WOLLONDILLY SHIRE COUNCIL

STONEQUARRY CREEK (PICTON) FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

FINAL REPORT

VOLUME I

SEPTEMBER 2020

Level 2, 160 Clarence Street
Sydney, NSW, 2000

Tel: (02) 9299 2855
Fax: (02) 9262 6208
Email: wma@wmawater.com.au
Web: www.wmawater.com.au

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Project Stonequarry Creek (Picton) Floodplain Risk Management Study and Plan	**Project Number** 117094
Client Wollondilly Shire Council	**Client's Representative** Ian Berthon
Authors Catherine Walker Isaac Kim David Billaud	**Prepared by** ***Erin Askew***
Date 17 September 2020	**Verified by** ***Erin Askew***

Revision	Description	Distribution	Date
3	Final Report	WSC, NSW DPIE	Sep 2020
2	Draft for Public Exhibition	WSC, NSW DPIE	Nov 2019
1	Draft for Review (Ch 1-9)	WSC, NSW DPIE	Oct 2019

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EXECUTIVE SUMMARY

Introduction

The Stonequarry Creek (Picton) Floodplain Risk Management Study and Plan follows on from the Stonequarry Creek at Picton Flood Study Update (Draft, 2018, Reference 7), and has been undertaken in accordance with the NSW Government's Flood Prone Land Policy. 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 and commercial properties, emergency response during a flood event, and the recovery of the community following a flood event. This Floodplain Risk Management Study and Plan (FRMS&P) represents a major revision to the previous Floodplain Management Study completed in 1996 (Reference 10), reassessing several flood risk mitigation options previously investigated as well as assessing new options using the most up to date data and modelling techniques available. WMAwater has undertaken the investigation and assessment for the Stonequarry Creek (Picton) Floodplain Risk Management Study and Plan under the guidance and direction of the Wollondilly Floodplain Risk Management Committee.

Existing Flood Environment

Picton is located approximately 90 km south west of Sydney in the Wollondilly Shire Council Local Government Area (LGA). The township is located on the banks of Stonequarry Creek, approximately 4.5 km upstream of its confluence with the Nepean River. Stonequarry Creek is a tributary of the Nepean River, and has a catchment of 84 km^2 to just downstream of the Stonequarry Creek (Picton) gauge. Stonequarry Creek receives inflows from four main tributaries: Racecourse Creek from the east, Crawfords Creek from the north, and Cedar and Mathews Creek to the west of Picton, with flood risk in the CBD primarily driven by Stonequarry Creek. The catchment shape is characterised by two distinct branches to the east (Racecourse Creek) and west (Stonequarry Creek) of the township.

Flooding in Picton can occur as a result of both 'mainstream flooding' in which flow breaking out of the main channel of Stonequarry Creek inundates the surrounding floodplain, as well as 'overland flow' caused when the runoff from local rain events exceeds the capacity of the local drainage network and makes its way to the creek. Compared to mainstream flooding, overland flow is generally shallow and less hazardous, and tends to drain quickly after the burst. Both of these mechanisms were experienced in June 2016, during which an East Coast Low brought extremely heavy rainfall to Picton (334 mm over 3 days), and Stonequarry Creek rose to 8.799 m at the gauge. Analysis undertaken in the Stonequarry Creek at Picton Flood Study Update (Reference 7) estimated that the flood event, which caused significant damage to commercial premises particularly along Argyle Street, had a recurrence interval between 200 and 500 years, indicating it was a particularly rare event.

Economic Impact of Flooding

A flood damages assessment was carried out for the residential and commercial properties in the Study Area, based on surveyed and estimated flood levels for over 903 properties. The damages assessment highlighted the low residential property flood affectation in Picton, with 649 properties in the Study Area outside of the PMF extent, and a further 326 not flooded in an event more frequent than the PMF. The commercial damages were also limited as a result of the deep, incised channel that characterises Stonequarry Creek in Picton. With its steep banks, Stonequarry Creek has capacity to convey flows in flood events up to and including a 5% AEP event, meaning that mainstream flooding does not cause property damage in the CBD until approximately the 2% AEP event (6.7 m at the gauge), when the Stonequarry Creek channel capacity is exceeded, and flows break out upstream of Argyle Street.

The annual average damages (AAD) is used to express the total damage caused by all floods over a long period of time divided by the number of years in that period. In Picton, the AAD for all residential and commercial/industrial properties was determined to be $333,900. In comparison, the damage incurred in the June 2016 is estimated to be in the order of $10M again reinforcing the magnitude of this event

Vegetation Management in Picton

Among its various existing flood risk management strategies, which include land use planning, a flood warning system, and community engagement, Wollondilly Shire Council undertakes a comprehensive vegetation management program to manage the density of riparian vegetation in Stonequarry Creek, Racecourse Creek, and other tributaries. The program, which involves vegetation thinning, crown lifting of in-channel trees, selective removal of regrowth, and weed control plays an essential role in the reduction of peak flood levels in Picton's CBD. Analysis using the modelling tools developed in the Flood Study Update showed that if Council *did not* continue these works, peak flood level would be 0.2 m higher in the CBD in the 1% AEP event, and up to 0.3 m higher in a 2% AEP event.

It is important however to note that the current level of vegetation removal is at the upper limit of what is practical before bank stability becomes compromised, potentially resulting in bank slump and a significant loss of conveyance capacity, which would have severe implications for flood risk in Picton. It is therefore not feasible to increase the amount of vegetation removal without artificially reinforcing banks or significantly reducing the steepness of the channel banks. Hydraulic assessment of this type of work showed that even with such modifications to the creek, significant flood risk would remain in the CBD during events greater than the 2% AEP. This indicates that a greater degree of vegetation removal is not a 'silver bullet' for reducing flood risk in Picton.

Floodplain Risk Mitigation Option Assessment

This FRMS&P identified and assessed a broad range of risk management measures to help mitigate flood risk, reduce existing and future flood damages, and improve community awareness and resilience. The assessment included (where relevant), flood impact assessment, economic assessment, and multicriteria assessment to capture intangible benefits and disadvantages. Measures were grouped into the following categories:

Flood Modification Measures modify the flood's physical behaviour (depth, velocity) by undertaking structural works in particular areas of the floodplain. Options assessed in this FRMS&P included major modifications to the creek channel and bridge structures, retarding basins, levees, and stormwater network upgrades. Benefits of flood modification measures are generally expressed as the reduction in property damages that would occur if implemented.

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 in the long term.

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. Options assessed in this study include a review of the Wollondilly Shire Flood Warning System, improvements to the coordination of emergency response agencies, and improvements to community flood awareness.

Assessment Outcomes

With property damages not incurred during mainstream flooding in events more frequent than a 2% AEP event, it is challenging for structural options to be economically viable. This is because the 'benefits' of structural measures (i.e. reduction in property damages) are unable to be realised in more frequent flood events, which are more likely to occur, and are thus weighted more heavily than rarer events in the calculation of AAD. In addition, for a structural option to have a material impact on flooding in the 1% AEP event (or the June 2016 event), a substantial structure (e.g. retarding basin or levee) is required, bringing with it significant capital costs, and often expensive land acquisition requirements.

Despite the significant damage that occurred in the June 2016 flood event, Picton has a relatively low flood risk during frequent events and thus structural options to manage the residual flood risk, when considered from a purely financial outlook, are not viable. However, structural options that have other benefits to the community and road users have been recommended for further investigation. Continuation of Council's vegetation management plan (CM4), research into and investment in temporary flood barriers for commercial properties (PM03), and improvements to planning and development policies (PM06 and PM07), are among the most effective methods to reduce flood risk in Picton. Following the assessment in this study, the Draft Stonequarry Creek (Picton) Floodplain Management Plan has been prepared, and is provided overleaf.

Table i Stonequarry Creek (Picton) Draft Floodplain Risk Management Study and Plan (Part 1 of 2)

	Option ID (Section)	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	B/C Ratio	Priority
Response Modification Options	**RM01 (11.3.1)**	Wollondilly Shire Flood Warning System Review	Review current flood warning system in relation to trigger levels, maintenance requirements, messaging and recipients (including identifying and prioritising vulnerable occupants). Conduct a high level assessment of alternative flash flood warning systems.	Improve current system using outputs from the Stonequarry Creek at Picton FRMS&P. Potentially increase warning time available to the community.	May not be possible to increase warning time in Picton due to short catchment response time. Trade off between accuracy and warning time is necessary.	SES, Council, gauge operators	SES and Council	$20,000 - $30,000	N/A	High
	RM02 (11.3.2)	Improve Flood Emergency Response Coordination	Ongoing improvements to the coordination between and within emergency service agencies. Improvements to volunteer coordination. Identify vulnerable occupants.	Improved understanding of roles and responsibilities for more effective, efficient, and safe actions during and following flood events.	Challenges include change of personnel, difficulty in organising meetings and exercises between flood events.	All response agencies, including but not limited to the SES, Council, RFS, Fire and Rescue, and community organisations.	May be eligible for NSW Government funding	Minimal - In house	N/A	Moderate
	RM03 (11.3.3)	Improve Community Flood Education and Awareness	Council to implement a flood education program to improve ongoing flood awareness in Picton using a range of approaches and engagement strategies.	Flood awareness significantly improves preparedness for and recovery from flood events, building a more flood resilient community.	Ongoing efforts to ensure information is not forgotten. Potential for residents to become bored or complacent with messaging.	Council in collaboration with other response agencies and community organisations.	May be eligible for NSW Government funding	Annual Budget to be determined and allocated.	N/A	High
Flood Modification Options	**CM3**	Removal of Buildings for Floodway Clearance	Purchase and demolition of buildings within the floodway to remove obstruction and improve conveyance. Rezoning of this and other land that is considered unsuitable for development.	Reduced peak flood levels across the CBD, prevention of future damage and losses, opportunity to create open area adjacent to the creek for public use.	Significant cost to acquire and demolish buildings. May face resistance from building owners.	Council	May be partially funded through NSW DPIE	Dependent on number of buildings included in project.	<0.1	Moderate
	CM4	Vegetation Management	Continuation of existing vegetation management plan to maintain vegetation density in Stonequarry Creek and Racecourse Creek.	If not undertaken, peak flood levels would increase substantially in the CBD in events including and greater than a 2% AEP event.	Community may perceive that current works are insufficient. Education required to communicate the importance of vegetation to bank stability, and that further removal of riparian vegetation would require artificial bank stabilisation or reducing the bank slope.	Council	May be partially funded through NSW DPIE	Approx. $65,000 annually	1.3	High
	RB01 (11.5.4.1)	Stonequarry Creek Western Catchment Retarding Basin Feasibility Study	Undertake a feasibility study to investigate appropriate site(s) and concept designs for a retarding basin on Stonequarry Creek, at a location upstream of Barkers Lodge Road.	Flood risk in the Picton CBD is driven by flow in Stonequarry Creek. If a suitable site(s) can be found, a retarding basin could act to reduce peak flood levels in the CBD and reduce hazard and property damages.	Steep topography limits the availability of appropriate sites for a basin. A significant storage capacity is needed to make a material difference in the CBD, likely leading to high capital costs. Impacts of coal extraction on flood behaviour needs to be considered.	Council	Feasibility studies may be partially funded through NSW DPIE	$40,000 - $60,000	NA	High
	L1 (11.5.5.1)	South Picton Diversion Bank	Low level embankment designed to divert shallow overland flow around residential properties, rather than through backyards and onto Menangle Street.	Reduced nuisance flooding in residential yards, and reduced hazard to motorists on Menangle Street.	Limited tangible benefits, potential requirement for acquisition of land for construction and maintenance easement, potential visual impacts for residents.	Council	May be partially funded through NSW DPIE	<$150,000	<0.1	Low
	D1 (11.5.6.1)	Menangle Street Culvert Upgrade	Duplication of the existing box culvert on Menangle Street south of Baxter Lane to increase capacity and reduce inundation over the road.	Reduce depth of flooding and duration that Menangle Street is inundated will improve motorist safety.	Option does not reduce flood risk to development. Significant capital costs for minor benefits.	RMS/Council	N/A	$250,000	<0.1	Low
	D2 (11.5.6.2)	Menangle Street Upgrade	Raise Menangle Street and associated culvert upgrade works to allow flood free access in a 1% AEP event. This option would be complemented by local drainage works to better manage localised flood behaviour in the adjacent area.	Reduced hazard to motorists, improved access and evacuation route. Reduced inconvenience to landholders.	High capital cost, no change to property affectation (low tangible benefits). Value of keeping Menangle Street flood free to be confirmed. Negotiations between RMS and Council required.	RMS/Council	N/A	~$1.5M	<0.1	Low
	D4 (11.5.6.1)	Argyle Street Pipe Upgrade	Argyle Street trunk drain upgrade, increase pipes from 750mm to 1200 mm diameter to increase capacity.	Improve flood drainage in Picton CBD area and decrease peak flood levels in the lower lying parts of the CBD, reducing duration of inundation (overland events only).	Limited benefits to property affectation, ineffective in flood events where the creek level is elevated. High capital cost and potential disruption to other belowground services. Negotiations between RMS and Council required.	Council	N/A	~$1.9M	<0.1	Low

Table ii Stonequarry Creek (Picton) Draft Floodplain Risk Management Study and Plan (Part 2 of 2)

	Option ID	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	B/C Ratio	Priority
Property Modification Options	**PM01 (11.4.1)**	Adoption of Flood Planning Levels	Council to adopt residential and commercial Flood Planning Levels as determined in this FRMS&P: Mainstream: 1% AEP + 0.5 m freeboard Overland: 1% AEP + 0.3 m freeboard. FPLs for critical facilities should be determined on a merits based approach considering events rarer than the 1% AEP. Update LEP and DCP definitions of the FPL.	FPLs are effective tools to limit property damage to new development and redevelopment. FPLs may pertain to minimum floor levels or flood proofing levels depending on the type of development.	A planning proposal is required to amend the LEP and implement the new FPL. May be considered more onerous for developers.	Council	N/A	Internal	N/A	High
	PM02 (11.4.2)	Revision of Flood Planning Area (FPA)	The FPL, and other flood related development controls, is applied to properties within the Flood Planning Area (FPA). Adopt associated Flood Planning Area map developed in this FRMS&P, which delineates mainstream and overland FPAs. Update LEP and DCP definitions of the FPA.	The FPA will provide clear guidance on the properties subject to flood related development controls.	A planning proposal is required to amend the LEP and implement the new FPA definition. Consultation would be required.	Council	N/A	Internal	N/A	High
	PM03 (11.4.3)	Flood Proofing Measures for Commercial Properties	Undertake a research project to determine the preferred temporary flood barrier product for business owners to purchase and implement in the event of a flood. This option is available to existing businesses, and could be encouraged for new business owners in the future.	Significantly reduce commercial property damages, and associated stress and trauma. Reduced burden on the SES to help businesses prepare for floods, and decrease recovery times following floods.	Staff to be regularly trained in the installation of temporary flood proofing measures. Implementation of measures at the time of construction may be considered onerous by developers. Range of aspects should be considered including cost, ease of installation, aesthetic (including heritage requirements).	Individual Business Owners and commercial organisations in Picton.	Community resilience grants may be available	TBD (varies depending on product) Expected to be <$2,500 ex GST per unit	>>1	High
	PM05 (11.4.5)	Voluntary Purchase	Feasibility study to further investigate a Voluntary Purchase scheme in Picton.	Remove residents and dwellings from high hazard areas, thus reducing risk to life, potential need for rescue, and increasing conveyance through the floodplain.	Community appetite for or acceptance of VP may be a challenge. VP schemes are long term options and may take approximately a decade to implement.	Council in consultation with affected residents.	Eligible for OEH funding	~$5M	<0.1	High
	PM06 (11.4.6)	Managing development in the FPA	Amendments to the Wollondilly DCP -Part 8 - Flooding to achieve the following: Consistency of terminology and definitions with the FRMS&P Consideration of development controls for commercial premises; and Addition of flood related development controls for above and below ground carparking.	Improve clarity of DCP (Flood for the benefit of both developers and Council assessors/approvers. Enable proponents to design, build and manage development using the best available flood information.	There may be resistance from developers who consider new controls to be onerous.	Council	NA	~$20k	NA	Moderate
	PM07 (11.4.7)	Managing development in Low Flood Risk Areas	Modify the LEP to enable Council to apply flood related development controls to critical utilities and vulnerable land uses between the FPA and PMF extent. Adopt development controls for such land uses in low risk areas.	Ensure critical utilities and vulnerable facilities are designed, constructed and managed in such a way as to minimise flood risk to the structure and (if relevant) its occupants.	This amendment to the LEP would require Council to submit a planning proposal, which could be lodged in conjunction with Option PM01.	Council	NA	Internal	NA	Moderate
	PM08 (11.4.8)	Provision of Flood Information to Residents via Section 10.7 Planning Certificates.	Increase depth of flood information to be provided on s10.7(2) and (5) certificates to identify the property's flood hazard, hydraulic category and whether or not flood related development controls apply using high resolution outputs from this study.	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.	Limited - s10.7(2) certificates already contain basic information, Council to provide further detail from current FRMS results. May increase demand on Council staff, however GIS systems can be established to provide this information efficiently.	Council	NA	Internal	NA	High

STONEQUARRY CREEK (PICTON) FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

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LIST OF ACRONYMS

AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval
ALS	Airborne Laser Scanning
ARR	Australian Rainfall and Runoff
BOM	Bureau of Meteorology
DECC	Department of Environment and Climate Change (now OEH)
DNR	Department of Natural Resources (now DPIE)
DPIE	Department of Planning, Industry and Environment
DRM	Direct Rainfall Method
DTM	Digital Terrain Model
GIS	Geographic Information System
GPS	Global Positioning System
IFD	Intensity, Frequency and Duration (Rainfall)
mAHD	metres above Australian Height Datum
OEH	Office of Environment and Heritage (Now DPIE)
PMF	Probable Maximum Flood
SRMT	Shuttle Radar Mission Topography
TUFLOW	one-dimensional (1D) and two-dimensional (2D) flood and tide simulation software (hydraulic model)
WBNM	Watershed Bounded Network Model (hydrologic model)

ADOPTED TERMINOLOGY

Australian Rainfall and Runoff (ARR, ed Ball et al, 2016) recommends terminology that is not misleading to the public and stakeholders. Therefore, the use of terms such as “recurrence interval” and “return period” are no longer recommended as they imply that a given event magnitude is only exceeded at regular intervals such as every 100 years. However, rare events may occur in clusters. For example, there are several instances of an event with a 1% chance of occurring within a short period, for example the 1949 and 1950 events at Kempsey. Historically the term Average Recurrence Interval (ARI) has been used.

ARR 2016 recommends the use of Annual Exceedance Probability (AEP). Annual Exceedance Probability (AEP) is the probability of an event being equalled or exceeded within a year. AEP may be expressed as either a percentage (%) or 1 in X. Floodplain management typically uses the percentage form of terminology. Therefore a 1% AEP event or 1 in 100 AEP has a 1% chance of being equalled or exceeded in any year.

ARI and AEP are often mistaken as being interchangeable for events equal to or more frequent than 10% AEP. The table overleaf describes how they are subtly different.

For events more frequent than 50% AEP, expressing frequency in terms of Annual Exceedance Probability is not meaningful and misleading particularly in areas with strong seasonality.

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.

The Probable Maximum Flood is the largest flood that could possibly occur on a catchment. It is related to the Probable Maximum Precipitation (PMP). The PMP has an approximate probability. Due to the conservativeness applied to other factors influencing flooding a PMP does not translate to a PMF of the same AEP. Therefore, an AEP is not assigned to the PMF.

This report has adopted the approach recommended by ARR and uses % AEP for all events rarer than the 50 % AEP and EY for all events more frequent than this.

Frequency Descriptor	EY	AEP (%)	AEP (1 in x)	ARI
Very Frequent	12			
	6	99.75	1.002	0.17
	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.5
	1	63.21	1.58	1
Frequent	0.69	50	2	1.44
	0.5	39.35	2.54	2
	0.22	20	5	4.48
	0.2	18.13	5.52	5
	0.11	10	10	9.49
Rare	0.05	5	20	20
	0.02	2	50	50
	0.01	1	100	100
Very Rare	0.005	0.5	200	200
	0.002	0.2	500	500
	0.001	0.1	1000	1000
	0.0005	0.05	2000	2000
Extreme	0.0002	0.02	5000	5000
			↓	
			PMP/ PMPDF	

FOREWORD

The NSW State Government's Flood Prone Land Policy provides a framework to ensure the sustainable use of floodplain environments. The primary objective of the NSW Government's Flood Prone Land Policy is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods. At the same time, the policy recognises the benefits flowing from the use, occupation and development of flood prone land (Reference 4).

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

1. Data Collection

- Compilation of existing data and collection of additional data.

2. Flood Study

- Determine the nature and extent of the flood problem.

3. Floodplain Risk Management

- Determines options in consideration of social, ecological and economic factors relating to flood risk.

4. Floodplain Risk Management Plan

- Preferred options are publicly exhibited and subject to revision in light of responses. Formally approved by Council after public exhibition and any necessary revisions due to public comments.

5. Implementation of the Plan

- Implementation of flood, response and property modification measures (including mitigation works, planning controls and flood warnings for example) by Council.

1. INTRODUCTION

This Study has been prepared by WMAwater on behalf of Wollondilly Shier Council (Council). The Study is comprised of two phases:

1. Stonequarry Creek (Picton) Floodplain Risk Management Study; and
2. Stonequarry Creek (Picton) Floodplain Risk Management Draft Plan.

This FRMS&P follows on from the Stonequarry Creek at Picton – Flood Study Update (Final Draft) (Reference 7), which determined the nature and extent of the flood risk in the township of Picton under existing conditions, in accordance with current industry guidelines. The Flood Study Update provided a significant revision to the Stonequarry Creek (Picton) Flood Study (Final Draft), Advisian, 2017 (Reference 5). Details of the update are provided in Section 2.9

Flood behaviour has been defined across a range of event sizes and include those which have been recorded in the past, as well as larger events which may occur in the future. This Floodplain Risk Management Study seeks to investigate methods by which to reduce flood risk in Picton and ultimately develop a Floodplain Risk Management Plan which can be implemented by Council. Detailed objectives of the Study are outlined in subsequent sections.

All levels provided in this report are to Australian Height Datum (AHD) or relate to the Stonequarry Creek gauge (m) at Picton (site number: 212053) which will be referred to as the Picton Gauge in this report for ease of reference. Note that the local gauge datum (referred to as “Gauge Zero”) equates to 147.803 mAHD (Australian Height Datum). A glossary of terms is provided in Section 15.

1.1. Study Objectives

1.1.1. Floodplain Risk Management Study Objectives

The overarching objective of the Floodplain Risk Management Study and Plan is to improve understanding of flood behaviour and impacts, and better inform management of flood risk in the study area in consideration of the available information, and relevant standards and guidelines, such as the NSW Government's Flood Prone Land Policy and the “Floodplain Development Manual: the management of flood liable land”, New South Wales Government, April 2005 (Reference 4).

The Floodplain Risk Management Study will increase understanding of the impacts of floods on the existing and future community. It also allows for testing and investigating practical, feasible and economic management measures to treat existing, future and residual risk. The Floodplain Risk Management Study will provide a basis for informing the development of a floodplain risk management plan. The specific objectives of the Floodplain Risk Management Study include:

- Review the current Draft Flood Study and, only if necessary**,** re-assess the design flood discharges, velocities, flood levels, hydraulic categories and other relevant flood information for the Study Area using the latest available data and technology, as appropriate (Refer to Section 2.9).

- Review Council's existing environmental planning policies and instruments including Council's long-term planning strategies for the study area.
- Identify works, measures and restrictions aimed at reducing the flood hazard and risk to people and property in the existing community and to ensure future development is controlled in a manner consistent with the flood hazard and risk to reduce public and private losses due to flooding over the full range of potential flood events (taking into account the potential impacts of climate change);
- To assess the effectiveness of these works and measures for reducing the effects of flooding on the community and development, both existing and future and taking into account the potential impacts of climate change;
- To consider whether the proposed works and measures might produce adverse effects (environmental, social, economic, or flooding) in the floodplain and whether they can be minimised;
- Protect and where possible enhance the creek and floodplain environment;
- Be consistent with the objectives of relevant State policies, in particular, the Government's Flood Prone Land and State Rivers and Estuaries Policies and satisfy the objectives and requirements of the Environmental Planning and Assessment Act, 1979;
- Ensure that the draft floodplain risk management plan is fully integrated with Council's existing corporate, business and strategic plans, existing and proposed planning proposals, meets Council's obligations under the Local Government Act, 1993 and has the support of the local community;
- Ensure actions arising out of the plan are sustainable in social, environmental, ecological and economic terms;
- Ensure that the draft floodplain risk management plan is fully integrated with the local emergency management plan (flood plan) and other relevant catchment management plans;
- Establish a program for implementation and suggest a mechanism for the funding of the plan which should include priorities, staging, funding, responsibilities, constraints, and monitoring; and
- Identification of modifications required to current policies in the light of investigations.

Specifically, the Floodplain Risk Management Study aims to:

- Utilise the separate public exhibition of the Draft Flood Study for data collection associated with the scope of this study;
- Consider the sensitivity of the existing modelling to ARR 2016 rainfall data (Refer to Section 2.9);
- Identify particular flood problems such as blockages of hydraulic structures;
- Identify local overland flow problems, map overland flow paths, set OLF classification and distinguish between overland flow and mainstream flooding;
- Identify flood related planning and development controls based on consideration of flood risk and categories of land use.· Identify flood mitigation options favoured by the community;

- Provide preliminary cost estimates for a range of flood mitigation works which can be implemented along with other options for consideration. These costs are to include both capital, ongoing maintenance and total lifecycle costs;
- Addressing emergency management issues associated with any identified hot spots; and
- Map areas requiring specific planning controls e.g. areas of no development, sensitive uses and vulnerable uses

1.1.2. Floodplain Risk Management Draft Plan Objectives

The floodplain risk management plan will document and convey the decisions on the management of flood risk into the future. Drawing on the investigations undertaken as part of the floodplain risk management study, the plan will outline a range of measures to manage existing, future and residual flood risk effectively and efficiently. This will include a prioritised implementation strategy, what measures are proposed and how they will be implemented.

1.2. Study Area

Picton is located approximately 90 km south west of Sydney in the Wollondilly Shire Council Local Government Area (LGA). The township is located on the banks of Stonequarry Creek, approximately 4.5 km upstream of its confluence with the Nepean River (see Figure A1). Stonequarry Creek is a tributary of the Nepean River, and has a catchment of 84 km^2. Stonequarry Creek receives inflows from four main tributaries: Racecourse Creek from the east, Crawfords Creek from the north, and Cedar and Mathews Creek to the west of Picton.

Picton has a population of approximately 3,500 (2016 census) with land use in the township predominantly composed of low-density residential development with some commercial development along the main street (Argyle Street) and light industrial areas at the southern end of the town. In addition, there are large areas of open space (rural landscape) surrounding the town centre, characterised by hills sloping down towards Stonequarry Creek. The local topography is presented on Figure A2.

Flooding in Picton can occur as a result of flow breaking out of the main channel of Stonequarry Creek and inundating the surrounding floodplain. In larger events, water that overtops the banks of Stonequarry Creek can inundate parts of the Town Centre and surrounding ubran areas. Local rainfall over Picton can also cause flash flooding, as runoff from the surrounding slopes enters the Town Centre and can exceed the stormwater network capacity. The Study Area (displayed on Figure A1) covers areas of Picton that contribute to overland flow, as well as the Stonequarry Creek floodplain between Abbotsford Road (in the town's west) and about 1 km downstream (south) of the railway viaduct, and approximately 1.5 km of Racecourse Creek between its confluence with Stonequarry Creek and the eastern boundary of Antill Country Golf Course. The Study Area covers an area of approximately 84.6 km^2.

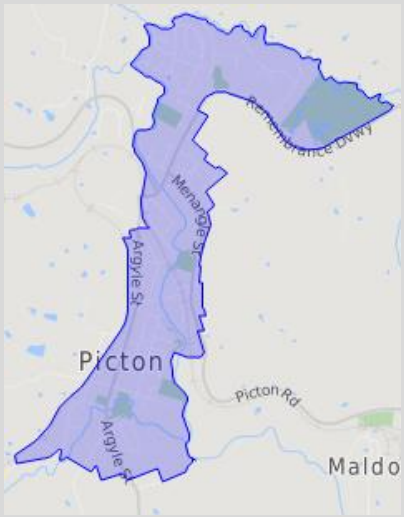
1.3. Land Use

Land use zoning is defined by the Wollondilly Local Environmental Plan (LEP 2011) and is shown on Figure A3. The majority of residential development within Picton is comprised of lots zoned *R2 Low Density Residential* with areas of *R3 Medium Density Residential* behind the town centre, and *R5 Large Lot Residential* west of Stonequarry Creek. A *B2 Local Centre* area which allows for commercial/industrial uses is situated along Argyle Street. Stonequarry Creek itself is classified as *E2 Environmental Conservation*, and it is bordered, generally on both sides, by *RE1 Public Recreation* and *RE2 Private Recreation* allowing for multiple uses including playing fields and golf course. There is a relatively small amount of *IN2 Light Industrial* area at the southern end of the town. Land use outside of the township of Picton is generally zoned *RU2 Rural Landscape*.

1.4. Demographic Overview

Understanding the social characteristics of the Study Area can help in ensuring appropriate risk management practices are adopted, and shape the methods used for community engagement. Census data regarding house tenure and age distribution can also provide an indication of the community's lived experience with recent flood events, and hence an indication of their flood awareness. The following information has been extracted from the 2016 Census for the town of Picton and is considered relevant, while Table 3 below shows some of the characteristics of Picton compared to the NSW average.

Picton Demographic Overview



Population: 3,454
No. of Private Dwellings: 1,365
No. of lone person households: 257
Property Tenure:

- 73.7% owned (either outright or with a mortgage)
- 23.6% rented

Language

- 90.2% of people speak only English at home

No. persons over the age of 75: 199
Elderly people may be unable to respond as quickly to flood emergencies without requiring some assistance.

No. single parent families: 160
Single parent families can mean a low adult-to-child ratio within the household and therefore can make evacuation more difficult.

Statistics from quickstats.censusdata.abs.gov.au/census_services/getproduct/census/2016/quickstat/UCL115112?opendocument

Table 3: Characteristics of Picton (Australian Bureau of Statistics, 2016)

	Picton (Town)	NSW
Population Age:		
0 – 14 years	20.0%	18.5%
15 - 64 years	66.1%	65.1%
> 65 years	13.9%	16.2%
Average people per dwelling	2.7	2.6
Own/mortgage property	73.7%	64.5%
Rent property	23.6%	31.8%
Other tenure type/not stated	2.7%	3.7%
No cars at dwelling	4.3%	9.2%
Speak only English at home	90.2%	68.5%

The characteristics noted above are considered in the community engagement strategy and when considering response modification options, such as flood education, warning or evacuation systems. Given the high proportion of English-only households, the delivery of community consultation material and flood warnings/ information in English is deemed appropriate. The community consultation activities undertaken as part of this study are described in Section 8.

The proportion of residents over the age of 65 is lower than the NSW state average, however aged residents are more likely to be frail and unable to respond as quickly to flood emergencies. These residents may also prefer to receive hardcopy newsletters than via online methods. Provision of assistance to such residents should be a key consideration when developing flood evacuation systems and the lead time with which warnings are provided. The family composition within a residence can also affect flood awareness and capacity to respond. In Picton there are 257 lone person households, who are at greater risk of being unaware of flood warnings or evacuation orders. There are also 160 single parent families, which can mean a low adult-child ratio and result in difficulties preparing for and safely undertaking evacuations.

1.5. Local Environment

1.5.1. Riparian Vegetation

The Stonequarry Creek catchment is characterised by grassed hills and areas of moderate to dense tree cover, with urban areas within the Picton township and parts of Thirlmere to the south. The Stonequarry Creek channel itself is characterised by a degraded sandstone gully forest with high levels of weed infestation primarily of privet, moth vine and honeysuckle. The most prominent native species of trees along the creek include the Broad-leaved Apple, Forest Red Gum, and River Oak (Reference 14).

Privet is the dominant roost tree particularly along the middle and upper reaches of the creek banks. Other non-natives along the banks dominate the mid and upper storey stratum. Many of these weeds outcompeted native growth following extensive clearing on both sides of the creek. There is also evidence of land slippage as a result of removal of native vegetation (non-natives species can be less effective at stabilising creek banks), or due to the removal of riparian vegetation entirely. Garden plants from residential properties in close proximity to the creek have also established themselves on the creek banks including Pampas Grass and Giant Bamboo.

Mature eucalyptus trees occupy the upper banks of the creek particularly on the eastern side. There has been work done in regard to actively removing weeds in the area and restoring some native vegetation. However, this can be challenging due to the steep banks of the creek (Reference 14).

1.5.2. Vegetation Management Practices

Riparian vegetation management can affect a range of factors including flood conveyance (by reducing hydraulic roughness), bank stability, reducing the occurrence of channel blockages, improving safety and amenity, and protecting ecological and geomorphic assets. Wollondilly Shire Council undertakes regular vegetation management activities as per guidelines in Council's *Stonequarry Creek Vegetation Management Plan, 1994)*, which strives to achieve a balance of the aforementioned factors.

Following the June 2016 flood event, Council engaged Soil Conservation Service in September 2016 to provide an assessment of river processes and erosion in Stonequarry Creek, review current vegetation management practices from a stream stability perspective, and provide a prioritised list of remedial works (Reference 15). The resulting report noted that *"Council's vegetation management practices, particularly crown lifting of in-channel trees, selective removal of regrowth, and weed control, appear to be producing no reach-scale instabilities (of the kind related to increased velocity of resultant floodwaters). It is recommended these be continued, due to their lessening backwater effects in flooding, and therefore favourable outcome in lessening flood peaks."*

In the past year, Council has specifically been working in Racecourse Creek and Stonequarry Creek north of Picton, to remove tree trunks (specifically Casuarinas) out of the creek bed and anchor them to the bank, such that the logs are aligned with the direction of flow. This significantly reduces the obstruction to flow, while achieving ecological outcomes in regards to the protection of native habitats. An example is shown in Photo 1 below. It is important to note the sensitive balance between maintaining a 'clear' channel (e.g. to increase flow conveyance), bank stability, and conservation of native species rather than weeds that may grow in their place if removed. It is also noted that appropriate vegetation may assist in attenuating flood flows and reducing downstream flood levels, and that 'creek clearing' in unsuitable locations may cause flood behaviour to be worsened elsewhere.

Photo 1: Fallen Casuarina logs anchored to Stonequarry Creek bank, just downstream of the Racecourse Creek confluence (WMAwater, 26/11/2018)

1.5.3. Local Fauna

There are a number of animal species that occupy the area, including frogs such as the Verreaux's Frog and Common Eastern Froglet. Additionally, there are species of skink including the Eastern Water-skink and Dark-flecked Garden Sunskink. With the exception of the Grey Headed Flying Fox there is little evidence of mammal activity (Reference 14).

The Stonequarry Creek flying fox camp is located between the railway Viaduct at the end of Webster Street and the Prince Street Bridge. The camp is home to some 2000 Grey Headed Flying Foxes (as of November 2016) which seasonally occupy the area. Council staff regularly undertake flying fox counts and are in the process of developing a camp plan of management. In addition, several bird species occupy the area which most commonly include the Superb Fairy Wren, Red-browed Finch and Australian Magpie (Reference 14).

2. PREVIOUS INVESTIGATIONS

2.1. Picton Flood Study Report, Department of Water Resources, 1989 (Reference 8)

In 1989, the NSW Department of Water Resources (DWR) completed the 'Picton Flood Study Report'. The project began in May 1986, when Wollondilly Shire Council requested the then Water Resources Commission initiate the flood study because of the increasing demand to develop areas that may be liable to flooding and the need to develop a floodplain management plan to reduce risk to life and property in Picton.

A RAFTS hydrological model was used to convert rainfall to runoff hydrographs. Once the hydrographs were determined, a one-dimensional HEC2 (Hydrologic Engineering Centre (1981)) model was developed for the hydraulic component of the flood study. The floodplain topography was defined by a series of surveyed cross sections across the channel or floodplain perpendicular to the direction of flow.

The study provided flood profiles and levels for the 20 year, 50 year, and 100 year ARI design events at 23 cross sections, determined hazard and hydraulic category mapping, and estimated flood damages. The results indicated that the floodway would pass through a large portion of the commercial centre of the town (i.e. Argyle Street). It was considered likely that any flows in this area would be extremely turbulent with localised variations in water level and velocity between buildings. The report identified that there was likely to be significant flood damages with 58 residential and 48 commercial properties subject to inundation in the 100 year ARI design flood. Many of these properties are along Argyle Street (between Menangle Street and Stonequarry Creek).

The Picton Flood Study Report also provided a preliminary consideration of a range of flood risk mitigation measures that may be suitable and effective in Picton. Below is a summary of the various types of structural mitigation options, and the findings of the report. The report also recommended improvements to flood warning systems, and the use of zoning and development controls as the most effective means of containing the growth of flood damages and complement any structural mitigation works. The report however noted that any decision to pursue such works would require detailed consideration by Council.

Table 4: Summary of mitigation options considered in the 1989 Flood Study (Reference 8)

Option	Description	Conclusion
Retarding Basins	Temporarily store water during a storm runoff period, and lessen flow rates and water levels downstream. Typically most effective in upper reaches of the catchment.	Considered impractical in Picton due to the steep nature of the catchment and a lack of suitable sites near the township. No analysis of basins was carried out.

Option	Description	Conclusion
Levee	Typically an embankment structure used to protect properties from flooding, providing account is taken of potential flow redistribution and the possibility of overtopping of the levee in floods greater than the design flood.	A 1 in 100 year flood level plus 1m freeboard (the then Dept. standard) would necessitate a levee up to 4 m high, which would be considered unsightly and block internal drainage unless specific allowance was made. The levee would increase peak flood levels by up to 1 m (near Elizabeth Street), and increase in-stream velocities, leading to scour and erosion in the channel. Analysis of the levee option resulted in a cost-benefit ratio of 0.77, indicating it would not be economically viable.
Major stream clearing & linear park project	Stream clearing should concentrate on the removal of weed growth, exotic species and any willows within the channel, and creating a park along both banks. Mature trees would generally be maintained and only removed if they obstruct flow or threaten to fall across the channel.	The option was tested by adjusting hydraulic roughness coefficients and indicated that with 'clear conditions' flood levels may be reduced immediately downstream of Stonequarry Bridge, however the impacts on in-stream velocities, bank stability and downstream peak flood levels were not assessed.
Re-shaping the channel	This option involves changing the bed width and side slopes, testing widths of 8 m and side slopes of 2:1 (horizontal/vertical) to bed widths of 20 m and side slopes of 4:1, in addition to the clearing works described above.	At the lower range, flood levels were dropped by a further 0.25 m on those estimated with clearing alone (excavation of approx. 63,200 m^3). Excavation of ~1.4 million cubic metres would be required to achieve the higher range, a degree of work not considered warranted. Ongoing maintenance costs and environmental impacts were not considered in the initial option assessment.

2.2. Stonequarry Creek Floodplain Management Study (Willing & Partners, 1992) (Reference 9)

Following on from the Picton Flood Study Report (Reference 8), the Stonequarry Creek Floodplain Management Study updated the RAFTS model to RAFTS-XP to obtain design discharge estimates for the 5%, 2%, 1% AEP and PMF. The HEC-2 surface profile model developed in the Flood Study was adopted as is. The Study assessed a range of structural and non-structural flood risk mitigation options summarised in Table 5.

Table 5: Options assessed in the 1992 Floodplain Management Study (Reference 9)

Option	Description	B/C Ratio	1% AEP Peak Level Reduction	Status
S1. Stream Clearing	Involves a major stream clearing project through Picton township, including removal of weed growth, exotic species and any willows within the channel. Mature trees on the banks would generally be maintained though would be removed if the pose a considerable obstruction to the 1% AEP flow, or threaten to fall across the creek.	2.2	0-0.6m	Recommended

Option	Description	B/C Ratio	1% AEP Peak Level Reduction	Status
S2. Channel Formalisation	Comprises channel formalisation and stream clearing. The channel downstream of Elizabeth St would be reshaped to provide a larger waterway and lined with rock-filled mattresses to prevent scour. Stream clearing would be carried out upstream of Elizabeth St and along the banks adjacent to the channel improvements.	0.4	0-0.6m	Not Recommended
S3. Retarding Basin 1	Construction of a 1700 ML retarding basin on Stonequarry Creek at the confluence with Cedar Creek. The basin would be formed by an 800,000 m^3 excavation and the construction of an embankment with a maximum height of approximately 7 m. Twin 3.6 m x 3.6 m box culverts would be required to prevent the spillway overtopping during the 1% AEP event. This basin would reduce the peak 1% AEP flood discharge to somewhere between the 2-5% flood discharge.	0.1	0-0.5m	Not Feasible
S4. Retarding Basins 1 & 2	Construction of an additional 1900 ML retarding basin in conjunction with Option 3 on Racecourse Creek (500 m upstream of the confluence with Stonequarry Creek). The additional basin would involve a 940,000 m^3 excavation and the construction of an embankment with a maximum height of approximately 10 m. A single 3.6 m x 3.6 m box culvert would be required to prevent the spillway overtopping during the 1% AEP event. These basins would reduce the peak 1% AEP flood discharge to a discharge equivalent to the peak 5% AEP flood discharge.	0.1	0-0.7m	Not Feasible
S5. Flood Protection Levee	Construction of a levee on both sides of Stonequarry Creek through Picton and reconstruction of the Stonequarry Creek Bridge. The levee and bridge would be constructed to a level 1 m above the 1% AEP flood level. This construction is in conjunction with Option 2. The resulting levee height would be approximately 2.5 m. Floodwalls would need to be constructed adjacent to the commercial centre due to space constraints.	0.3	0-0.4m	Not Feasible
P1. Zoning of Flood Liable Land to Control Development Type	Ensure that new development in flood liable areas are subject to minimum floor levels and other standards as set out in the Interim Flood Policy. Rezoning and subdivision should be considered on the merits of the particular case as well as in regards to the cumulative impact.	-	-	Recommended
P2. House Raising	A total of 19 residential properties were considered for house raising to a level of 0.5m above the 1% AEP flood level. The total estimated cost was $610,000.	0.3	-	Recommended
P3. Voluntary Purchase	Voluntary purchase is not a viable option as existing buildings within the high hazard floodway zones are generally located within the commercial area.	-	-	Not Feasible

Option	Description	B/C Ratio	1% AEP Peak Level Reduction	Status
P4. Flood Insurance	Flood insurance is not readily available to householders anywhere in NSW. It is therefore considered to not be a viable option in the Stonequarry Creek study area.	-	-	Not Feasible

The report arrived at a recommended Floodplain Management Strategy incorporating the items listed below:

- A committee should be formed to co-ordinate the preparation of the Floodplain Management Plan (see Reference 9);
- The implementation of the stream clearing option;
- Change the LEP to define the Flood Planning Level as the 1% AEP plus 0.5 m (in line with the NSW Floodplain Development Manual);
- Council to consider an amendment to the flood policy to allow alterations and additions to existing properties in accordance with the NSW Floodplain Development Manual;
- Prepare a flood response plan through the Local Emergency Management Committee to address flood warning, dissemination, evacuation and general community awareness of flooding risks and potential severity of flooding.

2.3. Stonequarry Creek Floodplain Management Plan (Willing & Partners, 1996) (Reference10)

Wollondilly Shire Council engaged Willing & Partners to produce the Stonequarry Creek Floodplain Management Plan, which followed on from the Picton Flood Study (Reference 8) and previous work by Willing & Partners on the Stonequarry Creek Floodplain Management Study (completed in 1992). The hydraulic model developed in Reference 8 was extended, and used to reassess several mitigation options. The measures assessed included:

- Vegetation management along Stonequarry Creek from the confluence with Racecourse Creek to the railway viaduct;
- Channel reconstruction and lining;
- Levee banks near the commercial centre and residences; and
- Retarding basins upstream of Picton, to hold back water during floods.

The Study found that the channel reconstruction and formalisation, levee bank and retarding basin measures were found to be very expensive in relation to the flood damage that could be prevented, and would also have a detrimental visual and environmental impact. The Floodplain Management Study recommended:

- Vegetation management of riparian areas (then referred to as ‘stream clearing’);
- House raising;
- Building and development controls;
- Flood warning; and
- Flood response and evacuation planning.

The preparation of this Floodplain Management Plan occurred at the same time as a Vegetation Management Plan (VMP) for the Stonequarry Creek corridor (Reference 11), and the FMP undertook the hydraulic assessments that underpin the recommendations in regards to vegetation management.

2.4. Stonequarry Creek Vegetation Management Plan, Ian Perkins Consultancy Services, April 1996 (Reference 11)

The Vegetation Management Plan (VMP) was developed for Wollondilly Shire Council as part of the Stonequarry Creek Floodplain Management Plan (Reference 10) in response to the recommended option of "stream clearing". The objective of the VMP was to provide a strategy for vegetation planning that will create a valuable corridor of vegetation without increasing flooding. The plan stresses that the proposed VMP is a compromise between the need to manage the creek system for flood hydraulics and the desire to improve biodiversity and the environmental attributes of the site. Accordingly, the management of vegetation was not aimed at restoring the structure of the original plant communities to its original condition, due to Engineering/ Social/ Economic and Environmental constraints. A structurally modified representation of the original plant communities was therefore recommended for most sections of the creek, informed by detailed site assessment and computer modelling of flood hydraulics.

The VMP noted the need for ongoing reassessment of creek vegetation (including existing, replanted and regenerated vegetation), to monitor the vegetation density. If vegetation densities exceed the target ranges for each zone recommended by the VMP, flood level increases may occur. The VMP divided the creek line into three distinct management zones, and described individual strategies for weed control, clearing, site stabilisation, revegetation and regeneration developed for each of these zones:

- **Zone 1**
  Between Racecourse Creek and Elizabeth Street. Vegetation communities in this zone were identified in the flood model as having a low influence on flood levels.
- **Zone 2**
  Between Elizabeth Street and Coull Street. Vegetation in this zone was identified as having a significant influence on flood levels.
- **Zone 3**
  Between Coull Street and the Viaduct. Vegetation in this zone was identified as generally having a moderate influence on flood levels.

It is noted that the FMP (Reference 10, Section 5.1) identified that stream vegetation works 'will reduce but not eliminate hazard to existing properties on the floodplain.' A range of other measures including house raising, flood proofing and voluntary purchase, flood response plans and improving community awareness were recommended to reduce the remaining damage potential.

2.5. Stonequarry Creek – 2D Modelling and WaterRIDE Application (Patterson Britton & Partners, 2006) (Reference 12)

Wollondilly Shire Council engaged Advisian (*then Patterson Britton & Partners)* in 2006 to update the 1989 Flood Study using current two-dimensional hydraulic modelling techniques. This involved updating the 1989 RAFTS hydrologic model to the then current catchment conditions, including increases to impervious area where urbanisation had occurred since 1989. Instead of updating the 1989 HEC-2 model, a new two dimensional RMA-2 model was developed covering the same extent as the 1989 HEC-2 model. The RMA-2 model was developed based on a Digital Terrain Model (DTM) derived from the digitised HEC-2 cross-sections, with roughness parameters initially adopted from the original HEC-2 model, then revised based on aerial photography and water level comparisons. More detail about the modelling approach and results are available in Reference 5.

2.6. Stonequarry Creek – 2D Modelling and Climate Change Assessment (WorleyParsons, 2011) (Reference 13)

This study was commissioned by Council in order to extend the 2006 RMA-2 flood model further upstream along Stonequarry, Racecourse and Crawfords Creek. The topographic data was based on a combination of detailed survey data and 2 metre contours provided by Council. The updated hydrologic modelling (still in RAFTS) found that a critical duration of 9 hours applied to the study area, generating the greatest discharge at the most downstream model node, longer than the 6 hour duration previously identified in the 1989 Flood Study (Reference 8), and increasing peak discharges by 15%-20% at the node furthest downstream.

In addition, an assessment of Climate Change conditions was completed based on adoption of the methods outlined in the NSW Department of Environment and Climate Change (DECC, now DPIE), document entitled ‘Practical Consideration of Climate Change’. A sensitivity analysis was carried out by increasing the 1% AEP rainfall intensities by 10%, 20% and 30% in the RAFTS hydrologic model, then re-running the RMA-2 hydraulic model to determine the impact on peak flood levels. The maximum increase in peak 1% AEP flood levels for a 10%, 20% and 30% increase in rainfall intensity was 0.5 m, 0.9 m and 1.3 m respectively, occurring immediately upstream of the railway viaduct. Throughout the Picton CBD, the increases were substantially less; approximately 0.2 m, 0.4 and 0.6 m respectively.

2.7. Picton / Stonequarry Creek Flood Study, Advisian, September 2017 (Reference 5)

The models developed and improved in the aforementioned previous reports formed the basis of the modelling in the Picton / Stonequarry Creek Flood Study (Reference 5), with the following primary modifications:

Hydrologic Model:

- Updated to a recent version of RAFTS (XP-RAFTS, Version 7.0, 2008);
- Updated to reflect current catchment conditions, namely an increase in the proportion of impervious areas determined based on a review of newly urbanised areas identified in recent aerial photography;
- Application of a critical duration of 9 hours (not 6 hours as in the 1989 Flood Study);
- Revision of initial and continuing loss rates for urban areas; and
- IFD parameters were reviewed and updated.

Hydraulic Model:

- The previous RMA-2 two-dimensional flood model developed in Reference 12 and updated in Reference 13 formed the basis of this Flood Study, and was updated to the latest version of RMA-2 (Version 85S);
- The DTM was updated to incorporate the LiDAR survey available to Council in 2012;
- Refinement of the existing model mesh using the LiDAR that provided improved channel definition of Stonequarry Creek and its tributaries, followed by the refinement of floodplain areas, major roadways and building footprints.
- Validation of the flood model to historic floods and comparison with the 1989 Flood Study results.

In the updated study, flood behaviour was defined for the 20%, 5%, 1%, 0.5% and 0.2% AEP design flood events and the Probable Maximum Flood (PMF). In addition, the potential impact of climate change on the 1% AEP levels was assessed. These design events were completed in 2014, prior to the June 2016 event. After the flooding Council collected High Water Mark (HWM) information for 76 locations along the creek system and across the floodplain. This data as well as recorded rainfall data from nearby rainfall and streamflow gauges was used to validate the newly developed XP-RAFTS and RMA-2 models relied upon by the Flood Study. The data collection and validation methodology was reported in the Picton Post Flood Event Analysis (Reference 6), described in Section 2.8.

The results indicate that at the peak of the 1% AEP flood, the majority of overbank inundation occurs across undeveloped areas upstream of the Picton town centre and through the town centre itself. Further downstream, significant inundation occurs at Victoria Park, upstream of the railway viaduct. In the 1% AEP event it was found that peak velocities through the town centre (between Argyle Street and Elizabeth Street) typically ranged from 0.4 m/s to 0.8 m/s, while on Argyle Street itself flows are ‘channelled’ between buildings, reaching velocities of up to 1.5 m/s and becoming highly hazardous. This is consistent with the findings of the 1989 Flood Study.

Table 7 in Reference 5 provides a comparison of peak discharges from the 1989 flood study with the results of the updated XP-RAFTS model. At the downstream extent of the study area, the Flood Study resulted in a peak 1% AEP flow of 574 m^3/s, compared to 494 m^3/s previously estimated in the 1989 Flood Study (Reference 8).

It is noted also that the flood model developed in this Flood Study did not consider overland flow generated locally, that flows through the urban areas of Picton towards Stonequarry Creek. In the June 2016 event, local overland flow due to stormwater runoff was noted to significantly affect businesses and residences in the town centre *prior* to Stonequarry Creek breaking its banks (referred to as 'mainstream flooding'). For this reason, this current report has incorporated overland flow into the flood modelling (see Section 2.9).

2.8. Picton Post Event Analysis, June 2016 Weather and Flood Event, Advisian, November 2016 (Reference 6)

Following the June 2016 flood event, Council collected High Water Mark (HWM) (as depth) information for 76 locations throughout the floodplain. These anecdotal or visual records of the peak flood depth are useful for calibrating and validating flood models. Council engaged Advisian to use the collected HWM information to validate the existing two dimensional RMA-2 model (most recently updated as per Reference 13, described in Section 2.6 above), and to comment on how the magnitude of the 2016 event compared to the 1% AEP event.

The model was validated by applying real rainfall data from the event to the XP-RAFTS hydrologic model, then running the model to produce the inflow hydrographs required for the RMA-2 hydraulic model. Initially, the XP-RAFTS model was used without adjusting any of the parameters, and was shown to predict flows within 20 m^3/s of the peak discharge determined from the gauged level and rating curve. However, the produced hydrograph did not align with the rising limb of the flood as per the then NSW Office of Water record. The initial and continuing loss rates were subsequently varied in the XP-RAFTS model to try to achieve a better 'fit' to the gauged data. The final values adopted were 35 mm and 2.2 mm/hr for initial and continuing loss respectively. The revised losses provided a much closer match to the peak flow rate recorded at the gauge (near the Railway Viaduct), with a modelled peak discharge of 578 m^3/s compared to the recorded peak flow of 575 m^3/s (as reported in Reference 6), however still did not match the shape of the recorded rising limb. It was suggested that initial rainfall losses of 80 to 100 mm would need to be applied to achieve a good fit. The RMA-2 hydraulic model produced peak flood levels for the June 2016 event that were on average 0.18 m lower than all 76 High Water Marks. This exercise was considered to provide an acceptable agreement between flood levels simulated using RMA-2 to the recorded HWM levels, and the model was considered to be validated.

The analysis also noted that the modelled peak flood levels in the simulated June 2016 event are between 0.02 m to 0.22 m higher than those predicted for the 1% AEP design event, and that the recorded rainfall exceeded the amount predicted for a 1% AEP event.

2.9. Stonequarry Creek at Picton Flood Study Update, WMAwater, 2019 (Reference 7)

At the commencement of the Stonequarry Creek at Picton Floodplain Risk Management Study and Plan, a detailed review of the models developed in the Draft Flood Study (Reference 5) was undertaken. The review found that, while the models had been developed using the best available data at the time, selection of various parameters tended to result in the overestimation of design peak flows in Stonequarry Creek. In addition, the release of ARR 2016 late in the Draft Flood Study project, availability of calibration data from the June 2016 event, consideration of Flood Frequency Analysis and a new interest in modelling overland flow behaviour led to a substantial update being undertaken.

The review and model updates are described in detail in Reference 7, and are summarised below:

- Conversion of the XP-RAFTS hydrologic model to WBNM, and refinement of the subcatchment delineation to better represent overland flow behaviour in Picton;
- Conversion of the RMA-2 hydraulic model to TUFLOW and expansion of model boundaries. TUFLOW readily allows for flood modification measures to be tested (as part of this Floodplain Risk Management Study), and is a widely industry standard package with well researched input parameters;
- Inclusion of recent residential development in the north and east of the Study Area;
- Flood Frequency Analysis completed at the Stonequarry Creek at Picton Gauge (212053), including research of Picton's flood history to provide greater context for peak flows observed within the relatively short record period. FFA results were used to validate the flows produced by the WBNM hydrologic model;
- The TUFLOW model was calibrated to the June 2016 flood event using high water marks surveyed at 76 locations. Modelled peak flood levels were on average, 0.02 m lower than recorded levels, with an even distribution above and below the recorded depths indicating that the model generally reproduced historic flood behaviour to a suitable degree and further, that there was no systematic bias that would overestimate or underestimate flood levels;
- Design flood modelling was undertaken based on the methodologies developed in Australian Rainfall and Runoff (ARR) 2019. Not only does the use of ARR 2019 methodologies represent current industry best practice, but it allows for the estimation of design flows using an ensemble of ten temporal patterns rather than a single pattern (as was applied in ARR 1987). Being derived from real, recorded storms in the 'East Coast South' region the ten temporal patterns provide a more realistic representation of storm behaviour in Picton than previously possible.

The design peak design flows and levels at the Stonequarry Creek Gauge are presented in Table 6.

Table 6: Design Peak Discharges at Stonequarry Creek Gauge (Gauge Zero: 147.803 mAHD)

Event	Peak Flow (WBNM) (m^3/s)	Peak Flow (TUFLOW) (m^3/s)	FFA Estimate (m^3/s) (See Note 2)	Peak Flood Level (mAHD)	Peak Flood Level (m Gauge Height)
20% AEP	67	66	68	151.0	3.2
10% AEP	135	138	121	152.2	4.4
5% AEP	191	193	193	152.9	5.1
2% AEP	356	349	330	154.5	6.7
1% AEP	461	452	473	155.3	7.5
0.5% AEP	492	484	-	155.6	7.8
0.2% AEP	553	542	-	156.0	8.2
PMF	3465	2771[1]	-	165.2	17.4

[1]Note: Due to a change in tributary inflow timing (especially from Racecourse Creek) due to backwatering, attenuation in the upper western areas and significant storage of floodwaters on the Victoria Park playing fields, the TUFLOW hydraulic model produces a lower peak flow rate than the WBNM hydrologic model in the PMF event. The total volume passing the gauge however is consistent between the two models.

[2]Estimates for flows rarer than the 1% AEP are beyond the extrapolation limits of the Flood Frequency Analysis, and are not reported due to the broad range across which the peak flow could be expected to occur (i.e. within the 90% confidence limits, as presented on Figure 8, Reference 7).

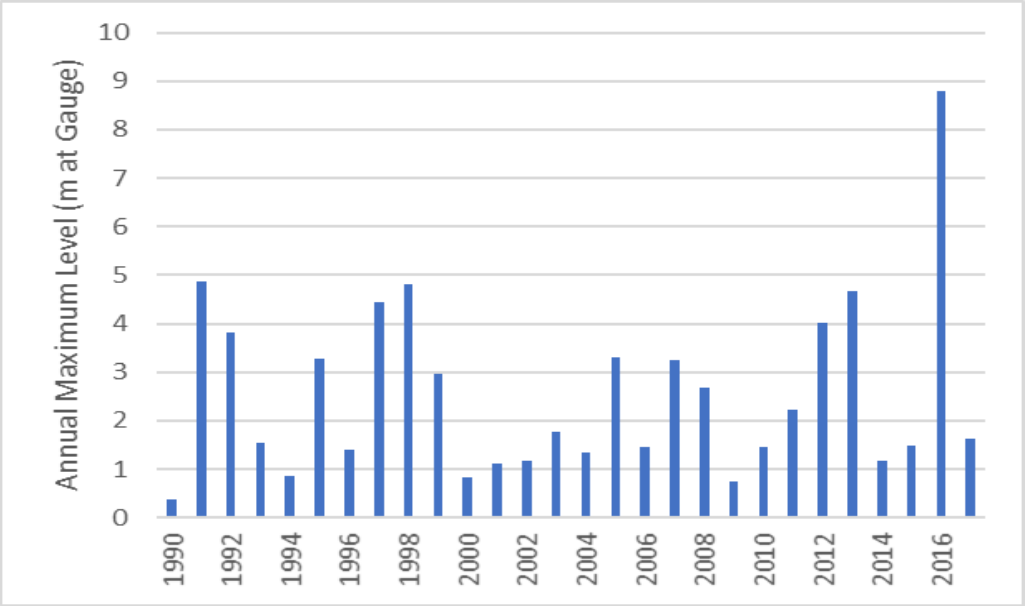
The design flood behaviour established in the Stonequarry Creek Flood Study Update (Reference 7) forms the basis of this Floodplain Risk Management Study and Plan. A detailed description of the design flood behaviour, and provision of a range of tools including hydraulic categorisation, hazard classification and flood emergency response classification are provided in Section 5.

3. FLOOD ENVIRONMENT

3.1. History of Flooding in Picton

Picton has a long history of flooding due to its location within the Stonequarry Creek floodplain, though formal gauging has only occurred since 1990 when the Stonequarry Creek at Picton gauge (no. 212053) was commissioned. In this period, the June 2016 event is by far the highest on record, as can be seen in Chart 1 below.

Chart 1: Annual Maximum Levels - Stonequarry Creek at Picton (Gauge No. 212053)



In order to gain a better understanding of floods that occurred prior to 1991, WMAwater has considered and researched the following:

- Historic floods described in previous reports (Draft Flood Study (Advisian, 2017), Picton Flood Study Report (NSW Department of Water Resources, 1989);
- Newspaper articles from the Picton Post (1855 to 1969), sourced through the National Library of Australia archives via *Trove* or previous reports;
- Long term rainfall record at the Picton Council Depot (dating back to 1880) and other nearby gauges;
- Anecdotal reports from members of the community and the Floodplain Management Committee referencing specific flood events in living memory.

The research revealed at least eight moderate to significant flood events that have occurred in Picton since 1911. There is also evidence of flooding prior to this date (e.g. in 1860, in which a flood was reported to have washed the Stonequarry Bridge away), however it is more difficult to estimate their relative magnitude as they occurred prior to the commissioning of the rainfall gauge at the Picton Council Depot (1880). A brief summary of the flood events is provided in Table 7, noting that the research is limited by the availability of newspaper articles on *Trove* and level detail provided specifically on consequences of flooding in Picton, especially if other regions were more severely affected. Nevertheless, the investigation has provided insight into the flood history within the Study Area, which has been used in the estimation of design flood discharges, described in Section 5.

Table 7: Summary of some significant flood events in Picton

Year	24 Hour Rain (mm)	2 Day Total (mm)	Summary of consequences	Source
1911	160.3	160.3	*Creek has risen over the town bridge.* *Several residents evacuated their houses to seek higher shelter. 871 points (307.3 mm) of rainfall recorded at Picton.* *Flooded creeks and waterholes in a very short time.* *7 days rain, 1125 points* *Stonequarry Creek Bridge - halfway up handrailing of the bridge. Ald. Grahams Residence flooded over floor, two feet high. T. Moraghan's drapery shop (Argyle Street) 1 ft deep. Several houses in low lying areas flooded. Mrs. Murray in Menangle Street West, Mr. J. York in Argyle Street removed from houses.* *Mr. J. Corbett's Blacksmith shop - as high as his bellows.* *Messrs. G. Barr & Sons Store - Cellar filled with water.* *Portion of Menangle street under water, as far as the kitchen of Mrs. Reeve's residence.* *Mr. J. Jessup's house completely surrounded by water.* *Damage to fencing, gardens, roads and footpaths.* *Water 4ft over Windsor Bridge.*	The Bathurst Times, *'The Big Storm',* 14 January 1911. The Picton Post, *'The Rainfall',* 18 January 1911. The Sun, *'Floods at Picton',* 31 January 1911. Camden News, *'Sensational Accidents,'* 16 February 1911.
1933	211.6	211.6	833 points (293.8 mm) of rain recorded from 9am Sunday to 9am Monday. General comments about storms and damages verifying the event but no specific locations of high water marks.	The Picton Post, *'Rain Records Go',* 25 January 1933.
1943	84.1	95.5	*"Water flowed over Argyle Street for hundreds of yards. Inundated low-situated houses on Argyle Street. Water rose above the stone supports on the bridge over Stonequarry Creek, but did not cover the decking."*	The Picton Post *'Splendid Rain', 20 May 1943*
1950	204.7	204.7	General comments about flood warnings: *"Relieving Post Master at the Picton Post Office, Mr. A.Cooper, this morning was notified of expected floods and gales in Southern and South Eastern districts, with rises on all rivers."*	The Picton Post, *'Further Rain and Gales',* 19 January 1950.
1952	163.8	163.8	*6 inches of rain recorded at Picton (152 mm)* *Wide areas of rich grazing property between Camden and Picton are under water, ranging in depth from 3 feet to 25 feet.*	Camden News, *'Nepean River Again in Flood',* 31 July 1952.
1956	216.7	216.7	*"Flood is worst in history of the town"* *"Shops suffer thousands of pounds loss"* *"water two feet six inches in St Marks"*	Department of Water Resources New South Wales, *'Picton Flood Study Report',* February 1989, Section 10.2

Year	24 Hour Rain (mm)	2 Day Total (mm)	Summary of consequences	Source
1964	201.9	201.9	Widespread flooding across Sydney. 3 inches of water in St Marks Church, little damage. *"Water overflowed from Stonequarry Creek in the main street and entered several shops and adjoining homes…"*	The Canberra Times, *'Rivers Burst Banks, Dams Overflow: Widespread Floods Force Many to Flee',* 12 June 1964. Picton Post 18/6/1964
1966	245.9	245.9	High rainfall readings at Picton Council Depot and surrounding gauges, e.g. Oakdale,	BOM Daily rainfall data
1969	156	156	Reports that the flood peaked 1 m above Argyle St bridge. A range of observed flood levels are provided in the 1989 Flood Study.	Department of Water Resources New South Wales, *'Picton Flood Study Report',* February 1989, Table 4.1.
2016	266	331.5	Worst flood on record – See detailed description below.	Note: Rain from Stonequarry Ck Gauge (Pluviograph)

Some key notes and recorded or anecdotal high water marks from the above flood events are shown on Figure A4, and a selection excerpts from the Picton Post on Figure A5.

3.2. Picton Flood Event – June 2016

Early on Sunday 5th June 2016, an East Coast Low developed causing heavy rain, strong winds and large waves along the NSW coast. The low pressure system brought widespread heavy rainfall to the northern coast and ranges, before the main rainfall focus shifted southwards to impact the south coast and ranges of NSW. Rain persisted through both Saturday and Sunday and many locations reported their wettest June on record in the first week of the month. Severe coastal erosion was reported in areas including Coogee and Collaroy. In the western areas of the Sydney Basin, major flooding occurred at Picton and Camden, with over 330 mm of rainfall observed during the event.

The gauge at Stonequarry Creek recorded a peak water level of 8.799 m (156.6 mAHD). The flooding caused damage to commercial and residential properties. Properties throughout the study area, including many along Argyle Street in the centre of town, experienced significant inundation with depths in excess of 1.5 metres recorded. A large number of trees and other in-bank vegetation were up-rooted during the flood event and conveyed downstream; a reflection of the significant volume and velocity of floodwaters along Stonequarry Creek and its tributaries. Following the event, Council collected High Water Marks at 76 locations throughout the floodplain, which have since been used to calibrate (and validate) hydraulic models. A selection of photos from the 2016 flood are shown on Figure A6.

The Flood Frequency Analysis undertaken in Reference 7 was used to estimate the magnitude of the June 2016 flood event. The analysis showed that the June 2016 flood event, which peaked at 8.799 m (with a flow rate of 580.1 m^3/s), has an annual recurrence interval of 157 years, approximately equivalent to a 0.6% AEP event. However, as the June 2016 event is the largest event on record, there is a high degree of uncertainty when estimating its magnitude. In this case, additional insight can be gained from other metrics including rainfall records and historic flood reports. Considering these sources, it is possible that the peak flow observed in the June 2016 event is even rarer than the FFA suggests, and could have a recurrence interval anywhere between 200 and 500 years.

3.3. Picton Flood Event – April 1969

Until the recent 2016 flood, the 1956 and 1969 floods were the largest floods on record at Picton. The Flood Study (Reference 5) notes the April 1969 flood is reported to have been the largest. Peaking at approximately 1 m above the deck of the Argyle Street Bridge (no equivalent gauge level recorded), the 1989 DWR Flood Study (Reference 8) determined that the flood was in the order of the 2% AEP flood event. For context, the 1969 flood reached 157.56 mAHD at the Westpac Bank, while the 2016 event was over a metre higher, reaching 158.70 mAHD at the same location (Reference 5).

4. AVAILABLE DATA

4.1. Topographic Data

Light Detection and Ranging (LiDAR) survey of the study area and its immediate surroundings was provided for the study by LPI. LiDAR is aerial survey data that provides a detailed topographic representation of the ground with a survey mark approximately every square metre. The data for the Picton area was collected in 2011. The accuracy of the ground information obtained from LiDAR survey can be adversely affected by the nature and density of vegetation, the presence of steeply varying terrain, the vicinity of buildings and/or the presence of water. The accuracy is typically ± 0.15 m for clear terrain. Topography in the immediate vicinity of the main creeks was retained from the RMA-2 model which used localised survey, and LiDAR was used in the remaining areas.

Where needed, the DEM was modified manually to represent recent development in the floodplain. In particular, parts of the Vault Hill Development had been constructed after the LiDAR was collected. Works as Executed Drawings of the North OSD basin were provided by Council (dated 31/1/28 and 12/4/18), and used to ensure details of the basin were appropriately represented. In addition, details of the roads, retaining walls and other features were taken from design drawings dated 26/8/16 (12122E4-SET F – Amended plans for Vault Hill, John M. Daly & Associates).

Towards the end of the project a revised LiDAR survey became available (captured 29/6/2019). Following public exhibition the DEM was subsequently revised in recent development areas where comprehensive details were not previously available, including the development at Jarvisfield. Mapping presented in this report utilises this updated DEM.

The data extent is shown on Figure A2. The model adopts a 2 m x 2 m grid resolution which is locally refined to show sub-grid elements such as kerbs and gutters (described in Reference 7). A 4 m x 4 m grid was adopted for the PMF event to prevent model instability due to high velocities in some areas.

4.2. Hydraulic Structures

A site inspection was undertaken in April 2018 to identify and measure key hydraulic structures, including culverts, bridges, and elements of the pit and pipe network. For larger bridges, measurements were estimated from photographs, LiDAR data and Works As Executed (WAE) drawings provided by Council where available. Information on culvert inverts and dimensions were taken from WAE and stormwater plans where available. Refer to Reference 7 for locations of bridges and culverts.

4.3. Pit and Pipe Network

A database of stormwater pits and pipes within the catchment was provided by Council. Where needed, additional details were gathered via visual inspection or assuming pipe diameters based on location and estimating pipe invert levels based on LiDAR data and reasonable pipe cover depths. Pit inverts were assumed to be 1-1.5 m below the ground level (from LiDAR), and were manually adjusted where needed to ensure no negative grades were assigned to pipes.

4.4. Design Rainfall

Design rainfall information for use with ARR 1987 methodologies was adopted directly from Reference 5. New Intensity Frequency Duration (IFD) for the Study Area was obtained from the Bureau of Meteorology (BoM) website for the purpose of the design flood modelling undertaken in Reference 7.

4.5. Floor Level Database

A floor level survey was commissioned by Council for properties estimated to be inundated in the 1% AEP event, and was undertaken by LandTeam Australia Pty Ltd in 2012. The survey included 251 properties in Picton, collecting (where available) details such as the Lot and Section number, street address, building description (construction type, number of stories), lowest property level and if applicable, lowest habitable floor level. The following were identified:

- 214 ground floor levels were surveyed;
- 168 of these were identified as ‘habitable’ floor levels;
- 32 spot heights were collected;
- 46 vacant lots were identified

This data set was supplemented by estimating floor levels of 903 (885 residential properties and 18 commercial) additional properties based on visual inspection to ensure all properties within the PMF extent were included in the database. For each property, the following details were recorded:

- Estimated floor height (m);
- Ground Level (m AHD);
- Street Address;
- Indication of house size (number of storeys);
- Location of the front entrance to the property; and
- Land Use (residential or commercial) based on information from the Wollondilly Local Environmental Plan (LEP) 2011.

The data was gathered in two stages. Stage 1 estimated properties within the preliminary PMF extent, excluding dwellings in the development zone north of Jarvisfield Road. The extension of the TUFLOW hydraulic model (discussed in Reference 7) introduced Stage 2, which is a continuation of the estimation including the developing residential properties north of Jarvisfield Road and Stargard Crescent, additional dwellings at Margaret St next to the central business district, and additional properties in the southern parts of the hydraulic model.

5. DESIGN FLOOD BEHAVIOUR

Design flood behaviour has been estimated using ARR 2016 methodologies. The modelling approach and selection of key model parameters (e.g. losses) are documented in detail in Reference 7. The results for the design flood events are presented in the following maps:

- Peak flood depth, extents and level contours on Figure A7 to Figure A14
- Peak flood level profiles (long sections) on Figure A15 to Figure A17 (chainages shown on Figure A18);
- Key Reporting Locations located on Figure A18;
- Hydraulic categories on Figure A19 to Figure A21;
- Hydraulic hazard based on the Australian Disaster Resilience Handbook (Reference 29) on Figure A22 to Figure A24.

A discussion of these results is provided in the following sections.

5.1. Description of Results

Flood risk in Picton arises from two different mechanisms: mainstream flooding, which occurs when flows in Stonequarry Creek exceed the capacity of the channel and break out of the banks, inundating adjacent land and properties; and overland flow, which refers to the runoff from the local catchment that flows towards Stonequarry Creek. The below sections describe the two sources separately. Peak flood level results are enveloped and provided as maps in Figure Set A capture the full range of flood risk across Picton.

5.1.1. Mainstream Flooding

In events up to and including the 20% AEP event, mainstream flows are generally contained within the main channels of Stonequarry Creek, Racecourse Creek and other tributaries. However, in events greater than the 20% AEP, flow breaks out of the main Stonequarry Creek channel and inundates the benched area along the left bank at the rear of properties along Davies Place (across the creek from Hume Oval). The capacity of this benched area is generally sufficient to contain the 1% AEP flow, however in events as frequent as the 5% AEP, flow breaks out from the main channel a little further downstream and flows northwards through an open drainage channel parallel to Barkers Lodge Road. In the 1% AEP event, Davies Place is overtopped to a depth of approximately 0.5 m.

Moving downstream to the town centre, the Stonequarry Creek channel contains flows in events up to the 5% AEP. However, in the 2% AEP event and above, the right bank is breached and flows break out into Argyle Street and Davidson Lane, inundating the St Mark's Anglican Church grounds and open areas around Elizabeth Street to depths of approximately 1.5 m in the 1% AEP event. The Argyle Street bridge has its deck level at 156.62 mAHD, and is overtopped to a depth of approximately 0.6 m in the 2% AEP event. The 5% AEP event reaches the underside of the bridge but is not shown to overtop the bridge deck.

Flood levels at the downstream end of Racecourse Creek are influenced by tailwater levels in Stonequarry Creek at the confluence, with elevated water levels in Stonequarry Creek causing flows to 'back up' along Racecourse Creek. The extent of this backwatering is evident in the design peak flood level profiles on Figure A16, and is most pronounced in the PMF, in which the backwatering extends for approximately one kilometre upstream of the confluence. Crawfords Creek, a tributary of Racecourse Creek, is similarly controlled by the water levels in Racecourse Creek, as indicated by the relatively flat water level on Figure A17.

5.1.2. Overland Flow

There are two main areas of Picton affected by overland flow: the eastern part of the town centre which receives runoff from Vault Hill, and the recently developed areas just south of Racecourse Creek. In each of these areas, overland flow is generally shallow (less than 0.1 m) in the 5% AEP event, deepening only in flatter, low lying areas closer to the main creeks. Flow from the north east of town approaches Margaret Street and continues down Argyle Street towards Stonequarry Creek. In the 1% AEP event and greater, depths in the major drainage lines in Jarvisfield such as the open channel between Coldenham Road and the Golf Course reach up to 0.8 m. High velocities in this channel leads to its classification as floodway, described in Section 5.3. Overland flow approaching Stonequarry Creek from the western side is generally limited, though there is a minor flow path along the Old Hume Highway (Argyle Street). In events including and greater than the 20% AEP event, Menangle Street is overtopped just south of Baxter Lane, to a depth of approximately 0.3 m in the 20% AEP event.

5.2. Design Peak Flows and Levels

The peak design flows and levels at the Stonequarry Creek Gauge are presented in Table 8.

Table 8: Design Peak Discharges at Stonequarry Creek Gauge (Gauge Zero: 147.803 mAHD)

Event	Peak Flow (WBNM) (m^3/s)	Peak Flow (TUFLOW) (m^3/s)	FFA Estimate (m^3/s)	Peak Flood Level (mAHD)	Peak Flood Level (m Gauge Height)
20% AEP	67	66	68	151.0	3.2
10% AEP	135	138	121	152.2	4.4
5% AEP	191	193	193	152.9	5.1
2% AEP	356	349	330	154.5	6.7
1% AEP	461	452	473	155.3	7.5
0.5% AEP	492	484	-	155.6	7.8
0.2% AEP	553	542	-	156.0	8.2
PMF	3465	2774[1]	-	165.2	17.4

[1]Note: Due to a change in tributary inflow timing (especially from Racecourse Creek) due to backwatering, attenuation in the upper western areas and significant storage of floodwaters on the Victoria Park playing fields, the TUFLOW hydraulic model produces a lower peak flow rate than the WBNM hydrologic model in the PMF event. The total volume passing the gauge however is consistent between the two models.

[2]Estimates for flows rarer than the 1% AEP are beyond the extrapolation limits of the Flood Frequency Analysis, and are not reported due to the broad range across which the peak flow could be expected to occur (i.e. within the 90% confidence limits, as presented on Figure 8, Reference 7).

The peak design levels for the 5%, 1%, and PMF events at key locations throughout the town centre are presented in Table 9. A map with the key locations has been provided on Figure A18.

Table 9: Peak Flood Heights at Key Locations

Location	Design Peak Flood Level (mAHD)		
	5% AEP	1% AEP	PMF
Picton Hotel (Corner of Menangle St & Argyle St)	157.0	158.0	166.6
Argyle Street Bridge (Over Stonequarry Creek)	155.6	157.8	166.4
Khan's SUPA IGA (Magnolis Ln)	157.8	158.2	166.8
George IV Inn (Corner of Argyle St & Crakanthorp Ln)	157.0	158.0	166.5
Liquorland Picton (Argyle St)	163.4	163.4	166.8

5.3. Hydraulic Categorisation

Hydraulic categorisation of the floodplain is used in the Floodplain Risk Management process to identify risk across the floodplain, assist in the assessment of the suitability of future types of land use and development and the formulation of floodplain risk management plans. The Floodplain Development Manual (Reference 4) defines land inundated in a particular event as falling into one of the three hydraulic categories listed in Table 10.

Table 10: Hydraulic Categorisation Definitions (*Floodplain Development Manual* (Reference 4))

Category	Definition
Floodway	• Those areas where a significant volume of water flows during floods; • Often aligned with obvious natural channels; • Areas that, even if only partially blocked, would cause a significant increase in flood levels and/or a significant redistribution of flood flow, which my adversely affect other areas; and • Often, but not necessarily, areas with deeper flow or areas where higher velocities occur.
Flood Storage	• 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, for example by the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased; and • Substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.
Flood Fringe	• 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.

To define the floodway, the Howells et al. (Reference 22) methodology was applied, which differentiates the floodway from other hydraulic categories by selecting a velocity-depth product criteria that exceeds a specific threshold. These parameters were confirmed iteratively through encroachment analysis, in which all areas not defined as 'floodway' were totally excluded from the modelling domain, and the subsequent impact on flood levels examined. If the reduction in conveyance area resulted in an increase in greater than 0.1 m to existing flood levels, the floodway

area was increased. This approach is informed by Section L4 of the Floodplain Development Manual (Reference 4), which defines Flood Storage areas as *"those areas outside floodways which, if completely filled with solid material, would cause peak flood levels to increase anywhere by more than 0.1 m and/or would cause the peak discharge anywhere downstream to increase by more than 10%."* The resulting parameters are provided in Table 11. Following application of these criteria, the resulting floodway areas were examined to ensure continuity of flowpaths, and to remove any isolated grid cells inappropriately classified as floodway (for example as an artefact of the modelling).

Table 11: Hydraulic Category Definition Parameters

Category	Floodway Definition Parameters
Floodway	VD > 0.3 m^2/s and V > 0.3 m/s;
Flood Storage	Areas outside floodway where D > 0.4 m
Flood Fringe	Areas outside floodway where D < 0.4 m

Hydraulic Categorisation for the 5% AEP, 1% AEP and PMF events are shown on Figure A19 to Figure A21 respectively. The analysis indicates that in the 5% AEP event, only the main creek channel and its tributaries are classified as floodways. Similarly, in the 1% AEP event, most of the floodway remains within the main Stonequarry Creek channel and its tributaries, with a few exceptions (described below), and out of bank flooding generally classified as flood storage or flood fringe. In particular, a major flood storage area is formed in and around Elizabeth Street. In the PMF event, most of the study area becomes a floodway with some flood storage and fringe areas closer to the edge of the floodplain.

In Stonequarry Creek in the 1% AEP event, the floodway extends along Argyle Street (between Coull Street and Walton Lane) and Davidson Lane at the rear of several commercial properties. The playing fields in Victoria Park become critical to the conveyance of flow in this size event, and are also classified as floodway due to the high velocities occurring in the open space. This is consistent with the flood behaviour observed in the June 2016 event.

In the northern section of the study area south of Racecourse Creek, three of the major local drainage lines area classified as floodway, including the Yallambi Street drain, the open channel behind properties on the western side of Old Racecourse Close, and the flow path between Coldenhan Road and the golf course.

5.4. Hydraulic Hazard Classification

Hazard classification plays an important role in informing floodplain risk management in an area as it reflects the likely impact of flooding on development, vehicles and people. In the Floodplain Development Manual (Reference 4) hazard classifications are essentially binary – either Low or High Hazard as described on Figure L2 of that document. However, in recent years there has been a number of developments in the classification of hazard especially in *Managing the floodplain: a guide to best practice in flood risk management in Australia (Third Edition)* (Reference 19). The Flood Study (Reference 5) presents hazard categorisation mapping based on the Floodplain Development Manual, while this study presents revised mapping based on the methodology outlined in Reference 19. The classification is divided into 6 categories (H1-H6), listed in Table 12, which indicate constraints of hazard on people, buildings and vehicles appropriate to apply in each zone. The criteria and threshold values for each of the hazard categories are presented in Diagram 1.

Table 12: Hazard Categories

Category	Constraint to people/vehicles	Building Constraints
H1	Generally safe for people, vehicles and buildings	*No constraints*
H2	Unsafe for small vehicles	*No constraints*
H3	Unsafe for vehicles, children and the elderly	*No constraints*
H4	Unsafe for vehicles and people	*No constraints*
H5	Unsafe for vehicles and people	All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure.
H6	Unsafe for vehicles and people	All building types considered vulnerable to failure

Diagram 1: Hazard Classifications

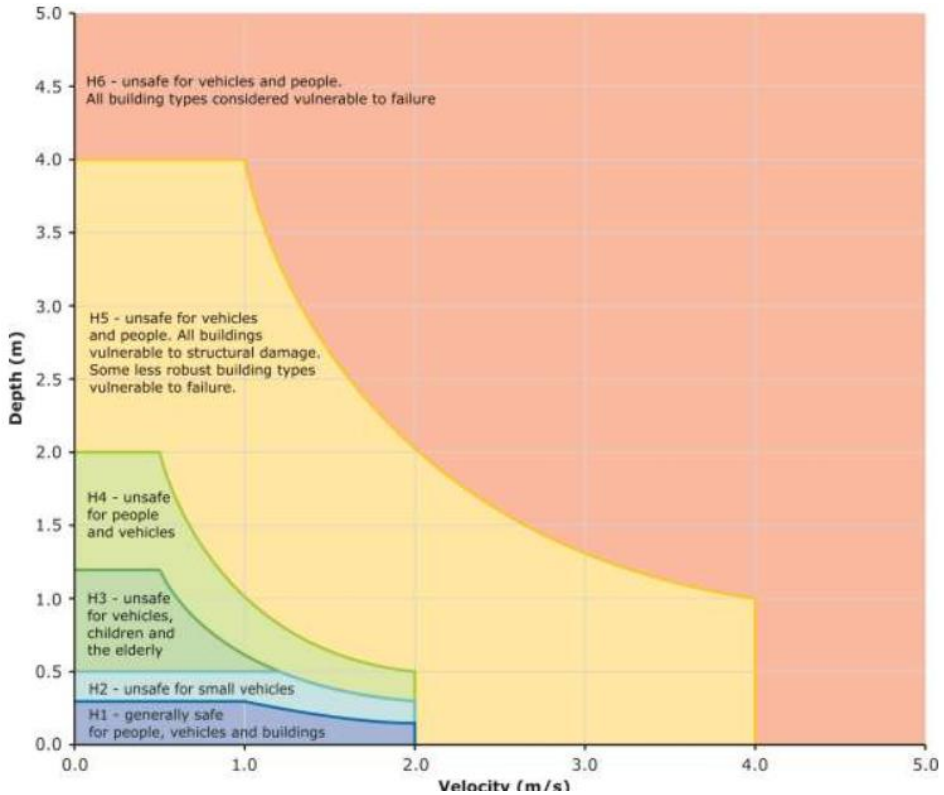


Figure A22 to Figure A24 present the hazard classifications based on the H1-H6 delineations for the 5% AEP, 1% AEP and PMF events respectively. In the 5% AEP event, all areas outside of the main channels of Stonequarry Creek and its tributaries are generally classified as H1 “generally safe for people, vehicles and buildings”. However, in the 1% AEP event, parts of the town centre become much more hazardous, with Argyle Street classified as H5 between Menangle Street and Stonequarry Creek.

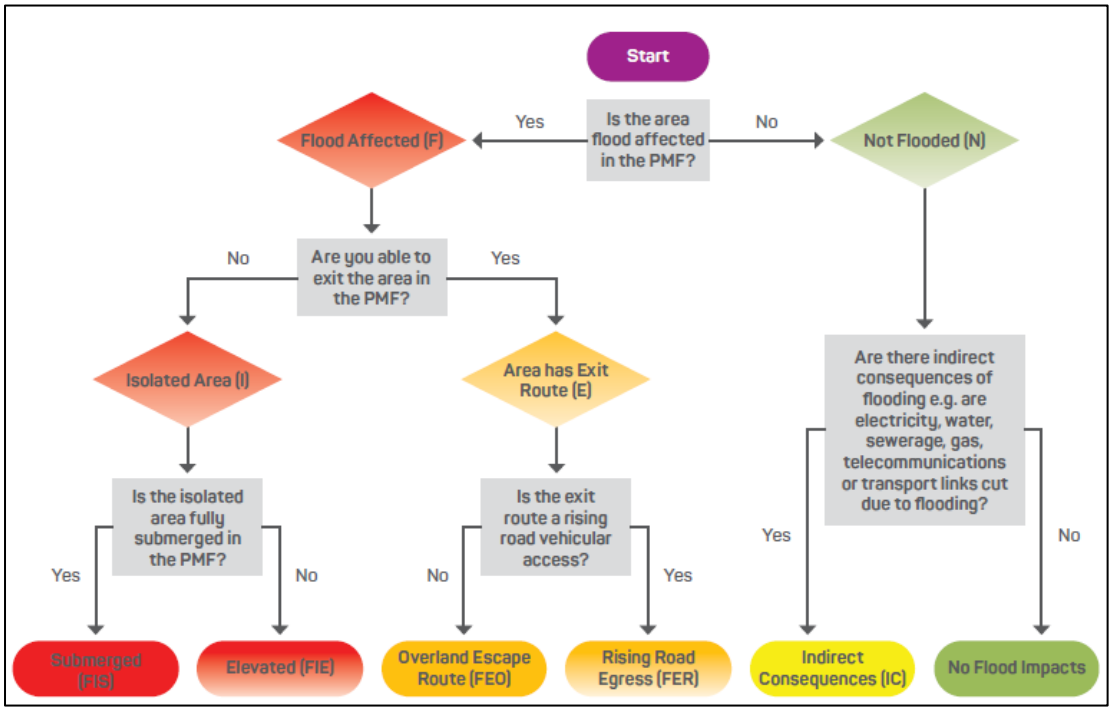
Further south, the Victoria Park playing fields are also classified as H3-H5, indicating that these areas would be dangerous for people and vehicles, and in parts, even buildings. Recently developed parts of Jarvisfield in the town’s north are generally classified as H1, indicating a relatively low level of hazard constraint. In sections where flow becomes faster, for example along defined drainage channels, or deeper (in small dams within the golf course) the hazard classification is elevated. The Yallambi Street drain in particular is classified as H5 in the 1% AEP, and given its proximity to residential development, public safety and the suitability of on-street parking may warrant further investigation as part of the flood risk mitigation option assessment.

5.5. Flood Emergency Response Classification

Flooding can result in the isolation of the landscape and the subsequent obstruction of evacuation routes and access to medical/emergency facilities. The Flood Emergency Response Classification (FERC) provides a basis for understanding the varying nature, seriousness and scale of these issues, particularly isolation, across the floodplain. The FERC for the study area was undertaken in accordance with the *Australian Disaster Resilience Handbook 7 Managing the Floodplain: A guide to best practice in flood risk management in Australia (AIDR 2017)* (Reference 29). The methodology (refer to Diagram 2) was applied to the PMF design event and the classification results are presented on Figure A25. Key community facilities have also been indicated on this figure for context regarding their location in the floodplain. This information will be provided to the SES upon completion of this project.

It is important to note that the FERC classification has been prepared based on existing development within Picton, and does not consider the classification that may pertain to new development on currently vacant land.

Diagram 2 Flow chart for determining flood emergency response classifications (Reference 27)



Outcomes of the FERC Classification are presented on Figure A25, and results summarised below:

- The area with the greatest risk of isolation is in and around Elizabeth Street. This area is classified as FIS (Submerged), consistent with anecdotes from the June 2016 flood of residents stranded by floodwaters, climbing trees to escape the rising water, and awaiting rescue. Options to reduce the flood risk to life (and property) at this location, and throughout Picton more broadly, are described in Section 10.4 of this report. Other areas that become at risk of isolation in rarer events include residences on Davies Place, and Magnolia Drive. These areas are also classified as FIS (Submerged);
- The remainder of properties in the floodplain (within the PMF extent) either have vehicular access to higher ground, and are classified as FER (Rising Road Egress), or FEO (Overland Escape Route). It is noted that the lower lying parts of Picton, particularly around the Argyle Street commercial precinct, are at considerably higher risk than the residential areas in Jarvisfield. This is due to the mainstream flood risk from Stonequarry Creek that exists in the town centre, as opposed to the much shallower overland flow that generally occurs in the northern parts of Picton. However, in a very rare event, residences along Racecourse Creek would also become subject to mainstream flood risk, though Racecourse Creek would break its banks at a much later stage than Stonequarry Creek. The areas classified as FER have been displayed to show the flood depth in the PMF to provide greater context to the flood risk at each location (on Figure A25); and
- The remaining development within the Study Area, outside of the PMF extent, is classified as IC (Indirect Consequences). Whilst not being directly affected by inundation, occupants of these properties would suffer indirectly due to the loss of access to services in Picton as a result of flooding, including for example, loss of utilities such as sewerage, power, or telecommunications, transport routes to the south, and access to key facilities such as grocery stores.

6. CURRENT FLOODPLAIN RISK MANAGEMENT

Picton has a long history of flooding, with significant events occurring in 1956, 1969, 1991, 2013 and recently in June of 2016. Over the years, Wollondilly Shire Council has adopted a range of measures and policies to manage the impacts of flooding on the community of Picton and the surrounding environment.

This section gives a brief overview of some of Council's current major floodplain risk management strategies, noting that it is not exhaustive, and a range of assets such as detention basins and drainage networks also contribute to the management of flood risk (particularly due to overland flow) in Picton.

Section 11 provides recommendations to further improve and complement these strategies.

6.1. Land Use Planning and Development Controls

Wollondilly Shire Council is responsible for managing development in flood prone areas. Land use planning limits and controls are an essential element in managing flood risk and the most effective way of ensuring future flood risk is managed appropriately (Reference 4). The Wollondilly LEP 2011 sets out the land use zoning in the Wollondilly LGA. Shown on Figure A3, the land use zoning guides the types of development permissible in different parts of the LGA. In the context of flooding, the Wollondilly LEP 2011 is used to ensure development is compatible with the flood risk at that location. In Picton specifically, the following characteristics of the land use zoning contribute to management of flood risk:

- Retention of E2 Environmental Conservation in the main channel of creeks, and either public or private recreation (RE1 or RE2 respectively) in the overbank areas;
- Zonings that support residential development are largely outside the 1% AEP flood extent, with the exception of R3 Medium Density Residential between Menangle Street and Stonequarry Creek;
- The lower lying parts of Argyle Street (subject to mainstream flood risk) is zoned as B2-Local Centre. The Manual (Reference 4) notes that businesses generally have greater flexibility in recovering financially from severe flood events (compared to residents). In the past, floor level controls have been applied to commercial developments to minimise the frequency of inundation and reduce property damages.

These factors have resulted in residential development being subject only to flood risk in rarer events, and more resilient land uses in higher risk areas. Further discussion of current controls is provided in Section 9, and recommendations provided in Section 11.4.

6.2. Flood Warning System

Flash floods are floods of a short duration and a relatively high flow that occur within six hours of rain falling (Bureau of Meteorology, BOM). While the BOM does not provide warnings for flash flood catchments (such as Stonequarry Creek), it does provide forecasts and warnings for severe weather conditions and potential heavy rainfall that can cause flash flooding. Flash flood warnings themselves are provided by state and local government where gauges and warning systems are available.

The Wollondilly Shire Flood Warning System is based on recorded real-time data from three gauges, with an alarm dial-out triggered at the following specific thresholds:

- 212053 - Stonequarry Creek at Picton: Gauge Height 3.5 m (between a 20% AEP (3.2 m) and 10% AEP (4.4 m))
- 568295 - Lakesland Road: Rainfall Intensity of 15 mm/hr*
- 568296 - Thurns Road: Rainfall Intensity of 15 mm/hr*

*Note: an intensity of 15 mm/hr over a 6 hour period is equivalent to a 5% AEP storm event, while the same intensity over a 9 hour period is equivalent to a 1% AEP event, according to ARR 2019 IFDs (Reference 1).

Appendix 3.1 of the *Operation of Flood Warning Network for Wollondilly Shire Council, Report for 2001 - 2002* (Reference 33), provides an overview of the rain gauge sites' flood warning alarm features. The dataloggers installed at the two rain gauges record rainfall intensity for 15 minute periods, and sum the previous 4 samples to determine the hourly rainfall intensity. As soon as the rainfall intensity over the past hour reaches 15 mm, the data logger rings State Emergency Services (followed by Wollondilly Shire Council) to indicate the alarm threshold has been reached. The system has since been updated to provide SMS and email notifications when the trigger levels have been reached, but no interpretation is provided (e.g. size or severity of flooding to expect, nor what actions to take).

Diagram 3 shows when rainfall trigger thresholds were reached in the lead up to the June 2016 flood event, in relation to recorded rainfall and the water level in Stonequarry Creek, and particularly, when the Argyle Street bridges was overtopped.

Recommendations regarding potential improvements to the Wollondilly Shire Flood Warning System are made in Section 11.3.1.

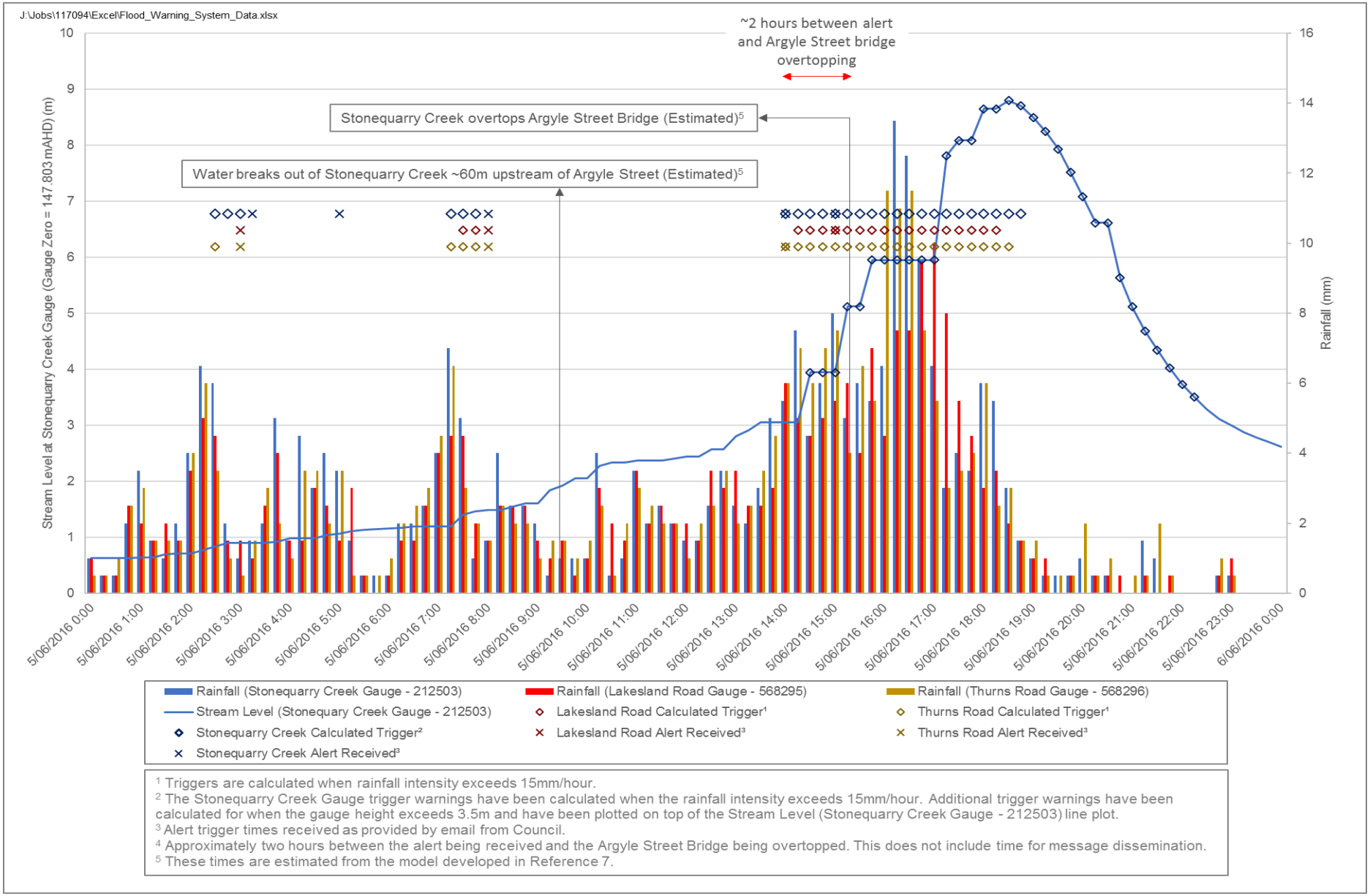


Diagram 3 Flood Warning Alerts during the June 2016 Event

6.3. Vegetation Management

Wollondilly Shire Council undertakes a comprehensive program to manage vegetation within and adjacent to Stonequarry Creek and Racecourse Creek, as well as other minor tributaries in the LGA. The vegetation management program came about following the initial Stonequarry Creek Floodplain Management Study (Reference 9) and Plan (Reference 10), which recommended 'stream clearing' as a means of reducing peak flood levels. Following this recommendation, the Stonequarry Creek Vegetation Management Plan was completed (Reference 11), which provided recommendations for the types and extent of works that would reduce the hydraulic roughness of the channel (and thus relieve flood levels) as much as possible without impacting on bank stability, acknowledging the essential role that riparian vegetation plays in bank stabilisation. Following the recommendations, Council currently undertakes regular vegetation thinning, vegetation debris removal, weed control and crown lifting.

Following the June 2016 event specifically, Council redoubled efforts to 'clean up the creek', with additional allocation of resources over the subsequent 3 years:

- 2016: 580 hours of labour;
- 2017: 100 hours, plus;
    - NSW Soil Conservation Service - tree removal and bank stabilisation
    - Stonequarry Creek River Process and Erosion Report complete –November 2017
- 2018: 160 hours, plus:
    - Opening up the channel behind the townhouses in Menangle St
    - Casuarina tree relocation to more stable position – August (Soil Con)

Bank stability plays an important role in the creek maintaining conveyance. The NSW Soil Conservation Service in the Stonequarry Creek River Process and Erosion Review completed in October 2017, (Reference 15), noted that the creek showed resilience to the June 2016 Event, with the in-stream vegetation contributing to the mitigation of channel damage. The report also noted that '*Councils vegetation management practices, particularly crown lifting of in-channel trees, selective removal of regrowth, and weed control, appear to be producing no reach-scale instabilities (of the kind related to increased velocity of resultant floodwaters). It is recommended these be continued, due to their lessening backwater effects in flooding, and therefore favourable outcome in lessening flood peaks.'* The current level of vegetation removal is at the upper limit of what is possible before bank stability becomes compromised, potentially resulting in bank slump and a significant loss of conveyance capacity. It is not feasible to increase the amount of vegetation removal without significantly altering the shape of the channel, specifically, much flatter banks would be needed. Further discussion regarding this is provided in Section 11.5.2.4. This Section also investigates how flood behaviour would be worsened if Council *did not* continue its current program, and quantifies the potential damage to property that would result.

6.4. Ongoing Community Resilience

Particularly following the June 2016 event, Wollondilly Shire Council led a range of programs and efforts to assist the community in recovering from severe flood events, and improving resilience and preparedness for future flood events. Council engaged Nemesis Consultancy Group to complete an Investigation Report – "Report on the Community Resilience Innovation Program, Wollondilly Shire Council arising from a significant storm event at Picton in June 2016" (Reference 20), which contained a number of recommendations for Council to progress, including several relating to community engagement. Part of this engagement included interactive workshops involving residents, community leaders and community organisations, providing a forum to reflect on the June 2016 flood event, and how improvements to emergency response and the immediate flood recovery period could be made.

Council is now facing the challenge of engaging with the community about flood risk three years on from the last major event, and in the midst of a period of drought. Undertaking Flood Studies and Floodplain Risk Management Studies contributes to keeping flooding on the agenda, as each study necessarily involves a degree of community consultation and public exhibition. Additionally, Council provides flood information from its adopted studies to residents via its online 'Flood Information Application (described further in Section 9.2.5). In addition to this, recommendations for strategies to continue engaging with the community and improving flood awareness are provided in Section 11.3.2.

7. ECONOMIC IMPACTS OF FLOODING

7.1. Background

A flood damages assessment has been undertaken to determine the economic costs of flooding due to the Stonequarry, Racecourse and Crawfords Creeks (and other tributaries), and overland flow in Picton. Damages can be defined either as tangible or intangible. Tangible damages are those for which a monetary value can be easily assigned, while intangible damages are those to which a monetary value cannot easily be attributed. Damages are further categorised as being either direct or indirect. Direct damages are caused by direct contact with flood water, for example, damages to buildings and their contents. Indirect damages refer to the knock-on effects of flood events, such as loss of wages or traffic disruption.

The below assessment focuses on the direct tangible damages to properties caused by flooding in Picton. It is noted that there are direct damages (e.g. to roads, bridges, other infrastructure) that are not included in the assessment as there is no clear methodology available to do so. The damages assessment forms the basis of quantifying the benefits of certain mitigation measures investigated later in this study. Analysis of other tangible damages, and intangible aspects, is captured via a multi-criteria matrix assessment in the option investigation process. The damages assessment methodology is based on DPIE guidelines and is summarised below.

7.2. Assessment Methodology

The flood damages assessment methodology is presented below:

- **Establish design flood modelling results** for the 20%, 10%, 5%, 1%, 0.5%, 0.2% AEP and the PMF events. Flood modelling results are derived from the models established in Reference 7, presented in Section 5 of this report;
- **Obtain floor level data (refer to Section 4.5):**
    - Surveyed floor level data was obtained for 168 properties that were estimated to be located within the 1% AEP flood extent;
    - Floor levels for another 903 properties were estimated by site visit and LiDAR data;
    - In total: 984 residential properties, and 87 commercial properties were included in the assessment.
- **Determine the peak flood depth** that would occur at each property during each design flood event;
- **Apply stage-damage curves** (derived from DPIE (formerly OEH) Guidelines, Reference 21) to relate the depth of flooding to a monetary cost in each design flood event;
- **Calculate the Average Annual Damage (AAD)**. The AAD represents the estimated tangible damages sustained every year (on average), over a long period of time.

Note that the results are not an indicator of individual flood risk exposure, but part of a regional assessment of flood risk. Furthermore, the purpose of the damages assessment amount is not to calculate the actual damage that would be incurred in a flood, but to form a basis of comparison with other flood prone communities throughout NSW, and a baseline against which mitigation options can be assessed.

7.3. Flood Damage Assessment Results

The flood damages assessment in Picton took into account damage from both mainstream flooding and overland flow mechanisms, and included direct damage to both residential and non-residential (i.e. commercial and industrial) property types. The overall results are summarised in Table 13, with a breakdown provided for residential provided in Table 14 and Table 15 respectively.

Table 13 Combined (Residential and Commercial/Industrial) Flood Damages for Picton

Event	No. Properties Affected (Flooded below floor)	No. Properties Flooded Above Floor Level	Total Damages for Event	Ave. Damage Per Flood Affected Property	% Contribution to AAD
20% AEP	17	1	$ 51,200	$ 11,707	2%
10% AEP	30	4	$ 394,800	$ 33,095	7%
5% AEP	41	10	$ 676,400	$ 35,383	8%
2% AEP	82	42	$ 5,240,800	$ 116,476	27%
1% AEP	114	63	$ 9,877,800	$ 166,524	23%
0.5% AEP	115	67	$ 10,724,800	$ 180,419	15%
0.2% AEP	122	74	$ 12,664,700	$ 205,158	11%
PMF	449	418	$ 74,772,700	$ 456,012	8%
Average Annual Damages (AAD)			**$ 333,900**	**$ 4,000**	**100%**

Table 14 Residential Flood Damages for Picton

Event	No. Properties Affected (Flooded below floor)	No. Properties Flooded Above Floor Level	Total Damages for Event	Ave. Damage Per Flood Affected Property	% Contribution to AAD
20% AEP	16	1	$ 42,200	$ 2,635	13%
10% AEP	19	2	$ 73,100	$ 3,849	12%
5% AEP	23	4	$ 181,600	$ 7,894	13%
2% AEP	36	7	$ 421,400	$ 11,706	19%
1% AEP	54	13	$ 1,022,800	$ 18,941	15%
0.5% AEP	55	14	$ 1,103,800	$ 20,070	11%
0.2% AEP	60	19	$ 1,651,000	$ 27,516	9%
PMF	376	345	$ 51,478,300	$ 136,910	10%
Average Annual Damages (AAD)			**$ 48,100**	**$ 100**	**102%**

Table 15 Commercial flood damages for Picton

Event	No. Properties Affected (Flooded below floor)	No. Properties Flooded Above Floor Level	Total Damages for Event	Ave. Damage Per Flood Affected Property	% Contribution to AAD
20% AEP	1	0	$ 9,100	$ 9,072	0%
10% AEP	11	2	$ 321,700	$ 29,246	6%
5% AEP	18	6	$ 494,800	$ 27,489	7%
2% AEP	46	35	$ 4,819,400	$ 104,769	28%
1% AEP	60	50	$ 8,855,000	$ 147,584	24%
0.5% AEP	60	53	$ 9,621,000	$ 160,349	16%
0.2% AEP	62	55	$ 11,013,800	$ 177,641	11%
PMF	73	73	$ 23,294,500	$ 319,102	8%
Average Annual Damages (AAD)			**$ 285,700**	**$ 3,900**	**100%**

7.3.1. Total Flood Damages

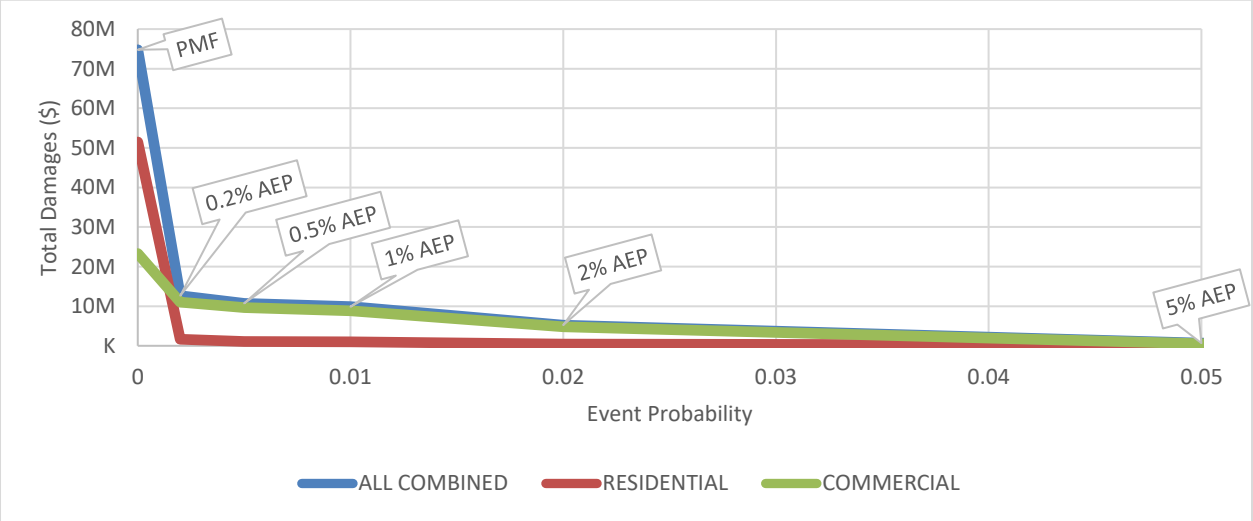
The total damages in each AEP event caused by flooding in Picton is shown in Chart 2. The results indicate two key characteristics of flood damage in Picton. Firstly, due to the deeply incised channel of Stonequarry Creek, mainstream flooding in events smaller (more frequent than) approximately a 2% AEP event is contained within the creek channel. It can be seen that at the end of the scale (5% AEP events), the total flood damage is relatively low as it is caused by overland flow affectation. Whilst overland flow can become quite deep and fast flowing along Argyle Street, it generally causes a far lower level of damage than the much greater flood depths that occur from mainstream out of bank flooding, which for Picton, only starts to occur at approximately the 2% AEP mark.

The second observation is that for events smaller than the 0.2% AEP, residential damages are very low, with the bulk of the total damages made up by the damage to commercial properties. This is consistent with the way in which Picton has been developed: the majority of residential dwellings are located on higher ground away from the Stonequarry Creek floodplain, while areas zoned for commercial or industrial land uses are located immediately adjacent to the river, and therefore subject to a great deal more flood risk than residential properties.

The two observations gleaned from the damages analysis can be used to develop a targeted approach to investigating suitable flood risk mitigation options. To have the most impact in reducing flood risk to properties in Picton, options need to a) be effective in mainstream events equal to and greater than the 2% AEP event, and b) assist in the reduction of damages to commercial properties. Mitigation options that meet these two criteria are identified and assessed further in Section 10.4.

Further, it is noted that the Insurance Council of Australia has estimated that the total value of insurance claims in Picton following the June 2016 event would have been in the order of $10M. This is in line with the estimates of the direct, tangible flood damages incurred in a design event in the order of a 1% AEP – 0.2% AEP event, which is consistent with the estimated magnitude of the June 2016 event. Further discussion on the current understanding of the size of the June 2016 event is provided in Reference 7.

Chart 2 Total Flood Damages



7.3.2. Annual Average Damages

Depending on its size (or severity), each flood will cause a different amount of flood damage within a flood prone area. Annual Average Damage (AAD) is the average damage per year that would occur in a nominated development situation (i.e. current catchment conditions in Picton) from flooding over a very long period of time (Reference 3). That is, the AAD is equal to the total damage caused by all floods over a long period of time divided by the number of years in that period. Note that it is assumed that the development situation is constant over the analysis period.

The AAD in Picton due to mainstream flooding from Stonequarry Creek and overland flow is summarised in Table 16.

Table 16 Annual Average Damages

Property Type	Annual Average Damages		% Contribution to total AAD
Residential	$	48,100	14%
Commercial	$	285,700	86%
Total	**$**	**333,900**	**100%**

The comparison shown in Table 16 reiterates the trends shown by the total flood damages results: that the bulk of flood damages in Picton are made up by commercial flood damages. Flood damages to commercial properties contributes approximately seven times as much to Picton's AAD as residential flood damages. This again is consistent with a large proportion of flood prone land being zoned for business or industry, with residential zonings generally located away from the immediate out-of-bank areas around Stonequarry Creek.

7.3.3. First Event Flooded

In addition to assessing potential tangible costs due to various flood events and AAD, the damages assessment is useful in identifying the frequency of event in which residential and commercial properties are likely to be first flooded above floor level. Figure A26 shows all properties in the Study Area that are estimated to be flooded above floor, categorised by the design event in which they are expected to be subject to over-floor flooding. The results indicate that residential dwellings in Picton are largely located outside of the PMF, with 649 properties not flooded over floor in any event, and a total of 348 properties (326 of which are residential) that are not flooded in an event more frequent than the PMF. This indicates that Wollondilly's land use planning controls have very effectively limited the exposure of residential properties to flood risk.

Conversely, commercial damages are incurred far more frequently, both due to overland flow entering premises (particularly along Argyle Street), and when Stonequarry Creek breaks its banks and inundates the CBD. Note that Commercial premises are indicated as squares on Figure A26. In addition, another contributing factor is that businesses tend to have lower floor levels than residential properties due to differing minimum floor level requirements contained within Development Control Plans. This is true of most urban areas, as businesses generally have a greater flexibility in managing risk and recovering financially from flooding (Reference 4). In Argyle Street businesses in particular, the competing objectives of accessibility, street activation and flood protection need to be balanced. Discussion on flood related development controls for commercial premises in Picton (for example, to set minimum floor level or flood proofing requirements) is provided in Section 11.4.

8. STAKEHOLDER ENGAGEMENT

One of the central objectives of the FRMS&P process is to actively engage with the community and stakeholders throughout the process to achieve the following key outcomes:

- Inform the community about the current study;
- Identify community concerns in regard to flooding;
- Gather ideas and information on potential management options for the floodplain; and
- Seek feedback on recommended options via Public Exhibition.

"Community" refers to government (both state and local departments), business, industry and the general public. Consultation with the community is an important element of the Floodplain Risk Management process facilitating community engagement, building confidence in flood modelling tools, and leading to acceptance and ownership of the overall project.

8.1. Floodplain Risk Management Committee

The process of managing flood risk in Picton is assisted by the Floodplain Risk Management Committee. The committee is made up of Councillors, Council Staff from a variety of areas across Council, NSW Government Agencies and Community representatives. 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.

8.2. Community Consultation

Following Wollondilly Shire Council's resolution in December 2017 to exhibit the Flood Study, initial community consultation for the recently commenced FRMS was undertaken in conjunction with the Public Exhibition of the Flood Study. Council noted that the key messages were that "Council wants to be proactive about flooding in Picton", and "Council has studied the possibilities for flooding in Picton and is looking for ways to mitigate risks for the community."

Community engagement was undertaken from the 19th March to the 28th April 2018 to promote awareness of flood behaviour and extents in Picton, give residents an opportunity to review and comment on the Stonequarry Creek (Picton) Flood Study (Advisian, 2017), and to begin a conversation with the community about possible options to mitigate flood risks in the future as part of the Stonequarry Creek (Picton) Floodplain Risk Management Study (FRMS).

Wollondilly Shire Council, with support from WMAwater, engaged with the community via a range of mediums to try and reach as broad an audience as possible. These strategies are outlined as follows:

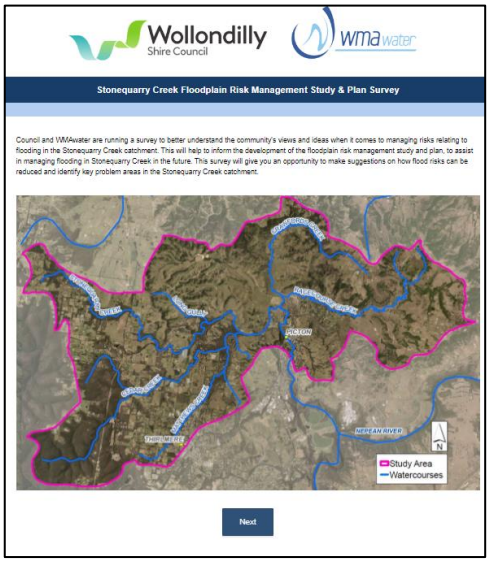
8.2.1. Targeted Letters

871 letters were sent out to key stakeholders within the Stonequarry Creek Floodplain informing them of the study and providing information on the ways they could be involved. The newsletter directed them to online information sources, such as www.Engage.Wollondilly.nsw.gov.au, which contained a link to the online survey, PDF copies of the Flood Study, and details about the community drop-in session. A copy of the newsletter is provided in Appendix B.

8.2.2. Questionnaire

A questionnaire was established to allow residents and business owners to make suggestions regarding potential flood risk mitigation options in Picton.

An online version was available via surveymonkey.com) and was available as a hardcopy on request. 24 online responses and 3 hardcopy responses were received, representing less than 5% of the targeted population. WMAwater contacted respondents to further discuss their suggestions and the concerns raised in their survey responses. A copy of the questionnaire is provided in Appendix B, and the outcomes are described in Section 8.3.



8.2.3. Online Information

Information was placed on www.Engage.Wollondilly.nsw.gov.au, such as links to relevant reports and the online survey.

8.2.4. Social Media

Seven social media (Facebook) posts were made about the public exhibition throughout the engagement period. The posts had an average audience reach of 1776 views, 6 interactions per post (likes, comments and shares) and 93 post clicks.

8.2.5. Newspaper & Other Media

Local print media is utilised where available to inform the community of the projects undertaken by Council, and to promote opportunities for participation. The articles and media releases distributed as part of this study are outlined below.

- Newspaper advertising about the public exhibition was placed in the Wollondilly Advertiser (28th March 2018) and District Reporter (30th March 2018);
- Information about the public exhibition was included in the Mayors Column which features in the Wollondilly Advertiser and District Reporter (4th April 2018);
- A media release was distributed to media outlets about the public exhibition (23rd March 2018);

- Information was sent to Wollondilly Anglican College, Picton High School, Picton Public School and St Anthony's Primary School for inclusion in the school newsletter (23rd March 2018).

8.2.6. Drop - In Session

A drop-in session was held on the 10th April 2018 at the Wollondilly Shire Hall (44-60 Menangle Street, Picton). 18 people attended the session, which was hosted by Wollondilly Shire Council staff with the WMAwater project team in attendance. The drop-in session provided an opportunity for discussion of the results of the Flood Study (Reference 5) as well as a place for residents and business owners to voice suggestions for mitigation options. These suggestions are in Section 8.3.

8.2.7. Engagement with St Anthony's Primary School

One of the most effective means of reducing flood risk is by improving residents' awareness and understanding of their own flood risk. As a result, Floodplain Risk Management Study and Plans can often make recommendations to improve flood education strategies within the community. One method by which this can be achieved is by engaging with school students. On the 10th April 2018 (prior to the drop-in session), representatives from Council and WMAwater visited two Grade 5 classes at St Anthony's Primary School, and ran two lessons on flood safety. The hour-long lessons involved a local knowledge quiz, group discussion (with lots of pictures and video clips) on the various reasons to never enter, play in or drive through floodwater, followed by an activity. The response from students was overwhelmingly positive, with all students getting involved in the discussion and activities. Students recalled the June 2016 flood event, in which St Anthony's was badly damaged and had to be closed for repairs for about 10 weeks, and were keen to share stories from their experience. The school visit forms a basis for continued collaboration between Council and St Anthony's Primary School (and potentially other schools) to improve flood awareness in Picton. The school visit had the added benefit that students could take the newsletters and questionnaires home, thereby extending the reach of the community consultation advertising efforts.

8.3. Outcomes

8.3.1. Questionnaire Responses

Chart 3 displays the preferences for various mitigation measures, ranked by respondents from least preferred to most preferred. As can be seen below, majority of respondents were supportive of vegetation management, and many respondents commented on specific locations believed to have obstructions in the waterway, such as fallen trees. The second most popular measures were local drainage infrastructure upgrades, followed by retention (detention) basins and improved flood warning systems and alerts. Note that suggestions received via written submissions have also been included in this chart.

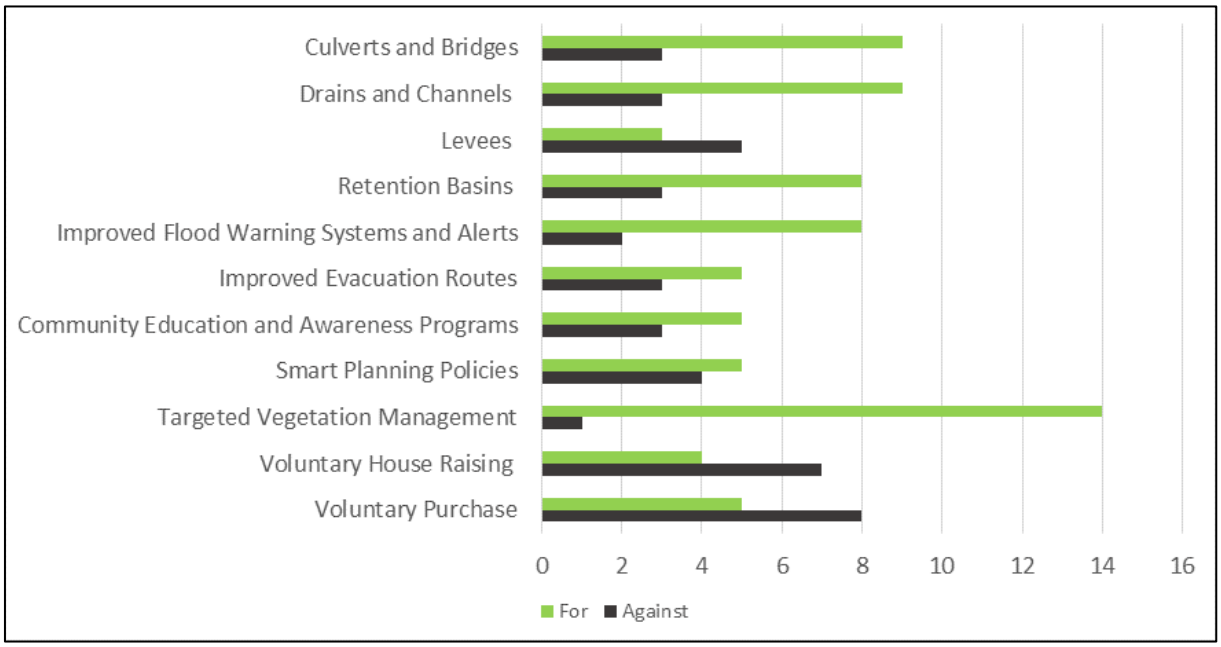


Chart 3: Preferences for Mitigation Options

8.3.2. Summary of Feedback

Residents, business owners and other stakeholders are often aware of or concerned about particular flooding hotspots, and may have suggestions for improving the flood risk in these locations. Suggestions were collected via the questionnaire, written submissions and via discussions with attendees at the drop-in session. The below list presents a summary of the key topics and suggestions that came up throughout the consultation period:

- Detention basins could be constructed upstream of Picton to control flows and lower peak flood levels. Potential locations for basins may include playing fields (e.g. Hume Oval) or vacant land upstream of Stonequarry Creek along each of its major tributaries;
- Consideration of levees to physically exclude floodwaters from particular areas, especially the town centre. Many respondents however acknowledged challenges associated with levees, including space constraints, visual amenity, flood impacts on other areas;
- Temporary flood barriers could be an effective means of protecting commercial premises;
- General improvements to kerb and guttering and drainage network, especially in Menangle Street and Argyle Street;

- Many residents commented on the potential benefits of vegetation management and removal of exotic species from Stonequarry Creek to reduce the hydraulic roughness and improve conveyance. It was also noted that vegetation is essential to prevent erosion and maintain bank stability;
- Requests for improved coordination between emergency management agencies, Council and the community;
- Community flood education would be of value, especially engaging with landowners adjacent to creeks to better manage debris/vegetation close to the creek; and
- A number of respondents commented on the impact of recent development in the floodplain, potentially reducing the opportunity to implement flood modification measures such as detention basins.

It is noted that a number of the suggested mitigation options have been previously assessed in earlier investigations (see Section 2), including levees, basins and channel modification works. Current modelling tools are significantly more sophisticated than those previously available, and enable such options to be reassessed in greater detail to determine their suitability in Picton in the contemporary context. This assessment is detailed in Section 10.4.

8.4. Public Exhibition

Public exhibition of the Draft Stonequarry Creek (Picton) Floodplain Risk Management Study and Plan is required by the Local Government Act (1993, Section 402). This section stipulates that Council must exhibit the studies and 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 Stonequarry Creek (Picton) Floodplain Risk Management Study and Plan was exhibited in conjunction with the Stonequarry Creek at Picton Flood Study Update, from February 18 to March 17 2020, with copies of the report available from:

- Council's Administration Centre, 62-64 Menangle, Picton during opening hours
- Wollondilly Library, 42 Menangle Street Picton, during opening hours
- Wollondilly Shire Council's website www.wollondilly.nsw.gov.au(External link)
- Your Say Wollondilly at www.yoursay.wollondilly.nsw.gov.au

Two drop-in sessions were held at the Wollondilly Shire Hall, Picton, from 2:00-4:00pm and 6:00-8:00 pm on Thursday March 5. Both sessions were well attended with a total of 57 attendees registered. The drop-in sessions provided an opportunity for residents and local business owners to discuss the Studies and their outcomes with WMAwater and Council staff in an informal setting.

Common themes arising from discussions with the public included:

- Management of vegetation in the creek, and the difficulties of striking a balance between reducing hydraulic roughness whilst maintaining bank stability and controlling erosion;
- The magnitude of the June 2016 flood event, and comparison to the February 2020 event;
- Effect of blockage at the Viaduct;
- Individual concerns relating to existing and proposed developments and infrastructure;

- Concerns of the impact of proposed options on localised inundation;
- Challenges to being able to completely remove (or significantly reduce) flooding from particular locations, and the difficulties in balancing objectives such as flood mitigation with the look and feel of Picton due to its proximity to Stonequarry Creek;
- Incremental improvement that can be made to flood warning and the challenges that the catchment response time imposes; and
- Land that is unsuitable for development.

In addition to attending the drop-in session, community members were invited to make written submissions via the following:

- Post: Wollondilly Shire Council, Infrastructure Strategy and Planning, PO Box 21, Picton NSW 2571
- In person delivery: Council Administration Building, 62-64 Menangle Street, Picton NSW
- Email: council@wollondilly.nsw.gov.au(External link); and
- Online via Your Say Wollondilly

In total, 13 submissions were received. A summary of the key points raised, responses and relevant changes to the document are provided in Appendix D.

9. PLANNING POLICY REVIEW

Wollondilly Council (Council) is responsible for local planning and land management in the Wollondilly LGA, including the management of the floodplain and drainage systems. The planning policies held and used by Council in their management of the floodplain are underpinned and bound by National and State Planning Legislation. It is important to understand the National and State context prior to making recommendations for Council to amend its own local planning policies to ensure that any changes are consistent with the requirements of state and national legislation. An overview of the national and state planning instruments is summarised below, with details provided in Appendix A for background.

9.1. National and State Planning Context

The national and state legislation instruments that influence or align with planning in relation to flood risk at the local government level have been listed below and are described in more detail in Appendix A.

- National Provisions – Building Code of Australia
- State Provisions:
    - NSW Environmental Planning and Assessment Act 1979;
    - Ministerial Direction 4.3;
    - NSW Flood Prone Land Policy;
    - Planning Circular PS 07-003;
    - Section 10.7 Planning Certificates (discussed in Section 9.2.4 below);
    - State Environmental Planning Policy (Exempt and Complying Development Codes (2008));
    - State Environmental Planning Policy (Exempt and Complying Development Codes Amendment (Housing Code) 2017; and
    - Rural Housing Code.

9.2. Local Planning Provisions

Appropriate planning controls 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 4) 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.

Environmental Planning Instruments (EPIs) such as Local Environmental Plans (LEPs) guide land use and development by zoning all land, identifying appropriate land uses allowed in each zone. Development in appropriate zones is then managed through other planning standards such as Development Control Plans (DCPs) which can contain flood related development controls.

9.2.1. Local Environmental Plan

Environmental Planning Instruments (EPIs) such as Local Environmental Plans (LEP) guide land use and development by zoning all land and identifying appropriate land uses allowed in each zone. At a high level, and if guided by available flood information, LEPs and supporting DCP controls can be used as tools to guide new development away from high flood risk locations and ensure that new development does not adversely affect flood behaviour. 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. Wollondilly LEP 2011 was prepared under the Standard Instrument LEP program. Clause 7.4 relates to flood planning, and states:

Wollondilly LEP 2011: Clause 7.4 Flood Planning

(1) The objectives of this clause are as follows:
- *(a) to minimise the flood risk to life and property associated with the use of land,*
- *(b) to allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change,*
- *(c) to avoid significant adverse impacts on flood behaviour and the environment.*

(2) This clause applies to land at or below the flood planning level.

(3) Development consent must not be granted 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) is not likely to 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) is not likely to significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and*

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

(4) A word or expression used in this clause has the same meaning as it has in the Floodplain Development Manual (ISBN 0 7 347 54760), published in 2005 by the NSW Government, 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 metre freeboard.

Recommendations relating to the LEP are provided in Section 11.4.6 as Option PM06.

9.2.2. Flood Planning Area

The Flood Planning Area (FPA) is an area to which LEP Clause 7.4 and other flood planning controls are applied. An FPA map is a required outcome of the FRMS&P and is recommended to be included in the DCP. In accordance with the Manual (Reference 4), the FPA is produced as an outcome of the FRMS&P, and is typically 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 Wollondilly Development Control Plan (DCP) 2016 (described in Section 9.2.3) references the Flood Planning Level but not the Flood Planning Area, nor does it currently contain a Flood Planning Area map. At the time of writing, Council was using the Flood Planning Area map developed in the 1996 Floodplain Management Plan (Reference 10), which has been revised to account for development along the flood fringe (for example at Davies Place). This map was originally prepared for the then 'Picton Interim Local Flood Policy' (since superseded by the current DCP). A revised FPA has been produced as part of this Study (and is a required output of the FRMS&P) and is discussed in Section 11.4.2.

9.2.3. Wollondilly Development Control Plan 2016

9.2.3.1. DCP Overview

Development Control Plans (DCPs) are used by Councils to regulate development on flood prone land in support of the objectives set out in the LEP. The *Wollondilly DCP 2016, Volume 1 (General), Part 8 – Flooding* contains objectives and controls pertaining to development within the FPA. Developers can determine the flood controls that apply to their proposed development by following the following steps:

1. Identifying the Land Use Category (e.g. residential, recreation, critical utilities etc.) (Table A);
2. Identifying the Flood Risk Precinct in which it is located (High, Medium or Low) (Table B);
3. Identifying the corresponding controls in Table C. Controls relate to floor levels, building components, structural soundness, flood affectation, evacuation and management & design.

The matrix notes that essential community facilities and critical utilities (such as child care centres, schools, seniors living, electricity generating works or other public utilities) are not suitable in medium and high flood risk precincts. In high flood risk precincts, the only permissible land use types are 'recreational & non-urban', which includes caravan parks and other recreation areas and facilities, and Concessional Development, which refers to additions or alterations to existing dwellings or buildings below a certain area threshold.

The flood risk precincts are currently defined as per Table B in the DCP (reproduced below), and are based on mapping produced in the 1996 FMP (Reference 10). Given that this map is not currently available in the DCP, it can be difficult and time-consuming for developers (and Council planners alike) to determine the appropriate risk precinct, and therefore, which controls are to be applied. Furthermore, the current map is limited only to areas affected by mainstream Stonequarry Creek flooding, as no assessment of overland flow in Picton has been made prior to this FRMS&P. The Flood Risk Precinct Definitions have been reproduced in Table 17.

Table 17: Flood Risk Precinct Definitions (Table B, reproduced from Wollondilly DCP 2016, V1 P8)

High Flood Risk Precinct In the absence of a detailed assessment with a Floodplain Risk Management Plan (that takes precedence over this definition), the following definition applies. The High Hazard Flood Risk Precinct has been defined as the area within the envelope of land subject to a high hydraulic hazard (as defined with the provisional criteria outlined in the Floodplain Development Manual and must be deemed to include the transition zone without a comprehensive study) in a 1% AEP (1in 100 year ARI) flood event.
Medium Flood Risk Precinct In the absence of a detailed assessment with a Floodplain Risk Management Plan (that takes precedence over this definition), the following definition applies. The Medium Hazard Flood Risk Precinct has been defined as land below the 1:100 year ARI flood level plus 0.5m freeboard (Flood Planning Level) that is not within the High Flood Risk Precinct.
Low Flood Risk Precinct In the absence of a detailed assessment with a Floodplain Risk Management Plan (that takes precedence over this definition), the following definition applies. The Low Hazard Flood Risk Precinct has has been defined as all other land within the floodplain (ie; within the extent of the Probable Maximum Flood or PMF) but not identified within either the High Flood Risk or the Medium Flood Risk Precinct where risk of damages are low for most land uses.

9.2.3.2. Challenges and Opportunities

Council engineering and planning staff have identified a number of opportunities to refine the planning controls for greater clarity for developers and improved risk management for Council. Some items for consideration include:

- Provision of up to date mapping of flood planning area and levels for both overland and mainstream flood risk;
- Revising the definition of flood risk precincts based on mapped outputs from this FRMS&P for ease of reference and interpretation;
- Guidelines for the appropriate redevelopment of commercial properties in high hazard flood areas;
- Management of risks associated with access and egress to shop-top dwellings;
- Management of risks associated with basement carparking within the floodplain;

- Achieving a reasonable balance between flood protection and urban design outcomes for street level activation (i.e. appropriate floor levels for commercial properties);
- Including reference to flooding (and reference to Volume 1 Part 8 of the Wollondilly DCP 2016) in Volume 4: Residential Development for the benefit of residential developers.

These items are discussed further in Section 11.4, which also contains recommendations for amendments to Wollondilly Council's planning controls as part of a suite of property modification measures. In addition, this FRMS&P will provide Council with up-to-date mapping for a range of flood metrics (depths, levels, hazard, hydraulic categorisation and Flood Planning Area) that can be utilised for the purposes of planning and assessment of development applications.

9.2.4. Section 10.7 Planning Certificates

Formerly known as Section 149 Planning Certificates, Section 10.7 Planning Certificates describe how a property may be used and the controls on development applicable to that property. The Planning Certificate is issued under Section 10.7 of the Environmental Planning and Assessment Act 1979. When land is bought or sold, the Conveyancing Act 1919 and Conveyancing (Sale of Land) Regulation 2010 requires that a Section 10.7 Planning Certificate be attached to the contract of sale for the land.

Section 10.7 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.

(5) A council may, in a planning certificate, include advice on such other relevant matters affecting the land of which it may be aware.

(6) A council shall not incur any liability in respect of any advice provided in good faith pursuant to subsection (5). However, this subsection does not apply to advice provided in relation to contaminated land (including the likelihood of land being contaminated land) or to the nature or extent of contamination of land within the meaning of Schedule 6.

(7) For the purpose of any proceedings for an offence against this Act or the regulations which may be taken against a person who has obtained a planning certificate or who might reasonably be expected to rely on that certificate, that certificate shall, in favour of that person, be conclusively presumed to be true and correct.

The Environmental Planning and Assessment Regulation 2000, Schedule 4 specifies the information to be disclosed on a Section 10.7 (2) Planning Certificate. In particular Schedule 4, 7A refers to flood related development control information and requires Councils to provide the following information:

1. *Whether or not development on that land or part of the land for the purposes of dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (not including development for the purposes of group homes or seniors housing) is subject to flood related development controls.*

2. *Whether or not development on that land or part of the land for any other purpose is subject to flood related development controls.*

3. *Words and expressions in this clause have the same meanings as in the Standard Instrument.*

Section 10.7 (2) and (5) certificates contain the information prescribed in Schedule 4 described above and additional information relating to the property. In a flooding context, additional information may include notations on flood hazard, percentage of the lot affected by flooding, or peak flood depths and levels on the property, or *"advice on other such relevant matters affecting the land of which it may be aware" (EP&A Act, 10.7 (5)).*

Wollondilly Shire Council currently provides a notification on Section 10.7(2) Planning Certificates indicating whether a property is inside or outside of the Flood Planning Area based on mapping from the 1996 Floodplain Management Plan (Reference 10). Planning staff at Council however noted that some properties beyond mapped flood extents can also be subject to flood risk, however do not receive a notification on the Planning Certificate. This can lead to disagreement between the developer, Council and a private certifier (if involved in the process). It is also noted that areas subject to overland flow would not be included in the 1996 Floodplain Management Plan mapping (Reference 10), which had focused only on mainstream flooding from Stonequarry Creek, downstream of the Racecourse Creek confluence.

No additional information is currently provided on the Section 10.7(2) and (5) Planning Certificates. This FRMS&P will provide up to date flood information for Council to include on Section 10.7 Planning Certificates, and Section 11.4.8 of this report provides suggestions for additional types of information to include on Section 10.7(2) and (5) Planning Certificates (e.g. peak flood depths and levels or hazard classification, whether the site is subject to overland flow or mainstream flood risk).

9.2.5. Online Application for Flood Information

Wollondilly Shire Council offers a free, online service through which residents or developers can request flood information for a specific site. The applicant submits their contact details and property information, and Council provides a letter outlining the current adopted 1% AEP flood level and current Flood Planning Level for the site based on results from the 1996 Floodplain Management Plan (Reference 10), as well as draft levels obtained from the Draft Flood Study (Reference 5). Where available, a surveyed floor level for the property is also provided, and if relevant, links to online versions of available reports are given.

Design flood metrics produced in this study, such as depths, levels, hazard, hydraulic categorisation and Flood Emergency Risk Precincts, will be provided to Council in usable GIS/WaterRide formats so that the latest Council-adopted results can be readily provided to residents and developers. This is described further in Section 11.4.8 as Option PM08.

10. FUTURE FLOOD RISK

10.1. Background

The Floodplain Development Manual places an emphasis on the importance of developing floodplain risk management plans that address existing, future and continuing flood risk for flood prone land on a strategic rather than an ad hoc or individual proposal basis (Reference 3). As well as considering the current flood risk in Picton, this Study therefore also considers the potential future land use scenarios, projected lot sizes and occupancy rates that may occur, and assesses how these future scenarios may impact or be impacted by flood risk. Consideration of future development enables Council to ensure that the management of flood prone land is consistent with flood risk and that such development does not cause undue future distress to individuals nor unduly increase potential flood liability to them or the community (Reference 3).

10.2. Future Growth Areas

The topography in Picton is such that that the floodplain is relatively confined between steeply rising banks. Further, much of the lower lying areas of Picton within the floodplain are already developed. As such, future development in Picton is inherently limited to areas away from the Stonequarry Creek floodplain, with areas for potential growth earmarked for Vault Hill, Picton East, Menangle Street and Abbotsford. New development within the PMF extent (e.g. north of Monds Lane) however will need to consider provision of safe evacuation routes if vehicular access is not already available. If new access roads are required (e.g. for a new subdivision) due consideration should be given to grading the roads to ensure a new low point is not introduced that may cause an area to become isolated during a flood event. Vacant land within the PMF at risk of isolation has been included in Flood Planning Constraint Category 2, described in Section 10.4.

Upon completion of this study, Council will be provided with high resolution GIS maps of a variety of design flood extents and metrics, which can be used when considering future growth areas and drafting (and assessing) rezoning proposals. The proposals known to Council at the time of writing are shown on Figure A27. It is noted that the majority of planning proposals currently underway however relate to areas outside of the hydraulic model extent developed for this study. If changes to land-use zoning is needed to support future development, additional studies may be required to define flood risk in these areas.

10.3. Cumulative Impact Assessment

10.3.1. Introduction

Cumulative impact assessments are a useful tool when considering future growth scenarios. The hydraulic modelling tools developed in the Stonequarry Creek at Picton Flood Study Update (Reference 7) can be used to simulate future development scenarios, and demonstrate how flood behaviour may be changed as a result of future growth as currently planned.

To assess the impacts of new development in the Stonequarry Creek (Picton) study area, two scenarios were modelled based on the following assumptions:

a) Development of vacant land in the floodplain currently zoned as 'residential';
b) Development of all vacant land (excluding sports fields) within the floodplain, with land rezoned where relevant to support development;

In each scenario, additional buildings were 'nulled out' of the model to represent the obstruction that would be caused to flow, consistent with the way in which existing buildings have been considered in the hydraulic model. Building footprints were assumed to cover greater than 50% of the total lot area. The proportion of impervious area was also increased to reflect the increase in paved surfaces associated with new development. Vacant lots were identified using aerial imagery from 2019, and land use zones were taken from the Wollondilly LEP 2011. Each scenario was modelled in the 1% AEP event, with the peak flood level results compared to the design 1% AEP results (existing conditions 'base case') produced in Reference 7.

10.3.2. Results and Discussion

Scenario A assessed the impacts of additional development in three key areas – the vacant land at the rear of the George IV Inn between Coull Street and Stonequarry Creek, Walton Lane, and Eliza Place. The results of the assessment are shown on Figure A27 and indicate that the area behind (downstream of) the George IV Inn is most sensitive to new development. This is consistent with a large portion of this area being categorised as 'floodway' (refer to Figure A20), wherein "even partial blockage would cause a significant redistribution of flood flow, or a significant increase in flood levels" (Reference 4). Construction of buildings in this area result in an increase in 1% AEP peak flood levels by over 0.5 m, and cause increases of up to 0.1 m on the other side of Stonequarry Creek (near St Anthony's), and upstream in and around Argyle Street, exacerbated by the new buildings on Walton Street. Development in the Eliza Place area does not materially affect flood behaviour in the 1% AEP, as it is high in the local catchment, and shallow overland flows can be directed around new buildings without causing an increase in flood risk elsewhere. Removal of this storage capacity through the construction of buildings in the area east of Elizabeth Street causes peak flood levels to increase locally and in Argyle Street by between 0.05 m - 0.1 m.

Scenario B included the same buildings as Scenario A, with the addition of new buildings upstream of Elizabeth Street/Cliffe Street, and at the rear of properties along Menangle Street, upstream of the Victoria Park playing fields, as well as further away from the creek in the local overland catchment. The results are also presented on Figure A27. The area upstream (west) of Elizabeth Street is classified as flood storage (Section 5.3). Development in this area results in local peak flood level increases of up to 0.1 m in the in the 1% AEP events. Development along Stonequarry Creek upstream of the Victoria Park playing fields would encroach on the floodway and cause peak flood level increases of up to 0.25 m at the rear of St Anthony's and towards Argyle Street. The results also indicate that new development southwest of town along the Old Hume Highway would not have a material influence on flood risk, as flooding in this area is characterised by shallow overland flow which is not significantly redistributed with the introduction of new structures.

10.3.3. Conclusion

An assessment of future development scenarios has identified the areas of Picton in which new development would have the most impact on flood behaviour. Development in areas categorised as floodways is not consistent with state policy, as buildings in such areas would be exposed to a high degree of flood risk associated with dangerous flow rates, depths and velocities, as well as causing adverse impacts elsewhere by obstructing and redistributing flows. Therefore, the areas between Coull Street and Stonequarry Creek, and on the opposite bank of the creek behind Menangle Street, are not considered to be suitable areas for future growth. In addition, the currently vacant land upstream of the CBD to the west of Elizabeth Street is not considered suitable for development. Constructing buildings in this area would reduce the flood storage capacity currently available within the site, causing increased flood levels in the CBD. In addition, buildings in this location (and their occupants) would be subject to a high degree of flood risk themselves.

Therefore, within the floodplain, the most suitable areas for development are on higher ground outside of the mainstream floodplain. While development in these areas would need to consider overland flow flood risk, the addition of new dwellings would not materially impact on the nature of flood behaviour nor increase the degree of flood risk along the overland flow paths.

It is noted also that the above assessment is limited to the available hydraulic model extent (indicated in black on Figure A27). If Council were to consider other areas of strategic development, additional hydrologic and hydraulic investigations may be needed to define the existing flood risk in these areas prior to making decisions about future land use zoning and development.

10.4. Flood Planning Constraint Categories

Guideline 7-5 of the Australian Disaster Resilience Handbook Collection (Reference 36) recommends using Flood Planning Constraint Categories (FPCCs) to better inform land use planning activities. These categories condense the wealth of flood information produced in a flood study and classify the floodplain into areas with similar degrees of constraint. These FPCCs can be used in high level assessments of land use planning to inform and support decisions. For detailed land use planning activities, it is recommended that the flood behaviour across the range of flood events be considered, depending on the level of constraint.

The Australian Disaster Resilience Handbook Collection (Reference 36) recommends the use of four constraint categories. It is recommended that isolation potential also be considered for the high constraint category. This could include areas classified as ‘Submerged’ (FIS) or ‘Elevated’ (FIE) (see Section 5.5 for details). In Picton, the isolation potential is relatively low, with much of the floodplain having access to higher ground, classified as ‘Overland Escape Route’ (FEO) or Rising Road Egress (FER). However, a localised area on Elizabeth Street and Menangle Street West is isolated prior to being submerged, and is classified as ‘Submerged’ (FIS). This area is included within the 1% AEP floodway and storage, and is therefore captured within FPCC1.

The constraints defined by Reference 36 have been adapted to suit Stonequarry Creek at Picton Study Area and are outlined in Table 18. The associated FPCC map can be found on Figure A29.

Table 18: Flood Planning Constraint Categories for the Stonequarry Creek Catchment

	Constraints[1]	Implications	Considerations	Application in Picton
FPCC 1	Floodway and flood storage areas in the 1% AEP event.	Any development is likely to affect flood behaviour in the 1% AEP event and cause impacts elsewhere.	Majority of developments and uses have adverse impacts on flood behaviour or are vulnerable. Consider limiting uses and developments to those that are compatible with flood function and hazard.	Includes the main channels of Stonequarry Creek, Racecourse Creek and other minor tributaries, Argyle Street (between the creek and Margaret Street, and the Elizabeth Street area.
	H6 hazard in the 1% AEP event	Hazardous conditions considered unsafe for vehicles and people, all types of buildings considered vulnerable to structural failure.		
FPCC 2	Floodway in the 0.2% AEP event	People and buildings in these areas may be affected by dangerous floodwaters in rarer events.	Many uses and developments will be more vulnerable in these areas. Consider limiting new uses to those compatible with flood function and hazard (including rarer flood flows) or consider treatments to reduce the hazard (such as filling). Consider the need for additional development control conditions to reduce the effect of flooding on the development and its occupants.	Limited in Picton, includes areas surrounded by FPCC 1 (e.g. between CBD and the creek, on the western side of Argyle Street).
	H5 flood hazard in the 1% AEP event	Hazardous conditions considered unsafe for vehicles and people, and all buildings vulnerable to structural damage.		
	H6 flood hazard in the 0.2% AEP event	Hazardous conditions develop in rare events which may have implications for the development and its occupants.		
	Areas of FPCC 3 surrounded by FPCC 2 or FPCC 1	Hazardous conditions arise due to isolation (see below)		
FPCC 3	Within the FPA	Hazardous conditions may exist creating issues for vehicles and people. Structural damage to buildings is unlikely.	Standard land use and development controls aimed at reducing damage and the exposure of the development to flooding are likely to be suitable. Consider additional conditions for critical utilities, vulnerable facilities and key community infrastructure.	Mainly relates to areas within the 'Overland Flow FPA', including areas north of Margaret Street and east of Menangle Street, as well as through Jarvisfield.
	Note: Areas classified as FPCC 3 that are surrounded by FPCC2 and/or FPCC1 have been reclassified as FPCC2.	Even if elevated, hazard may arise from the area being isolated and cut off by deep or fast flowing water. Without a safe evacuation route, risk to life exists even if the building itself is not threatened. Such areas are reclassified as FPCC2 (see above)	See FPCC 2	High ground west of Elizabeth Street is classified as FPCC 2 (see above) due to the potential for isolation.

	Constraints[1]	Implications	Considerations	Application in Picton
FPCC 4	Within the PMF extent	Emergency response may rely on key community facilities such as emergency hospitals, emergency management headquarters and evacuation centres operating during an event. Recovery may rely on key utility services being able to be readily re-established after an event.	Consider the need for conditions for emergency response facilities, key community infrastructure and land uses with vulnerable users.	Remainder of floodplain – areas only inundated in the PMF event.
	Note: Areas classified as FPCC 4 that are surrounded by FPCC2 and/or FPCC1 have been reclassified as FPCC2.	Even if elevated, hazard may arise from the area being isolated and cut off by deep or fast flowing water. Without a safe evacuation route, risk to life exists even if the building itself is not threatened. Such areas are reclassified as FPCC2 (see above)	See FPCC 2	Land around Davies Place and Magnolia Drive that become isolated have been classified as FPCC2 due to the potential for isolation In addition, vacant with a residential zoning that may become isolated has also been classified as FPCC2.
[1]Constraints applied in this FRMS&P to determine FPCCs. Based on the constraints defined in Reference 36)				

11. FLOODPLAIN RISK MANAGEMENT MEASURES

11.1. Categories of Available Measures

The 2005 NSW Government's Floodplain Development Manual (Reference 4) separates risk management measures into three broad categories.

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, emergency services, and improved awareness and education of the community.

Property modification measures modify existing properties, and land use and development controls for future new development or redevelopment. 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.

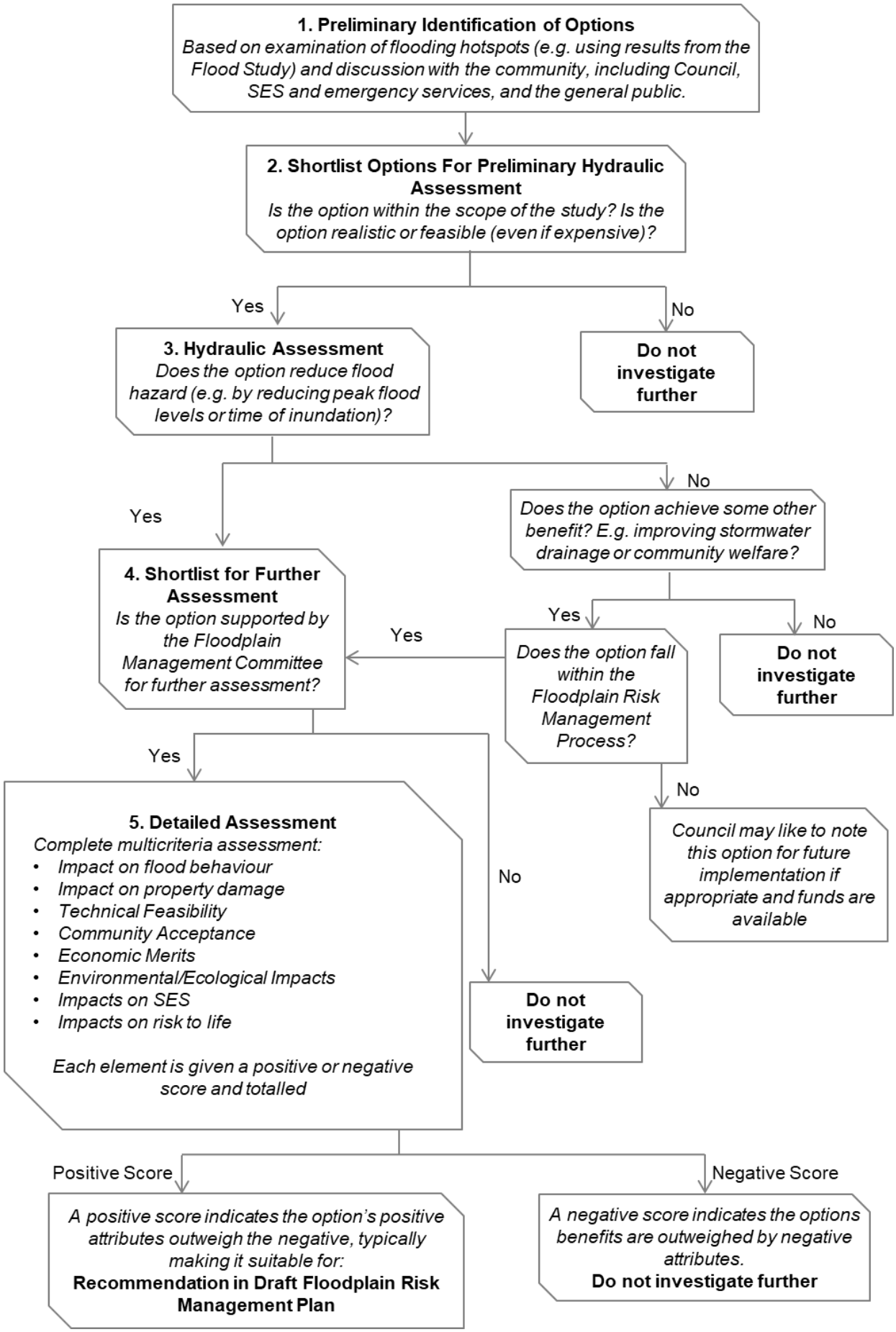
Flood modification measures modify the physical behaviour of a flood including depth, velocity and redirection of flow paths. Typical measures include flood mitigation dams, retarding basins, channel improvements, levees or defined floodways. Pit and pipe improvement and even pumps may be considered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

This study assesses options from each category.

11.2. Assessment Methodology and Identification of Options

The floodplain risk mitigation option assessment process starts with identifying options that may be effective in mitigating flood risk. Consideration is given to flooding hotspots (either observed or identified using design flood modelling (refer to Section 5) and areas with clusters of property damages (either observed or using the flood damages assessment, Section 6). In addition to these, suggestions for options are gathered from the community via the initial consultation period (see Section 8), as well as through discussions with Council, Emergency Services, and consideration of options investigated in previous studies. Options are then shortlisted for hydraulic assessment, and if effective, proceed to detailed assessment and multicriteria analysis. Options that are scored positively in the multicriteria analysis are typically included in the Draft Floodplain Risk Management Plan for implementation. The assessment process is illustrated in Diagram 4.

Diagram 4: Flood Mitigation Assessment Methodology



11.3. Response Modification Measures

The measures described in this section relate to how the Picton community receives information about floods, and responds to and recovers from flood emergencies. Options are designed to improve emergency management procedures, and to improve the response of the community, for example by educating flood affected property owners about the nature of flooding so that they can make better informed decisions.

11.3.1. Option RM01: Wollondilly Shire Flood Warning System Review

Recommendation RM01: Wollondilly Shire Flood Warning System Review

☑

Undertake a Review Wollondilly Shire Flood Warning System, including consideration of:

- Trigger levels;
- Maintenance Requirements;
- Messaging and Recipients (including identifying and prioritising vulnerable occupants); and
- High level assessment of alternative flash flood warning systems.

If appropriate, recommendation of a preferred system commensurate with the benefit it would offer.

Background

A description of the Wollondilly Flood Warning System is provided in Section 6.2. Some limitations of the current system, which was developed in the 1970s, became apparent in the June 2016 flood event. The current warning system is reliant on the Public Switched Telephone Network which was disconnected during the storm. Other limitations of the current system are due to it being based on only three gauges, with the Thurns Road gauge (268296) located close to the catchment boundary, and the Stonequarry Creek level gauge located downstream of Picton. Furthermore, the current system is based on a simplistic rainfall-flood relationship, which is likely to have changed over time and may warrant re-assessment and confirmation. The current system does not relate a particular rainfall trigger to a flood level or predicted flow, but rather simply records when a trigger threshold is reached. With the June 2016 event in the community's recent memory, the desire for a better warning system, and ultimately, more time for businesses to prepare for flooding, has been a key outcome of the community consultation, echoed by the Floodplain Risk Management Committee.

Total Flood Warning Systems

Flood warnings are effective if they enable people to take action to lessen the negative impacts of a flood and help agencies to carry out their essential tasks during flood events (Australian Institute for Disaster Resiliance, 2009). A total flood warning system includes a number of components that must be integrated for the system to operate effectively (Diagram 5) including:

- 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.

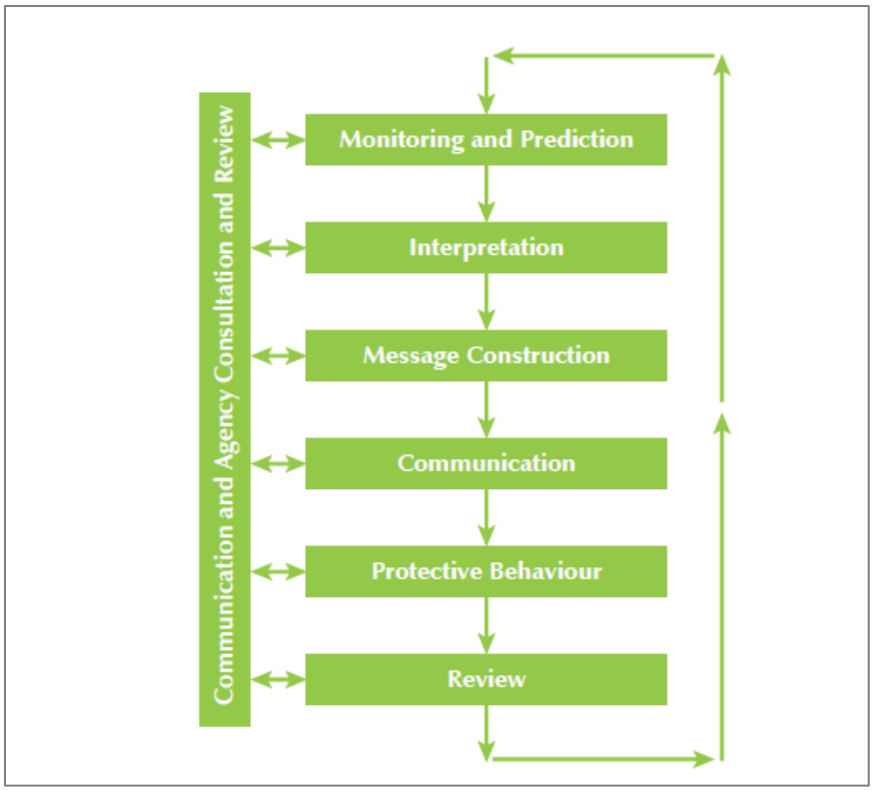


Diagram 5 Components of the total flood warning system - from (Australian Institute for Disaster Resilience, 2009).

A wide range of prediction tools are available, from basic flash flood information systems that use real-time rainfall triggers (such as that currently used in Picton), to complex flash flood warning systems that run real-time hydrodynamic models informed by radar rainfall estimates. Systems such as these have high computational requirements to continuously run detailed models, high initial and ongoing costs, and are generally unable to be run in-house within Council and so are typically outsourced to specialist consultancies. Hydrodynamic models are often not suitable for flash flood forecasting applications due to the time they take to run and the complex computing environment required. When determining a suitable warning system, there is therefore a need to find an appropriate balance between model complexity (and cost), length of warning time, and accuracy of prediction.

Discussion

Increasing the available warning time for flash flooding in Picton would be particularly beneficial for commercial premises. With greater warning time, shops and services may be able to cease business activities earlier and move stock to higher shelves, pack up important documents and hardware, and evacuate safely. If appropriately identified, greater warning time could also lead to improved outcomes for vulnerable occupants. However, as discussed by Ling et al, 2019 (Reference 35), increasing warning time generally comes at the cost of warning accuracy, as predictions must be based on forecast rainfall rather than recorded data.

Diagram 6 below illustrates the trade-off between accuracy and warning time. Extending the warning time in Picton would therefore also result in an increased frequency of false alarms, which in turn, may lead to complacency within residents and business owners (the “cry wolf” effect) and negative outcomes for vulnerable occupants who may be particularly sensitive to relocations associated with false alarms.

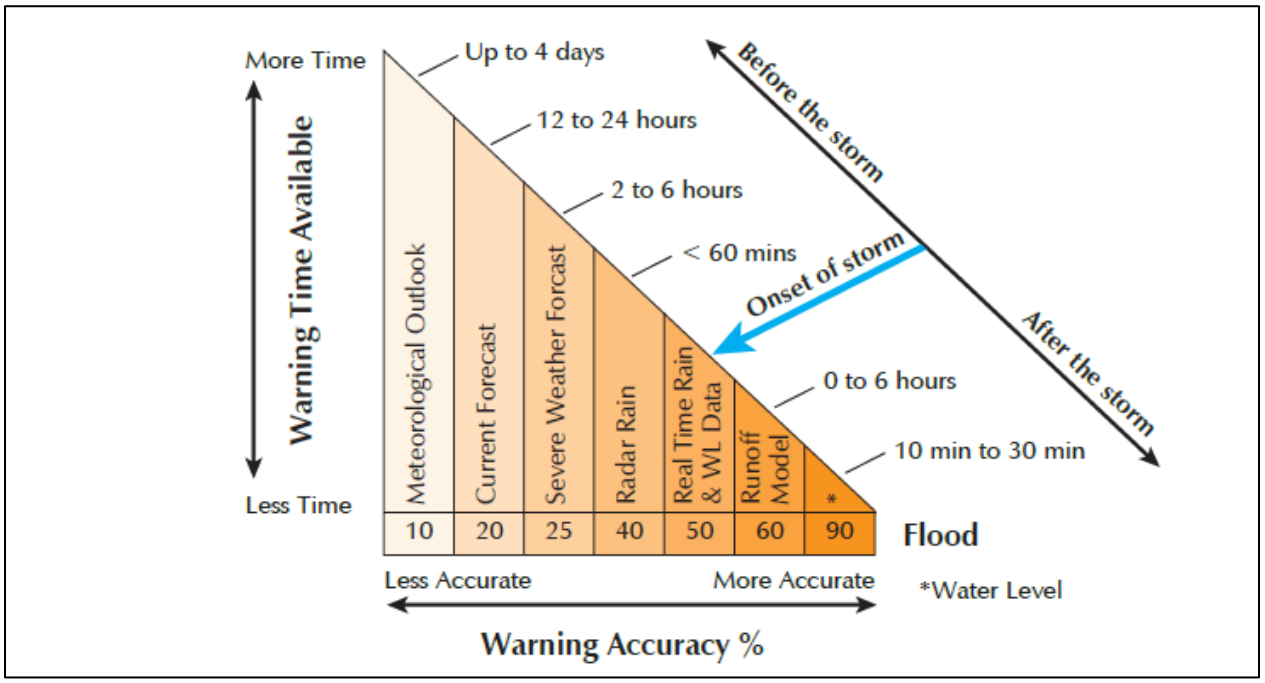


Diagram 6 Trade off between warning time and forecast accuracy for flash flooding (Australian Institute for Disaster Resilience (2009))

It is further noted that whilst an increase in the available warning time may reduce the damage to internal building contents, a flash flood warning system would not change the flood behaviour in any way. Specifically, investing in a warning system would not*:*

- Prevent or reduce structural damage to buildings;
- Prevent services from being disconnected (power, phone, water, sewer);
- Prevent or reduce clean-up requirements completely;
- Completely reduce period of time ‘out of action’; and
- Help prepare for or respond to local overland flow events as there are no rain gauges in the local catchment, and catchment response time (i.e. minutes between rainfall to overland flow event) makes warnings impractical.

Economic Considerations

Depending on the number and type of rain gauges involved, type of prediction model, and the interpretation and messaging system, the potential capital and ongoing costs of a total flood warning system can vary significantly. To give an indication of the potential costs involved in a Flash Flood Information system in Picton, the following assumptions are made regarding the components of the system (note that this system does not include an allowance for real time hydrologic/ hydrodynamic modelling, as it is unlikely there is sufficient time to run these models based on the short response time of Stonequarry Creek to catchment rainfall):

- Installation of two (2) additional automated water level and rainfall gauges in the upper catchment;
- Development of rainfall triggers for prediction based on rainfall/flood level relationships derived from the Stonequarry Creek at Picton Flood Study Update;
- Establishment of automated alerts to send to SES and Council when triggers are reached;
- Alternative telecommunications and messaging systems to ensure reliability if phone lines become disconnected.

A system with the above features would involve capital costs in the order of $190,000 (allowing $40,000 for research and design, and $150,000 for installation and commissioning). In addition to this, annual costs would include instrumentation maintenance in the order of $30,000 per year, as well as messaging subscription costs in the order of $6,000 per year.

Assuming that this type of system reduces commercial contents damages by 20% across the floodplain and full range of design events, the BC ratio would be in the order of ~0.7 (based on a 50 year period and discount factor of 7%). The low BC ratio indicates that this type of flood warning system is not economically viable. Part of the reason for this is that it is likely only a couple of hours additional warning time would be provided at most, meaning there would still be substantial damage to stock and internal fittings, as well as clean-up costs and external damages remaining, as seen in June 2016.

In addition, the limited benefit is attributed to the fact that most commercial premises are not affected by mainstream flooding in floods more frequent than a 2% AEP event (refer to Section 7.3). This means the benefits of a warning system (which would not necessarily assist in prediction of overland flow events) are not realised in more frequent mainstream events, limiting the reduction of total Annual Average Damages. Furthermore, the nature of overland flow in Picton is such that the time between rain falling, and runoff reaching the lower parts of Argyle Street, is too short to provide meaningful flood warnings, even if gauges were installed within the local catchment.

It is noted however that the economic assessment does not include consideration of intangible benefits, such as the potential reduction in risk to evacuees with a more timely and orderly evacuation, reduced stress for impacted residents/business owners who may be able to save some of their belongings, particularly memorabilia, and the manifold benefits of improved operation and coordination of emergency service agencies.

Recommendation

It is recommended that a review of the Wollondilly Shire Flood Warning System is undertaken. The review should include the following elements:

- Reassessment of the trigger levels upon which the current warning system is based using the hydrologic and hydraulic modelling provided in Reference 7;
- Assessment of the potential benefits of installing additional rain and/or stream level gauges and identification of suitable locations;
- A review of the existing maintenance requirements and costs, and messaging (alerts and recipients, including identifying vulnerable occupants);
- High level assessment of alternative flash flood information/warning systems; and
- Recommendation for an alternative system (if any), commensurate with the tangible and intangible benefits it would offer.

At the time of writing, a study with the above scope was expected to cost in the order of $25,000 - $35,000.

11.3.2. Option RM02: Flood Emergency Response Coordination

Recommendation RM02: Flood Emergency Response Coordination

☑ Ongoing facilitation of improved coordination between and within emergency service agencies is recommended to be continued, for example via the following:

- Regular meetings of all responders and 'peace time exercises' between flood events;
- Build relationships between Council, SES and Fire & Rescue and other community groups;
- Maintain an understanding of vulnerable occupants.

Improvement of volunteer coordination for more effective utilisation during clean-up and recovery.

Description

The NSW SES is the legislated Combat Agency for floods and is responsible for the control of flood operations, including the coordination of evacuation and welfare of affected communities. The SES Local Controller is responsible for dealing with floods as detailed in the NSW State Flood Plan. Further information is available from the NSW State Storm Plan (Reference 31), Section 5.7, which describes the framework within which evacuation orders are given and operations are carried out.

A key responsibility of the SES is the coordination of other agencies and organisations for flood management tasks. In Picton specifically, the SES coordinate with Wollondilly Shire Council, the Rural Fire Service and NSW Fire and Rescue, as well as interfacing directly with local business owners and residents. Effective communication, identification and prioritisation of vulnerable occupants, data sharing, and clarity of roles and responsibilities is essential for the efficient and safe execution of flood response actions.

Recommendation

The Floodplain Risk Management Committee highlighted the importance of volunteer coordination, particularly with the arrival of volunteers from outside the area. To make the most of available volunteer resources, it is recommended that investment is made in developing a clear action guide with well-defined and clearly communicated roles and responsibilities. This guide recommended to be developed during 'peace time', i.e. between floods (or other threats), and will be particularly beneficial for the recovery period immediately following a flood event.

The After Action Report (Reference 30) was prepared in response to the June 2016 flood event to "enhance the knowledge of public sector agencies and the community on emergency and crisis management response and recovery arrangements." The report recommended that Council take actions that would facilitate "closer collaboration and co-operation amongst the Emergency Services Agencies". Following on from this recommendation, the below suggestions are made to improve coordination between and within emergency service agencies.

- Regular Meetings of the Local Emergency Management Committee (Council), ensuring the inclusion and involvement of responders 'on the ground,' e.g. volunteers and Council outdoor staff, particularly for the benefit of new staff and volunteers that may have commenced their role since the June 2016 event;
- Hold 'peace time exercises' between flood events (or other threats) to maintain relationships and familiarity with roles and responsibilities;
- Develop plans for the effective coordination of out-of-area volunteers who may travel to Picton to assist during the recovery period immediately following a flood.

11.3.3. Option RM03: Improve Community Flood Education and Awareness

Recommendation RM03: Community Flood Education and Awareness

☑ It is recommended that Council establishes and implements an ongoing and collaborative education program to improve flood awareness within the Picton Community. A range of potential strategies for engaging with the community is provided in this section.

Description

A key step towards modifying the community's response to a flood event is to ensure that the community is fully aware that floods are likely to interfere with normal activities in the floodplain (Reference 4). Flood awareness is a vital component of flood risk management for people residing and working in the floodplain, as well as for those reliant on services operated from within flood prone areas. Flood awareness can be developed through a range of strategies with varying levels of community participation. Strong flood awareness can significantly improve the way a community prepares for, and recovers from flooding

Business owners and residents of Picton are generally reliant on the NSW SES to provide instruction and assistance in the event of a flood, although since the June 2016 event, the Picton Chamber of Commerce and associated businesses have been very active in improving flood resilience. The burden on the SES would be further reduced if business owners (and staff) had a better understanding of their flood risk, and were able to self-manage their own preparations and evacuations, with oversight from the SES. This would become even more important in larger flood events, where other areas of Picton, or towns further afield, may become vulnerable and place additional demands on SES resources.

It is noted that ongoing flood awareness campaigns can be costly and can become ineffective over time with residents becoming bored or ignorant of messaging, particularly in periods of little rainfall, unless messaging is targeted appropriately and continually evolving. However, it is key to keep flood awareness current, as awareness between events, particularly as residents move in and out of the area and flood awareness drops. To maintain a base level of flood awareness provision of basic flood information is recommended, for example to new residents or permanently on the Council website, to be supplemented with a range of events and other methods of engagement as described below.

Recommendation

It is recommended that Council invests in the ongoing improvement of community flood awareness in Picton. Suggestions for ways in which Council might deliver a community flood awareness program are provided below. This list is not exhaustive nor prescriptive, noting that innovative opportunities for the promotion of flood awareness may arise organically in conjunction with other Council projects and community events.

- **Site specific flood emergency management plans for commercial properties:**
    - Ensure staff understand the warning triggers applicable to their business, and are trained in how (and when) to prepare for a flood, for example;
        - Relocate stock to higher shelves or upstairs;
        - Install temporary flood proofing measures (refer to Option PM03, Section 11.4.3); and
        - Secure and exit business premises while evacuation routes are safe and accessible.
    - (The above will be particularly important if the warning system is upgraded);
    - Host day courses for training – perhaps run by Council with the SES or the Picton Chamber of Commerce; and
    - Encourage membership of the Picton Chamber of Commerce, and empower the organisation to run training sessions regularly.

- **Host an annual "Argyle Street Flood Prep" event:**
    - Discuss and coordinate flood preparations with staff and neighbouring businesses if assistance is needed;
    - Get to know the SES personnel and Council staff before an actual flood event;
    - Acknowledge anniversary(ies) of past flood events – perhaps host the "Flood Prep Event" to coincide with a significant anniversary (such as the June 2016 flood event);

  - If appropriate, encourage businesses on Argyle Street and surrounds to practise installing flood proofing measures (see Option PM03, Section 11.4.3) to identify and resolve any issues that may be found, and to understand the time required to safely implement the measures; and
  - Encourage proactive measures, such as storing stock a minimum of 0.3 m above the floor.

- **Distribute (existing) SES FloodSafe materials to residents and businesses:**
  - Provide information on what to do before, during and after a flood event;
  - Locations of evacuation centres within Picton and further afield if necessary;
  - Dangers of not responding to evacuation orders and becoming isolated;
  - Dangers of driving through floodwaters.
  - A range of materials is available online: https://www.ses.nsw.gov.au/disaster-tabs-header/flood/

- **School Projects on Flooding and Flood Safety:**
  - Improve local knowledge of flooding in Picton;
  - Incorporate messages about not playing or driving in floodwaters into appropriate lessons;
  - Host 'flood awareness" days including visits from the SES and/or hosting flood safety activities with students;
  - It is noted that school engagement is an excellent means of informing the younger generation about flooding and can lead to infiltration of flood awareness to parents. In particular, St Anthony's Primary School was closed following the June 2016 event to allow for significant repair and rebuilding. Sharing stories and photographs from this time, particularly around anniversaries, can assist in instilling flood awareness in new students and their families.

- **Use a range of media to publish interest pieces on flooding, and to promote flood awareness activities as necessary, including:**
  - Council newsletter and social media;
  - Local newspapers;
  - Continual engagement regarding the magnitude of the June 2016 event.

- **Include property – specific flood information on Section 10.7 Planning Certificates**
  - Detailed modelled flood information will be provided to Council upon completion of this FRMS&P;
  - Refer to Section 11.4.8 (Option PM08) for discussion and details.

- **Information Packs for new residents:**

Develop a brief information pamphlet to describe flood risk in Picton and direct new residents (and/or business owners) to sources of further information. The Floodplain Development Manual (Reference 4) contains suggestions for types of information to be provided (Section J3.2), including:

- Whether the area where they live is exposed to a risk of flooding. General historical flood information or photos could also be provided;
- What range of risk they are exposed to;
- The need to be flood ready indicating what they should do to plan for a future flood event. This could include an explanation on flood warnings and what the resident/ business owner should do in regard to warnings of different levels of flooding, as appropriate;
- Location of appropriate evacuation centres where applicable; and
- Contact details for provision of further information.

- **Visual Flood Markers:**

Installation of visual markers to assist in the community's understanding of flood risk and historic floods.

- Installation of gauge boards at Argyle Street Bridge to provide insight to residents regarding the 'size' of floods and greater context to flood warnings, which may be issued based on a predicted level in Stonequarry Creek (see Photo 2);
- Installation of Historic Flood Depth Markers in Picton (see Photo 3 and Photo 4). St Mark's Anglican Church is located in a flood prone part of Picton and could be an appropriate site for such a marker.
- It is also noted that during the Public Exhibition period a submission received from the Catholic Education Diocese of Wollongong identified that St Anthony's Catholic Primary School would be generally supportive of flood education signage being installed on the school boundary fencing in Mackillop Lane adjacent to Stonequarry Creek.

Photo 2 Railway bridge over the Katherine River due for repainting *Photo from Katherinetimes.com.au 2015*

Photo 3 Historical flood marker in Maitland, NSW *http://familypedia.wikia.com/wiki/Maitland,_New_South_Wales*

Photo 4 Flood Height Post, Gunnedah, NSW (*Photo C. Burgess 2016)*

Summary

It is recommended that Council implements an ongoing and collaborative community education program to maintain and improve flood awareness in Picton. It is recommended that a variety of approaches (such as listed above) are considered to keep messaging engaging and effective, and prevent residents from becoming bored, ignorant or complacent about flood risk in Picton. It is further recommended that Council collaborates with a range of community organisations (such as the Picton Chamber of Commerce and St Anthony's Catholic Primary School) and the NSW SES and develops innovative and engaging flood awareness improvement opportunities.

11.4. Property Modification Measures

Property modification measures aim to reduce flood risk to existing properties and future developments. Options such as voluntary house raising and flood proofing can be implemented to reduce damage to existing properties, while voluntary purchase schemes can be implemented to remove dwellings from areas of high flood hazard, thereby reducing the number of residents at risk and potentially improving flood conveyance. Flood risk to future developments can be managed via land use planning, and flood related development controls which regulate where and how various types of developments are constructed. The key tools Council uses to regulate development are the Local Environmental Plan and Development Control Plan. This section discusses each of these types of measures and assesses their suitability for implementation in Picton.

11.4.1. Option PM01: Flood Planning Level

Recommendation PM01: Adoption of Flood Planning Level

Adopt the following Flood Planning Levels:

☑ **Residential Flood Planning Levels**

- Mainstream Flood Planning Level: 1% AEP + 0.5 m
- Overland Flow Flood Planning Level: 1% AEP + 0.3 m

Commercial Flood Planning Levels

☑
- Mainstream Flood Planning Level: 1% AEP + 0.5 m
- Overland Flow Flood Planning Level: 1% AEP + 0.3 m

Note: Commercial FPLs may be implemented as minimum flood proofing levels if minimum floor levels are impractical.

Critical Facility and Vulnerable Land Use Flood Planning Levels

☑
- Locate outside PMF extent if possible;
- If not possible, merits based approach to determine the FPL, considering events including and rarer than the 1% AEP (including the June 2016 event).

Areas subject to either mainstream or overland flow affectation are shown on the Flood Planning Area Map (Figure A30) and defined in Section 11.4.2.

☑ Modify the Wollondilly LEP to contain the following definition, in place of the current definition:
flood planning level *means the level of a 1% AEP (annual exceedance probability) flood event plus 0.5 metre freeboard, or other level as determined by any floodplain risk management plan adopted by the Council in accordance with the Floodplain Development Manual.*
Update any definition within the DCP in line with the above.

11.4.1.1. Background

Flood Planning Levels (FPLs) are an important tool in floodplain risk management. Appendix K of the Floodplain Development Manual (the Manual, Reference 4) 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 provides a development control measure for managing future flood risk (e.g. by elevating floors above a particular flood level), reducing potential damage, and setting minimum levels for floodplain mitigation works.

The FPL for planning purposes is generally the height at which new (or redeveloped) building floor levels should be built to minimise frequency of inundation and associated damage. It may also refer to the height to which flood proofing should be applied to reduce damages to commercial properties. FPLs can vary for different types of land use categories. Recommendations for FPLs for the following land use types are recommended herein:

- Residential Development (Section 11.4.1.3);
- Commercial Development (Section 11.4.1.4); and
- Critical Facilities and Vulnerable Land Uses (Section 11.4.1.5).

The FPL is defined in the Wollondilly LEP. The current definition is ***flood planning level*** *means the level of a 1% AEP (annual exceedance probability) flood event plus 0.5 metre freeboard,* Adding the following to the clause allows for there to be flexibility in the FPL for different development types, *or other level as determined by any floodplain risk management plan adopted by the Council in accordance with the Floodplain Development Manual.*

The DCP also refers to the FPL and any definition should be updated in line with the recommendations herein.

A variety of factors need to be considered when calculating the FPL for an area. A key consideration is the flood behaviour and resultant risk to life and property. Selecting the appropriate FPL 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 Floodplain Development Manual (Reference 4) identifies the following issues to be considered:

- Risk to life;
- Long term strategic plan for land use near and on the floodplain;
- Existing and potential land use;
- Current flood level used for planning purposes;
- Land availability and its needs;
- FPL for flood modification measures (levee banks etc.);
- Changes in potential flood damages caused by selecting a particular flood planning level;
- Consequences of floods larger than that selected for the FPL;
- Environmental issues along the flood corridor;
- Flood warning, emergency response and evacuation issues;
- Flood readiness of the community (both present and future);

- Possibility of creating a false sense of security within the community;
- Land values and social equity;
- Potential impact of future development on flooding; and
- Duty of care.

As detailed in Section 1.1.2 of the Manual (Reference 4), the NSW Flood Prone Land Policy provides for a merit-based approach to selection of appropriate flood planning levels (FPLs). This recognises the need to consider the full range of flood sizes, up to and including the PMF and the corresponding risks associated with each flood, whilst noting that with few exceptions, it is neither feasible nor socially or economically justifiable to adopt the PMF as the basis for FPLs [for residential purposes]. FPLs for typical residential development would generally be based on the 1% AEP event plus an appropriate freeboard. Justification for the use of the 1% AEP event is provided below, and discussion on the determination of appropriate freeboard is provided in Section 11.4.1.2.

As a guide, Table 19 has been reproduced from the NSW Floodplain Development Manual (Reference 4) to indicate the likelihood of the occurrence of an event in an average lifetime or during the design life of a structure, to indicate the potential impact that may be experienced. The table shows that there is a 50% chance of a 100 year Annual Recurrence Interval (ARI) (1% AEP) event occurring at least once in a 70 year period. Given this potential, it is reasonable from a risk management perspective to give further consideration to the adoption of the 1% AEP flood event as the basis for the residential FPL. Given the social issues associated with a flood event, and the non-tangible effects such as stress and trauma, it is appropriate to limit the exposure of property to floods.

Note that there still remains a 30% chance of exposure to at least one flood of a 200 Year ARI (0.5% AEP) magnitude over a 70 year period. This gives rise to the consideration of the adoption of a rarer flood event (such as the PMF) as the flood planning level for some types of more vulnerable development (refer to Section 11.4.1.5).

Table 19: Likelihood of given design events occurring in a period of 70 years (Reference 4)

Size of Flood (Chance of occurrence in any year) ARI (AEP)	Probability of Experiencing the Given Flood in a Period of 70 years	
	At least once (%)	At least twice (%)
1 in 10 (10%)	99.9	99.3
1 in 20 (5%)	97.0	86.4
1 in 50 (2%)	75.3	40.8
1 in 100 (1%)	50.3	15.6
1 in 200 (0.5%)	29.5	4.9

11.4.1.2. Freeboard Selection

As noted above, the Flood Planning Level is typically derived from a design flood event (usually the 1% AEP) plus a freeboard allowance. The freeboard can be considered as a compulsory 'safety factor' used 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,
- Climate change and
- The cumulative effect of subsequent infill development.

This section discusses freeboard for development planning purposes only, however it should be noted that a greater freeboard is usually appropriate for mitigation works such as levees to account for structural factors such as settlement or defects that may occur over time.

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. This Floodplain Risk Management Study offers an opportunity to undertake a freeboard assessment to determine the suitability of this freeboard allowance as it applies to areas subject to flood risk in Picton. The freeboard assessment is presented in Appendix C, and considers mainstream and overland flow flood risk separately.

The assessment concluded that freeboard allowances of 0.5 m in areas subject to mainstream flood risk, and 0.3 m in areas affected by overland flow, are required to provide reasonable certainty that the flood risk in the 1% AEP is accounted for.

A lower freeboard is considered appropriate in overland areas as flow is typically shallow, and modelled flood levels are not as sensitive to factors such as wave action, wind setup or local obstructions. Importantly, the modelled flood behaviour in overland areas does not scale as significantly with event size, i.e., flood behaviour in the 0.5% AEP is generally equivalent to that of the 1% AEP, meaning that even if design rainfall estimates were to vary significantly (e.g. due to climate change), the overland flood behaviour would remain relatively consistent.

Section 5 defines mainstream and overland flow flood mechanisms and describes the flood behaviour associated with each in Picton. The distinction of the two mechanisms in terms of the Flood Planning Area (FPA) is shown on Figure A30. Note that the Mainstream FPA is formed by the extent of the 1% AEP plus 0.5 m, whereas the overland FPA is defined by the 1% AEP extent, with no modification or "stretching". This is described further in Section 11.4.2.

11.4.1.3. Residential Flood Planning Levels

The residential Flood Planning Level (FPL) is recommended to be based on the 1% AEP event plus freeboard. Justification for the selection of the 1% AEP event as the basis is provided in Section 11.4.1.1. The applicable freeboard is as described in Section 11.4.1.2. The following residential Flood Planning Levels are recommended for adoption:

- Mainstream Flood Planning Level: 1% AEP + 0.5 m
- Overland Flow Flood Planning Level: 1% AEP + 0.3 m

Residential FPLs in Action: Residential Flood Planning Levels are typically implemented via minimum floor level controls to ensure the lowest habitable floor level is above the FPL.

11.4.1.4. Commercial Flood Planning Levels

Depending on the nature of the development and the level of flood risk, commercial FPLs can be varied based on either the design flood event selected or the choice of freeboard, acknowledging that businesses may be better placed to recover from flood related damages or implement flood protection/mitigation measures compared to residents. Section K4.4.1 of the Manual (Reference 4) states the following:

"The greater flexibility of business in managing risk and recovering financially from flooding, means that FPLs for industrial and commercial development may be based upon a more frequent flood event. An acceptable level of risk may become a business decision for the owner or occupier. This allows for trade-offs between council's responsibility to present and future owners and occupiers and the latter's natural preference to accept the risk and potential damages as a business cost to lower initial set up costs." (Reference 4).

In some catchments, potential damages to commercial premises may be adequately avoided or limited by setting Flood Planning Levels based on a more frequent (i.e. 'smaller') design flood event. However, in Picton, the majority of the business commercial precinct is subject to mainstream flood risk and significant property damage, as recently experienced in the June 2016 event. With this recent flood event highlighting the vulnerability of commercial premises to flood damage and consequences to the community, it is not considered appropriate to base the commercial FPL on an event more frequent than the 1% AEP event.

The following FPLs are recommended for **commercial** development:

- Mainstream Flood Planning Level: 1% AEP + 0.5 m
- Overland Flow Flood Planning Level: 1% AEP + 0.3 m

Commercial FPLs in Action: Note that the above recommendation does not necessarily mean that commercial developments are to have floor levels at these levels (whether mainstream or overland). Along Argyle Street for example, the 1% AEP event is some 0.9 m – 1.6 m deep (refer to Table 20), meaning that the FPL would be over 1.8 m above ground (using the mainstream freeboard allowance of 0.5 m). As described further in Section 11.4.6, it is likely to be more appropriate to ensure new commercial developments (or redevelopments), are flood-proofed up to the FPL, in order to balance the competing objectives of street activation and flood protection.

11.4.1.5. Critical Utility and Vulnerable Facility Flood Planning Levels

The FPL may also be raised depending on the vulnerability of the building/development to flooding. The vulnerability of a building may arise from its use (e.g. power supply, sewerage treatment plant) or from its occupants (e.g. children or the elderly). The Manual (Reference 4) lists the following as examples of critical facilities: fire, ambulance and police stations, hospitals and nursing homes, schools, water and electricity supply installations, interstate highways, bus stations and chemical plants." For such facilities, the consequences of flooding are significantly more severe, and so the avoidance (or limitation) of flood damage is particularly important.

Due to Picton's topography, the floodplain is relatively constrained, and it is likely to be possible to avoid developing critical utilities or vulnerable facilities within the FPA or even floodplain (i.e. PMF extent) altogether. However, if it is necessary to develop a critical utility or vulnerable facility within the FPA, for example, for proximity to the CBD, it is appropriate to consider an event rarer than the 1% AEP event when determining the FPL. For context, Table 20 provides peak flood depths and levels on Argyle Street at the Menangle Street intersection, to indicate the relativity of scale between various events.

Table 20 Peak Flood Depths and Levels at the intersection of Argyle Street and Menangle Street

Flood Event	Peak Flood Level (mAHD)	Approx. Peak Flood Depth (m)
1% AEP	158.0	0.9
0.5% AEP	158.1	1.0
0.2% AEP	158.4	1.3
June 2016 (modelled)	158.6	1.6
PMF	166.6	9.4

In some catchments, the PMF is used as the FPL for critical utilities and vulnerable facilities, as it allows developers to design new utilities or facilities with the full range of flood risk that may occur at the site in mind. However, as shown in Table 20, the PMF is over 9 m deep on Argyle Street, and, building a hospital (for example) with a minimum floor level 9 m above ground is impractical and likely to be cost prohibitive.

It is therefore recommended that critical utilities and vulnerable facilities, if possible, are located outside of the PMF extent. If this is not possible, it is recommended that a merit- based approach

is taken to determine the appropriate FPL using the high-resolution results from this study, particularly for events greater than the 1% AEP. It is noted that the use of the 0.2% AEP + 0.5 m freeboard would offer flood protection to a level approximately equivalent to the June 2016 event. Use of a design event may be preferred over use of the modelled June 2016 event, as design events are derived from industry standard guidelines (described in Reference 7), whereas the flood levels estimated for the June 2016 event are based on a representation of a real flood event using the best available information and modelling techniques for the purpose of model calibration, and levels at specific locations may be questioned by developers based on lived experience.

As for commercial development, the FPLs for critical utilities may refer to the minimum level to which flood proofing is applied, if it is impractical to elevate floor levels to the FPL. However, the risk to the lives of occupants of vulnerable facilities must be appreciated when considering the application of the FPL requirement. If the lowest habitable floor level cannot practically be raised to the FPL, the suitability of the vulnerable facility (such as residential aged care or child care) in the proposed location must be carefully considered.

11.4.2. Option PM02: Flood Planning Area (FPA)

Recommendation PM02: Adoption of Flood Planning Area

☑ Adopt the following residential Flood Planning Area based on the following:

- Mainstream FPA: Based on the extent formed by the 1% AEP (12 hour duration) event plus 0.5 m freeboard (i.e. the Mainstream Flood Planning Level); and
- Overland Flow FPA: Based on the extent of the 1% AEP (1 hour duration) peak flood extent.

The Mainstream and Overland Flow FPAs are shown on Figure A30 are recommended to be adopted.

☑ Modify the Wollondilly LEP to contain the following definition:
flood planning area *means the area of land below the FPL (or the extent as otherwise determined by any floodplain risk management plan adopted by the Council in accordance with the Floodplain Development Manual) and thus subject to flood related development controls.*
Update any definition within the DCP in line with the above.

The FPL, and other flood related development controls, is applied to properties within the Flood Planning Area (FPA). The FPA is defined in the Manual (Reference 4) as the land at or below the FPL. It is important to define the boundaries of the FPA to ensure flood related planning controls are applied where necessary and not to those lots unaffected by flood risk. It is also important to define the FPA on criteria set out in the Manual (Reference 4). The FPA map has been produced as an output of this Study, developed through the below approach and is presented on Figure A30.

As described in Section 5, Picton is subject to flood risk due to two sources: mainstream flooding, which relates to flow that exceeds the capacity of the Stonequarry Creek channel, and overland flow, which is generally characterised by shallow local runoff flowing towards the major creek systems. The separation of flooding into mainstream and overland flow recognises the different degrees of risk associated with each mechanism, and acknowledges that mainstream flood levels will increase significantly in events rarer than the 1% AEP, while overland flooding is not typically significantly deeper in the PMF compared to the 1% AEP event. Whilst for mainstream flooding the FPA can be defined simply as the extent of the 1% AEP event plus freeboard (typically 0.5 m), such a method is sometimes not appropriate for areas subject to overland flow flooding as it may result in an FPA that extends significantly (potentially beyond the PMF extent) and encompasses land not subject to flood risk. The following approach has been undertaken to determine the FPA in Picton:

1. **Distinguish 1% AEP Mainstream and Overland Flow extents**
   Mainstream flooding occurs where water surcharges a natural watercourse (i.e. Stonequarry Creek and Racecourse Creek), while overland flooding occurs where water flows over the ground surface towards a watercourse or channel. In Picton, overland areas were defined as those where the 1 hour duration storm produces higher peak flood levels in the 1% AEP event, while the extent of mainstream flooding was defined by the peak flood levels generated by a 12 hour storm event. This is consistent with the critical duration assessment (Reference 7), and is typical of the duration of storms that drive each mechanism.

2. **Determine Mainstream FPA**

   Using the mainstream flood extents and levels, a freeboard of 0.5 m was added to the peak 1% AEP (12 hour) flood level and the resulting level was extended laterally ("stretched") on either side of the channel or creek, to intersect with the ground (using topographic data). This approximates the extent of a flood that is 0.5 m higher than the 1% AEP flood, and forms the boundary of the mainstream FPA. The Mainstream FPA therefore represents the area beneath the Mainstream Flood Planning Level, as defined in Section 11.4.1.

3. **Determine Overland Flow FPA**

   There are a range of approaches available for the determination of overland flow Flood Planning Areas. The aim is to define an area that appropriately accounts for the flood risk in the 1% AEP event, whilst not exaggerating the extent so as to include areas where the flood risk does not warrant it. The Mainstream FPA approach (i.e. addition of freeboard and "stretching" the overland flood extent to intersect with the surrounding topography) resulted in an FPA that extended well beyond the overland PMF extent, including properties not subject to flood risk (as defined in this FRMS&P). This approach was not deemed appropriate. Instead, the 1% AEP (1 hour duration) extent, with no extension, was determined to be appropriate for the application of flood related development controls in overland flow affected areas. This assumption is justified by the fact that the 0.2% AEP (1 hour duration) flood extent is generally consistent with the 1% AEP extent (as shown on Figure 33 of Reference 7), indicating that the 'scale' of flood risk between varying event sizes is limited for overland flow affected areas, i.e. there are no significant areas of new inundation in rarer events.

Conclusion

It is recommended that Council adopt the Flood Planning Areas defined in this FRMS&P as follows:

- Mainstream FPA: Based on the extent formed by the 1% AEP (12 hour duration) event plus 0.5 m freeboard (i.e. the Mainstream Flood Planning Level); and
- Overland Flow FPA: Based on the extent of the 1% AEP (1 hour duration) peak flood extent.

It is also recommended that the Wollondilly LEP is modified to contain the following definition:
flood planning area *means the area of land below the FPL (or the extent as otherwise determined by any floodplain risk management plan adopted by the Council in accordance with the Floodplain Development Manual) and thus subject to flood related development controls.*

The Flood Planning Area map, provided on Figure A30 is recommended to be adopted by Council. With the Flood Planning Area defined in the LEP, it is not necessary for the map itself to be contained within the LEP. The Flood Planning Area may be updated following future Floodplain Risk Management Studies in the LGA, and it is useful to be able to update the Flood Planning Area map as future FRMS&Ps are adopted, without going through the planning proposal process (to amend the LEP) each time a study is completed. This approach would operate in a similar manner to Council's Bushfire Prone Land Maps.

11.4.3. Option PM03: Flood Proofing Measures for Commercial Properties

Recommendation PM03: Flood Proofing Measures for Commercial Properties

☑ Undertake a project to research the various temporary flood barrier products currently available in the market, determine the preferred product (considering all aspects identified), and encourage businesses to invest in and become familiar with the installation of flood barriers. Refer also to Section 11.3.2 for suggestions for ways in which staff training can be used to improve community flood awareness.

Option Description

Flood proofing measures have been assessed as a method to reduce commercial property damages in Picton. 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 through use of water-resistant materials, locating electricals above the FPL, and facilitation of drainage and ventilation after flooding. Dry proofing aims to totally prevent flood waters from entering a building and is typically best incorporated into a structure at the construction phase (e.g. via development controls, described in Section 11.4.6), though can also be retrofitted to existing buildings. Dry proofing measures are typically installed at doorways or garage entry points, however other openings (such as for ventilation) should also be considered.

Suitability in Picton

Flood risk to commercial properties, particularly those on Argyle Street, can occur due to both overland flow, in which the local runoff exceeds the capacity of the below ground drainage system, and mainstream flooding from Stonequarry Creek when the flow exceeds the capacity of the channel and breaks its banks. Flooding in June 2016 caused closures of a number of shops and facilities, and incurred significant damage and clean-up costs, with damage caused by both of these mechanisms. Commercial properties generally attempted to prevent flooding using sandbags, which can be difficult to prepare and deploy in time particularly given the short warning time available and high demand in Picton and surrounding areas.

Given the limited warning time available in Picton, dry flood proofing measures such as doorframe-mounted barriers would be an effective alternative to sandbags as they can be stored on the premises and quickly installed in the event of a flood, or alternatively, permanent flood barriers could be retrofitted to existing doorframes. When installed properly, such barriers could be expected to have the following benefits:

- Can be implemented by business owners (with little or no SES or Council assistance);
- Reduce time needed to prepare the building, particularly if proactive measures are adopted (e,g, relocating stock etc), allowing more time for staff to evacuate safely;
- Reduce or eliminate need for sandbagging;
- Reduce property damages;
- Allow premises to reopen as soon as safe access and services are restored;
- Reduction of days of lost business during recovery period;

- Greatly reduce clean up required;
- Range of products available from $1,000 - $5,000;
- Create regular staff training and drills, providing opportunity for community activity and flood education implemented.
- Increased continuity of work (and hence wages) for employees of affected businesses; and
- Improved social amenity of being able to access and use key facilities and shops.

Access to community facilities, shops, healthcare services, sporting facilities and pubs are key to a community's recovery from a flood event and contribute significantly to community resilience and emotional recovery. While such premises would still not be operational during a flood nor immediately afterwards (pending safe access, reconnection of utilities etc.), flood proofing would significantly decrease the duration of business closures after the event. It is acknowledged also that temporary barriers are typically between 0.8-1.0 m tall – and as such would not have been an effective means of preventing damage in the June 2016 event, which reached over 1.6 m deep in some parts of Argyle Street.

It is noted however that flood proofing individual buildings would not reduce external flood damages (e.g. to carparks or stock yards). Furthermore, if buildings are wet-proofed there would still be clean-up costs incurred, as well as days of business lost during the flood itself and the immediate recovery period. Considerations for aesthetics and the streetscape (including heritage) amenity may apply if permanent barriers are proposed to be retrofitted to existing buildings (or installed in new developments).

Economic Assessment

The potential economic benefits of flood proofing commercial development in Picton have been estimated for the purpose of this FRMS&P based on the following assumptions:

- Commercial properties within the FPA were identified for inclusion in the scheme (total of 67 properties: 63 within the mainstream FPA and another 4 located within the Overland Flow FPA);
- 3 'Option Uptake' Scenarios were developed to compare the benefits available depending on the number of businesses that utilise temporary flood barriers:
    - 40% Participation (27 properties)
    - 70% Participation (47 properties)
    - 100% Participation (67 properties)
- Flood barriers were assumed to have a height of 0.8 m. This is a conservative assumption based on the range of products available which can reach up to over a metre high;
- The cost of each barrier is estimated at $2000 ex GST (also a conservative assumption based on the range of products available), with an additional 25% contingency applied to cover research and design, and a nominal allowance of $15,000 for consultation and training for businesses (as a flat rate). No ongoing or annual costs have been allowed for in this estimate, though ongoing training is likely to be beneficial to ensure staff are familiar with the installation of the barriers. The cost of this is expected to be insignificant.

Table 21 indicates the change in over-floor affectation based on the three participation scenarios, and the resulting change to the total Annual Average Damages (considering both commercial and residential flood damages). It is noted that for the 70% and 40% participation scenarios, participating properties were selected at random, and do not necessarily reflect the properties that would be most benefitted by the use of temporary flood barriers, or that have already elevated floor levels.

Based on the above assessment, a BC ratio was estimated by comparing the Net Present Value of the difference in Annual Average Damages over a 50 year period with a discount factor of 7%. It is noted that 50 years is likely to be greater than the design life of the barrier, however this period has been selected for consistency with NSW Treasury Guidelines to allow for the comparison of options across the state. The outcomes of the Cost-Benefit Analysis are shown in Table 21.

Table 21 Commercial Property Damages with use of temporary flood barriers

Event & Scenario	Total No. Commercial Properties Flooded Above Floor Level			
	Existing Case	100% participation (67 properties)	70% participation (47 properties)	40% participation (27 properties)
20% AEP	1	0	0	1
10% AEP	6	0	2	4
5% AEP	8	0	2	5
2% AEP	38	5	19	30
1% AEP	53	30	34	41
0.5% AEP	56	36	40	46
0.2% AEP	58	40	43	47
PMF	81	81	81	81
Total AAD (Residential and Commercial Combined)	**$392,470**	**$148,590**	**$223,264**	**$321,853**
Cost Estimate (ex GST)	**NA**	**$182,500**	**$132,500**	**$82,500**
Estimated BC Ratio	**NA**	**>>1**	**>>1**	**>>1**

Considerations for Option Implementation

Further investigation is required to identify temporary flood proofing barriers or other products that are affordable, can be implemented in existing buildings, and meet aesthetic (including heritage) and usability requirements of various businesses. There may be efficiencies in businesses using the same product (e.g. buying in bulk, hosting training sessions together), though depending on the building construction type, sizing and visual amenity this may not be possible.

As new development (and redevelopment) of commercial premises occurs in Picton, flood related development controls could be used as a way to ensure businesses demonstrate the buildings are either wet-proofed or dry-proofed (for example by committing to invest in and use temporary flood barriers). Site specific emergency management plans should be in place in all businesses, and annual staff training undertaken to ensure employees are aware of how and when to deploy

the flood barrier. Any tools needed for the installation should be kept with the flood barrier. The benefits of site-specific emergency management plans for businesses (with or without temporary flood barriers) are described in Section 11.3.2.

It is recommended that annual training drills are held, where all affected businesses practise deploying their flood barriers. This would assist in keeping current staff trained, ironing out any challenges, and identifying any difficulties or obstacles. It is also important to know how long it takes to install the barrier, as this may affect the warning time different businesses need, and where additional assistance may be needed. Annual drills could be coordinated by the SES and Council in collaboration with organisations such as the Picton Chamber of Commerce. Such drills would contribute to improvement of the community's flood education and awareness (described further in Option RM3, Section 11.3.2).

Recommendation

Commercial premises, particularly in the Argyle Street area, are the most at-risk properties in Picton in terms of flooding. Reduction of internal flood damages to these properties would yield significant benefits to the community in terms of property damage, reduced clean-up costs, swifter recovery from floods and greater community amenity. To this end, temporary flood barriers are an affordable and effective method by which existing commercial developments could reduce their individual flood risk. It is therefore recommended that a project is undertaken to research the various temporary flood barrier products currently available in the market, determine the preferred product, and encourage businesses to invest in and become familiar with the installation of flood barriers.

Ongoing training for the safe and effective use of temporary flood barriers is recommended, and could contribute to the improvement of community flood awareness, described further in Section 11.3.2 (Option RM3)

It is also recommended that Council include provision for use of temporary (or permanent) flood barriers in its DCP to enable new buildings to be developed with due consideration given to their flood risk and minimisation of internal flood damages. This is discussed further in Section 11.4.6 (Option PM07).

11.4.4. Option PM04: Voluntary House Raising in Picton

Recommendation PM04: Do not investigate Voluntary House Raising in Picton

☒ Voluntary House Raising (VHR) involves elevating the lowest habitable floor level of existing residential developments above the Flood Planning Level for the purpose of reducing internal flood damages. VHR is not considered suitable in Picton as the majority of residential dwellings are already above the FPL, and the few properties below the FPL are in hazardous locations within or near the floodway, and are not eligible for VHR. A VHR scheme is therefore not recommended for further investigation in Picton.

Option Description

Voluntary house raising (VHR) seeks to reduce the frequency of exposure to flood damage of residential dwellings and their contents by raising the house above the Flood Planning Level (FPL). This results in a reduction in the frequency of household disruption and associated trauma and anxiety, however other external flood risks remain, such as the need to evacuate prior to properties being isolated by floodwaters. VHR schemes are eligible for state government funding based on criteria set out in the *Guidelines for Voluntary House Raising Schemes* (Reference 24). According to these guidelines, VHR is generally excluded in floodways (as defined for Picton in Section 5.3), is limited to areas of low hazard (see Section 5.4), and applies only to houses constructed prior to 1986. House raising is most suitable for non-brick single storey buildings on piers, and is typically not feasible for slab-on-ground constructions. However, advancements in construction techniques and other alternatives may make house raising a viable option for slab-on-ground constructions, or alternatively, repurposing the ground floor for non-habitable use and constructing a second story (above the FPL) for habitable use.

Suitability in Picton

The following factors were considered when assessing the suitability of VHR in Picton:

- Prevalence of residential dwellings flooded above floor level in events including and more frequent than the 1% AEP event (refer to Figure A26);
- Location of dwellings that meet the above criteria in relation to the floodway (refer to Figure A20) and hazard classifications (Figure A23);
- Age and construction type of dwellings.

As identified via the Flood Damages Assessment and shown on Figure A26, the majority of residential development in Picton is located above the FPL as a result of appropriate land use planning and application of development controls in the past, as well as the natural topography of Picton with Stonequarry Creek being confined within steep, high banks. As a result, there are relatively few residential dwellings located within the flood planning area, that are not already above the FPL. The dwellings that do meet this criteria, for example in the Elizabeth Street/ Menangle Street west area, are also located within the floodway, and as such are not considered eligible for VHR, which is only appropriate in areas with low hazard classifications. These properties are considered to be more suitable candidates for Voluntary Purchase, described in Section 11.4.5. VHR is therefore not considered an effective means of reducing flood risk in Picton, and is not recommended to be investigated further.

Conclusion

Voluntary House Raising seeks to modify existing residential development in low hazard areas to elevate habitable floor levels above the FPL and reduce property damages by decreasing the frequency of above-floor inundation. Due to appropriate land use planning, the majority of residential development in Picton is already above the FPL, and would not benefit from a VHR scheme. The few properties that are below the FPL are also located in hazardous areas, within or adjacent to the 1% AEP floodway. It is more appropriate to consider the removal of these dwellings, both to remove occupants from dangerous flood areas and to improve the conveyance of flow. The NSW Government allows for the removal of eligible dwellings via its Voluntary Purchase scheme, which is described in Section 11.4.5. It is therefore not recommended that a Voluntary House Raising Scheme be further investigated in Picton.

11.4.5. Option PM05: Voluntary Purchase

Recommendation PM05: Undertake a feasibility study to further investigate a Voluntary Purchase Scheme in Picton

☑ A Voluntary Purchase Scheme is recommended for further investigation in Picton to remove residential dwellings and their occupants from areas classified as 'Floodway', thus reducing risk to life and improving the conveyance of key flowpaths.

Refer also to Recommendation CM3 (Section 11.5.2.3), which considers removal of commercial properties from the Floodway to improve conveyance of Stonequarry Creek, noting that commercial premises generally are not eligible for Voluntary Purchase.

Option Description

Voluntary Purchase (VP) Schemes are a long-term option to remove residential properties from areas of high flood hazard. Voluntary purchase (VP) is recognised as an effective floodplain risk management measure for existing properties in areas where:

- There are highly hazardous flood conditions and the principal objective is to remove people living in these properties and reduce the risk to life of residents and potential rescuers;
- A property is located within a floodway and its removal may contribute to a floodway clearance program that aims to reduce significant impacts of flood behaviour elsewhere in the floodplain by improving the conveyance of the floodway; or
- Purchase of a property enables other flood mitigation works to be implemented (e.g. channel improvements or levee construction).

In the NSW Government *Guidelines for Voluntary Purchase Schemes* (Reference 25), eligibility criteria notes that VP will be considered only where no other feasible flood risk management options are available to address the risk to life at the property (5.2), and, that subsidised funding is generally only available for residential properties and not commercial and industrial properties (5.3). Once a dwelling is purchased it would be demolished, and a restriction placed upon the lot to prevent future residential or commercial development.

Reference 25 sets out the way in which 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 impacted properties often have lower value.

Suitability in Picton

To identify properties that may be eligible for Voluntary Purchase in Picton, the 'first event flooded above floor' results were mapped atop the hydraulic categorisation in the 1% AEP event for the purpose of identifying buildings located within the floodway. From this analysis, it is clear that the area with dwellings subject to the greatest flood hazard, and importantly, at greatest risk of isolation by floodwaters, is the Elizabeth Street/ Menangle Street West area. As described in Section 5.5, this area is classified as FIS (Submerged), a classification consistent with anecdotes from the June 2016 flood of residents stranded by floodwaters, climbing trees to escape the rising water, and awaiting rescue. Removal of dwellings in this area would reduce the number of residents living (and sleeping) in highly hazardous areas, and additionally, reduce the potential need for rescue and the inherent endangerment of rescuers themselves. Further, the removal of these dwellings would open up the floodway area, and increase the floodplain storage available, alleviating the flood risk in adjacent areas of the CBD and Argyle Street.

However, there may be opposition to the demolition of some buildings in this area due to the heritage value of the building(s). If this is the case, it may be appropriate to consider purchase of the building and repurposing it (potentially via rezoning) for non-habitable uses, rather than knocking it down. Even if not removing the building from the floodway for the benefit of flow conveyance, the removal of occupants would reduce the risk to life associated with the dwelling, both of occupants and potential rescuers.

It is also noted that commercial buildings located within the floodway on Argyle Street would be currently contributing to the obstruction of flow in events where Stonequarry Creek breaks its banks. While commercial buildings are not typically eligible for Voluntary Purchase, their acquisition and removal via other means would result in a reduction in peak flood levels in the CBD and immediately upstream, reducing flood risk to many other commercial premises. This is discussed in more detail as a 'flood modification option' (Option CM3, Section 11.5.2.3).

Conclusion

It is recommended that Council investigate Voluntary Purchase in Picton in more detail via a feasibility study. The study should consider eligibility of dwellings based on their flood risk and potential to be isolated by floodwaters, appetite for Voluntary Purchase among eligible residents and/or owners, and other concerns that may be held by the community, for example, in relation to heritage considerations.

11.4.6. Option PM06: Managing Development in the Flood Planning Area

Development Control Plans (DCPs) are used by Councils to regulate development on flood prone land in support of the objectives set out in the LEP. The *Wollondilly DCP 2016, Volume 1 (General), Part 8 – Flooding* contains objectives and controls pertaining to development within the FPA. Section 9.2.3 of this report provides a summary and review of the Wollondilly Development Control Plan (DCP) 2016. In addition to appropriate land use planning via the Wollondilly LEP, the DCP has been used by Council to ensure residential development in particular has occurred away from the areas of greatest flood risk, with floor levels and building materials specified to ensure the structure is compatible with the flood risk at the site. As discussed in Section 6.1, the main area of flood risk is in the CBD, and development controls are necessary to ensure that commercial premises and community facilities are developed with due consideration of their flood risk.

A workshop was held with Council Planning Staff on the 20th August 2019, in which challenges of applying controls in the DCP were identified, as well as potential opportunities to improve the DCP and fill in any 'gaps' in controls pertaining to flood risk management. A range of recommendations have been developed for incorporation in the DCP to improve the clarity of controls for developers and planning staff alike, and to ensure that flood risk is appropriately considered and designed for at the DA stage across all types of development. The key recommendations are summarised below and discussed in greater detail in the subsequent sections.

Note: Recommendations regarding changes to flood related development plans and policies are intended to express the objective of the control, however the phrasing of specific controls is ultimately Council's decision. In addition, the recommendations made in this report pertain specifically to the management of flood risk in Picton, and the applicability and suitability of such controls for use in other parts of the Wollondilly LGA is to be confirmed prior to making any changes to the LEP or DCP.

Recommendation PM06: Managing Development in the Flood Planning Area

- ☑ PM06A: Update key terms and definitions using outputs from this FRMS&P
- ☑ PM06B: Consideration of Floor Level or Flood Proofing Controls for Commercial Development
- ☑ PM06C: Addition of flood related development controls for above and below ground carparking

11.4.6.1. PM06A: Updating key terms and definitions in the DCP using terms that are clear and consistent with outputs from this FRMS&P

A review of Wollondilly DCP 2016 has highlighted the potential benefit of replacing or updating key terms, and/or the ways in which controls are phrased, to bring them into line with outputs of the current study and improve their clarity and defensibility. Three key areas in which the DCP could be improved in this way are described below:

i. Replace "Flood Risk Precincts" with "Flood Planning Constraint Categories" and update definitions for consistency with this FRMS&P

The Wollondilly DCP 2016 assigns flood related development controls based on the "Flood Risk Precinct" in which the proposed development is located. The flood risk precincts are currently defined as per Table B in the DCP and are based on mapping produced in the 1996 FMP (Reference 10). Given that this map is not currently available in the DCP, it can be difficult and time-consuming for developers (and Council planners alike) to determine the appropriate risk precinct, and therefore, which controls are to be applied. Furthermore, the current map is limited only to areas affected by mainstream Stonequarry Creek flooding, as no assessment of overland flow in Picton has been made prior to this FRMS&P.

With the development of "Flood Planning Constraint Categories" (FPCCs), Council has a contemporary means of dividing the floodplain into subregions with common flood risk characteristics, for the appropriate application of development controls. FPCCs have been defined for Picton using the modelling developed for the Stonequarry Creek at Picton Flood Study Update (Reference 7), and are described in Section 10.4. The FPCCs take into account the Flood Planning Area (Figure A30), PMF extent (Figure A14); Hydraulic Categorisation (Figure A20) and Hydraulic Hazard (Figure A23), and have the benefit of also including areas affected by overland flow, for which flood information was not available in the 1996 FMP (Reference 10).

The current Flood Risk Precincts as used in the Wollondilly DCP 2016 are defined in Table 22. Consideration is required for Council to determine how best to translate current controls for application in each of the FPCCs, with due consideration to flood risk in other parts of the LGA. Note that definitions will also need to be updated to suit the FPCC terminology and for consistency with this FRMS&P.

Table 22 Flood Risk Precinct Definitions (Wollondilly DCP 2016)

Flood Risk Precinct	Current Definition (Wollondilly DCP 2016)
High	In the absence of a detailed assessment with a Floodplain Risk Management Plan (that takes precedence over this definition), the following definition applies. The High Hazard Flood Risk Precinct has been defined as the area within the envelope of land subject to a high hydraulic hazard (as defined with the provisional criteria outlined in the Floodplain Development Manual and must be deemed to include the transition zone without a comprehensive study) in a 1% AEP (1in 100 year ARI) flood event.
Medium	In the absence of a detailed assessment with a Floodplain Risk Management Plan (that takes precedence over this definition), the following definition applies. The Medium Hazard Flood Risk

	Precinct has been defined as land below the 1:100 year ARI flood level plus 0.5m freeboard (Flood Planning Level) that is not within the High Flood Risk Precinct.
Low	In the absence of a detailed assessment with a Floodplain Risk Management Plan (that takes precedence over this definition), the following definition applies. The Low Hazard Flood Risk Precinct has been defined as all other land within the floodplain (ie; within the extent of the Probable Maximum Flood or PMF) but not identified within either the High Flood Risk or the Medium Flood Risk Precinct where risk of damages are low for most land uses.

ii. Ensure terms are consistent with this FRMS&P

The current DCP uses a range of terms to describe parts of the floodplain to which various controls apply, for example 'floodway', 'high hazard floodway', 'high hazard areas'. It is recommended that such terms are updated or replaced with terms consistent with the mapped outputs from this FRMS&P. In particular, "high hazard" and "low hazard" should be replaced with the specific hazard classifications (H1-H6) defined in Section 5.5. Where appropriate, mapping should also be readily provided to allow developers to identify the hazard or hydraulic category at their site. Some Councils provide online portals where flood information (e.g. FPCC, hydraulic hazard, hydraulic categories) can be obtained at individual addresses.

iii. Ensure controls are clear, and if relevant, measurable

The DCP contains controls that require applicants to demonstrate that the proposed development will not adversely affect flood behaviour on adjacent properties. As an example, Control HY is reproduced below:

HY - Flood Affectation
HY3 Any permitted development must require adequate information to be provided by a competent engineer indicating that the proposed development will be unlikely to significantly increase the 5% AEP and 1% AEP flood levels or peak flood flow velocities on adjacent properties.

For ease of assessment of compliance, it is recommended that the wording 'unlikely to significantly increase' is either quantified or replaced with a less ambiguous criteria. The selection of an acceptable threshold for flood impact (e.g. in increase in peak flood level in a design event) depends on a range of factors, as described by Retallick et al in 'Defining acceptable impacts for flood impact assessment' (Reference 32). The paper considers defining acceptable impacts in relation to large, public infrastructure projects, as well as in the context of individual residential and commercial developments. Factors most relevant to consider for commercial or residential impact assessments include:

- Whether there is an existing flood problem;
- Whether there are sensitive receivers;
- Tangible increased risk to life;
- Risk of a flood occurring; and
- Scale of flood risk between events and potential need to assess the development in more frequent events.

While there is no 'one size fits all' approach to setting tolerable levels of impacts, it is common for Councils to allow a maximum increase in peak flood levels of 10 mm (usually in the 1% AEP event). It is noted that changes to peak flood levels less than 10 mm are typically considered to be within the precision tolerance for the model to assess (Reference 33). If available, Councils typically require the flood impact assessment to be undertaken using a hydraulic model developed as part of an adopted Flood Study or Floodplain Risk Management Study to ensure consistency between assessments.

11.4.6.2. PM06B: Consideration of Floor Level Controls or Flood Proofing Controls for Commercial Premises

The Wollondilly DCP currently does not contain a requirement for commercial premises to adhere to a minimum floor level, instead applying Control FL2 in medium flood risk precincts (reproduced below). Note: floor level controls do not apply for commercial land uses in low flood risk precincts, and commercial land uses are not permitted at all in high flood risk precincts.

FL - Floor Level
FL2-The floor level of a permitted structure must give due consideration to the flood damages associated with over floor flooding and complete an economic analysis if a floor level below the flood planning level is proposed.

While the above control is not prescriptive about minimum floor levels, it puts the onus on the proponent to justify the selection of floor level and 'complete an economic analysis'. Without providing clear guidance on how to undertake this analysis, it is considered unlikely that the typical proponent would be able to accurately predict potential losses in floods of varying magnitudes, and relate these to an appropriate floor level selection, without engaging a suitably qualified engineer. Furthermore, with the completion of this FRMS&P, Council will have a wealth of high resolution flood information that can be shared with developers and used to make decisions regarding minimum floor levels, without requiring proponents to undertake their own analysis.

In the interests of simplicity for both the proponent and Council assessors, and for consistency between Development Applications, it is recommended that the requirement for economic analysis to determine the appropriate floor level is replaced with alternative controls relating to minimum floor levels and/or minimum flood proofing levels. While the phrasing of controls is ultimately Council's decision, it is recommended that the following factors are given due consideration when drafting controls relating to commercial development:

- Merits-based approach to balance street activation outcomes and accessibility with minimisation of internal flood damages;
- Minimum flood proofing levels (e.g. to the FPL as defined in Section 11.4.1, or other level);
- Requirement for use of temporary flood barriers (see Recommendation PM03, Section 11.4.3);
- Requirement for floor levels to be a minimum height above natural surface (e.g. 300 mm) to reduce the frequency of nuisance flooding (local overland flow) (may also provide some protection from mainstream flooding);

- Importance of enabling businesses, particularly health facilities (see note below), to reopen as soon as possible following a flood event for the benefit of the community.

For the benefit of improving community flood awareness and education of business owners, it is considered valuable to retain the requirement for businesses to determine their financial liability in different sized flood events. For example, a prospective developer could be provided with peak flood level results at their site from the design events defined in the Flood Study Update (Reference 7). The proponent could then review their proposed fit-out and stock storage arrangements in relation to these levels to understand the potential range of damage that could be incurred (and with what likelihood). While this process may require substantial Council input and guidance, the benefit to the proponent's understanding of their flood risk, and ability to design and manage their business with this information, is significant. It is noted however that new tenants may take over a building and change the internal fit-out, without triggering a 'change of use' or requiring Council involvement. In such cases, the need for collaborative community flood awareness campaigns, particularly via involvement in community organisations such as the Picton Chamber of Commerce, to complement planning controls is highlighted.

Consideration of Health Service Facilities

As described in Section 9.2.3.1, the Wollondilly DCP 2016 applies development controls based on Land Use Category Definitions contained in Table A of the DCP. It is noted that 'Health Service Facilities' are currently defined as 'Commercial/Industrial' land use categories. Whilst this may be technically accurate description of the land use, as these facilities are essentially business premises, it may be appropriate to consider health services separately to other commercial premises for the purposes of flood risk management. The damage to health services on Argyle Street in the June 2016 flood meant that key services (such as dental, GP, optometrist) were not available to the community for an extended period following the flood. In the interests of reducing property damage, and thus reducing the time these services are unavailable to the community and demand on other facilities in the interim (e.g. hospitals), it is considered appropriate to ensure new (or renovated) health service facilities are designed to limit flood damage and recover more rapidly following a flood. This could be achieved either by implementing the minimum floor level or flood proofing controls described above to *all* commercial and industrial land uses.

11.4.6.3. PM06C: Addition of flood related development controls for above and below ground carparking

With continued growth in Picton, the demand for carparking in the floodplain is expected to increase, and basement carparking may become a viable or even preferred alternative to open carparking. At present, the Wollondilly DCP 2016 does not contain controls relating to above or below ground carparking, which, if designed without due consideration of flood risk, can become highly hazardous, posing risk to life, damage to development, and if vehicles become buoyant, risk to the broader floodplain may also be increased.

To enable Council to ensure carparking, both above and below ground, is designed and constructed appropriately, it is recommended that appropriate controls are incorporated into the DCP. The phrasing of development controls is ultimately Council's decision, however the following elements should be considered when drafting controls relating to belowground carparking:

- Prohibition of basement carparking in parts of the floodplain subject to the most risk (e.g. floodways, H4-H6 hazard categories, or within the FPA altogether);
- Consideration of minimum driveway crest levels (e.g. FPL or PMF, whichever is higher);
- Inclusion of warning signs or alarms at entry points and throughout carpark, stairwells (not lifts) for evacuation etc.
- Consideration of location of open carparks (e.g. outside of the FPA or in flood fringe areas only);
- Consideration of minimum surface levels for above ground carparks (e.g. 5% AEP level is used in some LGAs, subject to flood impact assessment);
- Consideration of requirement for open fencing that may assist in preventing vehicles from floating away and causing damage elsewhere.

11.4.7. Option PM07: Managing Development in Low Flood Risk Areas

Recommendation PM07: Managing Development in Low Flood Risk Areas

☑

- Modify the Wollondilly LEP to enable Council to apply flood related development controls to critical facilities and vulnerable land uses in 'low flood risk areas', i.e. between the FPA and PMF extent, as defined in this study.
- Adopt development controls to ensure critical utilities and vulnerable facilities are situated in suitable areas, and designed, constructed and managed with due consideration of the full range of flood risk at the site.

Note: This recommendation requires changes to the Wollondilly LEP

11.4.7.1. Development Controls on Low Flood Risk Areas

Clause 7.4 of the Wollondilly LEP enables Councils to apply development controls to land within the Flood Planning Area. However, as described in Appendix A, Planning Circular PS 07 - 003 notes that "*controls may need to apply to critical infrastructure (such as hospitals) and consideration given to evacuation routes and vulnerable developments (like nursing homes) in areas above the 100 year flood."*

Due to the relatively steep topography in Picton, the PMF extent is relatively constrained, and there is only a limited area between the Flood Planning Area and PMF extent, particularly through the CBD as shown on Figure A31. It is therefore likely to be feasible to locate critical utilities or vulnerable land uses outside of the floodplain altogether. Nevertheless, the CBD is likely to be the preferred location for facilities such as childcare or residential healthcare services for accessibility and proximity to other businesses. It is therefore prudent to consider the full range of flood risk to which new critical or vulnerable developments may be subject.

NOTE: the intent of these controls is not to *prohibit* the development of critical or vulnerable land uses between the FPA and PMF, but to empower Council to apply controls that ensure the developers of such facilities appropriately consider and plan for the full range of flood risk at the site, so as to reduce potential property damages and minimise the risk to life in future flood events.

Recommendation

It is recommended that the following clause is added to the LEP following Clause 7.4, to enable Council to apply appropriate development controls to critical and vulnerable land uses between the FPA and PMF extent:

7.4A Floodplain risk management

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

(a) in relation to development with particular evacuation or emergency response issues, to enable evacuation of land subject to flooding in events exceeding the flood planning level,

(b) to protect the operational capacity of emergency response facilities and critical infrastructure during extreme flood events.

(2) This clause applies to land between the flood planning level and the level of a probable maximum flood, but does not apply to land at or below the flood planning level.

(3) Development consent must not be granted to development for any of the following purposes on land to which this clause applies unless the consent authority is satisfied that the development is consistent with any relevant floodplain risk management plan adopted by the Council in accordance with the Floodplain Development Manual, and will not, in flood events exceeding the flood planning level, affect the safe occupation of, and evacuation from, the land—

a) caravan parks,
b) centre-based child care facilities,
c) correctional centres,
d) emergency services facilities,
e) group homes,
f) hospitals,
g) residential care facilities,
h) respite day care centres,
i) tourist and visitor accommodation.

(4) In this clause— probable maximum flood has the same meaning as it has in the Floodplain Development Manual.
Note. The probable maximum flood is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation.

11.4.7.2. Development Controls for Critical Utilities and Vulnerable Facilities in Low Flood Risk Areas

With the above LEP clause in place, Council is able to apply development controls to ensure the design, construction and management of critical utilities and vulnerable facilities is commensurate with their flood risk. A range of controls may be deemed appropriate, including controls relating to floor levels and building materials, such as those already in the DCP or described in the previous section of this report. In particular, the safety of employees and occupants of critical utilities and vulnerable facilities (and businesses in general) can be markedly 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 or critical equipment to higher shelves/ floors when flood warning is received (or adopting a policy of preventative measures, such as keeping critical equipment above the PMF level);
- Business Closure: If appropriate, businesses or facilities could close in event of flood to reduce number of persons on site;
- Evacuation Plan: Identifying safe access routes and time required for occupants/employees to safely leave the premises well before roads are overtopped.

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 the proponent and Council. Amending the LEP to include a provision for developments between the FPA and PMF (see above) will allow Council to enforce the requirement of site-specific emergency management and evacuation plans for critical facilities and vulnerable land uses outside of the FPA. If a proposal cannot demonstrate safe evacuation or planning is possible, the suitability of the facility at that site may need to be reconsidered. It is noted that the proposed development would also need to demonstrate compliance with other Council planning objectives set out in the LEP and DCP, e.g. relating to flood impacts, floor level controls, and flood compatible materials.

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.

11.4.8. Option PM08: Provision of Flood Information to Residents via Section 10.7 Planning Certificates

Recommendation PM08: Provision of flood information on Section 10.7 Planning Certificates

☑
- Use high-resolution flood information from this study (and others, as available) to provide a greater level of detail to residents via Section 10.7(2) and (5) Planning Certificates.

Background

Section 10.7 Planning Certificates (formerly S149 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 Section 10.7 Planning Certificate at any time to obtain information about his or her own property, but generally the 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 10.7 Planning Certificate be attached to the Contract for Sale.

Schedule 4 of the Environmental Planning and Assessment Regulations 2000 gives requirement for inclusions on Section 10.7 Planning Certificates under Section 10.7(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.

Recommendation

It is recommended that the high-resolution flood information developed in this Study and Reference 7 are used by Council to improve community flood awareness, by providing information to residents via Section 10.7 Planning Certificates. Section 17.2 and 17.3 of Appendix I to the FDM (Reference 4) detail typical examples of information for inclusion in Section 10.7 (2) and (5) Planning Certificates, and include the following:

- Whether the land is within the FPA (overland, riverine, or both) and if flood related development controls apply, (10.7(2));
- Design flood levels/depths specific to the property for the 1% AEP, 5% AEP and PMF events, (10.7 (2) and (5));
- Percentages of lots affected by the FPA(s) if not 100%, (10.7 (2) and (5));
- Likelihood of flooding and mechanism (riverine/ overland flow/ both) (10.7 (2) and (5));
- Flood hazard (10.7 (2) and (5));
- Hydraulic categorisation (e.g. floodway) (10.7 (2) and (5));
- Evacuation routes/ constraints (10.7(2) and (5)); and
- Associated Mapping for the above items (10.7 (2) and (5)).

The more informed a home owner is, the greater the understanding of their flood risk. During a flood event, having this understanding helps prepare residents for evacuation, and improves the ability of residents to recover following an event. Improved flood risk awareness may also 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.

Land owners will be required to be notified of changes to both the 10.7 (2) and 10.7 (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 S10.7 Planning Certificates.

11.5. Flood Modification Measures

11.5.1. Introduction

Flood modification measures aim to modify the behaviour of a flood itself by reducing flood levels or velocities or by excluding water from areas under threat. These measures usually involve structural works (often permanent, though temporary structures can also be assessed) which are generally installed to modify flood behaviour on a wider scale. A range of flood modification measures were assessed in the 1992 Stonequarry Creek Floodplain Management Study (Reference 9) using modelling tools available at the time. The development of more sophisticated modelling tools in this study, particularly with high resolution topographic data and the inclusion of overland flow behaviour, allows options previously investigated to be reassessed under current conditions. Reference 9 investigated options involving levees, retarding basins, and major changes to the channel shape of Stonequarry Creek, with the results and outcomes described in Section 2.2. In addition to revisiting such measures, this section assesses options relating to local drainage, changes to major hydraulic structures, and potential alternative locations for retarding basins.

Note: Peak flood level impact maps have been produced to display the effect that the various mitigation works would have on flood behaviour. These maps display the difference in peak flood level between a design flood event and the same event with the mitigation works implemented. Impacts maps are presented in Volume II, Appendix B. Intangible benefits and disadvantages of each option have been assessed via a Multi Criteria Matrix Assessment, presented in Section 12.

11.5.2. Major Channel Modification Options

Channel modification can include a range of works including increasing the size, shape or materials of a channel, to altering the natural surrounds or creek shape via dredging, lining (or naturalising lined channels), or other vegetation management practices. Channel modifications can help to reduce peak upstream flood levels by improving conveyance, although such measures may also increase flood levels in adjacent or downstream locations. Changes to velocity are also likely to occur as a result of changing the channel shape or size. In general, for channel modifications to be effective in reducing flood levels, significant excavation is required which can have a range of environmental impacts, including removal of riparian vegetation, and as a result, loss of native habitat and in some cases, bank stability.

In Picton specifically, Stonequarry Creek is characterised by steeply sloping banks and a deeply incised channel, which affords Picton a significant level of flood protection, as mainstream flood events more frequent than a 2% AEP are confined to the channel through town. Modifying the channel geometry must be considered carefully, as changes to the bank shape may result in the introduction of flood risk to Picton in a more frequent event. Two channel modification options have been assessed in Picton, and are described as follows.

11.5.2.1. Option CM1 – Stonequarry Creek Channel Modification

☒	**CM01: Expanding Creek Cross Section between Argyle Street Bridge and Victoria Park**
Description	Excavation of Stonequarry Creek banks (2 m depth, ~50,000 m^3) between Argyle Street Bridge and the Railway Viaduct;
Benefits	Reduces peak flood levels in the CBD by up to 0.2 m in the 1% AEP event;
Concerns	• Peak flood depths of 0.7 m remain in the CBD in the 1% AEP event. • Removal of riparian vegetation and potential reduction in bank stability; • Potential loss of habitat; • Causes out-of-bank flooding (and therefore greater flood risk) in more frequent events. • Acquisition of privately owned land adjacent to the creek would be necessary.
Outcome	Not recommended for further investigation.

Option Description

Option CM1 is similar to Option 2 in the 1992 FRMS (Reference 9) , and involved lowering the creek banks by 2 m, for a width of 25 - 50 m on either side of the creek, from downstream of the Argyle Street bridge to the railway viaduct. Over a length of 430 m on the right banks and 720 m on the left bank, this option requires the removal of approximately 50,000 m^3 of earth, which would need to be transported offsite to a location outside of the floodplain.

Modelled Impacts

The change to flood levels as a result of Option CM1 in the 1% AEP event is shown on Figure B1. In the 1% AEP event, the channel modification lowers peak flood levels by up to 0.2 m in Picton CBD. Upstream of the excavated area, the velocity within the Stonequarry Creek channel is increased by over 0.5 m/s, and velocities within Argyle Street are increased as a result (by up to 0.1 m/s). The increased flow in the channel leads to increased peak flood levels downstream at Victoria Park in the order of 0.05 m.

The peak flood level changes due to this option in the 5% AEP event are shown on Figure B2. In the existing case, the 5% AEP mainstream flooding is confined to the channel. With Option CM1 in place however, previously flood free land at the rear of properties along Menangle Street, and parts of Victoria Park would become inundated and subject to flood risk. In a 5% AEP event, peak flood levels within the channel itself are lowered, however this benefit does not result in the reduction of property damages (as there are no dwellings within the 5% AEP mainstream extent). Further it is noted that in both the 5% AEP and 1% AEP event, overland flow behaviour is unchanged.

Discussion of Other Concerns and Considerations

This option involves extensive excavation (over 50,000 m^3), and the removal of thousands of trees, having unacceptable environmental impacts. Even with the reduced flood levels, peak flood depths in the CBD would still reach up to 0.7 m in the 1% AEP event, indicating that this option does not effectively resolve flood risk in Picton. Given the extent of works, this option is not considered feasible, and has not been shortlisted for a full economic assessment in this Study. It is also noted that modifying the channel shape to this extent would affect bank stability and potentially affect sediment transfer behaviour in Stonequarry Creek (ultimately affecting long term conveyance capacity). Social impacts include the reduction of natural creek amenity, requirement of land acquisition and excavation of Victoria Park resulting in loss of sports grounds and community amenity.

Evaluation

Option CM1 is not considered a feasible method of reducing flood risk in Picton, and is therefore not recommended for further assessment. A similar option had been assessed in both the 1989 Flood Study (Reference 8) and the 1992 Floodplain Management Study (Reference 9), and both concluded that the minor changes to flood risk in Picton did not justify the major excavation works that would be required.

11.5.2.2. Option CM2 – Excavation upstream of Argyle Street Bridge

☒	**CM02: Excavation upstream of Argyle Street bridge**
Description	• Excavation of currently vacant land upstream of Elizabeth Street to provide flood storage capacity
Benefits	• NA – This option does not reduce flood risk in Picton
Concerns	• Flood affectation is introduced to the CBD earlier, and peak flood levels are raised as flow can now enter the area • Environmental impacts (removal of vegetation, potential loss of habitat) and potential loss of bank stability, public safety risk in Elizabeth Street and Argyle Street areas.
Outcome	Not recommended for further investigation.

Option Description

Approximately 400 m upstream of the Argyle Street Bridge, and 100 m west of Elizabeth Street, is an area of currently vacant land in Picton. The Picton community, Council staff and the Floodplain Risk Management Committee suggested considering the suitability of using this land for flood mitigation purposes. To this end, Option CM2 has been modelled based on the assumption that the ground levels to the west of Elizabeth Street (currently above the 1% AEP design flood level), are lowered to 1 m below the 1% AEP event; removing a total volume of approximately 10,000 m^3 over an area of 1.5 ha, allowing for additional flood storage and conveyance.

Modelled Impacts

The option was modelled in the 5% AEP event and 1% AEP event, with impacts shown on Figure B3. In the 1% AEP, the newly lowered ground allows flow to enter the vacant land, and continue eastward, exacerbating flooding in the CBD and increasing flood risk downstream. Peak flood levels on Argyle Street are increased by approximately 0.2 m in the 1% AEP event. While there are some minor reductions in peak flood levels upstream of the CBD, at the Picton Bowling Club and Hume Oval, the increase in property damage and hazard mean this option does not reduce flood risk in Picton.

Discussion of Other Concerns and Considerations

This option involves significant excavation on privately owned land, and is likely to incur substantial costs. The extent of works right on the creek bank would have a significant environmental impact, and considerable precautions would need to be taken to ensure spoil did not slip into the creek, that bank stability was maintained throughout and post construction, and that silt was adequately retained. Construction at this site would be particularly hazardous during wet periods, and flash flooding may destabilise building zones or wash away plants (such as excavators) and other materials.

Evaluation

The preliminary assessment of Option CM2 has shown that the excavation of land upstream of Elizabeth Street would worsen flood risk in the CBD and further downstream, and as such is not recommended for further investigation.

11.5.2.3. Option CM3 – Removal of Buildings for Floodway Clearance

☑	**Option CM3 – Removal of buildings for floodway clearance**
Description	• Purchase and demolition of buildings within the floodway to remove obstruction and improve conveyance. Rezoning of this land and other land unsuitable for development.
Benefits	• Reduced peak flood levels across the CBD; • Prevention of future damage and losses to businesses and other properties within the floodway; • Opportunity to create an open area for public use adjacent to the creek;
Concerns	Significant cost to purchase and demolish buildings;
Outcome	Recommended for further investigation

Option Description

This option investigates the potential benefits of removing commercial buildings located within the floodway in Picton, as defined in Section 5.3. While not a ‘channel modification’ in the traditional sense, removal of buildings close to the main channel changes the characteristics of the out-of-bank area, increasing the cross-sectional area available for the conveyance of flow, which is crucial in events equivalent to and greater than the 2% AEP in Picton.

This option follows on from the Voluntary Purchase scheme described in Section 11.4.5. One of the outcomes of Voluntary Purchase is that dwellings are removed from the floodway, thus removing an obstruction and improving flow conveyance. Land is either rezoned or restrictions placed to restrict unsuitable future development. However, NSW Government Guidelines stipulate that only residential properties are eligible to participate in a Voluntary Purchase (VP) scheme. Nevertheless, given the flood behaviour and properties at risk, the removal of *commercial* premises in the floodway warrants investigation to determine the potential reduction in flood risk that may result.

Further investigation and development of this options shall be extended to consider the potential rezoning of other land in the floodway that is unsuitable for development.

Modelled Impacts

As described in Section 7.5.5.5 of Reference 7, buildings are 'nulled out', or removed from the hydraulic model's computational grid to effectively exclude any flow from entering buildings. While this is not necessarily realistic (as flow can enter buildings), it is an appropriate method that simulates the obstruction that buildings can impose on floodwaters. It also assumes that flood storage is not available inside buildings. To simulate this option, a scenario was modelled without building polygons 'nulled out' inside the floodway – allowing flow to enter cells formerly nulled out of the model. In a 1% AEP event, this resulted in peak flood level reductions in a widespread area of the CBD and further upstream, with peak flood level reductions in the order of 0.1 m occurring broadly, and up to a maximum of 0.18 m immediately adjacent to the former building locations. Peak flood impact mapping and further details have been provided separately to Council due to the confidential nature of this option.

Additionally removal of buildings and limits on the construction of new building will reduce potential future flood impacts.

Economic Analysis

Using land value information from NSW LPI, and estimated business/building values, a high level cost estimate for this option has been prepared based on the purchase of two buildings. The removal of the two premises means that all future costs to these buildings due flood damage are avoided, including external and internal direct damage due to water ingress, indirect losses due to extended periods of the business being closed, loss of wages, etc, and intangible costs related to the stress and trauma associated with flood damage and recovery.

Despite reducing peak flood levels throughout the CBD by up to nearly 0.2 m, significant depths remain in a 1% AEP event (over 0.7 m in Argyle Street), and the economic benefits to remaining properties is limited compared to the cost of purchasing and removing the two buildings. This results in a low BC ratio (less than 0.1), indicating that on a purely economic basis this option would not be feasible. However, other intangible benefits to the broader community are available, and are described below. This assessment does not consider the potential future damages that may be prevented as a result of this option. Note that details of the economic analysis are provided separately to Council for confidentiality reasons.

Discussion of other concerns and opportunities

Once purchased, existing buildings will need to be demolished, and the lots either rezoned or a restriction placed upon its title to prevent future development. Removal of currently dilapidated buildings will have positive outcomes to the community in terms of public safety, creation of more open space near the creek, and improvements to visual amenity. The future use of the newly vacant area is to be carefully considered. Recreational uses such as creek-side picnic areas, open-air markets or parks would be considered appropriate, while the use of the area for carparking or caravan parks is not considered appropriate, as flash flooding can cause the creek to rise quickly without enough time for safe evacuation. Furthermore, any items such as picnic tables etc. would need to be secured to the ground to prevent them becoming buoyant and possibly causing blockage or damage downstream during a flood. Consideration could also be given to using the land for activities or installations that contribute to Picton's ongoing flood awareness, such as historic flood markers or a gauge at the bridge as described in Section 11.3.2.

Recommendation

The removal of commercial premises within the Stonequarry Creek floodway has been shown to yield flood level reductions across a broad area for the benefit of a large number of businesses, and would open up land beside the creek which could be used for recreational purposes and beautification of the CBD. While the purchase of commercial premises may not be funded via the NSW Government Floodplain Risk Management Program, it is recommended that this option be explored further as it is a relatively straightforward way (compared to more complex structural flood modification options that achieve similar outcomes, such as retarding basins) to reduce flood risk in the CBD, whilst also allowing new opportunities to improve the amenity of the creek-side areas in town. Further investigation should consider the rezoning of other land in the floodway which may be unsuitable for development. It is recommended that Council investigate the possibility of purchasing and removing buildings within the floodway in the CBD. The investigation should consider:

- Identification and prioritisation of buildings whose removal would provide the most benefit;
- Potential funding sources;
- Consideration of other land in the floodway for rezoing;
- Potential uses of the vacated land, including opportunities for community flood awareness improvements.

11.5.2.4. Option CM4: Vegetation Management

☑	**Option CM4 – Vegetation Management**
Description	• Continuation of existing Vegetation Management Program to maintain vegetation density in Stonequarry Creek and Racecourse Creek
Benefits	• If not undertaken, peak flood levels would be 0.2 m higher in the CBD in a 1% AEP event, and 0.3 m higher in a 2% AEP event;
Concerns	• Community perception that current works are insufficient; • If vegetation is thinned to a greater degree, bank stability may be compromised, potentially resulting in slump and significant loss of conveyance;
Outcome	Current vegetation management program to be continued and reviewed periodically.

Description

Vegetation management refers to the planning and implementation of the activities involved in managing native and exotic plant species within a particular area. Activities typically 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.

The removal of vegetation in riparian areas, such as Stonequarry Creek, also requires careful planning, as vegetation plays an essential role in erosion protection and stream bank stability. If vegetation is removed or thinned excessively, creeks can become susceptible to erosion and scouring, which among other things, may lead to banks slumping and greatly reducing the channel capacity, and impacting on flood behaviour. Wollondilly Shire Council currently has a comprehensive vegetation management plan in place for the management of riparian vegetation in Stonequarry Creek and Racecourse Creek particularly, as well as other minor tributaries in the LGA, as described in Section 6.3. Council's current practices in relation to riparian vegetation management are at the upper limit of what is safe to carry out before bank stability becomes compromised. Increasing the degree of vegetation thinning in Stonequarry is not feasible without major bank stabilisation works (such as reinforcement, or moving to flatter banks).

The hydraulic models developed in Reference 7, which form the basis of option assessment in this study, can be used to estimate how flood behaviour would change if Council did not continue its vegetation management practices. Without ongoing intervention, vegetation density would increase, resulting in an increase in the hydraulic roughness of the channel. Existing and potential future 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.

Modelled Impacts

To simulate the effect of ceasing vegetation management activities, the hydraulic roughness assigned to the in-bank area was increased in three 400 m sections of Stonequarry and Racecourse Creeks (from a 'Manning's 'n'' =0.04 to 'n' =0.075), that is, becoming as 'rough' as the adjacent out-of-bank area. The results indicated that in a 1% AEP event, peak flood levels in the CBD would be 0.2 m higher than under current conditions, and up to 0.3 m higher in a 2% AEP event.

Economic Impacts

A high level economic assessment has been prepared by comparing Council's annual vegetation management budget, to the additional Annual Average Damages that would be incurred if the works were not undertaken. Annually, Wollondilly Shire Council puts approximately $15,000 towards contractor maintenance work, with $10,000 spent internally on project management and delivery, works planning, monitoring, and contractor engagement. An allowance of $40,000 has been included for one-off activities, such as major studies or one-off bank stabilisation works, totalling $65,000 annually. The modelled impacts indicated that if this work was not undertaken, AAD would be 20% higher than it currently is. Over a 25 year period, continuation of the current vegetation management plan would have a BC ratio of 1.3, indicating the continuation of the program has economic merit.

Discussion

Results from the Stakeholder Engagement (Section 8) reflected a widespread belief that 'clearing the creek' would result in the reduction of flood risk in Picton. However, the current vegetation management activities are already at the upper limit of what is safe to carry out before bank erosion and stability becomes an issue. To 'clear the creeks' would therefore mean sacrificing bank steepness, which currently contributes to keeping Picton free from mainstream flood risk in events more frequent than a 2% AEP event. This would mean introducing flood risk to out-of-bank areas earlier as frequent events would no longer be contained within the channel. Furthermore, moving to a less steep bank is not feasible in Picton, as the creek is constrained by existing development, privately owned land, or recreation facilities, not to mention reducing the existing amenity of the creek and severely impacting on the local environment.

Recommendation

It is recommended that Council continue its riparian vegetation management plan as it plays a vital role in floodplain risk management in Picton. This plan should be reviewed on a regular basis, for example via future Floodplain Risk Management Studies and Plans, and following major flood events which may affect the vegetation characteristics and channel geometry of Stonequarry Creek.

11.5.3. Major Bridge Modification Options

Hydraulic controls such as bridges or major culverts on significant waterways can affect upstream flood levels due to backwatering effects. Increasing hydraulic conveyance through modification of these structures can lead to a decrease in flood levels upstream of a structure. Generally, the most effective method of increasing hydraulic conveyance is to increase a structure's cross-sectional area perpendicular to the flow direction. This is often done by lengthening bridge spans, raising deck levels or increasing the capacity of culverts. In Picton, the Argyle Street Bridge and the Railway Viaduct both span Stonequarry Creek, and are seen by the community as major hydraulic controls that, if "opened up" would relieve flood risk in Picton. These options have been assessed and are described below.

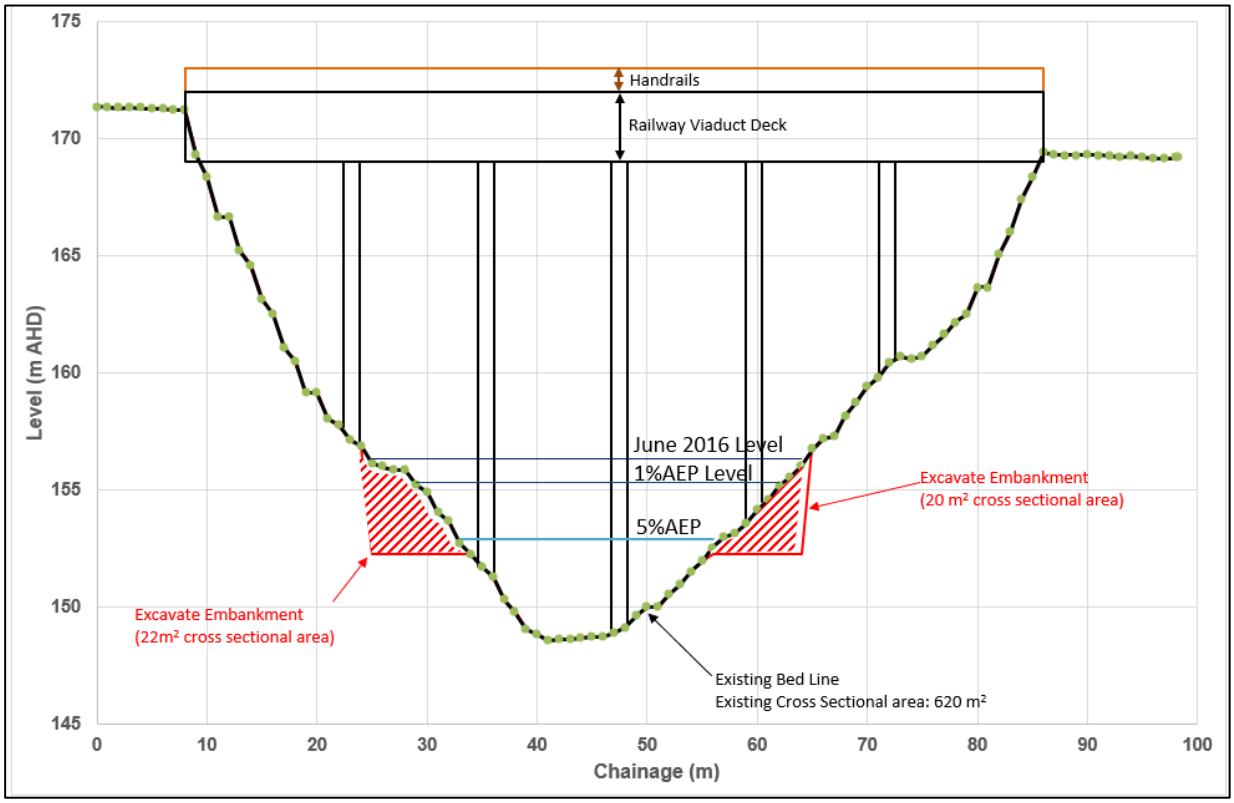
11.5.3.1. Option BM1 – Excavation of Railway Viaduct Abutments

	BM1: Excavation of Railway Viaduct Abutments
Description	• Aim: to increase conveyance through the Railway Viaduct to reduce peak flood levels and duration of inundation in the CBD; • Excavation of Stonequarry Creek banks over a 70 m length (including land upstream and downstream of the Viaduct, a total of 1500 m^3);
Benefits	• Reduces peak flood levels locally by up to 0.09 m in the 1% AEP event;
Concerns	• Benefits do not extend far enough upstream to reduce flood risk in the CBD; • Removal of riparian vegetation resulting in the potential reduction in bank stability and loss of native habitats; • Acquisition of privately owned land adjacent to the creek would be necessary; • Approvals of undertaking significant excavation in close proximity to the bridge abutments is likely to be challenging.
Outcome	Not recommended for further investigation.

Option Description

Option BM1 was modelled with the aim of increasing hydraulic capacity under the railway bridge by opening up the abutments on both right and left banks. This was modelled by the excavation of a total volume of 1,500 m^3 over the length of 70 m. Diagram 7 illustrates the flood level in the 1% AEP and 5% AEP events of the Stonequarry Creek cross section at Railway Viaduct. The red polygons represent the excavated areas suggested in Option BM1.

Diagram 7: Stonequarry Creek cross section at Railway Viaduct



Modelled Impacts

The results for the 1% AEP are shown on Figure B5. The Option results in a maximum peak flood level reduction of 0.09 m occurring in the area immediately upstream of the Viaduct. However, the steep slope of Stonequarry Creek (shown on Figure A15) means that the peak flood level reductions extend only 650 m upstream of the Viaduct, and flood behaviour within the CBD is not affected by the excavation, noting that in the 1% AEP design event, peak flood levels at Argyle Street are approximately 2.8 m higher than the flood level downstream at the Viaduct. With the increased channel capacity, there is a localised area through and immediately downstream of the Viaduct in which peak flood levels are increased by less than 0.05 m, however the flow in this area is confined to the channel and does not impact on development. Flood impacts in the 5% AEP event are shown on Figure B6 and show that opening up the abutments does not have a material impact on peak flood levels, with localised reductions in the order of 0.05 m. This indicates that in this size flood, the current viaduct abutments are not significantly obstructing flow.

Discussion of Other Concerns and Considerations

Option BM1 requires major works for the excavation of total 1,500 m^3 at the abutments. Due to the location of the construction areas, approval would be required for the works around the Viaduct abutments, driving up the cost of detailed design and bank stabilisation works, and may require additional works to ensure the structural integrity of the existing bridge footings. Additionally, the excavation is likely to cause environmental impacts that may also make approval challenging, including removal of vegetation (and possibly habitat), and the potential for resulting bank instability may add require additional costs for bank stabilisation works.

Evaluation

The excavation of the embankments immediately up and downstream of the Viaduct abutments provides localised reductions in flood levels, however does not influence nor improve flood risk (level or duration) in the Picton CBD. While the localised impacts would benefit some properties along Menangle Street, it is unlikely the benefits would outweigh the significant design, approvals and construction costs and environmental impacts that would be incurred. Option BM1 is not recommended for further investigation.

11.5.3.2. Option BM2 – Excavation of Argyle Street Bridge Abutments

	BM2: Excavation of Argyle Street Bridge Abutments
Description	• Aim: to increase conveyance through the Argyle Street Bridge to reduce peak flood levels and duration of inundation in the CBD; • Excavation of Stonequarry Creek banks (total of 275 m^3);
Benefits	• Reduces peak flood levels locally by up to 0.05 m in the 1% AEP event;
Concerns	• Removal of riparian vegetation resulting in the potential reduction in bank stability and loss of native habitats; • Acquisition of privately-owned land adjacent to the creek would be necessary; • Approval to undertake excavation in close proximity to the bridge abutments is likely to be challenging.
Outcome	*Not recommended for further investigation.*

Option Description

As for Option BM1, Option BM2 was modelled with the aim of increasing hydraulic capacity under Argyle Street bridge by widening the channel on both banks. This was modelled by lowering the left and right banks by up to 2.5m which represents an increase of 10 m^2 in the channel (as shown on Diagram 8), with a total excavated volume in the order of 275 m^3.

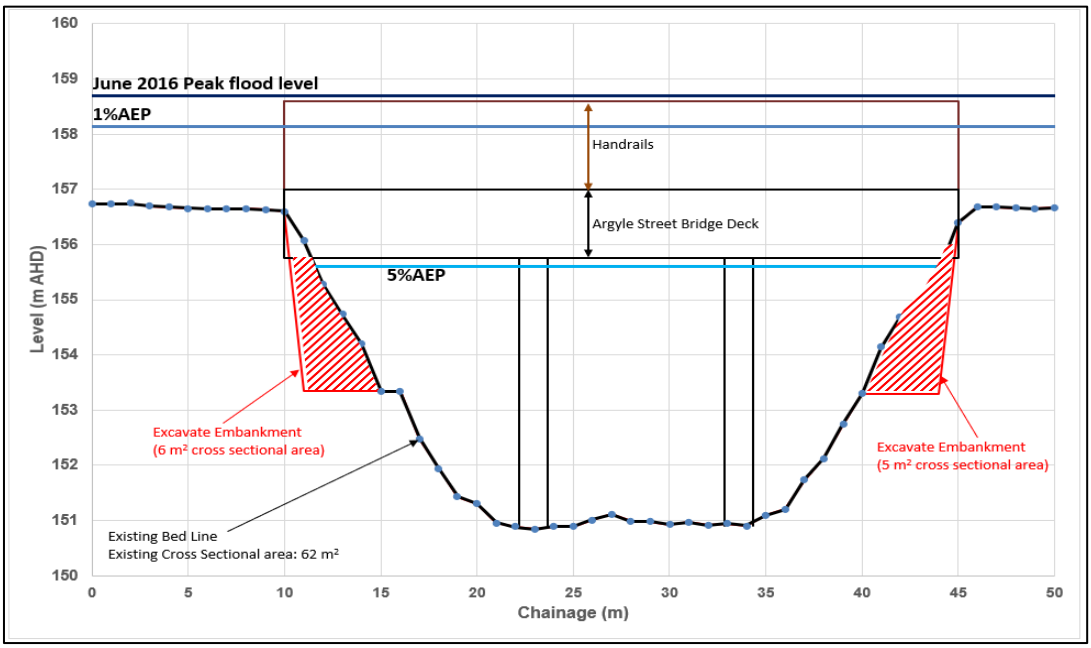


Diagram 8 Stonequarry Creek cross section at Argyle Street Bridge

Modelled Impacts

The peak flood level impacts in the 1% AEP event are shown on Figure B7, and indicate that the changes to the creek cross section at the Argyle Street bridge have limited impact on flooding in the CBD, reducing flood levels by less than 0.05 m. This is due to flow entering the CBD at a point approximately 60 m upstream of the Argyle Street bridge, and that flooding in the CBD is not occurring as a result of flow being held up behind the Argyle Street bridge. This is observed also in the long section (profile) of Stonequarry Creek (shown on Figure A15), which shows a consistent peak flood level either side of the Argyle Street bridge. It is noted that if the bridge structure was causing a significant obstruction to flow, the profile would show a notable afflux at the bridge, i.e. peak flood levels would be higher on the upstream side and lower on the downstream side. This is not the case in the 1% AEP design event.

Note also that the impacts in the 5% AEP event are limited to a local area up and downstream of the bridge as the CBD is not inundated from mainstream flooding in a 5% AEP event, as indicated on Figure B8.

Discussion of Other Concerns and Considerations

Excavation around the abutments of Argyle Street bridge is likely to incur high costs to ensure the structural integrity of the bridge abutments are not affected by removal of (potentially supporting) embankment material. The works area is limited to the beneath the bridge itself, so the environmental impacts are not considered to be a significant constraint. The excavation may require bank stabilisation works, and local traffic may be affected during the construction period.

Evaluation

The limited benefits associated with increasing the channel cross section at the Argyle Street means this option does not warrant further investigation as a flood mitigation option in Picton.

11.5.4. Retarding Basins

A retarding basin is a small dam that provides temporary storage for floodwaters (Reference 4), and works by capturing floodwaters during an event, to be released at a lower flow rate once the peak of the flood has passed. Retarding basins can be an effective means of reducing peak flood levels, however depending on the outlet design and operation, may increase the duration of flooding by prolonging the release of stored floodwaters.

Although commonly suggested by community members, there are a number of challenges and inherent disadvantages associated with retarding basins to be carefully evaluated, including:

- Availability of land and appropriate topography – a significant area is needed to achieve the necessary storage capacity;
- Public safety during and following a flood event need to be considered, particular for basins of significant area and/or depth;
- Risk of overtopping or failure if the dam is already full when additional rainfall occurs (e.g. long duration floods or multi-burst storms;
- Ongoing maintenance to ensure structural integrity of the basin wall/embankment, and to prevent outlet pipes and gates from silting up or being damaged.

In Picton specifically, the steep topography and deeply incised channel reduces the availability of appropriate sites for retarding basins. Five separate retarding basin options have been investigated for implementation in Picton following suggestions from the community, Council and the Floodplain Risk Management Committee. The options are described in the subsequent section.

11.5.4.1. Option RB1 – Stonequarry Creek Western Catchment Retarding Basin Feasibility Study

☑	**RB1: Stonequarry Creek Western Catchment Retarding Basin Feasibility Study**
Description	• Aim: to increase flood storage capacity on Stonequarry Creek to reduce peak flood levels in Picton; • Undertake a feasibility study to investigate appropriate site(s) and concept designs for retarding basin(s) in the western part of the Stonequarry Creek catchment, at location(s) upstream of Barkers Lodge Road
Benefits	• Assessment has shown the peak flood levels in the Picton CBD can be reduced by up to 0.12 m in the 1% AEP event as a result of reducing the peak flow from ~220 m^3/s to 200 m^3/s at the Barkers Lodge Road Bridge; • Potential for greater flood level reductions depending on storage capacity available; • Minimal earthworks and excavation required at the assessed location as naturally occurring benched areas are utilised;
Concerns	• Privately owned (currently undeveloped) land at the assessed location would be newly inundated in events including and greater than the 1% AEP; • Modification of Barkers Lodge Road bridge or other outlet locations would require significant approvals and involve design constraints; • Impacts of coal extraction on flood behaviour to be considered in future design stages;

Outcome	A feasibility study is recommended to determine a suitable location for the basin and outlet structure and optimisation of the storage/outlet arrangement.

Option Description

This option aimed to provide a proof of concept for the benefits of construction of a retarding basin in the western portion of the Stonequarry Creek catchment upstream of Barkers Lodge Road. Upstream of the Barkers Lodge Road bridge, the Stonequarry Creek channel shape is characterised by a deeply incised channel, with a relatively flat, benched area between the creek and Barkers Lodge Road (sitting 1 m – 2 m lower than the road level). This assessment explored the possibility of utilising the benched area for flood storage, and aimed to inundate this area in events equivalent to and rarer than the 2% AEP event, for the benefit of the CBD downstream. The assessment involves lowering the soffit of the Barkers Lodge Road bridge to obstruct flow, causing water to back up onto the currently vacant land and reduce the maximum discharge through the bridge. A cross section of the proposed bridge modification is shown in Diagram 9.

In a 1% AEP event, the arrangement shown in Diagram 9 causes 110,000 m^3 (110 ML) of floodwater to be stored, reducing the peak flow through the Barkers Lodge Road bridge from 220 m^3/s to 200 m^3/s. This arrangement was selected as it still allows enough flow beneath the bridge such that the bridge deck is not overtopped in the 1% AEP event. Diagram 10 shows the proposed Stonequarry Creek flood storage area investigated as part of this option, with a cross section through the site (indicating the benched area) shown in Diagram 11.

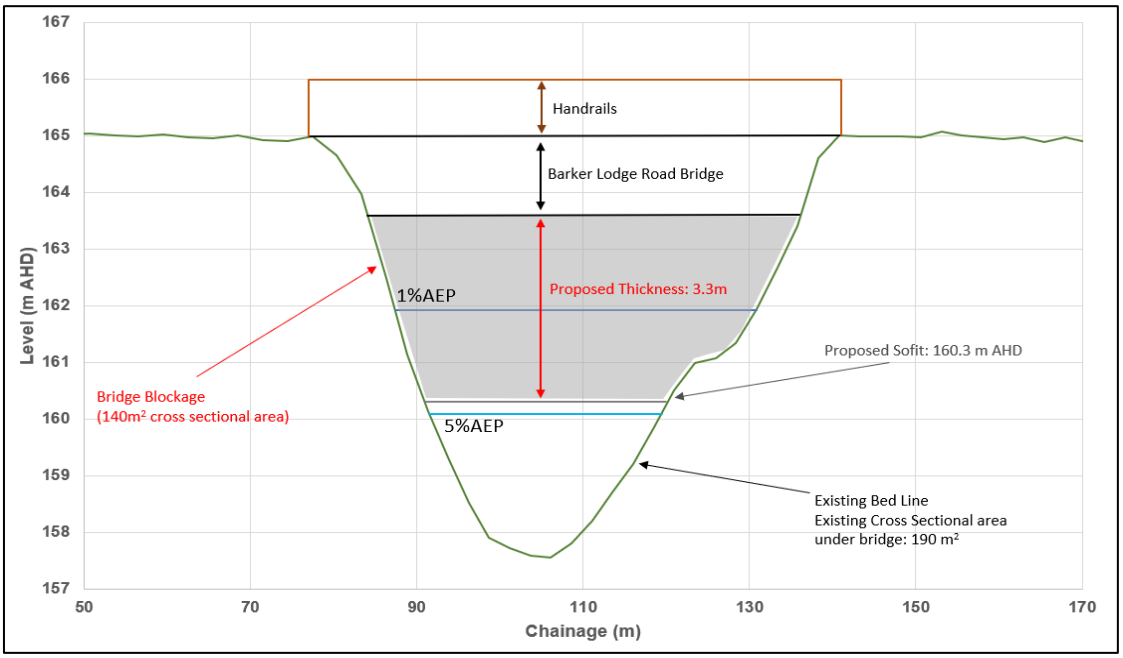


Diagram 9: Cross Section of proposed modification to Barkers Lodge Road Bridge

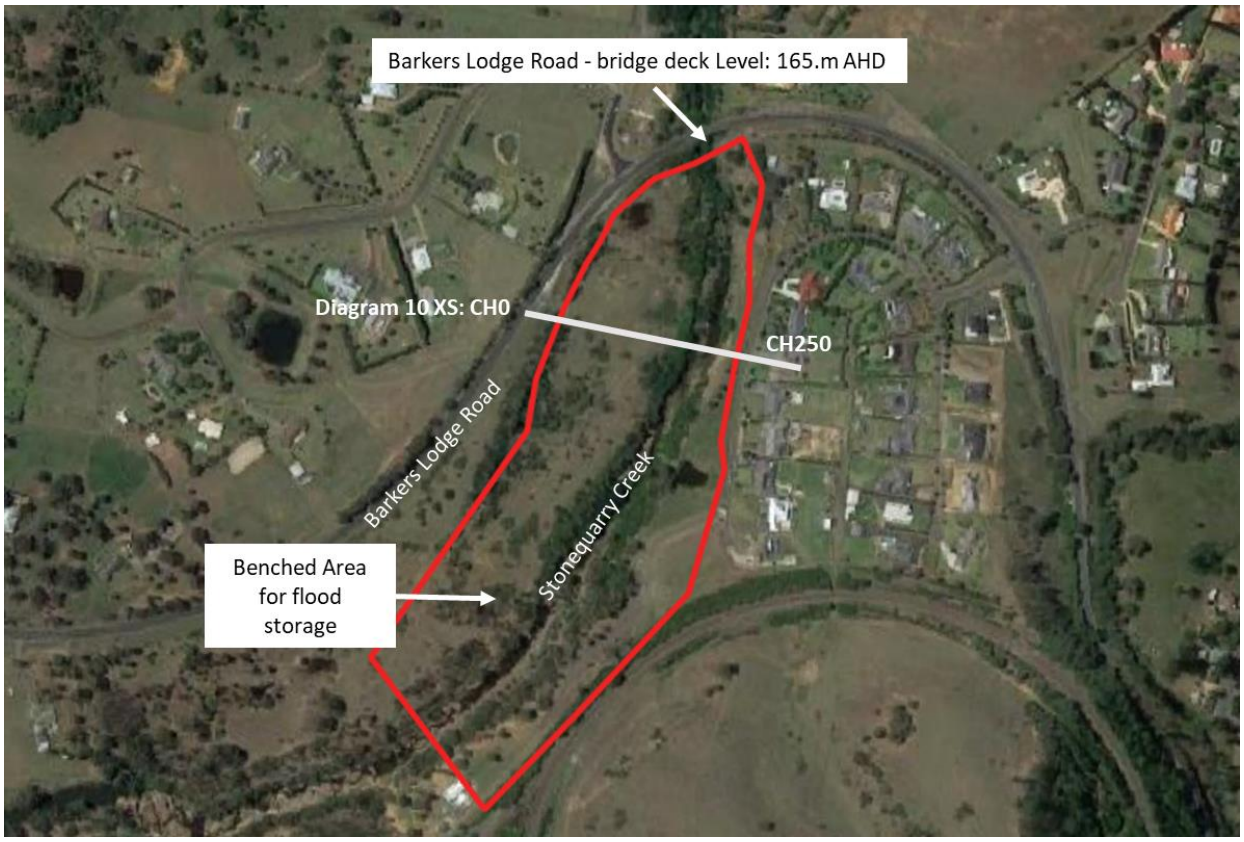


Diagram 10 Stonequarry Creek Flood Storage Area

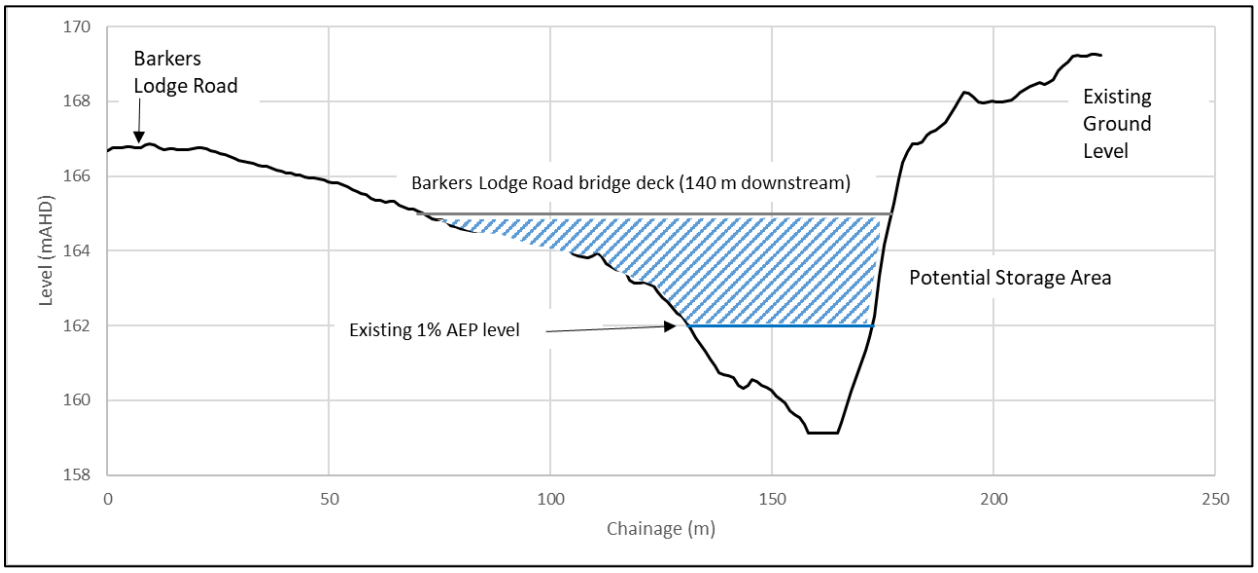


Diagram 11 Cross Section through vacant land upstream of Barkers Lodge Road bridge.

Modelled Impacts

The assessed basin site does not entirely fall within the current hydraulic model boundary, the basin was simulated by modifying flows in the hydrological model. The design inflow hydrograph for the 1% AEP event was modified to simulate the reduction in peak flow through the bridge from 220 m^3/s to 200 m^3/s in order to assess the downstream impacts that would result from this option (200 m^3/s represents the lowest discharge possible beneath the bridge without causing flow to back up so much as to overtop the Barkers Lodge Road bridge deck). As shown on Figure B9, the option results in widespread reductions in peak flood levels along Stonequarry Creek and the

floodplain in the 1% AEP event, with peak flood level reductions of 0.12 m in the CBD. The impacts upstream of the bridge have not been determined as part of this study as the affected land is upstream of the TUFLOW hydraulic model boundary. Investigation of the upstream impacts would be an important feature of a feasibility study if this option were to progress. A preliminary review of the available topographic data indicated that if the top water level is capped at 165 mAHD, 52 ha of land would be inundated (shown in Diagram 12)

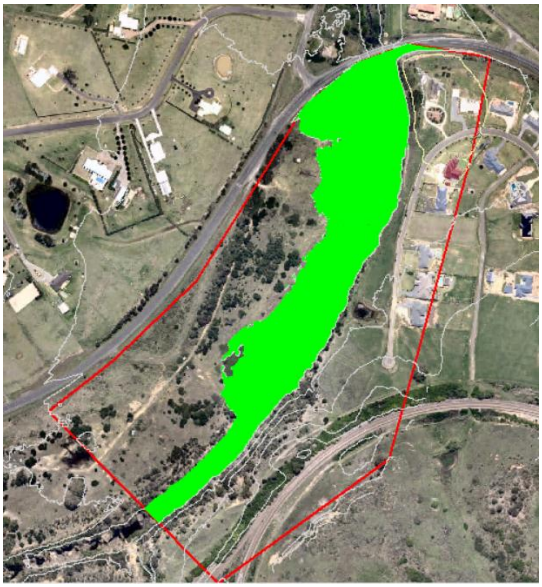


Diagram 12 52 ha of land inundated with a top water level of 165 mAHD

It is noted that with the assessed bridge modifications, no change in flood behaviour would occur in the 5% AEP event, as the peak level would still be lower than the proposed bridge soffit. In addition, the benefits of this option in events rarer than the 1% AEP event are expected to be limited as the flood storage area would be full prior to the arrival of the peak flow (e.g. in a 0.5% AEP or greater).

Economic Assessment

There are a number of uncertainties associated with this assessment which make it difficult to determine the capital cost and quantify the benefits, and a more detailed investigation is recommended. However, based on the assumption that the existing Barkers Lodge Road bridge is modified, capital costs in the order of $1.7 M are expected, with a large proportion of this cost driven by the lengthy design and approvals process required to modify such a bridge. With the current preliminary design, the reduction in property damages reduces the Annual Average Damages by only 5%, resulting in a BC ratio of less than 0.2, indicating the option is not economically viable. However, it is expected than there may be alternative sites more suited to the construction of a similar structure (or use of an embankment and culvert arrangement) with lower costs and a less onerous approvals process. In addition, it is expected that the design could be optimised to increase the storage capacity, thereby improving the benefits to properties, thus improving the cost-benefit ratio.

Discussion of Other Concerns and Considerations

Construction works associated with existing bridge structures can be difficult to gain approval for, and may need to be delayed to coincide with the bridge's major maintenance/replacement schedule (which could be decades). It may therefore be more appropriate to investigate a way to achieve a similar outcome without utilising the Barkers Lodge Road bridge structure, by assessing alternative sites further upstream along Stonequarry Creek and considering an embankment and culvert structure arrangement instead.

Regardless of the site, issues associated with land tenure, environmental impacts, and possible impacts to existing roads and infrastructure will need to be considered. Hydraulic impacts such as duration of inundation, extent and depth of newly inundated land, and changes to existing hazard classifications are to be investigated in more detail using modelling tools prepared in Reference 7, modified to allow assessment of flooding further upstream (west) along Stonequarry Creek.

Recommendation

The potential flood risk benefits of a retarding basin in the Stonequarry Creek Western Catchment (Matthews Creek, Cedar Creek etc) including are promising, however further investigation is required to determine a suitable location for the basin, design of the outlet structure (if not at Barkers Lodge Road bridge), and assessment of related social, economic and environmental issues.

A feasibility study is expected to cost approximately $40,000-$60,000, and may be eligible for partial funding via the NSW State Government Floodplain Risk Management Program.

11.5.4.2. Option RB2 – Picton Sportsground Retarding Basin

☒	**RB2: Picton Sportsground Retarding Basin**
Description	• Aim: to provide flood storage on Racecourse Creek to reduce peak flood levels downstream (in the Picton CBD); • Involved lowering the eastern playing field by 2 m (removal of 70,000 m^3), and construction of a 1 m high embankment around the eastern and southern sides, providing a total storage capacity of 110,000 m^3;
Benefits	• Minor peak flood level decrease (0.02 m) downstream of basin; • Construction proposed on Council owned land;
Concerns	• Significant cost of construction for limited benefit; • Ineffective in events more frequent than the 2% AEP; • Potential for flooding to be prolonged; • Public safety concerns as a significant depth (> 3 m) would be ponded within the playing field in a 1% AEP event; • Reduction in amenity and usability of the sportsground following rain events.
Outcome	*Not recommended for further investigation.*

Option Description

This option involves lowering the ground levels of the Picton Sportsground (eastern field only) by 2 m and constructing a 1 m high embankment around the southern and eastern sides to form a retarding basin. A 15 m wide inlet weir was incorporated to allow flow to enter the basin from Racecourse Creek in events equivalent to (and greater than) a 2% AEP event. This water would then be stored in the basin (which has a capacity of approximately 110,000 m^3, and later released via a 1.2 m outlet pipe on the southern side of the field.

Modelled Impacts

The option was modelled in the 1% AEP, and the changes to peak flood levels are shown on Figure B10. Results indicate the basin would result in very limited peak flood level reductions downstream (up to approximately 0.02 m in the CBD). The peak flood affectation in Picton is driven by the flow in Stonequarry Creek, rather than Racecourse Creek (or other tributaries as discussed in subsequent sections). Inflow from Racecourse Creek is held up at the confluence of Stonequarry Creek, as shown by the relatively level water surface shown on Figure A16, and an event on Racecourse Creek alone is unlikely to result in significant flooding in the CBD. Despite providing a significant storage capacity, Option RB2 does not change the peak flow in Stonequarry Creek, and therefore has little impact on the peak flood levels occurring in Picton. It is also noted that in the June 2016 event, a basin of this size would have already been full prior to the arrival of the peak flow, and is unlikely to have reduced flood affectation in the CBD.

Discussion of Other Concerns and Considerations

A high level cost estimate has been prepared, indicating that the capital costs to design and construct such a basin would be in the order of $5 M. With the limited flood benefits described above, and significant construction costs, this option is not considered feasible and has not been shortlisted for detailed assessment or full economic assessment.

Furthermore, use of the Picton Sportsground as a basin brings with it risk to public safety, as significant depths of floodwaters would be stored in the open area in large flood events. In addition, the drainage of local rain over the field may also be delayed, causing sporting fixtures to be cancelled, and reducing the usability and amenity of the field.

Recommendation

While the proposed basin location is on Council owned land, and therefore perhaps more readily feasible than other locations, the basin would require significant excavation and does not serve to reduce flood risk in Picton. Option RB2 is therefore not recommended for further investigation.

11.5.4.3. Option RB3 –Retarding Basins on Minor Tributaries

☒	**RB3: Retarding Basins on Tributaries**
Aim	To provide flood storage on Crawfords Creek and minor, unnamed tributaries, to reduce inflows to Stonequarry Creek and decrease peak flood levels.
Benefits	Limited reductions in peak flood levels throughout Picton.
Concerns	• Significant storage volume required for limited benefit; • Ineffective in events more frequent than the 2% AEP; • High capital and ongoing costs.
Outcome	*Not recommended for further investigation.*

Option Description

With the aim of reducing inflows into Stonequarry Creek, the construction of retarding basins on a number of tributaries has been considered. In this option specifically, Crawfords Creek, "Abbotsford Creek" (the unnamed watercourse running along Abbotsford Road), and two minor gullies draining from the east into Stonequarry Creek downstream (south) of Baxter Lane. To conceptually assess the viability of retarding basins on this system, two scenarios were assessed:

a) Impacts of reducing total inflows from these tributaries by 50%;
b) Storage volume required to reduce peak flood levels in the CBD by 0.5 m.

Scenario A: Reduction of inflows by 50%

This option was modelled by reducing the inflows from the hydrologic model into the TUFLOW hydraulic model by 50% to determine the potential benefits available. The results are presented on Figure B11, and indicate a maximum peak flood level reduction in the 1% AEP is 0.18 m in the CBD (on Argyle Street). It is noted that a depth of 1.5 – 1.8 m would remain in a 1% AEP, indicating that flood risk would not be removed. A significant storage volume would be required to achieve this.

Scenario B: Reduction of 1% AEP peak flood levels in the CBD by 0.5 m

In the Picton CBD, the peak flood levels in a 2% AEP event are approximately 0.5 m lower than in a 1% AEP event. As detailed in Table 8, the 1% AEP peak flow at the gauge is approximately 452 m^3/s, some 103 m^3/s higher than the 2% AEP peak flow (349 m^3/s). In order to achieve this reduction in peak flow (and hence an approximate drop in flood levels of 0.5 m in the CBD), inflows from Crawfords Creek and "Abbotsford Creek" would need to be reduced by 100%, which is not realistic. To achieve this reduction, retarding basins with the characteristics outlined in Table 23 would be required. Note that the two minor tributaries downstream of Baxter Lane have not been included in this option as they do not contribute to the flood risk in the CBD.

Table 23 Tributary Retarding Basins (to reduce peak flood levels in the CBD by 0.5 m)

Tributary	Crawfords Creek	Abbotsford Creek
Total Catchment Area (ha)	900	400
Storage Volume Required (m^3)	1.1M	254,000
Storage Volume Required (ML)	1100	254
Required Dam Height (exc. Freeboard) (m)	16	8.5
Footprint Width	65	33
Dam Length (m)	250	420
Area Inundated (ha)	23	12

Discussion

This option was suggested by the Floodplain Risk Management Committee with the thinking that minor gully dams across the creeks would be required to achieve reasonable benefits. However, due to the topographic characteristics of the two tributaries, significant embankment structures are needed to form the required storage. The channels are narrow and deeply incised, surrounded by relatively flat land. This means that there is limited storage capacity within the channels themselves, and the embankment needs to span across several hundred metres of relatively level ground to meet the next hill to form a gully dam of sufficient capacity. A typical section through Crawfords Creek is provided in Diagram 13 to illustrate the scale of the required embankment. The creek along Abbotsford Road, and its surrounds, has a comparable geometry.

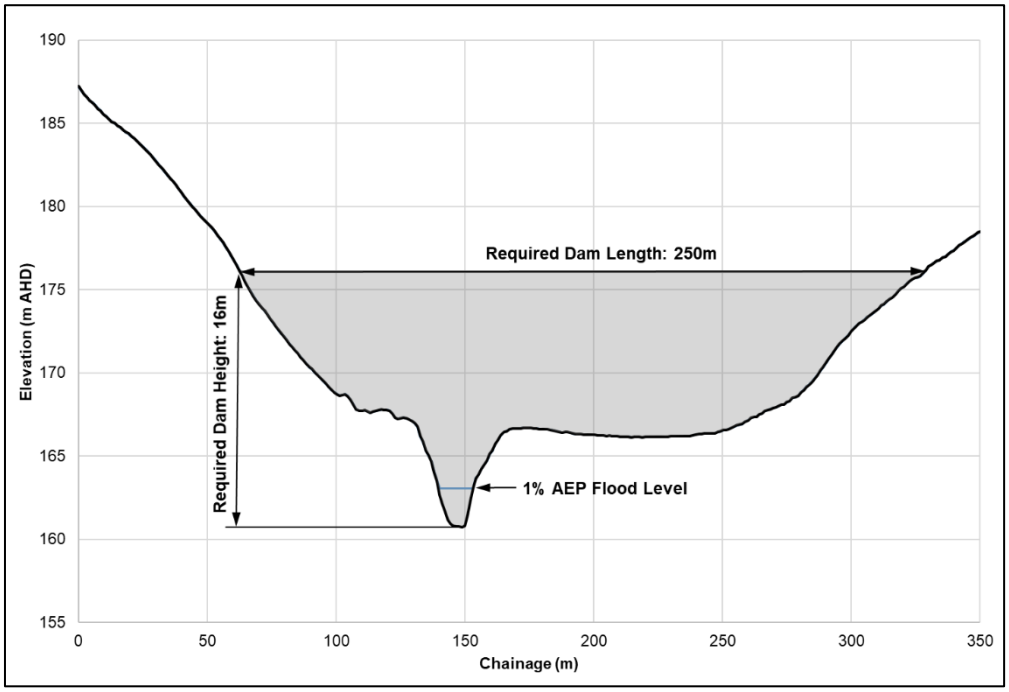


Diagram 13 Crawfords Creek Typical Cross Section

In addition, as discussed in the previous section, the peak flood affectation in Picton is generally driven by flooding in Stonequarry Creek, owing to the significant catchment area from which it receives inflows (5,256 ha upstream of the confluence with Racecourse Creek, compared to 900 ha to Crawfords Creek and 400 ha to "Abbotsford Creek"). Therefore, to have a material impact on the peak flood levels in the CBD, flows within Stonequarry Creek must be reduced. The two tributaries considered in this option have a relatively limited contribution to peak flood levels in the CBD, and hence are required to be stemmed completely to reduce peak flood levels in the CBD.

For the volume of earthworks required compared to the benefits available, retarding basins on minor tributaries are not considered feasible and have not been shortlisted for detailed investigation. In addition, issues associated with, land tenure, public safety, risk of dam failure, ongoing maintenance and potential environmental impact further contribute to this option not being a preferred means of flood risk mitigation. It is also noted that even with a reduction of 0.5 m, peak flood depths in the CBD would still reach up to 0.8 m in a 1% AEP event, indicating that a high degree of flood risk would still exist in the CBD with this option in place.

Evaluation

This option is not considered feasible due to the significant earthworks and limited reduction in flood risk for Picton. The construction of retarding basins on minor tributaries (such as Crawfords Creek and "Abbotsford Creek") are not recommended for further investigation.

11.5.4.4. Option RB4 – Hume Oval Retarding Basin

☒	**RB4: Hume Oval Retarding Basin**
Aim	To utilise Hume Oval to provide flood storage (to be filled from Stonequarry Creek) and decrease peak flood levels in the CBD.
Benefits	• Minor reductions in peak flood levels; • Potential improvements to spectator seating available;
Concerns	• Significant storage volume required for limited benefit; • Ineffective in events more frequent than the 2% AEP; • High capital and ongoing costs; • Obstruction to overland flow causing adverse impacts outside basin.
Outcome	*Not recommended for further investigation.*

Option Description

During community consultation, reference was made to Hume Oval being a former swamp, and the possibility of using this Council-owned land for a retarding basin was raised. To test the benefits that might be available, a basin was modelled by lowering the existing ground level by 2 m (approximately 42,700 m^3 to be excavated), with an additional 1-2 m high embankment around the eastern and southern sides (approximately 3,000 m^3 of fill).

Modelled Impacts

The option was modelled in the 1% AEP event, with resulting changes to peak flood levels shown on Figure B12. Although providing a significant storage volume (62 ML in a 1% AEP event), the option does not materially reduce flood affectation in the CBD, with peak flood levels only being reduced by 0.05 m. The basin at this location is ineffective for two reasons: firstly, there is no connected flowpath from Stonequarry Creek to the CBD through Hume Oval (as can be seen in the hydraulic categorisation shown on Figure A20) which means that construction of the basin and embankment does not obstruct a flowpath nor reduce peak flow through to the CBD. Secondly, flow breaks out of the Stonequarry Creek channel upstream of the Argyle Street bridge, and inundates the CBD from the south. This is the primary source of inundation in the CBD, and is not significantly relieved by the Hume Oval basin.

It is noted that the basin would not be effective in events more frequent than the 1% AEP event as mainstream flooding is retained within the channel of Stonequarry Creek adjacent to Hume Oval. However, the embankment would obstruct the flow of local runoff into the field from the east, exacerbating flood risk outside of the field. This is seen on Figure B12 and would also occur in more frequent events, as shown for the 5% AEP event on Figure B13.

Discussion of Other Concerns and Considerations

The Hume Oval retarding basin is likely to have high capital costs due to the large amount of excavation works. While this option has not been considered for a full economic assessment, in order to result in a cost-benefit ratio equal to 1, the capital costs would need to be less than $400,000. This is not considered realistic, and it is likely that the option would not be economically feasible. Modification of the Hume Oval Sportsground does offer the opportunity to improve the facility for spectator's viewing and seating areas. However, it requires major excavation and re-shaping of the natural creek bank, posing negative environmental impacts. Furthermore, the increase in duration of inundation would reduce amenity of the playing field for a prolonged period following an event and make the facility unusable.

Evaluation

The modelled option requires considerable capital works for very little benefit, which would have a significant cost and environmental impacts attached to it. With a small decrease in flood level of 0.05 m, it can be observed that the water coming from Hume Oval Sportsground flowpath into the CBD is very minimal, and that the Sportsground is not well positioned for a basin to have a major impact on flood risk in the CBD. Social and community impacts would also be significant as the basin would create highly hazardous depths of ponding (which would require fencing for public safety). Therefore, Option RB4 is not recommended for further investigation.

11.5.4.5. Option RB5 – Racecourse Creek Retarding Basins

	RB5: Racecourse Creek Retarding Basins
Aim	To provide flood storage along Racecourse Creek and decrease peak flood levels in the CBD.
Benefits	NA – this option does not reduce flood risk in Picton;
Concerns	• Steep natural terrain not suited to providing additional storage; • Considerable environmental impacts and high costs of excavation; • Local impacts on flood behaviour only.
Outcome	*Not recommended for further investigation.*

Option Description

During community consultation, the vacant land along the northern side of Racecourse Creek was identified for potential use in flood mitigation via the construction of a series of retarding basins. At this location however, Racecourse Creek is confined to a steep valley, and the topography and winding creek does not readily lend itself to the construction of basins as significant excavation of naturally occurring high ground would be needed to increase the storage available (see Diagram 14). Nevertheless, the hydraulic model developed in Reference 7 allows for the potential benefits of such an option to be readily determined, and so an option has been assessed involving the excavation of three “basins” along Racecourse Creek.

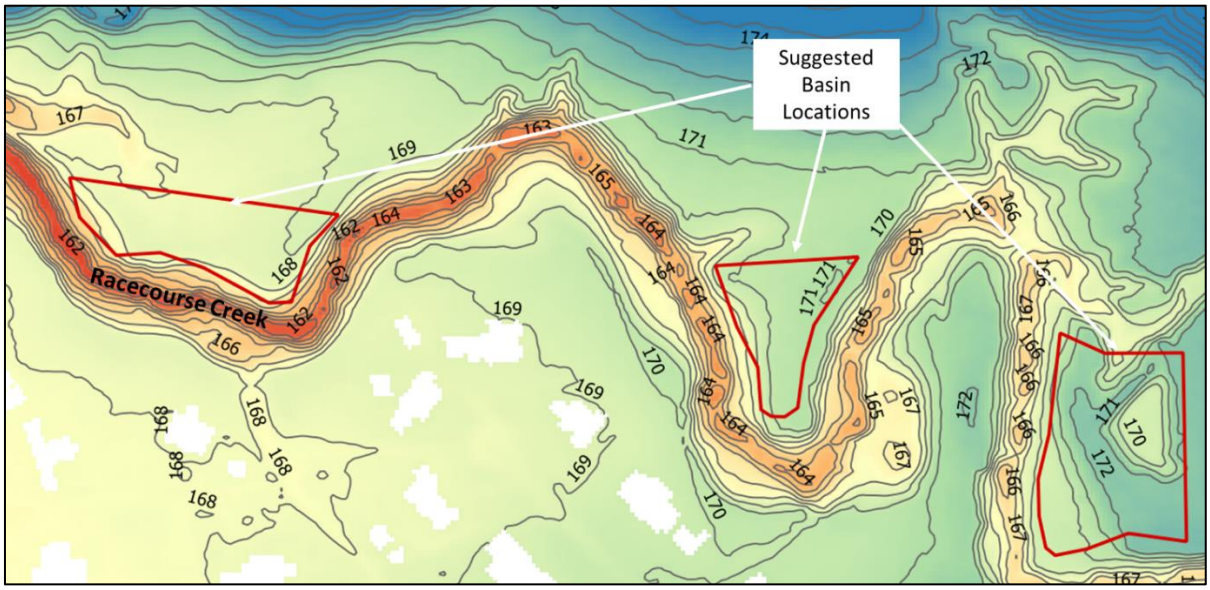


Diagram 14 Topography along Racecourse Creek

Given the challenging terrain, traditional basins that retain water temporarily, then release flows through a controlled outlet are not considered feasible. The ‘basins’ modelled in this option do not retain water with a formalised outlet, rather simply provide additional temporary storage areas to be filled by the creek as it flows towards Stonequarry Creek. This approach still involves significant excavation, as a portion of each hills is effectively removed (totalling 51,000 m^3) to create a broad area with a bed level equivalent to the Racecourse Creek bed (i.e. lowering ground levels by 5.8 m - 6.6 m). It is noted that this is not considered feasible, however has been assessed to confirm the hydraulic impacts available.

Modelled Impacts

The option was modelled in the 1% AEP event, with impacts shown in Figure B14. The results indicate that this option changes flood levels locally along Racecourse Creek, but does not impact on flood levels downstream of the western of the three basins.

Discussion of Other Concerns and Considerations

The construction of several retarding basins along an existing creek in the local areas would require significant excavation works that likely to have high capital costs associated with earthwork, environmental impacts, and disruption to the surrounding areas. Given the limited benefit to properties, the cost – benefit ratio for the option is likely to be too low to justify its implementation.

Evaluation

Option RB4 does not reduce flood risk in Picton, and would likely entail prohibitive capital costs and environmental impacts. This option is not recommended for further assessment.

11.5.5. 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 floodwaters backing up through the 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 a levee.

The crest height of a levee is set at a level that equals the height of the design flood event for which it 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. Levees would also be typically constructed with a spillway with a lesser amount of freeboard. A spillway is a lower portion of the levee which allows for controlled overtopping of the levee to minimise the damage to the structure in floods larger than the design level of protection. At this stage, a preliminary assessment of basic levee options has been undertaken (to assess alignments and heights), with no specific allowance for freeboard nor spillways included at this stage.

11.5.5.1. Option L1 – South Picton Diversion Bank

☑	**L1: South Picton Diversion Bank**
Description	• Low level embankment designed to divert overland flow around residential properties, rather than through backyards and onto Menangle Street;
Benefits	• Reduces nuisance flooding in residential yards and reduces hazard to motorists on Menangle Street;
Concerns	• Limited tangible benefits result in this option not being considered economically viable; • If acquisition of private property is needed, costs may be driven up substantially; • May be opposed due to visual amenity complaints from residents;
Outcome	Recommended as a low priority action item to be considered for further investigation in conjunction with other works in the area.

Option Description

Residential premises along Menangle Street opposite Victoria Park are subject to inundation from overland flow from the east. The dwellings have floor levels well above ground, and are not flooded over-floor by the shallow runoff. However, the flowpath heading from the east towards Stonequarry Creek flows between houses through backyards, and may be a source of nuisance flooding and external property damage. To remove this minor affectation altogether, this option proposes construction of a low earthen bund (up to 0.5 m above ground, for a length of 190 m), to divert overland flow to the north and around the dwellings.

Modelled Impacts

The option was modelled in the 1% AEP with impacts shown on Figure B15. The embankment successfully redirects water to the north of the affected properties and then west towards Stonequarry Creek, without significantly increasing flood levels on the upstream (eastern) side of the embankment. In addition, a localised portion of Menangle Street is no longer flooded as a result of the diversion bank, improving safety as even shallow flow across a road can be hazardous for motorists.

Economic Assessment

This option is estimated to have a relatively low capital cost, in the order of $150,000, owing to the relatively straightforward design and construction process for a low embankment. However, depending on the land tenure, and potential requirement for an easement, costs could increase markedly. Without reducing over-floor property damages, the direct, tangible benefits of this option are limited, and the Annual Average Damages is reduced by less than 1%. With a resulting BC ratio less than 0.1, this option is not economically viable. However, intangible benefits (described below and assessed in Section 12), must also be considered.

Discussion of Other Concerns and Considerations

Targeted consultation is recommended to ascertain the value this option would have for the affected residents and road users, and if any objections are raised (for example visual amenity of the constructed embankment). Depending on the siting of the embankment, establishment of an easement through private property to allow construction and maintenance may be needed. Consideration of constructing this diversion embankment in conjunction with other development or maintenance works may be the most cost effective approach.

Evaluation

Option L1 is recommended to be considered further as a low priority action item in the Floodplain Risk Management Plan. If this option were to proceed, targeted consultation and optimisation of the embankment height is recommended. It is likely that a lower embankment than what has been modelled in this option will be effective in diverting the shallow flow, and would reduce capital cost and visual amenity, making this option more cost effective and desirable to the community.

11.5.5.2. Option L2 and L3 – Stonequarry Creek Levees

	L2 & L3 – Stonequarry Creek Levees
Aim	To protect Picton from mainstream flooding in events up to the 1% AEP
Benefits	Reduced property damage in the CBD from mainstream flooding;
Concerns	• Internal drainage obstructed; • Space constraints and extensive land acquisition necessary; • High capital costs; • Levee approx. 2 m high, with significant visual impacts; • New bridge structure at Argyle Street necessary, as there is insufficient warning time to install temporary levee gates.
Outcome	*Not recommended for further investigation.*

Option Description

A levee option was previously assessed for Picton as Option S5 in the 1992 Stonequarry Creek Floodplain Management Study (Reference 9). In the 1992 Study, the proposed levee followed the creek line and involved an embankment approximately 2.5 m high on both sides of the creek. Two options have been assessed for Picton using current modelling tools. The first, L2, considers a levee only on the left bank of Stonequarry Creek, i.e. on the CBD side of the creek, while L3 adds another levee on the other side of the creek as well. Naturally occurring high ground on the western side of the creek (right bank) confines the creek, and reduces the length of levee needed. The option L3 right-bank levee could be constructed in two sections, of 200 m (near Davies Place) and 500 m across Argyle Street. However, on the left bank, a levee would be required to extend upstream beyond Hume Oval, with a total length of 1.5 km, to ensure all low points where the creek breaks out are adequately blocked. The levee alignments and peak flood impacts in the 1% AEP are shown on Figure B16 and Figure B17 for Option L2 and L3 respectively.

Modelled Impacts

Option L2 prevents mainstream flooding from entering the CBD, and instead confines flooding to the creek and pushes additional flow to the opposite bank, increasing peak flood levels around the George IV Hotel by up to 0.13 m in a 1% AEP event. Within the CBD, peak flood levels are significantly reduced, by up to 0.8 m in Argyle Street. It is noted that flood affectation is not removed altogether, as overland flow moving through the CBD towards the creek cannot escape to the river.

Option L3 constrains flow to the leveed channel, increasing flood levels by 0.5 m at the Argyle Street Bridge, and increasing the peak flood velocity at this location by 0.8 m/s. In the leveed areas, peak flood levels are significantly reduced, again by approximately 0.8 m in Argyle Street (on the northern side of the creek) and 0.6 m on the opposite (southern) side. The levee height varies with location, but would need to be approximately 1.4 m (plus freeboard) above ground level at Argyle Street in Option L3. The appropriate freeboard is likely to be over 0.5 m, resulting in a levee close to 2 m high.

Discussion of Other Concerns and Considerations

Option L2 results in an unacceptable increase in flood risk for properties on the opposite side of the creek, and is not recommended for further consideration. Option L3 would yield significant flood level reductions on both sides of Stonequarry Creek, however is not considered feasible in Picton for a range of reasons, particularly as a result of the significant levee height (approximately 2 m), which brings with it the following issues:

- Large footprint (approximately 9 m if using earthfill embankment construction), plus maintenance track resulting in high cost of land acquisition to establish an appropriate easement;
- Sheet-pile wall may be more feasible due to space constraints;
- Environmental impacts;
- Effects of higher velocities within the channel (i.e. scouring, removal of vegetation, bank instability);
- Visual amenity issues and restricted access to the creek;
- New bridge required at Argyle Street, as there is insufficient warning time to safely deploy temporary levee gates;
- Obstructions to local drainage even when creek levels are low;
- High capital costs due to quantity of materials required - over 22,000 m^3 of fill needed (if earthfill embankment construction), requirement to source clay core materials Capital costs are estimated to be in the order of $18 M, plus annual maintenance costs.

Community flood education would be required to ensure residents and business owners appreciate their residual flood risk – and understand that a levee is not a ‘cure all’ for flooding. A levee designed to withstand the 1% AEP event is likely to have been breached during the June 2016 event, potentially with catastrophic impacts. It is noted also that levee options received limited community support during the stakeholder consultation period (Section 8). Due to the topography, a levee in Picton would have little impact on property damages in events more frequent than a 2% AEP event, limiting the reduction in AAD and therefore the economic benefits available. Furthermore, with the land acquisition, approvals and design process, levee projects typically take 5-10 years (or more) before they are shovel ready – a delay unlikely to be palatable to the community.

Recommendation

In a 1% AEP flood event, Option L2 and L3 would provide significant reductions in flood affectation in properties in Picton CBD. However, these options would have a number of challenges in terms of easement acquisition, high capital costs, ongoing maintenance requirements, creek amenity, environmental impacts, and potential evacuation implications. It is considered that there are alternatives available to reduce flood damage in Picton that are less invasive, more cost-effective, and more readily implemented than a levee. Therefore, neither levee option (L2 nor L3) are recommended for further investigation.

11.5.6. Local Drainage Options

Local drainage systems typically reach capacity in an event equivalent to a 20% AEP, and excess runoff flows overland, potentially posing a threat to pedestrians, motorists, and if of sufficient depth, properties. The options assessed in the following section are intended to decrease the flood risk associated with overland flow in Picton. It is noted that these options are unlikely to have significant benefits in terms of reducing property damages, however the reduction in severity or frequency of nuisance inundation, particularly along roads, could be beneficial to the Picton community.

11.5.6.1. Option D1 – Menangle Street Culvert Upgrade

☑	**D1 – Menangle Street Culvert Upgrade**
Description	• Duplication of existing box culvert beneath Menangle Street south of Baxter Lane;
Benefits	• Reduces frequency of inundation over Menangle Street, thereby reducing hazard to motorists;
Concerns	• Limited tangible benefits result in this option not being considered economically viable; • Staged construction required to allow Menangle Street to remain trafficable; • Negotiations between RMS and Council required;
Outcome	Recommended as a low priority action item to be considered for further investigation in conjunction with other scheduled roadworks.

Option Description

Approximately 60 m south of Baxter Lane, an overland flow path crosses Menangle Street, resulting in shallow inundation (approximately 0.1 m deep) in the 5% AEP, and up to 0.4 m deep in the 1% AEP, as the capacity of the existing 3.6 m x 1.2 m high box culvert is exceeded. This option investigates the benefits of doubling the box culvert to increase available capacity beneath the roadway and reduce the frequency of Menangle Street being overtopped.

Modelled Impacts

The option was modelled in the 1% AEP and in the 5% AEP event, with impacts shown on Figure B18 and Figure B19 respectively. The flood level impacts show that in the 1% AEP event, the expansion of Menangle Street culvert does not entirely remove flood affectation, but does reduce the depths over road significantly by up to 0.05 m in the 5% AEP and 1% AEP. In the 1% AEP event, the extent of benefits is broader, reducing peak flood levels on properties to the south of the culvert. The option does not result in any change to above floor property affectation.

Discussion of Other Concerns and Considerations

Modification of the existing culvert section is considered technically feasible, however, the tangible benefits are limited as there is no change to over- floor property affectation or external flood damage to private property. However, reducing depths over Menangle Street during local rain events would improve driver safety, and is a relatively minor project that could be readily implemented and scheduled with other necessary roadworks, for example, when the existing culvert is due for replacement, or if remedial works are needed. RMS is the road authority responsible for Menangle Street and negotiations would need to undertaken between RMS and Council.

Evaluation

With an estimated capital cost in the order of $250,000, this option is recommended as a low priority action for the Floodplain Risk Management Plan, to be considered for implementation if the opportunity arises for works to be undertaken in conjunction with other scheduled works or projects at the site.

11.5.6.2. Option D2 –Menangle Street Upgrade

☑	**D2 – Menangle Street Upgrade**
Description	• Raising road levels and increasing culvert capacity (including local drainage) to allow Menangle Street to remain flood free in events up to the 1% AEP. This option would be complemented by local drainage works to better manage localised flood behaviour in the adjacent area;
Benefits	• Reduces frequency of inundation over Menangle Street and adjacent areas, thereby reducing hazard to motorists and inconvenience to landholders;
Concerns	• Limited tangible benefits result in this option not being considered economically viable; • Staged construction required to allow Menangle Street to remain trafficable; • Negotiations between RMS and Council required;
Outcome	Recommended as a low priority action item to be considered for further investigation in conjunction with other scheduled roadworks.

Option Description

This option involves raising sections of Menangle Street and increasing culverts with the aim of keeping Menangle Street flood free in the 1% AEP event south of Colden Street. Two sections of road are raised by 0.4 m, and additional culverts installed to increase capacity. Any works at this location would be coupled with local drainage infrastructure to improve the localised flood behaviour. These aspects would be considered during detailed design. The locations of the proposed works are shown on Figure B20.

Modelled Impacts

The option was modelled in the 1% AEP and 5% AEP events, with impacts shown on Figure B20 and Figure B21 respectively. Raising Menangle Street acts to obstruct shallow overland flow coming from the east, draining towards Stonequarry Creek, yielding benefits to properties affectation on the western side of the road as well as Menangle Street itself. The proposed culvert sizes were based on the aim to not let Menangle Street be overtopped by overland flow in the

1% AEP event, however the impacts shown on Figure B21 indicate that further optimisation of culvert sizing is required, as the greater culvert capacity could lead to increased peak flood levels on the downstream (western) side of the road in the 5% AEP event. Smaller scale drainage infrastructure has not been considered at this stage but shall be considered during further optimisation and design stages.

Discussion of Other Concerns and Considerations

Construction of Option D2 is likely to have a high cost relative to its flood mitigation effect regarding property inundation. During the construction period, the temporary closing of the street might produce some minor disruption to the community. There is likely to cause minor environmental impacts due to potential scour might occur downstream and localised impacts at the construction area. However, the implementation of Option D2 will improve safety for motorists and extended access during local rain events, further additional local drainage infrastructure is likely to improve localised flood behaviour, particularly in more frequent events. Further consultation is needed to develop a better understanding of the value this would have to the community, noting that alternative flood free access away from Picton also exists to the north via the Old Hume Highway. RMS is the road authority responsible for Menangle Street and negotiations would need to undertaken between RMS and Council.

Evaluation

It is recommended that further consultation is undertaken with emergency services and Council to ascertain the value in increasing the flood immunity of Menangle Street to the 1% AEP level. If it is determined to be a preferred option, it is recommended that the upgrades be staged to coincide with other roadworks as much as possible to limit the cost of the option.

11.5.6.3. Option D3 – Cliffe Street Drainage Line

☒	**D3 – Cliffe Street Drainage Line**
Description	• Installation of a new 600 mm pipe beneath Cliffe Street from Margaret Street westwards to Stonequarry Creek to augment the existing stormwater network;
Benefits	• Additional capacity relieves demand on the Argyle Street trunk drain resulting in minor peak flood level reductions, and reduced inundation, in the lower-lying parts of the CBD;
Concerns	• Limited tangible benefits to properties result in this option not being considered economically viable;
Outcome	Not recommended for further investigation, as Option D4 (Argyle Street Trunk Upgrade) is more effective in reducing flood risk in the CBD.

Option Description

A single 750 mm diameter pipe currently drains stormwater along Argyle Street to Stonequarry Creek and services most of the Picton CBD local catchment. Option D3 was modelled with the aim of relieving the demand on the current trunk drain, by directing a portion of the flow through a new 600 mm pipe beneath Cliffe Street out to Stonequarry Creek.

Modelled Impacts

The flood level impacts of Option D3 in the 1% AEP and 5% AEP events are shown on Figure B22 and Figure B23 respectively. Figure B22 shows that the added pipe has a limited impact on peak flood levels in Picton CBD in the 1% AEP event. This is mainly because peak flood levels in the CBD are caused by mainstream flooding, with overland flow only contributing a minor amount. In addition, in an event of such a size, the local drainage network is so overloaded that this additional pipe does not provide enough additional storage to materially reduce overland inundation. However, in the 5% AEP event the addition of the Cliffe St pipe does reduce peak flood levels (by up to 0.1 m), thereby improving motorist and pedestrian safety and reducing the duration of inundation in the CBD in local rainfall events.

Discussion of Other Concerns and Considerations

A key consideration for drainage lines that outfall to a creek or river is to ensure that they can be sealed effectively when the receiving waters are elevated. Inclusion of a flap valve or gate valve is critical to prevent the pipe from backwatering and exacerbating flooding within the CBD, and ongoing maintenance and checks required as such valves can be prone to being jammed open due to blockage or damage. The excavation of a trench beneath Cliffe Street is expected to be feasible, however the locations of existing services such as sewer, water, gas etc would need to be confirmed if the option were to proceed. There would be a temporary disruption to the community during the construction phase, though this is not expected to be a major issue.

While the flood level impacts are promising, preliminary assessment suggests that greater benefits may be had by upgrading the Argyle Street trunk drain instead of implementing Option D3. Option D4 in the subsequent section investigates this option.

Evaluation

Option D3 is technically feasible, however has limited benefits in terms of the reduction of peak flood levels in the CBD. It is not recommended for further investigation.

11.5.6.4. Option D4 – Argyle Street Pipe Upgrade

☑	**D4 – Argyle Street Pipe Upgrade**
Description	• Replacement of the existing 750 mm trunk drain below Argyle Street with a 1200 mm pipe to increase stormwater drainage capacity.
Benefits	• Additional capacity results in peak flood level reductions on Argyle Street and around commercial premises;
Concerns	• Limited tangible benefits to properties result in this option not being considered economically viable;
Outcome	Recommended as a low priority item for further investigation, to be considered in conjunction with other roadwork or pipe maintenance.

Option Description

As an alternative to install a pipe through Cliffe Street, Option D4 was modelled by increasing the Argyle Street trunk drain from 750 mm diameter pipes to 1200 mm diameter pipes over a length of 400 m. The existing alignment and pit inlets were retained, as well as the outfall to Stonequarry Creek. The existing 750 mm pipe is full in a 20% AEP event.

Modelled Impacts

The flood level impacts of Option D4 in the 1% AEP and 5% AEP events are shown on Figure B24 and Figure B25 respectively. In a 1% AEP event, a larger trunk drain on Argyle Street has a negligible impact on flood levels as it cannot discharge to Stonequarry Creek, and flood affectation is dominated by mainstream flooding. However, in a 5% AEP event the drain can function effectively reducing peak flood levels on and around Argyle Street by between 0.01 – 0.1 m, resulting in some lower lying areas being no longer inundated.

Discussion of Other Concerns and Considerations

The extent of impacts is localised to Argyle Street and Walton Street, which are most affected by overland flow as they are in the lower lying areas where shallow runoff accumulates. The option does not change over-floor property affectation, and the AAD is reduced by only 7%. Replacement of the existing 750 mm pipe with a 1200 mm pipe, plus the necessary associated changes to pit inlets, junctions, and road surface works, is estimated to cost in the order of $2 M. With the limited tangible benefits, the option is not considered economically viable. It is likely that upgrading the lowest portion of the pipe only would result in similar benefits, and would significantly reduce the cost of the option.

Intangible benefits include the reduced hazard to pedestrians and motorists as a result of reduced duration of inundation, and lower depths of flooding occurring in local rain events, as well as potentially reducing or preventing nuisance flooding in shops that are not elevated. In contrast to the Cliffe Street option (D3), there are considerably more challenges associated with the construction of this option, owing to traffic and the presence of existing below ground services, potentially including sewer, water mains, phone lines.

Evaluation

In terms of improving local drainage, Option D4 is preferred to Option D3 as it more effectively reduces peak flood levels in the CBD. However, the high capital cost and construction challenges in comparison to the available benefits mean the option, as currently proposed, is not economically viable. It is recommended that this option is included in the plan as a low priority item to be considered as part of future upgrades or maintenance works in Argyle Street. Further assessment to optimise the length of pipe to be upgraded is also recommended, as the benefits of only increasing capacity in the lower portion of the pipe are expected to be comparable to upgrading the entire trunk drain.

12. MULTI CRITERIA MATRIX ASSESSMENT

12.1. Introduction

The Floodplain Development Manual (Reference 4) recommends the use of multi-criteria assessment matrices when assessing flood risk mitigation measures. A multi-criteria matrix (MCA) provides a method by which options can be assessed against a range of criteria, and offers a greater breadth of assessment than is available by considering only the reduction in flood risk or economic damages, for example. Such additional criteria may include social, political and environmental considerations and intangible flood impacts that cannot be quantified or included in a Cost-Benefit Analysis. It should be noted that the assessment of the suitability of floodplain mitigation options is a complex matter, and an MCA will not give a definitive 'right' answer, but will provide a tool to debate the relative merits of each option.

12.2. Scoring System

A scoring system has been devised to allow stakeholders to assess the various options across a consistent basis to allow for direct comparison. The scoring system is divided into four key criteria: Flood Behaviour, Economic, Social and Environmental. Scores for each criterion are to be assigned to each option then summed to determine the overall score. 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. The scoring system is provided in Table 24, and outcomes of the assessment shown in Table 25. Discussion of the results is provided in Section 12.4.

Table 24 Multicriteria Matrix Assessment - Scoring System

	Criteria	Metric	Score -3	-2	-1	0	1	2	3
Economic	Economic Merits	*Comparison of the economic benefits against the capital and ongoing costs*	BC < 0.1	BC: 0.1- 0.5	BC: 0.5-0.9	BC = 1 (Or NA)	BC: 1.0 - 1.4	BC: 1.4 - 1.7	BC >1.7
	Implementation Complexity	*Potential design, implementation and operational challenges and constraints. Risk can increase with implementation timeframe*	Major constraints and uncertainties which may render the option unfeasible	Constraints or uncertainties which may significantly increase costs or timeframes	Constraints or uncertainties which may increase costs or timeframes moderately	NA	Constraints that can be overcome with moderate investment of time and resources	Constraints that can be overcome easily	No constraints or uncertainties
	Staging of Works	*Ability to stage proposed works*			Works cannot be staged	NA	Some minor components of the works may be staged	Some major components of the works may be staged	
Social	Impact on Emergency Services	*Change in demand on emergency services (SES, Police, Ambulance, Fire, RFS etc).*	Major disbenefit	Moderate Disbenefit	Minor Disbenefit	Neutral	Minor Benefit	Moderate Benefit	Major Benefit
	Emergency Access	*Flood depths and duration changes for critical transport routes*	Key access roads become flooded that were previously flood free	Significant increase in main road flooding	Moderate increase in local or main road flooding	No Change	Moderate decrease in local or main road flooding	Significant decrease in main road flooding	Local and main roads previously flooded now flood free
	Impact on critical and/or vulnerable facilities[1]	*Disruption to critical facilities*	Inoperational for several days	Inoperational for one day	Inoperational for several hours	No Change	Period of inoperation reduced by 0-4 hours	Period of inoperation reduced by > 4 hours	Prevents disruption of critical facility altogether
	Impact on Properties	*No. of properties flooded over floor. Across all events*	>5 adversely affected	2-5 adversely affected	<2 adversely affected	None	<2 benefitted	2 to 5 benefitted	>5 benefitted
	Impact on flood hazard	*Change in hazard classification*	Significantly increased in highly populated area (Increasing to H5/H6)	Moderately increased in populated area (Increasing by 2 or more categories)	Slightly increased (Increase by 1 category)	No Change	Slightly reduced (Decrease by 1 category)	Moderately reduced in populated area (Decrease by 2 or more categories)	Significantly reduced in highly populated area (Decrease from H5/H6)
	Community Flood Awareness	*Change in community flood awareness, preparedness and response*	Significantly reduced	Moderately reduced	Slightly reduced	No Change	Slightly improved	Moderately improved	Significantly improved
	Social disruption	*Closure of or restricted access to community facilities (including recreation)*	Normal access significantly reduced or facilities disrupted for > 5 days	Normal access routes moderately reduced or facilities disrupted for 2-4 days	No Change to acess but facilities disrupted for up to 12 hours	No Change	Reduces duration of access disruption or facility disruption by up to 12 hours	Reduces duration of access disruptioin or facility disruption by 2-4 days	Prevents disruption of access or facility altogether
	Community and stakeholder support[2]	*Level of agreement (expressed via formal submissions and informal discussions)*	Strong opposition by numerous submissions	Moderate opposition in several submissions	Individual submissions with opposition	Neutral	Individual submissions with support	Moderate support in several submissions	Strong support by numerous submissions
Environmental	Impacts on Flora & Fauna (inc. street trees)	*Impacts or benefits to flora/fauna*	Likely broad-scale vegetation/habitat impacts	Likely isolated vegetation/habitat impacts	Removal of isolated trees, minor landscapng.	Neutral	Planting of isolated trees, minor landscapng.	Likely isolated vegetation/habitat benefits	Likely broad-scale vegetation/habitat benefits
	Heritage Conservation Areas and Heritage Items	*Impacts to heritage items*	Likely impact on State, National or Aboriginal Heritage Item	Likely impact on local heritage item	Likely impact on contributory item within a heritage conservation area	No impact	Reduced impact on contributory item within a heritage conservation area	Reduced impact on local heritage item	Reduced impact on State, National or Aboriginal Heritage item
Other Aspects	Financial Feasibility and Funding Availability	*Capital and ongoing costs and funding sources available*	Significant capital and ongoing costs, or no external funding or assistance available	Moderate capital and ongoing costs, no funding available	High capital and ongoing costs, partial funding available	NA	Moderate capital and ongoing costs, partial funding available; or low capital and ongoing costs, no funding available	Low to moderate capital and ongoing costs, partial funding available	Full external funding and management available
	Compatibility with existing Council plans, policies or projects	*Level of compatibility*	Conflicts directly with objectives of several plans, policies or projects	Conflicts with several objectives or direct conflict with one or few objectives	Minor conflicts with some objectives, with scope to overcome conflict	Not relevant	Minor support for one or few objectives	Some support for several objectives, or achieving one objective	Achieving objectives of several plans, policies or projects

[1] Critical facilities are those properties that, if flooded, would result in severe consequences to public health and safety. These may include fire, ambulance and police stations, hospitals, water and electricity supply, buses/train stations and chemical plants. Vulnerable facilities refer to those properties with vulnerable occupants, such as nursing homes or schools.

[2] Community and stakeholder support scores will be completed following Public Exhibition

12.3. Results

Table 25 Multicriteria Matrix Assessment Results

				Economic			Social								Environmental		Other Aspects			
Category	ID	Section	Option	Economic Merits	Implementation Complexity	Staging of Works	Impact on Emergency Services	Emergency Access	Impact on critical and/or vulnerable facilities[1]	Impact on Properties	Impact on flood hazard	Community Flood Awareness	Social disruption	Community and Stakeholder Support[2]	Impacts on Flora & Fauna (inc. street trees)	Heritage Conservation Areas and Heritage Items	Financial Feasibility and Funding Availability	Compatibility with existing Council plans, policies or projects	Total Score	Overall Rank
Response Modification	RM01	11.3.1	Wollondilly Shire Flood Warning System Review	0	-1	1	3	0	1	0	0	1	0		0	0	2	0	7	15
	RM02	11.3.2	Flood Emergency Response Coordination	0	3	2	3	0	1	0	0	2	1		0	0	2	1	15	6
	RM03	11.3.3	Improve Community Flood Education and Awareness	0	1	2	3	0	1	0	0	3	1		0	0	2	3	16	5
Property Modification	PM01	11.4.1	Flood Planning Level	1	1	2	2	0	2	2	0	2	2		0	0	1	3	18	3
	PM02	11.4.2	Flood Planning Area	1	1	2	2	0	1	2	0	2	2		0	0	1	3	17	4
	PM03	11.4.3	Flood Proofing Measures for commercial properties	3	1	2	3	0	0	0	0	3	2		0	0	2	3	19	2
	PM04	11.4.4	Voluntary House Raising in Picton	0	-3	2	0	0	0	0	0	0	1		0	0	-1	0	-1	19
	PM05	11.4.5	Voluntary Purchase	-3	-2	2	3	0	0	0	1	1	0		0	-2	-1	0	-1	19
	PM06	11.4.6	Managing Development in the FPA	0	3	2	1	0	2	0	0	1	1		0	0	0	0	10	9
	PM07	11.4.7	Managing Development in Low Flood Risk Areas	0	3	2	1	0	3	0	0	2	1		0	0	0	2	14	7
	PM08	11.4.8	Provision of flood information to residents via Section 10.7 Planning Certificates	0	1	2	2	0	0	0	0	2	0		0	0	0	3	10	9
Flood Modification Options	CM1	11.5.2.1	Stonequarry Creek Channel Modification	-3	-3	2	-2	0	0	0	-1	0	0		-3	0	-3	-3	-16	27
	CM2	11.5.2.2	Excavation Upstream of Argyle Street Bridge	-3	-3	2	-2	0	0	-3	-2	0	0		-3	-2	-3	-3	-22	28
	CM3	11.5.2.3	Removal of Buildings in the Floodway	-2	-2	2	2	0	0	3	1	1	1		0	0	1	2	9	12
	CM4	11.5.2.4	Vegetation Management	1	3	2	2	1	0	3	2	1	1		3	1	2	3	25	1
	BM1	11.5.3.1	Excavation of Railway Viaduct Abutments	-3	-2	2	1	0	0	0	0	0	0		-2	-2	-3	0	-9	24
	BM2	11.5.3.2	Excavation of Argyle Street Bridge Abutments	-3	-2	2	1	1	0	0	0	0	0		-2	0	-1	0	-4	22
	RB1	11.5.4.1	Retarding Basin Upstream of Barkers Lodge Road	-2	-1	2	3	2	2	3	2	0	1		-2	1	-1	0	10	9
	RB2	11.5.4.2	Picton Sportsground Retarding Basin	-3	-3	2	1	1	0	2	0	0	0		-2	0	-3	-1	-6	23
	RB3	11.5.4.3	Retarding Basins on Minor Tributaries	-3	-3	2	2	1	1	3	1	0	1		-3	0	-1	0	1	18
	RB4	11.5.4.4	Hume Oval Retarding Basin	-3	-2	2	-1	-1	0	-1	-1	0	0		-2	0	-3	-1	-13	26
	RB5	11.5.4.5	Racecource Creek Basins	-3	-3	2	0	0	0	0	0	0	0		-3	0	-3	0	-10	25
	L1	11.5.5.1	South Picton Diversion Bank	-3	1	2	0	1	0	2	1	0	0		-1	0	2	0	5	16
	L2 and L3	11.5.5.2	Stonequarry Creek Levees	-3	-3	2	2	2	1	3	2	1	2		-3	-3	-1	-3	-1	19
	D1	11.5.6.1	Menangle Street Culvert Upgrade	-3	1	2	1	1	0	2	1	0	1		0	0	2	0	8	13
	D2	11.5.6.2	Raised Menangle Street	-3	-1	2	1	3	0	2	1	0	3		0	0	2	1	11	8
	D3	11.5.6.3	600m Pipe Through Cliffe Street to Stonequarry Creek	-3	-1	2	1	1	0	2	1	0	1		-1	0	2	0	5	16
	D4	11.5.6.4	Argyle Street Pipe Upgrade	-2	-1	2	1	1	0	3	1	0	1		0	0	2	0	8	13

[1] Critical facilities are those properties that, if flooded, would result in severe consequences to public health and safety. These may include fire, ambulance and police stations, hospitals,
[2] Community and stakeholder support scores will be completed following Public Exhibition

12.4. Discussion of Results

The multi-criteria matrix assessment results, presented in Table 25, can be used to both understand the benefits and disadvantages of individual options, but to also see trends across the full suite of options assessed in the FRMS&P. The following results and trends are noted:

- Continuation of Council's Vegetation Management Plan (CM4) received the highest score, as it delivers benefits across a range of criteria including economics, reduction in flood risk, property affectation, promotion of ecological values, as well as playing a role in community flood awareness;
- Adoption of the Flood Planning Level (PM01), Flood Planning Area (PM02), and further investigation of Flood Proofing measures for commercial properties (PM03) are the most cost effective methods to reduce property damages in Picton, and have additional benefits relating to improvements to community flood awareness. These options are the next highest scoring options following CM4.
- Response Modification Measures and Property Modification Measures tend to score more highly than Flood Modification measures, as they can be implemented for a relatively low cost, lead to the reduction of property damage and improvement in community resilience in the long term, and do not incur negative environmental impacts;
- Majority of flood modification measures, that is, structural options, do not score well in terms of economic merits. Reasons for this include:
    - "Tangible Benefits" included in the Cost Benefit Analysis are determined from the reduction in property damages (Annual Average Damages (AAD), Section 7). As relatively few properties are affected by flood events more frequent than a 2% AEP event, the benefits of structural options are not realised in these frequent events which are weighted more heavily in the calculation of AAD.
    - In the same vein, to reduce property damages, structural options need to effectively reduce flood risk in rare events (i.e. 2% AEP and greater). To do this, structural options need to be substantial in size, i.e. levee height or basin storage capacity – leading to high capital costs, land purchase requirements, and ongoing maintenance costs.
- The lowest scoring options include CM01 and CM02, which involve major excavation of the Stonequarry Creek channel. As described in Section 11.5.2.1 and 11.5.2.2 respectively, these options involve substantial capital works for very little benefit in terms of flood risk reduction (Option CM02 in particular actually worsens flood risk in the CBD), with severe environmental impacts and poor outcomes for the community.

13. DRAFT FLOODPLAIN RISK MANAGEMENT PLAN

This Plan summarises the recommended works investigated by the Stonequarry Creek (Picton) Floodplain Risk Management Study. The Study follows on from the Stonequarry Creek at Picton Flood Study Update (Reference 7), and represents an update to the 1996 Floodplain Risk Management Study and Plan (Reference 10).

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 26 and Table 27 list the mitigation measures assessed by the Stonequarry Creek (Picton) 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 11 of the Study, which also contains measures that were assessed but were not viable for recommendation.

Table 26 Stonequarry Creek (Picton) Draft Floodplain Risk Management Study and Plan (Part 1 of 2)

	Option ID (Section)	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	B/C Ratio	Priority
Response Modification Options	**RM01 (11.3.1)**	Wollondilly Shire Flood Warning System Review	Review current flood warning system in relation to trigger levels, maintenance requirements, messaging and recipients (including identifying and prioritising vulnerable occupants). Conduct a high level assessment of alternative flash flood warning systems.	Improve current system using outputs from the Stonequarry Creek at Picton FRMS&P. Potentially increase warning time available to the community.	May not be possible to increase warning time in Picton due to short catchment response time. Trade off between accuracy and warning time is necessary.	SES, Council, gauge operators	SES and Council	$20,000 - $30,000	N/A	High
	RM02 (11.3.2)	Improve Flood Emergency Response Coordination	Ongoing improvements to the coordination between and within emergency service agencies. Improvements to volunteer coordination. Identify vulnerable occupants.	Improved understanding of roles and responsibilities for more effective, efficient, and safe actions during and following flood events.	Challenges include change of personnel, difficulty in organising meetings and exercises between flood events.	All response agencies, including but not limited to the SES, Council, RFS, Fire and Rescue, and community organisations.	May be eligible for NSW Government funding	Minimal - In house	N/A	Moderate
	RM03 (11.3.3)	Improve Community Flood Education and Awareness	Council to implement a flood education program to improve ongoing flood awareness in Picton using a range of approaches and engagement strategies.	Flood awareness significantly improves preparedness for and recovery from flood events, building a more flood resilient community.	Ongoing efforts to ensure information is not forgotten. Potential for residents to become bored or complacent with messaging.	Council in collaboration with other response agencies and community organisations.	May be eligible for NSW Government funding	Annual Budget to be determined and allocated.	N/A	High
Flood Modification Options	**CM3**	Removal of Buildings for Floodway Clearance	Purchase and demolition of buildings within the floodway to remove obstruction and improve conveyance. Rezoning of this and other land that is considered unsuitable for development.	Reduced peak flood levels across the CBD, prevention of future damage and losses, opportunity to create open area adjacent to the creek for public use.	Significant cost to acquire and demolish buildings. May face resistance from building owners.	Council	May be partially funded through NSW DPIE	Dependent on number of buildings included in project.	<0.1	Moderate
	CM4	Vegetation Management	Continuation of existing vegetation management plan to maintain vegetation density in Stonequarry Creek and Racecourse Creek.	If not undertaken, peak flood levels would increase substantially in the CBD in events including and greater than a 2% AEP event.	Community may perceive that current works are insufficient. Education required to communicate the importance of vegetation to bank stability, and that further removal of riparian vegetation would require artificial bank stabilisation or reducing the bank slope.	Council	May be partially funded through NSW DPIE	Approx. $65,000 annually	1.3	High
	RB01 (11.5.4.1)	Stonequarry Creek Western Catchment Retarding Basin Feasibility Study	Undertake a feasibility study to investigate appropriate site(s) and concept designs for a retarding basin on Stonequarry Creek, at a location upstream of Barkers Lodge Road.	Flood risk in the Picton CBD is driven by flow in Stonequarry Creek. If a suitable site(s) can be found, a retarding basin could act to reduce peak flood levels in the CBD and reduce hazard and property damages.	Steep topography limits the availability of appropriate sites for a basin. A significant storage capacity is needed to make a material difference in the CBD, likely leading to high capital costs. Impacts of coal extraction on flood behaviour needs to be considered.	Council	Feasibility studies may be partially funded through NSW DPIE	$40,000 - $60,000	NA	High
	L1 (11.5.5.1)	South Picton Diversion Bank	Low level embankment designed to divert shallow overland flow around residential properties, rather than through backyards and onto Menangle Street.	Reduced nuisance flooding in residential yards, and reduced hazard to motorists on Menangle Street.	Limited tangible benefits, potential requirement for acquisition of land for construction and maintenance easement, potential visual impacts for residents.	Council	May be partially funded through NSW DPIE	<$150,000	<0.1	Low
	D1 (11.5.6.1)	Menangle Street Culvert Upgrade	Duplication of the existing box culvert on Menangle Street south of Baxter Lane to increase capacity and reduce inundation over the road.	Reduce depth of flooding and duration that Menangle Street is inundated will improve motorist safety.	Option does not reduce flood risk to development. Significant capital costs for minor benefits.	RMS/Council	N/A	$250,000	<0.1	Low
	D2 (11.5.6.2)	Menangle Street Upgrade	Raise Menangle Street and associated culvert upgrade works to allow flood free access in a 1% AEP event. This option would be complemented by local drainage works to better manage localised flood behaviour in the adjacent area.	Reduced hazard to motorists, improved access and evacuation route. Reduced inconvenience to landholders.	High capital cost, no change to property affectation (low tangible benefits). Value of keeping Menangle Street flood free to be confirmed. Negotiations between RMS and Council required.	RMS/Council	N/A	~$1.5M	<0.1	Low
	D4 (11.5.6.1)	Argyle Street Pipe Upgrade	Argyle Street trunk drain upgrade, increase pipes from 750mm to 1200 mm diameter to increase capacity.	Improve flood drainage in Picton CBD area and decrease peak flood levels in the lower lying parts of the CBD, reducing duration of inundation (overland events only).	Limited benefits to property affectation, ineffective in flood events where the creek level is elevated. High capital cost and potential disruption to other belowground services. Negotiations between RMS and Council required.	Council	N/A	~$1.9M	<0.1	Low

Table 27 Stonequarry Creek (Picton) Draft Floodplain Risk Management Study and Plan (Part 2 of 2)

	Option ID	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	B/C Ratio	Priority
Property Modification Options	**PM01 (11.4.1)**	Adoption of Flood Planning Levels	Council to adopt residential and commercial Flood Planning Levels as determined in this FRMS&P: Mainstream: 1% AEP + 0.5 m freeboard Overland: 1% AEP + 0.3 m freeboard. FPLs for critical facilities should be determined on a merits based approach considering events rarer than the 1% AEP. Update LEP and DCP definitions of the FPL.	FPLs are effective tools to limit property damage to new development and redevelopment. FPLs may pertain to minimum floor levels or flood proofing levels depending on the type of development.	A planning proposal is required to amend the LEP and implement the new FPL. May be considered more onerous for developers.	Council	N/A	Internal	N/A	High
	PM02 (11.4.2)	Revision of Flood Planning Area (FPA)	The FPL, and other flood related development controls, is applied to properties within the Flood Planning Area (FPA). Adopt associated Flood Planning Area map developed in this FRMS&P, which delineates mainstream and overland FPAs. Update LEP and DCP definitions of the FPA.	The FPA will provide clear guidance on the properties subject to flood related development controls.	A planning proposal is required to amend the LEP and implement the new FPA definition. Consultation would be required.	Council	N/A	Internal	N/A	High
	PM03 (11.4.3)	Flood Proofing Measures for Commercial Properties	Undertake a research project to determine the preferred temporary flood barrier product for business owners to purchase and implement in the event of a flood. This option is available to existing businesses, and could be encouraged for new business owners in the future.	Significantly reduce commercial property damages, and associated stress and trauma. Reduced burden on the SES to help businesses prepare for floods, and decrease recovery times following floods.	Staff to be regularly trained in the installation of temporary flood proofing measures. Implementation of measures at the time of construction may be considered onerous by developers. Range of aspects should be considered including cost, ease of installation, aesthetic (including heritage requirements).	Individual Business Owners and commercial organisations in Picton.	Community resilience grants may be available	TBD (varies depending on product) Expected to be <$2,500 ex GST per unit	>>1	High
	PM05 (11.4.5)	Voluntary Purchase	Feasibility study to further investigate a Voluntary Purchase scheme in Picton.	Remove residents and dwellings from high hazard areas, thus reducing risk to life, potential need for rescue, and increasing conveyance through the floodplain.	Community appetite for or acceptance of VP may be a challenge. VP schemes are long term options and may take approximately a decade to implement.	Council in consultation with affected residents.	Eligible for OEH funding	~$5M	<0.1	High
	PM06 (11.4.6)	Managing development in the FPA	Amendments to the Wollondilly DCP -Part 8 - Flooding to achieve the following: Consistency of terminology and definitions with the FRMS&P Consideration of development controls for commercial premises; and Addition of flood related development controls for above and below ground carparking.	Improve clarity of DCP (Flood for the benefit of both developers and Council assessors/approvers. Enable proponents to design, build and manage development using the best available flood information.	There may be resistance from developers who consider new controls to be onerous.	Council	NA	~$20k	NA	Moderate
	PM07 (11.4.7)	Managing development in Low Flood Risk Areas	Modify the LEP to enable Council to apply flood related development controls to critical utilities and vulnerable land uses between the FPA and PMF extent. Adopt development controls for such land uses in low risk areas.	Ensure critical utilities and vulnerable facilities are designed, constructed and managed in such a way as to minimise flood risk to the structure and (if relevant) its occupants.	This amendment to the LEP would require Council to submit a planning proposal, which could be lodged in conjunction with Option PM01.	Council	NA	Internal	NA	Moderate
	PM08 (11.4.8)	Provision of Flood Information to Residents via Section 10.7 Planning Certificates.	Increase depth of flood information to be provided on s10.7(2) and (5) certificates to identify the property's flood hazard, hydraulic category and whether or not flood related development controls apply using high resolution outputs from this study.	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.	Limited - s10.7(2) certificates already contain basic information, Council to provide further detail from current FRMS results. May increase demand on Council staff, however GIS systems can be established to provide this information efficiently.	Council	NA	Internal	NA	High

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15. GLOSSARY

Taken from the Floodplain Development Manual 2005 (Reference 4)

acid sulfate soils	Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
caravan and moveable home parks	Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.
Catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
consent authority	The Council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.
development	Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act). **infill development:** refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. **new development:** refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power.

	redevelopment: refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.
disaster plan (DISPLAN)	A step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.
Discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
ecologically sustainable development (ESD)	Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act 1993. The use of sustainability and sustainable in this manual relate to ESD.
effective warning time	The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood awareness	Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood education	Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves an their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
flood liable land	Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land covers the whole of the floodplain, not just that part below the flood planning level (see flood planning area).

flood mitigation standard	The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
Floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammetic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.
flood planning area	The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the Aflood liable land@ concept in the 1986 Manual.
Flood Planning Levels (FPLs)	FPLs are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the Astandard flood event@ in the 1986 manual.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.
flood readiness	Flood readiness is an ability to react within the effective warning time.
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. **existing flood risk:** the risk a community is exposed to as a result of its location on the floodplain. **future flood risk:** the risk a community may be exposed to as a result of new development on the floodplain. **continuing flood risk:** the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.

flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.
Freeboard	Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.
habitable room	**in a residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. **in an industrial or commercial situation:** an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
Hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.
Hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
Hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
Hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
local drainage	Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.
mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
major drainage	Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves: • the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or • water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or

- major overland flow paths through developed areas outside of defined drainage reserves; and/or
- the potential to affect a number of buildings along the major flow path.

mathematical/computer models

The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.

merit approach

The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State's rivers and floodplains.

The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.

minor, moderate and major flooding

Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood:

minor flooding: causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded.

moderate flooding: low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered.

major flooding: appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.

modification measures

Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.

peak discharge

The maximum discharge occurring during a flood event.

Probable Maximum Flood (PMF)

The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.

Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
Probability	A statistical measure of the expected chance of flooding (see AEP).
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
Stage	Equivalent to water level. Both are measured with reference to a specified datum.
stage hydrograph	A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
survey plan	A plan prepared by a registered surveyor.
water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
wind fetch	The horizontal distance in the direction of wind over which wind waves are generated.

Appendix A

APPENDIX A. PLANNING AND POLICY REVIEW

PAGE

A.1. Introduction

It is important to understand the national and state legislation to ensure proposed floodplain risk management measures are in keeping with national, state and local statutory requirements. This appendix describes the national and state legislative instruments that influence planning, specifically in relation to flood risk, at the local government level. Local planning instruments relating to flood risk in Picton are described in Section 11 of the main report.

It is noted that the policies presented and summarised in this Appendix were current at the time of writing, and that this document may not remain current as policies are amended (or repealed) over the years.

A.2. National Provisions – Building Code of Australia

The Building Code of Australia (BCA) is part of the National Construction Code (NCC) Series, an initiative of the Council of Australian Governments (COAG) developed to incorporate all on-site construction requirements into a single code. The BCA is produced and maintained by the Australian Building Codes Board on behalf of the Australian Government and each State and Territory Government.

The 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 'Defined flood event' (DFE) is "*the flood event selected for the management of flood hazard for the location of specific development as determined by the appropriate authority."* In NSW this is typically the 1% AEP event.

Flood hazard areas are identified by the relevant State/Territory or Local Government authority (such as via a Floodplain Risk Management Study). 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.

The BCA provides general requirements for measures to keep water out of the building structure and foundations, such as setting minimum heights above ground, and minimum paved apron requirements graded to direct runoff away from the building. Additional requirements for buildings in flood hazard areas, consistent with the objectives of the BCA, primarily aim to protect the lives of occupants of those buildings in events up to and including the defined flood event.

A.3. State Provisions – 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 the impact of 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. The policies and guidelines described in this Section fall under the EP&A Act. The objects of the Act are set out below:

Environmental Planning and Assessment Act 1979 No 203

1.3 Objects of Act

The objects of this Act are as follows:

(a) to promote the social and economic welfare of the community and a better environment by the proper management, development and conservation of the State's natural and other resources,

(b) to facilitate ecologically sustainable development by integrating relevant economic, environmental and social considerations in decision-making about environmental planning and assessment,

(c) to promote the orderly and economic use and development of land,

(d) to promote the delivery and maintenance of affordable housing,

(e) to protect the environment, including the conservation of threatened and other species of native animals and plants, ecological communities and their habitats,

(f) to promote the sustainable management of built and cultural heritage (including Aboriginal cultural heritage),

(g) to promote good design and amenity of the built environment,

(h) to promote the proper construction and maintenance of buildings, including the protection of the health and safety of their occupants,

(i) to promote the sharing of the responsibility for environmental planning and assessment between the different levels of government in the State,

(j) to provide increased opportunity for community participation in environmental planning and assessment.

A.3.1. Ministerial Direction 4.3

Direction 4.3 was one in a list of directions issued on the 1st July 2009. The directions were issued by the Minister for Planning to relevant planning authorities under section 117(2) of the *Environmental Planning and Assessment Act 1979.* Each of the directions apply to planning proposals lodged within the Department of Planning on or after the date the particular direction was issued. Direction 4 pertains to "Hazard and Risk", with Direction 4.3 relating specifically to Flood Prone Land. Direction 4.3 is provided below:

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.

Note: "Flood planning area", "flood planning level", "flood prone land" and floodway area" have the same meaning as in the Floodplain Development Manual 2005.

A.3.2. 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. Section 733 of the Local Government Act 1993 provides councils and statutory indemnity for decisions made and information provided in good faith from the outcomes of the management process (undertaken in accordance with the Manual).

The Manual outlines a merits approach based on floodplain management and recognises differences between urban and rural floodplain issues. 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.

A.3.3. 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). These areas are sometimes known as low flood risk areas. The package includes:

- an amendment to the EP&A Regulation 2000;
- Revised ministerial direction regarding flood prone land (issued under section 117 of the EP&A Act 1979); and
- A new Guideline concerning flood related development controls in low flood risk areas.

The changes follow community concern over notations about low flooding risk being included on Section 149 Planning Certificates *[now known as Section 10.7 Planning Certificates]* and the appropriate development controls that should apply to residential development in low flood risk areas.

The new Guideline notes that *"unless there are exceptional circumstances, councils should not impose flood related development controls on residential development on land above the residential flood planning level (FPL) (low flood risk areas)."*

The circular goes on to note: *"However the Guideline does acknowledge that controls may need to apply to critical infrastructure (such as hospitals) and consideration given to evacuation routes and vulnerable developments (like nursing homes) in areas above the 100 year flood."*

In Planning Circular PS 07-003 it is noted that: *"Section 733 of the* Local Government Act 1993 *(the LG Act) protects councils from liability if they have followed the requirements of the Manual. The Minister has notified that the Guideline should be considered in conjunction with the Manual under section 733(4) and (5) of that Act. Councils will need to follow both the Manual and the Guideline to gain the protection given by section 733 of the LG Act".*

A.3.4. Section 10.7 Planning Certificates

Formerly known as Section 149 Planning Certificates, Section 10.7 Planning Certificates describe how a property may be used and the controls on development applicable to that property. The Planning Certificate is issued under Section 10.7 of the Environmental Planning and Assessment Act 1979.

When land is bought or sold, the Conveyancing Act 1919 and Conveyancing (Sale of Land) Regulation 2010 requires that a Section 10.7 Planning Certificate be attached to the contract of sale for the land.

Section 10.7 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.

(5) A council may, in a planning certificate, include advice on such other relevant matters affecting the land of which it may be aware.

(6) A council shall not incur any liability in respect of any advice provided in good faith pursuant to subsection (5). However, this subsection does not apply to advice provided in relation to contaminated land (including the likelihood of land being contaminated land) or to the nature or extent of contamination of land within the meaning of Schedule 6.

(7) For the purpose of any proceedings for an offence against this Act or the regulations which may be taken against a person who has obtained a planning certificate or who might reasonably be expected to rely on that certificate, that certificate shall, in favour of that person, be conclusively presumed to be true and correct.

The Environmental Planning and Assessment Regulation 2000, Schedule 4 specifies the information to be disclosed on a Section 10.7 (2) Planning Certificate. In particular Schedule 4, 7A refers to flood related development control information and requires Councils to provide the following information:

1) *Whether or not development on that land or part of the land for the purposes of dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (not including development for the purposes of group homes or seniors housing) is subject to flood related development controls.*

2) *Whether or not development on that land or part of the land for any other purpose is subject to flood related development controls.*

3) *Words and expressions in this clause have the same meanings as in the Standard Instrument.*

Section 10.7 (2) and (5) certificates contain the information prescribed in Schedule 4 described above and additional information relating to the property. In a flooding context, additional information may include notations on flood hazard, percentage of the lot affected by flooding, or peak flood depths and levels on the property.

A.3.5. State Environmental Planning Policy (Exempt and Complying Development Codes (2008))

The aims of State Environmental Planning Policy (Exempt and Complying Development) 2008 are presented below.

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.

A.3.5.1. State Environmental Planning Policy (Exempt and Complying Development Codes) Amendment (Housing Code) 2017

Part 3 of the SEPP relates to the *"Housing Code".* This section replaces the former *"General Housing Code",* which was repealed in June 2017. Part 3 is divided into 5 "Divisions", with Division 2 containing General standards relating to land type. Part 3.5 specifically relates to Complying Development on flood control lots.

Section 3.5 is reproduced below.

3.5 Complying development on flood control lots

1) Development under this code must not be carried out on any part of a flood control lot, other than a part of the lot that the council or a professional engineer who specialises in hydraulic engineering has certified, for the purposes of the issue of the relevant complying development certificate, 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.

2) If complying development under this code is carried out on any part of a flood control lot, the following development standards also apply in addition to any other development standards:

a) if there is a minimum floor level adopted in a development control plan by the relevant council for the lot, the development must not cause any habitable room in the dwelling house to have a floor level lower than that floor level,

b) any part of the dwelling house or any attached development or detached development that is erected at or below the flood planning level is constructed of flood compatible material,

c) any part of the dwelling house and any attached development or detached development that is erected is able to withstand the forces exerted during a flood by water, debris and buoyancy up to the flood planning level (or if an on-site refuge is provided on the lot, the probable maximum flood level),

d) the development must not result in increased flooding elsewhere in the floodplain,

e) the lot must have pedestrian and vehicular access to a readily accessible refuge at a level equal to or higher than the lowest habitable floor level of the dwelling house,

f) vehicular access to the dwelling house will not be inundated by water to a level of more than 0.3m during a 1:100 ARI (average recurrent interval) flood event,

g) the lot must not have any open car parking spaces or carports lower than the level of a 1:20 ARI (average recurrent interval) flood event.

3) The requirements under subclause (2) (c) and (d) are satisfied if a joint report by a professional engineer specialising in hydraulic engineering and a professional engineer specialising in civil engineering states that the requirements are satisfied.

4) A word or expression used in this clause has the same meaning as it has in the Floodplain Development Manual, unless it is otherwise defined in this Policy.

5) In this clause:

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

***flood planning level** means:*
(a) the flood planning level adopted by a local environmental plan applying to the lot, or
(b) if a flood planning level is not adopted by a local environmental plan applying to the lot, the flood planning level adopted in a development control plan by the relevant council for the lot.

***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.*

A.3.5.2. Rural Housing Code

Part 3A of the SEPP contains the *"Rural Housing Code"*, which applies to development that is specified in clauses 3A.2–3A.5 on lots in Zones RU1, RU2, RU3, RU4, RU6 and R5. Section 3A.38 contains “Complying development on flood control lots”. The standards contained in this section are the same as those in Clause 3.5 provided in Section A.3.5.1, with the exception of Clause 2 (c) which states:

> *2 (c) any part of the dwelling house or any ancillary development that is erected is able to withstand the forces exerted during a flood by water, debris and buoyancy up to the flood planning level (or if an on-site refuge is provided on the lot, the probable maximum flood level)*

Appendix B

Stonequarry Creek Floodplain Risk Management Study & Plan Survey

Council and WMA Water are running a survey to better understand the community's views and ideas when it comes to managing risks relating to flooding in the Stonequarry Creek catchment. This will help to inform the development of the floodplain risk management study and plan, to assist in managing flooding in Stonequarry Creek in the future. This survey will give you an opportunity to make suggestions on how flood risks can be reduced and identify key problem areas in the Stonequarry Creek catchment.

Please complete this questionnaire and return to Council (PO Box 21, Picton, NSW, 2571) by **27 April 2018**.

1. Contact Details (Please Note: Your contact details are optional. If you do provide your contact details they will be kept confidentially and only used to contact you regarding this study)

   Name:

   Address:

   Telephone Number:

   Email Address:

2. Can we contact you directly for more information about your survey responses?

   ☐ Yes ☐ No

   If 'yes' please identify your preferred method of contact e.g. telephone, email, mail etc.

3. Do you live in the Stonequarry Creek catchment in Picton?

   ☐ Yes ☐ No ☐ Don't Know

4. How long have you lived in the area?

   ☐ Years ☐ Months

5. Do you think something should be done to reduce flood risk in Picton due to Stonequarry Creek?

☐ Yes ☐ No ☐ Don't Know

6. Please describe the location/s where you think flood risk should be considered in the Stonequarry Creek catchment:
(Please name the nearest street and cross street and any other useful information to identify the location of flood risk and the detail the type of problem that occurs)

7. Potential mitigation options:

There are a number of mitigation options that are commonly considered to manage flood risks in floodplain areas. Please identify if you prefer any of these options and where they could be utilized within the Stonequarry Creek floodplain (1 = least preferred option, 5 = most preferred option).

Culverts and Bridges (allow water to flow under roads, train tracks or similar obstructions. It can often be beneficial to increase the conveyance capacity of existing culverts, or install new culverts to decrease upstream water levels, however the downstream impacts must also be taken into account)

1 **2** **3** **4** **5**

Suggested location/comments:

Drains and Channels (increase the rate at which water is removed from a flood affected area. These structures are often situated in existing flow paths and are generally earthen or concrete lined)

1 **2** **3** **4** **5**

Suggested location/comments:

Levees (are used to exclude flood water from flood prone areas. Levees are often constructed from earth embankments, concrete walls or sheet piles)

1 **2** **3** **4** **5**

Suggested location/comments:

Retention Basins (are areas (such as playing fields) that store water and release it at a lower, more controlled rate to reduce downstream flood levels. Generally more suited to smaller, urban catchments)

1 **2** **3** **4** **5**

Suggested location/comments:

Improved Flood Warning Systems and Alerts (These options are best implemented in conjunction with the SES and local community groups)

1 **2** **3** **4** **5**

Suggestions:

Improved Evacuation Routes (may include road upgrades)

1 **2** **3** **4** **5**

Suggested locations:

Community Education and Awareness Programs (These options are best implemented in conjunction with the SES and local community groups)

1 **2** **3** **4** **5**

Suggestions:

Smart Planning Policies (can help reduce risk to residents, existing and new developments across the wider floodplain. These can include improvements to the Local Environment Plan and Development Control Plan)

1 **2** **3** **4** **5**

Suggested location/comments:

Targeted Vegetation Management (aims to manage density of riparian vegetation (especially exotics) to ensure flood conditions are not worsened over time. Note that broad scale clearing is generally not possible within current biodiversity guidelines)

1 **2** **3** **4** **5**

Suggested location/comments:

Voluntary House Raising (has been widely used throughout NSW to significantly reduce flooding of habitable floors particularly in lower flood hazard areas. Suitable houses are raised above the Flood Planning Level, to protect and reduce damages)

1 **2** **3** **4** **5**

Suggested location/comments:

Voluntary Purchase (involves the acquisition of flood affected properties situated in high hazard areas, and demolition of the residence to remove it from the floodplain. The floodplain is then reserved for a more appropriate land use)

1 **2** **3** **4** **5**

Suggested location/comments:

8. Do you have suggestions on how flood risks could be reduced?

☐ Yes ☐ No

If 'yes' please details your suggestions below:

Contacts:

Ian Berthon
Investigation & Design Engineer
Ian.Berthon@wollondilly.nsw.gov.au
Tel: 4677 1100

Catherine Goonan
Senior Engineer
picton@wmawater.com.au
Tel: 9299 2855

Appendix C

APPENDIX C. FREEBOARD ASSESSMENT

PAGE

C.1. EXECUTIVE SUMMARY

Planning measures (such as flood planning levels) and mitigation works are often designed based on a level of protection or capacity for a particular design flood event, such as the 1% AEP event. To provide reasonable certainty that this level is achieved, a freeboard is added to the selected design flood level. Freeboard is a factor of safety and can be different for flood planning levels and mitigation works due to the components applicable to each. The following components are generally included in the derivation of freeboard:

- Uncertainties in flood level estimates (due to ground survey, design flow accuracy, structure blockage);
- Local variations (surge) in flood level;
- Wave action;
- Changes in the catchment and design estimates over time resulting from climate change, development etc;
- Post construction settlement (for mitigation works); and
- Surface erosion, defects or shrinkage (for mitigation works).

This appendix assesses the freeboard requirements for residential Flood Planning Levels in Picton based on mainstream flooding from Stonequarry Creek and overland flow due to local runoff. The assessment has not considered freeboard for mitigation works, which would additionally incorporate allowance for settlement, erosion and other defects. The results of the freeboard assessment are summarised in Table 1. Discussion of how each factor is calculated is provided in the subsequent sections of this document.

The assessment found that the minimum appropriate freeboard for flood planning levels for properties affected by mainstream flooding in Picton is 0.5 m, and that for areas affected by overland flow, a freeboard of 0.3 m is appropriate.

Table 1 Picton Freeboard Assessment Results

	Mainstream Flooding			Overland Flow			Ref
	(A)	(B)	(A x B)	(C)	(D)	(C x D)	
Component	Allowance (m)	Probability	Final Component (m)	Allowance (m)	Probability	Final Component (m)	
Uncertainties in Estimated Flood Levels	0.2	1	0.2	0.2	1	0.2	C.2.1
Local Water Surge	0.3	0.5	0.15	0.1	0.5	0.05	0
Wave Action	0.02	0.4	0.01	0.02	0.4	0.01	C.2.3
Climate Change	0.15	1	0.15	0.04	1	0.04	C.2.4
Total			**0.5**			**0.3**	

C.2. DETERMINATION OF FREEBOARD COMPONENTS

Flood planning levels (FPLs) are an important tool in the management of flood risk. They are derived from a combination of a flood event (either an historic event or a design AEP event), and a freeboard (Reference 1). Section 10.50.1 of the main report provides justification for the selection of the 1% AEP event for the basis of flood planning levels, while this appendix identifies and subsequently quantifies the various components making up freeboard as they apply to residential flood planning levels in Picton.

C.2.1. Uncertainties in Estimated Flood Levels

C.2.1.1. Discussion

The determination of design flood levels comprises a number of factors and parameters, each containing a degree of uncertainty. These factors may include:

- How well the theoretical ARI-Discharge curve fits known flood events, and if it has changed since an historic event;
- Availability of detailed survey and other topographic data;
- Reliability of historical flood data; and
- Estimated parameters including afflux, surface roughness, evapotranspiration, rainfall patterns etc.

These uncertainties can have localised or cumulative effects on the accuracy of hydrologic and hydraulic modelling, and hence, the resulting design flood levels produced. A component of the freeboard accounts for this uncertainty in the design flood levels.

C.2.1.2. Component Determination

Uncertainties in flood level estimates can be approximated through an analysis of the sensitivity of design flood levels to changes in various modelling assumptions. A sensitivity analysis was undertaken as part of this freeboard assessment by varying hydraulic roughness parameters (‘Mannings ‘n’’) and blockage factors at hydraulic structures throughout the Study Area. The resulting average variation in peak flood level, is applied as the appropriate freeboard component. Results are presented in Table 2.

Table 2 Uncertainties in Estimated Flood Levels - Freeboard Components

Mechanism	Freeboard Component (m)
Mainstream	0.2
Overland	0.2

C.2.2. Local Water Surge

C.2.2.1. Discussion

Local flood water levels can be higher than the general flood level due to local blockages or obstructions in the floodplain, or, for mitigation works, if the levee alignment is oblique to the direction of the flow. Local surge can also be generated by trucks or boats passing through floodwaters. Some examples of local surge are shown below.

Examples of local surge

C.2.2.2. Component Determination

Results of flood modelling can be used to understand the sensitivity of design flood levels to the influences that cause local surge. The impacts of blockage (as a proxy for say, a truck driving through floodwater) were considered as part of the sensitivity analysis undertaken in this freeboard assessment, and this level of sensitivity has been used to derive the freeboard component related to local surge. The sensitivity assessment applied a blockage factor of 50% to all bridges, culverts and pit inlets within the study area.

A comparison of results in the blockage case and the design case indicated that peak flood levels in Picton are most sensitive to blockage at the Argyle Street bridge, where flood levels increase locally by approximately 200-400 mm (in a 1% AEP event) on both sides of the creek. A freeboard component of 0.3 m is considered appropriate for mainstream-affected areas in Picton.

In the areas subject to overland flow, flooding tends to be shallower (i.e. sheet flow across slopes) or in confined drainage lines. Generally, the peak flood levels are less sensitive to blockages at culvert entries and pit inlets. A freeboard component of 0.1 m is considered appropriate for overland flow areas in Picton. The results are summarised in Table 3.

Table 3 Local Water Surge - Freeboard Components

Mechanism	Freeboard Component (m)
Mainstream	0.3
Overland Flow	0.1

C.2.3. Wave Action

C.2.3.1. Discussion

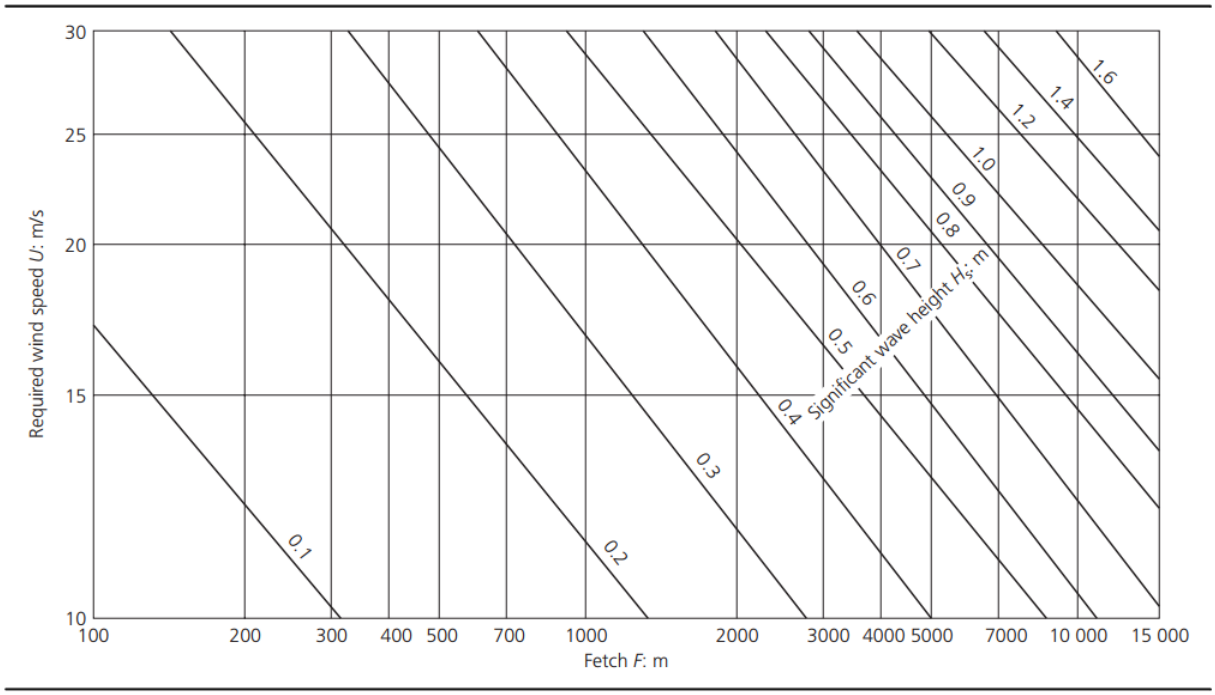
Increases in water level as a result of wave action are not determined in flood modelling. Design wave actions are a product of:

- Fetch – the distance the wave is assumed to travel;
- Wind speed and direction;
- Wave Height;
- Wind Set-up, and
- Wave Run-up – when a wave reaches a sloping embankment (e.g. levee) it will break on the embankment and run up the slope. Run-up would not apply to flood planning levels.

C.2.3.2. Component Determination

Wind-induced waves are important to consider where floodplains are expansive, with large stretches of open water (such as the Murrumbidgee River), where high windspeeds can generate significant surface waves. In such floodplains, the freeboard component associated with wave setup can be determined using the relationship between fetch and windspeed. Fetch can be measured from modelled flood behaviour, and directional windspeed can be determined based on data from the Bureau of Meteorology. These elements can be used in conjunction with the chart presented in Diagram 1, taken from Reference 4, to determine the Significant Wave Height, which is applied as the freeboard allowance for Wave Action.

Diagram 1 Simplified relationship between fetch length, wind speed and significant wave height (Reference 4)



In Picton, however, the Stonequarry Creek floodplain is confined by steep topography on both the left and right banks, limiting the fetch across which waves can propagate to less than 200 m

(occurring at the Victoria Park playing fields in a 1% AEP event). Existing commercial and residential development in and around Argyle Street and across the floodplain further limits the fetch across which surface waves would propagate.

Directional windspeed data taken from the Picton Council Depot (Site No. 068052) (Attachment A) indicates that 48% of all observed wind measurements are 'calm', with majority of other observations measuring less than 10 km/hr (~2.8 m/s). Windspeeds of less than 10 m/s are not included in the relationship chart (Diagram 1), and are not considered to cause surface waves of a significant height.

Therefore, it is not considered appropriate to apply the fetch-windspeed relationship shown in Diagram 1 in Picton. Rather, a nominal freeboard allowance of 0.02 m has been applied to both mainstream and overland flow areas to account for minor variations in estimated flood levels due to wind induced wave actions.

Table 4 Wave Action freeboard component

Mechanism	Wave Height Freeboard Component (m)
Mainstream	0.02
Overland	0.02

C.2.4. Climate Change

C.2.4.1. Discussion

The Floodplain Development Manual (Reference 1) indicates that climate change should be considered in the development and implementation of floodplain risk management works and planning controls, to ensure that the level of protection can be maintained under future conditions. The impacts of climate change on flood-producing rainfall events will have a flow on effect on flood behaviour. This may result in key flood levels being reached more frequently. The freeboard allowance required to cater for climate change is greatly affected by the uncertainties in future climate model projections, and is therefore somewhat of an estimation, though is considered appropriate for the purpose of this assessment.

C.2.4.2. Component Determination

The potential impacts of climate change, and the flood model's sensitivity to these impacts were assessed as part of the Stonequarry Creek at Picton Flood Study Update (Reference 3). Sensitivity analysis of an increase in rainfall intensity was undertaken by comparing the 0.5% and 0.2% AEP events with the 1% AEP event. These events are commonly used as proxies to assess an increase in rainfall intensity. Within the Stonequarry Creek catchment, these events correspond to an increase in rainfall intensity of approximately 7% for the 0.5% AEP event and 20% for the 0.2% AEP event.

For the purpose of this assessment, the differences in peak flood levels between the 1% AEP event and 0.5% AEP event are used to estimate the climate change freeboard component. A comparison of peak flood levels is provided on Figure 32 of Reference 3, and indicates that within mainstream-affected areas, the 0.5% AEP event is, on average, 0.15 m higher than the 1% AEP event. However, areas subject to overland flow affectation were fairly consistent between the two design events, and an allowance of 0.04 m is considered appropriate. The assigned components are summarised in Table 5.

Table 5 Climate Change Freeboard Component

Mechanism	Freeboard Component (m)
Mainstream	0.15
Overland	0.04

C.3. JOINT PROBABILITY ANALYSIS

Joint probability analyses are used to address the chance of two or more conditions occurring at the same time. The analysis recognises that design flood characteristics could result from a variety of combinations of flood-producing factors, and that in reality not all freeboard components would occur concurrently. Assigning probability factors to each component is therefore undertaken to determine the appropriate design freeboard.

The following probability factors have been assigned in this freeboard assessment, and have been based on those applied in Reference 4.

Table 6 Joint Probability Factors

Freeboard Component	Probability Factor
Uncertainties in Flood Levels	1
Local Water Surge	0.5
Wave Action	0.4
Climate Change	1

C.4. CONCLUSION

A freeboard assessment has been undertaken to determine the appropriate freeboard for residential flood planning levels in Picton. The assessment sought to quantify the following factors that can lead to flood levels being higher than the modelled estimates:

- Uncertainties in estimated flood levels;
- Local water surge;
- Wave action; and
- Climate change.

A summary of the freeboard assessment is presented in Table 7.

Table 7 Picton Freeboard Assessment Results

	Mainstream Flooding			Overland Flow			Reference
	(A)	(B)	(A x B)	(C)	(D)	(C x D)	
Component	Allowance (m)	Probability	Final Component (m)	Allowance (m)	Probability	Final Component (m)	
Uncertainties in Estimated Flood Levels	0.2	1	0.2	0.2	1	0.2	C.2.1
Local Water Surge	0.3	0.5	0.15	0.1	0.5	0.05	C.2.2
Wave Action	0.02	0.4	0.01	0.02	0.4	0.01	C.2.3
Climate Change	0.15	1	0.15	0.04	1	0.04	C.2.4
Total			0.5			0.3	

Considering the above factors and likelihood of concurrence, a minimum freeboard of 0.5 m is deemed appropriate for Flood Planning Levels in areas of Picton subject to mainstream flooding, and 0.3 m for overland flow affected areas.

The appropriate Flood Planning Levels (FPLs) for residential development in Picton are therefore:

- Mainstream: 1% AEP level plus 0.5 m freeboard;
- Overland Flow: 1% AEP level plus 0.3 m freeboard.

The adoption of two separate Flood Planning Level freeboard allowances for mainstream and overland flow flood mechanisms, and more specifically, selection of a freeboard of 0.3 m for overland areas, is not without precedent in New South Wales. A number of towns, including for example Boorowa, Condobolin, Crookwell, Gunning, Collector and Taralga have taken this approach via their respective Floodplain Risk Management Studies (References 6 and 7). This differentiation allows flood related development controls, particularly minimum floor level requirements, to be applied where they are warranted by the type of flood behaviour and degree of flood risk. Flood planning level requirements would be imposed on future development (and re-development) of properties within the Flood Planning Area. The Flood Planning Area is defined in Section 10.5.2 of the main report, and recommendations for flood related development controls are provided in Section 10.5.4.

C.5. REFERENCES

NSW Government
1. **Floodplain Development Manual**
April 2005

Department of Environment and Climate Change
2. **Floodplain Risk Management Guideline – Residential Flood Damages**
NSW State Government, October 2007

WMAwater
3. **Stonequarry Creek at Picton Flood Study Update (Final Draft)**
Wollondilly Shire Council, June 2019

Institute of Civil Engineers
4. **Floods and Reservoir Safety**
1996

NSW Department of Public Works
5. **Wagga Wagga Levee Upgrade – Flood Freeboard**
Report No. DC 10096
November 2010

Lyalls and Associates
6. **Boorowa Floodplain Risk Management Study and Plan**
Hilltops Council, March 2018

Lyalls and Associates
7. **The Villages of Crookwell, Gunning, Collector and Taralga Floodplain Risk Management Study and Draft Plan**
Upper Lachlan Shire Council, June 2017

Attachment A

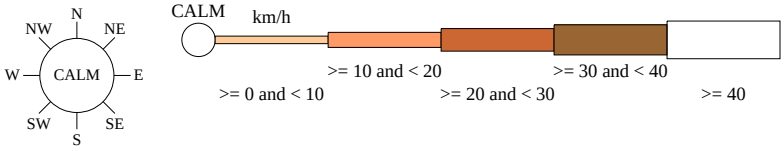
Rose of Wind direction versus Wind speed in km/h (02 Jan 1965 to 31 Dec 1975)

Custom times selected, refer to attached note for details

PICTON COUNCIL DEPOT

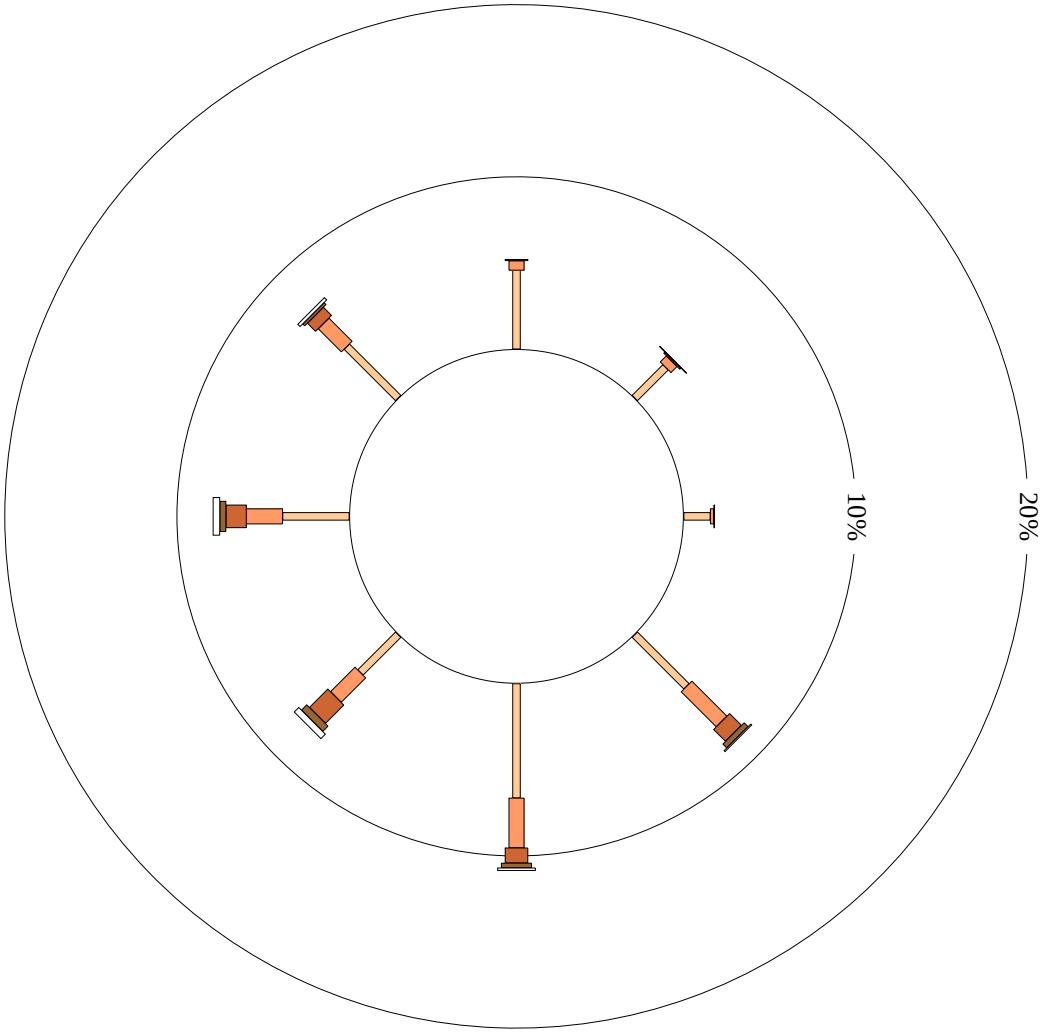
Site No: 068052 • Opened Jan 1880 • Still Open • Latitude: -34.1685° • Longitude: 150.6145° • Elevation 165m

An asterisk (*) indicates that calm is less than 0.5%.
Other important info about this analysis is available in the accompanying notes.



9 am
3803 Total Observations

Calm 48%



Appendix D

Item	Topic	Location2	Specific Comments	Response	Report Changes
1.1	Mitigation options - flood modification	Menangle Street	Concerns about the plan to raise Menangle Street (Flood Modification Option D2) stating that the water will flow into their house and the houses on the lower side of Menangle Street as a result.	The primary objective of Option D2 was to alleviate flooding on and in the vicinity of this location on Menangle Street. During future design stages, the local impacts of the works would be considered and offsetting measures such as additional drainage capacity would be designed, if required. Additional text has been added to the description of this option to clarify the intent and aspects to be considered in future design stages.	Clarification has been added to Table i, and Section 11.5.6.2
1.2	Drainage	Menangle Street	Concerns that there is not enough sub-surface drainage or inlet capacity in Menangle Street to cope with light rain and ponding occurs in front of their house.	Please refer to response to Item 1.1	Please refer to report changes for Item 1.1
2.1	Works in the floodplain	Stonequarry and Racecourse Creek Confluence	Concerns with the construction of the pedestrian bridge at the Stonequarry and Racecourse Creek confluence in 2017. Noting that the bridge is constructed below the 2016 flood level and are concerned that a similar event would cause "huge quantities of water" to enter property. The submission suggests Council would be liable for any damages caused.	The design of structures in the floodplain is a delicate balance of a range of criteria including design life and cost. Given the likely design life, structures are typically assessed for their impacts in the 1% AEP event. The 2016 event has been determined to be a much larger and less frequent event than the 1% AEP event. Despite this available modelling shows that the afflux (or relative impact) of the pedestrian bridge structure in both the 2016 and 1% AEP events to be less than 0.1m.	Nil

3.1	Mitigation options - flood modification	Study Area Wide	The submission notes significant runoff occurring across the catchment and suggests the construction of larger water catchments/dams or runoff tanks across the shire to reduce runoff entering Stonequarry Creek. The submission also suggests financial assistance could be provided.	This is a common suggestion that came out of discussions with the community and the floodplain risk management committee. Subsequently, a range of options were considered across the study area, including five specific locations for retarding basins (Options RB1 - RB5). In most cases the topography of the catchment required significant structures (dam walls) of a few hundred metres in length to provide the storage volume needed to reduce runoff volumes in the 1% AEP event. For this and other reasons (including effectiveness) a number of the considered options were not found to be viable. Option RB1 located upstream of Barker Lodge Road was found to result in significant benefits to flood behaviour and has been recommended for further investigation. The NSW Government provides technical and financial assistance to Councils to assess flood risk and implement measures through the Floodplain Risk Management Process, under which this study has been undertaken.	Nil
4.1	Impacts of flooding	LGA Wide	Endeavour Energy has stated that neither of their two substations are located within the hydraulic model extent and therefore flood information is not available at the sites from this study. The submission states however that neither site is likely to be significantly directly affected by flooding. The submission stressed the importance of maintaining road access to substations to allow for electricity supply to be maintained for a longer period and allow quicker restoration of supply.	The comments regarding road access to electrical supply facilities are noted.	Nil

4.2	Mitigation options - property modification	Study Area Wide	The submission also notes two recommendations from the FRMS related to electricity supply, including being regarded as critical facilities and not suitable in medium and high flood risk precincts, and flood proofing options for commercial properties / buildings to include ' locating electricals above the FPL, and facilitation of drainage and ventilation after flooding'.	The acknowledgment of these recommendations is appreciated.	Nil
5.1	General	N/A	The submission commends Council and WMAwater on the high quality layout and professionalism during the public drop in session on the 5th March.	This feedback is appreciated.	Nil
5.2	Flood behaviour	Menangle Street	The submission concurs with the representation of flood behaviour in the vicinity of their properties on Menangle Street.	Noted	Nil
5.3	Mitigation options - response modification	Menangle Street	The submission is supportive of improved flood warning and suggests that there is an opportunity to place signage in the Mackillop Lane car park to indicate the flood level reached in June 2016 and for flood education safety messages. The school would be supportive of the installation of such signage.	The comments regarding placement of flood education signage is noted and the suggested location has been included in the report text.	Section 11.3.3 has been amended

5.4	Future development	Coull Street	The submission is concerned that the impacts of development on flood behaviour, for currently zoned but yet undeveloped land, has not been considered as part of the study, with specific reference to 8-14 Coull Street. There is concern that development of this land will impact on flood behaviour as well as the environment. Noting that the site is classified as part flood storage and part floodway, the submission suggests development of this land would not be economically viable given the flooding constraints and subsequent planning controls. Suggesting that the land either be rezoned to private recreation or is voluntarily purchased.	The FRMS considers the potential impacts on flood behaviour of development on currently undeveloped land. The results of this assessment are discussed in Section 10 of the report. The discussion specifically references the Coull Street area as being unsuitable for future development due to the potential impacts on flood behaviour. The NSW Governments Voluntary Purchase scheme is limited to already developed properties and would not be a viable option for these properties. Option CM3 proposed floodway clearing, which would require rezoning of the associated land. This option has been expanded to include consideration of other land (including the identified properties) that may be unviable for development as part of this rezoning process.	Table i and Section 11.5.2.3 has been amended to include other land considered unviable for development.
6.1	Vegetation	Study Area Wide	Concerns that the study has not appropriately considered the effects associated with larger vegetation in the Stonequarry Creek channel, including potential water displacement and blockage. The submission is supported by a range of calculations. Suggestion that larger trees should be removed to allow smaller vegetation to grow and provide bank stability or for the channel to be concrete lined to avoid turbulence.	The reduced capacity of the Stonequarry Creek channel as a result of debris blockage was a common theme discussed with the community and the floodplain risk management committee. As a result, a range of options were considered as part of the study including broadscale clearing and improving conveyance of the Stonequarry Creek channel (Option CM1). While this option provided some improved flood behaviour through the Picton CBD, options must consider impacts beyond purely hydraulic performance such as visual and community amenity, environmental and habitat impacts, land acquisition and changes to flood risk. For these reasons, this option was not considered viable and was not recommended. Council undertakes an active vegetation management program which is informed by a third party assessment of suitable vegetation levels, habitat and bank stability. As part of this program Council has undertaken over 1000 hours of vegetation management since the 2016 flood event. Option CM4 recommends the continuation of these practices.	Nil

7.1	Mitigation options - flood modification	Menangle Street	Concerns about the plan to raise Menangle Street (Flood Modification Option D2) stating that the water will flow into their house and the houses on the lower side of Menangle Street as a result.	Please refer to response to Item 1.1	Please refer to report changes for Item 1.1
7.2	Drainage	Menangle Street	Concerns that there is not enough sub-surface drainage or inlet capacity in Menangle Street to cope with light rain and ponding occurs in front of their house.	Please refer to response to Item 1.1	Please refer to report changes for Item 1.1
7.3	Vegetation	Study Area Wide	Notes overgrowth and weeds in Stonequarry Creek behind their property and were concerned about the damage that debris can cause.	Please refer to response to Item 6.1	
8.1	Mitigation options - property modifications	LGA Wide	Generally speaking, the team is in support of the recommendations of the study. Seeking clarification on the following: - A suggestion to include in recommendation RM01 and RM02, to identify and prioritise any vulnerable people in the improved Flood Warning Systems (RM01) and Emergency Response Coordination efforts (RM02). - Clarification that PM01 Flood Planning Level is to essentially add "or other level as determined by any floodplain risk management plan adopted by the Council" to the existing clause. - Clarification that PM01 should also be extended to any DCP definition of the FPL. - Request for additional text to be added to PM03 Flood Proofing to ensure that any temporary flood barrier selected is sympathetic to the heritage values of the Picton area where possible.	This feedback is appreciated, and suggested clarifications will be included in the report text.	Table i, Sections 11.3.1, 11.3.2, 11.4.1, 11.4.2 and 11.4.3 amended as suggested.

9.1	Mitigation options - flood modification	Menangle Street	As the road authority responsible for Menangle Street, negotiations would need to be undertaken with Transport for NSW for Options D1 and D2. It is also suggested that the cost of D1 be increased to $250,000	This feedback is appreciated, and suggested clarifications and amendments will be included in the report text.	Table i, Sections 11.5.6.1 and 11.5.6.2 amended as suggested.
10.1	Mitigation options - property modifications	Picton CBD	Information has been requested as to the consequences for property development in areas identified as floodway and FPCC1.	The aim of the recommended property modification and planning measures are to ensure that development is compatible with the existing and future flood risk. At a high level development in these areas should be limited to those that are compatible with the flood risk. The Floodplain Development Manual, the guiding document under which this study is undertaken also acknowledges that the intent of the NSW Government Flood Prone Land Policy is not to sterilise land from appropriate development.	Nil
11.1	Flood behaviour	Jarvisfield	Concerns with the flood mapping in the Jarvisfield Estate potentially not including the changes to the terrain as a result of the recent development.	At the time of the flood modelling early in the overall project this area was under development and suitable details of the development were not available for inclusion in the model. It is recommended that at the next available opportunity this portion of the model be updated to included recently acquired LiDAR information. This will ensure that the flood behaviour in this area is representative of the current catchment and development conditions. **Update:** The topographic information in these areas have been updated to 2019 information and mapping revised as part of the final report.	Mapping and damages assessment updated
12.1	Flood behaviour	Study Area Wide	The submission notes that areas within the study area contain leases where future coal extraction may be planned. It notes that any analysis of flood behaviour or management strategies should consider the potential impacts of this extraction.	The comments made are noted and have been added to the report in relation to the recommended mitigation options.	Table i, Section 11.5.4.1

13.1	Mitigation options - flood modification	Commercial Areas	The submission states that "the extent of impacts of the 2016 storm event should never, never, ever be allowed to happen again" and identifies concerns that the Floodplain Risk Management Study focuses on preparedness and resilience rather than changes to physical flood behaviour.	The impacts of the 2016 flood were widespread and significant. An event like 2016 is unlikely but cannot be prevented. It is not to be expected but should be planned for. Picton and particularly the commercial centre are located on the banks of Stonequarry Creek and therefore subject to flood risk. There are no engineering works, without relocation of the commercial centre that would allow for the removal of this flood risk while maintaining the atmosphere that is unique to Picton. Hence the recommendations focus on preparedness and resilience, coupled with planning measures (such as flood compatible buildings) that aim to reduce or manage flood risk over time as the organic renewal process occurs. Work undertaken during the Floodplain Risk Management Study has shown that the 2016 event was a very large and rare flood event. When considering mitigation options a number of factors need to be balanced against each other including changes to flood behaviour, environmental impacts, benefits in the context of design life (including the event to mitigate against), acceptable levels of risk, costs, amenity, to name a few.	Nil
13.2	General	Commercial Areas	The submission acknowledges Council's thorough approach and extensive work that has been put into these investigations since the 2016 event.	This feedback is appreciated.	Nil
13.3	Mitigation options - flood modification	Commercial Areas	The submission raises concerns that Council needs to do more to gain access to funding and develop further options to reduce flood risk.	Council has undertaken this Floodplain Risk Management Study to allow for the identification of viable mitigation strategies and to allow for financial support to be received from the state government to implement these strategies. Approximately 40 physical options in addition to planning and response options have been assessed as part of this Floodplain Risk Management Study.	Nil

13.4	Mitigation options - flood modification	Commercial Areas	The submission suggests a target reduction in flood level (700mm) for the 1% AEP event should be applied. In addition, the submission suggests that five locations for retarding basins (such as RB01) should be identified.	A key objective of the NSW Government Flood Prone Land is to reduce the impacts of flooding, this can be achieved by a reduction in the physical flood level (although developed areas can impose a number of constraints meaning reduced flood levels may not be viable) but can also be achieved by managing how flooding impacts the community through localised measures such as flood barriers, improved preparedness and response, floodway clearing, continued vegetation management and appropriate development. Option RB01 was considered with retarding basins at four other locations in the catchment. Of those only, RB01 was found to have a measurable impact on flood behaviour. The topography and shape of the catchment presents a number of constraints to retarding basins at other locations, often showing that at other locations the desired reduction in flow is not achievable. Basins considered in the Racecourse Creek side of the catchment were found to be ineffective on flood levels in the CBD. In addition, due to the relative timing of flooding in different parts of the catchment a series of retarding basins will not achieve a directly cumulative reduction in flow. A 700mm reduction in flood level in the CBD would equate to reducing peak flows by 30% (or nearly 150m^3/s) in the 1% AEP event, which would then be equivalent to a 2% AEP event. Option RB01 achieves a reduction in peak flow of 20m^3/s using a storage volume equivalent to the size of 40 Olympic swimming pools. In addition, a reduction in flow of this level would impact across a range of events and would likely see large environmental consequences for the creek and its ecosystem.	Table i, Section 11.5.4.1

				Considering this the committee wished for a slight variation to be made to the RB01 recommendation to ensure that any opportunity to improve the performance of a basin in this part of the catchment is not missed. RB01 will be renamed Stonequarry Creek Western Catchment Retarding Basin Feasibility Study and the description to be "undertake a feasibility study to investigate appropriate site(s) and concept designs for retarding basin(s) in the western part of the Stonequarry Creek catchment, at location(s) upstream of Barkers Lodge Road."	
13.5	Mitigation options - flood modification	Commercial Areas	The submission closes with a number of high priority requests, including: - That the Barkers Lodge Road Retarding Basin (RB01) be fast tracked.	The first stage for the implementation of this mitigation option will be the development of a feasibility study which will develop a design and further investigate possible constraints. Council plans to seek funding to undertake this study.	Table i, Section 11.5.4.1
13.6	General	Commercial Areas	The Floodplain Risk Management Study and Flood Model be peer reviewed.	The study and associated modelling has been undertaken in accordance with industry best practice utilising the best available information, in addition the study has been undertaken under the guidance of the NSW Governments Floodplain Management Process. The developed flood models have been calibrated to historical events to improve confidence in the assessment produced by the model. Further, the modelling tools represent an advancement of the tools developed previously for the catchment dating back to the 1990's. The various stages of the project have been subject to input and review by Council, the floodplain management committee and state government departments.	Nil

13.7	Flood damages	Commercial Areas	That an independent review be completed reporting on actual and forecast Flood Damage impacts $ Value assessment be made, to support the Council submissions for funding of risk mitigation measures	Damages have been assessed as part of the Floodplain Risk Management Study using state government guidelines. The damage as a result of the 2016 flood event was significant and is representative of a single event. While gaining an insight into the actual damages experienced in a single event is useful information, the state government guidelines for the estimation of flood damages aim to provide an estimate of damages across all event sizes and to determine the average annual costs resulting from a succession of floods over a long period of time. This method is consistently applied across the state and allows for a comparison point for evaluating the economic benefits and suitability for funding of different mitigation measures within a catchment and across different areas of the state.	Nil
13.8	Mitigation options - response modification	Commercial Areas	That Council maintain and control a database of all businesses in the Picton CBD and take responsibility for forwarding all emergency SES warnings to those on the database, in addition to trials this communication.	The SES is the state's combat agency for flood and is legislatively responsible for the coordination of evacuations (including warnings and orders) which includes the collation, assessment and public dissemination of flood bulletins and local flood advices during events. A clear hierarchy is established and needs to be maintained during flood events to ensure that clear directions are given. The SES remain responsible for disseminating these messages. Option RM02 and RM03 are aimed at improving coordination between the SES and the relevant support agencies.	Nil
13.9	Mitigation options - flood modification	Commercial Areas	That education workshops be held in conjunction with WSC, Chamber and supplier of flood barriers so that premises can be protected from all low-level events	The responsibility for the selection and ongoing education regarding flood barriers would fall to the individual business or building owners. It has been suggested for the greater benefit that businesses act together in implementing this option. These events could be coordinated to achieve multiple objectives including training and education, but individual businesses would need to be the driving force.	Nil