LAKE MACQUARIE CITY COUNCIL

NORTH CREEK WARNERS BAY FLOOD RISK MANAGEMENT STUDY AND PLAN

DRAFT FINAL REPORT

OCTOBER 2025

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Project **North Creek Warners Bay Flood Risk Management Study and Plan**			**Project Number** **123045-01**		
Client Lake Macquarie City Council			**Client's Representative** Greg D Jones		
Project Manager Michael Reeves					
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Cover photo: New York Avenue Detention Basin (October 2023)

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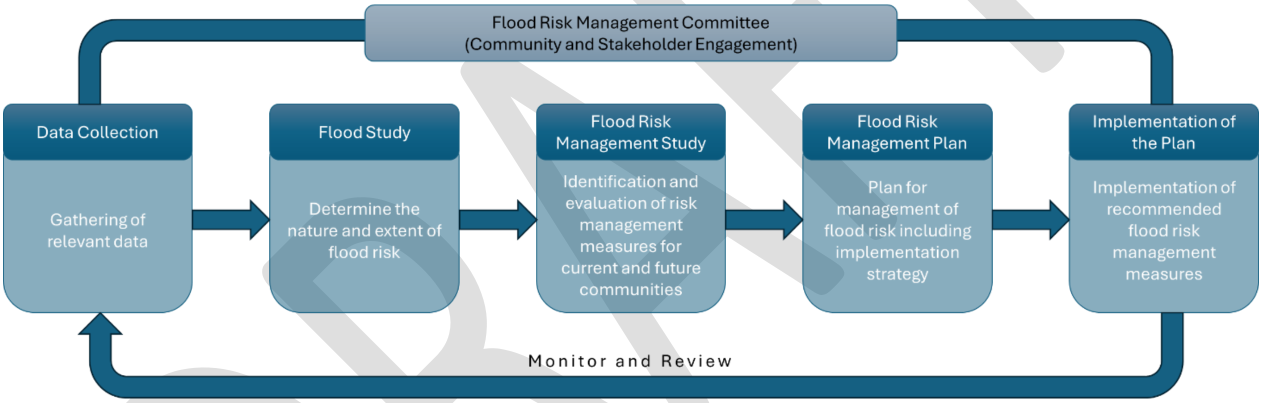
FOREWORD

The NSW State Government's Flood Prone Land Policy, contained in the Flood Risk Management Manual (NSW Department of Planning and Environment 2023), provides a framework to ensure the sustainable use of floodplain environments. The Policy is specifically structured to provide solutions to existing flooding problems in rural and urban areas. In addition, the Policy provides a means of ensuring that any new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

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

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



This document constitutes the third and fourth stages of the management process for the North Creek catchment. It presents a Flood Risk Management Study to assess potential flood risk mitigation measures and a prioritised list of measures that comprises the Flood Risk Management Plan for the catchment area.

This study was commissioned under the 2023 Flood Risk Management Manual (Reference 1), while it is recognised that the preceding flood study was developed under the 2005 NSW Floodplain Development Manual (Reference 2).

ACKNOWLEDGEMENTS

This study was undertaken by WMAwater Pty Ltd, on behalf of Lake Macquarie City Council. Lake Macquarie City Council has prepared this document with technical support from the NSW Government through its Floodplain Management Program. The document does not necessarily represent the opinions of the NSW Government or the Department of Climate Change, Energy, the Environment and Water.

A number of organisations and individuals have contributed both time and valuable information to this study. The assistance of the following in providing data and/or guidance to the study is gratefully acknowledged:

- Lake Macquarie Coastal Zone Management Committee
- Residents of the study area
- Lake Macquarie City Council
- Department of Climate Change, Energy, the Environment and Water
- NSW State Emergency Service

EXECUTIVE SUMMARY

Introduction

Lake Macquarie City Council engaged WMAwater to undertake the North Creek Warners Bay Flood Risk Management Study and Plan. The primary aim of this study is to provide a more informed understanding of flood risks and impacts across the study area and develop a long-term strategy to manage this risk. The Flood Risk Management Study seeks to investigate methods by which to manage existing, future and residual flood risk in the study area, assessing each option for its effectiveness in reducing flood risk in addition to its economic, environmental and social impacts. The Flood Risk Management Plan documents the decisions for the management of flood risk into the future by presenting a prioritised list of options to implement. This study provides an opportunity to revisit the existing North Creek Floodplain Risk Management Study and Plan (completed in 2010) and re-evaluate flood risk mitigation measures with up-to-date flood modelling undertaken as part of the North Creek Warners Bay Flood Study.

The study area comprises the entire North Creek catchment, located on the northern hinterland of Lake Macquarie. The catchment covers an area of approximately 5.3 km^2 and includes the suburb of Lakelands, the majority of the Warners Bay suburb and a small portion of the Speers Point suburb. The catchment is largely developed for residential and commercial/light industrial purposes. While North Creek is the primary waterway, there are a number of unnamed tributaries that traverse the catchment and join North Creek upstream of its outlet to Lake Macquarie at Warners Bay.

Available Data

WMAwater reviewed the existing studies related to flooding in North Creek, including the 2005 Flood Study, 2010 Floodplain Risk Management Study, 2012 Lake Macquarie Waterway Flood Study and the 2025 North Creek Warners Bay Flood Study, all completed by WMAwater.

Community Consultation

At the commencement of the project, information on the study was provided on Council's *Shape Lake Mac* website. Residents who participated in the North Creek Flood Study, either by responding to the initial survey or making a submission during public exhibition, were specifically contacted, informing them of Council's adoption of the Flood Study and the progression to the Flood Risk Management Study and Plan. The project was also overseen by the Coastal Zone Management Committee.

The Flood Problem

Flooding in the North Creek catchment may occur due to three key mechanisms:

- Local overland flooding;
- Mainstream (creek) flooding; and
- Lake Macquarie flooding.

This study investigates mitigating flood risks due to local catchment runoff, excluding flood risk due to Lake Macquarie. Flooding has occurred in the catchment in the past, most notably in 1990 and 2007.

Design Flood Event Results

Design flood event results used the modelling from the 2025 North Creek Warners Bay Flood Study, including the hydraulic hazard categorisation, flood function, flood emergency response classification and flood planning area, which were found to be suitable for the current study. 2050 and 2100 climate change scenarios were simulated as part of the current study, considering the combined effects of increased rainfall intensity and sea level rise. Flood hot spot areas were identified including New Road, Hughes Avenue, Lakelands Branch, the Hillsborough Road industrial area, local road low points in east Warners Bay, the King Street Branch, North Creek at the Hillsborough roundabout and the downstream area of North Creek.

Economic Impacts of Flooding

The economic impacts of flooding estimated in the 2025 flood study were reviewed and found to be appropriate. The assessment utilised a property database consisting of 1,483 properties. The average annual damage was estimated to be $1.6M. Approximately $900,000 of this was attributed to residential buildings, with the remaining being commercial, industrial and infrastructure damage. In the 1% AEP event, there was estimated to be over 600 properties affected, with 121 of these experiencing above floor flooding.

Floodplain Management Policy

Existing floodplain management policy was reviewed, including national provisions such as the Building Code of Australia, state provisions including the NSW Environmental Planning and Assessment Act 1979, NSW Flood Prone Land Policy, Section 733 of the Local Government Act 1993, the Flood Prone Land Package and a range of other provisions, and local provisions including the Lake Macquarie Local Environmental Plan, Lake Macquarie Development Control Plan and the Lake Macquarie Waterway Flooding and Tidal Inundation Policy.

Flood Risk Management Measures

A variety of flood risk management measures were investigated as part of this study. These measures can be separated into three broad categories:

- Flood modification measures, which modify the physical behaviour of a flood including depth, velocity and direction of flow paths.
- Property modification measures, which modify the existing land use and development controls for future development.
- Response modification measures, which modify the response of the community to flood hazard by educating flood affected residents about the nature of flooding so that they can make better informed decisions.

Options were identified and assessed with a high-level assessment, hydraulic assessment and detailed assessment (progressively and where applicable). A number of options such as culvert modifications, road raising, channel modifications and levees were not considered viable at the high-level assessment stage. Several options for detentions basins, low point relief and drainage upgrades were dismissed with a hydraulic assessment. A detailed assessment was undertaken for the remaining options, which included undertaking a cost-benefit analysis of flood modification options, considering the cost of construction versus the benefit to flood damages.

The options that were considered viable were then assessed using a multicriteria analysis, which considered not only flood impacts, but also construction feasibility, economic merits, social disruptions, environmental impacts, feasibility of the option, alleviation or exacerbation of property damages, risk to life and pressure on emergency responders among others.

Flood Risk Management Plan

The outcomes of the analysis undertaken in this study are presented herein with the recommended options for implementation in the Flood Risk Management Plan provided in Table 1 below.

Table 1: Flood Risk Management Plan

	Option ID Report Section	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	CBR	Priority
Flood Modification Options	FM01 8.3.2.4	Lakelands Embankment	Raising the existing embankment on the Lakelands Pond to 6 mAHD.	• Reduces flood levels downstream on Medcalf Street. • Reduces flood damages at properties downstream.	• May cause social disruption during construction. • Primarily commercial properties immediately downstream.	Council	May be eligible for NSW Government funding	$340,000	2.2	Low
	FM02 8.3.2.5	Wilton Close Basin	Increase storage capacity of existing reserve through excavation and construction of an embankment or wall.	• Reduces downstream inundation on private properties and roads. • Reduces flood damages.	• May cause social disruption during construction. • Safety and social perception of a high embankment in close proximity to residential properties.	Council	May be eligible for NSW Government funding	$490,000	2.6	Low
	FM03 8.3.3.1	Channel and Drainage Maintenance	Maintenance involves regularly removing unwanted vegetation and other debris from the drainage network, particularly at culverts, inlet pits and within channels. Council should identify specific areas prone to blockage and periodically review and update these areas based on feedback from the community. Council should also inspect and record channels and drainage structures following flood events to assess debris build up and clear blockages.	• Removal of vegetation and debris blockage from structures will enable a more efficient conveyance of water.	• The major release of debris is during the storm event, and hence regular maintenance may not necessarily reduce blockage during a flood event. • Vegetation in open channels is not a significant constraint to the hydraulic capacity of the channel.	Council	Internal	N/A	N/A	Low

	Option ID Report Section	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	CBR	Priority
Property Modification Measures	PM08 8.4.8	Future Flood Resilience Policy	A future flood resilience policy guides Council's operations and policies at a high level. This would likely feed into other Council operations such as coastal management, asset design, flooding and planning controls.	• Ensures future rainfalls are incorporated into current planning controls and infrastructure design (as sea level rise is currently).	• Uncertainties in future rainfall predictions. The changes expected for future rainfalls and runoff response is largely unknown.	Council	Internal	N/A	N/A	High
	PM04 8.4.4	Flood Planning Levels	The current adopted flood planning level is considered appropriate for mainstream flooding. It is recommended to use flood levels derived from the flood study. Levels could be updated considering: • Lower freeboard for overland flow situations. • Potential to include future climate (rainfall increase) – part of PM08. • PMF level for basement car parking.	• Ensures new buildings are protected to an appropriate level.	• Current freeboard of 500 mm in overland flow areas may be excessive given the scale in the range of flood events.	Council	Internal	N/A	N/A	High
	PM06 8.4.6	Flood Planning Policy	Flood planning policy is typically governed by the LEP and DCP, which outline flood-related development controls. Consideration should be given to the following: • Updating terminology and references. • Implementation of a matrix-style approach for controls. • Specifying requirements for modelling of flood impacts.	• Ensures adequate flood planning controls to reduce the flood damage and risk to life for new developments.	• Clarity in planning controls and their application to ensure adherence. • Will apply LGA-wide, so consistency and application across the entire LGA to be considered.	Council	Internal	N/A	N/A	High

	Option ID Report Section	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	CBR	Priority
Property Modification Measures			• Including controls for structural soundness and storage of hazardous goods. • Specifying evacuation or shelter-in-place requirements. • Application of the Special Flood Considerations in the LEP.							
	PM05 8.4.5	Flood Planning Area	It is recommended to adopt the provisional flood planning area as defined in the North Creek Flood Study.	• Ensures that flood planning controls are applied to lots that are flood affected.	• There are issues with the traditional approach of applying freeboard and 'stretching' the surface to identify the flood planning area, particularly with steep overland flow paths in urban areas.	Council	Internal	N/A	N/A	High
	PM07 8.4.7	Section 10.7 Certificates	Section 10.7 Certificates are required to show flood notation. This informs the land owner of flood risk and applicable development controls. Notations should be updated based on the flood planning area and Council to continue providing free flood information at the property level via the online tool.	• Informs land owners of flood affectation of the lot and applicable flood planning controls.	• Typically only accessed for the purpose of redevelopment or in the sale/purchase of land.	Council	Internal	N/A	N/A	High
	PM03 8.4.3	Flood Proofing	Flood proofing of non-residential buildings with temporary flood barriers (both existing and new structures, where floor levels are allowed to be lower). This could also be extended to existing residential development, but not recommended for new residential development – floor level controls should be applied instead.	• Reduces flood damage.	• Costs and implementation of flood proofing measures are the responsibility of the property owner / business.	Council (policy) and property owners (cost of flood proofing)	Internal (policy) Private (flood proofing)	Varies	N/A	Medium

	Option ID Report Section	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	CBR	Priority
	PM01 8.4.1	Voluntary House Raising	Physically raise existing dwelling structures above the flood planning level. Three main areas are identified for further investigation covering approximately 28 properties.	• Reduces exposure to flood damage.	• Generally there is a low uptake of voluntary house raising due to the cost and inconvenience.	Council and Owners	May be eligible for NSW Government funding, Owner	$30,000 to $100,000	<1	Very Low
Response Modification Measures	RM01 8.5.1	Flood Emergency Management Planning and Coordination	It is recommended that the SES: • Use the information and modelling developed as part of the North Creek Flood Study to update their flood intelligence and local flood plan for the Lake Macquarie LGA. • Consider providing an updated brochure or information on their website for the flood risk in the LGA – specifically creek and overland flooding. It is recommended that Council and SES: • Hold regular meetings of all responders and training exercises between flood events to identify roles and responsibilities in practice and build relationships between agencies and/or community groups.	• Flood emergency planning enables a more coordinated, timely and targeted response to flood events.	• As the interval between flood events increases, the coordination of flood response can lack attention.	Council and SES	Internal	N/A	N/A	High
	RM02 8.5.2	Community Flood Awareness and Education	It is recommended to design and implement an ongoing community flood education program to maintain a high level of flood awareness and understanding of the risk and	• An informed community can better respond to flood risks, including preparation for and	• Community education programs are typically well received by those interested in and already aware of flood risk, and it is difficult to engage the	Council	Internal with opportunities for State Government assistance.	Varies	N/A	High

	Option ID Report Section	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	CBR	Priority
Response Modification Measures			appropriate response to flooding in the North Creek catchment (likely in conjunction with the wider LGA).	making wise decisions during flood events.	wider community.					
	RM03 8.5.3	Flood Warning System	It is recommended that the severe weather and severe thunderstorm warnings issued by the BoM be used to prepare for potential flash flooding events. Community awareness campaigns may assist residents in interpreting warnings from the BoM, anticipating the impacts and preparing accordingly. The Lake Macquarie FloodWatch system provides a platform for monitoring current conditions during these events. Council and SES operations should also be reviewed in light of this study.	• Enable Council and SES to be on alert to potential flash flooding events. The community can also benefit by being aware of potential flash flooding and respond accordingly.	• Education about what these warnings mean and actions that should be taken by residents in different locations is key.	Council and SES.	Internal	N/A	N/A	Medium
	RM04 8.5.4	Improvements to Drive Safety	Installation of flood signs and flood depth indicators can improve driver safety, in conjunction with community education about the risks of driving through floodwaters. It is recommended that a detailed study is undertaken to confirm the preferred locations, residual flood risk (i.e. need for road closure) and safe alternative routes and how traffic can be diverted in flood events. Following the detailed study, installation can proceed in accordance with the outcomes of that study.	• One of the primary risks for flash flooding in urban areas is motorists driving through floodwaters. This reduces that risk by warning motorists of flooded roads.	• There is the chance that these signs and warnings will be ignored by motorists.	Council and TfNSW where applicable.	Council and TfNSW, with opportunities for State Government funding.	Not Estimated	N/A	Medium

LIST OF ACRONYMS

AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff
BASIX	Building Sustainability Index
BoM	Bureau of Meteorology
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DCP	Development Control Plan
DPIE	Department of Planning, Industry and Environment
ERP	Emergency Response Planning
EY	Exceedances per Year
FEO	Flooded Exit Overland
FER	Flooded Exit Road
FERC	Flood Emergency Response Classification
FIE	Flooded Isolated Elevated Areas
FIS	Flooded Isolated and Submerged Areas
FPL	Flood Planning Level
FRMS	Flood Risk Management Study
FRMS&P	Flood Risk Management Study and Plan
GPT	Gross Pollutant Trap
IC	Indirect Consequences
LEP	Local Environmental Plan
LGA	Local Government Area
LiDAR	Light Detection and Ranging (aerial survey technique)
mAHD	metres above Australian Height Datum
MHL	Manly Hydraulics Laboratory
OSD	On-Site Detention
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
SES	State Emergency Service
TUFLOW	1D and 2D flood and tide simulation software (hydraulic model)
VHR	Voluntary House Raising
VP	Voluntary Purchase
WBNM	Watershed Bounded Network Model (hydrologic model)
WSUD	Water Sensitive Urban Design

ADOPTED TERMINOLOGY

Australian Rainfall and Runoff (ARR, ed Ball et al, 2019) recommends terminology that is not misleading to the public and stakeholders. Therefore the use of terms such as “recurrence interval” and “return period” are no longer recommended as they imply that a given event magnitude is only exceeded at regular intervals such as every 100 years. However, rare events may occur in clusters. For example, there are several instances of an event with a 1% chance of occurring within a short period, for example the 1949 and 1950 events at Kempsey. Historically the term Average Recurrence Interval (ARI) has been used.

ARR 2019 recommends the use of Annual Exceedance Probability (AEP). AEP is the probability of an event being equalled or exceeded within a year. AEP may be expressed as either a percentage (%) or 1 in X. Floodplain management typically uses the percentage form of terminology. Therefore a 1% AEP event or 1 in 100 AEP has a 1% chance of being equalled or exceeded in any year.

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

For events more frequent than 50% AEP, expressing frequency in terms of Annual Exceedance Probability is not meaningful and misleading particularly in areas with strong seasonality. Therefore the term Exceedances per Year (EY) is recommended. Statistically a 0.5 EY event is not the same as a 50% AEP event, and likewise an event with a 20% AEP is not the same as a 0.2 EY event. For example an event of 0.5 EY is an event which would, on average, occur every two years. A 2 EY event is equivalent to a design event with a 6 month ARI where there is no seasonality, or an event that is likely to occur twice in one year.

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

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

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	19.5
	0.02	2	50	49.5
	0.01	1	100	99.5
Very Rare	0.005	0.5	200	199.5
	0.002	0.2	500	499.5
	0.001	0.1	1000	999.5
	0.0005	0.05	2000	1999.5
Extreme	0.0002	0.02	5000	4999.5
			↓	
			PMP/ PMP Flood	

1. INTRODUCTION

1.1. Study Objectives

Lake Macquarie City Council (Council) engaged WMAwater to undertake the North Creek Warners Bay Flood Risk Management Study and Plan (FRMS&P). A Flood Study (Reference 3) was completed by WMAwater prior to this FRMS&P to define the existing flood behaviour and current flood risk. The FRMS&P has been undertaken in accordance with the NSW Government's Flood Prone Land Policy and the 2023 Flood Risk Management Manual (Reference 1).

A FRMS&P (Reference 4) was previously completed in 2010 and this study constitutes a review and update of the previous study, utilising the latest available flood modelling undertaken as part of the recent flood study (Reference 3).

The primary aim of this FRMS&P is to provide a more informed understanding of flood risks and impacts across the study area and develop a long-term strategy to manage this risk. The FRMS&P expands upon the information provided in the updated Flood Study (Reference 3) to further understand and plan for the nature and extent of flood risk throughout the study area. The Flood Risk Management Study (FRMS) seeks to investigate methods by which to manage existing, future and residual flood risk in the study area, assessing each option for its effectiveness in reducing flood risk in addition to its economic, environmental and social impacts. The Flood Risk Management Plan documents the decisions for the management of flood risk into the future by presenting a prioritised list of options to implement. This study provides an opportunity to revisit the existing FRMS&P (completed in 2010) and re-evaluate flood risk mitigation measures with up-to-date flood modelling.

1.2. Study Area

The study area comprises the entire North Creek catchment, located on the northern hinterland of Lake Macquarie. The catchment covers an area of approximately 5.3 km^2 and includes the suburb of Lakelands, the majority of the Warners Bay suburb and a small portion of the Speers Point suburb. The catchment lies entirely within the Lake Macquarie City Council Local Government Area (LGA). The catchment is largely developed for residential and commercial/light industrial purposes. The only remaining areas of natural bushland are located in the eastern portion of the catchment and a narrow band along the catchment divide in the north, in addition to small pockets within the catchment. The majority of the urban development has a road system with kerb and gutter and piped drainage system. There are a number of culvert and bridge crossings of the waterways that flow through the catchment. Other informal structures such as fences have been constructed on the floodplain. The study area is shown in Figure 1.

1.3. Catchment Description

While the primary waterway is North Creek itself, it has a number of unnamed tributaries. Each of these are described below.

North Creek

North Creek itself drains a portion of the catchment to the east and becomes a formal channel upstream of a commercial area off Hillsborough Road (Photo 1). It crosses under two driveways, through a concrete channel (Photo 2) and under the Hillsborough Road service road (3 x 1.05 m diameter pipes) before running parallel to Hillsborough Road. It is here that North Creek officially commences and downstream of this location the creek is in a semi-natural state. It crosses the service road again (2 x 3.6 m x 0.8 m box culverts) and runs through a low-lying pocket of remnant vegetation where the creek spreads out laterally upstream of King Street (Photo 3). The King Street crossing is located near the roundabout intersecting King Street with Medcalf Street, Macquarie Road and Hillsborough Road. This intersection is quite low-lying and has been subject to inundation in the past (see Section 1.4). The creek is then conveyed under a pedestrian bridge, under King Street (4 x 2.4 m x 1.4 m box culverts) and two driveway crossings (Photo 4). The creek then narrows (Photo 5) as it is constricted between development to the Walker Street crossing (3 x 2.55 m x 2.0 m box culverts). Upstream of Walker Street a water level gauge has recently been installed. Downstream of Walker Street the creek is flanked by heavy vegetation and the creek has fairly flat banks. Flows in excess of the channel capacity can inundate large areas that include residential development. There is a low-level weir located just upstream of Martin Street (Photo 6) and there are also pedestrian bridges located at Albert Street (Photo 6) and John Street (Photo 7). The lower parts of North Creek are estuarine in character, with the main channel being approximately 10 m wide with an invert at approximately - 1 mAHD. The creek is conveyed under a bridge at The Esplanade (Photo 9) immediately before it discharges into Lake Macquarie (Photo 10).

Photo 1: Channel upstream of Hillsborough Road

Photo 2: Section of concrete channel through the Hillsborough Road commercial area

Photo 3: North Creek upstream of King Street

Photo 4: North Creek crossing King Street

Photo 5: North Creek channel upstream of Walker Street

Photo 6: North Creek at Martin Street (*Google Street View*)

Photo 7: North Creek at Albert Street (*Google Street View*)

Photo 8: North Creek at John Street (*Google Street View*)

Photo 9: The Esplanade bridge over North Creek

Photo 10: North Creek outlet to Lake Macquarie

King Street Branch

This branch drains the southeastern portion of the catchment. The flow path runs through a residential area and fills several low-lying areas. Downstream of Yorston Street there is a drainage swale that conveys overland flows (Photo 11). At King Street (Photo 12), flow is conveyed through a box culvert (2 x 1.8 m x 1.17 m) and into a series of concrete and grass-lined channels that cross through private property (Photo 13). The 2005 flood study (Reference 5) noted that there were several obstructions on this branch such as fences and private pedestrian bridges, which is assumed to still be the case (Photo 14). This branch joins North Creek just upstream of Walker Street.

Photo 11: Drainage swale downstream of Yorston Street (*Google Street View*)

Photo 12: Drainage swale upstream of King Street

Photo 13: King Street Branch downstream of King Street (*Google Street View*)

Photo 14: Example of a fence crossing the King Street Branch (*Reference 5*)

Lakelands Branch

The Lakelands Branch commences downstream of the Lakelands Pond which captures runoff from a portion of the Lakelands suburb. A surcharge pit (Photo 15) conveys flow to a box culvert (2.7 m x 0.75 m) when the water level in the pond rises high enough. The culvert discharges into a concrete lined open channel (Photo 16). The Lakelands Branch joins north Creek just upstream of the Martin Street weir.

Photo 15: Lakelands Pond surcharge pit

Photo 16: Concrete lined open channel downstream of Lakelands Pond

Western Tributary (Biddabah Creek)

The largest tributary of North Creek is referred to as the western tributary in the previous flood study (Reference 5), although is understood to be referred to as Biddabah Creek. The tributary originates from the headwaters of Munibung Hill and flows from north to south through the western portion of the North Creek catchment. A channel forms near Grasmere Way and traverses grassed and bushland areas around recent development in the upper catchment. Upstream of Windross Drive there is a small wetland area (Photo 17). Flows are conveyed under Windross Drive (Photo 18) via shallow box culverts (5 x 1.5 m x 0.6 m) and through a bushland area to the Medcalf Street culvert (2 x 1.05 m diameter pipes, Photo 19). Downstream of Medcalf Street, the creek is conveyed through a vegetated channel bordered by residential development (Photo 20). The tributary joins North Creek near Feighan Oval.

Photo 17: Biddabah Creek wetland

Photo 18: Biddabah Creek crossing Windross Drive

Photo 19: Biddabah Creek crossing Medcalf Street

Photo 20: Biddabah Creek channel downstream of Medcalf Street

Seaman Avenue Branch

The Seaman Avenue Branch (as it was called in the previous flood study, Reference 5) is also known as Bangalow Palm Creek, and is a branch of the Western Tributary. The upper portion of the branch is part of the urban drainage system, which discharges into a concrete-lined open channel downstream of Ruswell Avenue. This channel runs in a southeast direction and crosses Medcalf Street (3 x 0.95 m x 0.8 m box culvert, Photo 21) and Seaman Avenue (3.25 m x 0.8 m box culvert, Photo 22). Downstream of Seaman Avenue the channel is grass-lined and runs adjacent to Feighan Oval (Photo 23). This branch joins the Western Tributary at the northern corner of Feighan Park.

Photo 21: Concrete-lined open channel downstream of Medcalf Street (*Google Street View*)

Photo 22: Concrete-lined open channel upstream of Seaman Avenue

Photo 23: Open channel downstream of Seaman Avenue

Vermont Place Branch

The Vermont Place Branch begins at the Vermont Place basin in the east of the catchment. The basin outlets into an open concrete invert and grassed swale. The swale flows northwest and under Myles Avenue (2 x 1.85 m x 0.45 m box culvert, Photo 24). The channel continues northwest towards the New York Avenue basins (Photo 25). A Gross Pollutant Trap (GPT) diverts low flows to the basins with greater flows continuing in the channel (Photo 26). From New York Avenue the path flows through a vegetated section of channel (Photo 27), southwest of the Hillsborough commercial area and northeast of Warners Bay High School sports fields. The branch converges with North Creek immediately downstream of the Hillsborough Road, service road exit.

Photo 24: Vermont Place Branch crossing Myles Avenue

Photo 25: Open channel downstream of Myles Avenue

Photo 26: Looking upstream over New York Avenue GPT on Vermont Place Branch

Photo 27: Vegetated channel, north of New York Avenue basins

1.4. Demographics

Understanding the social characteristics of the study area can help in ensuring appropriate risk management practices are adopted, and shape the methods used for community engagement. Census data regarding house tenure and age distribution can also provide an indication of the community's lived experience with recent flood events, and hence an indication of their flood awareness. Information for the Warners Bay suburb was obtained from the latest 2021 census data from the Australian Bureau of Statistics (ABS). A summary of the relevant information is contained in Table 2.

Table 2: Demographic Overview of Warners Bay and Lakelands Suburbs (Reference 6)

Census Category	Census Statistic	Warners Bay	Lakelands	NSW
Population	Total Population	8,237	1,445	8,072,163
	Male	46.9%	48.3%	49.4%
	Female	53.1%	51.7%	50.6%
Age	Median	46	43	39
	0-14 years	16.0%	18.6%	18.2%
	15-64 years	58.4%	65.6%	64.1%
	65-84 years	22.4%	14.7%	15.4%
	> 85 years	3.2%	1.0%	2.3%
Dwellings	Occupied dwellings	94.6%	99.0%	90.6%
	Unoccupied dwellings	5.5%	0.8%	9.4%
	Separate house	67.6%	94.1%	65.6%
	Semi-detached	23.1%	5.7%	11.7%
	Flat/Apartment	8.9%	0.0%	21.7%
	Average people per dwelling	2.3	2.8	2.6
	No car at dwelling	5.0%	1.0%	9.0%
Households	Family households (%)	68.8%	81.3%	71.2%
	Lone person households (%)	29.1%	17.4%	25.0%
	Group households (%)	2.1%	1.4%	3.8%
Tenure	Owned (%)	75.1%	88.4%	64.0%
	Rented (%)	23.6%	10.3%	32.6%
Median Weekly Income	Personal	$766	$939	$813
	Family	$2,004	$2,705	$2,185
	Household	$1,494	$2,315	$1,829
Cultural Diversity	Country of birth	Australia (84.6%)	Australia (85.6%)	Australia (65.4%)
	Top Non-Australian countries of birth	England (3.1%)	England (2.1%)	China (3.1%)
		New Zealand (1.2%)	New Zealand (1.5%)	England (2.9%)
		Scotland (0.7%)	India (0.9%)	India (2.6%)
		Germany (0.7%)	Scotland (0.8%)	New Zealand (1.5%)
	English only used at home	91.2%	89.9%	67.6%
	Non-English language used at home	7.3%	11.1%	29.5%
	Top Non-English languages	Arabic, Macedonian, Mandarin, German, Spanish.	Punjabi, Cantonese, Mandarin, German, Sinhalese.	Mandarin, Arabic, Cantonese, Vietnamese, Hindi.
Education	Year 12 and above (%)	63.3%	73.2%	66.6%
Work	In Labour Force (%)	57.9%	67.8%	58.7%
	Work Full Time (%)	54.5%	53.6%	55.2%
	Work Part Time (%)	35.1%	37.7%	29.7%

The characteristics noted above are considered in the community engagement strategy and when considering response modification options, such as flood education, warning or evacuation systems. Key characteristics include:

- Approximately 17% of the population are under the age of 15 and 25% are over the age of 65. These groups of people are more likely to be vulnerable and require assistance during flood events to evacuate and more likely to require assistance with recovery following a flood. Warners Bay has a higher proportion of elderly people who are more likely to be vulnerable than the state average.
- There is a high proportion of dwellings that are separate and semi-detached houses. These houses can be affected by above floor flooding (more so than apartments). The occupancy rate is also higher than the state average and the occupants are likely to have access to a vehicle.
- Almost 30% of households in Warners Bay have single occupants. These people may be at a greater risk of being unaware of flood warnings or evacuation orders.
- There is a higher proportion of people who own their own home than the state average, which indicates that these households are more likely to be long-term residents who are more aware of local flooding issues. Home ownership may also affect the willingness to participate in property modification measures.
- The median weekly income for individuals, families and households is slightly lower than the state average for Warners Bay and higher than the state average for Lakelands. This may suggest that the value of house contents in Lakelands may be above average (for flood damages), and the ability to recover from flooding events may also be average or above average, while it may be lower for Warners Bay.
- Both Warners Bay and Lakelands have a high proportion of people who were born in Australia (approximately 85%) and a high proportion of people who speak only English at home (approximately 90%). This may indicate that flood signs, warnings, messages, brochures, etc. in English are likely to be understood by the majority of the population in the study area. The need for these materials to be translated or for interpretation services to be required during emergencies for effective public education strategies is likely to be limited.
- People are mostly well-educated (at least 60% attaining year 12 or above). This suggests that there is a reasonable capacity to understand technical information through education.
- Lakelands has a higher proportion of people in the work force at almost 70%, while Warners Bay is just under 60%. Of these people, approximately 90% are engaged in full time or part time work. This means that at least half the population are in the workforce and may not be at their property during a flood event. This may limit their ability to minimise property damage and may increase their potential exposure to flood risks during commutes.

1.5. Natural Environment

The Warners Bay area is largely developed for residential and commercial/light industrial purposes. The only remaining areas of natural bushland are located in the eastern portion of the catchment and a narrow band along the catchment divide in the north, in addition to small pockets within the catchment. The natural areas that do remain, however, are of ecological significance and have high conservation value as they provide habitat for threatened flora and fauna.

Native vegetation communities were mapped across the Lake Macquarie LGA by Stephen Bell and Collin Driscoll and periodically updated by Council. This mapping was updated in 2023 (version 2) and identifies the following in the study area:

- Hunter Valley Moist Forest on the western side of the catchment (Munibung Hill).
- Coastal Plans Stringybark – Apple Forest on the northern and eastern sides of the catchment, as well as around the Lakelands Pond.
- Sugarloaf Lowlands Bloodwood – Apple – Scribbly Gum Forest and Coastal Sheltered Apple – Peppermint Forest on the eastern side of the catchment.
- Lake Macquarie Spotted Gum Forest and Hunter Valley Moist Forest on the eastern and southern sides of the catchment.
- Estuarine Paperbark Scrub Forest around Lakelands Pond and upper North Creek catchment.
- Swamp Mahogany-Paperbark Forest on the North Creek banks upstream of Walker Street.
- Foreshore Redgum-Ironbark Forest, Mangrove-Estuarine Complex and Swamp Oak Rushland Forest on the North Creek banks downstream of Walker Street.
- Foreshore Redgum – Ironbark Forest on Biddabah Creek.
- Swamp Mahogany – Livistona Swamp Forest near Feighan Oval.
- Estuarine Paperbark Scrub Forest around the Lakelands Pond and upper North Creek catchment.

These areas are primarily located along waterways or in the upper catchment areas and hence these ecological communities should be considered when developing flood mitigation measures. In particular, there are communities that are listed as Threatened Species under the NSW Biodiversity Conservation Act 2016 and/or the Commonwealth Environment Protection and Biodiversity Conservation Act, specifically:

- Swamp Oak – Rushland Forest, listed as endangered (under Swamp Oak Floodplain Forest)
- Estuarine Paperbark Scrub Forest, listed as endangered (under Swamp Sclerophyll Forest on Coastal Floodplains)
- Foreshore Redgum – Ironbark Forest, listed as endangered (under River-flat Eucalypt Forest on Coastal Floodplains)

These areas in particular are located on Biddabah Creek, around the Lakelands Pond and on North Creek.

1.6. Heritage

In NSW, there are different types of statutory lists for local, state and national heritage items. Local heritage items are listed in the heritage schedule of a local council's Local Environmental Plan (LEP) or regional environmental plan. State heritage items are places and items of particular importance to the people of NSW, listed on the State Heritage Register. National heritage items are listed on the National Heritage List, established by the Australian Government to document places of outstanding heritage significance to Australia. In addition to these, there are other statutory listings such as the Aboriginal sites register. It is important in floodplain management and in the development of flood mitigation measures to be aware of these heritage items and where an additional heritage assessment may be required to ensure heritage items are preserved.

The State Heritage Inventory (Reference 7) is an online database containing heritage items in NSW including Aboriginal Places, State Heritage Register, Interim Heritage Orders, State Agency Heritage Registers and LEPs. In the North Creek catchment there are several sites located on the western edge of the catchment (near Speers Point) listed in the LEP, including:

- Cottage,
- Ali's Palace,
- The Knoll,
- Nature reserve with Permian fossil insect horizon.

There are no other listed heritage items within the North Creek catchment.

2. AVAILABLE DATA

2.1. Previous Studies

2.1.1. North Creek Flood Study, Webb, McKeown & Associates, 2005

Webb, McKeown & Associates (now WMAwater) completed the North Creek Flood Study for Lake Macquarie Council in 2005 (Reference 5). A WBNM hydrologic model and MIKE-11 hydraulic model were developed to simulate flood behaviour for North Creek and its tributaries. The WBNM model consisted of 35 sub-areas that simulated rainfall runoff for the North Creek catchment. The WBNM model adopted a catchment lag (C) value of 1.29, initial loss of 0 mm and continuing loss of 2.5 mm/h. The 1D MIKE-11 model covered the North Creek channel and main tributaries (as outlined in Section 1.2). A calibration was not undertaken due to the lack of available data and certainty of location combined with the limitations of the 1D modelling.

Design storms were simulated used Australian Rainfall and Runoff (ARR) 1987 (Reference 8). The 20%, 10%, 5%, 2%, 1% and 0.5% Annual Exceedance Probability (AEP) events and the Probable Maximum Flood (PMF) events were simulated. The study provided peak flood level profiles, hydraulic categorisation and hazard categorisation. A sensitivity analysis included testing of structure blockage, Mannings 'n' roughness, rainfall depths, catchment lag factor and Lake Macquarie tailwater level were undertaken. A flood damages assessment was also undertaken for 262 properties, with average annual damages (AAD) estimated to be $440,000 (2005 dollars).

While this modelling is now considered to be outdated, there are many components of this study that are relevant to the current study, including the survey of major cross-drainage structures, approximately 70 cross sections and floor levels for 160 buildings across the catchment, in addition to the flood information collected regarding the February 1990 event.

2.1.2. North Creek Floodplain Risk Management Study, WMAwater, 2010

WMAwater undertook the North Creek Floodplain Risk Management Study (FRMS) for City of Lake Macquarie Council in 2010 (Reference 4). The FRMS undertook a review of the Flood Study (Reference 5) modelling, considering the June 2007 event which occurred after the Flood Study was completed. Flood information from the 2007 event was obtained through a questionnaire sent out to residents, with 33 flood marks being subsequently surveyed. Parameters in the hydraulic model were adjusted in order to match the flood marks for the 2007 event. Design flood events were re-simulated with the updated flood model, including 100% blockage of key hydraulic structures.

The FRMS assessed that even in relatively frequent events (such as the 10% AEP), over 20 building floor levels would be inundated. The estimate of AAD for the catchment was $700,000 with the updated modelling. The FRMS investigated a range of flood risk mitigation measures including flood modification measures, property modification measures and response modification measures. Some of the recommended measures include:

- Retarding basins (for future development only);

- Removal of structures within channels and introduction of a maintenance scheme;
- Maintain a database of local drainage issues;
- Local Flood Plan to be prepared by the NSW State Emergency Service (SES);
- Implement a flood awareness program;
- Update Development Control Plan (DCP) to include variable flood planning levels (FPLs) for commercial and industrial development, and include minimum crest levels for basement carparks;
- Review on-site detention (OSD) policy and ensure that all development applications (DAs) in the floodplain are supported by a flood study;
- House raising to be investigated for 15 houses inundated in the 10% AEP event;
- Flood proofing to be promoted as a means of reducing flood damages for non-residential buildings;
- Undertaking a detailed flood study to identify overland flow areas;
- Progressively upgrade pipes when redevelopment occurs;
- Periodically review planning controls and optimise the policy on managing overland flow;
- Council to incorporate sea level rise and climate change into FPLs;
- Continued use of water sensitive urban design (WSUD) measures were supported.

2.1.3. Lake Macquarie Waterway Flood Study, WMAwater 2012

The 2012 Lake Macquarie Waterway Flood Study (Reference 9) was initiated by Council to research and update the prior 1998 Lake Macquarie Flood Study, to incorporate predicted impacts of climate change. It is of relevance to the present study as it provides design flood levels within Lake Macquarie waterway.

The study included modelling of the June 2007 long weekend event and incorporated detailed bathymetric survey within the Swansea Channel. The study established a hydrologic model (WBNM) and hydraulic model (TUFLOW), which were calibrated and validated to the February 1990 and June 2007 long weekend events. The following conditions were adopted for the design lake flood analysis:

- 0.1 mAHD initial water level in the Lake Macquarie waterway (average lake level);
- 48 hour critical rainfall storm duration inflows (for all design events except the PMF) in conjunction with the respective ocean tides;
- design ocean levels based on the design levels in Fort Denison/Sydney Harbour plus a wave setup component (0.2 m assumed for the 1% AEP event);
- all design tides assume the “shape” of the tidal hydrograph of the May 1974 east coast low event as recorded at Fort Denison in Sydney Harbour. This tidal hydrograph approximates the 1% AEP design ocean event;
- the wave setup component was assumed to increase linearly to peak at the same time as the ocean peak;
- the peak ocean level was coincided with the peak rainfall burst in the 48 hour duration event.

Peak ocean levels and peak catchment runoff are unlikely to coincide. The study used an envelope (i.e. whichever event produced the highest level) of the:

- 1% AEP catchment flood ("rain dominated event") in conjunction with a 5% AEP elevated ocean level ("ocean dominated event"); and
- 5% AEP catchment flood ("rain dominated event") in conjunction with a 1% AEP elevated ocean level ("ocean dominated event"),

to establish the 1% AEP design flood level for the lake. A similar approach was used for the other design events.

Design lake flood levels in Lake Macquarie waterway from Reference 9 are reproduced in Table 3 and are based on ARR 1987 (Reference 8) rainfall data. Climate change scenarios were analysed for the 20%, 5% and 1% AEP events and are also summarised in Table 3. The lake flood levels shown in Table 3 exclude wave runup on the foreshore areas within the lake or adjoining the Swansea Channel.

Table 3: Design Lake Flood Levels from Lake Macquarie Waterway Flood Study (Reference 9)

Event (AEP)	Peak Lake Level (m AHD)					
	Existing	Sea Level Rise		Rainfall Increase		
		+ 0.4m	+ 0.9m	10%	20%	30%
50%	0.65	1.04	1.54	0.71	0.77	0.83
20%	0.82	1.21	1.71	0.88	0.94	1.00
10%	0.94	1.32	1.81	1.03	1.11	1.19
5%	1.23	1.61	2.10	1.32	1.40	1.49
2%	1.38	1.74	2.20	1.50	1.61	1.72
1%	1.50	1.86	2.32	1.62	1.73	1.84
0.5%	1.69	2.05	2.51	1.81	1.92	2.03
0.2%	1.87	2.23	2.69	1.99	2.10	2.21
PMF	2.45	2.81	3.27	2.57	2.68	2.79

Note: Underlined levels have been derived from interpolation from model results rather than actual modelling

It should be noted that the application of the 2019 revision of ARR will change the design flood levels shown in Table 3.

2.1.4. North Creek Warners Bay Flood Study, WMAwater 2025

WMAwater completed the North Creek Warners Bay Flood Study for Lake Macquarie City Council in 2025 (Reference 3) and it represents the most up-to-date design flood modelling available. A WBNM hydrologic model and TUFLOW hydraulic model were developed to simulate flood behaviour for North Creek and its tributaries, as well as overland flow throughout the catchment. The WBNM model consisted of 245 sub-areas that simulated rainfall runoff for the North Creek catchment. The TUFLOW model consisted of a 1 m by 1 m regular 2D grid with adjustments made to ensure correct representation of hydraulic features such as channels. The stormwater network was represented as 1D elements and the simulated runoff hydrographs from the WBNM model applied to the TUFLOW model as inflows. The TUFLOW model was calibrated to the February 1990 and June 2007 flood events, with the June 2022 event used to validate the modelled water level and catchment response at the Walker Street gauge.

Design storms were simulated using ARR 2019 (Reference 10). The 50%, 20%, 10%, 5%, 2%, 1% and 0.5% Annual Exceedance Probability (AEP) events and the Probable Maximum Flood

(PMF) event was simulated. The adopted critical durations ranged from 30 minutes to 90 minutes. The study provided design flood depths, levels, velocities, hydraulic hazard and hydraulic categories. A sensitivity analysis included testing of structure blockage, Mannings ‘n’ roughness, rainfall losses, catchment lag factor and Lake Macquarie tailwater levels. Climate change sensitivity was also analysed considering increases in rainfall intensity and sea level rise. A flood damages assessment was also undertaken with a property database consisting of 1,483 properties. The AAD was estimated to be $1.6M. Approximately $900,000 of this was attributed to residential buildings, with the remaining being commercial, industrial and infrastructure damage. In the 1% AEP event, there was estimated to be over 600 properties affected, with 121 of these experiencing above floor flooding.

All the data compiled for the flood study was available for the current study. The flood models (WBNM and TUFLOW models) were adopted for the current study.

2.2. Site Visit

A site visit was conducted on 25 October 2023, attended by WMAwater staff and Council staff. Key flood problem areas were visited and the feasibility of potential management measures was considered.

3. COMMUNITY CONSULTATION

One of the central objectives of the FRMS process is to actively liaise with the community throughout the process, keeping them informed about the study as it progresses, identifying community concerns and gathering information from the community on potential management options and their support for them. The Flood Study (Reference 3) undertook extensive community consultation including obtaining flood information for the calibration of the flood model and identification of flood hot spots. Community consultation undertaken as part of this study is outlined in the following sections.

3.1. Provision of Information

Information on the study was provided on Council's *Shape Lake Mac* website (https://shape.lakemac.com.au/north-creek). This is the same page used for the North Creek Flood Study. Residents who made submissions during the flood study (either a response to the initial questionnaire or a submission on the draft report during public exhibition) were specifically contacted, informing them of the adoption of the flood study and the progression to the next stage being the FRMS&P.

3.2. Coastal Zone Management Committee

This FRMS&P was overseen by Council's Coastal Zone Management Committee (CZMC), consisting of councillors, Council staff, representatives from the community, SES and DCCEEW. Regular meetings were held in which CZMC members were provided an update on the progress of the project as well as the draft report. Input from the CZMC, including from community members was sought during the project.

3.3. Public Exhibition

To be completed.

4. THE FLOOD PROBLEM

Many catchments entering the Lake Macquarie waterway experience poor drainage due to a combination of flat terrain, densely developed areas which can restrict flow paths, restricted openings under road or rail crossings, the presence of localised sag points that are not drained adequately, and/or periodically elevated lake levels. Localised problems also arise due to the age, design and maintenance of urban drainage systems. These problems will likely be exacerbated as ocean and lake levels rise because of projected sea level rise or rainfall increase due to anthropogenic climate change.

4.1. Causes of Flooding

Flooding within the study area may occur due to three key mechanisms.

1. Intense rainfall over the local catchment which exceeds the capacity of the urban stormwater (pit and pipe network) and flows overland to creeks and waterways. This is known as overland flow. Runoff in excess of the stormwater network capacity can accumulate at sag points and in areas with very little ground slope to facilitate drainage.
2. Elevated water levels within North Creek and its tributaries as a result of intense rainfall over the North Creek catchment. This is known as mainstream flooding. The levels in the creek are driven by the amount of runoff produced by the catchment but can be affected by constrictions along the channel (such as culverts, blockages, vegetation, fences, etc.).
3. Elevated levels in the Lake Macquarie waterway due to intense widespread rainfall over the Lake Macquarie catchment. The water level in the lake rises when the rate of inflow into the lake is greater than the outflow to the ocean. The Swansea Channel, the outlet of Lake Macquarie to the ocean, can act as a significant constriction to outflows. Elevated ocean levels (for example a storm surge occurring at high tide) and local wind conditions (wind wave action) can also affect the levels in Lake Macquarie. The elevated levels in the lake cause a backwater effect into the North Creek channel. These elevated levels can exacerbate flooding due to local rainfall runoff flooding.

These mechanisms may occur in isolation or in combination with each other. Generally, the peak water level in Lake Macquarie will occur some 8 to 12 hours (or longer) after the peak rainfall over the lake catchment, while peak local catchment flood levels will typically have a much shorter response time (in the order of 1 to 2 hours). This means that even in large rainfall events, the two peaks are unlikely to coincide. The rainfall event causing flooding of the waterways within the North Creek catchment may occur as part of a longer duration storm that causes flooding on Lake Macquarie (as occurred in February 1990) or may occur due to an isolated short duration storm event that does not cause any appreciable rise in lake levels (as occurred in February 2023).

Local overland or stormwater flooding in the North Creek catchment is more frequent, with storms and nuisance local stormwater flooding often occurring several times a year. It is typically mainstream flooding, however, that causes significant issues such as roads being cut off and buildings being inundated, although this occurs less frequently.

4.2. Historical Flood Occurrences

In large rainfall events where the capacity of the pit and pipe system is exceeded, overland flow paths develop in North Creek and its tributaries causing inundation of low-lying land adjacent to the waterways. Some roads are also prone to flooding and present a risk to motorists. There have been numerous reports of flooding within the catchment, the most recent significant event being June 2007.

Lake Macquarie City Council has maintained a comprehensive database of peak flood levels in Lake Macquarie waterway since the 1930's. However, this is not a significant factor for the North Creek catchment as the peak lake level typically occurs several hours after the peak flow in North Creek and the rise in lake level is relatively small, with peak levels at approximately 1 mAHD in the February 1990 and June 2007 events. Council also holds information related to flooding specifically in the North Creek catchment and this was supplied for the North Creek Flood Study (Reference 5) and North Creek FRMS&P (Reference 4). This primarily covered the events of February 1990 and June 2007, with photographs and peak flood levels recorded. Council does not hold any information regarding flooding within the North Creek catchment after the 2007 event. A water level gauge was installed upstream of Walker Street on North Creek in June 2022, however, there have been no significant flood events since the gauge was installed. A summary of the historical events that have occurred in the North Creek catchment is provided in Table 4.

Table 4: Historic Flood Events in the North Creek Catchment

Event	Description	Source
1946	Appears to be inundation of low-lying areas most likely from elevated water levels in the Lake Macquarie waterway.	North Creek Flood Study (Reference 5)
1949	Appears to be inundation of low-lying areas most likely from elevated water levels in the Lake Macquarie waterway.	North Creek Flood Study (Reference 5)
1951	Three low lying properties affected. Minimal information available.	North Creek Flood Study (Reference 5)
February 1982	Photos provided of flooding in the vicinity of Fairfax Road.	North Creek Flood Study (Reference 5)
May 1988	One photo provided of inundation on Martin Street.	North Creek Flood Study (Reference 5)
February 1990	Flooding in the catchment due to intense rainfall. Inundation of King Street and the Hillsborough roundabout. Numerous properties downstream of King Street affected by flooding from North Creek in addition to overland flooding in the vicinity of Campbell Street.	North Creek Flood Study (Reference 5)
April 2001	Three photos provided of inundation on Sweet Street.	North Creek Flood Study (Reference 5)
June 2007	At least 16 building floors were inundated in the North Creek catchment causing significant	North Creek FRMS&P (Reference 4)

Event	Description	Source
	damage to both commercial and residential properties. King Street was overtopped, with inundation of the roundabout at Hillsborough Road. Numerous low-lying properties downstream of King Street were affected with several properties affected by overland flows (i.e. not inundated from elevated water levels in a creek or channel).	
April 2015	Known to be a large storm event in the wider Lake Macquarie and Hunter Valley region. Likely that the North Creek catchment experienced flooding to some extent.	-
February 2020	Known to be a large storm event in the wider Lake Macquarie and Hunter Valley region. Likely that the North Creek catchment experienced flooding to some extent.	-
May 2025	Largest event since the installation of the North Creek water level gauge. Water was still in bank at this location, so it is likely that the extent of flooding was minor. It is understood that the King Street and Hillsborough Road intersection was closed due to flooding in this event, although no photos could be found to confirm the extent.	-

5. DESIGN FLOOD EVENT RESULTS

5.1. Overview

Design flood events are presented in terms of a probability of a particular event being equalled or exceeded in any given year, referred to as annual exceedance probability, or AEP. For example a 1% AEP event has a 1%, or 1 in 100 chance of being equalled or exceeded in any given year. Similarly, a 50% AEP event has a 50%, or 1 in 2 chance of being equalled or exceeded in any given year. The probable maximum flood, or PMF event is the largest conceivable flood that could occur for a catchment in a given location. It is based on the physical characteristics of the atmosphere and how much moisture it can hold and release in a storm event.

The 50%, 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2% AEP and PMF events were simulated as part of the flood study. Design AEP, or annual exceedance probability provides A representative storm was adopted to simulate the critical duration across the catchment. The storms were run in the WBNM model and the resulting flows were input into the TUFLOW model to simulate flood behaviour across the study area. The results for the design flood events are documented in the Flood Study (Reference 3). A selection of results for the 1% AEP event are provided as part of this document.

5.2. Summary of Results

In frequent events, runoff is generally contained within the creeks and channels, with shallow overland flows (< 0.15 m deep) evident on streets as water moves toward the creeks. This runoff is typically contained within the gutters and dedicated drainage reserves across the catchment. In the 50% AEP event there are areas of ponding within the industrial area to the north of Hillsborough Road, between East Street and Chartley Street, to the west of New Road. Medcalf Street, Queen Street, Walker Street and Wilton Close have flood depths between 0.2 m and 0.4 m. Low-lying areas near North Creek (such as John Street, Charles Street, Martin Street and the Warners Bay netball courts) experience inundation. In the 20% AEP event, inundation of roads is more extensive, although still fairly shallow. Tributaries such as the King Street Branch upstream of Queen Street become continuous through properties. Inundation from North Creek spreads to the east (between Margaret Street and John Street) and west (between Albert Street and Charles Street).

There is increased extent and depth of inundation with rarer events. In the 1% AEP event flood depths exceed 0.5 m across a large area adjacent to North Creek downstream of Walker Street on both sides of the channel. There is inundation of properties downstream of the Lakelands Pond, in the industrial area north of Hillsborough Road and along the King Street Branch (downstream of Wilton Close). Properties on the western side of the catchment (Seaman Avenue Branch and Western Tributary) are subject to comparatively shallow inundation as flow paths are more dispersed than the western side of the catchment. Depths reach between 0.5 m and 1 m on several roads within the catchment. The peak flood depths and levels for the 1% AEP event are shown on Figure 2.

In the PMF event there are extensive inundation of areas adjacent to North Creek, typically between 1 m and 2 m deep. Along tributaries a large number of properties are impacted and water ponds on roads at low points to substantial depths (typically more than 0.5 m).

5.3. Hydraulic Hazard Categorisation

Hydraulic hazard is a measure of potential risk to life and property damage from flooding. Hydraulic hazard is typically determined by considering the depth and velocity of floodwaters. In recent years, there have been changes in the classification of hazards. Research has been undertaken to assess the hazard to people, vehicles and buildings based on flood depth, velocity and velocity-depth product. ARR 2019 (Reference 10) contains updated recommendations regarding the categorisation of flood hazard. A summary of this categorisation is provided in Diagram 1. This categorisation is based on an extensive literature review and laboratory testing. It considers hazard to people, vehicles and buildings to develop six categories of flood hazard based on flood depth, velocity and velocity-depth product.

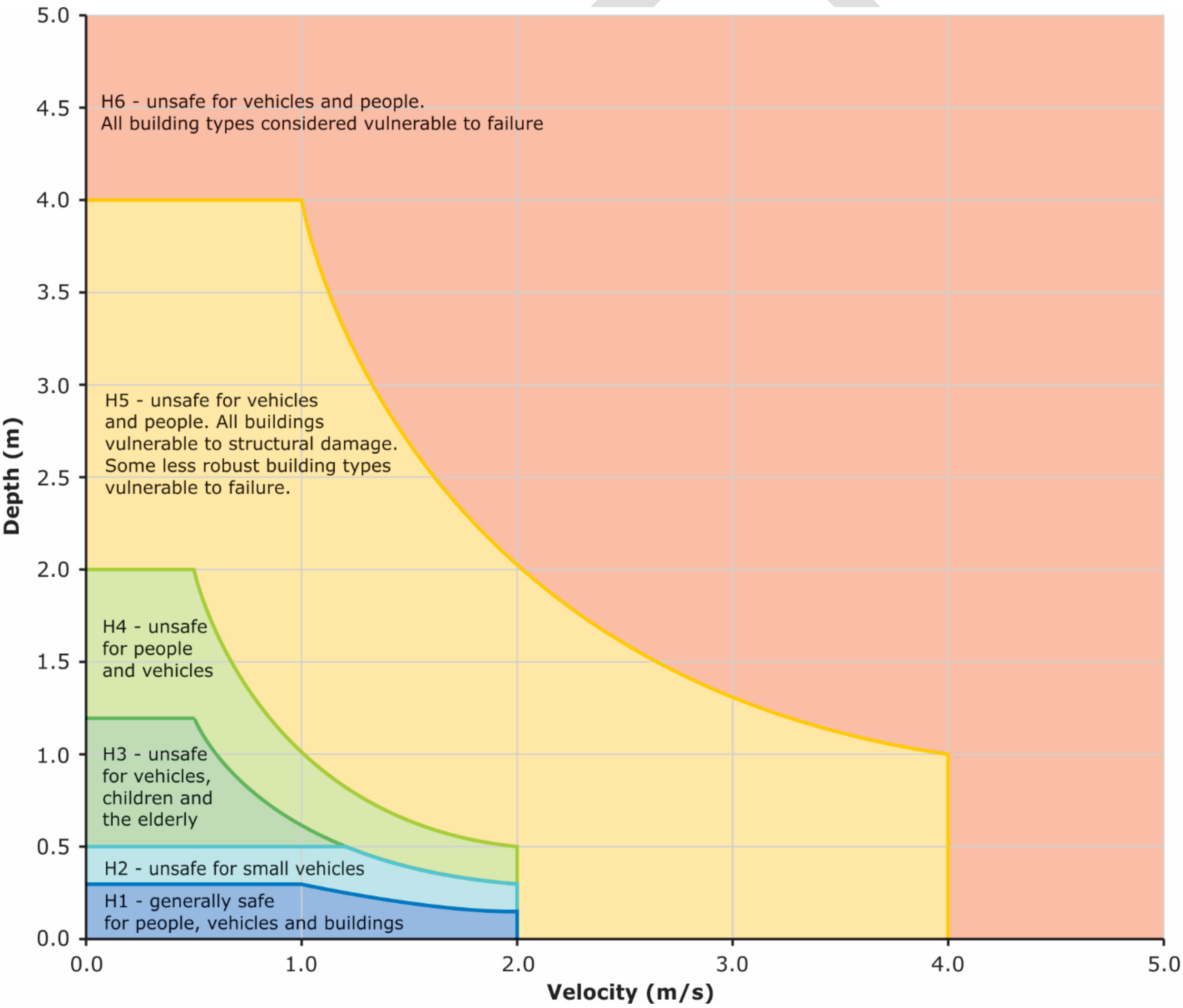


Diagram 1: General flood hazard vulnerability curves (Source: Reference 10)

The following 6 classes of hazard are defined:

- H1 – Generally safe for vehicles, people and buildings;
- H2 – Unsafe for small vehicles;

- H3 – Unsafe for vehicles, children and the elderly;
- H4 – Unsafe for vehicles and people;
- H5 – Unsafe for vehicles and people. All building types vulnerable to structural damage. Some less robust building types vulnerable to failure; and
- H6 – Unsafe for vehicles and people. All building types considered vulnerable to failure.

The hydraulic hazard defined in the Flood Study (Reference 3) was reviewed for consistency and no changes were made to the results. The hydraulic hazard for the 1% AEP event is provided in Figure 3.

In the 5% AEP event, much of the urban area affected by flooding is only H1 hazard, with areas of higher hazard (H3 and above) generally restricted to basins and creek channels (reaching H5). There are some regions of higher hazard outside these areas including the area around the Warners Bay netball courts, between Charles Street and John Street, the end of Martin Street, between East Street and Chartley Street and small areas of the industrial area north of Hillsborough Road.

In the 1% and 0.2% AEP events the higher hazard areas increase, covering a large portion of the North Creek floodplain downstream of Walker Street. Roads along the upstream portions of the King Street Tributary convey high hazard flows. In the PMF event, the North Creek channel becomes H6 hazard and the surrounding downstream floodplain is H5 hazard. H5 hazard is also evident on other tributary branches and roads that convey flows.

5.4. Flood Function

Flood function (or hydraulic categorisation) involves mapping the floodplain to indicate which areas are most important for the conveyance of floodwaters and the temporary storage of floodwaters. This can help in planning decisions about which parts of the floodplain are suitable for development, and which areas are not restricted to ensure that flooding impacts are not worsened compared to existing conditions.

The Flood Risk Management Manual (Reference 1) defines three hydraulic categories which can be applied to different areas of the floodplain depending on the flood function:

- Floodways;
- Flood Storage; and
- Flood Fringe

Floodways are generally areas which convey a significant portion of water during floods and are particularly sensitive to changes that impact flow conveyance. They often align with naturally defined channels. Flood storage areas are located outside of floodways and generally store a significant proportion of the volume of water. Flood behaviour in these areas is sensitive to changes that impact on the storage of water during a flood. Flood fringe areas are within the extent of flooding for a particular event but are outside floodway and flood storage areas. The flood fringe is less sensitive to changes in either flow conveyance or storage.

There is no quantitative definition of these three categories or accepted approach to differentiate between the various classifications. The delineation of these areas is somewhat subjective based on knowledge of an area and flood behaviour, hydraulic modelling and previous experience in categorising flood function. A number of approaches, such as that of Howells et al (2003, Reference 11), rely on combinations of velocity and depth criteria to define the floodway.

For the Flood Study (Reference 3), hydraulic categories were defined by the following criteria:

- Floodway is defined as areas where:
  - the peak value of velocity multiplied by depth (V x D) > 0.25 m^2/s, **AND** peak velocity > 0.25 m/s, **OR**
  - peak velocity > 1.0 m/s **AND** peak depth > 0.15 m;

  The remainder of the floodplain is either Flood Storage or Flood Fringe;
- Flood Storage comprises areas outside the floodway where peak depth > 0.2 m; and
- Flood Fringe comprises areas outside the Floodway where peak depth < 0.2 m.

The adopted parameters are consistent with those derived by WMAwater for similar catchments draining to the Lake Macquarie waterway. The flood function mapping was reviewed as part of the current study and is a reasonable representation of the flood function within this catchment. No changes were made to the results presented in the flood study. The 1% AEP flood function is shown in Figure 4.

As expected, the creeks and major flow paths are classified as floodways in the 1% AEP event, with flood storage areas where there are basins, around the Hillsborough Road roundabout and in the downstream low-lying floodplain of North Creek. In the PMF event, the floodway is quite extensive for North Creek, encompassing much of the floodplain. Flood storage areas are primarily found adjacent to the North Creek floodways with only shallow overland flow remaining as flood fringe.

5.5. Flood Emergency Response Classification

The Flood Risk Management Manual (Reference 1) requires flood studies to address the management of continuing flood risk to both existing and future development areas. As continuing flood risk varies across the floodplain, so does the type and scale of the emergency response problem and therefore the information necessary for effective Emergency Response Planning (ERP). Classification provides an indication of the vulnerability of the community in flood emergency response and identifies the type and scale of information needed by the NSW State Emergency Service (SES) to assist in ERP.

The Flood Emergency Response Classification (FERC) for the study area was undertaken in accordance with the *Australian Disaster Resilience Handbook 7 Managing the Floodplain: A guide to best practice flood risk management in Australia* (Reference 12). FERC classifications consider flood affected communities as those in which the normal functioning of services is altered, either directly or indirectly, and results in the need for external assistance. This impact relates directly to the operational issues of evacuation, resupply and rescue, which is coordinated by the SES.

The ERP classification for urban areas within the North Creek catchment were defined using the

PMF flood event as part of the flood study. The classification was undertaken on a precinct basis rather than lot-by-lot and is targeted at highlighting those areas which may require evacuation or assistance during a flood event. However, these classifications may vary depending on local flood characteristics and resultant flood behaviour, i.e. in flash flooding or overland flood areas. These categories are described in Diagram 2 below.

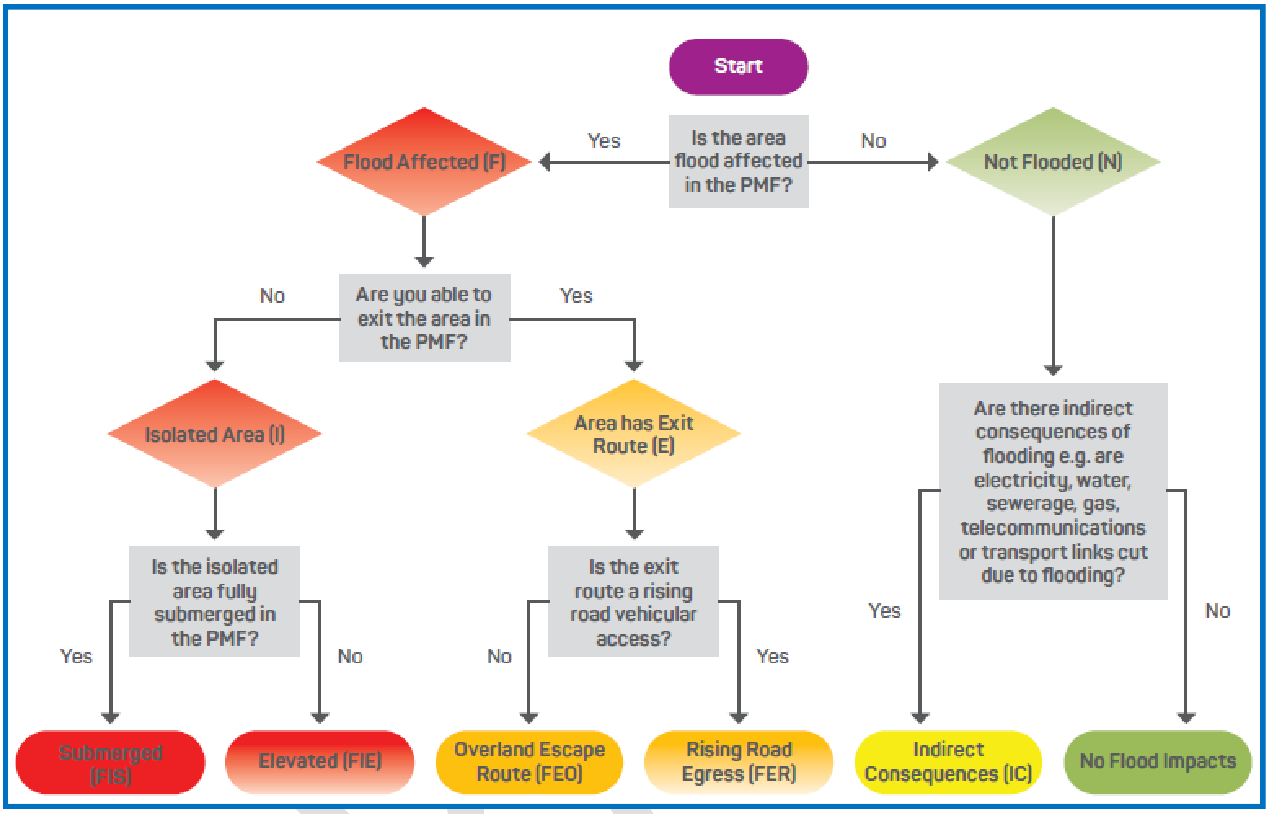


Diagram 2: Flow Chart for Determining Flood Emergency Response Classifications (Reference 12)

The FERC for the North Creek catchment defined in the Flood Study (Reference 3) was reviewed and found to be appropriate considering the flood behaviour. The FERC is shown in Figure 5. A summary of the FERC for North Creek is as follows.

- An area approximately 300 m wide adjacent to North Creek from the Hillsborough Road service road to the Esplanade is submerged (Flooded – Isolated – Submerged, FIS).
- Areas that are isolated (Flooded – Isolated – Elevated, FIE) include the industrial area north of Hillsborough Road, a residential area around Albert Street, Martin Street and Campbell Street, residential area between The Esplanade and New Road, Hughes Avenue, Milloba Close, between Albert Street and The Esplanade (adjacent to Lake Street) and along the King Street Branch, from East Street to Walker Street.
- There are large areas of residential and commercial land that is affected by flooding, but has rising road access (Flooded – Exit – Rising road access, FER) away from North Creek including east of Fairfax Road, the Hillsborough Road commercial area and around King Street.

- A number of open spaces and reserves may be affected by flooding and have adjacent roads that are inundated, however, typically access is available from these areas on foot (Flooded – Exit – Overland access, FEO).
- There are numerous other locations where roads are cut and people may be isolated, however, these areas are not directly affected by floodwaters and hence are classified as indirectly affected (Indirect Consequences, IC).

5.6. Flood Planning Area

5.6.1. Background

Land use planning is an effective means of minimising flood risk and damages from flooding. Land use planning for flooding can be achieved through the use of:

- A Flood Planning Area (FPA), which identifies land that is subject to flood related development controls; and
- A Flood Planning Level (FPL), which identifies the minimum floor level applied to residential development proposals within the FPA.

Defining FPAs and FPLs in urban areas can be complicated by the variability of flow conditions between mainstream and local overland flow (where there is no defined channel). Traditional approaches developed for riverine or “mainstream” flow areas often cannot be applied in steeper urban overland flow areas. Additionally, defining the area of flood affectation due to overland flow (which by its nature includes shallow flow) involves determining at which point flow is significant enough to be classified as “flooding” rather than just a drainage or local runoff issue. In some areas of overland flow, the difference in peak flood level between events of varying magnitude can be so minor that applying the typical freeboard can result in an FPL greater than the PMF level.

The FPA should include properties where development would result in impacts on flood behaviour in the surrounding area and in areas of high hazard where there is a risk to safety or life. The FPL is determined in addition to this with the purpose of decreasing the likelihood of damage such as over-floor flooding of houses and businesses.

The Flood Risk Management Manual (Reference 1) identifies that the FPL is generally based on the 1% AEP event plus an appropriate freeboard (typically 0.5 m). However, it also recognises that different freeboards may be deemed appropriate due to local conditions provided adequate justification is provided. For North Creek, the 1% AEP event with 0.9 m sea level rise was adopted.

The FPA derived as part of the flood study (Reference 3) was reviewed and was considered to be appropriate for the catchment. A summary of the derivation is provided below and the FPA is shown in Figure 6.

5.6.2. Methodology

The methodology used for defining the FPA is consistent with that adopted in similar studies throughout the Lake Macquarie LGA. It divides the flood area between “mainstream” and "overland" flooding areas using the following criteria:

- Mainstream flooding: In these areas, the flow is sufficiently deep and there is sufficient relief that freeboard can be added to the flood surface and the extent then "stretched" to include adjacent land. Mainstream flooding consisted of North Creek and other major tributaries as follows:
    - North Creek downstream of Myles Avenue;
    - Vermont Place Branch downstream of the Vermont Place basin;
    - Whitehaven Drive detention basin and downstream area through the industrial area north of Hillsborough Road;
    - King Street Branch downstream of King Street;
    - The Lakelands Pond and channel downstream of Medcalf Street;
    - Western Tributary downstream of Medcalf Street;
    - Seaman Avenue Branch downstream of Seaman Avenue.

  In other areas, such as the Seaman Avenue Branch upstream of Seaman Avenue, they were not included as "mainstream" since adding freeboard to the 1% AEP peak flood level in the channel and stretching results in all areas south of the channel being encapsulated by this level. The 1% AEP flood results (with 0.9 m sea level rise) for the "mainstream" areas were filtered to remove shallow inundation, based on a hazard classification of H3 or higher (see Section 5.3) and depths exceeding 0.15 m. This filtering identifies the main creek/tributary and overland flow paths and reduces the issues associated with attempting to add freeboard and stretch in minor overland flow areas. The FPA in the mainstream area was defined as the 1% AEP peak flood level (with 0.9 m sea level rise) plus 0.5 m freeboard, with the level extended perpendicular to the flow direction either side of the flow path, to where this surface intersects with the ground level. This extent defines the "mainstream" FPA.

- Overland flooding: For overland flow areas, addition of freeboard and stretching generally extends across land in a way that would not actually occur even in the PMF event (as discussed for the Seaman Avenue Branch). It is therefore considered appropriate to use the 1% AEP design flood results (with 0.9 m sea level rise) without freeboard. This approach considers a true flood surface, accounting for factors such as flow momentum rather than an artificial surface generated by adding freeboard. In overland flow areas, it was considered appropriate to use filtered results to remove those areas that are affected by very shallow runoff, considered to be 'stormwater' rather than 'flooding'. The following filters were applied to the 1% AEP event with 0.9 m sea level rise:
    - **Depth Filter** – Exclude results below 0.15 m depth, and
    - **Small Pond Filter** – Remove isolated 'puddles' or 'orphans' smaller than 100 m^2.

  The resulting extent was used to define the "overland" FPA.

5.7. Climate Change

Climate change is expected to increase sea levels and rainfall intensities. It is typical practice in catchment flood studies under the NSW flood program to model scenarios incorporating the effects of these impacts from climate change to understand the potential future changes in flood behaviour.

5.7.1. Sea Level Rise

Various projections of the likely increases to sea levels are available. Lake Macquarie Council engaged Manly Hydraulics Laboratory in 2012, 2015 and 2020 to analyse and report on Lake Macquarie water level trends. The latest report (Reference 13) concluded that the water levels at the Belmont gauge have risen by 2.74 mm/year over the last 33 years and 3.05 mm/year over the last 19 years.

The Lake Macquarie Waterway Flooding and Tidal Inundation Policy (2020, Reference 14) adopts sea level rise planning benchmarks established by the repealed *NSW Sea Level Rise Policy Statement* (2009, Reference 15). These benchmarks were a rise from 1990 levels of 0.4 m by 2050 and 0.9 m by 2100. These benchmarks have been adopted for some time as they are still reasonably close to the most recent reports and changing the planning levels too often would be unhelpful for owners, builders, developers and planners. Planning levels will be reviewed again when there is new scientific advice, or there is a change in government policy.

As a result of the information provided in the above and other documents, and to keep up-to-date with current best practice, this present study incorporates an assessment of climate change. However, it should be noted that climate change due to man-made or natural processes will still occur beyond the 2100 estimate.

5.7.2. Rainfall Intensity

Any increase in design flood rainfall intensities will increase the frequency, depth and extent of inundation across the catchment. The primary driver for this change is under a warmer climate, the atmosphere can hold more water, and hence more rainfall can occur in any given storm event. The design rainfall information currently provided by the BoM is based on historical climate data and does not currently include any allowance for likely increases to rainfall intensity in the future. ARR 2019 (Reference 10) provides some guidance about consideration of the impacts of climate change on design rainfall intensities.

Projected increases to evaporation under a warmer climate are also an important consideration because increased evaporation would lead to generally drier catchment conditions, resulting in lower runoff from rainfall. Mean annual rainfall is projected to decrease, which will also result in generally dryer catchment conditions.

The current NSW State Government's advice recommends sensitivity analysis on flood modelling should be undertaken to develop an understanding of the effect of various levels of change in the hydrologic regime on the study area (Reference 16). To understand potential changes to flood behaviour due to increased intensity of rainfall, the 0.5% AEP and 0.2% AEP events can be used as proxies for the future 1% AEP with climate change considerations, as suggested in the NSW Flood Risk Management Manual (Reference 16). These events provide an indication of how 1% AEP flood levels would change if the rainfall intensity increased to the point that it matches either the current 0.5% AEP (a 13% increase in intensity for the adopted critical duration) or 0.2% AEP (a 34% increase in intensity for the adopted critical duration).

5.7.3. Climate Change Sensitivity Results

The Flood Study (Reference 3) simulated sea level rise and rainfall intensity increase separately. In this study, these climate change aspects were combined to simulate potential future scenarios, as outlined in Table 5.

Table 5: 1% AEP climate change scenarios

Projection Year	Rainfall Increase	Sea Level Rise
2050	0.5% AEP (13% increase)	0.4 m
2100	0.2% AEP (34% increase)	0.9 m

The increase in peak flood level for the 1% AEP 2050 climate scenario is shown in Figure 7. The model results display increases that are typically 0.02 m higher on overland flow paths. Peak flood levels along tributaries increase by approximately 0.05 m to 0.1 m. Along North Creek, from the Hillsborough Road service road to John Street (including overbank areas), the flood level increases are in the range of 0.1 m to 0.2 m. Downstream of John Street, the increases are up to 0.4 m at outlet to Warners Bay (Lake Macquarie).

The increase in peak flood level for the 1% AEP 2100 climate scenario is shown in Figure 8. The model results display increases that are typically 0.05 m higher on overland flow paths and approximately 0.1 m to 0.2 m higher on the tributaries. Along North Creek, from the Hillsborough Road service road to John Street (including overbank areas), the flood level increase is approximately 0.3 m. The most sensitive area is between Walker Street and Martin Street, where flood level increases are just over 0.4 m. Downstream of John Street, the increases are up to 0.9 m at outlet to Warners Bay.

ARR was updated to version 4.2 in August 2024 with climate change guidance. This guidance has not been used to simulate climate change for the North Creek catchment. However, the 0.5% AEP event, with the 13% increase in rainfall is considered low based on this updated guidance. The lowest increase for the critical 1 hour duration storm (SSP1-2.6 for 2030 projection) is approximately 18%. The 0.2% AEP event, with the 34% rainfall increase roughly equates to a 2100 projection between SSP1-2.6 and SSP2-4.5, or a 2050 projection with SSP5-8.5.

5.8. Flood Hotspots

The design flood results were used to identify locations in the catchment which are exposed to a higher flood risk. These hotspots were generally locations where roads were high flood hazard and were required for evacuation access or locations where many properties were flooded above floor. Flood management options developed as part of this FRMS targeted these hotspots. This FRMS is not intended to address nuisance inundation or comprise a drainage study. Rather it has focussed on those areas where flood risk to people, vehicles and property is significant over a range of events, including infrequent floods such as the 1% AEP event. The hotspot locations are shown in Figure 10 and discussed in the following sections.

5.8.1. New Road

This area is located at the intersection of New Road and Seaman Avenue (Photo 28). Water ponds at a low point covering the intersection as well as several properties to the west of this and the corner of Feighan Oval. The area is drained by a single 675 mm diameter pipe that runs along the southern side of Feighan Oval and discharges into North Creek.

Photo 28: New Road looking west to Seaman Avenue at the low point (*Source: Google Street View*)

The peak flood depths and hydraulic hazard for the 1% AEP event are shown in Figure 11. Flood depths reach above 0.5 m in the 1% AEP event at properties on Seaman Avenue. Hydraulic hazard reaches H2 (unsafe for small vehicles) on the road and H3 on properties (unsafe for children and the elderly). One property is estimated to be subject to above floor flooding in the 20% AEP event and another in the 5% AEP event.

5.8.2. Hughes Avenue

Hughes Avenue, located on the western side of the catchment, is a cul-de-sac with a low point that is subject to inundation (Photo 29). There is a substantial upstream catchment that drains to this point on its path to the Seaman Avenue Branch concrete channel. The low point is drained by a 900 mm diameter pipe that discharges into the concrete open channel at the rear of properties on the southeastern side of Hughes Avenue.

The peak flood depths and hydraulic hazard for the 1% AEP event are shown in Figure 12. Flood depths reach above 0.5 m in the 1% AEP event at the low point on Hughes Avenue. Hydraulic hazard reaches H2 (unsafe for small vehicles) on the road and H3 in the gutters (unsafe for children and the elderly). This has the potential to cut off vehicle access to approximately 7 properties, although pedestrian access is available via an easement to Vincent Street. Overflow from the low point flows between two properties towards the open channel at the rear. These properties are estimated to be subject to above floor flooding in events larger than the 1% AEP.

Photo 29: Hughes Avenue low point (*Source: Google Street View*)

5.8.3. Lakelands Branch

The Lakelands Branch extends from the Lakelands Pond to North Creek (see Section 1.3). The primary flow path is conveyed via a 2.7 m (W) x 0.75 m (H) box culvert from the pond, under Medcalf Street, into a concrete lined open channel that discharges into North Creek. Areas of flood affectation on this branch include Medcalf Street (a main road in Warners Bay) and commercial/industrial lots located on the eastern side of the open channel (Photo 30).

The peak flood depths and hydraulic hazard for the 1% AEP event are shown in Figure 13. Flood depths reach 0.7 m in the 1% AEP event at the low point on Medcalf Street (the eastbound lanes in particular). Hydraulic hazard reaches H4 (unsafe for people and vehicles) on the road at the low point (noting that shallow flows up to 0.2 m deep reach H5 hazard due to high velocities on Medcalf Street to the west of the low point). Flood depths also reach above 0.5 m in parts of the commercial/industrial area to the east of the concrete channel downstream of Medcalf Street, with hazard reaching H3 (unsafe for vehicles, children and the elderly). There is estimated to be 6 commercial properties with above floor inundation in the 1% AEP event.

Photo 30: Medcalf Street low point downstream of Lakelands Pond (*Source: Google Street View*)

5.8.4. Hillsborough Road Industrial Area

The Hillsborough Road industrial area where there is flooding is located between Macquarie Road and Hillsborough Road. Runoff from the eastern portion of Lakelands is captured by the Whitehaven Drive detention basin, with flow from this basin conveyed by a 1.8 m (W) x 1.5m (H) box culvert under Macquarie Road and overland flow overtopping the road. Downstream of Macquarie Road, there is a small channel that conveys flow adjacent to a driveway (Photo 31). This channel discharges into a twin 1.2 m diameter culvert that conveys flow to North Creek at Hillsborough Road. A second flow path runs adjacent to Hillsborough Road, conveyed by a pipe ranging from 900 mm diameter at the upstream end to twin 1.35 m diameter at the downstream end.

Photo 31: Vegetated open channel adjacent to driveway downstream of Macquarie Road (*Source: Google Street View*)

The peak flood depths and hydraulic hazard for the 1% AEP event are shown in Figure 14. Throughout the industrial area, there are areas of flooding on large concrete open spaces where water ponds, primarily adjacent to Hillsborough Road. Flood depths reach up to 1 m in the 1% AEP event, with H3 hazard (unsafe for vehicles, children and the elderly) present at several locations. There is estimated to be 15 large buildings with above floor inundation in the 1% AEP event.

5.8.5. Local Road Low Points, East Warners Bay

There are several local road low points where flooding can occur in the eastern portion of Warners Bay. This area is in the vicinity of Myles Avenue and New York Avenue. Low points are present on Lawford Close, Myles Avenue, Nebraska Close, Colorado Close, Vermont Place, Harrison Street, Indiana Close and Aurora Court. Many of these local roads are cul-de-sacs, with flooding at the low point having the potential to cut off access to properties. The location with the deepest flooding is Aurora Court (Photo 32).

The peak flood depths and hydraulic hazard for the 1% AEP event are shown in Figure 15. The flood depths range between 0.3 m and 0.5 m at the low points throughout this area in the 1% AEP event. The hydraulic hazard is primarily H2 (unsafe for small vehicles), although reaches H3 (unsafe for vehicles, children and the elderly) on Aurora Court. While there are only 4 properties in this area estimated to be flooded above floor in the 1% AEP event, it is primarily access that is the concern for these low points.

Photo 32: Aurora Court Medcalf Street low point downstream of Lakelands Pond (*Source: Google Street View*)

5.8.6. King Street Branch

The upstream portion of the King Street Branch from Wilton Close to Queen Street has the potential to affect a number of properties along the flow path. Flows are conveyed by a single 1.2 m diameter pipe, with runoff in excess of this being conveyed overland. There are several low points on roads along the branch including Wilton Close, Nott Street and Yorston Street. The properties on the southern side of East Street are low lying and water can pond (primarily at the rear) at several properties (Photo 33). The flow path between Nott Street and Yorston Street is through properties. Downstream of Yorston Street there is a drainage swale, however, properties on the southern side of the swale can be affected in large events.

The peak flood depths and hydraulic hazard for the 1% AEP event are shown in Figure 16. The flood depths reach just over 0.5 m on Wilton Close and Yorston Street, and up to 1 m on Nott Street in the 1% AEP event. Flood depths also reach 1 m at low points on properties along the flow path, such as on the southern side of East Street and between Nott Street and Yorston Street. The hydraulic hazard reaches H4 (unsafe for people and vehicles) and H5 (all buildings vulnerable to structural damage) on roads. H3 (unsafe for vehicles, children and the elderly) and H4 hazard are present on properties with ponding on the southern side of East Street while the hazard reaches H5 between Nott Street and Yorston Street due to fast flowing water (> 2 m/s). There is estimated to be 13 properties with above floor flooding in the 1% AEP event.

Photo 33: Low lying land at the rear of properties on the southern side of East Street (*Source: Google Street View*)

5.8.7. North Creek at Hillsborough Roundabout

The roundabout intersection of Hillsborough Road, King Street, Medcalf Street and Macquarie Road is one of the most well-known areas of flooding in the area (Photo 34). Flooding has occurred here in the past, including the 1990 and 2007 events (flood study calibration events), and most recently May 2025. Flooding is estimated to break out of North Creek and impact King Street in the 20% AEP event, with substantial overtopping and inundation of Hillsborough Road in the 10% AEP event. In smaller events, North Creek is conveyed under King Street via 4 x 2.4 m x 1.4 m box culverts.

The peak flood depths and hydraulic hazard for the 1% AEP event are shown in Figure 17. The flood depths reach almost 1.5 m on King Street and 1.2 m on Hillsborough Road, with the hazard being H4 (unsafe for people and vehicles) on King Street and H3 (unsafe for vehicles, children and the elderly) on Hillsborough Road. While the area affected is reasonably large, there are only estimated to be 7 properties flooded above floor in the 1% AEP event. There are also access implications as this is an intersection of four main roads in the area and the primary route from Warners Bay to the north (to Cardiff) and northeast (to Hillsborough).

Photo 34: Hillsborough Road roundabout (*Source: Google Street View*)

5.8.8. North Creek Downstream Area

The area downstream of King Street adjacent to North Creek is flood prone. North Creek breaks out of bank and inundates low-lying land, particularly downstream of Walker Street. Areas affected are located at the end of Margaret Street, Martin Street, Albert Street, Charles Street and John Street on the southern side of the creek, and Albert Street, Charles Street and the Warners Bay netball courts on the northern side. These streets reduce in elevation towards North Creek, with the roads typically cut by the creek (i.e. the road on each side of the creek only extends to the bank of the creek (example in Photo 35)). It is only Walker Street that crosses North Creek, with a triple 2.55 m (W) x 2 m (H) box culvert underneath it. There are two pedestrian bridges at Albert Street and John Street that provide access across North Creek.

Photo 35: Martin Street on the southern side of North Creek, looking towards the creek (*Source: Google Street View*)

The peak flood depths and hydraulic hazard for the 1% AEP event are shown in Figure 18. The flood depths reach 0.8 m on Walker Street, over 1 m at the end of Martin Street (southern side) and typically up to 0.7 m on other streets adjacent to North Creek in the 1% AEP event. The hydraulic reaches H4 (unsafe for people and vehicles) over Walker Street, with H3 (unsafe for vehicles, children and the elderly) typically being reached on other streets and at properties subject to slow-moving floodwater. There is estimated to be approximately 60 properties with above floor flooding in the 1% AEP event in this area with access issues on several roads, although they typically rise away from the creek.

6. ECONOMIC IMPACTS OF FLOODING

6.1. Background

The impact of flooding can be quantified through the calculation of flood damages. Flood damage calculations do not include all impacts associated with flooding. They do, however, provide a basis for assessing the economic loss of flooding and also provide a non-subjective means of assessing the merit of flood mitigation works such as detention basins, levees, drainage enhancement etc. The quantification of flood damages is an important part of the flood risk management process. By quantifying flood damage for a range of design events, appropriate cost-effective management measures can be analysed in terms of their benefits (reduction in damages) versus the cost of implementation. The cost of damage and the degree of disruption to the community caused by flooding depends upon many factors including:

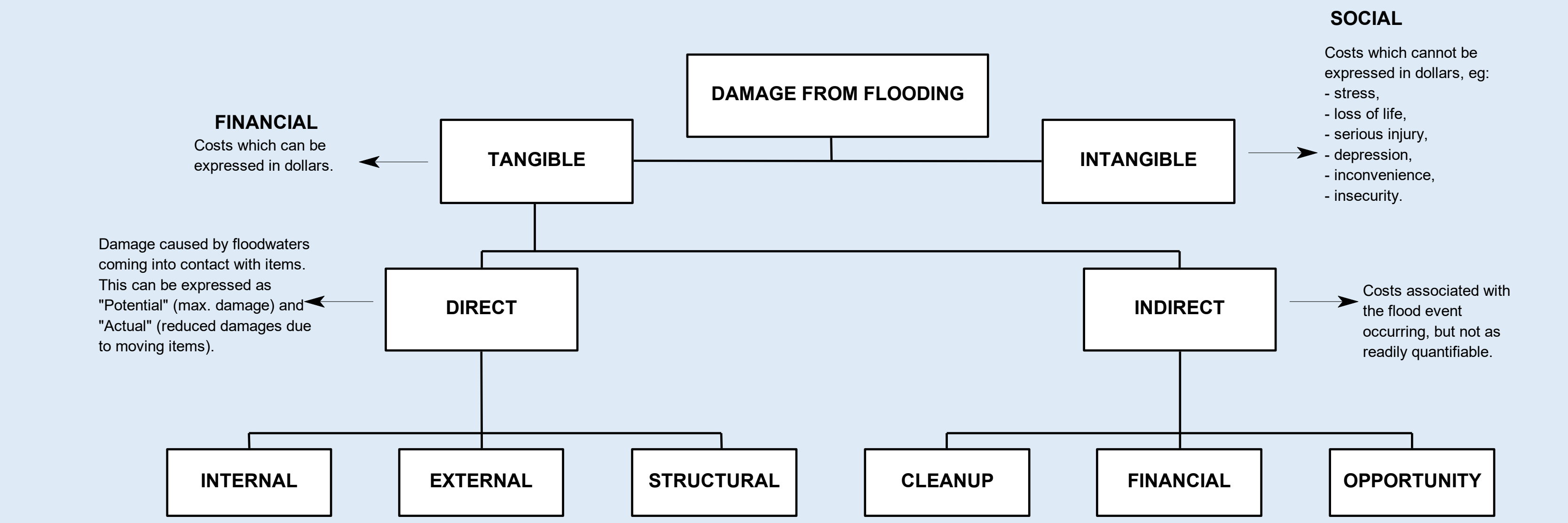
- The magnitude (depth, velocity and duration) of the flood,
- Land use and susceptibility to damages,
- Awareness of the community to flooding,
- Effective warning time,
- The availability of an evacuation plan or damage minimisation program,
- Physical factors such as failure of services (sewerage), flood borne debris, sedimentation, and
- The types of assets and infrastructure affected.

The estimation of flood damages tends to focus on the physical impact of damages on the human environment, but there is also a need to consider the ecological cost and benefits associated with flooding. Flood damages can be defined as being tangible or intangible. Tangible damages are those for which a monetary value can be easily assigned (for example damage to buildings, infrastructure, furnishings, goods or stock), while intangible damages are those to which a monetary value cannot easily be attributed (for example social costs such as increased levels of mental stress, loss of sentimental items, inconvenience to people, injury or loss of life). Types of flood damages are shown in Diagram 3.

The assessment of flood damages not only quantifies potential costs due to flooding but also identifies when properties are likely to become flood affected by either flooding on the property or by over floor flooding.

The standard way of expressing flood damages is in terms of average annual damages (AAD). AAD represents the equivalent average damages that would be experienced by the community on an annual basis, by taking into account the probability of a flood occurrence. By this means the smaller floods, which occur more frequently, are given a greater weighting than the rare catastrophic floods.

Diagram 3: Flood Damages Categories (including damage and losses from permanent inundation)



	INTERNAL	EXTERNAL	STRUCTURAL	CLEANUP	FINANCIAL	OPPORTUNITY
RESIDENTIAL	Contents of Buildings: Clothes, Carpets, Furniture, Valuables, Fittings, Appliances	External Items: Vehicles, Laundries, Caravans, Sheds, Tools, Gardens, Fences	Physical Damage to Buildings: Gyprock, Cupboards, Scour of Footings, Houses becoming buoyant (floating off footings)	Clean Carpets, Walls, Clothes; Re-instate Furniture; Remove Mud and Debris	Loss of wages, Living costs (temporary accomodation and food), Time to repair/replace damaged items	Not Applicable
RURAL	Contents of Buildings: Clothes, Carpets, Furniture, Valuables, Fittings, Appliances	External Items: Vehicles, Sheds (stables/barns), Machinery, Tools, Fences, Feed storage, Saddles, Crops &/or Stock, Irrigation Systems	Physical Damage to Structures: Damage to Homestead, Sheds, Access tracks, Protection levees	Clean Homestead and Out-buildings; Remove Debris; Dispose of affected crops &/or stock	Loss of Farm Production and Income, Re-instatement of Pastures, Supplementary feeding of stock (by hand or outside agistment), Stock movement/ transport, Living costs (temporary accomodation and food)	Sowing or harvesting of Crops, Sale of Stock (at depreciated value or dependent on market influences)
COMMERCIAL	Contents of Buildings: Products, Stock, Fittings, Tools, Machinery, Raw Materials	External Items: Vehicles, Machinery, Display, Raw Materials/Stockpiles, Fences	Physical Damage to Buildings	Dispose of damaged products, stock, materials; Cleaning and Re-instatement	Loss of Productivity and Income, Bank Interest Charges	Loss of existing &/or Potential Trade
PUBLIC AUTHORITIES	Contents of Public Buildings and Facilities	Public Property and Facilities: Parks, Signs, Machinery, Equipment	Physical Damage to Infrastructure: Electricity, Water, Telephone, Gas, Road & Rail Transport Links	Remove Mud & Debris from Facilities, Public & Private Property Repairs (temporary & permanent)	Disruption of Services, Community Service Relief Grants	Provision of Public Service

6.1.1. Tangible Flood Damages

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

While the total likely damages in a given flood are useful to get an indication for the magnitude of the flood problem, it is of little value for absolute economic evaluation, given the variability of flooding, property and content values. Flood damages estimates are also useful when studying the economic effectiveness of proposed management options. Understanding the total damages prevented over the life of the option in relation to current damages, or to an alternative option, can assist in the decision-making process. This is a function not only of the high damages which occur in large floods but also of the lesser but more frequent damages which occur in smaller floods.

6.1.2. Intangible Flood Damages

The intangible damages associated with flooding are inherently more difficult to estimate. In addition to the direct and indirect damages discussed above, additional costs/damages are incurred by residents affected by flooding, such as stress and anxiety, psychological impacts, living disruptions, loss of community, injury and loss of life. It is not possible to put a monetary value on the intangible damages as they are likely to vary dramatically between each flood, however some studies have adopted uplift factors on tangible flood damages of 60% to 120% to account for intangible flood damages. Intangible flood damages depend on a range of factors including the size of flood, the individuals affected, community preparedness etc. It is important that the consideration of intangible damages is included when assessing the impacts of flooding on a community. An overview of the types of intangible damages likely to occur within the study area is discussed below.

Isolation

Isolation (the ability to freely exit and enter your house) during flood events may become a significant factor for local residents. There is also a high level of community support and spirit, which can to some extent negate the effects of isolation and can certainly assist in a flood (as happened in the June 2007 long weekend event across the LGA). However, isolation is of significant concern if a medical or fire emergency arises during a flood, there is a need to pick up food or people or for other reasons. This is probably not a significant factor in the study area where there is a relatively short distance to travel to high ground and the roads are inundated for only a short time (say 2 hours).

Population Demographics

Analysis of the 2021 census data (see Section 1.4) indicates that there are no particular features of the population demographics of the community in the study area that might contribute to significant additional intangible damages, particularly community resilience.

The higher average age of the Warners Bay area indicates the possibility of slightly lower resilience for an aging population to adapt to change and respond in an emergency, therefore requiring local adaptation plans that acknowledge and respond to specific local challenges. Well-developed emergency preparedness, response and recovery programs are also required.

Stress

In addition to the stress caused during an event (from concern over property damage, risk to life for the individuals or their family, clean up etc.) many residents who have experienced a major flood are fearful of the occurrence of another flood event and its associated damage. The extent of the stress depends on the individual. To some extent, this does not appear to be a significant issue within the study area as a number of residents experienced both the February 1990 and June 2007 long weekend events and this issue has not become apparent in post flood surveys. The increasing hazard due to climate changes may add to community and individual stress, as it makes future events even more difficult to predict, and planning for the future even more uncertain.

Risk to Life and Injury

During any flood event there is the potential for injury as well as loss of life.

6.2. Approach

Estimation of flood damage was undertaken for the Flood Study (Reference 3) and was reviewed as part of the current study and found to be suitable for using as part of the FRMS for determining the benefit (reduction in flood damages) for flood management options. The assessment focussed on residential and community buildings in the study area using guidelines issued by the NSW Government (Reference 16) and recognised damage assessment methodologies. The assessment utilised flood damage data in the form of flood-damage curves for a range of property types, i.e. residential, commercial, public property, public utilities etc. These relate flood damage to depth of flooding above a threshold level (usually floor level). The estimation of damage is based upon a flood level relative to the floor level of a property. These damage curves were then factored by 6.26% (according to the consumer price index) to adjust the damages from its initial estimates (in 2022) to current day dollars. The assumed parameters and flood damage curve assumptions are outlined in the following sections.

6.2.1. Property Database

A property database was assembled using the available data, since it is not cost-effective to undertake detailed topographic survey of all or even a portion of flood prone properties across the study area. Floor levels of properties were estimated based on the following approach:

1. Obtained surveyed floor levels from the North Creek Flood Study (Reference 5), consisting of 170 properties. Surveyed floor levels were also obtained from the Lake Macquarie Waterway Floodplain Risk Management Study and Plan (Reference 9), consisting of 21 properties. These points were reviewed and GIS points placed appropriately for this study.

2. Determine properties affected by the 1% AEP flood extent (including those previously surveyed in point 1. above) for inclusion in the property database and estimate the height of the floor level above the ground level for these properties by undertaking a 'windscreen survey', utilising Google Street View where available. This involved looking at features such as the number of steps into the building, number of bricks to the floor level or other visible features which can be used to provide an estimate of the difference between the floor level and adjacent ground level. For properties where it was difficult to estimate the floor height above ground due to obstructions, the lower level of confidence in the estimate was noted in the database.
3. Based on the above analysis, an indicative average floor level height above adjacent ground levels was determined. It was found that the average height above ground was 0.33 m.
4. Determine additional properties flood affected up to the PMF and add these to the property database.
5. Determine the ground level adjacent to each building within the property database using LiDAR data.
6. Estimate the floor level using, in order of preference:
    - The surveyed floor level, where considered to still be valid. For properties that appeared to be redeveloped within the last 10 years (assessed based on aerial imagery and the 'windscreen survey') surveyed floor levels were not adopted.
    - Estimated floor level from ground level and task 2 (typically those within the 1% AEP extent where floor levels were visible from Google Street View). This included surveyed properties that were redeveloped since the previous survey was undertaken.
    - Estimated floor level from ground level and task 3 (typically those properties outside the 1% AEP extent up to the PMF extent).

The level of accuracy for the estimated floor heights is considered suitable for two reasons. Firstly, the estimation of property damage due to flooding is inherently difficult to estimate, given the large variation in building types, their contents, the duration of flooding and other factors, and so the accuracy of floor heights should be in line with the accuracy and applicability of the flood damage curves. Secondly, the economic damages assessment is only intended to be used as an estimate of the entire study area flood affectation and not on a per-property basis.

The location of each of the 1,843 properties in the database are shown in Figure 9.

6.2.2. Residential Flood Damages

Tangible flood damages are comprised of two basic categories; direct and indirect damages (refer Diagram 3). Direct damages are caused by floodwaters wetting goods and possessions thereby damaging them and resulting in either costs to replace or repair, or in a reduction to their value. Direct damages are further classified as either internal (damage to the contents of a building including carpets, furniture), structural (referring to the structural fabric of a building such as foundations, walls, floors, windows) or external (damage to all items outside the building such as cars, garages). Indirect damages are the additional financial losses caused by the flood for example the cost of temporary accommodation, loss of wages by employees etc.

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

The standard way of expressing flood damages is in terms of average annual damages (AAD). AAD represents the equivalent average damages that would be experienced by the community on an annual basis, by taking into account the probability of a flood occurrence. This means the smaller floods, which occur more frequently, are given a greater weighting than the rare catastrophic floods.

In order to quantify the damages caused by inundation for existing development, the floor level database was used (see Section 6.2.1) in conjunction with modelled flood level information to calculate damages. The flood damages assessment was undertaken for existing development in accordance with current NSW Government guidelines (Reference 16). The damages were calculated using a number of height-damage curves which relate the depth of water above the floor with tangible damages. Each component of tangible damages is allocated a maximum value and a maximum depth at which this value occurs. Any flood depths greater than this allocated value do not incur additional damages as it is assumed that, by this level, all potential damages have already occurred.

6.2.2.1. Direct Internal Damages

Internal damages were assumed to follow the default damages of $550 per square metre (in 2022 dollars) adopted in the guideline (Reference 16) for residential properties. The actual damage to contents in an event can be reduced by actions taken during the warning time available in response to a flood threat. These actions may include raising goods and furniture, moving valuable items to the kitchen benchtop, onto tables, or up to the second storey, and taking some valuables as part of evacuation, if possible. The default value of 0.9 for the actual to potential damage ratio in the guideline (Reference 16) was adopted for this study area.

6.2.2.2. Direct Structural Damages

Structural damages were assumed to follow the default damages relationships to the dwelling size and number of storeys adopted in the guideline (Reference 16). Damage per m^2 is assumed to be $2,280 for single storey houses and $2,620 for double storey houses and $2,730 for units and $2,620 for townhouses. As the dwelling size has not been obtained, all houses were assumed to have the default size of 220 m^2 and units and townhouses were assumed to be 100 m^2 and 160 m^2, respectively. In floods larger than the 1% AEP event there is the possibility that some buildings may collapse or have to be demolished. The cost of these damages was not included in the analysis.

6.2.2.3. Direct External Damages

The default external damages of $17,000 (in 2022 dollars) in the guideline (Reference 16) were adopted. This fixed external damage value was applied when the flood depth above ground level exceeded 300 mm or was above the habitable floor level.

6.2.2.4. Indirect Damages

Indirect damages were assumed to follow the default damage relationship in the guideline (Reference 16). That is, for residential clean-up costs of $4,500 (in 2022 dollars) and relocation costs of $609 per week (in 2022 dollars, median price for renting a 3 bedroom house in the area) will apply if over floor inundation exists. Non-residential indirect costs, which cover clean-up costs and loss of trading are 30% of the direct damages.

6.2.3. Non-residential Buildings

6.2.3.1. Commercial Properties and Public Buildings

Damage curves for commercial, industrial, and public buildings were adopted from the guideline (Reference 16). Direct damages (accounting for structural and contents damage) to these buildings are based on the value classification of the building as well as the floor area.

Commercial and industrial buildings are classified as low to medium, medium/default, and medium to high. The low to medium damage curves are factored by 0.6 of the default and medium to high damage curves are factored by 1.5. Commercial and industrial buildings used the medium/default damage curve as no further information on these buildings is available. As no information on floor area of each commercial and industrial building was provided, the default area of 418 m^2 was adopted. Actual to potential damage ratio was assumed to be 0.9.

Public buildings were classified as low/default and medium to high categories. The low/default damage curve for public buildings was assumed to be 40% of the medium/default commercial damage curve, whereas medium to high public buildings damage curve were assumed to be the same as the medium/default commercial damage curve.

6.2.4. Intangible Damages

Intangible damages were assumed to follow the default damage relationship in the guideline (Reference 16). These intangible damages cover social and wellbeing impacts of flooding to the community. These intangible damages have been incorporated in this assessment and were found to contribute only a small portion of the total flood damages (<5%).

6.3. Estimated Flood Damages

An estimation of the number of properties impacted (flooding occurring at the building), number of properties with above floor flooding and total damage costs for each modelled flood event was undertaken. Properties estimated to be flooded above floor are shown in Figure 9 according to the design event which first reaches above floor level.

The AAD value is determined by multiplying the damages that can occur in a given flood by the probability of that flood actually occurring in a given year, and then summing across a range of floods. This method allows smaller floods, which occur more frequently to be given a greater weighting than the larger catastrophic floods that only occur rarely. The AAD for the existing case then provides a benchmark by which to assess the merit of flood management options.

A summary of the flood damages is provided in Table 6. Residential damages and the total damages (which include residential, commercial and public buildings, along with infrastructure damages) are provided separately.

Table 6: Summary of Estimated Flood Damages for the North Creek Catchment

Flood Event		No. Lots Affected	No. Lots Flooded Above Floor Level	Total Damages for Event	Average Damage Per Flood Affected Property	% of AAD
Residential	50% AEP	28	0	$47,877	$1,710	1%
	20% AEP	125	1	$336,872	$2,695	7%
	10% AEP	234	8	$1,354,955	$5,790	10%
	5% AEP	329	30	$3,885,465	$11,810	15%
	2% AEP	446	67	$9,733,120	$21,823	23%
	1% AEP	539	89	$15,450,858	$28,666	14%
	0.5% AEP	618	122	$19,466,344	$31,499	10%
	0.2% AEP	700	150	$26,304,888	$37,578	8%
	PMF	1,198	450	$85,612,260	$71,463	13%
	Average Annual Damages			**$883,344**	**$737**	
Total	50% AEP	52	5	$242,778	$4,669	4%
	20% AEP	164	11	$849,144	$5,178	10%
	10% AEP	283	20	$2,736,091	$9,668	11%
	5% AEP	389	48	$6,520,565	$16,762	15%
	2% AEP	523	89	$14,736,580	$28,177	21%
	1% AEP	624	121	$22,759,315	$36,473	12%
	0.5% AEP	717	161	$29,624,034	$41,317	8%
	0.2% AEP	801	201	$40,798,719	$50,935	7%
	PMF	1,326	560	$148,063,336	$111,662	12%
	Average Annual Damages			**$1,606,102**	**$1,211**	

While there are no residential properties flooded above floor, there are 5 commercial/industrial properties flooded above floor in the 50% AEP event. Above floor inundation of residential properties commences in the 20% AEP event and steadily increases to 89 properties in the 1% AEP event, with residential damages exceeding $15M. There are over 500 residential properties estimated to be affected in the 1% AEP event. In the PMF event, there are over 1,300 properties affected, with 450 residential properties and 110 commercial/industrial properties flooded above floor. Residential flood damages reach $85M and total flood damages reach approximately $150M in the PMF event.

Average annual residential damages are approximately $880,000, with the total AAD reaching $1.6M. The AAD per flood affected property in the PMF is approximately $700 considering residential properties and $1,200 considering all flood affected properties in the PMF. It is the 2% AEP event that contributes the most to the AAD. This indicates that flood mitigation measures should target events of this magnitude.

The estimation of flood damages is a high-level exercise, intended to capture flood damages at the catchment scale, providing a good indication of average damages across a catchment. The accuracy of the results (flood depths) at individual properties can be affected by vagaries such as the variability in the flood level across the property, the location of the sampled flood level for the property, whether the floor level varies through the building, etc. The estimation of damages (flood damage curves) is subject to similar accuracy limitations at the property level. These variabilities tend to average out across the catchment, particularly if many properties are considered.

7. FLOODPLAIN MANAGEMENT POLICY

Council is responsible for local planning and land management in the Lake Macquarie LGA, including the management of the floodplain and drainage systems. The planning policies held and used by Council in their management of the floodplain are underpinned and bound by national and state planning legislation. It is important to understand the national and state context prior to making recommendations for Council to amend its own local planning policies to ensure that any changes are consistent with the requirements of state and national legislation.

An overview of the national and state planning instruments is provided below to provide this background.

7.1. National Planning Provisions - Building Code of Australia

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

The BCA is a uniform set of technical provisions for the design and construction of buildings and other structures throughout Australia (Reference 17). The goals of the BCA are to enable the achievement and maintenance of acceptable standards of structural sufficiency, safety, health and amenity for the benefit of the community now and in the future.

The BCA contains requirements to ensure new buildings and structures and, subject to State and Territory legislation, alterations and additions to existing buildings located in flood hazard areas do not collapse during a flood when subjected to flood actions resulting from the 'defined flood event' (DFE). The DFE is "*the flood event selected for the management of flood hazard for the location of specific development as determined by the appropriate authority*". In NSW this is typically the 1% AEP event.

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

The BCA provides general requirements for measures to keep water out of the building structure and foundations, such as setting minimum heights above ground, and minimum paved apron requirements graded to direct runoff away from the building. Section 3.1.2.3 of the BCA refers specifically to drainage of surface water and finished slab heights, and contains the requirements shown below. Additional requirements for buildings in flood hazard areas, consistent with the objectives of the BCA, primarily aim to protect the lives of occupants of those buildings in events up to and including the DFE.

Building Code of Australia 3.1.3.3 Surface water drainage

Surface water must be diverted away from Class 1 buildings as follows:

(a) Slab-on-ground — finished ground level adjacent to buildings:
the external finished surface surrounding the slab must be drained to move surface water away from the building and graded to give a slope of not less than (see Figure 3.1.2.2):
- (i) 25 mm over the first 1 m from the building in low rainfall intensity areas for surfaces that are reasonably impermeable (such as concrete or clay paving); or
- (ii) 50 mm over the first 1 m from the building in any other case.

(b) Slab-on-ground — finished slab heights:
the height of the slab-on-ground above external finished surfaces must be not less than (see Figure 3.1.2.2):
- (i) 100 mm above the finished ground level in low rainfall intensity areas or sandy, well-drained areas; or
- (ii) 50 mm above impermeable (paved or concreted areas) that slope away from the building in accordance with (a); or
- (iii) 150 mm in any other case.

7.2. State Planning Provisions

7.2.1. State Provisions – NSW Environmental Planning and Assessment Act 1979

The NSW Environmental Planning and Assessment Act 1979 (EP&A Act) provides the framework for regulating and protecting the environment and controlling the impact of development. Pursuant to Section 9.1(2) of the EP&A Act, the Minister has directed that councils have the responsibility to facilitate the implementation of the NSW Government's Flood Prone Land Policy. The policies and guidelines described in this Section fall under the EP&A Act. The objects of the Act are set out below.

Environmental Planning and Assessment Act 1979 No 203

1.3 Objects of Act

The objects of this Act are as follows:

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

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

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

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

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

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

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

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

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

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

7.2.2. NSW Flood Prone Land Policy

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

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

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

In doing so, community resilience to flooding is improved. The NSW Flood Risk Management Manual: the policy and manual for the management of flood liable land (2023, Reference 1) and its toolkit support the implementation of the policy through the combined efforts of all levels of government. This document incorporates the NSW Flood Prone Land Policy and supersedes the 2005 Floodplain Development Manual (Reference 2) as the NSW Government's manual relating to the management of flood liable land in accordance with section 733 of the Local Government Act 1993.

The Flood Risk Management Manual recognises that flood prone land is a valuable resource and the development applications and proposals for rezoning of flood prone land should be the subject of careful assessment which incorporates consideration of local circumstances. The manual outlines 10 principles for flood risk management in NSW:

1. Establish sustainable governance arrangements.
2. Think and plan strategically.
3. Be consultative.
4. Make flood information available.
5. Understand flood behaviour and constraints.

6. Understand flood risk and how it may change.
7. Consider variability and uncertainty.
8. Maintain natural flood functions.
9. Manage flood risk effectively.
10. Continually improve the management of flood risk.

7.2.3. Section 733 – Local Government Act 1993

Section 733 of the Local Government Act relates to Exemption from liability – flood liable land, land subject to risk of bush fire and land in coastal zone. Section 733 provides councils with statutory indemnity for decisions made and information provided in good faith from the outcomes of the management process (undertaken in accordance with the Flood Risk Management Manual). It states:

(1) A Council does not incur any liability in respect of:

- *(a) any advice furnished in good faith by the council relating to the likelihood of any land being flooded or the nature or extent of any such flooding, or*
- *(b) anything done or omitted to be done in good faith by the council in so far as it relates to the likelihood of land being flooded or the nature or extent of any such flooding.*

And;

(3) Without limiting subsections (1), (2) and (2A), those subsections apply to:

- *(a) the preparation or making of an environmental planning instrument, including a planning proposal for the proposed environmental planning instrument, or a development control plan, or the granting or refusal of consent to a development application, or the determination of an application for a complying development certificate, under the Environmental Planning and Assessment Act 1979 , and*
- *(b) the preparation and adoption of a coastal management program under the Coastal Management Act 2016 (and the preparation and making of a coastal zone management plan under the Coastal Protection Act 1979 that is continued in effect by operation of clause 4 of Schedule 3 to the Coastal Management Act 2016), and*
- *(c) the imposition of any condition in relation to an application referred to in paragraph (a), and*
- *(d) advice furnished in a certificate under section 149 of the Environmental Planning and Assessment Act 1979 , and*
- *(e) the carrying out of flood mitigation works, and*
- *(f) the carrying out of coastal protection works, and*
  - *(f1) the carrying out of bush fire hazard reduction works, and*
  - *(f2) anything done or omitted to be done regarding beach erosion or shoreline recession on Crown land (including Crown managed land) or land owned or controlled by a council or a public authority, and*
  - *(f3) the failure to upgrade flood mitigation works or coastal protection works in response to projected or actual impacts of climate change, and*
  - *(f4) the failure to undertake action to enforce the removal of illegal or unauthorised structures that results in erosion of a beach or land adjacent to a beach, and*
  - *(f5) the provision of information relating to climate change or sea level rise, and*
- *(g) any other thing done or omitted to be done in the exercise of a council's functions under this or any other Act.*

(4) *Without limiting any other circumstances in which a council may have acted in good faith, a council is, unless the contrary is proved, taken to have acted in good faith for the purposes of this section if the advice was furnished, or the thing was done or omitted to be done—*
   (a) *substantially in accordance with the principles contained in the relevant manual most recently notified under subsection (5) at that time, or*
   (b) *substantially in accordance with the principles and mandatory requirements set out in the current coastal management manual under the Coastal Management Act 2016 , or*
   (c) *in accordance with a direction under section 14(2) of the Coastal Management Act 2016 .*

7.2.4. Flood Prone Land Package

On the 14th July 2021, the Department of Planning, Industry and Environment (DPIE, now DCCEEW) implemented updates to the Flood Prone Land Package. The purpose of the package is to increase flood resilience in New South Wales, reduce loss of life and property damage. The package provides councils additional land use planning tools to manage flood risk beyond the 1% AEP flood event and strengthen evacuation considerations in land use planning.

The changes include:

- A revised Ministerial Direction 4.1 regarding flooding issued under Section 9.1 of the Environmental Planning and Assessment Act 1979.
- A revised planning circular on flooding.
- A new guideline: Considering Flooding in Land Use Planning.
- Revised Local Environmental Plan flood clauses.
- Amendments to Schedule 4, Section 7A of the Environmental Planning and Assessment Regulation 2000 (now Schedule 2, Section 9 of the Environmental Planning and Assessment Regulation 2021).
- State Environmental Planning Policy Amendment (Flood Planning) 2021.

The key changes and implications are outlined below.

- Amendments to Schedule 4 of EP&A Regulation including changes to Clause 7A(1), Clause 7A(2) (now Schedule 2, Clause 9(1) and 9(2), respectively). These amendments now require councils to note on Section 10.7 certificates if any flood related development controls apply to the land relating to either the FPA, hazardous materials / industry, sensitive, vulnerable or critical uses.
- The Ministerial Direction 4.3 has been amended to remove the requirement for councils to seek exceptional circumstances to apply residential development controls to land outside the 1% AEP flood event (currently included in Clause 7 of Direction 4.3).
- Two proposed LEP clauses relating to the FPA, and Special Flood Consideration.
    - The FPA clause (5.21) allows council to extend the FPA to include more extreme flood events where the flood risk requires land use planning tools. This was adopted as a standard clause on all NSW Council LEPs.
    - The clause (5.22) relating to Special Flood Consideration provides councils the mechanism to apply development controls to land outside the FPA but within the PMF. This clause is specific to land with a significant risk to life, sensitive,

vulnerable or critical uses, or land with hazardous materials or industry. This is an optional clause that Councils are required to ‘opt-in’ to include on their LEP. Council has not adopted this clause.

7.2.5. Ministerial Direction 4.1

Direction 4.3 was one in a list of directions issued on the 1st July 2009, and updated on the 14th July 2021 and again on 20th February 2023 (now Direction 4.1). The directions were issued by the then Minister for Planning to relevant planning authorities under Section 9.1(2) (previously Section 117(2)) of the EP&A Act. Direction 4 pertains to “Resilience and Hazards”, with Direction 4.1 relating specifically to Flooding. Direction 4.1 is provided below.

Objectives

(2) The objectives of this direction are to:

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

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

Application

This direction applies to all relevant planning authorities that are responsible for flood prone land when preparing a planning proposal that creates, removes or alters a zone or a provision that affects flood prone land.

Direction 4.1

(1) 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 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 Manual 2005 and adopted by the relevant council.*

(2) A planning proposal must not rezone land within the flood planning area from Recreation, Rural, Special Purpose or Conservation Zones to a Residential, Employment, Mixed Use, W4 Working Waterfront or Special Purpose Zones.

(3) 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 purposes 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.

(4) 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 a 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.

(5) 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

A planning proposal may be inconsistent with this direction only if the planning proposal authority can satisfy the Planning Secretary (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.*

Date commenced: 20 February 2023

7.2.6. Planning Circular PS 07-003 and PS 21-006

Planning Circular PS 07-003 (31st January 2007) provided advice on a package of changes concerning flood-related development controls for land above the 1-in-100 year flood and up to the PMF. A revised planning circular '*Considering flooding in land use planning: guidance and statutory requirements'* PS 21-006 was released with the recent changes to the Flood Prone Land Package on 14th July 2021. The revised circular provides advice on a package of changes regarding how land use planning considers flooding and flood-related constraints, including Section 10.7 Planning Certificates, local planning direction 4.3, LEP clauses and associated guidelines.

In Planning Circular PS21-006 it is noted that: *"Section 733 of the* Local Government Act 1993 *(the LG Act) protects councils from liability if they have followed the requirements of the Manual".*

7.2.7. Considering flooding in land use planning guideline

The guideline aims to provide councils with mechanisms to manage flood risk for the full range of flooding up to the PMF and give further consideration to evacuation constraints. Within the proposed Flood Prone Land package, there are two main categories council can use to address flooding impacts namely, FPAs or special considerations.

Historically, the focus has been on managing the 1% AEP flood event. The Flood Prone Land Package aims to provide councils the ability to apply development controls to areas outside the flood extent where the flood risk requires it. The Flood Risk Management Manual identifies either the 1% AEP flood event or an equivalent historic event as an appropriate starting point when selecting the DFE. However, it recommends considering selecting a more extreme flood event where there are significant economic, social, environmental or cultural risks associated with a larger event.

The Special Flood Considerations category provides council the ability to apply controls to land outside the FPA but within the PMF flood event where there is a significant risk to life or risk of hazardous material impacting the community or environment.

7.2.8. Section 10.7 Planning Certificates

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

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

> Section 10.7 of the EP&A Act states:
>
> *(1) A person may, on payment of the prescribed fee, apply to a council for a certificate under this section (a planning certificate) with respect to any land within the area of the council.*
> *(2) On application made to it under subsection (1), the council shall, as soon as practicable, issue a planning certificate specifying such matters relating to the land to which the certificate relates as may be prescribed (whether arising under or connected with this or any other Act or otherwise).*
> *(3) (Repealed)*
> *(4) The regulations may provide that information to be furnished in a planning certificate shall be set out in the prescribed form and manner.*
> *(5) A council may, in a planning certificate, include advice on such other relevant matters affecting the land of which it may be aware.*
> *(6) A council shall not incur any liability in respect of any advice provided in good faith pursuant to subsection (5). However, this subsection does not apply to advice provided in relation to contaminated land (including the likelihood of land being contaminated land) or to the nature or extent of contamination of land within the meaning of Schedule 6.*
> *(7) For the purpose of any proceedings for an offence against this Act or the regulations which may be taken against a person who has obtained a planning certificate or who might reasonably be expected to rely on that certificate, that certificate shall, in favour of that person, be conclusively presumed to be true and correct.*

The EP&A Regulation 2021, Schedule 2 specifies the information to be disclosed on a Section 10.7 (2) Planning Certificate. In particular, Schedule 2, Section 9 refers to flood related development control information and requires councils to provide the following information:

> *(1) If the land or part of the land is within the flood planning area and subject to flood related development controls.*
> *(2) If the land or part of the land is between the flood planning area and the probable maximum flood and subject to flood related development controls.*
> *(3) In this clause—*
> *flood planning area has the same meaning as in the Flood Risk Management Manual.*
>
> *Flood Risk Management Manual means the Flood Risk Management Manual, ISBN 978-1-923076-17-4, published by the NSW Government in June 2023.*
> *probable maximum flood has the same meaning as in the Flood Risk Management Manual.*

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

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

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

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

(a) providing exempt and complying development codes that have State-wide application, and
(b) identifying, in the exempt development codes, types of development that are of minimal environmental impact that may be carried out without the need for development consent, and
(c) identifying, in the complying development codes, types of complying development that may be carried out in accordance with a complying development certificate as defined in the Act, and
(d) enabling the progressive extension of the types of development in this Policy, and
(e) providing transitional arrangements for the introduction of the State-wide codes, including the amendment of other environmental planning instruments.

Part 3 of the SEPP contains standards relating to development in flood control lots. This is described below.

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

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

3.5 Complying development on flood control lots

1) *Development under this code must not be carried out on any part of a flood control lot, other than a part of the lot that the council or a professional engineer who specialises in hydraulic engineering has certified, for the purposes of the issue of the relevant complying development certificate, as not being any of the following:*
    a) *a flood storage area,*
    b) *a floodway area,*
    c) *a flow path,*
    d) *a high hazard area,*
    e) *a high risk area.*
2) *If complying development under this code is carried out on any part of a flood control lot, the following development standards also apply in addition to any other development standards:*
    a) *if there is a minimum floor level adopted in a development control plan by the relevant council for the lot, the development must not cause any habitable room in the dwelling house to have a floor level lower than that floor level,*

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

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

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

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

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

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

3) *The requirements under subclause (2) (c) and (d) are satisfied if a joint report by a professional engineer specialising in hydraulic engineering and a professional engineer specialising in civil engineering states that the requirements are satisfied.*
4) *A word or expression used in this clause has the same meaning as it has in the* Floodplain Development Manual*, unless it is otherwise defined in this Policy.*
5) *In this clause:*

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

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

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

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

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

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

7.3. Local Planning Provisions

Updated and relevant planning controls are important in flood risk management. Appropriate planning restrictions, ensuring that development is compatible with flood risk, can significantly reduce future flood damages. Planning instruments can be used as tools to guide new development away from high flood risk locations and ensure that new development does not increase flood risk elsewhere. They can also be used to develop appropriate evacuation and disaster management plans to better reduce flood risks to the existing population. Councils use LEPs and DCPs to govern control on development with regards to flooding.

7.3.1. Local Environmental Plan

Environmental Planning Instruments such as LEPs guide land use and development by zoning all land and identifying appropriate land uses allowed in each zone. LEPs are used as tools to guide new development away from high flood risk locations and ensure that new development does not adversely affect flood behaviour. LEPs can also be used to develop appropriate evacuation and disaster management plans to better reduce flood risks to the existing population.

The Lake Macquarie LEP (Reference 18) was developed in 2014 and the most current version was last updated 22 November 2024. On the 14th July 2021, the NSW Government's Flood Prone Land Package commenced and a revised flood clause (Clause 5.21 Flood Planning) was introduced across all LEPs in NSW, including the Lake Macquarie LEP 2014. This clause allows for the FPA to include areas outside the 1% AEP event where the damages in more extreme flood events warrant additional development controls. The standard instrument clause is shown below.

(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—
***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.*
***flood planning area** has the same meaning as it has in the Flood Risk Management Manual.*
***Floodplain Risk Management Manual** means the Flood Risk Management Manual, ISBN 978-1-923076-17-4, published by the NSW Government in June 2023.*

The Flood Prone Land Package included a second optional clause '5.22 Special flood considerations' which provides councils the mechanism to apply development controls to land outside the FPA but within the PMF. This clause is specific to land with a significant risk to life, sensitive, vulnerable or critical uses, or land with hazardous materials or industry. The current LEP has not adopted this clause. The standard instrument clause is shown below.

Provides specific controls relating to risk to life, hazardous materials and sensitive, vulnerable or critical uses. It provides councils mechanisms to additional development controls where there is a risk to life. Key extracts included in this clause are:
(1) The objectives of this clause are as follows—
(a) to enable the safe occupation and evacuation of people subject to flooding,
(b) to ensure development on land is compatible with the land's flood behaviour in the event of a flood,
(c) to avoid adverse or cumulative impacts on flood behaviour,
(d) to protect the operational capacity of emergency response facilities and critical infrastructure during flood events,
(e) to avoid adverse effects of hazardous development on the environment during flood events.
(2) This clause applies to—
(a) for sensitive and hazardous development—land between the flood planning area and the probable maximum flood, and
(b) for development that is not sensitive and hazardous development—land the consent authority considers to be land that, in the event of a flood, may—
(i) cause a particular risk to life, and
(ii) require the evacuation of people or other safety considerations.
(3) Development consent must not be granted to development on land to which

this clause applies unless the consent authority is satisfied that the development—

(a) will not affect the safe occupation and efficient evacuation of people in the event of a flood, and

(b) incorporates appropriate measures to manage risk to life in the event of a flood, and

(c) will not adversely affect the environment in the event of a flood.

(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:

***Considering Flooding in Land Use Planning Guideline**—see clause 5.21(5).*

***flood planning area**—see clause 5.21(5).*

***Floodplain Risk Management Manual**—see clause 5.21(5).*

***probable maximum flood** has the same meaning as it has in the Flood Risk Management Manual.*

***sensitive and hazardous development** means development for the following purposes—*

(a) [list land uses]

***Direction—** Only the following land uses are permitted to be included in the list—*

(a) boarding houses,
(b) caravan parks,
(c) correctional centres,
(d) early education and care facilities,
(e) eco-tourist facilities,
(f) educational establishments,
(g) emergency services facilities,
(h) group homes,
(i) hazardous industries,
(j) hazardous storage establishments,
(k) hospitals,
(l) hostels,
(m) information and education facilities,
(n) respite day care centres,
(o) seniors housing,
(p) sewerage systems,
(q) tourist and visitor accommodation,
(r) water supply systems.

7.3.2. Development Control Plan

DCPs support the implementation of the objectives of the LEP, providing specific guidance for design and assessment of proposed developments. The Lake Macquarie City Council LGA is covered by the Lake Macquarie DCP 2014 (Reference 19) which has had several updates with the latest being adopted on 11 November 2024.

The DCP is structured such that different development zones are contained in different parts:

- Part 2: Development in Rural Zones
- Part 3: Development in Residential Zones

- Part 4: Development in Centres and Mixed Use Employment Zones
- Part 5: Development in Productivity Support, Industrial and Infrastructure Zones
- Part 6: Development in Recreation and Tourist Zones
- Part 7: Development in Environment Protection Zones
- Part 8: Subdivision Development

Flood-related development controls are contained in Section 2.8 and 2.9 (sometimes Section 2.9 and 2.10) of each part, for ‘Catchment flood management’ and ‘Lake flooding and tidal inundation (incorporating sea level rise)’, respectively. Controls for catchment flooding cover the following aspects:

1. Consistency with the current Flood Risk Management Manual.
2. Consideration of flooding hazards.
3. Buildings to be located outside an identified floodway.
4. Buildings and structures must not impede floodwaters.
5. Habitable rooms to have floor levels 500 mm above the 1% AEP flood level.
6. Non-habitable rooms to have floor levels at or above the 5% AEP flood level.
7. Fill is not permitted within the 1% AEP extent.
8. Lesser provisions may be acceptable where the proposed use poses no significant risk to life.
9. Any fill must not substantially impede flow or exacerbate flooding on other properties.
10. Additions or alterations will be assessed on merits.
11. Development on flood prone land should incorporate flood risk management measures as recommended by a local flood study or FRMS&P.
12. Development affected by flooding must use flood compatible material.
13. Development on lots adjoining areas affected by the 1% AEP flood will be subject to minimum floor levels.
14. Development where 1% AEP flood levels are not available and may be flood liable should be designed to meet an acceptable level of risk from flood damage.

Applicable minimum floor levels for catchment flooding specified in the DCP are summarised in Table 7.

Table 7: Minimum floor levels for catchment flooding specified in the Lake Macquarie DCP 2014

Development Type	Minimum Floor Level
Habitable floor (dwelling, medium and high density residential)	1% AEP flood level + 500 mm
Non-habitable floor and garages (dwelling, medium and high density residential)	5% AEP flood level
Carports, boat shed, garden shed and ancillary structures (dwelling, medium and high density residential)	No requirement
Commercial, retail, mixed use	1% AEP flood level + 500 mm
Industrial	1% AEP flood level
Basement car parking entrance (medium and high density residential, commercial, retail, mixed use)	1% AEP flood level + 500 mm Failsafe means of evacuation and pump-out
Unsealed electrical installations (all types of development except sensitive uses)	1% AEP flood level + 500 mm
Sensitive uses (residential care, hospitals, etc.)	PMF level

Flood-related development controls for areas only affected by inundation from Lake Macquarie or the ocean (tidal inundation) cover the following aspects:

1. Development must implement measures to mitigate adverse effects of projected sea level rise.
2. Development should be designed and situated to reduce the risk from the effects of sea level rise.
3. Development should not be located in areas predicted to be permanently inundated during the life of the asset (50 – 100 years).
4. Special consideration may be given to increased fill allowances in areas affected by sea level rise.
5. Development should comply with minimum floor height requirements.
6. The assessing officer may determine that the development proposal is of a minor nature and that there is no need for a Flood Safety Audit and Management Plan.

Applicable minimum floor levels for lake and tidal inundation specified in the DCP are summarised in Table 8.

Table 8: Minimum floor levels for lake and tidal inundation specified in the Lake Macquarie DCP 2014

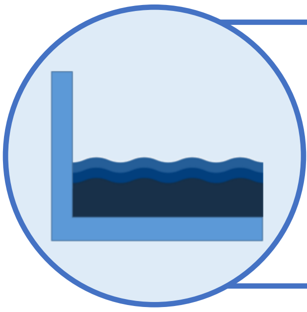
Development Type	Minimum Floor Level
Habitable floor (dwelling, commercial and retail)	2.36 mAHD (2050 1% AEP flood level + 500 mm)
Habitable floor (medium and high density residential, mixed use)	2.82 mAHD (2100 1% AEP flood level + 500 mm)
Non-habitable floor and garages (dwelling)	1.61 mAHD (2050 5% AEP flood level)
Non-habitable floor and garages (medium and high density residential)	2.10 mAHD (2100 5% AEP flood level)
Carports, boat shed, garden shed and ancillary structures (dwelling, medium and high density residential)	No requirement
Industrial	1.86 mAHD (2050 1% AEP flood level)
Basement car parking entrance (medium and high density residential, mixed use)	2.82 mAHD (2100 1% AEP flood level + 500 mm) Failsafe means of evacuation and pump-out
Basement car parking entrance (commercial and retail)	2.36 mAHD (2050 1% AEP flood level + 500 mm) Failsafe means of evacuation and pump-out
Unsealed electrical installations (dwelling, commercial, retail and industrial)	2.36 mAHD (2050 1% AEP flood level + 500 mm)
Unsealed electrical installations (medium and high density residential, mixed use)	2.82 mAHD (2100 1% AEP flood level + 500 mm)
Sensitive uses (residential care, hospitals, etc.)	3.27 mAHD (2100 PMF level)

The lake flooding section of the DCP is supported by Council's *Lake Macquarie Waterway Flooding and Tidal Inundation Policy* (Reference 14). This policy outlined the adoption of sea level rise projections of 0.4 m by 2050 and 0.9 m by 2100, for use by Council staff and the community to proceed with risk assessment, policy development, community empowerment, and planning and development decisions. The flood planning levels are based on the results of the *Lake Macquarie Waterway Flood Study* (Reference 9).

The DCP controls are also supported by the Flood Management Guideline (Reference 20), which provides additional information on flood management. It outlines the relevant State government policies and manuals as well as completed Lake Macquarie flood studies and plans. It specifically draws attention to key information from these documents to assist developers to understand requirements for flood management. This guideline, adopted in 2013, now contains outdated information.

8. FLOOD RISK MANAGEMENT MEASURES

The 2023 NSW Government's Flood Risk Management Manual (Reference 1) separates risk management measures into three broad categories, as shown below.



FLOOD MODIFICATION MEASURES

Modify the physical behaviour of a flood including depth, velocity and direction of flow paths. Typical measures include flood mitigation dams, retarding basins, channel improvement, levees, culvert or bridge modifications, flow path redirection and defined floodways. Pit and pipe improvement and even pumps may also be considered where practical.

PROPERTY MODIFICATION MEASURES

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

RESPONSE MODIFICATION MEASURES

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

A summary of the typical flood risk management measures that have been assessed for the current study is shown in Table 9. These options are discussed in detail in the subsequent sections.

Table 9: Flood Risk Management Measures

Flood Modification	Property Modification	Response Modification
Levees	Voluntary house raising	Flood warning
Temporary defences	Voluntary purchase	Flood emergency management
Channel construction	Flood proofing	Community awareness
Channel modification	Land use zoning	Improved evacuation access
Major structure modification	Flood planning levels	Flood plan / recovery plan
Drainage network modification	Flood planning area	
Drainage maintenance	Changes to planning policy	
Retarding basins	S10.7 Certificates	
	Flood Insurance	

8.1. Identification of Options and Assessment Methodology

This FRMS assessed a range of options for the management of flood risk within the North Creek catchment. The flood risk management option assessment process starts with identifying options that may be effective in mitigating flood risk. Consideration is given to areas where flood problems exist (either observed or modelled at properties and on roads) and areas with high property damages (either observed or using the flood damages assessment).

Options were identified from the existing FRMS (Reference 4) for the North Creek catchment. In addition, following a site visit and upon review of the design flood modelling results, further options were identified. These were typically options for overland flow areas that were not previously investigated.

This identification process resulted in over 20 options to be investigated. Once these options were identified, an assessment process was undertaken, as outlined in Diagram 4. A high-level assessment was undertaken as a screening tool to eliminate options that would not be feasible or effective. Factors considered include:

- Physical and technical feasibility
- Support by the community and key decision-makers
- Compatibility with the management of other hazards and issues
- Effectiveness of reducing flood risk to the community
- Potential impacts on flooding to the existing community that cannot be offset
- Indicative costs and potential disbenefits
- Adaptability to address future risks

Property and response modification options that were not eliminated were progressed to the multi-criteria analysis stage. Flood modification options that were not eliminated were subject to two intermediate steps. Firstly, a hydraulic assessment was conducted by undertaking flood modelling for the option to determine the extent of impact on flood behaviour. The 1% AEP event was initially run for this assessment. Options that had a favourable outcome were subject to a detailed assessment including modelling of all design flood events, calculation of the reduction in flood damages and an estimation of the capital and ongoing maintenance costs to conduct a cost-benefit analysis. Flood modification options having a cost-benefit ratio close to or greater than 1 were progressed to the multi-criteria analysis stage. The multi-criteria analysis assessed the relative benefits of options to inform the overall prioritisation of option implementation.

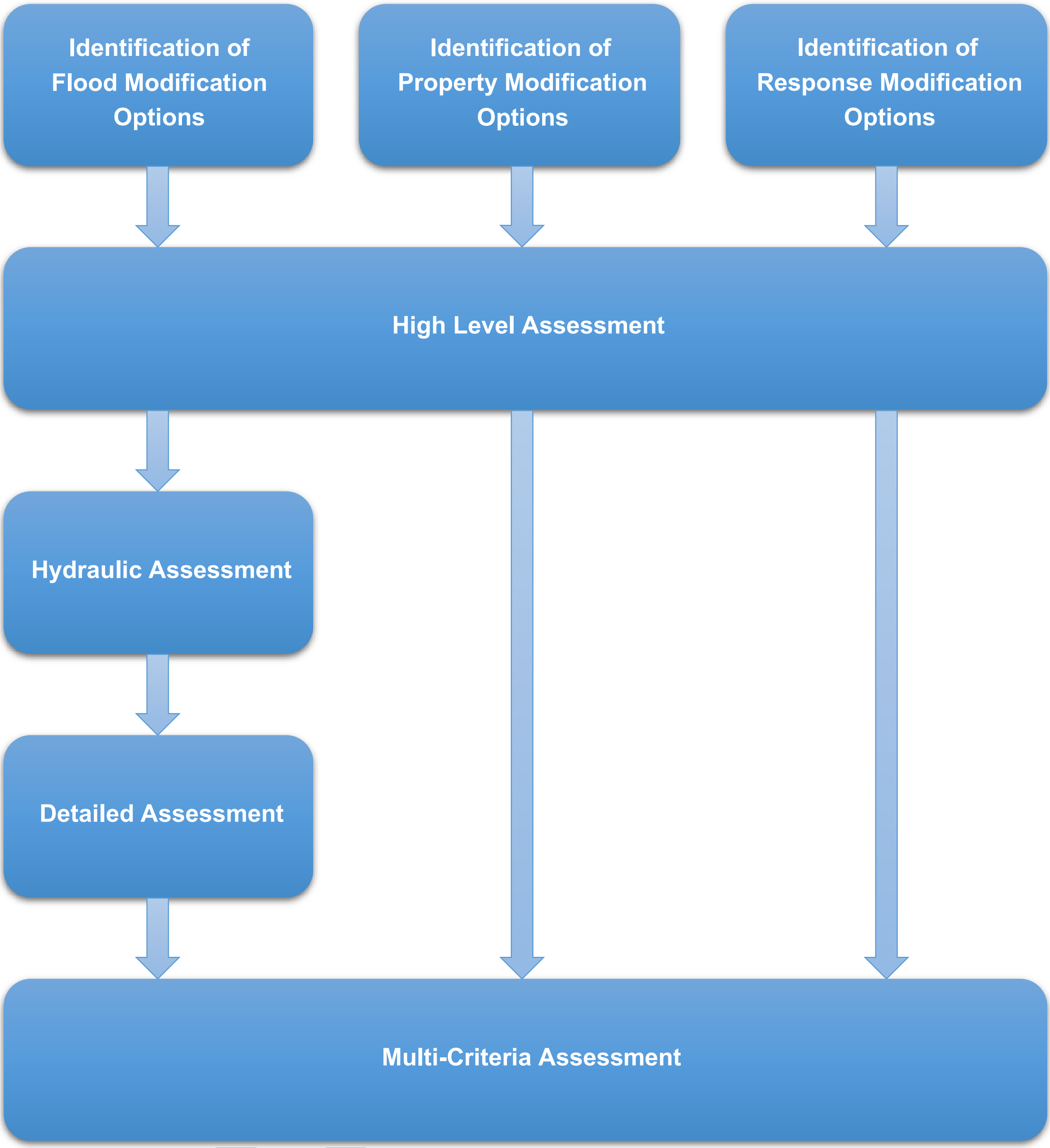


Diagram 4: Floodplain Risk Management Option Assessment Methodology

8.2. Previous FRMS Options

The previous North Creek Floodplain Risk Management Study (Reference 4) was reviewed and a summary of the options assessed and recommended a part of that study is provided in Table 10.

Table 10: Summary of 2010 North Creek Floodplain Risk Managment Study Options

Option	2010 FRMS Recommendation	Comment
Flood Modification Options		
Dams and retarding basins	Not recommended. Considered for new urban areas only.	With detailed overland flow modelling, several basin locations are considered in this study.
Channel modifications	Not recommended. Not viable except for removal of small structures (e.g. King Street Branch downstream of King Street) and preventative maintenance.	This study agrees with the conclusions of the 2010 FRMS.
Levees, floodgates and pumps	Not applicable.	This study agrees with the conclusions of the 2010 FRMS, although further demonstrated in this report (see Section 8.3.2).
Local drainage	Recommended that a flooding and drainage issues database be maintained to enable Council to identify and resolve them.	This study agrees with the conclusions of the 2010 FRMS (see Section 8.3.3.1).
Storm surge and wave runup	Not applicable.	This study agrees with the conclusions of the 2010 FRMS.
Property Modification Options		
Flood Planning Level (FPL)	Possible amendments to FPL recommended for basement car parks.	DCP has been updated since the 2010 FRMS, however, FPLs are also considered in this study (see Section 8.4.4).
Development control planning	Possible amendments to the DCP recommended, including on-site detention (OSD) requirements and flood impact assessment requirements.	DCP has been updated since the 2010 FRMS, however, the DCP is also considered in this study (see Section 8.4.6).
House raising	The high cost is noted as prohibitive, but recommended to be further investigated.	This study agrees with the conclusions of the 2010 FRMS, with specific areas identified for investigation (see Section 8.4.1).
Voluntary purchase	Not recommended. No applicable houses identified.	This study agrees with the conclusions of the 2010 FRMS (see Section 8.4.2).
Flood proofing	Recommended. Suitable for non-residential buildings and to be promoted where applicable.	This study agrees with the conclusions of the 2010 FRMS (see Section 8.4.3).
Response Modification Measures		
Flood warning	Not recommended. Not viable.	This study agrees with the conclusions of the 2010 FRMS, although general flood warnings are considered in this study (see Section 8.5.3).
Evacuation planning	Recommended. NSW State Emergency Service (SES) to prepare	A Local Flood Plan now exists and this was reviewed as part of the

Option	2010 FRMS Recommendation	Comment
	a Local Flood Plan.	current study.
Public information and education	Recommended. The continual effort required was identified.	This study agrees with the conclusions of the 2010 FRMS (see Section 8.5.2).
Overland Flow Areas		
Identify houses inundated	An overland flooding study to be considered.	The North Creek Warners Bay Flood Study (Reference 3) defined the overland flow behaviour.
Retarding basins	Not recommended. Not considered to be viable.	With detailed overland flow modelling, several basin locations are considered in this study.
OSD	OSD policy could be expanded, but not recommended due to limited benefits.	This study agrees with the conclusions of the 2010 FRMS.
Pit and pipe upgrades	The high cost and difficulty in upgrading the stormwater network is noted, but recommended to continue existing stormwater management program but recommended to include upgrades on private property when redevelopment occurs.	This study generally agrees with the conclusions of the 2010 FRMS, supported with detailed modelling (see Section 8.3.1.4).
Planning controls	Recommend continual review of DCP for managing overland flow.	DCP has been updated since the 2010 FRMS, however, the DCP is also considered in this study with regard to overland flow (see Section 8.4.6).
Development Measures		
Climate change	Recommended to expand the climate change policy adopted for Lake Macquarie flooding to all local catchments.	This study agrees with the conclusions of the 2010 FRMS (see Section 8.4.8).
Development intensification	The existing water quality controls were considered adequate, however, updates were recommended to manage the adverse effects of development.	DCP has been updated since the 2010 FRMS, however, the DCP is also considered in this study with regard to flood impact requirements (see Section 8.4.6).
Reduce potable water demand	Recommended to be promoted to minimise runoff volume and rate of runoff through Building Sustainability Index (BASIX), rainwater tanks, etc.	Not considered in this study.
Minimise wastewater generation	Not considered in the 2010 FRMS.	Not considered in this study.
Treat urban stormwater	Recommended to be promoted to improve runoff quality.	Not considered in this study.

8.3. Flood Modification Options

Flood modification measures aim to modify the behaviour of a flood itself by reducing flood levels or velocities, or by excluding water from areas under threat. Typical measures involve structural works such as levee banks, retarding basins and drainage networks, and are generally installed to modify flood behaviour on a wider scale. Depending on the type of flood behaviour, spatial constraints and catchment conditions, different flood modification measures will be better suited to reducing flood risk than others. A key consideration when assessing potential flood modification options is ensuring that, in the pursuit of reducing flood risk in one area, the option (e.g. a basin or levee) does not adversely affect other areas.

A brief overview of some common types of flood modification measures appropriate for the study area is provided below. Other options, such as diversion channels, major channel modification, and dams are only relevant to larger riverine floodplains, and therefore have not been considered as part of this FRMS. Given the highly urbanised nature of the catchment, there are significant limitations to the construction of flood modification measures. The measures are required to be compatible with the existing land use, considering aspects such as land availability, land ownership, existing assets and constructability. It was the aim of this FRMS&P to develop solutions that are practical and feasible, giving Council the means to target options that are achievable and would provide tangible benefits to reducing flood risk in the catchment.

8.3.1. Flood Modification Option Types

8.3.1.1. Detention Basins

Detention basins work by storing floodwaters during an event and controlling the release of the water. They can be built above or below ground and can be installed either as part of a new development to prevent increases in runoff rates or retrofitted into existing catchment drainage systems to assist in alleviating existing flood problems. Like the rest of the drainage system, detention basins have maintenance requirements.

The effectiveness of detention basins depends on their capacity, which for retrofitting options, can be significantly constrained by existing assets and development. However, they can also substantially reduce peak flows and are typically cost effective and easy to implement, provided there is a suitable location available. Hydraulic structures, such as low flow culverts at the bottom of a basin, can be used to restrict the discharge rates from the basin to a variable rate, dependent on rainfall volumes and the water level in the detention basin. Depending on the outlet design and operation, however, they can increase the duration of flooding by prolonging the release of floodwaters.

Whilst detention basins appear to be a fairly simple and effective means of controlling runoff and water quality in urban catchments there are a number of potential issues that need to be considered, including:

- Basins only reduce flood levels downstream, not upstream. Unless considerable excavation is undertaken the flood levels at the site of the basin and possibly upstream will increase.

- Specific flood benefits of basins can be difficult to quantify, as it depends on the basin and storm characteristics. Small basins generally provide the greatest peak flow reduction in small more frequent events, when the basin volume is a high percentage of the total flood volume. However, in these events there is often only minor above floor damage or minor hazard to mitigate. In large events, basins (unless very big) are largely ineffectual from both a water quality and peak flow reduction perspective. Also, for multi-peaked rainfall events the basin may provide some benefit in the initial peak but very little when the second or third peak arrives. The basin will be most effective when it is empty before the arrival of the storm burst, however, this is not always the case.
- Availability of land and appropriate topography – a significant area is needed to achieve the necessary storage capacity.
- Basin costs can sometimes be difficult to quantify at early planning stages, since significant excavation is usually required and the presence of utilities, services, rock, hazardous fill, etc. can significantly increase costs.
- The intentional impounding of water can produce hazardous depths within the basin, and public safety measures such as limiting the basin depth, shallow batters or fencing may need to be considered. Basins with dual purposes (such as playing fields) can increase the utility of the land but can also pose safety risks. The risk of failure and release of water from the basin also needs to be considered.

All basins will provide some flow mitigation and water quality benefit. The benefit that can be achieved must be balanced against the loss of use of the land, the economic, social and environmental costs and concerns about liability if construction of a basin increases the flood hazard in the area.

8.3.1.2. Levees

Levees involve the construction of raised embankments between the watercourse and flood affected areas to prevent the ingress of floodwater up to a design height. Levees usually take the form of earth embankments but can also be constructed of concrete walls or similar where there is limited space or other constraints. They are more commonly used on large river systems, for example on the Hunter River at Maitland, but can also be found on small creeks in urban and rural areas and in overland flow situations where they usually take the form of smaller bunds. The levee needs to tie in with high ground in order to fully protect an area and the crest can also be used as an access path or road.

Once constructed, levee systems generally have a low maintenance cost although the levee system needs to be inspected on a regular basis for erosion or failure. Although a levee can keep out flood waters, flooding can occur within the levee due to local runoff being unable to drain. Flood gates, non-return valves and pumps are often associated with levees to prevent backing up of drainage systems in the area protected by a levee and/or to remove ponding of local water behind the levee. Management of the local drainage from behind a levee is a major design challenge for these structures. In addition, as the levee causes a displacement of water from one area of the floodplain to another, the design requires consideration of hydraulic modelling to ensure the levee does not increase flood risk to an adjacent area.

The design height of the levee is the event for which it prevents flooding and usually also includes a freeboard to allow for settlement of the structure overtime or variations in flood levels due to the behaviour of the flood event, wave action from passing vehicles and effects of wind. Levees, however, can obstruct views of the waterway and provide those protected with a false sense of security, increasing flood risk in the event of overtopping or failure.

8.3.1.3. Temporary Flood Barriers

Temporary flood barriers include demountable defences, wall systems and sand bagging which are deployed prior to the onset of flooding and removed once the event has receded. Demountable defences can be used to protect large areas or specific buildings and are often used to assist current mitigation measures rather than sole protection measure (for example, fill gaps in levees or low points of road crossings, or to raise them as the risk of levee overtopping develops). The effectiveness of these measures relies on sufficient warning time, the availability of a workforce to install them, and suitable sites for storage when not in use. They are more likely used for mainstream riverine flooding which have sufficient warning time and are not suitable technically for smaller catchments with limited warning times. Temporary flood barriers may provide some benefit as a property-level protection measure, and this is discussed further in Section 8.4.3.

8.3.1.4. Road Raising

Depending on the topography of an area, floods can leave communities isolated by overtopping access routes. Raising roads to provide flood free access to such areas is commonly investigated in the flood risk management process as it can reduce evacuation time and improve accessibility as the flood progresses. Raised roads can also act like levees and increase flood levels unless culverts or overland bridge spans are upgraded as well (discussed below). Road raising may not only need to consider construction of the road, but also technical issues with existing services and infrastructure, as well as the possibility of diverting floodwaters into property or simply creating new flood paths across roadways.

8.3.1.5. Bridge and Culvert Modifications

Hydraulic controls such as bridges or major culverts on significant waterways can affect upstream flood levels due to backwatering effects. By increasing hydraulic conveyance, flood levels upstream of a structure can be decreased (and vice versa). Generally, the most effective way of increasing hydraulic conveyance is by increasing the cross-sectional area (normal to the flow direction). This is often done by increasing the size of a culvert, widening a bridge or raising the deck level. However, as flood levels are reduced upstream there is less temporary floodplain storage upstream and thus a slight increase in peak flow downstream. Reducing the structure capacity will increase flood level upstream and possibly reduce them downstream.

8.3.1.6. Channel Modifications

Channel modifications are undertaken to improve the conveyance and/or capacity of a creek or drainage system. This includes a range of measures from straightening, concrete lining, removal / augmentation of structures, dredging and vegetation clearing. Channel modifications may reduce flood levels at the location of the works but need careful planning to ensure that the flood risk is not exacerbated downstream, or that the works do not create ongoing difficulties and expense with maintenance and erosion.

8.3.1.7. Channel Construction

New channels or flow path diversions can sometimes be an effective way to transfer and confine flow in a flooding situation and can aid in reducing peak flood levels, extents and duration, particularly in overland flow areas. In the North Creek catchment, there is generally little scope to undertake this measure as there are existing development constraints, and where viable will often have already been undertaken (for example the Seaman Avenue Branch). This measure may require additional land take, will generally involve significant costs and may have adverse environmental impacts.

8.3.1.8. Local Drainage Network Modification

The drainage network outside the creek and open channel system comprises Council's pit and pipe network. Local drainage systems typically reach capacity in an event equivalent to a 20% AEP event and excess runoff flows overland, potentially posing a threat to pedestrians, motorists, and if of sufficient depth, properties. Increasing the size of pipes or installing more inlet capacity (possibly to compensate for blockage) will have some benefit, decreasing the quantity of overland flow and thus flood levels. Hydraulic restrictions in the system affect upstream flood levels due to backwatering effects. However, due to the relatively small percentage of flow carried by the pipe system in a large (e.g. 1% AEP) event any improvements will have minimal benefit except in the smaller events (typically < 10% AEP).

As such, these types of works will have minimal benefit in the large floods which generally are the cause of above floor inundation, however, may reduce the severity or frequency of nuisance inundation, particularly along roads, which could be beneficial to the community. It is noted that local drainage network modifications may fall into the purview of Council's stormwater management rather than flood risk management, however they have still been investigated and modelled (where appropriate) as part of this study.

8.3.1.9. Drainage Network Maintenance

Maintenance of the drainage network is important to ensure it is operating with maximum efficiency and to reduce the risk of blockage or failure. Maintenance involves regularly removing unwanted vegetation and other debris from the drainage network, particularly at culverts and small bridges. Blockage has the potential to increase peak flood levels as water is unable to efficiently drain away. A proactive approach to drainage maintenance will help manage the risk of blockage occurring during a flood event. Installation of gross pollutant traps, particularly in proximity to at risk structures, can also ensure that the structures remain clear.

A common issue with all residents in flood liable areas is the perceived lack of maintenance within the creek or piped drainage systems. This perception arises as residents see the build-up of debris either before, during or after the event and think that this is a major contributor to flooding. Whilst debris build-up does contribute to increased flood levels the issue is more complex than may be first assumed for the following reasons:

- Council already has a routine debris removal program for GPTs;
- Council does undertake creek maintenance and cleaning of pits and pipes if advised of major debris build up (fallen trees, blocked drains, etc.);
- It is generally only during a storm event that there is a major release of debris into the drainage system due to fallen trees, wheelie bins swept into the creek, fences fall over or water and wind sweeping debris from yards or other sources. Maintenance prior to the event does little to reduce these debris sources;
- Blockage of small culverts has little impact in large events as the percentage of flow in these structures is very small and thus has only a small impact on peak flood levels.

Structure blockage can be improved with the introduction of maintenance protocols or policies to ensure that drainage assets are effectively managed and regularly maintained. These policies aim to ensure that assets will perform when they are needed. Alternatively, the implementation of trash racks or bollards upstream of structures could be considered by Council to keep structures free of debris (example shown in Photo 36). The cost of trash racks or bollards varies greatly depending upon the nature of the structure.

Photo 36: Debris control structure on the outlet of the Vermont Place detention basin

Some Councils have introduced silt and vegetation management plans to address this issue. However, it is acknowledged that these schemes are costly for Councils to operate and must be continued in perpetuity to be effective. These schemes are generally welcomed by the residents who appreciate that Council is listening and addressing their concerns.

8.3.2. Flood Modification Options Rejected with High Level Assessment

The high level assessment was undertaken as a screening tool to eliminate options that would not be feasible or effective. Based on the outcome of this assessment, the option was either not pursued further, or was subject to a hydraulic assessment. This section records those options that were not pursued further, as presented in Table 11.

Table 11: Flood Modification Measures Rejected with High Level Assessment

Option	Description/Comment
Temporary Flood Barriers	There are no locations identified where temporary flood-barriers could be implemented on a large scale that would protect property, particularly given the lack of warning and short lead time between rainfall and flooding in the catchment.
Bridge and Culvert Modifications	There were no significant areas of constraint that would benefit from culvert or bridge upgrades without causing downstream impacts. The peak water level profiles in the Flood Study (Reference 3) did not suggest there were any obvious areas of improvement.
Road Raising	There are several local sag points that could be raised to improve flood immunity of roads, however, this would only benefit the road (no reduction in flood damages) and there would be significant issues with tying into existing development, such as driveways.
Channel Construction	No areas identified that would be feasible for the construction of a new channel.
Channel Modification	There were no areas identified that would be feasible to implement channel upgrades. For example, the Lakelands Branch channel from Medcalf Street to North Creek (Photo 16) is known to have little capacity, however, there is little opportunity to increase conveyance to provide any substantial benefit, due to the existing development and grade constraints.
Levee	The North Creek floodplain downstream of Walker Street is simply too vast to be able to construct a levee that would contain flows to North Creek. Any levee system would: • Need to be continuous. A levee would need to span the entire creek length from Walker Street to the Esplanade bridge. Any levee that did not span this entire length would simply allow backwater from North Creek to pass around the levee to fill the area behind the levee. • Need to be very high. A levee that would contain the peak 1% AEP flood level would need to be approximately 1 m high at locations adjacent to private property (not accounting for any increase in flood level that the levee would cause and not including any freeboard). A levee this high is unlikely to be feasible and unlikely to be supported by the community. • Cause flood level increases. A levee on this floodplain would increase flood levels within North Creek. This may have adverse

Option	Description/Comment
	impacts on flood levels on North Creek upstream, adjacent to and downstream of the levee. This has the potential to affect properties not protected by the levee (for example, upstream of the levee or on the opposite side of the creek if the levee was to only protect one side). • Cause local drainage issues. The draining of runoff from behind levees is a significant issue and the levee would only serve to cause ponding of local flows behind the levee that would be difficult to drain, especially with elevated North Creek flood levels. The local tributaries (such as the Lakelands Branch and Seaman Avenue Branch) would also need to be considered. Given the above constraints, a levee system for North Creek is not considered viable.

8.3.1. Flood Modification Options Rejected with Hydraulic Assessment

The hydraulic assessment stage involved undertaking flood modelling of the options to determine the extent of their impactws on flood behaviour. The 1% AEP event was initially run for this assessment. The results of this assessment were used to determine if the option provided any substantial benefit to flooding. Based on the outcome of this assessment, the option was either not pursued further, or was subject to a detailed assessment. Options that were rejected at this stage are summarised in the following sections.

8.3.1.1. Detention Basins

While detention basins were not recommended in the previous FRMS (Reference 3), however, several locations were investigated as part of the current study, as described below.

Biddabah School Field:
The Biddabah School Field receives overland flows from a flow path originating from Munibung Hill toward the Seaman Avenue Branch concrete open channel. However, flow at this location is shallow and spread out, flowing not only over the field, but through properties and along Fairfax Road. As such, it is difficult to capture these flows into a 'basin' that could be formed by constructing an embankment on the southern half of the field (see Figure B1). The embankment itself would prevent some of the overland flows from entering the basin and the benefit to downstream 1% AEP flood levels is less than 0.1 m (see Figure B2). Due to the shallow nature of flooding, there is minimal benefit to downstream properties.

Hillsborough Road Detention Basin:
A detention basin (embankment) upstream of King Street was tested in the hydraulic model, to see if flows could be contained within the area bounded by Warners Bay High School and Hillsborough Road. This would improve the flood immunity of the Hillsborough Road roundabout and potentially downstream areas affected by inundation from North Creek. This would effectively act as a detention basin, with the proposed embankment shown in Figure B3. The embankment was modelled to be approximately 1.5 m high at King Street.

With the existing peak flood depth at King Street to be almost 1.5 m deep in the 1% AEP event, the peak flood level only increased by approximately 0.05 m upstream of King Street, with impacts further upstream reaching 0.1 m as water is diverted onto Hillsborough Road upstream of the levee, as shown in Figure B4. There was no substantial benefit downstream. There is simply too much flow arriving at this location for an embankment to be able to contain the water and this option was not considered viable.

Queen Street Detention Basin:
A detention basin upstream of King Street, in between the two ends of Queen Street was considered. Floodwater on the King Street Branch ponds within a small grassy reserve at this location before crossing King Street. The aim of a detention basin at this location is to contain flow and prevent overtopping of King Street. This option was tested in the hydraulic model by excavating the reserve to the invert of the culvert under King Street and raising an embankment approximately 1 m high to contain water. This option is shown in Figure B5.

Upstream of King Street, peak flood levels in the 1% AEP event increase by 1 m, in line with the raised embankment (impact shown in Figure B6). This increase affects the Queen Street cul-de-sac on the southern side (increases up to 0.07 m), with the street now conveying shallow overland flow (typically less than 0.1 m deep). There is an open channel that runs along the western side of Queen Street (to the north of the basin), which is low-lying and the increased tailwater level in the proposed basin causes backwater up this channel, such that more flow spills into Myles Avenue, with some localised impacts. Downstream of King Street, there are significant reductions on Walker Street (approximately 0.1 m), while there are slight increases on the King Street Branch at the rear of the Walker Street properties. At the flow path's junction with North Creek, these increases are exacerbated with impacts reaching 0.04 m. While there is some benefit to the basin, particularly on Walker Street, the basin is too small to provide any substantial benefit and the improvements on Walker Street are primarily due to a re-distribution of flow. There are also concerns with low lying land upstream of the basin where elevated water levels in the basin cause impacts. This option was not considered viable.

8.3.1.2. Flood Storage

Additional flood storage on the North Creek floodplain was investigated by lowering Feighan Park. The elevations on the oval currently are between approximately 1.8 mAHD and 3.2 mAHD. The option assessed lowering the 3 fields that comprise Feighan Park to 1.5 mAHD (shown in Figure B7). This area covers almost 50,000 m^2. The area would drain overland to North Creek (provided there is some grade on the land).

Instead of the park being subject to shallow overland flow, the entire area was modelled to be inundated to a level of approximately 1.8 mAHD (0.3 m deep) in the 1% AEP event (impact shown in Figure B8). Flood levels decreased by approximately 0.1 m on New Road, 0.07 m on Seaman Avenue and 0.03 m across the wider North Creek floodplain from Albert Street to John Street. While there are numerous properties benefited, the magnitude of benefit is relatively small. While excavation of the playing fields may be relatively straightforward, there is also the need to consider surrounding infrastructure such as lighting on the field and the potential for acid sulfate soils. The lowering of the fields may mean that they are inundated in a 50% AEP Lake Macquarie event in

2100 (0.9 m sea level rise), or a 5% AEP Lake Macquarie event in 2050 (0.4 m sea level rise), rather than the current flood immunity of approximately 0.2% AEP event (see Table 3). This option was not considered to be viable.

8.3.1.3. Low Point Relief

There were several low points identified in the eastern portion of the catchment where inundation of roads occurs. While these are relatively shallow depths, even in the 1% AEP event, they may restrict access for vehicles. The hydraulic hazard classification indicates that 0.3 m depth is when floodwater may be unsafe for small vehicles. Where possible, these low points could be relieved by providing an overland flow path from the top of the gutter to an adjacent flow path. This would improve the reliability of access during flood events. This option was simulated in the hydraulic model for the low points on Myles Avenue (just north of New York Avenue), Vermont Place, Indiana Close and Wilton Close, in addition to two further locations on Whitehaven Drive (near Lonsdale Grove) and The Esplanade (near Fairfax Road). These locations are shown in Figure B9, with the Indiana Close low point shown in Photo 37 as an example.

Photo 37: Indiana Close low point at the end of the road, with an embankment restricting overland flows to the flow path (*Source: Google Street* View)

The impact of relieving these low points in the 1% AEP event is shown in Figure B10. The results indicate that flood levels reduce by approximately 0.02 m at Whitehaven Drive and Myles Avenue, while there was a negligible change at Vermont Place. Larger benefits were modelled at Indiana Close (up to 0.2 m), Wilton Close (up to 0.15 m) and The Esplanade (up to 0.08 m). There will, however, always be ponding at these sag points in large rainfall events and relieving these provides minimal benefit. The duration of inundation of these low points is reasonably short, with the duration of inundation in the 1% AEP event above 0.1 m depth for approximately 1 hour (based on the adopted 1 hour critical duration storm), and typically less than 30 minutes for depths above 0.3 m. It is only recommended to pursue this option for individual sites if there is evidence of regular ponding that disrupts traffic.

8.3.1.4. Drainage Upgrades

There are several areas where drainage upgrades may improve flood conditions and provide benefits to road users and adjacent properties. These upgrades were investigated in this study and as described below.

New Road:
Ponding at the intersection of New Road and Seaman Avenue can affect properties on Seaman Avenue (see Section 5.8.1). There is an existing 675 mm diameter pipe that drains this low point to North Creek. A drainage upgrade in this location was tested by tripling the existing pit inlet capacity and duplicating the existing pipe twice (i.e. installing two additional 675 mm diameter pipes). This drainage upgrade is shown in Figure B11.

This option was simulated with the 1% AEP event and the change in peak flood levels is shown in Figure B12. The results indicate that the peak flood levels at the New Road and Seaman Avenue intersection reduce by approximately 0.03 m. This reduction also extends onto private property. There are only 2 properties estimated to be flooded above floor in the 1% AEP event at this location and the hazard still reaches H2 on the road with this upgrade. This upgrade would be relatively expensive for the minimal benefit it provides.

Hughes Avenue:
Hughes Avenue is a prominent sag point in the western portion of the catchment (see Section 5.8.2). There is an existing 900 mm diameter pipe that drains this low point to the Seaman Avenue open channel. A drainage upgrade in this location was tested by doubling the existing pit inlet capacity and duplicating the existing pipe (i.e. installing an additional 900 mm diameter pipe). This drainage upgrade is shown in Figure B13.

This option was simulated with the 1% AEP event and the change in peak flood levels is shown in Figure B14. The results indicate that the peak flood levels on Hughes Avenue reduce by 0.07 m. There are reductions in flood levels adjacent to the downstream properties of up to 0.3 m, although these properties are only estimated to be inundated above floor in events larger than a 1% AEP. The hazard still reaches H2 on the road with this upgrade. This upgrade would be relatively expensive for the minimal benefit it provides.

Ramsbury Close:
Ramsbury Close is located on a flow path downstream of the Forrester Close detention basin. The water is collected by a headwall in bushland upstream of Ramsbury Close and conveyed via a 600 mm diameter pipe to Ramsbury Close. Flow in excess of the culvert capacity is conveyed overland through private properties to Ramsbury Close. The pipe continues under Ramsbury Close as a 750 mm pipe and outletting to the Vermont Place Branch at Indiana Close as a 900 mm pipe. A drainage upgrade in this location was tested by upgrading the 600 mm diameter pipe from the headwall to Ramsbury Close, and removing the design blockage of 50%, assuming that a

debris control structure is installed at the headwall. A bund is also proposed along the rear of the properties to prevent overland flows through them. The bund would be approximately 1.5 m high at the low point. This drainage upgrade is shown in Figure B15.

This option was simulated with the 1% AEP event and the change in peak flood levels is shown in Figure B16. The results indicate that the bund prevents all overland flows through properties on Ramsbury Close, with the upgraded culvert conveying flow. The reductions in peak flood level on Ramsbury Close and downstream roads and properties are up to 0.1 m. The reduction on the Vermont Place flow path open channel is approximately 0.07 m. While there are widespread reductions in flood affectation, there are only two properties on Myles Avenue that are estimated to be inundated above floor level in the 1% AEP event that would benefit from this option. The flood hazard on roads remains largely the same. This upgrade, while reasonably simple (upgrade of a pipe within an easement and construction of a bund) would need to consider environmental and social impacts, particularly the bund at the rear of the properties. Without the bund there are only localised reductions in flood level to properties on Ramsbury Close.

Aurora Court:
Aurora Court has one of the largest low points of all the local roads, with 1% AEP flood depths reaching over 0.5 m. The low point is drained by a 375 mm pipe from the road to the New York Avenue detention basins. A drainage upgrade in this location was tested by upgrading the existing pipe to a 900 mm diameter pipe and tripling the existing pit inlet capacity. This drainage upgrade is shown in Figure B17.

This option was simulated with the 1% AEP event and the change in peak flood levels is shown in Figure B18. The results indicate that the peak flood levels on Aurora Court reduce by approximately 0.1 m. There are reductions in flood levels on private property adjacent to the low point of the same magnitude, two of which are estimated to be inundated above floor in the 1% AEP event. The hazard on the road reduces from H3 to H2 with this upgrade. There are minor increases (approximately 0.03 m) within one of the New York Avenue basins.

Nott Street and Yorston Street:
Nott and Yorston Streets are subject to flooding from the King Street flow path and one of the primary overland flow paths with significant affectation at private properties (see Section 5.8.6). There is a 1.2 m diameter pipe that services this flow path, which runs under private property in some locations. A drainage upgrade in this location was tested by duplicating the existing 1.2 m diameter pipe (i.e. installing an additional 1.2 m diameter pipe) and tripling the existing pit inlet capacity along the route from the East Street and Nott Street intersection, to the pipe's outlet at Elizabeth Street. This drainage upgrade is shown in Figure B19.

This option was simulated with the 1% AEP event and the change in peak flood levels is shown in Figure B20. The results indicate that the peak flood levels on Nott Street reduce by approximately 0.15 m. On private properties between Nott and Yorston Streets, the reduction is approximately 0.1 m. On Yorston Street and properties downstream of this, flood levels are lowered by approximately 0.05 m. On Elizabeth Street the flood levels remain largely the same.

While the reductions are not insignificant, it is noted that this route is a substantial distance (approximately 340 m) and crosses private property, with driveways and other structures (sheds, fences, etc) on top of the existing pipe alignment. The upgrade would have a significant cost (nominally at least $3.5 M, without consideration of piping under private property).

Summary:
In each of these cases, the change in peak flood levels is generally small (<0.1 m), with no significant change in flood behaviour (roads and properties are typically still subject to inundation). Drainage upgrades such as these are typically expensive, involving substantial excavation work (including road surfaces and in some cases through private property adjacent to buildings), laying considerable lengths of new pipe, installing new inlets (typically pits) and outlets (typically headwalls) and remediation works such as re-surfacing roads and landscaping. Total project costs are typically in the range of $10,000 per metre of pipe to be laid. This means that even short sections of pipe (such as Hughes Avenue where approximately 50 m of pipe is required), may cost in the order of $500,000, while the Nott and Yorston Street works may be at least $3.5 M. A preliminary estimate of costs and benefits yielded a cost-benefit ratio of approximately 0.2. The cost of drainage works compared to the benefits to flooding that they provide does not result in a favourable economic outcome and these are not recommended to be pursued for the purpose of flood mitigation.

While these drainage upgrades are not recommended, it is recommended to undertake regular maintenance of the drainage network, described in Section 8.3.1.9, and continue to upgrade stormwater infrastructure when the opportunity arises.

8.3.2. Flood Modification Options Subject to Detailed Assessment

Options that provided reasonable benefits to flooding at the hydraulic assessment stage were subject to a detailed assessment. This included modelling of all design flood events, calculation of the reduction in flood damages and an estimation of the capital and ongoing maintenance costs to conduct a cost-benefit analysis. Based on the outcome of this assessment, the option was either not pursued further, or was included in the multi-criteria assessment. These options are shown in Figure 19.

8.3.2.1. Flood Modification Option Costs

A preliminary cost estimate was undertaken for options which progressed to the detailed assessment stage. Costs were estimated using a schedule of rates for tasks and materials required. The source of these rates was primarily from Rawlinsons Australian Construction Handbook (Reference 21). The rates published for Sydney (the upper rate if a range was supplied) was used for this investigation. It was assumed that the regional cost factor for Lake Macquarie is 1.01 (i.e. the same as Newcastle). There are several factors which affect construction costs and the estimates provided here are preliminary estimates for the purpose of determining a cost-benefit ratio. The schedule of rates is contained in Appendix D.

A set of standard costs were included for each option, related to direct costs incurred by Council, pre-construction costs and construction contingencies as outlined in Table 12.

Table 12: Additional Costs Factored into Costing

Item	Cost / Rate
Pre-construction Costs	
Design (including survey, investigation design, geotechnical investigations, review of environmental factors, detailed design, etc.)	15% of construction cost
Project Management of Design	15% of design costs
Pre-construction contingency	40% of total pre-construction costs
Construction Costs	
Establishment (project inception, management and coordination)	$10,000
Preparation and implementation of preliminaries (construction environmental management plan, safety management plan, traffic control plan, quality management plan, etc)	$20,000
Construction management / supervision	15%
Construction contingency	40% of total construction costs

The following assumptions were also made:

- No major tree clearing is necessary.
- All excavations are in 'light soil'. Costs will be higher in soils with high clay content or through rock.
- No service relocation costs were included, which can be significant if required.
- No land acquisition costs were included.

Breakdowns of the cost estimates for each option are contained in Appendix D.

8.3.2.2. Flood Modification Option Benefits

The benefits to flooding for most options were mapped for the 5% AEP and 1% AEP flood events. These maps show the change in peak flood level and indicate the magnitude and extent of flood benefits. The economic benefits of the options were quantified by estimating the reduction in AAD. AAD was estimated using the same methodology outlined in Section 6. It is likely that options may also provide additional benefits that were not quantified in this assessment. These might include increased access during floods for emergency services, evacuation and reduced travel disruptions in general for those options that improve flooding on roads.

8.3.2.3. Flood Modification Option Cost-Benefit Analysis

A cost-benefit analysis (CBA) was undertaken to determine a cost-benefit ratio (CBR). This was done by comparing the Net Present Value (NPV) of the reduction in AAD (benefit) with the capital cost of the works. To calculate NPV, an asset life of 25 years with a discount rate of 7% was applied (in accordance with NSW Treasury Guidelines, Reference 22). It is assumed that capital works costs are the only costs, with no additional annual costs (such as maintenance of the stormwater system) incurred to Council beyond current expenditure.

8.3.2.4. FM01: Lakelands Embankment

Description of Flooding

The Lakelands Pond is located at the southern end of the Lakelands suburb. Discharges from the basin form the Lakelands Branch (see Section 1.3). The pond holds permanent water at a maximum level estimated to be 4.67 mAHD. Above this, a raised pit structure (Photo 15) captures flow and discharges it under Medcalf Street via a 2.7 m (W) x 0.75 m (H) box culvert to an open channel that flows to North Creek. The pond is estimated to overtop the embankment (level of approximately 5.6 mAHD) in the 10% AEP event, inundating Medcalf Street and several properties downstream. The worst affected are commercial/industrial lots located on the eastern side of the open channel. Flood depths reach 0.7 m on Medcalf Street in the 1% AEP event.

Option Description

This option involves construction of an embankment on the southern side of the Lakelands Pond, to a minimum level of 6 mAHD. This level was selected based on the existing tennis courts that are located between the pond and Medcalf Street, which has a minimum level of approximately 6.1 mAHD. The selected elevation is the highest possible without causing inundation of the tennis courts in the 1% AEP event. This embankment will enable more water to be retained within the Lakelands Pond. This embankment is proposed to be located along the existing shared path that runs parallel to Medcalf Street, as shown in Photo 38.

Photo 38: Lakelands Pond Proposed Embankment (*Source: Google Street View*)

The existing profile along the shared path based on the available LiDAR data is shown in

Diagram 5, with the proposed embankment also shown. The maximum height of raising is approximately 0.7 m. The embankment on the eastern side of the tennis courts already has a minimum elevation of approximately 6 mAHD such that the proposed works are located to the west of the tennis courts along a total length of approximately 90 m. This proposed embankment was implemented in the TUFLOW model, as shown in Figure C1. There were no other proposed changes to the outlet structure or any works within the pond itself.

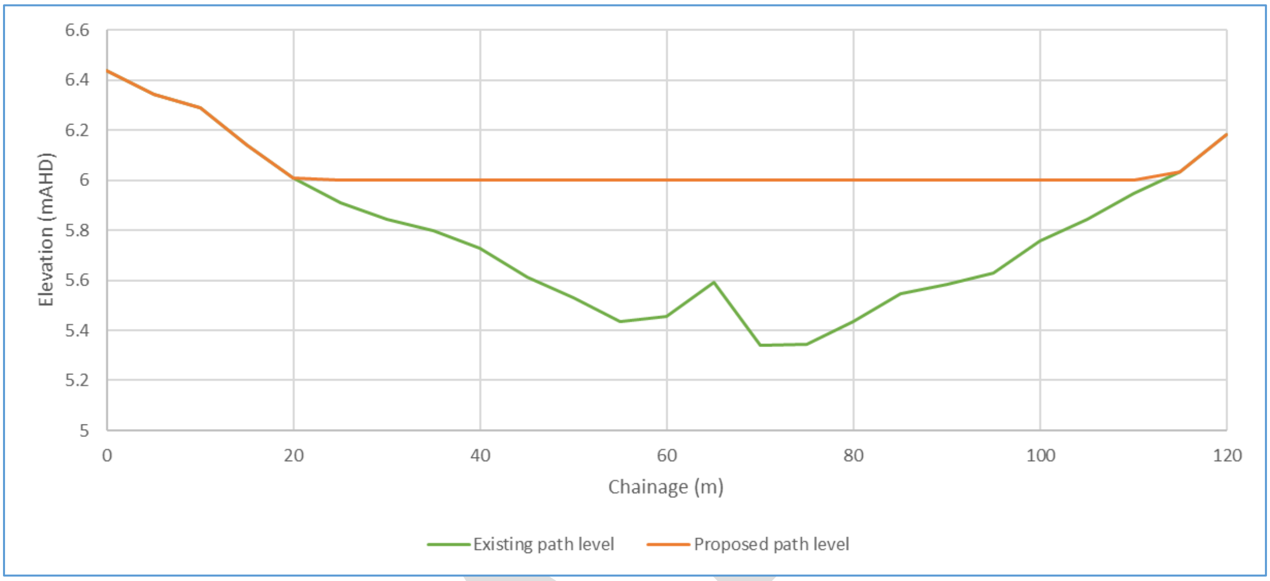


Diagram 5: Lakelands Pond Proposed Embankment Profile

This option is feasible to construct and involves earthworks to form the embankment. There is an existing embankment and shared pathway, so these works simply involve raising this pathway. The length of the works is expected to be less than 100 m and the path would be reinstated on top of the new embankment, tying into the existing path. Given that the maximum height of the embankment is approximately 0.7 m, there is considered sufficient space to construct this without substantial batters. Trees in the vicinity of the path are proposed to remain. It is unlikely that any services would be impacted.

It is recommended that the original design of the Lakelands Pond be investigated to ensure that the proposed works do not significantly change the intended function of the pond. It is also recommended that detailed survey be conducted of assets and infrastructure surrounding the pond to ensure that the higher water levels in the pond will not have any adverse impacts. It appears that the pond can accommodate additional capacity without any detriment, however, this should be confirmed through a detailed investigation of the site. Consideration could also be given to increasing flood storage by lowering the low flow outlet level.

Option Impacts

Peak flood level impacts due to this option are presented in Figure C2 and Figure C3, for the 5% AEP event and 1% AEP event, respectively. With the proposed embankment, the overtopping event is now the 2% AEP rather than the 10% AEP. In the 5% AEP event, the water level within the pond increases by 0.06 m, with a negligible change to the flood extent. On Medcalf Street and the channel downstream, flood levels reduce by up to approximately 0.1 m, with some areas no longer flooded through the commercial/industrial area.

In the 1% AEP event, peak water levels in the pond increase by approximately 0.18 m. The embankment overtops at a similar location to the existing case and there are reductions immediately downstream of approximately 0.05 m – 0.1 m. Reductions in peak flood levels persist downstream through North Creek where there are benefits of approximately 0.03 m at Margaret Street and reducing to 0.01 m at John Street.

Some social impacts are associated with this option as there would be minor disruptions during construction including the requirement to close the shared path for the duration of construction and potentially closing of one lane of Medcalf Street for some time within the construction period.

There are trees between the existing path and the Lakelands Pond that are proposed to be retained and the project would only serve to enhance the environmental value of this area with additional plantings. There are not expected to be any adverse impacts due to short-duration inundation of plants in large flood events.

Cost-Benefit Analysis

The cost of implementing this option was estimated to be approximately $340,000, with no ongoing maintenance costs directly associated with this option. Details of costs are provided in Appendix D.

The benefit of this option was assessed by comparing the AAD of the option with the base case. The benefit to AAD was estimated to be approximately $60,000. The NPV of this benefit was estimated to be approximately $730,000 (increases to $830,000 if a timeframe of 50 years is assessed). A summary of the benefits to flood damages is provided in Table 13. For the change in the number of properties affected, a negative number indicates a decrease in the number of properties affected and a positive number indicates an increase in the number of properties affected.

Table 13: Summary of Flood Damage Benefits for FM01 Lakelands Embankment

Event	Residential Flood Damages			Total Flood Damages		
	Change in # Properties Affected	Change in # Properties Flooded Above Floor	Change in Damages	Change in # Properties Affected	Change in # Properties Flooded Above Floor	Change in Damages
50% AEP	0	0	$-	0	0	$-
20% AEP	0	0	$-	0	0	$-
10% AEP	0	0	-$5,863	0	0	-$6,450
5% AEP	0	-1	-$449,510	-5	-3	-$677,971
2% AEP	-4	-5	-$643,478	-6	-6	-$891,336
1% AEP	0	-1	-$591,481	-1	-3	-$1,047,214
0.5% AEP	-1	-2	-$387,955	-3	-3	-$656,123
0.2% AEP	-1	-2	-$238,383	-1	-2	-$288,477
PMF	0	0	$37,782	0	0	$103,237
Average Annual Damages			-$37,836	Average Annual Damages		-$58,855

The CBR of this option was therefore estimated to be approximately 2.2, which indicates that it is economically viable.

Summary and Recommendation

	FM01 Lakelands Embankment
Description	• Construct an embankment up to 0.7 m high along the existing path on the downstream side of the Lakelands Pond
Benefits	• Reduces overtopping from first occurring in the 10% AEP event to the 2% AEP event • Reduces road inundation on Medcalf Street • Reduces property impacts downstream
Concerns	• May cause social disruption during construction • Primarily commercial properties immediately downstream
Approximate Cost	$340,000
CBR	2.2
Responsibility	Council
Outcome	Recommended for further investigation
Priority	Low

8.3.2.5. FM02: Wilton Close Basin

Description of Flooding

The Wilton Close detention basin is proposed to be located in a reserve between Wilton Close, Chartley Street and East Street, on the upper reaches of the King Street Branch. The reserve is located at the junction of several flow paths, at the intersection of Wilton Close and Whyte Street, as well as the discharge location for the stormwater network that drains the catchment to this point. The reserve is a natural area of depression that is currently heavily vegetated. Historical Google Street View imagery indicates that the reserve was a drainage channel that was planted between 2008 and 2010 (see Photo 39). The reserve is drained by the 1.2 m diameter pipe that commences the main drainage pipe of the King Street Branch to Queen Street (see Photo 40).

Photo 39: Evolution of the Wilton Close reserve (*Source: Google Street View*)

Photo 40: Culvert inlet that drains the Wilton Close reserve

The area acts as a detention basin, with water ponding to a depth of just over 3 m at the 1.2 m diameter culvert inlet. Water spills out of this low point in events as frequent as the 20% AEP and inundates downstream low points in the back yards of properties on East Street (see Section 5.8.6).

Option Description

This option involves construction of an embankment or wall surrounding the drainage reserve plus some excavation works to increase the capacity of the detention basin. The top level of the embankment was modelled to be 22 mAHD, with a lower level along the western boundary at 21.5 mAHD to provide a designated overtopping location. A profile along the boundary of the lot is shown in Diagram 6 from the available LiDAR data. The proposed structure would be a maximum of 2 m high and cover a length of approximately 150 m.

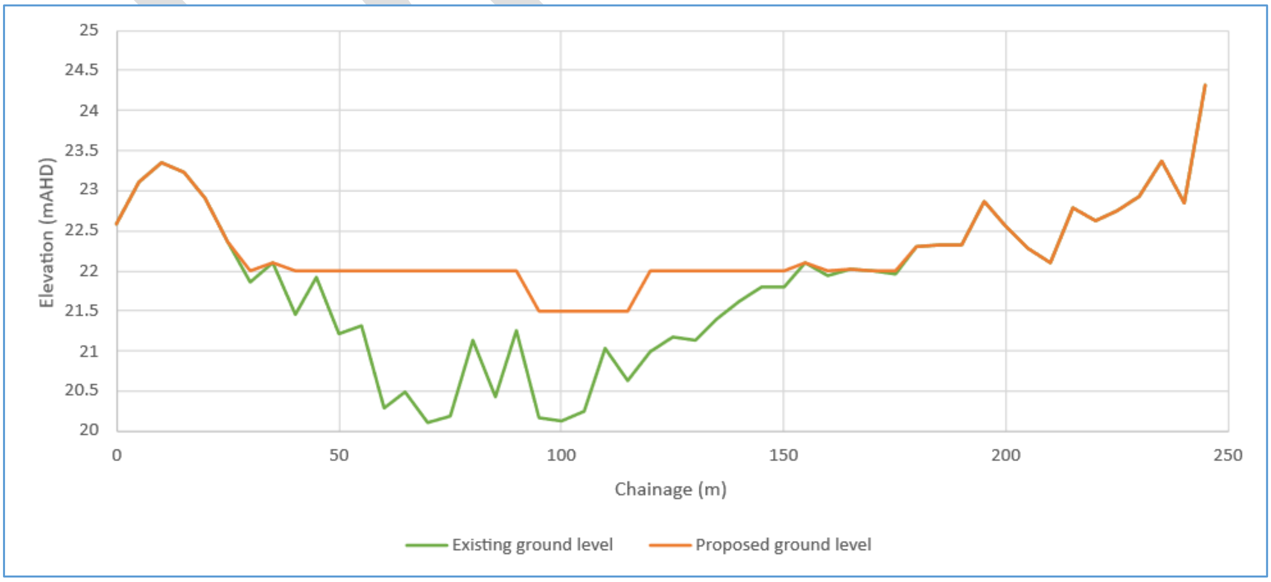


Diagram 6: Wilton Close Proposed Embankment Profile

The embankment or wall, as modelled in TUFLOW, follows the lot boundary (shown in Figure C1). In reality this may be offset from the boundary or shaped in a more natural configuration. It could consist of a low earthen embankment or block wall structure. The area to be excavated is currently a grassed area on the northern side of the reserve. It is proposed to excavate this area to 19 mAHD. The low point of the reserve, where the culvert outlet is located, is approximately 18 mAHD. Further investigations could also indicate a different basin configuration that would change the storage characteristics. There were no other proposed changes to the drainage infrastructure. The proposed works are depicted in Photo 41.

Photo 41: Wilton Close Reserve Proposed Embankment and Excavation, looking north from the culvert inlet

This option is feasible to construct and involves earthworks to form the embankment, or construction of a solid block wall. The material excavated could be used to shape the embankment. The reserve already consists of a basin-type structure and the proposed works would enhance the functioning of this and provide the opportunity to renew this area (as was done in 2008-2010). The length of the embankment or wall is approximately 130 m, with a maximum height of 1.8 m (typically 1 m). Space is constrained by the surrounding properties, however, there is an option to construct a vertical wall-type structure instead of an embankment. Trees in the reserve are proposed to be retained (as far as possible). It is unlikely that any services would be impacted. The existing drainage infrastructure would remain.

It is recommended that the previous design of the reserve (constructed 2008-2010) be consulted to ensure that the proposed works do not significantly change the intended function of the reserve. There may also be dam safety concerns with having an above-ground embankment retaining water in close proximity to residential properties.

Option Impacts

Peak flood level impacts due to this option are presented in Figure C5 and Figure C6, for the 5% AEP event and 1% AEP event, respectively. With the proposed basin works, the overtopping event is now the 5% AEP rather than the 20% AEP. In the 5% AEP event, the water level within the reserve increases by 0.7 m, with a small change to the flood extent. The increases in flood level are contained within the reserve and do not extend onto Wilton Close. Immediately downstream of the basin, flood levels reduce by approximately 0.2 m through the low point on the East Street properties. Further downstream the decreases in flood level are between 0.15 m and 0.2 m on Nott Street and between 0.05 m and 0.1 m on Yorston Street, with some flow paths through private property no longer activated. The reductions persist along the King Street Branch downstream of King Street and into North Creek with reductions typically between 0.01 m and 0.05 m.

In the 1% AEP event, peak water levels in the reserve increase by approximately 0.9 m. The spilling out of the reserve is more controlled, although this results in localised flood level increases on one property. The reductions in peak flood levels downstream are approximately 0.01 m to 0.05 m. Reductions in peak flood levels persist downstream through North Creek where there are benefits of approximately 0.03 m at Margaret Street and reducing to 0.01 m at John Street. The benefits extend into North Creek, albeit minor (0.01 m reduction).

Some social impacts are associated with this option as there would be minor disruptions during construction, particularly to the surrounding properties, and access through the reserve would be limited.

The reserve currently consists of grass areas with shrubs and trees. It is proposed to retain the trees in the reserve (where possible) and the project would serve to enhance the environmental value of this area with additional plantings. There are not expected to be any adverse impacts due to short-duration inundation of plants in flood events.

Cost-Benefit Analysis

The cost of implementing this option was estimated to be approximately $490,000, with no ongoing maintenance costs directly associated with this option. Details of costs are provided in Appendix D.

The benefit of this option was assessed by comparing the AAD of the option with the base case. The benefit to AAD was estimated to be approximately $100,000. The NPV of this benefit was estimated to be approximately $1,300,000 (increases to $1,500,000 if a timeframe of 50 years is assessed). A summary of the benefits to flood damages is provided in Table 14. For the change in the number of properties affected, a negative number indicates a decrease in the number of properties affected and a positive number indicates an increase in the number of properties affected.

Table 14: Summary of Flood Damage Benefits for FM02 Wilton Close Basin

Event	Residential Flood Damages			Total Flood Damages		
	Change in # Properties Affected	Change in # Properties Flooded Above Floor	Change in Damages	Change in # Properties Affected	Change in # Properties Flooded Above Floor	Change in Damages
50% AEP	0	0	$-	0	0	$-
20% AEP	0	0	-$4,397	0	0	-$4,837
10% AEP	-8	-2	-$163,545	-8	-2	-$222,514
5% AEP	-12	-9	-$1,074,474	-12	-9	-$1,383,621
2% AEP	-11	-7	-$842,195	-11	-8	-$964,460
1% AEP	-11	-1	-$308,835	-11	-1	-$382,334
0.5% AEP	-2	-5	-$481,411	-3	-5	-$614,782
0.2% AEP	-1	-2	-$139,361	-1	-2	-$197,223
PMF	1	0	-$45,957	1	0	-$73,825
	Average Annual Damages		-$77,604	Average Annual Damages		-$102,978

The CBR of this option was therefore estimated to be approximately 2.6, which indicates that it is economically viable.

Summary and Recommendation

	FM02 Wilton Close Basin
Description	• Construct an embankment or wall up to 1.8 m high and excavate to increase storage capacity of existing reserve.
Benefits	• Reduces overtopping from first occurring in the 20% AEP event to the 5% AEP event. • Reduces downstream inundation on private properties and roads.
Concerns	• May cause social disruption during construction. • Safety and social perception of a high embankment in close proximity to residential properties.
Approximate Cost	$490,000
CBR	2.6
Responsibility	Council
Outcome	Recommended for further investigation
Priority	Low

8.3.3. Catchment-Wide Flood Modification Options Investigated

A number of additional flood modification options were investigated that are not site-specific, but rather are catchment-wide strategies. These are discussed in the following sections.

8.3.3.1. FM03: Channel and Drainage Maintenance

Option Description

Maintenance of the drainage network is important to ensure it is operating with maximum efficiency and to reduce the risk of blockage or failure. Maintenance involves regularly removing unwanted vegetation and other debris from the drainage network, particularly at culverts, inlet pits and within channels.

Blockage has the potential to increase peak flood levels as water is unable to efficiently drain away. A proactive approach to drainage maintenance will help manage the risk of blockage occurring during a flood event. Installation of gross pollutant traps, particularly in proximity to at risk structures, can also ensure that the structures remain clear.

Discussion

Whilst debris buildup does contribute to increased flood levels, the issue is more complex than may be first assumed for the following reasons.

- It is generally only during a storm event that there is a major release of debris into the drainage system due to fallen trees, wheelie bins swept into the creek, fences fallen over or water and wind sweeping debris from yards or other sources. Maintenance prior to the event does little to reduce these debris sources;
- Blockage of small culverts has little impact in large events as the percentage of flow in these structures is very small and thus has only a small impact on peak flood levels.

A sensitivity analysis of the adopted design blockage factors for hydraulic structures in the TUFLOW model was undertaken for the Flood Study (Reference 3). It was concluded that blockage of pipes, culverts and bridges contributed to minor changes in flood levels across the wider North Creek catchment (up to 0.02 m), although locally immediately upstream of structures and within basins the change in peak flood level can be up to 0.2 m, for the tested 5% and 1% AEP events. Blockage of pit inlets resulted in negligible change to peak flood levels except in localised areas where peak flood levels change by up to 0.05 m. Overall, the North Creek catchment is relatively insensitive to blockage of structures.

Vegetation within channels is also a form of blockage. It is often community perception that an open channel full of vegetation has significantly less capacity and exacerbates overbank flooding. The real benefits to ‘clearing out the creek’, however, are minimal and there are numerous environmental limitations (driven by factors such as habitat destruction and bank stability). Two tests were completed in the TUFLOW hydraulic model to simulate vegetation removal.

- Remove all vegetation within North Creek. This was simulated by reducing the Manning’s ‘n’ roughness of 0.035 to 0.025 (essentially concrete-lined) for North Creek, from its formation downstream of Myles Avenue to the Esplanade Bridge.
- Remove all vegetation within North Creek (as above) and removal of dense vegetation within the overbank areas between the Hillsborough Road service road and Walker Street. This is the most densely vegetated reach of North Creek (see Photo 3 and Photo 5). This was simulated by reducing the Manning’s ‘n’ roughness of 0.12 to 0.04 (grassed / light

vegetation).

The results of removing vegetation within the North Creek channel itself are shown in Figure C8 and Figure C9 for the 5% AEP and 1% AEP events, respectively. The results indicate that downstream of King Street to John Street there is a reduction in peak flood level between 0.01 m and 0.02 m in the 1% AEP event. In the 5% AEP event, the reduction is slightly larger, up to 0.03 m on the floodplain. Between John Street and The Esplanade bridge there are larger reductions up to 0.07 m within the creek, however, this does not affect any private properties. This reduction in flood level is very small in comparison to the scale of flooding in this downstream area of North Creek.

The results of removing overbank vegetation adjacent to the North Creek channel (in addition to the channel clearing described above) are shown in Figure C10 and Figure C11 for the 5% AEP and 1% AEP events, respectively. The removal of overbank vegetation can influence flood levels, with a reduction simulated upstream of King Street of 0.2 m to 0.3 m in the 5% AEP and 1% AEP events. The largest reductions were between King Street and Walker Street, reaching over 0.5 m. However, there are increases in flood level downstream of Walker Street of approximately 0.1 m, however, this reduces further downstream. Increases in flood levels are approximately 0.05 m at Martin Street, 0.03 m at Albert Street and 0.02 m at John Street.

Council has an existing policy titled *Improvements and Maintenance of Watercourses and Drainage Channels* (Reference 23). The purpose of the policy is to define Council's obligations regarding maintenance, improvements and rehabilitation of watercourses including Drainage Reserves and Channels. The policy recognises that where possible, watercourses and drainage channels and their associated vegetation should be left undisturbed unless extraordinary circumstances apply. Council recognises that there are instances in which the condition of watercourses may deteriorate because of erosion and/or sedimentation, weed growth, dumping or accumulation of rubbish. In such cases, maintenance and/or rehabilitation of these waterways may be required.

In 2025-2026, Council is proposing to introduce an annual Stormwater Management Services Charge to residential and business properties. This charge, established under the *Local Government Act 1992*, will be applied for the first time in the Lake Macquarie LGA to enhance the stormwater network services. The charge will support:

- Construction of new stormwater quality improvement devices;
- Restoration and rehabilitation of creek beds;
- Drainage infrastructure including pipes, pits and culverts;
- Maintenance of swales and drainage channels.

This proposed levy will help fund regular maintenance of stormwater infrastructure such as the 'pit and pipe' network and channels, in addition to new works. It is recommended that a regular maintenance program be implemented as part of these changes to Council's operation, including the following:

- Regular maintenance and clearing of GPT devices.
- Maintenance of the North Creek channel.

- Maintain a database of flooding and drainage issues (including blockages). This would be populated by Council staff inspections and issues reported by residents. This was recommended in the previous FRMS (Reference 3) and would enable Council to identify and resolve issues with the drainage infrastructure (such as where upgrades may be required) and regularly inspect assets known to be prone to blockage. Council should periodically review and update this register based on feedback from the community.

Residents can report issues such as blocked drains to Council via their website. The reporting of stormwater issues is encouraged by residents as Council are unable to regularly inspect every asset, however, this reporting system can draw Council's attention to specific areas that require attention. Council can also inspect and document channels and drainage structure conditions following flood events to assess debris build up and clear blockages.

Summary and Recommendation

	Channel and Drainage Maintenance
Description	• Maintenance involves regularly removing unwanted vegetation (such as weeds) and other debris from the drainage network, particularly at culverts, inlet pits and within channels.
Benefits	• Removal of vegetation and debris blockage from structures will enable a more efficient conveyance of water.
Concerns	• Environmental concerns including water quality, erosion, habitat removal, etc. • The major release of debris is during the storm event, and hence regular maintenance may not necessarily reduce blockage during a flood event. • Vegetation in the North Creek channel is not a significant constraint to the hydraulic capacity of the channel, although overbank vegetation can influence flood levels.
Responsibility	Council
Outcome	Council already has an appropriate policy for the maintenance of watercourses and drainage channels (Reference 23) and is proposing to implement an annual stormwater management services charge to enable funding of a maintenance and improvement program. Council can identify specific areas prone to blockage and periodically review and update these areas based on feedback from the community. Council can also inspect and document channels and drainage structure conditions following flood events to assess debris build up and clear blockages.
Priority	Low

8.4. Property Modification Options

Property modification measures aim to reduce flood risk to existing and future developments. Options to modify the existing land use include voluntary house raising and flood proofing that can be implemented to reduce damage to existing properties, while voluntary purchase schemes can be implemented to remove houses from areas of high flood hazard, thereby reducing the number of residents at risk and potentially improving flood conveyance. Flood risk to future developments can be managed via land use planning and flood related development controls. These regulate where and how various types of developments are constructed based on the flood affectation of the land. The key tools Council uses to regulate development are the LEP and the DCP. This section discusses each of the property modification options investigated and assesses their suitability for implementation in the study area.

8.4.1. PM01: Voluntary House Raising

Option Description

Voluntary house raising (VHR) seeks to reduce the frequency of exposure to flood damage of the house and its contents by raising the house above the FPL. This results in a reduction in the frequency of household disruption and associated trauma and anxiety, however other external flood risks remain, such as the need to evacuate prior to the property being isolated by floodwaters.

VHR schemes are eligible for state government funding based on criteria set out in the *Guidelines for Voluntary House Raising Schemes* (Reference 24). In accordance with these guidelines, VHR is generally excluded for properties located within floodways; is limited to low hazard areas; and applies only to houses constructed before 1986. House raising is most suitable for non-brick single storey buildings on piers and is typically not feasible for slab-on-ground constructions. However, advances in construction techniques and other alternatives may make house raising a viable option for slab-on-ground properties and therefore individual assessments are required. Repurposing the ground floor for non-habitable use and constructing a second story (above the FPL) for habitable uses may also be a possibility. The VHR guideline states that "*VHR can be an effective strategy for existing properties in low flood hazard areas where mitigation works to reduce flood risk to properties are impractical or uneconomical*" (Reference 24).

An indicative cost to raise a house is between $30,000 and $100,000 (Reference 25) though this can vary considerably depending on the specific details of the house (such as topography, structural integrity of the house, services to reconnect, access stairs, laying of a slab underneath, etc.). Additionally, the type of construction of a house can make raising unfeasible, either technically or economically. There can be many additional construction difficulties (brick fire place, brick garage attached to house, awnings or similar attached to a house, etc.). Additional costs relate to temporary relocation costs during construction and unwillingness of the homeowner to pay the unfunded portion of the raising costs.

Discussion

VHR as a mitigation measure has been successful in the past in areas where regular mainstream flooding occurs frequently. However, as these older houses are nearing the end of their useful life, re-building has become comparatively much cheaper than in the past and landowners want modern features in their houses (en-suite, air conditioning, several bathrooms, new kitchen, etc.) thus there are few opportunities for house raising to be a viable measure. This trend has been further increased with developers and landowners seeing the opportunity to re-develop an old house as a dual occupancy. As an example, one property on Seaman Avenue was identified as a potential candidate for VHR, however, the adjacent four houses have recently been redeveloped such that raising this house is unlikely to be taken up and redevelopment, consistent with the surrounding properties, is likely to be more favourable.

There were several areas where VHR may be viable. These areas were located adjacent to North Creek and are likely to have been built prior to 1986. These dwellings were typically fibro/weatherboard structures on piers. The flood damages assessment indicated that these properties are typically inundated above floor in the 5% AEP to 1% AEP events and subject to H3 hazard in the 1% AEP event. As such, these properties may be eligible for VHR. These areas are shown on Figure 20 and include:

- Properties at the end of Martin Street (southern side of North Creek);
- Properties at the end of Albert Street (both northern and southern sides of North Creek);
- Properties on Charles Street.

These areas include approximately 28 properties. Council should review the year of construction of these properties to confirm if they are eligible for the VHR scheme (constructed prior to 1986). A VHR feasibility study could be conducted including discussions with property owners to assess the full viability of this option. Surveyed floor levels of these properties could also be undertaken to more accurately determine the above floor flood affectation of individual dwellings.

Experience has also shown that many owners of houses that potentially could be raised are not interested for reasons such as:

- they do not want an elevated entry to their house,
- the house is old without modern facilities and will be re-developed in the near future,
- owners will have to live elsewhere during the construction phase (possibly 2 months),
- owners are unwilling to pay the costs not funded under the grant scheme (attached garage or fireplace),
- flood insurance is available,
- the owners of any low lying building that has experienced frequent above floor inundation over the past 30+ years will generally have addressed the issue. Typically by modifying the entrance to the building (constructing minor walls or landscaping) as the above ground water depths are generally shallow (less than 0.5m) and thus a local measure can eliminate or significantly reduce the problem.

Summary and Recommendation

	PM01: Voluntary House Raising
Description	• Physically raise existing dwelling structures above the FPL
Benefits	• Reduce exposure to flood damage
Concerns	• Generally there is a low uptake of VHR due to the cost and inconvenience.
Approximate Cost	$30,000 to $100,000
CBR	Typically <1, but depends on frequency of inundation
Responsibility	NSW State Government, Council and Owner
Outcome	Feasibility of voluntary house raising for identified areas recommended
Priority	Very Low

8.4.2. PM02: Voluntary Purchase

Option Description

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

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

In the NSW Government *Guidelines for Voluntary Purchase Schemes* (Reference 26), the eligibility criteria notes that VP will be considered only where no other feasible flood risk management options are available to address the risk to life. Subsidised funding is generally only available for residential properties. Once a house is purchased it would be demolished, and a restriction placed upon the lot to prevent future residential or commercial development.

The Guideline sets out the way in which a VP scheme should be undertaken and how properties should be valued. Valuations are to assume there are no flood related development constraints applied to the property. The aim of this is to allow those who take up VP to be able to buy a similar property in a location not subject to flood risk, acknowledging that flood impacted properties often have lower value.

Discussion

VP is an effective strategy where it is impractical or uneconomic to mitigate high flood hazard to an existing property and it is often employed as part of a wider management strategy. The median house price in the study area is between $960,000 and $1.3M, depending on the suburb. Based on the median house price, discount rate of 7% and flood benefits expected to last for 25 years, the current AAD for the property considered for VP must be approximately $80,000 to $100,000 or more for VP to be economically viable.

The only properties with high hazard (H4 and above) in the 1% AEP event were those on the King Street flow path between Nott Street and Yorston Street. This flow path is along the driveways of two dual occupancy lots on Nott Street and Yorston Street. Purchasing of these properties would enable the flow path to be formalised through open space and reduce flood risk. The buildings themselves, however, would likely not be subject to high hazard and were constructed after 1986. Therefore, there were no properties identified in the North Creek catchment that were eligible for VP.

Summary and Recommendation

	PM02: Voluntary Purchase
Description	• Purchase existing properties to remove them from high hazard.
Benefits	• Reduce exposure to flood damage • Reduce exposure of residents and rescuers from high flood hazard
Concerns	• High cost of properties reduces economic viability and there were no eligible properties identified
Approximate Cost	~$1M per property
CBR	<1
Responsibility	NSW State Government, Council and Owner
Outcome	Not recommended

8.4.3. PM03: Flood Proofing

Option Description

Flood proofing is a strategy that is often applied to non-residential buildings and is often divided into two categories; wet proofing and dry proofing. Wet proofing assumes that water will enter a building and aims to minimise damages and/or reduce recovery times through use of water-resistant materials, locating electricals above the FPL, and facilitation of drainage and ventilation after flooding. Dry proofing aims to totally prevent flood waters from entering a building and is typically best incorporated at the construction phase, though can also be retrofitted to existing buildings. Dry proofing measures are typically installed at doorways or garage entry points, however other openings (such as for ventilation) should also be considered.

Retrofitting permanent flood proofing measures can be difficult and costly, and therefore permanent flood proofing is best implemented during construction and when permitted under development controls, although this should not replace or be used instead of minimum floor level controls. As such, flood proofing can be suggested within Council's DCP for structures to improve flood resilience above the standard for minimum floor levels. For example, for industrial property, controls may allow floor levels at a lower level (1% AEP) with flood proofing suggested up to the 1% AEP + 0.5 m.

As an alternative to retrofitting permanent flood proofing measures to existing properties, individual temporary flood barriers can be used. These include sandbags, plastic sheeting and flood barriers which fit over doors, windows and vents and are deployed by the occupant before the onset of flooding. Temporary flood barriers such as sandbagging and floodgates can be a cost-effective option for existing properties and can be useful where there is frequent shallow flooding. However, it relies on someone being available to implement it and therefore requires adequate flood warning times. Sandbagging, often used in conjunction with plastic sheeting, can provide a solution for dealing with flooding in smaller areas and at individual properties. Whilst sandbags and plastic sheeting seldom prevent the ingress of floodwaters entirely, they can substantially decrease the depth of over floor flooding and the foulness of floodwaters, thus aiding the clean-up process.

Discussion

Given the limited warning time available in the study area, dry flood proofing measures such as doorframe-mounted barriers would be an effective alternative to sandbags as they can be stored on the premises and quickly installed in the event of a flood, or alternatively, permanent flood barriers could be retrofitted to existing doorframes. Existing basement driveways which are impacted by flooding can be retrofitted with automatic hydraulic flood barriers which do not rely on electricity to operate (raised by floatation).

When installed properly, such barriers could be expected to have the following benefits for non-residential buildings.

- Can be implemented by business owners (with little or no SES or Council assistance).
- Reduce time needed to prepare the building, particularly if proactive measures are adopted (e,g. relocating stock etc.), allowing more time for occupants to evacuate safely.
- Reduce or eliminate need for sandbagging.
- Reduce property damages.
- Allow premises to reopen as soon as safe access and services are restored.
- Reduction in days of lost business during the recovery period.
- Greatly reduce clean up required.
- Range of products available from $1,000 to $10,000.
- Create regular staff training and drills, providing opportunity for community activity and flood education to be implemented.
- Increased continuity of work (and hence wages) for employees of affected businesses.
- Improved social amenity of being able to access and use key facilities and shops.

There have been considerable advances in the principles and approaches to flood proofing properties, both in the retrofitting and construction phases, to commercial and residential properties. Two guidelines of particular note are:

- *Reducing Vulnerability of Buildings to Flood Damage: Guidance on Building in Flood Prone Areas* (2006), Hawkesbury-Nepean Valley Floodplain Management Steering Committee (Reference 27).
- *Flood Resilient Building Guidance for Queensland Homes* (2019), State of Queensland (Reference 28).

Many councils support flood proofing principles for existing development which are below the FPL to reduce flood damages. This includes considering flood compatible material to reduce impacts during a flood event, ease clean up afterwards, maintain structural integrity; and locating electrical fixtures and sewer services above the FPL.

Access to community facilities, shops, healthcare services, sporting facilities and pubs are the key to a community's recovery from a flood event and contribute significantly to community resilience and emotional recovery. While such premises would still not be operational during a flood nor immediately afterwards (pending safe access, reconnection of utilities etc.), flood proofing would significantly decrease the duration of business closures after the event. It is noted however that flood proofing individual buildings would not reduce external flood damages (e.g. to carparks). Furthermore, if buildings are wet-proofed there would still be clean-up costs incurred, as well as days of business lost during the flood itself and the immediate recovery period.

Flood proofing can also be an option for sensitive and hazardous land uses, where controls could require aspects to the essential operation, such as generators to be located above the FPL, while allowing a lower floor level. The risks and consequences of a lower floor level would need to be assessed.

The Flood Risk Management Manual (Reference 1) allows for greater flexibility for business to manage and recover from flooding. Specifically, referencing that FPLs could be based upon more frequent flood events than required for residential purposes. By allowing FPLs for floor levels to be lower, but still requiring or allowing flood proofing to a higher FPL, damages can be minimised and the acceptable level of risk becomes a business decision, trading off potential damages with lower initial set up costs.

New commercial buildings can be required to be flood proofed to the FPL when construction includes consideration of suitable materials, electrical and other service installations, and efficient sealing of any possible entrances for water. Council would make these requirements through planning controls in the DCP, by stipulating an FPL for flood proofing. Council already partially implements this by requiring all unsealed electrical installations to be at the 1% AEP flood level + 500 mm. It is recommended that planning controls allow some flexibility in the type of proofing adopted. Flood policy is further discussed in Section 8.4.6.

The areas within the North Creek catchment that would benefit from flood proofing include the Hillsborough Road commercial/industrial area (bounded by Hillsborough Road and Macquarie Road) and the commercial/industrial properties located to the south of Medcalf Street.

Flood proofing is the responsibility of the property owner or business, and as such there is no

Government funding for flood proofing of commercial and industrial buildings.

Summary and Recommendation

	PM03: Flood Proofing
Description	• Flood proofing of non-residential buildings with temporary flood barriers (both existing and new structures, where floor levels are allowed to be lower). This could also be extended to existing residential development, but not recommended for new residential development where floor level controls should be applied instead.
Benefits	• Reduce exposure to internal flood damage
Concerns	• Costs and implementation of flood proofing measures are the responsibility of the property owner / business.
Outcome	Flood proofing to be promoted for existing buildings, particularly industrial and commercial premises. Include options for the use of flood proofing to the FPL for non-residential land uses within Council's DCP (in addition to but not replacing minimum floor level requirements). This will enable new and existing buildings to be developed with due consideration given to their flood risk and minimisation of internal flood damages.
Priority	Medium

8.4.4. PM04: Flood Planning Levels

FPLs are an important tool in flood risk management. The FB01 guideline *Understanding and Managing Flood Risk*, part of the Flood Risk Management Manual (Reference 1), provides a comprehensive guide to the purpose and determination of FPLs. The FPL is derived from a combination of a flood event and a freeboard and provides a development control measure for managing future flood risk (e.g. by elevating floors above a particular flood level), reducing potential damage and setting minimum levels for flood mitigation works. Typically, this level would be the 1% AEP flood level plus a freeboard of 500 mm for residential development.

The FPL for planning purposes is generally the height at which new (or redeveloped) building floor levels should be built to minimise the frequency of inundation and associated damage. It may also refer to the height to which flood proofing could be applied to reduce damages to commercial properties, required levels for evacuation or height of storage for hazardous goods. FPLs can vary for different types of land use categories depending on the level of risk, consequences of inoperability or vulnerability of occupants. For example, residential development could be considered more vulnerable due to the potential for people being present 24/7, whilst commercial development could be considered less vulnerable, acknowledging that businesses typically operate within certain hours and may be better placed to recover from flood related damages or implement flood protection/mitigation measures compared to residents. Less vulnerable development could therefore be prescribed lower floor levels but may then be subject to other controls, such as flood proofing, up to the level of the FPL. This allows a decision around the acceptable level of risk to be a business decision, allowing a trade-off of responsibility between

Council and present and future business owners. For developments more vulnerable to flooding (hospitals, schools, electricity substations, seniors housing, etc.) consideration should be given to events rarer than the 1% AEP when determining their FPL or situating those developments outside the floodplain where possible.

Until recently the NSW Government planning framework allowed for the FPL to be initially defined within the LEP and supported through subsequent controls in the DCP. Recent changes to the NSW Government planning framework in relation to flooding came into effect on the 14th July 2021 (discussed in Section 7.2.4). These changes removed the definition of the FPL from the LEP. Flood planning controls for Lake Macquarie are defined via the DCP, which is consistent with the changes that came into effect on 14th July 2021. Flood policy is further discussed in Section 8.4.6. A summary of flood planning levels according to the Lake Macquarie DCP (Reference 19) is provided in Table 7 and Table 8 of Section 7.3.2.

Discussion of Design Event

FPLs for typical residential development would generally be based on the 1% AEP event plus an appropriate freeboard. Assuming the average lifetime or the design life of a structure is 70 years, the likelihood of at least one 1% AEP flood event occurring is 50%. Given this potential, it is considered reasonable from a risk management perspective to adopt the 1% AEP flood as the design flood event for residential development. Consideration of more or less frequent events can be appropriate for different land uses, with due concern for the level of risk, consequences of inoperability or vulnerability of occupants. In the case of sensitive and hazardous uses and the available land within this zone, it is appropriate for the PMF to be considered. This aligns with the FPLs in the Lake Macquarie DCP (discussed further in Section 8.4.6).

It is also considered reasonable to include climate change projections for the design flood event. FPLs will be used for setting floor levels of buildings that will have a certain design life, typically in the order of 50 to 100 years. In this circumstance, it is reasonable to assume that these buildings will be subject to a future climate and should be protected considering potential future design flood levels. This is discussed further in Section 8.4.8.

Discussion of Freeboard

As noted above, the FPL is typically derived from a design flood event (usually the 1% AEP) plus a freeboard allowance. The freeboard can be considered as a compulsory ‘safety factor’ used to provide reasonable certainty that the reduced flood risk exposure provided by selection of a particular flood as the basis of an FPL, is actually provided given the following factors:

- Uncertainty in estimating flood levels,
- Differences in water level because of local factors,
- Increases due to wave action,
- The cumulative effect of subsequent infill development.

The Flood Risk Management Manual (Reference 1) states that, in general, the FPL for a standard residential development would be the 1% AEP event plus a freeboard which is typically 0.5 m.

This FRMS offers an opportunity to consider if a 0.5 m freeboard is appropriate. The current DCP already specifies minimum freeboard requirements based on the type of development.

A key aspect to consider is the scale of flood behaviour that occurs within the catchment. Typically, overland flooding is shallower in nature, in most circumstances, and flood levels are generally not sensitive to factors such as wave action, wind setup or local obstructions. Importantly, the modelled flood behaviour in overland areas does not scale as significantly with event size, i.e., flood behaviour in the 0.5% AEP is generally not significantly greater than that of the 1% AEP, meaning that even if design rainfall estimates were to vary significantly (e.g. due to climate change), the overland flood behaviour would remain relatively consistent.

In the study area within North Creek, flood levels generally vary between 0.7 m and 1.4 m between the 50% AEP and the 1% AEP events. On the tributaries, the flood level difference is approximately 0.4 m to 0.7 m. Beyond these mainstream areas, flood levels are relatively consistent and typically vary between 0.1 m to 0.3 m. These aspects suggest that in some circumstances a freeboard less than 0.5 m may be appropriate to provide reasonable certainty that the flood risk in the 1% AEP is accounted for. Consideration was also given for very low risk overland flow areas, with flood depths less than 150 mm excluded from the FPA (see Section 5.6).

Discussion of Critical and Sensitive Uses

The FPL may also be raised depending on the vulnerability of the building/development to flooding. The vulnerability of a building may arise from its use (e.g. power supply, sewerage treatment plant) or from its occupants (e.g. children or the elderly). Examples of critical facilities include fire, ambulance and police stations, hospitals, residential care facilities, schools, water and electricity supply installations, etc. For such facilities, the consequences of flooding are significantly more severe, and so the avoidance (or limitation) of flood damage and risk to life is particularly important. In addition, the changes to the NSW Government planning framework in relation to flooding that came into effect on the 14th July 2021, allows councils to opt-in to a second LEP clause. This allows controls to be applied to those more vulnerable land uses, particularly in the area between the FPA and the PMF extents, or land that is subject to non-direct evacuation constraints. Lake Macquarie has currently not adopted this clause, although the DCP does apply controls for sensitive uses between the FPA and PMF.

The flood behaviour in the study area results in the floodplain (not including shallow overland flows) being relatively constrained, and it is generally possible to avoid developing critical utilities or vulnerable facilities within the FPA or even floodplain (i.e. PMF extent) altogether. The Lake Macquarie DCP adopts the PMF for the FPL for sensitive uses, allowing developers to design new utilities or facilities with consideration of the full range of flood risk that may occur. With these controls, critical utilities and vulnerable facilities, if possible, would be located outside of the PMF extent.

Summary and Recommendation

	PM04: Flood Planning Levels
Description	• FPLs are typically based on a design flood event plus freeboard. It is used to determine the FPA and set minimum floor levels.
Considerations	• Minimum floor levels in the current DCP are typically based on the 1% AEP event with some variation for non-habitable development and sensitive uses. Consideration is given to potential future climate scenarios for Lake flooding only. Potential future climate change (rainfall increase) for catchment flooding should be considered. This is further discussed in Section 8.4.8. • The current FPLs for residential and commercial properties are considered appropriate. Consideration could be given to adopting a lower freeboard for shallow overland flows (such as 300 mm). • The current DCP requires sensitive uses to have habitable floors at the PMF level. This is considered appropriate for this land use type. The application of development controls outside the FPA is discussed further in Section 8.4.6. • The requirement to have basement car parking entrances at the 1% AEP level + 500 mm freeboard is considered appropriate, with the residual risk to be managed by failsafe evacuation and pump-out. Potential for specifying the minimum level to be the PMF would mitigate the residual risk to life, with the current control being a provision if the PMF level is not feasible.
Outcome	The current DCP, in terms of setting FPLs, is considered appropriate for most developments. It is recommended that overland flow be considered for application of a lower freeboard requirement. This may be a new concept as many of the existing Lake Macquarie flood studies focus on mainstream flooding only. Consideration of flood behaviour across the entire LGA should be considered when selecting an appropriate delineation method and freeboard for overland flow areas. Consideration should also be given to adopting the PMF level as the default requirement for basement car parks. Climate change (rainfall intensity increase) could be considered for FPLs (as sea level rise is currently).
Priority	High

8.4.5. PM05: Flood Planning Area

Option Description

The FPA is the area of land at or below the FPL and identifies the area to which flood planning controls apply.

Discussion

The definition of the FPA for the North Creek catchment is outlined in Section 5.6. The FPA includes the standard definition of the 1% AEP + 500 mm freeboard for the mainstream areas. For overland flow areas, however, the 1% AEP extent with no freeboard was adopted, for the reasons identified in Section 5.6.2. This is allowed in the Flood Risk Management Manual (Reference 1) as it recognises issues with applying freeboard to local overland flooding situations. The Manual allows for setbacks (sometimes referred to as horizontal freeboard) to negate the need for development controls in areas further away from the flow path where flows are unlikely to impact on properties significantly. Filtering was also applied to the 1% AEP extent to remove very shallow inundation not considered to be ‘flooding’. The derived FPA extent, for both mainstream and overland areas, is appropriate for identifying properties that need to apply development controls.

Summary and Recommendation

	PM05: Flood Planning Area
Description	• The FPA is the area of land at or below the FPL to which flood planning controls apply.
Considerations	• There are issues with the traditional approach of applying freeboard and ‘stretching’ the surface to identify the FPA, particularly with overland flow paths in urban areas.
Outcome	It is recommended to adopt the provisional FPA as defined in the North Creek Flood Study (Reference 3) and replicated in this study.
Priority	High

8.4.6. PM06: Flood Planning Policy

Option Description

Appropriate planning instruments ensure that development can be undertaken considering compatibility with the flood risk. Effective planning instruments can reduce residual flood risk over time as redevelopment occurs. Planning instruments can be used as tools to:

- Reduce risk to life,
- Reduce damage to the proposed development itself, and
- Reduce damage to the broader floodplain and existing development.

The types of controls (this list is not exhaustive) that achieve each of the objectives listed above are shown in Table 15.

Table 15: Planning Instrument Objectives – Control Type

Objective	Type of Control
Reduce Risk to Life	Evacuation considerations, vulnerable land use and occupant considerations, flood awareness and education (Section 10.7 certificate), prevention of ingress of water to basement car parks.
Flood Damage to New Development	FPLs, location considerations including, hydraulic hazard and category considerations, structural requirements.
Flood Damage to Existing Development	Flood impact consideration, design considerations, location considerations including, hydraulic hazard and category considerations.

The primary planning instruments used by local Councils are the LEP and DCP. The LEP is a legal planning instrument that guides planning decisions for Council through zoning and development controls. They provide a framework for the way land can be developed and used. The DCP support the objectives of the LEP and are used by Council to define and articulate the specific standards needed for different types of developments. Flood related development controls are a key aspect for development that occurs on flood prone land.

Discussion

Examination of existing risk throughout the study area indicates that managing this risk is problematic due to the very short warning times available. However, effective planning policy has the power to reduce this risk over time as the areas redevelop. Council should consider the long-term management of these areas and how this can be facilitated by planning tools. Rezoning and redevelopment reduce flood risk through the application of planning controls such as setting minimum floor levels and ensuring safe flood refuges are available.

Development in the Lake Macquarie LGA is currently governed by the Lake Macquarie LEP 2014 (Reference 18) and Lake Macquarie DCP 2014 (Reference 19). In general, Section 5.21 of the LEP 2014 (Reference 18) contains the overall objectives and guidance for development on flood prone land, while Sections 2.8 and 2.9 (sometimes Sections 2.9 and 2.10) of Parts 2 – 8 of the DCP 2014 (Reference 19) contain specific flood-related development controls, for different development types. The LEP and DCP are comprehensive and cover a range of flood aspects. Key considerations and whether they are included in the documents are provided in Table 16.

Table 16: Flood-related Development Control Considerations

Aspect/Control	Contained in LEP/DCP	Comment
Terminology	Partial	Uses terminology consistent with the Floodplain Development Manual 2005 and ARR 1987. Consideration should be given to updating references and terminology consistent with the new Flood Risk Management Manual 2023. For example, ARI terminology recommended to be changed to AEP. The DCP references 'the current floodplain development manual', however, the weblink provided is no longer valid. The associated guideline (Reference 20) is also outdated and should be updated with references to new policies and studies.
Objectives	Yes	The objectives in the DCP are stated to be minimisation of adverse

Aspect/Control	Contained in LEP/DCP	Comment
		impacts of flooding on the proposed development or on other properties, and to ensure that measures re implemented to reduce the impact of flooding and flood liability on owners and occupiers. These objectives are adequate, although they do not directly align with the LEP objectives.
Approach to Controls	Yes	The approach to controls is less prescriptive than other Councils. This can be good for a merit-based approach, but leaves the assessment criteria open to the developer and/or their consultant to demonstrate an acceptable design. This can lead to inconsistencies in assessments and outcomes. More prescriptive controls are recommended.
Flood Planning Level	Yes	Discussed in Section 8.4.4.
Flood Planning Area	Yes	Discussed in Section 8.4.5. Ensure map is available on Council's website if separate from the DCP, since changes to the NSW Government planning framework in relation to flooding has removed the FPA overlay from the LEP.
Consideration of flood affectation and land use	Partial/Yes	Development controls consider land use, although this primarily extends only to FPLs. The DCP is reasonably broad in its requirements, allowing for varying degrees of complexity in preparing a flood assessment for a development. Development controls do not consider the flood risk. For example, there is no distinction between mainstream and overland flooding, or application of different development controls commensurate with the flood risk such as a matrix-style approach recommended in the FB01 guideline of the Flood Risk Management Manual. Consideration could be given to implementing a matrix approach, with differing requirements specified depending on the flood risk and type of development.
Minimum Floor Level	Yes	Minimum floor levels are specified and clearly defined for a range of development types.
Minimum Car Park Level	Yes	Minimum basement car park levels are specified in the DCP at an appropriate level (1% AEP level plus 500 mm). Consideration should be given to specifying the maximum of the PMF level and the 1% AEP level plus 500 mm. Where the 1% AEP level plus 500 mm is lower than the PMF, this should only be allowed as the FPL for basement car parks where the PMF level is not feasible and a failsafe method of evacuation and pump-out is provided (as per the current requirement). This is described in Section 8.4.4.
Flood Proofing	Partial	Consideration of flood compatible building materials and electrical equipment are included in the DCP. There is no consideration of structural soundness or storage of hazardous materials. These aspects, although not critical, should be considered. For example, with the short critical duration of the catchment, safe evacuation is often not viable. As such, all new buildings should be required to be to be structurally sound (certified by a structural engineer) during a flood up to 0.5 m above the 1% AEP (same as the floor level).

Aspect/Control	Contained in LEP/DCP	Comment
		Residents may therefore be able to safely shelter in place until the flood passes (typically < 1 hour).
Flood Impacts	Yes/Partial	The DCP requires that buildings and other structures must be designed to not impede the flow of floodwaters and restrictions on the use of fill. The DCP does not specifically require demonstration of negligible impacts on other lands, except where 1% AEP flood levels are not available (i.e. a local flood study is required). Consideration should be given to requiring demonstration of flood impacts of any works within the 1% AEP flood extent using flood modelling tools.
Evacuation	No	There are currently no evacuation considerations in the DCP, apart from the requirement for failsafe evacuation of basement car parks. The DCP mentions the development 'must mitigate risks to life', but it is not prescriptive. The full range of flood conditions (up to the PMF) should be considered for evacuation requirements. Evacuation could be specified as reliable access for pedestrians and/or vehicles in a PMF event or if appropriate, a shelter-in-place response if a flood refuge above the PMF level is available. It is recommended that the SES be consulted with regard to evacuation and shelter in place as floodplain management strategies, in addition to the recently published shelter-in-place guideline (Reference 29).
Fencing and Landform	Yes	Fencing and landform requirements are prescribed in the DCP, including requirements for structures, including fencing, to be designed so as not to impede the flow of floodwater or entrap debris. While not explicit, this is assumed to apply to overland flow paths. Restrictions on filling of land within the 1% AEP extent are also in the DCP.
Special Flood Considerations	Partial	The LEP currently does not include the *Special Flood Considerations* clause (5.22). Changes to the NSW Government planning framework in relation to flooding allows Council the opportunity to include this second flood clause within their LEP. This applies to land between the FPA and the PMF extent and considers sensitive and hazardous uses in addition to those uses which may have evacuation constraints. This inclusion empowers Council to apply controls that ensure the developers of such facilities appropriately consider and plan for the full range of flood risk at the site. This is to reduce potential property damages and minimise the risk to life in future flood events. There are controls in the DCP to this effect, which should be applied by including the *Special Flood Considerations* clause in the LEP. This would also require a map of the area to which this clause applies to be available.
Future Climate	Partial	The DCP currently only considers climate change for Lake Macquarie flooding. This is supported by the *Lake Macquarie Waterway Flooding and Tidal Inundation Policy* (Reference 14), which identified the adopted future sea level rise conditions. It is noted that the adopted FPA for this study also utilises these sea

Aspect/Control	Contained in LEP/DCP	Comment
		level rise projections. The DCP is clear in specifying horizons that apply and levels. Climate change features strongly in the objectives for lake flooding, contained in 4 of the 6 objectives. The objectives also cover permanent inundation of land and setbacks, allowance for filling and consideration of future flood risks, which is commended. There is, however, no consideration of increase in rainfall intensity in the DCP. The DCP should be updated to incorporate climate change for rainfalls in two ways. Firstly, climate change should be considered as part of a flood impact assessment. Climate change impacts should be modelled to manage risk of future climate change. Secondly, development controls should be updated with consideration of climate change. As discussed in Section 8.4.4 in regard to FPLs, it is recommended that Council includes climate change in flood-related development controls considering best available climate change data to combat increased rainfall intensity in a similar way to how future sea level rise is currently accommodated. Future flood resilience policy is discussed further in Section 8.4.8.

Summary and Recommendation

	PM06: Flood Planning Policy
Description	• Flood planning policy is typically governed by the LEP and DCP, which outline flood-related development controls.
Benefits	• Appropriate flood development controls ensure future developments have reduced flood risk.
Concerns	• Only provides benefits to at risk properties during redevelopment.
Outcome	Consideration should be given to updating the DCP for the following: • Updating terminology and references. • Implementation of a matrix-style approach for controls that considers the relative flood risk. • Specifying requirements for modelling of flood impacts. • Controls for structural soundness and storage of hazardous materials. • Specifying evacuation or shelter-in-place requirements. Consideration should also be given to applying the *Special Flood Considerations* in the LEP so that the DCP controls up to the PMF are supported by legislation. These policy updates would apply to all flood-prone areas of the LGA, and as such consideration of wider flood behaviour and development in other catchments requires consideration.
Priority	High

8.4.7. PM07: Section 10.7 Certificates

Option Description

Section 10.7 Planning Certificates (formerly S149 Planning Certificates) are issued in accordance with the *Environmental Planning & Assessment Act 1979*. They contain information on how a property may be used and the restrictions on development that apply. A person may request a Section 10.7 Planning Certificate at any time to obtain information about their own property, but generally the certificate will be requested when a property is to be redeveloped or sold. When land is bought or sold the *Conveyancing Act 1919* requires that a Section 10.7 Planning Certificate be attached to the Contract for Sale.

Schedule 4 of the *Environmental Planning and Assessment Regulations 2000* gives requirements for inclusion on Section 10.7 Planning Certificates under Section 10.7(2) of the Act. Schedule 4, Clause 7A refers to flood related development control information and requires that Council include whether or not development on the land or part of the land is subject to flood related development controls. Schedule 4 of the *Environmental Planning and Assessment Regulations 2000* has since been updated to Schedule 2 of the *Environmental Planning and Assessment Regulations 2021*. Clause 9 of Schedule 2 of the new regulation requires the planning certificate to include whether the land or part of the land is within the FPA and subject to flood related development controls (1) as well as if the land or part of the land is between the FPA and PMF and is subject to flood related development controls (2).

Discussion

Council currently provides flood information on Section 10.7 certificates in terms of land that is subject to flooding in the 1% AEP (Clause 9(1)) and the PMF (Clause 9(2)). Landowners will be required to be notified of changes to both the 10.7 (2) and 10.7 (5) Planning Certificates. Landowners can be concerned as to how a notification may impact on their property value or insurance, for example. The Insurance Council of Australia provides detailed fact sheets on how flood information is used for insurance pricing. This should be considered when developing a consultation strategy for notification of any changes related to Section 10.7 Planning Certificates.

The more informed a homeowner is, the greater the understanding of their flood risk. During a flood event, having this understanding helps prepare residents for evacuation, and improves the ability of residents to recover following an event. Improved flood risk awareness may also reduce the number of residents that elect to shelter in place in high hazard areas, which can increase pressure on the SES if they are isolated or their homes are inundated. Residents can also request flood information for their property from Council via a free online tool (https://propertyinfo.lakemac.com.au/floodtool/), which includes more detailed information such as:

- Maximum flood levels (5% AEP, 1% AEP and PMF),
- Flood planning level,
- Minimum and maximum ground levels,
- Flood hazard classification,

- Map showing the 1% AEP flood extent.

Council can also provide a Flood Certificate or Flood/Tidal Inundation Certificate with this information for a fee.

Summary and Recommendation

	PM07: Section 10.7 Certificates
Description	Section 10.7 Certificates are required to show flood notation. This informs the landowner of flood risk and applicable development controls.
Outcome	The current provision of information (Section 10.7 notification) to landowners is considered adequate and should be updated with information from this FRMS&P. Council should continue to provide free flood information at the property level via the online tool.
Priority	High

8.4.8. PM08: Future Flood Resilience Policy

Option Description

In August 2008, Council adopted the *Lake Macquarie Sea Level Rise Risk Preparedness Adaptation Policy* that required the consideration of future sea level rise when planning for lake flooding and coastal erosion. It was one of the first local governments in Australia to plan and prepare for future sea level rise. Currently, the *Lake Macquarie Waterway Flooding and Tidal Inundation Policy* (adopted in July 2020, Reference 14), is in place and specifies the sea level rise projections for 2050 (0.4 m) and 2100 (0.9 m). This policy feeds into the DCP and FPLs due to Lake Macquarie flooding account for future sea level rise projections. This policy, however, only considers sea level rise as a result of climate change, and does not consider potential rainfall intensity increases. A policy identifying future climate conditions for rainfall-induced flooding should be produced in a similar manner to the current sea level rise policy.

Discussion

The results of the impact of climate change for both rainfall intensity increases and sea level rise projections were documented separately in the Flood Study (Reference 3) and combined in the current study (see Section 5.7). These results indicate that for rainfall intensity increases, 1% AEP flood levels in North Creek may increase by up to 0.15 m with a 13% increase in rainfall and up to 0.4 m with a 34% increase in rainfall intensity.

Recently, ARR (version 4.2) summarised a wealth of recent research into changing rainfalls with a warmer climate and provided advice about factoring design rainfall estimates for future climates. This guidance should be used to define planning horizons (as for the sea level rise considerations in the DCP) and emissions scenarios that can be adopted and incorporated into a Council policy (similar to the sea level rise policy) that identifies future rainfall factors. An overarching future flood resilience (due to rainfall intensity increase) policy would ensure consistency in Council's approach to future flood conditions, across a range of asset design and maintenance sectors as well as coastal and floodplain management. This would ultimately feed into flood policy (Section 8.4.6), FPAs (Section 8.4.5) and FPLs (Section 8.4.4), as does the current sea level rise policy.

Summary and Recommendation

	PM08: Future Flood Resilience Policy
Description	• A future flood resilience policy guides Council's operations and policies at a high level. This would likely feed into other Council operations such as coastal management, asset design, flooding and planning controls. This would build upon the existing sea level rise policy to include consideration of projected rainfall intensity increases.
Benefits	• Allows for uniform approach to rainfall intensity increases across the entire LGA. • Improves Council's climate change adaptability and resilience. • Ensures future flood conditions are incorporated into current planning controls and infrastructure design.
Concerns	• There are uncertainties in future rainfall predictions. The changes expected for future rainfalls and runoff response is largely unknown.
Outcome	It is recommended that Council pursues a future flood resilience policy for projected rainfall intensity increases, in a similar manner to the current sea level rise policy. This requires a holistic approach from Council, as flooding affects a range of Council assets, plans and policies. It is recommended that the policy outlines the scientific basis for climate change, adopts a planning horizon (or different planning horizons for different applications) and specifies rainfall increase parameters, and outlines its application to Council's operations, planning instruments, policies and floodplain management strategy.
Priority	High

8.5. Response Modification Options

The measures described in this section relate to how the Warners Bay community receives information about floods, responds to and recovers from flood emergencies. Response modification options aim to reduce risk to life and property in the event of flooding through improvements to flood prediction and warning, improvements to emergency management capabilities, evacuation and planning, and supporting greater community flood awareness and preparedness.

8.5.1. RM01: Flood Emergency Management Planning and Coordination

Option Description

The SES is the legislated combat agency for flood, storm and tsunami response, responsible for the control of operations. The SES prepares a range of documents that cover preparedness, response and coordination measures that are essential to the management of storm and flood risk. These documents include information brochures about storms and flooding, Local Flood Plans, regionally based information webpages (Lake Macquarie), unit based webpages (Cooranbong, Lake Macquarie City and Swansea Units) in addition to information and brochures on preparedness strategies for urban areas. The SES website (www.ses.nsw.gov.au) also contains an array of information that residents can access.

During a flood event in the North Creek catchment, the two main response agencies are the SES and Council. Each have defined roles and responsibilities, as outlined in the Lake Macquarie LGA Local Flood Emergency Sub Plan (Reference 30). Council plays a significant role in ensuring the safety of its community in times of emergency, including preparedness of the organisation in the lead up to an event such as a flood, its response, integration with other emergency services and recovery from the event. During a flood event, Council is responsible for responding to issues relating to public areas and infrastructure, for example, road closures, operation of the flood warning system, operation of flood mitigation works and managing and protecting council-owned infrastructure.

The SES is responsible for the control of flood operations, including the coordination of evacuation, undertaking flood rescues, assisting with flood damage and welfare of affected communities. The SES can respond to calls regarding private property, including storm damage, evacuations (if appropriate) and rescues (e.g. motorists or pedestrians who have entered floodwaters). It is important to share information about the typical roles of each agency with community members, to allow them to contact the appropriate agency in the event of a flood related emergency, to ensure their call is responded to without unnecessary delay and not place additional burden on agencies that cannot assist directly.

Discussion

Flood emergency planning and coordination is an important aspect of reducing flood risk in the study area. In terms of planning, dissemination of information to the community is an integral aspect. An information brochure containing flood information, emergency contact information, and guidance on preparation and response can be distributed to the community. Although the information may be general, it provides information to residents on flood risks, how to prepare and what to do during a flood. This brochure could be updated and included as part of an ongoing flood education and awareness program (see Section 8.5.2).

A Local Flood Plan is also available for the Lake Macquarie LGA, updated in November 2022 (Reference 30). The document sets out the multi-agency arrangements for the emergency management of flooding in the Lake Macquarie City LGA, as contained in Volume 1. Typically, Volume 2 of local flood plans are not publicly available and contain an overview of the flood hazard and risk in an area. While the plan applies to the entire Lake Macquarie LGA, it is recommended that this is periodically updated as new flood studies (such as the North Creek Warners Bay Flood Study) are completed. Council also has an internal procedure document *Closing Roads Prone to Flooding* that should also be updated with information from the North Creek Warners Bay Flood Study.

Coordination between responsible agencies (primarily Council and SES) is critical to providing an adequate level of service during flood events. It is recommended that regular meetings and exercises be held to improve plans at the strategic level. There would be significant benefit in including a broader range of representatives from each agency at these meetings including Council engineering and outdoor staff. SES volunteers and volunteer coordinators, would ensure that the individuals who are most likely to be active during the event would benefit from the training exercises, and could add input from their own experience. Not only will this help more responders prepare for flood events but increase familiarity between representatives of each agency.

Difficulties in achieving the above objectives stem from the logistics of gathering the relevant parties at a mutually convenient time, staff changeover within agencies, and location and availability of out-of-area volunteers. It may be more feasible to have regular, smaller meetings, where representatives from each agency can attend and report back to their teams, and perhaps aim to hold a larger scale gathering and training day on an annual basis to ensure individuals can plan their attendance well in advance.

Summary and Recommendation

	RM01: Flood Emergency Management Planning and Coordination
Description	• The NSW SES is the legislated combat agency for floods, including the preparation, response and recovery phases. The SES provides information to residents and assists during flood events. Council also has responsibilities and works with the SES to achieve these goals.
Responsibility	SES and Council
Outcome	It is recommended that the SES: • Use the information and modelling developed as part of the North Creek Flood Study and FRMS&P to update their flood intelligence and Local Flood Plan for the Lake Macquarie LGA. • Consider creating and distributing brochures or information on their website specific on the flood risk in the LGA – specifically creek and overland flooding. It is recommended that Council and SES hold regular meetings of all responders to identify roles and responsibilities in practice and build relationships between agencies and/or community groups.
Priority	High

8.5.2. RM02: Community Flood Awareness and Education

Option Description

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

Key messages to be communicated to the community include the following.

- General information about how overland flow in the Warners Bay catchment is generated, where it is conveyed and typical duration of inundation.
- Specific information about flow paths and associated flood behaviour (for key areas at risk).
- Guidance on the roles and responsibilities of the SES and Council with contact details of each agency.
- What to do when the BoM issues a severe weather warning for the study area.
- General information regarding personal safety during a flash flood event, particularly, the risks of driving across flooded roads, even if the flow is shallow.

Based on learnings from recent disasters, the focus of community disaster education has now turned from a concentration on raising awareness and preparedness to building community resilience through learning. Simply disseminating information to the community does not necessarily trigger changed attitudes and behaviours. Flood education programs are most effective when they:

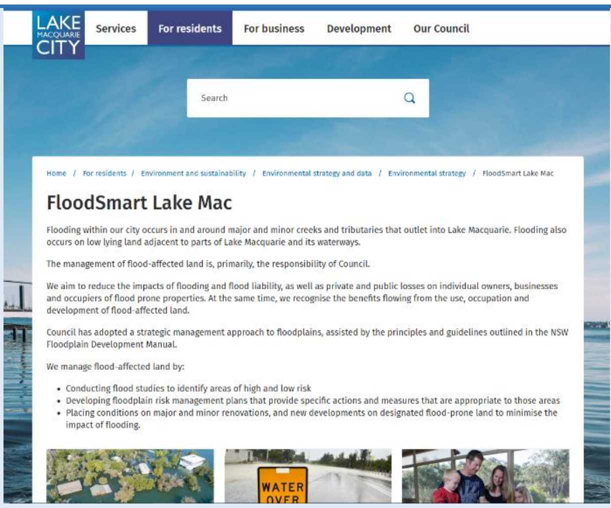
- Are participatory i.e. not only consisting of top-down provision of information but where the community has input to the development, implementation and evaluation of education activities;
- Involve a range of learning styles including experimental learning (e.g. field trips, flood commemorations), information provision (e.g. via pamphlets, videos, the media), collaborative group learning (e.g. scenario role plays with community groups) and community discourse (e.g. forums, post-event debriefs);
- Are aligned with structural and other non-structural methods used in flood risk management and with emergency management measures such as operations and flooding;
- Are ongoing programs rather than one-off, unintegrated 'campaigns', with activities varied for the learner.

It is difficult to accurately assess the benefits of a community flood education program, but the consensus is that the benefits far outweigh the costs. Nevertheless, sponsors must appreciate that ongoing funding is required to sustain the gain that has been made.

Ongoing flood awareness campaigns can be costly and can become ineffective over time with residents becoming bored or dismissive of messaging, particularly in periods of little rainfall. The community's perception of flooding may be more driven by flood risk occurring in Lake Macquarie or large creek systems, and overland flow flood risk may be perceived as less important or hazardous in comparison. Overland flow events do occur, and bring with them their own risks, particularly relating to flash flooding of roads, and driver safety. It is key to keep overland flow flood awareness current, as flash floods can occur frequently and quickly.

Table 17 provides a list of commonly applied methods to build and sustain flood readiness, which may be developed and supported by NSW SES and Council. These include methods both to inform and to prepare the community, with the objective of building resilience.

Table 17: Methods to Increase Flood Awareness and Preparedness

Method	Comment
Council website	 Council already provides flood information on their website, via the "FloodSmart Lake Mac" section, which provides information on property flood data and development controls, preparing for an emergency and Lake Macquarie's FloodWatch service, the adopted flood study and FRMS&P reports, some history of floods in Lake Macquarie and the opportunity for residents to share their experiences. While these sections are useful to the community, an additional section which provides an overview of the flood behaviour in the LGA and the flood risk management process is recommended. This section would give the community a general understanding of the type of flooding expected (in particular creek and overland flooding for the Warners Bay catchment) and process by which Council manages the flood risk. Council already provides flood preparation information on their website via the "Prepare for an emergency" section. However, Council should consider continuing to update and expand their website to provide qualitative information on how residents can make themselves flood aware. This would provide an excellent source of knowledge on flooding within the study area (and elsewhere in the LGA) as well as on issues such as climate change. Information about what to do in the event of a flood, and how to stay safe, could also be provided. This could include, for example, links to SES materials and campaigns such as "15 to Float", "If it's

Method	Comment
	flooded forget it" and "Turn Around Don't Drown", which aim to improve driver safety during flood events. It is recommended that Council's website continue to be updated as and when required.
Community Champions Program	There could be an opportunity for the SES and Council to liaise with these trusted community members to trial a community champion program. This would also provide a valuable two-way conduit between the local residents and Council. The SES Community Action Team Volunteers is an SES program where community members volunteer to help prepare and protect their community during severe weather events. There may be members of the local community well suited for involvement in a SES Community Action Team group and this team should be more widely promoted to encourage involvement.
Community Working Group	Council could initiate a Community Working Group framework (undertaken in other catchments elsewhere) and this would provide a valuable two-way conduit between residents and Council.
Letter/pamphlet from Council	A leaflet containing specific information about flood behaviour, and what to do in the event of a flash flood is an effective way of providing information without necessarily requiring active participation from residents. A leaflet/pamphlet from Council may be sent (annually or biannually) with the rate notice (electronically or by mail). A Council database of flood liable properties/addresses makes this a relatively inexpensive measure which can be effective if residents take the time to absorb and apply the suggestions. The pamphlet can inform residents of on-going implementation of actions identified in the FRMS&P, changes to flood levels or development controls, reinforce the differences between sources of flooding, provide information on the actions Council is taking to reduce the flood risk in their area and direct residents to further information. It could also be combined with other general council information, reducing the potential fatigue from repeated messages. 
School engagement	Engagement with school students can be a successful means of not only informing the younger generation about flooding but can also lead to infiltration to parents. This can be implemented through various techniques including: • adopting messaging about not playing in or driving in floodwaters into appropriate lessons, • school projects where students can learn about historical floods by interviewing older residents and documenting what happened, • and hosting "flood awareness" days where members of the local SES visit schools and participate in flood safety activities. While this FRMS focuses on flood risk only, this approach can be combined to include other topics relating to water quality, drainage management, etc.
S10.7 certificate notifications	This option is discussed in detail in Section 8.4.7, and is a useful tool as a 'point in time' awareness exercise, but has limited use as a method to maintain flood awareness in the community, as generally the certificates will only be requested when a property is to be redeveloped or sold. Council may wish to advise interested parties, when they inquire during the property purchase process, regarding flood information currently available, how it can be obtained and the cost. Some Councils have conducted "briefing" sessions with real estate agents

Method	Comment
	and conveyancers.
A range of media	A range of media and community engagement methods should be used to publish interest pieces on flooding, and to promote flood awareness activities. Communication might include council newsletters, social media, local newspapers and the radio. Ongoing pieces in newsletters or the local paper will ensure that flood issues are not forgotten.
Library display	The library could collect historical flood photos and stories to prepare a display, which could be accompanied by appropriate flood safety messages and tips for responding to future flood events. This could also be set up at any number of other sites, such as shopping centres.
NSW SES Business Breakfast	The NSW SES has prepared material for business emergency planning to help protect them from the impacts of floods. A breakfast barbeque could be convened at an appropriate location to promote completion of plans and to provide site-specific flood information.
'Meet the street' events	'Meet-the-street' events involve NSW SES and Council setting up a 'stall' at an appropriate time and visible location. The event would be advertised through a specific letter box drop to the targeted neighbourhood or vulnerable site. The stall could consist of flood maps on boards, NSW SES banners, NSW SES materials to hand out. These materials are used to engage with people and make them aware of flood risk, encourage preparedness behaviours (e.g. develop emergency plans) and help them understand what to do during and after a flood. A meeting could also encourage property owners to develop self-help networks and particularly people checking on neighbours if a flood is imminent. Longer-term residents with flood experience could be used to help provide other residents with an understanding of previous floods and how to prepare for future flooding.
Flood Information Signage	Flood information signs could be implemented in locations known to flood to inform residents of the risk, and appropriate responses. Examples include the 'Floodway' signs around the New York Avenue basins. This can also take the form of historical flood markers, where signs or marks can be prominently displayed on telegraph poles or such like to indicate the level reached in previous floods. Depth indicators advise of potential hazards. These are inexpensive and effective but in some flood communities are not well accepted as it is considered that they affect property values. 
Collection of peak water level data from future floods	Collection of data (photographs) assists in reinforcing to the residents that Council is aware of the problem and ensures that the design flood levels are as accurate as possible. This might also include establishment of peak water level marker poles and localities where house floors have been inundated previously.

Discussion

These options for community education include both passive (pamphlet, flood signage, library displays, etc) and interactive methods of engagement (community champions, SES breakfast, 'Meet the Street' events and school engagement, etc.), and target various sectors of the community (businesses, residents, school children, etc.), and can be implemented by various organisations (Council, SES, schools, community groups). It is therefore recommended that a program which utilises a variety of approaches and looks to engage a wide cross section of the community is developed, for ongoing implementation over the coming 5-10 years. Learnings from other recent engagement activities can be used to formulate a program most suited to the Lake Macquarie LGA and its community.

Summary and Recommendation

	RM02: Community Flood Awareness and Education
Description	Flood awareness is a vital component of flood risk management for people residing and working in the floodplain. Flood awareness can be developed through a range of strategies with varying levels of community participation. Strong flood awareness can significantly improve the way a community prepares for, responds to, and recovers from flooding.
Responsibility	Council and SES
Outcome	It is recommended to design and implement an ongoing community flood education program to maintain a high level of flood awareness and understanding of the risk and appropriate response to flooding in the North Creek catchment (and likely in conjunction with the wider LGA).
Priority	High

8.5.3. RM03: Flood Warning Systems

Option Description

The purpose of a flood warning is to provide advice on impending flooding so people can take action to minimise its negative impacts. Where effective flood warnings are provided, risk to life and property can be significantly reduced. Studies have shown that flood warning systems generally have high benefit / cost ratios if sufficient warning time is provided and if the population at risk is aware of the threat and prepared to respond appropriately.

A wide range of prediction tools are available, from basic flash flood information systems that use real-time rainfall triggers, to complex flash flood warning systems that run real-time hydrodynamic models informed by radar rainfall estimates. There is a need to find the appropriate balance between the risk presented by the flooding, model complexity (and cost), available warning time, and accuracy of prediction. The flood prediction then needs to be interpreted in terms of what area, people and infrastructure are at risk. This is then required to be disseminated to the appropriate people and areas for them to take appropriate action. Providing sufficient warning time is necessary for people to prepare and act (for example, moving goods to a higher level and evacuating to higher ground) has the potential to reduce the social impacts of the flood as well as reducing the strain on emergency services.

Discussion

The BoM is responsible for monitoring and predicting flood events. Flood Watches and Flood Warnings, however, are only provided for large river systems where it is possible to predict flooding more than 6 hours in advance. There are no Flood Watches or Flood Warnings available for the North Creek catchment. Typical critical durations across the study area range from 20 minutes on overland flow paths in the upper catchment to a maximum of 180 minutes (3 hours) at the downstream end of North Creek. This would be categorised as 'flash flooding', that is typically the result of intense local rainfall and characterised by rapid rises in water levels, occurring within 6 hours.

While the BoM does not provide warnings for flash flood catchments, it does provide forecasts and warnings for severe weather conditions that can potentially cause flash flooding. The BoM issues severe weather warnings for potentially hazardous or dangerous weather that is not solely related to severe thunderstorms, tropical cyclones or bushfires. This warning can include factors such as damaging winds and heavy rain that may lead to flash flooding. Warning times can vary from an hour to 36 hours. The BoM also issues severe thunderstorm warnings for severe or very dangerous thunderstorms. This warning can include factors such as large hail, damaging winds, tornadoes and intense rainfall that may lead to flash flooding. These alerts are available through the BoM website, BoM weather app, the SES website and a variety of other platforms (such as news outlets and social media). Recently, the BoM updated its app so that users can receive push notifications for severe weather warnings.

Manly Hydraulics Laboratory (MHL), on behalf of Council, operates Lake Macquarie FloodWatch, a Flood and Coastal Intelligence Tool that provides near real-time monitoring of rainfall and water levels across the Lake Macquarie catchment. The web-based platform (https://mhl.nsw.gov.au/users/LakeMac/) provides information on actual rainfall and water levels in the area that indicate if flooding is likely. This information is used by decision makers to have knowledge on current conditions within the catchment and utilise forecasts from the BoM to plan for deployment of resources. Part of the network of monitors includes the North Creek water level gauge (2114110) and nearby pluviograph rainfall stations of Eleebana (561158) and Windale No 2 WWPS (561172). The website indicates that the community should be aware if there is 70 mm of rainfall in 3 hours or 150 mm of rainfall in 24 hours. The system itself does not provide predictions of flooding but rather enables users to monitor rainfall and water level conditions in real time.

Due to the nature of overland flow in the study area, flood warnings are difficult to prepare and disseminate. The quick catchment response time does not allow time to interpret recorded rainfall data, construct and disseminate a flash flood warning, with enough time for the community to be able to take meaningful action to prepare. It is also difficult to strike a balance between accurate flash flood warnings that provide adequate warning time and the potential for triggering false alarms due to inherent uncertainties in predictions.

As an alternative to a flash flood warning system for the North Creek catchment, severe weather and thunderstorm warnings issued by the BoM can be used as a warning of the potential onset of flooding in overland flow areas coupled with education and awareness. For example, an at-risk business aware of a severe thunderstorm that may cause flash flooding can prepare by elevating stock or erecting a temporary flood barrier before finishing work for the day; or a flood-prone resident may gather an emergency kit and be more aware of conditions outside in case evacuation is necessary; or a member of the community may postpone an errand to avoid driving in dangerous conditions. The Lake Macquarie FloodWatch system allows the community to view conditions in real time and be more aware of surrounding conditions during such events. These two systems (BoM warnings and FloodWatch) allow the public to be aware of potential flash flooding and can monitor it.

The water level gauge on North Creek, located immediately upstream of the Walker Street crossing, provides valuable information to Council, SES and the community regarding flooding in North Creek. The usefulness of this gauge in understanding wider flooding throughout the catchment, however, is limited. As outlined in the Flood Study (Reference 3), the nature of the catchment is such that it is more likely that flooding will occur from an intense, short duration local storm. These storms may cause severe flooding on one tributary, but not another, or cause flooding of North Creek in the upstream areas and not downstream. It is difficult to take a water level at the Walker Street gauge and accurately determine the water level (and extent of flooding) upstream and downstream of this location, as is typically done on larger river systems such as the Hunter River. However, the design flood results can be used to inform an estimation of flood impacts in the vicinity of the gauge.

The design flood modelling results were used to provide indicative gauge levels when certain consequences occur. These are summarised in Table 18 below and shown visually on the gauge rating curve in Diagram 7. Gauge zero is understood to be 0 mAHD (that is, gauge levels are in mAHD).

Table 18: North Creek Gauge Levels and Consequences

Gauge Level (mAHD)	Consequence
2.1	Martin Street cul-de-sac (eastern side of North Creek) begins to be inundated.
2.37	50% AEP level.
2.5	Albert Street cul-de-sac (eastern side of North Creek) begins to be inundated.
2.6	King Street overtopped.
2.98	20% AEP level.
3.0	Walker Street overtopped.
3.1	Margaret Street cul-de-sac (eastern side of North Creek) begins to be inundated.
3.22	10% AEP level.
3.39	5% AEP level.
3.5	Floor levels of houses on the downstream North Creek floodplain estimated to begin flooding above floor.
3.58	2% AEP level.
3.72	1% AEP level.
3.85	0.5% AEP level.
4.04	0.2% AEP level.
5.47	PMF level.

Note: Consequences are indicative and based on design flood event modelling. Actual gauge levels and consequences may vary with real flood events.

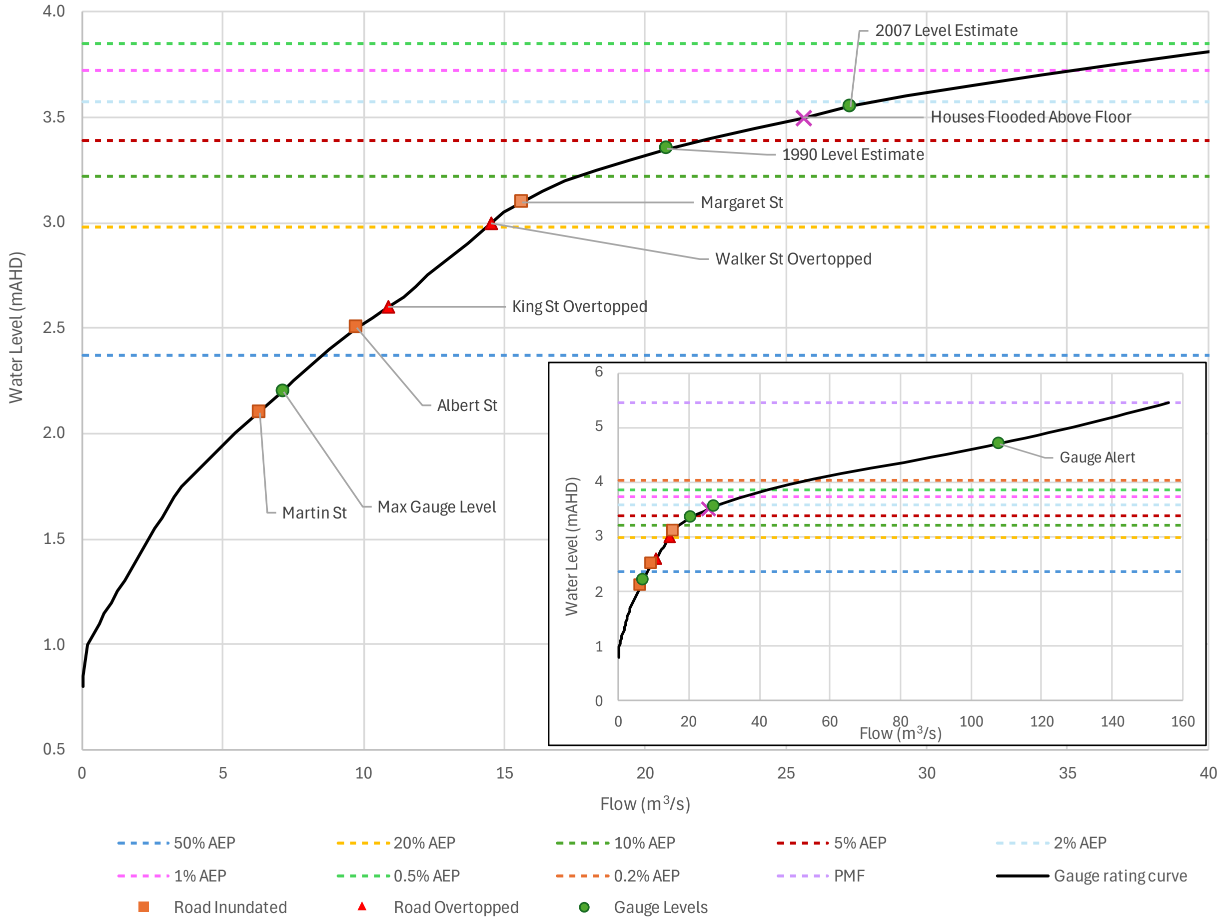


Diagram 7: North Creek Gauge Levels and Consequences

The maximum gauge level since the installation of the gauge in June 2022 was in the recent May 2025 event, where a level of approximately 2.2 m was recorded. The level of the 1990 flood (estimated based on modelling of this event) was approximately 3.35 m (slightly less than the 5% AEP level) and the level of the 2007 flood (estimated based on modelling of this event) was approximately 3.55 m (slightly less than the 2% AEP level). These historic levels align well with design flood levels considering the rarity of the rainfall events and the critical duration of the catchment (see the Flood Study for further information, Reference 3).

It is understood that the North Creek gauge automatically issues SMS and email alerts to registered users from Council, MHL and the SES when the gauge reaches 4.7 mAHD. Based on the modelling that has been undertaken, this is between the 0.2% AEP and PMF events. This alert level is too high to be of any practical use. It results from a flow 4 times the 2007 event and almost 2 times the 0.2% AEP flow. It is recommended that a lower alert level be adopted based on the above information. A level of perhaps 3.5 mAHD may be more appropriate, being between a 5% AEP and 2% AEP event when the floor levels of houses may be inundated. At this level inundation of roads is also likely to have taken place, including overtopping of King Street and Walker Street, and inundation of roads that terminate at North Creek. Based on the estimation of levels for the historic events, the 1990 event would not have triggered this alert, however, the 2007 event would have triggered this alert.

Is it also recommended that Council's internal procedure document *Closing Roads Prone to*

Flooding be updated considering information contained in the Flood Study (Reference 3).

Summary and Recommendation

	RM03: Flood Warning System
Description	A flood warning system is designed to provide advice on impending flooding so people can take action to minimise its negative impacts.
Outcome	A dedicated flash flood warning system for the North Creek catchment is not viable. It is recommended that the severe weather and severe thunderstorm warnings issued by the BoM be used to prepare for potential flash flooding events. Community awareness campaigns may assist residents in interpreting warnings from the BoM, anticipating the impacts and preparing accordingly. The Lake Macquarie FloodWatch system provides a platform for monitoring current conditions during these events. Council and SES operations should also be reviewed, in particular the road closure procedures and North Creek gauge alerts.
Priority	Medium

8.5.4. RM04: Improvements to Driver Safety

Option Description

One of the key hazards associated with flooding in the study area is inundation of roads. In urban areas such as Warners Bay, the risk to life is generally low if people stay indoors. Usually, the riskiest thing to do in a flood event is drive a vehicle. It can be difficult to estimate the depth of water and velocity of flow over a road, and many people attempt to cross flooded roads, believing that the vehicle is safe to do so. Research has shown that a small car can begin to lose traction in just 15 cm of water. In urban areas, the duration of inundation is typically short, and alternative routes are often available. Flood signage can be an effective measure to inform drivers of road inundation and deter them from attempting to drive through flood waters.

Discussion

This section contains a discussion of the practical considerations that are involved when installing new flood signage on roads that are subject to inundation, in addition to some suggested locations. It is recommended that an investigation be undertaken by Council to confirm the most appropriate locations and types of flood signage, and complementary education programs to reduce flood risk most effectively to motorists and consequences to flood behaviour in surrounding areas (such as wave action and flow diversion). Flood depth signage may also act as a passive reminder to residents of the potential for flooding on local streets.

Due to the flash flooding nature of the North Creek catchment, water can rise to dangerous depths and velocities before a formal road closure can be implemented and traffic rerouted safely. Flooding in the study area can cause several roadways to become overtopped, depending on the location and intensity of rainfall. In most cases, alternative safe routes can be taken, however, unless residents are aware of them, some may attempt to cross through flood waters, putting themselves and others at risk. This is particularly likely if visibility is poor during heavy rain, as water over the road is either not noticed, or the risk of driving through it is not appreciated.

A recent campaign by the Victorian Sate Government (15tofloat.com.au) highlighted that “a small car can be moved by water only 15 cm deep”. Driving through even shallow floodwater can put the driver at risk and increase the demand on SES resources (and risk to their lives) if rescue is required. It is noted that deeper water at lower velocities is also hazardous to vehicles, as identified in Reference 10, which has been used to categorise the design flood behaviour in the study area into 6 hazard categories, from H1 to H6. The hazard over roads in both the 20% AEP (representing frequent flooding) and in the 1% AEP (representing a large flood event) was checked across the catchment. In general roads that experienced at least H2 (unsafe for small vehicles) in the 20% AEP event and H3 (unsafe for vehicles, children and the elderly) in the 1% AEP event were identified. Consideration was also given to the nature of the road (for example, a main road compared to a cul-de-sac) and length of inundation to assess an indicative risk. In some cases H5 or H6 was triggered due to high velocities (irrespective of depth), in which case flood depth indicators may do little to deter motorists. A total of 6 locations were identified across the catchment that were considered a flood risk to road users. These are listed in Table 19 and shown in Figure 21.

Table 19: Potential Locations for Flood Warning Signage and/or Depth Markers

ID	Location	Hazard Classification in 20% AEP event	Hazard Classification in 1% AEP event
1	Medcalf Street at Lakelands Branch	**H2**	**H4**
2	Wilton Close at King Street Branch	**H2**	**H3**
3	Nott Street at King Street Branch	**H2**	**H4**
4	Yorston Street at King Street Branch	**H2**	**H4**
5	King Street at North Creek	**H2**	**H4**
6	Walker Street at North Creek	**H1**	**H4**

Other locations, such as no through roads adjacent to North Creek were not included as it is difficult to place flood depth markers on roads that slope down toward the creek. Flood depth indicators are more useful at sag points in roads and where flow paths cross roads.

From the locations identified in Table 19, the following comments are provided.

1. Medcalf Street is a main thoroughfare for the study area and modelling indicates hazardous inundation across a range of flood events, particularly in the eastbound lanes adjacent to the Lakelands Pond. There is historical evidence of inundation at this location in previous events (Reference 3). A flood depth indicator or warning sign at this location is recommended.
2. Wilton Close is a local road and the length of inundation is relatively short. A flood depth indicator or warning sign may, however, be appropriate and signs may be place adjacent to the Wilton Close reserve.
3. Nott Street can experience hazardous flooding at the low point. Flood warning signs may be placed at this location, however, since it is a local road in a residential area, these signs are unlikely to be supported by the community. There is also no evidence of

historical inundation at this location.

4. Yorston Street can experience hazardous flooding at the low point. Flood warning signs may be placed at this location, however, since it is a local road in a residential area, these signs are unlikely to be supported by the community. There is also no evidence of historical inundation at this location.
5. King Street at North Creek is a main road and can be cut off from inundation from North Creek when the capacity of the culverts under the road is exceeded. This has occurred in the past and there is evidence of cars being inundated at this location (Reference 3). Council is responsible for closing the road when inundation occurs (most recently closed in May 2025). This location, however, already has flood depth indicators installed (see Photo 42). The location and effectiveness of these flood depth indicators should be reviewed considering the recent flood event (for example, are the depth indicators adequate with Council's road closure procedure or would a warning sign with flashing lights further mitigate risks to motorists? Is the location appropriate for inundation on Hillsborough Road as well?)
6. Walker Street at North Creek is the most downstream road crossing of North Creek. While the flood hazard is only H1 in the 20% AEP event, it reaches H4 in the 1% AEP event and would be an appropriate location for a flood warning sign or flood depth indicator. Overtopping of the road is known to have occurred in the past and this is the location of the North Creek gauge.

Photo 42: Flood depth indicator on King Street at North Creek (*Source: Google Street View*)

To communicate potential flood risk to drivers, it is recommended that appropriate signage is installed at key locations. Such signage might include depth indicators, warning signs, hinged flood signs, or signs fitted with flashing lights.

Flood signs must be installed in accordance with AS1742.2-2009 *Manual of Uniform Traffic Control Devices* (Reference 31) *Part 2: Traffic Control Devices for General Use*, which stipulates that *"The 'ROAD SUBJECT TO FLOODING, INDICATORS SHOW DEPTH' sign shall be erected on the left side of the road on which Depth Indicators are used, to advise drivers that the road ahead may be covered by floodwaters…the NEXT x km sign may be used in conjunction with this sign when there are two or more floodways ahead, not more than 2km apart." (Clause 4.10.6.9)*

Where flood depths are more than 1.5 m, the G9-22-1 depth indicator sign is to be used (refer to Diagram 8).

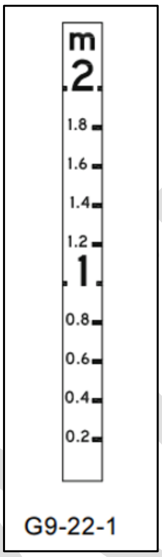


Diagram 8: G9-22-1 Flood Depth Indicators (Reference 31)

Where special attention is required due to the "extreme severity of the hazard to which they refer, or lack of adequate sight distance to the hazard, or a combination of the two", flashing lights can be set up alongside the warning signs. The flashing lights must comply with the requirements of AS2144 and consist of *200 mm diameter traffic signal lanterns flashing at a rate of 40 to 60 flashes per minute with the light on for 40 to 60% of the time* (Reference 31). An example is provided in Diagram 9.

Diagram 9: Examples of Warnings Signs with Flashing Lights (Reference 31)

With the potential for Council resources to be focused on storm-related responses (e.g. debris removal from roads), it is recommended that where possible, flood signs that require manual activation are not installed. Instead, warning signs and/or depth indicators (with or without automated flashing lights), that can give information to or warn drivers, without increasing the burden on Council's staff are preferable. Depending on the location and size of the event, installation of depth indicators or warning signs will not replace the need for Council to formally close roads, though they may assist in dissuading drivers to enter flood waters before the road is officially closed.

Placement of depth markers in an overland flow area requires careful consideration. If depth markers are placed where flooding is short-lived or shallow, they may be dismissed, which may lead to drivers ignoring depth markers at roads overtopped by fast flowing water. In addition, residents may be concerned that installation of depth markers or other flood warning signs may detract from the amenity of their area, and/or perceived to affect property values. Conversely, if road closure signs are left out for hours or days after the water has drained away, drivers are likely to ignore the signs and drive through. This may lead to future complacency or dismissiveness when the road is flooded.

Installation of depth markers or other flood signs should be undertaken in conjunction with extensive community education, for three key reasons:

- to ensure drivers understand what the depth marker shows (i.e. depth of water over road),
- to educate the community about the potential flood risk associated with water at that depth, and the danger of driving through even shallow water, as velocity can be hard to judge,
- to educate the community regarding the potential consequences to flood behaviour such as wave generation, flow diversion and impacts on property.

Recommendations relating to community flood education and awareness are provided in Section 8.5.2.

Summary and Recommendation

	RM04: Improvements to Driver Safety
Description	Installation of flood signs and flood depth indicators can improve driver safety, in conjunction with community education about the risks of driving through floodwaters.
Responsibility	Council and/or Transport for NSW
Outcome	Specific locations have been identified as potential flood sign locations. Further consideration of the factors discussed above is needed to identify the most appropriate type of sign, specific placements and accompanying community education needed to convey flood risk most effectively to motorists. It is recommended that a detailed study is undertaken to confirm the preferred locations, residual flood risk (i.e. need for road closure) and safe alternative routes and how traffic can be diverted in flood events. Following the detailed study, installation can proceed in accordance with the outcomes of that study.
Priority	Medium

9. MULTI-CRITERIA MATRIX ASSESSMENT

The Flood Risk Management Manual (Reference 1) recommends the use of a multi-criteria matrix assessment (MCMA) when comparing flood risk management measures. An MCMA provides a method by which options can be assessed against a range of criteria and offers a greater breadth of assessment than is available by considering only the reduction in flood risk or economic damages. Such additional criteria may include social, political and environmental considerations and intangible flood impacts that cannot be quantified or included in a cost-benefit analysis. It should be noted that the assessment of the suitability of flood risk management options a complex matter, and an MCMA will not give a definitive ‘right’ answer. Rather, it provides a tool to debate the relative merits of each option.

9.1. Scoring System

A scoring system has been devised to assess the various options across a consistent basis to allow for direct comparison. The scoring system is divided into key areas such as flood behaviour, economic, social and environmental considerations. Scores for each criterion are to be assigned to each option then summed to determine the overall score. Options with higher scores indicate benefits across a range of criteria and should be prioritised over those with lower positive scores, which may be more neutral or have a combination of positive and negative aspects. Conversely, options with the lowest negative scores indicate the option would cause adverse outcomes in several criteria and should not be considered further. The scoring system is provided in Table 20, and the outcomes of the assessment shown in Table 21. Discussion of the results is provided in Section 9.3.

Table 20: Multi-criteria Matrix Assessment – Scoring System

	Criteria	Metric	Score -3	-2	-1	0	1	2	3
Economic	Economic Merits	Comparison of the economic benefits against the capital and ongoing costs (BC may be estimated)	BC < 0.1	BC: 0.1- 0.5	BC: 0.5-0.9	BC = 1	BC: 1.0 - 1.4	BC: 1.4 - 1.7	BC >1.7
Economic	Technical Feasibility	Potential design, implementation and operational challenges and constraints. Risk can increase with implementation timeframe	Major constraints and uncertainties which may render the option unfeasible	Constraints or uncertainties which may significantly increase costs or timeframes	Constraints or uncertainties which may increase costs or timeframes moderately	NA	Constraints that can be overcome easily	No constraints or uncertainties	No construction requirements
Economic	Long term performance	Maintenance burden, design life	Significant increase requiring additional resources and / or <10 year design life	Moderate increase in maintenance requirements, <20 year design	Minor increase in maintenace requirements	No change	Can be incorporated in current planned maintenance	Some reduction to current maintenance requirements, > 30 year design life	Some reduction to current maintenance requirements, > 30 year design life
Economic	Staging of works	Ability to stage works	NA	NA	NA	Works cannot be staged	Some minor components of the works may be staged	Some major components of the works may be staged	NA
Social	Impact on Emergency Services	Change in demand on emergency services (SES, Police, Ambulance, Fire, RFS etc).	Major Disbenefit	Moderate Disbenefit	Minor Disbenefit	Neutral	Minor Benefit	Moderate Benefit	Major Benefit
Social	Road Access	Flood depths and duration changes for critical transport routes	Key access roads become flooded that were previously flood free	Significant increase in main road flooding	Moderate increase in local or main road flooding	No Change	Moderate decrease in local or main road flooding	Significant decrease in main road flooding	Local and main roads previously flooded now flood free
Social	Impact on critical and/or vulnerable facilities[1]	Disruption to critical facilities	Inoperational for several days	Inoperational for one day	Inoperational for several hours	No Change	Period of inoperation reduced by 0-4 hours	Period of inoperation reduced by > 4 hours	Prevents disruption of critical facility altogether
Social	Impact on Properties	No. of properties flooded over floor. Across all events	>5 adversely affected	2-5 adversely affected	<2 adversely affected	None	<2 benefitted	2 to 5 benefitted	>5 benefitted
Social	Impact on flood hazard	Change in hazard classification	Significantly increased in highly populated area (Increasing to H5/H6)	Moderately increased in populated area (Increasing by 2 or more categories)	Slightly increased (Increase by 1 category)	No Change	Slightly reduced (Decrease by 1 category)	Moderately reduced in populated area (Decrease by 2 or more categories)	Significantly reduced in highly populated area (Decrease from H5/H6)
Social	Community Flood Awareness	Change in community flood awareness, preparedness and response	Significantly reduced	Moderately reduced	Slightly reduced	No Change	Slightly improved	Moderately improved	Significantly improved
Social	Climate Change Adaptability	Performance under future climate change conditions, contribution to mitigation of or adaptation to changing climate	Increases risk	Benefits entirely eroded in future	Benefits partially eroded in future	Neutral	Provides some mitigation to changing climate	Provides moderate mitigation to changing climate	Entirely mitigates changing climate
Social	Social disruption	Closure of or restricted access to community facilities (including recreation)	Normal access significantly reduced or facilities disrupted for > 1 day	Normal access routes moderately reduced or facilities disrupted for 6-24 hours	No change to access but facilities disrupted for up to 6 hours	No Change	Reduces duration of access disruption or facility disruption by up to 6 hours	Reduces duration of access disruptioin or facility disruption by 6-24 hours	Prevents disruption of access or facility altogether
Social	Community and stakeholder support	Level of agreement (expressed via formal submissions and informal discussions)	Strong opposition by numerous submissions	Moderate opposition in several submissions	Individual submissions with opposition	Neutral	Individual submissions with support	Moderate support in several submissions	Strong support by numerous submissions
Environmental	Environmental and Ecological Impacts	Impacts or benefits to flora/fauna	Likely broad-scale vegetation/habitat impacts	Likely isolated vegetation/habitat impacts	Removal of isolated trees, minor landscapng.	Neutral	Planting of isolated trees, minor landscapng.	Likely isolated vegetation/habitat benefits	Likely broad-scale vegetation/habitat benefits
Environmental	Heritage Conservation Areas/Items	Impacts to heritage items	Likely impact on State, National or Aboriginal Heritage Item	Likely impact on local heritage item	Likely impact on contributory item within a heritage conservation area	No impact	Reduced impact on contributory item within a heritage conservation area	Reduced impact on local heritage item	Reduced impact on State, National or Aboriginal Heritage item
Environmental	Acid Sulfate Soils and Contaminated Land	Disruption of PASS and/or Disruption of Contaminated Land		Any works within Class 1 or 2 ASS area or Excavation >1m within Class 3 ASS area or Excavation >1m within Class 4 ASS area	Surface works within Class 2 ASS area or Excavation <1m or surface works within Class 3 ASS area or Excavation <2m or surface works within Class 4 ASS area	Works not within areas identified as PASS or contaminated land	NA	NA	NA
Other Aspects	Financial Feasibility and Funding Availability	Capital and ongoing costs and funding sources available	Significant capital and ongoing costs, or no external funding or assistance available	Moderate capital and ongoing costs, no funding available	High capital and ongoing costs, partial funding available	NA	Moderate capital and ongoing costs, partial funding available	Low to moderate capital and ongoing costs, partial funding available	Full external funding and management available
Other Aspects	Compatibility with existing Council plans, policies or projects	Level of compatibility	Conflicts directly with objectives of several plans, policies or projects	Conflicts with several objectives or direct conflict with one or few objectives	Minor conflicts with some objectives, with scope to overcome conflict	Not relevant	Minor support for one or few objectives	Some support for several objectives, or achieving one objective	Achieving objectives of several plans, policies or projects

Notes:

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

Table 21: Multi-criteria Matrix Assessment – Results

Category	ID	Detailed Assessment Options	Economic Merit: Economic Merit	Economic Merit: Technical Feasibility	Economic Merit: Long Term Performance	Economic Merit: Staging of Works	Social: Impact On Emergency Services	Social: Road Access	Social: Impact On Critical and/or Vulnerable Facilities	Social: Impact On Properties	Social: Impact On Flood Hazard	Social: Community Flood Awareness	Social: Climate Change Adaptability	Social: Social Disruption	Social: Community and Stakeholder Support	Environmental: Impacts On Flora and Fauna	Environmental: Heritage Conservation Areas and Heritage Items	Environmental: Acid Sulfate Soils and Contaminated Land	Other: Financial Feasibility and Funding Availability	Other: Compatibility With Existing Council Plans, Policies, or Projects	Total Score	Overall Rank
Flood Modification Measures	FM01	Lakelands Embankment	3	1	1	0	1	2	0	2	1	0	1	-1	0	-1	0	0	2	1	13	11
	FM02	Wilton Close Basin	3	-1	-1	0	1	1	0	3	1	0	1	0	0	-2	0	0	2	1	9	13
	FM03	Channel and Drainage Maintenance	1	2	0	0	0	1	0	0	1	1	1	0	0	0	0	0	1	2	10	12
Property Modification Measures	PM01	Voluntary House Raising	-2	-1	0	2	1	0	0	2	0	1	3	-1	0	0	0	0	1	1	7	14
	PM02	Voluntary Purchase	NOT RECOMMENDED																			
	PM03	Flood Proofing	3	1	0	2	1	0	0	3	1	1	0	2	0	0	0	0	2	2	18	8
	PM04	Flood Planning Levels	3	3	1	0	1	0	3	3	1	1	2	0	0	0	0	0	2	3	23	2
	PM05	Flood Planning Area	3	3	1	0	1	0	1	3	0	1	2	0	0	0	0	0	2	3	20	4
	PM06	Flood Planning Policy	3	3	1	0	0	0	3	3	1	1	2	0	0	0	0	0	2	3	22	3
	PM07	Section 10.7 Certificates	3	3	1	0	0	0	0	3	0	2	2	0	0	0	0	0	2	3	19	7
	PM08	Future Flood Resilience Policy	3	3	2	0	1	1	2	3	1	2	3	0	0	0	0	0	2	1	24	1
Response Modification Measures	RM01	Flood Emergency Management Planning	3	3	1	3	3	0	0	0	0	1	2	0	0	0	0	0	2	2	20	4
	RM02	Community Flood Awareness and Education	2	3	0	3	3	0	0	0	0	3	2	0	0	0	0	0	1	3	20	4
	RM03	Flood Warning Systems	2	3	0	1	1	0	0	0	0	2	2	0	0	0	0	0	1	2	14	10
	RM04	Improvements to Driver Safety	1	2	0	2	3	0	0	0	1	2	2	0	0	0	0	0	1	2	16	9

Note: Community and stakeholder support scores will be completed following Public Exhibition

9.2. MCMA Results

The results of the multicriteria assessment are provided in Table 21, with each of the assessed management measures scored against the range of criteria. It is important to note that the approach undertaken does not provide an absolute “right” answer as to what should be included in the Management Plan but is rather for the purpose of providing an easy framework for comparing the various options on an issue by issue basis, which stakeholders can then use to make a decision.

For the same reason, the total score given to each option, is only an indicator to be used for general comparison. Options with positive scores indicate that the benefits of the option outweigh negative aspects. These options have been recommended for inclusion in the Flood Risk Management Plan.

9.3. Discussion of MCMA Results

The multi-criteria matrix assessment results, presented in Table 21, can be used to both understand the benefits and disadvantages of individual options, but to also see trends across the full suite of options assessed in the FRMS&P. The following results and trends are noted:

- Property Modification Measures related to policy changes or updates ranked the highest, as they are cost effective methods to reduce property damages in the study area, and have additional benefits relating to improvements to community flood awareness.

- Response Modification Measures also rank higher than Flood Modification Measures, as they also are relatively cost-effective to implement and can have substantial impact on the preparedness for floods, as well as changes to the actions and attitudes of the community.
- Flood Modification Measures rank the lowest, with varying degrees of benefits and disbenefits across the range of criteria assessed.

The results of the MCMA have been used to identify a priority list of options, shown in Table 22.

Table 22: Rank of Flood Risk Mitigation Measures

Rank	Option	Priority
1	PM08 Future Flood Resilience Policy	High
2	PM04 Flood Planning Levels	High
3	PM06 Flood Planning Policy	High
4	PM05 Flood Planning Area	High
4	RM01 Flood Emergency Management Planning	High
4	RM02 Community Flood Awareness and Education	High
7	PM07 Section 10.7 Certificates	High
8	PM03 Flood Proofing	Medium
9	RM04 Improvements to Driver Safety	Medium
10	RM03 Flood Warning Systems	Medium
11	FM01 Lakelands Embankment	Low
12	FM03 Channel and Drainage Maintenance	Low
13	FM02 Wilton Close Basin	Low
14	PM01 Voluntary House Raising	Very Low
NA	PM02 Voluntary Purchase	Not Recommended

This forms the basis of the Flood Risk Management Plan (Section 10).

10. DRAFT FLOOD RISK MANAGEMENT PLAN

The FRMP summarises the recommended measures that have been investigated as part of the FRMS. Measures have been assessed for effectiveness against a range of criteria including how the option affected property damages, community flood awareness, impact on the SES, and economic merits, and a range of other factors. Recommended options are prioritised based upon how readily the management measures can be implemented, their capital cost, what constraints exist and the effectiveness of the measures. Measures with little cost that can readily be implemented, and which are effective in reducing damage or personal danger would have high priority. The FRMP is contained in Table 1 in the executive summary, together with a figure that summarises the FRMP.

The FRMP was prepared in accordance with the NSW Flood Risk Management Manual (Reference 1) and

- *Is based on a comprehensive and detailed evaluation of factors that affect and are affected by the use of flood prone land;*
- *Represents the considered opinion of the local community on how to best manage its flood risk and its flood prone land; and*
- *Provides a long-term path for the future development of the community.*

The FRMP provides input into the strategic and statutory planning roles of Council and provides a plan for Council to effectively manage flood liable land. It lists the management measures that have been recommended in the FRMS for implementation and describes the purpose of the measure, as well as its priority, cost and the party responsible for its implementation. Detailed descriptions of each recommendation are provided in Section 8 of the Study.

10.1. Funding and Implementation

There are several sources of funding for the investigation and implementation of the recommended flood risk management measures. The DCCEEW offers support to local Councils through Floodplain Management Grants. Assistance under this program is usually provided at a ratio of 2:1 State Government funding to local council funding. There are also schemes such as Resilience NSW's Get Ready Program which distributes practical resource kits and supports local councils to build resilient communities and help prepare for disasters such as flooding. There are also schemes supported by the Federal Government that are typically channelled through the State Government.

In addition to government funding, Council could also approach other organisations (such as TfNSW and SES) or private owners (such as property developers where appropriate) to assist with funding of measures.

Implementation of the Plan should be overseen by the Coastal Zone Management Committee and the local community should continue to be informed of progress through regular updates.

10.2. Ongoing Review of the Plan

This FRMP should be reviewed and amended as required over time. It is recommended that this occurs every 10 years at a minimum. This ensures the Plan remains relevant to the requirements of the area. Reviews can also be undertaken following flood events, or when new information becomes available that may be relevant. Changes in State or Local Government legislation or alterations to funding availability may also trigger the need for a review.

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