BYRON SHIRE COUNCIL

NORTH BYRON FLOODPLAIN RISK MANAGEMENT STUDY AND DRAFT PLAN

FINAL

wma water

OCTOBER 2020

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Project North Byron Floodplain Risk Management Study and Draft Plan	**Project Number** 117098
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Date 22 October 2020	**Verified by**

Revision	Description	Distribution	Date
6	Final	Byron Shire Council	22 OCT 2020
5	Final for Public Exhibition	FMC, BSC, Public Exhibition	9 APR 2020
4	Final Draft FRMS	FMC and BSC only	20 MAR 2020
3	Revised Draft FRMS Report	Community Consultation	17 JAN 2020
2	Revised Draft FRMS Report	FMC and BSC only	20 DEC 2019
1	Draft FRMS Report	FMC only	12 NOV 2019

NORTH BYRON FLOODPLAIN RISK MANAGEMENT STUDY AND DRAFT PLAN

TABLE OF CONTENTS

PAGE

LIST OF TABLES

APPENDICES:

LIST OF FIGURES

APPENDICES:

LIST OF DIAGRAMS

LIST OF ACRONYMS

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

ADOPTED TERMINOLOGY

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

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

ARI and AEP are often mistaken as being interchangeable for events equal to or more frequent

than 10% AEP. The table 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 Average Recurrence Interval where there is no seasonality, or an event that is likely to occur twice in one year.

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

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

Frequency Descriptor	EY	AEP (%)	AEP (1 in x)	ARI
Very Frequent	12			
	6	99.75	1.002	0.17
	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.5
	1	63.21	1.58	1
Frequent	0.69	50	2	1.44
	0.5	39.35	2.54	2
	0.22	20	5	4.48
	0.2	18.13	5.52	5
	0.11	10	10	9.49
Rare	0.05	5	20	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	

EXECUTIVE SUMMARY

Background

This report comprises an overview of the work that has been undertaken by WMAwater on the North Byron Floodplain Risk Management Study. It provides an understanding of the current and future flood risk within the catchment and investigates a suite of management options to manage this risk. In accordance with the Brief, it includes a discussion of:

- flood behaviour including hydraulic and hazard categorisation;
- future development scenarios;
- review of potential climate change impacts on the flood behaviour and risks;
- flood damages assessment; and
- emergency management.

The Study, which follows on from the North Byron Flood Study delivered in 2016 (Reference 5), has been undertaken in accordance with the NSW Government's Flood Prone Land Policy and the Floodplain Development Manual (Reference 4). A full assessment of the existing flood risk in the catchment has been carried out, including flood hazard across the catchment, over-floor flooding of residential, commercial and industrial properties, road inundation and emergency response during a flood event. A range of measures aimed at managing this flood risk were also assessed for their efficacy across a range of criteria, informed through community consultation,, which allowed certain options to be recommended. These recommendations form the basis of the subsequent draft Floodplain Risk Management Plan (FRMP) for the area.

Existing Flood Environment

The catchment is predominantly green space made up of nature reserve and rural land for primary production and agricultural purposes. There are six townships within the catchment – Mullumbimby, Billinudgel, South Golden Beach, Ocean Shores, New Brighton and Brunswick Heads. These townships comprise mainly low density residential development, light and general industrial and some commercial.

Flooding within the North Byron study area can result from either elevated ocean conditions, catchment flooding, or a combination of both. Historically, flooding has occurred as a result of ex-Tropical Cyclones or East Coast Lows generating flooding from both mechanisms. Whilst catchment flood events represent the dominant form of flooding in the catchment, low lying areas such as Brunswick Heads are more vulnerable to ocean derived flooding.

Economic Impact of Flooding

A flood damages assessment was carried out for the inundation of residential and commercial properties. The assessment was based on surveyed and estimated flood levels for all properties in the study area. The annual average damages for residential and commercial/industrial properties was estimated to be $2,667,100.

Floodplain Risk Management Options

The Floodplain Risk Management Study includes an investigation of possible options for the management of flood risk in the study area. These included flood modification works such as the construction of levees and significant drainage upgrades, as well as land use planning measures and response modification options. The measures were assessed for their ability to reduce flood risk while also considering their economic, social and environmental impact. A multi-criteria matrix assessment was used to directly compare the options. The results from this assessment are shown below. Further details of these options are found in Section 11.

Table 1: Asessment of Floodplain Risk Management Options

ID	Section	Option	Total Score	Overall Rank
PM04	11.6.4	Flood Planning Levels revised based on the recommendations of the FRMS.	20	1
PM09	11.6.9	Section 10.7 (5) certificates to provide further detail of flood behaviour. Consideration to providing property-level flood information via an online GIS platform.	18	2
RM02	11.5.2	Byron Shire Council and SES to consider the findings and recommendations of the FRMS in the development of the Flood Warning Network for North Byron.	18	2
RM05	11.5.5	Identify key roads and implement automatic warning signs and depth indicators.	16	4
PM06, PM07, PM08 (part), PM10	11.6.6,11.6.7, 11.6.8, 11.6.10	Council consider updating the DCP to incorporate the recommendations detailed in the FRMS; Provide more detailed guidance on the principles of wet proofing, appropriate design and materials, with direct reference to available guideliness; include a requirement for an assessment of property level protection as part of the DCP2014 planning matrix criteria FL4; Implement the recommendations regarding appropriate fill areas in the DCP2014.	16	4
CDM	11.4.6	Development a whole of catchment drainage model and overland flow path investigation.	16	4
PM08 (part)	11.6.8	Undertake more detailed assessment of properties which may benefit from property level protection	16	4
FDC	11.4.6	Implement debris control measures for Federation Bridge and Billinudgel Railway Bridge.	16	4
RM07	11.5.7	Undertake an Evacuation Assessment for Mullumbimby.	16	4
PM03	11.6.3	Changes to land use zoning should consider flood compatibility based on the recommendations of the FRMS.	16	4
PM01	11.6.1	Further investigate raising eligible residential properties to reduce flood damages.	15	11
SC	12.1.4	Further detailed assessment of Saltwater Creek upgrade assessment and mitigation options for Mullumbimby.	15	11
IC	12.3.2	Form a committee, comprising council, state, emergency services and community member representatives to oversee the implementation of the FRMP.	15	11
RM01	11.5.1	Council and the SES to update the Local Flood Plan based on findings of the FRMS.	15	11

PM05	11.6.5	Revise the Flood Planning Area based on the recommendations of the FRMS.	14	15
RM06	11.5.6	Engage with the community to prepare an ongoing flood education program, with appropriate evaluation by Council and SES following implementation.	14	15
AC	12.1.3	Further consideration of Avocado Court drainage modification.	14	15
PM11	11.6.1	Byron Shire Council compliance team investigate illegal builds south of North Heads Road.	14	15
RW02	11.4.3	Develop a sediment transport model to investigate modification to the rock walls, as part of the Coastal Management Program for the Brunswick Estuary.	14	15
BM	12.1.2	Further consideration of Billinudgel infrastructure improvements.	13	20
WFG	11.4.4	Develop guidance on the design and installation of fencing traversing waterways and channels.	13	20
PM02	11.6.2	Consider establishing a Voluntary House Purchase scheme for eligible properties.	13	20
RM03	11.5.4	More detailed assessment of potential raising of River Street to provide improved flood immunity and evacuation.	11	23
SGBA	11.4.1	Implement the recommendations of the South Golden Beach levee audit.	7	24
NCD	11.4.5	Further consider viable options to implement the recommendations of the New City Road drainage assessment.	4	25

1. INTRODUCTION

Byron Shire Council engaged WMAwater to undertake the North Byron Floodplain Risk Management Study and Draft Plan. This study is jointly funded by Department of Planning, Industry and Environment (formerly known as Office of Environment and Heritage) and Byron Shire Council.

1.1. Study Area

The study area for the North Byron Floodplain Risk Management Study (herein FRMS) includes the townships of Mullumbimby, Brunswick Heads, Ocean Shores, and villages of New Brighton, South Golden Beach and Billinudgel. Figure 1 shows the extent and location of the North Byron study area. Covering an area of approximately 55 km^2, land in the catchment includes diverse environments, generally comprising dense vegetation in the hinterlands and coastal villages to the east of the catchment.

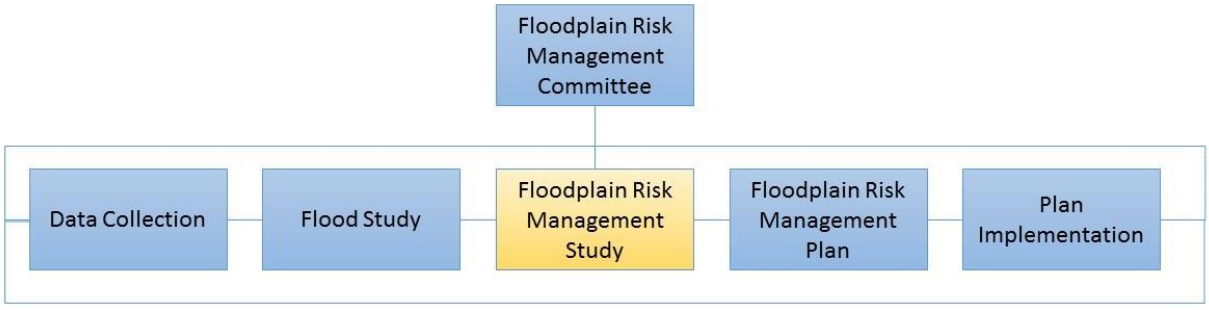
Ocean Shores is the largest town in the study area and primarily contains residential development. Mullumbimby is the administration centre of the shire and has a strong mix of commercial and residential urban uses. Brunswick Heads is located just south of Brunswick River and is a small, primarily residential township and a popular tourist destination. The rural village of Billinudgel is located directly west of the Pacific Highway and primarily comprises of business and industrial land uses. Almost directly opposite of Billinudgel to the east of the Pacific Highway are the residential townships of South Golden Beach, New Brighton and Ocean Shores.

The Byron Shire Community Strategic Plan (Reference 3) sets out a vision for the region and also identifies some of the pressures the region faces including high tourist numbers each year influenced by the areas proximity to South East Queensland, a changing future climate and increase in future population.

1.2. The Floodplain Risk Management Process

As described in the Floodplain Development Manual (Reference 4) the floodplain risk management process is formed of sequential stages as shown in Diagram 1:

Diagram 1: Floodplain Risk Management Process



In alignment with the Floodplain Development Manual, the Byron Shire Floodplain Management Committee (FMC) assists Council through the floodplain risk management process, acting as both a focus group and forum.

The North Byron Shire Flood Study was completed in 2016 by BMT-WBM (Reference 5). The Floodplain Risk Management Study and Plan (FRMS&P) are being undertaken for the catchment in two phases:

Phase I – Floodplain Risk Management Study in which the floodplain management issues confronting the study areas are assessed, management options investigated, and recommendations made. Specific objectives for this phase include:

- Identifying innovative solutions to the management of flood hazards within the study area under current and future conditions,
- Emergency management planning for existing and future development,
- Strategic and development scale land-use planning to manage growth in flood risk,
- Review and discuss strategies for raising the awareness of flood risk and the level of flood preparedness in the catchment,
- Selection of practical, feasible and economic measures for treatment of risk.

Phase II – Draft Floodplain Risk Management Plan which is developed from the floodplain risk management study details how flood prone land within the study areas is to be managed moving forward. The primary aim of the Plan is to reduce the flood hazard and risk to people and property in the existing community and to ensure future development is controlled in a manner consistent with the flood hazard and risk at this time and ensuring that such plans are informed to a degree by climate change sensitivity.

1.3. Available Data

In preparing this study, a wide range of existing data has been made available for use. Full details of the data used in the study have been logged and provided to Council.

2. NORTH BYRON CATCHMENT

2.1. Overview

The study area (Figure 1) for the North Byron studies consists of the Brunswick River, Marshalls Creek and Simpsons Creek catchments, located in the north part of the Byron Shire Council Local Government Area (LGA).

Marshalls Creek is the northern major tributary of the Brunswick River, with a catchment area of approximately 42 km^2 and includes the town of Ocean Shores and the villages of Billinudgel, South Golden Beach and New Brighton. Marshalls Creek flows south parallel to the coastal dune system prior to joining the Brunswick River. The catchment is traversed by the Pacific Highway and the railway line. To the north, the catchment links to the Yelgun catchment at Kallaroo Circuit in the Capricornia Canal.

The Brunswick River catchment covers an area of approximately 111 km^2 and includes the major towns of Mullumbimby and Brunswick Heads. It is also bisected in a north-south direction by the Pacific Highway and railway line.

To the south, the Simpsons Creek catchment, covers an area of approximately 66 km^2. Its confluence with the Brunswick River is on the southern bank, opposite Marshalls Creek confluence.

2.2. Social Characteristics

The North Byron catchment includes the townships of Mullumbimby, Brunswick Heads, Ocean Shores, and villages of South Golden Beach, New Brighton, Billinudgel, as well as numerous rural and rural-residential dwellings.

Information is available from the 2016 census (http://www.abs.gov.au/) which helps to define social characteristics of this study area. Understanding the social characteristics of the area can be used to inform the risk assessment process through providing metrics for some of the aspects which influence the vulnerability of a community. These include:

- **physical vulnerability:** measured through age demographics with the young (<14) and the elderly (>65 as defined by the United Nations) considered the more vulnerable in a community.
- **flood awareness:** measured through years lived in current location, mortgage or homeowners, ability to speak English, and having access to the internet at home.
- **mobility**: measured through having access to a car at home, and the number of people per dwelling
- **financial resilience:** measured through average incomes and proportion of low income earners.

Table 2 below shows the 2016 census statistical for the available State Suburbs (SSCs) compared to the NSW average.

Table 2: 2016 Census Data

	NSW	Mullumbimby	Brunswick Heads	New Brighton	Ocean Shores	Billinudgel	South Golden Beach
Population demographics:							
Median age	38	46	50	46	44	47	40
0 – 14 years	18.5%	18.3%	13.6%	18.0%	17.6%	18.1%	21.5%
15 - 64 years	65.1%	61.9%	63.%	65.8%	64.8%	67.6%	70.1%
> 65 years	16.2%	19.8%	23.1%	16.1%	17.6%	14.3%	8.4%
Average people per dwelling	2.6	2.4	2	2.1	2.4	2.5	2.5
Average children per family	1.9	1.7	1.6	1.7	1.7	1.5	1.8
Own/mortgage property	64.5%	65.8%	53.5%	73.1%	70.3%	60.5%	61.8%
Rent property	31.8%	30.1%	40.8%	26.9%	26.5%	35.5%	35.4%
Moved into area:							
- within last year	19.4%	22.0%	21.4%	28.0%	19.1%	18%	18%
- within last five years	38.9%	38.0%	38.7%	48.7%	36.4%	34%	45%
No vehicles at dwelling	9.2%	4.7%	8.0%	2.3%	2.4%	3.9%	3.7%
Ave vehicles per dwelling	1.7	1.7	1.5	1.7	1.8	1.9	2.5
Speak only English at home	68.5%	82.9%	86.5%	79.3%	85.4%	82.6%	85.1%
Households where non-English is spoken	26.5%	8.5%	6.3%	5.8%	9.1%	9.7%	7.8%
Other languages spoken		German (1%), Hebrew (1.1%), Japanese (1%), Italian (0.7%), French (0.7%)	French (0.6%), Japanese (0.5%), Cantonese (0.5%), German (0.4%), Hebrew (0.4%)	French (1.4%) German (0.9%)	German (1%), Hebrew (0.9%), Italian (0.6%), French (0.5%), Portuguese (0.5%)	Italian (1.8%), French (1.4%), Spanish (1.4%), Maori (1.4%)	Australian sign language (1%), German (0.9%), Italian (0.7%), Dutch (0.5%), Swedish (0.4%)
Internet not accessed at home	14.7%	16.0%	19.2%	11.8%	12.2%	12.8%	8.3%
Median weekly income	$1,486	$998	$844	$1,160	$1,096	$955	$1,130
< $650 gross per week	19.7%	29.6%	36.2%	26.7%	24.7%	34.4%	26.2%

The key variance from NSW averages are discussed below.

Metric	Trends	Impact[1]
Physical Vulnerability	Generally all suburbs have a higher median age than NSW average	Increased vulnerability (all suburbs)
	Brunswick Heads having a notably higher proportion of over 65s (and correspondingly lower proportion of under 14 years old)	Increased vulnerability (Brunswick Heads)
Flood Awareness	Brunswick Heads has a higher proportion of renters	Increased vulnerability (Brunswick Heads)
	New Brighton and Ocean Shores have a higher proportion of homeowners / mortgage	Decreased vulnerability (New Brighton, Ocean Shores)
	New Brighton has a higher percentage of new residents in both the <1 year and <5 year metrics	Increased vulnerability (New Brighton)
	All areas have a higher than average prevalence of English, with fewer residents speaking any other languages	Decreased vulnerability (all suburbs)
	Brunswick Heads has a higher proportion of residents without internet at home	Increased vulnerability (Brunswick Heads)
Mobility	High rate of vehicle ownership, particularly Mullumbimby, Ocean Shores and New Brighton	Decreased vulnerability (all suburbs)
	Slightly below average number of people per property	Decreased vulnerability (all suburbs)
Financial resilience	All areas had a higher proportion of lower income earners, and lower median weekly income, particularly Mullumbimby and Brunswick Heads	Increased vulnerability (all suburbs)

It is also noted that there is relatively high number of homeless people (compared to the base population) recorded in the North Byron catchment. These vulnerable people are typically without the information networks or resources to respond to or recover from flood events, and require different forms of support before, during and after flood events.

2.3. Vulnerable Properties

A number of vulnerable properties are located within the study area including two aged-care facilities, one community hall used for aged-care purposes, seven early learning centres / preschools, ten schools, five caravan parks and four medical centres. Figure 2 shows locations of these properties throughout the study area. 25 of these properties are within the PMF flood extent and of these, 12 experience above floor flooding in the PMF. Section 7.6.1 discusses the flood exposure of these properties in more detail.

[1] This is a generalised qualitative indication of the impact on community vulnerability at a catchment scale.

2.4. Environmental Features

The study area comprises a variety of land uses of which a large proportion includes agricultural uses. Major water uses in the Brunswick River catchment are primarily for grazing, cropping and horticulture with the bulk of town water supply being supplied from the Richmond River catchment (Reference 6). The following information has been extracted directly from the NSW Office of Water for the Brunswick River catchment.

2.4.1. Key water management issues

Due to a high density of rural settlement, the region's rivers and estuaries tend to be affected by changed run-off conditions caused by land clearing and agricultural use, urban development and recreation. Many streams on the coastal floodplain have been straightened and channelised.

Most of the rivers and creeks in the Brunswick River basin are unregulated, without major storages to capture and control flows. As in most unregulated rivers, there is high pressure on river flows during relatively dry times, when water is low and demand high. The Upper Brunswick River is regarded as a stressed river with a high potential demand for extraction relative to the natural flows in the creek. Water sharing plans have been introduced to balance the needs of water users and the environment.

2.4.2. Environmental Values

Over 20 km^2 of wetland along the coastal zone of the Brunswick catchment are protected under Coastal Management Act 2018. The largest of these are Cumbebin Swamp at Byron Bay and Billinudgel Creek. Billinudgel Creek is listed as nationally significant in the Directory of Important Wetlands in Australia. The Billinudgel Nature Reserve, located north of Ocean Shores, is considered to have environmental significance and protects important remnant coastal habitat.

The coastal plain of the Brunswick catchment has been extensively cleared. Remnants of Big Scrub lowland rainforest that previously covered 750 km^2 of the far north coast, are to be found south of the catchment. Less than one per cent of this endangered ecological community remains today.

2.5. Built Environment

Figure 3 shows the land use within the North Byron Shire floodplain, as defined by the current Local Environment Plan (2014). The catchment is predominantly zoned as rural land, residential, national parks and nature reserves and coastal habitat zones. There are six townships and villages located in the study area with the largest industrial located in Billinudgel and the largest local centre located in Mullumbimby and Brunswick Heads.

As part of the FRMS a comprehensive floor level survey was undertaken of all properties in the floodplain. This comprised manual field survey of all buildings within the 1 in 500 AEP extent, and desktop extraction of all other property floor levels up to the PMF extent. Desktop extraction uses Google Street View to determine the building type (e.g. high set, low set) in conjunction with the

ground level taken from the digital elevation model to estimate a floor level. North Byron is a particularly vegetated area and where the property could not be seen from Google Street View, a building type was assumed based on neighbouring properties.

There are approximately 3,700 properties included in the property database, of which approximately 3,400 are within by the PMF flood event (i.e. experience either above floor flooding or over lot flooding).

The majority of properties recorded in the property data base are residential land uses. Diagram 2 below shows the breakdown of land uses.

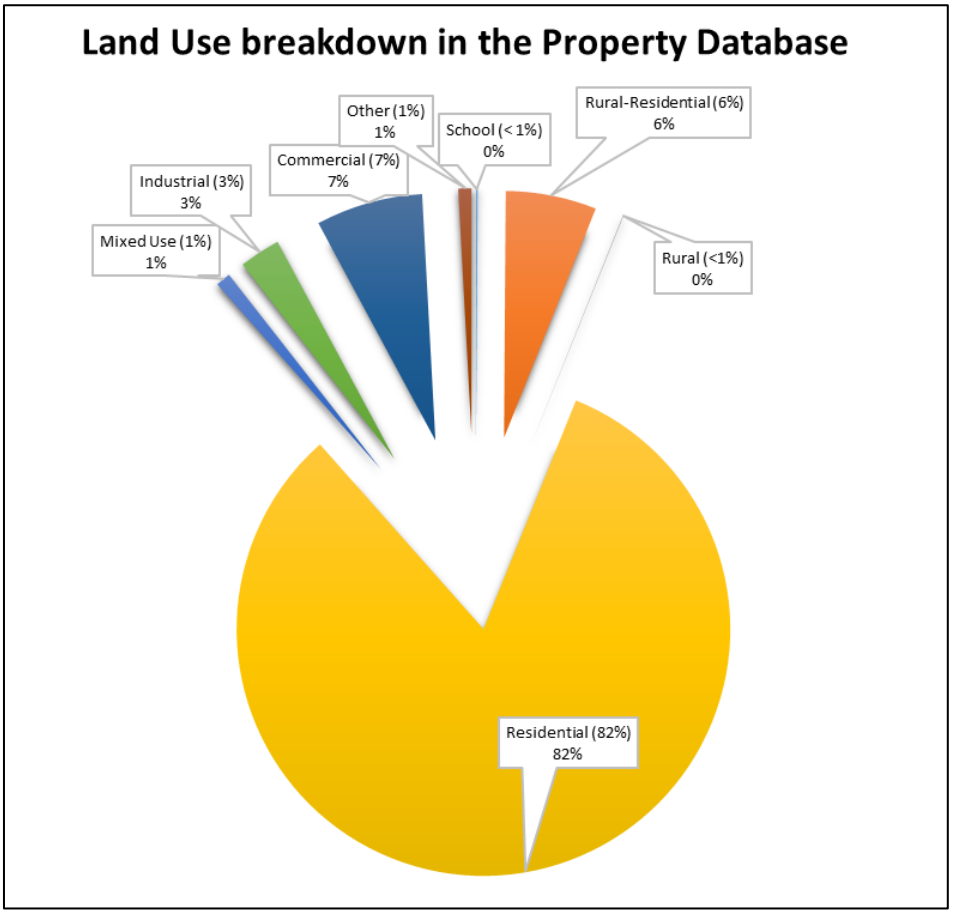


Diagram 2: Land Use breakdown in the Property Database

There are approximately 3,000 residential properties within the PMF flood event and approximately 2,870 experience above floor flooding. Table 3 shows the breakdown of residential building type, with 45% of the properties in the floodplain being recorded as slab on ground properties.

Table 3: Breakdown of building type for residential buildings

Building Type*	Count
High Set	752
Low Set	537
Multiple Storey	268
Slab on ground	1299
Slab on ground, multiple buildings	3
Slab on ground, multiple buildings and multiple stories	5
Slab on ground, multiple stories	8
Total residential property	**2872**

* building types were approximated where they could not be viewed from Google Street view.

2.6. Flood Behaviour

Flooding in North Byron catchment most often results from either tropical cyclones or east coast lows producing both heavy rainfalls and elevated ocean levels. The three catchments have distinct flood behaviour, as documented in the Flood Study (Reference 5), with key sections reproduced below. Further detail on the design flood behaviour is provided in Section 7.

2.6.1. Marshalls Creek Flood Behaviour

The Marshalls Creek system is characterised by a complicated interaction between the Yelgun, Mooball and Marshalls Creeks.

The Yelgun Creek catchment lies between the Mooball catchment to the north and the Marshalls Creek catchment to the south. Upstream of the Pacific Highway, the catchment is predominantly agricultural and forested land, whilst downstream the relatively large floodplain comprises a mixture of urban and forested area.

Two major bunds influence the interaction between the creek systems.

- A north / south bund just west of South Golden Beach,
- A west / east bund located North of South Golden Beach commonly known as the North Ocean Shores bund. There are two breaches in this bund.

Due to this complex topography, Yelgun creek either flows north into Mooball Creek or south through Capricornia Canal, under Kallaroo Circuit and into Marshalls Creek depending on the relative flood levels.

The flood behaviour across Kallaroo Circuit has changed considerably over the years due to development. The below summarises key changes, based on Council supplied information;

- A partial bund at Kallaroo Circuit, with an opening of 21 m^2 at the 1% AEP flood level, existed during the May 1987 flood and the canal was unobstructed.
- During the June 2005 flood, the Kallaroo Circuit bund was configured with two small cross-drainage culverts (2 x 900 mm diameter circular pipes).
- During the January 2012 event, the March 2017 event and as per current day, an additional set of three rectangular culverts (4.8 m wide by 1.5 m high) present.

Those hydraulic structures had and still have a significant impact on flood behaviour in Yelgun Creek. Flow can occur in either direction depending on the relative flood levels and can change during a single event.

The entrance to Marshalls Creek is constricted by rock walls with two openings. The eastern opening is 42 m wide and is tidal for tidal heights greater than 0.4 m AHD. The internal wall is a low level rock wall further north-west of the eastern opening and is approximately 300m in length. The height of this rock wall ranges from 0.2 mAHD to 0.4 mAHD and is tidal for heights greater than 0.4 mAHD. During flood events, the low level rock wall operates primarily as a submerged weir. The western opening is 37 m wide and is free flowing. As such, there is a considerable artificial restriction of flood flows draining from Marshalls Creek in a rainfall dominated event or flowing upstream in an ocean dominated event.

There is historical evidence of an ocean outlet existed at Wooyung which is believed to have been blocked as a result of the sand mining operations. There is also strong community debate regarding a number of other historical openings through the dune network. The effect dune openings had on previous flood behaviour, and the benefit they may provide to mitigate the impacts under current conditions, is a passionately discussed topic. Section 11.4.3 discusses the investigations undertaken as part of the FRMS to assess the impact dune openings could have on the flood behaviour in a large (1% AEP) event.

2.6.2. Brunswick River Flood Behaviour

Brunswick Catchment is characterised by wide floodplains for much of the river system. Upstream of Mullumbimby, Brunswick River runs parallel to Main Arm Road and crosses several subsidiary roads. It also crosses Main Arm Road, once just downstream of Main Arm township at Williams Bridge and another time at Durrumbul (Sherry's Bridge). Water overtops Main Arm Road in major flood events.

The town of Mullumbimby is located on the junction of the Brunswick River and Mullumbimby Creek. Near Mullumbimby there is a complex interaction of the various rivers and creeks. In larger flood events some of the water from Mullumbimby Creek enters the Brunswick River, but much of the water flows to Kings Creek and Saltwater Creek. This water then flows through the openings in the railway line south of Mullumbimby and enters the Brunswick River through Kings Creek.

Downstream of Mullumbimby the floodplain of the Brunswick River is relatively large. The flow is constrained through the Pacific Highway, before the confluence of Marshalls Creek and Simpsons Creek, both of which join Brunswick River very close to the ocean outlet. There are several rock walls and groynes which influence the flows in this region, and the mouth itself is constrained with rock walls built in the 1960s.

2.6.3. Simpsons Creek Flood Behaviour

The flood behaviour of Simpsons Creek is simpler than the other two catchments. A number of smaller tributaries join together in the vicinity of Tyagarah, downstream of which the floodplain is constrained to a width of approximately 250 m by Anderson's Ridge along which Tandys Lane

runs. North of this ridge the floodplain widens again, where there are large low-lying areas to the east and west of the creek. The creek flows northward for approximately 4 km to the confluence with Brunswick River.

2.7. Drainage Structures and Features

Mullumbimby and Brunswick Heads both have areas with a formalised pit and pipe network, as discussed in the following sections.

2.7.1. Mullumbimby

Most of the Mullumbimby urban area lies near an open waterway. As such, the stormwater network comprises several discrete networks which discharge directly in the nearest creek or river and are characterised by short pipe lengths and/or swales.

The most significant structures in the area are shown in Diagram 3 and described below:

- 750 mm diameter pipeline beneath Burringbar Street (approximately 400 m in length), discharging to the Brunswick River,
- The Station Street network consisting of a 750 mm pipe discharging to a drainage swale along the railway that drains to the Brunswick River,
- The stormwater network of the Mullumbimby urban catchment located north of Burringbar Street and west of the Railway (“Mullumbimby Centre”), which drains from south to north and consists of drainage swales located on both side of the streets (Gordon Street, Dalley Street, Stuart Street and two unnamed tracks).
- The 450 mm to 600 mm diameter pipeline along Orchid Place discharging to Saltwater Creek,
- The swale/pipe network along Ann Street draining to Kings Creek,
- The swale/pipe network along Argyle Street draining to Brunswick River downstream of the town,
- The swale/pipe network along Chinbible Avenue discharging to the Brunswick River,
- Two sets of Pipeline (600 mm to 750 mm diameter) discharging to Yalgan Gully and Yoga-Bera Gully then Chinbible Creek,
- The pipeline network under Cudgerie Court discharging to the Brunswick River (450 mm to 525 mm diameter),
- The pipeline network under Riverside Drive discharging to the Brunswick River (375 mm to 750 mm diameter).

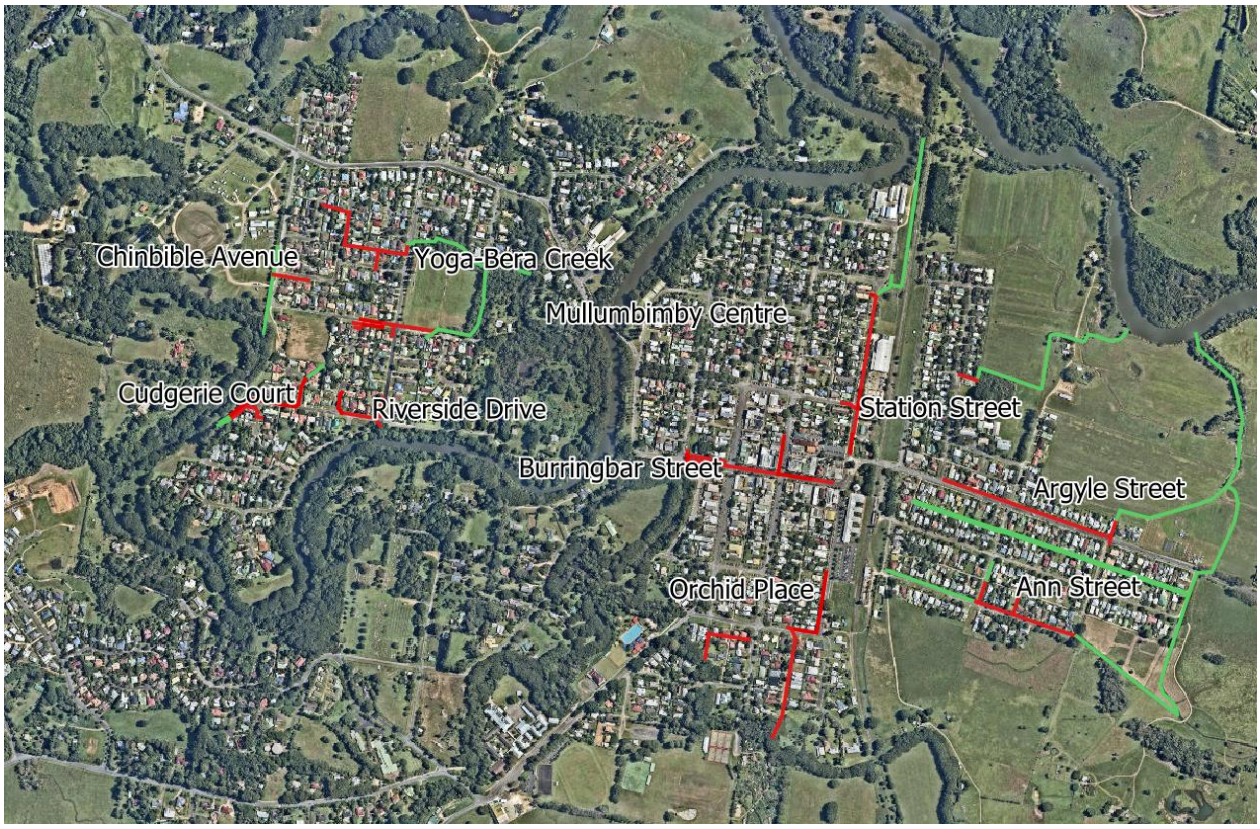


Diagram 3: Mullumbimby main drainage feature

2.7.2. Brunswick Heads

The main stormwater pipe in Brunswick Heads runs along Tweed Street. It discharges directly the Brunswick River, draining a total urban area of approximately 16 ha. The pipe diameter increases from 375 mm to 1050 mm at the outlet.

There are three other pipelines (with diameter ≥600 mm) in Brunswick Heads, as shown in Diagram 4:

- Along Tweed Street south, discharging to Simpsons Creek and draining a total urban area of 1.3 ha,
- Along Sharpcott Lane and Park Street south, discharging to Simpsons Creek and draining a total urban area of 3.5 ha,
- Along Park Street north discharging to Simpsons Creek and draining a total urban area of 1.0 ha.

Diagram 4: Brunswick Heads main drainage features

3. PREVIOUS FLOOD STUDIES AND INVESTIGATION

A significant number of studies have previously been carried out within the North Byron catchment since the early 1980s. These studies include:

- Brunswick Valley Flood Plain Management Study, Hydrology Report, 1984
- Marshalls Creek Flood Study, 1986
- Brunswick Valley Floodplain Management Study, 1987
- Flood Mitigation Options for Billinudgel, 1988
- Brunswick River Floodplain Management Investigation, 1989
- Proposed Levees and South Golden Beach, 1989
- Marshalls Creek Dredging Investigations Stage 1 Report,1992
- Mullumbimby Floodplain Management Study Re-evaluation of Options, 1992
- Report on Feasibility of an EIS for North Ocean Shores Flood Outlet, 1992
- Draft Mullumbimby Floodplain Management Plan, 1993
- Draft Kallaroo Circuit Bund Culvert Amplification Hydraulic Impact Assessment, 1996
- Marshalls Creek Floodplain Management Plan, 1997
- Brunswick River Tidal Data Collection, 2008
- North Byron Shire Flood Study ,2016

A summary of these reports and their findings are provided in detail in Appendix B, with key reports discussed below.

3.1. Brunswick Valley Floodplain Management Study, 1987

Byron Shire Council engaged Webb, McKeown & Associates to complete a Floodplain Management Study for the Brunswick Valley Floodplain. This study was delivered in April 1987 and considered the flood mitigation potential from three flood modification options and also assessed the hydraulic impacts from development proposals in the Brunswick River Valley.

The following options were evaluated for their potential flood mitigation benefits:

1. Lowering the bed level of the Brunswick River entrance by 0.5, 1.5 and 2.5m. Results showed no significant benefits to flood affected areas.
2. Construction of a 1km long flood by-pass weir between Marshalls Creek and the ocean, immediately to the north of the present Brunswick River entrance. Results indicated a reduction of flood levels in some areas (New Brighton: 0.4m - 0.5m reduction in 1% flood levels; Mullumbimby and Billinudgel: a maximum 0.05m reduction in 1% flood levels). The assessment was limited due to a feasibility investigation of flood hydraulics under design flood conditions (multi-disciplinary detailed study required).
3. Construction of a floodway linking Mullumbimby Creek to Kings Creek. This option provided no significant benefit.

3.2. Flood Mitigation Options for Billinudgel, 1988

The report prepared by Ray Sargent and Associates focused on flood mitigation options for Billinudgel. The 1987 Brunswick Valley Floodplain Management study showed minimal impacts on flood levels from filling. However, this report notes that increases in flood levels of 50mm could impact on existing properties and inundate previously dry properties. As the impact from filling land is very low, the report concludes the levees are likely to have minimal impact but while noting this, it does not continue to investigate this option further.

To reduce the risk of flooding and prevent a deterioration of the flood problem, the following actions were recommended:

- Floodways blocked by vegetation growth should be cleared and maintained.
- The creek channel should be controlled by dredging, vegetation clearing and partial re-routing. However, some siltation at the downstream confluence of Marshalls Creek and Brunswick River is expected and the half-tide training wall at the creek mouth is a likely contributing factor.

3.3. Brunswick River Floodplain Management Investigation, 1989

The Brunswick River Floodplain Management Investigation was completed in November 1989 by Webb, McKeown & Associates in conjunction with the Brunswick River Floodplain Management Committee. The floodplain management investigation was in response to requests to investigate flooding problems in the area and development applications to re-zone and develop flood prone land in the Marshall Creek floodplain.

This investigation primarily looked at the Development Concept Plan put forward by the Ocean Shores Development Corporation (OSDC). Separate to the OSDC Development Concept Plan, the investigation also considered the future development of land owned by Crown Land and land owned by Mr J Mangleson. The investigation looked at flood mitigation options to both protect existing development and manage the impacts of possible future development.

The Floodplain Management Committee also requested the assessment of the several flood mitigation options. The study concluded that:

- To mitigate the impacts from the proposed development, a combination of flood mitigation works is required and would need to either include dredging of Marshall Creek or the North Ocean Shores flood outlet.
- A levee around South Golden Beach would increase flood levels at new Brighton and would require a levee on the northern boundary.
- It is expected a levee around New Brighton without additional flood mitigation works would have impacts on upstream flood levels. For New Brighton, flood proofing measures were suggested.
- Should part of the development on Mr Mangleson's land proceed independently of the remainder of the proposal, a section of the floodway proposed opposite the land should be constructed.

- Development on Site B Mangelson land may have significant hydraulic impacts as the land is low-lying and forms part of the floodway. These impacts would not be easily mitigated.

3.4. Mullumbimby Floodplain Management Study, 1989

The Mullumbimby Floodplain Management Study was completed in December 1989 in consultation with the Brunswick River Floodplain Management Committee. The report focused on investigating flood mitigation options and assessing the potential impacts future development could have on flood levels. Considerable flood damage was caused during the May 1987 flood event. Residents put forward that the recently raised railway line had caused an increase in flood damages seen. However, study results showed that the changed railway level had no significant impact on flood levels.

Subsequently, the following flood management options were assessed, and the results are presented below:

- A diversion of floodwaters down Saltwater Creek provides no flood mitigation benefits and would have adverse impacts on other properties.
- Raising of houses or additional local flood protection would be not viable due to the number of houses affected and cost. In combination with other options, house raising may have potential.
- A flood warning system could reduce flood damages however, due to the short response time of the catchment was not considered a solution.
- Dredging of the Brunswick River would not eliminate the flood problem but in combination with other options could be more effective.
- Lowering or removal of the railway line would reduce flood levels on the upstream side of the railway line, as the line restricts flow across the floodplain at Mullumbimby. However, lowering of the line would increase flood levels on the downstream side and increase flow velocities at Station Street.
- Improved drainage through the railway line by adding culverts under the line would have a similar effect as the lowering of the line. A significant number of culverts (approx. 70) would be necessary to have a significant impact on flood levels upstream.
- A levee bank around the western part of the town would protect 30% of the flood prone properties but would have a negative impact on flood levels upstream of the levee. Associated drainage required with this option includes 4 culverts under the railway line and some additional culverts through the levee. Negative impacts caused by the levee could be mitigated by dredging of the Brunswick River, or stream clearing near the railway bridges to the south of Mullumbimby.
- Development of the proposed Industrial Estate located on Football Club Road would significantly increase flood levels downstream of the railway line. However partial development of the site may be possible.
- A levee bank around the eastern part of the town would protect 56% of the flood prone properties. While there were found to be no negative impacts on flood levels upstream of the railway line, a levee bank would cause a 10mm increase in flood levels downstream of the line. This option would require raising parts of Argyle Street and the construction of a 16-hectare storage basin inside the levee.

- Widening of the Main Road 524 bridge on Kings Creek by over double and lowering of Main Road 524 to ground level would reduce the 1% AEP flood levels by up to 20mm and 50mm respectively. Lowering of MR524 is expected to have impacts to trafficability during flood events. The report concludes neither option is cost efficient.

3.5. Proposed Levees around South Golden Beach, 1989

This report was prepared by Webb McKeown & Associates and looks at managing flood risk in the residential development at South Golden Beach. This development is divided by Capricornia Canal and the proposal looked at a potential levee system around the eastern and western sections up to the 1% AEP event. The project considered the impacts of a 3.2m AHD levee. In comparison the May 1987 flood level was 2.7m AHD and the 1% AEP level is 3.2m AHD.

To manage the potential local drainage problems within the leveed area, the project investigated the effects of flap gated culverts. For operational and maintenance reasons, the use of flood pumps was not recommended here as a solution. While the flap gated culverts were found to be effective at preventing water entering the leveed area, ponding was still found to be a problem. Approximately 30 properties would experience worsening of a maximum afflux of 17mm. A flood compensation fund was suggested for those residents affected by the afflux.

3.6. Report on Feasibility of an EIS for North Ocean Shores Flood Outlet, 1992

The construction of a flood outlet located in the North Ocean Shores area was proposed as possible flood mitigation measure in the Brunswick River Floodplain Management Investigations. Council subsequently commissioned Webb, McKeown and Associations to undertake further investigations into possible flood outlets at North Ocean Shores. The Floodplain Management Investigation found that while the outlet at North Ocean Shores provided flood mitigation benefits for floods of a greater magnitude than the 5% AEP, when this option is considered in conjunction with other mitigation measures such as dredging of Marshalls Creek and the levee at South Golden Beach benefits provided by the outlet are reduced.

This report concludes it is not feasible to undertake an EIS for a flood outlet at North Ocean Shores. This is primarily due to the potential economic and environmental impacts including a long term financial commitment from Council to maintain the structure, potential impacts to dune stability, impact on the local flora and fauna from increased salinity levels in the connecting channel and Capricornia Canal and the relatively low benefit / cost ratio.

3.7. Draft Mullumbimby Floodplain Management Plan, 1993

Following the completion of the Mullumbimby Floodplain Management Study, Byron Shire Council prepared the draft Mullumbimby Floodplain Management Plan. The Floodplain Management Committee considered mitigation options assessed in the Floodplain Management Study and concluded flood mitigation dams or catchment treatment were not viable options.

Recommendations made in the plan were:

- Advise the Roads and Traffic Authority (RTA) to consider effects of flood levels when investigating further works on Main Road 524,
- RTA to improve drainage at Kings Creek bridge,
- Remove obstructions in Saltwater Creek catchment and maximise the flows under the railway bridges,
- Increase the capacity of the Myokum street culverts,
- Future buildings to have floor levels of the 1% AEP floor level plus 500mm,
- A 15m floodway to the western and eastern side of the North Coast Railway Line,
- A floodway over Hieronymus' property,
- Installation of a flood warning system in the Brunswick River catchment.

Recommended development Controls within floodways:

- Maintain floodways ability to pass water,
- No works in the floodway that would decrease flow capacity,
- No building development within the floodway,
- No filling within the floodways,
- No fences within the floodway, as they may decrease flow capacity,
- Land uses to be compatible with flood behaviour.

Recommendations for the eastern Mullumbimby floodplain:

- Raise or flood proof all residential buildings impacted by a flood similar to the 1987 event or the 1% AEP event. Habitable floors should be 500mm above the 1% flood level.
- Filling is limited to the level created by a 1% grade line from the road centre line. It is considered this level of filling will not cause drainage problems for neighbouring properties.

Recommendations for Western Mullumbimby/Saltwater Creek Floodplain:

- Raise or flood proof all residential buildings impacted by a flood similar to the 1987 event or the 1% AEP event. Habitable floors should be 500mm above the 1% flood level.
- Habitable floors in new developments should be 500mm above the 1% flood level,
- Commercial and industrial floors should be the 1% flood level or higher,
- Residential properties that are raised should have floor levels 500mm above the 1% flood level.

3.8. Marshalls Creek Floodplain Management Plan, 1997

Paterson Consultants Pty Ltd completed the Marshalls Creek Floodplain Management Plan in 1997. The plan looked at the current flood risk in the floodplain including an assessment of the economic impacts. At the time the report was produced, 71 residential and commercial properties were identified to be flood liable in the 1% AEP flood event. The average annual damages (AAD) of tangible damages for the Marshalls Creek floodplain was $198,000.

The plan assessed a number of options against four key performance criteria namely, flood mitigation effectiveness, environmental impacts, social impacts and economic performance. Recommended measures included in the plan were flood proofing, improvement of flood warning procedures and a community education program, prohibition on further development on the floodplain and floor level controls for new construction.

3.9. North Byron Shire Flood Study, 2016

Byron Shire Council commissioned BMT to undertake the North Byron Shire Flood Study (Reference 5). The Flood Study forms the second phase of the Floodplain Risk Management Process and was completed by BMT in 2016. The Flood Study provides the technical basis for this floodplain risk management study to further understand flood behaviour in the North Byron floodplain. Appendix G provides a more detailed description of the North Byron Shire model as part of the model review process.

4. FLOOD STUDY MODELLING REVIEW AND UPDATE

As part of the initial stages of this study, WMAwater undertook a peer review of the hydrologic and hydraulic models developed in the North Byron Shire Flood Study (Reference 5). The initial review established that:

- The hydrologic model which has been developed using XP-RAFTS was fit-for-purpose and appropriately set up;
- The hydraulic model, developed using TUFLOW (version 2013-12AE-w64), was running, working well and met standard quality criteria;
- Notwithstanding this, it was recommended the following updates are undertaken:
    - Incorporate latest topographic features and detail of missing structures into the hydraulic model configuration;
    - Incorporate the March 2017 event into model calibration and verification;
    - Further sensitivity tests of the form losses upstream of Mullumbimby;
    - Sensitivity tests on the initial losses for forested areas in design events, and
    - Sensitivity tests on the manning's n values adopted in the hydrologic model.

Model updates recommended from the initial review and model calibration using the March 2017 flood event data highlighted additional issues with the modelling package. Full details of the review, updates and results are provided in Appendix G, with a summary provided in the following sections.

4.1. Hydrologic Model

The model review found the hydrologic model to be fit for the purpose, however recommended sensitivity tests be carried out on the manning's 'n' values and the initial losses for forested areas in design events. Results of these sensitivity tests are detailed in Appendix D and Appendix F respectively.

The following refinements were made to the XP-RAFTS hydrologic model:

- All catchment slope values were revisited using the equal area method, which was found to approximately match the average slope recommended by XP-RAFTS;
- The manning's 'n' roughness coefficient for each subcatchment was revised using a weighted average of the different land uses in each subcatchment and manning's 'n' values applied in line with experience and industry guidance;
- Consistent initial and continuing loss values were applied across the entire catchment in line with recommended values from ARR2019;
- The storage coefficient multiplication factor (Bx) of 1.5 was removed with no additional storage applied across the model, as the addition of an extra parameter was not found to add any improved representation of the catchment response; and
- The basin at Williams Bridge was removed from the hydrologic model.

4.2. Hydraulic Model

The following refinements were made to the TUFLOW hydraulic model:

- Bend losses defined for the Brunswick River in Mullumbimby were identified as being high. Following sensitivity tests (detailed in Appendix E), these have been refined as follows:
    - between 0 and 1.0 upstream of Federation Bridge,
    - between 0 and 3.0 downstream.
- A number of hydraulic structures were identified as missing. Data provided by Byron Shire Council allowed the following features to be included:
    - Tuckeroo Avenue Culverts (Mullumbimby),
    - Drain/Bund south of Mullumbimby,
    - Orana Road Culvert (Ocean Shores),
    - Balemo Drive South Culvert (Ocean Shores),
    - Terrara Court Culvert (Ocean Shores),
    - Golf Course Bridge (Ocean Shores),
    - Bonanza Drive Culvert (Billinudgel),
    - Wilfred Street Culvert (Billinudgel),
    - Pacific Motorway Culvert (Billinudgel),
    - Balemo Drive North Culvert and road level (Billinudgel/Ocean Shores),
    - Narooma Drive Culvert (Ocean Shores),
    - Ocean Shores golf course culvert,
    - Additional detail about the Ocean Shores golf course bridge.
- The topography was updated to include the following recent developments:
    - Tallow Wood Estate Stage 4 (Mullumbimby),
    - Waterlily Park survey (Ocean Shores),
    - Shara Boulevard Sports field (Billinudgel),
    - Orchid Place (Mullumbimby),
    - Rajah Road Subdivision (Ocean Shores).
- Bathymetric survey captured in November 2017 was used to update the river channel traversing from 2 km upstream of the Pacific Highway to the mouth of Brunswick River and from the Pacific Highway Bridge at Marshalls Creek to the mouth of Brunswick River.
- Extensions and modifications were made to the hydraulic model grid including:
    - Extension of the main 12.5 m grid 2.1 km upstream of Sherry's Bridge (Main Arm), and
    - Ocean Shores and New Brighton were included within the nested 5 m grids in addition to South Golden Beach, Mullumbimby and Brunswick Heads.
- The downstream tidal boundary condition at Brunswick Heads was modified to be consistent with the latest OEH guidelines (Reference 7) as detailed below in Section 4.2.1.

Following the community consultation of the draft FRMS, further developments were identified for inclusion in the model. Appendix T provides further details of this additional work, which included the following sites:

- 115 Station Street Mullumbimby (filling and box culverts, 2018/2019)
- Manns Road (opposite Smith Street) Mullumbimby (filling, 2014)
- Towers Drive (south side) Mullumbimby (filling, 2015)
- 56 – 80 Redgate Road, South Golden Beach (filling, 2016)
- 3A – 3C Byron Street, New Brighton (filling, 2014)
- Additional changes to Tallowood Subdivision, and
- Topographical changes to Orchard Place.

4.2.1. Brunswick Heads Tidal Boundary Condition

Brunswick Heads estuary is classified as a *Group 3 Wave Dominated Estuary* (Reference 7) where the entrance is permanently open with high connectivity between the river channel and tidal inlet, however is relatively narrow due to the wave-deposited beach sand. Brunswick Heads estuary can be further classified as *Type B Waterway Entrance Type* (Reference 7) with a fully trained entrance and un-navigable port.

In reality, catchment flooding and oceanic inundation are generated by the same storm event and when determining fit-for-purpose design events the two mechanisms should be considered together. The guidelines in Reference 7 provide recommended combinations of catchment and oceanic inundation as detailed in Table 4. For each design AEP flood event, the peak of both the catchment scenario and oceanic scenario should coincide to provide the highest water levels. Design flood behaviour for the 1% AEP flood event is determined by using an envelope to produce flood levels and a separate coincident event to produce flood velocities (Table 4). It should be noted that the catchment flood scenario is also made up of an envelope as outlined in Section 4.5.

Table 4: Combination of Catchment Flooding and Oceanic Inundation Scenarios

Design AEP for peak levels	Catchment Flood Scenario	Ocean Water Level Boundary Scenario	Ocean Boundary Peak Tailwater Level (m AHD)
0.2 EY	0.2 EY	HHWS(SS)*	1.25
5% AEP	5% AEP	HHWS(SS)*	1.25
2% AEP	2% AEP	5% AEP	2.00
1% AEP (envelope level)	5% AEP	1% AEP	2.10
	1% AEP	5% AEP	2.00
1% AEP (envelope velocity)	1% AEP	ISLW**	-0.95
0.5% AEP	0.5% AEP	1% AEP	2.10
0.2% AEP	0.2% AEP	1% AEP	2.10
PMF	PMF	1% AEP	2.10

*High High Water Springs (Solstice Spring) ** Indian Springs Low Water

4.3. Australian Rainfall and Runoff 2019 (ARR2019)

The ARR2019 (replacing the 2016 edition of ARR) introduces new flood modelling techniques. ARR2019 (Reference 2) discusses the changes between the ARR1987 (Reference 1), ARR2016 and ARR2019 versions in detail. However the key changes from 1987 relating to this project are summarised below:

- Revised Intensity – Frequency – Duration (IFDs),
- Areal Reduction Factors developed based on Australian data and available for all durations,
- Changes in initial and continuing losses,
- Ensemble of 10 temporal patterns in replacement of the traditional single burst temporal pattern, and
- A move towards the Monte Carlo approach to flood modelling.

While the new ARR is considered best-practice and uses the best available information, the Flood Study (Reference 5) was developed prior to the release of ARR2016 and ARR2019 and subsequently uses ARR1987. To adopt ARR2019 completely would be a timely exercise and would not greatly improve the understanding of flood risk within the catchment or the ability to assess management options. Instead WMAwater undertook a review of available new information in ARR2019 and have updated the hydrologic models to be consistent with guidance from ARR2019 on initial and continuing loss conditions.

As part of the model review and update, WMAwater undertook a rainfall frequency analysis to understand if there was any significant bias between the at-site rainfall data and the ARR 2016 and 1987 IFDs. This analysis is included in Appendix C. The analysis found that neither the ARR 2016 IFDs or the 1987 IFDs exhibited consistent over or underestimation of rainfall across the study area. Whilst the analysis did find the ARR 2016 IFDs were a substantial improvement upon the 1987 IFDs, it concludes that before moving to ARR 2019 consideration should be given to other changes in ARR2019 methodology and that a comparison to the Flood Frequency Analysis (FFA) at the Durrumbul gauge is undertaken.

The Flood Study models (Reference 5) have been endorsed by the FMC and adopted by council in February 2016. ARR2019 provides guidance detailing that where there is available at-site data to undertake an FFA, this is the preferred method for estimating peak design flows and determining catchment loss parameters to use. The North Byron models provide a good fit to the FFA undertaken at the Durrumbul gauge. Given an FFA is the preferred ARR2019 approach and in conjunction with the model's ability to replicate past historical events well, it was recommended by WMAwater and agreed by the FMC that the models, with the updates detailed herein, remain fit for the purpose of the FRMS and a full ARR2019 update is not required at this stage. Guidance is provided in Reference 8 on incorporating ARR2019 into existing studies and of relevance to this study Reference 8 recommends that a move to ARR2019 may be required should there be any structural mitigation options that move to the preliminary design phase.

4.4. March 2017 Calibration Event

On the 31 March 2017, ex-Tropical Cyclone Debbie crossed into the Northern Rivers region in New South Wales subjecting the Brunswick River catchment to heavy rainfall. As a result of this, Mullumbimby, Ocean Shores, New Brighton, Billinudgel, Brunswick Heads and Main Arm experienced severe flooding. This flood event saw homes inundated, residents forced to evacuate, roads closed and thousands of people without power. Comments from both the community survey (discussed in Section 5) and the community consultation on the draft FRMS, indicate this flood event was traumatic for many residents with lasting long term emotional impacts.

Flood information including rainfall gauges, stream gauges and survey of flood marks were collected, and an initial review was undertaken by BMT (presented in Reference 9). WMAwater used this flood information from the March 2017 event to improve calibration of the hydrologic and hydraulic model. Appendix G outlines the adopted calibration process and details the findings.

Calibration to the March 2017 flood event show the North Byron hydrologic and hydraulic models reproduce the March 2017 flood event well and provide a good replication of the January 2012 verification event, with improvements on the original calibration results.

4.5. Design Event

Design events produced for the North Byron FRMS are made up of an envelope of catchment flood events and coincident oceanic inundation. The scenarios used for each design flood event are outlined in Table 5 below. Mapping has been produced for each design event and is provided in Figure 4 through to Figure 11. The existing flood behaviour in the North Byron Study Area is discussed further in Section 7. Peak flood level mapping for the 10% AEP, 1% AEP and PMF flood events has been produced and provided in Appendix O.

Table 5: Oceanic scenarios and catchment scenarios used for each design flood event.

Design Event	Oceanic Inundation	Catchment Inundation	
		Scenario	Duration
0.2EY	HHWS*	5 year ARI	12hr
			24hr
			36hr
10% AEP	HHWS	10% AEP	12hr
			24hr
			36hr
5% AEP	5% AEP ocean level	5% AEP	12hr
			24hr
			36hr
2% AEP	2% AEP ocean level	2% AEP	12hr
			24hr
			36hr
1% AEP	5% AEP ocean level	1% AEP	12hr
			24hr

			36hr
	1% ocean level	5% AEP	12hr
			24hr
			36hr
	ISLW**	1% AEP	12hr
			24hr
			36hr
0.5% AEP	1% AEP ocean level	0.5%	12hr
			24hr
			36hr
0.2% AEP	1% AEP ocean level	0.2%	12hr
			24hr
			36hr
PMF Event	1% AEP ocean level	PMF	12hr
			24hr

* HHWS – High Water Springs (Solstice Spring)

** ISLW – Indian Springs Low Water

5. COMMUNITY CONSULTATION

One of the central objectives of the FRMS is to actively liaise with the community throughout the process, keep them informed about the current study, identify community concerns and gather information from the community on potential management options for the floodplain. The consultation programme consists of:

- Media release
- Distribution of questionnaire survey to community;
- Consult with other key stakeholders;
- Consultation on the draft FRMS including a public meeting,
- Formal public exhibition of the final FRMS and draft FRMP, including public meetings.

A copy of the consultation material is provided in Appendix H.

5.1. Community Questionnaire Results

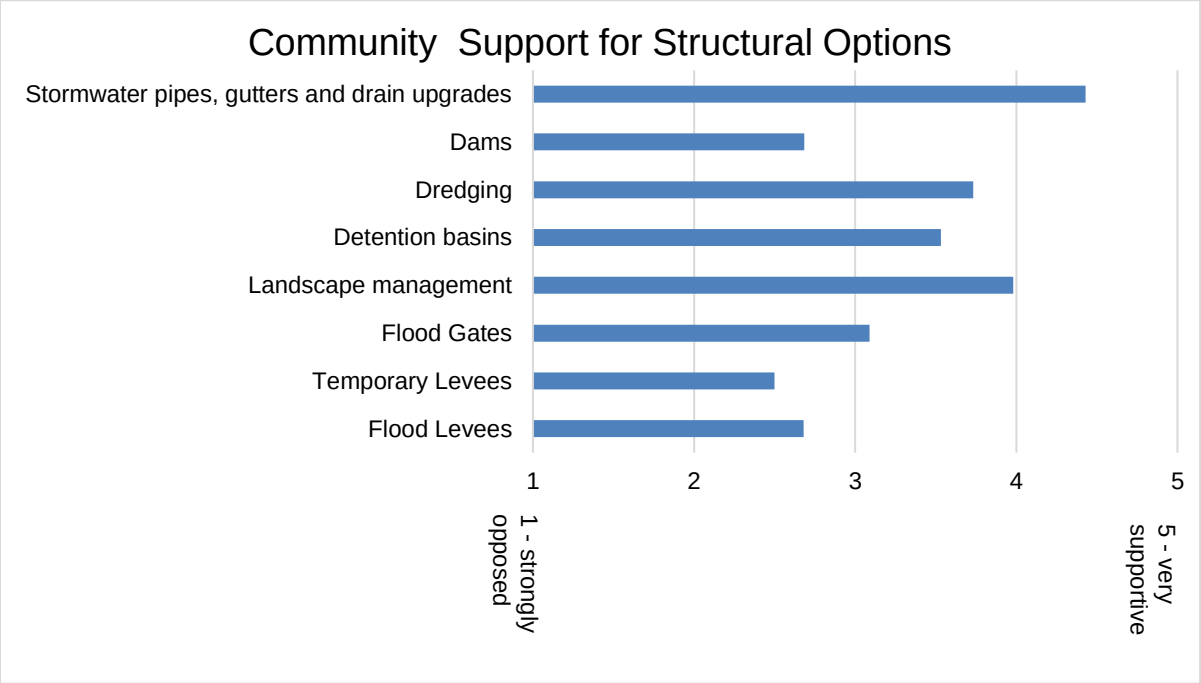
An online community survey was open for consultation in June 2018, with paper copies also provided for collection from Council offices and libraries. 252 electronic and 89 hard copy responses were received, providing an excellent response rate to this type of survey.

Full analysis of the survey results is provided in Appendix I. Key findings include:

- The top three structural options the community support, based on the responses from the structural mitigation question (Question 13 of Appendix H) are:
    - Stormwater pipes, gutters and drain upgrades
    - Landscape management
    - Dredging
- The three most important outcomes to the community when considering flood management options are:
    - Increases community safety during floods
    - Reduces the cost of floods
    - Does not disadvantage other parts of the community
- There were a significant number of comments requesting blockages within drains and streams are regularly cleared,
- Respondents are generally supportive of alterations to the Marshalls Creek rock walls provided appropriate investigation is carried out prior,
- There is significant support for more investigations into the construction and management of dune openings,
- The community are willing to support each other. The survey results included a number of comments saying neighbours have helped in past flood events or that past learnings are to check in on their neighbours, particularly the elderly,
- Comments throughout the survey show the community trust the local knowledge within the catchment and would look to key community members during events,
- Respondents are concerned about the increasing insurance prices in the area,

- 13% of respondents would never evacuate their home,
- 63% of respondents have received conflicting information during an event in the past, with a number of comments from people who did not receive any information at all,
- 54% of respondents want flood information as early as possible and 81% of respondents would like this information via emergency SMS. A number of comments requested accurate and timely information during flood event,
- In addition to assistance during flood events, respondents have indicated they require assistance to continue after the flood event has past, and
- Respondents want to see appropriate development within the floodplain. There were a little under 50 comments relating to land use planning decisions, with a number of comments specifically about the potential development on Lot 22.

There is support from the community for most structural options, as seen in Graph 1, however the comments indicate that the community want more research carried out before any mitigation measures are implemented.



Graph 1: Average level of support for each structural mitigation option.

5.2. Community Consultation on Draft FRMS

The draft North Byron FRMS was released for community consultation in January 2020 with comments provided in February 2020. A drop-in session was hosted by Byron Shire Council on the 7 February 2020. It is understood the Mullumbimby Residence Association also held a feedback night in February to provide residents the chance to hear about the study and contribute to comments included in the submission. Substantial feedback was received with 54 letter responses, 17 email submissions and 5 discussions. This is excellent for this type of community consultation and shows the North Byron community are invested in the management of their floodplain.

As each submission included a number of comments on differing aspects of the FRMS, a database was established to ensure each response was duly considered. This resulted in 150 comments, with detailed responses provided in a database, and where appropriate, modification to the FRMS report in an effort to incorporate the feedback received

The priority concerns of the community are:

- Development of the South Mullumbimby Affordable Housing Precinct and the Mullumbimby Industrial Estate and what this may do to the flood risk in Mullumbimby,
- Maintenance and improvements to the stormwater network. This is discussed in detail in Section 5.2.1, however was a consistent concern from all residents in the North Byron community irrespective of town or village,
- The Marshalls Creek rock walls and their potential environmental impact and contribution to increased siltation,
- Further investigation into environmental and flood mitigation benefits from dune openings,
- Improved environmental flows in Saltwater Creek, and
- Further investigation into areas that may be sensitive to future development.

Specific options that received support from the community are listed below (in no particular order of priority):

- PM06 – Council consider updating the DCP to incorporate the recommendations detailed in the FRMS;
- PM10 – Implement the recommendations regarding appropriate fill areas in the DCP2014;
- CDM – Develop a whole of catchment drainage model and overland flow path investigation;
- WFG – Develop guidance on the design and installation of fencing traversing waterways and channels;
- SC – Further detailed assessment of Saltwater Creek upgrade assessment and mitigation options for Mullumbimby;
- RM07 – Undertake an Evacuation Assessment for Mullumbimby;
- FDC – Implement debris control measures for Federation Bridge and Billinudgel Railway Bridge;
- PM01 – Further investigate raising eligible residential properties to reduce flood damages;
- PM02 – Consider establishing a Voluntary House Purchase scheme for eligible properties;
- RM02 – Byron Shire Council and SES to consider findings and recommendations of the FRMS in the development of the Flood Warning Network for North Byron;
- PM09 – Section 10.7 (5) certificates to provide further detail of flood behaviour. Consideration to providing property-level flood information via an online GIS platform;
- RW02 – Develop a sediment transport model to investigate modification to the rock walls, as part of the Coastal Management Program for the Brunswick Estuary; and
- BM – Further consideration of Billinudgel infrastructure improvements.

This has been included in the multi-criteria assessment as support from the community with varying degrees depending on the number of responses.

5.2.1. Drainage Maintenance

The most consistent and common concern from the North Byron community is around the maintenance and effectiveness of the drainage infrastructure. There were numerous comments from residents experiencing frequent inundation within close proximity to their homes. Key themes in comments relating to drainage maintenance are:

- Creeks are overgrown and fallen trees are blocking waterways and culverts,
- Garden waste is being dumped in waterways,
- Current infrastructure is not being maintained and residents are concerned about the structural integrity in some locations, and
- Infrastructure upgrades are required, particularly in locations of no kerb and channel.

While most comments were general in their request for drainage maintenance some residents noted specific locations of blockages or under capacity infrastructure. These specific locations have been collated and provided to council.

The purpose of this FRMS is to consider the regional impacts from riverine flooding and identify management options to address this risk. While flooding from overland flow or inadequate stormwater infrastructure is out of the scope of this study, the community consultation has identified this as a priority for the North Byron community. Flooding from overland flow or inadequate stormwater infrastructure and flooding from riverine sources are two different mechanisms and require separate studies to ensure they are appropriately considered. To effectively model the drainage network capacity and assess potential drainage upgrade solutions, a more detailed catchment drainage model is required that includes a formal stormwater network. The potential for a detailed catchment drainage model is discussed further in Section 11.4.5.

6. FLOODPLAIN MANAGEMENT POLICY

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

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

Pursuant to Section 117(2) of the EP&A Act, the Minister has directed that Councils have the responsibility to facilitate the implementation of the NSW Government's Flood Prone Land Policy. Specifically, Direction 4.3 states:

Objectives

The objectives of this direction are:

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

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

Clause (3) of Direction 4.3 states:

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

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

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

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

- *A planning proposal must not contain provisions that apply to the flood planning areas which:*

    - *permit development in floodway areas,*

    - *permit development that will result in significant flood impacts to other properties,*

    - *permit a significant increase in the development of that land,*

- *are likely to result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services, or*

- *permit development to be carried out without development consent except for the purposes of agriculture (not including dams, drainage canals, levees, buildings or structures in floodways or high hazard areas), roads or exempt development.*

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

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

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

  - *the planning proposal is in accordance with a floodplain risk management plan prepared in accordance with the principles and guidelines of the Floodplain Development Manual 2005, or*

  - *the provisions of the planning proposal that are inconsistent are of minor significance.*

6.1. NSW Flood Prone Land Policy

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

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

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

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

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

The Manual recognises differences between urban and rural floodplain issues. Although it maintains that the same overall floodplain management approach should apply to both.

6.2. Section 10.7 Planning Certificates

In accordance with Section 10.7 (formerly Section 149) of the EP&A Act, Councils can issue planning certificates which describe planning and development matters relating to a piece of land. The two planning certificates are available under the EP&A Act are Section 10.7 (2) and 10.7 (5) planning certificates. Obtaining a Section 10.7 certificate is required under the Conveyancing Act 1919 and Conveyancing (Sale of Land) Regulation 2010 when land is bought or sold.

Specifically, 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.*

6.2.1. Schedule 4 Planning Certificates

Schedule 4 of the EP&A Regulation sets out which matters are to be included in a planning certificate under Section 10.7 (2) of the EP&A Act and includes but is not limited to information such as planning instruments that apply to development, zoning and land use under relevant Local

Environmental Plans (LEPs) and State Environmental Planning Policy (SEPP) and complying development.

Specific to flood related development controls information, Schedule 4, 7A of the EP&A regulation states:

7A Flood related development controls information

> *(1) Whether or not development on that land or part of the land for the purposes of dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (not including development for the purposes of group homes or seniors housing) is subject to flood related development controls.*
>
> *(2) Whether or not development on that land or part of the land for any other purpose is subject to flood related development controls.*
>
> *(3) Words and expressions in this clause have the same meanings as in the Standard Instrument.*

Section 10.7 (2) and 10.7 (5) certificates are more detailed certificates and includes all information specified in Schedule 4 and any additional information Council may choose to provide. Types of flood related information that could be provided in a Section 10.7 (2) and 10.7 (5) planning certificate include design flood depths, percentage of the lot flood affected or evacuation information (note that this is not an exhaustive list).

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

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

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

- *providing exempt and complying development codes that have State-wide application, and*
- *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*
- *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*
- *enabling the progressive extension of the types of development in this Policy, and*

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

6.3.1. Housing Code

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

Division 1 of Part 3 of the SEPP, which comprises clauses 3.1-3.3 of the SEPP, relates to ***Requirements for complying development under this code***. Clauses 3.1 (1) states:

> ***3.1 Development that is complying development under this code***
>
> *(1) The following development is complying development under this code –*
>
> *a. the erection of new 1 or 2 storey dwelling house and any attached development,*
>
> *b. the alteration of, or an addition to, a 1 or 2 storey dwelling house (including any addition that results in a 2 storey dwelling house) and any attached development,*
>
> *c. the erection of detached development and the alteration of, or an addition to, any detached development.*

and

> *(3) Lot requirements*
> *Complying development specified for this code may only be carried out on a lot that meets the following requirements –*
>
> *a. the lot must be in Zone R1, R2, R3, R4 or RU,*
>
> *b. the area of the lost must not be less than 200m^2,*
>
> *c. the width of the lot must be at least 6m measured at the building line,*
>
> *d. there must only be 1 dwelling house on the lot at the completion of the development,*
>
> *e. the lot must have lawful access to a public road at the completion of the development,*
>
> *f. if the development is on a battle-axe lot – the lot must be at least 12m by 12m (not including the access laneway) and must have an access laneway that is at least 3m wide.*
>
> *g. If the development is on a corner lot – the width of the primary road boundary of the lot must be at least 6,.*
>
> *h. the erection of new 1 or 2 storey dwelling house and any attached development,*

Division 2 of Part 3 of the SEPP "***General standards relating to land type****"* contains Clause 3.5 *"Complying development on flood control lots"*

A *"flood control lot"* is defined in the SEPP as:

flood control lot *means a lot to which flood related development controls apply in respect of development for the purposes of industrial buildings, commercial premises, dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (other than development for the purposes of group homes or seniors housing).*

> ***Note.*** *This information is a prescribed matter for the purpose of a certificate under section 10.7 (2) of the Act.*

As such, a *"flood control lot"* is a lot where the Council has provided for flood related development controls, which are all lots with notation on a 10.7 Planning Certificate that flood related development controls apply. This is generally land which falls within the *"Flood Planning Area"*.

Clause 3.5 states

> ***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 flood 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.*

Note 1. ***Council, flood control lot, habitable room*** *and* ***professional engineer*** *are defined in clause 1.5*
Note 2. A section 10.7 certificate from a Council will state whether or not a lot is a flood control lot.

6.4. Summary of State Legislative and Planning Policies

From the above discussion of the Housing Code, it is clear that, unless a lot affected by flooding is included as a *"flood control lot"*, a s.10.7 notification is not applied and, as a result, planning

controls relating to flooding do not apply and Exempt Development can be undertaken. This highlights the importance of Council undertaking Flood Studies (such as this FRMS) to ensure appropriate properties are tagged and planning controls applied to reduce the risk and impact of flooding for current and future occupants.

6.5. Local Council Policy

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 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 Local Environmental Plans (LEPs) and Development Control Plans (DCPs) to govern control on development with regards to flooding.

An LEP guides land use and development by zoning all land, identifying appropriate land uses that are allowed in each zone, and controlling development through other planning standards and DCPs. LEPs are made under the EP&A Act 1979 which contains mandatory provisions on what they must contain and the steps a Council must go through to prepare them. In 2006 the NSW Government initiated the Standard Instrument LEP program and produced a new standard format which all LEPs should conform to.

6.5.1. Byron Local Environment Plan

The North Byron catchment is covered by two LEPs, the Byron LEP (1988) and the Byron LEP (2014). The latter was prepared under the Standard Instrument LEP program and is discussed below.

The BLEP 2014 applies for all areas except those zoned as Deferred Matters (DM), generally these are areas with environmental values. For areas zoned DM the BLEP1988 applies.

Clause 6.3 of BLEP 2014 relates to flood planning and states:

6.3 Flood planning

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

(a) to minimise the flood risk to life and property associated with the use of land,

(b) to allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change,

(c) to avoid significant adverse impacts on flood behaviour and the environment.

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

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

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

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

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

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

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

(4) In determining a development application at or below the future flood planning level, the consent authority must in addition to matters referred to in subclause (3), also consider the following matters:

(a) the proximity of the development to the current flood planning area,

(b) the intended design life and scale of the development,

(c) the sensitivity of the development to managing the risk to life from any flood,

(d) the potential to modify, relocate or remove the development.

(5) A word or expression used in this clause has the same meaning as it has in the Floodplain Development Manual (ISBN: 0 7347 5476 0), published by the NSW Government in April 2005, unless it is otherwise defined in this clause.

(6) In this clause:

***flood planning area** means the area of land that is at or below the flood planning level.*

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

***future flood planning level** means the level of a 1 in 100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard, plus allowances for projected climate change to the year 2100.*

6.5.2. Byron Shire Development Control Plan

The North Byron catchment is similarly covered by two DCPs. The DCP2014, discussed below, applies to all land zoned in 2014 LEP, whilst the DCP2010 applies to DM zones (those define by 1988 LEP).

Chapter C2 of the Byron DCP2014 applies to Areas Affected by Flood. The purpose of the chapter is stated as *"to identify requirements relating to development on **flood liable land** that is appropriate to the degree of flood hazard on that land.*" The Chapter seeks to achieve 7 objectives, with the underlying principle of

> *…any new development or modifications to existing development should always, as far as practical, result in an improvement to the existing flood risk and in no circumstances should the flood risk be made worse."*

The DCP provides a flow chart outlining the process for determining the flood planning controls applicable to the proposed development. It incorporates the various Flood Studies and Management Studies which have been prepared by Council, the Byron Climate Change Strategic Planning Policy (CCSPP), and a Flood Planning Matrix contained within the DCP.
The Flood Planning Matrix applies controls relating to:

- Land use suitability and fill level
- Floor level
- Building components
- Structural soundness
- Flood effect
- Evacuation and access.

The controls are varied based on the hazard classification (no hazard, low/intermediate hazard and high hazard), and the climate change planning horizon.

The DCP also includes sections on Flood Proofing, which encompasses flood compatible material, services and enclosures, and Special provision areas. Within the North Byron Catchments study area, special provisions apply to the townships of New Brighton, South Golden Beach and Billinudgel and rural areas.

6.5.3. Byron Shire Council Climate Change Strategic Planning Policy (CCSPP)

The CCSPP sets out Byron Shire Council's policy position relating to climate change, effective from July 2014. The CCSPP sets out scenarios to be modelled and mapped in Flood Studies and Floodplain Management Studies, as well as identifying planning horizons to be used in development applications. The CCSPP also outlines an approach to determining Flood Planning Levels, which differentiates based on land topography being less than or greater than 4m AHD.

7. EXISTING FLOOD ENVIRONMENT

7.1. Flood Behaviour Overview

Section 2.6 provides overview of the existing flood behaviour in each of the catchments. The following sections provide more detailed design event information and assessment of existing risk for the North Byron catchment

7.1.1. Design Flood Data

Peak flood level for key locations (Figure 12) across the catchment are produced in Table 6 for the 10%, 5%, 1% AEP and PMF design events. Peak flood level mapping with contours has been produced and is presented in Appendix O.

Table 6: Design Flood Levels at Key Locations

ID	Location	Peak Flood Level (mAHD)			
		10% AEP	5% AEP	1% AEP	PMF
1	Main Arm - Main Arm Road	17.6	18.0	18.6	20.3
2	Mullumbimby - Coral Avenue	6.4	6.9	7.7	9.1
3	Mullumbimby - Federation Bridge	4.4	4.7	5.0	6.4
4	Mullumbimby - Jubilee Avenue	4.3	4.4	4.7	5.9
5	Brunswick Heads- Pacific Motorway	1.6	1.7	2.6	5.3
6	Brunswick Heads - Brunswick Mouth	1.3	1.3	2.1	4.6
7	Brunswick Heads - South Beach Road	1.7	2.0	2.5	5.2
8	The Pocket - The Pocket Road	8.7	8.8	8.9	9.4
9	Billinudgel - Railway Bridge	3.7	3.9	4.2	5.8
10	Ocean Shores - Orana Bridge	1.7	1.9	2.7	5.2
11	South Golden Beach - Capricornia Canal	2.4	2.6	2.9	5.2

7.1.2. Hydraulic Structures Blockage Sensitivity Assessment

The hydraulic structures represented in the model have been tested for their sensitivity to potential debris blockage during an event.

Any structure less than 7m in the diagonal have been assumed either 50% or 100% blocked and modelled for the 1% AEP event. Mapping is presented in Appendix S. Compared to the base case (no blockage), there is minimum impact as a result of blockage, with localised impacts seen in Mullumbimby and Billinudgel. This is because most of the major structures are far greater in size than the blockage threshold.

Community comments noted that culverts underneath the railway line opposite Mill Street have been blocked with sandbags. While it is unclear why these sandbags have been placed here, a blockage assessment was conducted to understand if they cause any impact to flood levels. The assessment looked at a 50% and 100% blockage scenario and was modelled for the 1% AEP flood event. The results of this assessment show there is almost no impact when 50% blocked and limited impact to property when 100% blocked. These results show the sandbags are unlikely

to make a significant impact to flood levels for the 1% AEP flood event.

While structures larger than 7m have not been included in the blockage assessment, there is still potential for these to become blocked should large tree branches or logs become lodged. There have been a number of community comments from residents who believe there was a log jam or blockage of some kind at Federation Bridge. A number of community members recall seeing fig tree cuttings being carried by floodwaters from the Mullumbimby showground. While it can be difficult to verify this, given the dense vegetation in the upper parts of the catchment this is a real possibility. A mitigation measure to manage this blockage potential at Federation Bridge is explored further in Section 11.4.6.

7.2. Hydraulic and Hazard Classification

For the purposes of floodplain risk management in NSW, floodplains can be divided into hydraulic and hazard categories. Details of this process are provided in the NSW Governments Floodplain Development Manual (2005, Appendix L) (Reference 4) and *Managing the floodplain: a guide to best practice in flood risk management in Australia* (Reference 10), as well as briefly described below.

Hydraulic categories describe the flood behaviour by categorising areas depending on their function during the flood event, specifically, whether they transmit large quantities of water (floodway), store a significant volume of water (flood storage) or do not play a significant role in either storing or conveying water (flood fringe). The floodway represents areas of the floodplain that typically have high velocities and high flood flows. Development or changes to topography in these areas can have significant impact on flood behaviour. Flood storage areas of the floodplain are usually subject to relatively low velocities and high depths. While these areas are not used to convey large volumes of water, topographical changes that remove storage area can have impacts on flood behaviour. Understanding the flood function across the floodplain is important to ensure appropriate future planning decisions are made.

Although the three categories of hydraulic function are described in the Floodplain Development Manual (The Manual) (Reference 4), their definitions are largely qualitative, and the manual does not prescribe a method to determine each area. The manual gives one indication of how to quantitatively differentiate floodway and flood storage, when it states that flood storage areas, when completely filled with solid material, will not raise peak flood levels by “more than 0.1 m and/or would cause the peak discharge anywhere downstream to increase by more than 10%”.

The floodway is initially defined using a combination of depth and velocity criteria. This initial categorisation is then tested using the encroachment test where areas outside of the identified floodway are blocked significantly increasing manning’s ‘n’. Where this blockage results in more than a 0.1 m impact, the initial depth and velocity criteria used are altered. Subsequently, this can be quite an iterative process and different combinations of depth and velocity were used for different sections of the floodplain. The resulting parameters are provided in Table 7.

Table 7: Floodway Definition Parameters

Waterway	Floodway Definition Parameters
Brunswick River Simpsons Creek Marshalls Creek (downstream of Billinudgel)	Both VD > 0.35 m^2/s and V > 0.35 m/s, or V > 1 m/s
Marshalls Creek (upstream of Billinudgel) Capricornia Canal at South Golden Beach	Both VD > 0.25 m^2/s and V > 0.25 m/s, or V > 1 m/s

Hydraulic categories have been defined by considering detailed assessment of flood behaviour, the available topographic information and interpretation of the hydraulic model results and knowledge of the catchment. Figure 13 and Figure 14 show the categorisation for the 1% AEP flood event.

While the majority of the floodway is located in uninhabited areas, there are 53 properties identified within the floodway and 212 identified within the flood storage areas. A large proportion of these properties within the floodway are located in Mullumbimby.

As with hydraulic categories, hazard classification plays an important role in informing floodplain risk management in an area. Previously, hazard classifications were binary – either Low or High Hazard as described in the Manual. However, in recent years there has been a number of developments in the classification of hazard. Reference 10 provides revised hazard classifications which add clarity to the hazard categories and what they mean in practice. The classification is divided into six categories (Diagram 5) which indicate the restrictions on people, buildings and vehicles:

- H1 - No constraints;
- H2 – Unsafe for small vehicles;
- H3 - Unsafe for all vehicles, children and the elderly;
- H4 - Unsafe for all people and all vehicles;
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction; and
- H6 – Unsafe for people or vehicles. All buildings types considered vulnerable to failure.

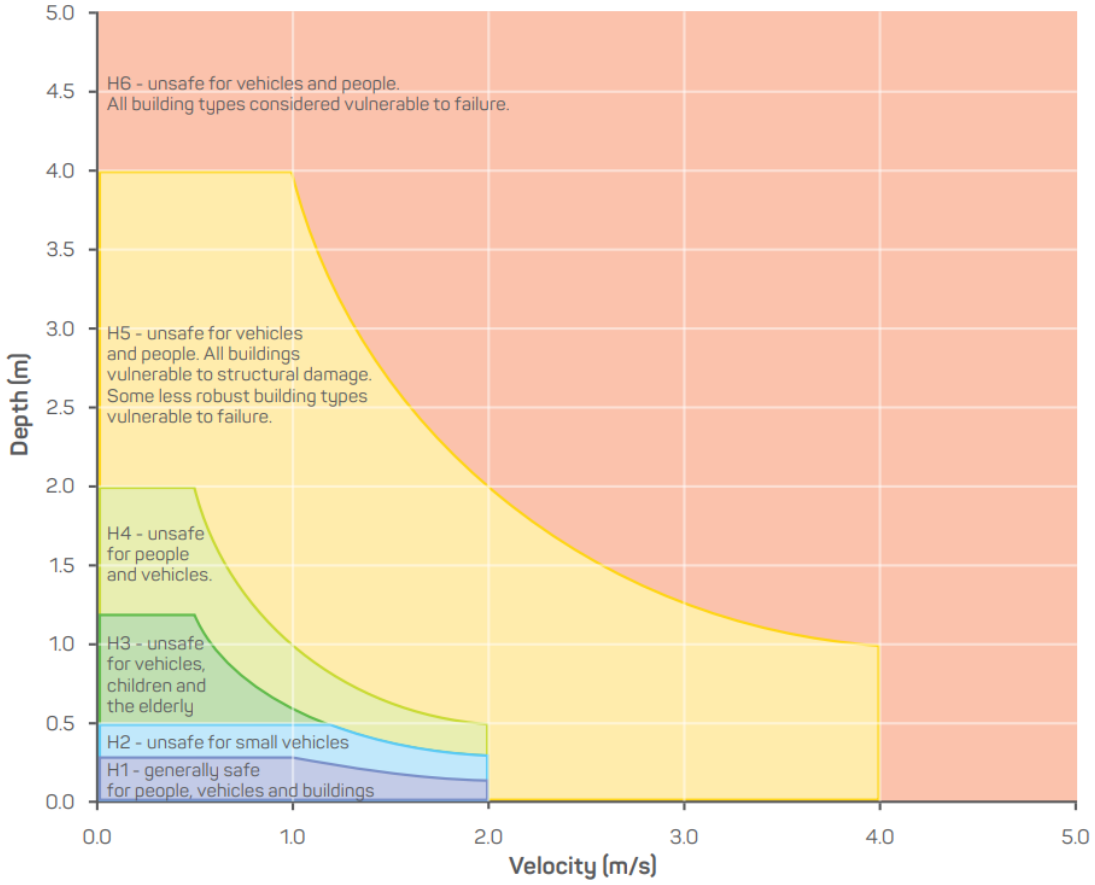


Diagram 5 Hazard Classifications

Figure 15 to Figure 22 provide the hazard classification for all the design events. H5 and H6 represent areas of the floodplain that are most hazardous, and these areas are considered unsafe for all people, cars and buildings. H3 and H4, while less hazardous are generally both considered to be unsafe for all vehicles and most people and therefore the consequences should people be in these areas are still high. H1 and H2 are the lease hazardous areas of the floodplain and while considered generally safe for people, some smaller vehicles may be at risk.

In the 1% AEP flood event (Figure 19) the most hazardous areas of the floodplain (H5 and H6) are typically constrained to the waterways but also cover some non-habitable areas including forested land, rural agricultural land and parts of the Ocean Shores Golf Club. Residential properties within the 1% AEP are located primarily within H1 – H3 areas of the floodplain.

Table 8 below shows the number of residential properties located in high hazard zones (H4 - H6) for each design flood event. Of note, there are eight properties exposed to high hazard in the 2% AEP flood event or more frequent. Areas of high hazard were used to inform the identification of hot spots across the floodplain, as is detailed further in Section 7.8.

Table 8: Residential properties located in high hazard zones (H4 - H6) for each design flood event

	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
Residential properties impacted	2	3	11	19	33	68	201	2599

The Manual requires that other factors also be considered in determining the "true" hazard such as size of flood, effective warning time, flood readiness, rate of rise of floodwaters, depth and velocity of flood waters, duration of flooding, evacuation problems, effective flood access, type of development within the floodplain, complexity of the stream network and the inter-relationship between flows. As well as considering the provisional (hydraulic) hazard it also incorporates threat to life, danger and difficulty in evacuating people and possessions and the potential for damage, social disruption and loss of production. The classification is a qualitative assessment based on a number of factors as listed in Table 9. A weighting of 1 or 2 would reduce the provisional hazard severity, 3 would have no impact, and 4 or 5 would increase the hazard severity.

Table 9: Hazard Classification

Criteria	Weight	Comment
Size of flood	3	Whilst there are some residential properties located in areas unsafe for people / vehicles, the majority of residential properties are located in the lower hazard areas for all events except the PMF. However, property numbers within high hazard areas do increase gradually as the size of the flood increases, particularly for New Brighton.
Flood Awareness of the Community	2	Recent flooding from Ex-Tropical Cyclone Debbie has elevated communities' awareness of flooding. Results from the community consultation indicate there is a lot of local knowledge within the community and that the community are willing to support their neighbours.
Depth and Velocity of Floodwaters	3	Already accounted for in the provisional hazard.
Effective Warning and Evacuation Times	3	Warning time available in the North Byron Study area varies from slow onset of flooding providing time to evacuate and prepare to floodwater arriving with little warning time meaning residents may be caught off guard. However, a large proportion of the residential hubs (e.g. Mullumbimby and Brunswick Heads) are located downstream and therefore provides opportunity to ensure effective warning can be provided.
Evacuation Difficulties	4	There are some pockets of the floodplain where evacuation routes are cut early meaning residents may be trapped. In addition to this, there are a number of residential areas identified as Low Flood Islands, for example Mullumbimby and a small area of Brunswick Heads.
Rate of Rise of Floodwaters	2	While March 2017 exhibited characteristics similar to flash flooding and also showed the variable nature of flood events, flooding in North Byron typically progresses slowly provided people time to prepare.
Duration of Flooding	2	Durations of flooding varies across the catchment with Mullumbimby experiencing shorter durations of flooding and New Brighton and

		Billinudgel experiencing longer durations. While New Brighton and Billinudgel are inundated for longer periods of time than Mullumbimby, these areas are generally not expected to be isolated or flooded for substantial durations of time (e.g. longer than a day).
Effective Flood Access	4	Flood access is a concern for the catchment with a number of evacuation routes inundated in frequent flood events leaving some areas trapped.

Based on the above assessment, the provisional flood hazard categorisations will not be changed and already capture the true hazard satisfactorily.

Determining flood risk is done by considering the potential likelihood and associated consequences from flooding. Hydraulic hazard is only one input into understanding flood risk. Other important factors include: the exposure such as the land use or development, vulnerability of the community (for example able bodied adults compared to the elderly), evacuation or isolation constraints, any loss of critical services such as power or water and also the community's tolerability. While tolerability is typically considered as part of the planning scheme process, these other factors are considered in the sections below.

7.3. Flood Emergency Response Classifications

The Manual (Reference 4) 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 State Emergency Service (SES) to assist in ERP.

Criteria for determining flood ERP classifications and an indication of the emergency response required for these classifications are provided in the Floodplain Risk Management Guideline, 2007 (Flood Emergency Response Planning: Classification of Communities). Reference 11 summarises the response required for areas of different classification. However, these may vary depending on local flood characteristics and resultant flood behaviour, i.e. in flash flooding or overland flood areas.

Table 10: Response Required for Different Flood ERP Classifications

Classification	Response Required		
	Resupply	Rescue/Medivac	Evacuation
High Flood Island	Yes	Possibly	Possibly
Low Flood Island	No	Yes	Yes
Area with Rising Road Access	No	Possibly	Yes
Area with Overland Escape Routes	No	Possibly	Yes
Low Trapped Perimeter	No	Yes	Yes
High Trapped Perimeter	Yes	Possibly	Possibly
Indirectly Affected Areas	Possibly	Possibly	Possibly

The ERP classifications for regions within the hydraulic model extent have been defined for the entire floodplain, as represented by the PMF flood extent and is shown in Figure 23. The classification has been undertaken on a precinct basis rather than lot-by-lot and is targeted at those areas which may require evacuation or assistance during a flood event. Classification of the floodplain is done by considering all design flood events and more importantly how each precinct of the floodplain floods. For example, is the area first isolated and then inundated? Is the area trapped by something other than flood water (e.g. the ocean, a cliff face etc.)? Is there an available evacuation route via road or on foot?

Preliminary classification of low flood islands was done by identifying islands in the 10% AEP flood event. These islands were further refined by considering how the flood progresses for larger design events and additional islands were identified. Areas within North Byron classified as indirectly affected are those areas outside of the floodplain but may still be impacted by loss of electricity, water supply or transportation. These areas indirectly affected by flooding extend outside of the study area as there are pockets of communities that may be impacted.

The ERP classification for each identified hot spot is described in Table 11 below.

Table 11: ERP Categorisation for Hotspot Locations PMF event

Area*	Emergency Response Planning Categorisation
Hotspot A – Mullumbimby	Low Flood Island
Hotspot B – Riverside Crescent	Low Flood Island
Hotspot C – New Brighton	Low Trapped Perimeter
Hotspot D – New Brighton (Casons Road)	Low Trapped Perimeter
Hotspot E - Billinudgel	Rising Road Access

* refer Section 7.8

7.4. Access and Movement during Flood Events

Any flood response measure suggested as part of this FRMS must take into account the availability of flood free access and the ease with which movement may be accomplished. A review of the existing access roads and evacuation arrangements has been undertaken and is discussed in the following sections.

7.4.1. Access Road Flooding

7.4.1.1. Evacuation Routes

The Byron Shire Local Flood Plan (2013) (Reference 12) identifies nominated evacuation centres and evacuation routes to those centres, as shown on Figure 25.

The Local Flood Plan has identified the following primary and secondary evacuation centres:

- Primary Evacuation Centres:
  - Ocean Shores Country Club, Orana Road ♦,
- Secondary Evacuation Centres:
  - Seventh Day Adventist Centre, Shara Boulevard, Ocean Shores North ♦,
  - Memorial Hall, Fingal Street, Brunswick Heads ♦,
  - RSL Club, Dalley St, and Civic Hall, Mullumbimby ♦,
  - Wilsons Creek Community Hall, Wilsons Creek Road,
  - Byron Bay RSL Club, Jonson Street,
  - Durrumbul Hall, Mud Brick lane off Coopers lane, Durrumbul ♦,
  - Community Hall at Wilson Creek Road and
  - Upper Main Arm Public School, Upper Main Arm Road.

There are several additional evacuation centres identified by the Local Emergency Management Committee including the following:

- Byron Bay High School, Byron Bay,
- Byron Bay Scout Hall, Byron Bay,
- Cavanbah Centre, Byron Bay,
- A & I Hall, Bangalow Showgrounds,
- Konihur Hall, Main Arm.

Only those annotated with a "♦" are locating within the North Byron study area.

Available evacuation routes were identified for each locality from the Local Flood Plan and are detailed below. It should be noted evacuation routes are described generally and not all local streets are included.

- South Golden Beach / North Ocean Shores evacuation routes
  - Beach Avenue, Kallaroo Circuit, Pacific Highway (towards Byron Bay), Orana Road,
  - Beach Avenue, Kallaroo Circuit, Pacific Highway (towards Byron Bay), Rajah Road, Warrambool Road, Orana Road,
  - Shara Boulevard
- New Brighton
  - River Street, The Esplanade, Orana Road, Strand Avenue.
- Ocean Shores
  - Local streets to Orana Road,
  - Local streets to Pacific Highway, Rajah Road, Warrambool Road, Orana Road,
- Billinudgel
  - Local streets to Wilfred Street, Pacific Highway, Orana Road,
  - Local streets to Wilfred Street, Pacific Highway, Rajah Road, Warrambool Road, Orana Road,

- Mullumbimby
    - Local Streets to Main Arm Road, Coolamon Scenic Drive, Tincogan Street, Dalley Street,
    - Local Streets to Jubilee Avenue, Dalley Street,
- Brunswick Heads
    - Local Streets to park Street or Old Pacific Highway, Fawcett Street.

Understanding any constraints to the trafficability of these evacuation routes is critical to emergency decision making. This includes time to inundation and key levels at gauges where evacuation routes are no longer available. Linking decision points to a corresponding level at a gauge ensures that the time available is relative to something that is measurable as opposed to the onset of a flood event, which is difficult to determine in real time.

Appendix J provides detail on timing of inundation affecting the trafficability of each evacuation route. It also includes corresponding long profiles which show the level of the road and the level of each design event along the road, highlighting areas which may be particularly vulnerable. These profiles are supported by tables detailing the gauge level at time of first flooding for each road.

Table 12 and Table 13 below list the evacuation routes that have been included in this assessment and a summary of their flood affectation. Evacuation routes and corresponding evacuation centres are shown in Figure 25.

Table 12: Flood Affected Evacuation routes Locations

ID	Road Location	Route locations with highest exposure
1	Brunswick Heads Evacuation Route	Old Pacific Hwy roundabout to Cnr Newberry Parade to Cnr Fingal street
2	Mullumbimby East Evacuation Route	Queen street
3	Mullumbimby West Evacuation Route	Riverside Drive
4	Mullumbimby South Evacuation Route	Near Mullumbimby High school
5	New Brighton Evacuation Route	River Street
6	Ocean Shores Evacuation Route	Cnr of Reka Way to Cnr of Wehlooga Way
7	South Golden Beach and Ocean Shores Evacuation Route	Rangal Road and Shara Boulevard
8	Billinudgel Evacuation Route	Wilfred Street

Table 13: Inundation of Evacuations routes

Location	Road Level (mAHD)	First Event Flooded (AEP)	Peak Velocity 1% AEP (m/s)	Rate Of Rise 1% AEP (m/hr)	Time Of Inundation 1% AEP (hour)	Peak Flood Level (mAHD)			
						0.2EY	5% AEP	2% AEP	1% AEP
1	2.10	2%AEP	0.75	0.52	9.5	/	/	4.72	5.00
2	4.88	2%AEP	0.40	0.35	11.4	/	/	4.98	5.08
3	5.15	1%AEP	0.39	0.27	5.4	/	/	/	5.06
4	4.50	10%AEP	0.88	1.12	5.5	/	4.80	4.92	5.07
5	1.97	2%AEP	0.87	0.47	11.2	/	/	4.07	4.23
6	2.27	2%AEP	0.04	0.97	11	/	/	4.08	4.17
7	3.42	10%AEP	0.81	0.25	2.1	/	3.22	3.75	4.08
8	3.27	0.2EY	0.1	0.2	22	3.3	3.6	3.7	3.9

7.4.1.2. Rising Road Access

Rising Road Access are roads rising steadily uphill and away from the rising floodwaters as defined by the Emergency Response Classification (ERC). The details of flood affectation of key rising roads (refer Figure 24) across the catchment area are provided below.

Table 14: Flood Affected Road Locations

ID	Road Location
1	Mullumbimby - Azalea Street
2	Mullumbimby – Left Bank Road
3	Mullumbimby – Coolamon Scenic Drive
4	Mullumbimby – Mullumbimby Road
5	Brunswick Heads – Pacific Motorway
6	Brunswick Heads – Old Pacific Highway
7	Billinudgel – Wilfred Street
8	Ocean Shores – Brunswick Valley Way
9	Ocean Shores – Orana Road
10	Ocean Shores – Warrambool Road
11	Ocean Shores – Rajah Road

Table 15: Inundation of Access Road

Location	Road Level (mAHD)	First Event Flooded (AEP)	Peak Velocity 1% AEP (m/s)	Rate Of Rise 1% AEP (m/hr)	Time Of Inundation 1% AEP (hour)	Peak Flood Level (mAHD)			
						0.2 EY	5% AEP	2% AEP	1% AEP
1	3.41	0.2 EY	0.3	0.3	26	5.4	5.5	5.6	5.6
2	3.41	0.2 EY	0.3	0.3	3	5.4	5.5	5.6	5.6
3	4.12	0.2 EY	1.2	0.1	8	4.3	4.4	4.5	4.5
4	2.58	5% AEP	0.3	0.2	26	/	2.9	3.2	3.4
5	3.73	PMF	/	/	/	/	/	/	/
6	4.03	PMF	/	/	/	/	/	/	/
7	3.27	0.2 EY	0.1	0.2	22	3.3	3.6	3.7	3.9
8	*Flood free*								
9	*Flood free*								
10	*Flood free*								
11	*Flood free*								

7.5. Town Flooding

Figure 26 and Figure 27 provide some indicative inundation timings for each township within the study area. Each figure notes where key locations become first flooded. Appendix K provides tables detailing the corresponding gauge level for when each location first becomes inundated, and the time available from when the gauge hits minor to first flooding.

Flooding at Mullumbimby and Brunswick Heads is linked to levels at the Federation Bridge gauge and flooding at Billinudgel, New Brighton and Ocean Shores is linked to levels at the Billinudgel gauge. These figures are only an indication of the potential inundation timing for each town. As the March 2017 showed, flooding is variable and warning time available will change with each flood event. Of note however, there is limited time between when the Billinudgel gauge reaches minor and flooding along Wilfred Street at the hotel.

7.6. First Event Flooded

The property database (refer Section 2.5) developed for the North Byron floodplain provides useful information to better understand the flood risk at an individual property level and can inform both evacuation planning and other floodplain management measures.

41% of all flood affected residential properties are located in Mullumbimby, increasing 52% of those affected in the 1% AEP event. Mullumbimby also has 43% of the residential properties impacted above floor level (30% in the 1% AEP event), making it by far the most flood affected suburb in the catchment. Table 16 shows the breakdown of all properties, and Table 17 of properties impacted by the 1% AEP event.

Table 16: Total residential properties impacted by suburb for the PMF event

Suburb	Number of Residential Properties Flood Affected (% of catchment total)	Number of Residential Properties Flood Above Floor (% of catchment total)
Billinudgel	35 (1%)	23 (1%)
Brunswick Heads	531 (18%)	401 (15%)
Mullumbimby	1233 (41%)	1178 (43%)
New Brighton	196 (7%)	192 (7%)
Ocean Shores	650 (22%)	614 (22%)
South Golden Beach	358 (12%)	352 (13%)

Table 17: Residential properties impacted by suburb for the 1% AEP event

Suburb	Number of Residential Properties Flood Affected (% of catchment total)	Number of Residential Properties Flood Above Floor (% of catchment total)
Billinudgel	17 (2%)	5 (1%)
Brunswick Heads	94 (8%)	63 (13%)
Mullumbimby	581 (52%)	152 (30%)
New Brighton	156 (14%)	105 (21%)
Ocean Shores	69 (65)	38 (8%)
South Golden Beach	0	0

Mapping showing the first event properties become inundated above floor has been developed and is provided in Figure 28 through to Figure 33. These figures also detail the design event each evacuation route first becomes inundated.

7.6.1. Vulnerable Properties

As previously outlined in Section 2.3, there are 29 vulnerable properties identified within the North Byron study area. Table 18 provides detail on the number of vulnerable properties flooded above floor in each design event and is also shown in Figure 34. Of note, there is a preschool located within the high hazard category for the 1% AEP event. Whilst this property does not experience above floor flooding, it is a particularly vulnerable use exposed to hazardous flood behaviour.

The vulnerable property database has been provided to Byron Shire Council.

Table 18: Vulnerable properties flooded above floor level

Design Event	Number flooded above floor
10% AEP	N/A
5% AEP	1
2% AEP	4
1% AEP	4
0.5% AEP	5
0.2% AEP	7
PMF	12
Not Flooded Above Floor	13

7.6.2. Critical Infrastructure

An assessment of the flood exposure for critical infrastructure across the study area has been carried out. This information has not been reported within the FRMS due to its sensitive nature, however has been provided to both the SES and Byron Shire Council to inform their emergency response.

7.7. Isolated Properties

Properties that are isolated may require an emergency response such as resupply, rescue or evacuation depending on the duration of isolation, size of the area isolated and potential for the area to become inundated. An assessment of isolation was conducted for each of the design flood events and results are shown in Figure 35 through to Figure 42. Isolation numbers are also provided in Table 19 below.

Table 19: Isolated houses for the full range of design flood events.

Suburb	0.2EY	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
Billinudgel	10	5	3	1	29	18	6	0
Brunswick Heads	0	3	0	0	13	3	0	51
Main arm	4	4	4	4	9	8	4	4
Middle pocket	0	0	1	1	1	6	1	1
Mullumbimby	9	110	639	390	296	255	161	2
Myocum	1	1	0	0	0	0	0	0
New Brighton	20	20	15	2	1	1	0	11
Ocean Shores	0	0	3	10	11	25	63	2
South Golden Beach	0	0	0	0	0	0	26	0
The Pocket	1	1	1	0	0	0	0	0
TOTAL	**45**	**144**	**666**	**408**	**360**	**316**	**261**	**71**

7.8. Hot Spot Identification

A number of areas of the catchment have been identified as flood risk 'hotspots'. These have been identified based on a range of factors including inundation frequency, property type, emergency response classification, flood function and hazard category, and represent areas of relative high flood risk. These hotspots have been refined through discussion with the FMC.

A brief discussion of those identified is presented below.

7.8.1. Mullumbimby

A large area of Mullumbimby has been identified as a hotspot due the proportion of frequently inundated residential property. Some residential properties are inundated as frequently as the 0.2EY and the 10% AEP flood event, and a large proportion inundated in the 5% AEP and 2% AEP

flood events. As shown in Figure 23, this area has also been identified as a low flood island meaning this area is firstly becomes surrounded by flood waters, isolating the area, before being inundated. This places a much higher risk on safe evacuation and can place additional load on emergency responders.

The community consultation undertaken in June 2018 received 93 responses from Mullumbimby residents. Of these respondents, 7 residents reported having experienced above floor flooding previously and 22 respondents said they had been unable to access their usual travel routes. Several respondents didn't answer this question but commented that both their yard and house had been inundated or that their neighbour had experienced above floor flooding.

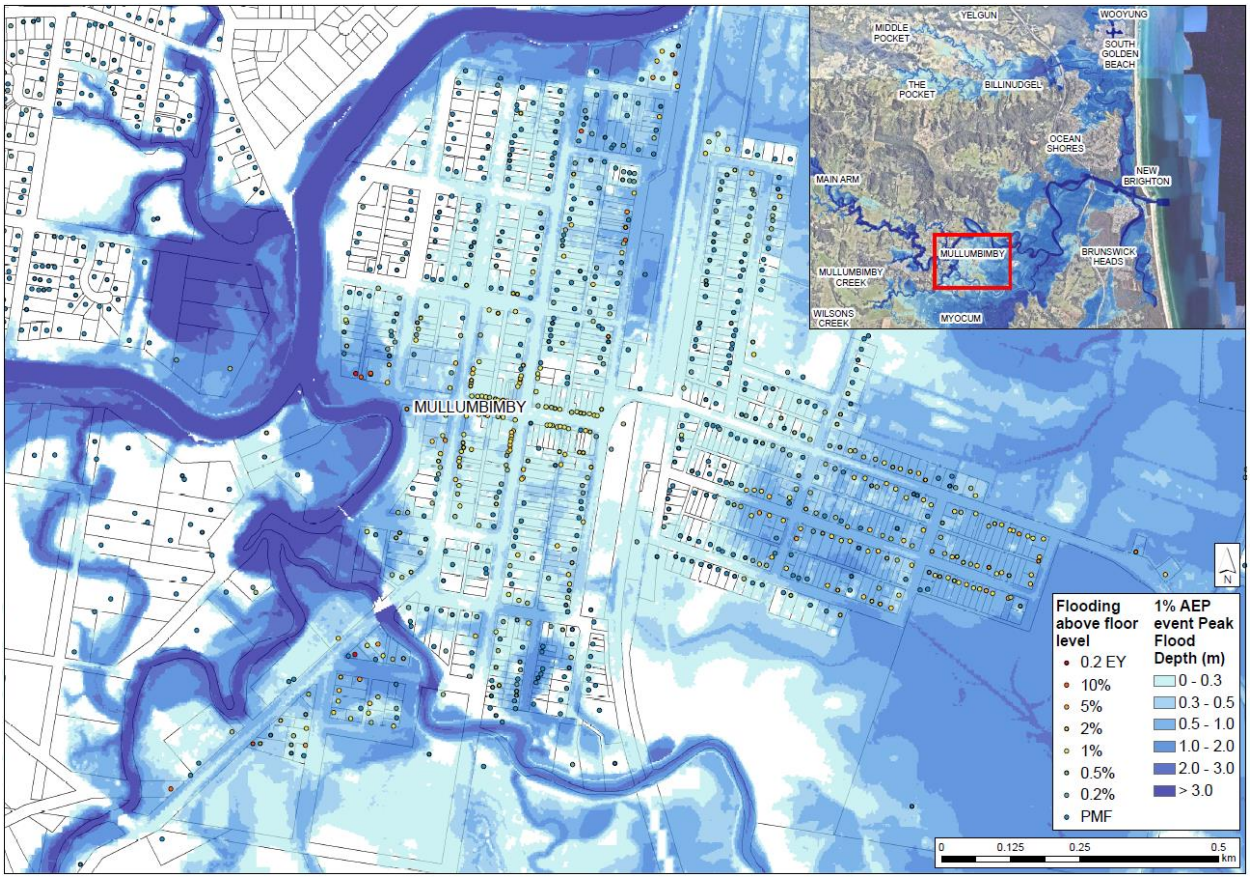


Diagram 6: Mullumbimby hotspot

7.8.2. Riverside Crescent, Brunswick Heads

The small pocket of residential properties in Riverside Crescent has been identified as a hotspot as these properties are inundated as frequently as the 10% AEP flood event. In addition to this, Riverside Crescent surrounding these properties is inundated in the 0.2EY flood event, leaving these properties isolated before becoming inundated.

Reflections Holiday Park Reserve has been identified in the vulnerable properties list and is located in this pocket of properties. Caravan parks can be particularly vulnerable to flooding due to both the susceptibility to being damaged by flood waters and also the associated difficulty in transporting permanent caravans. Given this area is also a low flood island, there is a higher risk to safe evacuation and potential additional burden on emergency responders.

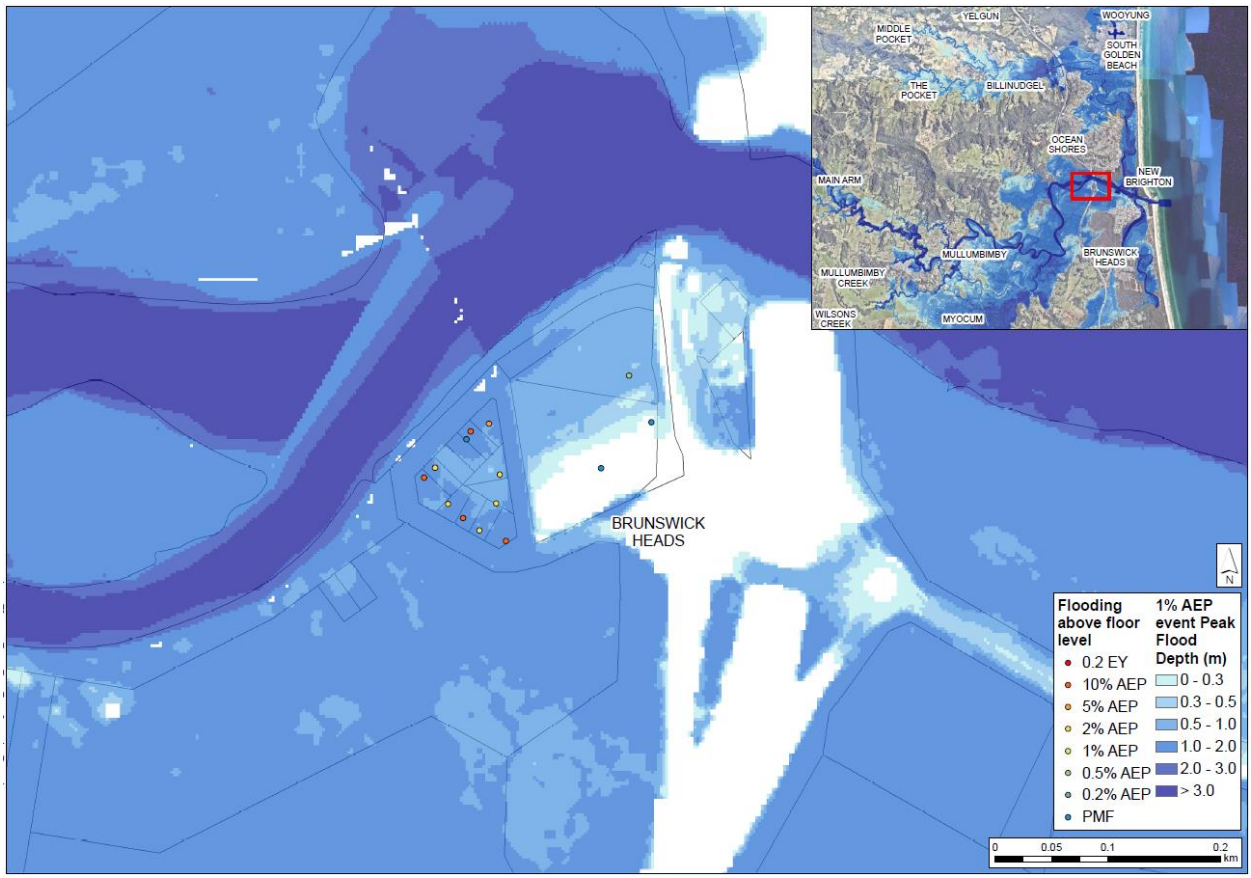


Diagram 7: Riverside Crescent hotspot

7.8.3. New Brighton

There are two hotspots identified in New Brighton, the first located to the west of The Esplanade and the second in the vicinity of Casons Road (as shown in Diagram 8 and Diagram 9). While New Brighton isn't directly impacted from the east by floodwaters, the ocean does act as a barrier. Furthermore, there is a coastal hazard. The only available evacuation routes are cut leaving the New Brighton community trapped. The evacuation route for New Brighton starts at River Street (near Casons Road), continues along The Esplanade and crosses Strand Avenue and Orana Bridge. The evacuation centre is located in Ocean Shores at the Ocean Shores Country Club, however residents in New Brighton are unable to access the evacuation routes to reach this evacuation centre. River Street is inundated as frequently as 0.2EY and Strand Avenue is inundated as frequently as the 2% AEP flood event. As such, this area has been classified as a low trapped perimeter, a classification that has a higher risk to life. Properties located here are inundated frequently inundated with some properties impacted in the 0.2EY and 10% AEP flood events.

While the property database does include properties south of North Heads Road, these developments are no longer legally allowed. It is understood that most developments here have been demolished however there is a known issue of some illegal builds remaining and this is being further investigated by Byron Shire Council.

The second hotspot at New Brighton is another small pocket of frequently inundated properties, with some impacted as frequently as the 0.2EY.

The community consultation received 34 responses from New Brighton residents with 15 residents answering their house has previously been flooded. A number of residents did not answer this part of the survey but commented they had previously been flooded and that their access was cut. One responded answered they were *'unable to leave New Brighton by road at all'.* However, one New Brighton resident has noted that Gaggin Street is flood free and the beach can be easily accessed. This option of seeking evacuation on foot via the beach is available from most of the beach front roads. While this is a viable option for floods without increased ocean water levels, it would not be recommended for events with high ocean water levels.

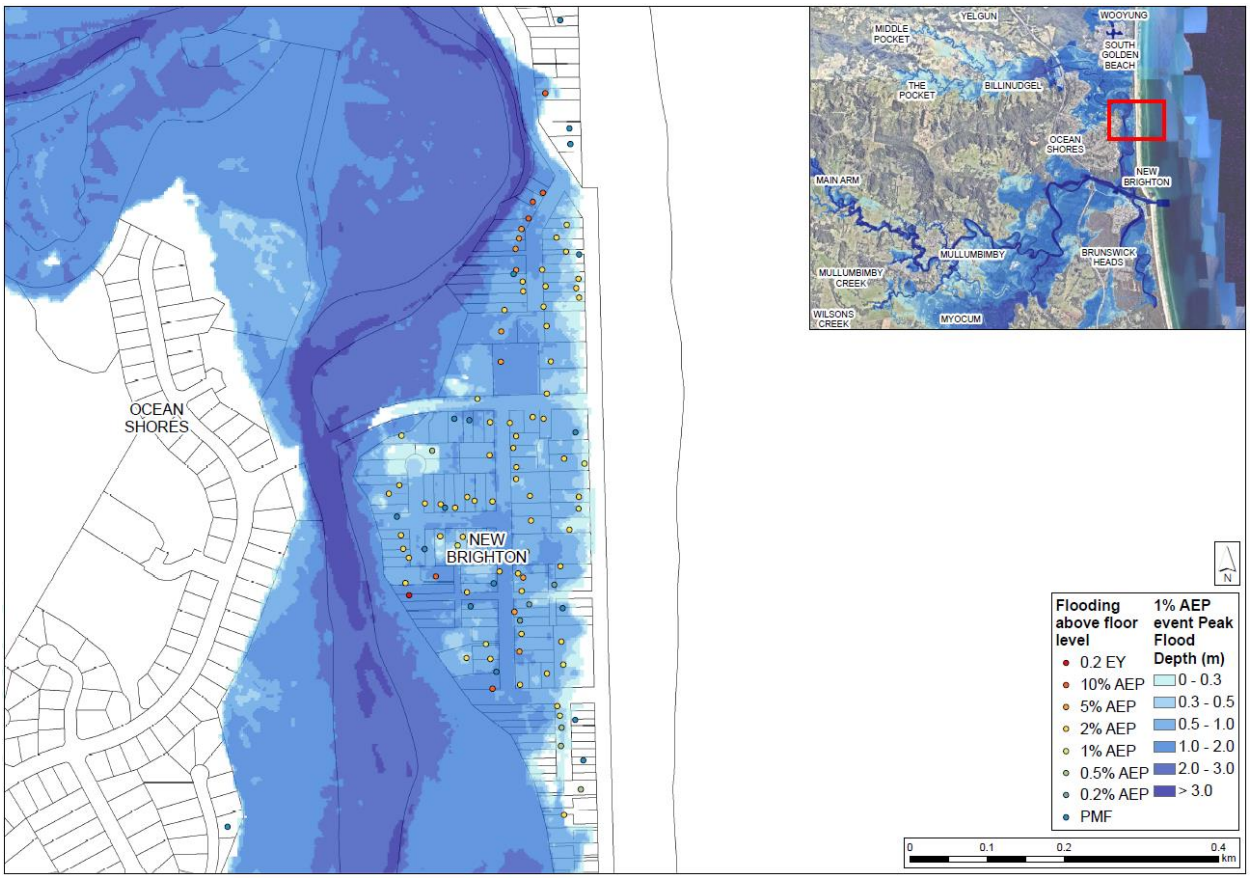


Diagram 8: New Brighton hotspot

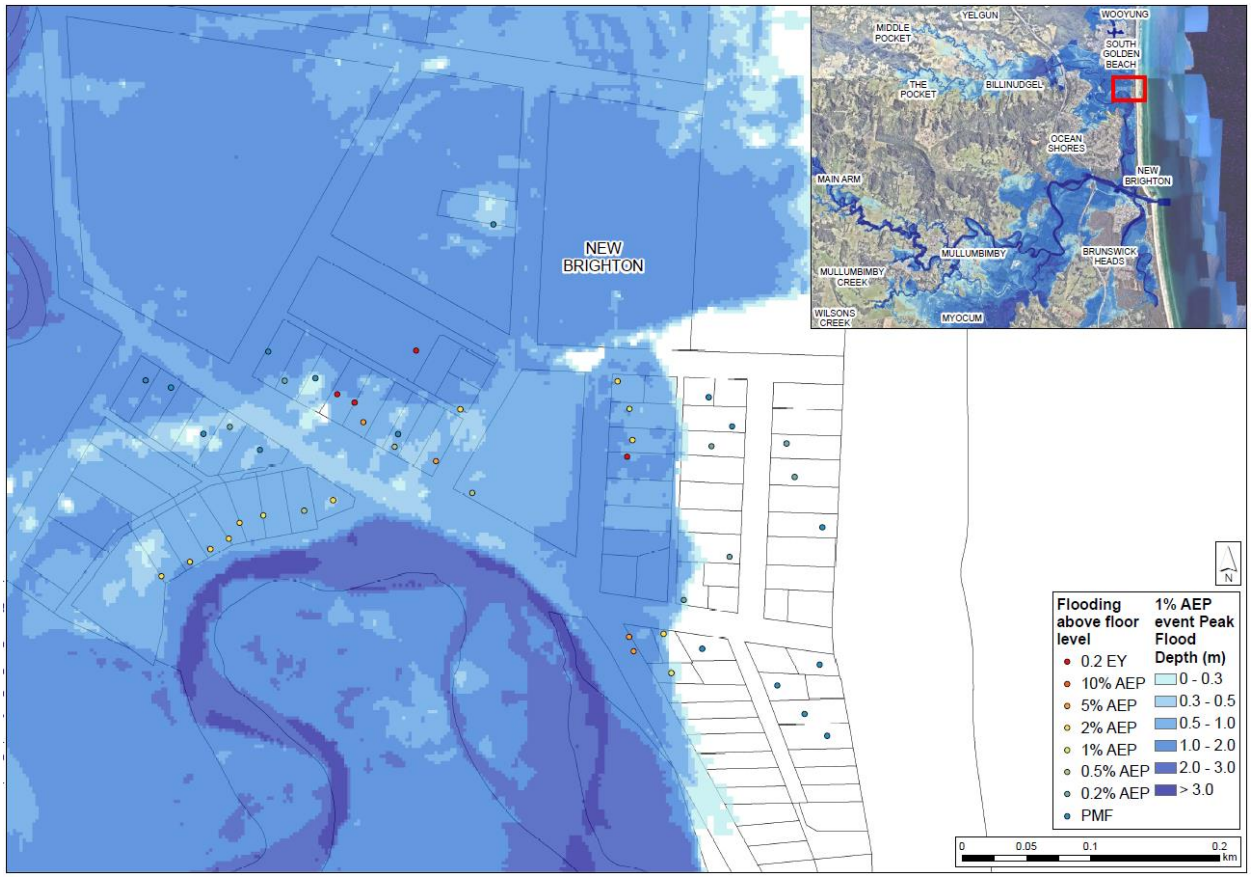


Diagram 9: Casons Road, New Brighton hotspot

7.8.4. Billinudgel

A large number of properties that are inundated in the 0.2EY event are located in Billinudgel, including both residential and commercial properties. Wilfred Street is identified as the main evacuation route for Billinudgel and currently is cut off in the 0.2EY flood event. There are some locations in Billinudgel that may be able to evacuate by overland escape route, however two pockets have been identified as low flood islands. Given the frequent inundation and evacuation constraints, this area has been identified as a flooding hotspot.

The community survey received 13 responses from people who lived in Billinudgel. One of the business respondents said their business had experienced above floor flooding. Of the respondents, only one person answered their house had been previously flooded and two residents reported their access being cut off.

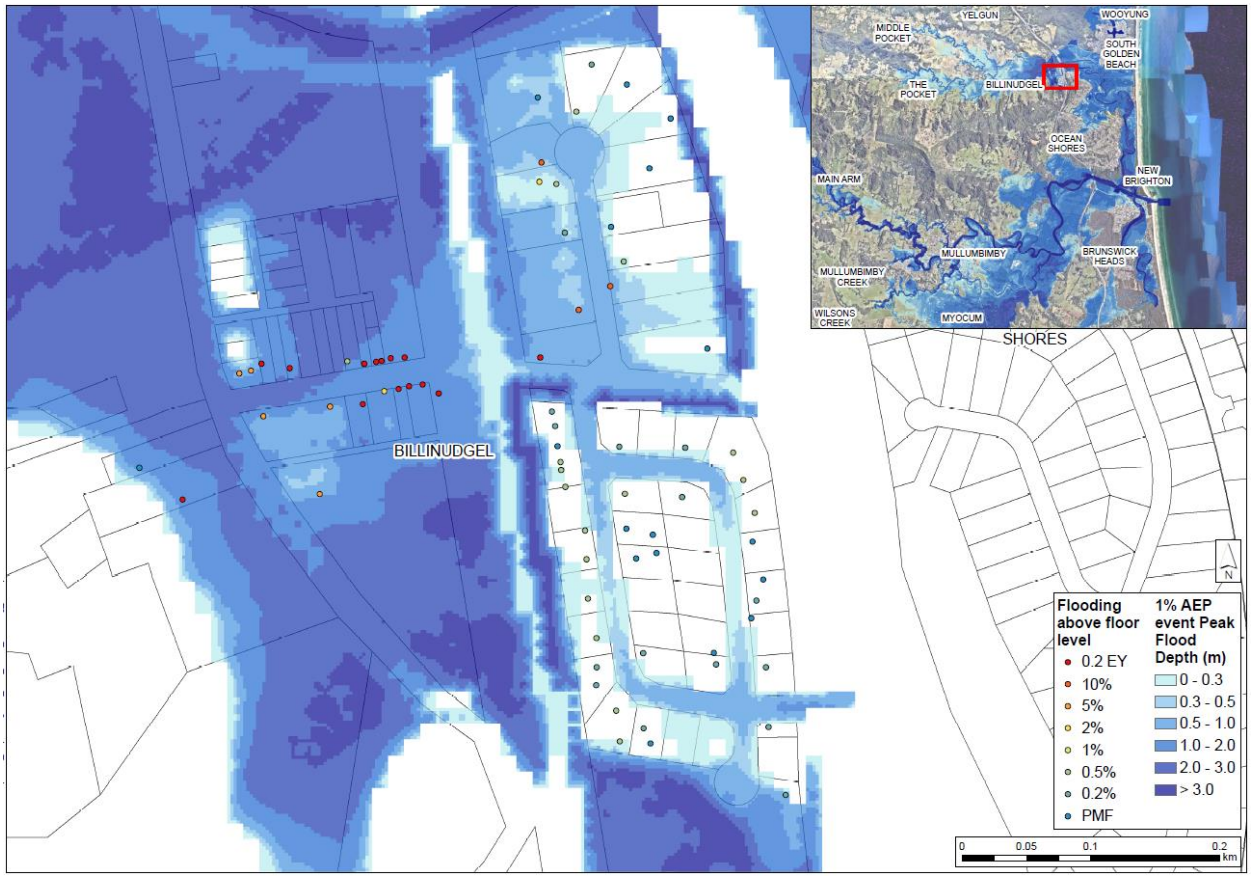


Diagram 10: Billinudgel hotspot

8. FUTURE FLOOD ENVIRONMENT

The following sections consider the potential changes to the flood environment as a result of future conditions, specifically increased development in the catchment, and change in climate.

8.1. Changes due to development

Development in the floodplain will inevitably, and unavoidably, result in some change to flood behaviour. The wide scale adoption of two dimensional hydraulic models has provided a tool for assessing the impacts of floodplain management measures, development proposals, and infrastructure projects, on adjoining properties and communities.

An assessment of potential landform changes in the catchment resulting from future development under current and future climate conditions, will provide an understanding of how development may impact flood behaviour. This can then be used to inform development controls and land use responses to ensure flood risk is not exacerbated through development.

As development within a catchment increases, the relatively minor impacts from each development individually can accumulate and cause a much larger impact on a broader regional scale, particularly if this development occurs in areas of the floodplain that are sensitive to landform changes (including the use of fill to achieve flood planning levels). It is important to understand the floodplains sensitivity to increased development, specifically the cumulative impact of future potential development on the flood risk, conveyance and flood damages.

8.1.1. Zoning Categorisation

Areas identified as having future development potential were categorised based on current land use zones identified in the Byron Local Environmental Plan 2014 (Figure 3) and areas identified for possible new residential development within Byron Shire Councils Draft Residential Strategy. These development scenarios represent maximum *potential* development that could in theory occur based on current land use zoning.

For the purposes of representation in the model, the areas were categorised as either:

- Rural Residential
- Low density urban,
- Low / medium density urban,
- Medium density urban,
- Commercial / industrial, and
- Other (not identified as developable land).

8.1.2. Development Potential

Lots identified as either rural residential, low density urban, low / medium density, medium density urban or commercial / industrial may be available for future development. The property database was used to identify lots that are already developed and unless these lots have been identified for

consolidation, these were classified as fully developed. In addition to land use zones identified in the Byron Local Environmental Plan (2014), outcomes from the Residential Strategy for Byron Shire Council (2019), Business and Industrial Strategy for Byron Shire Council (2019), and the Marshalls Creek Floodplain Management Plan (1997) were also incorporated in the assessment. Appendix P provides figures for each component, which are briefly discussed below.

8.1.2.1. Byron Shire Council Residential Strategy, and Business and Industrial Strategy (2019)

These strategies provide guidance on the likely areas for future consolidation and new development. Locations within the study area targeted for future development are:

- Billinudgel industrial consolidation,
- Mullumbimby expansion,
- Residential infill within Mullumbimby, Brunswick Heads, Ocean Shores and New Brighton,
- Vacant undeveloped land available for residential development within Mullumbimby and Brunswick Heads.

8.1.2.2. Marshalls Creek Floodplain Management Plan

As part of the Marshalls Creek Floodplain Management Plan (1997), areas of the Marshalls Creek floodplain in the vicinity of Ocean Shores were identified as no fill zones. While this action was not directly included within the Byron Shire Council Planning Policy it has been included as part of this assessment to understand the impacts on flood behaviour.

8.1.3. Development Scenarios

Broad scale assumptions need to be made regarding how future development will change the landform of the catchment. Two scenarios were developed.

CD1 – Cumulative Development Scenario 1 – filling of available land up (based on land uses and approximate site coverage) to the flood planning level (FPL) for an expected site area of 50% (and 500 m^2 for rural residential lots) and increasing manning's roughness elsewhere in the areas identified as developable. No development was considered for areas identified as no fill zones within the Marshalls Creek Floodplain Management Plan or identified as high hazard (H4-H6).

CD2 – Cumulative Development Scenario 2 – filling of available land up (based on land uses and approximate site coverage) to the future FPL **including climate change** for an expected site area of 100% (and 1000 m^2 for rural residential lots) and increasing manning's roughness elsewhere. No development was considered for areas identified as high hazard (H4-H6). Development has been included for areas identified as no fill zones within the Marshalls Creek Floodplain Management Plan.

Figure 43 and Figure 44 show the lots identified for future development and detail the areas of fill and increased roughness for both Cumulative Development Scenario 1 and Scenario 2.

8.1.4. Assessment

Cumulative Development Scenario 1 and Scenario 2 were assessed for the 1% AEP, 0.5% AEP and Climate Change Sensitivity Test 2 (1% AEP + 30% rainfall increase + 2.9m tailwater). Results are provided in Figure 45 to Figure 50. There are substantial impacts for both scenario CD01 and scenario CD02, with Mullumbimby being particularly sensitive to changes in roughness and fill.

8.1.4.1. Cumulative Development Scenario 1 Results

For the 1% AEP event the most substantial impacts are seen within Mullumbimby, with some areas experiencing increases in peak flood levels up to 0.2 m and some areas newly flooded.

There are minor impacts in Billinudgel, Ocean Shores and Brunswick Heads. Within Brunswick Heads, the majority of development is outside the 1% AEP flood extent are. There are small sections south of Brunswick Heads that may have future development and these areas experience impacts of up to 0.05m.

These impacts are exacerbated under future climate conditions, and for flood events larger than the 1% AEP event. Mullumbimby remains the most sensitive to future development changes. Within the 0.5% AEP flood event, there are large areas of newly flooded land and impacts in Mullumbimby increase significantly.

8.1.4.2. Cumulative Development Scenario 2 Results

As outlined in Section 8.1.3, the difference between CD01 and CD02 are the proportion of the lot to be filled, the fill level and the inclusion of development within the no fill zones from the Marshalls Creek Floodplain Management Plan.

With an increase in fill and land available for future development, impacts from CD02 increase substantially. For the 1% AEP event, there are some areas with increases in peak flood levels of up to above 0.5 m within Ocean Shores and Mullumbimby. There are areas of newly flooded land in Mullumbimby. Increased impacts are seen in Billinudgel and Ocean Shores with some small areas with increases in peak flood levels up to 0.5 m.

CD02 highlights the sensitivity to topographical changes particularly within Mullumbimby, with large areas of widespread impacts, and areas newly flooded. There are some areas within Mullumbimby where flood levels have decreased, this is most likely because area available for flood storage was removed from the floodplain causing increases downstream and decreases upstream.

Impacts seen from CD02 only become more pronounced under future climate conditions. For the climate change scenario assessed, there are large areas of newly flooded land within Mullumbimby and the area seeing increases in flood levels of up to 0.5m increases substantially.

8.1.5. Additional Scenarios

Impacts from the initial CD01 and CD02 development scenarios were analysed to identify areas most sensitive to landform changes. A number of additional iterations were considered to further understand which areas are driving the impact. The original CD02 development scenario was used as the base and additional changes were made based on this scenario. These iterations include a combination of protecting the floodway (in addition to the high hazard areas), the identified areas sensitive to changes and as well as number of combinations. The purpose of this work was to identify the key areas of the floodplain where the use of fill would result create unacceptable impacts in surrounding areas.

The additional iterations assessed are as follows:

1. Original CD02 development scenario including protecting the floodway from development,
2. Original CD02 development scenario including protecting the identified sensitive areas (**Note:** Iteration 2 was also tested looking at development in Billinudgel and Ocean Shores separately to determine if there was any interaction between these areas),
3. A combination of iteration 1 (protecting the floodway) and iteration 2 (protecting the areas identified as sensitive),
4. Original CD02 development scenario including protecting the identified sensitive areas from Iteration 2 (with the exclusion of Azalea Street) and additional sensitive areas.

The areas identified as being sensitive to landform are discussed in more detail below.

8.1.5.1. Iteration 2 Additional Areas

Azalea Street, Mullumbimby

The area circled in Diagram 11 below is a restricted flow point. Eliminating fill in this area was thought to potentially alleviate the impact and was modelled in the additional scenarios discussed in Section 8.1.5. Results of this testing is discussed in Section 8.1.6.

Diagram 11: Area near Azalea Street, Mullumbimby, identified as being sensitive to landform changes (1% AEP event, CD02 scenario)

Mullumbimby Creek

The flow path between Mullumbimby Creek and Brunswick River is another area of restriction. Removing fill adjacent to the waterway area was modelled to determine if it reduced the observed impacts. Results are discussed in Section 8.1.6.

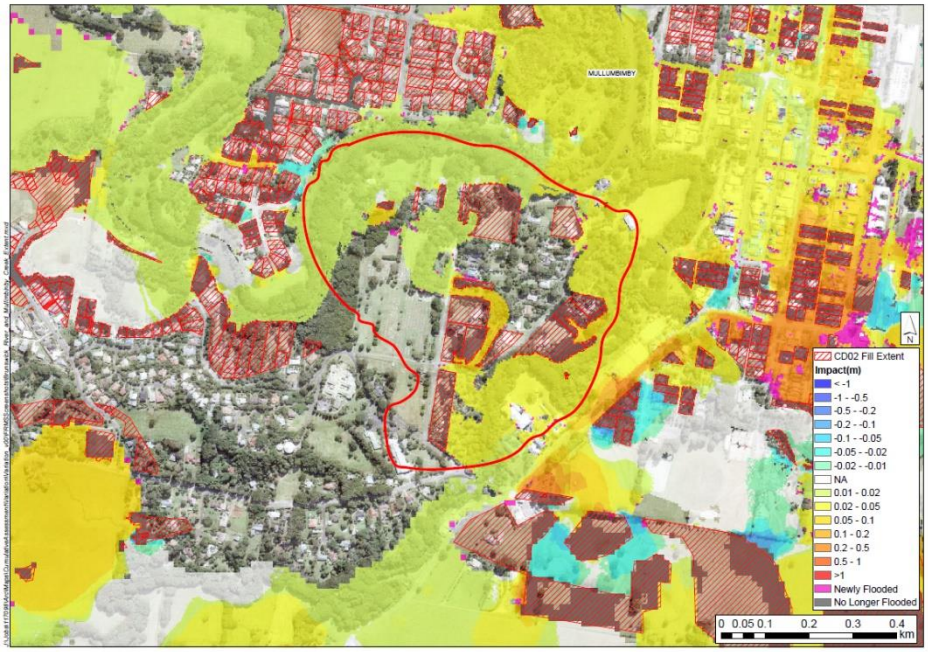


Diagram 12: Area between Mullumbimby Creek and Brunswick River identified as being sensitive to landform changes (1% AEP event, CD02 scenario)

Mullumbimby South

The area in south Mullumbimby (shown in Diagram 13), in the vicinity of Dalley Street and Argyle Street, has been identified as being very sensitive to filling. Landform changes in this area can have an impact on flood levels within Mullumbimby. This area has been included in the testing undertaken outlined above. Results are discussed in Section 8.1.6.

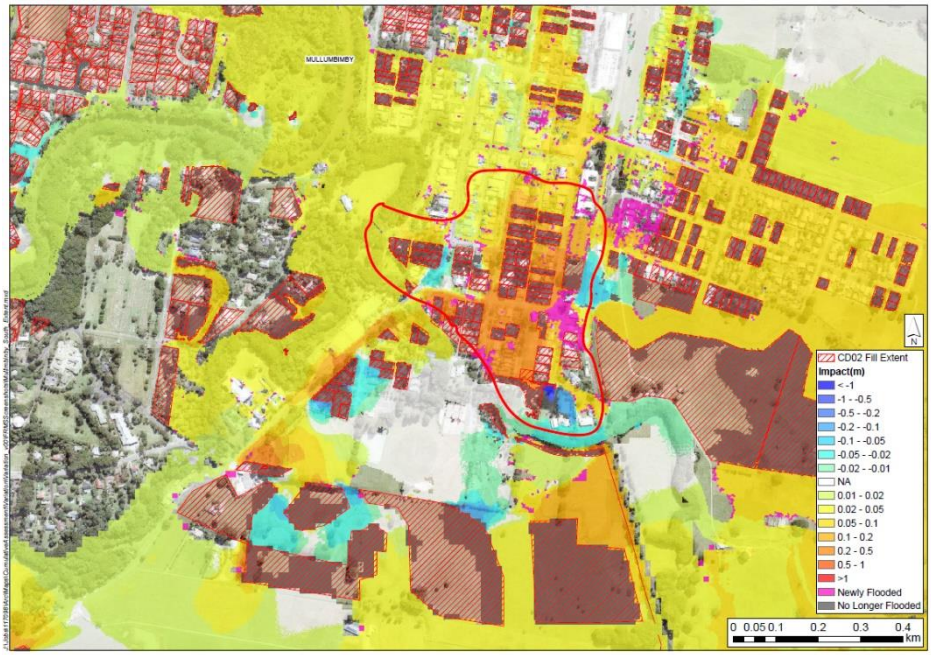


Diagram 13: Area within south Mullumbimby identified as being sensitive to landform changes (1% AEP event, CD02 scenario)

Chinbible Creek, Mullumbimby

The area near Chinbible Creek (Diagram 14), is another location of restricted flow, which water from flowing downstream. This area has been included in the testing undertaken outlined above. Results are discussed in Section 8.1.6.

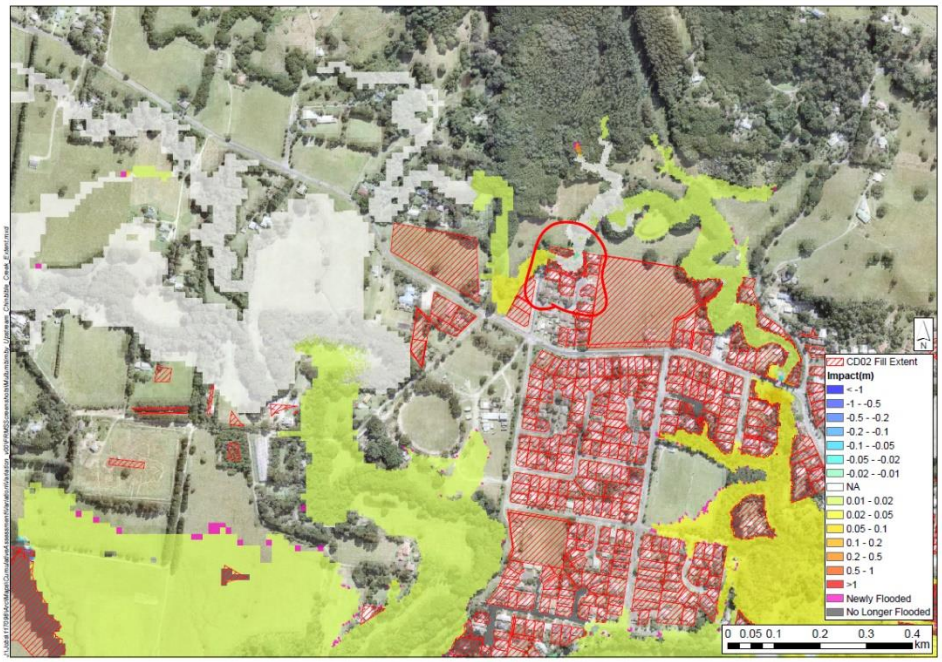


Diagram 14: Area near Chinbible Creek within Mullumbimby identified as being sensitive to landform changes (1% AEP event, CD02 scenario)

Billinudgel

Infill in Billinudgel (Diagram 15) has a large impact on flood levels within Billindugel. This area has been investigated to understand if halving the fill in this area would decrease the impacts. Protecting the properties along the Pacific Motorway may reduce impacts upstream. This area has been included in the testing undertaken outlined above. Results are discussed in Section 8.1.6.

Diagram 15: Billinudgel identified as being sensitive to landform changes (1% AEP event, CD02 scenario)

Ocean Shores

Increasing development along Aloota Crescent in Ocean Shores prevents water from draining east. The increased fill here causes water to pond in Balemo Driver and floods adjacent lots. Reducing the increased fill for these four lots may reduce the impact. This area has been included in the testing undertaken outlined above. Results are discussed in Section 8.1.6.

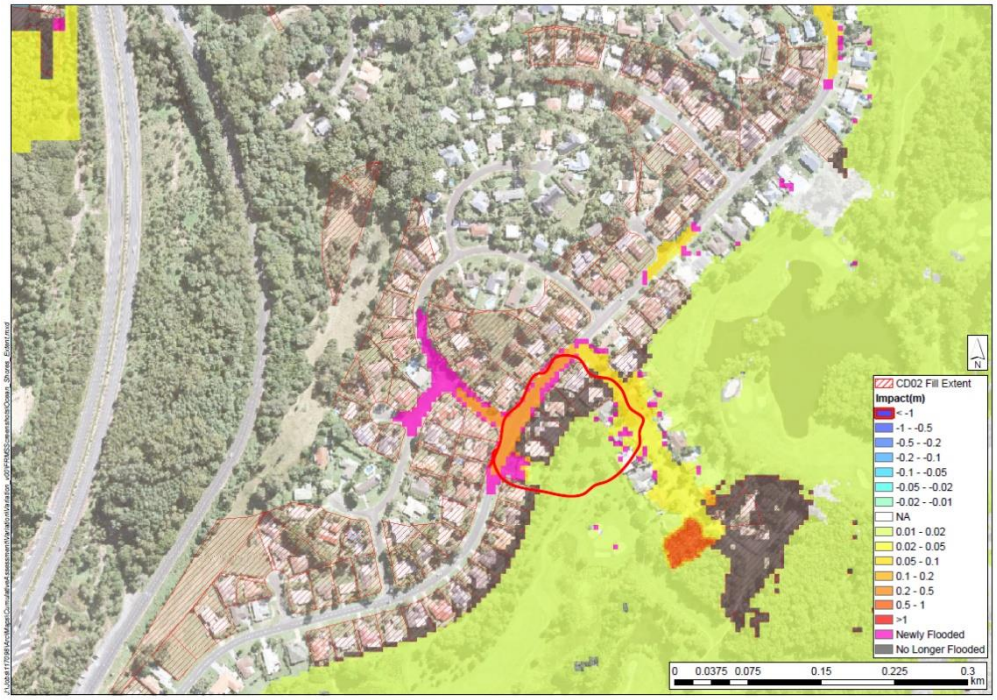


Diagram 16: Ocean Shores area identified as being sensitive to landform changes (1% AEP event, CD02 scenario)

8.1.5.2. Iteration 4 Additional Areas

Following review of the results from Iteration 2, additional areas were identified where fill in these areas may also impact flood levels. These additional areas have been tested as described above in Iteration 4. Iteration 4 also includes all areas from Iteration 2 found to reduce the impact from future potential development. Results from Iteration 2 testing are discussed in more detail in Section 8.1.6.2, however testing has shown that the area near Azalea Street in Mullumbimby is not sensitive to landform changes. Subsequently, this area has not been included in Iteration 4.

Additional areas included in Iteration 4 are described below.

Ocean Shores

In conjunction to the area already identified in Ocean Shores (Diagram 16) another area where fill may impact flood levels has been identified. As shown in Diagram 17, landform changes in this area is thought to impact flood levels in Aloota Crescent and Balemo Drive. This area will be included in Iteration 4 testing to understand if protecting these areas in Ocean Shores (Diagram 16 and Diagram 17) will reduce the impact from future development. This area has been included in the testing undertaken outlined above. Results are discussed in Section 8.1.6.

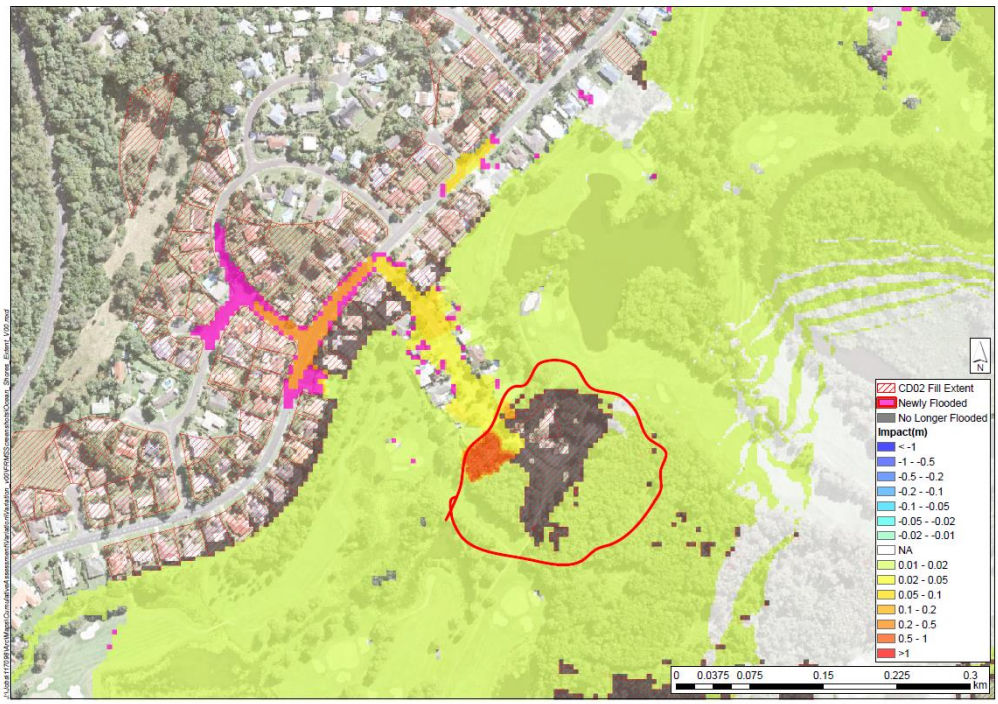


Diagram 17: Ocean Shores additional area identified as being sensitive to landform changes (1% AEP event, CD02 scenario)

Mullumbimby Jubilee Avenue

A number of areas within Mullumbimby have already been identified as being sensitive to landform changes including the area near Mullumbimby Creek, Chinbible Creek and some areas in Mullumbimby South (near Dalley and Argyle Street). Protecting the areas east of Jubilee Avenue (as shown in Diagram 18) is expected to reduce impacts from future development in this area. This area has been included in the testing undertaken outlined above. Results are discussed in Section 8.1.6.

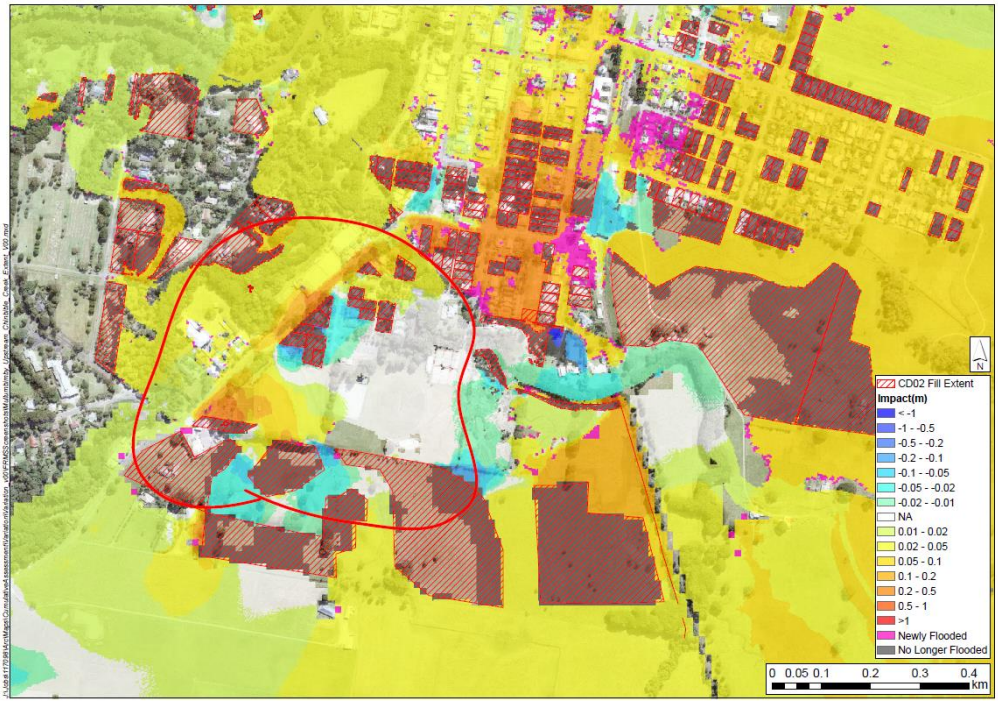


Diagram 18: Area in Mullumbimby near Jubilee Avenue identified as being sensitive to landform changes (1% AEP event, CD02 scenario)

Mullumbimby Queen Street

Development in the area to the east of Queen Street (as shown in Diagram 19) is thought to impact flood levels. Protecting this area from topographical changes may reduce impacts from future development. This area has been included in the testing undertaken outlined above. Results are discussed in Section 8.1.6.

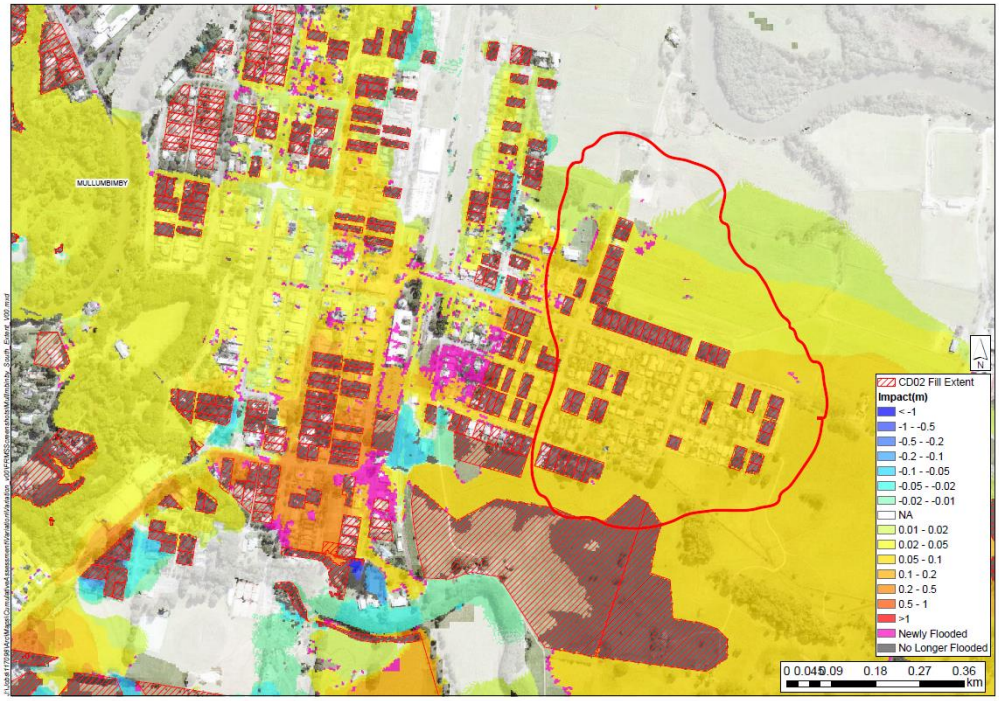


Diagram 19: Area in Mullumbimby east of Queen Street identified as being sensitive to landform changes (1% AEP event, CD02 scenario)

Mullumbimby Road

While currently, the industrial development south of Towers Drive along Mullumbimby Road (as shown in Diagram 20) reduces flood levels to the east, it also increases flood levels to the west. Protecting this area from topographical fill may reduce the impacts seen to west. This area has been included in the testing undertaken outlined above. Results are discussed in Section 8.1.6.

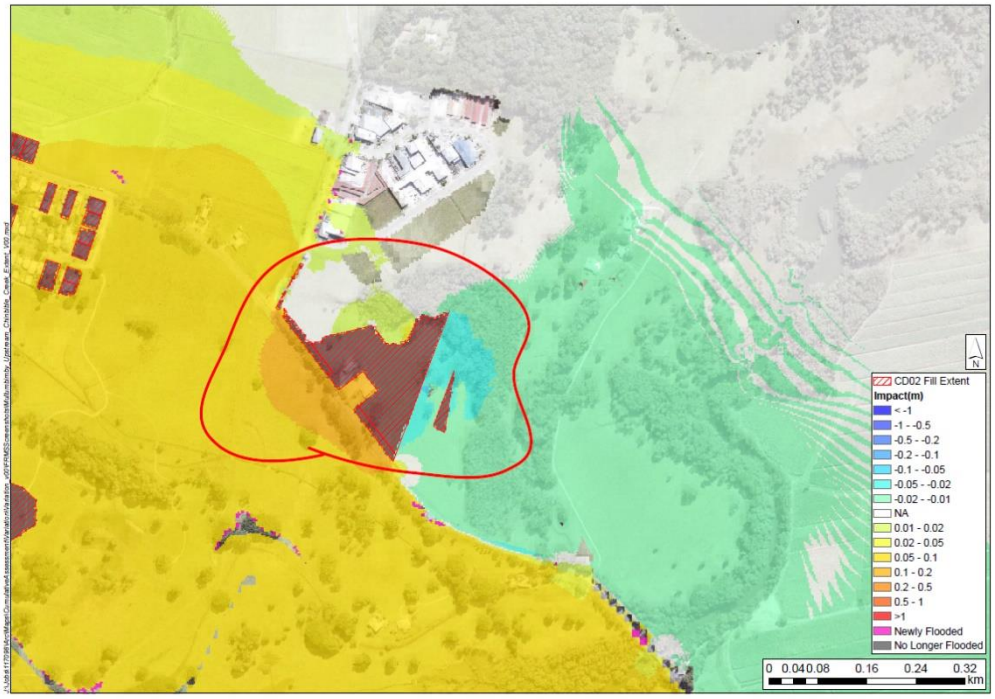


Diagram 20: Area south of Towers Drive identified as being sensitive to landform changes (1% AEP event, CD02 scenario)

8.1.6. Results

8.1.6.1. Iteration 1 Results

Iteration 1 was based on the CD02 development footprint but also protected the floodway from topographical changes. The function of the floodway is to convey large volumes of water and subsequently topographical changes in these areas will have regional impacts. Whilst the majority of the floodway overlaps with the high hazard area, which current council policy already restricts the use of land fill, there were some areas where the floodway is outside the high hazard area.

Results are provided in Appendix U, Figure U 1. As expected, the results are largely the same as the results from the base case CD02 scenario because the floodway and high hazard areas are extremely similar. Some minor reductions (0.2m to 0.5 m near Jubilee Avenue reduced to 0.1 m to 0.2 m and mitigation of some impacts south of Jubilee Avenue) were observed in Mullumbimby, particularly to the south.

8.1.6.2. Iteration 2 Results

Iteration 2 was based on the CD02 with the protection of additional areas described in Section 8.1.5.1. Results from this iteration are provided in Appendix U, Figure U 2.

A reduction in impacts can be seen within Mullumbimby and Billinudgel and to a lesser extent within Ocean Shores. The largest reduction in impacts to property can be seen within the town centre of Mullumbimby. Within the base CD02 scenario for the 1% AEP flood event, there was a small pocket of increases in flood levels between 0.2m – 0.5m seen in South Mullumbimby. Iteration 2 has reduced this impact substantially. While there are still widespread impacts seen within Mullumbimby, these are generally in the range of 0.02m to 0.05m with only some impacts up to 0.1m.

Protecting the area identified near Azalea Street, as shown in Diagram 11, from fill had no effect on reducing impacts from future development. This area will not be included in Iteration 4.

The Billinudgel floodplain is very sensitive to topographical changes. The flood function in the Billinudgel town centre is primarily floodway and flood storage. This means flood levels are extremely sensitive to development including fill. Without completely limiting future infill in the Billinudgel town centre, it will be challenging to mitigate all impacts. However, by protecting the properties along the highway (Diagram 15), impacts to upstream properties can be managed. The impact along Mogo Place and Wilfred Street is reduced from up to 0.5 m to less than 0.4 m.

Within Ocean Shores, impacts are primarily only up to 0.02m, with limited impact to properties. There is a small area in Ocean Shores along Balemo Drive where there are newly flooded areas and an area with impacts up to 0.5m.

While there are impacts in Brunswick Heads, there are no properties impacted by future development. South Golden Beach is protected by the levee from riverine flooding up to the 0.2% AEP flood event. However, it is important to note this does not include protection from any localised flooding behind the levee.

8.1.6.3. Iteration 3 Results

Iteration 3 is the combination of Iteration 1 (protecting the floodway) and Iteration 2 (protecting the identified sensitive areas). The results are essentially a combination of what is seen in Iteration 1 and Iteration 3. Appendix U, Figure U 3 provides the result for this iteration.

8.1.6.4. Iteration 4 Results

Iteration 4 was based on Iteration 2 with the inclusion of additional areas discussed in Section 8.1.5.2. As noted above, the area near Azalea Street was not included in this iteration. Results from this iteration are provided in Appendix U, Figure U 4.

Results from Iteration 4 show a substantial reduction in impacts form future development. Within the Mullumbimby town centre, impacts have almost all been managed with a large portion of the town centre with no impacts at all and a small area with either less than 0.02m or 0.05m. The iteration has removed newly flooded areas and impacts to properties in the town centre up to 0.1m to 0.5m has been managed.

Within south Mullumbimby near Stuart Place and Orchid Place, impacts in the base CD02 were up to 0.3 m, however protecting no fill areas in the vicinity of this area reduce the impacts to approximately 0.02 m.

As discussed above in Section 8.1.6.2, Billinudgel is an extremely sensitive area. Within Billinudgel, no additional areas have been included in Iteration 4.

The area in in Ocean Shores along Balemo Drive, where there were newly flooded areas and impacts up to 0.5 m now only experiences impacts up to 0.02 m and a very small section with impacts up to 0.05 m. This impact is considered to be within an acceptable range.

8.1.6.5. Recommended No Fill Areas

The recommended no fill areas can be seen in Figure U 5, of Appendix U. These include areas in the floodway (Iteration 1) and areas identified as being sensitive to topographical changes in Iteration 4 (including the original areas identified in Iteration 2).

This recommended footprint scenarios has been run for both scenario CD01 and scenario CD02 for the 1%, 0.5% AEP and the climate change scenario 1% AEP including 30% increase in rainfall and 2100 sea level rise. Results are shown in Figure U 6 through to Figure U 11 of Appendix U.

8.1.7. Recommendations

It is recommended that the Byron Shire Council DCP2014 be updated to include areas where fill is prohibited to ensure future development does not cause an unacceptable impact. The recommended no fill zones from the 1997 Marshalls Creek Floodplain Management Plan that was assessed in Development Scenario CD01 are not recommended for inclusion in the DCP2014.

The footprint of the recommended areas where fill should be avoided can be seen in Figure U 5 of Appendix U. These areas include:

- 1% AEP floodway,
- The area identified near Mullumbimby Creek (Diagram 12),
- South Mullumbimby near Dalley Street and Argyle Street (Diagram 13),
- Near Chinbible Creek, Mullumbimby (Diagram 14),
- Near Aloota Crescent, Ocean Shores (Diagram 16),
- East of Aloota Crescent, Ocean Shores (Diagram 17),
- East of Jubilee Avenue, Mullumbimby (Diagram 18),
- East of Queen Street, Mullumbimby (Diagram 19), and
- Future industrial development south of Towers Drive (Diagram 20).

As discussed, Billinudgel was shown to be particularly sensitive, and impacts of more than 0.3 m are observed even with the above exclusions applied. Results for the 1% AEP event for the CD01 scenario, which assumes lots are only filled to a maximum of 50% of the lot area, showed impacts in Billinudgel reduced to 0.05 m or removed in some areas. As such, for Billinudgel town centre,

it is recommended that the following conditions apply:

- Maximum development footprint of 50% of the total lot area,
- Maximum **fill** level set to the 1% AEP + 0.5m freeboard, although minimum habitable floor levels greater than this may still apply (detailed in Section 11.6.4).

It should be noted that the inclusion of these no fill areas will only reduce the impacts of development on flood behaviour, but do not entirely mitigate it. Ensuring that the above controls are applied so as to manage future impacts of flood behaviour will require enforcement of planning approvals.

8.2. Changes due to climate variation

Whilst there is general consensus that the climate in the future will be different from current conditions, there is uncertainty in the magnitude, and even the direction, of that change. Climate change has the potential to impact flooding through changes in the frequency, intensity, spatial extent, duration and timing of extreme weather and climate events, and through sea level rise. However, quantifying the effects of climate change on these factors is a difficult task, and includes large uncertainties. As such, using an approach based on a sensitivity analysis of different scenarios, and focusing on the consequences facilitates an assessment of the potential impacts of climate change despite this uncertainty.

Climate change scenarios have been modelled in alignment with current Byron Shire Council Climate Change Strategic Planning Policy (2014) (refer Section 6.5.3). The scenarios and corresponding design events and tailwater conditions modelled in response to this policy is detailed below, and mapping provided in Figure 51 through to Figure 91.

Scenario	Modelled Event and Tailwater Conditions
Current Conditions	Modelled in accordance with DPIE (formerly OEH) guidance, *Modelling the interaction of catchment flooding and oceanic inundation in coastal waterways* (2015)
2050 plus 0.4m sea level rise	5% AEP + 2.6m AHD tailwater 1% AEP + 2.4m AHD tailwater 0.2% AEP + 2.6m AHD tailwater PMF + 2.6m AHD tailwater
2100 plus 0.9m sea level rise	5% AEP + 3.1m AHD tailwater 1% AEP + 2.9m AHD tailwater 0.2% AEP + 3.1m AHD tailwater PMF + 3.1m AHD tailwater
Sensitivity test 1	5% AEP + 10% rainfall increase + 2.6m tailwater 1% AEP + 10% rainfall increase + 2.4m tailwater

	0.2% AEP + 10% rainfall increase + 2.6m tailwater PMF + 10% rainfall increase + 2.6m tailwater
Sensitivity test 2	5% AEP + 30% rainfall increase + 3.1m tailwater 1% AEP + 30% rainfall increase + 2.9m tailwater 0.2% AEP + 30% rainfall increase + 3.1m tailwater PMF + 30% rainfall increase + 3.1m tailwater
Sensitivity test 3	1% AEP + 30% rainfall increase + 3.1m tailwater (0.2% AEP and PMF scenarios covered in Sensitivity Test 2)

The consequences of climate change were assessed based on the impact on estimated flood damages, changes to above-floor property inundation and extent of hazardous (H4, H5, H6) areas.

8.2.1. Impacts on Property Inundation and Flood Damages

The impact of the climate change scenarios on property and flood damages for the 1% AEP event is presented in Table 20. This shows the catchment is sensitive to changes in climate conditions, with property affectation quickly rising (including above floor inundation). As a result the impact on tangible damages also quickly rises under future climate conditions.

Figure 92 through to Figure 100 shows the location of properties newly flooded above floor as a result of the various sensitivity runs. Property in South Golden Beach and Mullumbimby are particularly sensitive to the change in climatic conditions.

Table 20: Impact on Tangible Residential Damages and Above Floor Affectation, 1% AEP event

Scenario*	No. Properties Affected (change from existing)	No. Flooded Above Floor (change from existing)	Approximate Total Damages for Event (% change from existing)
Existing *2.1 m AHD (ocean dominated)* *2.0 m AHD (rain dominated)*	1117	503	$42.5m
2050 Sea Level Rise *2.6 m AHD (ocean dominated)* *2.2 m AHD (rain dominated)*	1195 (+7%)	568 (+13%)	$48.5m (+14%)
2100 Sea Level Rise *3.1 m AHD (ocean dominated)* *2.9 m AHD (rain dominated)*	1470 (+32%)	713 (+42%)	$63.6m (+50%)
Sensitivity Test 1 *2.6 m AHD (ocean dominated)* *2.2 m AHD (rain dominated)* *+10% rainfall*	1494 (+34%)	788 (+57%)	$66.6m (+57%)
Sensitivity Test 2 *3.1 m AHD (ocean dominated)* *2.9 m AHD (rain dominated)* *+30% rainfall*	2371 (+112%)	1456 (+189%)	$131.4m (+209%)
Sensitivity Test 3 *3.1 m AHD (ocean and rain dominated)* *+30% rainfall*	2438 (+118%)	1556 (+209%)	$141.7m (+233%)

* Scenarios are based on the 1% AEP envelope (rain and ocean dominated)

8.2.2. Impact on Flood Hazard

A comparison of the 2100 sea level rise scenario, and the sensitivity Test 3 from BSCCCP against the existing 1% AEP hazard classification is shown on Figure 90 and Figure 91 respectively.

For the sea level rise only scenario, there is a fairly constrained increase in the hazardous areas (H4 – H6), with most changes occurring near Ocean Shores and New Brighton, as well as to the east and south of Mullumbimby.

Under the increased rainfall and sea level rise scenario however, there is a widespread increase in hazardous areas, particularly H5 category, and many of the urban centres becoming more hazardous.

9. EXISTING FLOOD MANAGEMENT MEASURES

Flooding has occurred in the North Byron catchment many times in the past and the area has been subject to a substantial number of investigations, as summarised in Section 3 and Appendix B. As a result of these investigations, there are already a range of flood management measures in place, as described below, in addition to the land use planning and development controls described in Section 6.

9.1. Existing Structural Mitigation Measures

The community at South Golden Beach are currently protected from flooding by a levee along the eastern and western sections of Capricornia Canal. This levee was constructed in 1989 with pumps installed in 2006 to reduce flooding behind the levee. The levee is currently set at a level of 3.2 m AHD to protect South Golden Beach properties within the 1% AEP flood event and the location is shown in Diagram 21.

An overtopping / levee failure assessment was undertaken for the 1% AEP design event and the PMF design event to understand the potential impact to flood risk should the levee fail. Figure 101 through to Figure 102 present the results for the levee failure assessment. For the 1% AEP design event an additional 272 properties in South Golden Beach will be impacted from flooding with depths ranging from 0.1m to over 1m. The levee is already overtopped in the PMF design event and therefore there are negligible impacts seen in the peak level difference mapping.

Diagram 21: South Golden Beach Levee

The NSW Department of Works undertook a visual audit of the South Golden Beach levee in 2014 (Reference 14). The report documenting this audit (reference DC13063) includes a number of recommendations, predominantly regarding the clearing of vegetation and ongoing maintenance of the levee. Council should continue to work to implement these actions.

9.2. Flood Emergency Response Arrangements

Emergency response measures are an effective means of reducing the costs of flooding and managing the continuing and residual risks in an area. Current emergency response arrangements for the North Byron catchment are discussed below.

9.2.1. Emergency Response Planning Documentation

The North Byron catchment is covered by the Tweed Byron Local Emergency Management Plan (EMPLAN) September 2016 (Reference 15). The plan covers and details arrangements for the prevention, preparation, response and recovery for emergencies within the area. The plan has identified flood as an extreme risk priority for the Tweed / Byron local government areas. The EMPLAN identifies that the combat agency for flooding is the NSW SES, with the Byron Shire Local Flood Plan (Reference 12) developed as the sub plan of the Local EMPLAN.

The only major arterial road within the catchment identified in the Local EMPLAN is the Pacific Motorway.

The current Byron Shire Local Flood Plan was approved in July 2013 and covers preparedness measures, response operations and immediate recovery for both flooding and coastal erosion within the Byron Shire Local Government Area. The NSW SES Byron Shire Local Controller is responsible for responding to flooding as per the NSW State Flood Plan. Section 1.5 of the Local Flood Plan outlines the specific responsibilities relating to preparedness, response and recovery for relevant organisations including but not limit to the following; NSW SES Local Controller, NSW SES Mullumbimby Unit Members, Byron Local Emergency Operations Controller (LEOCON), Byron Shire Council Local Emergency Management Officer and Byron Shire Council.

Byron Shire Council is responsible for closing and reopening local roads and RMS is responsible for closing and reopening the Pacific Highway. While NSW Police Force do have the authority to close and reopen roads, this will typically only occur if council or RMS have not yet acted.

The plan notes that the ability to provide substantial property protection within the Byron Shire LGA may be limited due to the significant number of properties affected and also the depths associated with Brunswick River flooding. This supports a need to investigate alternatives to providing property protection such as adopting flood resilient design or retrofitting. Section 11.6 provides more detail on this.

There are two gauges within the catchment used for emergency response namely, the Federation Bridge gauge 202402 at Mullumbimby and the Billinudgel gauge 202400. Of these, the Bureau of Meteorology only provides flood warnings for Federation Bridge.

9.3. Evacuation Planning

During a flood which triggers evacuation, locations will need to be identified which are safe and able to accommodate the affected individuals. The Byron Shire Local Flood Plan details available evacuation centres within the catchment and evacuation routes for each locality.

The Byron Shire Local Flood Plan lists potential general conditions that may trigger evacuation in the Shire including failure of essential services, flooding of properties, isolation of properties and structural collapse. Specifically, for the localities of Mullumbimby and Brunswick Heads consideration of evacuation is triggered when Brunswick River at Federation Bridge is expected to rise above 3.5 m and 4.5m respectively. The Local Flood Plan notes that Brunswick Heads is vulnerable to tidal conditions and evacuation may be considered earlier if a high tide is expected. For South Golden Beach, the trigger for evacuation consideration is when it is expected floodwaters at the Billinudgel Gauge will rise above 3.5 m. South Golden Beach is protected by a levee as detailed in Section 9.1, and evacuation may be considered for this area when properties may be at risk of flooding from local runoff.

Of the evacuation centres located within the floodplain, the two evacuation centres in Mullumbimby, Civic Memorial Hall and the Ex-Services Club, experience above floor flooding in the 0.5% AEP event. The remaining evacuation centres do not experience above floor flooding in

the PMF flood event, however the Brunswick Heads Memorial Hall does experience flooding on the lot within the PMF flood event. Provided residents are able to promptly evacuate and reach these evacuation centres before access routes area cut, there are safe locations for residents to seek shelter. The majority of properties within Mullumbimby (identified as a Low Flood Islands) do not experience flooding until either the 0.2% AEP or PMF flood event. Either evacuation to the evacuation centres or sheltering-in-place would be possible for residents in Mullumbimby, assuming neighbours with raised floor levels would be willing to act as shelters for others in their community, however this is only viable for flood events up to the 0.5% AEP event. For events larger than 0.5% AEP, providing shelter to Mullumbimby residents will be challenging.

It is necessary to consider whether buildings are able to withstand the forces of floodwater, buoyancy and debris in large events, and remain safe for the entire duration of a flood. It is beyond the scope of this study to assess this on a building by building basis. In general however, light-framed weatherboard or timber dwellings sitting on stumps are at greater risk of being removed from their foundations, and brick, two-storey dwellings would generally be preferred as local refuges.

Isolation is another consideration. The tolerability of isolation reduces as the duration of flooding increases. In the modelled 1% AEP event affected residents would generally be isolated for no more than 20 hours. Whilst this is not ideal, and may be uncomfortable for residents, it is a tolerable duration of time to remain in situ.

The following section explores the evacuation constraints associated with each town in more detail.

9.3.1. Billinudgel

Billinudgel is primarily a commercial and industrial area, however contains some residential properties. The current evacuation trigger for Billinudgel is when the Billinudgel gauge reaches 3m and the Bureau predicts it with reach or exceed 3.5m. Evacuation for Billinudgel is via Wilfred Street, the Pacific Highway to Orana Road and eventually to the Ocean Shores Country Club. Ocean Shores Country Club is also the primary evacuation centre for Ocean Shores, South Golden Beach and New Brighton.

Wilfred Street becomes inundated prior to evacuation being triggered in Billinudgel. For the 2017 flood event, Wilfred Street was cut when the Billinudgel gauge reached approximately 2.8 mAHD. Depending on the timing of the flood and location of rainfall, the Billinudgel gauge level at which Wilfred Street is cut varies from approximately 1.9 mAHD up to 2.8 mAHD. Orana Road is inundated between the Kiah Close and Narooma Drive preventing access to Ocean Shores Country Club, however an alternate route has been identified via Brunswick Valley Way to Rajah Road, Warrambool Road to Ocean Shores Country Club.

There are 5 residential properties with above flood floor flooding in the 1% AEP flood event (Billinudgel gauge 4.2 mAHD) and these people could seek shelter with neighbouring properties. Billinudgel has been identified as a low flood island and the flood risk increases as events become larger leaving people trapped. Within the 0.2% AEP event (Billinudgel gauge 4.5 mAHD) there are

still some areas dry within Billinudgel and given the risk associated with people becoming trapped, consideration could be given to an alternate evacuation centre within Billinudgel safe from flooding above the PMF level.

9.3.2. Ocean Shores

Ocean Shores primarily comprises residential properties and has been identified as largely an area with rising road access meaning residents should be able to escape via road and the potential for residents to become isolated and trapped is not as high.

Evacuation of Ocean Shores is triggered when the Billinudgel gauge is predicted to exceed 3.5 mAHD. Evacuation is via local streets to Orana Road however Orana Road can become inundated between Kiah Close and Narooma Drive. An alternate route has been identified via Brunswick Valley Way to Rajah Road, Warrambool Road to Ocean Shores Country Club. It is recommended this route be promoted as the primary evacuation route for Ocean Shores.

Approximately 120 properties experience above floor flooding in the 1% AEP flood event and 614 properties in the PMF flood event. While there are significant numbers of residential properties inundated in Ocean Shores, there are safe means of evacuation to higher ground.

9.3.3. South Golden Beach

South Golden Beach is currently protected by a levee, however there may still be some flooding due to local drainage behind the levee. Section 9.1, explores the increased flood risk should the levee fail or overtop. Current evacuation trigger is when Billinudgel gauge reaches 3 mAHD and the Bureau also predict the gauge will reach or exceed 3.5 mAHD.

The primary evacuation centre for South Golden Beach is the Ocean Shores Country Club and evacuation is via Beach Avenue, Kallaroo Circuit, towards Brunswick Valley Way, Orana Road towards the country club. Shara Boulevard (the road out of South Golden Beach towards Brunswick Valley Way) is cut approximately when the Billinudgel gauge reaches 2.5 mAHD and prior to South Golden Beach experiencing flooding.

While South Golden Beach is protected by the levee, there still needs to be safe evacuation available should the levee fail or overtop. The Seventh Day Adventist is the alternate evacuation centre within South Golden Beach and is more viable for residents as access to Shara Boulevard is not required. The most vulnerable roads are Berrimbillah Court and Rangal Road, with Rangal Road typically being cut when the Billinudgel gauge reaches approximately 4 mAHD.

The Seventh Day Adventist has a short term capacity of 110 evacuees and a long term capacity of 63. The evacuation centre is not suitable for pets and does not have a back-up generator. Should evacuation via air be required, the Local Flood Plan notes the Community Building on Helen Street has capability of landing a helicopter. Within the 1% AEP flood event there are no residential properties that experience above floor flooding (not including any flood from local drainage), however there are 95 residential properties with above flood flooding in the 0.2% AEP flood event.

9.3.4. New Brighton

There are considerable evacuation constraints for New Brighton and the entire town has been identified as a low trapped perimeter with the main evacuation route experiencing frequent inundation often becoming cut prior to residents experiencing flooding. Flooding of this nature poses a real risk to life as people are isolated initially with no means of evacuation by foot or road and then become inundated.

The current evacuation trigger for New Brighton is when the Billinudgel gauge reaches 3 mAHD and the Bureau predict it will reach or exceed 3.5 mAHD. Evacuation is via River Street, The Esplanade, Strand Avenue to Orana Road. River Street starts overtopping at approximately when the Billinudgel gauge reaches 3.5 m AHD however depending on the timing and duration of the flood can be cut earlier. If required, evacuation via helicopter can occur via the New Brighton soccer field.

Approximately 105 residential properties are flooded above flood in the 1% AEP flood event and 192 in the PMF flood event. The constraints and potential recommendations for New Brighton are discussed further in Section 11.5.

9.3.5. Brunswick Heads

Brunswick Heads has been classified as an area with primarily rising road access meaning majority of people should be able to evacuate via road or on foot. The evacuation trigger for Brunswick Heads is when the Federation Bridge gauge at Mullumbimby is predicted to exceed 4.5 mAHD and evacuation is via local streets to Park Street or the Old Pacific Highway. If required, helicopters are able to land at the Brunswick Heads park adjacent to the war memorial and also at the sportsground south of the town near the Bowling Club.

The evacuation centre is noted in the Local Flood Plan as the RSL Hall on the corner of Park Street and Fawcett Street, however the plan also notes the Memorial Hall on Fingal Street. The Memorial Hall has been included within the Evacuation Centre Profiles at March 2019 and therefore has been considered the primary evacuation hall for Brunswick Heads.

Vulnerable roads in Brunswick Heads include roads from the Pacific Motorway roundabout to the corner of Fawcett Street, with Tweed Street being cut when the Federation Bridge gauge approximately reaches 4.3 mAHD. As no two floods are the same, the gauge level at which Tweed Street is impacted may change and for some event durations the Federation Bridge gauge level can be up to 5 mAHD or 5.5 mAHD.

9.3.6. Mullumbimby

Mullumbimby has been classified as either low flood island, overland escape route or rising road access. The majority of Mullumbimby with residential and commercial development has been classified as a low flood island as most roads in and out are cut. Evacuation for Mullumbimby is triggered when Federation Bridge reaches 3.5 mAHD. The primary evacuation centre is the Mullumbimby Ex-Servicemen’s club and the alternate evacuation centre is the Mullumbimby Civic

Memorial Hall (directly opposite the Ex-Services club). Evacuation for west Mullumbimby is via local roads to Main Arm Road, Coolamon Scenic Drive, Tincogan Street to Dalley Street. For south Mullumbimby, evacuation is via local streets to Jubilee Avenue to Dalley St. The roof of the old Mullumbimby Hospital used to be suitable for helicopters to land, however as the hospital has now been demolished the only alternate option is the Mullumbimby showgrounds. As these grounds are flood prone, a new area should be investigated that is appropriate to land a helicopter during flood events.

For residents in east Mullumbimby, access to the evacuation centres is less restricted than for those in west and south Mullumbimby. However the area is classified as a low flood island with majority of roads within the area being inundated early. Of particular note is the area around Argyle Street which becomes isolated before being inundated meaning people may not be able to access the evacuation centres without sufficient warning. A large proportion of the area is inundated in a 1% AEP flood event (Federation Bridge gauge 5.3 mAHD). Dalley Street (location of both evacuation centres) is generally overtopped when the Federation Bridge gauge reaches 5 mAHD. Mullumbimby Road is a known access road in and out of Mullumbimby, and while it is outside the study area it has been noted this road is frequently inundated due to flash flooding.

West Mullumbimby is relatively dry in the 1% AEP flood event and both Federation Bridge and Main Arm Road are still open. However Main Arm Road is cut further upstream from west Mullumbimby. In a 0.2% AEP flood event (Federation Bridge gauge 5.7 mAHD), west Mullumbimby still has some areas that are free from flooding. For residents in west Mullumbimby, evacuation to the Mullumbimby Civil Memorial Hall requires people to potentially traverse floodwaters before reaching the evacuation centre. Depending type of flood event Tincogan Street can be overtopped when the Federation Bridge gauge reaches anywhere between approximately 3.5 mAHD to 5 mAHD. For the 2017 flood event, Tincogan Street was overtopped when the Federation Bridge gauge reached 5.11 mAHD.

South Mullumbimby is isolated first with Jubilee Avenue being overtopped in events as frequent as the 0.2 EY event. For the 2017 flood event Jubilee Avenue was overtopped at the high school when the Federation Bridge gauge reached 4.51 mAHD, however depending on the flood behaviour, the road can be cut when the gauge reaches just over 3 mAHD.

For the 1% AEP flood event and larger there is limited dry land in East Mullumbimby. Priority should be for those in the vicinity of Argyle Street as the area is isolated first preventing access to the evacuation centres. Community education should focus on ensuring these residents are aware of their risk and evacuation routes. For the 0.2% AEP flood event when the Federation Bridge gauge level is approximately 5.7 mAHD, there is still dry land in west Mullumbimby and South Mullumbimby. However, this is an extremely complex area of the catchment with three waterways interacting resulting in cross floodplain flowpaths. For rarer flood events land available for shelter in west and south Mullumbimby decreases as does access out of the floodplain.

9.3.7. Evacuation Centre Capacity

9.3.7.1. Brunswick Heads

The current evacuation centre in Brunswick Heads, Brunswick Civic Memorial Hall, only has a short term evacuation capacity of 200 people a long term capacity of 114. The Hall is not suitable for pets and does not have a backup power source. For the 1% AEP flood event there are 63 residential properties[2] (approximately 126 residents) that experience above floor flooding and this increases to 401 (approximately 802 residents) in the PMF flood event. A breakdown of potential evacuee numbers is provided in Table 21 below. While this evacuation centre does not have capacity to provide shelter to the anticipated number of residents, for events up to the 0.2% AEP flood event there is still substantial flood free land and these residents could seek shelter with neighbours free from floodwaters.

Table 21: Estimated Brunswick Heads residents whi may require shelter based on the census average people per dwelling.

Event	No. of Properties Flooded Above Floor Level	Estimated people based on census average people per dwelling (2)
0.2 EY	0	0
10% AEP	4	8
5% AEP	5	10
2% AEP	23	46
1% AEP	63	126
0.5% AEP	83	166
0.2%PMF	101	202
PMF	401	802

Consideration needs to be given for events larger than the 0.2% AEP (Federation Bridge gauge approximately exceeds 5.68 mAHD) or for events with significant tidal influence as the number of evacuees increases substantially. However, the area is primarily rising road access therefore residents should be able to seek shelter at nearby evacuation centres outside the flood extent.

9.3.7.2. Ocean Shores, Billinudgel, South Golden Beach and New Brighton

Ocean Shores Country Club is the primary evacuation centre for Ocean Shores, Billinudgel and New Brighton. The short term capacity of Ocean Shores Country Club is 600 evacuees and a long term evacuation capacity of 260 evacuees. For the PMF flood event, 23 residential properties (approximately 58 residents) in Billinudgel experience over floor flooding, 192 (approximately 403 residents) in New Brighton, 614 (approximately 1474 residents) in Ocean Shores, and 352 (approximately 880 residents) in South Golden Beach. Table 22 through to Table 25 provide a breakdown of potential evacuee numbers in each town. However, residents from South Golden Beach, Billinudgel and New Brighton may not be able to evacuate to Ocean Shores due to evacuation routes being cut.

[2] It is not possible to determine the number of residents based solely on the property database created for this study. Census data for each town provides an average number of residents per property. Numbers in brackets and tables represent the calculated residents based on this average, but must be considered approximate only.

Table 22: Estimated Billinudgel residents who may require shelter based on the census average people per dwelling.

Event	No. of Properties Flooded Above Floor Level	Estimated people based on census average people per dwelling (2.5)
0.2 EY	1	3
10% AEP	2	5
5% AEP	3	8
2% AEP	3	8
1% AEP	5	13
0.5% AEP	11	28
0.2%PMF	15	38
PMF	23	58

Table 23: Estimated New Brighton residents who may require shelter based on the census average people per dwelling.

Event	No. of Properties Flooded Above Floor Level	Estimated people based on census average people per dwelling (2.1)
0.2 EY	5	11
10% AEP	11	23
5% AEP	24	50
2% AEP	97	204
1% AEP	105	221
0.5% AEP	109	229
0.2%PMF	120	252
PMF	192	403

Table 24: Estimated Ocean Shores residents who may require shelter based on the census average people per dwelling.

Event	No. of Properties Flooded Above Floor Level	Estimated people based on census average people per dwelling (2.4)
0.2 EY	0	0
10% AEP	0	0
5% AEP	2	5
2% AEP	14	34
1% AEP	38	91
0.5% AEP	46	110
0.2%PMF	120	288
PMF	614	1474

Table 25: Esimtated South Golden Beach residents who may require shelter based on the census average people per dwelling.

Event	No. of Properties Flooded Above Floor Level	Estimated people based on census average people per dwelling (2.5)
0.2 EY	0	0
10% AEP	0	0
5% AEP	0	0
2% AEP	0	0
1% AEP	0	0
0.5% AEP	0	0
0.2%PMF	95	238
PMF	352	880

Residents in South Golden Beach are largely protected from flooding up to and including the 0.2% AEP event (Billinudgel gauge approximately 4.51 mAHD). Those who do experience above floor flooding in the 0.2% AEP could evacuate to Seventh Day Adventist or seek shelter with neighbours. There is a real evacuation risk should the levee at South Golden Beach fail or overtop and there would likely be an emergency rescue response required in this event.

There are still areas of Ocean Shores outside the PMF flood extent and Ocean Shores has been identified as a rising road access area. Flood free properties in these areas could provide shelter to those evacuating to reduce the number of evacuees seeking shelter at the country club.

Residents in northern New Brighton are trapped and need both another evacuation centre to seek shelter and also improved access. New Brighton has been identified as a low trapped perimeter and due to the risk to life and evacuation constraints it is expected there may be emergency evacuation response requirements for residents in these areas. Potential management measures for New Brighton are explored further in Section 11.5.3.

Billinudgel is mostly industrial and commercial, however for the residents in Billinudgel there is the potential to become trapped. While there is still dry land in a 0.2% AEP event, consideration needs to be given to either improving flood access to evacuate or identify an alternate evacuation centre in Billinudgel above the PMF. As discussed in Section 9.3 of the FRMS, this does not take into account whether buildings can structurally withstand the force of the water. Section 12.1.1 and Section 11.5.4 explore structural options to improve the flood risk in Billinudgel and also increasing the immunity of Wilfred Street, the main evacuation route out. If it is expected evacuation numbers are likely to exceed the capacity of the Ocean Shores Country Club, residents from Billinudgel could be directed to the Wilsons Creek Community Hall. This hall is well outside the study area and it is unclear what the flood risk may be through these areas. Evacuation capacity of Wilsons Creek Community Hall is only 40 people short term and 23 people long term.

9.3.7.3. Mullumbimby

There are two available evacuation centres in Mullumbimby with a combined short term stay evacuation capacity of 400 people. Mullumbimby Civic Memorial Hall is flooded above ground level in the 1% AEP flood event and is flooded above floor level in the 0.5% AEP event (Federation Bridge gauge 5.49 mAHD). The short term evacuation capacity is 200 evacuees and long term capacity is 114. The hall is not suitable for pets and does not have a backup power supply. The Mullumbimby Ex-Services club experiences above ground flooding for the 2% AEP flood event and above floor flooding for the 0.5% AEP event. The ex-services club has a similar evacuation capacity to the memorial hall, is not suitable for pets however does have a back up generator for the main club.

Approximately 152 residential properties (approximately 365 residents) experience above floor flooding in the 1% AEP flood event, and up to 1178 residential properties (approximately 2827 residents) in the PMF flood event. Mullumbimby does not have the capacity to provide shelter to the potential number of residents seeking shelter. In a 0.2% AEP event (Federation Bridge gauge approximately 5.68 mAHD), there are still approximately 495 residential properties (approximately 1188 residents) with above floor flooding. Table 26 provides a breakdown of potential evacuee numbers in Mullumbimby.

Table 26: Estimated Mullumbimby residents who may require shelter based on the census average people per dwelling.

Event	No. of Properties Flooded Above Floor Level	Estimated people based on census average people per dwelling (2.4)
0.2 EY	2	5
10% AEP	8	19
5% AEP	25	60
2% AEP	87	209
1% AEP	152	365
0.5% AEP	303	727
0.2%PMF	495	1188
PMF	1178	2827

For events up to the 0.5% AEP event residents will be able to seek shelter either at the evacuation centres or with neighbours who are safe from above floor flooding. However, for events larger than the 0.5% AEP the evacuation centres become inundated and are no longer viable for safe refuge. While there is still flood free land available in the 0.2% AEP flood event, there needs to be an alternative evacuation centre within Mullumbimby that can provide a space safe from flooding up to the PMF event.

There is a risk that as the magnitude of flood events increase, residents within Mullumbimby may become isolated without anywhere to seek refuge. Unless evacuation occurs early enough, there may not be enough time for everyone to evacuate to centres outside the flood extent and the risk to life increases. Given the complexity of this area and to fully understand the potential constraints, it is recommended an evacuation assessment is conducted for Mullumbimby.

10. ECONOMIC IMPACT OF FLOODING

10.1. Overview

Economic assessments of flooding consider the costs caused by damage to communities as a result of flood events. This damage can be defined as either tangible or intangible. Tangible damages are those for which a monetary value can be easily assigned, while intangible damages are those to which a monetary value cannot easily be attributed. Damages are further categorised as being either direct or indirect. Direct damages are caused by direct interaction with the floodwaters, causing damage or disruption. Indirect damages are the knock-on effects from the flood events, such as loss of wages, traffic disruption, and loss of community welfare.

The common categories of flood damages are shown in Diagram 22.

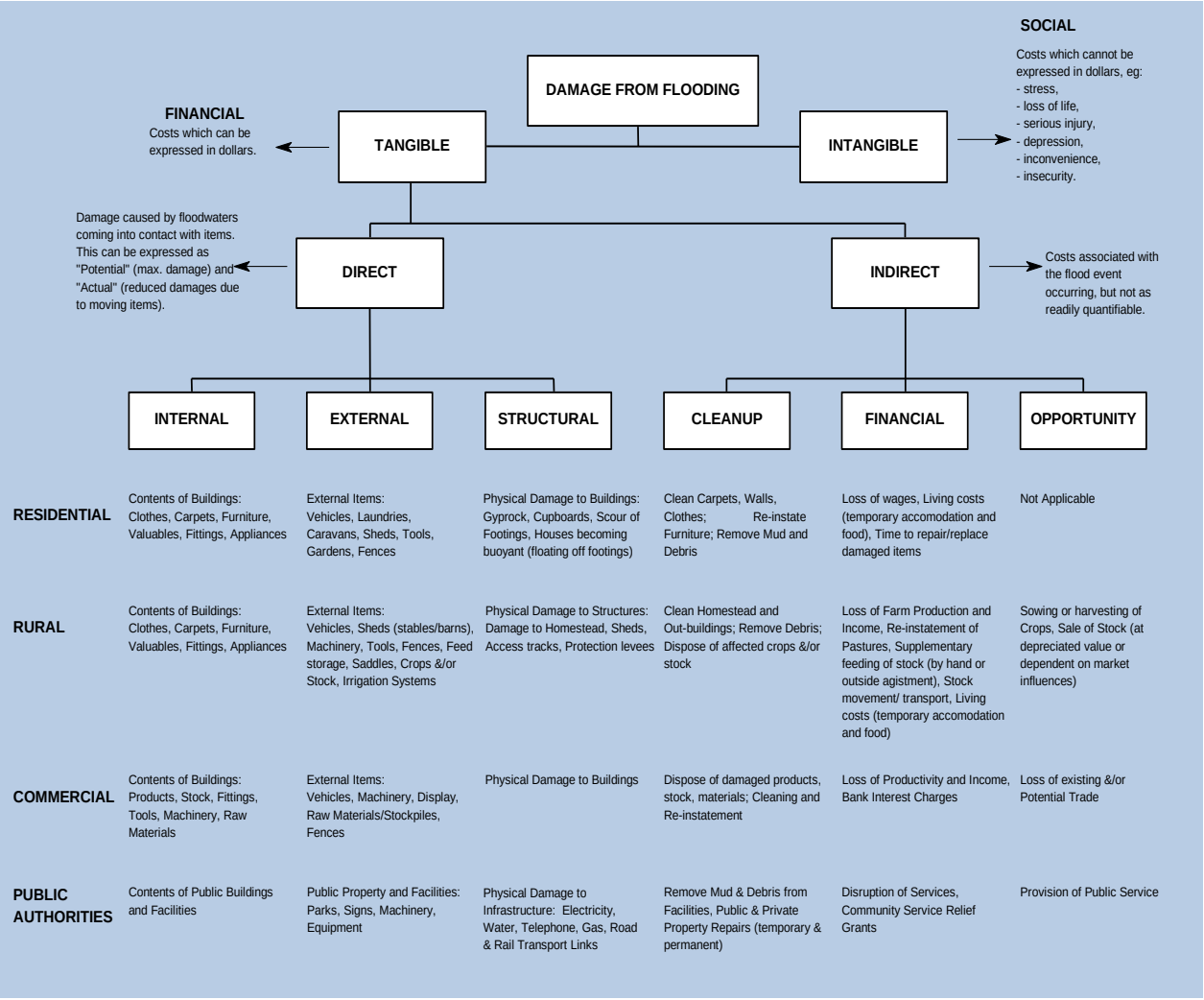


Diagram 22: Flood Damages Categories

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 asset and infrastructure affected.

Flood damage assessments attempt to quantify this wide range of impacts to provide an assessment of the economic loss caused by flooding. This can then be used to determine the benefits of proposed mitigation strategies, whereby the reduction in damage is considered the benefit of the mitigation option. When compared to the cost of implementing the measure, this results in the determination of a benefit cost ratio, with anything over one considered economically viable, or delivering value for money.

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.

10.2. Flood Damages Assessment

Damage calculations were carried out for all properties within the PMF extent, using the survey data and modelled flood level information. 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.

The total estimated damages from both residential and non-residential properties are provided in Table 27. Damages were calculated for residential and commercial/industrial properties separately as discussed in the following sections.

The flood damages estimates do not include the cost of restoring or maintaining public services and infrastructure. It should also be noted that damages calculations do not take into account flood damages to any basements or cellars, hence where properties have basements, damages can be under estimated.

The damage calculations are based on the property survey, described in Section 2.5. The classification of a “habitable” floor was based on visual inspection only. As such, properties which

may have created habitable spaces in under croft areas which do not mean Building Code or Council's planning requirements will still be recorded as habitable in this survey. As such, some of the above floor inundation determined below may include damages associated illegal building structures.

Table 27: Estimated Total Flood Damages (residential & non-residential) for North Byron catchment

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property
0.2 EY	75	21	$1,893,200	$25,240
10% AEP	166	45	$3,616,800	$21,790
5% AEP	381	89	$8,009,700	$21,020
2% AEP	800	314	$25,153,400	$31,440
1% AEP	1118	503	$42,514,900	$38,030
0.5% AEP	1416	753	$63,194,200	$44,630
0.2%PMF	2158	1208	$106,413,500	$49,310
PMF	3374	3122	$391,795,500	$116,120
Average Annual Damages (AAD)			**$2,667,100**	**$ 790**

10.2.1. Residential Properties

Table 28 provides the calculation of damages for residential properties only in the catchment. Residential property damage contributes 77% of the average annual damage in the North Byron catchment. 89% of the total number of properties flood affected and 88% of properties inundated above floor are residential. For the 1% AEP event, residential properties account for 82% of the flood affected properties in the catchment and contribute 73% of the total tangible damages calculated.

Table 29 to Table 34 provide a breakdown of residential damage by suburb.

Table 28: Estimated Total Flood Damages (residential) for North Byron catchment

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property
0.2 EY	52	8	$734,600	$14,130
10% AEP	130	25	$1,989,500	$15,300
5% AEP	337	59	$5,330,300	$15,820
2% AEP	654	224	$18,306,000	$27,990
1% AEP	917	363	$31,089,900	$33,900
0.5% AEP	1158	552	$47,368,600	$40,910
0.2%PMF	1853	946	$84,607,600	$45,660
PMF	3002	2759	$348,147,100	$115,970
Average Annual Damages (AAD)			**$1,837,200**	**$ 610**

Estimated damages for each suburb are provided below. Damages resulting from residential properties in Mullumbimby contributes 45% of the overall residential damages, with a further 27% from the residential properties in New Brighton.

Table 29: Estimated Total Flood Damages (residential) for Billinudgel

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property
0.2 EY	12	1	$ 147,100	$ 12,260
10% AEP	14	2	$ 233,600	$ 16,690
5% AEP	14	3	$ 270,500	$ 19,320
2% AEP	15	3	$ 329,100	$ 21,940
1% AEP	17	5	$ 426,700	$ 25,100
0.5% AEP	23	11	$ 801,600	$ 34,860
0.2%PMF	29	15	$ 1,196,100	$ 41,250
PMF	35	23	$ 2,473,900	$ 70,680
Average Annual Damages (AAD)			**$ 74,100**	**$ 2,120**

Table 30: Estimated Total Flood Damages (residential) for Brunswick Heads

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property
0.2 EY	1	0	$ 2,900	$ 2,890
10% AEP	7	4	$ 149,000	$ 21,290
5% AEP	10	5	$ 334,000	$ 33,400
2% AEP	37	23	$ 1,595,700	$ 43,130
1% AEP	94	63	$ 4,867,700	$ 51,780
0.5% AEP	115	83	$ 6,780,000	$ 58,960
0.2%PMF	141	101	$ 9,316,600	$ 66,080
PMF	531	401	$ 45,638,600	$ 85,950
Average Annual Damages (AAD)			**$ 187,900**	**$ 350**

Table 31: Estimated Total Flood Damages (residential) for Mullumbimby

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property
0.2 EY	18	2	$ 205,100	$ 11,390
10% AEP	70	8	$ 803,00	$ 11,470
5% AEP	240	25	$ 2,815,900	$ 11,730
2% AEP	423	87	$ 7,989,300	$ 18,890
1% AEP	581	152	$ 14,195,500	$ 24,430
0.5% AEP	774	303	$ 26,601,800	$ 34,370
0.2%PMF	998	495	$ 43,317,300	$ 43,400
PMF	1233	1178	$146,961,700	$ 119,190
Average Annual Damages (AAD)			**$ 833,400**	**$ 680**

Table 32: Estimated Total Flood Damages (residential) for New Brighton

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property
0.2 EY	21	5	$ 379,500	$ 18,070
10% AEP	38	11	$ 802,400	$ 21,120
5% AEP	68	24	$ 1,755,800	$ 25,820
2% AEP	150	97	$ 7,222,600	$ 48,150
1% AEP	156	105	$ 8,625,100	$ 55,290
0.5% AEP	158	109	$ 9,403,800	$ 59,520
0.2%PMF	169	120	$ 11,897,000	$ 70,400
PMF	196	192	$ 28,948,400	$ 147,700
Average Annual Damages (AAD)			**$ 504,200**	**$ 2,570**

Table 33: Estimated Total Flood Damages (residential) for Ocean Shores

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property
0.2 EY	0	0	$ -	$ -
10% AEP	1	0	$ 1,500	$ 1,500
5% AEP	5	2	$ 154,000	$ 30,800
2% AEP	29	14	$ 1,169,400	$ 40,300
1% AEP	69	38	$ 2,974,900	$ 43,100
0.5% AEP	88	46	$ 3,781,300	$ 43,000
0.2%PMF	230	120	$ 11,139,300	$ 48,400
PMF	650	614	$ 77,674,300	$ 119,500
Average Annual Damages (AAD)			**$ 172,200**	**$ 270**

Table 34: Estimated Total Flood Damages (residential) for South Golden Beach

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property
0.2 EY	0	0	$ -	$ -
10% AEP	0	0	$ -	$ -
5% AEP	0	0	$ -	$ -
2% AEP	0	0	$ -	$ -
1% AEP	0	0	$ -	$ -
0.5% AEP	0	0	$ -	$ -
0.2%PMF	286	95	$ 7,741,300	$ 27,070
PMF	358	352	$ 46,540,700	$ 130,000
Average Annual Damages (AAD)			**$ 65,600**	**$ 180**

10.2.2. Non-residential – Commercial and Industrial

The total non-residential damages for the North Byron catchment are shown in Table 35. Whilst only 11% of the properties are non-residential, they are contributing to 31% of the AAD. This is due to a higher proportion of non-residential properties inundated in the more frequent events and generally received higher depths of inundation.

Table 35: Estimated Total Flood Damages (commercial and industrial) for North Byron catchment

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property
0.2 EY	23	13	$1,158,600	$50,370
10% AEP	36	20	$1,627,300	$45,200
5% AEP	44	30	$2,679,400	$60,900
2% AEP	146	90	$6,847,400	$46,900
1% AEP	201	140	$11,424,900	$56,840
0.5% AEP	258	201	$15,825,600	$61,340
0.2%PMF	305	262	$21,805,900	$71,500
PMF	372	363	$43,648,400	$117,330
Average Annual Damages (AAD)			**$829,800**	**$ 2,230**

11. FLOODPLAIN RISK MANAGEMENT MEASURES

This FRMS aims to identify and assess risk management measures which could be put in place to mitigate flood risk and reduce flood damages. As well as the hydraulic impacts, flood risk management measures are assessed against the legal, structural, environmental, social and economic conditions or constraints of the local area. In the following sections a range of management options are considered to determine the effectiveness in managing existing and future flood risks in the North Byron catchment.

11.1. Categories of Floodplain Risk Management Measures

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

- **Flood modification measures (Section 11.4)** modify the physical behaviour of a flood including depth, velocity and redirection of flow paths. Typical measures include flood mitigation dams, retarding basins, channel improvement, levees or defined floodways. Pit and pipe improvement and even pumps may also be considered where practical.

- **Response modification measures (Section 11.5)** modify the response of the community to flood hazard by educating flood affected property owners about the nature of flooding so that they can make better informed decisions. Examples of such measures include provision of flood warning and emergency services, improved information, awareness and education of the community, and provision of flood insurance.

- **Property modification measures (Section 11.6)** modify the existing land use and development controls for future development. This is generally accomplished through such means as flood proofing, house raising or sealing entrances, strategic planning such as land use zoning, building regulations such as flood-related development controls, or voluntary purchase / voluntary house raising.

Table 36 provides a summary of all the options considered in this study.

Table 36: North Byron Catchment management long-list of options considered and initial assessment recommendations

Category	Option	ID	Description	Recommended for further assessment
Flood Modification Measures	Levee	BL	Billinudgel Levee	**See CB02**
		SGBA	South Golden Beach levee audit recommendations	**Yes**
	Channel Modification	BP01	Kings Creek Bypass Floodway	No
		BP02	Saltwater Creek Upgrade	**Yes**
		DO	Dune Openings	No
		RW	Rock Wall Modifications	No
		TW	Removal of Brunswick River Training Wall	No
	Channel Maintenance	BRM01	Brunswick River Dredging at Mullumbimby	No
		BRM02	Brunswick River and Tributaries	No

Category	Option	ID	Description	Recommended for further assessment
		MC	Marshalls Creek Dredging at Ocean Shores	No
	Drainage Modification	AC	Avocado Court	**Yes**
		NCD	Options identified in New City Road drainage assessment	**Yes**
		CDM	Catchment wide drainage and overland flow model	**Yes**
	Drainage Maintenance	FDC	Debris Control Measures for Federation Bridge and the Billinudgel Railway Bridge	**Yes**
	Hydraulic Structures	GCW	Ocean Shores Golf Course Weir Lowering	No
		BM	Billinudgel Infrastructure Improvements	**See CB02**
	Flood Storage Areas	SW	Saltwater Creek Flood Storage Area	No
	Combined Option	CB01	Marshalls Creek Dredging (MC), Dune Openings (OO), Rock Wall Modification (RW) and Kallaroo Circuit Bund Modification	No
		CB02	Billinudgel Infrastructure (BM) and Billinudgel Levee (BL)	**Yes**
	Fencing across waterways	WFG	Develop guidance on the design and installation of fencing traversing waterways and channels	**Yes**
Response Modification Options	Emergency Planning	RM01	Update the Local Flood Plan based on outcomes of this report and collaboration between Council and the SES.	**Yes**
	Flood Warning	RM02	Byron Shire Council and SES to consider learnings and recommendations from this FRMS in the development of the Flood Warning Network for North Byron.	**Yes**
	Improving road access	RM03	Raising River Street to provide 1% AEP flood immunity and investigating a location for a new Evacuation Centre near Gaggin Street or Terrace Street.	**Yes**
		RM04	Raising Wilfred Street to provide 1% AEP flood immunity.	No
	Road Closures	RM05	Identify key roads and implement automatic warning signs and depth indicators.	**Yes**
	Community Education and Awareness	RM06	Community engagement to prepare an ongoing flood education program (and appropriate evaluation system)	**Yes**
	Mullumbimby Evacuation Assessment	RM07	Undertake a detailed evacuation assessment for the Mullumbimby township for a range of design events.	**Yes**
Property Modification Options	Voluntary House Raising	PM01	Assesses raising eligible residential properties to reduce flood damages.	**Yes**
	Voluntary House Purchase	PM02	Assesses purchasing eligible residential properties to remove residents from high flood risk areas and reduce floodway obstruction.	**Yes**
	Land Use Zoning	PM03	Changes to land use zoning should consider flood compatibility using outcomes from this report. Update flood hazard overlay based on the findings of this study	**Yes**
	Flood Planning Levels	PM04	Revise Flood Planning Levels based on the findings of this study	**Yes**
	Flood Planning Area	PM05	Updated FPA based on the findings of this study	**Yes**
	Changes to Development Control Plan	PM06	DCP updated with based on recommendations of this FRMS	**Yes**
	Flood Proofing	PM07	Provide more detailed guidance on the principles of wet proofing, appropriate design and materials, with direct reference to available guidelines	**Yes**
	Property Level Protection	PM08	Undertake more detailed assessment of properties which may benefit from property level protection	**Yes**
	S10.7 Certificates	PM09	Provide flooding info on Council's website, include up to date flooding info on future s10.7 (2) and (5) certificates requested	**Yes**
	Future Development controls	PM10	Further investigation into appropriate controls to manage impacts from future development	**Yes**

11.2. Assessment Methodology

The assessment process starts with identifying a wide range of options that may have the potential to reduce flood risk across the catchment. To date, these options have been gathered from the community via the initial consultation period, as well as discussions with Council and the Floodplain Management Committee (FMC). The options are initially assessed for the 1% AEP design event only[3], to determine the extent of impact on flood behaviour. Those which are shown to have favourable impacts would then be subjected to a more detailed assessment, which considers a range of factors including environmental, social, financial and economic impacts. The assessment process is illustrated below.

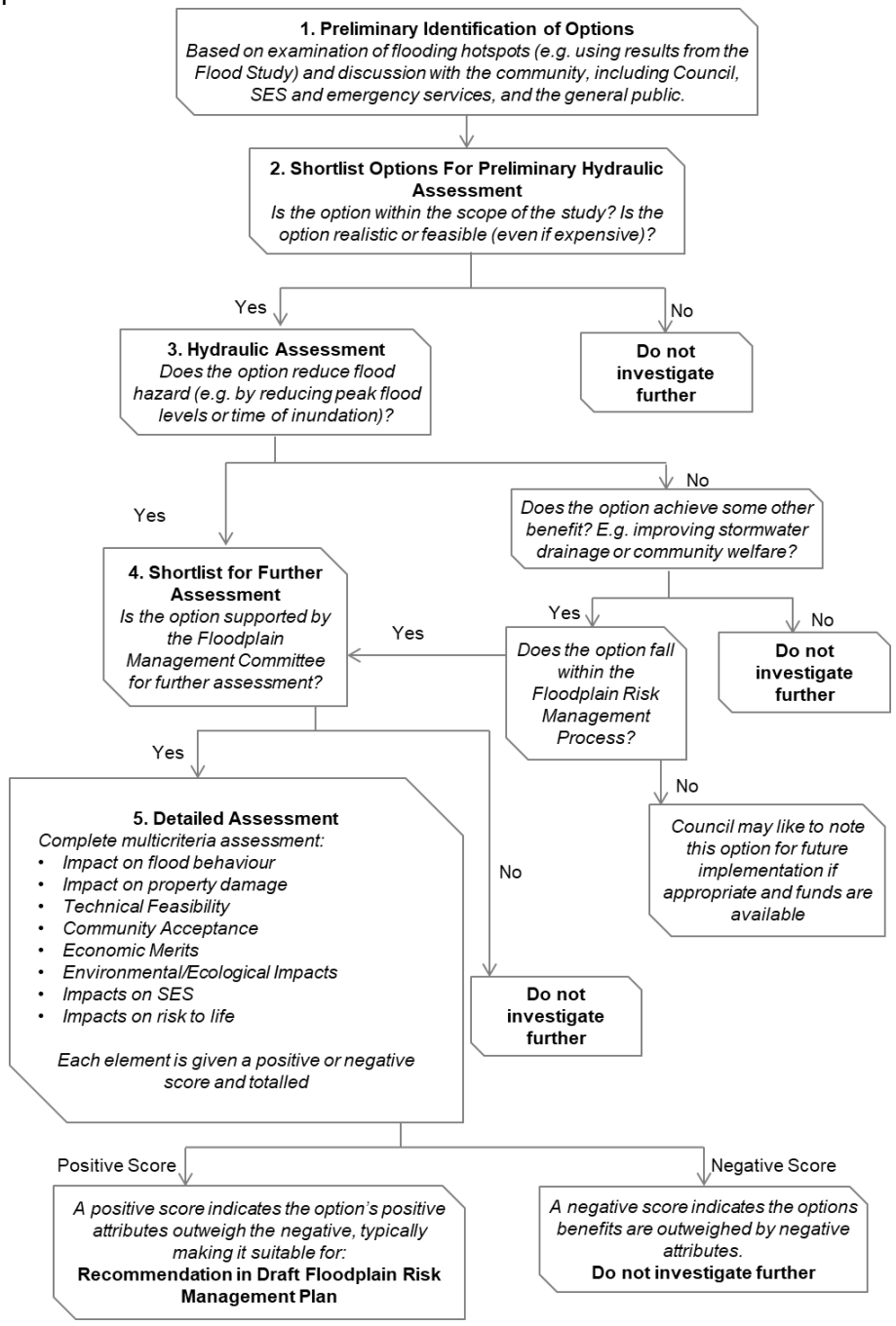


Diagram 23: Flood Mitigation Assessment Methodology

[3] As discussed in Section 4.2.1 and Section 4.5, the 1% AEP event is an envelope of a number of scenarios which consider both ocean dominated, and rainfall dominated events. In accordance with DPIE guidance, each design event is determined from the peak of both the catchment scenario and oceanic scenario to provide the highest water levels.

11.3. Community Input

As part of the community survey carried out in June 2018, community members provided valuable insight into problematic flooding hotspots, and offered a range of suggestions of possible solutions. The inclusion of community suggestions in the subsequent option assessment is critical to identifying useful and effective flood risk mitigation options, as well as fostering a sense of ownership of the Floodplain Risk Management Study in the community. Some key findings from the community consultation relevant to the identification and assessment of floodplain risk management options for the North Byron study area are detailed below.

The top three structural options the community support are:

1. Stormwater pipes, gutters and drain upgrades
2. Landscape management
3. Dredging

The top three management options important to the community are:

1. Removal of blockages and debris from streams
2. Early flood warning (e.g. mobile phone alerts)
3. Structures such as detention basins and levees

The three most important outcomes to the community when considering flood management options are:

1. Increases community safety during floods
2. Reduces the cost of floods
3. Does not disadvantage other parts of the community

11.4. Flood Modification Measures

11.4.1. Levees and Embankments

Levees involve the construction of raised embankments between the watercourse and flood affected areas so as 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.

Flood gates, flap valves and pumps are often associated with levees to prevent backing up of drainage systems in the area protected by a levee and/or to remove ponding of local water behind the levee. These types of infrastructure are vital for the effectiveness of a levee. In addition, as the levee causes displacement of water from one area of the floodplain to another they need to be carefully design so as to ensure the levee does not increase flood risk to adjacent areas.

The crest height of a levee is set at a level that equals the height of the design flood event for which it is designed to protect against, plus an allowance for freeboard. The freeboard allows for: settlement of the structure overtime, variations in flood levels due to the behaviour of the flood event, wave action from passing vehicles or watercraft and effects of wind. A preliminary freeboard of 0.5 m has been assumed for the options discussed below, however the appropriateness of this

freeboard allowance would need to be confirmed via a detailed freeboard assessment if the option were to progress. Levees would also be typically constructed with a spillway with a lesser amount of freeboard. A spillway is a lower portion of the levee which allows for controlled overtopping of the levee to minimise the damage to the structure in floods larger than the design level of protection. As the subsequent section is a preliminary assessment only, no spillway has been included in the modelled options.

Once constructed, levee systems generally have a low maintenance cost though the levee system needs to be inspected on a regular basis. In 2014 the NSW Department of Works undertook a visual audit of the South Golden Beach levee (Reference 14). This report included a number of recommendations for implementation, predominantly linked to vegetation management and ongoing maintenance. These recommendations have been recommended for implementation as part of the ongoing flood management strategy for the catchment.

ASSESSMENT

Option BL – Billinudgel Levee

A levee for the township of Billinudgel has been considered **(Option BL)** as part of this FRMS. A levee option for Billinudgel was originally investigated in the Brunswick River Floodplain Management Investigation delivered in 1989 (Webb McKeown & Associates, 1989) and was found to have minimal adverse impacts downstream, however the option was not explored any further.

A variation of this levee option has been assessed and was extended further west to capture additional properties behind the levee. Modelling of this option includes a levee of approximately 650 m in length and runs from west to east along Gerald Street and O'Donnells Lane just south of Marshalls Creek. The levee level was set to 4.7 m AHD (approximately 0.2 m to 0.3 m above 1% AEP peak flood level) but varies depending on the ground level and can reach 3.5 m in some areas. Details of the levee configuration are shown in Diagram 24.

Option BL Preliminary Results

Preliminary results for the 1% AEP flood event for a levee at Billinudgel indicated widespread reduction in flood levels of up to 0.38 m. Increases in flood levels are relatively minor (approximately 0.05 m) extending approximately 1.5 km upstream of the railway and primarily in areas without properties. The area behind the levee is still flood affected due to overland flow from the southern catchment.

Results from the community survey indicate the North Byron community are generally neutral about building flood levees in the North Byron catchment with responses ranging from very supportive to strongly oppose with approximately equal weighting. The respondents from Billinudgel ranged in support levels for levees, however more respondents were opposed. Should this option be considered further, it is recommended the Billinudgel community be consulted with further about levees in this area of the floodplain.

Diagram 24: Option BL - Billinudgel levee.

It is recommended this option be considered further and progress to a detail assessment.

SUMMARY

	Levee Recommendations
☑	**Option BL** - A levee for Billinudgel should be considered further as part of the detailed assessment.
☑	**Option SGBA -** Implement the recommendations of the South Golden Beach levee audit.

11.4.2. Temporary Flood Barriers

Temporary flood barriers include demountable defences, wall systems and sandbagging for deployment prior to the onset of flooding. Demountable defences can be used to protect large areas and are often used to assist in current mitigation measures rather than as sole protection measures. For example, they are best used to fill gaps in levees or to raise them as the risk of levee overtopping develops. The effectiveness of these measures relies on sufficient warning time and the availability of a workforce to install them, and suitable sites for storage when not in use. They are more likely to be used for mainstream fluvial flooding from rivers which have sufficient warning time and are not a suitable technique for smaller catchments with shorter response times. No locations for temporary flood barriers were identified.

SUMMARY

	Temporary Flood Barriers Recommendations
☒	No suitable locations for temporary flood barriers

11.4.3. Channel Modification

Channel modifications are undertaken to improve the conveyance and/or capacity of a river/creek system. This includes a range of measures from straightening, concrete lining and removal/augmentation of structures. While channel modifications can help to reduce peak upstream flood levels, they may also increase flood levels in adjacent or downstream locations. The effectiveness of channel modifications depends upon the characteristics of the river channel and valley in which it lies.

Floodways are lower overbank areas which can carry significant flow volumes in times of flood and occur naturally on some floodplains. In some instances, on smaller streams, an artificial floodway can be created in an environmentally sensitive manner to achieve a reduction in upstream flood levels.

A number of channel modification options have been considered, specifically:

- Kings Creek modification
- Saltwater Creek modification
- Brunswick River mouth rock wall removal
- Rock wall modification at Marshalls Creek east, and the confluence with Brunswick River
- Ocean outlet management

ASSESSMENT

Option BP01 – Kings Creek Bypass Floodway

This option assessed the excavation of a new bypass channel from Mullumbimby to the east via Kings Creek. Modelling of this option looked at excavating a 5 m wide channel approximately 1 m deeper than the existing Kings Creek. This equates to the removal of approximately 15,000 m^3 of creek bed material.

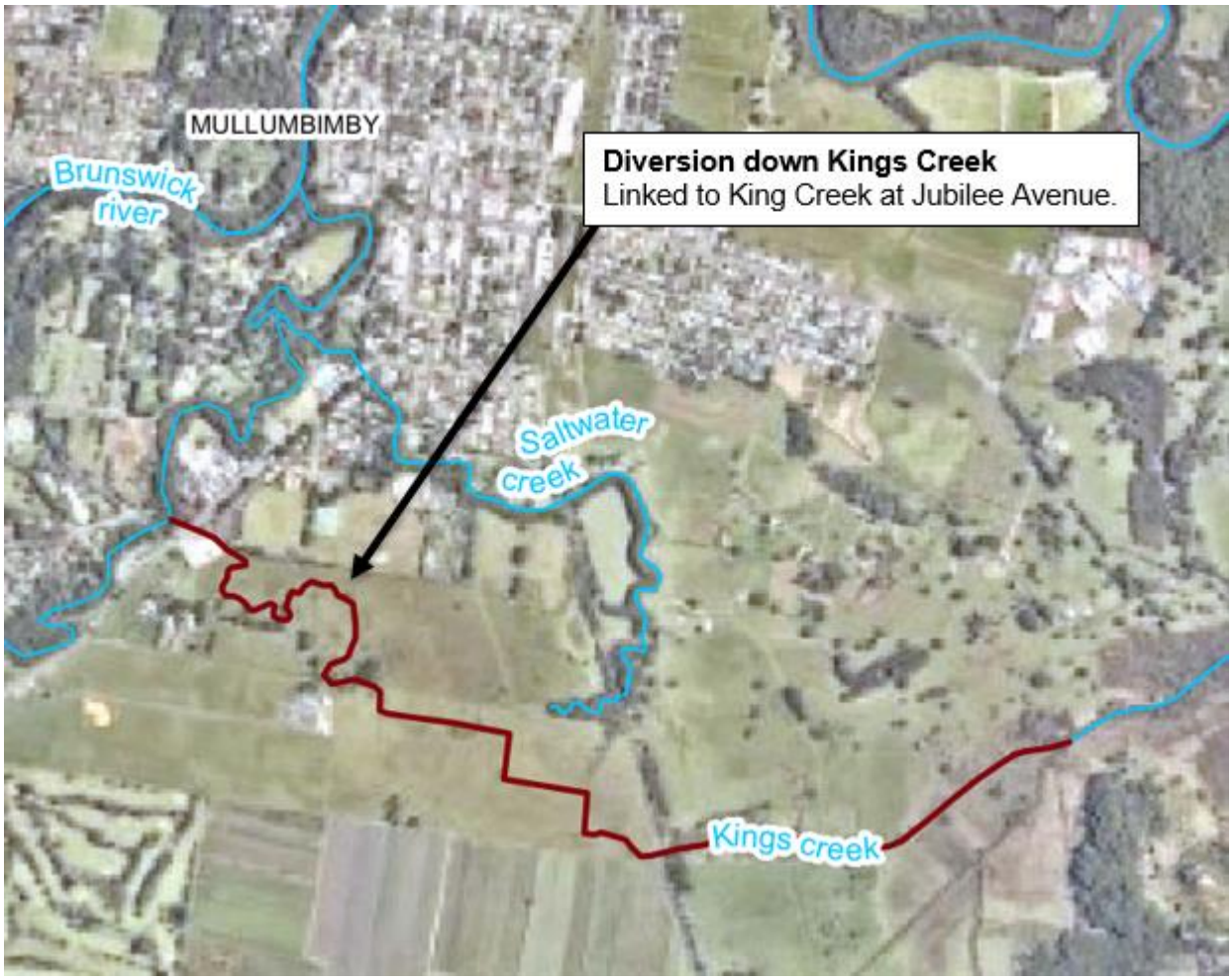


Diagram 25: Option BP01 - Diversion of floodwaters down Kings Creek.

Option BP01 Preliminary Results

Preliminary results from option BP01 for the 1% AEP flood event show relatively minor reductions in levels of only up to up to 0.08 m seen just south of Mullumbimby to the east of Coolamon Scenic Drive. Increases in levels of up to 0.07 m are seen along Kings Creek immediately downstream of Jubilee Avenue.

Due to the limited flood mitigation benefit provided and the considerable economic and environmental impacts associated, this option is not recommended for further consideration.

Option BP02 – Saltwater Creek Upgrade

This option examined the potential flood benefits that could be provided by increasing the capacity of Saltwater Creek. The option looked at excavating a 5 m – 10 m wide channel and dredging an additional 1 m along the existing Saltwater creek river bed. Option BP02 also includes the upgrade of Jubilee and Myokum culverts by lowering the invert level by 1 m. This option would require the removal of approximately 20,000 m^3 of creek bed material.

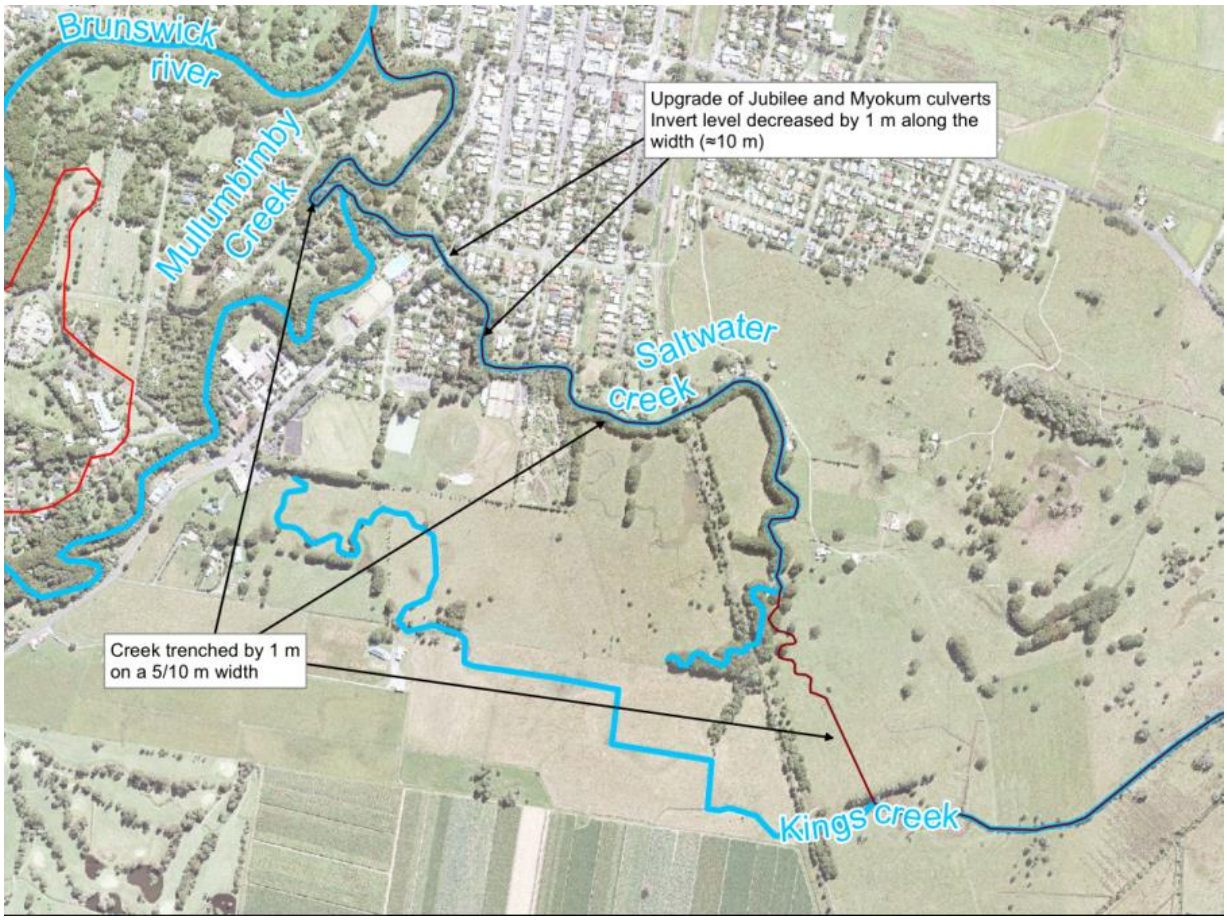


Diagram 26: Option BP02 - Saltwater Creek upgrade.

Option BP02 Preliminary Results

Results for the 1% AEP flood event for option BP02 show only a minor reduction in flood levels of up to 0.05 m along Jubilee Avenue. An increase in flood levels by up to 0.12 m is shown along Kings Creek immediately downstream of the railway.

Whilst this option showed limited flood mitigation benefit, it is recommended that the option is considered further to ensure all potential options of formalising Saltwater Creek as a flood relief channel are explored.

Option DO – Dune Openings

There is historic evidence of a flood outlet along the coastline at Wooyung. 67% of the North Byron community were in favour of the construction and management of flood outlets along the coastline. However, residents are generally supportive provided there is no disruption to indigenous heritage sites and that there is adequate consideration for the dune and environmental health.

This option was modelled as four dune openings located as detailed in Diagram 27 below. Each of the openings were modelled with a 20m wide opening set to the existing level each side of the dune. This is approximately at 1.5 m AHD on each side of the dune.

Specific locations of these dune openings are as follows:

- At Wooyung 3.5 km north of South Golden Beach,
- Just north (1 km) of South Golden Beach,
- Just south (500 m) of South Golden Beach,
- Just south (500 m) of New Brighton.

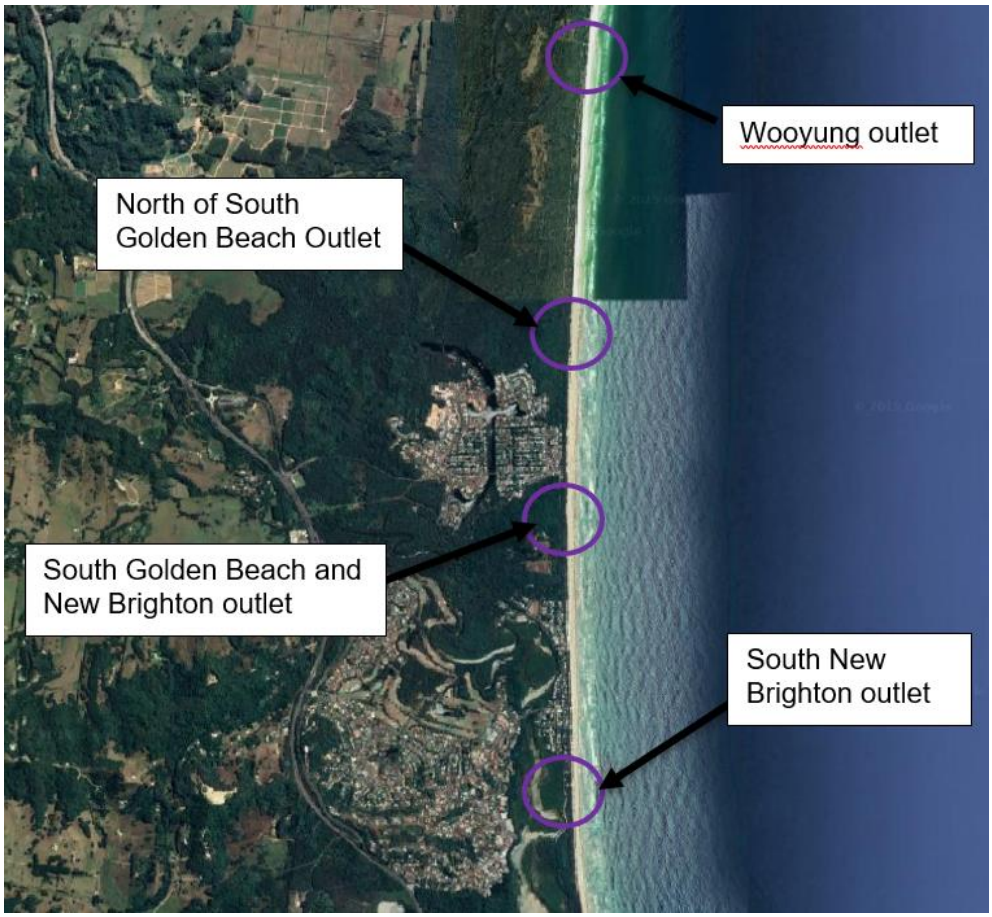


Diagram 27: Option DO – Construction of Dune Openings.

Option DO Preliminary Results

Flood mitigation benefits from the dune openings for the 1% AEP flood event show that while benefits are widespread, reductions in levels are not substantial and range from approximately 0.05 m in Brunswick Heads and New Brighton to 0.1 m in Ocean Shores. Furthermore, during an ocean dominated event, flood levels may in fact increase as a result of the openings.

Due to the limited impact on flood behaviour, and likely substantial costs and environmental impacts, it is not recommended this option is considered further.

Option RW – Rock Wall Modifications

There are a number of rock walls on Brunswick River located between the river mouth and the Brunswick marina, as shown on Diagram 28. These rock walls are located at the confluence where Marshalls Creek and Simpsons Creek both join Brunswick River. Construction of the rock walls at Brunswick Heads begun in 1959 and was primarily to improve navigation of the Brunswick River entrance. The Marshalls Creek training wall is approximately 500 m in length at a height of

approximately 1.7 m AHD. The Marshall Creek training wall running north to south is approximately 300 m long at approximately 0.4 m AHD.

This option modelled the impact of complete removal of Marshalls Creek east wall and lowering of the minor wall at the confluence of Marshalls Creek and Brunswick River.

There has been considerable commentary from the community requesting investigations be done into the removal or alterations of the Brunswick River rock walls. Specifically, there have been comments detailing the east rock wall is impeding flow from Marshalls Creek and is forcing flow to exit further north at a choke point. Results from the community survey showed the community were primarily concerned that any options considered all possible consequences including environmental, trafficability of the river and impacts to flooding. 35% of respondents supported changes to the rock wall at the mouth of Marshall Creek, 20% of respondents supported other alterations to the rock walls, 31% of respondents supported maintaining the rock walls as they are and 15% of respondents felt they did not understand the potential impacts to comment.

While investigation into the rock walls impact on sediment transport within Brunswick River and Marshalls Creek is outside the scope of this study, community consultation indicates the rock walls may have caused increased sedimentation in Readings Bay and Marshalls Creek. This study can only investigate the impacts on flood levels, however it is recommended removal or modification to of the rock walls be investigated for the potential to improve sediment transport within Marshalls Creek.

Diagram 28: Option RW - Rock wall modifications.

Option RW Preliminary Results

In the 1% AEP event this option had no impact on flood levels, as the walls are already submerged in larger flood events and therefore modification is not shown to improve flooding in the area. Consequently, it is not recommended this option be progressed to detailed assessment.

It is recommended council consider development of a sediment transport model to investigate modification to the rock walls for the purpose of improved sediment transport.

Option TW – Removal of Brunswick River Training Walls

This option modelled the removal of training walls located at the mouth of Brunswick River. Both training walls were removed, and the ground level was set to the adjacent sea level (from 0 m AHD to -5 m AHD). The Brunswick River training walls were constructed in the 1960's and over time they have most likely altered the accretion and erosion patterns within Brunswick River and along the adjacent beaches. Coastal processes are complex and further investigation would be required to understand the impact removal of the Brunswick River training walls would have on sediment transport and trafficability of Brunswick River. While this option was not requested by the community as part of the rock wall modification, it was investigated in this study to understand if there was any impact on flood levels.

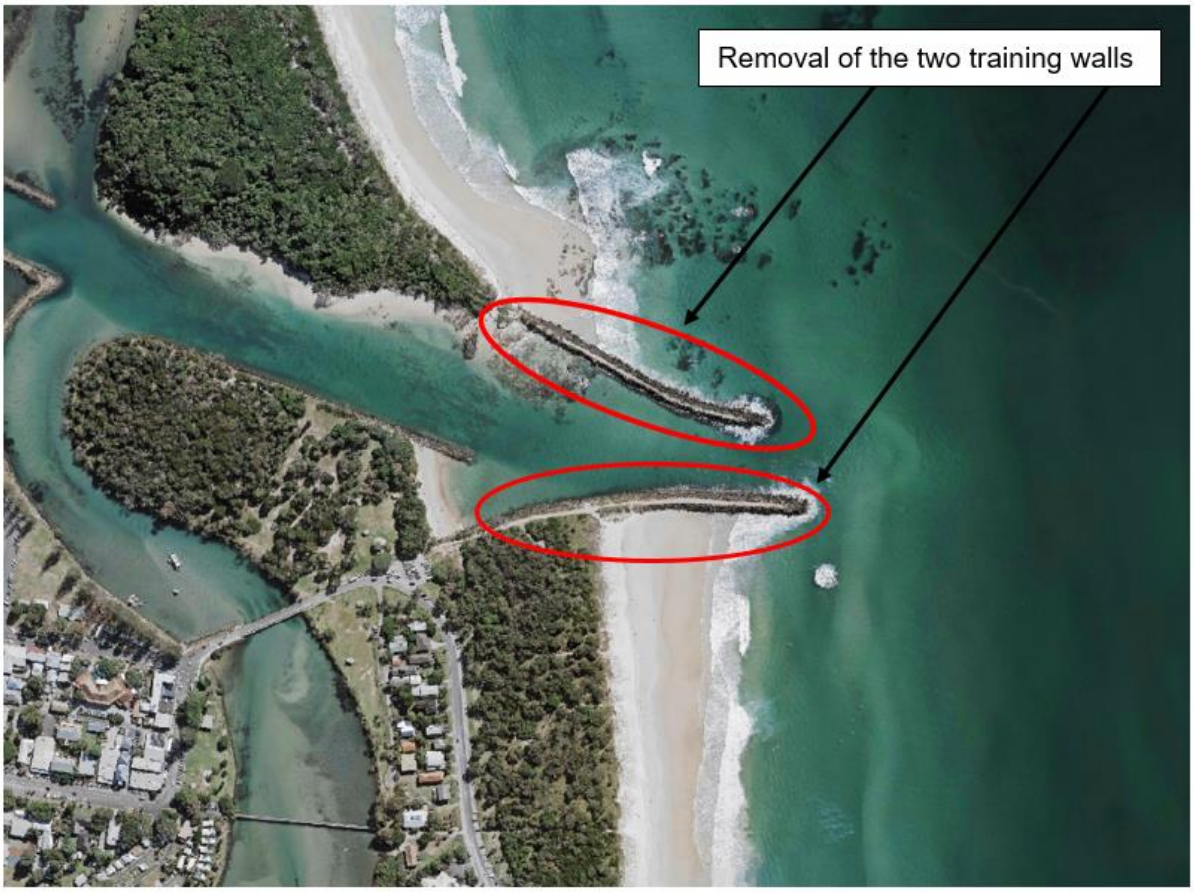


Diagram 29: Option TW - removal of Brunswick River training walls.

Option TW Preliminary Results

Preliminary results for the removal of the Brunswick River training walls show a widespread decrease in flood levels, however this decrease is a maximum of up to 0.1 m at Brunswick Heads and 0.03 m at New Brighton and at the Pacific Motorway. Benefits extent approximately 4 km upstream of the mouth, however are relatively minor.

Due to the limited flood mitigation benefits that could be provided and the uncertainty of the potential impact on coastal processes in the area, this option is not recommended to proceed to detailed investigation.

SUMMARY

	Channel Modification Recommendations
☒	**Option BP01** – Kings Creek bypass is not recommended as a flood management option
☑	**Option BP02 –** Further assessment of Saltwater Creek upgrade is recommended
☒	**Option DO –** Dune openings are not recommended for as a flood management option
☒	**Option RW –** Rock wall modifications are not recommended as a flood management option
☒	**Option TW –** Training wall removal is not recommended as a flood management option
☑	**Option RW02 –** Develop a sediment transport model to investigate modification to the rock walls, as part of the Coastal Management Program for the Brunswick Estuary.

11.4.4. Channel Maintenance

Blockage has the potential to considerably increase flood levels in the catchment. A proactive approach to channel and drainage maintenance will help manage the risk of blockage occurring during a flood event. Dredging is a retroactive solution that has been assessed for effectiveness as a flood management strategy below, however is usually a costly exercise with negative environmental impacts and is not likely to be recommended.

Dredging is a temporary solution and to be effective requires considerable ongoing costs to dredge on a regular basis. In addition to this, dredged material can sometimes be hazardous and there may be additional costs associated with the safe disposal. Environmental impacts from dredging can include disruptions to the natural ecosystem such as affecting the health of aquatic species, water quality and also impact bank stability increasing potential erosion. Environmental impacts can occur directly from the dredging process and also as a result of the disposal of contaminated material. The community can be impacted by the economic and environmental costs associated and also disruption to recreational activities along the river.

Three channel maintenance options have been considered in Brunswick River, its tributaries, and

in Marshalls Creek, discussed below. Submissions from initial community consultation on the draft FRMS showed there was varying degrees of opposition and support to dredging from community members.

In addition to these options, it was noted during site visits that a number of the waterways are crossed by agricultural fencing. Ensuring that this fencing is designed so as not to cause an obstruction to flood flow will generally improve the conveyance of this system. Whilst no modelling was undertaking, it is recommended that Council consider preparing guidelines on the design and installation of fencing traversing watercourses and channels.

ASSESSMENT

Option BRM01 – Brunswick River Dredging at Mullumbimby

Option BRM01 was modelled with the aim of increasing Brunswick River flow capacity through Mullumbimby by lowering the Brunswick River bed. This option models dredging the river by approximately 0.5 m across a width of 20 m to 30 m depending of the river location along a length of approximately 3 km as shown in Diagram 30.

Diagram 30: Option BRM01 - Mullumbimby dredging.

Option BRM01 Preliminary Results

Results from the preliminary assessment indicate there are limited impacts on flood levels, with maximum decrease in levels of approximately 0.05 m in the vicinity of Mullumbimby. When considering these results, it is important to note that the modelled results are representative of the maximum benefit that could be provided. Sediment in the river channel will natural accrete over time, and a flood event may occur any time between immediately after dredging and immediately

prior to dredging. This means benefits provided will be varied and dependent on the timing of the flood event and dredging cycle.

Due to the minor impact on flood behaviour, and the likely considerable economic and environmental impacts, this option is not recommended for further consideration.

Option BRM02 – Brunswick River and Tributaries

Option BRM02 extends the dredging modelled in BRM01 into the nearby tributaries, Chinbible Creek, Mullumbimby Creek and Saltwater Creek. Modelling of this options assumed the bed level is dredged by approximately 0.5 m across a 5 m - 10 m width depending on tributaries profile. The bed level of the two waterway openings under the railway at Saltwater Creek and Kings Creek were reduced by approximately 1 m. Details of the dredging extent and location are provided in Diagram 31.

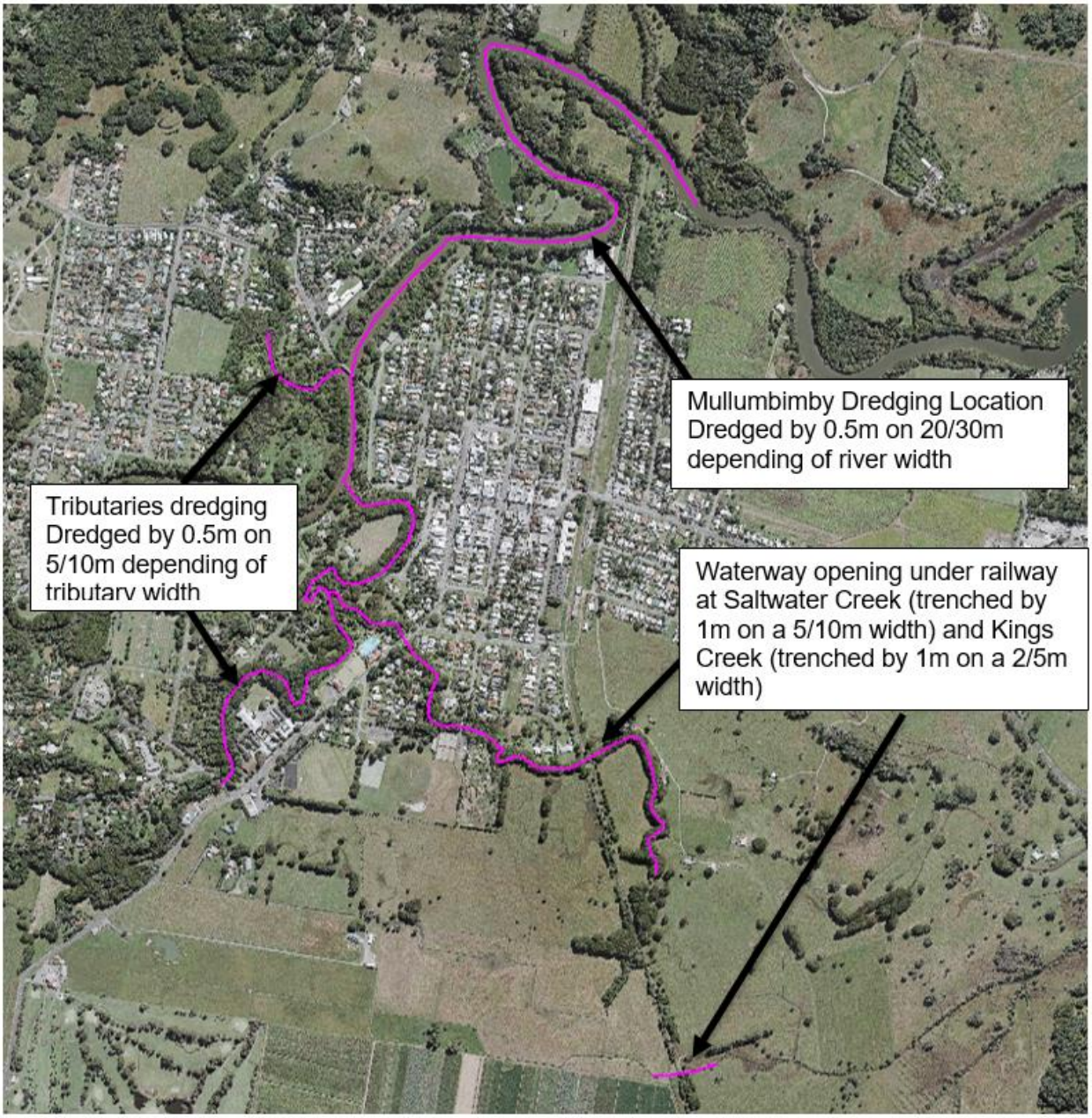


Diagram 31: Option BRM02 - Mullumbimby and tributaries dredging.

Option BRM02 Preliminary Results

Preliminary results for BRM02 show a maximum decrease in flood levels of potentially 0.12 m in the Mullumbimby Community Garden and only approximately 0.05m in Mullumbimby. As detailed above, results shown are indicative of the maximum potential benefit and in reality the mitigation benefit provided could be less.

Due to the limited impact on flood behaviour, and the likely considerable economic and environmental impacts, this option is not recommended for further consideration.

Option MC – Marshalls Creek Dredging at Ocean Shores

Option MC investigates dredging along Marshalls Creek. The option is modelled assuming the river bed was lowered by 0.5 m from just to the east of the Pacific Motorway Bridge near Billinudgel down to the confluence of Marshalls Creek with Brunswick River (approximately 7.5 km). Diagram 32 shows the location and extent of dredging along Marshalls Creek.

Diagram 32: Option MC - Marshalls Creek Dredging.

Option MC Preliminary Results

Preliminary results for MC show a maximum decrease in flood levels of potentially up to 0.05 m in Ocean Shores and New Brighton and 0.01 m in South Golden Beach.

Due to the limited impact on flood behaviour, and the likely considerable economic and environmental impacts, this option is not recommended for further consideration.

Option WFG Discussion

It was noted during site visits and confirmed in discussion with Council that a number of the waterways in the catchment area are crossed by agricultural fencing. These fences can potential

become sources of blockage during events if debris is washed into them, creating adverse flood impacts. Ensuring that this fencing is designed so as not to cause an obstruction to flood flow will generally improve the conveyance of this system. Whilst no modelling was undertaking, it is recommended that Council consider preparing guidelines on the design and installation of fencing traversing watercourses and channels.

SUMMARY

	Channel Maintenance Recommendations
☒	**Option BRM01 –** dredging of Brunswick River is not recommended as a flood management option
☒	**Option BRM02–** dredging of Brunswick River tributaries is not recommended as a flood management option
☒	**Option MC -–** dredging of Marshalls Creek is not recommended as a flood management option
☑	**Option WFG** - Develop guidance on the design and installation of fencing traversing waterways and channels.

11.4.5. Drainage Modification

Ongoing maintenance of the drainage network is important to ensure it is operating with maximum efficiency and to reduce risk of blockage or failure. Maintenance involves regularly removing unwanted vegetation and other debris from the drainage network, particularly at culverts and small bridges. For natural channels, environmental policy can govern how the creek channel is maintained by restricting creek clearing and vegetation management.

Modification of existing drainage systems through the installation of new or larger drainage channels or culverts can increase conveyance and help to reduce upstream peak flood levels or reduce the duration of inundation. Drainage network modifications can also be used to divert flows from one area to another.

ASSESSMENT

The focus of this FRMS is on flooding resulting from the river or creeks system. Notwithstanding this, it is a recognised issue within the North Byron catchment that the existing drainage network is believed to be well below capacity for the current development and overland flow paths are not well defined. In areas where there is significant development pressure, an assessment of the drainage network and overland flow routes should be undertaken.

A drainage assessment was undertaken for New City Road, Mullumbimby, in 2018 (Reference 20). The assessment identified a number of issues at this location, including blockage, sedimentation and vegetation issues and insufficient culvert capacity.

The assessment recommended two actions, namely:

- Construction of culvert outlets with flap gates under the existing earth bund to enable discharge of the channel to Kings Creek,
- Upgrade the culvert crossings and thorough maintenance of the drainage channel by

slashing the existing vegetation and sediment removal.

As part of the FRMS, it is recommended that the further investigation into the appropriate design solution to meet the requirements identified in this assessment is undertaken.

As part of this FRMS however, one drainage modification option has been considered at Avocado Court. This area was subject to significant flooding during the recent March 2017 event and a number of properties were flooded above floor.

Option AC – Avocado Court

In North Mullumbimby in the vicinity of Avocado Court, as shown in Diagram 33, flow currently either drains to two sets of pipes discharging east to Yalgan Gully and Yoga-Bera Gully or to the swale along Chinbible Avenue. In the existing stormwater configuration, the swale along Chinbible Avenue discharges to Brunswick River.

Option AC looks at altering Avocado Court to act as a formal flow path redirecting flow from residential development along the Yoga Bera Gully pipeline to the Chinbible Avenue swale. This flow path was modelled using DRAINS Mullumbimby stormwater model and was configured as a 1 m wide channel with a 0.5 % slope.

Diagram 33: Option AC - Avocado Court Flow Path.

Option AC Preliminary Results

Results from the DRAINS assessment indicate that peak flood depths in Grevilia Avenue decrease

by approximately 0.04m for the 1% AEP design event and decrease by approximately 0.02m for the 0.2 EY event. The option would see increases in flood depths along Chinbible Avenue of up to 0.02m.

Whilst this option showed limited flood benefit, it is recommended that this option undergoes more detailed assessment to determine if further optimisation of the drainage network and overland flow paths can provide a reduction in flood risk at this location.

Option CDM – Detailed Catchment Drainage Model

As outlined in Section 5, there was substantial feedback from the community with respect to improved drainage in the North Byron catchment in both the initial community consultation and as part of the community consultation on the draft FRMS. Concern has been raised around the effectiveness of the current drainage network and the maintenance of this network.

It is recommended a detailed catchment drainage model of the formal pipe network and overland flow paths be developed. The aim of this type of model is to be able to assess the flood risk from flooding of this mechanism. As either part of this study, or as follow on work, the model should be used to inform the identification of drainage hot spots and consider drainage upgrades or maintenance programs to manage this risk. An outcome of this work should be to develop a prioritised plan for the continued maintenance of and improvements to the drainage network.

SUMMARY

	Drainage Modification Recommendations
☑	**Option NCD –** Further consider viable options to implement the recommendations of the New City Road drainage assessment.
☑	**Option AC –** Further consideration of Avocado Court drainage modification.
☑	**Option CDM –** Development of whole of catchment drainage model and overland flow path investigation.

11.4.6. Drainage 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. Community consultation showed the community consider removal of blockages and debris from streams to be one of the most important factors for managing flood risk in the catchment. There were a considerable number of comments from community members about soil and debris causing blockages at structures and increasing flooding to nearby residences.

It is not possible to completely prevent the occurrence of blockages at structures and within the creek channel. It is a natural effect of flooding and even with regular large scale clearing of the creek channel, floodwaters will still collect debris and block drainage structures to some extent. It is considerably more efficient to manage pollutant loads prior to their entry into waterways. This means implementing good landscape management practices to retain soil on the ground. These

landscape management practices include work such as riparian revegetation and bank stabilisation to reduce erosion potential, which have the added benefit of improving ecosystem health. However, in parts of the North Byron catchment the naturally occurring dense vegetation would be a source of blockage material and difficult to prevent entering the waterways.

Drainage maintenance options have been considered for Federation Bridge and the Railway Bridge in Billinudgel.

ASSESSMENT

Option FDC - Debris Control Measures for Federation Bridge and the Billinudgel Railway Bridge

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 (to prevent large debris entering creeks) upstream of structures could be considered by Council to keep structures free of debris. The cost of trash racks or bollards varies greatly depending upon the nature of the structure. Consideration needs to be given to the type of debris these structures are designed to capture and for what size flood event. For example, the structure needs to be designed to ensure it will not silt up and become blocked in low flow flood events.

These structures will collect substantial amounts of debris and require regular and continual maintenance, which can become costly and resource intensive. An indicative establishment cost is $5,000 to $20,000 per item and examples are provided in Image 1. The concept is to direct debris above the culvert or over the road in the second example below. In the latter the pedestrian railing is held by bolts which are designed to shear under the force of debris and water and so collapse preventing damage to the railing and allowing quick re-installation.

Image 1: Examples of structures to reduce blockage of a culvert and pedestrian bridge.

While the above examples are primarily for smaller pedestrian bridges or culverts, for larger structures like Federation Bridge and the Billinudgel Railway Bridge debris fins or debris sweepers can be used to control debris. Debris fins - Image 2 (left) - are typically either concrete or steel thin walls installed upstream of the bridge and aligned in the direction of the flow. These structures encourage debris to align with the bridge opening and prevent accumulation and blockages of debris. Debris sweepers (right) are rotating devices that move as the water level rises and falls and similar to debris fins encourage debris to align with the bridge opening and prevent blockage.

Image 2: Examples of debris control measures for large hydraulic structures. Left – example of debris fins. Right– an example of a debris sweeper (2005, US Department of Transport Federal Highway Administration).

As part of the FRMS, a sensitivity assessment was carried out to determine the potential impact blockage at Federation Bridge would cause. A 25% blockage factor was applied to Federation Bridge and while the impacts were widespread, increases in flood levels were primarily less than 0.05m and there was a negligible introduction of newly flooded land.

Due to the substantial community support for drainage maintenance measures, it is recommended to consider this option further.

SUMMARY

☑	**Drainage Maintenance Recommendations** **Option FDC –** Implement debris control measures for Federation Bridge and Billinudgel Railway Bridge.

11.4.7. Hydraulic Structures

Hydraulic controls such as bridges, weirs or major culverts on significant waterways can affect upstream flood levels due to backwatering effects. Increasing hydraulic conveyance through modification of these structures can lead to a decrease in flood levels upstream of a structure. Generally, the most effective method of increasing hydraulic conveyance is to increase a structure's cross-sectional area perpendicular to the flow direction. This is often done by lengthening a bridge, raising a deck level, increasing the size of a culvert or reducing the structure's crest height.

ASSESSMENT

Two modifications to hydraulic structures have been considered at the Ocean Shores Golf Course Weir and improvements to the infrastructure at Billinudgel.

Option GCW – Ocean Shores Golf Course Weir lowering

Option GCW assesses lowering the weir located on the Ocean Shores golf course just north of Terrara Court by approximately 1 m as shown in Diagram 34.

Diagram 34: Option GCW – Lowering of the Golf Course weir.

Option GCW Preliminary Results

The 1% AEP peak level impacts show this option has negligible impact on flood levels (peak flood levels were reduced by no more than 0.01 m). As such, it is not recommended for further assessment.

Option BM – Billinudgel Infrastructure Improvements

The Billinudgel area is a major flow constriction for Marshalls Creek with the railway and the Pacific Motorway acting as two major infrastructures crossings. Option BM looks at increasing the hydraulic capacity of the railway bridge by widening the opening an additional 5 m on either side.

The capacity of hydraulic structures in the vicinity of Bonanza Drive and Wilfred Street were also increased as described below:

- 1 rectangular culvert (H: 1.8m, W: 2m) added to the existing culvert under the Railway,
- 2 rectangular culverts (H: 1.8m, W: 1.8m) added to the existing 2 culverts under Bonanza Drive,
- 2 rectangular culverts (H: 1.8m, W: 1.8m) added to the existing 2 culverts Wilfred Street,
- 4 new 1800mm diameter pipes added to the existing 2 x 1800mm diameter pipes under Pacific Motorway, and
- 2 new 600mm diameter pipes added to the existing 2 x 600mm diameter pipes under Balemo Drive.

Locations of these changes are detailed below in Diagram 35.

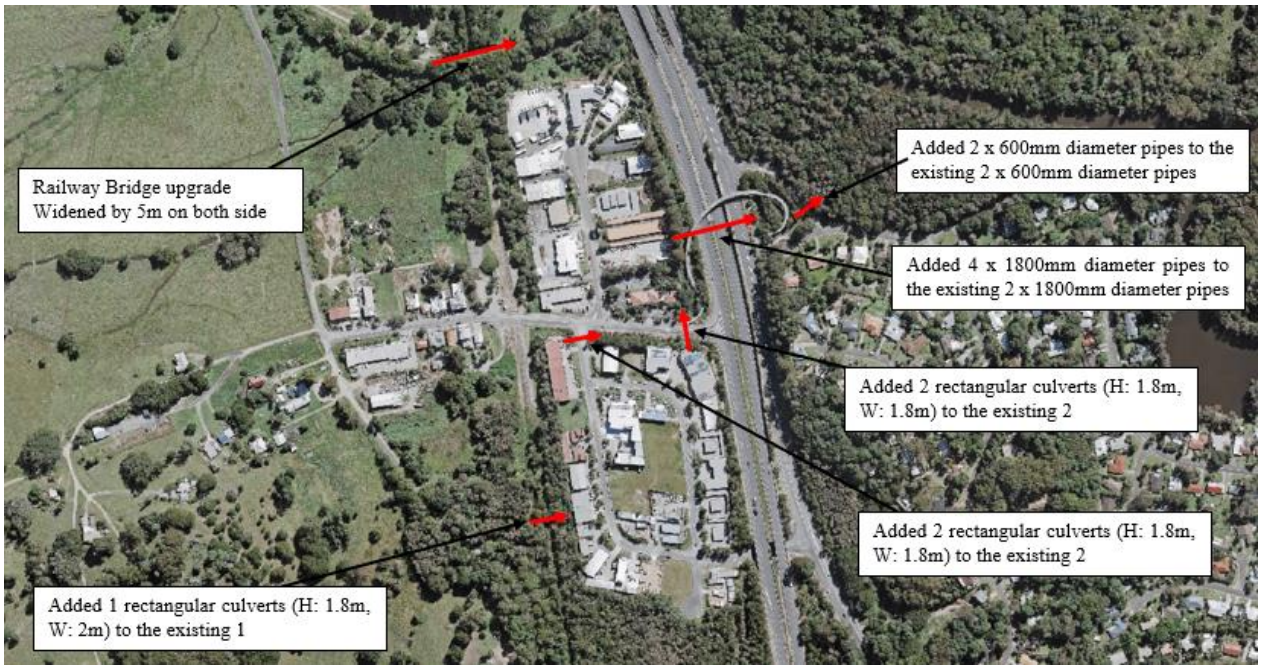


Diagram 35: Option BM - Billinudgel Infrastructure improvements.

Option BM Preliminary Results

Preliminary results for the 1% AEP flood event for option BM01 show only minor reductions in flood levels of up to 0.02 m for a distance of up to 1.5 km upstream of the railway bridge. There are more significant decreases in levels just west of the Pacific Motorway in Wilfred Street of up to 0.22 m.

Due to the limited impacts and considerable likely costs, this option is not recommended to proceed to detailed investigation on its own, however further optimisation is recommended in combination with the Billinudgel Levee.

SUMMARY

☒	**Hydraulic Structures Recommendations** **Option GWC –** modification to the golf course weir is not recommended for flood management purposes

☑ **Option BM –** infrastructure improvements in Billinudgel are recommended for consideration in conjunction with **Option BL**

11.4.8. Flood Storage Areas

Flood storage areas, more commonly referred to as detention basins, are designed to temporarily store floodwaters during a flood event to reduce nearby flooding and then control the release of the water once the peak has passed. These can be either installed 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. They can be designed to act as either wet or dry detention basins and can act as multipurpose uses such as parks, sporting fields or water bodies such as wetlands.

Flood storage areas can significantly 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 these areas, can be used to restrict the discharge rates from site to a variable rate, dependent on rainfall volumes and the hydraulic head in the basin.

Large flood storage areas can be a safety hazard. Appropriate safety controls such as fencing, and signage should be included as part of the overall asset. In NSW, particularly large basin areas may be prescribed by the Dam Safety Committee (DSC) which means that the DSC will maintain a continuing oversight of their safety. This is applicable to basins identified as a possible threat to communities downstream in case of failure. Like the rest of the drainage system, detention basins have maintenance requirements. Regular checks and maintenance will be required by Council or agreements put in place with the developer and land holder. This is particularly applicable to basins identified as being a threat to communities downstream in case of failure.

One location has been considered for a flood storage area at the Saltwater Creek Wetland.

ASSESSMENT

Option SW – Saltwater Creek Flood Storage Area

An area adjacent to the railway line was identified as a location for a potential flood storage area. Diagram 36 shows the location of this flood storage area and the topographic changes modelled to represent this area. In the existing case, the ground level of this area is approximately 3 m AHD on the northern side of the wetland and around 2 – 2.5 m AHD on the southern side. The ground level has been reduced to 2 m AHD (as shown in Diagram 36) and the area has been modelled as initially dry prior to the onset of flooding.

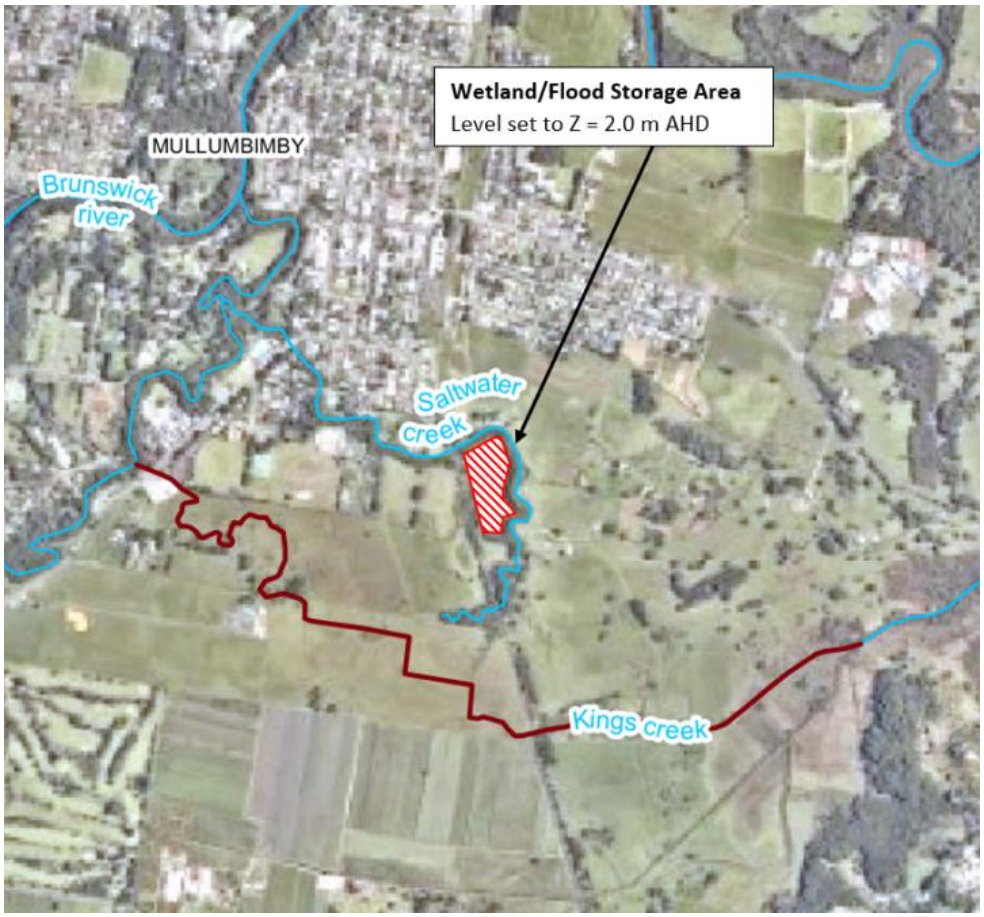


Diagram 36: Option SW – Saltwater Creek Flood Storage Area.

Option SW Preliminary Results

The preliminary results for option SW for the 1% AEP flood event show minor impacts seen to the south of the wetland area, however do not impact on any existing property. For flood mitigation purposes alone, the flood storage area also provides some benefit to Lot 22. Decreases in flood levels are seen in the vicinity of Orchard Place and surrounding residential streets of up to 0.05m. Benefits are primarily minor and limited to a small localised area.

It is not recommended to consider this option further as a flood modification option due to the limited benefit provided. However, it may warrant further investigation as part of the Lot 22 assessment as it may be able to provide multi-benefits, for example to water quality or stormwater management.

SUMMARY

	Flood Storage Area Recommendations
☒	**Option SW** – saltwater creek wetland is not recommended as a flood storage area

11.4.9. Dams

Dams are built to control and store large quantities of water. They are built for a variety of purposes, including water supply, irrigation, flood control, environmental control and hydro-electricity. They may be built to solely serve one of these objectives, or multiple purposes.

Dams serve a flood mitigation role by impounding flood waters and releasing them at lower, controlled rates, thereby reducing flood levels downstream of the dam.

No appropriate locations for the construction and management of a dam were identified for preliminary assessment.

SUMMARY

	Dams Recommendations
☒	No appropriate sites for dams were identified in the North Byron catchment

11.4.10. Combined Options

Two combination options were also modelled at the preliminary stage, as discussed below.

CB01 – Marshalls Creek Dredging (MC), Dune Openings (OO), Rock Wall Modification (RW) and Kallaroo Circuit Bund Modification

Option CB01 looks at the combined flood mitigation potential of MC (Marshalls Creek Dredging), RW (Rock wall modifications at Brunswick Head) and OO (Dune openings). Option CB01 also included a modification of Kallaroo Circuit bund at South Golden Beach, an option not explored individually. The culvert in Kallaroo Circuit bund was lowered by 1 m (reduced from 0.975m AHD to -0.025m AHD)

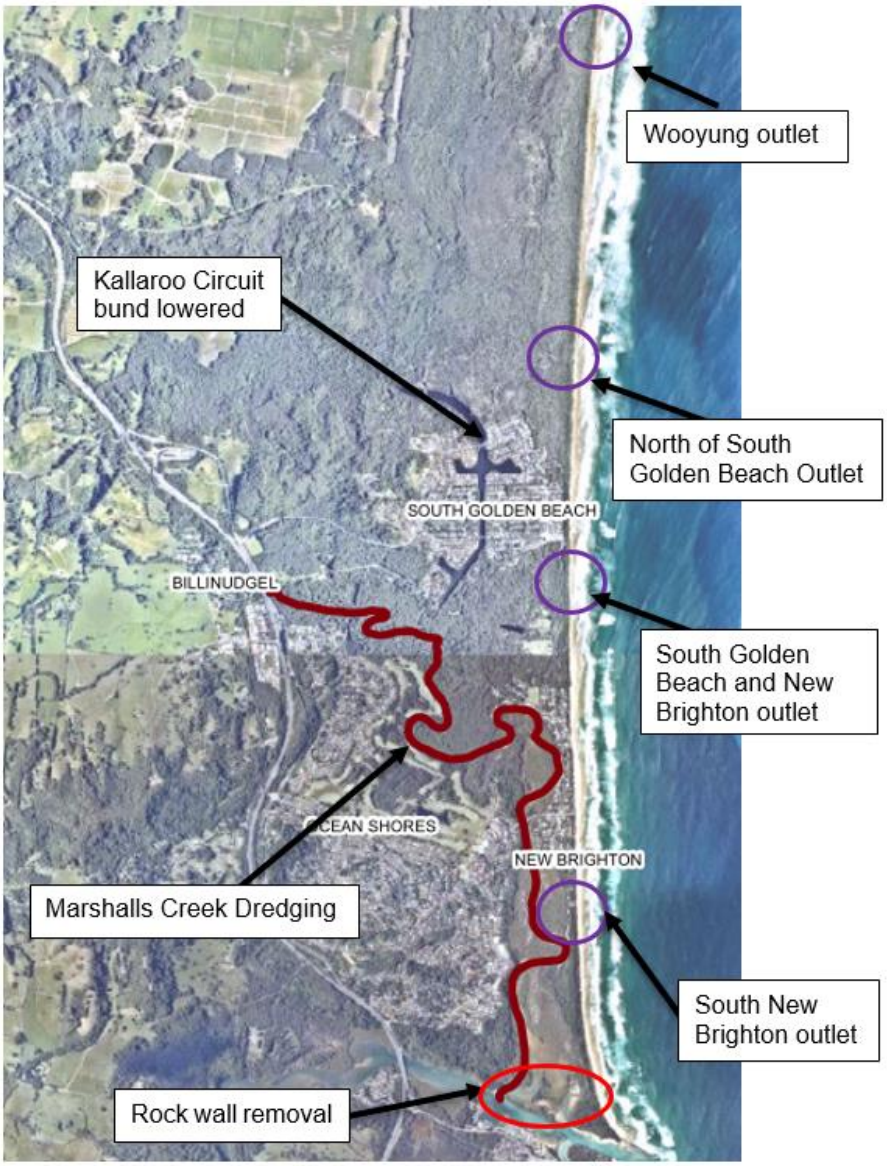


Diagram 37: Option CB01 - combined flood modification measures.

Option CB01 Preliminary Results

Combined option CB01 provides widespread flood mitigation benefit, however reductions in levels are limited to up to 0.15 m in South Golden Beach, 0.06 m at Ocean Shores, up to 0.08 m in New Brighton and 0.04 m in Brunswick Heads, with very limited properties located in the area benefiting. Results for this flood event scenario are not indicative of the performance of dune openings in all types of flood events. Flooding from different mechanisms (ocean inundation versus catchment flooding) will produce a different outcome. Dune openings are likely to cause a negative impact for a flood event with high ocean levels, either from tides and storm surge or increasing ocean levels from climate change. Flooding within the Brunswick River Catchment has historically resulted from an East Coast Low or ex-Tropical Cyclone, which typically induces both ocean flooding and catchment flooding. It is expected dune openings would provide benefit in some flood events and dis-benefits in other types of flood events. The preceding sections for dredging, rock wall modification and construction of dune openings discuss the relevant

considerations for each flood modification option.
As such, there are substantial environmental and economic considerations that need to be considered further should this option progress.

Due to the associated economic and environmental considerations and limited flood mitigation potential, this combination of flood modification options is not recommended.

Combined Option CB02 – Billinudgel Infrastructure (BM) and Billinudgel Levee (BL)

Combined option CB02 looks at the flood mitigation potential from both the Billinudgel Infrastructure works (Option BM) and construction of the Billinudgel levee (Option BL). These options were considered in combination to identify if the infrastructure improves mitigate the flood level increases resulting from the levee.

A detailed description for both these options is provided in 11.4.1and Section 11.4.7.

Option CB02 Preliminary Results

Preliminary results for option CB02 are show that the Billinudgel levee implemented in conjunction with the Billinudgel Infrastructure upgrades will provide benefit to properties protected by the levee but also alleviates the impact upstream of the Pacific Motorway introduced by the levee. Reductions in flood levels for the 1% AEP flood event are up to approximately 0.5 m behind the levee, however there are some minor areas of impact in the order of 0.02 m – 0.05 m.

Due to the potential flood mitigation benefit provided by these combined options and the relatively small impacts, it is recommended these options are considered further.

SUMMARY

	Combination Option Recommendations
☒	**Option CB01 –** this combination of options is not recommended for the purposes of flood management
☑	**Option CB02 –** more detailed assessment of this combination of Billinudgel Levee and Infrastructure Improvements is recommended.

11.5. Response Modifications

Response modification measures aim to reduce risk to life and property in the event of flooding through improvements to flood prediction and warning, improvements to emergency management capabilities, evacuation and planning, and better flood-educated communities. Early warning and communication have been emphasised as being particularly important for the community in North Byron both in the community survey undertaken at the onset of the study and in feedback during the community consultation on the draft FRMS. The March 2017 flood event saw much of the North Byron community flooded without warning, power or telecommunications. The following options explored in this section aim to identify strategies to improve emergency response within the North Byron floodplain, improve evacuation coordination and improve flood intelligence and

community education.

11.5.1. RM01: Flood Emergency Management Planning

Effective planning for emergency response is a vital way of reducing risk to life and property, particularly for infrequent floods that are not managed through flood or property modification. The NSW State Emergency Service (SES) is the legislated combat agency for floods in NSW and is responsible for the control of flood operations. Residents living in and proprietors working on the floodplain can also prepare individual plans tailored to their situation.
The North Byron study area is currently covered by the Byron Shire Local Flood Plan. Planning for flooding is a vital way of reducing flood risks to life and property. Plans need to be reviewed after flooding and after new information is made available from flood investigations, such as the Flood Study and this FRMS. This FRMS provides useful information to inform emergency planning including an assessment of flood behaviour, isolation, access and movement, vulnerable and critical infrastructure and information to support evacuation planning. NSW SES has the lead role in planning for and responding to floods and should coordinate with Councils on concerns such as road closures and establishing flood-free detours. During community consultation respondents were marginally in support of flood emergency management planning.

Collaboration between Council and SES is recommended to review and update the Local Flood Plan, a document which would note hotspots as identified in Section 7.8, identify roads affected by inundation and outline flood warning and evacuation protocols, which are described in the subsequent sections. Based on the findings of this FRMS, specific changes to the Local Flood Plan include:

- Consider adopting the Seventh Day Adventist Church as the primary evacuation centre in South Golden Beach and investigate funding opportunities to obtain a generator for the church,
- Consider adopting the Brunswick Civil Memorial Hall as the primary evacuation centre for Brunswick Heads,
- Consider adopting the alternate Ocean Shores evacuation route via Brunswick Valley Way to Rajah Road, Warrambool Road to Ocean Shores Country Club, as the primary evacuation route.
- Identify an additional evacuation centre within Mullumbimby that can provide flood free refuge up to and including the PMF.

SUMMARY

☑ **RM01: Recommendation**
Council and the SES to update the Local Flood Plan based on findings of the FRMS.

11.5.2. RM02: Flood Warning and Emergency Response Strategies

Early evacuation is the NSW SES's preferred emergency response for flooding. This reflects the understanding that the safest place to be in a flood is well away from the affected area (Reference

18). Evacuation should be the primary strategy where the available warning time and resources permit (Reference 18). The alternative to evacuating is shelter-in-place which is to shelter in a building within the floodplain.

The SES contends that sheltering in a building that does not have a habitable floor level above the level of the PMF is not low risk and does present a number of concerns:

- Floodwater reaching the place of shelter (unless the shelter is above the PMF level);
- Structural collapse of the building that is providing the place of shelter (unless the building has been designed to withstand the forces of floodwater, buoyancy and debris in a PMF);
- Isolation, with possible loss of power, water and sewerage;
- People's unpredictable behaviour (e.g. drowning if they change their mind and attempt to evacuate through flooded roads);
- People's mobility (not being able to reach the highest part of the building);
- People's safety (fire and accident); and
- People's health (pre-existing condition or sudden onset e.g. heart attack).

Accordingly, where sufficient warning time for safe evacuation is available, evacuation from the floodplain is recommended.

DISCUSSION

As described in Section 9.2, the North Byron Study Area is covered by the Byron Shire Local Flood Plan, which contains evacuation planning and trigger levels for each locality in the community. The current gauges located within the study area used for warnings are:

- Federation Bridge gauge at Mullumbimby, and
- Billinudgel gauge at Billinudgel.

While the Local Flood Plan does link some consequence information to levels at gauges through the identification of trigger levels for evacuation and some road closures, this should be updated with new information developed as part of this FRMS. In addition to this, consideration should be given to how this information can be provided to the community in a timely manner before and during an event.

11.5.2.1. Flood Warning Network

The March 2017 flood event differed from past flood events and showed the variability possible by providing limited warning time to North Byron residents. Floodwaters rose quickly and residents were inundated in the middle of the night. This flood event highlighted a need for a flood warning system to ensure all measures are taken to provide warning time to both the community members and first responders. Byron Shire Council are currently in the process of developing a flood warning network for North Byron. Learnings from this FRMS should be considered as part of the development of this system.

Results from the community consultation undertaken as part of this project provide relevant insight into the community profile and their needs of a flood warning network. Key findings from the

community consultation that are particularly relevant include what information the community want and how the community want this information. In particular, the community want timely and accurate information on road closures, expected flood levels at their property and key locations across the catchment, impacts to power and water supply and an indicative comparison to past flood events. Different members of the community have indicated they may need different types of flood intelligence and this should be considered as part of the development of the flood warning network. For example, a respondent to the community survey indicated that they would want to know when and where to move their cattle.

This system should also recognise that there is a need to capture and document personnel based intel accumulated over many years of working within the catchment. This will ensure this local knowledge is not lost when these key members retire or move on.

11.5.2.2. Opportunities for Increasing Available Warning Time

Decisions made on the basis of rainfall observations carry a significant degree of uncertainty. Forecast Rainfall has an even greater degree of uncertainty associated with estimating flood affectation. Evacuations based on uncertain triggers 'may be theoretically defensible in a purely risk-avoidance context but are likely to be viewed as socially and economically unsustainable' (Reference 18). Frequent 'false alarms' could lead to a situation where warnings are ignored by most of the community. While not suitable for making decisions on evacuations or road closures, use of forecast rainfall can improve the understanding of possible future outcomes and can be used to inform both first responders and the community of the possibility of a flood event and to remain alert.

It is recommended the flood warning network consider incorporating use of forecast rainfall to inform emergency management decisions.

11.5.2.3. Opportunities for Reducing Warning Time

Opportunities to reduce the required warning time can also be considered. There are a number of mechanisms to achieve this. An important question is how the people affected by flooding can best be given the appropriate information. 81% of community consultation respondents would prefer to receive flood warnings via an emergency SMS. Emergency Alert is the national telephone warning system that may be used by the NSW SES during a flood event. This system uses the telecommunications network to identify and send alerts to mobile phones and landlines in the emergency area. As alerts are sent based on location not all residents will receive an alert. This system is not used in all instances and is dependent on the nature and magnitude of the disaster. It is important to avoid duplication of emergency alerts, however an automated opt-in text messaging system that compliments the Emergency Alert system could be implemented for North Byron. The ability of such a system to quickly reach a large number of subscribers is often beneficial for mitigating flood risk. While doorknocks and phone calls are likely to still be required, use of an emergency SMS may reduce the load.

A number of respondents indicated they would prefer to actively seek flood warning information prior to receiving these warnings. The NSW SES and Byron Shire Council could consider an online

system that provides key emergency information including, weather warnings, emergency warnings, river heights, school closures, road conditions, power and water outages, emergency contacts, links to relevant social media pages etc. There are numerous examples of systems like this across the country, however a good example is the Ipswich City Council emergency management dashboard. A system like this, tailored for the North Byron community, would mean the community would be able to receive meaningful flood warning information and in conjunction with community education would be aware of any required actions associated with this information (e.g. raising belongings, moving cattle, preparing for evacuation etc.).

It is expected that as part of the flood warning network, additional opportunities for reducing required warning time will be identified and explored.

SUMMARY

The development of the North Byron Flood Warning Network is a good opportunity to consider measures to both increase the available warning time and reduce the required warning time. The above sections discuss some possible opportunities and it is recommended these are considered further as part of this project, however key considerations are:

- Consider learnings from this FRMS and results of the community consultation as part of the development of the Flood Warning Network for North Byron.
- Consider incorporation of forecast rainfall as a tool in the Flood Warning Network.
- In conjunction with NSW SES, Council to consider development of an automated emergency SMS system.
- NSW SES and Byron Shire Council to consider development of an online system where flood warning can be easily accessed.

☑ **RM02: Recommendations**
Byron Shire Council and SES to consider the findings and recommendations of the FRMS in the development of the Flood Warning Network for North Byron.

11.5.3. RM03: Improved Flood Access – River Street, New Brighton

As described in Section 7.8.3, the pocket of residential properties in New Brighton located along River Street and Casons Road are unable to access evacuation routes. Table 37 shows the number of properties impacted by the frequent inundation of River Street. Improving flood access could significantly improve a community's response to flooding, as well as reducing risk to life, burden on SES resources and flood damages. It should be also noted this area is at risk of coastal inundation, and improvements to this evacuation route may also support mitigation of coastal risk.

Table 37: Properties experiencing above floor flooding with River Street as the only evacuation route available.

Flood Event	Properties Flood Above Floor
0.2EY	3
10% AEP	3
5% AEP	5
2% AEP	12
1% AEP	13
0.5% AEP	15
0.2% AEP	17
PMF	24

ASSESSMENT

River Street currently has less than a 0.2EY flood immunity and while it would not be feasible to upgrade the road to be completely flood free, improving immunity along this length of road to the 1% AEP would improve access for this New Brighton community and would allow for evacuation to flood free land.

This option involves raising River Street from the corner of Casons Road to past the corner of Oceans Avenue to provide flood immunity up to and including the 1% AEP flood event. This involved raising the road by approximately 0.5 m to up to 1.5 m depending on the location. Noting there is no available land or council owned buildings for an evacuation centre, NSW SES and Byron Shire Council could investigate a new assembly point along Gaggin Street or Terrace Street to evacuate residents. Raising of River Street has been modelled for the 1% AEP flood event for the extent shown below in Diagram 38.

Diagram 38: The section of River Street that has been raised tothe 1% AEP flood level.

Model results for this option show widespread impacts (refer to Figure 103) with increases in flood levels to properties in Ocean Shores of up to 0.05 m and up to 0.2 m in New Brighton. However, given the risk to life for properties along River Street and Casons Road a road raising option needs to be further considered in this location. A feasibility assessment could investigate other design options to mitigate adverse impacts to other properties but still provide improved flood access to properties in this hotspot. For example, one potential option that could be investigated to reduce impacts is adding pipes underneath River Street in conjunction with raising River Street to the 1% AEP flood level.

SUMMARY

While the current option results in widespread impacts across Ocean Shores and New Brighton, there is substantial risk to life for the properties trapped in the vicinity of Casons Road. It is recommended further investigation into the combined option of raising River Street and an additional assembly point along Gaggin Street or Terrace Street be undertaken. Given the widespread impacts across Ocean Shores and New Brighton, this option would only be feasible if appropriate drainage measures and maintenance were investigated to mitigate impacts. As part of further assessment of this option, consider testing a number of options including raising River Street past Pacific Street.

☑ **RM03: Recommendations**
More detailed assessment of potential raising of River Street to provide improved flood immunity and evacuation.

11.5.4. RM04: Improved Flood Access – Wilfred Street

Those located in the flooding hot spot location of Billinudgel are unable to evacuate via road as Wilfred Street is inundated in the 0.2 EY flood event. Properties in this area include commercial, residential and industrial land uses. Improving the immunity of Wilfred Street will provide residents more time to evacuate decreasing the risk to life and burden on emergency services. It was noted there could be some logistical issues to raising the road at this location.

ASSESSMENT

This option involves raising the entire length of Wilfred Street (approximately 450m) as shown below in Diagram 39 to provide 1% AEP flood immunity for properties in Billinudgel. Wilfred Street functions as a floodway so any topographical changes are likely to impact on nearby flood levels.

Diagram 39: Raising of Wilfred Street to the 1% AEP flood level.

This option was modelled for the 1% AEP flood event to understand if raising Wilfred Street has negative impacts on nearby properties. Figure 104 shows widespread impacts of up to 0.05 m in Billinudgel, with some locations impacted by up to 0.2 m and some areas that are newly flooded. Flood modification Option CB02 looks at a combined option of a levee and infrastructure improvements for Billinudgel and is described in further detail in Section 12.1.1. Option CB02 provides a reduction in flood levels of approximately 0.5 m along Wilfred Street for the 1% AEP flood event, which while does not provide 1% AEP immunity will provide additional time for people to evacuate. Should Option CB02 progress to a detailed assessment, there would be merit investigating if raising Wilfred Street is viable in conjunction.

SUMMARY

It is not recommended that raising of Wilfred Street be considered further due to both the negative impacts caused and also the costs associated with these road works. However, should CB02

progress to detailed assessment phase it is recommended raising Wilfred Street be considered again at this stage.

☒	**RM04: Recommendations** It is not recommended raising of Wilfred Street be considered solely, however it is recommended this option be revisited should flood modification option CB02 or BM progress to detailed assessment.

11.5.5. RM05: Road Closures, Early Notifications and Creek Crossing Deterrents

Alternatives to raising access roads are considered to mitigate the potential risk of motorists and pedestrians using flooded roads. Options include road closures, warning signs and depth mark indicators. Section 7.4 provides detail on the exposure of evacuation routes and access roads for a range of flood events.

11.5.5.1. Automatic Road Closures and Boom Gates

Currently, road closures are only implemented by Council or SES once they have been notified of flooding of an access road. This means that the road is flooded well before it is closed thus greatly increasing the risk or pedestrians and motorists attempting to cross floodwaters.

Automated road closures could provide a viable alternative through either:

1. Automated warning signs and boom gates that signal (using telemetry technology) once a trigger level has been reached at a nearby gauge. This would significantly reduce the time taken to close roads by negating the need for Council and SES personnel to determine the need for, and travel to, the road closure site. Cost per gate including telemetry technology is estimated to be $20,000 not including the cost of the gauge. Boom gates introduce the potential risk of people becoming trapped should the gates be activated after a car crossing. Consideration should also be given to the type of road these gates are installed on and the timing to ensure the gates do not unintentionally isolate or trap people in areas without a safe area to seek shelter.

2. Flood gates which self-deploy during periods of high flow. The flood gates are locked in the open position at low-lying crossings and are designed to automatically unlock and close road access when floodwaters reach a pre-set depth. In flood situations the gates provide a highly visual barrier to warn motorists and discourage attempts to cross flooded waterways. When water recedes to an acceptable level the flood gate is deactivated by Council officers to allow vehicle access to the crossing. The cost per gate is estimated to be $60,000.

A system which allows a visual check may be required to prevent accidents or injury caused by automated boom gate closure.

11.5.5.2. Automatic Warning Signs and Depth Indicators

In addition or as an alternative to closing flooded roads, warning signs, lights and depth indicators could be used to alert drivers of flooded roads (and their potential closure).

Automatic flashing warning signs (triggered by the Federation Bridge gauge and Billinudgel gauge) and real-time notification of flooded roads could be used. Automatic flashing warning signs are estimated to cost approximately $20,000 not including the cost of the gauge, and depth indicators are estimated to cost $5,000 per location.

As discussed above in Section 9.3.6, Mullumbimby Road experiences frequent flash flooding, primarily due to flow constraints from inadequate cross drainage. Council should consider either changes to the road design, improved culvert capacity or installation of automatic flood warning signs and depth indicators.

SUMMARY

The above sections discuss some possible opportunities and it is recommended these are considered further, however key considerations are:

- Automatic warning signs and depth indicators for the Pocket Road, Sherry's Bridge on Main Arm Road, Myocum Road, Coolamon Scenic Drive, Wilsons Creek Road, Gulgan Road and Left Bank Road; and
- Investigate either potential upgrades to Mullumbimby Road including improved culvert capacity or automatic warning signs and depth indicators.

☑ ***RM05: Recommendation***
Identify key roads and implement automatic warning signs and depth indicators.

11.5.6. RM06: Community Flood Education

DESCRIPTION
Actual flood damages can be reduced, and safety increased, where communities are flood-ready:

'People who understand the environmental threats they face and have considered how they will manage them when they arise will cope better than people who lack such comprehension…Many people who live and work in flood liable areas have little idea of what flooding could mean to them – especially in the case of large floods of severities well beyond their experience or if a long period has elapsed since flooding last occurred. It falls to the combat agency, with assistance from councils and other agencies, to raise the level of flood consciousness and to ensure that people are made ready for flooding. In other words, flood-ready communities must be purposefully created. Once created, their flood-readiness must be purposefully maintained and enhanced.' (Reference 19).

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 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, DVDs, 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 floodplain risk management and with emergency management measures such as operations and flooding; and
- 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.

Table 38 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.

A priority for the North Byron catchment should be ensuring the vulnerable population without a permanent resident are included in community flood awareness and preparedness and are aware of the risks of flooding, who they can trust and where they may be able to seek shelter during flood events. This population could be reached through a number of the methods below, however a tailored approach may be needed.

Table 38: Methods to Increase Flood Awareness and Preparedness

Method	Comment
S10.7 certificate notifications	Section 10.7 planning certificates record whether the land is subject to any planning and development controls due to its flood affectation. Council also the opportunity to provide more detailed information about the land's flood affectation under S10.7(5) of the EP&A Act 1979. This information may be particularly valued by prospective purchasers but has a limited reach and is typically issued only upon request and payment of a fee. Results from the community consultation indicated some respondents were not aware what S10.7 (formerly known as S149) certificates were.

Council website	Currently, Byron Shire Council does not have flood awareness mapping available online. Consideration should be given to providing online flood awareness mapping and flood risk information at the property level on Byron Shire Council's website. This mapping should provide an indication of the associated flood risk for the full extent of the floodplain. Also providing past historical flood extents are a useful way to link back to past events the community may be familiar with. This community awareness information could be provided through a flood information dashboard that could be used both as an awareness tool during dry periods and also in times of flooding to advise the community of locations of expected flooding, road closures, evacuation centres and nearby hospitals etc. In addition to information on existing flood risk, the community awareness dashboard could also include other information such as preparing properties for storm events, correct disposal of trees, debris and cuttings.
Community Champions Program	The community consultation undertaken as part of this FRMS indicated there are a number of trusted community members with substantial local knowledge. Respondents indicated they would trust their neighbours and members of the community with local knowledge of past flood events for information before and during flood events. 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. There are already current programs in place through the *Tweed and Byron Community Resilience Innovation Program* and the *SES Community Action Team Volunteers*. The *Tweed and Byron Community Resilience Innovation Program* has looked at managing spontaneous volunteers during disaster events. This program may either provide the appropriate avenue to coordinate a community champions program or may have already set in place appropriate protocols for a program like this. 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 North Byron community well suited for involvement in an SES Community Action Team group and this team should be more widely promoted to encourage involvement.

Letter/certificate/ pamphlet from Council	These may be sent annually with a rates notice or separately, including information stickers in power boxes at properties. A Council database of flood liable properties makes this a relatively inexpensive and effective measure. A similar approach has been adopted successfully in Benalla (Reference 19). The intention of flood certificates is to inform individual property owners of the flood situation (flood levels, ground levels) at their particular property. It is the site-specific nature of this advice that offers a chance to provide tailored flood risk information for residents. Useful information that could be included are: • Helpful contacts (SES, Emergency Services, nearby hospitals, council etc.), • Information on current Council flood planning policy including appropriate fill areas, • Link to the Byron Shire Council website flood awareness page or flood information dashboard, • minor, moderate and major flood levels at their closest gauge and the associated consequences (to contextualise a warning from the Bureau of Meteorology), • ground levels, • past historical flood levels, • trigger levels for a nearby gauge that may mean evacuation is necessary, • information on preparing properties for storm events, and • correct disposal of trees, debris and cuttings. A pamphlet can inform residents of the on-going implementation of the Floodplain Risk Management Plan and provide tips to respond appropriately to flooding (e.g. shelter-in-place). Proactive and regular issuance is desirable.
Information packs for new residents	Closely linked to providing letters/certificates or pamphlets, information packs could be developed for new residents describing the flood risk in North Byron and include references to other sources for further information. The Floodplain Development Manual (Reference 4) contains suggestions for types of information to be provided (Section J3.2), including: • Whether the area where they live is exposed to a risk of flooding. General historical flood information or photos could also be provided; • What range of risk they are exposed to; • The need to be flood ready indicating what they should do in planning for a future flood event. This could include an explanation on flood warnings and what the resident should do in regard to warnings of different levels of flooding, as appropriate; • Location of appropriate evacuation centres where applicable; and • Contact details for provision of further information.
School project	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.
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 means 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. Historical features and remembrance of past events are interesting for local residents and can provoke preparedness for future events.
Library display	The library could collect historical flood photos and stories to prepare a display, which could be accompanied by appropriate flood safety messages.
Mobile display	Less than 20% of respondents to the community consultation had an emergency plan and emergency kit prepared. Such a display as described above (Library display) could also be used at local festivals and for school visitations, accompanied by NSW SES staff, who should be trained to encourage and equip households to prepare flood emergency plans and emergency kits.
NSW SES FloodSafe Guide	Continued distribution of the local FloodSafe guide which should be revised based on the findings of the current study, and again upon implementation of the FRMP. This information is critical to distribute to the community as it provides vital information including: • location of evacuation centres, • the dangers associated of not responding to evacuation orders and becoming isolated, • dangers of driving through floodwaters, • information on how to care for pets before and during disaster events, • other useful material can be found online at: https://www.ses.nsw.gov.au/disaster-tabs-header/flood/
NSW SES Business FloodSafe Breakfast	The NSW SES has prepared a FloodSafe Business template, which businesses can use to plan for flooding. 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.

Historical flood markers and flood depth markers	Signs or marks can be prominently displayed on telegraph poles or similar to indicate the level reached in historical and design floods. Depth indicators advise of potential hazards, particularly to drivers. These are inexpensive and effective but in some flood communities are not well accepted as it is perceived that they affect property values. Flood marker poles could be installed in frequently visited locations to show the height flood waters reached in previous historic flood events.
Flood Information Signage	Flood information signs could be implemented in locations known to be popular for vulnerable and mobile members of the communities to seek shelter. These signs should include safe evacuation routes, locations of nearby evacuation centres and emergency phone numbers.
Targeted community education for evacuation planning	While there is evacuation planning in place through the SES Local Flood Plan, it is essential the community are aware of their flood risk and have an appropriate plan in place. The North Byron floodplain has a number of areas that become isolated or evacuation routes are cut early, increasing the risk to the community. Through targeted education ensuring the community are aware of their evacuation routes and closest evacuation shelters, the risk to life could be reduced.
Community education for South Golden Beach residents	The levee at South Golden Beach does reduce the flood risk from riverine flooding in this township, however the community may still experience flooding from local drainage. In addition to this, when the levee is overtopped, or should the levee fail the flood risk in this area increases substantially. Targeted community education about the flood risk in South Golden Beach is recommended.

SUMMARY

☑ **RM06: Recommendation**
Engage with the community to prepare an ongoing flood education program, with appropriate evaluation by Council and SES following implementation

11.5.7. RM07: Mullumbimby Evacuation Assessment

Section 9.3.6 and Section 9.3.7.3 explore the evacuation capability of Mullumbimby and capacity of Mullumbimby evacuation centres in detail. Safe evacuation is possible for flood events up to the 0.5% AEP flood event, provided neighbours are willing to provide shelter to those in need. For flood events of a larger magnitude than the 0.5% AEP event, evacuation centres become inundated and the number of people who may seek safe shelter increases substantially.

Section 9.3.7.3 highlights that if evacuation does not occur early enough, there may not be enough time to evacuate Mullumbimby residents to evacuation centres outside of the flood extent and the risk to life in this situation is high. In addition to this, Mullumbimby is a complex area of the floodplain with the Brunswick River, Mullumbimby Creek, Kings Creek and Saltwater Creek all interacting. A more detailed evacuation assessment is required to better understand the constraints associated and identify suitable evacuation centres that are flood free up to and including the PMF flood event.

SUMMARY

☑ **RM07: Recommendation**
Undertake an Evacuation Assessment for Mullumbimby.

11.6. Property Modification

11.6.1. PM01: Voluntary House Raising

Voluntary House Raising involves lifting the main habitable floors above a designated design level (typically the 1% AEP or PMF). It has been widely used throughout NSW to eliminate or significantly reduce flooding particularly in lower hazard areas of the floodplain, albeit in limited overall numbers. However it is not suitable for all building types, where the building construction makes it infeasible, or for properties in high hazard areas as it does not sufficiently mitigate the risk to life.

The benefit of house raising is that it eliminates above floor flooding and consequently reduces flood damages. It is best suited to non-brick, single storey houses. House raising can also provide a safe refuge during a flood, assuming that the building is suitably designed for the water and debris loading. However, the potential risk to life is still present if residents choose to enter floodwaters or are unable to leave the house during larger floods than the design flood, particularly in high hazard areas. Ideally floor levels should be raised to be above the level of the PMF and therefore areas with deep flood depths during this event may not be suitable for house raising.

The cost of raising a house can vary considerably depending on the specific details of the house. Additionally, the type of construction of a house can make raising unfeasible, either technically or economically and not all buildings are viable for raising for the following reasons:

- it is more cost effective to construct a new house;
- generally only single storey houses can be raised;
- generally only timber, fibro and other non-masonry construction can be raised;
- generally only pier and non-slab on ground construction can be raised;
- there can be many additional construction difficulties (brick fireplace, brick garage attached to house, awnings or similar attached to house); and
- funding is only available for properties where the buildings were approved and constructed prior to 1986.

ASSESSMENT

The property floor level database was used to identify potential properties which could be considered for Voluntary House Raising. There are limitations to the property database and should a voluntary house raising program be formalised a more detailed investigation should be conducted to confirm construction type and floor levels of all potentially eligible properties. Due to

the limitations of the property database, there may be additional properties eligible and these could be identified using local knowledge. This process, which involved filtering the properties which may be suitable for raising based on the criteria discussed below, should be considered an initial screening process only.

Properties which met all of the following criteria have been identified in the database:

- residential or rural-residential property,
- inundated above floor in flood events more frequent than the 1% AEP (i.e. 2% AEP or more frequent)
- construction type recorded as either cladding, weatherboard or other (excludes brick, block and render)
- property located in hazard categories H1, H2 or H3 only.

A summary of the number of potentially eligible properties (those that meet the above screening criteria) by suburb is provided below:

Table 39: Properties potentially eligible for inclusion in Voluntary House Raising program

Suburb	Total Potential Prop.	Event first inundated above floor			
		5y ARI	10% AEP	5% AEP	2% AEP
Billinudgel	1	0	1	0	0
Brunswick Heads	0	0	0	0	0
Mullumbimby	37	0	2	7	28
Ocean Shores	0	0	0	0	0
Myocum	0	0	0	0	0
New Brighton	20	0	0	1	19
The Pocket	0	0	0	0	0

Grant funding is available from the NSW Flood Program to support the implementation of an eligible voluntary house raising scheme. The grants for funding of this measure generally only cover the basic cost of raising the structure. The subsidy is usually offered on a relative basis depending on the severity of the problem and the potential damage. Residents will most likely have to contribute their own funds to make up any difference and to facilitate the associated works or modifications.

The costs of basic house raising is typically in the order of $60,000 per house, although it can be as high as $120,000.

A cost benefit analysis was undertaking assuming either $60,000 or $90,000 allowance per property, and a a 20% capital cost contingency. Over a 50 year period with a 7% discount rate (set by NSW Treasury Guidelines), the benefits and costs of two options have been calculated. Option 1 assumes all 58 buildings are raised to the current day 1% AEP level + 500 mm freeboard. Option 2 only raises the 11 buildings inundated in the 5% AEP event or more frequent, to the level of the current day 1% AEP level + 500 mm freeboard.

Table 40: Preliminary economic assessment of voluntary house raising program

Option	Reduction in AAD	NPV (Benefit)	Cost	Cost incl 20% contingency	BCR	Net Benefit
Option 1a ($60,000)	$199,030	$2,939,036	$3,480,000	$4,176,000	0.70	-$1,236,957
Option 1b ($90,000)	$199,030	$2,939,036	$5,220,000	$6,264,000	0.47	$349,542
Option 2a ($60,000)	$77,305	$1,141,542	$660,000	$792,000	1.44	-$3,324,957
Option 2b ($90,000)	$77,305	$1,141,542	$990,000	$1,188,000	0.96	-$46,458

From this, Option 2a is shown to be economically viable, with a BCR exceeding 1 and a Net Benefit of nearly $350,000, with Option 2b very nearing a BCR of 1. It is therefore recommended that a better understanding of the costs of house raising for the 11 properties identified is obtained to refine the economic analysis presented here.

An indication of property's eligibility for house raising could be recorded on Part 5 of the Section 10.7 certificate to ensure future potential purchase are made aware of their options.

SUMMARY

Council should further investigate the costs for raising the 11 properties identified in the above assessment. Assuming the total costs is note estimated $1.4m, Council should consider formalising a voluntary house raising scheme, and contact the 11 identified property owners should be made to determine appetite for house raising. Council may wish to include an indication of the property's eligibility on Section 10.7 (5) certificates. A list of the identified properties will be provided to council as part of the handover.

☑ **PM01: Recommendation**

Further investigate raising eligible residential properties to reduce flood damages.

11.6.2. PM02: Voluntary Purchase

Voluntary purchase involves the acquisition of high risk flood affected properties, particularly those frequently inundated in high hazard areas, or located within the floodway, and demolition of the residence to remove it from the floodplain. Removal of properties can help to restore the natural hydraulic capacity of the floodplain and reduces the number of people living in high flood risk areas.

Voluntary purchase is mainly used in more hazardous areas over the long term as a means of removing isolated or remaining buildings to free both residents and potential rescuers from the danger and cost of future floods. The land is given over to public space and should be rezoned as an appropriate use such as E2 Environmental Conservation or similar in the LEP so that no future development can take place. Voluntary purchase can be 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. Government funding for voluntary purchase schemes can be made available through the Floodplain Development Program as long as a number of complying criteria are met.

Voluntary purchase has no environmental impacts although the economic and social costs can be high. Residents can be reluctant to accept voluntary purchase offers because it would have a significant impact on their community and way of life. Other issues encountered with voluntary purchase schemes include:

- difficulty in establishing a market value of the property that is acceptable to both the State Valuation Office and the resident,
- residents may not wish to move even for a reasonable purchase price
- progressive removal of properties may impose stress on the social fabric of an area,
- it may be difficult to find alternative equivalent priced housing in the nearby area with similar aesthetic values or features.

It is not uncommon for the uptake of voluntary purchase properties to slow right down once most of the owner occupied housing stock has been purchased. This can create fragmented neighbourhoods where the remaining housing is dominated by rental properties and visually unappealing businesses. The voluntary purchase zone can also create a perverse incentive for rental investors to hold on to properties.

Land swap schemes can help accelerate the clearance of the floodway such as that undertaken in Grantham, Lockyer Valley, Queensland, following the January 2011 floods. Through such a scheme, people who own land within the floodway would be offered deeds for another parcel of land outside the floodway, in return for their current property to be returned to Council for demolition and clearance.

ASSESSMENT

Voluntary purchase is the most cost effective management strategy for properties located in the floodway who are frequently flooded and subject to high hazard.

The property floor level database was used to identify potential properties which could be considered for voluntary purchase. Similar to the VHR assessment, there are limitations to the property database and should a voluntary purchase be formalised a more detailed investigation should be conducted to confirm construction type and floor levels of all potentially eligible properties. This process, which involved filtering the properties which may be suitable for raising based on the criteria discussed below, should be considered an initial screening process only.

Properties which met the following criteria have been identified in the database:

- residential or rural-residential property,
- inundated above floor in flood events more frequent than the 1% AEP (i.e. 2% AEP or more frequent)
- property located in hazard categories H4, H5 or H6, or the 1% AEP floodway.

A summary of the 15 potentially eligible properties (those that meet the above screening criteria) by suburb is provided below. A list of the identified properties will be provided to council as part of the handover.

Table 41: Properties potentially eligible for inclusion in Voluntary House Purchase program

Suburb	Number of potentially eligible properties
Billinudgel	1
Brunswick Heads	1
Mullumbimby	9
New Brighton	4

The now Department for Planning, Industry and Environment (formerly OEH) have developed guidelines for voluntary purchase schemes (OEH, 2013) which requires consideration of the issues in Table 42. If approved for a voluntary purchase scheme Council would have access to the state-wide Voluntary Purchase / Voluntary House Raising pool for a three-year period. State funding is only available for properties where the buildings were approved and constructed prior to 1986. Council would need to develop a policy or strategy as to how this action might be funded in respect to Council's contribution, including prioritisation of any properties to be acquired and how acquired land will be managed (community gardens, cycleway links, etc.).

Table 42: Voluntary House Purchase considerations

Consideration	Comments
Flood hazard classification and associated risk to life	Property database used to identify residential properties with hazard classification H4, H5 or H6 (see hydraulic hazard maps in Figure 15 - Figure 22)
Hydraulic classification	Property database used to identify residential properties located in the floodway (see flood function mapping, Figure 13 and Figure 14)
The benefits of floodway clearance to flood affected areas	Hydraulic modelling was undertaken which removed the identified properties. The impacts were limited, mapping has been provided to Council for consideration.
Economic, social and environmental costs and benefits	The cost of house purchase extends beyond the acquisition costs. The social costs are generally high to the occupants moved from their homes, however this is considered to be outweighed by the social benefits in reduced damage (tangible and intangible) from flood inundation and risk to life. The social implications for those who chose to stay are potential isolation, fragmentation and sustained flood damages (tangible and intangible). Environmentally the costs of the scheme are negligible. Potential benefits depending on the reuse of the land (e.g. for habitat creation, reconnection of waterway etc)
Viability of the scope and scale of the scheme	15 properties identified as potentially eligible, which is considered a financially reasonable scope of acquisition.

Prioritisation of properties in the scheme	Whilst all identified properties can be considered high priority, further prioritisation criteria are suggested (where 1 is the highest) *(1)* inundated above floor in 0.2EY or 10% AEP event and classified H4 or floodway (7 properties) *(2)* inundated above floor in 5% AEP event and classified H4 or floodway (2 properties) *(3)* located in floodway and inundated above floor in 2% AEP event (6 properties)
Community support of the VP scheme, as determined through consultation	Initial consultation could be undertaken as part of the engagement period for the FRMS. However, further consultation for the potentially impacted communities is recommended.
An implementation plan for the VP scheme	An implementation plan for the scheme would need to be developed in consultation with Council, DPIE and the affected residents.

SUMMARY

☑ **PM02: Recommendation**
Consider establishing a Voluntary House Purchase scheme for eligible properties.

11.6.3. PM03: Land Use Zoning

Land use zones are one of the tools within Local Environmental Plans (LEPS) to guide planning decisions in local government areas. Together with development controls, they provide the framework for the way land can be used and shape the future of the communities. Appropriate land use zoning ensures the land is allocated to the best use, taking into consideration a wide range of factors, of which flood risk is just one part.

Appropriate land use planning can assist in reducing flood risk and ensure development on flood affected areas is flood compatible. Progressive zoning can be used to encourage long term change in flood resilience, whilst overly restrictive zoning can discourage redevelopment that is more flood compatible causing areas to degenerate over time.

The current land use zones for the North Byron catchment area are presented in Figure 3.

ASSESSMENT

The current land use zoning was reviewed against a range of information generated from this floodplain risk management study including:

- Current and future flood hazard
- Flood emergency response classification
- Evacuation route / flood free access

In general, the current zones are consistent with the potential constraints and can be managed through development controls. The exception to this is three potential areas, as shown in Figure 105.

The R2, R5 and B2 zoning within Mullumbimby township falls in one of the catchment hotspots, which is also classified a low flood island. This area has higher flood risk than other parts of the catchment. Council may wish to consider if the zoning suitably aligns with the identified risk, and / or whether additional development control measures may be needed in these locations.

The industrial areas to the east of Mullumbimby and near the Pacific Highway and railway bridge in Billinudgel are also located in high hazard areas. The land use zoning may be appropriate in these locations, but careful consideration should be given to the storage and safety of potentially hazard materials or pollutants which may contaminate local floodwaters.

There are two areas of 2(a) Residential zoned land in South Golden Beach and New Brighton which are located in high and intermediate hazard. Council may wish to consider if the zoning suitably aligns with the identified risk, and / or whether additional development control measures may be needed in these locations.

Council also include a flood hazard overlay map as part of the Land Use planning maps, which indicates areas defined as Low, Intermediate and High Hazard. It is recommended that this map is updated based on the design event data produced as part of this FRMS and derived from the H1 to H6 categories as defined in Section 7.2 of this report, and shown in Figure 106.

☑ **PM03: Recommendation**

Changes to land use zoning should consider flood compatibility based on the recommendations of the FRMS.

11.6.4. PM04: Flood Planning Levels

Flood Planning Levels (FPLs) are an important tool in floodplain risk management. Appendix K of the Floodplain Development Manual (the Manual) provides a comprehensive guide to the purpose and determination of FPLs. The FPL provides a development control measure for managing future flood risk and is derived form a combination of a flood event and a freeboard. The Manual states that, in general, the FPL for a standard residential development would be the 1% AEP event plus a freeboard which is typically 500 mm.

The purpose of the freeboard, as described in the Manual, is to provide reasonable certainty that the reduced flood risk exposure provided by selection of a particular flood as the basis of the FPL, is actually provided given the:

- Uncertainty in estimating flood levels;
- Differences in water level because of local factors; and
- Potential changes due to climate change.

The FPL is used to in planning control primarily to define minimum habitable floor levels but also for other factors such as evacuation, storage of hazardous goods, etc.

ASSESSMENT

Byron Shire Council use a number of flood planning levels, specifically

- 10% AEP plus 0.3m freeboard
- Current 1% AEP plus 0.5m freeboard
- 2050 1% AEP plus 0.5m freeboard
- 2100 1% AEP plus 0.5m freeboard

The revised modelling undertaken as part of the FRMS&P should be used to define FPLs in the catchment, and references within the DCP should be made to this FRMS&P once formally adopted.

In defining the 2050 and 2100 Flood Planning Level, consideration has been given to the results of the sensitivity analysis undertaken in accordance with Byron Councils Climate Change Policy (see Section 8.2). The sensitivity assessment showed that the impacts from rising sea levels alone extend only as far inland as the motorway in the northern area (east of Billinudgel) and the railway line near Mullumbimby, in effect creating no change to current levels for Mullumbimby and Billinudgel. However, when increased rainfall was also considered, the impacts on levels was seen across the full catchment. As such it is proposed that the 2050 Flood Planning Level is derived from Sensitivity Test 1 of Byron Councils current climate change policy, which incorporates a 0.4 m sea level rise and 10% increase in rainfall. It is recommended that the 2100 Flood Planning Level is based on a 0.9 m sea level rise and 20% increase in rainfall. Whilst this does not align directly with a scenario in Council's current policy, it has been recommended in recognition of providing some allowance for additional future rainfall whilst acknowledging there is a greater uncertainty in the predicted changes to rainfall.

SUMMARY

Flood Planning Levels revised based on the recommendations of this FRMS including:

- FPLs should be revised based on the findings of this study and mapped in Figure 107 and Figure 108.
- 2050 Flood Planning Level should be based on the 1% AEP with 0.4 m sea level rise and 10% rainfall increase and 500 mm freeboard.
- 2100 Flood Planning Level should be based on the 1% AEP with 0.9 m sea level rise and 20% rainfall increase and 500 mm freeboard.

☑ **PM04: Recommendation**

Flood Planning Levels revised based on the recommendations of the FRMS.

11.6.5. PM05: Flood Planning Area

The Flood Planning Area (FPA) is an area to which flood planning controls are applied. An FPA map is a required outcome of the FRMS&P.

It is important to define the boundaries of the FPA to ensure flood related planning controls are applied where necessary and not to those lots unaffected by flood risk. Typically, and as per the Floodplain Development Manual, the FPA will be based on the flood extent formed by the 1% AEP mainstream flooding event plus 500 mm freeboard, and therefore, extend further than the extent of the 1% AEP event. Planning controls may therefore be applied to development which is not flooded in a 1% AEP event. The purpose of extending the FPA past the 1% AEP flood extent is to allow for model uncertainties, any future increases in flood extent due to climate change, as well as allow for differences between flood behaviour during events.

The NSW Standard Instrument LEP does not include a specific land use zone classification for flood prone land, rather it permits a Flood Planning Area map to be included as a layer imposed across all land use zones.

The FPA as defined by the Floodplain Development Manual is suitable for areas of mainstream flooding. An FPA based on the current day 1% AEP event plus 500 mm freeboard has been produced, as shown in Figure 109. However, given the catchment's sensitivity to a changing climate and to ensure that future development adequately considers the real and present flood risk, it is recommended that the FPA is derived from the 1% AEP with 0.9 m sea level rise and 20% rainfall increase and 500 mm freeboard, as shown in Figure 110.

☑ **PM05: Recommendation**

Revise the Flood Planning Area based on the recommendations of this FRMS.

11.6.6. PM06: Development Control Plan

A Development Control Plan (DCP) provides guidelines to support the planning controls in the Local Environmental Plan developed by a council. As discussed in Section 6.5.2, Byron Shire Council DCP (2014) contains Chapter C2 *Areas Affected by Flood*, which seeks to ensure development of flood liable land is appropriate to the degree of flood hazard in that location.

A review[4] of the current DCP requirements with regards to flood liable land was undertaken, to establish:

- if the information contained within the DCP was up-to-date and reflective of current best practice
- whether information emerging from the current FRMS could be incorporated to further support the application of the DCP.

ASSESSMENT

- Section C2.1.2 of the DCP articulates the objectives of the Chapter. Objectives 5, 6, and 7 are noted as reflective of the current risk based approach to land use planning, which aims to align development uses with the hazard, and go further than just ensuring no

[4] It should be noted that the review has been undertaken by an experienced flood engineer and the comments are made from the perspective of flood management practice. A strategic and/or local land use planning perspective may alter or override the suggestions expressed below.

worsening of flood risk as a result of development to seeking to improve existing risk.

- Section C2.2 (2) "*… Council will not support filling beneath the building footprint of the proposed development unless it is demonstrated that it will not adversely impact the floodplain."* As discussed in Section 8.1, the reliance on individual lot-based assessments of the impacts from fill does not consider the potential cumulative impact of numerous developments with "acceptable impacts" on the flood behaviour. It is recommended that the findings from Section 8.1 (and subsequent actions), are incorporated into the DCP, with greater restriction placed on development located in the areas identified as "floodplain sensitivity to landform changes". The current clause C2.2 (2) could remain appropriate for land located outside this area.

- Section C2.2 (3) "…*the applicant* ***should*** *consider redesigning the whole building …"* [emphasis added]. Recognising the intent of this clause is to highlight that for certain structures, full redesign may create a better outcome in terms of flood appropriate design and planning, it is questioned whether the current phrasing creates a sufficient incentive for this approach to be adopted by applicants, given there is likely to be an increase upfront cost in adopting such an approach. If Council wish to strengthen these criteria, the onus could be put on applicants to demonstrate that the proposal matches the outcomes of a redesign scenario, or the barriers to full redesign are prohibitive to development.

- The Flood Planning Matrix is reflective of current best practice with regards to tailoring flood design principles to varying land uses and development. Council may wish to consider two additional development types, namely **subdivision** and **fencing**. Subdivisions intensify the population potentially at risk and the DCP may which to specify explicit criteria to ensure adequate on site refuge, or flood free access routes, to service both the existing and future community. Fencing of both urban and rural land has the potential to create significant barriers to flow. This is particularly relevant to the North Byron catchment, where there are a number of rural fences which traverse the creek system. Ensuring they are designed to fail or to not to impede flood waters would provide flood benefit across the catchment.

- Council may wish to satisfy themselves that the control measures which relate to "minimum fill level" are not creating a perverse flood impact. Whilst the control measure directs consideration of the other controls, it may be possible to incorporating the findings of Section 8.1 (and subsequent actions)to ensure that land fill is not the default practice in locations where topographic changes can impact flood behaviour.

- Section C2.3.4 contain the requirements with regards to flood proofing. As discussed in Section 11.6.7 below, Council may wish to include specific reference to some available guidance to support the implementation of these measures.

- Council should consider applying more stringent, and specific, planning and development controls to the areas classified as Low Flood Islands / Low Trapped Perimeter Areas.

- Control measure FL1 of the flood planning matrix in the DCP, requires non habitable rooms/buildings to be equal to or above 10% AEP flood level plus 0.3 m. This creates an inequitable flood planning level as 0.3m above the 10% AEP flood level provides a different level of protection dependant on the flood characteristics of the area. It is suggested that FL1 be changed to "All floor levels to be greater than or equal to the 5% AEP flood level" to provide consistency across the floodplain and with clause 3C.6(2)(g) of State Environmental Planning Policy (Exempt and Complying Development Codes) 2008, which states "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".

- Control measure FL4 of the flood planning matrix in the DCP includes provisions relating to "weatherproof area". There is no definition in the DCP or LEP for "weatherproof area" and as such a definition should be included to explain the intent of this control measure. It is suggested that the DCP be amended to include a definition such as "weatherproof area means the gross floor area of habitable rooms with floor levels below the 2050 flood planning level".

- Consideration of whether the headings of the flood planning matrix in the DCP could be reworded to align with clause 6.3 (6) of BLEP 2014 and whether the controls are consistent with the provisions of clause 6.3 (3) and (4) of BLEP 2014. That is, should the headings "Primary Constraints" and "Additional Constraints" be "Flood Planning Level Constraints" and "Future Flood Planning Level Constraints" respectively. Consider if the controls under each of these headings suitably provide for the provisions of clause 6.3(3) and 6.3(4) respectively.

- Consideration of whether the flood planning matrix in the DCP should include provisions for satisfactory access during a flood. For example, clauses 3C.6 (2) (e) & (f) of State Environmental Planning Policy (Exempt and Complying Development Codes) 2008, state:
  - *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,*
  - *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,*

SUMMARY

The Byron Shire Council DCP (2014) contains a number of relevant provisions relating to development and land uses in flood liable locations. In general, it is consistent with current best practice, particularly with regards to:

- Risk based planning principles of aligning development and design with hazard
- Consideration of future climate conditions
- Incentivising future development to improve existing flood risk
- Use of a flood planning matrix.

A review of the DCP identified some suggestions where further refinement may support the

objectives of the intention of a DCP and the usability of the document by applicants. Community comments from submissions received to the draft FRMS showed the community would like to see improved development controls that encourage risk-appropriate development in the catchment.

☑ **PM06: Recommendation**
Council consider updating the DCP to incorporate the recommendations detailed in the FRMS

11.6.7. PM07: Flood Proofing

This measure applies to all future developments undertaken within the flood planning area (as defined in Section 11.6.5), including retrofitting of existing dwellings and construction of new buildings.

As detailed in Section 6.4 of this report, Part 3 of the SEPP relates to the *"Housing Code"*. Under Section 3.5, the following two clauses specify that for comply development on flood control lots

> *(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),*

Flood proofing is a permanent measure which can be into two categories: wet proofing and dry proofing. Wet proofing assumes that water will enter a building and aims to minimise damage and/or reduce recovery times by choice of materials which are resistant to flood waters and facilitate drainage and ventilation after flooding. Dry proofing aims to totally exclude flood waters from entering a building and is best incorporated into a structure at the construction phase.

There have been considerable advances in the principles and approaches to flood proofing properties, both in the retrofitting and construction phases. 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
- *Flood Resilient Building Guidance for Queensland Homes* (2019), State of Queensland (Queensland Reconstruction Authority)

Brisbane City Council have also recently piloted the Flood Resilient Homes Program to increase the uptake of flood proofing for high risk (50% AEP) properties, which is now being rolled out across the LGA (see https://www.citysmart.com.au/floodwise/ for further information).

SUMMARY

The current DCP includes provisions for applying flood proofing, depending on the land use and level of flood hazard. To further support this approach, Council may wish providing further guidance on the principles and appropriate materials, as discussed in the Queensland and Hawkesbury – Nepean documents mentioned above.

☑ **PM07: Recommendation**

Provide more detailed guidance on the principles of wet proofing, appropriate design and materials, with direct reference to available guidelines.

11.6.8. PM08: Property Level Protection

As an alternative to retrofitting permanent flood proofing measures to existing properties, property level protection approaches can be used. These temporary measures include sandbags, plastic sheeting and other smaller 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 cheaper option for existing properties and can be useful where there is frequent shallow flooding, although it relies on someone 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.

For existing slab on ground properties for which retrofitting options for flood proofing (as discussed *Flood Resilient Building Guidance for Queensland Homes* (2019)) is not practical or possible, property level protection may be an option. Further assessment of potential homes and options for deployment would need to be considered. Where possible, options which are stored on site for deployment (door or window gates) are preferable to those which would require collection from an external site during an event (e.g. sandbags).

Requirement FL4 of the DCP (2014) flood planning matrix could also be modified to include an assessment of the property level protection options available for the site of interest.

☑ **PM08: Recommendation**

Undertake more detailed assessment of properties which may benefit from property level protection and include a requirement for an assessment of property level protection as part of the DCP2014 planning matrix criteria FL4.

11.6.9. PM09: Section 10.7 Certificate

As discussed in Section 6.2 of this report, Schedule 4 of the Environmental Planning and Assessment Regulation 2000 (the Regulation) prescribes the format of the Planning Certificate. Because of the wide range of different flood conditions across NSW, there is no standard way of

conveying flood related information. As such, Councils are encouraged to determine the most appropriate way to convey information for their areas of responsibility. This will depend on:

- The type of flooding;
- Whether flooding is from major rivers or local overland flooding; and
- The extent of flooding (whether widespread or relatively confined).

It should be noted that the section 10.7 Planning Certificate only relates to the subject land and not any specific building on the property.

While the legislation currently does not mandate revealing the extent of flood inundation in a 10.7(2) Planning Certificate, there is scope within a 10.7(5) Planning Certificate for providing this additional type of information.

There can be a general perception from the public that insurance companies, lending authorities or other organisations may disadvantage flood liable properties that have only a very small part of their property inundated by floodwaters. Some Councils have addressed this concern by adding information in 10.7(5) Planning Certificates to show the percentage of the property inundated as well as floor levels and other flood related information. In addition, the hazard category could be provided, and also advice regarding climate change increases in flood level.

More sophisticated data and mapping produced in this study will assist in the dissemination of accurate and site-specific information to the community. A GIS based map can provide useful information to a property owner and simplify the identification of issues by a Council staff member. Section 17.2 and 17.3 of Appendix I to the Floodplain Development Manual (Reference 4) detail typical examples of information for inclusion in Section 10.7 (2) and (5) Planning Certificates, and include the following:

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

The more informed a home owner is, the greater the understanding of their flood risk. During a flood event, having this understanding may help prepare residents for evacuation and reduce the number of residents that elect to shelter in place in high hazard areas, which can increase pressure on the SES if they are isolated or their homes inundated.

Land owners will be required to be notified of changes to both the 10.7 (2) and 10.7 (5) Planning Certificates. Land owners can be concerned as to how a notification may impact on their property value or insurance, for example. The Insurance Council of Australia provides detailed fact sheets on how flood information is used for insurance pricing. This should be taken into account when developing a consultation strategy for notification of any changes related to s10.7 Planning Certificates.

SUMMARY

Data from the hydraulic modelling used in this FRMS should be incorporated into Council's 10.7 Planning Certificate database. Providing this information to residents via an online GIS platform would further support other recommended initiatives to raise community awareness.

☑ **PM09: Recommendations**

Section 10.7 (5) certificates to provide further detail of flood behaviour. Consideration to providing property-level flood information via an online GIS platform.

11.6.10. PM10: Use of fill for future development

Section 8.1 discusses the potential impacts to flood levels from future development in the North Byron Shire floodplain. A number of iterations were tested to identify areas particularly sensitive to topographical changes. Section 8.1.6.5 details the areas across the floodplain where fill should be avoided.

It is important that future development does not produce unacceptable impact on existing properties. However, it is also important that future development is not unnecessarily restricted. To ensure future development can occur without causing an unacceptable impact, it is recommended that the Byron Shire Council DCP2014 be updated to identify areas where filling should be avoided. These areas are provided in Figure U 5 of Appendix U.

For the Billinudgel town centre, identified for industrial and commercial consolidation, it is recommended, future development should comply with the following:

- Maximum development footprint of 50% of the total lot area,
- Maximum **fill** level set to the 1% AEP + 0.5m freeboard, although minimum habitable floor levels greater than this may still apply (detailed in Section 11.6.4).

Council should also consider appropriate methods of enforcing the above restrictions.

☑ **PM10: Recommendations**

Implement the recommendations regarding appropriate fill areas in the DCP2014.

11.6.11. PM11: Investigate incompatible builds

As previously discussed in Section 7.8.3, development in the area south of North Heads Road (the area formerly known as Sheltering Palms) is not permitted due to the incompatible risk.

However, there are known builds still remaining in this area. Where there is an incompatible risk, development should not continue and steps should be taken to ensure these development controls are implemented.

It is recommended that Byron Shire Council compliance team investigate these builds and take actions to demolish these buildings.

☑	**PM11: Recommendations** Byron Shire Council compliance team investigate illegal builds south of North Heads Road.

12. OPTION ASSESSMENT

12.1. Detailed Assessment of Structural Options

As discussed in Section 11.4 a number of structural options were recommended for more detailed assessment. Where appropriate this process involved further consideration and optimisation of the proposed configuration, assessment of impacts for the full range of design flood events (current and future conditions), high-level cost estimate and quantification of benefits. The cost effectiveness of management measures in reducing flood liability within the catchment was determined using the benefit/cost (B/C) approach. A costing was estimated for each measure and this was compared, where appropriate, to the measure's reduction in AAD. Where no significant benefit to AAD was found, the measure's cost effectiveness was assessed qualitatively.

This is discussed in more detail in the following sections.

12.1.1. Option CB02 – Billinudgel Levee and Billinudgel Infrastructure

Preliminary results detailed in Section 11.4.10, show a combined option including a levee at Billinudgel in conjunction with infrastructure improvements could provide widespread reductions in flood levels for Billinudgel. Further detailed assessment of this option is described below.

12.1.1.1. Option CB02 – Design

High level design drawings for this option are provided in Appendix L, with key features described below.

The proposed levee has a total length of approximately 650m, with the alignment shown in Diagram 24. The design level was set to 4.7m AHD which equates to the peak 1% AEP level with a 300 mm freeboard allowance. This results in a varying height of between 1.5 m – 3 m depending on the local topography. This equates to a total fill volume of approximately 12 000 m^3

A number of structural modifications are included in this option, as shown on Diagram 35, specifically

- Railway bridge capacity is increased by widening the opening by 5 m on either side,
- One additional rectangular culvert (H: 1.8m, W: 2m) added under the Railway,
- Two rectangular culverts (H: 1.8m, W: 1.8m) added to the existing two culverts at Bonanza Drive,
- Two rectangular culverts (H: 1.8m, W: 1.8m) added to the existing two culverts at Wilfred Street,
- Four new 1800 mm diameter pipes added to the existing two 1800 mm diameter pipes at Pacific Motorway,
- Two new 600 mm diameter pipes added to the existing two 600mm diameter pipes at Balemo Drive.

12.1.1.1. Option CB02 – Impacts

The inclusion infrastructure upgrades in Billinudgel was shown to offset most of the increased flood levels resulting from the levee alone – impact maps are provided in Appendix M.

A small area of increased flood levels remains downstream of the widened railway bridge. However the increases are marginal, (<0.02m) localised and occurring in the naturally vegetated area.

The impact on property is shown below.

Table 43: Existing and Option CB02 Impacts on Property – Billinudgel Only

Event	Existing - Properties Flood Affected	Existing - Properties Flooded Above Floor Level	Option - Properties Flood Affected	Option - Properties Flooded Above Floor Level	Difference - Properties Flood Affected	Difference - Properties Flooded Above Floor Level
0.2 EY	30	14	28	12	2	2
10% AEP	36	17	34	17	2	0
5% AEP	37	23	36	21	1	2
2% AEP	40	25	40	24	0	1
1% AEP	45	27	42	26	3	1
0.5% AEP	64	47	64	47	0	0
0.2% AEP	82	64	81	64	1	0
PMF	98	86	98	86	0	0
1% CC[5]	80	64	49	32	31	32

Currently, Wilfred Street in Billinudgel is inundated as frequently as the 0.2 EY flood event. This road is the only evacuation access onto the Pacific Motorway for Billinudgel residents. While Option CB02 does not provide flood free access for Wilfred Street, it does provide improved flood immunity for Wilfred Street along Billinudgel with reductions in flood levels of up to 0.2 m to 0.5 m.

12.1.1.2. Option CB02 - Economic Assessment

Appendix N includes the data sheets for the benefit and cost calculations, summarised below.

The levee and infrastructure improvements were estimated to cost $1,520,000, with an annual maintenance costs of $5,000. The reduction in average annual damage (AAD) was calculated as $75,395. Assuming a 50 year time period, using a 7% discount rate, and allowing for a 20% contingency on capital costs, the resulting benefit cost ratio is 0.58.

[5] 1% AEP climate change scenario based on Sensitivity Test 2, includes 0.4 m sea level rise and 10% rainfall increase

12.1.2. Option BM – Billinudgel Infrastructure Upgrade

The original Billinudgel Infrastructure Upgrade option, detailed in Section 11.4.7 and included in the combined option above, comprised a combination of culvert upgrades. While the results were promising the benefits of the option alone were only minor. As part of the detailed assessment phase, the project team undertook another site visit to further consider the option configuration. As a result of this, it was identified that other improvements to the existing Billinudgel infrastructure could be made other than those detailed in Option CB described above. The revised Billinudgel Infrastructure options has been modified from culvert upgrades to channel widening to improve conveyance.

Initial modelling of these infrastructure enhancements showed widespread benefit, and as such the option was included in the detailed assessment.

The assessment below considers possible improvements to Billinudgel infrastructure, however does not identify a final configuration. The option is recommended for further assessment and as part of this assessment, further optioneering and testing should be conducted to optimise the flood mitigation potential for Billinudgel.

12.1.2.1. Option BM – Design

High level design drawings for this option are provided in Appendix L, with key features described below and shown in Diagram 40.

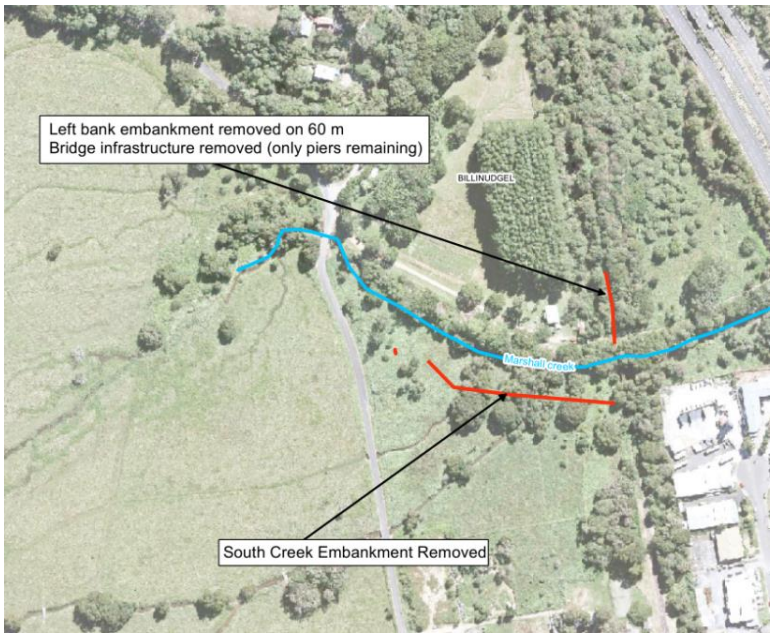


Diagram 40: Option BM – Billinudgel Infrastructure Upgrade.

The left bank of the railway alignment was lowered for a length of 60 m, by a depth varying between 1.5 m to 2.5 m. This equates to the removal of approximately 3500 m^3 of material. The left bank of the creek was also lowered for a length of 150 m, by a depth varying between 0.5 m to 1 m. This equates to the removal of approximately 1000 m^3 of material. In addition, the railway bridge infrastructure (timber beams and steel tracks) was removed for a width of 50 m across the

waterway area.

12.1.2.2. Option BM – Impacts

The alternate infrastructure upgrades in Billinudgel was shown to have a widespread benefit, with a large area seeing peak levels reduced by up to 0.5 m in the 1% AEP event (see Appendix M for the impact map). Downstream of the railway bridge an increase in peak flood levels occurs as a result of the increased conveyance through this constriction. Peak levels generally increase by up to 0.05 m, although larger increases are noted immediately downstream of the bridge. However, this area is vegetated land without property.

The impact on property is shown below.

Table 44: Existing and Option BM Impacts on Property – Billinudgel Only

Event	Existing - Properties Flood Affected	Existing - Properties Flooded Above Floor Level	Option - Properties Flood Affected	Option - Properties Flooded Above Floor Level	Difference - Properties Flood Affected	Difference - Properties Flooded Above Floor Level
0.2 EY	30	14	25	11	5	3
10% AEP	36	17	32	14	4	3
5% AEP	37	23	36	21	1	2
2% AEP	40	25	38	23	2	2
1% AEP	45	27	42	27	3	0
0.5% AEP	64	47	64	47	0	0
0.2% AEP	82	64	81	64	1	0
PMF	98	86	98	86	0	0
1% CC[6]	80	64	50	33	30	31

As discussed above in Section 12.1.1 the evacuation route for Billinudgel, Wilfred Street, has limited flood immunity. Option BM provides similar improved flood immunity for Wilfred Street as Option CB02 with reductions in levels of up to 0.2 m to 0.5 m. There is potential to consider upgrades to Wilfred Street to improve flood access in combination with Option BM in the future.

12.1.2.3. Option BM - Economic Assessment

Appendix N includes the data sheets for the benefit and cost calculations, summarised below.

The infrastructure improvements were estimated to cost $850,000, with a $3,000 annual maintenance cost. The reduction in average annual damage (AAD) was calculated as $106,609. Assuming a 50 year time period, using a 7% discount rate, and allowing for a 20% contingency on capital costs, the resulting benefit cost ratio is 1.47.

Option BM shows infrastructure improvements within Billinudgel have the potential to provide

[6] 1% AEP climate change scenario based on Sensitivity Test 2, includes 0.4 m sea level rise and 10% rainfall increase

substantial flood mitigation benefits. There may be additional infrastructure options that have not been considered and this should be further explored in the detailed design of this option.

12.1.3. Option AC – Avocado Court Drainage Improvements

Section 11.4.5 details the preliminary assessment of drainage improvements to Avocado Court. Initial results showed peak flood depths could be decreased by up to 0.04 m and 0.02 m for the 1% AEP and 0.2 EY flood events respectively, however saw increases in levels along Chinbible Avenue. The option was altered to increase inlet and pipe capacity in the vicinity of Avocado Court and Grevillea Avenue and to regrade the overland flow path between Grevillea Avenue and Pine avenue to improve drainage to the flow path.

The below assessment identifies an option that provides significant flood mitigation benefits for properties within the vicinity of Avocado Court. Community comments as part of the community consultation on the draft FRMS show varying degrees of support and opposition for Option AC. However, a consistent request was for additional investigation to establish the primary cause of flooding in the Avocado Court area during the March 2017 flood event. Comments from the community suggested that the floodwaters may have come from Brunswick River via the Mullumbimby showgrounds. As detailed further below in Section 12.2, Option AC is recommended for further investigation. As part of this investigation, further study should be done to understand the flood behaviour in more detail in this area.

12.1.3.1. Option AC – Design

High level design drawings for this option are provided in Appendix L, with key features described below and shown in Diagram 41.

Diagram 41: Option AC – Avocado Court / Grevillea Avenue Drainage Upgrade.

The capacity of the four existing pipes was increased:

- 600 mm diameter pipe running from Avocado Court to Grevillea Avenue increased to 900 mm
- 600 mm diameter pipe in Grevillea Avenue increased to 900 mm
- 750 mm diameter pipe running from Grevillea Avenue to Pine Avenue increased to 1200 mm
- 900 mm diameter pipe in Pine Avenue increased to 1200 mm

Three additional pipes have been included to connect three additional inlets

- One new inlet (1.2 m lintel) and one connecting pipe (375 mm diameter, 23 m length) on Avocado Court
- Two new inlets (1.2 m lintels), with two new connecting pipes (375 mm diameter, 7 m length) and a new junction pit on Grevillea Avenue

12.1.3.1. Option AC – Impacts

As outlined in Section 11.4.5, Option AC was assessed using the DRAINS 1D modelling package and while it does not produce flood extent mapping it does provide flood levels. Results of the assessment are provided in Appendix M. For the 1% AEP flood event, flood levels are reduced by 0.25 m along the overland flow path between Avocado Court and Grevillea Avenue and by 0.7 m along the overland flow path from Grevillea Avenue to Pine Avenue. In the 0.2 EY flood levels are reduced by 0.2 m path between Avocado Court and Grevillea Avenue and there is no longer flooding between Grevillea Avenue to Pine Avenue.

The impact on property is shown below.

Table 45: Existing and Option AC Impacts on Property – Mullumbimby Only

Event	Existing - Properties Flood Affected	Existing - Properties Flooded Above Floor Level	Option - Properties Flood Affected	Option - Properties Flooded Above Floor Level	Difference - Properties Flood Affected	Difference - Properties Flooded Above Floor Level
0.2 EY	22	3	0	0	22	3
10% AEP	25	9	3	0	22	9
5% AEP	31	14	9	1	22	13
2% AEP	33	15	12	4	21	11
1% AEP	35	19	16	6	19	13
PMF	50	41	45	35	5	6

12.1.3.2. Option AC - Economic Assessment

Appendix N includes the data sheets for the benefit and cost calculations, summarised below.

The infrastructure improvements were estimated to cost $550,000, with an annual maintenance cost of $2,000. The reduction in average annual damage (AAD) was calculated as $161,473. Assuming a 50 year time period, using a 7% discount rate, and allowing for a 20% contingency on capital costs, the resulting benefit cost ratio is 3.43.

12.1.4. Option SC – Saltwater Creek Upgrade

The initial assessment for Saltwater Creek (Option BP02 described in Section 11.4.3) found limited flood benefit from the particular option which was modelled, however indicated there could be potential for Saltwater Creek to take more of the flows during an event, effectively acting as a bypass channel, reducing the impacts for property in Mullumbimby. Mullumbimby has been identified as a flood hot spot due to the frequency of above floor inundation, the number of residents impacted, and the evacuation constraints associated with its classification as a low flood island. As such a number of options were modelled, discussed below. A preferred configuration was not identified through this process, and therefore a more localised assessment, including refinement of the model in this area, is recommended. The model developed in the North Byron Shire Flood Study (Reference 5) included the section of creek locally known as Stewy's swimming hole, where Saltwater Creek and Mullumbimby Creek meet. The creek no longer follows the same path and follows a more direct route. It is recommended that when the mitigation Option SC is investigated further that this is updated in the model to reflect the current path.

A number of suggestions were put forward from the community as part of the community consultation on the draft FRMS with mention of replacing the Myokum Street and Jubilee Avenue culverts with bridges, widening Kings Creek Bridge on Mullumbimby Road or installation of large openings under the train line south of Saltwater Creek. Generally there was strong support for an option that improved environmental flows in Saltwater Creek. It is recommended that any mitigation works considered further ensure there are no negative impact to properties elsewhere in the floodplain.

An economic assessment was not undertaken, however the design configuration and impacts observed for the 1% AEP design event are discussed below.

12.1.4.1. Option SC2 – Removal of Myokum Street embankment and increased Jubilee Avenue culvert capacity

Design

Diagram 42 shows an overview of the option configuration. 30m of the road embankment at Myokum Street which crossed Saltwater Creek was removed from the model, which equates to a volume of 750 m3.

The Jubilee Avenue culvert capacity was also substantially increased from 2.5 m wide x 2 m high to 8 m wide x 2.5 m high.

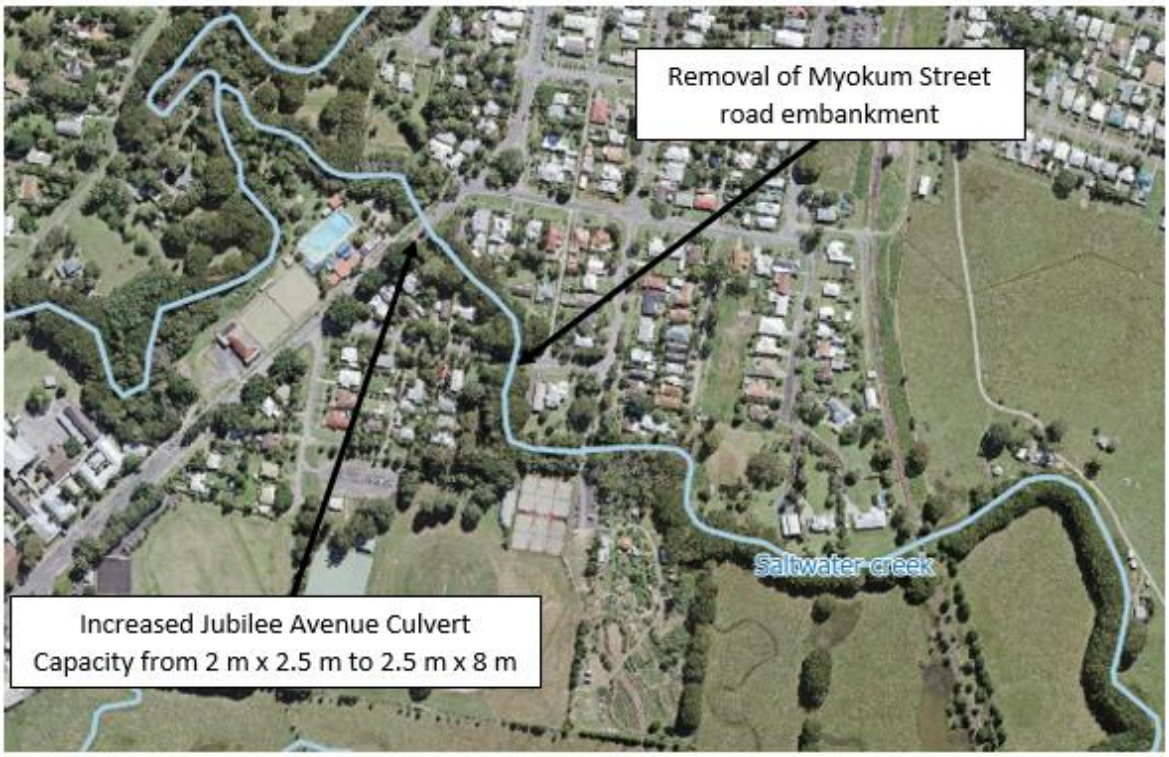


Diagram 42: Option SC2 - Removal of Myokum Street embankment and increased Jubilee Avenue culvert capacity.

Impacts

Option SC was shown to have widespread benefit, as shown in Appendix M, however in the developed areas this was generally limited to no more than up to a 0.05m reduction in peak levels. Flood levels were also shown to increase in the area sounding Saltwater Creek, by up to 0.05 m.

The impact on property is shown below.

Table 46: Existing and Option SC2 Impacts on Property – 1% AEP event, Mullumbimby Only

Scenario	Total No. Properties affected	Total No. properties flooded above floor	Residential Properties affected	Residential Properties flooded above floor
Existing	739	262	585	153
Option SC2	711	257	562	154
Difference	-28	-5	-23	+1

12.1.4.2. Option SC2b – Removal of Myokum Street embankment, increased Jubilee Avenue culvert capacity and increased capacity

Design

Diagram 43 shows an overview of the option configuration. The modifications to Myokum Street road embankment and Jubilee Avenue culvert were modelled as per Option SC2. In addition, Saltwater Creek was widened by 5 – 10 m and formally connected with Kings Creek (1500 m of channel length modified). The swale east of the railway line, running adjacent to Saltwater Creek was also widened by 5 -10m, for a length of 400 m.

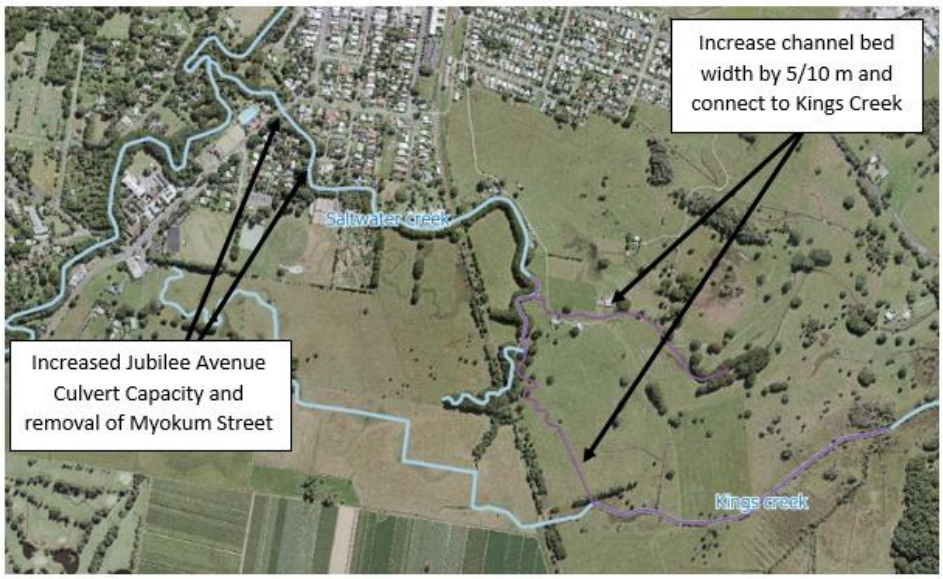


Diagram 43: Option SC2b - Removal of Myokum Street embankment, increased Jubilee Avenue culvert capacity and increased capacity

Impacts

Similar to Option SC2, Option SC2b was shown to have widespread benefit, as shown in Appendix M, however in the developed areas this was generally limited to no more than up to a 0.05m reduction in peak levels. The additional capacity east of the railway line reduced the areas of increased flood levels, however, flood levels were still shown to increase in the area sounding Saltwater Creek, by up to 0.05 m.

The impact on property is shown below.

Table 47: Existing and Option SC2b Impacts on Property – 1% AEP event, Mullumbimby Only

Scenario	Total No. Properties affected	Total No. properties flooded above floor	Residential Properties affected	Residential Properties flooded above floor
Existing	739	262	585	153
Option SC2	711	257	562	154
Difference	-28	-5	-23	+1

12.1.4.3. Option SC3 – Combination of BP02 and SC2

Design

Diagram 44 shows an overview of the option configuration. This option combined the channel modifications considered in BP02 (Saltwater Creek is widened and deepened for a total length of 3.5 km, connecting it with Kings Creek) with the structural modifications of Option SC (removal of Myokum Street road embankment and increase of Jubilee Avenue culvert capacity).

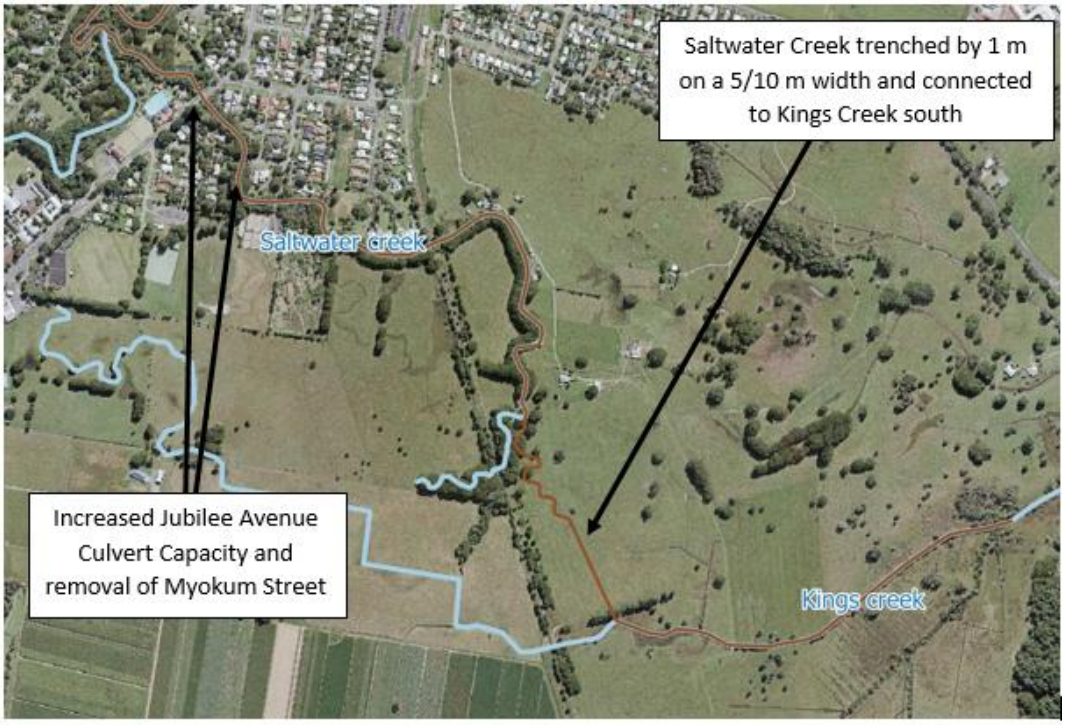


Diagram 44: Option SC3 - Combination of BP02 and SC2

Impacts

Option SC3 again was shown to have widespread benefit, as shown in Appendix M, with levels in the developed areas decreasing by up to 0.2 m. To the east of the railway line there is a large area where flood levels increase, by up 0.1 m.

The impact on property is shown below.

Table 48: Existing and Option SC3 Impacts on Property – 1% AEP event, Mullumbimby Only

Scenario	Total No. Properties affected	Total No. properties flooded above floor	Residential Properties affected	Residential Properties flooded above floor
Existing	739	262	585	153
Option SC3	711	249	560	147
Difference	-28	-13	-25	-6

12.1.4.4. Option RR – Removal of Myokum Street embankment, increased Jubilee Avenue culvert capacity and removal of railway embankment

Design

Diagram 45 shows an overview of the option configuration. This option combined the structural modifications of Option SC (removal of Myokum Street road embankment and increase of Jubilee Avenue culvert capacity) with removal of 2.4 km of the railway embankment lying between Brunswick River and Kings Creek.

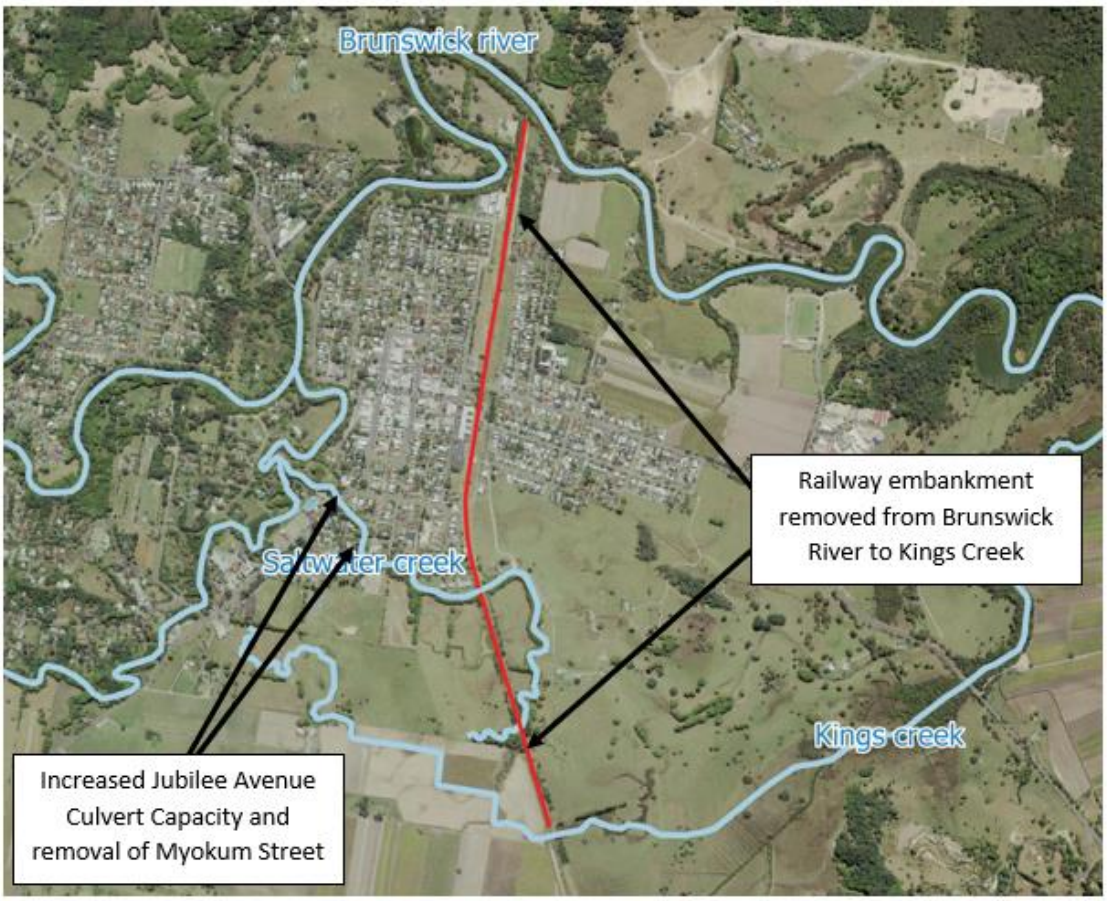


Diagram 45: Option RR - Removal of Myokum Street embankment, increased Jubilee Avenue culvert capacity and removal of railway embankment

Impacts

Option RR showed extensive areas of reduced levels, as shown in Appendix M. For the properties immediately west of the removed railway embankment reductions of up to 0.2 m are shown. However this corresponded with increases of up to 0.2 m on the eastern side of the removed railway line.

The impact on property is shown below.

Table 49: Existing and Option RR Impacts on Property – 1% AEP event, Mullumbimby Only

Scenario	Total No. Properties affected	Total No. properties flooded above floor	Residential Properties affected	Residential Properties flooded above floor
Existing	739	262	585	153
Option RR	686	249	543	155
Difference	-53	-13	-42	+2

12.2. Recommendations from Detailed Assessment

As a result of the assessments detailed above, the following recommendations are made. Note, all options recommended for flood management require further investigation and assessment, but at this stage of analysis indicate potential to support flood risk reduction in the catchment.

	Detailed Assessment Recommendations
☒	**Option CB02** – Billinudgel Levee and drainage improvements are not recommended
☑	**Option BM –** Further consideration of Billinudgel infrastructure improvements.
☑	**Option AC –** Further consideration of Avocado Court drainage modification.
☑	**Option SC –** Further detailed assessment of Saltwater Creek upgrade assessment and mitigation options for Mullumbimby.

12.3. Multi-Criteria Assessment

12.3.1. Background

Multi-criteria decision matrices are recommended in the Floodplain Development Manual (Reference 4) as a tool to guide the prioritisation and assessment of flood management measures. The matrices allow the consideration of a number of factors such as technical feasibility, community acceptance, environmental impacts, to be included, building on the assessment of change in flood behaviour, property damage and benefit cost ratios.

The draft criteria recommended for inclusion in the matrix for the North Byron catchment are:

- Economic merits
- Technical feasibility
- Long term performance
- Impact on emergency services,
- Impacts on critical and/or vulnerable facilities,
- Impact on properties,
- Impact on flood hazard / risk to life,
- Community flood awareness,
- Climate change adaptability,
- Community and stakeholder support / impacts,
- Environmental and ecological impacts,
- Legislative compliance, including requirement for approvals
- Financial feasibility
- Compatibility with existing Council plans, policy and strategic direction.

The associated scoring system for the above criteria is provided in Table 50.

Table 50: Matrix Scoring System

Criteria	Metric	Score						
		-3		-1	0	1	2	3
Economic Merits	*Comparison of the economic benefits against the capital and ongoing costs*	BC < 0	BC: 0.1- 0.5	BC: 0.5-0.9	BC = 1 (Or NA)	BC: 1.0 - 1.5	BC: 1.5 - 2.0	BC >2.0
Technical Feasibility	*Potential design, implementation and operational challenges and constraints.*	Major constraints and uncertainties which may render the option unfeasible	Constraints or uncertainties which may significantly increase costs or timeframes	Constraints or uncertainties which may increase costs or timeframes moderately	NA	Constraints that can be overcome with moderate investment of time and resources	Constraints that can be overcome easily	No constraints or uncertainties
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	Considerable reduction in maintenance requirements, >30 year design life
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
Impact on Critical and/or Vulnerable Facilities	*Disruption to critical facilities*	Significant increase in flood risk	Moderate increase in flood risk	Minor increase in flood risk	No Change	Minor reduction in flood risk	Moderate reduction in flood risk	Significant reduction in flood risk
Impact on Properties	*No. of properties flooded over floor. Across all events*	Above floor inundated increased	Moderate increase to number of lots affected	Some increase to number of lots affected	None / change acceptable (e.g. non habitable land)	Redcution to number of lots affected	Reduction to number of lots affected, minor reduction to above floor inundation	Above floor inundation reduced, signifncat reduction in lot affectation
Impact on Flood Hazard / Risk to Life	*Change in hazard classification*	Significantly increased in highly populated area	Moderately increased in populated area	Slightly increased	No Change	Slightly reduced	Moderately reduced in populated area	Significantly reduced in highly populated area
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
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 moederation mitigation to changing climate	Entirely mitigates changing climate
Community and Stakeholder Support / Impacts	*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 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	Opportunity for planting of isolated trees, minor landscapng.	opportunity for moderate enhancement of disparate area	Opportunity for large scale enhancement / improved connectivity of habitats
Legislative Compliance (including requirement for approvals)	*Consistency with legislative or policy requirements*	Non compliant	Compliance issues considered possible to overcome	Resource burden to navigate approvals	Neutral	Minor approvals required, compliant	No approvals required, compliant	Improves compliance
Financial Feasibility	*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	No relevant	Moderate capital and ongoing costs, partial funding available; or low capital and ongoing costs, no funding available	Low to moderate capital and ongoing costs, partial funding available	Full external funding and management available
Compatibility with existing Council plans, policies or strategic direction	*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

It is important to note that the approach undertaken does not provide an absolute "right" answer as to what should be included in the Management Plan but is rather for the purpose of providing an easy framework for comparing the various options on an issue by issue basis which stakeholders can then use to make a decision. For the same reason, the total score given to each option, and the subsequent rank, is only an indicator to be used for general comparison.

12.3.2. Results

The results of the multi-criteria assessment are summarised below, with further detail provided in Appendix Q.

It is recommended a committee is formed to oversee the implementation of the below actions. The role of this committee would be agreed at the inception, however should aim to ensure actions are appropriately investigated and implemented, and align with the intention of the FRMS.

ID	Section	Option	Total Score	Overall Rank
PM04	11.6.4	Flood Planning Levels revised based on the recommendations of the FRMS.	20	1
PM09	11.6.9	Section 10.7 (5) certificates to provide further detail of flood behaviour. Consideration to providing property-level flood information via an online GIS platform.	18	2
RM02	11.5.2	Byron Shire Council and SES to consider the findings and recommendations of the FRMS in the development of the Flood Warning Network for North Byron.	18	2
RM05	11.5.5	Identify key roads and implement automatic warning signs and depth indicators.	16	4
PM06, PM07, PM08 (part), PM10	11.6.6,11.6.7, 11.6.8, 11.6.10	Council consider updating the DCP to incorporate the recommendations detailed in the FRMS; Provide more detailed guidance on the principles of wet proofing, appropriate design and materials, with direct reference to available guideliness; include a requirement for an assessment of property level protection as part of the DCP2014 planning matrix criteria FL4; Implement the recommendations regarding appropriate fill areas in the DCP2014.	16	4
CDM	11.4.6	Development a whole of catchment drainage model and overland flow path investigation.	16	4
PM08 (part)	11.6.8	Undertake more detailed assessment of properties which may benefit from property level protection	16	4
FDC	11.4.6	Implement debris control measures for Federation Bridge and Billinudgel Railway Bridge.	16	4
RM07	11.5.7	Undertake an Evacuation Assessment for Mullumbimby.	16	4
PM03	11.6.3	Changes to land use zoning should consider flood compatibility based on the recommendations of the FRMS.	16	4
PM01	11.6.1	Further investigate raising eligible residential properties to reduce flood damages.	15	11
SC	12.1.4	Further detailed assessment of Saltwater Creek upgrade assessment and mitigation options for Mullumbimby.	15	11
IC	12.3.2	Form a committee, comprising council, state, emergency services and community member representatives to oversee the implementation of the FRMP.	15	11

RM01	11.5.1	Council and the SES to update the Local Flood Plan based on findings of the FRMS.	15	11
PM05	11.6.5	Revise the Flood Planning Area based on the recommendations of the FRMS.	14	15
RM06	11.5.6	Engage with the community to prepare an ongoing flood education program, with appropriate evaluation by Council and SES following implementation.	14	15
AC	12.1.3	Further consideration of Avocado Court drainage modification.	14	15
PM11	11.6.1	Byron Shire Council compliance team investigate illegal builds south of North Heads Road.	14	15
RW02	11.4.3	Develop a sediment transport model to investigate modification to the rock walls, as part of the Coastal Management Program for the Brunswick Estuary.	14	15
BM	12.1.2	Further consideration of Billinudgel infrastructure improvements.	13	20
WFG	11.4.4	Develop guidance on the design and installation of fencing traversing waterways and channels.	13	20
PM02	11.6.2	Consider establishing a Voluntary House Purchase scheme for eligible properties.	13	20
RM03	11.5.4	More detailed assessment of potential raising of River Street to provide improved flood immunity and evacuation.	11	23
SGBA	11.4.1	Implement the recommendations of the South Golden Beach levee audit.	7	24
NCD	11.4.5	Further consider viable options to implement the recommendations of the New City Road drainage assessment.	4	25

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Figures

Appendix A

Appendix A. **GLOSSARY**

Taken from the Floodplain Development Manual (April 2005 edition)

acid sulfate soils — Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.

Annual Exceedance Probability (AEP) — The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).

Australian Height Datum (AHD) — A common national surface level datum approximately corresponding to mean sea level.

Average Annual Damage (AAD) — Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.

Average Recurrence Interval (ARI) — The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.

caravan and moveable home parks — Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.

catchment — The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.

consent authority — The Council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.

development — Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act).

infill development: refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development.

new development: refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power.

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

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

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

- major overland flow paths through developed areas outside of defined drainage reserves; and/or

- the potential to affect a number of buildings along the major flow path.

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

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

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

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

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

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

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

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

no fill area — Represent areas of the floodplain where use of fill can cause an unacceptable impact to existing development. Protection of these areas ensures that future development can occur without causing an unacceptable impact.

peak discharge — The maximum discharge occurring during a flood event.

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

Probable Maximum Precipitation (PMP) — The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of

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

Appendix B

Appendix B. PREVIOUS FLOOD STUDIES AND INVESTIGATION

A significant number of studies have previously been carried out within the North Byron catchment investigations into flooding have been on-going in the area since the early 1980s. A summary of these reports and their findings are listed below.

B.1. Brunswick Valley Floodplain Management Study Hydrology Report, 1984

Byron Shire Council commissioned Laurie, Montgomerie & Pettit in conjunction with Webb, McKeown & Associates to prepare a hydrologic model and corresponding report. The report outlines the data collection and review of available rainfall and stream data and details the development and calibration of the rainfall-runoff hydrologic model. Flow hydrographs were prepared for past flood events and also produced for the 5% AEP and 1% AEP design flood events.

B.2. Marshalls Creek Flood Study, 1986

Investigations into the flood behaviour in Marshalls Creek were carried out by Webb McKeown & Associates and completed in November 1986. The Marshalls Creek flood study defines design flood levels for 1% and 5% AEP events under existing catchment conditions. The study area includes the floodplain from just upstream of Billinudgel to the Brunswick River confluence.

The study used the quasi-two-dimensional model from the Brunswick River Flood Study and extended the hydraulic boundary upstream to incorporate Marshalls creek. Flood events in March 1974, February 1976, March 1978 and July 1985 were used for the model calibration and validation. The absolute accuracy of flood levels reproduced by the model is about 0.2m due to gaps and low quality in historic data records. Following the study, the 1 % AEP flood was adopted as standard for floodplain management along the Marshalls Creek Floodplain.

B.3. Brunswick Valley Floodplain Management Study, 1987

Byron Shire Council engaged Webb, McKeown & Associates to complete a Floodplain Management Study for the Brunswick Valley Floodplain. This study was delivered in April 1987 and assessed the hydraulic impacts of 9 development proposals in the Brunswick River Valley.

The following options were evaluated for their potential flood mitigation benefits:

1. Lowering the bed level of the Brunswick River entrance by 0.5, 1.5 and 2.5m. Results showed no significant benefits to flood affected areas.
2. Construction of a 1km long flood by-pass weir between Marshalls Creek and the ocean, immediately to the north of the present Brunswick River entrance. Results indicated a reduction of flood levels in some areas (New Brighton: 0.4m - 0.5m reduction in 1% flood levels; Mullumbimby and Billinudgel: a maximum 0.05m reduction in 1% flood levels).

The assessment was limited due to a feasibility investigation of flood hydraulics under design flood conditions (multi-disciplinary detailed study required).

3. Construction of a floodway linking Mullumbimby Creek to Kings Creek. This option provided no significant benefit.
4. Protection for a proposed residential development west of Mullumbimby. Two options were considered: (a) levee 0.5m above the 1% flood and (b) levee at the extreme flood level. Results showed for (a) a significant increase in flood level near the showground; and (b) not enough protection of development in extreme flood events.
5. Filling of land near Billinudgel on the MarshalIs Creek floodplain. Flood levels upstream of Billinudgel were increased by a maximum of 0.08m.
6. Filling of land to the west of Brunswick Heads for a proposed residential development. This saw a maximum increase of 0.13m in the 1% flood levels immediately upstream of the development.

7.a. Filling of the land considered in option 6 and the additional filling further west of Brunswick Heads. Results shows a maximum increase of 0.3m in the 1% flood levels immediately upstream of the development.

7.a. Filling of the land considered in option 7.a. and a proposed floodway channel through the filled area. The proposed floodway channel was found to not be large enough to mitigate impacts from filling.

8. Filling of land east of Mullumbimby and south if Argyle street for future industrial development. Results showed no significant benefit to flood affected areas.
9. Filling of land north of Argyle Street for future industrial development Results showed no significant benefit to flood affected areas.

B.4. Flood Mitigation Options for Billinudgel, 1988

The report prepared by Ray Sargent and Associates focused on flood mitigation options for Billinudgel. The 1987 Brunswick Valley Floodplain Management study showed minimal impacts on flood levels from filling. However, this report notes that increases in flood levels of 50mm could impact on existing properties and inundate previously dry properties. As the impact from filling land is very low, the report concludes the levees are likely to have minimal impact but while noting this, it does not continue to investigate this option further.

To reduce the risk of flooding and prevent a deterioration of the flood problem, the following actions are recommended:

- Floodways blocked by vegetation growth should be cleared and maintained.
- The creek channel should be controlled by dredging, vegetation clearing and partial re-routing. However, some siltation at the downstream confluence of Marshalls Creek and Brunswick River is expected and the half-tide training wall at the creek mouth is a likely contributing factor.

B.5. Brunswick River Floodplain Management Investigation, 1989

The Brunswick River Floodplain Management Investigation was completed in November 1989 by

Webb, McKeown & Associates in conjunction with the Brunswick River Floodplain Management Committee. The floodplain management investigation was in response to requests to investigate flooding problems in the area and development applications to re-zone and develop flood prone land in the Marshall Creek floodplain.

This investigation primarily looked at the Development Concept Plan put forward by the Ocean Shores Development Corporation (OSDC). This plan includes the following:

- Residential subdivision surrounding a 16-ha lake linked to the present canal system within North Ocean Shores,
- Tourist development on part of the flat grassland area behind the beach dune system near Wooyung,
- The Holiday Village Site, a 13-hectare tourist development on land between New Brighton and South Golden Beach,
- Residential development in South Ocean Shores Golf Course,
- Residential and a combination of commercial and educational development on the land adjacent to Shara Boulevarde,
- Rural residential development within the Yelgun Creek catchment.

Separate to the OSDC Development Concept Plan, the investigation also considered the future development of land owned by Crown Land and land owned by Mr J Mangleson. The investigation looked at flood mitigation options to both protect existing development and manage the impacts of possible future development. The Floodplain Management Committee requested the assessment of the several flood mitigation options. A description of these is provided below.

- Levee around South Golden Beach, New Brighton or Billinudgel showed no additional benefits,
- Lowering of railway line at Mullumbimby was found to have no significant impact on flood levels.
- Results show widening of the road and rail bridges at Billinudgel would have minimal impact on flood levels.

In addition to the above flood mitigation options the following mitigation options were assessed:

- Flood outlets at three locations,
- Dredging of Marshall Creek,
- Widening of Orana Bridge,
- Floodway across South Ocean Shores Golf Course,
- Separation of Yelgun Creek and Marshall Creek systems including a flood-gated system,
- Widening of the link between Yelgun Creek and Marshall Creek, and
- Floodway immediately downstream of the Pacific Highway.

The study assessed the proposed flood mitigation options individually and three combinations of flood mitigation options. The study concluded that:

- To mitigate the impacts from the proposed development, a combination of flood mitigation works is required and would need to either include dredging of Marshall Creek or the North Ocean Shores flood outlet.
- A levee around South Golden Beach would increase flood levels at new Brighton and would require a levee on the northern boundary.

- It is expected a levee around New Brighton without additional flood mitigation works would have impacts on upstream flood levels. For New Brighton, flood proofing measures are suggested.
- Should part of the development on Mr Mangleson's land proceed independently of the remainder of the proposal, a section of the floodway proposed opposite the land should be constructed.
- Development on Site B Mangelson land may have significant hydraulic impacts as the land is low-lying and forms part of the floodway. These impacts would not be easily mitigated.

B.6. Mullumbimby Floodplain Management Study, 1989

The Mullumbimby Floodplain Management Study was completed in December 1989 in consultation with the Brunswick River Floodplain Management Committee. The report focused on investigating flood mitigation options and assessing the potential impacts future development could have on flood levels. Considerable flood damage was caused during the May 1987 flood event. Residents put forward that the recently raised railway line had caused an increase in flood damages seen. However, study results showed that the changed railway level had no significant impact on flood levels.

Subsequently, the following flood management options were assessed, and the results are presented below:

- A diversion of floodwaters down Saltwater Creek provides no flood mitigation benefits and would have adverse impacts on other properties.
- Raising of houses or additional local flood protection would be not viable due to the number of houses affected and cost. In combination with other options, house raising may have potential.
- A flood warning system could reduce flood damages however, due to the short response time of the catchment was not considered a solution.
- Dredging of the Brunswick River would not eliminate the flood problem but in combination with other options could be more effective.
- Lowering or removal of the railway line would reduce flood levels on the upstream side of the railway line, as the line restricts flow across the floodplain at Mullumbimby. However, lowering of the line would increase flood levels on the downstream side and increase flow velocities at Station Street.
- Improved drainage through the railway line by adding culverts under the line would have a similar effect as the lowering of the line. A significant number of culverts (approx. 70) would be necessary to have a significant impact on flood levels upstream.
- A levee bank around the western part of the town would protect 30% of the flood prone properties but would have a negative impact on flood levels upstream of the levee. Associated drainage required with this option includes 4 culverts under the railway line and some additional culverts through the levee. Negative impacts caused by the levee could be mitigated by dredging of the Brunswick River, or stream clearing near the railway bridges to the south of Mullumbimby.

- Development of the proposed Industrial Estate located on Football Club Road would significantly increase flood levels downstream of the railway line. However partial development of the site may be possible.
- A levee bank around the eastern part of the town would protect 56% of the flood prone properties. While there were found to be no negative impacts on flood levels upstream of the railway line, a levee bank would cause a 10mm increase in flood levels downstream of the line. This option would require raising parts of Argyle Street and the construction of a 16-hectare storage basin inside the levee.
- Widening of the Main Road 524 bridge on Kings Creek by over double and lowering of Main Road 524 to ground level would reduce the 1% AEP flood levels by up to 20mm and 50mm respectively. Lowering of MR524 is expected to have impacts to trafficability during flood events. The report concludes neither option is cost efficient.

B.7. Proposed Levees around South Golden Beach, 1989

This report was prepared by Webb McKeown & Associates and looks at managing flood risk in the residential development at South Golden Beach. This development is divided by Capricornia Canal and the proposal looked at a potential levee system around the eastern and western sections up to the 1% AEP event. The project considered the impacts of a 3.2m AHD levee. In comparison the May 1987 flood level was 2.7m AHD and the 1% AEP level is 3.2m AHD.

To manage the potential local drainage problems within the leveed area, the project investigated the effects of flap gated culverts. For operational and maintenance reasons, the use of flood pumps was not recommended here as a solution. While the flap gated culverts were found to be effective at preventing water entering the leveed area, ponding was still found to be a problem. Approximately 30 properties would experience worsening of a maximum afflux of 17mm. A flood compensation fund was suggested for those residents affected by the afflux.

B.8. Marshalls Creek Dredging Investigations Stage 1 Report

The Ecology Lab carried out an investigation of Marshall's creek marine ecology identified significant mangrove stands, seagrass beds, saltmarshes and sand flats in the proposed dredging area. Five species of mangroves were identified in this estuary and the Tweed River is the only other estuary in NSW with this many species. The report notes that NSW Fisheries considered Marshall's Creek as a potential aquatic reserve, however this was not formalised. The investigation considered 5 dredging options and put forward that low volume dredging was identified as the least damaging options to the environment.

B.9. Mullumbimby Floodplain Management Study

Re-evaluation of Options, 1992

Byron Shire Council formed a new Floodplain Management Committee to assess possible flood mitigation options for Mullumbimby. Hydraulics and hydrologic assessments were carried out by Webb McKeown and Associates.

The following options were recommended:

- House raising/flood proofing,
- Council to be responsible for a press release, newsletter and public meeting, and
- Flood indicators of the 1987 flood and rates notices should provide information on flooding. and

The FMC recommended levees in East and West Mullumbimby, however the community were not supportive of this option and it was rejected by Council.

B.10. Report on Feasibility of an EIS for North Ocean Shores Flood Outlet, 1992

The construction of a flood outlet located in the North Ocean Shores area was proposed as possible flood mitigation measure in the Brunswick River Floodplain Management Investigations. Council subsequently commissioned Webb, McKeown and Associations to undertake further investigations into possible flood outlets at North Ocean Shores. The Floodplain Management Investigation found that while the outlet at North Ocean Shores provided flood mitigation benefits when modelled separately, when considered in conjunction with other mitigation measures such as dredging of Marshalls Creek and the levee at South Golden Beach benefits provided by the outlet are reduced.

This report concludes it is not feasible to undertake an EIS for a flood outlet at North Ocean Shores. This is primarily due to the potential economic and environmental impacts including a long term financial commitment from Council to maintain the structure, potential impacts to dune stability, impact on the local flora and fauna from increased salinity levels in the connecting channel and Capricornia Canal and the relatively low benefit / cost ratio.

B.11. Draft Mullumbimby Floodplain Management Plan, 1993

Following the completion of the Mullumbimby Floodplain Management Study, Byron Shire Council prepared the draft Mullumbimby Floodplain Management Plan. The Floodplain Management Committee considered mitigation options assessed in the Floodplain Management Study and concluded flood mitigation dams or catchment treatment were not viable options. Initially, the Committee recommended levees in east and west Mullumbimby. However, due to a lack of community support, these options did not progress.

The draft plan includes a table of proposed works and discusses the benefits that could be incurred from each option and the associated costs. The proposed works were grouped into major and minor works and were all considered to be medium priority and independent of other works. Recommendations made in the plan are:

- Advise the Roads and Traffic Authority (RTA) to consider effects of flood levels when investigating further works on Main Road 524,
- RTA to improve drainage at Kings Creek bridge,
- Remove obstructions in Saltwater Creek catchment and maximise the flows under the railway bridges,
- Increase the capacity of the Myokum street culverts,
- Future buildings to have floor levels of the 1% AEP floor level plus 500mm,
- A 15m floodway to the western and eastern side of the North Coast Railway Line,
- A floodway over Hieronymus' property,
- Installation of a flood warning system in the Brunswick River catchment.

Recommended development Controls within floodways:

- Maintain floodways ability to pass water,
- No works in the floodway that would decrease flow capacity,
- No building development within the floodway,
- No filling within the floodways,
- No fences within the floodway, as they may decrease flow capacity,
- Land uses to be compatible with flood behaviour.

Recommendations for the eastern Mullumbimby floodplain:

- Raise or flood proof all residential buildings impacted by a flood similar to the 1987 event or the 1% AEP event. Habitable floors should be 500mm above the 1% flood level.
- Filling is limited to the level created by a 1% grade line from the road centre line. It is considered this level of filling will not cause drainage problems for neighbouring properties.

Recommendations for Western Mullumbimby/Saltwater Creek Floodplain:

- Raise or flood proof all residential buildings impacted by a flood similar to the 1987 event or the 1% AEP event. Habitable floors should be 500mm above the 1% flood level.
- Habitable floors in new developments should be 500mm above the 1% flood level,
- Commercial and industrial floors should be the 1% flood level or higher,
- Residential properties that are raised should have floor levels 500mm above the 1% flood level.

The management plan considered the impact potential future development could have on flood behaviour. The sites for future development are:

A. An urban development near the showground,
B. The Subdivision of 0.4ha lots at the confluence of the Brunswick river and Mullumbimby Creek,
C. An urban development south of Ann Street towards Saltwater Creek,
D. Commercial or Industrial development north of Argyle street,
E. Commercial or Industrial development adjacent to Football Club Road.

Recommendations specific to potential future development are:

- No filling to occur within floodways,
- Development at sites C and D could occur provided that flood storage is maintained or a

flood study is completed to show that levels within the Mullumbimby floodplain would not be affected,

- Habitable floors in new developments should be 500mm above the 1% flood level,
- Ensure development at site D does not negatively impact neighbouring areas or levels in the Mullumbimby floodplain,

Future development should not increase flood levels for other development in the floodplain.

B.12. Draft Kallaroo Circuit Bund Culvert Amplification Hydraulic Impact Assessment, 1996

This impact assessment was completed by WP Geomarine and discusses the potential hydraulic and environmental impacts from the proposed amplification of the existing Kallaroo Circuit Bund. At the time of the report, the bund had twin 900mm culverts at -0.2m AHD allowing flow from Yelgun creek and Mooball/Crabbes creek to the north. The proposal included increasing the culvert size to twin 2.1 x 3.1m box culverts at -0.2m AHD and a 900mm pipe at -0.3m AHD. Increasing flow capacity at the bund showed the potential to lower flood levels upstream of the bund and reduce existing flood inundation periods by 10% and 70%.

The report looked into the environmental concerns that increasing the drainage capacity at the bund could lower the local groundwater table and may expose potential acid sulfate soils (PASS). The study carried out some sediment sampling and found there was high potential of acid discharge upon oxidisation, which could have negative impacts on water quality and the local ecology. Due to the small site area, the report concludes that the environmental impacts from the amplification are not expected to be significant. However, it notes that the long term environmental impacts may be higher but are difficult to quantify.

B.13. Brunswick River Tidal Data Collection, 2008

The Department of Environment & Climate Change NSW commissioned Manly Hydraulics Laboratory to carry out tidal data collection within the Brunswick River. The aim of this data collection was to better understand the hydraulic processes operating in the Brunswick estuary. Water levels were monitored at 14 sites between 30 April and 3 November 2007. Tidal velocities were monitored at 5 sites on the 31 August 2001 over the spring, flood-ebb semi-diurnal tidal cycle.

Analysis of the data showed the Brunswick River has typical hydraulic characteristics and water quality characteristics seen in estuaries. The study found the tidal limit extends 14km upstream from the ocean and that measured water quality parameters were considered acceptable as set out by the 1992 ANZECC guidelines.

B.14. Marshalls Creek Floodplain Management Plan, 1997

Paterson Consultants Pty Ltd completed the Marshalls Creek Floodplain Management Plan in 1997. The plan looked at flood behaviour within the Marshalls Creek floodplain and found that the majority of flood-liable land is classified as high hazard and flood storage.

At the time the report was produced, 71 residential and commercial properties were identified to be flood liable in the 1% AEP flood event. The average annual damages (AAD) of the potential direct residential flood damages was $55,800. The AAD of direct damage to commercial and industrial properties is $55,100 and 97% of this damage occurs in Billinudgel. The flood damages assessment found that the largest proportion of flood damages occurs in New Brighton.

Floodplain management measures in place at the time of the report include: 1% AEP as a flood standard, minimum habitable floor level controls, a levee system at South Golden Beach and Ocean Shores North and the development of a flood warning system.

As part of the plans community consultation, a Value Management workshop was held in June of 1995 and identified four management options for consideration:

A. Dredging of Marshalls Creek and lowering of training walls at the mouth of Marshalls and Brunswick River,
B. Lengthening of Orana Bridge,
C. The construction of flood outlets at Wooyung, Ocean Shores North and Holiday Village. Fully open the Kallaroo Circuit bund and Capricornia Canal,
D. A quarantine on future development on the floodplain.

During this management plan, Paterson Consultants reviewed the coastal processes in the study area and concluded that if the openings from Marshalls Creek to the Pacific Ocean existed, these would be non-permanent openings. The report concludes that options A to C would not be effective but suggests house raising and flood proofing could significantly reduce the impact of flooding on residential properties.

The floodplain management strategy put forward the following options:

- Voluntary house-raising and flood proofing of houses not appropriate for raising, particularly in in New Brighton,
- A community education program to ensure residents understand the risks associated with flooding,
- A habitable floor level of the 1% AEP flood level with a minimum 0.5m freeboard,
- Limit fill in the floodplain to achieve the minimum habitable floor level and instead use highset building types where appropriate, and
- Properties protected by the South Golden Beach levee should still adopt the minimum habitable floor level,
- Adopt the proposed ‘Quarantine’ measure on future development, and
- Minimum lot levels and minimum habitable floor levels for rural properties in the Yelgun-Wooyung areas.

B.15. North Byron Shire Flood Study, 2016

Byron Shire Council commissioned BMT to undertake the North Byron Shire Flood Study (Reference 5). The Flood Study forms the second phase of the Floodplain Risk Management Process and was completed by BMT in 2016. The Flood Study provides the technical basis for

this floodplain risk management study to further understand flood behaviour in the North Byron floodplain. Appendix G provides a more detailed description of the North Byron Shire model as part of the model review process.