 and 17.3 of Appendix I to the FDM (Reference 1) detail typical examples of information for inclusion in 149 certificates, and include the following:

- Whether the land is within the FPA and flood related development controls apply, (149(2));
- Design flood levels/depths specific to the property for the 1% AEP, 5% AEP and PMF events, (149(5));
- Percentages of lots affected by the FPA if not 100%, (149(5));
- Likelihood of flooding and mechanism (riverine/ overland flow/ both) (149(5));
- Flood hazard (149(5));
- Hydraulic categorisation (e.g. floodway) (149(5));
- Evacuation routes/ constraints (149(5)); and
- Associated Mapping for the above items (149(5)).

The more informed a home owner is, the greater the understanding of their flood risk. During a flood event, having this understanding may help prepare residents for evacuation and reduce the number of residents that elect to shelter in place in high hazard areas, which can increase pressure on the SES if they are isolated or their homes inundated. This can support flood response strategies detailed in Section 9.8.

Land owners will be required to be notified of changes to both the 149 (2) and 149 (5) Planning Certificates. Land owners can be concerned as to how a notification may impact on their property value or insurance, for example. The Insurance Council of Australia provides detailed fact sheets on how flood information is used for insurance pricing. This should be taken into account when developing a consultation strategy for notification of any changes related to s149 Planning Certificates.

9.7.4. Controls to Reduce Risk to Proposed Development

9.7.4.1. Option PL6: Controls to set Minimum Floor Levels

The main tool that Council has for ensuring proposed development is protected from flood risk is by controlling the floor level using the FPL. The FPL for residential development in Wagga Wagga is set at the 1% AEP Level + 0.5 m freeboard (described in Section 9.7.1.2) and is based on the updated modelling results from this Study. The FPA refers to land within the floodplain that is at or below the FPL. Lots within this area are subject to flood related development controls contained within Wagga Wagga DCP 2010.

Depending on the type of development, different minimum floor levels may be appropriate. Some common examples used by other LGAs, as applied to areas of high flood hazard, include:

- Residential (habitable floor levels): 1% AEP + 0.5 m
- Commercial development: 5% AEP + 0.5 m
- Utilities/ Critical Facilities: PMF Level

A similar approach could be adopted for other land use types, with appropriate levels as determined by Council. According to the Floodplain Development Manual (Reference 1, Section K2). Higher FPLs may be necessary for aged care facilities and other types of developments with particular evacuation or emergency response issues (discussed in Reference 1, Section L6). Consideration should also be given to using the PMF as the FPL when siting and developing emergency response facilities such as police stations, hospitals, SES headquarters, and critical infrastructure, such as major telephone exchanges, if possible.

It is recommended that Council evaluate their current floor level controls and ensure they are worded appropriately as they are converted to the matrix DCP format.

9.7.4.2. Option PL7: Controls to set Minimum Flood Proofing Levels

The DCP can also be used to impose flood proofing restrictions on non-residential development to reduce flood damages. For example it may be unrealistic to require a warehouse to be built above the residential FPL, whereas damages and inconvenience due to flooding could be significantly reduced if it were flood proofed appropriately. Flood proofing, as described in Section 9.6.2 can either totally prevent water from entering a building, or ensure that the building can tolerate being wetted by flood waters. The former, ‘dry proofing’ can be more expensive and involve the installation of flood gates or sand-bagging in the event of a flood. The latter could simply be having a hard floor rather than carpet, and power points installed above the higher flood planning level. The option of dry or wet proofing should be available as the type of stock held on the premises will vary in its sensitivity to water ingress.

9.7.4.1. Option PL8: Controls to ensure appropriate building design and materials

New performance requirements for buildings in flood hazard areas were introduced in the National Construction Code (NCC) in 2013 with The Australian Building Codes Board (ABCB)'s 'Construction of Buildings in Flood Hazard Areas' and the accompanying Handbook (References 22 and 23). This Standard contains requirements to ensure new buildings and structures, located in flood hazard areas do not collapse during a flood when subjected to flood actions and includes consideration of appropriate construction, use of appropriate materials, electrical, plumbing and drainage installation as well as setting floor levels. It applies to residential buildings (Classes 1, 2, 3 and 4) and health care buildings (Classes 9a and 9c). The Standard is not intended to override any land use planning controls imposed by Council or the appropriate authority, but to support them in managing flood risk.

9.7.5. Controls to Reduce Risk to the Wider Floodplain

A key objective of all flood related control policies is to avoid significant adverse impacts, including cumulative impacts, on flood behaviour, flood risk and the environment. The environment includes existing development as well as all elements of the natural environment including vegetation and animal habitats. The following sections describe the ways in which Council can use the DCP to achieve these objectives.

9.7.5.1. Option PL9: Controls to manage off-site impacts: Flood Impact Assessment

Council's policies can act to manage off-site impacts on a local scale by requiring all proposed developments in appropriate areas, for example the floodway or H5 and H6 hazard zones, to provide a 'flood impact assessment' (FIA). An FIA involves modelling the proposed works and comparing the results to the 'base case'. Generally, the base case is the design flood modelling presented in this report.

A key principle of the Floodplain Development Manual (Reference 1) is to reduce flood risk across the floodplain into the future by prohibiting development in the floodway. However, with the broad extent of the floodway in Wagga Wagga, it is acknowledged that some development will occur with replacement of existing dwellings or works to support agricultural activities. In these cases, a proponent may be required to prove their development will not have adverse impacts elsewhere in the floodplain via provision of a flood impact assessment. In order to determine appropriate thresholds at which flood impact assessments should be required, the effect of cumulative development should be considered. Cumulative development in the floodplain has been examined as part of this Study, and examines the possible impact of broad scale development, that is, construction of individual buildings or works (i.e. fill) on a large number of lots within the floodway. While the impact of an individual development may be minor, if every lot in the region also constructed something similar, the combined impact would be much more substantial.

Requirement of a flood impact assessment could be triggered by proposed footprint size limits. The limits would be set by Council based on modelled cumulative development scenarios that consider future residential, commercial and primary production land uses.

To establish appropriate limits on development size before triggering the requirement of a flood impact assessment, future development scenarios were modelled for residential, commercial and primary production land uses.

9.7.5.2. Option PL10: Controls to manage off-site impacts: Appropriate Dwelling Design

Without prohibiting development, one of the most effective means of ensuring a new development does not impact on existing properties is to ensure the new dwelling is designed appropriately. The following considerations can contribute to managing offsite flood impacts, and may have added benefits of reducing flood damages or hazard to the occupants of the proposed dwelling:

- Relocate the dwelling to a lower hazard location within the lot if possible;
- Have an equivalent or smaller footprint size as the original dwelling, and if not, assess flood impacts via a flood impact assessment (See Section 9.7.5.1);
- Be oriented with the longest side in the direction of the flow path; and
- Have open fencing/ lattice/ piers to allow flow conveyance beneath the property, and ensure the lowest floor level is raised above the FPL.

Similar control measures are currently in place in rural towns subject to riverine flooding. The controls also serve to reduce the long-term flood risk of a region, as houses are rebuilt the property damages are reduced as the susceptibility to over-floor inundation is reduced.

9.7.6. Summary of Proposed Changes and Clauses

Section 9.7 of this report contains a number of recommendations for the restructuring of Council's current development control documents (LEP and DCP), and the improvement of the controls contained within them. These recommendations are summarised below. Also note that changes to the LEP will require a Planning Proposal.

Planning and Development Controls: Recommended Amendments and Inclusions

General changes to policy structure (applies to LEP and DCP):

☑
- Move Flood Planning Area mapping into the Wagga Wagga DCP, whilst retaining the definition of the Flood Planning Area and Flood Planning Level in the Wagga Wagga LEP;
- Restructure DCP as a matrix for ease of interpretation;
- Ensure all controls are phrased as controls, not conditions or objectives.

Controls to Reduce Risk to Life (applies to LEP, DCP and s149 Planning Certificates)

☑
- Control critical facilities and vulnerable land uses between the FPA and PMF extent;
- Require site specific emergency flood plans
- Provide greater detail on flood risk in s149(2) and s149(5) Planning Certificates

Controls to Reduce Risk to Proposed Development (applies to DCP)

☑
- Control minimum floor level requirements
- Control minimum flood proofing level requirements
- Ensure appropriate building design and construction materials

Controls to Reduce Risk to Wider Floodplain (applies to DCP)

☑
- Controls to manage flood impacts
- Controls requiring appropriate building design to minimise flood impacts

9.8. Response Modification Measures

Response modification measures aim to reduce risk to life and property in the event of flooding, through improvements to flood prediction and warning, improvements to emergency management capabilities and planning, and through better flood-educated communities.

9.8.1. Option RE1: Flood Warning System

DESCRIPTION

The purpose of a flood warning is to provide advice on impending flooding so people can take action to minimise its negative impacts. An effective flood warning system requires integration of a number of components (Reference 10):

- modelling and monitoring of rainfall and river flows that may lead to flooding;
- prediction of flood severity and the time of onset of particular levels of flooding;
- interpretation of the prediction to determine the likely flood impacts on the community;
- construction of warning messages describing what is happening and will happen, the expected impact and what actions should be taken;
- dissemination of warning messages;
- response to the warnings by the agencies involved and community members; and
- review of the warning system after flood events.

Where effective flood warnings are provided, risk to life and property can be significantly reduced. Studies have shown that flood warning systems generally have high B/C ratios if sufficient warning time is provided and if the population at risk is aware of the threat and prepared to respond appropriately.

The forecasting responsibility for floods at Wagga Wagga is the statutory responsibility of the Bureau of Meteorology (BOM). BOM issues Flood Watch and Flood Warning products, not Council or NSW SES. Any improvements to current warning products is to be undertaken by BOM itself, in conjunction with NSW SES and Council.

DISCUSSION

A number of aspects indicate a successful or quality flood warning including:

- comparison of predicted peak to the observed peak height;
- target warning lead times for minor, moderate and major are achieved; and
- the wording of the messages.

A review of the operations of the flood warning system at Wagga Wagga for the December 2010 and March 2012 floods has been conducted and is included in Section 5.9.4. The review highlighted that while predictions at Wagga Wagga have been within the acceptable range of +/- 0.3m that there is a range of actions and consequences at the upper end of that scale and improvements would be warranted. In addition, improvements in information applicability and consistency are required.

Discussions with the Bureau of Meteorology indicate that there have been significant advances in flood forecasting since 2012. Implementation of the Bureau's next-generation Hydrological Forecasting System (HyFS) provides access to a suite of rainfall models to better understand potential scenarios. In time the Bureau may introduce probabilities into its public flood warning product to better quantify hydrological uncertainty. This should assist the SES in its decision-making in relation to evacuations. Another improvement since 2012 is the closer association between meteorologists and hydrologists during floods.

Discussions with the SES and Council indicate that there is some room for improvement in the delivery of flood warnings and evacuation warnings/orders. This includes:

- Better engagement of the media, including consistent messages from the emergency services and countering of false information;
- Multi-platform delivery of messages to the public including through social media, SMS and Apps such as EWN (Early Warning Network);
- The use of graphics in Evacuation Orders;
- Delivery of messages by known, trusted persons;
- Ongoing community engagement – the SES attributes good compliance with the Evacuation Order for North Wagga in March 2012 partly to community engagement following the December 2010 flood.

Oura Progress Association also requested a local water level sensor that could send alarms to the RFS Captain. The Eringoarrah gauge is located on the Murrumbidgee River upstream of the Tarcutta Creek junction, so is not an ideal location for alerting Oura. Being located about 27 km (by river) downstream of Oura, the main Wagga Wagga gauge is also not ideal, even though the Wagga Wagga Flood Intelligence Card includes some information for Oura.

The NSW SES have recommended investigating the use of "DipStik" or similar to provide early water level alerts. DipStik is an independent flood level monitoring and alert device. Communities can set up each DipStik unit to send flood alert information back to key stakeholders, such as the NSW SES and Council. For example, if a trigger point reaches a set water height, DipStik will send warning messages to recipients within minutes. Each unit runs on solar power, allowing DipStik to track water levels at all times and in all conditions as it does not rely on an external power source. The units can also have flashing lights and be used to alert motorists to water over roads.

At the time of writing, the NRMA was trialling DipStik at six flood prone locations throughout NSW as part of their commitment to help communities understand natural disaster risks.

SUMMARY

Flood warning is a vital component of Wagga Wagga's flood risk management strategy, since it is sufficiently far downstream that adequate time is typically available for the evacuation of people and property in advance of the flood's arrival. This review has indicated that while there is general satisfaction with the flood warning system, the March 2012 flood demonstrated room for improvement.

Flood Warning Recommendations

- ☑ Continue to enhance the accuracy and timeliness of flood predictions for Wagga Wagga (Bureau of Meteorology)
- ☑ Update the flood forecasting chapter of the Wagga Wagga Flood Operations Manual to incorporate floods since 2010 (Council/SES)
- ☑ Develop and refine a communications plan to ensure coordinated, multi-pronged approach to delivering accurate and persuasive messages during flooding (SES/Council)
- ☑ Consider installing a local water level recorder (e.g. "DipStik") at Oura that issues alarms to Council and NSW SES personnel when pre-determined level reached (Council/SES)

9.8.2. Option RE2: Flood Emergency Management Planning

DESCRIPTION

Effective planning for emergency response is a vital way of reducing risks to life and property, particularly for infrequent floods that are not controlled by flood mitigation works or the risk of which is not fully managed through property modification measures including land use planning.

The NSW State Emergency Service (SES) is the legislated combat agency for floods in NSW and is responsible for the control of flood operations. This role is undergirded by detailed flood planning. The SES maintains the Wagga Wagga Local Flood Plan (Reference 13) and a Flood Intelligence Card for the Wagga Wagga gauge (Reference 14). These planning documents are reviewed in Section 5.9.5, and the appropriateness of the minor/moderate/major flood classifications is reassessed.

Council also plays a key role in emergency response and has a Flood Operations Manual (Reference 15) including a detailed Flood Emergency Plan listing actions to be undertaken or consequences at 0.1m intervals, such as closing floodgates.

A number of other aspects of flood emergency management planning are also considered in this section, including suggestions from the community.

DISCUSSION

Wagga Wagga Local Flood Plan

Wagga Wagga Local Flood Plan (LFP) is a Sub-Plan of Wagga Wagga Local Disaster Plan and is dated January 2006. As required under Clause 2.1.1 of the LFP, the LFP is in need of a review, given the lessons learned from flood operations over the last 10 years, new flood investigations (assessing mainstream Murrumbidgee River flooding, flooding of its tributaries at Tarcutta, Ladysmith and Uranquinty, as well as local overland flows) and new floodplain exposures. The LFP also needs to be reworked to match the new NSW SES LFP template. At the time of writing, this document was being reviewed by the SES for the purpose of enhancing relevance and ease of use.

The LFP will also require revision if and when any flood mitigation works such as levee raising are implemented.

Comments on the current (2006) LFP are included in Appendix I.

Wagga Wagga Flood Intelligence Card

A flood intelligence card (FIC) for the gauge located at Hampden Bridge (410001) was only recently updated (September 2015). Nonetheless, its contents have been inspected and some changes are recommended (see Appendix I). Intelligence in relation to levee crest levels and design flood heights needs to be verified against the latest flood modelling. The current North Wagga levee, for example, is overtopped at about 9.7m on the Wagga Wagga gauge, not 9.9m as currently stipulated in the FIC. Care needs to be taken to replace intelligence from superseded sources. The WMAwater reports pre-dating 2014 have all been superseded. Also, where historic flood heights are listed, these should be linked to a date and consequences.

The FIC will also require revision if and when any flood mitigation works such as levee raising are implemented.

Review of flood categories for Wagga Wagga gauge

Current flood categories for the Wagga Wagga gauge are set out in Table 24. These are used for flood warnings, with different target warning lead times required for each category (Table 22). Given the community's familiarity with these categories, and the existing use of these categories in the Local Flood Plan, Flood Intelligence Card, State Flood Plan and Service Level Specifications, deciding to change the flood categories would not be straightforward and should not be undertaken unnecessarily.

The 'minor', 'moderate' and 'major' classifications have been found to be reasonable and justified. Consideration could be given to adding a fourth category, recognising the 'extreme' consequences that would occur if the main Wagga levee was overtopped. It is noted that the Flood Intelligence Card does list levee operating levels (though one needs to be corrected). But given the different intensity of consequences with different magnitudes of flooding above the major flood level, there would be advantage in having separate flood categories that adopted language such as 'extreme' and 'catastrophic' to capture this.

If and when any flood mitigation works such as levee raising are implemented, the major category (and any categories implemented for higher floods) could be reassessed.

Wagga Wagga City Council Flood Operations Manual

Council's Flood Operations Manual (Reference 15) collates Council's accumulated wisdom of managing flood events. It is a vital means for retaining and disseminating flood knowledge through the organisation. However, apart from the chapter on flood forecasting, it has not been updated since 1993, and it is likely that considerable knowledge over that time has not been preserved for posterity. It is recommended that the Flood Operations Manual be reviewed, updated and regularly maintained as a high priority. This may require formal knowledge transfer from recently retired staff.

The Flood Emergency Plan incorporated into the Flood Operations Manual looks particularly valuable, but could make clear whether the actions such as closing flood gates are actions to be commenced at the stipulated gauge height or must be concluded by that height.

Private Flood Emergency Response Plans

As well as updating their own flood plans, there would be benefit in SES and Council encouraging and helping key floodplain exposures to prepare and update their own flood emergency response plans. The process of preparing plans would in itself be an important process of raising awareness and preparedness, and could be linked to a Business FloodSafe breakfast. SES has developed an online residential and commercial private flood plan template which can be used to implement this option.

Oura Village Local Evacuation Centre

An important lesson from the 2012 flood was the need for Oura village to have access to a public building above the flood level serving as both a local emergency operations centre and as a local evacuation centre (Table 23). At the time of writing, Oura Progress Association has purchased the disused Presbyterian Church located at the corner of Adams and Alfred Streets, with the intention to renovate so that it may be used for this purpose. Flood modelling suggests that this building is located just beyond and above the PMF extent, and is relatively central for the village, making it an appropriate location. Jarvis Street and Adams Street would require upgrade (or at least sealing) to be trafficable to reach the evacuation centre. The SES has delivered a "Flood Cache" to Oura to be stored at the evacuation centre, containing sandbags, shovels, jigs etc.

Other Operational Issues

The community has made a number of other suggestions for improved management of future flood operations (Table 23), which mainly relate to the NSW SES.

After floodwater has receded from roads, businesses in East Wagga would like more timely reopening of closed roads so they can resume business activity as soon as possible.

Residents of North Wagga outside the levees feel that more common-sense approaches are required, recognising the greater building resilience (e.g. higher ground and floor levels) of many homesteads when compared to those within the levee such that, for most floods, isolated residents should not be subject to mandatory Evacuation Orders. Also, pass-outs could be issued to allow isolated residents who go to town for supplies or work to return to their homes. Recognising that both of these suggestions places a greater burden on the SES to maintain the comings and goings of residents and to activate rescues for those who chose to stay at isolated property and later wish to be evacuated. Residents' concerns about security could be met if the Police had access to boats and regularly patrolled the flooded area.

Residents of North Wagga inside the levees would welcome earlier announcements of Evacuation Warnings and Orders than was provided in March 2012, recognising that elevating or relocating property off the floodplain can take a considerable time. Also, better intelligence of the protection afforded by the levees along Hampden Avenue might provide more time for relocation of this property. It would also help if Council could make available an area to store relocated furniture etc.

SUMMARY

Planning for flooding is a vital way of reducing flood risks to life and property. The Wagga Wagga Local Flood Plan, Flood Intelligence Card for the Wagga Wagga gauge and Council's Flood Operations Manual all need to be reviewed, updated and maintained to incorporate information from recent floods and flood investigations. Best practice teaches that better results are achieved if individual floodplain exposures also prepare tailored flood emergency plans.

Flood Emergency Management Planning Recommendations

- ☑ Review and update Wagga Wagga Local Flood Plan, drawing on flood intelligence from recent floods and latest modelling, and with significant input from each community to prepare realistic sector evacuation plans (refer Appendix I) (SES)
- ☑ Confirm integrity and maintenance arrangements for unofficial levees along North Wagga evacuation route, since this may influence evacuation trigger for North Wagga, potentially allowing residents more time to relocate property and provide findings to the SES (WWCC)
- ☑ Review and update Wagga Wagga Flood Intelligence Card, drawing on flood intelligence from recent floods and latest modelling (refer Appendix I) (SES)
- ☑ Review and update Flood Operations Manual, drawing on flood intelligence from recent floods and latest modelling (WWCC)
- ☑ Assist key floodplain exposures to prepare tailored individual flood emergency plans (SES and WWCC)
- ☑ Assist Oura Progress Association to refurbish the Presbyterian Church building located above the PMF for use as an emergency operations and evacuation centre (WWCC)
- ☑ Upgrade Adams Street and Jarvis Street to allow access to the evacuation centre during flood events (WWCC)
- ☑ Consider the other suggestions put forward by community members for improved flood operation management (refer Table 23) (SES and WWCC)

9.8.3. Option RE3: Community Flood Education

DESCRIPTION

Actual flood damages can be reduced, and safety increased, where communities are flood-ready:

> *'People who understand the environmental threats they face and have considered how they will manage them when they arise will cope better than people who lack such comprehension… Many people who live and work in flood liable areas have little idea of what flooding could mean to them – especially in the case of large floods of severities well beyond their experience or if a long period has elapsed since flooding last occurred. It falls to the combat agency, with assistance from councils and other agencies, to raise the level of flood consciousness and to ensure that people are made ready for flooding. In other words, flood-ready communities must be purposefully created. Once created, their flood-readiness must be purposefully maintained and enhanced.'* (Reference 16)

Based on lessons from recent disasters, the focus of community disaster education has now turned from a concentration on raising awareness and preparedness to building community resilience through learning. Simply disseminating information to the community does not necessarily trigger changed attitudes and behaviours. Flood education programs are most effective when they:

- Are participatory i.e. not consisting only of top-down provision of information but where the community has input to the development, implementation and evaluation of education activities;
- Involve a range of learning styles including experiential learning (e.g. field trips, flood commemorations), information provision (e.g. via pamphlets, DVDs, the media), collaborative group learning (e.g. scenario role plays with community groups) and community discourse (e.g. forums, post-event de-briefs);
- Are aligned with structural and other non-structural methods used in floodplain risk management and with emergency management measures such as operations and planning; and
- Are ongoing programs rather than one-off, unintegrated 'campaigns', with activities varied for the learner.

In NSW, the NSW State Emergency Service (SES) is responsible for public dissemination of information relating to floods (State Emergency Service Act 1989 (NSW)).

It is difficult to accurately assess the benefits of a community flood education program but the consensus is that the benefits far outweigh the costs. Nevertheless, sponsors must appreciate that ongoing funding rather than one-off program funding is required to sustain gains that have been made.

DISCUSSION

After a 19-year period from 1991 without major or moderate Murrumbidgee River floods, and not even a minor flood between 1996 and 2010 (Diagram 1), the December 2010 event put flooding back on Wagga Wagga's agenda. It also gave the SES an opportunity for practising evacuation. But as a 'near miss' in many areas, consultation with communities including Oura and North Wagga (inside the levee) indicates that it caused some complacency in the March 2012 event, when people failed to prepare as well as they had previously and suffered higher losses than they might otherwise have done. The March 2012 flood would have raised awareness of the flood threat throughout the city, but might have reinforced perceptions of safety for those protected by the CBD Levee. Consultation since the 2012 flood (Section 6), ongoing coverage of the assessments of flood mitigation works, and minor flooding in September and October 2016 would have maintained flooding as a prominent local issue. The challenge for the SES and Council will come when there is another prolonged period without floods, especially for communities protected by levees (probably even higher levees than are currently in place) who may incorrectly assume they are protected from all floods.

Table 98 provides a list of potential methods to build and sustain flood readiness, which may be developed and supported by the SES and Council. These include methods both to inform and to prepare the community, with the objective of building resilience.

Table 98: Methods to Increase Flood Awareness and Preparedness

Method	Comment
S149 certificate notifications	Section 149 planning certificates should record whether the land is subject to any planning and development controls due to its flood affectation. Council also has opportunity to provide more detailed information about the land's flood affectation under S149(5) of the EP&A Act 1979. This information may be particularly valued by prospective purchasers but has a limited reach and is typically issued only upon request and payment of a fee.
Letter/certificate/ pamphlet from Council	These may be sent annually with a rates' notice or separately. A Council database of flood liable properties makes this a relatively inexpensive and effective measure. Although some community members have indicated objection to receiving the additional information with rates notices, which increases the costs to Council. The intention of flood certificates is to inform individual property owners of the flood situation (flood levels, ground levels) at their particular property. It is the site-specific nature of this advice that offers a chance of overcoming the scepticism typical of a community that has not experienced serious flooding for some years. The use of detailed mapping outputs from this study and relating levels to real events can assist in developing an understanding of the flood risk. Only after floodplain occupants accept that they could have a problem are they ready to take on board ideas about addressing that problem. A pamphlet can inform residents of the on-going implementation of the Floodplain Risk Management Plan and provide tips to respond appropriately to flooding (e.g. evacuate early; never drive, ride or walk through floodwater).

Method	Comment
Council website	Wagga Wagga City Council already provides extensive flood information on its website. This includes information about flood services, flood management studies, flood history, flood modelling, levee banks, flood recovery and what to do in the event of flooding. Nonetheless, there may be opportunity to enhance its coverage and to streamline the presentation of the content.
School project	School students can learn about historical floods by interviewing older residents and documenting what happened. A project could also involve talks from various authorities (e.g. SES) and can be combined with topics relating to water quality, drainage management, etc.
Articles in local newspapers	Ongoing articles in the *Daily Advertiser* and other newspapers will help to ensure that the flood issues are not forgotten. Historical features and remembrance of past events are interesting for local residents (e.g. see www.dailyadvertiser.com.au/story/1583702/gallery-historic-wagga-floods/). These should include the March 2012 flood as a prominent recent flood.
Library/museum display	The library collected flood stories in its oral history project following the March 2012 flood. These could be joined with flood photos to prepare a visual display, which could be accompanied by appropriate flood safety messages.
Mobile display	Such a display as described above could also be used at local festivals and for school visitations, accompanied by SES staff, who should be trained to encourage and equip households to prepare flood emergency plans.
Guided walking tour	Wagga Wagga has a rich flood history and could develop a guided walking tour to describe flood stories and mitigation, similar to the walk developed for Maitland.
NSW SES FloodSafe Guide	FloodSafe guides were prepared previously for Wagga and North Wagga. But these are dated 2004 and do not incorporate flood intelligence from the recent floods or the latest flood modelling. When the choice of levee options has been confirmed, production of revised FloodSafe guides for these communities could be prepared.
NSW SES Business FloodSafe Breakfast	The SES has recently revised its FloodSafe Business template, which businesses can use to plan for flooding. A breakfast barbeque could be convened in East Wagga to promote completion of plans, to provide site-specific flood information, and to provide the business community an opportunity to directly provide feedback to the SES on flood operations.
Community outreach	The study area contains distinct communities with particular flood risks including Oura, Gumly, East Wagga, North Wagga and Wagga CBD. These communities prefer direct, targeted and two-way outreach at local meetings. As the 'dust' settles from the March 2012 flood, flood investigations and subsequent flood mitigation works, it will be important to continue to work with communities to encourage flood preparedness and train for flood responses. The SES has a community engagement officer who is already working in this capacity. Local meetings could also encourage property owners to develop self-help networks. Longer-term residents with flood experience could be used to help provide newer residents with an understanding of previous floods and how to prepare for future flooding.

Method	Comment
Historical flood markers and flood depth markers	Signs or marks can be prominently displayed on telegraph poles or similar to indicate the level reached in historical and design floods. The height reached by the 1974 flood is indicated on several signs around the Wagga floodplain. An historic flood marker was installed in the Hampden Bridge Amphitheatre on the anniversary of the 2012 flood.

In addition to the methods employed to build and sustain community readiness, careful consideration is required for the messages. In particular, the construction or raising of levees presents a challenge for floodplain managers, since communities will on average be less exposed to direct flooding and may reach the conclusion that they do not need to evacuate or take steps to protect property. Complacent attitudes need to be gently targeted, such as through these messages:

- A levee does not keep out all floods, and one day a bigger flood will come;
- Levees do overtop (e.g. Nyngan 1990; North Wagga 2012; Lismore 2017);
- Flood prediction is not an exact science;
- Freeboard cannot be relied upon for evacuation decisions (in March 2012, the Wagga CBD community found it difficult to understand why evacuation was based on a design levee height that did not include the freeboard);
- Don't gamble your family's life;
- Isolation can be:
    - stressful: are you prepared to be surrounded by water for days?;
    - uncomfortable: electricity and sewerage services may be compromised, snakes and vermin may be driven into your house;
    - unsafe: you may not have access to fire or health services.

Also, people in NSW continue to drown when they enter floodwater. The September-October 2016 floods in western NSW saw the SES mount a sustained and varied campaign to target this behaviour, using a range of messages including 'Never drive, ride, walk or play in floodwater', 'If it's flooded, forget it' and 'Turn around, don't drown'.

SUMMARY

Although recent flood events and the flood risk management process have raised community flood awareness, if and when a decade-long period without floods returns, this heightened awareness is expected to wane. The proposed raising of levees may exacerbate the 'protected' community's complacency. Ongoing flood education will be required to build and maintain flood resilience and to prepare the community for larger and faster-rising floods than it has previously experienced. Strategies should be coupled with those for major overland flow areas.

Council will need to develop a program from the above measures after taking into account the views of the local community, funding considerations and other education programs within the LGA. However, for the purposes of this FRMS&P, a range of measures are recommended.

Flood Education Recommendations

- ☑ Engage with community to prepare an ongoing flood education program, with appropriate methods for program evaluation (SES and WWCC)
- ☑ Prepare a library flood photo and story display (WWCC and NSW SES)
- ☑ Commemorate the 10th anniversary of the 2012 flood (SES and WWCC)
- ☑ Update Wagga Wagga and North Wagga FloodSafe guides (SES and WWCC)
- ☑ Host a Business FloodSafe breakfast for East Wagga's businesses (SES and WWCC)
- ☑ Regular community outreach for distinct flood-prone communities (SES and WWCC)
- ☑ Installation of March 2012 flood markers (WWCC)
- ☑ Direct education efforts towards overcoming the complacency that can arise for communities partly protected by levees (eg. American Society of Civil Engineer's 'So You Live Behind a Levee' pamphlet) (SES and WWCC)
- ☑ Direct education efforts towards discouraging people's risk-taking behaviour particularly driving, riding, walking or playing in floodwater (SES and WWCC)

10. MULTI CRITERIA ASSESSMENT

10.1. Background

As described in Section 9.1.2, each flood mitigation option investigated in this report is scored against a range of criteria in order to gain a better picture of the option's feasibility. BC ratios are often relied upon for this decision, and while they do indicate an option's economic viability, they do not reflect the broader range of issues to be considered, including social impacts, technical feasibility and environmental impacts.

The discussion of each criteria and individual scores assigned for each option are included throughout Section 9, and are combined in this section for the purpose of summarising and comparing the assessed options. Note that the planning and response modification options have been excluded from the matrix as these options have clear benefits and can be readily implemented. The main purpose of the matrix is to compare options with varying pros and cons to determine which options should be preferred and investigated further.

The scoring system for the assessment criteria is provided in Table 99. The scores for each criteria are summed, and a resulting positive score indicates that the option has more pros than cons, while a negative score indicates the option has more cons and typically would not be considered viable. Options with higher scores indicate benefits across a range of criteria and should be prioritised over those with lower positive scores, which may be more neutral or have a combination of pros and cons. Conversely, options with the lowest negative scores indicate the option would cause adverse outcomes in a number of criteria and should not be considered further.

Table 99 Matrix Scoring System

	-3	-2	-1	0	1	2	3
Impact on Flood Behaviour	>100mm increase	50 to 100mm increase	<50mm increase	no change	<50mm decrease	50 to 100mm decrease	>100mm decrease
Number of Properties Benefitted	>5 adversely affected	2-5 adversely affected	<2 adversely affected	none	<2	2 to 5	>5
Technical Feasibility	major issues	moderate issues	minor issues	neutral	moderately straight-forward	Straight-forward	no issues
Community Acceptance[1]	majority against	most against	some against	Neutral	minor	Most for, some against	majority
Economic Merits[2]	major disbenefit BC < 0.4	moderate disbenefit BC: 0.4 – 0.7	minor disbenefit BC 0.7 – 1.0	Neutral BC = 1.0	Low BC:1.0-1.3	Medium BC: 1.3 – 1.6	High BC > 1.6
Financial Feasibility	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Environmental and Ecological Benefits	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Impacts on SES[3]	major disbenefit	moderate disbenefit	minor disbenefit	neutral	minor benefit	moderate benefit	major benefit
Risk to Life[4]	major increase	moderate increase	minor increase	neutral	minor benefit	moderate benefit	major benefit

Notes:
[1]Community Acceptance: Scores for community acceptance were allocated based on the written submissions and verbal feedback received during the Public Exhibition period.

The following scores were allocated:

Score	Description of Community Feedback
-3	Overwhelmingly negative response, no support for the option
-2	Largely negative response, but some support for the option
-1	Minor negative responses
0	Balanced positive and negative feedback, or no feedback on the option
1	Minor positive response
2	Largely positive response, but some opposition to the option
3	Overwhelmingly positive response, no opposition to option

[2]Economic Merits: Scores for the economic merit of each option was allocated based on the options cost-benefit (BC) ratio. The following scores were assigned:

Score	BC Ratio
-3	< 0.4
-2	0.4 – 0.7
-1	0.7 - 1
0	1
1	1-1.3
2	1.3-1.6
3	> 1.6

[3]Impacts on SES: The scores were allocated based on if an option would increase or decrease community reliance on, or the demand on the SES. It must be noted that the SES is not an infinite resource, and that the SES volunteers are generally already stretched during flood events in Wagga Wagga. Therefore, any option which increases the demand on the SES is scored negatively in the Multi Criteria Matrix Assessment.

[4] Risk to life is a factor against which flood risk mitigation options are assessed, and relates generally to safety of people. Aspects that may impact the risk to life score include:

- Proximity to highly hazardous flooding (great depths or significant velocity);
- Evacuation time and constraints;
- Ability to self-evacuate over the full range of flood events (i.e. road access);
- Community behaviour;
- Vulnerability of the occupants;
- Population; and
- Period of isolation (and associated health and social risks).

Positive scores indicate that the proposed option will improve these aspects, and vice versa for negative scores. The scoring for these individual factors is shown in Table 101.

The sum of scores in the Risk to Life breakdown assessment (Table 101) is assigned a score in the “Risk to Life” column of the overall multicriteria matrix analysis (Table 100) based on the following ranges:

Risk to Life breakdown Total Score (Table 101)	Assigned Risk to Life Score (Table 100)
>15	6
13 to 15	4
10 to 12	3
5 to 9	2
1 to 4	1
0	0
-1 to -4	-1
-5 to -9	-2
-10 to -12	-3
-13 to -15	-4
< -15	-6

10.2. Results

The assessment matrix is provided in Table 100, with each of the assessed management options scored against the range of criteria. It is important to note that the approach undertaken does not provide an absolute “right” answer as to what should be included in the Management Plan but is rather for the purpose of providing an easy framework for comparing the various options on an issue by issue basis which stakeholders can then use to make a decision. For the same reason, the total score given to each option, and the subsequent rank, is only an indicator to be used for general comparison. Options highlighted in blue have been recommended by the Wagga Wagga Floodplain Risk Managament Advisory Committee for inclusion in the Draft Floodplain Risk Management Plan.

Table 100 Floodplain Risk Mitigation Options: Multi Criteria Assessment Matrix

Ref	Option	Impact on Flood Behaviour	Impact on Property Damage	Technical Feasibility	Community Acceptance	Economic Merits	Environmental/ Ecological Benefits	Impact on SES	Risk to Life*	Total Score
L1	Oura 1% AEP Levee	-1	0	0	1	-2	-1	-1	-2	-6
L2	Gumly Gumly 1% AEP Levee	-2	-2	-2	-1	-3	-1	-2	-4	-17
L3A	1% AEP North Wagga Levee Upgrade	-3	-3	-2	2	3	-1	-3	-6	-13
L3B	1% AEP North Wagga Levee Upgrade with Hampden Ave Embankment	-2	-2	-3	2	1	-2	-2	-3	-11
L3C	1% AEP North Wagga Levee Upgrade with Hampden Ave Overland Bridge	-1	-2	-3	2	-2	-2	-2	-3	-13
L4A	5% AEP North Wagga Levee Upgrade	-1	-2	-2	-1	3	-1	-3	-3	-10
L4B	5% AEP North Wagga Levee Upgrade with Hampden Ave Upgrade and Conveyance Improvements through Wilks Park	1	-1	-3	-1	2	-2	-1	-2	-7
L4C	5% AEP North Wagga Levee Upgrade with Hampden Ave Overland Bridge	2	0	-3	-1	-2	-2	-1	-2	-9
L5	Removal of North Wagga Levee	-3	-3	-2	-2	-3	-2	-2	-2	-19
L6	Opening of North Wagga Levee	-3	-3	-1	-1	-3	-1	-2	-2	-16
A1	Future Option: Increase Conveyance beneath Wiradjuri Bridge	3	1	-3	2	-3	-3	3	1	1
CM1	Malebo Gap Excavation	1	1	-3	1	-3	-3	0	0	-6
CM2	Gobbagombalin Bridge Excavation	1	1	-3	0	-3	-3	0	0	-7
BF1	North Wagga Bypass Floodway	1	1	-3	0	-3	-3	-2	-2	-11
R1	Oura Road Raising	-1	-1	-1	3	0	1	3	2	6
R2	Sturt Hwy Raised (RMS)	2	0	1	3	0	2	3	2	13
VMP	Vegetation Management Plan	1	0	3	1	0	3	0	0	8
PR1 - VHR	Voluntary House Raising Scheme	2	3	-2	1	1	1	-2	-3	1
PR1- VP	Voluntary House Purchase Scheme	3	3	-1	2	-1	2	3	6	17
PR1	Combined Voluntary House Raising and Voluntary Purchase Scheme	3	3	-2	2	0	2	1	2	11

Indicates options recommended in the Draft Floodplain Risk Management Plan

* Detailed breakdown of risk to life scores is provided in subsequent table.

Table 101 Risk to Life: Detailed breakdown of contributing factors

Ref	Option	FERC	Warning Time	Time to Evacuate	Flood Hazard	Community Behaviour and consequences	Population Numbers	Period of Isolation/Inundation	Total Score
L1	Oura 1% AEP Levee	-1	0	1	-1	-2	-1	-1	-5
L2	Gumly Gumly 1% AEP Levee	-3	0	-2	-1	-3	-1	-3	-13
L3A	1% AEP North Wagga Levee Upgrade	-3	0	-2	-3	-3	-2	-3	-16
L3B	1% AEP North Wagga Levee Upgrade with Hampden Ave Embankment	-1	0	1	-3	-2	-2	-3	-10
L3C	1% AEP North Wagga Levee Upgrade with Hampden Ave Overland Bridge	-1	0	1	-3	-2	-2	-3	-10
L4A	5% AEP North Wagga Levee Upgrade	-3	0	-1	-2	-2	-2	-2	-12
L4B	5% AEP North Wagga Levee Upgrade with Hampden Ave Upgrade and Conveyance Improvements through Wilks Park	-2	0	1	-2	-1	-2	-2	-8
L4C	5% AEP North Wagga Levee Upgrade with Hampden Ave Overland Bridge	-2	0	1	-2	-1	-2	-2	-8
L5	Removal of North Wagga Levee	-3	0	-2	-3	1	-2	0	-9
L6	Opening of North Wagga Levee	-3	0	-1	-3	1	-2	-1	-9
A1	Future Option: Increase Conveyance beneath Wiradjuri Bridge	1	0	1	1	0	0	0	3
CM1	Malebo Gap Excavation	0	0	0	0	0	0	0	0
CM2	Gobbagombalin Bridge Excavation	0	0	0	0	0	0	0	0
BF1	North Wagga Bypass Floodway	-1	0	-2	-2	0	0	0	-5
R1	Oura Road Raising	2	0	2	0	0	0	2	6
R2	Sturt Hwy Raised (RMS)	2	0	2	0	0	0	2	6
VMP	Vegetation Management Plan	0	0	0	0	0	0	0	0
PR1 - VHR	Voluntary House Raising	-3	0	0	0	-3	-2	-2	-10
PR1 - VP	Voluntary House Purchase Scheme	3	0	3	3	3	2	3	17
PR1	Combined Voluntary House Raising and Voluntary Purchase Scheme	0	0	3	3	0	0	1	7

Indicates options recommended in the Draft Floodplain Risk Management Plan

11. SUMMARY OF ASSESSED OPTIONS BY FLOODPLAIN COMMUNITY

This section summarises the floodplain risk mitigation options assessed for each floodplain community, and whether or not they are recommended to be pursued further based on the analysis undertaken as part of this FRMS.

Note that vegetation management activities are recommended to be carried out across the study area in accordance with the Vegetation Management Plan provided in Appendix H, and have not been individually noted in the subsequent summary tables. Note also that the Planning Measures, Property Modification Measures and Response Modification Measures considered are consistent across each floodplain community and include:

PROPERTY MODIFICATION MEASURES		Recommended to pursue further (Yes/No)	Ref
PR1	Voluntary House Raising & Voluntary Purchase Scheme	Yes	9.6.1
PR2	Flood Proofing	Yes	9.6.2

PLANNING MEASURES		Recommended to pursue further (Yes/No)	Ref
PL1	Move FPA mapping into the Wagga Wagga DCP whilst retaining the definition of FPA and FPL in the Wagga Wagga LEP	Yes	9.7.2.1
PL2	Reformat DCP to Matrix style document	Yes	9.7.2.2
PL3	Add clause to LEP to control critical facilities and vulnerable land uses between the FPA and PMF extent.	Yes	9.7.3.1
PL4	Requirement of Site Specific Flood Emergency Plans	Yes	9.7.3.2
PL5	Flood Risk Info on s149 Planning Certificates	Yes	9.7.3.3
PL6	Controls to set Minimum Floor Levels	Yes	9.7.4.1
PL7	Controls to set Minimum Flood Proofing Levels	Yes	9.7.4.2
PL8	Controls to ensure appropriate building design and materials	Yes	9.7.4.1
PL9	Controls to manage offsite impacts: Flood Impact Assessment	Yes	9.7.5.1
PL10	Appropriate Dwelling Design	Yes	9.7.5.2

RESPONSE MODIFICATION MEASURES		Recommended to pursue further (Yes/No)	Ref
RE1	Flood Warning System	Yes	9.8.1
RE2	Flood Emergency Management Planning	Yes	9.8.2
RE3	Community Flood Education	Yes	9.8.3

Options Assessed: OURA		Recommended to pursue further (Yes/No)	Ref
L1	Oura Levee – 1% AEP level of protection	No	9.3.1.1
R1	Improve access to Oura via Oura Road (or other route)	Yes	9.3.1.2
PR1	Voluntary House Raising & Voluntary Purchase Scheme	Yes	9.6.1
PR2	Flood Proofing	Yes	9.6.2
PL	All Planning Measures	Yes	9.7
RE	All Response Measures	Yes	9.8

Options Assessed: GUMLY GUMLY		Recommended to pursue further (Yes/No)	Ref
L2	Gumly Levee – 1% AEP level of protection	No	9.3.2.1
R1	Improve access to Gumly Gumly via Sturt Highway (or other route)	Yes	9.3.2.2
PR1	Voluntary House Raising & Voluntary Purchase Scheme	Yes	9.6.1
PR2	Flood Proofing	Yes	9.6.2
PL	All Planning Measures	Yes	9.7
RE	All Response Measures	Yes	9.8

Options Assessed: NORTH WAGGA		Recommended to pursue further (Yes/No)	Ref
L3(A)	Levee Upgrade (1% AEP) Only	No	9.3.3.1
L3(B)	Levee Upgrade (1% AEP) with Hampden Avenue upgraded (as embankment)	No	9.3.3.2
L3(C)	Levee Upgrade (1% AEP) with Hampden Avenue upgraded (as overland bridge)	No	9.3.3.3
L4(A)	Levee Upgrade (5% AEP) Only	No	9.3.3.4
L4(B)	Levee Upgrade (5% AEP) with Hampden Avenue upgraded (as embankment) and conveyance improvements through Wilks Park.	Yes	9.3.3.5
L4(C)	Levee Upgrade (5% AEP) with Hampden Avenue upgraded (as overland bridge)	No	9.3.3.6
L5	Removal of North Wagga Levee	No	9.3.3.7
L6	Opening of North Wagga Levee (lowering spillways to 20% AEP)	No	9.3.3.8
PR	All Property Measures	Yes	9.6
PR1	Voluntary House Raising & Voluntary Purchase Scheme	Yes	9.6.1
PR2	Flood Proofing	Yes	9.6.2
RE	All Response Measures	Yes	9.8

Options Assessed: WEST WAGGA		Recommended to pursue further (Yes/No)	Ref
CM1	Excavation of Malebo Gap	No	9.3.5.1
CM2	Excavation beneath Gobbagombalin Bridge	No	9.3.5.2
PR1	Voluntary House Raising & Voluntary Purchase Scheme	Yes	9.6.1
PR2	Flood Proofing	Yes	9.6.2
PL	All Planning Measures	Yes	9.7
RE	All Response Measures	Yes	9.8

Options Assessed: WAGGA FLOODPLAIN		Recommended to pursue further (Yes/No)	Ref
A1	Increase Conveyance beneath Wiradjuri Bridge	Yes	9.3.4.1
BF1	North Wagga Floodplain Bypass Floodway	No	9.3.4.2
PR1	Voluntary House Raising & Voluntary Purchase Scheme	Yes	9.6.1
PR2	Flood Proofing	Yes	9.6.2
PL	All Planning Measures	Yes	9.7
RE	All Response Measures	Yes	9.8

Options Assessed: WAGGA CBD		Recommended to pursue further (Yes/No)	Ref
PR1	Voluntary House Raising & Voluntary Purchase Scheme	Yes	9.6.1
PR2	Flood Proofing	Yes	9.6.2
PL	All Planning Measures	Yes	9.7
RE	All Response Measures	Yes	9.8

Options Assessed: EAST WAGGA		Recommended to pursue further (Yes/No)	Ref
PR1	Voluntary House Raising & Voluntary Purchase Scheme	Yes	9.6.1
PR2	Flood Proofing	Yes	9.6.2
PL	All Planning Measures	9.7	9.7
RE	All Response Measures	0	9.8

Options Assessed: EUNONY		Recommended to pursue further (Yes/No)	Ref
PR1	Voluntary House Raising & Voluntary Purchase Scheme	Yes	9.6.1
PR2	Flood Proofing	Yes	9.6.2
PL	All Planning Measures	Yes	9.7
RE	All Response Measures	Yes	9.8

12. DRAFT FLOODPLAIN RISK MANAGEMENT PLAN

This Draft Plan summarises the recommended works investigated by the Wagga Wagga Revised Murrumbidgee River Floodplain Risk Management Study. The Study follows on from the Wagga Wagga Detailed Flood Model Revision and (Reference 2) represents an update to the 2009 Floodplain Risk Management Study and Plan (Reference 3). Key updates include the upgrade to the Wagga CBD levee (to the 1% AEP level of protection) and addition of flow paths that could previously not be represented adequately in the 1D model.

Recommended options are prioritised based upon how readily the management measures can be implemented, what constraints exist, and how effective the measures are. Measures with little cost that can readily be implemented and which are effective in reducing damage or personal danger should have high priority.

Table 102 to Table 105 list the mitigation measures assessed by the Wagga Wagga Revised Murrumbidgee River Floodplain Risk Management Study that have been recommended for implementation. The tables describe the purpose of the measure, as well as its priority, cost, timeframe and the party responsible for its implementation. Detailed description of each recommendation is provided in Section 9 of the Study, which also contains measures that were assessed but were not viable for recommendation.

Table 102 Draft Floodplain Risk Management Plan: Flood Modification Options

Reference	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	B/C Ratio	Priority
FLOOD MODIFICATION MEASURES									
L4B*	Feasibility Study to investigate North Wagga Levee Upgrade to 5% AEP level of protection including upgrade to Hampden Avenue to equivalent level (as embankment) and conveyance improvements through Wilks Park. Feasibility study is to be conducted in conjunction with Option PR1 (see below)*.	Undertake a study to further investigate and determine the feasibility of raising the North Wagga Levee to a 5% AEP level of protection, and raising Hampden Avenue to an equivalent level with some excavation of Wilks Park. The feasibility study is to include EIS for the park excavation, geotechnical assessment of existing levee, site-by-site assessment of third party impacts and extensive community consultation.	Moderate reduction in frequency of inundation and property damages in North Wagga and minor benefits upstream due to increased flow conveyance beneath the newly excavated Wilks Bridge.	Significant concerns regarding risk to life of residents inside levee: ongoing education required to ensure residents fully understand the level of protection the levee would offer. Raising the levee has external adverse flood impacts on a number of properties which require further investigation. The upgrade involves additional excavation beneath Wilks Park Bridge which is likely to have associated environmental impacts. Other concerns include the high capital cost and the need for ongoing maintenance.	Council responsible for undertaking feasibility study.	Funding may be available for an 'Investigation, design and/or feasibility study (where required) for works identified in a floodplain risk management plan' (Application made under Stage 3 of funding schedule).	$7.6M (Development) + Ongoing Costs	1.35	High*
A1	Future consideration of increasing conveyance beneath Wiradjuri Bridge by extending span and/or excavating beneath the bridge.	Future Option: use planned upgrades to Wiradjuri Bridge (maintenance/ traffic capacity upgrade etc.) as an opportunity to improve flood conveyance between North and South Wagga.	Increasing flow conveyance reduces flood levels across the floodplain upstream of Wiradjuri Bridge and reduces flood damages in the CBD, Wagga Floodplain and parts of North Wagga.	There may be adverse impacts downstream of the bridge, high capital costs and ongoing maintenance costs. Would have to be undertaken in conjunction with other bridge works.	Council	Not specifically	Estimated at $27M	0.03	Low
R1	Improved Access to Oura	Long term, staged upgrades to raise Oura Road (or other route) above the 1% AEP flood level.	Flood free access east-west across Wagga Wagga to Oura is beneficial not only to residents of Oura but to communities across the Riverina.	This road intersects several major flow paths and would require significant culverts/ bridge sections. Costs would be significant.	Council would be responsible for construction and maintenance.	Not specifically	Not Estimated	N/A	Low
R2	Improved Access to Gumly Gumly	Long term, staged upgrades to raise or divert the Sturt Highway (or other route) above the 1% AEP between East Wagga and Gumly Gumly.	Flood free access east-west across Wagga Wagga to Oura is beneficial not only to residents of Gumly Gumly but to communities across the Riverina.	This road intersects several major flow paths and would require significant culverts/ bridge sections. Costs would be significant. Sturt Highway is owned by RMS.	RMS are responsible for the Sturt Highway, Council are responsible for local roads (e.g. Pioneer Rd)	Not specifically	Not Estimated	N/A	Low
VMP	Update the recently completed Vegetation Management Plan to consider new state biodiversity legislation instruments, then draft Standard Operation Procedures for selected recommended activities.	The recently completed VMP was written in accordance with new biodiversity legislation, however implementation guides and instruments were not available at the time of writing. Following completion, Council is to select recommended activities to progress, and draft Standard Operating Procedures for these items.	Controlled vegetation management ensures that in the long term, vegetation does not roughen the riparian zone excessively, and to protect areas of ecological value (especially habitat for native fauna).	There is a perception that broadscale clearing may occur, however vegetation management activities will be targeted and controlled. Vegetation management will not explicitly reduce flood affectation, however will ensure that over time flood behaviour is not worsened by increased riparian roughness due to increased vegetation density.	Council	Funding may be available for the planning stages, not for ongoing maintenance.	Not Estimated	N/A	High
*Feasibility studies are to be undertaken in conjunction to determine a) if options are feasibile, and if so, b) the preferred of the two options.									

Table 103 Draft Floodplain Risk Management Plan: Response and Property Modification Measures

RESPONSE MODIFICATION MEASURES									
RE1	Improve Flood Warning System	Various measures to continue and improve on Wagga Wagga's existing flood warning systems, both to enhance flood forecasting and dissemination of information to the public, including investigation of "DipStik" to be installed at Oura to provide water level alerts.	Improved warning systems will better increase the accuracy and timeliness of flood predictions and improve the communication methods to deliver accurate and persuasive messages during flooding.	BOM is responsible for issuing Flood Watch and Flood Warnings.	SES and Council in cooperation	OEH Funding Available under 'Projects to improve flood warning'	Minor	High	High
RE2	Flood Emergency Management Planning	Review and update current Council and SES emergency flood response documents, drawing from latest modelling and recent floods.	Improved flood planning reduces flood risk to life and property, assisting residents of flood prone areas better prepare themselves and their property for flooding.	There are a number of documents to be updated and coordinated.	SES and Council in cooperation	Funding may be available.	Moderate initial and ongoing costs.	High	High
RE3	Community Flood Education	Ongoing community engagement is key to maintaining flood awareness, which can wane as time between flood events increases.	A flood aware community is generally better prepared for flooding, more responsive to evacuation orders and more resilient in recovery.	Levee upgrades can cause increased complacency in residents, which needs to be gently targeted with ongoing flood education campaigns.	SES and Council in cooperation	Funding may be available.	Moderate initial and ongoing costs.	High	High
PROPERTY MODIFICATION MEASURES									
PR1	Feasibility study to investigate a Voluntary House Raising & Voluntary Purchase Scheme in Wagga Wagga Study Area. The feasibility study is to be investigated in conjunction with Option L4B*.	Residential properties located outside leveed areas may be eligible for voluntary house raising which aims to reduce property damages to residential dwellings, or voluntary purchase, which aims to remove residents from high hazard areas and prevent future development of the purchased lot. Feasibility study is to include economic appraisal of both options, eligibility criteria for participation, identification of construction constraints and extensive community consultation to determine likely participation rates.	The frequency of overfloor inundation (and hence property damage) is significantly reduced by raising the dwelling above the Flood Planning Level. This option can provide benefits to many dwellings across the floodplain without impacting others. Voluntary purchase reduces the number of residents in high hazard areas and can improve conveyance by removing dwellings and rezoning lots to prevent future development.	Suitability for house raising depends on building footings (slab on ground not appropriate), which may limit participation. Some residents may not want stairs due to health and mobility issues. Economic viability of this scheme would be directly linked with participation rates. Raised houses could encourage residents to 'shelter in place' during floods, however isolation and long durations of floods put them at high risk. Significant ongoing education efforts will be required to ensure any evacuation orders are heeded.	Council in consultation with property owners.	Funding may be available for an 'Investigation, design and/or feasibility study (where required) for works identified in a floodplain risk management plan' (Application made under Stage 3 of funding schedule).	TBD	TBD	High*
*Feasibility studies are to be undertaken in conjunction to determine a) if options are feasibile, and if so, b) the preferred of the two options.									

Table 104 Draft Floodplain Risk Management Plan: Planning Measures (Part 1)

PLANNING MEASURES - Part 1								
Ref	**Option**		**Description**	**Benefits**	**Concerns**	**Responsibility**	**B/C Ratio**	**Priority**
PL1	General Changes	Move Flood Planning Area mapping into the Wagga Wagga DCP, whilst retaining the definition of the Flood Planning Area and Flood Planning Level in the LEP.	A general definition of both FPL and FPA is to remain in LEP, with FPA mapping provided in the DCP for ease of updating following the completion of future studies.	By keeping the FPA mapping in the DCP, Council would not be required to prepare a Planning Proposal each time the FPA map is updated (e.g. with completion of future flood studies).	This amendment to the LEP would require Council to submit a planning proposal.	Council	N/A	High
PL2		Reformat DCP to Matrix style document	The Development Control Plan (DCP) is currently a long, wordy and cumbersome document. Reverting to a matrix style format will make it easier for Council and the public to apply and understand.	Matrix style with controls dependent on hydraulic categorisation and hydraulic hazard will be clearer and simpler to interpret. Controls specific to each precinct are not necessary.	There may be resistance to moving away from precinct-centric controls, however the proposed format would be more equitable and clearer about which controls apply to a proposed development.	Council	N/A	High
PL3	Controls to reduce risk to life	Add clause to LEP to control critical facilities and vulnerable land uses between the FPA and PMF extent.	This clause empowers Council to apply appropriate flood related controls to critical facilities and vulnerable land uses within the PMF extent that fall outside the FPA (which are not subject to the DCP).	Critical facilities including schools, aged care facilities, childcare facilities outside of the FPA are not currently subject to development controls, however are vulnerable to flood risk in events greater than the 1% AEP. This clause will require development of critical facilities to consider and prepare for flooding during the	This amendment to the LEP would require Council to submit a planning proposal, which could be lodged in conjunction with Option PL1.	Council	N/A	High
PL4		Requirement of Site Specific Flood Emergency Plans	Certain types of developments will be required to provide site specific emergency flood plans to demonstrate how occupants and stock will be kept safe during and after flood events.	Preparation of a plan increases the flood awareness of the business owner and reduces risk to life of staff or occupants by improving evacuation efficiency and preparedness. Increased awareness can also reduce property damages by preparing the site for flooding.	There may be resistance from developers, as preparation of a site-specific flood plan may be considered onerous to prospective developers.	Council	N/A	High
PL5		Flood Risk Info on s149 Planning Certificates	Increase depth of flood information to be provided on s149(2) and (5) certificates to identify the property's flood hazard, hydraulic category and whether or not flood related development controls apply.	The more informed a home owner is, the greater the understanding of their flood risk. During a flood event this information can help prepare residents to evacuate and reduces the number of residents that elect to take shelter in high hazard areas.	None - s149 certificates already contain basic information, Council to provide further detail from current FRMS results.	Council	N/A	High

Table 105 Draft Floodplain Risk Management Plan: Planning Measures (Part 2)

PLANNING MEASURES - Part 2								
Ref	**Option**		**Description**	**Benefits**	**Concerns**	**Responsibility**	**B/C Ratio**	**Priority**
PL6	Controls to reduce risk to proposed development	Controls to set Minimum Floor Levels	The Flood Planning Level (FPL) for a variety of types of development is set at a design flood event level plus a freeboard.	Incidences of overfloor inundation can be reduced for new developments by ensuring their floor levels are set at the FPL (as a minimum).	FPL and FPA to be updated based on results from this FRMS and applied appropriately to various types of development.	Council	N/A	High
PL7		Controls to set Minimum Flood Proofing Levels	Flood proofing to the FPL is to be required for certain types of development to reduce flood damages.	Implementation of a minimum flood proofing level can lead to reduced flood damages. Wet or dry flood proofing could be allowed at the developer's discretion.	FPL and FPA to be updated based on results from this FRMS and applied appropriately to various types of development.	Council	N/A	High
PL8		Controls to ensure appropriate building design and materials	Certain developments are to be certified by an engineer to ensure they can withstand flooding forces, buoyancy and debris.	Developments in higher hazard areas or the floodway may be subject to fast flowing or deep floodwaters, and buoyant debris. This control will ensure such buildings are constructed suitably to withstand such forces and reduce damages and hazard.	There may be resistance from developers, as engineering certification may be considered onerous to prospective developers.	Council	N/A	High
PL9	Controls to Reduce Risk to the Wider Floodplain	Controls to Manage Offsite Impacts: Flood Impact Assessment	A flood impact assessment can be used to demonstrate that a proposed development will not have any adverse flood impacts elsewhere in the floodplain (e.g. on a neighbouring property).	Developments in higher hazard areas or the floodway may cause adverse flood impacts to other properties and contribute to impacts of cumulative development. This control requires developments of a certain size to submit an impact assessment to demonstrate no offsite flood impacts occur.	There may be resistance from developers, as a flood impact assessment may be considered onerous to prospective developers.	Council	N/A	High
PL10		Appropriate Dwelling Design	Redevelopment of existing dwellings should be undertaken so as to improve flood risk where possible, and development controls can be used to achieve improvement over time.	The proposed controls seek to reduce the flood impacts of a replaced dwelling by, for example, locating it on the part of the lot with the lowest hazard, orienting the dwelling to cause least obstruction of flow, requiring minimum floor levels above the FPL, and using open piers to allow flow beneath the property.	There may be limited scope to change the siting of the dwelling or resistance to having open space beneath houses.	Council	N/A	High

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14. REFERENCES

NSW Government
1. **Floodplain Development Manual**
2005

Wagga Wagga City Council
2. **Wagga Wagga Detailed Flood Model Revision**
WMAwater, August 2014

Wagga Wagga City Council
3. **Wagga Wagga Floodplain Risk Management Study and Plan**
WMAwater, May 2009

Wagga Wagga City Council
4. **Murrumbidgee River Wagga Wagga Flood Study**
Webb, McKeown & Associates, September 2004

Wagga Wagga City Council
5. **Murrumbidgee River Model Conversion Project**
WMAwater, September 2010

NSW State Government
6. **Burrinjuck Flood Mapping. NSW State Government, 1994**
1994.

Department of Environment and Climate Change
7. **Flood Emergency Response Planning Classification of Communities**
NSW State Government, October 2007

NSW Office of Public Works
8. **Wagga Wagga Levee Upgrade – Flood Freeboard**
Report Number: DC 10096, November 2010

WMAwater
9. **Letter to NSW Public Works regarding North Wagga Damage Assessment**
30 April 2015

Attorney General's Department
10. **Flood Warning – Australian Emergency Manuals Series, Manual 21**
Commonwealth of Australia, 2009

NSW State Emergency Service
11. **Draft NSW SES Flood Evacuation Capacity Assessment Guideline**
2013
Bureau of Meteorology

12. **Service level Specification for Flood Forecasting and Warning Services for New South Wales – Version 2.0**
2013

NSW State Emergency Service
13. **Wagga Wagga Local Flood Plan**
January 2006

NSW State Emergency Service
14. **Flood Intelligence Card Wagga Wagga (410001)**
4 September 2015

Wagga Wagga City Council
15. **The Wagga Wagga Flood Operation Manual**
December 1993

Keys, C.
16. **'A combat agency and its hazard: a New South Wales State Emergency Service perspective on the management of flooding',** ***Australian Journal of Emergency Management*****, 17(2), 14-18, 50-55**
2002

NSW Office of Public Works
17. **North Wagga Wagga Levee Options and Third Party Impacts – North Wagga Wagga Structural Assessment**
10 March 2015

Department of Environment and Climate Change
18. **Floodplain Risk Management Guideline – Residential Flood Damages**
NSW State Government, October 2007

Wagga Wagga City Council
19. **Wagga Wagga Major Overland Flow – Model Update Report**
WMAwater, November 2015

20. NSW Office of Environment and Heritage
Floodplain Management Program
Guidelines for voluntary house raising schemes
February 2013

21. NSW Office of Environment and Heritage
Floodplain Management Program
Guidelines for voluntary purchase schemes
February 2013

22. **Construction of Buildings In Flood Hazard Areas – ABCB Standard**
Australian Building Codes Board, Version 2012.2

23. **Construction of Buildings In Flood Hazard Areas – Information Handbook**
Australian Building Codes Board, Version 2012.3

Bureau of Meteorology
24. **Special Climate Statement 39: Exceptional heavy rainfall across southeast Australia**
6 March 2012

Wagga Wagga City Council
25. **Flood Futures: Options for North Wagga**
Available from http://www.yoursaywagga.com.au/floodfutures/documents

Australian Bureau of Statistics
26. **North Wagga: Age Structure – Service Age Groups**
Available from http://profile.id.com.au/wagga-wagga/service-age-groups?EndYear=2006&DataType=EN&WebID=180

NSW Dept of Commerce- DNR
27. **Visual Audit of Urban Levees – Non Tidal Areas of NSW**
Wagga Wagga Levee
March 2007 DC07039

Stanton, C, Stanton Associates
28. **Flood Levee Design Based on Progressive Failure Probability**
March 2007 DC07039

Smith G and Cox R
29. **Book 6 Chapter 7: Safety Design Criteria in Australian Rainfall and Runoff: A Guide to Flood Estimation**
Editors Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M and Testoni I
Commonwealth of Australia (Geoscience Australia), 2016

Davidson, James
30. **Residential Design in Flood Affected Heritage Areas**
FMA National Conference 2017, presentation available:
http://www.floodplainconference.com/papers2017/3C%20%20James%20Davidson.pdf