Ballina Shire Council

Ballina Island and West Ballina Overland Flood Study and Flood Protection Feasibility Study and Plan

Draft Report

October 2021

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Abbreviations

AEP	Annual Exceedance Probability
AHD	Australian Height Datum
AIDR	Australian Institute for Disaster Resilience
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff
BSC	Ballina Shire Council
DEM	Digital Elevation Model
DCP	Development Control Plan
DPIE	NSW Department of Planning, Industry and Environment
FPL	Flood Planning Level
FMRS	Flood Risk Management Study
GIS	Geographic Information System
HAT	Highest Astronomical Tide
IPCC	Intergovernmental Panel on Climate Change
LAT	Low Astronomical Tide
LEP	Local Environmental Plan
LGA	Local Government Area
LiDAR	Light Detection And Ranging survey technique
MHL	DPIE Manly Hydraulics Laboratory
MHWN	Mean High Water Neap tide level
MHWS	Mean High Water Spring tide level
MLWN	Mean Low Water Neap tide level
MLWS	Mean Low Water Spring tide level
NSW	New South Wales
OEH	NSW Office of Environment and Heritage (now DPIE)
PMF	Probable Maximum Flood
RCP	Representative Concentration Pathway (gas emission scenario)
SLR	Sea Level Rise
SFC	Special Flood Considerations
2D	Two-dimensional

1. Introduction

1.1 Study Area

The study area is comprised of Ballina Island and West Ballina, both suburbs of the township of Ballina located in the Northern Rivers region of New South Wales (NSW). The populations of Ballina Island and West Ballina are 7,426 and 3,171 respectively. By year 2036, the population is expected to grow by approximately 3%. Figure 1-1 illustrates the extent of the local study area.

Ballina's town centre is located on Ballina Island which is bounded by the Richmond River to the south, North Creek to the east, and the North Creek Canal to the north-west which joins North Creek and the Richmond River. West Ballina is located to the west of Ballina Island and is bordered by the Richmond River to the south, Emigrant Creek to the west and Fishery Creek to the East/North East.

Due to the low lying topography of Ballina and proximity to riverine, creek and coastal waterways, the study area is exposed to an existing and future risk of flooding with significantly larger consequences estimated to occur under future climate scenarios.

1.2 Background

In 2008, the Ballina Flood Study Update (WBMBMT, 2008) was completed to develop an improved understanding of existing and future flood risk in Ballina and surrounding communities. This included the development of updated flood models and flood inundation mapping for riverine, creek and ocean driven design flood events.

In 2012, the Ballina Floodplain Risk Management Study (WBMBMT, 2012) was completed to identify and evaluate options available to manage riverine, creek and oceanic flood risk in the township of Ballina and its surrounding communities. This was followed by development of the Ballina Floodplain Risk Management Plan (WBMBMT, 2015) in accordance with the NSW Floodplain Risk Management Process (refer Section 1.5).

The objective of the *Ballina Island and West Ballina Overland Flood Study and Flood Protection Feasibility Study and Plan* is to develop a strategic plan to mitigate localised existing and future flood risk in Ballina Island and West Ballina (Study Area) by providing practical information in regard to recommended floodplain management measures such as timing, priority, expense and responsibility, or recommendation for further investigation.

1.3 Project Overview

In order to develop an understanding of the degree of flood risk from local overland flooding and to further assess potential flood mitigation measures in Ballina Island and West Ballina, GHD was commissioned by Ballina Shire Council (BSC) to undertake the *Ballina Island and West Ballina Overland Flood Study and Flood Protection Feasibility Study and Plan*. The project includes the following stages:

- Stage 1: Data collection including survey of the existing stormwater network of Ballina Island and West Ballina.
- Stage 2: Ballina Island and West Ballina Overland Flood Study.
- Stage 3a: Identification and Preliminary Assessment of Floodplain Management Options.
- Stage 3b: Detailed Assessment of Shortlisted Floodplain Management Options
- Stage 4: Development of a Strategic Plan of Flood Protection.

1.4 Purpose of this Report

The purpose of this report is to provide a summary of the methodology and outcomes of project *Stage 3a: Identification and Preliminary Assessment of Mitigation Options*, project *Stage 3b: Detailed Assessment of Shortlisted Mitigation Options,* and project *Stage 4: Development of a Strategic Plan of Flood Protection*.

This report follows and draws upon the findings of the Ballina Island and West Ballina Overland Flood Study (GHD, 2020) which was completed during Stage 2 of the project.

1.5 NSW Government's Floodplain Management Process

The prime responsibility for planning and management of flood prone lands in NSW rests with local government, namely Ballina Shire Council in this case. The NSW Government provide assistance with state-wide policy issues and technical support. Financial assistance is also provided to undertake flood behaviour and floodplain management studies, and for the implementation of works identified in these studies.

A Flood Prone Land Policy and a Floodplain Development Manual (NSW, 2005) forms the basis of floodplain management in NSW. The primary objectives of the Policy is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods, utilising ecologically positive methods where possible.

The Policy provides direction for Councils and other public authorities and their staff for their issuing of advice or granting approvals on floodplains. It expects that they act substantially in accordance with the principles contained in the Floodplain Development Manual. The implementation of the Flood Prone Lands Policy generally culminates in the preparation and implementation of a Floodplain Management Plan.

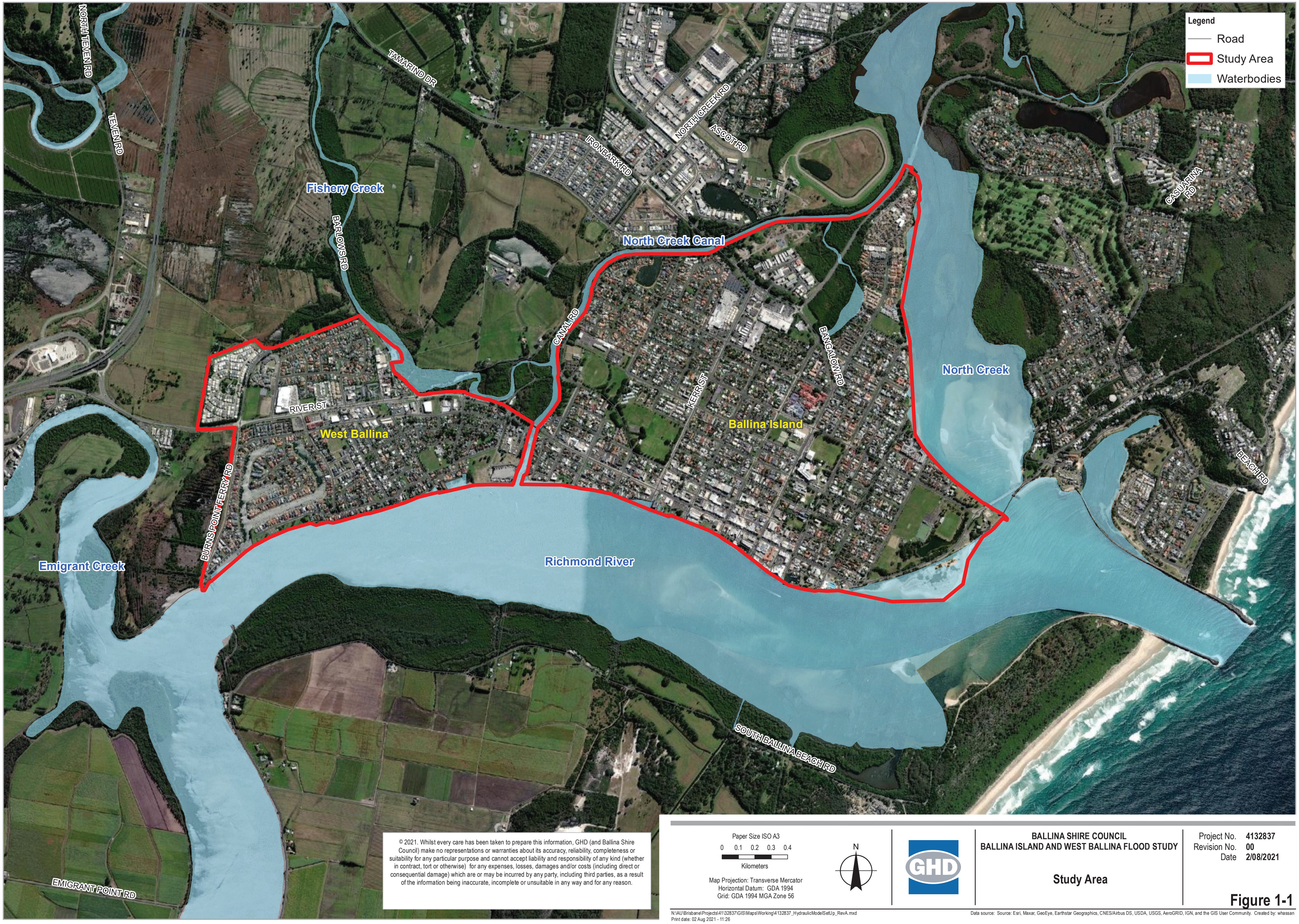
To support this policy, the Floodplain Development Manual identifies four main stages in the floodplain risk management process which includes the following:

- Flood Study: Determines the nature and extent of flooding behaviour.
- Floodplain Risk Management Study: Identifies, develops and compares various floodplain management options utilising the results of the Flood Study as well as assessment of social, economic, ecological and cultural issues.
- Floodplain Risk Management Plan: Formalises outcomes of the previous studies and present the necessary information to enable relevant authorities to plan for the future.
- Plan Implementation: Includes construction of structural floodplain management measures as well as incorporation of non-structural measures into existing Local Authority Environmental and Development Control Plans.

As previously mentioned, the following studies have been completed in this regard:

- Ballina Flood Study Update (BMTWBM, 2008).
- Ballina Floodplain Risk Management Study (BMTWBM, 2012).
- Ballina Floodplain Risk Management Plan (BMTWBM, 2015).

The outputs from those studies have been used to inform this project and its focus on local catchment flood risk within the Study Area.



BALLINA SHIRE COUNCIL
BALLINA ISLAND AND WEST BALLINA FLOOD STUDY

Study Area

Project No. 4132837
Revision No. 00
Date 2/08/2021

Figure 1-1

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Data source: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Created by: whassan

1.6 Assumptions and limitations

The project activities completed to inform this report have been carried out according to the following assumptions:

- The proposed mitigation options assessed in this study to address flooding from riverine, creek and oceanic sources are based on digital design event flood surfaces adopted by BSC. These were originally derived from two-dimensional hydraulic modelling scenarios completed by BMTWBM as part of the Ballina Floodplain Risk Management Study (BMTWBM, 2012) and the Ballina Integrated Model updates (BMTWBM, 2019). It is noted that Council's Year 2050 and Year 2100 flood scenarios include provision for a mean sea level rise (SLR) of 40cm for the Year 2050, and 90cm for Year 2100 (with SLR relative to 1990 mean sea levels). At the time, this was consistent with the NSW Sea Level Rise Policy Statement (DECCW, 2009). No independent verification or review of the design event flood surfaces or hydrologic or hydraulic models that were used to develop these surfaces has been undertaken by GHD.
- Flood model results from the Ballina Island and West Ballina Overland Flood Study (GHD, 2020) have been used to inform this phase of work. The overland flood modelling results adopted to inform preliminary assessment of mitigation options were based on the stormwater network included in the overland flow path hydraulic model, which was in turn based on Council's GIS stormwater network database and Abbott & MACRO survey. Assumptions have been made on pipe invert levels and pipe diameters where those data were not available in either Council's GIS database or Abbott & MACRO survey.
- The flood levee concept provided in this report is conceptual only and has been developed to a concept level that is commensurate with 0 to 2% project maturity.
- All cost estimates presented in this report have been developed at a high level (AACE Class 5) which is commensurate with a project maturity level definition of 0 to 2%. They should be used with caution, only for the purposes of relative comparison of strategic planning considerations.

1.7 Disclaimer

This report has been prepared by GHD for Ballina Shire Council and may only be used and relied on by Ballina Shire Council for the purpose agreed between GHD and the Ballina Shire Council as set out in Section 1.4 of this report.

GHD otherwise disclaims responsibility to any person other than Ballina Shire Council arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Ballina Shire Council and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

GHD has prepared the preliminary cost estimates set out in this report using information on hand the GHD employee(s) who prepared this report at the time of its preparation; and based on assumptions and judgments made by GHD. Cost Estimates have been prepared to provide a Class 5 level estimate of cost and must not be used for any purpose other than relative comparison of presented options during strategic considerations. Cost Estimates are preliminary estimates only, and may not include all site and case specific works, activities and arrangements necessary plan, design, manage, implement and operate the options presented. Actual prices, costs and other variables may be different to those used to prepare Cost Estimates and may change. Unless as otherwise specified in this report, no detailed quotation has been obtained for actions identified in this report. GHD does not represent, warrant or guarantee that the works can or will be undertaken at a cost which is the same or less than the Cost Estimates.

Where estimates of potential costs are provided with an indicated level of confidence, notwithstanding the conservatism of the level of confidence selected as the planning level, there remains a chance that the cost will be greater than the planning estimate, and any funding would not be adequate. The confidence level considered to be most appropriate for planning purposes will vary depending on the conservatism of the user and the nature of the project. The user should therefore select appropriate confidence levels to suit their particular risk profile.

2. Flood Risk in Ballina Island and West Ballina

2.1 Sources of Flooding

2.1.1 Riverine, creek and ocean flooding

There are three main sources of flooding in the study area as identified in the Ballina Floodplain Risk Management Study (WBMBMT, 2012):

1. Richmond River Flooding:

   The Richmond River flows in a north easterly direction adjacent to the coastline through a large rural floodplain. It turns east at its confluence with Emigrant Creek before passing Ballina and meeting North Creek near its outfall into the Pacific Ocean.

   Richmond River flooding is caused by widespread storm systems with precipitation typically occurring over many days across the broader Richmond River catchment. These floods rise and fall relatively slowly at Ballina, with flood conditions lasting multiple days.

   Flood water on the Richmond River travels in a north easterly direction towards Ballina, spilling out into the floodplain to the south and west of Ballina. These floodwaters also affect flooding on the local catchment creeks, especially in their lower reaches.

2. Creek Flooding from Emigrant Creek, Maguires Creek and North Creek:

   Emigrant Creek flows in a southerly direction through Cumbalum before joining the Richmond River at West Ballina. Maguries Creek flows in a south easterly direction from Teven and joins Emigrant Creek on the lower floodplain. North Creek flows in a southerly direction from Ross Lane passing Ballina Nature Reserve on its right bank before passing through Ballina Island and East Ballina at its confluence with the Richmond River.

   Flooding from these local creek catchments is caused by smaller storm systems with intense rainfall bursts typically lasting less than 12 hours. Flood waters rise and fall quickly with this form of flooding presenting a high hazard due to short warning times and fast flowing floodwater.

3. Ocean Storm Surge Flooding:

   Ocean storm surge flooding caused by low pressure systems, strong onshore winds and storm wave conditions, which lead to high than usual ocean levels. This form of flooding is influenced by tides and will typically occur in combination with one or two high tides.

   Ocean storm flooding dominates in the lower reach of the Richmond River and North Creek, thus affecting parts of West Ballina and Ballina Island. These areas constitute the most concentrated urban development, which highlights the importance of this form of flooding in Ballina.

2.1.2 Overland flooding

In addition to the above sources of flooding, low lying areas of Ballina Island and West Ballina are subject to overland flooding from local rainfall-runoff and backwater surcharge of the stormwater network during high tide events.

2.1.2.1 Local runoff

Over 60% of Ballina Island is a "trapped low point" where conveyance is achieved exclusively by piped drainage through surrounding higher ground. The centre of the island is characterised by a "bowl" formation with the lowest points of the island generally around Tamar Street, Grant Street and Moon Street. These unusual conditions demonstrate complex overland flooding characteristics which are largely driven by the interaction between rainfall runoff, surface storage, pipe capacity and tide oscillations. Historically, damages caused by overland flooding on Ballina Island and West Ballina usually occurs when continuous rainfall bursts in excess of 2 hours coincides with a high tide event, however there is little correlation with rainfall intensity alone and severity of observed overland flooding.

2.1.2.2 Tidal backflow inundation

Low lying areas of Ballina Island and West Ballina are known to experience inundation caused by tidal backflow through the stormwater drainage network during twice annual seasonal high astronomical tide conditions. This can and does occur without coincident local rainfall runoff or coincident riverine or creek flood events.

Anecdotal evidence collected by BSC indicates that backflows from these “King Tides” tend to affect the road network to a greater degree than private properties, with approximately 20 properties in the study area required to drive through saline water in road gutters (up to 300mm deep) during two weeks of the year to access properties. During such events, media releases are issued to warn the public of flood affected roads and inundated areas.

It is noted that the highest astronomical tide recorded in Ballina (without coincident riverine flood) during the period January 1991 to February 2018 was 1.29m AHD, occurring 3rd January 2018. This is generally accepted by BSC as the highest “King Tide” event on record.

2.2 Flood Inundation

2.2.1 Regional Flood Inundation

As part of the Ballina Floodplain Risk Management Study (BMTWBM, 2012) and the Ballina Integrated Model updates (BMTWBM, 2019)., riverine, creek and ocean storm surge flood modelling and inundation mapping was completed for a range of design events for current climate, and the following future climate scenarios[1]:

- A 10% increase in rainfall intensity together with a sea level increase above 1990 mean sea levels of 40cm by 2050.
- A 10% increase in rainfall intensity together with a sea level increase above 1990 mean sea levels of 90cm by 2100.

To provide context for this current scope of work, Figures 2-1 to 2-6 have been provided to illustrate 1% annual exceedance probability (AEP)[2] maximum expected flood depths and flood hazard across Ballina Island and West Ballina for current climate, Year 2050 and Year 2100 future climate scenarios. These figures represent the ‘envelope of maxima’ of flooding from riverine dominant events, creek dominant events and ocean (storm surge) dominant events. It is noted that

- Flood maps have been generated using outputs from the latest ‘Integrated Flood Model’ of the Ballina floodplain as provided by BMT WBM on 24th January 2020.
- Flood hazard has been mapped in accordance with the Australian Disaster Resilience Guideline 7-3 Flood Hazard (AIDR 2017) flood hazard vulnerability classifications illustrated in Figure 2-7.

Figures 2-4 to 2-6 illustrate the significant increase in flood hazard across Ballina Island and West Ballina under future climate conditions.

[1] Rainfall intensity increases were adopted based on consideration of the *Practical Consideration of Climate Change* (DECCW, 2007) and discussion with the OEH. Sea level rise estimates were based on guidance provided in *Adapting to Sea Level Rise* (DoP, 2010).
[2] 1% AEP is also commonly referred to as 100 year average recurrence interval (ARI)

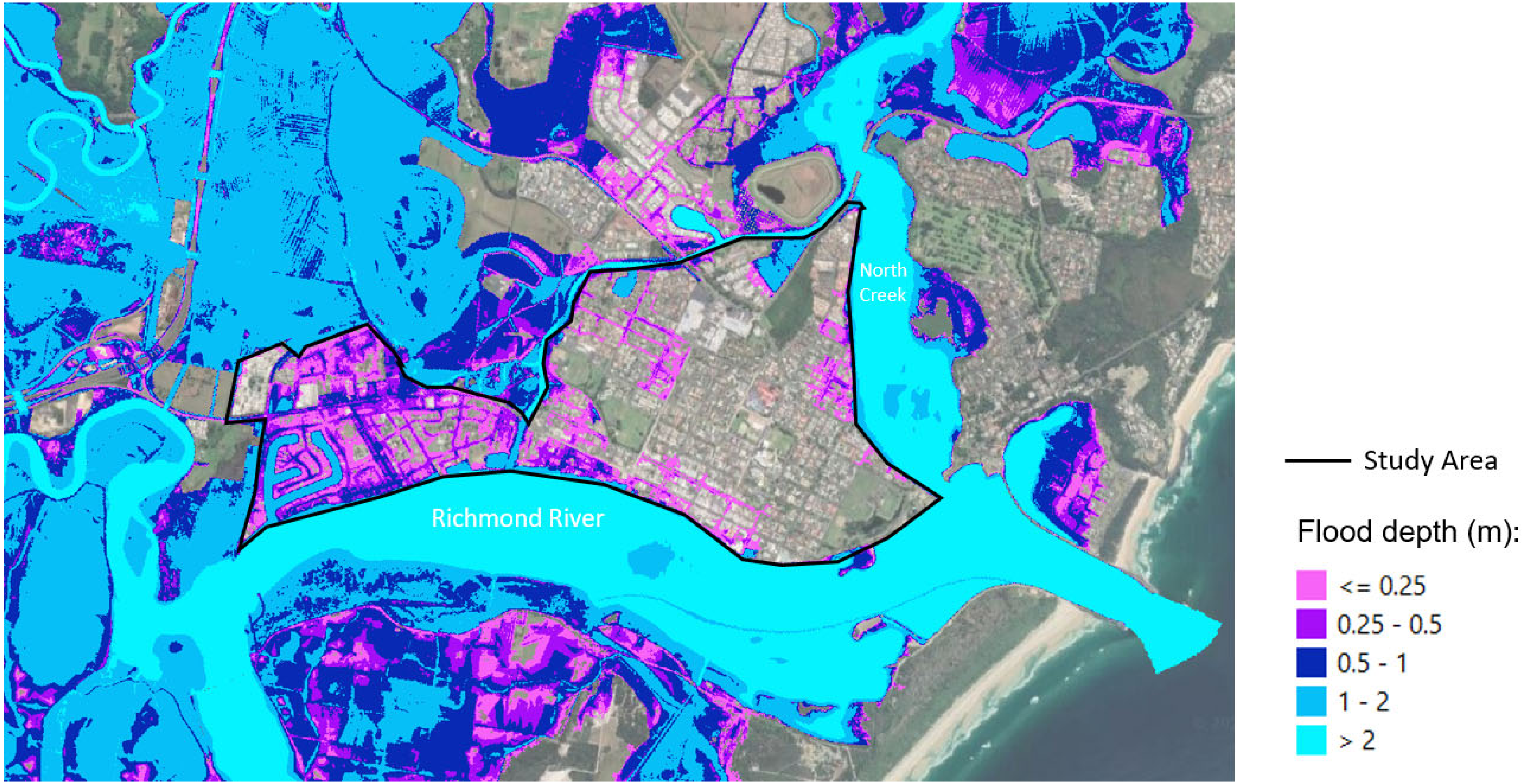


Figure 2-1 Regional Flooding – 1% AEP Flood Depth (Current Climate)

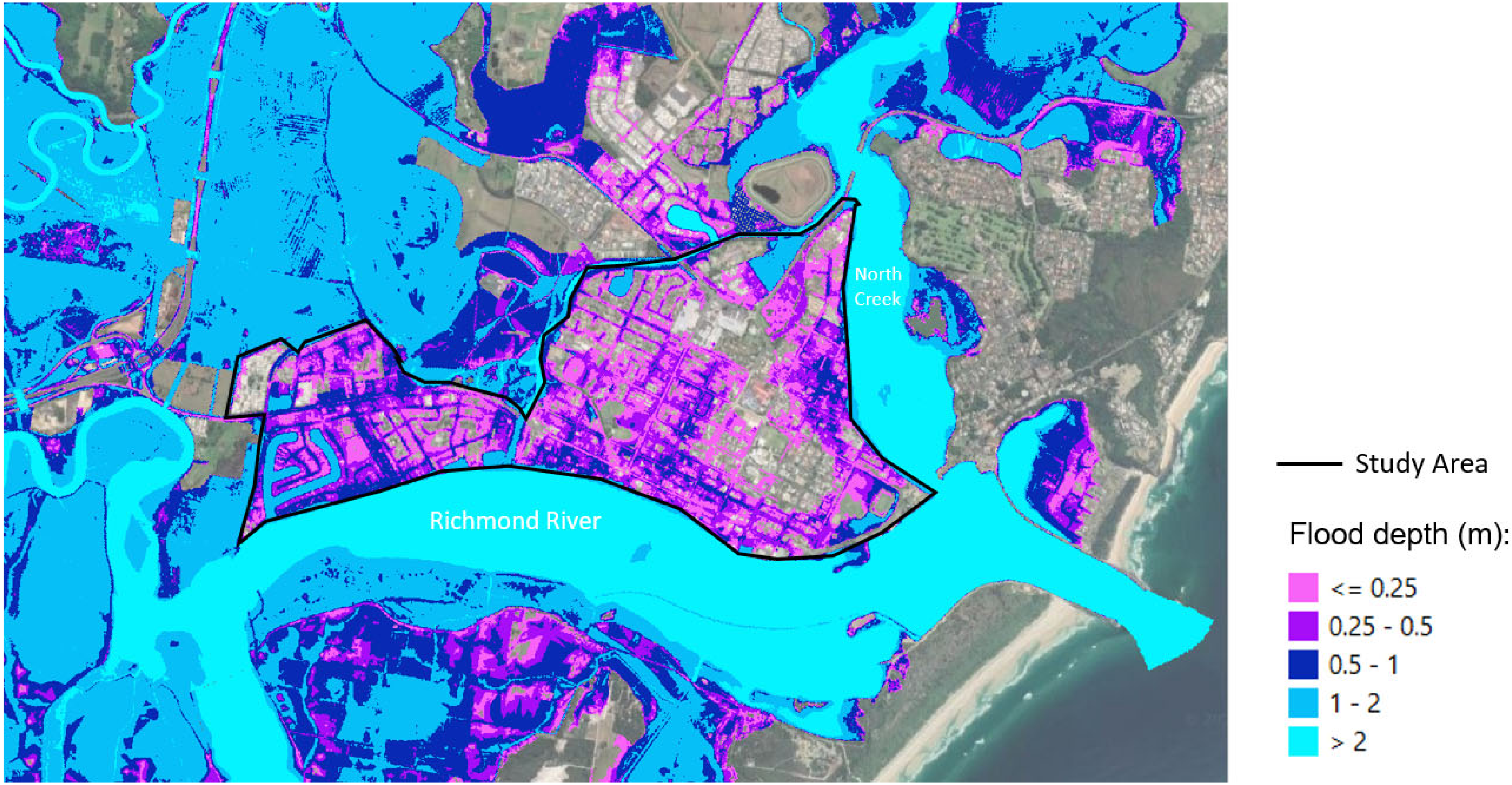


Figure 2-2 Regional Flooding – 1% AEP Flood Depth (Year 2050 Climate)

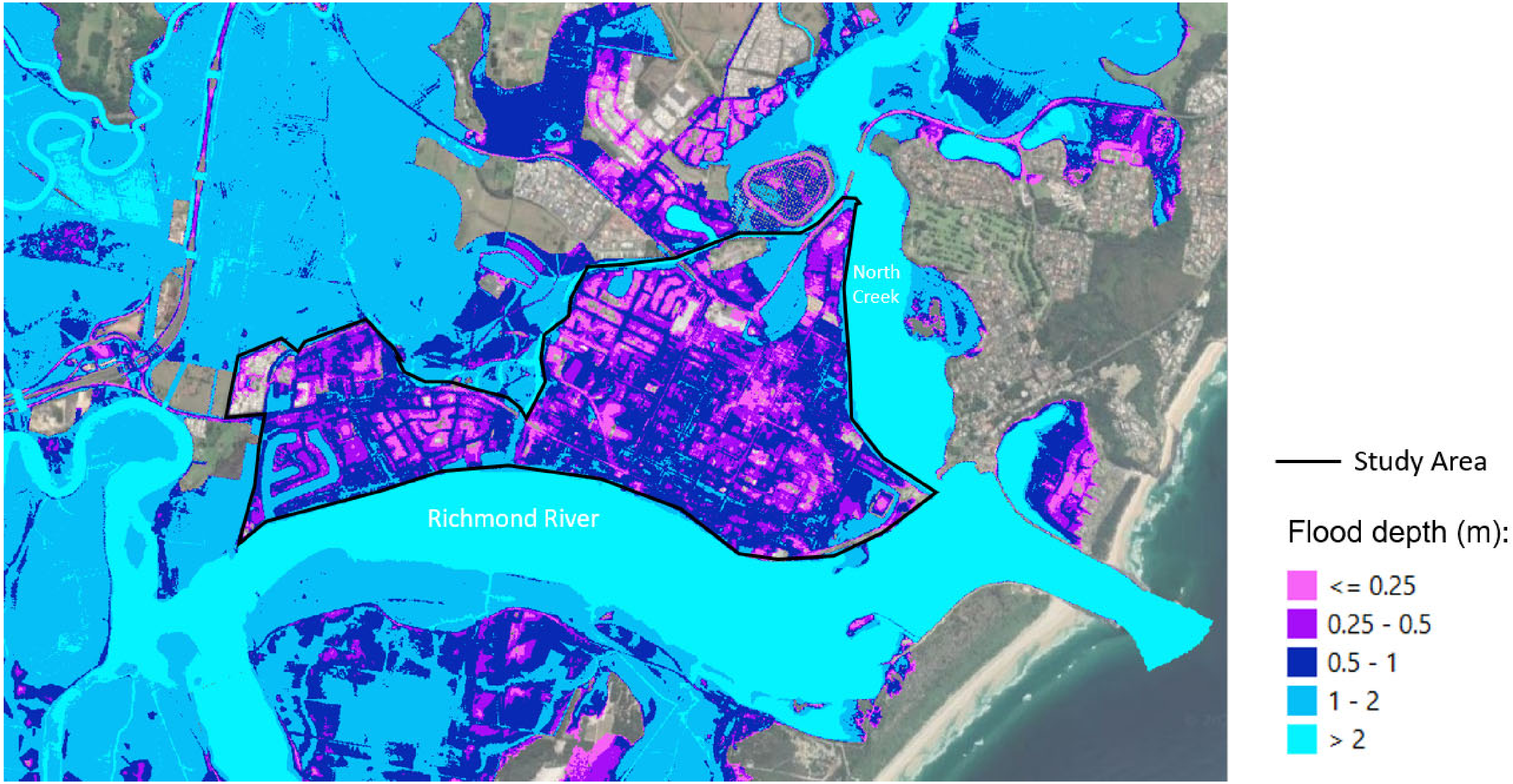


Figure 2-3 Regional Flooding – 1% AEP Flood Depth (Year 2100 Climate)

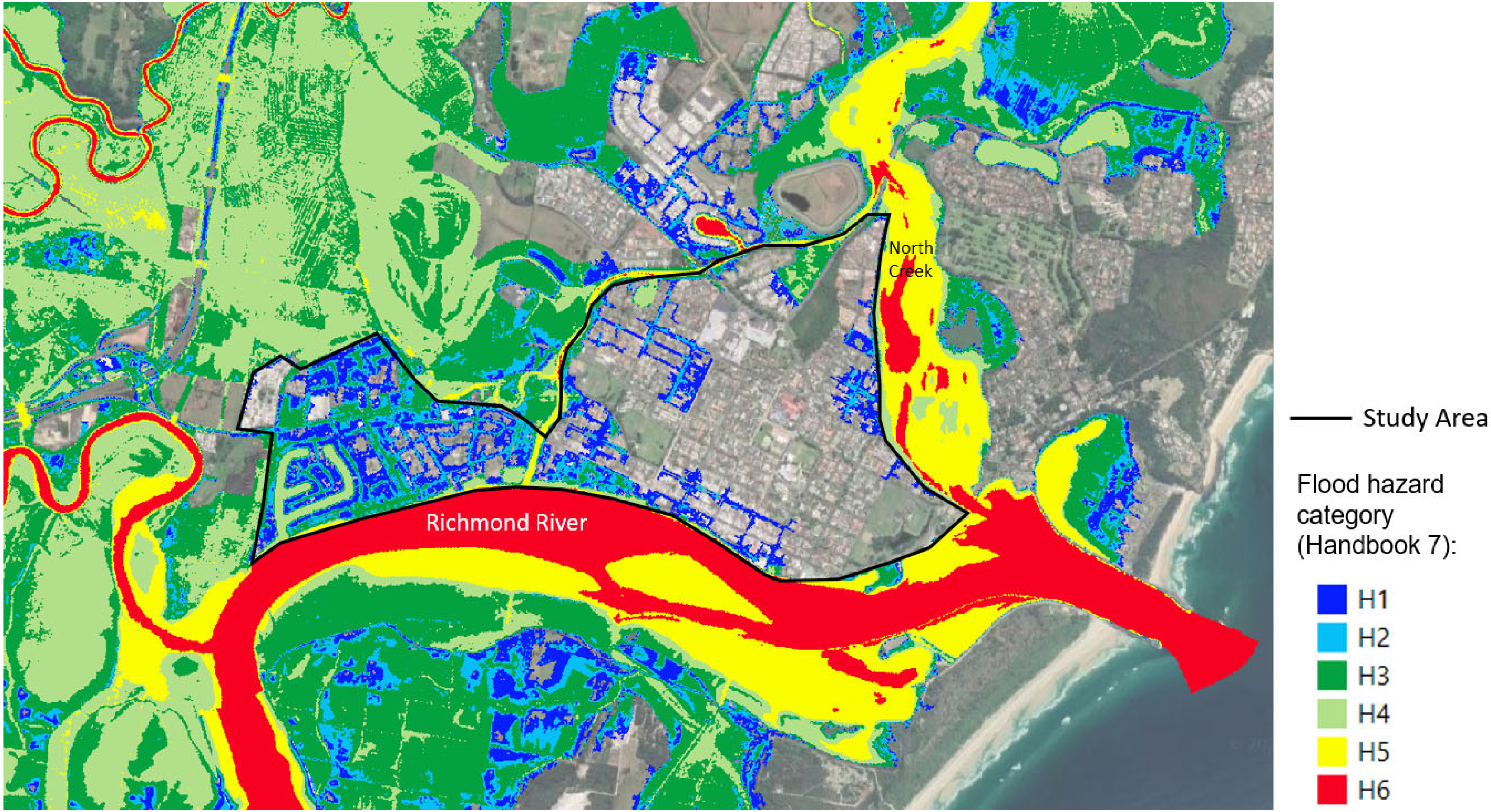


Figure 2-4 Regional Flooding – 1% AEP Flood Hazard (Current Climate)

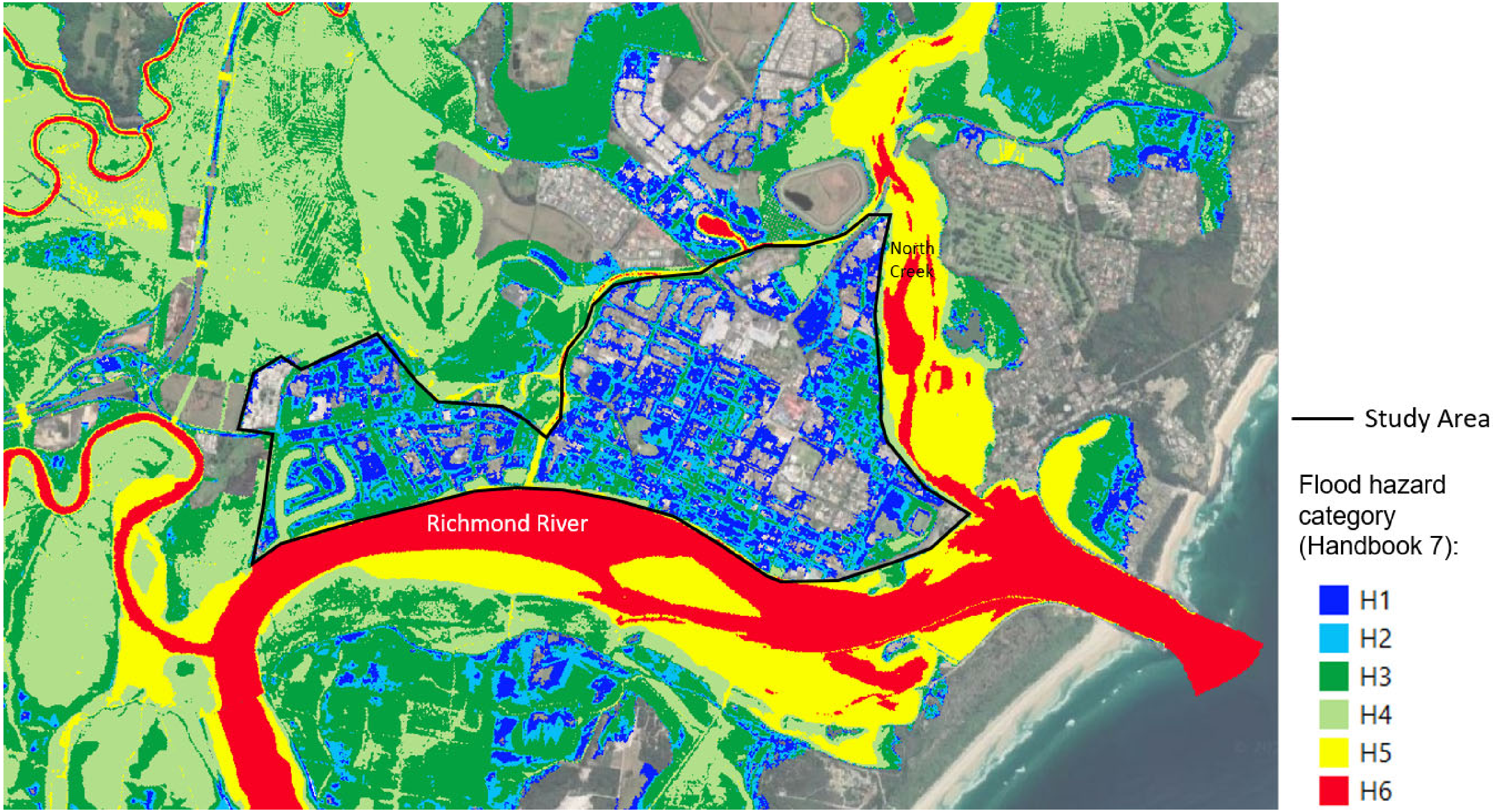


Figure 2-5 Regional Flooding – 1% AEP Flood Hazard (Year 2050 Climate)

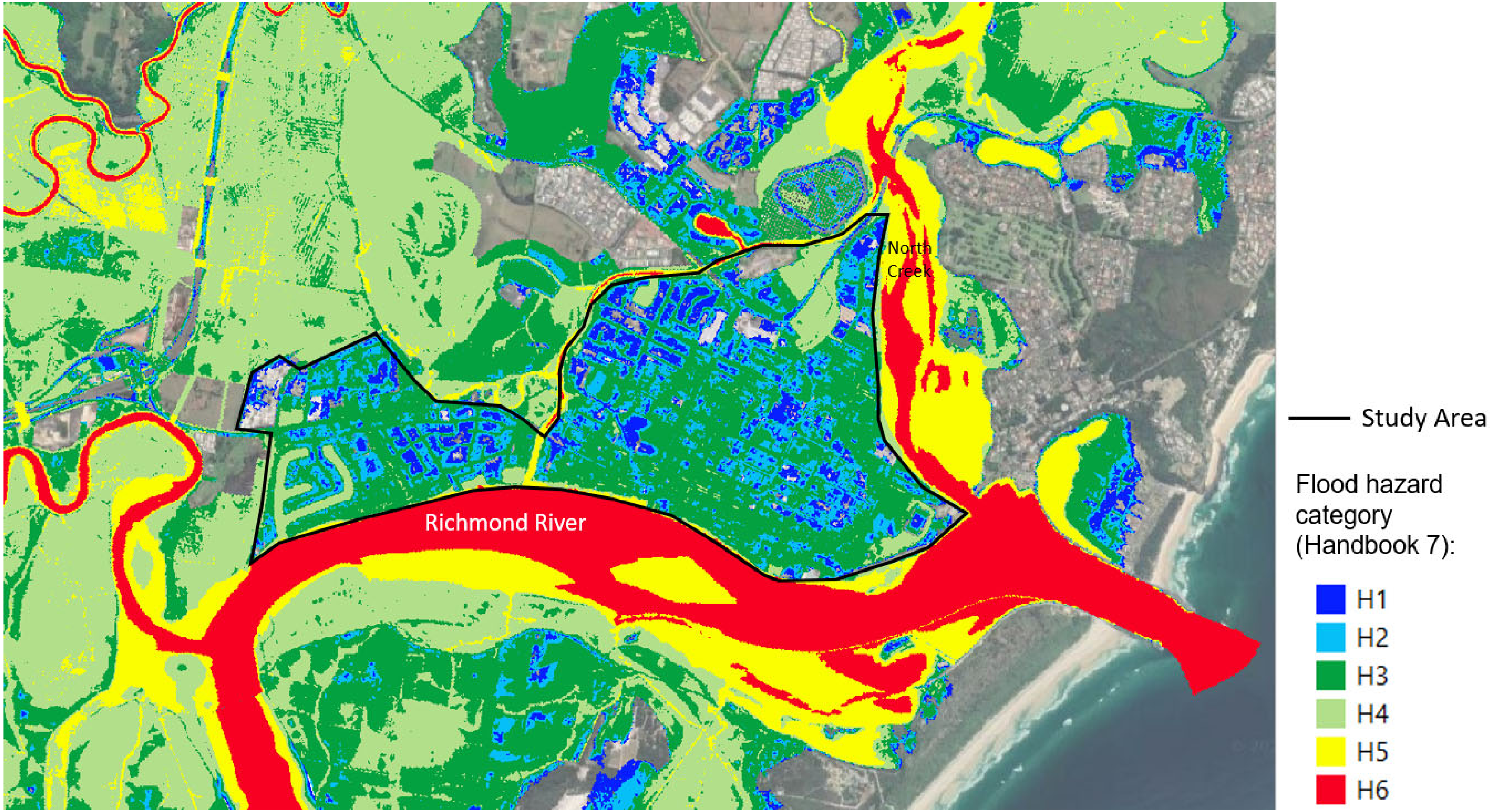
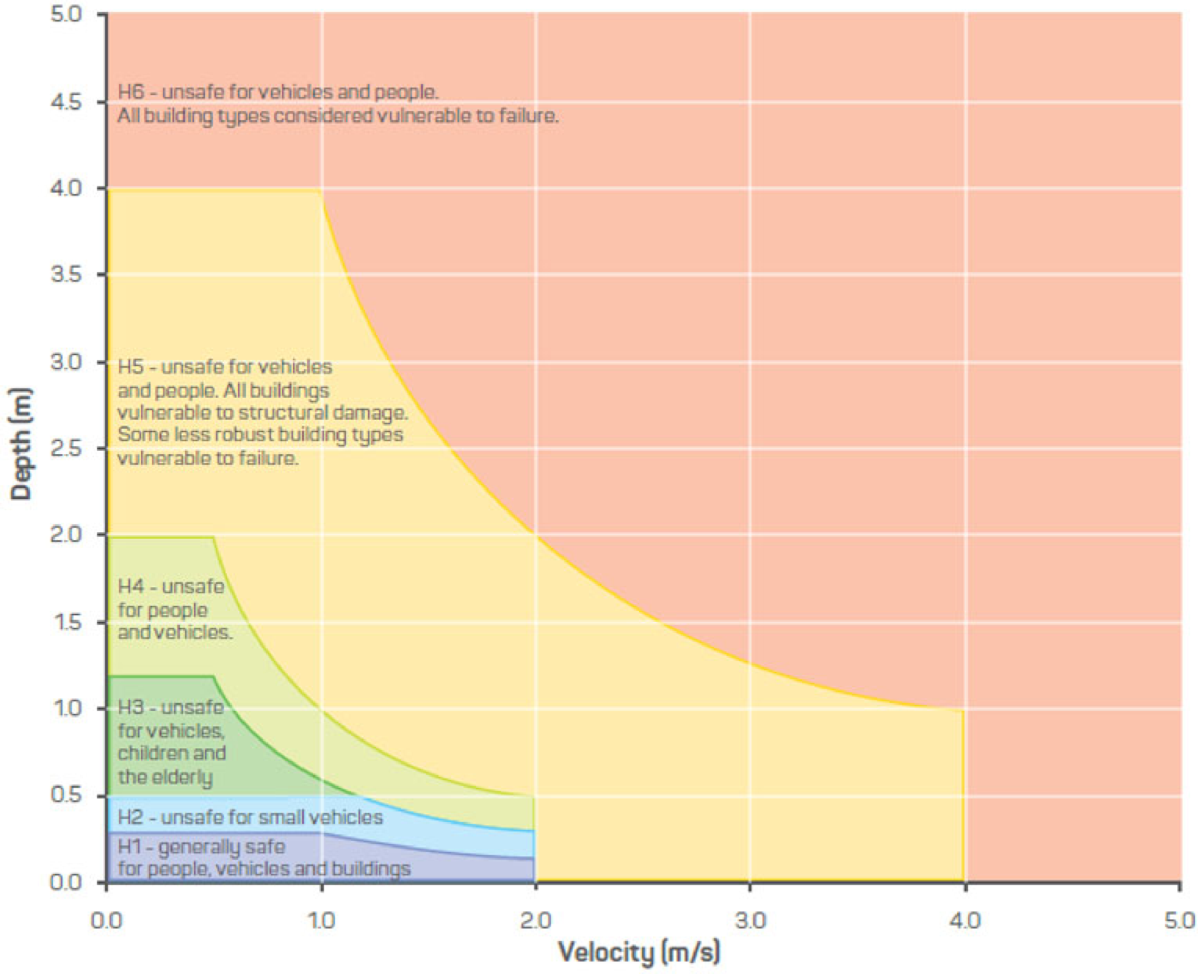


Figure 2-6 Regional Flooding – 1% AEP Flood Hazard (Year 2100 Climate)



Hazard Vulnerability Classification	Description
H1	Generally safe for vehicles, people and buildings.
H2	Unsafe for small vehicles.
H3	Unsafe for vehicles, children and the elderly.
H4	Unsafe for vehicles and people.
H5	Unsafe for vehicles and people. All building types vulnerable to structural damage. Some less robust building types vulnerable to failure.
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure.

Source: Australian Disaster Resilience Guideline 7-3 Flood Hazard (AIDR 2017)

Figure 2-7 AIDR Flood Hazard Vulnerability Classification

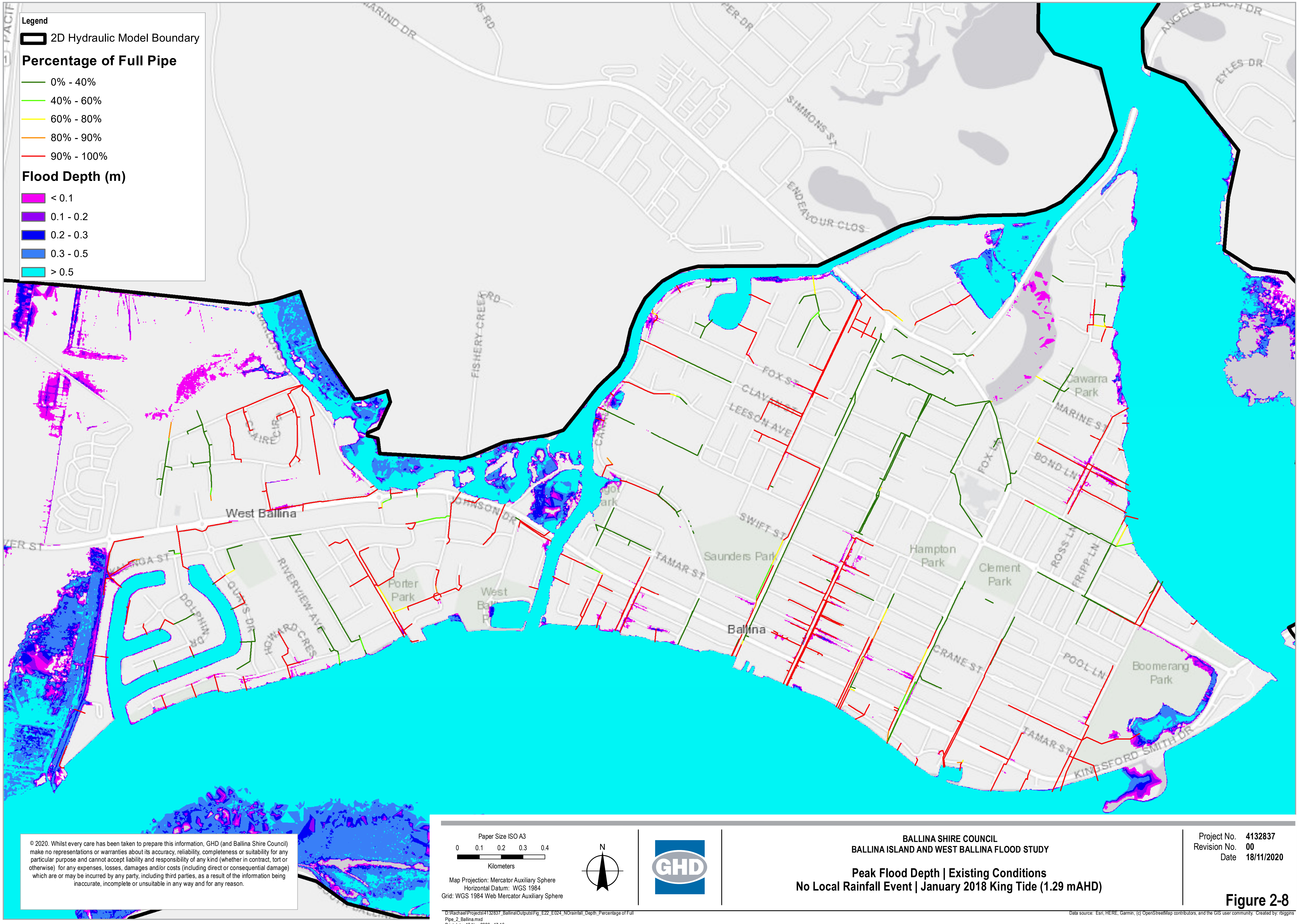
2.2.2 Overland Flow Flood Inundation

During Stage 2 of this project, a two-dimensional hydraulic model of Ballina Island and West Ballina (the Overland Flood Model) was developed to simulate and map overland flow flood inundation from the following sources of flooding during current and future climate horizons:

- Local rainfall storm events.
- High tide conditions (including storm surge events).
- Local rainfall storm events with coincident high tides.

The Ballina Island and West Ballina Overland Flood Study Report (GHD, 2020) was subsequently prepared to summarise the methodology and results of Stage 2. The report includes a detailed set of overland flow flood level, depth, velocity and hazard inundation maps. A small selection of these is reproduced herein to illustrate typical overland flooding characteristics and to highlight:

- The reduction in stormwater network capacity and surcharge resulting from high tide only conditions (refer Figure 2-8).
- The relatively shallow depths of inundation experienced during 1% AEP design storm events under Mean High Water Spring (MHWS) tide conditions (refer Figure 2-9).
- The predominance of H1 and H2 flood hazard conditions during 1% AEP MHWS design storm events (refer Figure 2-10).
- The predominance of H1 and H2 flood hazard conditions during 1% AEP MHWS design storm events under Year 2100 climate conditions (refer Figure 2-11).



BALLINA SHIRE COUNCIL
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Peak Flood Depth | Existing Conditions
No Local Rainfall Event | January 2018 King Tide (1.29 mAHD)

Project No. 4132837
Revision No. 00
Date 18/11/2020

Figure 2-8

D:\Rachael\Projects\4132837_Ballina\Outputs\Fig_E22_E024_NOrainfall_Depth_Percentage of Full Pipe_2_Ballina.mxd
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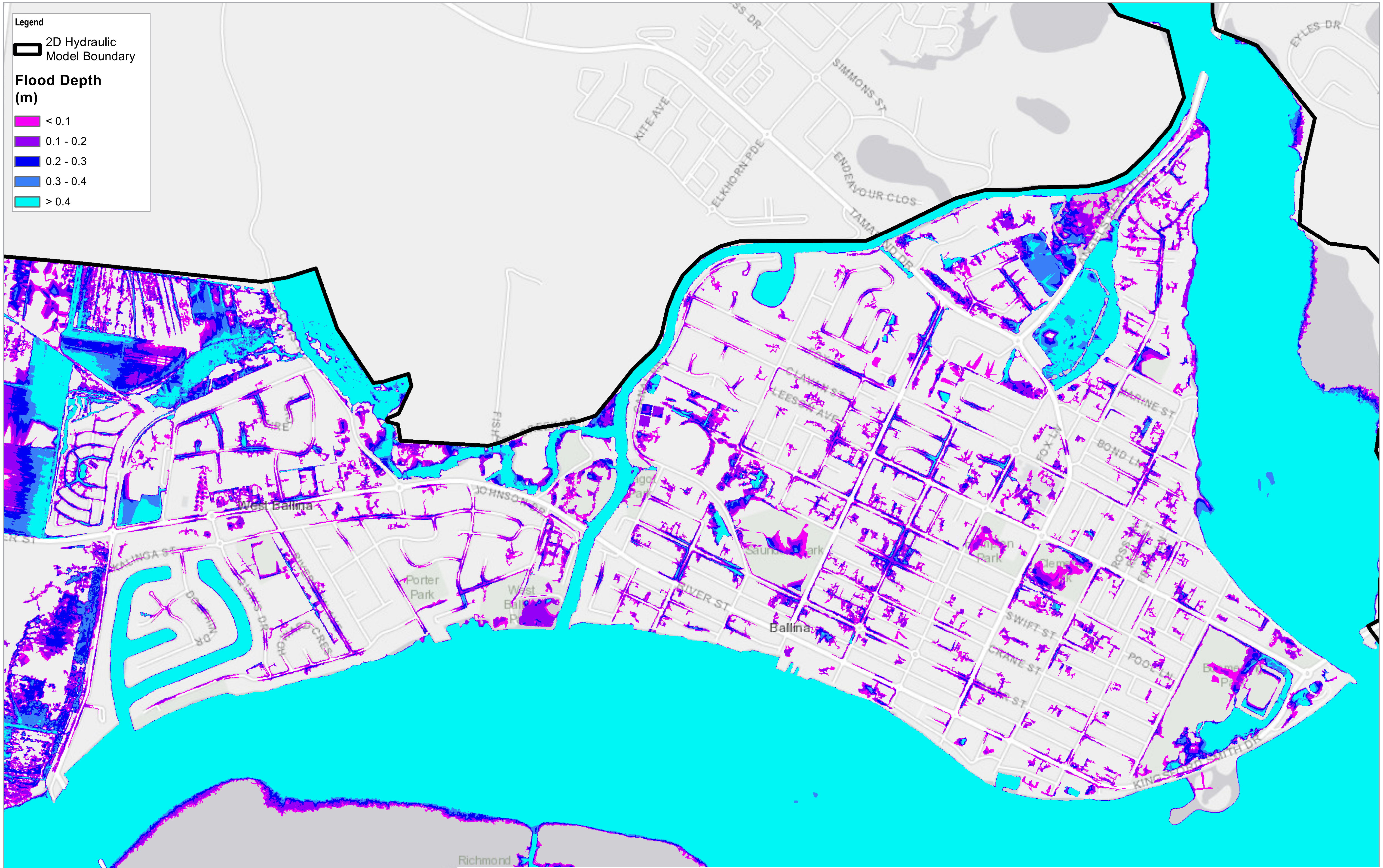
Data source: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community. Created by: rbiggins



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Kilometers

Map Projection: Mercator Auxiliary Sphere
Horizontal Datum: WGS 1984
Grid: WGS 1984 Web Mercator Auxiliary Sphere

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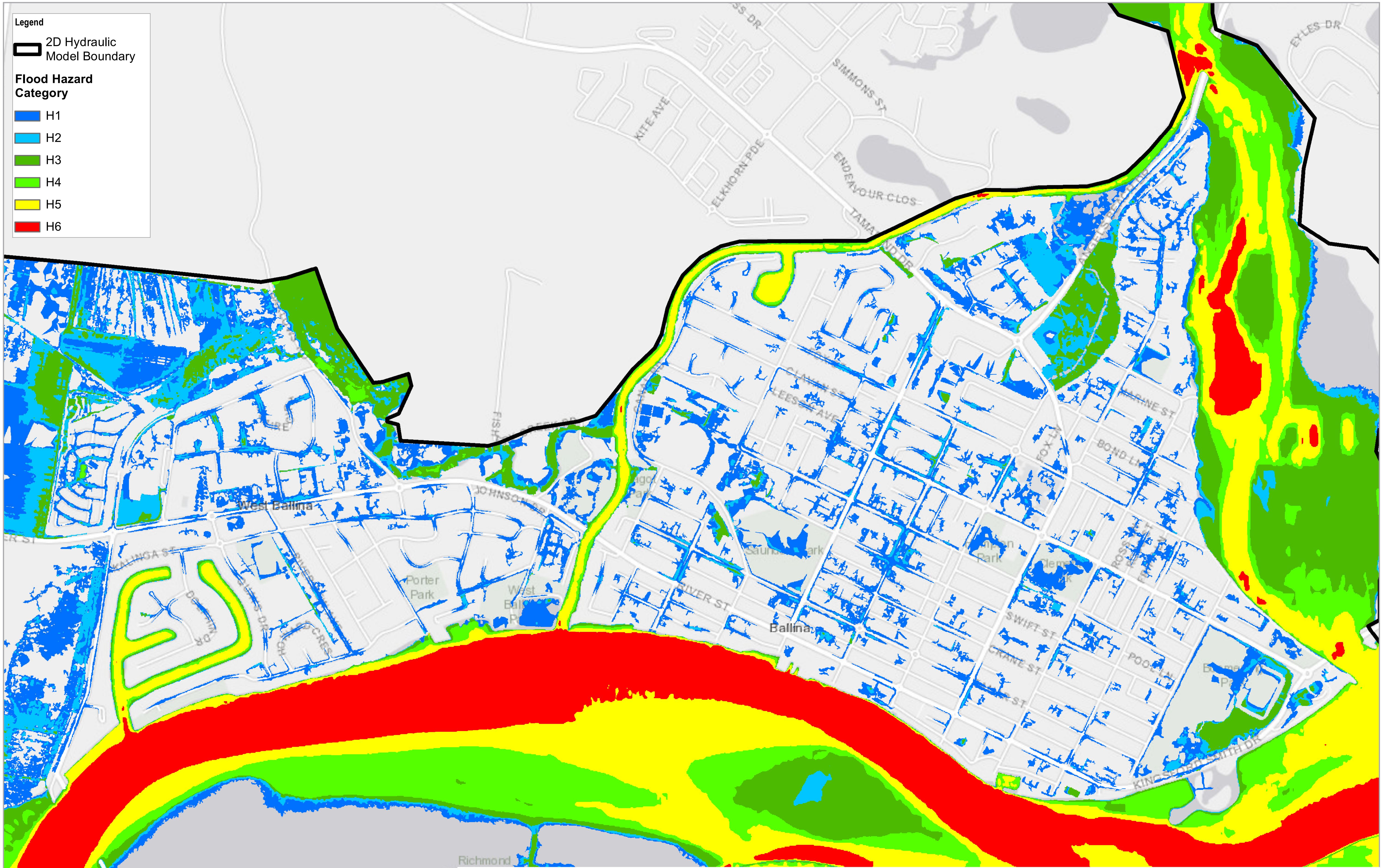
BALLINA SHIRE COUNCIL
BALLINA ISLAND AND WEST BALLINA FLOOD STUDY

Peak Flood Depth | Existing Conditions
1% AEP Design Flood Event | MHWS Tide Level

Project No. 4132837
Revision No. 00
Date 22/09/2020

Figure 2-9



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Kilometers

Map Projection: Mercator Auxiliary Sphere
Horizontal Datum: WGS 1984
Grid: WGS 1984 Web Mercator Auxiliary Sphere

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GHD

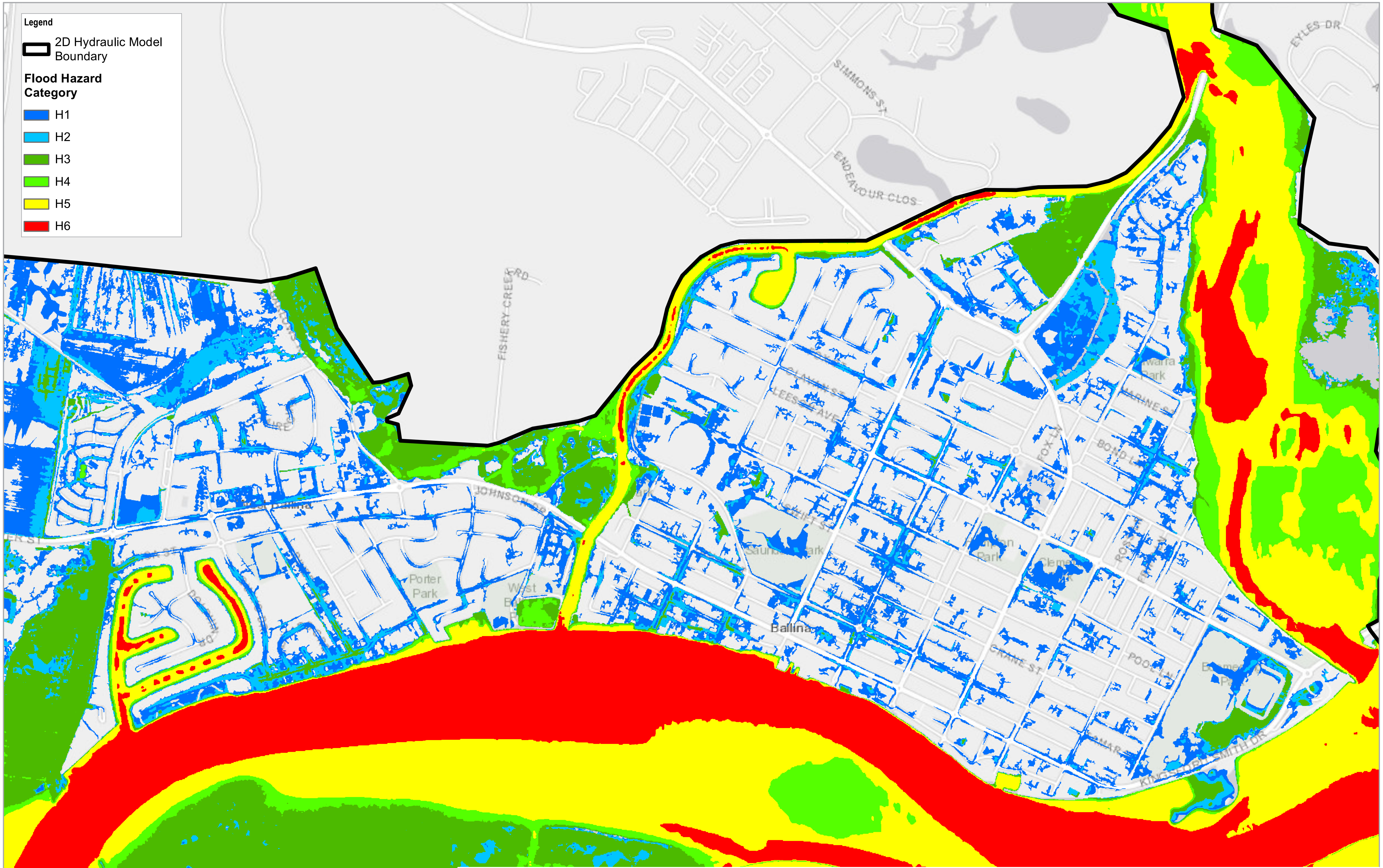
BALLINA SHIRE COUNCIL
BALLINA ISLAND AND WEST BALLINA FLOOD STUDY

Peak Flood Hazard | Existing Conditions
1% AEP Design Flood Event | MHWS Tide Level

Project No. 4132837
Revision No. 00
Date 28/09/2020

Figure 2-10

Data source: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community. Created by: rbiggins



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Kilometers

Map Projection: Mercator Auxiliary Sphere
Horizontal Datum: WGS 1984
Grid: WGS 1984 Web Mercator Auxiliary Sphere

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GHD

BALLINA SHIRE COUNCIL
BALLINA ISLAND AND WEST BALLINA FLOOD STUDY

Peak Flood Hazard | Year 2100 Climate Change Scenario 1% AEP
Local Rainfall Event | MHWS Tide Level + Sea Level Rise

Project No. **4132837**
Revision No. **00**
Date **18/11/2020**

Figure 2-11

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Print date: 18 Nov 2020 - 14:42

Data source: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community. Created by: rbiggins

2.3 Flood damages

As part of the Ballina Floodplain Risk Management Study (BMTWBM, 2012), average annual flood damages were estimated for existing and future climate conditions for riverine, creek and ocean driven flood inundation.

Table 2-1 and Table 2-2 provide a summary of the increase in expected average annual flood damages (AAD) and net present value (NPV) of damages under Year 2050 and 2100 climate conditions in Ballina Island and West Ballina.

Table 2-1 Average Annual (Flood) Damages (AAD)

Location	Current AAD	2050 Horizon AAD	2050 Horizon AAD Increase	2100 Horizon AAD	2100 Horizon AAD Increase
Ballina Island	$3,857,490	$12,384,450	$8,526,960	$69,808,050	$65,950,560
West Ballina	$3,944,070	$9,899,370	$5,955,300	$26,463,060	$22,518,990
Total:	**$7,801,560**	**$22,283,820**	**$14,482,260**	**$96,271,110**	**$88,469,550**

Note: The above values were derived by applying a 1.17 inflation factor to the AAD values presented in Table 4-2 of the Ballina Floodplain Risk Management Study (WBMBMT, 2012).

Table 2-2 Net Present Value of AAD

Location	Current NPV	2050 Horizon NPV	2050 Horizon NPV Increase	2100 Horizon NPV	2100 Horizon NPV Increase
Ballina Island	$92,023,376	$170,914,652	$78,891,276	$963,403,187	$871,379,811
West Ballina	$54,431,109	$136,618,694	$82,187,584	$310,778,868	$256,347,758
Total:	**$146,454,486**	**$307,533,346**	**$161,078,861**	**$1,274,182,055**	**$1,127,727,569**

Note: Net Present Values were calculated by discounting the Average Annual Damages from Table 1-1 at a rate of 7% over a period of 50 years.

Table 2-1 and Table 2-2 indicate that the consequence of predicted flood risk under future climate conditions was found to have a marked impact on the damage bill caused by flooding. The reason for such a large increase is that the relatively frequent smaller floods impose far more damage under a future climate than they do under the current day climate.

Effective management of the current and future flood risk in Ballina Island and West Ballina poses a significant challenge to Ballina Shire Council.

2.4 Socio-Economic Impacts of Flooding

The major impacts of flooding can be devastating causing a great deal of distress to people's lives and livelihoods. Impacts can range from death, injury and harm from sources such as contaminated water or hydraulic impact, through to lasting psychological consequences caused by damaged homes, loss of personal possession, loss of income, and cost and efforts of recovery and reestablishment of normality follow a flood event.

Social impacts are often intangible damages and relate to changes to social networks, lifestyles, community activities and individual state of well-being. The degree of disruption to people's lives depends on the severity of flooding and the ability of the community and individuals to recover from the flood event.

Flooding impacts within Ballina Island and West Ballina are concerned with residential and commercial areas, and the associated loss and damages caused by flooding. Social impacts may include stress for community members related to the loss of sentimental and personally valuable items including stock and vehicles. These social impacts are particularly difficult to quantify as the personal and emotional value of the loss often exceeds that of material value. Anxiety, panic and insecurity may also increase amongst the community as a response to the possibility of future flood events.

It is generally acknowledged that the degree of social impact caused by flooding is likely to reduce if the community is well prepared for a flood event and has adequate access to adequate and appropriate support services. In addition, small communities are known for their close relationships and ability to support each other through disasters and distressing events.

Damages to local businesses pose economic risks for the local community. Flooding has the potential to cause disruption to business activities such as trading capacity and employment routines due to the isolation caused by floodwaters. Residential damages may also have the potential to cause lifestyle changes as members of the community adjust personal activities to address flood damages.

Whilst consideration of direct economic impacts is important, it is not unusual to base flood mitigation schemes on largely socio-economic grounds such as intangible costs and social disruption. Economic costs would depend on the level of physical flood damage, the nature of the premises impacted, level of community flood 'readiness', and the level of readily available assistance.

In addition to damages to individual properties, there may also be disruptions and damage community services, community assets, and to public infrastructure such as roads, electricity, telecommunications and water supply.

A summary of the key potential impacts of flooding on the socio-economic character of the Ballina Island and West Ballina community is summarised in the Table 2-3 below.

Table 2-3 Potential Socio-Economic Impacts

Direct	Indirect	Intangible
Residential Areas		
Property damages including structural, contents and gardens Clean-up costs Replacement and repairs	Relocation costs Loss of ability to work Changes to work routines Disruption to community cohesion	Stress and Anxiety Loss of sentimental items Lifestyle changes Loss of amenity Restricted access
Commercial Businesses and Community Facilities		
Property damages including structural, internal and outdoor areas Clean-up costs Infrastructure damages Restricted access for community members	Loss of revenue/profit Loss of productivity Disruption to employment Loss of patronage	Stress and Anxiety Loss of sentimental items Lifestyle changes Loss of amenity Drop in property values Disruption to community services and social capital

3. Identification and Preliminary Assessment of Floodplain Management Measures

In accordance with the NSW Government Floodplain Development Manual (2005), this report considers various floodplain risk management measures. Risk management measures can be broadly categorised into three categories as shown in Figure 3-1.

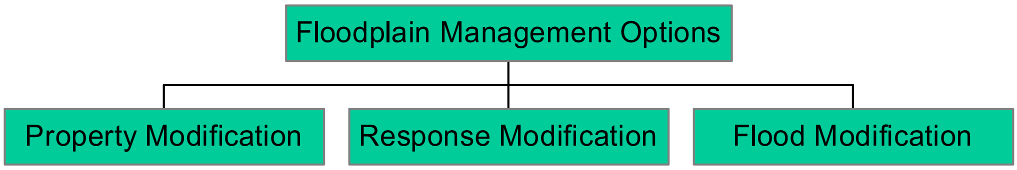


Figure 3-1 Floodplain Management Measures

More specifically, Council have nominated the requirement to:

- Identify potential land-use planning based strategies.
- Undertake a high level assessment of the feasibility of a flood protection levee around Ballina Island and West Ballina.
- Consider holistic road raising and infilling of lots.
- Consider raising of evacuation routes.
- Identify overland flooding 'hotspots' and identify potential flood mitigation measures in high priority problem areas.

In this context, the following discussion follows the NSW Government Floodplain Development Manual (2005) risk management process, however prioritising and focussing on Council's specific requirements, noted above.

3.1 Property Modification

Property modification measures are approaches to floodplain management that apply to existing properties and proposed developments. While these modifications will reduce damages and risk to life and property, they may not prevent flooding of premises. Thus, they will not necessarily address all the social and economic impacts of flooding.

3.1.1 P1 - Land Use Planning

Land use planning is an essential element in managing flood risk and the most effective way of ensuring future flood risk is managed if implemented appropriately. Limiting development on land with high flood hazard or land that has the potential to impact flood behaviours in other areas, is a fundamental element of sound floodplain management and a valuable long-term solution. This can be achieved through inclusion of provisions in Council's Local Environment Plan (LEP) and Development Control Plans (DCP). Planning instruments can also be used as a floodplain management tool by controlling floor levels, freeboard, fill or excavation in the floodplain, site access during flood events, location of utilities and services, on-site detention, building materials and structural fitness of buildings when subject to flooding.

Land use planning is an essential element in managing flood risk and the most effective way of ensuring future flood risk is managed appropriately

Advantages

- Provides for targeted flood mitigation commensurate with level of flood risk.
- Provides an adaptable approach in which development controls can be updated or amended as the understanding of flood risk improves with time (e.g. climate change impacts).
- Provides for avoidance of flood damages by allowing only flood resilient uses within flood prone areas.
- Relatively low cost of implementation.

Disadvantages

- Complex development controls can result in interpretation difficulties and create challenges for developers and planners.
- When applied retrospectively, does not provide an immediate solution as flood risk mitigation effectively occurs over time.

Department of Planning, Industry and Environment (DPIE) Floodprone Land Package

It is highlighted that the Department of Planning, Industry and Environment (DPIE) have recently prepared the Floodprone Land Package effective 14th July 2021. This includes a raft of measures to assist Council with flood planning including:

- An amendment to schedule 4, section 7A (planning certificates) of the Environmental Planning and Assessment Regulation 2000 (the Regulation).
- A revised local planning direction regarding flooding issued under section 9.1 of the Environmental Planning and Assessment Act 1979 (the Act).
- Revised standard Local Environmental Plan (LEP) flood clauses ensuring evacuation and wider community costs are considered in DAs and introducing new Flood Planning Area, Regional Evacuation Consideration Area and Special Flood considerations.
- A new guideline: Considering Flooding in Land Use Planning (2020).
- Revoking the Guideline on Development Controls on Low Flood Risk Areas (2007).

- A State Environmental Planning Policy (SEPP) amendment to replace Councils existing flood planning clause with a new mandatory standard instrument clause.
- A new planning circular: Considering flooding in land use planning: guidance and statutory requirements (and revoking the existing planning circular PS 07-003).

Recommendations

It is recommended that land use planning management measures be further considered including:

- Updating the LEP and DCP to reflect the new DPIE Floodprone Land Package.
- Alternative solutions to Council's current fill policy including phased retreat, adoption of building envelopes, innovative building design, on-site detention, provision of safe evacuation routes, and early warning systems.
- Limitations on sensitive uses like seniors living, boarding houses, nursing homes, residential aged care facilities etc in flood affected areas (partially addressed in current DCP).
- Apply additional controls requiring flood investigations/ filling to demonstrate appropriate evacuation routes in the DCP.
- Consideration of overland flooding issues and in particular the outputs of the Ballina Island and West Ballina Overland Flood Study (GHD, 2020).
- Preparation of more detailed flood inundation mapping delineating type of flood hazard and commensurate risk (i.e. riverine, creek, oceanic and overland flow paths).
- Year 2050 and 2100 future climate conditions.

☑	*Land Use Planning is an important tool to manage flood risk while assessing development.* *It is recommended that land use planning management measures be explored in more detail during the detailed options assessment phase.*

3.1.2 P2 - Voluntary House Raising

House raising is a voluntary structural solution to lift buildings above the flood planning level or in overland flood problem areas to avert damage to buildings, improve personal safety and reduce stress and post-flood trauma.

Consideration must be given to the type of house being raised, the level of hazard to be avoided, the duration of the flooding expected and social issues (physical access to the dwelling and ability to raise the balance of funding). An important consideration is that house raising will not mitigate flood risk entirely, since:

- Below floor level uses and infrastructure may still be impacted; and
- The effects of a flood of greater magnitude than the design flood (potentially up to the Probable Maximum Flood (PMF)) could still result in risk and damage.

House raising at times attracts two-thirds funding from State Government, with the balance of funding provided by Council and/or property owner, however a number of funding models exist across NSW. The property value would be based on a determination by the State Valuer.

Advantages

- Reduced tangible flood damage.
- Reduced risk to life and reduced intangible costs due to reduced anxiety and stress.
- Potentially higher resale value of property.
- Potential for under-house storage.

Disadvantages

- This is likely to occur on an ad hoc basis.
- People occupying raised houses may be less likely to evacuate during a flood event resulting in increased risk to life.
- Potential for house to become isolated during time of flood resulting in risk to emergency services.
- Risk of structural damage if not appropriately designed.
- Reduced visual amenity if design contrasts with neighbouring houses.
- Not suitable for elderly or those with disabilities.

☑	*Voluntary house raising has the potential to reduce the damage cost to individual dwellings however, this measure needs to be coupled with an effective evacuation plan.* *It is recommended that voluntary house raising be included in the final strategy.*

3.1.3 P3 - Flood Proofing of Buildings

Flood proofing of buildings involves designing and constructing buildings with appropriate water resistant building materials to reduce flood damage. This solution reduces damage to the building structure but in most cases does not protect building contents. For existing structures, flood proofing would need to be retro-fitted to existing buildings or included as a development control to building extensions. Given the age and state of many of the buildings in Ballina Island and West Ballina, and that the Ballina Development Control Plan 2012 would provide for future development, flood proofing through retrofitting is not considered viable as a broad flood risk management option.

Amongst other NSW guidelines, the Hawkesbury-Nepean Floodplain Management Steering Committee provides advice on building in flood prone areas entitled “Reducing Vulnerability of Buildings to Flood Damage (2007)”. This provides general guidance on building in flood-prone areas.

☑	*Flood proofing of buildings not considered viable as a broad floodplain risk management option on its own. However, innovative building design should be considered as part of the development controls associated with P1-Land Use Planning measures.*

3.1.4 P4 - Voluntary Purchase of High Hazard Properties

To avoid the economic and social expenses of flooding in high hazard areas, it may be viable for Council to purchase flood affected properties at an equitable price, where voluntarily offered. The property should then be rezoned to a flood compatible use, such as open space. It is important to note, that this option is ‘voluntary’ and the implementation strategy could be long-term..

Voluntary purchase at times attracts two-thirds funding from State Government, with the balance of funding provided by Council. The property value would be based on a determination by the State Valuer. Voluntary purchase will likely impact the Councils rates base.

☑	*It is recommended that a voluntary purchase scheme be considered to facilitate purchase of high hazard properties on a case by case basis where other measures are impractical or uneconomic.* *It is recommended that this option be included in the final strategy.*

3.2 Response Modification Measures

Response modification measures aim to improve how the community prepares and responds to flood events. Response modification measures are reactions to flooding, during and immediately after flood events, that reduce potential social, economic and environmental damages from flooding. While response modifications will reduce risk to life and direct economic losses, they will not prevent flooding. Therefore, they will not address all the social impacts or reduce all direct and indirect damages associated with flooding.

3.2.1 P5 - Insurance

While insuring properties against flooding is a method of reducing the duration and financial impacts of recovery, there is limited overall benefit of this flood risk management option because insurance does not mitigate flooding. Additionally, traditional insurance products do not cover ‘backwater’ flooding of the stormwater network which is a key characteristic of the study area. Therefore, issues of community disruption, property values, flood hazards and safety remain. Flood insurance can also be difficult to purchase as many insurance companies are unwilling to insure against floods, particularly after the Brisbane flood in 2011. Insurance premiums have in recent times become expensive for many properties in flood prone areas.

3.2.2 P6 – Improve Flood Warning System and Evacuation Management

The Ballina Floodplain Risk Management Plan (WBMBMT, 2015) identifies a number of response modification measures that are relevant to Ballina Island and West Ballina. These include:

- R1: Finalise Selection of Evacuation Centres.
- R2: Update Evacuation Planning.
- R3: Develop Community Engagement Strategy.
- R4: Extend Gauge Network.
- R5: Develop Flood Intelligence Cards.
- R6: Assess Alternative Evacuation Order Methods.
- R7: Investigate Flood Warning and Prediction System Options.
- R8: Raise Low Points on Evacuation Routes.

In 2016, the Richmond River Flood Warning and Evacuation Management Review (WBMBMT,2016) was prepared for Richmond River County Council (now Rous County Council (RCC). The document included a number of recommendations that broadly comprised:

- Improved flood monitoring (implementation by: Bureau of Meteorology (BoM), NSW Office of Environment and Heritage (OEH) now known as NSW Department of Planning, Industry and Environment (DPIE) and RCC).
- Improvements to flood forecasting and warning (implementation by: BoM).
- Improved flood response (implementation by: State Emergency Service (SES), RCC and Councils).
- Community education and flood information (implementation by: SES, RCC and Councils).

☑	*In light of the existing and future flood risk in Ballina Island and West Ballina, it is recommended that Council review the status of Items R1 to R8 of the Ballina Floodplain Risk Management Plan (WBMBMT, 2015) and the recommendations of the Richmond River Flood Warning and Evacuation Management Review (WBMBMT,2016), and determine if any outstanding items can be actioned.* *It is recommended that this option be included in the final strategy.*

3.2.3 P7 – Evacuation Route Raising

A summary of the existing evacuation zones and routes in Ballina Island and West Ballina is provided in Table 3-1 with the location of evacuation zones and routes indicated in Figure 3-2.

Table 3-1 Evacuation Routes and Zones

Zone	Area	Evacuation Route	Evacuation Destination
Zone A	Ballina Island (West)	Angels Beach Drive	East Ballina (Southern Cross Public School)
Zone B	Ballina Island (East)	Kingsford Smith Drive	East Ballina (Southern Cross Public School)
Zone D	West Ballina	Old Pacific Highway / Bruxner Highway	Alstonville

In order to improve evacuation potential during flood conditions under existing and future climate scenarios, the following road raising options were identified for consideration in consultation with Council:

- Case 1: Raise existing evacuation routes to above 1.8m AHD[3].
- Case 2: Raise existing evacuation routes to elevations consistent with Councils existing fill policy (approximately 1.9m AHD to 2.2m AHD across study area) as defined by Map 1A in the Ballina Shire Development Control Plan 2012, Chapter 2b – Floodplain Management (BSC, 2012).
- Case 3: Raise existing evacuation routes to be above the 100 year ARI Year 2050 design flood (riverine, creek, ocean) level (approximately 2.1m AHD to 2.3m AHD across study area).
- Case 4: Raise existing evacuation routes to be above the 100 year ARI Year 2100 design flood (riverine, creek, ocean) level (approximately 2.4m AHD to 2.7m AHD across study area).

High level cost estimates for each of the above cases are provided in Table 3-2. Costs have been estimated based on the required height of road raise identified in Figures A1 to A4 in Appendix A, together with the per lineal m rates of road raising provided in Appendix B.

Table 3-2 Evacuation Route Raising Cost Estimates

Case No.	Description	Cost estimate (indicative Class 5)
Case 1	Raise existing evacuation routes to above 1.8m AHD.	~ $39M
Case 2	Raise existing evacuation routes to elevations consistent with Councils existing fill policy.	~$90M
Case 3	Raise existing evacuation routes to be above the 100 year ARI Year 2050 design flood level.	~$100M
Case 4	Raise existing evacuation routes to be above the 100 year ARI Year 2100 design flood level.	~$172M

[3] Level nominated by Council, equivalent to current H.A.T. level of 1.11m AHD plus ~0.7m allowance for future sea level rise and local tidal anomaly.

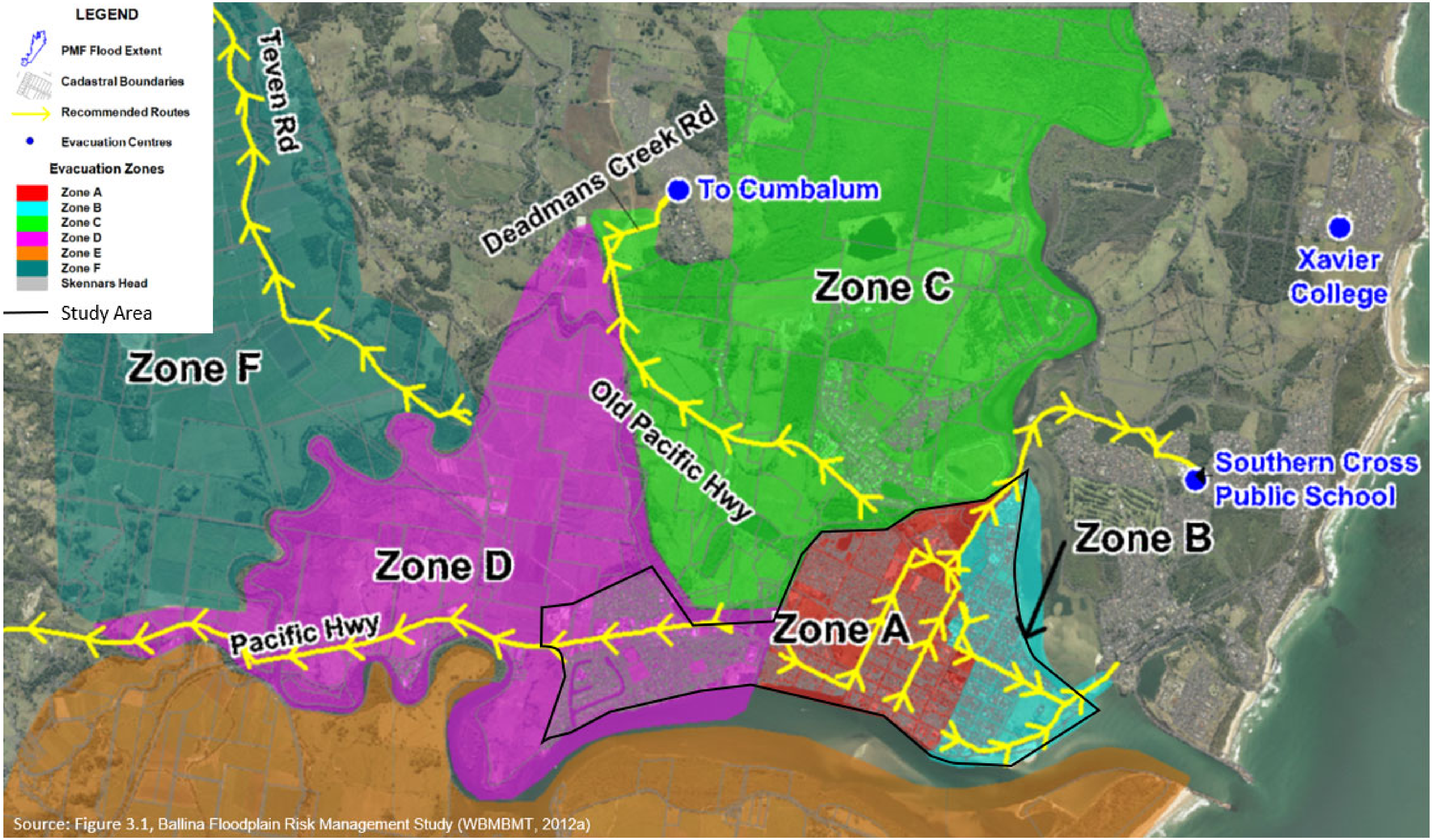


Figure 3-2 Evacuation Routes and Zones

A summary of the key advantages and disadvantages of raising evacuation routes is provided below.

Advantages

- Reduced flood impacts on evacuation routes from Richmond River flooding, creek flooding, sea level rise, and ocean driven events.
- Reduction of risk to life thought improved evacuation capacity and timeframes (particularly with respect to future climate horizons).
- Reduced potential for isolation and subsequent demands on emergency services.
- Reduction in road repair time and costs.
- May reduce business costs as routes remain open for longer and are not as frequently inundated in smaller more frequent floods than its design flood immunity.
- Can improve access to services by reducing the overall time of closure of a road caused by flooding.
- Implementation can be staged.

Disadvantages

- This would result in evacuation routes that are higher than adjacent roads and private and public land.
- May have physical or technical constraints e.g. sufficient space to achieve required embankments.
- Potential to cause adverse impacts on local overland flow paths including afflux and changes to duration of inundation on adjacent properties.
- Significant cost.
- Cases 3 and 4 would need to be combined with filling private and public land to similar levels (e.g. a whole of study area fill policy where land is filled to the 100 year ARI 2050 design level or the 100 year ARI Year 2100 design level). It would not be practical to implement these options in isolation.

☑	*It is recommended that this option be considered further during the detailed options assessment and in the next update of the Ballina Floodplain Risk Management Study.*

3.3 Flood Modification

Flood modification measures are those that alter the flood conditions to reduce the flood hazard or change the flood behaviour. Flood modification is generally the only measure that will minimise both the social impacts and the risk to property and life. However, it is rarely viable to design for the PMF (the upper envelope of floods) and thus a residual risk will exist, associated with floods exceeding the design level of service provided by the flood modification scheme.

3.3.1 P8 – Preliminary Assessment of Ballina Island and West Ballina Flood Levees

The purpose of levees is to mitigate flooding and associated economic and social consequences of flooding, by preventing floodwaters from entering portions of the floodplain.

Background

The concept of building a levee around Ballina Island and West Ballina to protect these areas from existing and future riverine, creek and ocean flooding sources has been previously raised by others as a potential flood mitigation measure.

In specifically addressing the projected future risk of flooding in Ballina Island, the Ballina Floodplain Risk Management Study (BMTWBM, 2012) considered the option of building a system of levees and pumps. However, it was determined that *"levees introduce risk of breach, overtopping and an increased maintenance burden on the community"* and a land use planning based approach was adopted as a *"gradual and adaptive floodplain management option*" that was *"well suited to dealing with the impacts of climate change".* In contrast, the Ballina Floodplain Risk Management Plan (BMTWBM, 2015) included a recommendation (ID F8) to *"Investigate the feasibility of alternative systems of flood structural measures that may include a combination of levees, pump and floodgates to provide protection for the Ballina Island precinct".*

In light of the above and following a number of discussions with BSC, it was agreed that a high-level, conceptual, assessment of a levee alignment around Ballina Island and West Ballina be undertaken based on the indicative levee alignment concepts illustrated in Figure 3-3 and Figure 3-4 respectively (with typical conceptual cross sections provided in Figure 3-5 and Figure 3-6). Key components of the levee systems include: earth embankments, sheet piles, concrete walls, road raising, temporary levee's at road crossings and gated hydraulic structures in waterways.

With respect to the levee concept, it is noted that:

- The proposed levee crest level of 2.3m AHD to 2.4m AHD was selected in consultation with Council, and would provide a varying degree of protection against the following riverine, creek and ocean levels:
    - 1% AEP Defined Flood Event (DFE) flood level envelope4. (existing climate conditions).
    - 1% AEP storm tide levels of approximately 2.0m AHD (existing climate conditions).
    - Year 2100 King Tide Estimate of 2.19 m AHD (1.29m AHD + 900mm sea level rise).
    - Year 2100 Highest Astronomical Tide (HAT) level of approximately 2.01m AHD.
    - 1% AEP Year 2050 flood level (riverine, creek, ocean) envelope (with limited freeboard).
- Redesigning River Street to function as a levee was deemed to be a more preferable levee alignment than constructing a levee immediately along the foreshore of the Richmond River (refer to the Alternative River Foreshore Alignment illustrated in Figure 3-3). This is because of the significant design, constructability, land acquisition, tidal works approvals/permits, and cost associated with the foreshore levee alignment.

  Further consideration regarding flood mitigation or rezoning of properties located on the Richmond River side of the River Street levee would be required. This has not been considered at this stage.
- In order to manage coincident local overland flooding and seepage within the area protected by the levee, a number of pump stations are likely to be required in low lying areas located behind the levee alignments. The location, size and details of pump requirements would need to be determined through a detailed internal drainage assessment. This would facilitate identification of: an appropriate coincident design event, the nature and degree of flood risk, design criteria and optimisation of the mitigation strategy.

[4] Represents envelope of maxima of 1% AEP riverine, creek and oceanic conditions.

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA94 MGA zone 56

BALLINA SHIRE COUNCIL
BALLINA ISLAND AND WEST BALLINA FLOOD STUDY

Ballina Island Levee System

Project No. **4132837**
Revision No. **00**
Date **26/03/2021**

Figure 3-3

G:\41\32837\GIS\Maps\MXD\Levee\Proposed_Flood_Levee_Imagery.mxd
Print date: 26 Mar 2021 - 16:17

Data source: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Created by: lyoconnor

BALLINA SHIRE COUNCIL
BALLINA ISLAND AND WEST BALLINA FLOOD STUDY

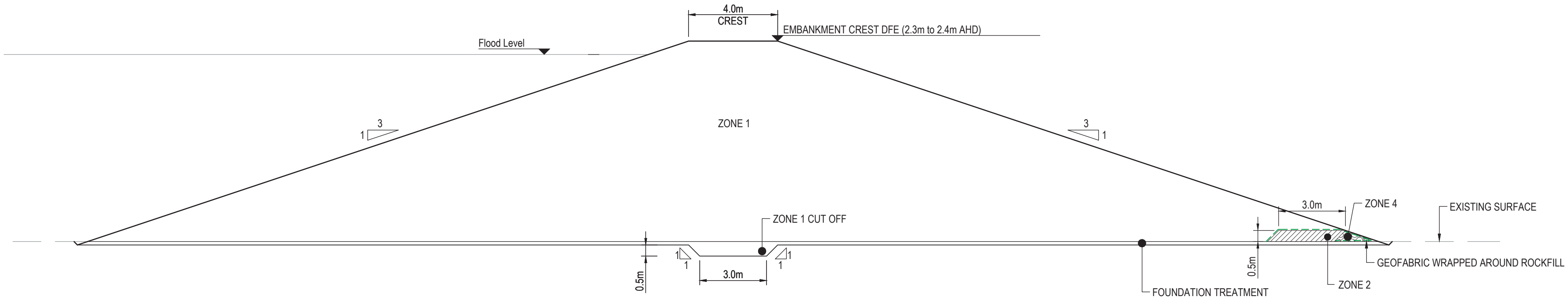
Proposed Flood Levee Alignment

Project No. 4132837
Revision No. 00
Date 17/05/2021

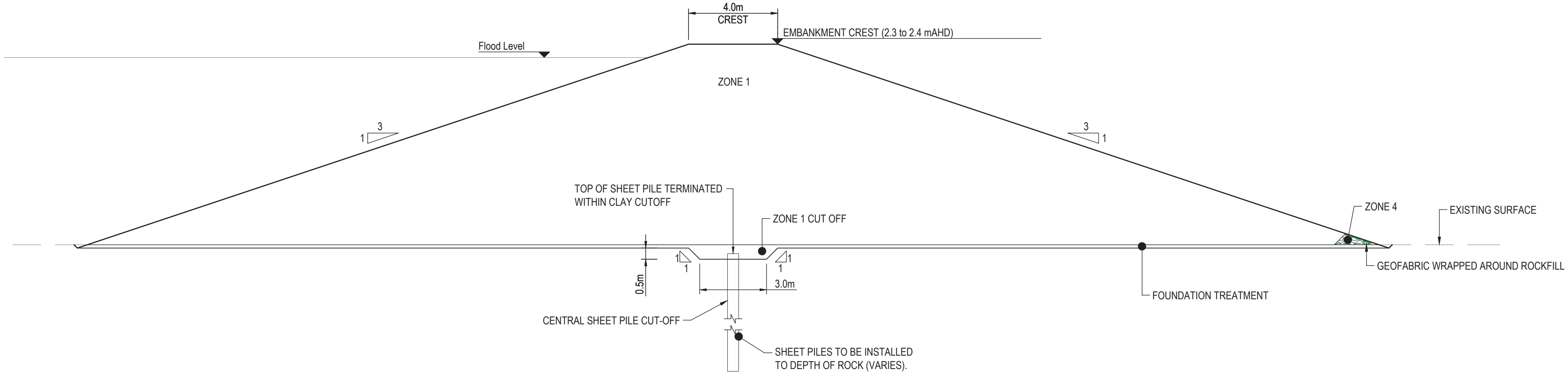
Figure 3-4

G:\41\32837\GIS\Maps\MXD\Levee\Proposed_Flood_Levee_Imagery_West_Ballina.mxd
Print date: 17 May 2021 - 17:08

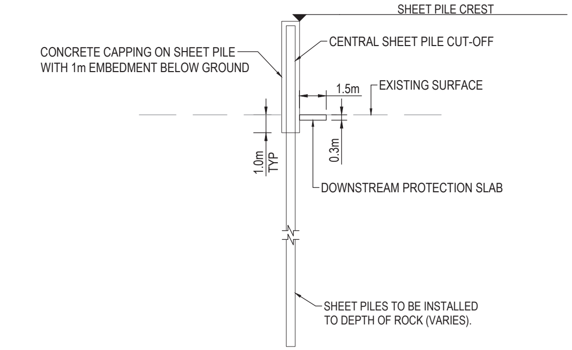
Data source: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Created by: lyoconnor



TYPICAL SECTION - TYPE 1 LEVEE WALL (EMBANKMENT)
SCALE 1:100



TYPICAL SECTION - TYPE 2 LEVEE WALL (EMBANKMENT)
SCALE 1:100



TYPICAL SECTION - TYPE 3 LEVEE WALL (SHEET PILE)
SCALE 1:150

PRELIMINARY

Rev	Description	App'd	Date
A	ISSUED FOR REVIEW	J. POLIN*	25.06.21

0 1 2 3 4 5m
SCALE 1:100 AT ORIGINAL SIZE

0 1.5 3.0 4.5 6.0 7.5m
SCALE 1:150 AT ORIGINAL SIZE

GHD
145 Ann St Brisbane QLD 4000 Australia
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www.ghd.com

Scale for A1

Status code

Project No. 4132837

Figure 3-5

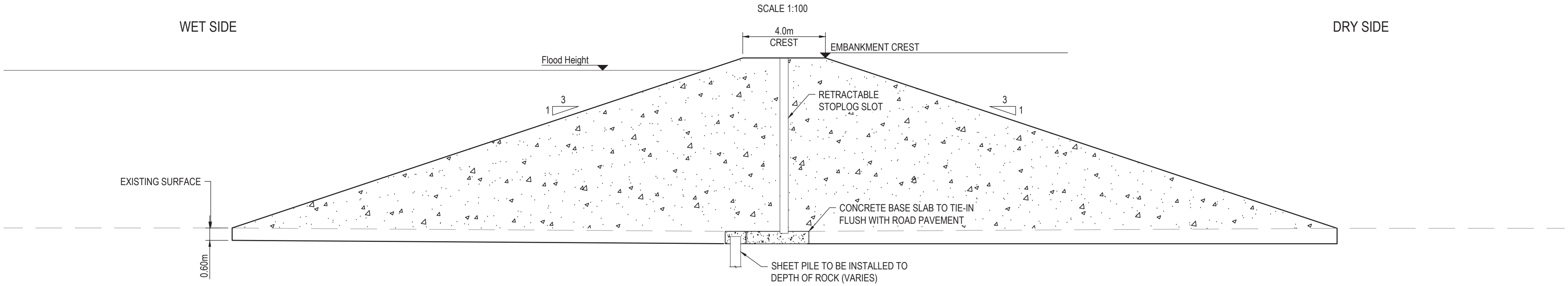
TYPICAL LEVEE SECTIONS

Size A1

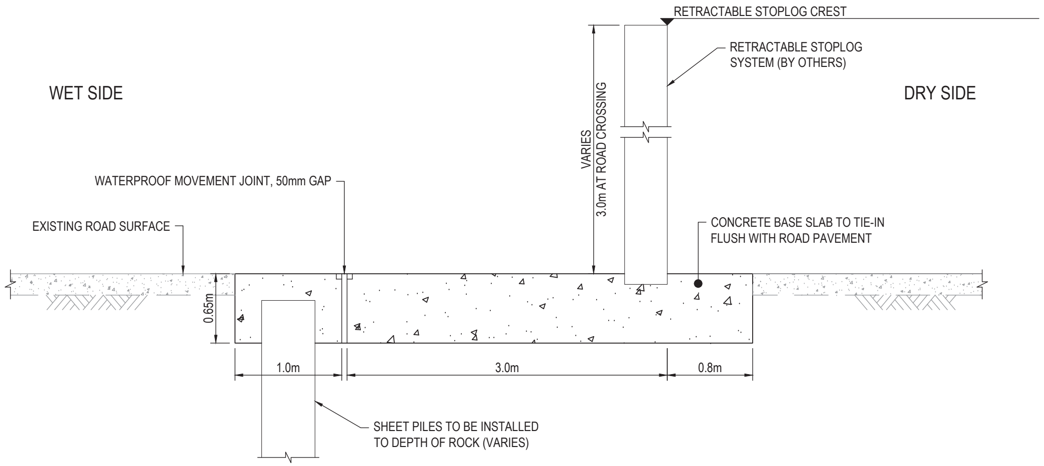
Sketch no. 4132837-SK1

Rev no. A

Plot Date: 25 June 2021 - 1:04 PM Plotted by: Kheenan Katene File Name: G:\41\12528648\CADD\Drawings\12528648-SK310.dwg



TYPICAL SECTION - CONCRETE ABUTMENT TYPE 2 TEMPORARY LEVEE (ROAD CROSSING)
SCALE 1:100



TYPICAL SECTION - TYPE 2 TEMPORARY LEVEE (ROAD CROSSING)
SCALE 1:25

PRELIMINARY

Rev	Description	App'd	Date
A	ISSUED FOR REVIEW	J. POLIN*	25.06.21

0 0.25 0.5 0.75 1.0 1.25m
SCALE 1:25 AT ORIGINAL SIZE

0 1 2 3 4 5m
SCALE 1:100 AT ORIGINAL SIZE

GHD
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Scale for A1

Status code

Project No. 4132837

Figure 3-6
TYPICAL TEMPORARY
ROAD CROSSING

Sketch no. 4132837-SK02

Size A1

Rev no. A

Plot Date: 25 June 2021 - 3:25 PM Plotted by: Kheenan Katene File Name: G:\41\12528648\CADD\Drawings\12528648-SK311.dwg

Preliminary Assessment

Whilst the Ballina Island and West Ballina levee options may provide significant reductions in flood damage costs, the levee alignment concept options are not considered on balance to be a viable flood mitigation measure due to the main constructability challenges, operational risks, environmental constraints, social impacts and high upfront costs listed below.

Constructability challenges:

- There are a large number of existing construction constraints along the levee alignments including private properties, existing infrastructure and service clashes.
- Construction of a levee around the Ballina Island would face several geotechnical challenges. These relate to an alluvial geology of considerable depth and nature. In general, the geotechnical conditions on the island comprise a 'crust' of silt, sand and clay up to around 3 m thickness. This crust is drier than the underlying materials which comprise layers of silt sand and clay as well. Some of the silt and clay layers at depth are very soft and prone to consolidation under load. Other layers are more strong and provide founding mediums for moderate sized structures. Rock tends to be in excess of 15 m in depth, with the depth to rock being variable over short distances. The presence of the near surface 'crust' generally allows for residential style loads to be tolerated with manageable settlements, however larger loads from say filling in excess of 1.5 m in height can lead to consolidation induced settlements that can continue for long durations. In addition to this, much of Ballina Island includes zones of near surface sand that ranges in density, but often is very lose. Whilst reasonable for support and settlements on sand are immediate, such materials are hydraulicly conductive, and may overly compressible silt and clay at depth.

  These conditions could lead to:

  - Extensive settlement of levee banks, that would need to be mitigated by deep piling to provide support. In some cases earth levees may not be practicable and piled concrete structures may be more economic.
  - Infiltration of flood waters below levees, which would require installation of sheet piles or cut off walls to manage subsoil floodwater ingress.
  - Slope stability issues.

  As the geology of the floodplain alluvium in the locality is complex (a stack of anastomosing alluvial deposits of variable thickness and nature) detailed geotechnical investigation would be required to adequately understand the magnitude of the issues requiring additional subsurface treatments along the length of any levee wall.

- In order to achieve the desired level of flood protection, the levee sections proposed for both Ballina Island and West Ballina would need to all be constructed during a single period of construction (i.e. one construction phase).
- A large number of approvals would be required for this type of flood management system in comparison to alternative mitigation measures.

Operational risks

- There is risk of failure of levee closure systems including temporary flood gates across roads, mechanical gates across canal entrances, and gates on levee through-culverts.
- A number of pump stations are likely to be required to manage local overland flows and ponding from coincident storm events across the area protected by the levee. There is a risk of pump failure associated with this infrastructure resulting in adverse flooding consequences within the protected area.
- There is a risk of piping failure or levee breach during flood events resulting in increased flood velocities and risk to people, property and infrastructure.
- Levee options do not eliminate the need to evacuate during floods. Flood events larger than the levee design height can still overtop the levee and can pose a significant flood risk to the local community.

Environmental constraints:

- West Ballina and Ballina Island and West Ballina are primarily located on acid sulphate soils (refer Figure 3-7). The construction of levees has the potential to disturb acid sulphate soils resulting in adverse environmental impacts.
- Levee alignments are likely to traverse sensitive ecosystems and areas of high biodiversity including coastal wetlands (refer Figure 3-8).
- The levee systems would cause a change in Richmond River flood characteristics including level, velocity and duration of inundation within the river and floodplain. This may result in adverse impacts within sensitive receptors such as the Richmond River Nature Reserve.
- Both levee systems include gated hydraulic structures across canal entrances which can result in adverse impacts to aquatic flora and fauna.
- Due to the potential for environmental impacts, a complex environmental approvals process is likely to be required which would be time consuming and costly.

Social Impacts:

- A large number of properties would need to be acquired to construct the proposed levee systems resulting in dislocation of occupants from their preferred location of residence.
- Levee alignments will have an adverse impact on visual amenity by obstructing views.
- Levee alignments will result in a disconnection of a large number of properties to waterways.
- Construction of a levee has the potential to result in a lowered community awareness of the risks of flooding and increased development in the protected area. This can result in greater consequences during overtopping events.
- Levee alignments have the potential to increase flood levels (cause afflux) within the Richmond River floodplain which may result in and land use impacts and flood damages.
- Some community members will be opposed to levee concepts and alignments.

Figure 3-7 Acid Sulfate Soils

- Class 1: Acid sulfate soils in a class 1 area are likely to be found on and below the natural ground surface.
- Class 2 : Acid sulfate soils in a class 2 area are likely to be found below the natural ground surface.
- Class 3: Acid sulfate soils in a class 3 area are likely to be found beyond 1 metre below the natural ground surface.
- Class 4: Acid sulfate soils in a class 4 area are likely to be found beyond 2 metres below the natural ground surface.
- Class 5: Acid sulfate soils are not typically found in Class 5 areas. Areas classified as Class 5 are located within 500 metres on adjacent class 1,2,3 or 4 land.

Source: https://www.planningportal.nsw.gov.au/spatialviewer/

Figure 3-8 Coastal Wetlands

Source: https://www.planningportal.nsw.gov.au/spatialviewer

Costs:

- Due to the length and complexity of the Ballina Island and West Ballina levee systems, levee capital costs are expected to be significant. The Ballina Island levee system has been estimated to cost approximately $103M as a minimum, with the cost of the West Ballina levee system estimated to cost at least $59M. It is noted that these represent high level cost estimates (AAACE Class 5) that are commensurate with a project maturity level definition of 0 to 2%. A breakdown of levee cost estimates is provided for the Ballina Island Levee system and the West Ballina Levee System in Appendices C and D respectively. Cost estimates provided are lower bound Class 5 assessments, including in respect of the nature type and functionality of canal gates/barrages. The canal gates costed are simple conceptual implementations of practical maximum size 'drop board' style gates. Higher degrees of operational and navigational functionality and or the impacts of gates on navigational amenity and safety are likely to result in substantially increased capital and operational costs.
- In order to construct the Ballina Island and West Ballina levee systems, approximately 85 and 114 private properties respectively would need to be acquired with property acquisition costs expected to exceed approximately $150M based on recent average real estate sales prices.
- There will be ongoing levee maintenance costs including but not limited to embankment and wall repairs, repairs to hydraulic infrastructure, and periodic inspections.

A levee at crest level 2.3m AHD to 2.4m AHD around Ballina Island and West Ballina is not considered to be a viable option due to existing constructability challenges, operational risks, property acquisition impost, environmental constraints, social impacts and high upfront capital costs.

No further consideration of this option is recommended.

3.3.2 P9 – Filling of Private Properties and Raising Roads in Ballina Island and West Ballina

A long term strategy to raise existing ground levels in private properties together with roads in Ballina Island and West Ballina was requested for high level cost assessment by BSC for the following scenarios:

- Case 1: Raise private properties and roads to 1.8m AHD[5].
- Case 2: Raise private properties and roads to elevations consistent with Councils existing fill policy (approximately 1.9m AHD to 2.2m AHD across study area) as defined by Map 1A in the Ballina Shire Development Control Plan 2012, Chapter 2b – Floodplain Management (BSC, 2012).
- Case 3: Raise private properties and roads to be above the 100 year ARI Year 2050 design flood (riverine, creek, ocean) level (approximately 2.1m AHD to 2.3m AHD across study area).
- Case 4: Raise private properties and roads to be above the 100 year ARI Year 2100 design flood (riverine, creek, ocean) level (approximately 2.4m AHD to 2.7m AHD across study area).

High level cost estimates for each of the above cases are provided in Table 3-3.

[5] Level nominated by Council, equivalent to current H.A.T. level of 1.11m AHD plus ~0.7m allowance for future sea level rise and local tidal anomaly.

Table 3-3 Cost of Raising Private Properties and Roads

Case No.	Description	Cost of Raising Ground Elevations in Private Properties	Cost of Raising Roads
Case 1	Raise private properties and roads to 1.8m AHD.	$26M	$373M
Case 2	Raise private properties and roads to elevations consistent with Councils existing fill policy.	$54M	$650M
Case 3	Raise private properties and roads to the 100 year ARI Year 2050 design flood level.	$66M	$764M
Case 4	Raise private properties and roads to the 100 year ARI Year 2100 design flood level.	$136M	$1,143M

The cost of raising ground elevations in private properties was estimated by calculating required fill volumes at a cost of fill rate of $50/m^3. Maps illustrating the depth of fill required across the study area for Cases 1 to 4 are provided in Appendix E. Road raising costs have been estimated based on the required height of road raise identified in Figures F1 to F4 in Appendix F, together with the per lineal metre rates of road raising provided by Council (refer Appendix B).

The volume of fill required to raise properties and the level of road raising required have both been estimated using Council supplied 2017 LIDAR data. It is noted that existing ground elevations may have changed since this survey was captured.

Advantages

- The filling of private properties as a flood management measure forms a key component of Council's existing Development Control Plan (BSC, 2012) however, there is no provision for the raising of public infrastructure such as roads. A strategy that also includes road raising would address this deficiency.
- Filling of private properties by owners provides a cost effective method for managing existing and future flood risk.
- Raising roads will increase road flood immunity, evacuation capability and reduce road flood damage costs.

Disadvantages

- Filling of private properties by owners in accordance with Council's existing Development Control Plan (BSC, 2012) will result in ad hoc filling of the floodplain over time. This can result in an adverse impact to streetscape amenity.
- Filling of private properties can result in a reduction of flood storage and obstruction of overland flow paths which has the potential to cause adverse flood impacts to adjacent properties.

☑ *It is recommended that a review of Council's existing fill policy be undertaken in conjunction with Flood Management Measure P1 during the detailed options assessment phase of the project with consideration given to protecting public infrastructure.*

Raising of all roads to a minimum level of 1.8m AHD is considered to be cost prohibitive and is consequently not recommended.

Note: Although the cost of infill private properties across Cases 1 to 3 may be feasible over a long time horizon, no recommendations are made for hydraulic modelling and detailed assessment as significant consideration is required to strategically plan suitable infill based on a number of criteria such as flood hazard and regime categories, aesthetics, environmental assessment, impacts on local drainage, and integration with existing built form and infrastructure (e.g. roads, services, etc.).

3.3.3 P10 – Overland flood mitigation measures

As described in Section 2.1.2, Ballina Island and West Ballina are susceptible to local overland flooding. To develop a detailed understanding of the degree of flood risk associated with overland flooding, the Ballina Island and West Ballina Overland Flood Study (GHD, 2020) was completed during Stage 2 of the project. This included development of a high resolution two-dimensional (2D) hydrodynamic model (TUFLOW) of the study area including the trunk drainage system, and simulation and flood inundation mapping of:

- Local design storm events for existing and future climate scenarios.
- Backwater inundation from high tide scenarios.
- Local storm events with coincident high tides.

To provide an indication of the types of flood mitigation measures that may be required at a broader scale, the outputs of the overland flood study have been used to identify local overland flooding and drainage flooding 'hotspots' and five (5) priority areas for mitigation works. The identification and preliminary assessment of these options is detailed in Section 4.

In order to improve the performance of the existing drainage network and further reduce the risk of overland flooding, it is also recommended that a comprehensive local drainage management strategy and proof of concept study be developed by BSC as a separate project taking into account physical constraints of the proposed drainage alignments (including existing underground utilities) , existing and future climate change conditions including increased rainfall intensities and sea level rise.

☑ *It is recommended that proof of concept hydraulic modelling of the mitigation measures proposed at each of the five (5) priority 'hot spots' be undertaken during the detailed options assessment phase of this project for the following design events:*

- *1% AEP design rainfall[6] with mean highwater spring tide (current climate)*
- *1% AEP design rainfall[6] with mean highwater spring tide (Year 2100 climate)*

Additionally, it is recommended that a comprehensive Local Drainage Management Plan be developed by BSC as a separate project. This should consider other lower priority hotspots, known issues and constructability constraints.

[6] For predominant critical storm duration and temporal pattern.

4. Identification and Preliminary Assessment of Overland Flood Mitigation Measures

Preliminary mitigation options for overland flooding have been identified in key problem areas by adopting the following methodology:

- Step 1: Fourteen (14) locations throughout Ballina Island and West Ballina were identified as flooding hotspots (refer Section 4.1).
- Step 2: Five (5) of these flooding hotspots were classified as priority areas on the basis of prioritisation criteria developed in consultation with Council (refer Section 4.2).
- Step 3: Identification and preliminary assessment of potential mitigation options aimed at mitigating the overland flooding issues at each priority flooding hotspots was completed (refer Section 4.2).

4.1 Identification of overland flooding hotspots

In order to identify problem flooding and drainage 'hotspots' and priority areas for potential flood mitigation works, a detailed analysis of the Ballina Island and West Ballina Overland Flood Study (GHD,2020) model results was undertaken.

4.1.1 Criteria adopted for the selection of flooding hotspots

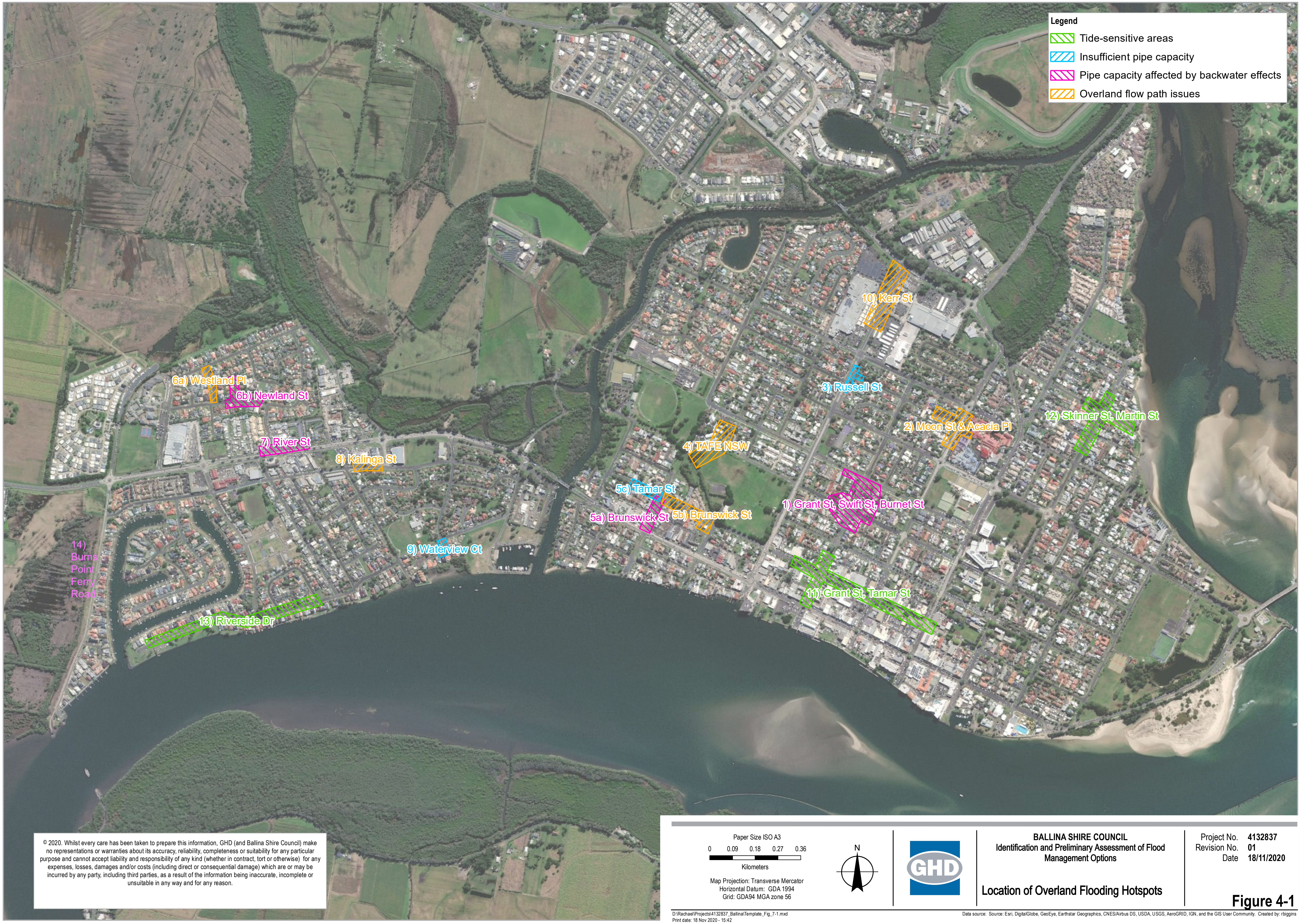
Flooding hotspots in Ballina Island and West Ballina have been identified according to the following criteria determined in consultation with Council:

- According to the Stormwater Management Standards for Development guidelines (BSC, 2016), the Annual Return Interval (ARI) design flood event to be adopted in BSC for the design of minor stormwater network systems ranges from 1 in 5-year ARI (i.e., 20% AEP) for Rural and Urban Residential to 1 in 10-year ARI (i.e., 10% AEP) for Commercial/Industrial land-use category. Given that flooding issues generated by local rainfall events are mainly associated with the capacity of the existing stormwater network system, the 20% AEP design flood event has been adopted as a reference for the identification of flooding hotspots resulting from overland flows in West Ballina and Ballina Island.
- The identification of flooding hotspots has been performed through analysis of model results for design event scenarios with coincident Highest Astronomical Tide conditions.
- The flooding hotspots have been identified as inundated areas with flood depths greater than 200 mm in the 20% AEP event.
- The areas most sensitive to high tide levels have been included among the flooding hotspots. The most "tidally sensitive" areas have been identified by considering the scenario characterised by no local rainfall event while applying King Tide levels as downstream boundary conditions.

4.1.2 Flooding hotspots

A detailed review of the West Ballina and Ballina Island overland flow path model results identified ten (10) stormwater system flooding and drainage hotspots that experience relatively high degrees of flood hazard vulnerability, and four (4) flooding hotspots most sensitive to high tide levels.

The location of these flooding hotspots is provided in Figure 4-1, with ‘zoomed-in’ flood inundation maps provided for each flooding hotspot in Appendix G. Table 4-1 summarises the nature of the flooding issues at each of the flooding hotspot locations, the flood hazard vulnerability of each flooding hotspot and the exacerbation of the flooding issues induced by high tide levels.



BALLINA SHIRE COUNCIL
Identification and Preliminary Assessment of Flood Management Options

Location of Overland Flooding Hotspots

Project No. **4132837**
Revision No. **01**
Date **18/11/2020**

Figure 4-1

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Data source: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Created by: rbiggins

Table 4-1 Preliminary Assessment of Flood Impacts and Risk

Hotspot ID	Location description	Description of flooding issues		
		Source of flooding	Flood hazard	Impacts of high tide levels
1	Grant St, Swift St, Burnet St	Pipe capacity affected by backwater effects from the Richmond River	Up to H2 category in 20%, 5% and 1% AEP flood events	Flooding issues exacerbated by backflows due to high tide levels
2	Moon St and Acacia Pl	Overland flow path issue due to a lack of stormwater drainage system	Mostly H2 category, with small spots characterised by H3 category in 20%, 5% and 1% AEP events	No exacerbation of flood levels due to high tide levels is observed at this location when considering MHWS tide and HAT levels
3	Russell St	Insufficient capacity of drainage system	Up to H2 category in 20%, 5% and 1% AEP flood events	No exacerbation of flood levels due to high tide levels is observed at this location when considering MHWS tide and HAT levels
4	TAFE NSW	Overland flow path issue due to a lack of stormwater drainage system	Up to H3 category in 20%, 5% and 1% AEP flood events	No exacerbation of flood levels due to high tide levels is observed at this location when considering MHWS tide and HAT levels
5	Tamar St and Brunswick St	Pipe capacity affected by backwater effects from the Richmond River along Brunswick St (Location 5a) Overland flow path issue due to a lack of stormwater drainage system along Tamar St east of intersection with Brunswick St (Location 5b) Insufficient capacity of drainage system along Tamar St west of intersection with Brunswick St (Location 5c)	Mostly H2 category, with an area characterised by H3 category along Tamar St east of Brunswick St in 20%, 5% and 1% AEP flood events	Flood levels along Brunswick St are exacerbated by high tide levels No exacerbation of flood levels due to high tide levels is observed on Tamar St east of Brunswick St
6	Newland St and Westland Pl	Pipe capacity affected by backwater effects from the Richmond River on Westland Pl (Location 6a) Overland flow path issue due to a lack of stormwater drainage system along Newland St (Location 6b)	H2 category in 20% AEP event Up to H3 category in 5% and 1% AEP events	No exacerbation of flood levels due to high tide levels is observed at this location when considering MHWS tide and HAT levels
7	River St between Sunset Ave and Ronan Pl	Pipe capacity affected by backwater effects from the Richmond River	H2 category in 20%, 5% and 1% AEP events	Flood levels are strongly exacerbated by high tide levels

Hotspot ID	Location description	Description of flooding issues		
		Source of flooding	Flood hazard	Impacts of high tide levels
8	Kalinga St	Overland flow path issue due to a lack of stormwater drainage system	H2 category in 20%, 5% and 1% AEP events	No exacerbation of flood levels due to high tide levels is observed at this location when considering MHWS tide and HAT levels
9	Waterview Ct	Insufficient capacity of drainage system	H2 category in 20%, 5% and 1% AEP events	No exacerbation of flood levels due to high tide levels is observed at this location when considering MHWS tide and HAT levels
10	Kerr St	Overland flow path issue due to poor stormwater drainage system	H2 category in 20% and 5% AEP events Up to H3 category in 1% AEP event	No exacerbation of flood levels due to high tide levels is observed at this location when considering MHWS tide and HAT levels
11	Grant St and Tamar St	Inundation due to backflows through the stormwater pipe network during King Tide levels	H1 category	Flood levels are strongly exacerbated by higher tide levels
12	Skinner St and Martin St	Inundation due to backflows through the stormwater pipe network during astronomical tide (King Tide) levels	H1 category	Flood levels are strongly exacerbated by higher tide levels
13	Riverside Dr	Inundation due to backflows through the stormwater pipe network during network during astronomical tide (King Tide) levels	H1 category	Flood levels are strongly exacerbated by higher tide levels
14	Burns Point Ferry Road	Burns Point Ferry Road has historically experienced partial inundation from the ingress of tidal waters during high tide events resulting from backflows through the stormwater drainage system into the gutters of Burns Point Ferry Road. In very high tide peaks, the river bank is breached. Council have subsequently installed a backflow prevention devices on drainage network and constructed a road hump (roll over) to mitigate this. Minor local overland flooding issues can still result during coincident local rainfall and high tide events.	H1 to H2 category	Generally mitigated by Council works including installation of backflow prevention device and construction of a road hump (roll over) to mitigate against tidal inundation.

4.2 Prioritisation of overland flooding hotspots

Five (5) flooding hotspots were identified as priority flooding areas through application of the following criteria determined in consultation with Council:

- Deficiency: priority has been given to hotspots where overland flooding was generated by drain capacity < 50% AEP.
- Conveyance: priority has been given to hotspots where overland flooding was associated with trunk stormwater drainage.
- Pipe dependency: priority has been given to hotspots where overland flooding was generated by pipe capacity issues rather than overland flow path issues.
- Tidal sensitivity: priority has been given to the hotspots where high tides exacerbated overland flooding.

A score has been assigned to each prioritisation criteria as summarised in Table 4-2. A summary of the scores applied to each overland flooding hotspot and the final rank is provided in Table 4-3.

Table 4-2 Score Criteria

Prioritisation criteria	Applied score	
	+1 point	0 points
Deficiency	Flooding generated by drain capacity < 50% AEP	Flooding generated by drain capacity ≥ 50% AEP
Conveyance	Flooding generated by trunk stormwater drainage	Flooding generated by reticulation stormwater drainage
Pipe dependency	Flooding generated by pipe capacity issues	Flooding generated by overland flow path issues
Tidal sensitivity	Flooding exacerbated by high tides	No exacerbation of flooding from high tides

Table 4-3 Prioritisation of Overland Flooding Hotspots

Hotspot ID	Location	Score					Final rank
		Deficiency	Conveyance	Pipe dependency	Tidal sensitivity	Total score	
1	Grant St, Swift St, Burnet St	1	0	1	1	**3**	**1**
2	Moon St and Acacia Pl	1	0	0	0	**1**	**10**
3	Russell St	1	0	1	0	**2**	**6**
4	TAFE NSW	0	0	0	0	**0**	**12**
5	Tamar St & Brunswick St	1	0	1	1	**3**	**2**
6	Newland St and Westland Pl	1	0	1	0	**2**	**7**
7	River St between Sunset Ave and Ronan Pl	0	1	1	1	**3**	**3**
8	Kalinga St	0	0	0	0	**0**	**14**
9	Waterview Ct	0	0	1	0	**1**	**11**
10	Kerr St	1	1	0	0	**2**	**8**
11	Grant St and Tamar St	0	1	1	1	**3**	**4**
12	Skinner St and Martin St	0	0	1	1	**2**	**5**
13	Riverside Dr	0	0	1	1	**2**	**9**
14	Burns Point Ferry Road	0	1	0	0	**1**	**13**

4.3 Identification and Preliminary Assessment of Overland Flooding Mitigation Options

At each of the five (5) overland flooding 'hotspots', proposed flood mitigation measures have been identified. These include:

- Installation of additional stormwater pits and/or pipes to provide additional drainage capacity (e.g. stormwater pipe duplication or upgrade).
- Installation of backflow prevention devices at stormwater outlets to reduce backwater ingress during high tide events.
- Local drainage works to redirect overland flows to the existing stormwater network.

A description of the mitigation measures proposed at each of the priority overland flooding hotspots is summarised in Table 4-4 with high-level concept plans provided in Appendix H.

Preliminary cost estimates for each of the identified local overland flood mitigation measures are provided in Table 4-5. The minimum total cost for mitigation of these five flooding hotspots has been estimated to be in the order of $2.55M with the basis for these costs estimates provided in Appendix I.

Table 4-4 Proposed Overland Flood Mitigation Options

Rank	Hotspot ID	Location	Mitigation Option ID	Mitigation Option Description	Benefits
1	1	Grant St, Swift St, Burnet St	O1	1) Tide flap device at the pipe outlet on Richmond River at the end of Grant St	1) Maintain full capacity of pipe during local rainfall events by reducing backwater effects from Richmond River
2	5a	Brunswick St	O2	1) Augmentation of stormwater drainage pipe along Brunswick St 2) Tide flap device at the pipe outlet on Richmond River at the end of Brunswick St	1) Maintain full capacity of pipe during local rainfall events by reducing backwater effects from Richmond River 2) Increase pipe capacity to accommodate flows up to 20% AEP local rainfall events
	5b	Tamar St east of Brunswick St	O3	1) Excavation of swales along Tamar St east of Brunswick Rd to redirect the flows toward the stormwater drainage network of Canal Rd	1) Reduced water ponding because flows are collected into the new stormwater system and conveyed into the existing underground stormwater system

Rank	Hotspot ID	Location	Mitigation Option ID	Mitigation Option Description	Benefits
			O4	1) New pit and pipe stormwater system along Tamar St east of Brunswick Rd to redirect the flows toward the stormwater drainage network of Tamar St west of Brunswick Rd	1) Reduced water ponding because flows are collected into the new stormwater system and conveyed into the existing underground stormwater system 2) Cost-effective solution
	5c	Tamar St west of Brunswick St	O5	1) Augmentation of stormwater drainage pipe along Tamar St west of Brunswick St 2) Tide flap device at the pipe outlet on Fishery Creek at the end of Tamar St	1) Maintain full capacity of pipe during local rainfall events by reducing backwater effects from Richmond River 2) Increase pipe capacity to accommodate flows up to 20% AEP local rainfall events
3	7	River St between Sunset Ave and Ronan Pl	O6	1) Tide flap device at the pipe outlet on Fishery Creek at the end of River St 2) Excavation of swale to facilitate conveyance of flows into stormwater pipes and provide temporary additional water storage 3) Augmentation of existing pipe network along River St	1) Maintain full capacity of pipe during local rainfall events by reducing backwater effects from Richmond River 2) Increase pipe capacity to accommodate flows up to 20% AEP local rainfall events 3) Reduced water ponding because flows are collected into the new stormwater system (pipe or swale) and conveyed into the existing underground stormwater system
4	11	Grant St and Tamar St	O7	1) Tide flap device at the pipe outlet on Richmond River at the end of Grant St (as per hotspot #1) 2) Augmentation of existing pipe network along Tamar St to convey flows into stormwater network located along Grant St and Cherry St	1) Maintain full capacity of pipe during local rainfall events by reducing backwater effects from Richmond River 2) Increase pipe capacity to accommodate flows up to 20% AEP local rainfall events

Rank	Hotspot ID	Location	Mitigation Option ID	Mitigation Option Description	Benefits
5	12	Skinner St and Martin St	O8	1) Tide flap device at the pipe outlet on North Creek at the end of Skinner St	1) Maintain full capacity of pipe during local rainfall events by reducing backwater effects from North Creek

Table 4-5 Preliminary cost estimates

Hotspot Identifier	#1	#5	#7	#11	#12
Length of new pipes (m)	N/A	1300	810	270	N/A
Approx. number of structures	N/A	30	20	6	N/A
Cost	$156,000	$1,295,000	$692,000	$343,000	$66,000
Total Hotspot mitigation cost: $2.55M					

5. Shortlisting of Floodplain Management Options

In Sections 3 and 4, a preliminary assessment of potential flood mitigation options aimed at reducing flood risk in Ballina Island and West Ballina from riverine, creek, oceanic and overland flooding sources was undertaken.

Table 5-1 provides a summary of identified management options and indicates those shortlisted for further detailed assessment.

Table 5-1 Summary of Recommendations

Item No.	Floodplain management option description	Potential mitigation measure	Recommended for further assessment in the Detailed Options Assessment phase of project
P1	**Land Use Planning:** *It is recommended that land use planning management measures be explored in more detail. This could include consideration of:* • *Updating the LEP and DCP to reflect DPIE Floodprone Land Package.* • *Alternative solutions to Council's current fill policy including phased retreat, adoption of building envelopes, innovative building design, on-site detention, provision of safe evacuation routes, and early warning systems.* • *Limitations on sensitive uses like seniors living, boarding houses, nursing homes, residential aged care facilities etc in flood affected areas (partially addressed in current DCP).* • *Application of additional controls requiring flood investigations/ filling to demonstrate appropriate evacuation routes in the DCP.* • Consideration of overland flooding issues and in particular the outputs of the Ballina Island and West Ballina Overland Flood Study (GHD, 2020). • *Preparation of more detailed flood inundation mapping delineating type of flood hazard and commensurate risk (i.e. riverine, creek, oceanic and overland flow paths).* • *Year 2050 and 2100 future climate conditions.*	☑	☑

P2	**Voluntary House Raising:** *Voluntary house raising has the potential to reduce the damage cost to individual dwellings however, this measure needs to be coupled with an effective evacuation plan.* *It is recommended that voluntary house raising be included in the final strategy however, no further assessment is required.*	☑	☒
P3	**Flood Proofing of Buildings:** *Flood proofing of buildings not considered viable as a broad floodplain risk management option on its own. However, innovative building design should be considered as part of the development controls associated with P1-Land Use Planning measures.*	☑	☑
P4	**Voluntary Purchase of High Hazard Properties** *It is recommended that a voluntary purchase scheme be considered to facilitate purchase of high hazard properties on a case by case basis where other measures are impractical or uneconomic.* *It is recommended that this option be included in the final strategy with no further consideration required.*	☑	☒
P5	**Improve Flood Warning System and Evacuation Management** *In light of the existing and future flood risk in Ballina Island and West Ballina, it is recommended that Council review the status of Items R1 to R8 of the Ballina Floodplain Risk Management Plan (WBMBMT, 2015) and the recommendations of the Richmond River Flood Warning and Evacuation Management Review (WBMBMT,2016), and determine if any outstanding items can be actioned.* *It is recommended that this option be included in the final strategy with no further consideration required.*	☑	☒
P7	**Evacuation Route Raise** *It is recommended that this option be considered further and in the next update of the Ballina Floodplain Risk Management Study.*	☑	☑

P8	**Ballina Island and West Ballina Flood Levees** *A levee at crest level 2.3m AHD to 2.4m AHD around Ballina Island and West Ballina is not considered to be a viable option due to existing constructability challenges, operational risks, property acquisition impost, environmental constraints, social impacts and high upfront capital costs.* *No further consideration is recommended.*	☒	☒
P9	**Filling of Private Properties and Raising Roads in Ballina Island and West Ballina** *It is recommended that a review of Council's existing fill policy be undertaken in conjunction with Flood Management Measure P1 during the detailed options assessment phase of the project. Raising of all roads to a minimum level of 1.8m AHD is considered to be cost prohibitive.*	☑	☑
P10a	**Overland flood mitigation measures** *It is recommended that proof of concept hydraulic modelling of the mitigation measures proposed at each of the five (5) priority 'hot spots' be undertaken during the detailed options assessment phase of this project for the following design events:* • *1% AEP design rainfall[7] with mean highwater spring tide (current climate)* • *1% AEP design rainfall[6] with mean highwater spring tide (Year 2100 climate)* *Where appropriate, this should include consideration of the application of dynamic tidal conditions.*	☑	☑
P10b	*It is recommended that BSC commission a 'Local Stormwater Drainage Management Study and Plan' to assess the existing minor stormwater network and determine if any network upgrades are required to meet minimum desired levels of service.*	☑	☒

[7] For predominant critical storm duration and temporal pattern.

6. Detailed Options Assessment

6.1 Introduction

The preliminary assessment of floodplain management options shortlisted the following options for further assessment:

- Land Use Planning (P1) including recommendations for Flood Proofing of Buildings (P3).
- Evacuation Route Raise (P7).
- Filling of Private Properties and Raising Roads (P9).
- Overland Flood Mitigation (P10a).

A series of workshops was then held with key BSC stakeholders on the 30th July, 24th of August, 31st of August and 1st of September to discuss these options. The following scope of work was subsequently agreed to form the basis of the detailed options assessment:

- Assess the hydraulic impact of raising existing evacuation routes on local overland flood behaviour for the 1% AEP design event under existing and Year 2100 climate conditions.
- Undertake hydraulic modelling of flood mitigation measures at the five (5) identified overland flood hotspots for the 1% AEP design event under existing and Year 2100 climate conditions.
- Assess the hydraulic impact of filling low lying private properties (below 1.8m AHD) on overland flood levels for the 1% AEP design event under existing and Year 2100 climate conditions.
- Undertake a high level review of the flood related aspects of Council's existing Development Control Plan (2012) including consideration of filling of private properties, flood resilient building design and recommendations to achieve improved flood risk management.

A summary of the detailed assessment of these items and key conclusions are provided in the following sections.

6.2 Overland flood impact assessment of evacuation route raise

Hydraulic modelling[8] was undertaken to assess the potential impact of raising existing flood evacuation routes (to a minimum level of 1.8m AHD) on overland flooding in Ballina Island and West Ballina.

Figure 6-1 and Figure 6-2 illustrate the location of evacuation roads and the potential impact of raising evacuation roads on 1% AEP overland flood levels under existing climate conditions and a Year 2100 future climate scenario. Results indicate that raising evacuation routes is likely to result in localised increases in flood level of 10mm to 35mm at the following locations:

- Riverbend Drive park (located to the west of Bunnings Ballina).
- Hibiscus Gardens caravan park located on River Street.
- At the intersection of Acacia Place and Moon Street, mostly limited to Acacia Place.
- On Tamar Street at the intersection of Tamar Street and Moon Street.
- North-east of the intersection of Bangalow Road and Cherry Street.

In order to reduce the increase in overland flood levels (afflux) at these locations to a degree that was acceptable to Council, local drainage works would need to be incorporated into the evacuation road raise design. To this end, the drainage works illustrated in Figure 6-3 were identified at a conceptual level and a preliminary hydraulic assessment undertaken using the Overland Flood Model. Additional conceptual plans focused on each of the locations where drainage works are likely to be required are provided in Appendix J.

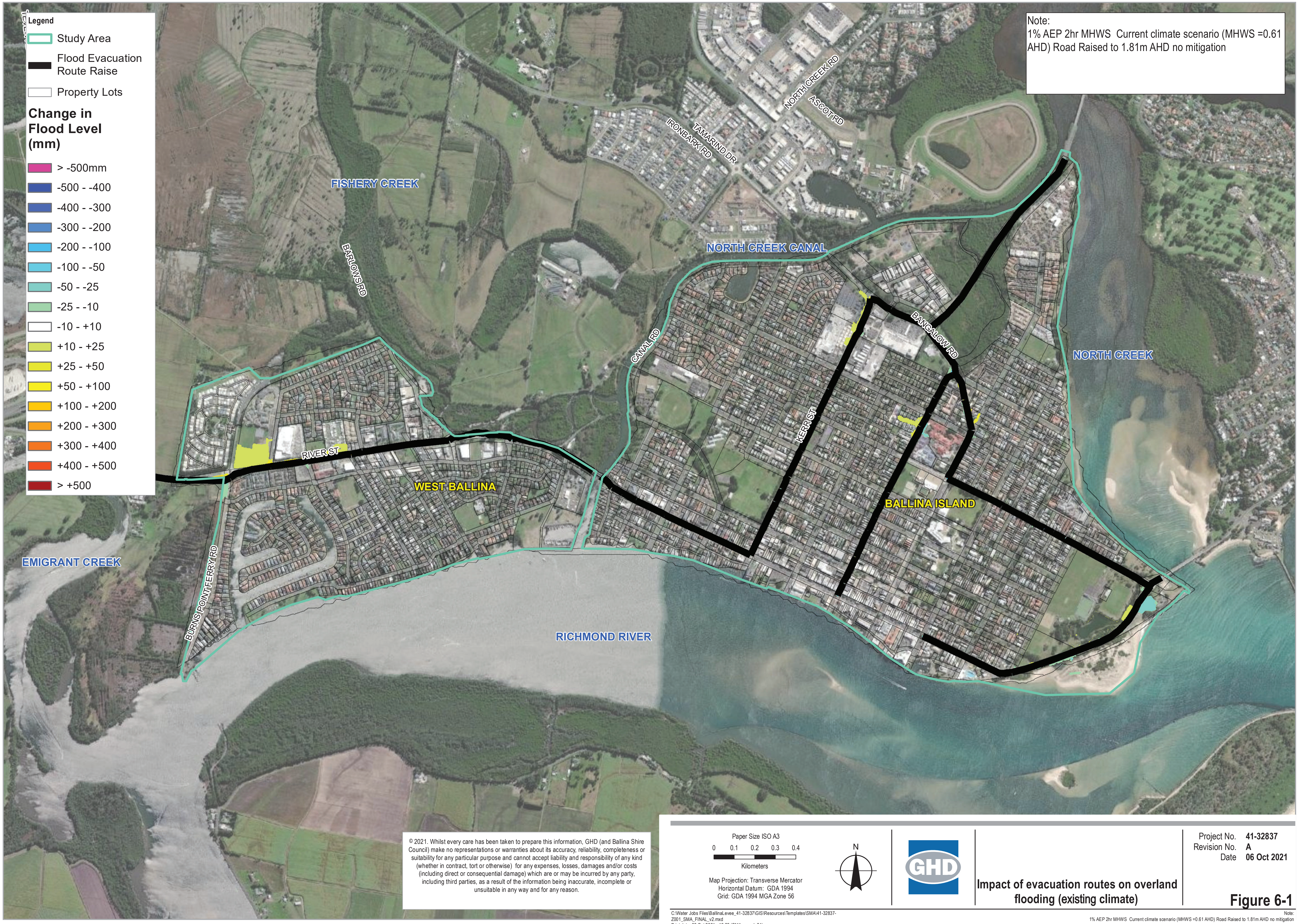
Figure 6-4 illustrates the change in flood level (afflux) resulting from the evacuation road raise (including drainage works) compared to pre-road raise overland flood levels under existing climate conditions. Comparison of Figure 6-4 to Figure 6-1 illustrates that these mitigation works would reduce the extent and magnitude of flood level impact under existing climate conditions.

Figure 6-5 illustrates the afflux resulting from the evacuation road raise (including drainage works) compared to pre-road raise overland flood levels under a Year 2100 future climate scenario. Comparison of Figure 6-5 to Figure 6-2 illustrates that the drainage works would not provide significant benefit under a Year 2100 future climate scenario.

Key Conclusions

The results of the overland flood impact assessment indicate that raising existing evacuation routes to a minimum level of 1.8m AHD has the potential to result in some localised areas of minor overland flood afflux in the 1% AEP design event. If this flood risk management option were to be progressed further (e.g. to preliminary design), a more detailed analysis of local drainage requirements would be needed as part of the design process.

[8] Hydraulic modelling was undertaken using the Overland Flood Model of Ballina Island and West Ballina (GHD, 2020).



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Revision No. A
Date 06 Oct 2021

Impact of evacuation routes on overland flooding (existing climate)

Figure 6-1

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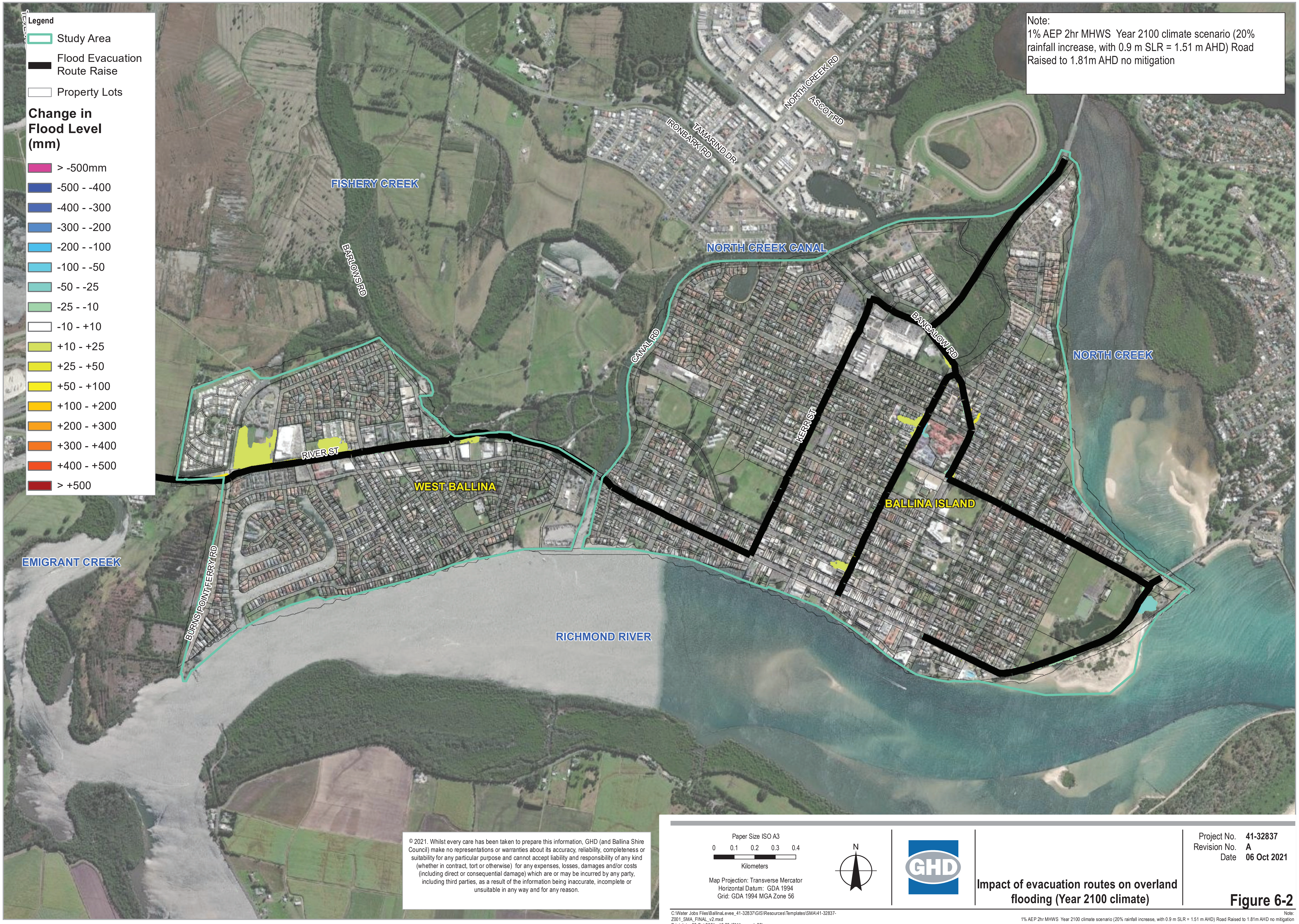
Note:
1% AEP 2hr MHWS Current climate scenario (MHWS =0.61 AHD) Road Raised to 1.81m AHD no mitigation



GHD

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Revision No. **A**
Date **06 Oct 2021**

Impact of evacuation routes on overland flooding (Year 2100 climate)

Figure 6-2

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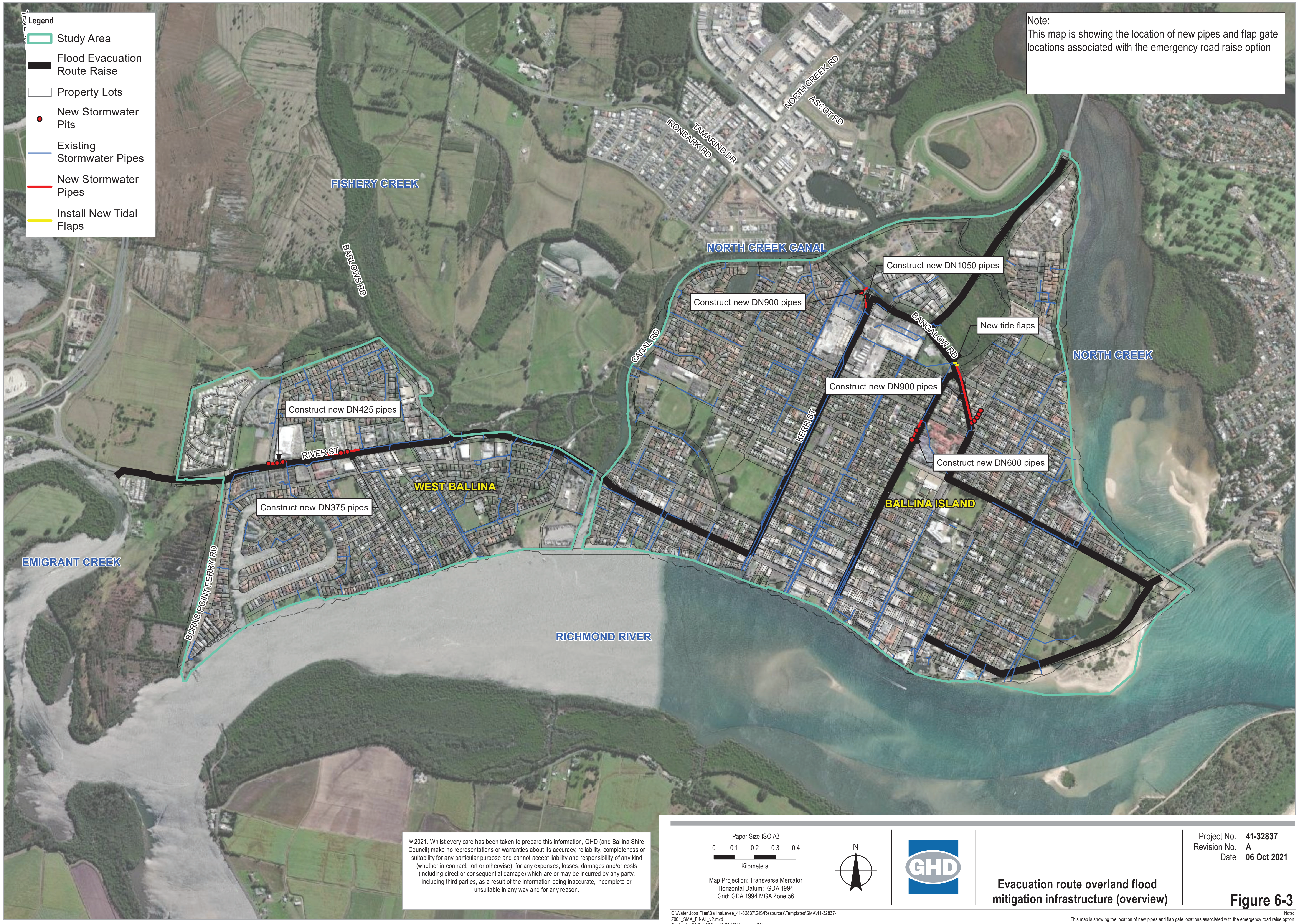
Print date: 06 Oct 2021 - 19:23 (SMA record: 22)

Note:
1% AEP 2hr MHWS Year 2100 climate scenario (20% rainfall increase, with 0.9 m SLR = 1.51 m AHD) Road Raised to 1.81m AHD no mitigation



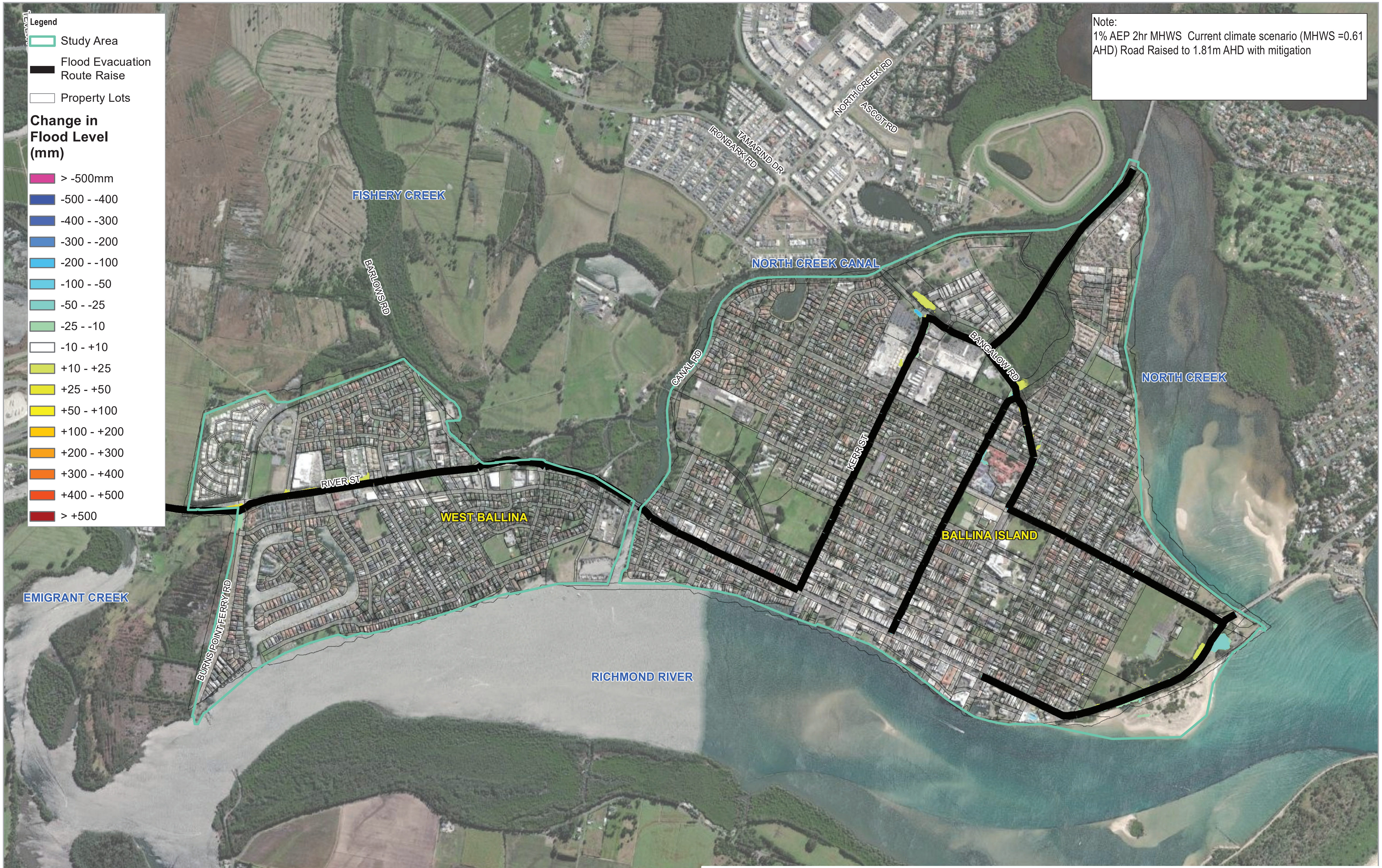
Project No. 41-32837
Revision No. A
Date 06 Oct 2021

Evacuation route overland flood mitigation infrastructure (overview)

Figure 6-3

C:\Water Jobs Files\BallinaLevee_41-32837\GIS\Resources\Templates\SMA\41-32837-Z001_SMA_FINAL_v2.mxd
Print date: 06 Oct 2021 - 19:23 (SMA record: 23)

Note:
This map is showing the location of new pipes and flap gate locations associated with the emergency road raise option



Impact of evacuation routes (with flood mitigation) on overland flooding (current climate)

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Figure 6-4

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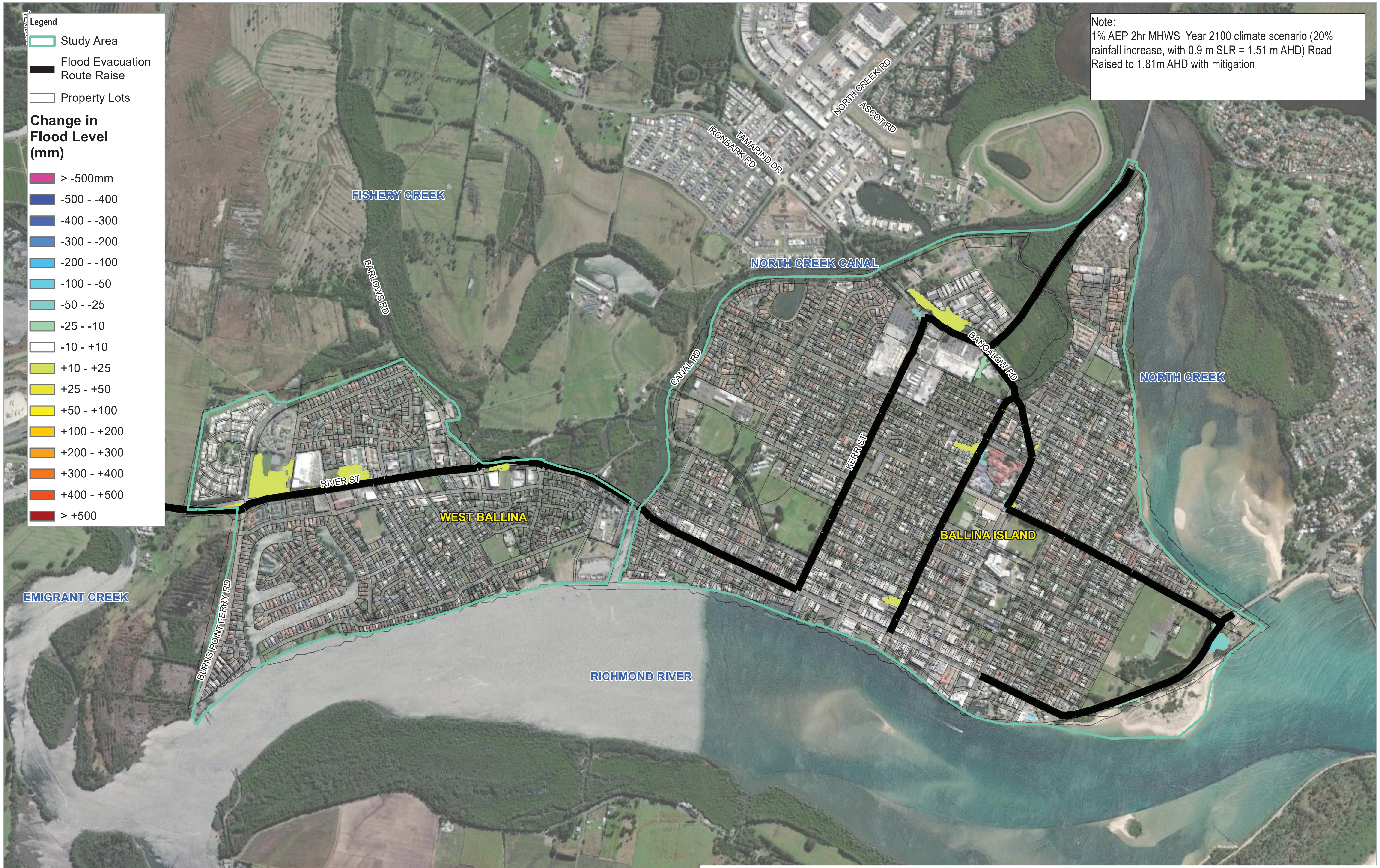
Print date: 06 Oct 2021 - 19:23 (SMA record: 24)

Note:
1% AEP 2hr MHWS Current climate scenario (MHWS =0.61 AHD) Road Raised to 1.81m AHD with mitigation



Paper Size ISO A3
0 0.1 0.2 0.3 0.4
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Impact of evacuation routes (with flood mitigation) on overland flooding (Year 2100 climate)

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Date 06 Oct 2021

Figure 6-5

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Print date: 06 Oct 2021 - 19:23 (SMA record: 25)

Note:
1% AEP 2hr MHWS Year 2100 climate scenario (20% rainfall increase, with 0.9 m SLR = 1.51 m AHD) Road Raised to 1.81m AHD with mitigation

6.3 Overland flood impact assessment of hotspot mitigation measures

Hydraulic modelling[9] was undertaken to assess the impact of the flood mitigation works identified in Section 4.3 at each of the identified five (5) overland flooding hotspot locations. Figure 6-6 illustrates the location and details of the flood mitigation works at a conceptual level with additional plans focused on each of the hotspot locations provided in Appendix K.

Table 6-1 provides a summary of the scenarios simulated in the hydraulic model to assess the performance of the mitigation works. Hydraulic modelling was undertaken for the 1% AEP design event for existing and Year 2100 climate conditions for both Mean High Water Spring (MHWS) and Mean Low Water Spring (MLWS) tide conditions.

Table 6-1 Design events assessed

Case	AEP	Climate	Tide	Floodplain conditions
1	1% AEP	Existing	MHWS	Existing floodplain conditions (no mitigation works)
2	1% AEP	Year 2100	MHWS	Existing floodplain conditions (no mitigation works)
3	1% AEP	Existing	MLWS	Existing floodplain conditions (no mitigation works)
4	1% AEP	Year 2100	MLWS	Existing floodplain conditions (no mitigation works)
5	1% AEP	Existing	MHWS	With mitigation works
6	1% AEP	Year 2100	MHWS	With mitigation works
7	1% AEP	Existing	MLWS	With mitigation works
8	1% AEP	Year 2100	MLWS	With mitigation works

Notes: Year 2100 climate conditions includes a 20% increase in rainfall intensity and 900mm of sea level rise. MHWS = Mean high water spring tide, MLWS= Mean Low Water Spring tide.

A summary of the reduction in flood levels provided by the overland flooding hotspot mitigation works is provided in Table 6-2, with the location and magnitude of flood level changes illustrated in Figure 6-7 to Figure 6-10 as follows:

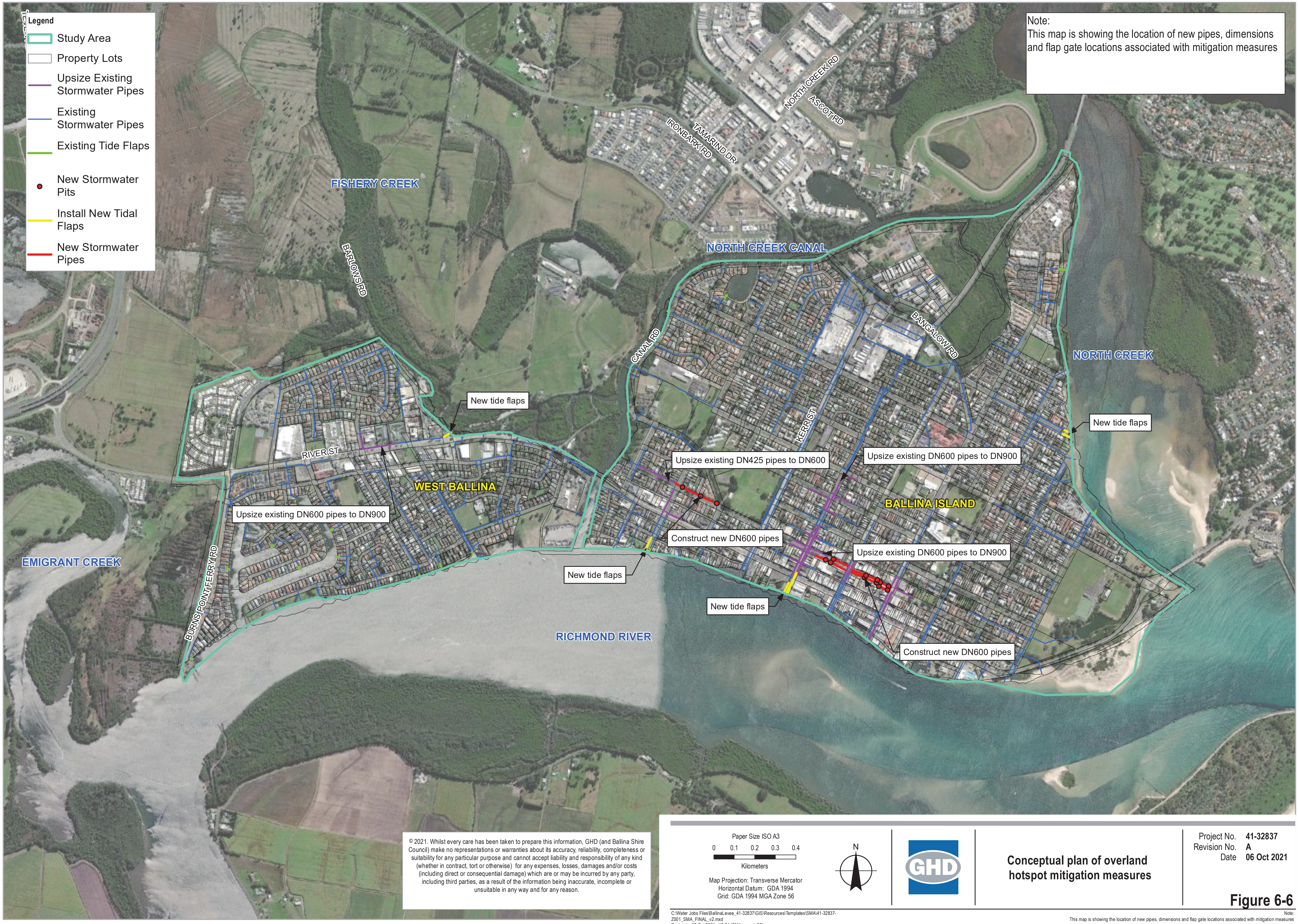
- Figure 6-7 illustrates the impact of overland flood mitigation works for the 1% AEP existing climate under MHWS tide conditions (i.e. Case 5 vs Case 1).
- Figure 6-8 illustrates the impact of overland flood mitigation works for the 1% AEP Year 2100 climate under MHWS tide conditions (i.e. Case 6 vs Case 2).
- Figure 6-9 illustrates the impact of overland flood mitigation works for the 1% AEP existing climate under MLWS tide conditions (i.e. Case 7 vs Case 3).
- Figure 6-10 illustrates the impact of overland flood mitigation works for the 1% AEP Year 2100 climate under MLWS tide conditions (i.e. Case 8 vs Case 4).

[9] Hydraulic modelling was undertaken using the Overland Flood Model of Ballina Island and West Ballina (GHD, 2020).

Table 6-2 Summary of overland flood mitigation impacts

Hotspot ID	Location	1% AEP Current Climate MHWS Tide	1% AEP Year 2100 Climate MHWS Tide	1% AEP Current Climate MLWS Tide	1% AEP Year 2100 Climate MLWS Tide
1	Grant St, Swift St, Burnet St	Reduction in flood level of approximately 17 mm	Approximately 800 m^2 of the inundated area to the south of Hotspot 1 has a reduction in flood level of approximately 16 mm	Reduction in flood level of 20mm	Reduction in flood level of 15 mm
5 a,b,c	Brunswick St and Tamar Street	Reduction in flood level of 15 mm which is mainly confined to Hotspot 5a	No change in flood level	Reduction in flood level of about 14 mm which is mainly confined to Hotspot 5a.	Approximately 160 m^2 of the area on Brunswick Street at Hotspot 5a has a reduction in flood level of 12 mm
7	River St between Sunset Ave and Ronan Pl	Reduction in flood level of 20 mm	No change in flood level	Reduction in flood level of 20 mm	Reduction in flood level of 15 mm
11	Grant St and Tamar St	Close to the intersection of Tamar Street and Grant Street, there is a reduction in flood level ranging from 10 to 100 mm	Reduction in flood level of 15 mm	Close to the intersection of Tamar Street and Grant Street, there is a reduction in flood level ranging from 10 to 40 mm	Close to the intersection of Tamar Street and Grant Street, there is a reduction in flood level ranging from 10 to 125 mm
12	Skinner St and Martin St	No reduction in flood level due to backwater prevention as ponding from overland flow remains.	No reduction in flood level due to backwater prevention as ponding from overland flow remains.	No reduction in flood level due to backwater prevention as ponding from overland flow remains.	No reduction in flood level due to backwater prevention as ponding from overland flow remains.

Notes: Year 2100 climate conditions includes a 20% increase in rainfall intensity and 900mm of sea level rise. MHWS = Mean high water spring tide, MLWS= Mean Low Water Spring tide.



Conceptual plan of overland hotspot mitigation measures

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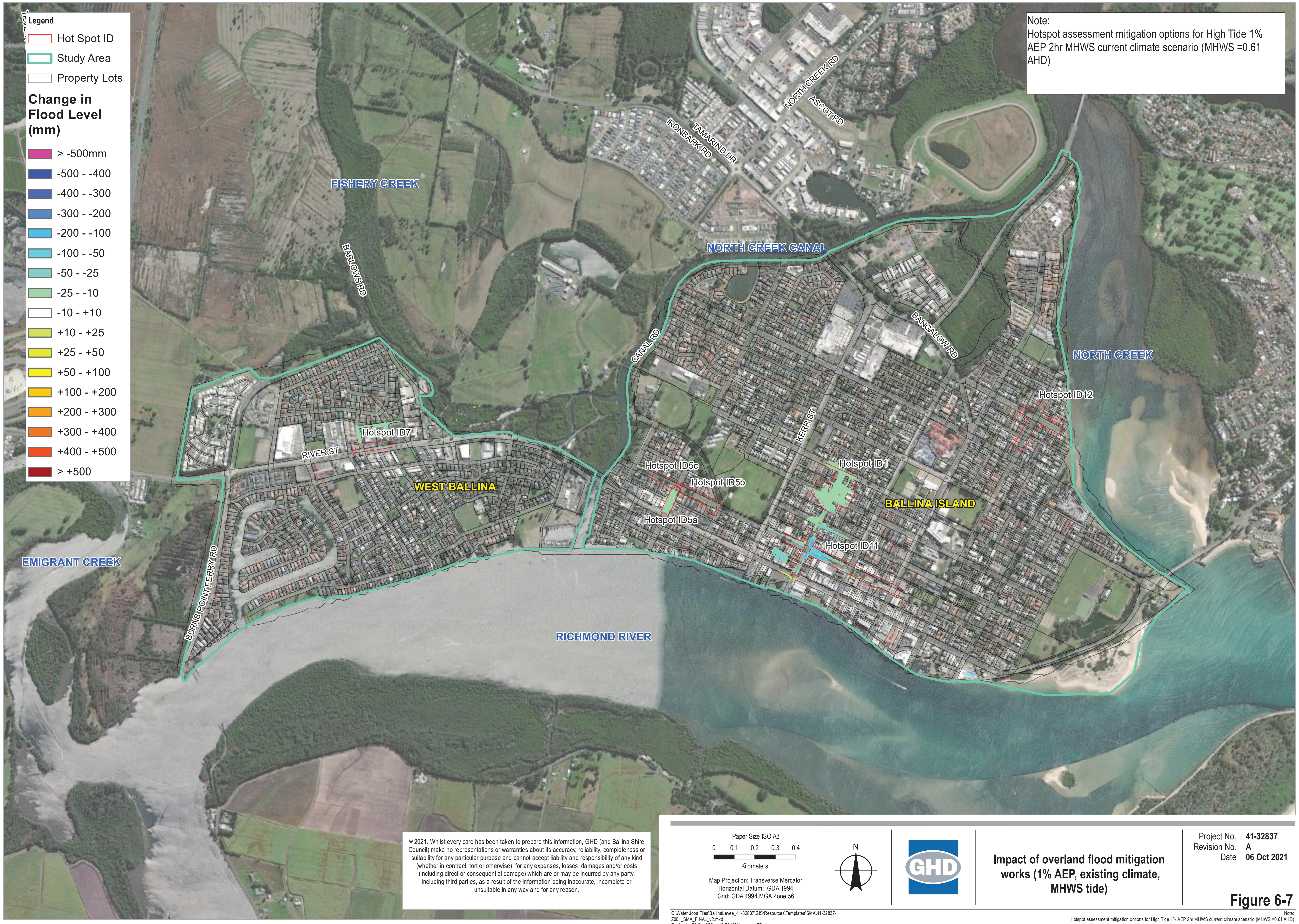
Figure 6-6

C:\Water Jobs Files\BallinaLevee_41-32837\GIS\Resources\Templates\SMA\41-32837-Z001_SMA_FINAL_v2.mxd
Print date: 06 Oct 2021 - 19:24 (SMA record: 26)

Note:
This map is showing the location of new pipes, dimensions and flap gate locations associated with mitigation measures

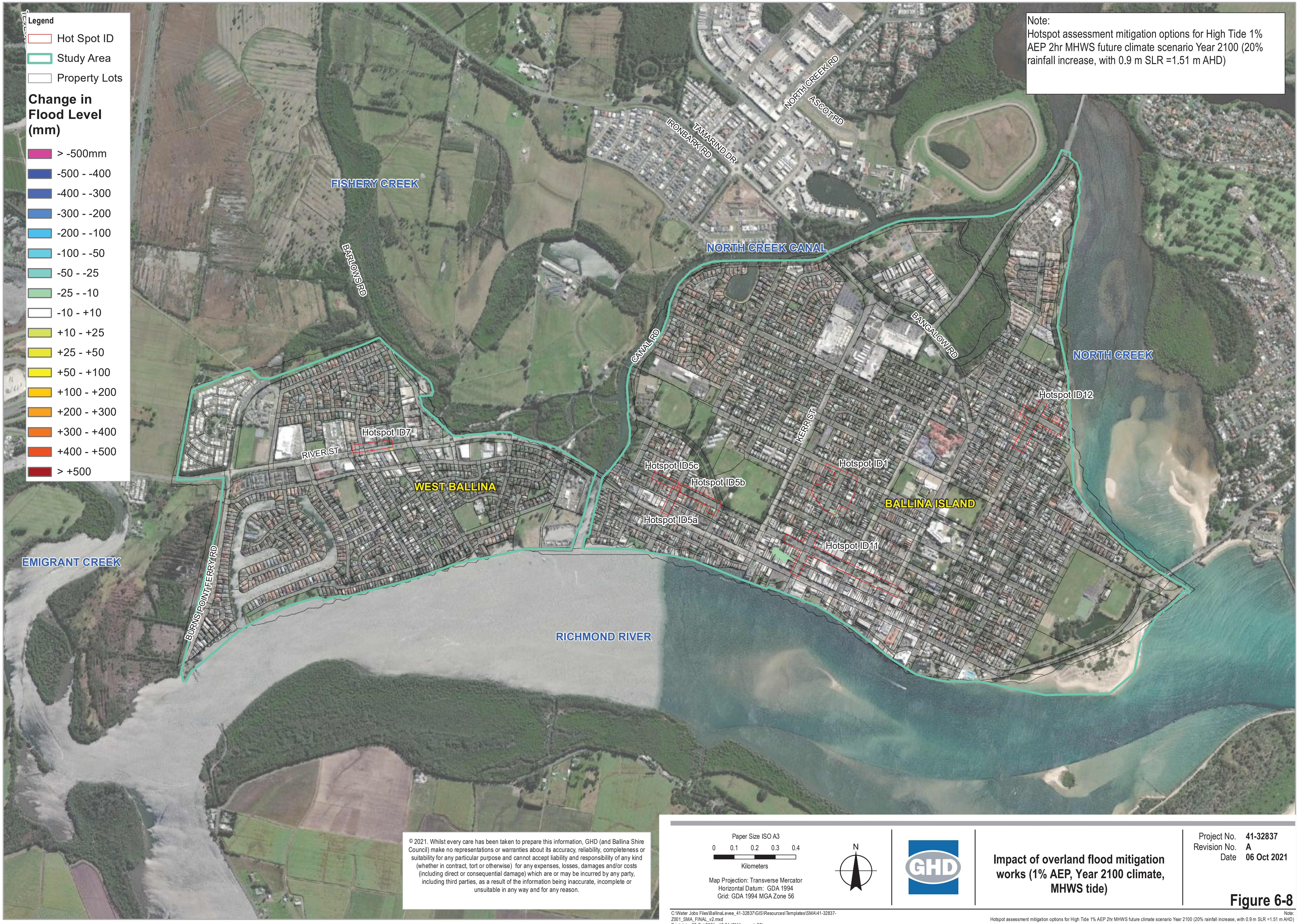


Impact of overland flood mitigation works (1% AEP, existing climate, MHWS tide)

Figure 6-7

C:\Water Jobs Files\BallinaLevee_41-32837\GIS\Resources\Templates\SMA\41-32837-Z001_SMA_FINAL_v2.mxd
Print date: 06 Oct 2021 - 19:24 (SMA record: 27)

Note:
Hotspot assessment mitigation options for High Tide 1% AEP 2hr MHWS current climate scenario (MHWS =0.61 AHD)



Impact of overland flood mitigation works (1% AEP, Year 2100 climate, MHWS tide)

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Figure 6-8

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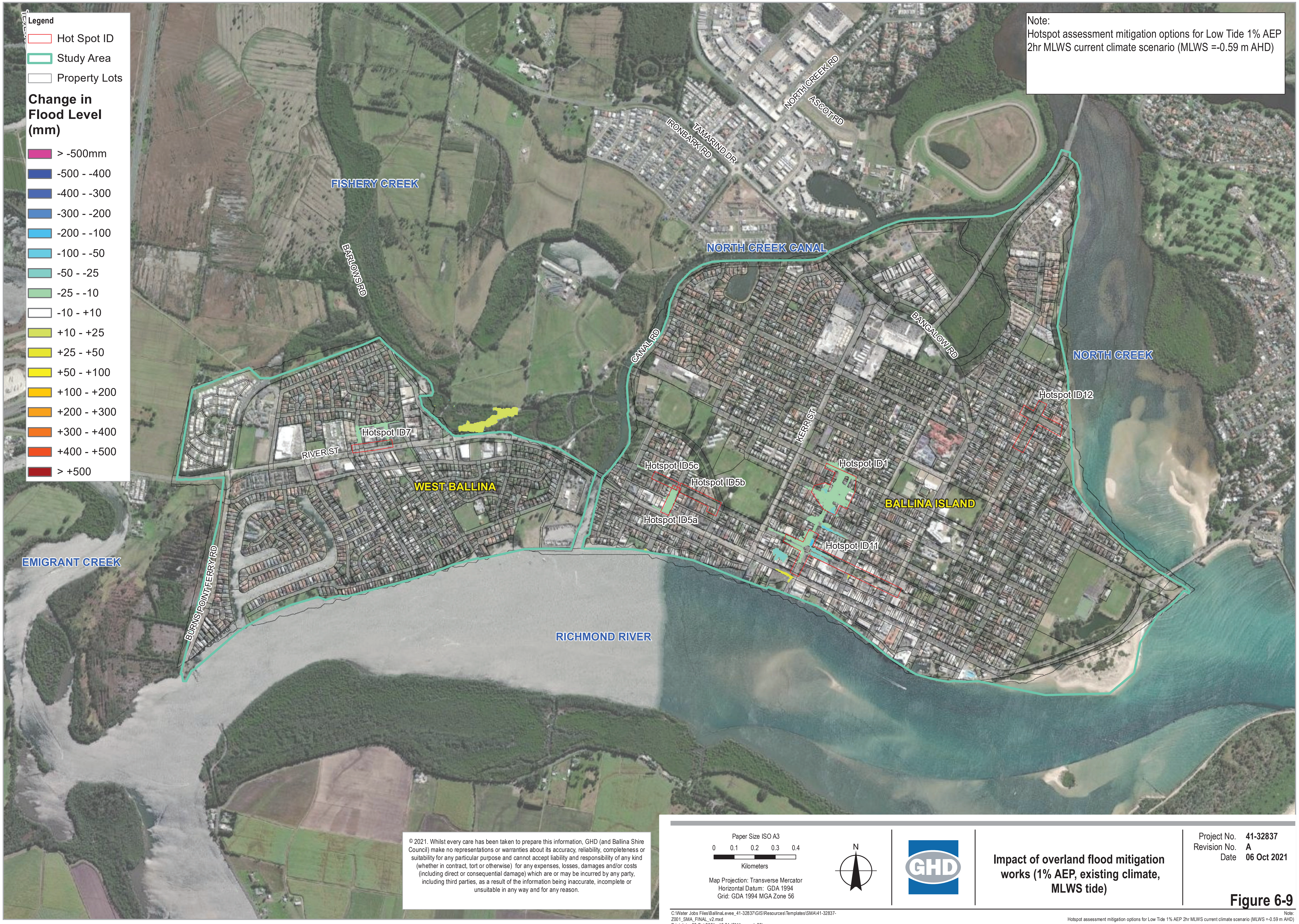
Print date: 06 Oct 2021 - 19:24 (SMA record: 28)

Note:
Hotspot assessment mitigation options for High Tide 1% AEP 2hr MHWS future climate scenario Year 2100 (20% rainfall increase, with 0.9 m SLR =1.51 m AHD)



Impact of overland flood mitigation works (1% AEP, existing climate, MLWS tide)

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Figure 6-9

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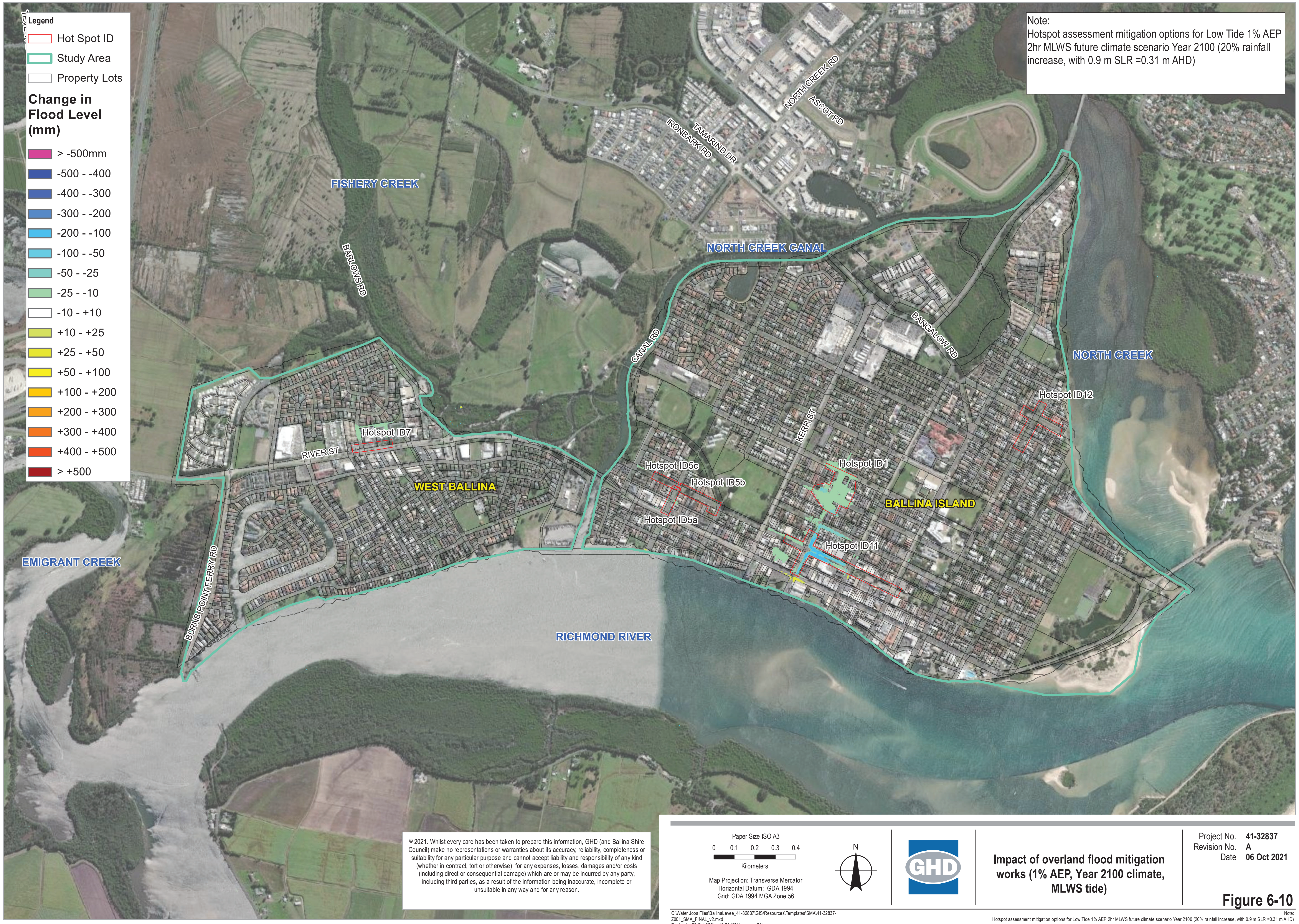
Print date: 06 Oct 2021 - 19:24 (SMA record: 29)

Note:
Hotspot assessment mitigation options for Low Tide 1% AEP 2hr MLWS current climate scenario (MLWS =-0.59 m AHD)



Impact of overland flood mitigation works (1% AEP, Year 2100 climate, MLWS tide)

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Date 06 Oct 2021

Figure 6-10

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Print date: 06 Oct 2021 - 19:24 (SMA record: 30)

Note:
Hotspot assessment mitigation options for Low Tide 1% AEP 2hr MLWS future climate scenario Year 2100 (20% rainfall increase, with 0.9 m SLR =0.31 m AHD)

Key Conclusions

Results indicate that the reduction in overland flood levels provided by the mitigation works at each of the hotspot locations is generally less than 25mm, with the exception of Hotspot ID11 (on Tamar Street in the vicinity of the intersection with Grant Street). At this location, flood level reductions of up to 125mm are estimated for existing climate conditions, reducing to 25mm under the Year 2100 future climate scenario. Overall, the estimated reduction in overland flood levels provided by the mitigation measures is not considered to be significant enough to justify the scale and cost of such works. This is particularly the case when climate change induced sea level rise is likely to progressively reduce the capacity of the existing stormwater network via increased tide levels at stormwater outlets.

6.4 Overland flood impact assessment of filling low-lying private properties

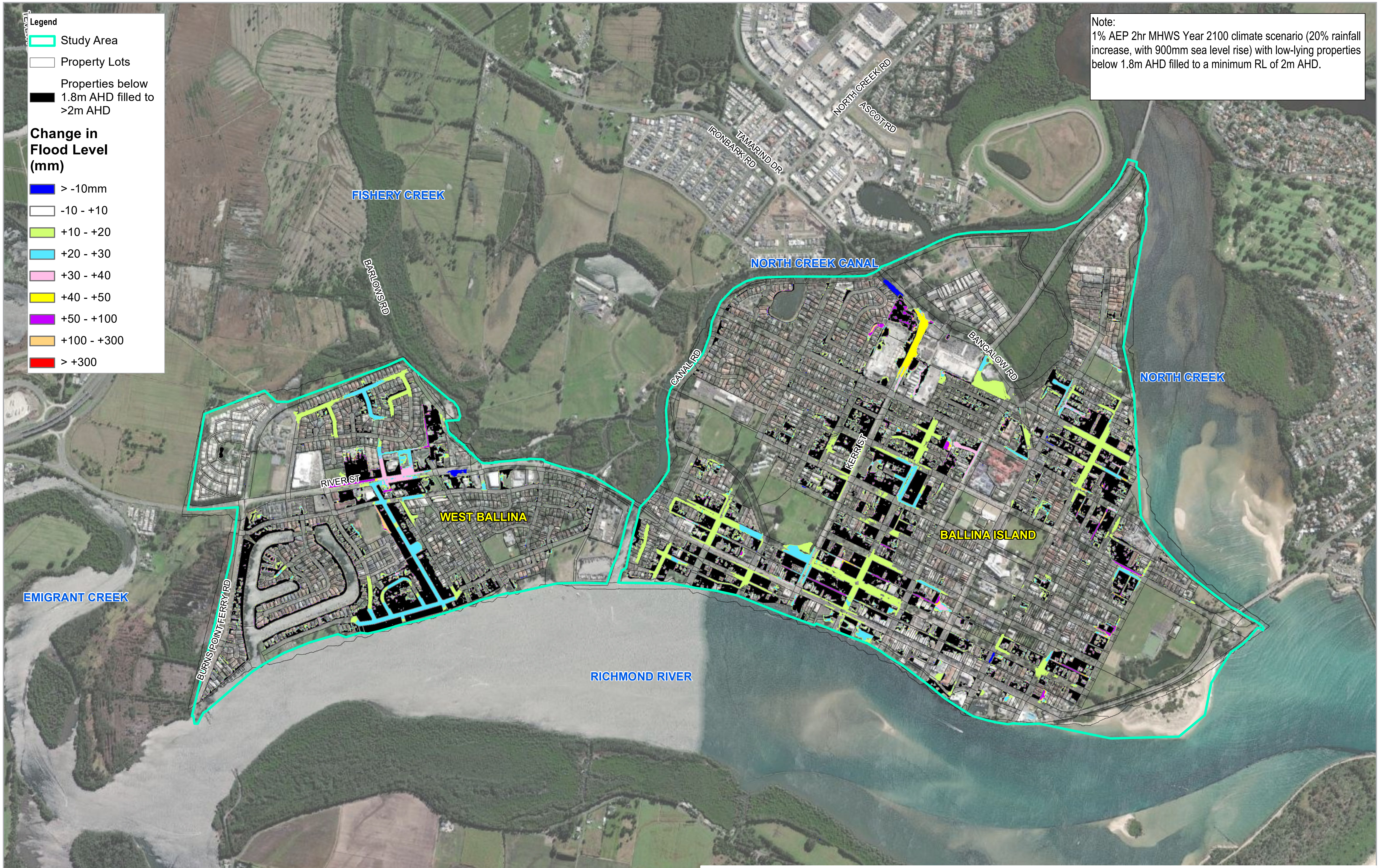
Hydraulic modelling[10] was undertaken to assess the potential cumulative impact of filling low-lying private land (with ground elevations less than 1.8m AHD) to a minimum level of 2.0m AHD on overland flooding in Ballina Island and West Ballina. The assessment was undertaken for the 1% AEP design event under Year 2100 climate conditions with MHWS tide[11]. Figure 6-11 illustrates the location of the private fill assessed and the estimated change in 1% AEP (Year 2100 climate) overland flood depths resulting from this fill scenario.

Key Conclusions

Model results indicate that overland flood level increases are expected to be predominantly less than 30mm, with maximum expected flood level increases of up to 100mm on some roads. Given the low velocity of overland flow (generally less than 0.25m/s) and the relatively minor increase in flood depths predicted to occur on roads, filling of existing low lying private properties is not expected to materially increase the degree of existing flood hazard on roads.

[10] Hydraulic modelling was undertaken using the Overland Flood Model of Ballina Island and West Ballina (GHD, 2020).

[11] The Year 2100 climate scenario includes a 20% increase in rainfall intensity and 900mm of sea level rise.



Impact of Private Property Fill on Overland Flooding (1% AEP Year 2100 Climate)

Figure 6-11

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Print date: 01 Oct 2021 - 14:47 (SMA record: 21)

Note:
1% AEP 2hr MHWS Year 2100 climate scenario (20% rainfall increase, with 900mm SLR =1.51 m AHD) – with fill to 1.81 m AHD on residential properties

6.5 Land Use Planning Recommendations

The preliminary assessment of floodplain management options identified land use planning and development controls as the most effective method of managing future flood risk. This is consistent with the outcomes of the *Ballina Floodplain Risk Management Study (BMTWBM, 2012)* which also highlighted that land use planning and development controls provide a flexible and adaptive mechanism for managing increased flood risk due to climate change.

A review of BSC's existing Local Environmental Plan (LEP), Development Control Plan (2012), flood related guidelines and studies, finds the following eighteen recommendations for BSC consideration to facilitate enhanced management of flood risk in Ballina Island and West Ballina:

R1: Update BSC Local Environmental Plan (LEP) 2012 to reflect relevant the Department of Planning, Industry and Environment (DPIE) Floodprone Land Package 2021 requirements including:

- New Clause 5.21 identified as part of *DPIE's Floodprone Land Package* has now been gazetted in LEP instruments across NSW, including *Ballina Local Environmental Plan 2012*.
- Council to consider the inclusion of new Clause 5.22 relating to special flood considerations (SFC) for sensitive developments depending on outcomes of R4 and R5 below. If Council chooses to adopt the optional SFC clause in their LEP, it is suggested that Council includes the relevant SFCs in its *Ballina Shire Development Control Plan 2012 Chapter 2b Floodplain Management DCP* (refer R2 below).

R2: Simplify the readability of the Ballina Shire Development Control Plan 2012 Chapter 2b Floodplain Management. Revise and update the document, including:

- Maintain a minimum fill height policy with a level to be determined based on updated modelling and mapping (also refer to R3, R4, R5). It is noted that maintenance of existing minimum fill levels is likely to require acceptance of tidal inundation of low-lying areas and infrastructure (e.g. roads) from King Tide levels under future climate scenarios, and an acceptance of residual flood risk to flood affected areas in major riverine, creek or ocean driven events.
- Develop separate flood policy with prescriptive guidelines for developing flood studies and models in 'higher risk' flood risk precincts that require detailed flood studies. It is noted that these may be located outside of Ballina Island and West Ballina.
- Encourage alternate building typologies other than slab on ground solutions which rely on extensive filling to achieve compliance. For example, the elevated Timber Floor – Hardwood construction type presents a viable option for an adaptive response as an alternative to filling to achieve slab on ground construction. This could include referencing the following guidelines:
    - *Edge Environment (2015), Report for Ballina Shire Council – Housing Resilience Investigation and Options Report*
    - *Queensland Reconstruction Authority (2019), Flood Resilient Building Design for Queensland Homes, Brisbane.*
    - *Hawkesbury-Nepean Floodplain Management Steering Committee (2006) Reducing Vulnerability of Buildings to Flood Damage, Guidance On Building Design in Flood Prone Areas, Parramatta.*

- Improved articulation of suitable flood compatible materials and construction considerations to assist development industry. This could include reference to the building guidelines noted above.
- Consider including an improved flowchart to assist the community/ development industry in better understanding the process to follow when developing flood prone land.
- Review and update Schedule D Prescriptive Measures matrix and land uses within each category (in line with R8 outcome).
- Review and update Schedule A Dictionary to more clearly articulate flood hazard and risk terminology to the community (e.g. H1 to H6 flood hazard categories).
- Update mapping to identify low lying private lots (e.g. less than 1.8mAHD) or areas of overland flooding (refer Item R14).
- The *Ballina Shire Council Development Control Plan 2012 Chapter 2b Floodplain Management* has a number of sections that relate to overland flow or drainage that could benefit through cross reference to Section 2 of the Development Control Plan and to the *Stormwater Management Standards for Development as referenced in Chapter 2, Section 3.9 of the Ballina Shire Council Development Control Plan 2012, 1st February 2016 Amendment.*

R3: BSC to consider adoption of Year 2100 planning horizon in Ballina Island and West Ballina. This may require an increase to existing Flood Planning Levels and minimum fill levels based on outcomes of R4 and R5.

R4: Update Richmond River and Creek Flood Study and review existing FPL's accordingly.

The Flood Planning Levels (FPL's) in the *Ballina Shire Development Control Plan 2012 Chapter 2b Floodplain Management* have been established by BSC using hydrologic and hydraulic model results from the *Ballina Flood Study Update (BMT, 2010)* and *Ballina Floodplain Risk Management Study (BMTWBM, 2012).* The adopted FPL's have been determined through consideration of the envelope of maxima of design event riverine, creek and storm surge flood inundation levels for current climate, Year 2050 climate conditions and Year 2100 climate conditions. It is recommended that consideration be given to reviewing and updating the existing hydrologic and hydraulic models that underpin the existing FPL's through completion of a revised flood study, including:

a. Consideration of Australian Rainfall and Runoff (2019) guidelines, including but not limited to application of ARR2019 datahub design event rainfall intensities and temporal patterns and interaction of coastal and catchment flooding guidelines.
b. Development of a hydrologic model of the Richmond River catchment and ARR2019 design event hydrographs to inform the hydraulic model. This should include comparison of derived design event peak flow rates to the existing design event flow rates and flood levels adopted at the upstream boundary of the Richmond River in the existing flood model.
c. Where required, develop updated hydrologic models of creek catchments and ARR(2019) design event hydrographs to inform updated hydraulic modelling.
d. Review Scenario A, B and C approach including consideration of:
    i. *OEH (2015) Floodplain Risk Management Guide: Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways, NSW Office of Environment and Heritage, 2015.*
    ii. *ARR(2019) guidelines (Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2019, Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia).*
e. Consideration of the outcomes of the Richmond River Floodplain Prioritisation Study (UNSW, Manly Hydraulic Laboratory &Fisheries NSW, work in progress).

f. Review of Year 2050 and 2100 design event rainfall intensities consistent with ARR2019 and other relevant guidelines. It is noted that for the Year 2050, and 2100 FPL's in the 2012 DCP, a 10% increase in rainfall intensity has been previously assumed for both the Year 2050 and Year 2100 future climate design flood events. Typically, Year 2100 rainfall intensities are greater than Year 2050 intensities. An upward revision of Year 2100 rainfall intensities is likely to result in higher Year 2100 design event riverine and creek flood levels relative to Year 2050 design event flood levels.
g. Review of Year 2050 and Year 2100 sea level rise predictions with consideration given to the latest Intergovernmental Panel on Climate Change (IPCC) sea level predictions, NSW DPIE guidance and DPIE/Manly Hydraulics Laboratory (MHL) Tidal planes and MHL tide modelling of Ballina area.
h. Ensuring the hydrologic and hydraulic models accurately represent existing floodplain fill conditions, including recent and soon to be completed developments.
i. Simulation of an ultimate catchment land use/floodplain scenario representing catchment land use and likely cumulative fill.
j. Prepare updated flood hazard maps using H1 to H6 categories in accordance with *Australian Disaster Resilience Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia (AIDR 2017)*.
k. Review of existing BSC building floor level database. Where required, commission survey to update the building floor level database.
l. Review and update flood damage estimates for the full range of AEP design events for existing and future (e.g. Year 2050 and Year 2100) climate scenarios, and re-estimate average annual flood damage for existing and future climate scenarios.

Once the updated flood study has been completed, it is recommended that a review of the flood risk precincts currently defined in Figure 1 of the *Ballina Shire Development Control Plan 2012 Chapter 2b Floodplain Management* (refer R8) and the existing adopted Flood Planning Levels (FPL's) be undertaken with consideration given to the updated model results including those for future climate scenarios.

R5*: Review Minimum Fill Levels in consideration of updated flood study results*

The minimum fill levels adopted in the *Ballina Shire Development Control Plan 2012 Chapter 2b Floodplain Management*, are understood to be based on a Year 2100 King Tide scenario of 1.8m AHD.

It is recommended that following completion of the updated flood study (refer to R1), the minimum fill levels (currently adopted in Maps 1a and 1b of the 2012 DCP) be reviewed together with the other recommendations (R6, R7, R8) contained herein relating to Council's existing fill policy.

R6: Establish maximum allowable fill level to limit height of fill and encourage alternatives to slab on ground type construction (refer R2).

The maximum allowable fill level could be limited to the minimum fill level or where this does not provide adequate gravity drainage of runoff to street, it could be limited to the maximum adjacent street elevation plus a nominal freeboard of say 300mm.

R7: For each FPL, adopt a singular FPL value across Ballina Island and West Ballina.

In the *Ballina Shire Development Control Plan 2012 Chapter 2b Floodplain Management*, FPL's are currently determined from the maps contained in Schedule F of the DCP. These maps illustrate a variable flood profile surface (based on envelope of maxima from Scenario A, B and C flood model results). Given the relatively small variation in flood levels across Ballina Island and West Ballina, consideration could be given to simplifying the determination of applicable FPL's by adopting a consistent FPL across the Ballina Island and West Ballina areas.

R8: Review of the flood risk precincts currently defined in Figure 1 of the Ballina Shire Development Control Plan 2012 Chapter 2b Floodplain Management.

The low, medium, high and extreme risk areas in Figure 1 of the *Ballina Shire Development Control Plan 2012 Chapter 2b Floodplain Management* should be revised following completion of modelling updates as per R4. The future climate horizons used to inform the designation of risk zones should also be re-considered (as per R3). Consideration could also be given to replacing the application of flood related development controls against these adopted risk categories to flood related development controls that relate to defined Flood Planning Constraint Categories (refer to Section 2.1) of *Technical flood risk management guideline: Flood information to support land-use planning (aidr.org.au)* as per *Australian Disaster Resilience Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia (AIDR 2017*). The definition of these categories should consider both flood function and flood hazard based on the H1 to H6 flood hazard vulnerability zones (Refer Figure 1 and Table 1) as defined in the *Australian Disaster Resilience Handbook Collection, Guideline 7-3 Flood Hazard*. It is noted that Handbook 7 and its associated guidelines are considered to be best practice in terms of flood risk management.

R9: When required, ensure adequate provision of design flood information to building designers/engineers to support flood resilient building design.

The *Australian Building Codes Board Standard: Construction of buildings in flood hazard areas 2012.3 (Feb, 2019)* requires buildings constructed in flood hazard areas to be designed/built in a manner that appropriately considers the hydrodynamic forces and flood conditions imposed by the defined flood event. Given that new buildings will have a life span of approximately 60 years (until 2081), new buildings will need to consider the hydrodynamic forces and flood conditions associated with Year 2050 to Year 2100 flood events. It is recommended that velocities, levels and depths from the updated flood model (refer R4), be made available by Council to building designers and engineers etc to ensure flood resilient design. This information could be provided via a web based geospatial platform.

R10: Consider incentives for consolidating and amalgamating lots to facilitate higher density development where more holistic solutions to flooding/ stormwater can be achieved.

An alternative to the promotion of the typical single detached dwellings within the study area might involve encouraging higher density living using podium style typology with smaller footprints on larger allotments. Council may consider offering incentives through savings on developer contributions where more holistic solutions can be achieved regarding flooding. Consideration would still need to be given to maintaining a minimum fill height policy, drainage capacity and access to emergency egress routes.

R11: Updating Planning Certificates to reflect relevant DPIE Floodprone Land Package 2021 requirements.

This will ensure the community are informed about the impacts of flooding and the controls to be considered if purchasing land within a flood prone area. The production of flood planning certificates could be automated through the application of software such as waterRIDE.

R12: Updated flood planning levels based on the envelope of maxima of riverine, creek and storm tide design events are likely to provide sufficient freeboard to overland flow path flooding.

The minimum fill levels and Flood Planning Levels (FPL's) required by the *Ballina Shire Development Control Plan 2012 Chapter 2b Floodplain Management* are considered to provide a sufficient level of protection to above floor flooding from overland flow path flooding. As such, separate FPL's for overland flooding are not considered to be necessary for the Ballina Island and West Ballina study area.

R13: Consider development of an overland flood hazard overlay map or map showing low lying land vulnerable to overland flow/ponding/local drainage issues.

Council to consider the development of an overland flood hazard overlay or map showing low lying land vulnerable to overland flow/ponding/ local drainage issues. This could be useful to prospective purchasers of house/land and the general community to better understand the existing risk and need for redevelopment considerations. Given that the overland flow path model results indicate that there are very few well defined overland flow paths (in areas other than roads), and flood hazards are predominantly in the H1 to H2 flood hazard category (as per as per *Australian Disaster Resilience Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia (AIDR 2017)),* consideration will need to be given to the definition of what constitutes an 'overland flow path' and whether there is actually any merit in mapping these areas. Note: Figure 6-12 and Figure 6-13 have been included to illustrate flood hazard (H1 to H6) for the 1% AEP overland flood design event for existing and Year 2100 climate conditions.

R14: Develop policy position to address loss of overland flood storage (due to minimum fill requirement) associated with infill development on single dwelling residential lots.

It is noted that *Section 3.12ii Third Party Impacts of Development on Flood Liable Land of Ballina Shire Development Control Plan 2012 Chapter 2b Floodplain Management* states:

"Filling of land in Low and Medium Flood Risk Precincts in areas already mapped by Council has been examined generally. Applicants for development within these Precincts may not be required to assess flood impact on third parties"

It is acknowledged that the above statement was likely to have been developed in consideration of riverine, creek and ocean driven flood inundation (and not overland flooding). For infill development on residential sites located in Ballina Island and West Ballina, filling of low-lying lots to achieve minimum fill policy or to provide site to street gravity drainage may result in a loss of overland flow flood storage that could potentially result in an adverse impact to an adjacent low-lying property and/or increased discharge volume to street. Whilst cut-off drains (or the fill) may prevent sheet flow from adjacent properties from entering the developed land, the developed (filled) lot may still impart an adverse impact on the adjacent low-lying (unfilled) neighbouring property due to loss of overland flood storage on the developed site.

It is recommended that Council clarify the requirements (or allowable exceptions) in situations regarding the loss of overland flood storage associated with filling of single residential sites located in Ballina Island and West Ballina to minimum required fill level, considering both the *Ballina Shire Development Control Plan 2012 Chapter 2b Floodplain Management*, and the *Ballina Shire Council Stormwater Management Standards for Development (2016).*

In this regard, it is noted that Section 2.3.1 of the *Ballina Shire Council Stormwater Management Standards for Development (2016)* states the following principles which may not necessarily be fully met through application of the minimum fill policy to infill development on residential sites subject to overland flow runoff/ponding:

> *2.3.1 Principles*
>
> *1. Changes to the natural or pre-development runoff volume, peak discharge rate, frequency, duration and velocity of stormwater by development and associated stormwater systems shall be managed to ensure no significant adverse flooding or ecological impacts on downstream land, landuse and receiving systems.*
>
> *2. Stormwater runoff shall not be concentrated or diverted in a manner that causes any significant adverse flooding impacts, damages or nuisance to any downstream persons, public property or private property.*

R15: Update BSC Stormwater Management Standards for Development (2016) to reference Australian Rainfall and Runoff (2019) and the Queensland Urban Drainage Manual (2018).

Update the Stormwater Management Standards for Development as referenced *in Chapter 2, Section 3.9 of the Ballina Shire Council Development Control Plan 2012, 1st February 2016 Amendment* which currently reference *Australian Rainfall and Runoff Volume 2 (1987)* and the *Queensland Urban Drainage Manual (QUDM), Third edition 2013-provisional*. Consideration could be given to updating the guidelines and methods to reference ARR2019, and the current version of QUDM (2018).

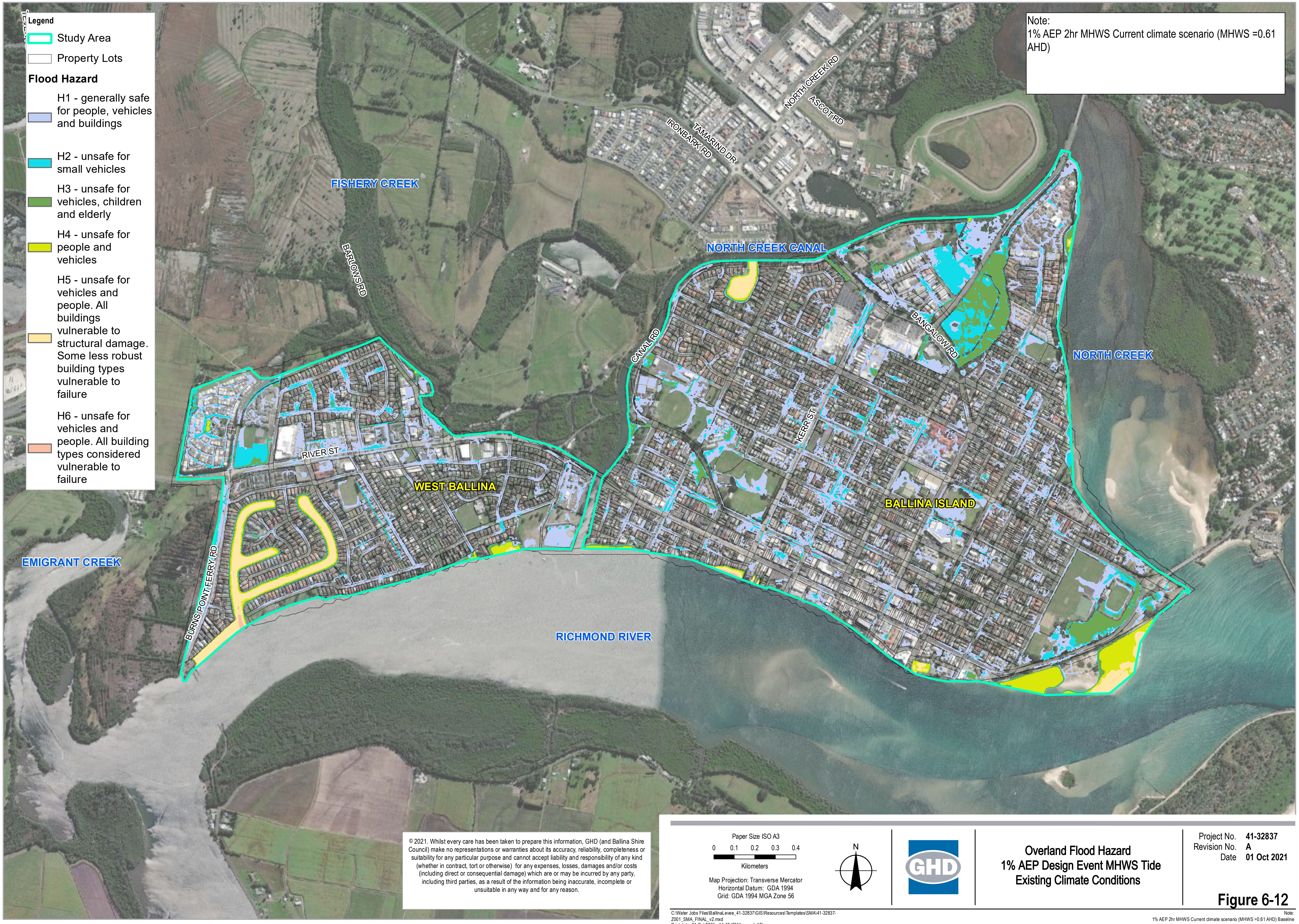
R16: Update BSC Stormwater Management Standards for Development (2016) to include consideration of future climate rainfall intensities and sea level conditions.

The Stormwater Management Standards for Development as referenced in *Chapter 2, Section 3.9 of the Ballina Shire Council Development Control Plan 2012, 1st February 2016 Amendment* could be updated to specify whether stormwater assessments require consideration of future climate rainfall intensities and sea level conditions (e.g. Year 2050, 2100 future climate).

R17: Undertake overland flood studies, prepare overland flood hazard maps and develop an Overland Flood Policy in areas located outside of Ballina Island and West Ballina.

It is recommended that Council give consideration to undertaking overland flood studies in key areas outside of Ballina Island and West Ballina, development of overland flood risk mapping and development of an Overland Flood Policy that is applicable to those areas where overland flood hazard and risk may be higher than that for Ballina Island and West Ballina.

R18: Consider amendment to Ballina LEP to restrict the siting of more flood sensitive land uses (such as nursing homes, retirement villages and residential aged care facilities) to identified evacuation routes subject to the updated flood modelling identified in R4.



Overland Flood Hazard
1% AEP Design Event MHWS Tide
Existing Climate Conditions

Project No. 41-32837
Revision No. A
Date 01 Oct 2021

Figure 6-12

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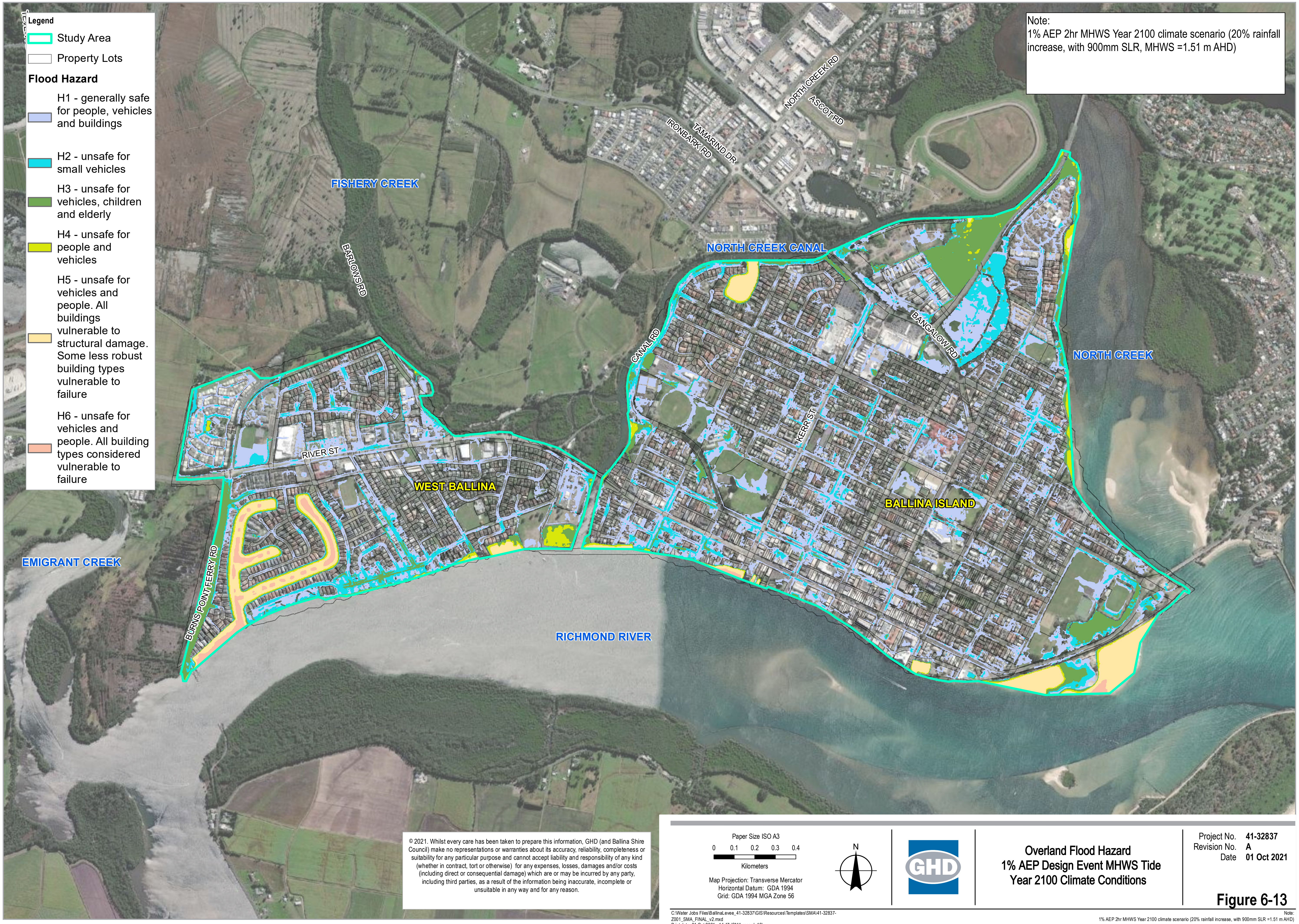
Print date: 01 Oct 2021 - 14:47 (SMA record: 18)

Note:
1% AEP 2hr MHWS Current climate scenario (MHWS =0.61 AHD) Baseline



GHD

Overland Flood Hazard
1% AEP Design Event MHWS Tide
Year 2100 Climate Conditions

Project No. **41-32837**
Revision No. **A**
Date **01 Oct 2021**

Figure 6-13

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Print date: 01 Oct 2021 - 14:47 (SMA record: 19)

Note:
1% AEP 2hr MHWS Year 2100 climate scenario (20% rainfall increase, with 900mm SLR =1.51 m AHD)

7. Strategic Plan

A strategic plan for improved flood protection of Ballina Island and West Ballina has been developed in consultation with Ballina Shire Council. The plan is based on the outcomes of the following project stages:

- Stage 1: Data collection including survey of the existing stormwater network of Ballina Island and West Ballina.
- Stage 2: Ballina Island and West Ballina Overland Flood Study.
- Stage 3a: Identification and Preliminary Assessment of Floodplain Management Options.
- Stage 3b: Detailed Assessment of Shortlisted Floodplain Management Options.

The strategic plan is summarised in Table 7-1 and includes proposed timeframes for key actions to be initiated.

Table 7-1 Strategic Plan

<table>
<tr><th>Strategy Item No.</th><th>Required Actions</th><th>Timeframe</th></tr>
<tr><td>1</td><td>Update existing riverine and creek flood studies:

Update Richmond River and creek flood studies in accordance with latest industry guidelines including but not limited to:

• Australian Rainfall and Runoff 2019.
• Australian Disaster Resilience Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia (AIDR 2017).
• Floodplain Risk Management Guide: Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways, NSW Office of Environment and Heritage, 2015.</td><td>Within 2 years</td></tr>
<tr><td>2</td><td>Review and update existing land using planning and development controls:

Implement the land use planning and development control recommendations detailed in Section 6.5 of this report, including:

• Update BSC Local Environmental Plan (LEP) 2012 to reflect relevant the Department of Planning, Industry and Environment (DPIE) Floodprone Land Package 2021 requirements.
• Simplify the readability of the Ballina Shire Development Control Plan 2012 Chapter 2b Floodplain Management.
• Maintain a minimum fill height policy with a level to be determined based on updated riverine and creek studies (refer Strategy Item 1). It is noted that maintenance of existing minimum fill levels is likely to require acceptance of tidal inundation of low-lying areas and infrastructure (e.g. roads) from King Tide levels under future climate scenarios, and an acceptance of residual flood risk to flood affected areas in major riverine, creek or ocean driven events.</td><td>Within 2 years</td></tr>
</table>

- Develop separate flood policy with prescriptive guidelines for developing flood studies and models in ‘higher risk’ flood risk precincts that require detailed flood studies. It is noted that these may be located outside of Ballina Island and West Ballina.
- Encourage alternate building typologies other than slab on ground solutions which rely on extensive filling to achieve compliance.
- Improved articulation of suitable flood compatible materials and construction considerations to assist development industry. This could include reference to the building guidelines noted above.
- Consider including an improved flowchart in the DCP to assist the community / development industry to better understand the process to follow when developing flood prone land.
- Update mapping to identify low lying private lots (e.g. less than 1.8mAHD) or areas of overland flooding.
- The *Ballina Shire Council Development Control Plan 2012 Chapter 2b Floodplain Management* has a number of sections that relate to overland flow or drainage that could benefit through cross reference to Section 2 of the Development Control Plan and to the *Stormwater Management Standards for Development* as referenced in *Chapter 2, Section 3.9 of the Ballina Shire Council Development Control Plan 2012, 1st February 2016 Amendment.*
- BSC to consider adoption of Year 2100 planning horizon in Ballina Island and West Ballina.
- Review existing Flood Planning Levels and Minimum Fill Levels in accordance with the outcomes of the updated flood modelling recommended in Strategy Item No.1.
- Establish maximum allowable fill level to limit height of fill and encourage alternatives to slab on ground type construction.
- For simplicity, for each defined Flood Planning Level in the DCP, adopt a singular FPL value across Ballina Island and West Ballina (i.e. no spatial variance of FPL’s).
- Review and update the flood risk precincts currently defined in *Figure 1* of the *Ballina Shire Development Control Plan 2012 Chapter 2b Floodplain Management*, taking into account the results of the updated flood studies recommended in Strategy Item No.1
- When required, ensure adequate provision of design flood information to building designers/engineers to support flood resilient building design.

	• Consider incentives for consolidating and amalgamating lots to facilitate higher density development where more holistic solutions to flooding/ stormwater can be achieved. • Update Planning Certificates to reflect relevant DPIE Floodprone Land Package 2021 requirements. • Consider development of an overland flood hazard overlay map or map showing low lying land vulnerable to overland flow/ponding/local drainage issues. • Develop policy position to address loss of overland flood storage (due to minimum fill requirement) associated with infill development on single dwelling residential lots. • Update *BSC Stormwater Management Standards for Development (2016*) to reference *Australian Rainfall and Runoff (2019)* and the *Queensland Urban Drainage Manual (2018).* • Update *BSC Stormwater Management Standards for Development (2016)* to include consideration of future climate rainfall intensities and sea level conditions. • Consider amendment to *BSC Local Environmental Plan* to restrict the siting of more flood sensitive land uses (such as nursing homes, retirement villages and residential aged care facilities) to identified evacuation routes subject to the updated flood modelling recommended in Strategy Item No.1. • Undertake overland flood studies, prepare overland flood hazard maps and develop an Overland Flood Policy in areas located outside of Ballina Island and West Ballina.	
3	**Develop a voluntary house raising scheme:** It is recommended that the potential for a subsidised voluntary house raising scheme for existing at risk dwellings in Ballina Island and West Ballina be investigated following completion of updated riverine and creek flood studies (refer Strategy Item No.1).	Within 5 years
4	**Develop voluntary purchase scheme for high hazard properties** It is recommended that a voluntary purchase scheme be developed to facilitate purchase of high hazard properties on a case by case basis where other measures are impractical or uneconomic. It is recommended that this be undertaken following completion of updated riverine and creek flood studies (refer Strategy Item No.1).	Within 5 years

5	**Improve flood warning system and evacuation management** In light of the existing and future flood risk in Ballina Island and West Ballina, it is recommended that Council review the status of Items R1 to R8 of the Ballina Floodplain Risk Management Plan (WBMBMT, 2015) and the recommendations of the Richmond River Flood Warning and Evacuation Management Review (WBMBMT,2016), and determine if any outstanding items can be actioned.	Within 2 years
6	**Raising of existing evacuation road routes** It is recommended that consideration be given to raising low-lying sections of existing evacuation routes in Ballina Island and West Ballina to a minimum level of 1.8m AHD. It is recommended that this option be considered further following future updates of the Richmond River and local creek flood studies (refer Strategy Item 1) and as part of the next update of the Ballina Floodplain Risk Management Study.	Within 10 years
7	**Commission a Local Stormwater Drainage Management Study and Plan** It is recommended that BSC commission a 'Local Stormwater Drainage Management Study and Plan' to assess the existing minor stormwater network and determine if any network upgrades are required to meet minimum desired levels of service.	Within 3 years

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