Tamworth City Wide Floodplain Risk Management Study and Plan

Report

Volume 1

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Prepared for
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Table of Abbreviations

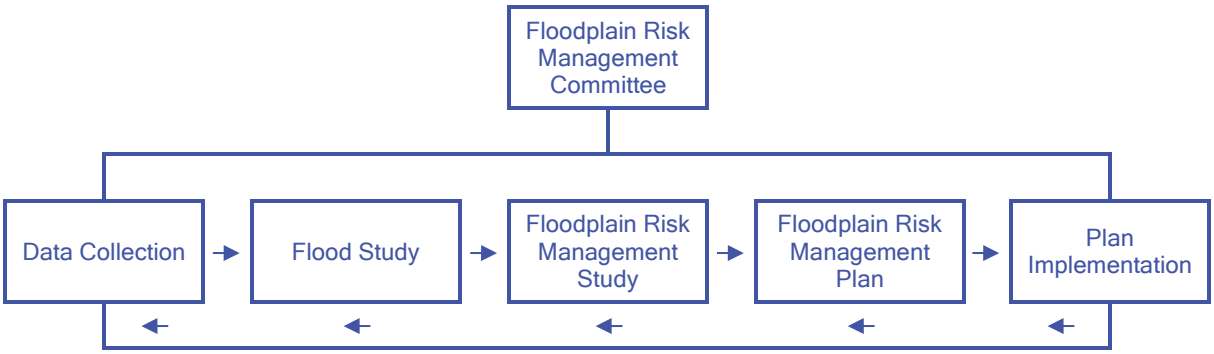
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
AAD	Average Annual Damage
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff
DEM	Digital Elevation Model
EY	Exceedances per Year
FMC	Floodplain Management Committee
FPA	Flood Planning Area
FPL	Flood Planning Level
LGA	Local Government Area
LiDAR	Light Detection and Ranging
NSW	New South Wales
OEH	Office of Environment and Heritage
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
SES	State Emergency Services

Forward

Flood-Related Legislation, Policies and Guidelines

The New South Wales (NSW) State Government's *Flood Prone Land Policy* places the primary responsibility for floodplain risk management with Councils and the *Local Government Act 1993 – Section 733* indemnifies Council from liability if the Council has acted in "good faith" in relation to floodplain risk management. Additionally, the State Government, through the Department of Planning and Environment (DPE), provides financial and technical support to Council in meeting its floodplain risk management obligations.

The NSW *Floodplain Development Manual* (2005) supports the NSW *Flood Prone Land Policy*. The manual provides direction on the floodplain risk management process, as detailed below.



Compilation of existing data and collection of additional data.

Defines the nature and extent of the flood problem, in technical rather than map form.

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

Preferred options publicly exhibited and subject to revision in light of responses.

Implementation of flood response and property modification measures (including mitigation works, planning controls, flood warnings, flood readiness and response plans, environmental rehabilitation, ongoing data collection and monitoring) by Council.

There are a number of industry guidelines that provide technical guidance through the floodplain risk management process. This includes the *Australian Emergency Management Series* (particularly *Handbook 7: Managing the Floodplain Best Practice in Flood Risk Management in Australia*), and *Australia Rainfall and Runoff* (ARR). ARR has undergone several revisions since its inception; with the first publication in 1958, the second publication in 1977, the third publication in 1987 and the fourth (and latest) publication in 2019.

The current study has been undertaken in accordance with the aforementioned legislation, policies and guidelines.

Terminology

ARR 2019 has standardised the design flood terminology used in the industry. Very frequent events are expressed as Exceedances per Year (EY), frequent to very rare events are expressed as Annual Exceedance Probability (AEP) as a percentage, and very rare to extreme events are expressed as a 1 in x AEP. This is detailed in Table 0-1, which has been extracted from Section 2.2.5., Chapter 2, Book 1 of ARR 2019.

Table 0-1: Design Event Terminology

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	

Executive Summary

Overview

The NSW State Government, through the Department of Planning and Environment (DPE), oversee the Floodplain Management Program. The program provides support to local councils in the implementation of the NSW Government's Flood Prone Land Policy as outlined in the NSW Government's Floodplain Development Manual. The primary objective of the policy and manual is to reduce the impacts of flooding and flood liability on individual owners and occupiers of flood prone property.

As part of the Floodplain Management Program, Tamworth Regional Council and DPE commissioned the Tamworth City Wide Floodplain Risk Management Study and Plan (FRMS&P). This study included the catchments of the Peel River, Cockburn River, Goonoo Goonoo Creek, Tangaratta Creek, Timbumburi Creek, Boltons Creek, Murroon Creek, Oxley Vale and the East and North Tamworth area.

Identifying Options

A number of flood mitigation options were identified and investigated, including:

- Potential flood modification measures:
  - FM01 – Levee on Timbumburi Creek
  - FM02 – Pump out from behind the levee
  - FM03 – Additional pressure tunnels
  - FM04 – Computerised flood gates
  - FM05 – Detention basins upstream of East and North Tamworth
  - FM06 – Diversion of Barnes Gully
- Potential property modification measures:
  - PM01 – Update development controls
  - PM02 – Voluntary property purchase
  - PM03 – Voluntary house raising
  - PM04 -Flood proofing properties
- Potential response modification measures
  - RM01 – Flood education programs
  - RM02 – Early warning system
  - RM03 – Improved access to Calala

Assessing Options

The flood mitigation options investigated were assessed against a multi-criteria matrix. This included assessment of the change in flood behaviour, the economic impacts, the social impacts, the environmental and heritage impacts.

Recommended Options

Based upon the multi-criteria assessment of the flood mitigation options, a number of options were recommended for implementation. The measures identified would require a total capital expenditure of approximately $17,875,000. This is summarised in Table 0-1.

Table 0-1: Summary of recommended measures

Measure ID	Measure Description	Cost	Timeframe (Budget Dependent)	Priority
PM01	Update development controls	$10,000	1 year	High

RM01	Flood education programs	$10,000	1 year	High
FM02	Pump out from behind the levee	$7,743,000	3 years	High
FM04	Computerised flood gates	$285,000	5 years	Medium
RM02	Early warning system	$75,000	5 years	Medium
FM05	Detention basins upstream of East and North Tamworth	$7,682,000	10 years	Medium
PM03	Voluntary house raising	$966,000	10 years	Medium

1 Introduction

1.1 Overview

Tamworth Regional Council, with the support of the NSW DPE, has commissioned HydroSpatial Pty Ltd to prepare the following Tamworth City Wide FRMS&P.

1.2 Study Objectives

The objectives of the Tamworth City Wide FRMS&P were to utilise the hydrologic and hydraulic models, developed as part of the Tamworth City Wide Flooding Investigation (Lyall and Associates, 2019) and the East and North Tamworth Drainage Study (Lyall and Associates, 2021) to:

- Review and update the hydrologic and hydraulic models;
- Identify potential flood mitigation measures;
- Estimate the cost to undertake the potential mitigation measures;
- Assess the benefit-cost of the potential mitigation measures;
- Recommend mitigation measures to be implemented; and
- Provide input into the priorities and timing on implementation of recommended mitigation measures.

2 Study Methodology

The following tasks were undertaken as part of the Tamworth City Wide Floodplain Risk Management Study and Plan:

- Analysis of catchment characteristics;
- Review of hydrologic and hydraulic modelling;
- Assessment of flood behaviour;
- Assessment of flood response arrangements;
- Assessment of flood planning policies;
- Investigate the consequences of flooding; and
- Investigate flood modification measures.

An analysis of catchment characteristics was carried out to gather information on the varied effects of flooding. These included social, sensitive land use, cultural and heritage, environmental, and levee system characteristics. This data was later used to inform the assessment of mitigation options. Further details on the catchment characteristics analysis are discussed in Section 4.

A review of hydrologic and hydraulic modelling was undertaken to assess the effectiveness and accuracy of the modelling, as well as the currency of the data and guidelines used. Further details on the hydrologic and hydraulic modelling review are discussed in Section 5.

An assessment of existing flood response arrangements was undertaken to determine the effectiveness of current response arrangements, as well as determine whether an update to existing arrangements was necessary. This included an assessment of the existing Local Emergency Plan, Flood Emergency Sub Plan, and evacuation centres. Further details on the existing flood response assessment are discussed in Section 7.

An assessment of existing flood planning policies was carried out to determine the effectiveness of current flood planning policies, as well as whether an update to existing policies was necessary. Multiple relevant NSW state planning policies were assessed, as well as applicable ministerial directions. Furthermore, Council's planning policies were assessed, including the Tamworth Regional Local Environmental Plan (LEP) 2010 and the Tamworth Regional Development Control Plan (DCP) 2010. Further details on the existing flood planning policies assessment are discussed in Section 8.

An investigation into the consequences of flooding under existing conditions was carried out to assess the economic, social, heritage and environmental impacts of flooding. The economic impacts were also quantified for the direct flood damages impacting both residential and commercial premises. Further details on the flooding consequences investigation are discussed in Section 9.

An investigation into flood mitigation measures was carried out in order to identify, assess, recommend and prioritise a number of potential mitigation measures. Options were identified through the analysis of existing flood behaviour, as well as through consultation with Council and the community. Identified options were then assessed through a multi-criteria matrix system, in order to recommend and prioritise their implementation. Further details on the flood mitigation measures investigation are discussed in Section 10.

3 Consultation

As part of this study, consultation has been undertaken with a number of stakeholders, as discussed within the following.

3.1 Community Consultation

3.1.1 First Round

A community consultation process was undertaken during the data collection stage of the study through the July-August 2020 period. The purpose of this community consultation work was to gather data from the community regarding their views on flood response and flood mitigation strategies. As part of this community consultation a newsletter and questionnaire were distributed, and a community drop-in meeting was held.

The community drop-in meeting was held at the Tamworth Community Centre on Darling Street on the 23 July 2020 between 3pm and 7pm. The community meeting was attended by representatives from HydroSpatial and Council. The occupants from approximately a dozen properties attended this drop-in meeting.

Following on from the community drop-in meeting, 136 written responses were received. The majority of these were from residential properties (accounting for approximately 61% of responses) and commercial properties (accounting for approximately 20% of responses). Furthermore, a significant number of responses had lived at their current address for more than 20 years.

From the written responses, it was found that the majority of respondents would not evacuate in the event of a flood and that the majority of respondents have not thought about an evacuation plan (shown in Chart 3-1 and Chart 3-2). It was also found that the majority of respondents would not require assistance in the event of a flood evacuation; however, of the small number that would require assistance, many do not have a designated person to assist them (shown in Chart 3-3). There was also found to be a low likelihood of respondents carrying out property specific flood mitigation measures, such as sand bagging (shown in Chart 3-4).

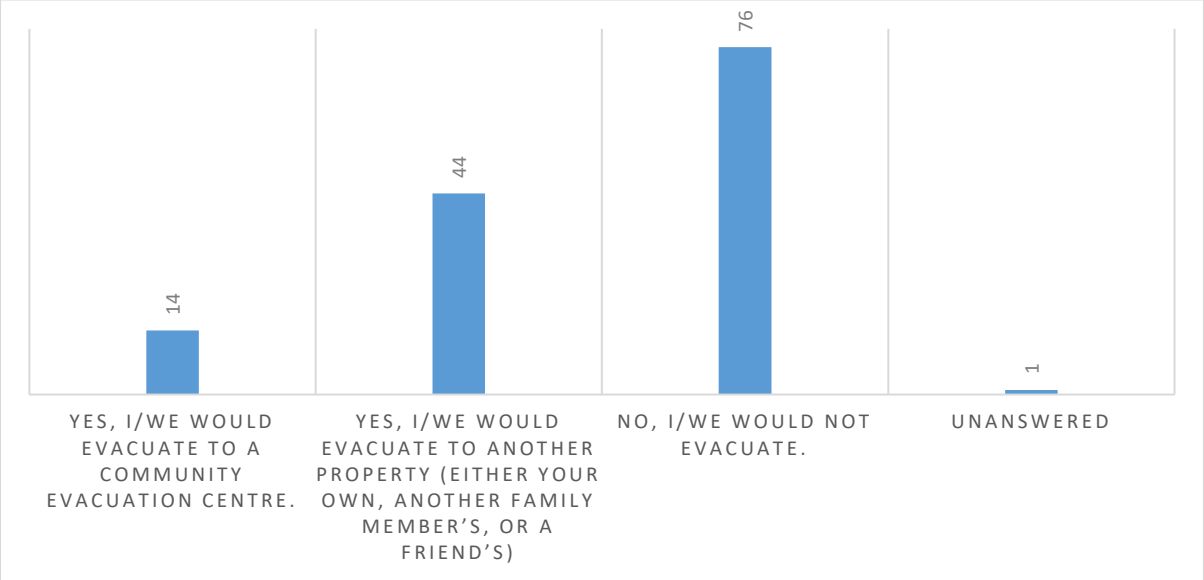


Chart 3-1: Evacuation likelihood

Chart 3-2: Evacuation plan

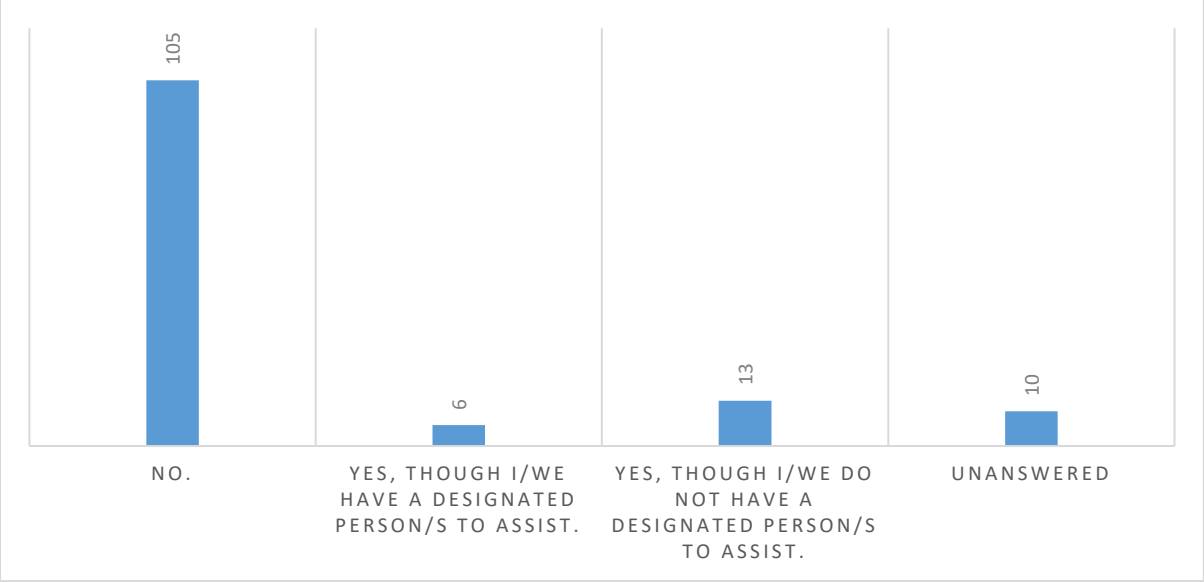


Chart 3-3: In need of assistance

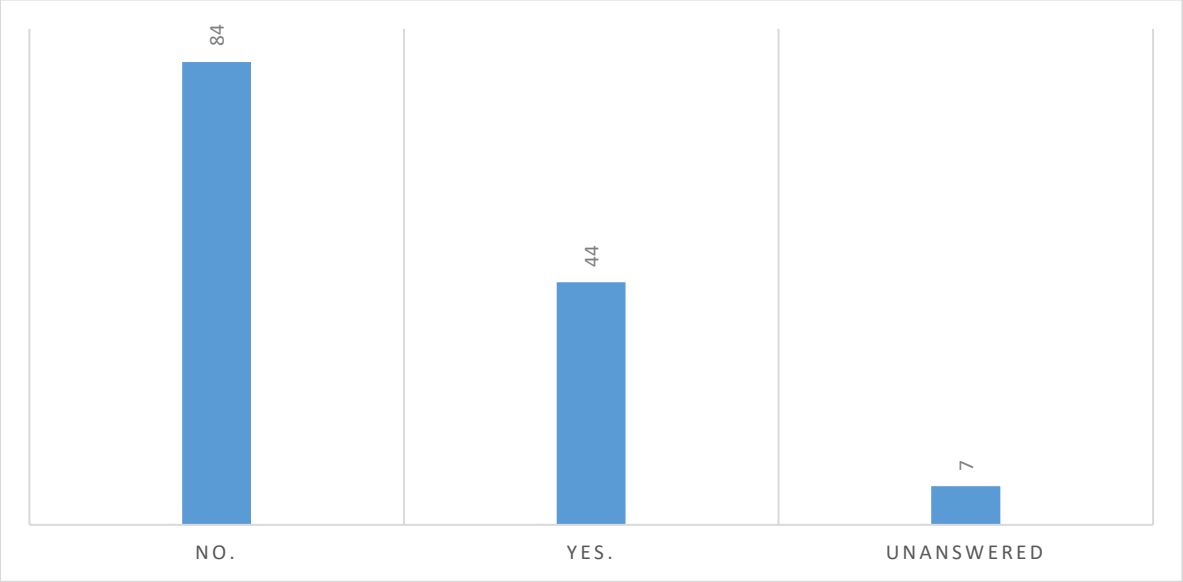


Chart 3-4: Property protection likelihood

Additionally, the community consultation survey asked respondents to rank their interest in generalised flood mitigation strategies, as well as allowing respondents to note any other mitigation strategies/options that they would like to see investigated. From the responses, it was found that the most popular mitigation strategies were to apply development controls to new developments in flood affected area, and the upgrade of major drainage pipes or channels within residential and commercial areas. Conversely, the least popular mitigation strategies were the voluntary purchase of existing residential property in high hazard flood areas, and to subsidise voluntary raising of existing residential buildings above a specific flood level.

Over 50 respondents also included additional comments regarding potential mitigation options. From these comments, it appears that areas of particular interest in the community include the effects of new development on flood behaviour, adequate street drainage, and the clearing of debris from waterways and hydraulic structures.

4 Catchment Characteristics

4.1 Social Characteristics

The social characteristics of an area influences the community's response to a flood event; including the ability to prepare before a flood event, the ability to respond during a flood event and the ability to recover after a flood event has occurred.

4.1.1 Existing Social Characteristics

To quantify the social characteristics of the study area, the 2016 Australian Bureau of Statistics Census data was analysed. This is detailed in Table 4-1.

Table 4-1: Census Statistics (2016)

	Tamworth (UCL)	NSW
Population		
Total Population	35,415	8,072,163
< 4 years	6.3%	5.8%
5 - 14 years	13.7%	12.4%
15 - 64 years	60.2 %	64.2%
> 65 years	19.8%	17.7%
Assistance		
Core activity need for assistance	7.4%	5.8%
Volunteering		
Provided unpaid assistance to a person with a disability (last two weeks)	12.4%	11.5%
Did volunteer work through an organisation or group (last 12 months)	13.4%	13.0%
Language		
English only spoken at home	83.5%	67.6%
Language top responses (other than English)	Mandarin 1.1%	Mandarin 3.4%
	Vietnamese 1.0%	Arabic 2.8%
Internet Access		
Internet not accessed from dwelling	N/A	N/A
Internet accessed from dwelling	N/A	N/A
Not stated	N/A	N/A
Registered Motor Vehicles		
None	8.4%	9.0%
1 or more motor vehicles in occupied private dwellings	89.7%	89.4%
Not stated	1.9%	1.5%
Housing Density		

	Tamworth (UCL)	NSW
Average number of people per household	3	3.1
Median Weekly Income		
Personal	$750	$813
Family	$1,706	$2,185
Household	$1,328	$1,829
Property Tenure		
Owned outright	29.3%	31.5%
Owned with a mortgage	26.1%	32.5%
Rented	40.8%	32.6%
Not stated	1.9%	1.5%
Housing Payments		
Households where rent payments are greater than or equal to 30% of household income	33.8%	35.5%
Households where mortgage payments are greater than or equal to 30% of household income	10.0%	17.3%

According to the 2021 Census, Tamworth has a population of 35,415 people with a median age of 37. Of this population, the proportion of people aged under 4 years and between 5 and 14 years was relatively similar to the NSW average, though slightly higher. However, the proportion of people aged over 65 years was moderately higher than the NSW average. Furthermore, the proportion of the population that requires assistance in one or more of the three core activities of self-care, mobility and communication accounted for 7.4% of the population. These vulnerable community members are likely to require additional assistance during a flood event.

The proportion of the population that were involved in volunteer work and had provided unpaid assistance to a person with a disability was relatively similar to the NSW average. This indicates an average willingness to support others in the community and a likelihood that the community will provide assistance to each other during a flood event.

The linguistic diversity of Tamworth is relatively low, with a large proportion of the area speaking English exclusively at home. This proportion was far greater than the NSW average. However, of those that do speak another language at home, while the majority rated their proficiency in speaking English as “very well or well”, A significant minority of approximately 18.3% rated their proficiency in speaking English as “not well or not at all”. Additionally, of the overseas migrants living in the area, approximately three quarters have lived in Australia for less than 10 years as of 2021. As such, it is somewhat likely that translation services will be required to disseminate flood preparation material and flood warnings in the lead up to a flood event.

Within Tamworth, the proportion of the population with internet access within their homes was less than the NSW average. Therefore, it is advisable that any flood preparation initiatives and flood warnings provide information across a range of different media forms to communicate with a wider breadth of the community.

The number of homes with a registered motor vehicle in Tamworth was relatively similar to the NSW average and accounted for a large proportion of the population. Therefore, the

community have an average ability to self-evacuate and are not more likely to require assistance during a flood event.

The median family/household income in Tamworth and the number of properties that are owned outright were both lower than the NSW average. Furthermore, while the proportion of mortgagees experiencing housing payment stress (typically defined as mortgage/rent payments greater than 30% of the household income) was lower than the NSW average, the proportion of renters experiencing housing payment stress was roughly equal to the NSW average. Therefore, the community is less likely to be financially resilient or able to recover after a flood event.

The proportion of properties within Tamworth that were rented was slightly higher than the NSW average, and the proportion of the population that had the same residential address 5 years prior to the 2021 Census was slightly low (accounting for approximately 48% of the population). As such, the population of Tamworth could be considered slightly unstable. This decreases the likelihood that community flood preparations and/or flood awareness initiatives will be retained.

4.1.2 Historical Social Characteristics

To quantify the changing historical social characteristics of the study area, the 2006, 2011, 2016 and 2021 Australian Bureau of Statistics Census data was analysed. This is detailed in Table 4-2.

Table 4-2: Tamworth Census Statistics (2006, 2011, 2016)

Tamworth	2006	2011	2016	2021
Population				
Total Population	33,475	36,131	33,885	35,415
< 4 years	7.0%	7.4%	6.9%	6.3%
5 - 14 years	14.5%	13.7%	13.3%	13.7%
15 - 64 years	62.6%	62.3%	61.3%	60.2 %
> 65 years	15.9%	16.6%	18.5%	19.8%
Assistance				
Core activity need for assistance	5.0%	5.4%	6.2%	7.4%
Volunteering				
Provided unpaid assistance to a person with a disability (last two weeks)	11.2%	11.3%	11.8%	12.4%
Did volunteer work through an organisation or group (last 12 months)	20.8%	19.5%	19.6%	13.4%
Language				
English only spoken at home	94.0%	92.2%	87.1%	83.5%
Language top responses (other than English)	Cantonese 0.2%	Tagalog 0.2%	Mandarin 0.6%	Mandarin 1.1%

Tamworth	2006	2011	2016	2021
	Mandarin 0.1%	Cantonese 0.2%	Tagalog 0.6%	Vietnamese 1.0%
Internet Access				
Internet not accessed from dwelling	47.0%	28.7%	23.6%	N/A
Internet accessed from dwelling	50.1%	67.0%	72.6%	N/A
Not stated	2.9%	4.4%	3.7%	N/A
Registered Motor Vehicles				
None	11.4%	9.2%	8.4%	8.4%
1 or more motor vehicles in occupied private dwellings	84.8%	86.7%	86.1%	89.7%
Not stated	3.%	4.1%	5.4%	1.9%
Housing Density				
Average number of people per household	2.4	2.4	2.4	3
Median Weekly Income				
Personal	$418	$531	$631	$750
Family	$1,048	$1,192	$1,389	$1,706
Household	$809	$962	$1,121	$1,328
Property Tenure				
Owned outright	32.9%	30.7%	29.8%	29.3%
Owned with a mortgage	28.8%	29.8%	26.8%	26.1%
Rented	33.2%	35.3%	39.1%	40.8%
Not stated	4.3%	3.5%	3.6%	1.9%
Housing Payments				
Households where rent payments are greater than or equal to 30% of household income	--	12.8%	15%	33.8%
Households where mortgage payments are greater than or equal to 30% of household income	--	6.6%	4.2%	10.0%

According to the 2021, 2016, 2011 and 2006 Census, Tamworth has had a population increase of 5.8% over the last 15 years. During this time, the proportion of people aged over 65 years has shown a slight increase of 3.9 percentage points. Furthermore, the proportion of the population that requires assistance in one or more of the three core activities of self-care, mobility and communication has increased by 2.4 percentage points between 2006 and 2021.

This appears to indicate an aging population that is becoming more likely to require additional assistance during a flood event.

The proportion of the population that provided unpaid assistance to a person with a disability stayed relatively consistent between 2006 and 2021. However there was a decrease of 7.4 percentage points in people engaging in volunteer work through an organization or group.

The linguistic diversity in Tamworth has increased from 2006 to 2021, with a 10.5 percentage point decrease in the proportion of the population speaking only English at home. Of the population of overseas migrants in Tamworth in 2021, 18.3% rated their proficiency in speaking English as "not well or not at all", increased from 3% in 2006. Additionally, between 2021 and 2006, the proportion of overseas migrants that had arrived within the previous 10 years had increased from approximately 24.7% to 76.4%. As such, it appears to be increasingly likely that translation services will be required to disseminate flood preparation material and flood warnings in the lead up to a flood event.

The proportion of the population within Tamworth with internet access within their homes has increased from 50.1% in 2006 to 72.6% in 2016. Although this indicates a trend in increased internet accessibility within Tamworth, as this proportion is still below the NSW average, it is still advisable that any flood preparation initiatives and flood warnings provide information across a range of different media forms.

Within Tamworth, the number of homes with a registered motor vehicle grown slightly, with a increase of 4.9 percentage points.

The median family/household income in Tamworth did increase from 2006 to 2021, however the number of properties that were owned outright has decreased by 3.6 percentage points. The proportion of mortgagees in Tamworth experiencing housing payment stress (typically defined as mortgage/rent payments greater than 30% of the household income) increased by 3.4 percentage points between 2011 and 2021, and the proportion of renters experiencing housing payment stress has greatly increased by 21 percentage points in the same period. The proportion of the population experiencing housing payment stress in 2006 is unknown as this data was not provided in the 2006 Census Community Profile.

The proportion of properties within Tamworth that were rented has increased from 2006 to 2021 by 7.6 percentage points. Additionally, while the proportion of the population that had the same residential address 5 years prior to the Census increased from approximately 44% in 2006 to approximately 48% in 2021, this is still lower than the approximate 53.9% of the NSW population.

4.2 Sensitive Land Use Characteristics

Sensitive land uses can be characterised as:

- Vulnerable community facilities, such as aged care centres, childcare centres, and schools, etc.
- Critical community facilities, such as law enforcement centres (police stations, correctional centres etc.), emergency services centres (fire stations, RFS Brigade Stations, NSW SES Unit Headquarters etc.) and health services centres (hospitals, medical centres etc).
- Critical community infrastructure, such as electricity substations, pumps for potable water or sewage water, sewage treatment plants, and waste depots etc.

The location and flood affectation of sensitive land uses in an area influences the community's response to a flood event; including planning before a flood event, the ability to respond during a flood event and the ability to recover after a flood event has occurred. Therefore, the sensitive land uses in the study area have been investigated.

The sensitive land uses found within the study area are detailed in Table 4-3 and the location of these sensitive land use sites is shown on Figure B 2.

Table 4-3: Sensitive Land Uses - Vulnerable Community Facilities

Type	Name	Address
Aged Care	Aveo Freedom Aged Care Tamworth	51-61 Marius St, North Tamworth NSW 2340
Aged Care	Ingenia Gardens Tamworth	52-62 Johnston St, North Tamworth NSW 2340
Aged Care	Kurrajong Village	3 Barton Ln, North Tamworth NSW 2340
Aged Care	Mountview Village	51-61 Marius St, Tamworth NSW 2340
Aged Care	Oak Tree Retirement Village	17 Warwick Rd, Hillvue NSW 2340
Aged Care	Tamworth Easy Living Villas	19 Power St, West Tamworth NSW 2340
Aged Care	Tamworth Gardens Retirement Estate	36 Johnston St, North Tamworth NSW 2340
Aged Care	Tamworth Masonic Village	16 Kitchener St, Tamworth NSW 2340
Aged Care	The Benevolent Society	Ground Floor/462/464 Peel St, Tamworth NSW 2340
Aged Care	Uniting House	Cnr Tribe Street &, Manilla Rd, Tamworth NSW 2340
Childcare	Bambini Boutique Childcare	79 Piper St, North Tamworth NSW 2340
Childcare	Centrepoint Childcare Centre	374 Peel St, Tamworth NSW 2340
Childcare	Community Kids Tamworth Early Learning Centre	2A Kenny Dr, Tamworth NSW 2340
Childcare	Esteem Kids Group	27-37 Robert St, South Tamworth NSW 2340
Childcare	Esteem Kids Group	143 Carthage St, Tamworth NSW 2340
Childcare	Impressionable Kids Tamworth	66 Johnston St, North Tamworth NSW 2340
Childcare	Janelle Street Centre	4 Janelle St, South Tamworth NSW 2340
Childcare	Little Kindy Tamworth	ETMC Building, Level 2/279B Marius St, Tamworth NSW 2340
Childcare	Little Stars Childcare Tamworth	3-7 Hercules St, Tamworth NSW 2340
Childcare	Milestone Early Learning Oxley Vale	2 Conimbla Cres, North Tamworth NSW 2340
Childcare	Nido Early Learning	2/1A Wirraway St, Taminda NSW 2340
Childcare	Sherpa Kids St Edwards Tamworth	Robert St, South Tamworth NSW 2340

Child Care	Sherpa Kids St Nicholas	east 2340, 143 Carthage St, East Tamworth NSW 2340
Childcare	Billabong Kids Central	2 Evans St, Westdale NSW 2340
School	Bullimbal School	Bullimbal School, 18-36 Degance St, South Tamworth NSW 2340
School	Calrossy Anglican School	140 Brisbane St, East Tamworth NSW 2340
School	Carinya Christian School	25 Boronia Dr, Calala NSW 2340
School	Farrer Memorial Agricultural High School	585 Calala Ln, Calala NSW 2340
School	Goodstart Early Learning Calala	49-51 Calala Ln, Tamworth NSW 2340
School	Goodstart Early Learning Tamworth	172 Brisbane St, Tamworth NSW 2340
School	Goodstart Early Learning Tamworth South	358 Goonoo Goonoo Rd, South Tamworth NSW 2340
School	Hillvue Public School	Hillvue Rd, Tamworth NSW 2340
School	Liberty Christian Primary School	582-588 Goonoo Goonoo Rd, Hillvue NSW 2340
School	McCarthy Catholic College	Tribe St, North Tamworth NSW 2340
School	MET School	7-11 Monteray St, North Tamworth NSW 2340
School	Milestones Early Learning Tamworth	1/3 Bligh St, North Tamworth NSW 2340
School	Nemingha Public School	145 Nundle Rd, Nemingha NSW 2340
School	Nurture One Tamworth Childrens Centre	8 Patrick St, Tamworth NSW 2340
School	Oxley High School	Piper St, North Tamworth NSW 2340
School	Oxley Vale Public School	Manilla Rd, Tamworth NSW 2340
School	Peel High School	88 Gunnedah Rd, Tamworth NSW 2340
School	Peter Pan Preschool	24-28 Larool St, South Tamworth NSW 2340
School	Poppins Playhouse	116-118 Kent St, South Tamworth NSW 2340
School	Rainbow Cottage Occasional Childcare	134 Marius St, Tamworth NSW 2340
School	Saint Nicholas Catholic Primary School	143 Carthage St, Tamworth NSW 2340
School	St Edwards Catholic Primary School (Infants Campus)	29 Robert St, South Tamworth NSW 2340

School	St Edwards Catholic Primary School (Primary Campus)	Hillvue Rd, South Tamworth NSW 2340
School	St Josephs Catholic Primary School	76 Denison St, West Tamworth NSW 2340
School	St Marks Preschool	15 Heugh St, South Tamworth NSW 2340
School	St Peters Preschool	34 Vera St, South Tamworth NSW 2340
School	Tamworth Family Daycare	81 Denison St, Tamworth NSW 2340
School	Tamworth High School	14 Robyn St, South Tamworth NSW 2340
School	Tamworth Primary School	Napier St, East Tamworth NSW 2340
School	Tamworth South Public School	Petra Ave, Tamworth NSW 2340
School	Tamworth TAFE	13 Janison St, Tamworth NSW 2340
School	Tamworth West Public School	65 Bridge St, West Tamworth NSW 2340
School	Westdale Primary	Gunnedah Rd, Westdale NSW 2340

Table 4-4: Sensitive Land Uses - Critical Community Facilities

Type	Name	Address
Cemetery	Tamworth Cemetery	Showground Rd, Taminda NSW 2340
Cemetery and Crematorium	Lincoln Grove Memorial Garden and Crematorium	Workshop La, Westdale NSW 2340
Correctional Facilities	Juvenile Justice Community Services	1 Darling St, Tamworth NSW 2340
Correctional Facilities	Tamworth Community Corrections Office	Level 2/155-157 Marius St, Tamworth NSW 2340
Correctional Facilities	Tamworth Correctional Centre	152-160 Johnston St, North Tamworth NSW 2340
Emergency Services	Fire and Rescue NSW South Tamworth Fire Station	16 The Ringers Rd, Hillvue NSW 2340
Law Enforcement	Tamworth Police Station	40-42 Fitzroy St, Tamworth NSW 2340
Medical	Acacia Sleep/National Clinical Services	149 Johnston St, North Tamworth NSW 2340
Medical	Calala Respiratory Clinic	6/10 Campbell Rd, Calala NSW 2340
Medical	Castlereagh Imaging	201-203 Peel St, Tamworth NSW 2340
Medical	Country Podiatry	252 Goonoo Goonoo Rd, South Tamworth NSW 2340
Medical	Dentist Smiles Tamworth	Dentist, Tamworth NSW 2340

Medical	Han Hua Chinese Medical Centre	267 Goonoo Goonoo Rd, South Tamworth NSW 2340
Medical	Hunter New England Local Health Network	Suite 9/468-472 Peel St, Tamworth NSW 2348
Medical	J L Ying Acupuncture Clinic	75 Robert St, South Tamworth NSW 2340
Medical	Laverty Pathology	Tamwell Medical Centre, 121 Johnston St, Tamworth NSW 2340
Medical	Laverty Pathology	Pathology Suite, 30, Marius St, Tamworth NSW 2340
Medical	Laverty Pathology	128 Marius St, Tamworth NSW 2340
Medical	Laverty Pathology	Tamworth General Practice, 516 Peel St, Tamworth NSW 2340
Medical	Laverty Pathology	Southgate, 4, 10 Kathleen St, Tamworth NSW 2340
Medical	Laverty Pathology	Oxley Health Care, 255 Goonoo Goonoo Rd, Tamworth NSW 2340
Medical	Laverty Pathology	437 Goonoo Goonoo Rd, Hillvue NSW 2340
Medical	Leibenson Specialists Clinic	25 Bligh St, North Tamworth NSW 2340
Medical	Marius Street Physiotherapy	125 Marius St, Tamworth NSW 2340
Medical	McKellar & Associates Psychological Services	139 Marius St, Tamworth NSW 2340
Medical	Tamworth Periodontics and Implants	103 Peel St, Tamworth NSW 2340
Medical	Mudgee Denture Clinic	145 Church St, North Tamworth NSW 2340
Medical	My GP Health	5/43 Gipps St, West Tamworth NSW 2340
Medical	My GP Tamworth	Shop 32-34/432-452 Peel St, Tamworth NSW 2340
Medical	North West Health	East Tamworth Medical Centre, 279B Marius St, Tamworth NSW 2340
Medical	North West Skin Cancer Medical Practice	114 Piper St, North Tamworth NSW 2340
Medical	North West Thermal Imaging	17 Ebsworth St, West Tamworth NSW 2340
Medical	Regional Specialists Tamworth	21-23 The Ringers Rd, Hillvue NSW 2340
Medical	Sensosaurus	7 Monteray St, North Tamworth NSW 2340
Medical	Tamara Private Hospital	2 Dean St, Tamworth NSW 2340

Medical	Tamworth Aboriginal Medical Service	1/180 Peel St, Tamworth NSW 2340
Medical	Tamworth Dental, Oral Surgery and Implants	Tamworth Shopping Village, 15/80 Robert St, Tamworth NSW 2340
Medical	Tamworth Eye Centre	136 Marius St, Tamworth NSW 2340
Medical	Tamworth GP and Skin Cancer Clinic	516 Peel St, Tamworth NSW 2340
Medical	Tamworth Respiratory Clinic	255a Goonoo Goonoo Rd, Tamworth NSW 2340
Medical	Tamworth Rural Hospital	Dean St, North Tamworth NSW 2340
Medical	Total Care Physiotherapy	33 Darling St, Tamworth NSW 2340
Medical	Urology New England	9 Dean St, Tamworth NSW 2340
Medical	Warden Chiropractic Centre	108A/108 Nundle Rd, Nemingha NSW 2340
Tourist Recreation Zones	Tamworth Racecourse	Britten Rd, Taminda NSW 2340
Tourist Recreation Zones	Tamworth Regional Sporting Complex	Hillvue NSW 2340
Tourist Recreation Zones	Tamworth Athletics Centre	537 Goonoo Goonoo Rd, Hillvue NSW 2340
Tourist Recreation Zones	Australian Equine and Livestock Events Centre (AELEC)	503 Goonoo Goonoo Rd, Tamworth NSW 2340
Transport Facility	Tamworth Regional Airport	Basil Brown Dr, Westdale NSW 2340

Table 4-5: Sensitive Land Uses - Critical Community Infrastructure

Type	Name	Address
Public Utility Undertaking		Johnston St, North Tamworth NSW 2340
Public Utility Undertaking	Westdale Wastewater Treatment Plant	300 Wallamore Rd, Westdale NSW 2340
Public Utility Undertaking	Tamworth Substation	Goonoo Goonoo Rd, Hillvue NSW 2340
Public Utility Undertaking	Calala Water Treatment Plant	Calala Ln, Calala NSW 2340

4.3 Cultural and Heritage Characteristics

The preservation of the cultural and heritage characteristics of an area needs to be considered when investigating modification measures. Therefore, the cultural and heritage characteristics

of the study area have been investigated and discussed below; with the location of these sites shown on Figure B 3.

4.3.1 Indigenous Australian Cultural Heritage

The Indigenous Australian cultural heritage sites were found through a search of the Aboriginal Heritage Information Management System (AHIMS) in January 2020. From this, 71 Aboriginal heritage sites were found in the study area. The heritage feature type of these sites included:

- 52 were the site of an artefact;
- 13 were the site of a modified (carved or scarred) tree;
- 3 were the site of a grinding groove;
- 2 were the site of a quarry; and
- 1 was the site of a water hole.

The organisations that had recorded the heritage sites (and that may be contacted for further information) were the Tamworth Local Aboriginal Land Council (LALC), Central West Archaeological and Heritage Services Pty Ltd, Archaeological Surveys and Salvage, Davies Heritage Consultants Pty Ltd, and Armidale National Parks and Wildlife Service (NPWS).

4.3.2 Non-Indigenous Australian Cultural Heritage

The non-Indigenous Australian cultural heritage sites were found through searches of:

- Local heritage items from the Tamworth Regional Council Local Environmental Plan (LEP) 2010
- State heritage items from the NSW State Heritage Inventory (which includes items listed on the State Heritage Register, items listed on State Agency Heritage Registers, and listed Interim Heritage Orders).
- National heritage items from the Australian Heritage Database (which includes the World Heritage List, the Commonwealth Heritage List, the National Heritage List, and the Register of the National Estate; however the latter register was closed in 2007 and is no longer a statutory list).

From this, the following non-Indigenous Australian cultural heritage sites within the study area were:

- ANZ Bank
- Anzac Park Gates, Gazebo and Street Lamps
- Baptist Church
- Brewery Building (former) - 130-138 Peel Street
- Carinya Garden
- Central Hotel
- Church - 150, 152-154 and 156 Marius Street
- Church of England School and School Masters Residence (former)
- Commercial Building - 226 Peel Street
- Commonwealth Bank Building
- Courthouse Hotel
- Dominican Roman Catholic Convent
- East Tamworth Station Pedestrian Bridge
- Entrance to Endeavor Drive of Brisbane Street - Street Lights
- Grandstand (at race track)
- Group of Shops - 164 Peel Street
- Group of Shops - 235 and 237 Peel Street
- Group of Shops - 239 Peel Street
- Hotel "Allambie"
- Hotel and Shops - 395-401 Peel Street
- Hotel Tattersalls

- Imperial Hotel
- King George V Memorial Avenue of Oaks
- Lands Office
- Main Northern Railway over the Peel River
- Main School Building "Calrossy"
- Masonic temple
- Mechanics Institute (former)
- Monument - cnr Piper and Peel Streets
- Monuments at the Tamworth Cemetery
- National Australia Bank Building
- Nemingha Anglican Church
- Nemingha Hall
- Nemingha School
- Northern Daily Leader
- Office Building - 12A Burke Street
- Old Courthouse Building
- Old Hotel Building - 143-145 Marius Street
- Original AA Building Site
- Peel River Rail Bridge
- Power House Motel and Monument
- Railway House
- Shop - 227 Peel Street
- Shop - 265-267 Peel Street
- Shopfront Glass - 78-80 Brisbane Street
- Square Man Hotel and Old Flour Mill (former)
- St John's Church
- Tamworth Gaol (former)
- Tamworth Hospital (main block only)
- Tamworth Hotel
- Tamworth Peel Barracks
- Tamworth Post Office
- Tamworth Primary School
- Tamworth Railway Station and Yard Group
- Tamworth Town Hall
- War Memorial - Gipps Street
- Wells and Pumping Station off Peel River
- Wesley Uniting Church
- West Tamworth Railway Station
- 3 Tobacco Kiln sites
- 16 Named Residences
- 6 Cottages
- 1 Dwelling
- 121 Houses

The vast majority of these sites were located within the suburbs of Tamworth, North Tamworth, East Tamworth, and West Tamworth.

4.4 Environmental Characteristics

The preservation of the environmental characteristics of an area needs to be considered when investigating modification measures. To identify the environmental characteristics of the study area the following searches have been undertaken.

4.4.1 Contaminated Land

The NSW Environmental Protection Agency's (EPA) list of notified contaminated land was consulted to determine whether any known contaminated sites existed within the Tamworth catchment. Three known sites were discovered in the catchment, including:

- A current amended Declaration of Significantly Contaminated Land at the Coles Express Tamworth (251 – 253 Goonoo Goonoo Road).
- A former revoked Section 35 EHC Act Order at the Gunnedah Road Site (49 Gunnedah Road).
- A former repealed Declaration of Significantly Contaminated Land at the Woolomin Gold Rush Store (65 Nundle Road).

4.4.2 Acid Sulfate Soils

Acid Sulfate Soils (ASS) are the result of soils containing iron sulfides being exposed to air and consequently oxidizing to sulfuric acid. In inland regions such as the Tamworth area, this occurs most commonly along water courses, as the result of excavation. As the presence of sulfuric acid can detrimentally affect the environment, it is important to be aware of the distribution of ASS throughout the catchment area.

The NSW Government has little data available regarding inland acid sulfate soil distribution.

4.4.3 Flora and Fauna

A search was conducted using the NSW Bionet Wildlife Atlas on the 28 January 2020 for sighted flora and fauna in a 66 km by 48 km area including the catchment. This search returned a total of 343 species of fauna , most of which were vulnerable, protected, or endangered, and 1,465 species of flora.

A search was conducted in the area utilizing the Environmental Protection and Biodiversity Act 1999 (EPBC Act) Protected Matters Search Tool. This search identified:

- 5 wetlands of international importance
  - Banrock Station Wetland Complex
  - Gwydir wetlands; Gingham and Lower Gwydir (big leather) Watercourses
  - Hunter Estuary Wetlands
  - Riverland
  - The Coorong, and Lakes Alexandrina and Albert Wetland
- 6 threatened ecological communities
  - Central Hunter Valley Eucalypt Forest and Woodland
  - Lowland Rainforest of Subtropical Australia
  - Natural Grasslands of the basalt and fine-textured alluvial plains of northern New South Wales and southern Queensland
  - New England Peppermint (Eucalyptus Nova-anglica) Grassy Woodlands
  - Weeping Myall Woodlands
  - White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grasslands
- 52 threatened species
- 15 migratory species

Table 4-6: Flora and Fauna

Name	Status
Birds	
Anthochaera Phrygia	Critically Endangered

Regent Honeyeater [82338]	
Botaurus Poiciloptilus Australasian Bittern [1001]	Endangered
Calidris Ferruginea Curlew Sandpiper [856]	Critically Endangered
Erythrotriorchis Radiatus Red Goshawk [942]	Vulnerable
Geophaps Scripta Scripta Squatter Pidgeon (Southern) [64440]	Vulnerable
Grantiella Picta Painted Honeyeater [470]	Vulnerable
Hirundapus Caudacutus White-throated Needletail [682]	Vulnerable
Lathamus Discolor Swift Parrot [744]	Critically Endangered
Numenius Madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered
Rostratula Australis Australian Painted Snipe [77037]	Endangered
Fish	
Bidyanus Bidyanus Silver Perch, Bidyan [76155]	Critically Endangered
Maccullochella Peelii Murray Cod [66633]	Vulnerable
Frogs	
Litoria Booroolongensis Booroolong Frog [1844]	Endangered
Mammals	
Chalinolobus Dwyeri Large-eared Pied Bat, Large Pied Bat [183]	Vulnerable
Dasyurus Maculatus Maculatus (SE mainland population) Spot-tailed Quoll, Spotted-tail Quoll, Tiger Quoll (southeastern mainland population) [75184]	Endangered
Nyctophilus Corbeni Corben's Long-eared Bat, South-eastern Long-eared Bat [83395]	Vulnerable

Petauroides Volans Greater Glider [254]	Vulnerable
Petrogale Penicillata Brush-tailed Rock-wallaby [225]	Vulnerable
Phascolarctos Cinereus Koala [85104]	Vulnerable
Potorous Tridactylus Tridactylus Long-nosed Potoroo (SE Mainland) [66645]	Vulnerable
Pseudonyms Novaehollandiae New Holland Mouse, Pookila [96]	Vulnerable
Pseudomys Oralis Hastings River Mouse, Koontoo [98]	Endangered
Pteropus Poliocephalus Grey-headed Flying-fox [186]	Vulnerable
Plants	
Acacia Pubifolia Velvet Wattle [19799]	Vulnerable
Androcalva Procumbens [87153]	Vulnerable
Cadellia Pentastylis Ooline [9828]	Vulnerable
Callistemon Pungens [55581]	Vulnerable
Cryptostylis Hunteriana Leafless Tongue-orchid [19533]	Vulnerable
Cynanchum Elegans White-flowers Wax Plant [12533]	Endangered
Dichanthium Setosum Bluegrass [14159]	Vulnerable
Diuris Pedunculata Small Snake Orchid, Two-leaved Golden Moths, Golden Moths, Cowslip Orchid, Snake Orchid [18325]	Endangered
Eucalyptus Caleyi subsp. Ovendenii Ovenden's Ironbark [56193]	Vulnerable
Eucalyptus Mckieana McKie's Stringybark [20199]	Vulnerable

Eucalyptus Nicholii Narrow-leaved Peppermint, Narrow-leaved Black Peppermint [20992]	Vulnerable
Eucalyptus Rubida subsp. Barbigerorum Blackbutt Candlebark [64618]	Vulnerable
Euphrasia Arguta [4325]	Critically Endangered
Hakea Pulvinifera Lake Keepit Hakea [14228]	Endangered
Haloragis Exalata subsp. Velutina Tall Velvet Sea-berry [16839]	Vulnerable
Homopholis Belsonii Belson's Panic [2406]	Vulnerable
Homoranthus Prolixus [55198]	Vulnerable
Marsdenia Longiloba Clear Milkvine [2794]	Vulnerable
Picris Evae Hawkweed [10839]	Vulnerable
Pomaderris Brunnea Rufous Pomaderris [16845]	Vulnerable
Prasophyllum sp. Wybong (C.Phelps ORG 5269) A leek-orchid [81964]	Critically Endangered
Swainsona Murrayana Slender Darling-pea, Slender Swainson, Murray Swainson-pea [6765]	Vulnerable
Tasmannia Glaucifolia Fragrant Pepperbush [21975]	Vulnerable
Thesium Australa Austral Toadflax, Toadflax [15202]	Vulnerable
Tylophora Linearis [55231]	Endangered
Reptiles	
Anomalopus Mackayi Five-clawed Worm-skink, Long-legged Worm-skink [25934]	Vulnerable
Aprasia Parapulchella	Vulnerable

Pink-tailed Worm-lizard, Pink-tailed Legless Lizard [1665]	
Uvidicolus Sphyrurus Border Thick-tailed Gecko, Granite Belt Thick-tailed Gecko [84578]	Vulnerable
Wollumbinia Belli Bell's Turtle, Western Sawshelled Turtle, Namoi River Turtle, Bell's Saw-shelled Turtle [86071]	Vulnerable

5 Computational Modelling

More details on the review and update of the hydrologic and hydraulic models are provided in the Tamworth City Wide Floodplain Risk Management Study and Plan: Addendum 1.

6 Assessment of Existing Flood Behaviour

6.1 Assessment of Time to Peak

The time between the rainfall commencing and the flood level reaching its peak is shown on Figure B 5. It should be noted that this time to peak was dependent upon the storm duration and that the critical storm duration was the one that produced the highest average flood flow. Therefore, there could be storm events that have a shorter time to peak but a lower flood level/flow than the critical storm.

For the Peel River model, the time to peak during the 1% AEP storm (with a 720 minute storm duration) ranged from 7 to 17 hours. The time to peak generally increased linearly along the Peel River and Goonoo Goonoo Creek as flood flow moved further downstream.

For the Goonoo Goonoo Creek model, the time to peak during the 1% AEP storm (with a 45 minute duration) largely ranged from 9 to 12 hours, with small sections of urban area reaching peak flood levels in under an hour. Generally, urban areas of the model experienced the shortest time to peak.

For the Timbumburi Creek model, the time to peak for the 1% AEP storm (with a 120 minute storm duration) largely ranged from less than 1 hour to 7 hours. Generally, urban areas of the model experienced the shortest time to peak.

For the Murroon Creek model, the time to peak during the 1% AEP storm (with a 90 minute storm duration) ranged from less than 1 hour to 4 hours.

For the Boltons Creek model, the time to peak for the 1% AEP storm (with a 120 minute duration) largely ranged from 1 to 4 hours, with small sections of commercial area reaching peak flood levels in under an hour.

For the Tangaratta Creek model, the time to peak for the 1% AEP storm (with a 270 minute duration) ranged from less than 1 hour to 7 hours. Generally, the time to peak was shortest in areas furthest from Tangaratta Creek.

For the Nemingha model, the time to peak for the 1% AEP storm (with a 120 minute duration) ranged from 1 to 8 hours. The time to peak generally increased linearly along the Cockburn River as flood flow moved further downstream.

For the Calala Creek model, the time to peak for the 1% AEP storm (with a 30 minute storm duration) ranged from less than 1 hour to 4 hours.

For the Oxley Vale model, the time to peak for the 1% AEP storm (with a 45 minute duration) ranged from less than 1 hour to 3 hours. Generally, urban areas of the model experienced the shortest time to peak.

For the East and North Tamworth model, the time to peak for the 1% AEP storm (with an envelope of critical durations) generally ranged from less than 1 hour to 4 hours outside of the Peel River, with the river reaching peak flood levels in 10 to 11 hours.

6.2 Assessment of Duration of Inundation

The duration of time between the beginning and end of inundation with flood depths greater than 0.3 m is shown in Figure B 6. It should be noted that this duration of inundation was dependent upon the storm duration and that the critical storm duration was the one that produced the highest average flood level (for the overland, urban area of the catchment). Therefore, there could be storm events that have a longer duration of inundation but a lower flood level than the critical storm.

For the Peel River model, the duration of inundation during the 1% AEP storm (with a 720 minute storm duration) ranged from less than 1 to greater than 10 hours, with areas directly adjacent to the Peel River and Goonoo Goonoo Creek generally experiencing the largest durations of inundation.

For the Goonoo Goonoo Creek model, the duration of inundation during the 1% AEP storm (with a 720 minute storm duration) largely ranged from less than 1 hour to greater than 10 hours, with urban areas generally experiencing the shortest durations of inundation.

For the Timbumburi Creek model, the duration of inundation for the 1% AEP storm (with a 270 minute storm duration) largely ranged from less than 1 hour to greater than 10 hours, with urban areas generally experiencing the shortest durations of inundation.

For the Murroon Creek model, the duration of inundation during the 1% AEP storm (with a 90 minute storm duration) ranged from less than 1 hour to 4 hours, with durations of greater than 1 hour largely occurring within flood storages and floodways.

For the Boltons Creek model, the duration of inundation for the 1% AEP storm (with a 120 minute duration) ranged from less than 1 hour to 4 hours, with durations of greater than 1 hour largely occurring within flood storages and floodways.

For the Tangaratta Creek model, the duration of inundation for the 1% AEP storm (with a 270 minute duration) ranged from less than 1 hour to greater than 10 hours, with durations of greater than 1 hour largely occurring within flood storages and floodways.

For the Nemingha model, the duration of inundation for the 1% AEP storm (with a 720 minute duration) ranged from less than 1 hour to greater than 10 hours, with urban areas generally experiencing the shortest durations of inundation.

For the Calala Creek model, the duration of inundation for the 1% AEP storm (with a 120 minute duration) ranged from less than 1 hour to 5 hours, with durations of greater than 1 hour largely occurring within flood storages and floodways.

For the Oxley Vale model, the duration of inundation for the 1% AEP storm (with a 45 minute duration) ranged from less than 1 hour to 3 hours, with durations of greater than 1 hour largely occurring within flood storages and floodways.

For the East and North Tamworth model, the duration of inundation for the 1% AEP storm (with a 120 minute duration) generally ranged from less than 1 hour to greater than 10 hours, with urban areas away from the levee generally experiencing the shortest durations of inundation.

7 Assessment of Existing Flood Response Arrangements

7.1 Flood Emergency Response Documents

7.1.1 Local Emergency Management Plans

The Local Emergency Management Plan (EMPLAN) (Tamworth Regional Council, 2016) governs a range of potential hazards across the council area; including flood hazards, fire hazards, and earthquake hazards, etc. The EMPLAN was prepared in accordance with the State Emergency & Rescue Management Act 1989 by the Tamworth Regional Council Local Emergency Management Committee (LEMC). The purpose of the EMPLAN is to detail the roles and responsibilities of various agencies in an emergency (including preparing for, responding to and recovering from emergencies). The EMPLAN is supported by a collection of hazard/emergency specific sub plans, such as the Tamworth Regional Flood Emergency Sub Plan (discussed in Section 7.1.2).

From the EMPLAN, the NSW SES are tasked with the role of combat/responsible agency for both riverine flood emergencies and flash (or overland) flood emergencies in the Tamworth Regional Council area. Across the council area, the NSW SES units available are the NSW SES Barraba Unit, the NSW SES Manilla Unit, the NSW SES Nundle Unit, and the NSW SES Tamworth Unit.

According to the EMPLAN, the LEMC are expected to review the EMPLAN every three years, which is scheduled for May 2019 based upon the date the current EMPLAN was approved.

7.1.2 Flood Emergency Sub-Plan

The Tamworth Regional Flood Emergency Sub Plan was prepared in accordance with the *State Emergency Service Act 1989 (NSW)* by the NSW SES and the Tamworth Regional LEMC. It is the flood specific sub plan that support the Tamworth Regional EMPLAN (discussed in Section 7.1.1).

The Flood Emergency Sub Plan outline the preparation, response, and recovery steps for flood emergencies in the Tamworth Regional Council area. It solely focuses on flooding emergencies and details the roles and responsibilities of all parties involved in the event of a flood. They also note key roads that may become flood affected, and lists Council as being responsible for road closures and reopening.

7.2 Evacuation Centres

The Tamworth Regional Flood Emergency Sub Plan provides details for seven evacuation centres across the council area. Of the seven evacuation centres listed in the Flood Emergency Sub Plan, the two located within the study area were the Tamworth Community Centre (Darling Street, Tamworth) and the Seven Day Adventist Church and Scout Hall (Kent Street, West Tamworth).

8 Assessment of Existing Flood Planning Policies

8.1 State Government Planning Policies

The role of state government legislation is to provide a robust framework for all local legislation and planning policies to be based upon. Local floodplain management policies must be developed in accordance with relevant state legislation. This section discusses relevant state government legislation regarding flood planning.

8.1.1 NSW Environment Planning and Assessment Act 1979

The NSW Environmental Planning and Assessment Act 1979 governs the use, development and protection of land in NSW, and is the framework upon which various relevant local government and the NSW SES plans are based. The objects of this Act are:

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.

8.1.2 Ministerial Direction 4.1 (issued 20 February 2023)

As per Section 9.1 of the Environmental Planning and Assessment Act, the Minister for Planning issued direction 4.1 in February of 2023 to local governments requiring they implement the NSW Flood Prone Land Policy into their Local Environmental Plans.

The objectives of the direction and obligations of relevant planning authorities in relation to the direction are:

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

Where this direction applies

2) This direction applies to all relevant planning authorities that are responsible for flood prone land within their LGA.

When this direction applies

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

What a relevant planning authority must do if this direction applies

4) *A planning proposal must include provisions that give effect to and are consistent with*
    a) *the NSW Flood Prone Land Policy,*
    b) *the principles of the Floodplain Development Manual 2005,*
    c) *the Considering the flooding in land use planning guideline 2021, and*
    d) *any adopted flood study and/or floodplain risk management plan prepared in accordance with the principles of the Floodplain Development Manal 2005 and adopted by the relevant council.*
5) *A planning proposal must not rezone land within the flood planning area from Recreation, Rural, Special Purpose or Environmental Protection Zones to a Residential, Business, Industrial or Special Purpose Zones.*
6) *A planning proposal must not contain provisions that apply to the flood planning area which:*
    a) *permit development in floodway areas,*
    b) *permit development that will result in significant flood impacts to other properties,*
    c) *permit development for the purpose of residential accommodation in high hazard areas,*
    d) *permit a significant increase in the development and/or dwelling density of that land,*
    e) *permit development for the purpose of centre-based childcare facilities, hostels, boarding houses, group homes, hospitals, residential care facilities, respite day care centres and seniors housing in areas where the occupants of the development cannot effectively evacuate,*
    f) *permit development to be carried out without development consent except for the purposes of exempt development or agriculture. Dams, drainage canals, levees, still require development consent,*
    g) *are likely to result in a significantly increased requirement for government spending on emergency management services, flood mitigation and emergency response measures, which can include but are not limited to the provision of road infrastructure, flood mitigation infrastructure and utilities, or*
    h) *permit hazardous industries or hazardous storage establishments where hazardous materials cannot be effectively contained during the occurrence of a flood event.*
7) *A planning proposal must not contain provisions that apply to areas between the flood planning area and probable maximum flood to which Special Flood Considerations apply 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 dwelling density of that land,*
    d) *Permit the development of centre-based childcare facilities, hostels, boarding houses, group homes, hospitals, residential care facilities, respite day care centres and seniors housing in areas where the occupants of the development cannot effectively evacuate,*
    e) *Are likely to affect the safe occupation of and efficient evacuation of the lot, or*
    f) *Are likely to result in the significantly increased requirement for government spending on emergency management services, and flood mitigation and emergency response measures, which can include but not limited to road infrastructure, flood mitigation infrastructure and utilities.*
8) *For the purposes of preparing a planning proposal, the flood planning area must be consistent with the principles of the Floodplain Development Manual 2005 or as*

otherwise determined by a Floodplain Risk Management Study or Plan adopted by the relevant council.

Consistency

9) *A planning proposal may be inconsistent with this direction only if the planning proposal authority can satisfy the Secretary of the Department of Planning, Industry and Environment (or their nominee) that:*
   a) *the planning proposal is in accordance with a floodplain risk management study or plan adopted by the relevant Council in accordance with the principles and guidelines of the Floodplain Development Manual 2005, or*
   b) *where there is no council adopted floodplain risk management study or plan, the planning proposal is consistent with the flood study adopted by the council prepared in accordance with the principles of the Floodplain Development Manual 2005 or*
   c) *the planning proposal is supported by a flood and risk impact assessment accepted by the relevant planning authority and is prepared in accordance with the principles of the Floodplain Development Manual 2005 and consistent with the relevant planning authorities' requirements, or*
   d) *the provisions of the planning proposal that are inconsistent are of minor significance as determined by the relevant planning authority.*

Note: In this direction:

   a) *"flood prone land" "flood storage" "floodway" and "high hazard" have the same meaning as in the Floodplain Development Manual 2005.*
   b) *"flood planning level" "flood behaviour" and "flood planning area" has the same meaning as in the Considering flooding in land use planning guideline 2021.*
   c) *Special flood considerations are outlined in the Considering flooding in land use planning guideline 2021 and an optional clause in the Standard Instrument (Local Environmental Plans) Order 2006.*
   d) *Under the floodplain risk management process outlined in the NSW Government's Floodplain Development Manual 2005, councils may produce a flood study followed by a floodplain risk management study and floodplain risk management plan.*

8.1.3 NSW Flood Prone Land Policy (2005)

The *Floodplain Development Manual* (2005) supports the NSW the NSW Government's *Flood Prone Land Policy* in its goal of developing sustainable strategies for human occupation and use of floodplains. The manual was primarily written for the use of local governments, providing guidance for the undertaking of flood studies and floodplain risk management plans.

The *Floodplain Development Manual* details the roles and responsibilities of various NSW agencies and includes information on:

- *the preparation of flood studies, floodplain risk management studies and plans;*
- *floodplain risk management options;*
- *flood planning levels and areas;*
- *hydraulic and hazard categorisation; and*
- *emergency response planning.*

8.1.4 Planning Circular PS 21-006

Planning Circular PS 21-006 (14 July 2021) replaces Planning Circular PS 07-003, and acts as an overview of various changes made regarding flood related land use planning and constraints. These changes include:

- An amendment to clause 7A of Schedule 4 to the *Environmental Planning and Assessment Regulation 2000* that requires councils include a notation on section10.7

planning certificates if the land or part of the land is within the flood planning area or between the FPA and the PMF.

- A revised local planning direction regarding flooding issued under section 9.1 of the *Environmental Planning and Assessment Act 1979* which removes the need for exceptional circumstances when applying flood-related residential development controls above the 1% AEP flood level. It also ensures planning proposals consider flood risks and do not permit residential accommodation in high hazard areas and other land uses on flood prone land where the development cannot effectively evacuate, as well as making provision for special flood considerations where councils have chosen to adopt the optional Special flood considerations clause in an LEP.
- Two local environmental plan (LEP) clauses which introduce flood related development controls, namely the Flood Planning and Special Flood Considerations clauses.
- The implementation of a new guideline *Considering Flooding in Land Use Planning (2021)*
- Revoking the *Guideline on Development Controls on Low Flood Risk Areas (2007)*.

8.1.5 Considering Flooding in Land Use Planning (2021)

The NSW Department of Planning, Industry and Environment published the Considering Flood in Land Use Planning guideline in July of 2021 in order to provide advice to councils on flood-related land use planning and outline the two newly introduced Flood Planning and Special Flood Considerations LEP clauses.

The Flood Planning clause is a mandatory provision for local environmental plans, and introduces the Flood Planning Areas (FPAs) category for flood-related development controls, the clause defines:

- Flood Planning Area as *the area of land at or below the flood planning level (FPL)*,
- Flood Planning Level as *a combination of the flood level from the defined flood event (DFE) and freeboard selected for flood risk management purposes*, and
- Defined Flood Event as *the flood event selected as a general standard for the management of flooding to development* (with the manual identifying the 1% AEP flood event, or an equivalent historic flood, as an appropriate starting point for determining the DFE).

This clause allows councils to define multiple FPAs/FPLs when applicable based on factors such as differing flood risks in different catchments as identified through the FRM process, or differing land use types (for example, residential, industrial, commercial developments).

The Special Flood Considerations clause is an optional provision for local environmental plans. It allows for the addition of particular flood risk considerations that must be satisfied to obtain consent for certain types of development that have been identified by councils and the state government as having a higher risk to life and warranting the consideration of the impacts of rarer flood events on land located outside the FPA. The special flood considerations include that the development:

1) *will not affect the safe occupation of and efficient evacuation of people in the event of a flood, and*
2) *incorporates appropriate measures to manage risk to life from flood, and*
3) *will not adversely affect the environment in the event of a flood.*

8.1.6 State Environmental Planning Policy 2008 – Exempt and Complying Development Codes

The State Environmental Planning Policy (SEPP) aims to provide streamlined assessment processes for development that complies with specified development standards by providing exempt and complying development codes that have State-wide application. Developments that pose minimal environmental impact do not require development consent.

Part 3A Division 3 Subdivision 9 Section 3A.38 of the SEPP relates to Complying Development on "flood control lots", which must satisfy the following criteria:

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 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) *Development that is carried out under this code on any part of a flood control lot must meet the following requirements—*
    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 ancillary development that is erected at or below the flood planning level is constructed of flood compatible material,*
    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),*
    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.*

8.2 Local Government Planning Policies

It is important for local Councils to ensure land use and development is compatible with flood risk and does not increase the impact of flooding or the damage to public or private assets associated with flooding.

Environmental planning tools, such as Local Environmental Plans (LEPs) guide planning decisions for local government areas. This is done through zoning and development controls that provide a framework for the way land can be used and developed. Development Control Plans (DCPs) are a planning tool that provides detailed planning and design guidelines to support the planning controls detailed in the LEPs.

LEPs are made under the *Environmental Planning and Assessment Act 1979*. All LEPs should conform to a standard format. This standardisation was initiated by the NSW state government in 2006, through the Standard Instrument LEP program.

8.2.1 Tamworth Regional Local Environmental Plan 2010

The Tamworth Regional Local Environmental Plan was adopted in January of 2011. In this, the flood controls are stated in Clause 5.21 as follows:

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 flood function and behaviour on the land, taking into account projected changes as a result of climate change,*
c) *to avoid adverse or cumulative impacts on flood behaviour and the environment,*
d) *to enable the safe occupation and efficient evacuation of people in the event of a flood.*

2) *Development consent must not be granted to development on land the consent authority considers to be within the flood planning area unless the consent authority is satisfied the development—*
   a) *is compatible with the flood function and behaviour on the land, and*
   b) *will not adversely affect flood behaviour in a way that results in detrimental increases in the potential flood affectation of other development or properties, and*
   c) *will not adversely affect the safe occupation and efficient evacuation of people or exceed the capacity of existing evacuation routes for the surrounding area in the event of a flood, and*
   d) *incorporates appropriate measures to manage risk to life in the event of a flood, and*
   e) *will not adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses.*
3) *In deciding whether to grant development consent on land to which this clause applies, the consent authority must consider the following matters—*
   a) *the impact of the development on projected changes to flood behaviour as a result of climate change,*
   b) *the intended design and scale of buildings resulting from the development,*
   c) *whether the development incorporates measures to minimise the risk to life and ensure the safe evacuation of people in the event of a flood,*
   d) *the potential to modify, relocate or remove buildings resulting from development if the surrounding area is impacted by flooding or coastal erosion.*
4) *A word or expression used in this clause has the same meaning as it has in the Considering Flooding in Land Use Planning Guideline unless it is otherwise defined in this clause.*
5) *In this clause—*
   a) **Considering Flooding in Land Use Planning Guideline** *means the Considering Flooding in Land Use Planning Guideline published on the Department's website on 14 July 2021.*
   b) **flood planning area** *has the same meaning as it has in the Floodplain Development Manual.*
   c) **Floodplain Development Manual** *means the Floodplain Development Manual (ISBN 0 7347 5476 0) published by the NSW Government in April 2005.*

8.2.2 Tamworth Regional Development Control Plan 2010

The Tamworth Regional Development Control Plan was adopted in October 2010. The purpose of this DCP is to provide planning and design guidelines to support the planning controls detailed in the Tamworth Regional LEP 2010.

Step 4 of the DCP includes a section relating to Development on Flood Affected Land and includes guidance for residential and non-residential land use types, as well as for land behind levees, access requirements, on-site sewer management, subdivision and landfilling. The general development requirements for flood control lots listed in this section of the DCP are as follows:

1) *No building or work (including land filling, fencing, excavation) shall be permitted on flood affected land where in the opinion of Council, such building or work will obstruct the movement of floodwater or cause concentration or diversion of floodwaters.*
2) *DA must demonstrate the building or structure can withstand the force of flowing floodwaters, including debris and buoyancy forces as appropriate.*
3) *A survey plan prepared by a registered surveyor showing existing ground levels, finished ground levels, finished floor levels, flood levels and location of existing/proposed buildings and safe evacuation path on the site relative to AHD.*
4) *All materials used in construction shall be flood compatible.*
5) *Development must be designed in accordance with the Flood Proofing Guidelines (refer Discretionary Development Standards).*
6) *This information must be supplied for development within the 1% ARI flood level and the Sunny Day Failure of Dungowan Dam for properties between the Ogunbil Bridge and Dungowan Dam.*

Additionally, residential developments on flood control lots are subject to the following requirements:

1) *Floor levels of all habitable rooms, or rooms with connection to sewer infrastructure shall not be less than 500mm (freeboard) above the 1% ARI flood level, except for those properties between the Ogunbil Bridge and Dungowan Dam where the applicable flood height is 500mm above the Sunny Day Failure of Dungowan Dam.*
2) *Upon completion and prior to the occupation (where relevant), a certificate by a registered surveyor showing the finished ground and floor levels conform to approved design levels shall be submitted to Council.*
3) *Additions to existing buildings will only be permitted, with limitations, as follows:*
    a) *where the floor level of the proposed addition is located below the standard 1% ARI or the Sunny Day Failure of Dungowan Dam for properties between the Ogunbil Bridge and Dungowan Dam, the maximum increase in floor area is not to exceed 10% of the floor area of the existing dwelling; or*
    b) *where the floor level of the proposed addition is located above the standard 1% ARI or the Sunny Day Failure of Dungowan Dam for properties between the Ogunbil Bridge and Dungowan Dam, the maximum increase in habitable floor space shall not exceed 100m2 .*
4) *Where additions are below the 500mm "freeboard" or the Sunny Day Failure of Dungowan Dam for properties between the Ogunbil Bridge and Dungowan Dam, Council must be satisfied that the addition will not increase risk to inhabitant in the event of a flood.*
5) *Rebuilding part of a dwelling may be permitted provided the building maintains the same dimensions which result in the same impact on flood behaviour.*

9 Consequences of Flooding

9.1 Overview

Flood damages (or the consequences of flooding) are typically broken down into four categories; tangible direct, tangible indirect, intangible direct and intangible indirect. Tangible damages are those that can be quantified in a monetary sense, such as the cost of rebuilding a house. Whereas intangible damages are generally difficult to quantify in terms of dollar value, such as the stress placed on families and business owners as a result of flooding. In-direct damages are those damages that occur but are not a direct result of flood waters, for example the loss of business after a flood occurs. This is shown graphically in Chart 9-1.

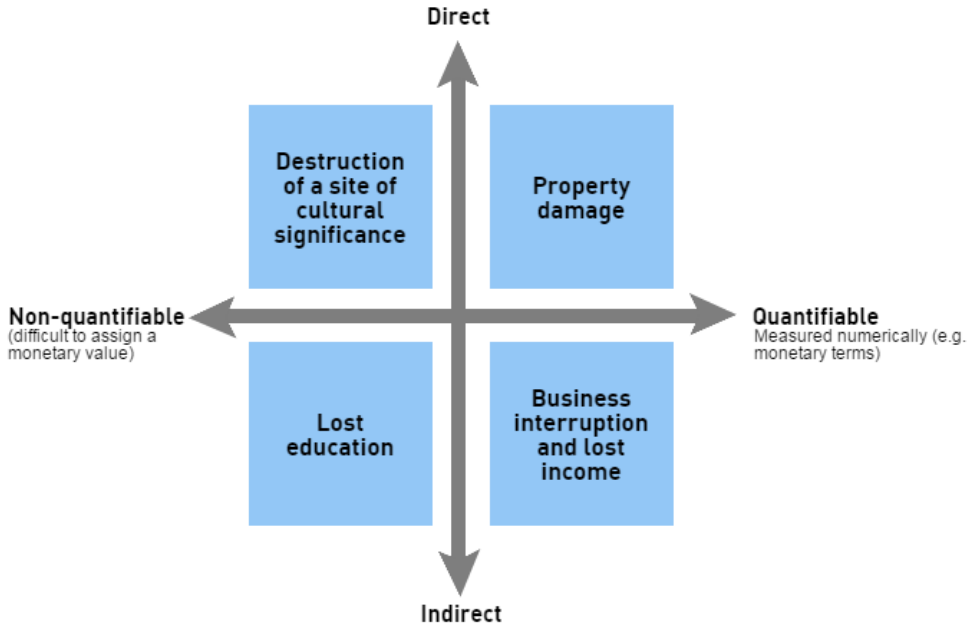


Chart 9-1: Flood Damage Representation (Source - UNISDR: Prevention Web, Direct and Indirect Losses, 2014)

The economic impacts, social impacts, heritage impacts and environmental impacts as a result of flooding are discussed in the following.

9.2 Property Impacts

9.2.1 Methodology

There are a number of methods available for calculating tangible, direct flood damages, including; the Rapid Appraisal Method (RAM), ANUFLOOD Method and the depth-damage curves developed by the NSW Government (2007).

The tangible, direct flood damages to residential property were calculated using the depth-damage curves developed by the NSW Government (2007). This method requires a number of parameters to be specified for the catchment, which is discussed in Section 9.2.1.1.

The tangible, direct flood damages to commercial property were calculated using the depth-damage curves from the ANUFLOOD method. This method requires a number of parameters to be specified for the properties, which is discussed in Section 9.2.1.2.

These depth-damage relationships were then intersected with the number of properties affected by above floor flooding (with the floor level estimation discussed in Section 9.2.1.3)

and above ground flooding (with the flood level estimation to be the maximum flood level from within a 3m radius of the building for each flood event was then assigned to each building) to estimate the total tangible, direct flood damages within the study area.

The tangible, indirect flood damages to both residential and commercial properties were calculated as 15% of the tangible, direct flood damages.

9.2.1.1 Residential Depth-Damage Relationship

The NSW Government (2007) method calculates the depth-damage relationship based upon a number of parameters, the values and description of which is shown in Table 9-1.

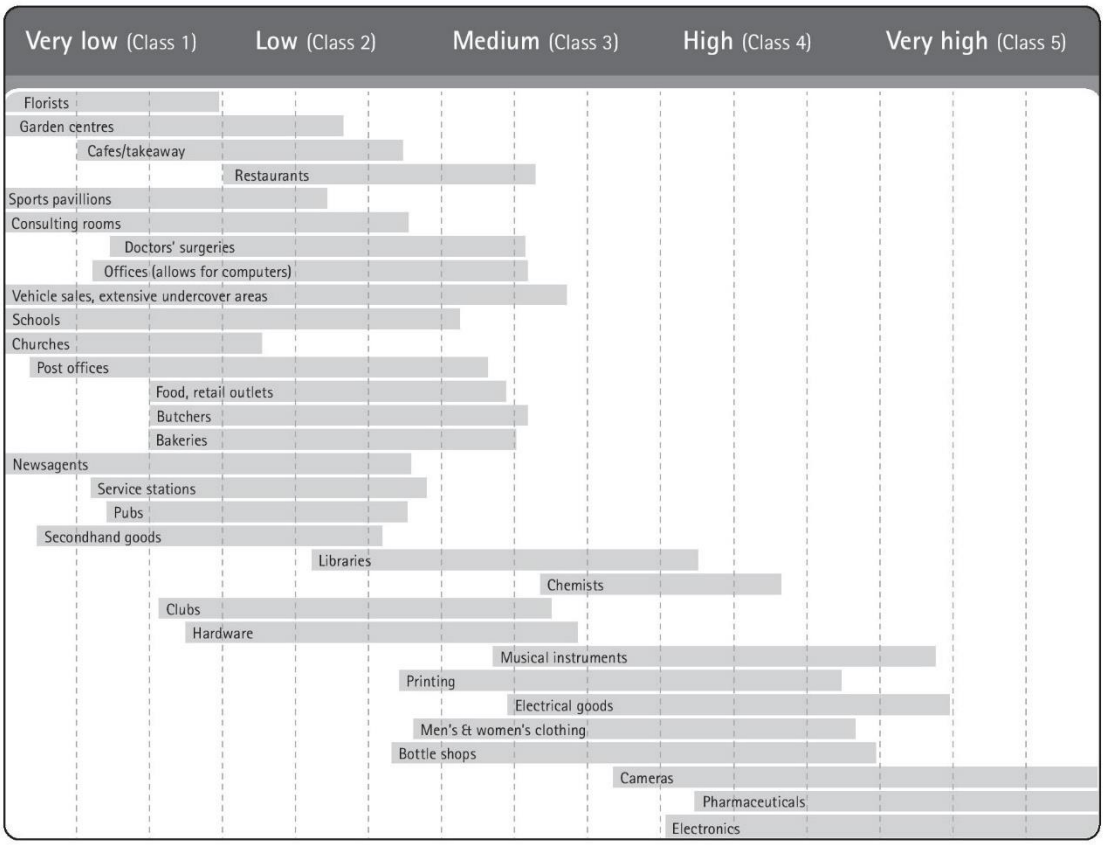
Table 9-1: Residential damage parameters

Input Parameter	Value Adopted	Explanation
Regional Cost Variation Factor	1.05	Costs adjusted based on Rawlinsons (2021) for Tamworth.
Post 2001 Adjustment Factor	2.04	Costs adjusted to account for changes to average weekly earnings since the estimates were calculated in 2001, based on the Australian Bureau of Statistics data from November 2022.
Post Flood Inflation Factor	1.2	Ranges from 1.0 to 1.5 (NSW Government, 2007), based on the recommended factor for medium scale impacts on a regional city.
Typical House Size	205 m^2	Based upon the digital schematisation of buildings in the study area from the aerial photography.
Typical Duration of Immersion	6 hours	
Building Damage Repair Limitation Factor	0.9	Based on a moderate duration flood event.
Average Contents Value	$51,250	Based upon the typical house size in the study area.
Contents Damage Repair Limitation Factor	0.8	Based on a moderate duration flood event.
Typical Table/Bench Height	0.9 m	0.9 m is the default.
Level of Flood Awareness	Low	'Low' is the default.
Effective Warning Time	3 hours	Given the moderate duration and rate at which road access is cut during the storm events that cause flooding in the study area,

		an effective warning time of 3 hours was deemed appropriate.

9.2.1.2 Non-Residential Depth-Damage Relationship

The ANUFLOOD method calculates the depth-damage relationship based upon the size of the commercial property and the commercial usage of the property. The commercial property sizes are classified as either small commercial (less than 186 m2), medium commercial (between 186 m2 to 650 m2), or large commercial (greater than 650 m2). The commercial usage is classified as either Class 1 (very low), Class 2 (low), Class 3 (medium), Class 4 (High), or Class 5 (very high); as shown in Chart 9-2.



Reproduced from Centre for Resource and Environmental Studies (Australian National University) 1992, ANUFLOOD: A Field Guide, *prepared by D.I. Smith and M.A. Greenaway, Canberra.*

Chart 9-2: Commercial damage categories based on the commercial usage of the property

Within the Tamworth study area, it was found that the majority of the commercial properties were within the Class 2 category.

9.2.1.3 Floor Level Estimation

Floor levels were estimated using Google Street View and the LiDAR data. Google Street View images were interrogated for each house within the study area to estimate the height above ground level of the lowest habitable floor based upon the entryway door. The estimated floor height above ground level was then intersected with the LiDAR surveyed ground level to

produce an estimated floor level. However, buildings identified as sheds were excluded from the assessment.

9.2.2 Residential and Non-Residential Damage Results

The direct damages as a result of flooding have been calculated for each individual flood event. The Average Annual Damages (AAD) and Net Present Value (NPV) of these direct flood damages have also been calculated. AAD is a measure of the average damage due to flooding experienced by an area over a large period of time. This is to account for the different amount of damage caused by different events of varying magnitude (i.e. large, less frequent floods generally cause more damage than small, more frequent floods). The AAD per annum in present terms is then adopted for each year of the NPV of damages estimation (assuming a 50 year economic life).

Table 9-2 details the direct flood damages due to flooding within the Peel River model area. From this, the AAD was $1,112,606 and the NPV was $16,467,400.

Table 9-2: Direct flood damages - Peel River Model

Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
0.2% AEP					
Residential	129	51	$8,586,372	$1,287,956	$9,874,328
Commercial	182	65	$2,714,573	$407,186	$3,121,759
Sub-Total	311	116	$11,300,945	$1,695,142	$12,996,087
1% AEP					
Residential	81	27	$5,004,704	$750,706	$5,755,410
Commercial	82	33	$1,774,022	$266,103	$2,040,126
Sub-Total	163	60	$6,778,727	$1,016,809	$7,795,536
5% AEP					
Residential	52	14	$2,872,751	$430,913	$3,303,663
Commercial	54	23	$1,191,446	$178,717	$1,370,163
Sub-Total	106	37	$4,064,197	$609,630	$4,673,826
20% AEP					
Residential	24	1	$1,009,683	$151,452	$1,161,135
Commercial	35	14	$531,992	$79,799	$611,791
Sub-Total	59	15	$1,541,675	$231,251	$1,772,927

Table 9-3 details the direct flood damages due to flooding within the Goonoo Goonoo Creek model area. From this, the AAD was $10,225,646 and the NPV was $151,347,198.

Table 9-3: Direct flood damages - Goonoo Goonoo Creek Model

Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
0.2% AEP					
Residential	2174	26	$92,163,560	$13,824,534	$105,988,094
Commercial	28	28	$1,012,077	$151,812	$1,163,888
Sub-Total	2202	54	$93,175,637	$13,976,346	$107,151,982
1% AEP					
Residential	1473	12	$61,777,888	$9,266,683	$71,044,571
Commercial	16	16	$582,180	$87,327	$669,507
Sub-Total	1489	28	$62,360,067	$9,354,010	$71,714,078
5% AEP					
Residential	772	2	$31,957,243	$4,793,586	$36,750,829
Commercial	7	7	$269,632	$40,445	$310,077
Sub-Total	779	9	$32,226,875	$4,834,031	$37,060,907
20% AEP					
Residential	600	0	$24,587,462	$3,688,119	$28,275,581
Commercial	5	5	$184,258	$27,639	$211,897
Sub-Total	605	5	$24,771,720	$3,715,758	$28,487,478

Table 9-4 details the direct flood damages due to flooding within the Timbumburi Creek model area. From this, the AAD was $8,085,287 and the NPV was $119,668,277.

Table 9-4: Direct flood damages - Timbumburi Creek Model

Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
0.2% AEP					
Residential	1596	6	$67,653,078	$10,147,962	$77,801,039
Commercial	103	1	$4,405	$661	$5,066
Sub-Total	1699	7	$67,657,483	$10,148,622	$77,806,105
1% AEP					
Residential	1250	2	$52,568,394	$7,885,259	$60,453,653
Commercial	58	0	$-	$-	$-
Sub-Total	1308	2	$52,568,394	$7,885,259	$60,453,653

Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
5% AEP					
Residential	580	0	$24,407,766	$3,661,165	$28,068,931
Commercial	33	0	$-	$-	$-
Sub-Total	613	0	$24,407,766	$3,661,165	$28,068,931
20% AEP					
Residential	459	0	$19,201,649	$2,880,247	$22,081,896
Commercial	33	0	$-	$-	$-
Sub-Total	492	0	$19,201,649	$2,880,247	$22,081,896

Table 9-5 details the direct flood damages due to flooding within the Murroon Creek model area. From this, the AAD was $197,740 and the NPV was $2,926,696.

Table 9-5: Direct flood damages - Murroon Creek Model

Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
0.2% AEP					
Residential	31	0	$1,295,348	$194,302	$1,489,650
Commercial	11	0	$-	$-	$-
Sub-Total	42	0	$1,295,348	$194,302	$1,489,650
1% AEP					
Residential	20	0	$847,824	$127,174	$974,997
Commercial	5	0	$-	$-	$-
Sub-Total	25	0	$847,824	$127,174	$974,997
5% AEP					
Residential	13	0	$561,027	$84,154	$645,181
Commercial	3	0	$-	$-	$-
Sub-Total	16	0	$561,027	$84,154	$645,181
20% AEP					
Residential	12	0	$511,640	$76,746	$588,386
Commercial	1	0	$-	$-	$-
Sub-Total	13	0	$511,640	$76,746	$588,386

Table 9-6 details the direct flood damages due to flooding within the Boltons Creek model area. From this, the AAD was $43,279 and the NPV was $640,565.

Table 9-6: Direct flood damages - Boltons Creek Model

Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
0.2% AEP					
Residential	8	0	$350,912	$52,637	$403,549
Commercial	37	0	$-	$-	$-
Sub-Total	45	0	$350,912	$52,637	$403,549
1% AEP					
Residential	6	0	$255,084	$38,263	$293,346
Commercial	30	0	$-	$-	$-
Sub-Total	36	0	$255,084	$38,263	$293,346
5% AEP					
Residential	5	0	$210,115	$31,517	$241,632
Commercial	22	0	$-	$-	$-
Sub-Total	27	0	$210,115	$31,517	$241,632
20% AEP					
Residential	2	0	$81,100	$12,165	$93,265
Commercial	16	0	$-	$-	$-
Sub-Total	18	0	$81,100	$12,165	$93,265

Table 9-7 details the direct flood damages due to flooding within the Tangaratta Creek model area. From this, the AAD was $109,792 and the NPV was $1,625,000.

Table 9-7: Direct flood damages - Tangaratta Creek Model

Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
0.2% AEP					
Residential	13	1	$643,006	$96,451	$739,457
Commercial	3	0	$-	$-	$-
Sub-Total	16	1	$643,006	$96,451	$739,457
1% AEP					
Residential	12	0	$599,668	$89,950	$689,618

Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Commercial	3	0	$-	$-	$-
Sub-Total	15	0	$599,668	$89,950	$689,618
5% AEP					
Residential	9	0	$385,571	$57,836	$443,407
Commercial	3	0	$-	$-	$-
Sub-Total	12	0	$385,571	$57,836	$443,407
20% AEP					
Residential	6	0	$253,611	$38,042	$291,652
Commercial	3	0	$-	$-	$-
Sub-Total	9	0	$253,611	$38,042	$291,652

Table 9-8 details the direct flood damages due to flooding within the Nemingha model area. From this, the AAD was $436,503 and the NPV was $6,460,564.

Table 9-8: Direct flood damages - Nemigha Model

Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
0.2% AEP					
Residential	49	23	$3,593,904	$539,086	$4,132,990
Commercial	48	5	$79,783	$11,967	$91,751
Sub-Total	97	28	$3,673,687	$551,053	$4,224,740
1% AEP					
Residential	45	17	$2,989,161	$448,374	$3,437,535
Commercial	37	1	$4,405	$661	$5,066
Sub-Total	82	18	$2,993,566	$449,035	$3,442,600
5% AEP					
Residential	35	7	$1,808,835	$271,325	$2,080,160
Commercial	21	0	$-	$-	$-
Sub-Total	56	7	$1,808,835	$271,325	$2,080,160
20% AEP					
Residential	21	0	$860,390	$129,059	$989,449
Commercial	19	0	$-	$-	$-
Sub-Total	40	0	$860,390	$129,059	$989,449

Table 9-9 details the direct flood damages due to flooding within the Calala Creek model area. From this, the AAD was $10,726,882 and the NPV was $158,765,852.

Table 9-9: Direct flood damages - Calala Creek Model

Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
0.2% AEP					
Residential	887	6	$38,641,981	$5,796,297	$44,438,279
Commercial	0	0	$-	$-	$-
Sub-Total	887	6	$38,641,981	$5,796,297	$44,438,279
1% AEP					
Residential	850	5	$36,323,003	$5,448,450	$41,771,454
Commercial	0	0	$-	$-	$-
Sub-Total	850	5	$36,323,003	$5,448,450	$41,771,454
5% AEP					
Residential	792	1	$33,549,957	$5,032,494	$38,582,450
Commercial	0	0	$-	$-	$-
Sub-Total	792	1	$33,549,957	$5,032,494	$38,582,450
20% AEP					
Residential	688	0	$28,665,862	$4,299,879	$32,965,742
Commercial	0	0	$-	$-	$-
Sub-Total	688	0	$28,665,862	$4,299,879	$32,965,742

Table 9-10 details the direct flood damages due to flooding within the Oxley Vale model area. From this, the AAD was $7,594,964 and the NPV was $112,411,130.

Table 9-10: Direct flood damages - Oxley Vale Model

Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
0.2% AEP					
Residential	858	6	$36,688,949	$5,503,342	$42,192,291
Commercial	14	0	$-	$-	$-
Sub-Total	872	6	$36,688,949	$5,503,342	$42,192,291
1% AEP					

Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Residential	758	1	$31,820,572	$4,773,086	$36,593,658
Commercial	11	0	$-	$-	$-
Sub-Total	769	1	$31,820,572	$4,773,086	$36,593,658
5% AEP					
Residential	625	0	$25,728,639	$3,859,296	$29,587,935
Commercial	9	0	$-	$-	$-
Sub-Total	634	0	$25,728,639	$3,859,296	$29,587,935
20% AEP					
Residential	467	0	$19,059,729	$2,858,959	$21,918,689
Commercial	9	0	$-	$-	$-
Sub-Total	476	0	$19,059,729	$2,858,959	$21,918,689

Table 9-11 details the direct flood damages due to flooding within the East North Tamworth model area under the gates closed scenario. From this, the AAD was $25,717,475 and the NPV was $380,637,821.

Table 9-11: Direct flood damages - East North Tamworth Model

Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
0.2% AEP					
Residential	2079	11	$87,781,724	$13,167,259	$100,948,982
Commercial	397	24	$822,929	$123,439	$946,369
Sub-Total	2476	35	$88,604,653	$13,290,698	$101,895,351
1% AEP					
Residential	2005	6	$83,324,177	$12,498,627	$95,822,804
Commercial	378	0	$-	$0	$-
Sub-Total	2383	6	$83,324,177	$12,498,627	$95,822,804
5% AEP					
Residential	1935	0	$79,889,196	$11,983,379	$91,872,575
Commercial	352	0	$-	$0	$-
Sub-Total	2287	0	$79,889,196	$11,983,379	$91,872,575
20% AEP					
Residential	1697	0	$69,309,766	$10,396,465	$79,706,231

Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Commercial	300	0	$-	$0	$-
Sub-Total	1997	0	$69,309,766	$10,396,465	$79,706,231

10 Floodplain Risk Management Measures

10.1 Overview

The NSW Floodplain Development Manual (NSW Government, 2005), categorises the modification measures that can be investigated to mitigate the flood risks to a community as:

- Flood Modification Measures – These options aim to reduce flood risk by altering the flood behaviour, such as decreasing flood levels, velocities or extents.
- Property Modification Measures – These options aim to reduce flood risk by altering the existing properties and/or imposing planning controls to future properties.
- Response Modification Measures – These options aim to reduce flood risk by altering the way the community responds to a flood event.

The mitigation measures identified and investigated in this study span the range of mitigation measures (i.e. flood, property and response) and are discussed in the following.

10.2 Options Identification

10.2.1 Potential Flood Modification Measures

10.2.1.1 Option FM01 - Levee on Timbumburi Creek

This option proposed the construction of an earthen levee to protect properties in Westdale from inundation from Timbumburi Creek. The levee was located to the east of Flinders Street and Nowland Crescent; with a crest height of the 1% AEP peak flood level plus a 1m freeboard. Additionally, stormwater pipes with flap gates were included through the levee to allow the drainage of local overland flooding prior to the flood peak on the Timbumburi Creek.

To balance the protection of residential buildings against the minimisation of adverse (increases in) flood level impacts in areas not protected by the proposed levee, the levee was located proximate to the residential buildings. Therefore, the levee bisects some properties and would require an easement over the levee and consultation with the residents before being adopted.

10.2.1.2 Option FM02 - Pump out from behind the levee

This option proposed the installation of pumps at three locations to facilitate the drainage of local ponding behind the levee into the Peel River. The locations included:

- Peel Street, adjacent to Viaduct Park, north of the Railway Viaduct.
- The park adjacent to the intersection of Peel Street and Darling Street.
- Bicentennial Park, south of Bridge Street and west of Kable Avenue.

The pump out rate of these pumps was 3 m^3/s, based upon the pump out rate suggested in the East and North Tamworth Drainage Study (Lyall and Associates, 2019).

10.2.1.3 Option FM03 - Additional pressure tunnels

Currently, there are a number of stormwater pressure tunnels that drain flood water from inside the levee into the Peel River. This option proposed the construction of two additional pressure tunnels; one located along Fitzroy Street from the south-west side of the Railway Tracks into the Peel River, and the other located along Roderick Street from the south-west side of Byrnes Avenue into the Peel River.

10.2.1.4 Option FM04 - Computerised flood gates

Currently, there are manually operated flood gates on the stormwater pipes that drain flood water from inside the levee into the Peel River. As these flood gates are manually operated, they are closed in advance of a flood event occurring.

This option proposed to install computerised control on the flood gates. This would allow the gates to be opened for longer before the river rises and allow more local overland flood water to discharge into the river.

10.2.1.5 Option FM05 – Detention basins upstream of East and North Tamworth

This option proposed the construction of three detention basins upstream of East and North Tamworth. These detention basins were located on:

- Rifle Range Gully, south-east of the intersection of Janison Street and Daruka Road, within the grounds of Tamworth TAFE.
- Long Gully, north-east of the intersection of Bourke Street and Endeavour Drive, within the grounds of Victoria Park.
- Garrieties Gully, west of the intersection Raglan Street and Murray Street.

This option also included the construction of a pressure tunnel along Roderick Street and the upgrading of pipes (to 1.2m diameter pipes) between the pressure tunnel up to the detention basin.

10.2.1.6 Option FM06 - Diversion of Barnes Gully

This option proposed the construction of a channel connecting Barnes Gully to Goonoo Goonoo Creek. The channel was located through Locks Lane, to the east of the Goonoo Goonoo Road and George Street intersection. The aim of this option was to allow flow along Barnes Gully to divert into Goonoo Goonoo Creek before the latter peaks, thereby increasing the time to peak and the effective warning time downstream of Barnes Gully. This was particularly important for the evacuation of the downstream Gipps Street Sports Field that is used by visitors who camp during social events such as the Tamworth Music Festival. As these visitors are often not local to the area, their flood awareness of this area would also be relatively low.

10.2.2 Potential Property Modification Measures

10.2.2.1 Option PM01 – Update Development Controls

Development controls are often applied so as to protect future development from flood risk and flood damage. These are generally applied through the establishment of development controls within Council's Development Control Plan (DCP) and Section 10.7(2) Planning Certificates issued by Council for individual properties.

This option includes:

- Specific flood-related development controls on property affected by overland flooding (determined to be property with greater than 10% of their area affected by greater than 0.15m deep of flooding in the 1% AEP event). For overland flooding, the Flood Planning Level would be the 1% AEP peak flood level plus a freeboard of 300mm (whereas for mainstream flooding the Flood Planning Level would be the 1% AEP peak flood level plus a freeboard of 500mm)
- Additional requirements to be applied to subdivision applications that would require the applicant to demonstrate that the proposed subdivision has flood-free access.

10.2.2.2 Option PM02 - Voluntary property purchase

Voluntary purchase is a property modification measure wherein council purchases land affected by high flood hazard. Buildings that are purchased are then demolished, and the land is rezoned to a more appropriate classification. This is seen as a last resort option, and is used only when other mitigation options are not feasible in the given area.

DPE has made available guidelines for voluntary purchase schemes to assist in the determination of whether this modification option is suitable for the area (DPE, 2022). These guidelines recommend that voluntary purchase is effective in areas where:

- there are highly hazardous flood conditions from riverine or overland flooding 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 the removal of a building may be part of a floodway clearance program that aims to reduce significant impacts on flood behaviour elsewhere in the floodplain by enabling the floodway to more effectively perform its flow conveyance function.
- purchase of a property enables other flood mitigation works (such as channel improvements or levee construction) to be implemented because the property will impede construction or may be adversely affected by the works with impacts not able to be offset.

Highly hazardous flood conditions were defined using the 1% AEP flood event. Of the residential properties identified within the study area, 102 were determined to have been subjected to highly hazardous flood conditions within the 1% AEP flood event. Of these residential properties, 3 were found to have above floor level flooding of greater than 1 m, 13 others experienced above floor level flooding of greater than 0.5 m, 33 properties experienced above floor level flooding of less than 0.5 m, and the remaining 53 properties experienced below floor level flooding.

In order to implement this option, a voluntary purchase policy would need to be developed that would outline circumstances under which Council would acquire suitable properties. Council would then need to prepare a voluntary purchase scheme, which would detail:

- All properties subject to the scheme;
- The relative acquisition priority of the properties;
- The cost of the acquisition; and
- The anticipated acquisition schedule.

Importantly, resident participation in a scheme of this nature is entirely voluntary. It is expected that residents will likely not be amenable to such a scheme at the present time. However, support from the residents may change in the future, in the event of a large flood that may highlight the need for such a scheme. Should this option gain support in the future, it is recommended that priority be given to those properties with the most significant above floor level flooding.

10.2.2.3 Option PM03 – Voluntary house raising

Voluntary house raising is a property modification measure wherein a house is raised above the minimum flood design level. DPE has made available guidelines for voluntary house raising schemes to assist in the determination of whether this modification measure is suitable for the area (DPE, 2022). These guidelines list the eligibility criteria for funding for voluntary house raising as the following:

- The property must be residential, not commercial or industrial.
- The building was approved and constructed prior to 1986.
- The property is not benefiting substantially from other floodplain mitigation measures, such as houses already protected by a levee or those that will be.

To determine if a house is included in this option a threshold of 0.3m of above-floor inundation in the 1% AEP event was adopted. Based on this criteria, 14 houses were proposed to be included in this voluntary house raising option. Of these 14 houses, all 14 also meet the criteria for voluntary purchase as discussed in Section 10.2.2.2.

10.2.2.4 Option PM04 - Flood proofing buildings

As commercial property is ineligible for funding for voluntary purchase or voluntary house raising, this option proposes that these commercial properties that are affected by over-floor flooding in the 1% AEP event be considered for inclusion in a flood proofing scheme.

The exact nature of the flood proofing measures would be dependent on an assessment of the existing building and consideration of the building's current usage. For example, this option could include installation of flood doors (to prevent the egress of flood water into the building); replacement of building materials that are liable to be damaged by flood water with flood compatible materials; and/or raising electrical outlets to be above the Flood Planning Level for the site.

To determine if a commercial premise is included in this option a threshold of 0.3m of above-floor inundation in the 1% AEP event was adopted. Based on this criteria, 11 buildings were proposed to be included in this flood proofing option.

10.2.3 Potential Response Modification Measures

10.2.3.1 Option RM01 - Flood education programs

Council and the NSW SES could increase flood awareness within the community through a flood education program that includes flood information provided on their websites and social media pages, as well as information flyers included in the distribution of Council rates or a more general letter-box drop. The information flyers could be sourced from the NSW SES, such as the Business FloodSafe toolkit available online from the NSW SES.

10.2.3.2 Option RM02 - Early warning system

This option proposed an early warning system be developed for some of the mid-sized creeks within the study area (this excludes the Peel River system as this is already covered by the Bureau of Meteorology's warning system). As a first priority this could include an early warning system on the Goonoo Goonoo Creek.

Furthermore, as an early warning system has already been developed for Council for the Nundle and Woolomin areas, it would be recommended that this option utilises the same operating system as the existing early warning system for compatibility, consistency and ease of use. A flood warning would then be issued via a geo-targeted emergency alert, with a pre-recorded telephone voice message to landline phones and text messages to mobile phones within a defined area of Tamworth.

10.2.3.3 Option RM03 – Improved access to Calala

There were two access routes investigated to improve access to Calala. These were:

- Calala Lane where Goonoo Goonoo Creek crosses to the west of Inala Crescent.
- Calala Lane where Calala Creek crosses to the east of Burgess Lane, as well as O'Briens Lane at the Peel River crossing.

At all of these locations an existing bridge would need to be raised to prevent inundation of the road and allow vehicle access to Calala.

10.3 Options Assessment Process

The Floodplain Development Manual (NSW Government, 2005) and the Australian Emergency Management Handbook 7 (AEMI, 2017) recommend that a multi-criteria assessment (MCA) be carried out to assess each of the potential mitigation measures. An MCA considers the economic, social and environmental impacts of the potential mitigation measures. The multi-criteria matrix system that was used for the current assessment is detailed in Table 10-1.

Table 10-1: Multi-criteria matrix system

Category	Criteria	Score						
		-3	-2	-1	0	1	2	3
Flood Behaviour (Weighted 3)	Impact on Flood Behaviour	> 100 mm increase or newly flooded	50 to 100 mm increase	< 50 mm increase	No change	< 50 mm decrease	50 to 100 mm decrease	> 100 mm decrease or no longer flooded
Economic (Weighted 2)	Benefit Cost Ratio	< 0.15	0.15 to 0.5	0.5 to 1.0	1.0	1.0 - 1.2	1.2 - 1.5	> 1.5
	Average Annual Damages	>$80,000 increase	$40,000 to $80,000 increase	< $40,000 increase	No Change	< $40,000 decrease	$40,000 to $80,000 decrease	> $80,000 decrease
	Cost of initiating management measure	> $7,500,000	$7,500,000 to $5,000,000	$5,000,000 to $2,500,000	$2,500,000 to $1,000,000	$1,000,000 to $750,000	$750,000 to $500,000	> $500,000
Social (Weighted 1)	Social Disruption (during construction of measure)	Works within 10m of socially significant sites	Works within 20m of socially significant sites	Works within 30m of socially significant sites	No Impact	N/A	N/A	N/A
	Community Support	Strongly Disagree	Moderately Disagree	Minorly Disagree	Neutral	Minorly Agree	Moderately Agree	Strongly Agree
Environmental (Weighted 1)	Biodiversity Impacts	Works within 10m of known biodiversity sites	Works within 20m of known biodiversity sites	Works within 30m of known biodiversity sites	No Impact	N/A	N/A	N/A
	Heritage Impacts	Works within 10m of known heritage sites	Works within 20m of known heritage sites	Works within 30m of known heritage sites	No Impact	N/A	N/A	N/A

10.4 Options Assessment Results

10.4.1 Potential Flood Modification Measures

10.4.1.1 Option FM01 - Levee on Timbumburi Creek

Flood Behaviour Assessment

Figure D 1 to Figure D 3 shows the flood level impact of this option over a range of flood event magnitudes. As a result of this mitigation option, there was a decrease in flood levels directly behind the levees, and an increase in flood levels between the levees along Timbumburi Creek in all events. However, in larger events the area of increased flood levels spread further downstream.

Economic Assessment

Table 10-2 details the economic assessment of this option. From this it was found that while there was a marginal decrease in damages across most events, these was a marginal increase in damages in smaller events such as the 20% AEP.

Table 10-2: FM01 Economic Assessment

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before Mitigation	0.2% AEP	1699	7	$67,657,483	$10,148,622	$77,806,105
	1% AEP	1308	2	$52,568,394	$7,885,259	$60,453,653
	5% AEP	613	0	$24,407,766	$3,661,165	$28,068,931
	20% AEP	492	0	$19,201,649	$2,880,247	$22,081,896
	AAD (before mitigation measure)					$8,085,287
	NPV (before mitigation measure)					$119,668,277
After Mitigation	0.2% AEP	1698	7	$67,625,612	$10,143,842	$77,769,454
	1% AEP	1304	1	$52,352,764	$7,852,915	$60,205,678
	5% AEP	605	0	$24,041,560	$3,606,234	$27,647,794
	20% AEP	496	0	$19,360,904	$2,904,136	$22,265,039
	AAD (after mitigation measure)					$8,132,759
	AAD Reduction					-$47,472
	NPV (after mitigation measure)					$120,370,897
	NPV Reduction					-$702,620
	Estimated Cost of Mitigation Measure					$761,000
	B/C Ratio					-0.9

Heritage Assessment

Implementation of this option would not affect items of known heritage significance.

Environmental Assessment

Implementation of this option would not affect items of known environmental significance.

10.4.1.2 Option FM02 – Pump out from behind the levee

Flood Behaviour Assessment

Figure D 4 to Figure D 6 shows the flood level impact of this option over a range of flood event magnitudes. As a result of this mitigation option, there was a significant decrease in flood levels in the area directly inside the levee, and an increase within the Peel River across all events.

Economic Assessment

Table 10-3 details the economic assessment of this option. From this it was found that there was a marginal decrease in damages across all events except the 20% AEP event, where there was a marginal increase.

Table 10-3: FM02 Economic Assessment

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before Mitigation	0.2% AEP	2476	35	$88,604,653	$13,290,698	$101,895,351
	1% AEP	2383	6	$83,324,177	$12,498,627	$95,822,804
	5% AEP	2287	0	$79,889,196	$11,983,379	$91,872,575
	20% AEP	1997	0	$69,309,766	$10,396,465	$79,706,231
	AAD (before mitigation measure)					$25,717,475
	NPV (before mitigation measure)					$380,637,821
After Mitigation	0.2% AEP	2480	16	$87,897,920	$13,184,688	$101,082,608
	1% AEP	2378	6	$83,322,704	$12,498,406	$95,821,110
	5% AEP	2284	0	$79,764,258	$11,964,639	$91,728,897
	20% AEP	1997	0	$69,315,657	$10,397,349	$79,713,006
	AAD (after mitigation measure)					$25,711,467
	AAD Reduction					$6,008
	NPV (after mitigation measure)					$380,548,905
	NPV Reduction					$88,916
	Estimated Cost of Mitigation Measure					$7,743,000
	B/C Ratio					0.01

Heritage Assessment

Implementation of this option would not affect items of known heritage significance.

Environmental Assessment

When considering the works necessary to implement this flood mitigation option, it was found that part of these works would occur directly within the forested wetlands along the Peel River, and have a high likelihood of impacting the environment.

10.4.1.3 Option FM03 – Additional pressure tunnels

Flood Behaviour Assessment

Figure D 7 to Figure D 9 shows the flood level impact of this option over a range of flood event magnitudes. As a result of this mitigation option, it was found that flood levels were minimally impacted across most flood events, with a minor decrease in flood levels directly inside the levee in larger events.

Economic Assessment

Table 10-4 details the economic assessment of this option. From this it was found that damages were either largely unaffected or marginally decreased across all events.

Table 10-4: FM03 Economic Assessment

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before Mitigation	0.2% AEP	2476	35	$88,604,653	$13,290,698	$101,895,351
	1% AEP	2383	6	$83,324,177	$12,498,627	$95,822,804
	5% AEP	2287	0	$79,889,196	$11,983,379	$91,872,575
	20% AEP	1997	0	$69,309,766	$10,396,465	$79,706,231
	AAD (before mitigation measure)					$25,717,475
	NPV (before mitigation measure)					$380,637,821
After Mitigation	0.2% AEP	2478	34	$88,587,917	$13,288,188	$101,876,105
	1% AEP	2382	6	$83,324,177	$12,498,627	$95,822,804
	5% AEP	2287	0	$79,875,940	$11,981,391	$91,857,331
	20% AEP	1997	0	$69,309,766	$10,396,465	$79,706,231
	AAD (after mitigation measure)					$25,716,190
	AAD Reduction					$1,285
	NPV (after mitigation measure)					$380,618,805
	NPV Reduction					$19,016
	Estimated Cost of Mitigation Measure					$3,069,000
	B/C Ratio					0.01

Heritage Assessment

When considering the works necessary to implement this flood mitigation option, it was found that these works would come within 20m of Tamworth Post Office, and have a moderate likelihood of affecting the heritage structure.

Environmental Assessment

When considering the works necessary to implement this flood mitigation option, it was found that part of these works would occur directly within the forested wetlands along the Peel River, and have a high likelihood of impacting the environment.

10.4.1.4 Option FM04 – Computerised flood gates

Flood Behaviour Assessment

Figure D 10 to Figure D 12 shows the flood level impact of this option over a range of flood event magnitudes. As a result of this mitigation option, it was found that flood levels decreased inside the levee across all flood events magnitudes, with some distributed flood level increases in smaller events.

Economic Assessment

Table 10-5 details the economic assessment of this option. From this it was found that there was a marginal decrease in damages across all events except the 5% AEP event, where there was a marginal increase.

Table 10-5: FM04 Economic Assessment

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before Mitigation	0.2% AEP	2476	35	$88,604,653	$13,290,698	$101,895,351
	1% AEP	2383	6	$83,324,177	$12,498,627	$95,822,804
	5% AEP	2287	0	$79,889,196	$11,983,379	$91,872,575
	20% AEP	1997	0	$69,309,766	$10,396,465	$79,706,231
	AAD (before mitigation measure)					$25,717,475
	NPV (before mitigation measure)					$380,637,821
After Mitigation	0.2% AEP	2480	32	$88,512,286	$13,276,843	$101,789,129
	1% AEP	2383	6	$83,321,231	$12,498,185	$95,819,416
	5% AEP	2288	0	$80,013,550	$12,002,033	$92,015,583
	20% AEP	1994	0	$69,309,766	$10,396,465	$79,706,231
	AAD (after mitigation measure)					$25,723,703
	AAD Reduction					-$6,228
	NPV (after mitigation measure)					$380,730,009
	NPV Reduction					-$92,188
	Estimated Cost of Mitigation Measure					$173,000
	B/C Ratio					-0.5

Heritage Assessment

Implementation of this option would not affect items of known heritage significance.

Environmental Assessment

When considering the works necessary to implement this flood mitigation option, it was found that these works would occur directly within the forested wetlands along the Peel River, and have a high likelihood of impacting the environment.

10.4.1.5 Option FM05 – Detention basins upstream of East and North Tamworth

Flood Behaviour Assessment

Figure D 13 to Figure D 15 shows the flood level impact of this option over a range of flood event magnitudes. As a result of this mitigation option, it was found that flood levels generally decreased inside the levee across all flood events magnitudes. However, flood levels within the areas of the Peel River increased in some events.

It was also noted that a localised increase in flood levels occurred to the south of the TAFE detention basin whilst flood levels decreased in Rifle Range Gully directly downstream of the TAFE detention basin in the larger magnitude flood events. This was due to the detention basin design being at a preliminary stage with no spillway to direct overtopping flows into Rifle Range Gully.

Economic Assessment

Table 10-6 details the economic assessment of the TAFE basin. From this it was found that there was a decrease in damages across some events, with other events experiencing a marginal increase.

It is assumed that damages to the south of the TAFE detention basin will be offset with a spillway designed to direct overtopping flow into Rifle Range Gully at the detailed design stage or feasibility study stage.

Table 10-6: FM05 Economic Assessment – TAFE Basin

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before Mitigation	0.2% AEP	2476	35	$88,604,653	$13,290,698	$101,895,351
	1% AEP	2383	6	$83,324,177	$12,498,627	$95,822,804
	5% AEP	2287	0	$79,889,196	$11,983,379	$91,872,575
	20% AEP	1997	0	$69,309,766	$10,396,465	$79,706,231
	AAD (before mitigation measure)					$25,717,475
	NPV (before mitigation measure)					$380,637,821
After Mitigation	0.2% AEP	2491	34	$89,304,128	$13,395,619	$102,699,747
	1% AEP	2378	6	$83,091,970	$12,463,795	$95,555,765
	5% AEP	2287	0	$79,892,142	$11,983,821	$91,875,963
	20% AEP	1996	0	$69,292,781	$10,393,917	$79,686,698
	AAD (after mitigation measure)					$25,743,274
	AAD Reduction					-$25,799
	NPV (after mitigation measure)					$381,019,662
	NPV Reduction					-$381,841
	Estimated Cost of Mitigation Measure					$1,119,000

	B/C Ratio	-0.3

Table 10-7 details the economic assessment of the Victoria Park basin. From this it was found that there was a marginal decrease in damages across all events except the 1% AEP event, where there was a marginal increase.

Table 10-7: FM05 Economic Assessment - Victoria Park Basin

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before Mitigation	0.2% AEP	2476	35	$88,604,653	$13,290,698	$101,895,351
	1% AEP	2383	6	$83,324,177	$12,498,627	$95,822,804
	5% AEP	2287	0	$79,889,196	$11,983,379	$91,872,575
	20% AEP	1997	0	$69,309,766	$10,396,465	$79,706,231
	AAD (before mitigation measure)					$25,717,475
	NPV (before mitigation measure)					$380,637,821
After Mitigation	0.2% AEP	2475	29	$88,168,859	$13,225,329	$101,394,188
	1% AEP	2381	4	$83,336,372	$12,500,456	$95,836,828
	5% AEP	2285	0	$79,781,803	$11,967,270	$91,749,073
	20% AEP	1993	0	$69,165,239	$10,374,786	$79,540,025
	AAD (after mitigation measure)					$25,645,565
	AAD Reduction					$71,910
	NPV (after mitigation measure)					$379,573,499
	NPV Reduction					$1,064,322
	Estimated Cost of Mitigation Measure					$1,984,000
	B/C Ratio					0.5

Table 10-8 details the economic assessment of the Murray Street basin. From this it was found that there was a decrease in damages across all events.

Table 10-8: FM05 Economic Assessment - Murray Street Basin

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before Mitigatio	0.2% AEP	2476	35	$88,604,653	$13,290,698	$101,895,351
	1% AEP	2383	6	$83,324,177	$12,498,627	$95,822,804
	5% AEP	2287	0	$79,889,196	$11,983,379	$91,872,575

	20% AEP	1997	0	$69,309,766	$10,396,465	$79,706,231
	AAD (before mitigation measure)					$25,717,475
	NPV (before mitigation measure)					$380,637,821
After Mitigation	0.2% AEP	2471	35	$88,226,947	$13,234,042	$101,460,989
	1% AEP	2382	6	$83,312,612	$12,496,892	$95,809,504
	5% AEP	2289	0	$79,837,176	$11,975,576	$91,812,752
	20% AEP	1967	0	$68,407,666	$10,261,150	$78,668,816
	AAD (after mitigation measure)					$25,515,253
	AAD Reduction					$202,222
	NPV (after mitigation measure)					$377,644,788
	NPV Reduction					$2,993,033
	Estimated Cost of Mitigation Measure					$4,579,000
	B/C Ratio					0.7

Heritage Assessment

Implementation of this option would not affect items of known heritage significance.

Environmental Assessment

When considering the works necessary to implement this flood mitigation option, it was found that these works would occur directly within the forested wetlands along the Peel River and the dry Sclerophyll forests to the north of Tamworth, having a high likelihood of impacting the environment.

10.4.1.6 Option FM06 - Diversion of Barnes Gully

Flood Behaviour Assessment

Figure D 16 to Figure D 18 shows the flood level impact of this option over a range of flood event magnitudes. As a result of this mitigation option, there was a small area of decreased flooding at the location of the diversion across all events, with a small localised area of increased flooding in smaller events.

Economic Assessment

Table 10-9 details the economic assessment of this option. From this it was found that there was a marginal decrease in damages in larger events, however there was also a marginal increase in damages in smaller events.

Table 10-9: FM06 Economic Assessment

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before Mitigatio	0.2% AEP	2202	54	$93,175,637	$13,976,346	$107,151,982
	1% AEP	1489	28	$62,360,067	$9,354,010	$71,714,078
	5% AEP	779	9	$32,226,875	$4,834,031	$37,060,907

	20% AEP	605	5	$24,771,720	$3,715,758	$28,487,478
	AAD (before mitigation measure)					$10,225,646
	NPV (before mitigation measure)					$151,347,198
After Mitigation	0.2% AEP	2210	54	$93,483,837	$14,022,576	$107,506,412
	1% AEP	1484	28	$62,136,697	$9,320,505	$71,457,202
	5% AEP	781	9	$32,281,465	$4,842,220	$37,123,684
	20% AEP	611	5	$25,028,276	$3,754,241	$28,782,518
	AAD (after mitigation measure)					$10,265,402
	AAD Reduction					-$39,756
	NPV (after mitigation measure)					$151,935,605
	NPV Reduction					-$588,407
	Estimated Cost of Mitigation Measure					$49,000
	B/C Ratio					-12.0

Heritage Assessment

Implementation of this option would not affect items of known heritage significance.

Environmental Assessment

When considering the works necessary to implement this flood mitigation option, it was found that these works would occur directly within the forested wetlands along Goonoo Goonoo Creek, and have a high likelihood of impacting the environment.

10.4.2 Potential Property Modification Measures

10.4.2.1 Option PM01 - Update Development Controls

Flood Behaviour Assessment

As a result of this mitigation option, there was no change to the flood behaviour across the range of flood events.

Heritage Assessment

Implementation of this option would not affect items of known heritage significance.

Environmental Assessment

Implementation of this option would not affect items of known environmental significance.

10.4.2.2 Option PM02 - Voluntary property purchase

Flood Behaviour Assessment

As a result of this mitigation option, there was no change to the flood behaviour across the range of flood events.

Economic Assessment

Table 10-8 details the economic assessment of this option. From this it was found that there was a decrease in damages across all events.

Table 10-8: PM02 Economic Assessment

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before Mitigation	0.2% AEP	6750	74	$266,717,964	$40,007,695	$306,725,659
	1% AEP	5695	28	$219,366,122	$32,904,918	$252,271,041
	5% AEP	4498	7	$170,024,910	$25,503,736	$195,528,646
	20% AEP	3799	0	$141,728,863	$21,259,329	$162,988,193
	AAD (before mitigation measure)					$54,259,892
	NPV (before mitigation measure)					$803,086,895
After Mitigation	0.2% AEP	6695	55	$263,040,183	$39,456,027	$302,496,210
	1% AEP	5644	13	$216,325,880	$32,448,882	$248,774,762
	5% AEP	4451	1	$167,691,521	$25,153,728	$192,845,249
	20% AEP	3766	0	$140,428,436	$21,064,265	$161,492,702
	AAD (after mitigation measure)					$53,672,484
	AAD Reduction					$587,408
	NPV (after mitigation measure)					$794,392,822
	NPV Reduction					$8,694,073
	Estimated Cost of Mitigation Measure					$55,718,000
	B/C Ratio					0.16

Heritage Assessment

Implementation of this option would not affect items of known heritage significance.

Environmental Assessment

Implementation of this option would not affect items of known environmental significance.

10.4.2.3 Option PM03 - Voluntary house raising

Flood Behaviour Assessment

As a result of this mitigation option, there was no change to the flood behaviour across the range of flood events.

Economic Assessment

Table 10-9 details the economic assessment of this option. From this it was found that there was a decrease in damages across all events.

Table 10-9: PM03 Economic Assessment

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before Mitigation	0.2% AEP	2358	107	$99,461,457	$14,919,219	$114,380,676
	1% AEP	1610	60	$66,897,971	$10,034,696	$76,932,667
	5% AEP	869	22	$35,192,534	$5,278,880	$40,471,414
	20% AEP	657	5	$26,102,293	$3,915,344	$30,017,637
	AAD (before mitigation measure)					$10,944,017
	NPV (before mitigation measure)					$161,979,618
After Mitigation	0.2% AEP	2344	93	$97,721,177	$14,658,177	$112,379,354
	1% AEP	1596	46	$65,353,689	$9,803,053	$75,156,742
	5% AEP	855	11	$34,011,446	$5,101,717	$39,113,163
	20% AEP	648	5	$25,689,645	$3,853,447	$29,543,092
	AAD (after mitigation measure)					$10,714,552
	AAD Reduction					$229,465
	NPV (after mitigation measure)					$158,583,361
	NPV Reduction					$3,396,257
	Estimated Cost of Mitigation Measure					$966,000
	B/C Ratio					3.5

Heritage Assessment

Implementation of this option would not affect items of known heritage significance.

Environmental Assessment

Implementation of this option would not affect items of known environmental significance.

10.4.2.4 Option PM04 - Flood proofing buildings

Flood Behaviour Assessment

As a result of this mitigation option, there was no change to the flood behaviour across the range of flood events.

Economic Assessment

Table 10-10 details the economic assessment of this option. From this it was found that there was a decrease in damages across all events.

Table 10-10: PM04 Economic Assessment

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before Mitigation	0.2% AEP	2306	98	$97,820,624	$14,673,094	$112,493,718
	1% AEP	1558	49	$64,677,961	$9,701,694	$74,379,655
	5% AEP	821	16	$33,728,344	$5,059,252	$38,787,596
	20% AEP	619	5	$25,276,561	$3,791,484	$29,068,046
	AAD (before mitigation measure)					$10,583,330
	NPV (before mitigation measure)					$156,641,178
After Mitigation	0.2% AEP	2295	87	$97,173,486	$14,576,023	$111,749,509
	1% AEP	1547	38	$64,139,738	$9,620,961	$73,760,699
	5% AEP	813	8	$33,424,944	$5,013,742	$38,438,686
	20% AEP	613	0	$25,092,303	$3,763,846	$28,856,149
	AAD (after mitigation measure)					$10,498,675
	AAD Reduction					$84,655
	NPV (after mitigation measure)					$155,388,227
	NPV Reduction					$1,252,951
	Estimated Cost of Mitigation Measure					$1,139,000
	B/C Ratio					1.1

Heritage Assessment

Implementation of this option would not affect items of known heritage significance.

Environmental Assessment

Implementation of this option would not affect items of known environmental significance.

10.4.3 Potential Response Modification Measures

10.4.3.1 Option RM01 – Flood education programs

Flood Behaviour Assessment

As a result of this mitigation option, there was no change to the flood behaviour across the range of flood events.

Heritage Assessment

Implementation of this option would not affect items of known heritage significance.

Environmental Assessment

Implementation of this option would not affect items of known environmental significance.

Overall Assessment

This option has a relatively low cost to implement and benefits the community by improving community preparedness and community response time.

10.4.3.2 Option RM02 – Early warning system

Flood Behaviour Assessment

As a result of this mitigation option, there was no change to the flood behaviour across the range of flood events.

Economic Assessment

It was assumed that this option would cost a similar amount to implement as the early warning system developed for the Nundle and Woolomin areas. Therefore, this option was estimated to cost $75,000 to implement.

Heritage Assessment

Implementation of this option would not affect items of known heritage significance.

Environmental Assessment

Implementation of this option would not affect items of known environmental significance.

Overall Assessment

This option had a relatively low cost to implement and, given that it would be located on one or more of the major creek systems, it would be servicing an area with a moderate to high risk to life as a direct result of flooding.

10.4.3.3 Option RM03 – Improved access to Calala

Flood Behaviour Assessment

As a result of this mitigation option, there was no change to the flood behaviour across the range of flood events.

Economic Assessment

To upgrade Calala Lane over Gooonoo Goonoo Creek was estimated to cost in the order of $114 million. Alternatively, to upgrade Calala Lane over Calala Creek as well as O'Brien's Lane over the Peel River was estimated to cost in the order of $202 million. Both options are prohibitively expensive; particularly for an area with very little above floor flood affectation and an above floor flood affectation that is relatively shallow (less than 0.3m in events up to and including the 2% AEP event).

Heritage Assessment

Implementation of this option would not affect items of known heritage significance.

Environmental Assessment

When considering the works necessary to implement this flood mitigation option, it was found that these works would occur within 30m of the forested wetlands along Goonoo Goonoo Creek, and have a low likelihood of impacting the environment.

Overall Assessment

This option would result in very little financial benefit although it would have a high cost to implement. Furthermore, given the shallow depth of above floor flood affectation, there is a relatively low risk to life as a direct result of flooding in the area.

10.4.4 Summary of Modification Measures Results

Table 10-10 presents the preliminary results of the multi-criteria assessment for all of the above discussed mitigation options. Following consultation with the FRMC and the community, the relative community support factor for each option will be tabulated, and the overall weighted score and ranking calculated.

Table 10-10: Multi-criteria matrix assessment

Option ID	Impact on flood behaviour	Benefit Cost Ratio	Average Annual Damages	Cost of initiating measure	Social disruption	Community support	Biodiversity impacts	Heritage impacts	Weighted score	Ranking
FM01	-1	-3	3	2	0	TBC	0	0	1	5
FM02	2	-3	1	3	0	TBC	-3	0	5	2
FM03	0	-3	1	-1	-2	TBC	-3	-2	-13	14
FM04	1	-3	-1	3	0	TBC	-3	0	-2	11
FM05A	0	-3	-1	0	-3	TBC	0	0	-11	13
FM05B	2	-1	2	0	0	TBC	-3	0	5	4
FM05C	1	-1	3	-1	-1	TBC	-3	0	1	6
FM06	0	-3	1	3	0	TBC	-3	0	-1	10
PM01	0	N/A	N/A	N/A	0	TBC	0	0	0	8
PM02	0	-2	3	-3	0	TBC	0	0	-4	12
PM03	0	3	3	0	-3	TBC	0	0	9	1
PM04	0	1	3	-2	-3	TBC	0	0	1	7
RM01	0	N/A	N/A	N/A	0	TBC	0	0	0	9
RM02	0	N/A	N/A	3	0	TBC	0	0	6	3
RM03	0	-3	0	-3	0	TBC	-1	0	-13	15

11 Floodplain Risk Management Plan

11.1 Recommended Measures

Based upon the multi-criteria assessment of the flood mitigation options, the following options are recommended for implementation:

- FM02 – Pump out from behind the levee
- FM04 – Computerised flood gates
- FM05 – Detention basins upstream of East and North Tamworth
- PM01 – Update development controls
- PM03 – Voluntary house raising
- RM01 – Flood education programs
- RM02 – Early warning system

11.2 Implementation

Implementing the aforementioned recommended measures requires information on the following details:

- The agency or organisation primarily responsible for project managing the implementation of the measure;
- The financial requirements to implement the measure; and
- The priority for implementation of the measure.

Table 11-1 lists the implementation plan with consideration given to the aforementioned details. The measures identified would require a total capital expenditure of approximately $16,771,000.

The plan is expected to be executed over a ten year timeframe. The scheduling of the works proposed will be dependent upon the financial commitments of the agencies or organisations responsible.

11.3 Maintenance

A floodplain risk management plan is an ongoing procedure, and is not over at the completion of the report.

A management plan should be based on the best knowledge currently available. Therefore, due to key factors of the study area changing over time, such as social, economic, and catchment conditions that may affect flooding behaviours, the management plan should be reassessed periodically. It is advised that plan reassessment take place every five years or following a significant flood event.

Table 11-1: Implementation plan

Measure ID	Measure Description	Responsibility	Cost	Timeframe (Budget Dependent)	Priority
PM01	Update development controls	Council	$10,000	1 year	High
RM01	Flood education programs	Council / NSW SES	$10,000	1 year	High
FM02	Pump out from behind the levee	Council / DPE	$7,743,000	3 years	High
FM04	Computerised flood gates	Council / DPE	$285,000	5 years	Medium
RM02	Early warning system	Council	$75,000	5 years	Medium
FM05	Detention basins upstream of East and North Tamworth	Council / DPE	$7,682,000	10 years	Medium
PM03	Voluntary house raising	Council / DPE	$966,000	10 years	Medium

12 References

Ref 1: Australian Emergency Management Institute (2017), *Australian Emergency Management Handbook 7: Managing the Floodplain Best Practice in Flood Risk Management in Australia*, AEMI, Canberra

Ref 2: Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) (2019), *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Commonwealth of Australia

Ref 3: BMT WBM (2018), *TUFLOW User Manual*

Ref 4: Boyd, M., Rigby, E., VanDrie, R. (2017), *Watershed Bounded Network Model (WBNM) User Guide*

Ref 5: Institute of Engineers, Australia (1987), *Australian Rainfall and Runoff: A Guide to Flood Estimation, Vol. 1*, Editor-in-chief D.H. Pilgrim, Revised Edition 1987 (Reprinted 1998), Barton, ACT

Ref 6: Lyall and Associates Pty Ltd (2019), *Tamworth City Wide Flood Investigation*, Tamworth Regional Council

Ref 7: Lyall and Associates Pty Ltd (2021), *East and North Tamworth Drainage Study*, Tamworth Regional Council

Ref 8: NSW Government (2005), *Floodplain Development Manual: The management of flood liable land*, Department of Infrastructure, Planning and Natural Resources, NSW Government, Sydney

APPENDIX A
GLOSSARY

The following glossary has been extracted from the Australian Emergency Management Handbook 7 (Ref 1).

Annual Exceedance Probability (AEP)	The likelihood of the occurrence 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 flow of 500 m3/s has an AEP of 5%, it means that there is a 5% chance (that is, a one-in-20 chance) of a flow of 500 m3/s or larger occurring in any one year (see also average recurrence interval, flood risk, likelihood of occurrence, probability).
Astronomical tide	The variation in sea level caused by the gravitational effects of (principally) the moon and sun. It includes highest and lowest astronomical tides (HAT and LAT) occur when relative alignment and distance of the sun and moon from the earth are 'optimal'. Water levels approach to within 20 cm of HAT and LAT twice per year around mid-summer and mid-winter 'king tides'.
Australian Height Datum (AHD)	A common national survey height datum as a reference level for defining reduced levels; 0.0 m AHD corresponds approximately to 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. If the damage associated with various annual events is plotted against their probability of occurrence, the AAD is equal to the area under the consequence-probability curve. AAD provides a basis for comparing the economic effectiveness of different management measures (i.e. their ability to reduce the AAD).
Average Recurrence Interval (ARI)	A statistical estimate of the average number of years between the occurrence of a flood of a given size or larger than the selected event. For example, floods with a flow as great as or greater than the 20-year ARI (5% AEP) flood event will occur, on average, once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event (see also annual exceedance probability).
Catchment	The area of land draining to a particular site. It is related to a specific location, and includes the catchment of the main waterway as well as any tributary streams.
Catchment flooding	Flooding due to prolonged or intense rainfall (e.g. severe thunderstorms, monsoonal rains in the tropics, tropical cyclones). Types of catchment flooding include riverine, local overland and groundwater flooding.
Chance	The likelihood of something happening that will have beneficial consequences (e.g. the chance of a win in a lottery). Chance is often thought of as the 'upside of a gamble' (Rowe 1990) (see also risk).
Coastal flooding	Flooding due to tidal or storm-driven coastal events, including storm surges in lower coastal waterways. This can

	be exacerbated by wind-wave generation from storm events.
Consent authority	The authority or agency with the legislative power to determine the outcome of development and building applications.
Consequence	The outcome of an event or situation affecting objectives, expressed qualitatively or quantitatively. Consequences can be adverse (e.g., death or injury to people, damage to property and disruption of the community) or beneficial.
Defined Flood Event (DFE)	The flood event selected for the management of flood hazard to new development. This is generally determined in floodplain management studies and incorporated in floodplain management plans. Selection of DFEs should be based on an understanding of flood behaviour, and the associated likelihood and consequences of flooding. It should also take into account the social, economic, environmental and cultural consequences associated with floods of different severities. Different DFEs may be chosen for the basis for reducing flood risk to different types of development. DFEs do not define the extent of the floodplain, which is defined by the PMF (see also design flood, floodplain and probable maximum flood).
Design flood	The flood event selected for the treatment of existing risk through the implementation of structural mitigation works such as levees. It is the flood event for which the impacts on the community are designed to be limited by the mitigation work. For example, a levee may be designed to exclude a 2% AEP flood, which means that floods rarer than this may breech the structure and impact upon the protected area. In this case, the 2% AEP flood would not equate to the crest level of the levee, because this generally has a freeboard allowance, but it may be the level of the spillway to allow for controlled levee overtopping (see also annual exceedance probability, defined flood event, floodplain, freeboard and probable maximum flood).
Development	Development may be defined in jurisdictional legislation or regulation. This may include erecting a building or carrying out of work, including the placement of fill; the use of land, or a building or work; or the subdivision of land. Infill development refers to the development of vacant blocks of land within an existing subdivision 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 is intensification of use with development of a completely different nature to that associated with the former land use or zoning (e.g. the urban subdivision of an area previously used for rural purposes). New developments generally involve rezoning, and associated consents and approvals. It may require major extensions of existing urban

	services, such as roads, water supply, sewerage and electric power. Redevelopment refers to rebuilding in an existing developed 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.
Ecologically sustainable development	Using, conserving and improving 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.
Effective warning time	The effective warning time available to a floodprone community is equal to the time between the delivery of an official warning to prepare for imminent flooding and the loss of evacuation routes due to flooding. The effective warning time is typically used for people to self-evacuate, to move farm equipment, move stock, raise furniture, and transport their possessions.
Existing flood risk	The risk a community is exposed to as a result of its location on the floodplain.
Flash flood	Flood that is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. It is generally not possible to issue detailed flood warnings for flash flooding. However, generalised warnings may be possible. It is often defined as flooding that peaks within six hours of the causative rain.
Flood	Flooding is a natural phenomenon that occurs when water covers land that is normally dry. It may result from coastal or catchment flooding, or a combination of both (see also catchment flooding and coastal flooding).
Flood awareness	An appreciation of the likely effects of flooding, and a knowledge of the relevant flood warning, response and evacuation procedures. In communities with a high degree of flood awareness, the response to flood warnings is prompt and effective. In communities with a low degree of flood awareness, flood warnings are liable to be ignored or misunderstood, and residents are often confused about what they should do, when to evacuate, what to take with them and where it should be taken.
Flood damage	The tangible (direct and indirect) and intangible costs (financial, opportunity costs, clean-up) of flooding. Tangible costs are quantified in monetary terms (e.g. damage to goods and possessions, loss of income or services in the flood aftermath). Intangible damages are difficult to quantify in monetary terms and include the increased levels of physical, emotional and psychological health problems suffered by flood-affected people that are attributed to a flooding episode.

Flood education	Education that raises awareness of the flood problem, to help individuals understand how to manage themselves and their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
Flood emergency response plan	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. The objective is to ensure a coordinated response by all agencies having responsibilities and functions in emergencies.
Flood emergency management	Emergency management is a range of measures to manage risks to communities and the environment. In the flood context, it may include measures to prevent, prepare for, respond to and recover from flooding.
Flood fringe areas	The part of the floodplain where development could be permitted, provided the development is compatible with flood hazard and appropriate building measures to provide an adequate level of flood protection to the development. This is the remaining area affected by flooding after flow conveyance paths and flood storage areas have been defined for a particular event (see also flow conveyance areas and flood storage areas).
Flood hazard	Potential loss of life, injury and economic loss caused by future flood events. The degree of hazard varies with the severity of flooding and is affected by flood behaviour (extent, depth, velocity, isolation, rate of rise of floodwaters, duration), topography and emergency management.
Floodplain	An area of land that is subject to inundation by floods up to and including the probable maximum flood event – that is, flood-prone land.
Floodplain management entity (FME)	The authority or agency with the primary responsibility for directly managing flood risk at a local level.
Floodplain management plan	A management plan developed in accordance with the principles and guidelines in this handbook, usually includes both written and diagrammatic information describing how particular areas of flood-prone land are to be used and managed to achieve defined objectives. It outlines the recommended ways to manage the flood risk associated with the use of the floodplain for various purposes. It represents the considered opinion of the local community and the floodplain management entity on how best to manage the floodplain, including consideration of flood risk in strategic land-use planning to facilitate development of the community. It fosters flood warning, response, evacuation, clean-up and recovery in the onset and aftermath of a flood, and suggests an organisational structure for the integrated management for existing, future and residual flood risks. Plans need to be reviewed regularly to assess progress and to consider the

	consequences of any changed circumstances that have arisen since the last review.
Flood Planning Area (FPA)	The area of land below the flood planning level, and is thus subject to flood-related development controls.
Flood Planning Level (FPL)	The FPL is a combination of the defined flood levels (derived from significant historical flood events or floods of specific annual exceedance probabilities) and freeboards selected for floodplain management purposes, as determined in management studies and incorporated in management plans.
Flood-prone land	Land susceptible to flooding by the probably maximum flood event. Flood-prone land is synonymous with the floodplain. Floodplain management plans should encompass all flood-prone land rather than being restricted to areas affected by defined flood events.
Flood proofing of buildings	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures that are subject to flooding, to reduce structural damage and potentially, in some cases, reduce contents damage.
Flood readiness	An ability to react within the effective warning time (see also flood awareness and flood education).
Flood risk	The potential risk of flooding to people, their social setting, and their built and natural environment. The degree of risk varies with circumstances across the full range of floods. Flood risk is divided into three types – existing, future and residual.
Flood severity	A qualitative indication of the 'size' of a flood and its hazard potential. Severity varies inversely with likelihood of occurrence (i.e., the greater the likelihood of occurrence, the more frequently an event will occur, but the less severe it will be). Reference is often made to major, moderate and minor flooding (see also minor, moderate and major flooding).
Flood storage areas	The parts of the floodplain that are important for temporary storage of floodwaters during a flood passage. 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 (see also flow conveyance areas and flood fringe areas).
Flood study	A comprehensive technical investigation of flood behaviour. It defines the nature of flood hazard across the floodplain by providing information on the extent, level and velocity of floodwaters, and on the distribution of flood flows. The flood study forms the basis for subsequent management studies and needs to take into account a full range of flood events up to and including the probable maximum flood.
Flow	The rate of flow of water measured in volume per unit time – for example, cubic metres per second (m3/s). Flow 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).
Flow conveyance areas	Those areas of the floodplain where a significant flow of water occurs during floods. They are often aligned with naturally defined channels. Flow conveyance paths are areas that, even if only partially blocked, would cause a significant redistribution of flood flow or a significant increase in flood levels. They are often, but not necessarily, areas of deeper flow or areas where higher velocities occur, and can also include areas where significant storage of floodwater occurs. Each flood has a flow conveyance area, and the extent and flood behaviour within flow conveyance areas may change with flood severity. This is because areas that are benign for small floods may experience much greater and more hazardous flows during larger floods (see also flood fringe areas and flood storage areas).
Freeboard	The height above the DFE or design flood used, in consideration of local and design factors, to provide reasonable certainty that the risk exposure selected in deciding on a particular DFE or design flood is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels and so on. Freeboard compensates for a range of factors, including wave action, localised hydraulic behaviour and levee settlement, all of which increase water levels or reduce the level of protection provided by levees. Freeboard should not be relied upon to provide protection for flood events larger than the relevant defined flood event of a design flood. Freeboard is included in the flood planning level and therefore used in the derivation of the flood planning area (see also defined flood event, design flood, flood planning area and flood planning level).
Frequency	The measure of likelihood expressed as the number of occurrences of a specified event in a given time. For example, the frequency of occurrence of a 20% annual exceedance probability or five-year average recurrence interval flood event is once every five years on average (see also annual exceedance probability, annual recurrence interval, likelihood and probability).
Future flood risk	The risk that new development within a community is exposed to as a result of developing on the floodplain.
Gauge height	The height of a flood level at a particular gauge site related to a specified datum. The datum may or may not be the AHD (see also Australian height datum).
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, it refers to 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 handbook, the hazard is flooding, which has the potential to cause damage to the community.
Hydraulics	The study of water flow in waterways; in particular, the evaluation of flow parameters such as water level, extent and velocity.
Hydrograph	A graph that shows how the flow or stage (flood level) at any particular location varies with time during a flood.
Hydrologic analysis	The study of the rainfall and runoff process, including the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
Intolerable risk	A risk that, following understanding of the likelihood and consequences of flooding, is so high that it requires consideration of implementation of treatments or actions to improve understanding, avoid, transfer or reduce the risk.
Life-cycle costing	All of the costs associated with the project from the cradle to the grave. This usually includes investigation, design, construction, monitoring, maintenance, asset and performance management and, in some cases, decommissioning of a management measure.
Likelihood	A qualitative description of probability and frequency (see also frequency and probability).
Likelihood of occurrence	The likelihood that a specified event will occur. (With respect to flooding, see also annual exceedance probability and average recurrence interval).
Local overland flooding	Inundation by local runoff on its way to a waterway, rather than overbank flow from a stream, river, estuary, lake or dam. Can be considered synonymous with stormwater flooding.
Loss	Any negative consequence or adverse effect, financial or otherwise.
Mathematical and 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 wellbeing of rivers and floodplains. This approach operates at two levels. At the strategic level, it allows for the consideration of flood hazard and associated social, economic, ecological and cultural issues in formulating statutory planning instruments, and development control plans and policies. At a site specific level, it involves consideration of the best way of

	developing land in consideration of the zonings in a statutory planning instruments, and development control plans and policies.
Minor, moderate and major flooding	These terms are often used in flood warnings to give a general indication of the types of problems expected with a flood.
Probability	A statistical measure of the expected chance of flooding. It is the likelihood of a specific outcome, as measured by the ratio of specific outcomes to the total number of possible outcomes. Probability is expressed as a number between zero and unity, zero indicating an impossible outcome and unity indicating an outcome that is certain. Probabilities are commonly expressed in terms of percentage. For example, the probability of 'throwing a six' on a single roll of a die is one in six, or 0.167 or 16.7% (see also annual exceedance probability).
Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from PMP 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 (WMO 1986). It is the primary input to probable maximum flood estimation.
Rainfall intensity	The rate at which rain falls, typically measured in millimetres per hour (mm/h). Rainfall intensity varies throughout a storm in accordance with the temporal pattern of the storm (see also temporal pattern).
Residual flood risk	The risk a community is exposed to that is not being remedied through established risk treatment processes. In simple terms, for a community, it is the total risk to that community, less any measure in place to reduce that risk. The risk a community is exposed to after treatment measures have been implemented. For a town protected by a levee, the residual flood risk is the consequences of the levee being overtopped by floods larger than the design flood. For an area where flood risk is managed by land-use planning controls, the residual flood risk is the risk associated with the consequences of floods larger than the DFE on the community.

Risk	'The effect of uncertainty on objectives' (ISO31000:2009). NOTE 4 of the definition in ISO31000:2009 also states that 'risk is often expressed in terms of a combination of the consequences of an event (including changes in circumstances) and the associated likelihood of occurrence'. Risk is based upon the consideration of the consequences of the full range of flood behaviour on communities and their social settings, and the natural and built environment (see also likelihood and consequence).
Risk analysis	The systematic use of available information to determine how often specified (flood) events occur and the magnitude of their likely consequences. Flood risk analysis is normally undertaken as part of a floodplain management study, and involves an assessment of flood levels and hazard associated with a range of flood events (see also flood study).
Risk management	The systematic application of management policies, procedures and practices to the tasks of identifying, analysing, assessing, treating and monitoring flood risk. Flood risk management is undertaken as part of a floodplain management plan. The floodplain management plan reflects the adopted means of managing flood risk (see also floodplain management plan).
Riverine flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam. Riverine flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.
Runoff	The amount of rainfall that drains into the surface drainage network to become stream flow; also known as rainfall excess.
Stage	Equivalent to water level. Both stage and water level are measured with reference to a specified datum (e.g., the Australian height datum).
Storm surge	The increases in coastal water levels above predicted astronomical tide level (i.e., tidal anomaly) resulting from a range of location dependent factors including the inverted barometer effect, wind and wave setup and astronomical tidal waves, together with any other factors that increase tidal water level (see also astronomical tide, wind set-up and wave set-up).
Stormwater flooding	Is inundation by local runoff caused by heavier than usual rainfall. It can be caused by local runoff exceeding the capacity of an urban stormwater drainage systems, flow overland on the way to waterways or by the backwater effects of mainstream flooding causing urban stormwater drainage systems to overflow (see also local overland flooding).
Temporal pattern	The variation of rainfall intensity with time during a rainfall event.

Tidal anomaly	The difference between recorded storm surge levels and predicted astronomical tide level.
Treatment options	The measures that might be feasible for the treatment of existing, future and residual flood risk at particular locations within the floodplain. Preparation of a treatment plan requires a detailed evaluation of floodplain management options (see also floodplain management plan).
Velocity of floodwater	The speed of floodwaters, measured in metres per second (m/s).
Vulnerability	The degree of susceptibility and resilience of a community, its social setting, and the natural and built environments to flood hazards. Vulnerability is assessed in terms of ability of the community and environment to anticipate, cope and recover from flood events. Flood awareness is an important indicator of vulnerability (see also flood awareness).
Wave set-up	The increase in water levels in coastal waters (within the breaker zone) caused by waves transporting water shorewards. The zone of wave set-up against the shore is balanced by a zone of wave 'set-down' (i.e. reduced water levels) seawards of the breaker zone. Wave setups of 2-4 m could occur during tropical cyclones.
Wind set-up	The increase in water levels in coastal waters caused by the wind driving the water shorewards and 'piling it up' against the shore. Wind set-up can be as high as 10 m in an extreme case, and often exceeds 2-3 m in typical tropical cyclones.

APPENDIX B
EXISTING CATCHMENT CHARACTERISTICS

Please refer to the Tamworth City Wide Floodplain Risk Management Report Volume 2.

FIGURES