Notice of Meeting

Floodplain Management Advisory Committee Meeting

A Floodplain Management Advisory Committee Meeting of Byron Shire Council will be held as follows:

Venue	**Conference Room, Station Street, Mullumbimby**
Date	**Tuesday, 14 May 2024**
Time	**11.30am**

Phil Holloway
Director Infrastructure Services

I2024/725
Distributed 09/05/24

BYRON SHIRE COUNCIL

CONFLICT OF INTERESTS

What is a "Conflict of Interests" - A conflict of interests can be of two types:

Pecuniary - an interest that a person has in a matter because of a reasonable likelihood or expectation of appreciable financial gain or loss to the person or another person with whom the person is associated.

Non-pecuniary – a private or personal interest that a Council official has that does not amount to a pecuniary interest as defined in the Code of Conduct for Councillors (eg. A friendship, membership of an association, society or trade union or involvement or interest in an activity and may include an interest of a financial nature).

Remoteness – a person does not have a pecuniary interest in a matter if the interest is so remote or insignificant that it could not reasonably be regarded as likely to influence any decision the person might make in relation to a matter or if the interest is of a kind specified in the Code of Conduct for Councillors.

Who has a Pecuniary Interest? - a person has a pecuniary interest in a matter if the pecuniary interest is the interest of the person, or another person with whom the person is associated (see below).

Relatives, Partners - a person is taken to have a pecuniary interest in a matter if:

- The person's spouse or de facto partner or a relative of the person has a pecuniary interest in the matter, or
- The person, or a nominee, partners or employer of the person, is a member of a company or other body that has a pecuniary interest in the matter.

N.B. "Relative", in relation to a person means any of the following:

(a) the parent, grandparent, brother, sister, uncle, aunt, nephew, niece, lineal descends or adopted child of the person or of the person's spouse;

(b) the spouse or de facto partners of the person or of a person referred to in paragraph (a)

No Interest in the Matter - however, a person is not taken to have a pecuniary interest in a matter:

- If the person is unaware of the relevant pecuniary interest of the spouse, de facto partner, relative or company or other body, or
- Just because the person is a member of, or is employed by, the Council.
- Just because the person is a member of, or a delegate of the Council to, a company or other body that has a pecuniary interest in the matter provided that the person has no beneficial interest in any shares of the company or body.

Disclosure and participation in meetings

- A Councillor or a member of a Council Committee who has a pecuniary interest in any matter with which the Council is concerned and who is present at a meeting of the Council or Committee at which the matter is being considered must disclose the nature of the interest to the meeting as soon as practicable.
- The Councillor or member must not be present at, or in sight of, the meeting of the Council or Committee:

  (a) at any time during which the matter is being considered or discussed by the Council or Committee, or

(b) at any time during which the Council or Committee is voting on any question in relation to the matter.

No Knowledge - a person does not breach this Clause if the person did not know and could not reasonably be expected to have known that the matter under consideration at the meeting was a matter in which he or she had a pecuniary interest.

Non-pecuniary Interests - Must be disclosed in meetings.

There are a broad range of options available for managing conflicts & the option chosen will depend on an assessment of the circumstances of the matter, the nature of the interest and the significance of the issue being dealt with. Non-pecuniary conflicts of interests must be dealt with in at least one of the following ways:

- It may be appropriate that no action be taken where the potential for conflict is minimal. However, Councillors should consider providing an explanation of why they consider a conflict does not exist.
- Limit involvement if practical (eg. Participate in discussion but not in decision making or vice-versa). Care needs to be taken when exercising this option.
- Remove the source of the conflict (eg. Relinquishing or divesting the personal interest that creates the conflict)
- Have no involvement by absenting yourself from and not taking part in any debate or voting on the issue as of the provisions in the Code of Conduct (particularly if you have a significant non-pecuniary interest)

Committee members are reminded that they should declare and manage all conflicts of interest in respect of any matter on this Agenda, in accordance with the Code of Conduct.

RECORDING OF VOTING ON PLANNING MATTERS

Clause 375A of the Local Government Act 1993 – Recording of voting on planning matters

(1) In this section, **planning decision** means a decision made in the exercise of a function of a council under the Environmental Planning and Assessment Act 1979:

   (a) including a decision relating to a development application, an environmental planning instrument, a development control plan or a development contribution plan under that Act, but
   (b) not including the making of an order under that Act.

(2) The general manager is required to keep a register containing, for each planning decision made at a meeting of the council or a council committee, the names of the councillors who supported the decision and the names of any councillors who opposed (or are taken to have opposed) the decision.

(3) For the purpose of maintaining the register, a division is required to be called whenever a motion for a planning decision is put at a meeting of the council or a council committee.

(4) Each decision recorded in the register is to be described in the register or identified in a manner that enables the description to be obtained from another publicly available document and is to include the information required by the regulations.

(5) This section extends to a meeting that is closed to the public.

OATH AND AFFIRMATION FOR COUNCILLORS

Councillors are reminded of the oath of office or affirmation of office made at or before their first meeting of the council in accordance with Clause 233A of the Local Government Act 1993. This includes undertaking the duties of the office of councillor in the best interests of the people of Byron Shire and the Byron Shire Council and faithfully and impartially carrying out the functions, powers, authorities and discretions vested under the Act or any other Act to the best of one’s ability and judgment.

BUSINESS OF MEETING

1. APOLOGIES

2. DECLARATIONS OF INTEREST – PECUNIARY AND NON-PECUNIARY

3. ADOPTION OF MINUTES FROM PREVIOUS MEETINGS

4. STAFF REPORTS

Sustainable Environment and Economy

Infrastructure Services

ADOPTION OF MINUTES FROM PREVIOUS MEETINGS

Report No. 3.1 Adoption of Minutes from Previous Meeting

Directorate: Infrastructure Services

File No: I2024/682

RECOMMENDATION:

That the minutes of the Floodplain Management Advisory Committee Meeting held on 13 February 2024 be confirmed.

<Section5>

Attachments:

1 Minutes 13/02/2024 Floodplain Management Advisory Committee, I2024/181 , page 8⇩

Report

The attachment to this report provides the minutes of the Floodplain Management Advisory Committee Meeting of 13 February 2024 .

Report to Council

The minutes were reported to Council on 18 April 2024.

Comments

In accordance with the Committee Recommendations, Council resolved the following:

24-177 Resolved that Council defers the report on the Floodplain Management Advisory Committee Meeting held on 13 February 2024.

Minutes of Meeting

Floodplain Management Advisory Committee Meeting

Venue	**Conference Room, Station Street, Mullumbimby**
Date	**Tuesday, 13 February 2024**
Time	**9.00am**

BYRON SHIRE COUNCIL

BYRON SHIRE COUNCIL

Minutes of the Floodplain Management Advisory Committee Meeting held on Tuesday, 13 February 2024

File No: I2024/181

ATTENDANCE:

Councillors:	Cr M Lyon (Mayor)	In person
	Cr D Dey	In person
	Cr Coorey	Absent
Staff:	Phil Holloway	Apology
	Samuel Frumpui (Manager Works)	In person
	James Flockton (Infrastructure Planning Coordinator)	In person
	Steve Twohill (Flood and Drainage Engineer)	In person
	Chloe Dowsett (Coast and Biodiversity Coordinator)	Apology
	Dominika Tomanek	In person
	Honey Ayres	In person
Invited members:	Scott Moffett DCCEEW	In person
	Martin Rose DCCEEW	Apology
	Peter Mair (State Emergency Service) – voting member	In person
	Jeremy Carpenter (SES)	In person
Community:	Karl Allen	In person
	Matthew Lambourne	In person
	Steven Harris	In person
	Catherine Lane	In person
	Robert Crossley	Apology

Visitors:

Cr Lyon (Chair) opened the meeting at 9:10am and acknowledged that the meeting was being held on Bundjalung Country.

BYRON SHIRE COUNCIL

FLOODPLAIN MANAGEMENT ADVISORY COMMITTEE MEETING MINUTES 13 FEBRUARY 2024

ATTENDANCE VIA AUDIO-VISUAL LINK:

APOLOGIES:

Robert Crossley

Martin Rose

Phil Holloway

Chloe Dowsett

Cr Coorey (Absent)

DECLARATIONS OF INTEREST – PECUNIARY AND NON-PECUNIARY

There were no declarations of interest.

ADOPTION OF MINUTES FROM PREVIOUS MEETINGS

Report No. 3.1 **Adoption of Minutes from Previous Meeting**
File No: I2024/145

Committee Recommendation:

That the minutes of the Floodplain Management Advisory Committee Meeting held on 8 December 2023 be confirmed. (Lyon/Lane)

The recommendation was put to the vote and declared carried.

BUSINESS ARISING FROM PREVIOUS MINUTES

The Floodplain Management Advisory Committee acknowledges that Rebecca Brewin has resigned from the Committee effective immediately.

The Committee acknowledges that Ziwar Sattouf has not attended the last three meetings, and as such recommends that he is released from the Committee.

The Committee has decided not to advertise the position.

STAFF REPORTS - INFRASTRUCTURE SERVICES

Report No. 4.1 Floodplain Management Advisory Committee Goals for 2024
File No: I2024/129

Committee Recommendation:

1. **That the Floodplain Management Advisory Committee note the report.**

2. **Council includes an assessment of an option which is the removal of Myokum Street embankment, and increase of Jubilee avenue culvert capacity, in the technical brief of the future North Byron Flood study, and associated risk management study and plan. (This is part of item 12 in the action list).**

3. **That Council notes its intention to make Flood Certificate information publicly available for all properties covered by suitable floodplain plans.** (Lyon/Lane)

The recommendation was put to the vote and declared carried.

Report No. 4.2 Community Education Strategy and Review of Flood Options - Project Update
File No: I2024/157

Committee Recommendation:

That the Floodplain Management Advisory Committee:

1. **Note the update on the 'Community Education Strategy and Review of Flood Options' project which focusses on the Northern Byron Shire communities.**

2. **Recommend that the DCCEEW be requested to commission animation graphic models of the 2022 flood event and provide to Council to assist in future community engagement.** (Lyon/Lambourne)

The recommendation was put to the vote and declared carried.

Report No. 4.3 Post 2022 Event Flood Behaviour Analysis - Brunswick River - Final Draft Report - September 2023-NSW Department of Planning & Environment
File No: I2024/178

Committee Recommendation:

1. **That the Flood Advisory Committee notes that DCCEEW has issued its "Post 2022 Event Flood Behaviour Analysis - Brunswick River - Final Report "**

2. **That Council adhere to the North coast settlement planning guidelines 2019,**

and not develop areas either where the land is flood prone at 1% AEP, or where there is no evacuation route.

3. **That Council use the higher of two sets of levels, as the basis for determining flood planning levels: 1. Levels from the three adopted FPMS&P; 2. Levels from a peak water surface established from community data throughout the floodplains (peak levels February and March 2022).** (Dey/Lyon)

The recommendation was put to the vote and declared carried.

There being no further business the meeting concluded at 11:12am.

STAFF REPORTS - SUSTAINABLE ENVIRONMENT AND ECONOMY

Report No. 4.1 Amendments to Byron Shire DCP 2014 Chapter C2: Areas Affected by Flood - Draft for Exhibition

Directorate: Sustainable Environment and Economy

Report Author: Alex Caras, Land Use Plannning Coordinator
Kristie Hughes, Natural Disaster Policy Planner

File No: I2024/661

Summary:

A report presenting draft amendments to the Byron Shire DCP 2014, Chapter ‘C2: Areas Affected by Flood’ was considered at the 18 April 2024 Council Meeting. The proposed changes to DCP 2014 Chapter ‘C2’ reflect current policies and legislation that should be considered when addressing ‘flood risk’ in planning decisions (both rezoning and development application assessment).

The report recommended that Council to place the document on public exhibition for a minimum period of 28 days, with engagement activities to include presentation of updates to the Floodplain Management Advisory Committee by the reviewing consultant, BMT.

A copy of the 18th April council report and Draft DCP chapter C2 (marked up version) are contained in Attachments 1 & 2, respectively, as supporting reference material for BMT’s presentation to the Committee.

RECOMMENDATION:

That the Floodplain Management Advisory Committee:-

1. **Note the information presented by BMT and as contained in the report attachments; and**

2. **Is invited to make a submission to the proposed amendments to Byron Shire DCP 2014, Chapter ‘C2: Areas Affected by Flood’, for Council’s consideration prior to final adoption.**

Attachments:

1 Attachment 1 - copy of 18 April Report 13.13 - PLANNING - Amendments to Byron Shire DCP 2014 Chapter C2 - Areas Affected by Flood, E2024/50245 , page 17⇩

2 Attachment 2 - Amended Draft DCP chapter C2 - marked up version showing new additions in yellow highlight, deleted items in red strikethrough_7-12-23, E2023/129624 , page 24⇩

Report

Council engaged BMT WBM to review Chapter ‘C2 Areas Affected by Flood’ in Byron Development Control Plan 2014 (DCP) in order to:

- Ensure consistency of terminology
- Place greater emphasis on the safe occupation and efficient evacuation of people in the event of a flood
- Replace outdated flood study references
- Implement relevant actions (where possible) identified in North Byron Floodplain Risk Management Study.

A report presenting draft amendments to the Byron Shire DCP 2014, Chapter ‘C2: Areas Affected by Flood’ was considered at the 18 April 2024 Council Meeting. The proposed changes to DCP 2014 Chapter ‘C2’ reflect current policies and legislation that should be considered when addressing ‘flood risk’ in planning decisions (both rezoning and development application assessment).

The report recommended that Council to place the document on public exhibition for a minimum period of 28 days, with engagement activities to include presentation of updates to the Floodplain Management Advisory Committee by the reviewing consultant, BMT.

A copy of the 18th April council report and Draft DCP chapter C2 (marked up version) are contained in Attachments 1 & 2, respectively, as supporting reference material for BMT’s presentation to the Committee.

Strategic Considerations

Community Strategic Plan and Operational Plan

CSP Objective	CSP Strategy	DP Action	Code	OP Activity
4: Ethical Growth	4.1: Manage responsible development through effective place and space planning	4.1.4: LEP & DCP - Review and update the Local Environmental Plan and Development Control Plans	4.1.4.2	Review and update Local Environmental Plan and Development Control Plans to reflect strategic land use priorities and/or legislative reforms

Recent Resolutions

21-285

24-182

Legal/Statutory/Policy Considerations

The review of the DCP planning controls will be used to inform Council's future strategic land use planning and development control framework. The proposed amendments will be exhibited as per the statutory requirements.

Financial Considerations

This is a Council initiated DCP amendment that has been funded by Natural Disaster Funding grant. All other processing costs will be borne by Council.

Consultation and Engagement

In addition to BMT's presentation to the Floodplain Management Advisory Committee, Council also resolved (Res 24-182) to arrange a community meeting with residents in the north of the shire to inform and discuss the draft DCP Chapter C2 proposal flood affected areas in the north.

BYRON SHIRE COUNCIL
STAFF REPORTS - SUSTAINABLE ENVIRONMENT AND ECONOMY 13.13

Report No. 13.13 PLANNING - Amendments to Byron Shire DCP 2014 Chapter C2: Areas Affected by Flood - Draft for Exhibition

Directorate: Sustainable Environment and Economy

Report Author: Kristie Hughes, Natural Disaster Policy Planner

File No: I2024/437

Summary:

This report presents draft updates to the Byron Shire DCP 2014, Chapter ‘C2: Areas Affected by Flood’. An updated flood planning framework benefits both the community and developers by ensuring better alignment with Council’s adopted flood risk management studies and plans, in addition to NSW government legislation and policy changes, including the Flood Prone Land Package and relevant recommendations arising from the 2022 NSW flood Inquiry. The updated DCP Chapter also addresses safe occupation and evacuation of people, a critical component of managing the economic and social impacts of flooding.

This report outlines the scope of DCP matters identified for review and highlights key changes proposed to draft DCP Chapter C2 (Attachment 1).

Staff seeks endorsement by Council to place the document on public exhibition for a minimum period of 28 days. Engagement will also include a presentation to the Floodplain Management Advisory Committee by the consultant, BMT. At the conclusion of this process, a further report will be brought back to Council detailing the feedback received and the next steps within the review.

In accordance with the provisions of S375A of the Local Government Act 1993, a Division is to be called whenever a motion for a planning decision is put to the meeting, for the purpose of recording voting on planning matters. Pursuant to clause 2(a) under the heading Matters to be Included in Minutes of Council Meetings of Council's adopted Code of Meeting Practice (as amended) a Division will be deemed to have been called by the mover and seconder of all motions relating to this report.

BYRON SHIRE COUNCIL
STAFF REPORTS - SUSTAINABLE ENVIRONMENT AND ECONOMY 13.13

RECOMMENDATION:

That Council:

1. **Proceeds to exhibit the draft DCP 2014 Chapter C2: Areas Affected by Flood, as contained in Attachment 1 (E2023/129624) for a minimum period of 28 days; and**

2. **Following exhibition, receives a further report detailing submissions made and any recommended changes.**

Attachments:

1 Amended Draft DCP chapter C2 - marked up version showing new additions in yellow highlight, deleted items in red strikethrough_7-12-23, E2023/129624
2 Form of Special Disclosure of Pecuniary Interest, E2012/2815

BYRON SHIRE COUNCIL

STAFF REPORTS - SUSTAINABLE ENVIRONMENT AND ECONOMY 13.13

Report

Background

Several policy and statutory changes have been implemented in relation to addressing flood risk and considering flood-related constraints in land use planning in recent years.

In July 2021 the Department of Planning and Environment introduced the Flood-prone land package to provide advice to councils on considering flooding in land use planning and the areas where flood-related development controls should apply. Council at its 5 August 2021 Planning Meeting considered a report on the NSW government's Flood Prone Land Package, following it's commencement on 14 July 2021.

This package included the Considering flooding in land use planning guideline which advised councils should also update their development control plans (DCPs) to indicate the relevant flood planning levels and flood planning areas that have been identified through the Flood Risk Management process and where they apply.

In early 2022 regions across NSW experienced significant flood events. This was followed by the NSW Flood Inquiry, an independent inquiry, the findings of which were published in July 2022.

As a result of the above events and following Council's adoption of the North Byron Floodplain Risk Management Study & Plan, Council engaged BMT WBM to review Chapter 'C2 Areas Affected by Flood' in Byron Development Control Plan 2014 (DCP) in order to:

- Ensure consistency of terminology
- Place greater emphasis on the safe occupation and efficient evacuation of people in the event of a flood
- Replace outdated flood study references
- Implement relevant actions (where possible) identified in North Byron Floodplain Risk Management Study.

Scope of DCP matters identified for review

The review of Chapter C2 was structured as follows:

General (whole of Chapter 'C2')

- Review how each of the adopted flood management plans define the "*flood planning area"* and ensure DCP consistency;
- Ensure terminology aligns with the new BLEP 2014 flood planning cl 5.21 and optional 'Special flood considerations' cl. 5.22 (e.g. DCP objectives, application, key terms/ definitions, LEP references, etc), as well as with current NSW flood policy and legislation; For example, the relationship between *Flood Planning Area* (new cl 5.21) and *Future Flood Planning Level* (current DCP) needs to be clarified and chapter 'C2' and Part A of DCP 2014 updated accordingly. Include definition for '*Probable Maximum Flood*' in anticipation of new optional LEP clause 5.22 Special flood considerations;

Specific sections

- Review of chapter objectives (**C2.1.2**)
- **C2.3.1** - Update adopted flood study references and Figure C2.1 flow chart (where applicable). Consider whether this section should be more general to allow for future updates to Flood Studies and Flood Risk Management Plans without the need to update the DCP;
- **C2.3.3 / Table C2.1** Flood Planning Matrix – update to:
  (i) address absence of 'future flood planning level' definition in new LEP clause 5.21;
  (ii) address control measures regarding purpose of "minimum fill level" ; and
  (iii) reflect new optional LEP clause *5.22 Special flood considerations*;
- **C2.3.5** Special Provisions – update to reflect adopted North Byron FRMP and references to other applicable floodplain management plans
- Other DCP updates to high priority actions identified in North Byron Floodplain Risk Management Study and Plan (namely *11.6.6. PM06: incorporate the recommendations detailed in the FRMS; 11.6.7 PM07: guidance on the principles of wet proofing, appropriate design and materials, with direct reference to available guidelines;* and 11.6.8 *PM08: Property Level Protection*)
- Any corresponding updates to definitions contained in DCP 2014 Part A - Preliminary.

New sections

- Include new DCP section/s to provide guidance regarding:
  - "safe occupation and efficient evacuation of people in the event of a flood";
  - "measures to manage risk to life in the event of a flood";
  - "detrimental increases in the potential flood affectation of other development or properties" (ie. need to quantify acceptable threshold)
  - 'overland flow' and 'fill exclusion' areas
  - building controls to be applied "fill exclusion zones"
- additional provisions for those parts of the LGA that don't have an adopted flood risk management study or plan

BYRON SHIRE COUNCIL
STAFF REPORTS - SUSTAINABLE ENVIRONMENT AND ECONOMY 13.13

Key changes proposed

The more notable changes to Chapter C2 (Attachment 1) include:

1. Replacement of reference to ‘future flood planning level’ with ‘*flood prone land’*, with the latter defined as “lands at or below the probable maximum flood level. Also called flood liable land”;

   This aligns with terminology in LEP 2014 clauses 5.21 & 5.22 and the former Department of Planning, Industry and Environment’s publication Considering flooding in land use planning – Guideline.

2. Introduces the following new terms:

   - Defined flood event
   - Flood function
   - Probable maximum flood (PMF)
   - Probable maximum precipitation (PMP)

   Following exhibition, these will be transferred to Part A – Preliminary, which includes definitions of DCP words and phrases.

3. Updated to reflect most current adopted ‘catchment-based’ flood studies.

4. Figure ‘C2.1 – Flow chart illustrating process for determining flood planning controls on flood prone land’

   Updated to reference:

   a) development types specifically identified in Council’s Climate Change Strategic Planning Policy, namely: New Release Areas (including rezonings for development), Critical Facilities and Special Purpose Facilities;

   b) recently introduced LEP 2014 flood clauses 5.21 & 5.22;

   c) application to include planning proposals, in addition to DA’s;

BYRON SHIRE COUNCIL

5. Flood Planning Matrix

   Expanded to enable users to identify the relevant flood management elements to guide development form. Updates include:

   a) Simplification of flood plan area constraints columns to incorporate climate change into present considerations (rather than two columns, present and future, which previously caused confusion).

   b) Expansion and further clarification of elements to be assessed when considering development, these include;

      - Minimum Fill Levels
      - Minimum Floor Level
      - Building Components
      - Structural Soundness
      - Flood Effect
      - Flood Emergency

6. Flood Proofing

   References to relevant external guidelines have been included. These may assist with recommendations for flood proofing of buildings undergoing construction or retrofit.

7. Special Provisions

   Addition of the following new sections:

   2. Cumulative Development and No-fill (or No Development) Zones

   8. Rural Crossings

8. Flood Emergency Management

   Provides current information and guidance to consider Flood Risk Management for the following;

   - Redevelopment & Infill
   - Greenfield Developments, rezoning & new communities
   - Evacuation capability assessment

   This includes flowcharts for the first two planning categories above, sourced from [Flood Risk Management Guide EM01 (DPE, 2022)](#) .

Conclusion and Recommendation

The proposed amendments to DCP 2014 Chapter 'C2' reflect current policies and legislation that should be considered when addressing 'flood risk' in planning decisions. It is recommended that Council place the draft DCP chapter on exhibition for a minimum period of 28 days and receives a submissions report following exhibition. During exhibition, the consultant undertaking the review (BMT WBM) will present the proposed DCP changes to the Floodplain Management Advisory Committee.

Strategic Considerations

Community Strategic Plan and Operational Plan

CSP Objective	CSP Strategy	DP Action	Code	OP Activity
4: Ethical Growth	4.1: Manage responsible development through effective place and space planning	4.1.4: LEP & DCP - Review and update the Local Environmental Plan and Development Control Plans	4.1.4.2	Review and update Local Environmental Plan and Development Control Plans to reflect strategic land use priorities and/or legislative reforms

Recent Resolutions

21-285

Legal/Statutory/Policy Considerations

The review of the DCP planning controls will be used to inform Council's future strategic land use planning and development control framework. The proposed amendments will be exhibited as per the statutory requirements.

Financial Considerations

This is a Council initiated DCP amendment that has been funded by Natural Disaster Funding grant. All other processing costs will be borne by Council.

Consultation and Engagement

It is recommended that the DCP be exhibited for a minimum of 28 days as per legislative requirements. Exhibition will include Consultants presenting to the Floodplain management advisory committee.

Byron Shire
Development Control Plan 2014

Chapter C2
Areas Affected by Flood

TRADITIONAL HOME OF
THE BUNDJALUNG PEOPLE

ALL COMMUNICATIONS TO BE
ADDRESSED TO THE GENERAL MANAGER
PO Box 219 Mullumbimby NSW 2482 (70 Station Street)
E: council@byron.nsw.gov.au
P: 02 6626 7000 F: 02 6684 3018
www.byron.nsw.gov.au ABN: 14 472 131 473

Draft Byron Shire Development Control Plan 2014 Chapter C2 Areas Affected by Flood

Adopted Effective

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~~Figures~~

Draft Byron Shire Development Control Plan 2014 Chapter C2 Areas Affected by Flood

Adopted Effective

Document History

Document Number	Date Amended	Details e.g.Resolution No
#E2014/20006	20 March 2014	Res 14-118 - Public exhibition version
#E2014/26916	—	Draft to 26 June 2014 Extraordinary Meeting - for adoption
#E2014/42986	26 June 2014	Adopted Version – Res 14-315
E2022/87926	October 2022	Draft - pdf attachment to Council meeting 13/10/2022 DCP 2014 Amendments 2022, amendments in red text
E2022/78436	October 2022	Res 22-554 Public Exhibition and Adopted version
E2023/129624	March 2024	Draft to 18 April Council Meeting - for public exhibition

Glossary of Key Terms

- ***annual exceedance probability*** - The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 100 m^3/s has an AEP of 1%, it means that there is a 1% chance of a peak flood discharge of 100m^3/s or larger occurring in any one year.
- ***average recurrence interval*** - The long-term average number of years between the occurrence of a flood equal to or larger in size than the selected event.
- ***Critical Facilities*** - means development where any inundation or loss of function in an PMF would represent an unacceptable level of risk. It includes emergency service facilities (e.g. SES command centres, police stations, fire stations / RFS, ambulance stations, hospitals, public halls used as flood evacuation centres), intensive aged care, nursing homes, correctional facilities, telephone exchanges, telecommunication repeaters, flood evacuation centres and flood refuges, and critical service facility components (e.g. essential components of sewage treatment plants, essential water supply reservoirs).
- ***defined flood event (NEW)*** - is the flood event selected as a general standard for the management of flooding to a development type.
- ***flood function (NEW)*** - The flood related functions of floodways, flood storage and flood fringe areas within a floodplain These functions are normally derived as part of a flood study based on a hydraulic categorisation. Floodways generally convey a significant discharge of water during floods, flood storage areas are normally outside floodways and generally provide for temporary storage of floodwater during the passage of a flood. Flood fringe areas are those remaining inundated areas not assessed as floodway or flood storage.
- ***flood hazard*** – generally defined as a combination of flood velocity and depth (i.e. velocity depth product). Higher flood hazards present a greater risk to loss of life, injury or economic loss.
- ***flood planning area*** – this is the area of land at or below the flood planning level. It is the area within which developments are subject to flood related development controls and can include future climate change parameters.
- ***flood planning level*** – is a combination of the flood level from the defined flood event and freeboard selected for flood risk management purposes.
- ***flood prone lands*** – lands at or below the probable maximum flood level. Also called flood liable land.
- ***freeboard*** – allowance applied to the defined flood event level to reach the flood planning level.
- ***probable maximum flood (PMF) (NEW)***- The largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation (PMP), and where applicable, snow melt, coupled with the worst flood-producing catchment conditions. The PMF is also referred to as an extreme event.

- ***probable maximum precipitation (PMP) (NEW)*** - The greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year.
- ***projected 2050 Flood Planning Level*** – This is the peak flood level for a 1% AEP event with 2050 climate change conditions plus 0.5m freeboard, as per s3.5 of Byron Shire Council's Climate Change Strategic Planning Policy.
- ***projected 2100 Flood Planning Level*** - This is the peak flood level for a 1% AEP event with 2100 climate change conditions plus 0.5m freeboard, as per s3.5 of Byron Shire Council's Climate Change Strategic Planning Policy.
- ***Special Purpose Facility*** *- means development where inundation or loss of function at the typically accepted flood planning level may still present an unacceptable level of risk. Development in this category includes boarding houses, caravan parks, early education and care facilities, eco-tourist facilities, educational establishments, group homes, hazardous industries, hazardous storage establishments, hostels, information and education facilities, respite day care centres, seniors housing, tourist and visitor accommodation.*

Note: items highlighted ***Yellow*** represent *new* or *revised* flood planning terms that will be included in Part A – Appendix 1 of DCP 2014

Draft Byron Shire Development Control Plan 2014 Chapter C2 Areas Affected by Flood

Adopted Effective

C2.1 Introduction

C2.1.1 Purpose of this Chapter

The purpose of this Section is to identify requirements relating to development~~ on **flood liable land** that is appropriate to the degree of flood hazard on that land.~~ primarily within **flood planning areas**, and for specific developments and development types, to lands beyond the **flood planning areas** to the extent of the **probable maximum flood** (**PMF**).

Note, lands below the level of the **PMF** may also be referred to as 'flood prone lands'.

Refer to glossary of terms for further details of specific words.

C2.1.2 Objectives of this Chapter

The Objectives of this Chapter are to:

1. Support and implement the objectives and provisions of the Byron LEP 2014 relating to development on flood prone lands.~~ development on land at or below the relevant **flood planning level**.~~
2. Provide a holistic approach to managing development on flood prone lands; ~~**flood liable lands.**~~
3. Ensure development maintains the existing flood regime and flow conveyance capacity;
4. Consider the future projected impacts of climate change on the floodplain in accordance with Council's adopted Climate Change Strategic Planning Policy;
5. Reduce the impact of flooding and flood liability on communities, ~~and~~ individual owners and occupiers of flood prone lands;
6. Reduce public and private losses resulting from floods, using ecologically positive methods wherever possible;
7. Encourage the development of and use of flood prone land in a manner compatible with ~~the flood hazard~~. its flood risk;
8. Development applications and proposals on flood prone lands to be individually considered with the objective of achieving a reasonable balance of land use and flood risk.

> **Note:** An underlying principle of this Chapter is that any new development or modifications to existing development should always, as far as practical, result in an improvement to the existing flood risk and in no circumstances should the flood risk be made worse.

C2.1.3 Application of this Chapter

The planning provisions of this Chapter apply to flood prone lands, i.e. all land below the level of the **PMF**. ~~all land at or below the **future flood planning level**.~~ The **flood planning matrix** (Table C2.1) contains more specific information about the nature and types of development controlled by this DCP Chapter.

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This DCP is primarily applicable to development applications.

Planning proposals that enable future development in flood prone areas must consider the provisions of this DCP, in addition to the Local Planning Direction requirements, particularly 4.1 - Flooding.

C2.1.4 Planning Objectives and Development Controls

The provisions of this Chapter are based on a range of control measures in relation to particular development ~~/~~ and building types. Development proposals must be consistent with ~~the~~ planning objectives ~~for the Chapter.~~. Such consistency is typically demonstrated by compliance with the identified development controls, although there may be circumstances where an alternative to the application of a development control is consistent with the planning objectives. Such alternatives will be considered with regard to risk management principles.

C2.1.5 Relationship to Byron LEP 2014

This Chapter provides more detailed development controls to enable the effective implementation of the following clauses in Byron LEP 2014:

- ~~Clause 6.3 Flood planning~~
- ~~Clause 6.4 Floodplain risk management~~
- Clause 5.21 Flood planning
- Clause 5.22 Special flood considerations

C2.1.6 Climate Change and Flood Planning

The Byron Shire Council Climate Change Strategic Planning Policy ('Policy') sets out Council's accepted climate change parameters to inform the decision making process for strategic, infrastructure and operational planning. The flood planning provisions in this Chapter have been developed having regard to the overall framework of that Policy.

C2.1.7 Relationship to other Chapters in this DCP

This Chapter needs to be read in conjunction with the following Chapters (as applicable): D1 Residential Development in Urban and Special Purpose Zones, D2 Residential Accommodation and Ancillary Development in Rural Zones, D3 Tourist Accommodation, D4 Commercial and Retail Development, D5 Industrial Development and or D6 Subdivision, for development on ~~land at or below the **future flood planning level**.~~ flood prone land.

The provisions in this Chapter prevail over the provisions of other Chapters, unless otherwise specified, where there is an inconsistency.

C2.1.8 Background Information

Council has carried out a number of Flood Studies within its local government area as described further in Section 2.3.1.

The studies for the Belongil Creek, ~~Marshalls Creek,~~ Brunswick River and Tallow Creek catchments have all ~~acknowledged~~ considered climate change as per Council's Climate Change Strategic Planning Policy. ~~but have been based on different climate change parameters.~~

~~The above studies~~ These flood studies and floodplain risk management studies/plans along with Council's Climate Change Strategic Planning Policy are the principal reference documents for implementing the provisions of this Chapter.

C2.2 General Assessment Criteria

1. Council will not consent to any development on land within ~~at or below~~ the **flood planning area** if there is sufficient suitable area on that land ~~above~~ outside the **flood planning area** on which to carry out the development. Note that **flood planning area** is the area below the **flood planning level** in a given catchment.

2. Where the development is on land ~~below the **flood planning level**~~ within the flood planning area, floor levels of any buildings must be constructed at or the above the **flood planning level**. ~~Council will not support filling beneath the building footprint of the proposed development unless it is demonstrated that it will not adversely impact on the floodplain. Filling outside the building footprint generally will not be permitted, other than for driveways and/or pedestrian pathways immediately adjoining the walls of the building.~~ Depending on the development type, different **flood planning levels** may be applicable.

3. Some areas are restricted from filling for development purposes due to risks of cumulative flood impacts – refer to section C2.3.2. Where filling will not create an adverse impact on flood behaviour, filling should be limited to the access & parking areas and/or pedestrian pathways immediately adjoining the walls of the building.

4. Where extensive additions are proposed to lightweight buildings (e.g. dwellings made primarily from timber, fibrous-cement materials, etc) the applicant should consider redesigning the whole building to comply with current flood planning controls. Alternatively, the applicant will need to demonstrate that the proposed alterations and additions satisfactorily minimises flood risk to life.

5. The adaptability of the development in the face of climate change will be considered in the development approval process. Adaptable developments have the ability to be designed to the **Projected 2050 Flood Planning Level** instead of the **Projected 2100 Flood Planning Level** in most instances.

6. Byron Shire Council has adopted a nominal 500mm (0.5m) freeboard allowance on top of the Defined Flood Event peak flood level (incorporating allowance for climate change) to produce the Flood Planning Levels.

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C2.3 Development Controls

The following steps should be taken to ascertain the flood planning controls relating to development on lands within the **flood planning area**: ~~land at or below the future flood planning level:~~

Step 1 Consider the applicable Flood Study and or Floodplain Risk Management Plan for the catchment in which the land is situated. These studies will provide information on flood planning levels and flood hazards (Section C2.3.1).

Step 2 Consider the specific ~~Flood Planning~~ provisions for the type of development and flood hazard as set out in the **flood planning matrix** (Table C2.1 below).

Step 3 Consider any special requirements or standard designs for particular localities ~~(Section C2.3.5).~~ (Section C2.3.4).

Note: If no applicable study exists (Step 1 above), applicants shall refer to the relevant flood planning requirements set out in Council's Climate Change Strategic Planning Policy and in Section C2.3.2 and Section ~~C2.3.5~~ C2.3.4 below (as applicable); then return to Step 1 upon completion of a study.

A flow chart illustrating the process for determining flood planning controls ~~on land at or below the **future flood planning level**~~ on flood prone land is included at the end of Section C2.3.1 below (Figure C2.1).

C2.3.1 Applicable Flood Study

The following catchment-based flood studies and floodplain risk management plans have been endorsed by Council:

~~2. Brunswick River Catchment~~

~~*a) Brunswick River Flood Study (1986)*~~

~~i) includes Mullumbimby and Brunswick Heads. The extent of the Brunswick River catchment is shown in Map C2.2.~~

~~Note: this document does not include a climate change assessment; refer to Council's *Climate Change Strategic Planning Policy* for **flood planning level** methodology and requirements.~~

~~*b) North Byron Coastal Creeks Flood Study (in preparation)*~~

~~i) includes Mullumbimby, Brunswick Heads, Ocean Shores, New Brighton, South Golden Beach and Billinudgel.~~

~~ii) the study area for the North Byron Coastal Creeks Flood Study combines the Brunswick River, Marshalls Creek and Simpsons Creek catchments. The extent of the North Byron Coastal Creeks catchment is shown in Map C2.3.~~

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~~c) *North Byron Coastal Creeks Floodplain Risk Management Study & Plan (planned to commence in future)*~~

~~APPLICATION:~~

~~Until such time as the *North Byron Coastal Creeks Flood Study* is adopted, the **Projected 2050 Flood Planning Level** applies as follows:~~

- ~~where the site of the development is at or below 4m AHD, an additional 0.4m shall be applied to the estimated 1 in 100 year flood level, in addition to the normal 0.5m freeboard.~~
- ~~where the site of the development is above 4m AHD, the estimated 1 in 100 year flood level shall be used, together with the normal 0.5m freeboard .~~

~~3. Marshalls Creek Catchment~~

~~a) *Marshalls Creek Floodplain Management Plan (1997)*~~

~~b) *Tweed – Byron Coastal Creeks Flood Study (2010)*~~

~~c) *Tweed – Byron Coastal Creeks Flood Study BSC Climate Change Assessment (2010)*~~

~~i) includes Ocean Shores, New Brighton, South Golden Beach and Billinudgel. The extent of the Marshalls Creek catchment is shown in Map C2.4.~~

~~d) *North Byron Coastal Creeks Flood Study (in preparation)*~~

~~i) refer to Brunswick River catchment~~

~~APPLICATION:~~

~~Until such time as the *North Byron Coastal Creeks Flood Study* is adopted, the following climate change scenarios shall apply:~~

- ~~2050 Climate Change scenario shall be used for the 2050 Climate Change planning horizon.~~
- ~~2100 Climate Change scenario shall be used for the 2100 Climate Change planning horizon.~~

North Byron

The study area for the North Byron Flood Study combines the Brunswick River, Marshalls Creek and Simpsons Creek catchments and includes the townships and localities of Mullumbimby, Brunswick Heads, Ocean Shores, New Brighton, South Golden Beach and Billinudgel. The extent of the North Byron catchment is shown in Map C2.1.

Further details can be found here.

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Belongil Creek

Includes Byron Bay township, Arts and Industry Estate, and Sunrise estate. The extent of the Belongil Creek catchment is shown in Map C2.1.

Further details can be found here.

~~1. Belongil Creek Catchment~~

~~*a) Belongil Creek Flood Study (2009)*~~

~~i) includes Byron Bay township and industrial estate, West Byron and Sunrise estate. The extent of the Belongil Creek catchment is shown in Map C2.1.~~

~~*b) Belongil Creek Floodplain Risk Management Study & Plan* (in preparation)~~

~~APPLICATION:~~

~~Until such time as the *Belongil Creek Floodplain Risk Management Study & Plan* is adopted, the following climate change scenarios in the Belongil Creek Flood Study (2009) shall apply:~~

- ~~2050 Climate Change scenario shall be used for the 2050 Climate Change planning horizon.~~
- ~~2100 Climate Change scenario shall be used for the 2100 Climate Change planning horizon.~~

Tallow Creek

Includes Suffolk Park, and the estates of Byron Hills and Baywood Chase. The extent of the Tallow Creek catchment is shown in Map C2.1

Further details can be found here.

~~1. Tallow Creek Catchment~~

~~*a) Tallow Creek Flood Study (2002)*~~

~~*b) Tallow Creek Floodplain Risk Management Study and Plan (2009)*~~

~~i) includes Suffolk Park, and the estates of Byron Hills and Baywood Chase. The extent of the Tallow Creek catchment is shown in Map C2.5.~~

~~ii) applies until superseded by a more current flood study and management plan for this catchment:~~

~~APPLICATION:~~

~~In the absence of more updated flood mapping for this catchment, the following climate change scenarios in the *Tallow Creek Floodplain Risk Management Study and Plan* shall apply:~~

- ~~2050 Climate Change scenario shall be used for the 2050 Climate Change planning horizon.~~
- ~~2100 Climate Change scenario shall be used for the 2100 Climate Change planning horizon.~~

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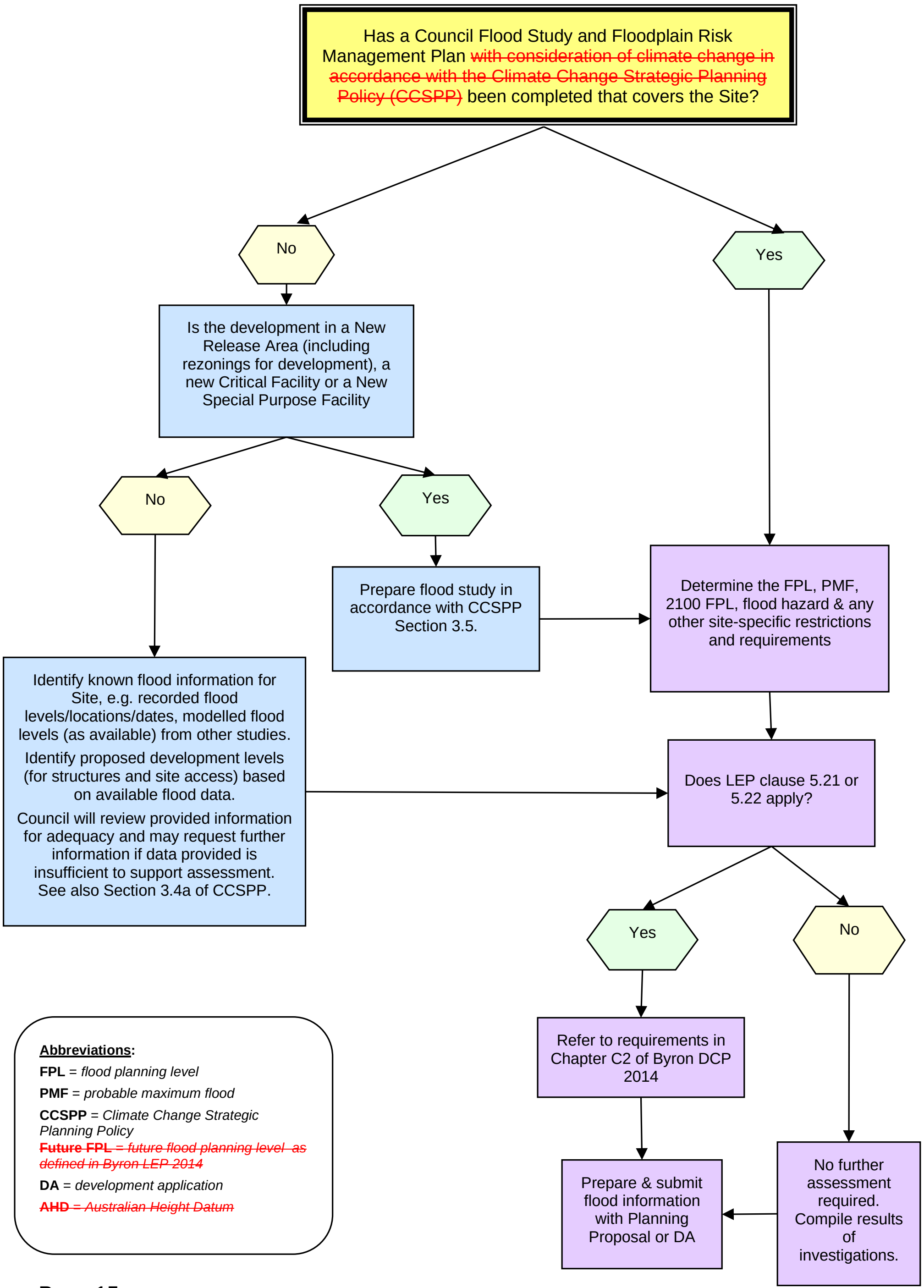
Figure C2.1 – Flow chart illustrating process for determining flood planning controls on flood prone land



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C2.3.2 Flood Planning Matrix

The **flood planning matrix** below sets out general planning considerations for development based on the following key elements:

1. Minimum Fill Levels
2. Minimum Floor Level
3. Building Components
4. Structural Soundness
5. Flood Effect
6. Flood Emergency

Elements are evaluated against differing flood hazard categories which are indicative of some aspects of flood risk.

~~The **flood planning matrix** below sets out general planning requirements for “low / intermediate” and “high” hazard flood categories. The flood affectation or hazard of a property or part of a property may change when considering climate change.~~

To satisfy the provisions of the LEP, developments must ~~not only~~ demonstrate compliance with the *Flood Planning Area* ~~*Primary*~~ *Constraints* in the **flood planning matrix.** ~~but must also demonstrate compliance with the *Additional Constraints*~~ The *Flood Planning Area Constraints* relate to land to which LEP clause 5.21 applies (i.e. land within the **flood planning area**) ~~(i.e. land at or below the **flood planning level**)~~, while additional constraints relate to land to which LEP clause 5.22 applies (i.e. all flood prone lands).

Clauses 5.21 (Flood Planning) requires Council to consider the effects of flooding on a development, and conversely the development’s effects on flooding. Council needs to be satisfied that future developments are not adversely impacted by flooding, i.e. floods pose an acceptable risk to life and property, and that future occupants of a development can be evacuated or they can safely refuge in a nominated location.

In terms of flood effect, new developments can give rise to off-site impacts that can materially worsen flooding on adjoining lands and property, as such impacts of this nature need to be within acceptable limits. In considering flood effects, Council must not only consider impacts as likely to be experienced in the current climate, but also those that may be experienced in the future with climate change, and those resulting from likely future development, which is also known as ‘cumulative’ impact.

~~The **flood planning matrix** will not prevail over any special provisions set out in Section C2.3.5.~~

The **flood planning matrix** makes provision for these aspects, however it does not prevail over any special provisions set out in Section C2.3.4.

The following provides further context around the above flood planning elements and considerations.

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Minimum Fill Levels

1. Certain types of development e.g. **critical facilities** and are not recommended for filling and may need to be located outside of flood prone land.
2. Filling may not be suitable in some locations due to its flood function and or hazard.
3. Placement of fill can generate off-site flood impacts; these impacts may require assessment as part of a Planning Proposal and or Development Application.
4. Existing overland flow paths should not be obstructed by placement of fill without provision of suitable alternative drainage solutions.
5. Filling may not be possible in some locations due to the potential cumulative impacts of development in that region, reference should be made to Council's Online Mapping Tool for details of no-fill areas and Council's adopted flood studies and management plans. However, flood impacts associated with filling can be mitigated on some sites with approaches such as cut and fill balancing.
6. If filling is permissible in a location and flood impacts are acceptable, this element provides details of the minimum fill level applicable to the development.

~~C2.3.2 Minimum Floor Levels~~

~~7. The finished floor level of **habitable rooms** must be above the relevant level defined by the **flood planning matrix**. Analysis and certification by a suitably qualified structural engineer will be required where the finished floor level of enclosed 'non-habitable' rooms is more than 1.0 metre below the 1:100 year flood level.~~

~~8. Developments in **new release areas**, certain rezoning proposals, **critical facilities** and **special purpose facilities** requiring a longer flood planning horizon are generally required to achieve the **Projected 2100 Flood Planning Level.**~~

~~9. New dwellings in existing residential areas are generally required to achieve the **Projected 2050 Flood Planning Level**. Adaptable building design is encouraged so that dwellings on piers, posts, columns or piles can be raised in future to accommodate climate change. Where concrete slab on ground is necessary the slab level shall be finished at least 300mm above the surrounding ground, as well as achieve the **Projected 2050 Flood Planning Level**.~~

~~10. Commercial and Industrial floor levels are generally required to achieve the **Projected 2050 Flood Planning Level**. Where this cannot occur, Council will consider flood proofing and emergency storage above the **Projected 2050 Flood Planning Level** to minimise damage that may occur during flooding (refer to sections C2.3.4 Flood Proofing and C2.3.5 Special Provisions).~~

Minimum Floor Levels

~~1.~~ The finished floor level of **habitable rooms** must be above the **relevant** ~~level~~ **flood planning level** defined by the **flood planning matrix**. Analysis and certification by a suitably qualified structural engineer may be required where the finished floor level of enclosed 'non-habitable' rooms is ~~more than 1.0 metre below the 1:100 year flood level.~~ below the flood planning level. This will need to be consistent with the National Construction Code requirements for buildings in flood hazard areas.

2. Developments in **new release areas**, certain rezoning proposals, **critical facilities** and **special purpose facilities** requiring a longer flood planning horizon are generally required to achieve the **Projected 2100 Flood Planning Level.**

3. New dwellings in existing residential areas are generally required to achieve the **Projected 2050 Flood Planning Level**. Adaptable building design is encouraged so that dwellings on piers, posts, columns or piles can be raised in future to accommodate climate change. Where concrete slab on ground is necessary the slab level shall be finished at least 300mm above the surrounding ground, as well as achieve the **Projected 2050 Flood Planning Level**.

4. Commercial and Industrial floor levels are generally required to achieve the **Projected 2050 Flood Planning Level**. Where this cannot occur, Council will consider flood proofing and emergency storage above the **Projected 2050 Flood Planning Level** to minimise damage that may occur during flooding (refer to sections C2.3.3 ~~C2.3.4~~Flood Proofing and C2.3.4 ~~C2.3.5~~ Special Provisions).

5. Some **Critical Facilities** and **Special Purpose Facilities** will require minimum floor levels above the **Projected 2100 Flood Planning Level** to meet the requirements of LEP clause 5.22 Special Flood Considerations, which considers specific sensitive and hazardous development types.

Building Components and Structural Soundness

1. Relates to the design and material requirements for differing types of structures located in different flood hazard categories. Noting that requirements increase for buildings subject to increased depths and velocities of inundation.

Flood Effect

1. Development in flood prone areas has the potential to impact on flood behaviour in locations external to the development itself.

2. The degree of impact varies based on a number of factors including the scale of the development, its location in a catchment and the magnitude of the flood event.

3. In instances a Flood Impact Assessment study may be required to define the location and degree of impact expected as a result of the development.

Flood Emergency Management

1. Flood emergency considerations are important in determining land use suitability. There is a requirement to ensure that the intended land uses and associated infrastructure, such as access and egress routes, can ensure the safe occupation and efficient evacuation of persons in the event of a flood.

2. Flood emergencies must be considered for all new developments on flood prone lands.

3. Applicants may be required to provide information to support their development.

4. Information requirements may increase for larger developments, particularly those catering to vulnerable community and development located in locations likely to be inundated or isolated for extended periods during flood.

5. Elements of flood emergency information may be available in the Local Flood Plan for existing urban areas, other data will be available in flood studies and flood plain risk management studies.

6. Council will be responsible for assessing many types of development, however, some developments may be referred to State government agencies (including the SES) which may have alternative or additional flood emergency planning requirements.

EXPLANATORY NOTE – Using Table C2.1 Flood Planning Matrix

The aim of the flood planning matrix is to enable users to identify the relevant flood management elements to guide development form. The matrix will provide a unique set of guidance for individual and diverse developments.

Use the matrix to identify the relevant requirements for each element type. Requirements identified for each element add context to the degree of flood management effort that will be required to support different types of development in differing locations through the Shire.

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Table C2.1 – Flood Planning Matrix

(continued overleaf)

ELEMENTS	DEVELOPMENT / BUILDING TYPE	Flood Planning Area Constraints[1] Existing Climate Flood Hazard Categories		
		No Hazard	Low/Intermediate Hazard	High Hazard
~~Land Use~~	~~Development in New Release Areas, unless separately defined below~~	~~N/A~~	~~SF2~~	
	Development in New Release Areas, unless separately defined below	N/A	SF2	
~~Suitability &~~ Minimum Fill Level	Development in all other areas unless separately defined below	N/A	SF1	
	Non-habitable building or room (e.g. shed, carport, garage, toilet, laundry, shelter, etc)	N/A	SF1	SF1
	~~Emergency Services~~ New Critical Facilities Site ~~(Hospitals, etc)~~ → see glossary for definition	N/A	SF3a	
	New Special Purpose Facilities → see glossary for definition	N/A	SF3b	
Minimum Floor Level	Development in New Release Areas unless separately defined below	FL3	FL3	
	Development in all other areas unless separately defined below	FL2	FL2	
	Dwelling additions, except in New Release Areas	N/A	FL4	
	Non-habitable building or rom (e.g. shed, carport, garage, toilet, laundry, shelter, etc)	N/A	FL1	
	New Critical Facilities ~~(Hospitals, etc.) or Special Purpose Facilities (School, etc.)~~	FL3a	FL3a	
	New Special Purpose Facilities	FL3	FL3	

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ELEMENTS	DEVELOPMENT / BUILDING TYPE	Flood Planning Area Constraints[1] Existing Climate Flood Hazard Categories		
		No Hazard	**Low/Intermediate Hazard**	**High Hazard**
Building Components	All	N/A	BC1	
Structural Soundness	Ancillary Building (e.g. shed, carport)	N/A	SS1	SS1
	Other Building	N/A	SS1	SS2
Flood Effect	Development in **New Release Areas**, unless separately defined	N/A	FE2	
	Development in all other areas unless separately defined below	N/A	FE2	
	Alterations and additions, non-habitable building or room (e.g. shed, carport, garage, toilet, laundry, shelter, etc)	N/A	FE1	
	Other developments (road raising, etc)	N/A	FE3	FE3
Flood Emergency Management ~~**Evacuation & Access**~~	Development in all other areas unless separately defined below	N/A	EA1	
	Development in **New Release Areas**, unless separately defined	N/A	EA2	
	Critical Facilities	N/A	EA3a	
	Other **Special Purpose Facilities**	N/A	EA3b	

Legend to above table:

1. Refer to relevant flood study for definition of hazard categories. Generally flood studies reference a low, intermediate and high hazard category definition. The North Byron Floodplain Risk Management Study references a six-band (H1-H6) hazard categorisation as per the *Australian Disaster Resilience Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia AIDR 2017*. Council generally regards Low Hazard as H1 and H2, Intermediate as H3 and High Hazard as H4 to H6, although this is an approximation only.

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ELEMENTS	DEVELOPMENT / BUILDING TYPE	Flood Planning Area Constraints[1] Existing Climate Flood Hazard Categories		
		No Hazard	**Low/Intermediate Hazard**	**High Hazard**

N/A = Element Not Applicable

= Unsuitable Land Use - Not considered suitable for development

Table C2.1 – Flood Planning Matrix (continued from previous page)

CONTROL MEASURES	
	MINIMUM FILL LEVEL
SF1	~~Consider for development subject to the controls below.~~ No minimum fill level required.
SF2	~~Consider for development subject to the controls below.~~ For new residential, commercial and industrial release areas, the minimum fill level to be greater than or equal to the 1 in 100 ARI (average recurrent interval) flood event plus projected climate changes allowances for the year 2100.
SF3a	~~Consider for development subject to the controls below. Where possible Emergency Services should be located on land currently flood free during the **PMF** event.~~ Minimum fill level should be greater than or equal to the existing climate **PMF** flood level.
	~~Where practical the minimum fill level should be greater than or equal to the existing climate **PMF** flood level.~~
SF3b	~~Consider for development subject to the controls below. Council to give consideration on the benefits of using the development during and after a flood emergency~~ Minimum fill level to be greater than or equal to the 1 in 100 ARI flood event plus projected climate changes allowances for the year 2100. Higher fill levels may be required to further reduce risk depending on site use and specifics.
	~~existing climate **PMF** flood level.~~

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FL1	**MINIMUM FLOOR LEVEL** All floor levels to be greater than or equal to the ~~5% AEP flood level.~~ 20 year **ARI** flood level plus 0.3m.
FL2	All floor levels to be greater than or equal to the ***Projected 2050 Flood Planning Level***. ~~(FPL2).~~
FL3	All floor levels to be greater than or equal to the ***Projected 2100 Flood Planning Level***. ~~(FPL3).~~
FL3a	~~If practical, all floor levels to be greater than or equal to the **Projected 2100 Flood Planning Level** (FPL3), so that these buildings will be available for accommodation / storage during and after a flood emergency.~~ If practical, all floor levels to be greater than or equal to the existing climate **PMF** flood level.
FL4	Floor levels to be as close to the *minimum floor level* above ~~(FPL2)~~ as practical and not less than the floor level of the existing building being extended if the existing floor level is less than or equal to the minimum floor level. If the extended weatherproof area[1] exceeds 50% of the existing weatherproof area, the extension is treated as a new building. The extended weatherproof area is measured as the cumulative area of any previous extensions plus the proposed extension. Temporary flood protections to be considered for dwellings that have a residual flood risk that could reasonably be mitigated with such approaches, e.g. sandbagging or other barriers to limit flood water ingress. If building is identified as being suitable for voluntary house raising scheme, Council to discuss potential house raising with owner.
BC1	**BUILDING COMPONENTS** Buildings to have **flood compatible material** below the relevant **flood planning level** according to development/building type. Refer to Flood Proofing Section 2.3.3.
SS1	**STRUCTURAL SOUNDNESS** No structural soundness requirements for the force of floodwater, debris & buoyancy. Must still comply with the National Construction Code (formerly BCA) requirements. If structure is to be used for Shelter in Place refuge during flood events, engineers report will be required to considered structural integrity is maintained up to and including the PMF event.
SS2	Engineers report to prove that structures subject to a flood up to the ~~100 year event can withstand the force of floodwater, debris & buoyancy.~~ PMF can withstand the force of floodwater, debris & buoyancy provided the structure serves no role in providing safe refuge during a flood event (i.e. shelter in place). If structure is to be used for Shelter in Place refuge during flood events, engineers report will be required to consider structural integrity is maintained up to and including the PMF event.
FE1	**FLOOD EFFECT** No action required.

[1] Weatherproof Area is defined as 'gross floor area of habitable rooms with floor levels below the 2050 flood planning level'.

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FE2	The flood impact of the development to be considered by Council, with Council having the right to request an engineer's report (see FE3 below).
FE3	~~Engineers report required to prove that the development will not result in adverse flood impact elsewhere.~~ Engineers report required demonstrating development achieves an acceptable level of flood impact external to development site (e.g. afflux or increase in peak flood level) in the current climate and also as a result of climate change. In urban areas afflux must be limited to no more than 10mm. Refer to Flood Impact and Risk Assessment guidelines for example (include link).
EA1	**FLOOD EMERGENCY MANAGEMENT** ~~Council to provide information on flood evacuation strategy.~~ Provide flood emergency information as per Section C2.3.5 'Infill Development and Redevelopment'.
EA2	~~Site specific Flood Evacuation Strategy be developed consistent with Council / SES overall Flood Evacuation Strategy.~~ Provide information as per Section 2.3.5 'Greenfield developments, rezonings and new communities'. If the location is outside the current coverage of the Local Flood Plan, an Evacuation Capability Assessment may also be required.
EA3a	~~Emergency service site - should have good access up to the **PMF** and preferably not cut-off from the main residential area(s).~~ Generally **Critical Facilities** should be at or above the **PMF** level, however, further information may be required in respect of access and egress routes to and from the Site during flood events.
	~~Council to evaluate suitability of site in this respect.~~
EA3b	~~If site to be used during and after a flood emergency (see FL3a above), should have good access up to the **PMF** and preferably not cut-off from the main residential area(s).~~ Provide flood emergency information as per Section C2.3.5 'Infill Development and Redevelopment'.

~~C2.3.4~~ C2.3.3 Flood Proofing

1. Flood Compatible Material

Materials located below the relevant level defined by the **flood planning matrix** must be capable of resisting damage, deterioration, corrosion or decay taking into account the likely time the material would be in contact with flood water and the likely time it would take for the material to subsequently dry out. The following guidelines may provide further details of flood proofing of buildings undergoing construction or retrofit:

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

2. Services

Services and related equipment, other than electricity meters, must not be located below the relevant **flood planning level** defined by the **flood planning matrix** unless they have been designed specifically to cope with flood water inundation. The location of electricity meters is regulated by the electricity supply authority.

Unless the electricity supply authority determines otherwise, electrical switches must be placed above the relevant level defined by the **flood planning matrix**. Electrical conduits and cables installed below the relevant level defined by the **flood planning matrix** must be waterproofed or placed in waterproof enclosures.

3. Enclosures

Any enclosure located below the relevant level defined by the **flood planning matrix** must have openings to allow for automatic entry and exit of floodwater for all floods up to the relevant level defined by the **flood planning matrix**.

~~C2.3.5~~ C2.3.4 Special Provisions

1. CBD infill development

For infill development in a commercial centre, change of use and additions to existing commercial premises, the current floor level (compatible with the footpath level) can be retained. However buildings must comply with section ~~C2.3.4~~ C2.3.3 Flood Proofing.

For car parking, there may be instances where it is not possible to comply with minimum floor level for parking space (ie due to gradients), especially in Mullumbimby, New Brighton, Ocean Shores, Billinudgel. Variation/s under such circumstances will be considered on their merits.

2. Cumulative Development and No-fill (or No Development) Zones

Due to the potential effects of ongoing catchment development, particularly in highly sensitive areas, no-fill zones and other development restrictions have been identified across the Shire based on assessments completed as part of the Floodplain Risk Management Studies. Reference should be made to Council's Online Mapping Tool for details of no-fill areas.

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Development in no-fill zones may be possible in certain instances where impacts of flooding have been mitigated through an appropriate design response.

~~2.~~3. New Brighton, South Golden Beach and Billinudgel

Dwellings in this area are subject to frequent low level flooding.

~~Refer to Councils Marshalls Creek Floodplain Management Plan (1997) for land that cannot be filled.~~ Preferable building type is on piers, with car parking located under, and with under floor area to remain clear of infill construction. The area shall not be used for storage, nor infilled at a later date.

For the Billinudgel town centre, it is recommended that development should comply with the following:

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

The restrictions are suggested to reduce the impact of development on flood behaviour, but are not expected to entirely mitigate it.

~~3.~~ 4. Tallow Creek Flood Study Catchment ~~(Map C2.5)~~

This study found that buildings / dwellings should be 0.5m above the 2100 Climate Change flood levels.

~~Refer to the Tallow Creek Floodplain Management Plan (2009) for land that cannot be filled. Preferable~~
For future development in 'no fill' areas, building type should be on piers, with car parking located under, and with under floor area to remain clear of infill construction. The area shall not be used for storage, nor infilled at a later date.

~~4.~~ 5. Bangalow

Council does not currently have any adopted flood studies or management plans for Bangalow. Where development is proposed on land that is or may be considered ~~at or below the **flood planning level**~~ within a **flood planning area**, the applicant will be required to submit a report using local flood information to satisfy the provisions in the **flood planning matrix**. In some instances a professional Civil / Hydraulic Engineer (with qualifications suitable for admission as a corporate Member of Engineers Australia) will be required to prepare this report or a flood study (Refer to Section B3.2.3 of Chapter B3 Services for further guidance).

Local flood information could be anecdotal flood heights (i.e. highest recorded flood height) or flood studies carried out for previous rezoning or large development applications.

5. 6. Basement Car Parks

Any basement car park shall incorporate design elements (e.g. ramps etc) or automatic mechanisms (e.g. hydraulic barriers etc) to prevent the ingress of flood waters. The design elements or mechanisms are to comply with at a minimum the **Projected 2050 Flood Planning**

Level. The basement shall also include facilities for the pumping of water in the event of failure, or larger flood events.

~~6.~~ 7. Rural Areas

Council does not hold plans or records for flooding in most rural areas, other than in the defined catchments (refer to Section C2.3.1 and Map C2.1). Flood models do exist in some rural areas and discussion with Council's flood planning staff should occur prior to their use to ascertain their applicability and limitations. For instance the models developed for the major catchments discussed in Section C2.3.1 have been developed in accordance with the procedures outlined in the NSW Floodplain Development Manual (now known to as the Flood Risk Management Manual). ~~In certain rural areas, floodplains may be steep and narrow, and are liable to rapid flood inundation with little warning.~~

In the absence of current flood information, persons proposing new developments in rural areas near rivers, streams and gullies that could be subject to flood inundation should seek out and use reliable local historical information on peak flood levels experienced during prior flood events as an initial guide. ~~Catchment flood studies may be required to establish design flood levels, flow rates for structural design, and to assess the potential impact of the development on local flood behaviour. Refer to Section B3.2.3 of Chapter B3 Services for further guidance.~~

A catchment based flood study may be required to establish **flood planning levels**, flow velocity and depths for structural design, and resultant flood impacts resulting from development, , e.g. generation of flood afflux or changes in flow velocity and direction, etc.

Where development is proposed on flood prone rural land ~~that may be considered **flood liable land**,~~ the applicant will be required to submit a report using local flood information, establishing the levels on the site ~~equivalent to the **Projected 2050 Flood Planning Level** in relation to any dwelling, residential, tourist or commercial project~~ appropriate to the development type as per the **flood planning matrix**. In some instances a professional Civil / Hydraulic Engineer (with qualifications suitable for admission as a corporate Member of Engineers Australia) will be required to prepare this report or a flood study.

The floor level of any **dwelling** shall be at or above the **Projected 2050 Flood Planning Level** while the floor level for other types of development will be determined on a case-by-case basis.

8. Rural Crossings

Within upper catchment areas there are many minor road crossings And typically, flood runoff rises and falls quickly in these parts of the catchment in response to rainfall. As such these crossings need to be designed to provide a reasonable level of service (i.e. trafficability) having regard to the extent of upstream development they service, and the nature of inundation experienced at the crossing location, i.e. peak flood levels and duration of inundation, etc.

Access roads and driveways servicing more than three (3) dwellings are to provide flood crossings with an immunity in accordance with Council's adopted engineering standards. Where less than three (3) dwellings are serviced and Council's adopted engineering standards are too onerous, the access or driveway is not to be inundated by more than 200mm depth with a velocity x depth ratio of less than 0.6 m^2/s during a 20% AEP flood and a time of closure not exceeding 6 hours. Appropriate warning signage and depth indicators must be provided. Variations must be supported with a report prepared by a suitably qualified engineer demonstrating the safety of people and vehicles during a flood.

It is likely a professional Civil / Hydraulic Engineer (with qualifications suitable for admission as a corporate Member of Engineers Australia) will be required to prepare a flood study to provide this information.

~~Deleted~~ Insert deleted maps if necessary

~~Map C2.1 – Belongil Creek Flood Study Area Locality Plan~~

~~Map C2.2 – Brunswick River Flood Study Area Locality Plan~~

~~Map C2.3 – North Byron Coastal Creeks Flood Study Area Locality Plan~~

~~Map C2.4 – Marshalls Creek Flood Study Area Locality Plan~~

~~Map C2.5 – Tallow Creek Flood Study Area Locality Plan~~

C2.3.5 Flood Emergency Management

Introduction

The SES is the lead agency for flood emergency management and flood combat in NSW. Within the Byron Shire, the SES has prepared the Byron Local Flood Plan (LFP) as the lead document to be applied during a flood event.

The Byron LFP (external link here) has been prepared to cover all relevant flood threats to community and strategies available to emergency managers to these minimise risks where information has been available to inform it.

The Byron LFP has been prepared to account for the variability of flood events, their severity and available information to predict their evolution. Currently, the Byron LFP reflects flood knowledge compiled by Byron Shire Council in its available flood studies and floodplain risk management plans. Hence, there are some limitations in the extent of detailed coverage within the LFP as not all portions of the Byron Shire are covered by Council flood studies.

Currently, the SES recommends evacuation as the primary response to flooding. This involves evacuation of the community that is likely to be flood affected, to an area outside of the effects of flooding that has adequate facilities to maintain the safety of the evacuated community for the duration of the event.

In locations where there is a fast response to flooding, i.e. the time to peak flooding is up to or less than six hours, there is likely to be a reduced ability to evacuate community in these areas due the likely rapid onset of the flood event, and an inability to mobilise an effective evacuation in such a limited timeframe. In these locations a potentially suitable response is to seek refuge in a dwelling, also known as 'shelter-in-place'. This is where community reside in structurally sound buildings that are resistant to flood flows, that also provide refuge above the **probable maximum flood** (**PMF**) level.

NSW Government is currently considering potentially acceptable conditions for 'shelter in place' to be adopted. These will need to balance the benefits of this action, versus the risks. There are many unknown risks that can present to those sheltering in place during flood events, e.g. medical emergencies, fire, loss of communication, impact of isolation on mental health, etc. These potential emergencies may result in rescue attempts that place both the occupants and rescuers in danger.

It is possible that shelter-in-place requirements will become more accepted and standardised across NSW, however, evacuation is the SES's preferred outcome. Accordingly greenfield habitable (i.e. residential) development should not recommend shelter-in-place as a primary response to flooding.

The SES also does not support the adoption of individual development-specific flood emergency response plans as a means to support development approval. These plans are considered ineffective in the strategic management of flood risks across a community during a flood event.

Infill Development and Redevelopment

Byron Shire Council will generally be responsible for determining new development applications that may be considered to be infill or redevelopment in nature.

This is where the proposed development is largely consistent with existing zoning, however, if within the **flood planning area**, the applicant may need to demonstrate to Council that flood risks have been appropriately considered.

Generally, infill development and redevelopment in the major urban centres of the Shire (i.e. Byron Bay, Mullumbimby, Brunswick Heads, Suffolk Park, etc) will be covered under existing flood emergency arrangements outlined in current the Local Flood Plan. For locations outside of existing Local Flood Plan coverage, Figure C2.2 below provides a flowchart of flood emergency considerations.

The applicant in working through the flowchart would necessarily provide the following types of information to Council for consideration:

- Proposed use and tenure of the land (tenure may be body corporate)
- Number and demographic of occupants, noting if future users of the site will be known to have increased vulnerability to flood risks (e.g. child-care, or aged-care, mobile homes, etc)
- Identification of flood characteristics including flood hazard and peak flood levels for the **Projected 2050 Flood Planning Level** and **Projected 2100 Flood Planning Level** and **PMF** flood events across the development area noting that for some large rural sites, these may vary over the property.
- Provide details of likely type of flooding to be experienced at the site (e.g. rapid flooding, riverine, etc) and associated time to onset of flooding and likely duration of flooding (for 100 year **ARI** event and **PMF**).
- Identify if self-evacuation of the Site is possible (noting that this is preferred), and if so what is the intended mode of transport, evacuation route and intended evacuation location.
- If shelter in place is proposed, identify specifics of the refuge (elevation, size, facilities, etc) and its suitability as a refuge identifying any contingencies in place for complete loss of services.

Evacuation routes should not involve egress along roads also subject to inundation above the 1% AEP event unless it can be demonstrated that the inundation of the egress routes will remain safe and provide ample time for evacuation prior to this inundation occurring.

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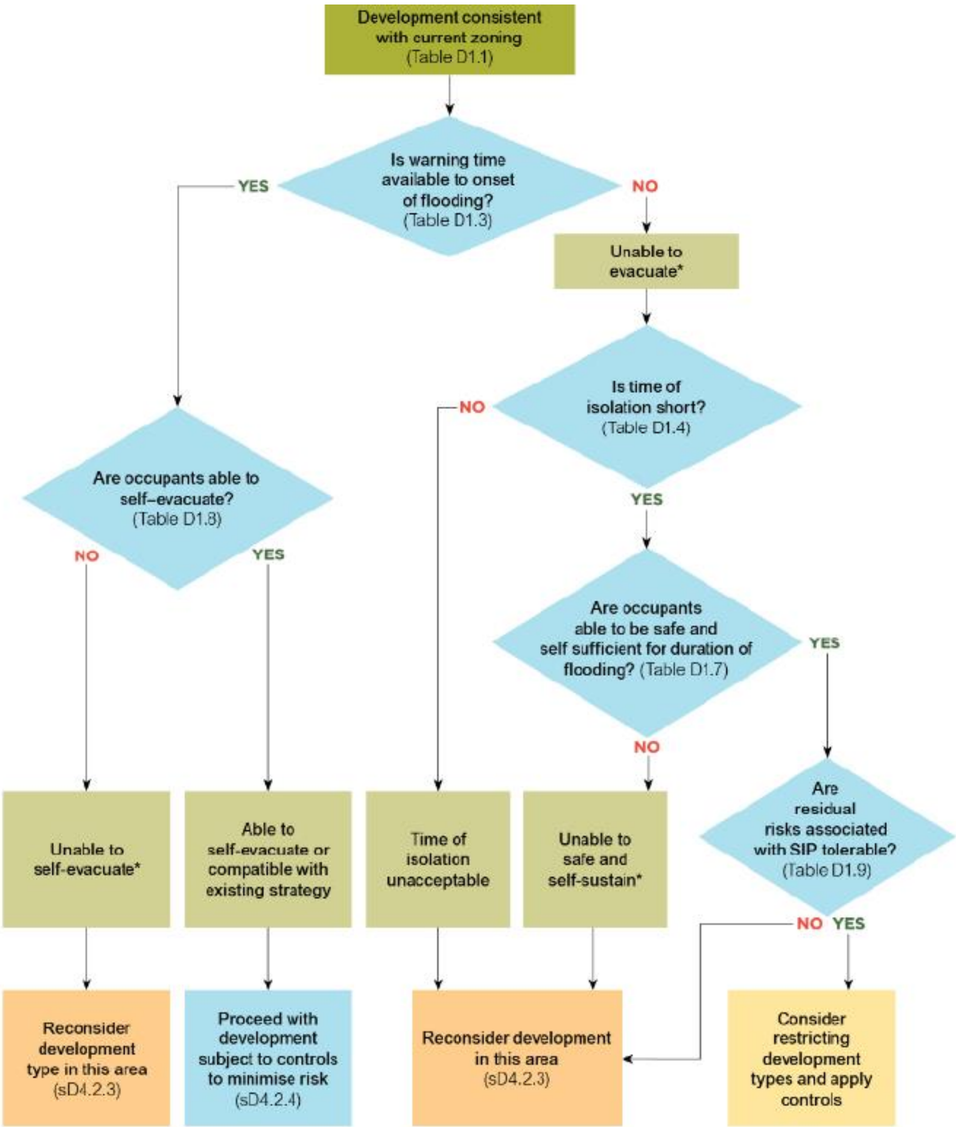
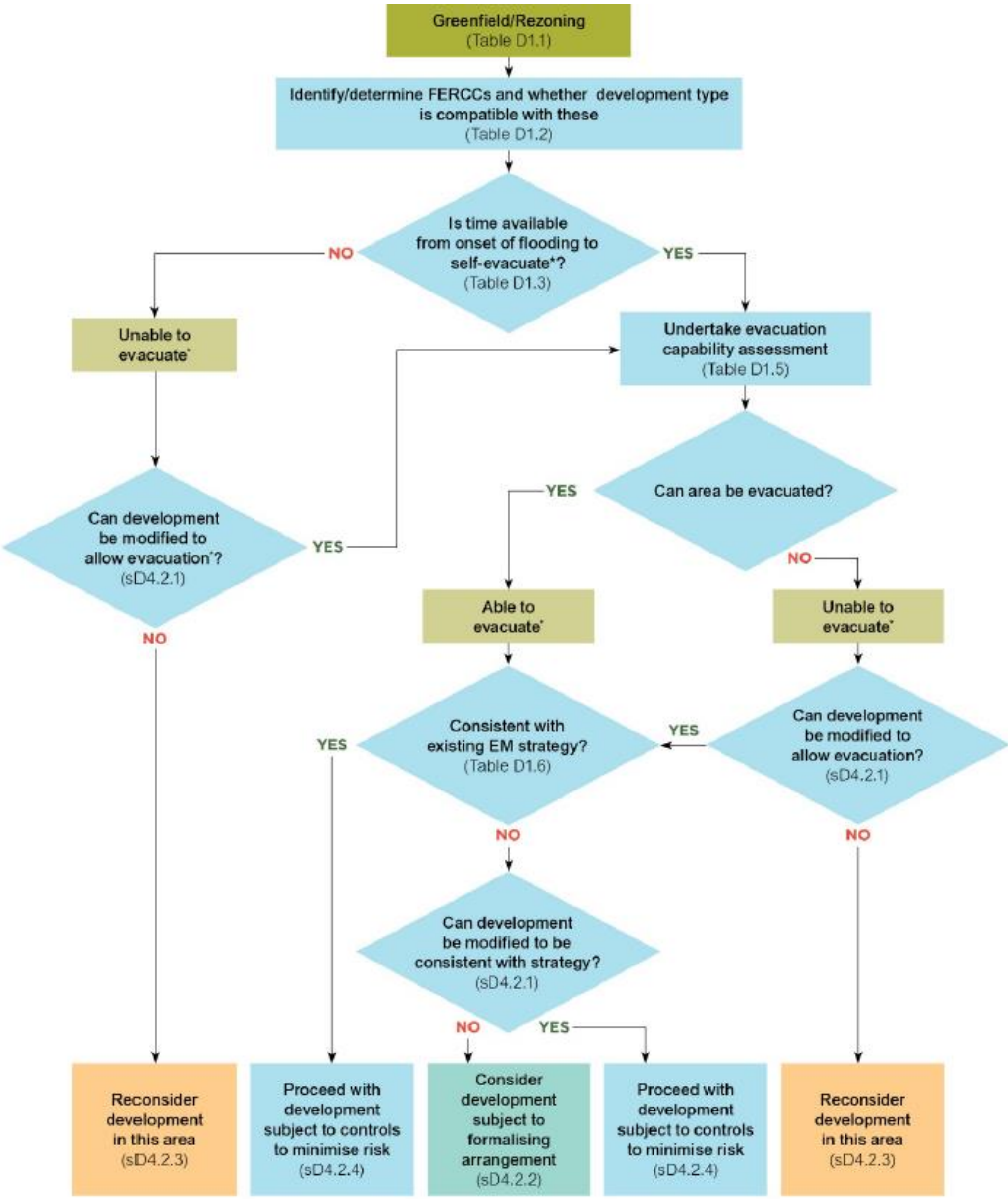


*'Evacuate' or 'Evacuation' means self evacuation based on flood triggers to an area outside of floodwaters with adequate services to sustain evacuees

Figure 21 Considering emergency management in redevelopment or infill development compatible with existing zoning

Figure C2.2 Redevelopment and Infill Development (DPE, 2022)

This document is available on the Council's website



*'Evacuate' or 'Evacuation' means self-evacuation based on flood triggers to an area outside of floodwaters with adequate services to sustain evacuees

Figure 20 Considering emergency management in greenfield developments, rezoning and creating new communities

Figure C2.3 Greenfield Developments, Rezoning and New Communities (DPE, 2022)

Evacuation Capability Assessment

Greenfield developments and or new community areas outside of locations detailed under an existing Local Flood Plan should complete a detailed evacuation capability assessment. The assessment will consider in detail the specifics of a proposal and its relationship to existing community features (e.g. evacuation routes and centres).

The assessment would consider a variety of factors that describe the size, nature, design and setting of the development in its existing environment. Particularly the assessment may consider the proposed land use change, development density/populations and likely demographics (and associated vulnerability of these demographics). Internal development layouts, proposed topography and relationship to surrounding topographic features (if relevant). The assessment may identify the locations of internal roads and their linkages to existing road networks.

Details of evacuation strategies, such as dedicated transport or self-drive options should be identified. Details of available flood warning systems relevant to the proposal should be outlined. Examples of flood warning systems may include presence of nearby rainfall and water level gauges (particularly those with real-time systems updating via the internet). Note, some water level gauges (such as those on the Bureau of Meteorology website) have flood classes associated with water levels indicating the current status of flooding as either minor, moderate or major which can be of assistance. Some catchments may have specific and dedicated flood warning systems already which can be accessed for information or relied upon to some extent for evacuation purposes.

Overall, the evacuation capability assessment should be able to identify that if site evacuation were required there would exist sufficient time for those required to evacuate to safely travel via the identified means of transport and evacuation route(s) to the nominated evacuation centre or area, allowing for contingencies and uncertainties. Shelter in place is not likely to be a suitable option for a greenfield habitable (i.e. residential) development or new community. Temporary sheltering in place may be acceptable for non-habitable development types provided the refuge is of a suitable design and is sufficiently equipped for the emergency.

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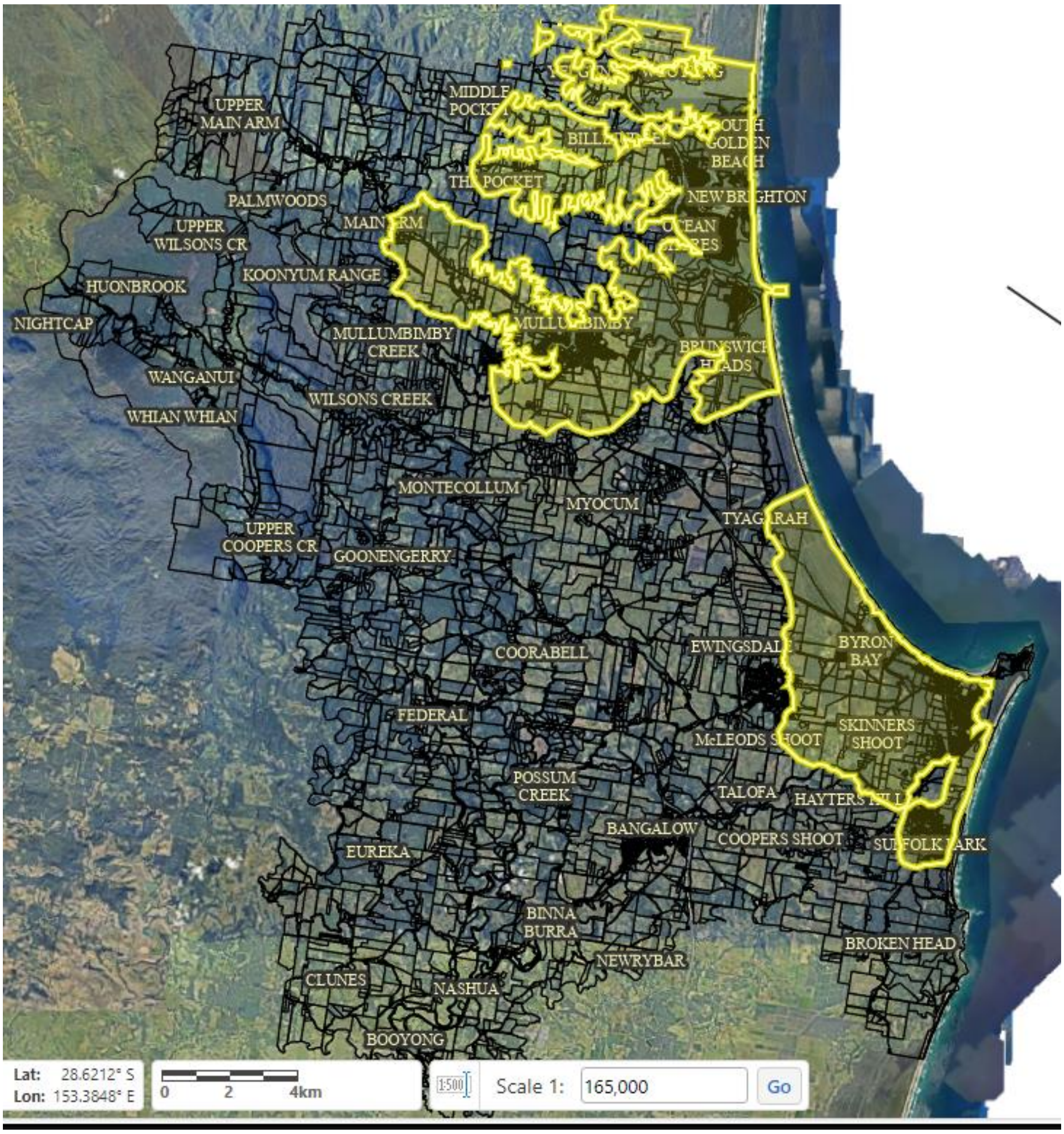
Map C2.1 – Byron Shire Flood Studies Locality Plan



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ANNEXURE 1 – Additional Information

Relationship of Average Recurrence Internal (ARI) and Annual Exceedance Probability (AEP)

The Australian Rainfall and Runoff Guidelines (2019) have recently adopted alternative terminology to describe the flood probability of a design flood event. In the past, flood probabilities have been described in terms of 'average recurrence intervals' (ARI) such as "100 years". However, due to the potential for misinterpretation of this descriptor (the assumption that a "100 year flood" will only happen once in every 100 years), the current approach is to describe flood probabilities in terms of the 'annual exceedance probability' (AEP). Using this language, the design flood size which was previously known as a "100 year flood" is now referred to as a "1% AEP flood", meaning that there's a 1% chance that a flood of this size or larger will occur in any given year. The following are common interchangeable terms:

- 18% AEP – 5 year ARI
- 10% AEP - 10 year ARI
- 5% AEP - 20 year ARI
- 2% AEP - 50 year ARI
- 1% AEP - 100 year ARI
- 0.2% AEP - 500 year ARI

Flood Emergency Response Classification of Communities (FERCCs)

The flood emergency response classification of communities (FERCCs) is a classification of regions within flood prone areas that distinguishes differences based on isolation or inundation by floodwaters and surrounding topography and its ability to support evacuation.

FERCCs are useful in support of emergency management planning and management of actual flood risks as the classification provides an understanding of isolation and potential risks and associated consequences for certain flood events.

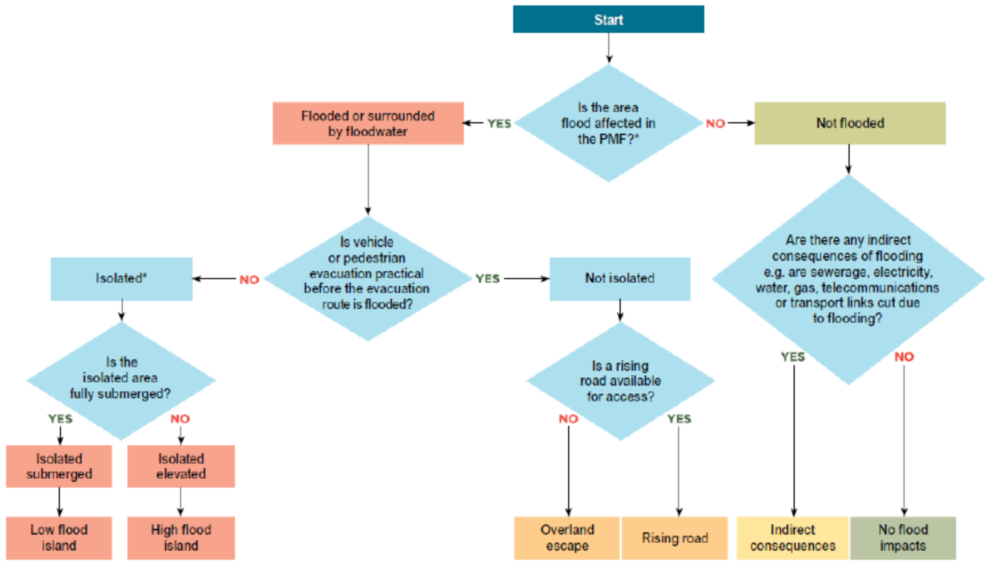
FERCCs are also useful in land use and infrastructure planning as they can be used to inform development patterns. Ideally new development and communities will avoid expansion into increasingly isolated areas and or those exposed to higher flood risk. Infrastructure provision can also consider FERCCs in locating essential or support infrastructure.

Classifications typically used are detailed below and are based on consideration as to whether the area is flooded, isolated and the consequence of flooding in that area. The following are examples of types of FERCCs that may be identified in a catchment.

- Flood Island – High and low flood islands, high and low trapped perimeter areas
- Areas with rising access out of the floodplain, areas with rising road access and areas with overland escape route
- Indirectly affected areas
- Overland refuge area

FERCCs have been mapped for the parts of the Byron Shire, with some classifications such as low flood islands and low trapped perimeter areas being identified as potentially requiring further detailed planning and development control due to their inherent risks topographic challenges in times of flood.

If not mapped already, the FERCCs can be determined by reference the following flowchart



Note:
*This is either the PMF, equivalent or the event being used to determine the Flood Emergency Response Classification

Figure 17 Flowchart for determining flood emergency response classifications for flood and flood risk management studies

STAFF REPORTS - INFRASTRUCTURE SERVICES

Report No. 4.2 Flood Levee Raising Investigation - South Golden Beach

Directorate: Infrastructure Services

Report Author: Isabella Avelino Gianelli, Project Engineer

File No: I2024/161

Summary:

The report documents the constraints and feasibility assessment to improve the levee flood protection by raising the levee by 300mm or 600mm. It also presents high level costings to repair and remediate the levee in accordance with a recent levee audit (Engeny, 2022).

The findings of the Wilde Engineering Consulting (WEC)report indicate that the existing levee's flood immunity exceeds the 1% Annual Exceedance Probability (AEP) event, which is high compared to other Northern Rivers levees. Raising the levee would only marginally impact the Average Annual Damage (AAD) caused by floods, as it would only improve protection against rare floods. Moreover, significant constraints suggest that the cost and complexity of raising the levee would significantly outweigh the benefits, resulting in a low cost-benefit ratio. Based on this, the report recommends no raising is undertaken.

The WEC report also provides cost estimates and probable funding source (Council or NSW Public Works Flood Levee Repair and Maintenance Program) to undertake the 20 action items identified in the 2022 levee audit and identifies 2 additional actions. The estimated annual cost to undertake all recommended works for Council-funded maintenance actions is $85,300. An additional one-off cost of $1,150 is needed for clearing a blocked flood gate. The NSW Public Works Flood Levee Repair and Maintenance Program can fund recommended levee actions totalling a one-off cost of $59,250.

RECOMMENDATION:

That Council, based on the reasons discussed in this report, it is recommended that raising the levee by either 300mm or 600mm is not undertaken.

Attachments:

1 P23008.RO1_SGB Levee Maintenance and Raising Investigation_001_FINAL, E2024/47780 , page 66⇩

Report

Background and Introduction

Following the 2022 floods, the NSW and Australian Governments announced funding for urban flood levees under the Disaster Recovery Funding Arrangements (DRFA). This program, involving 13 Local Government Areas including Byron Shire, aims to assess, repair, and improve levees. Council is considering using this funding to:

a) Repair and improve the SGB flood levee, which protects urban areas along the Capricornia Canal, in accordance with a recent levee audit (Engeny, 2022).

b) Raise the levee by either 300mm or 600mm to improve flood immunity of the area.

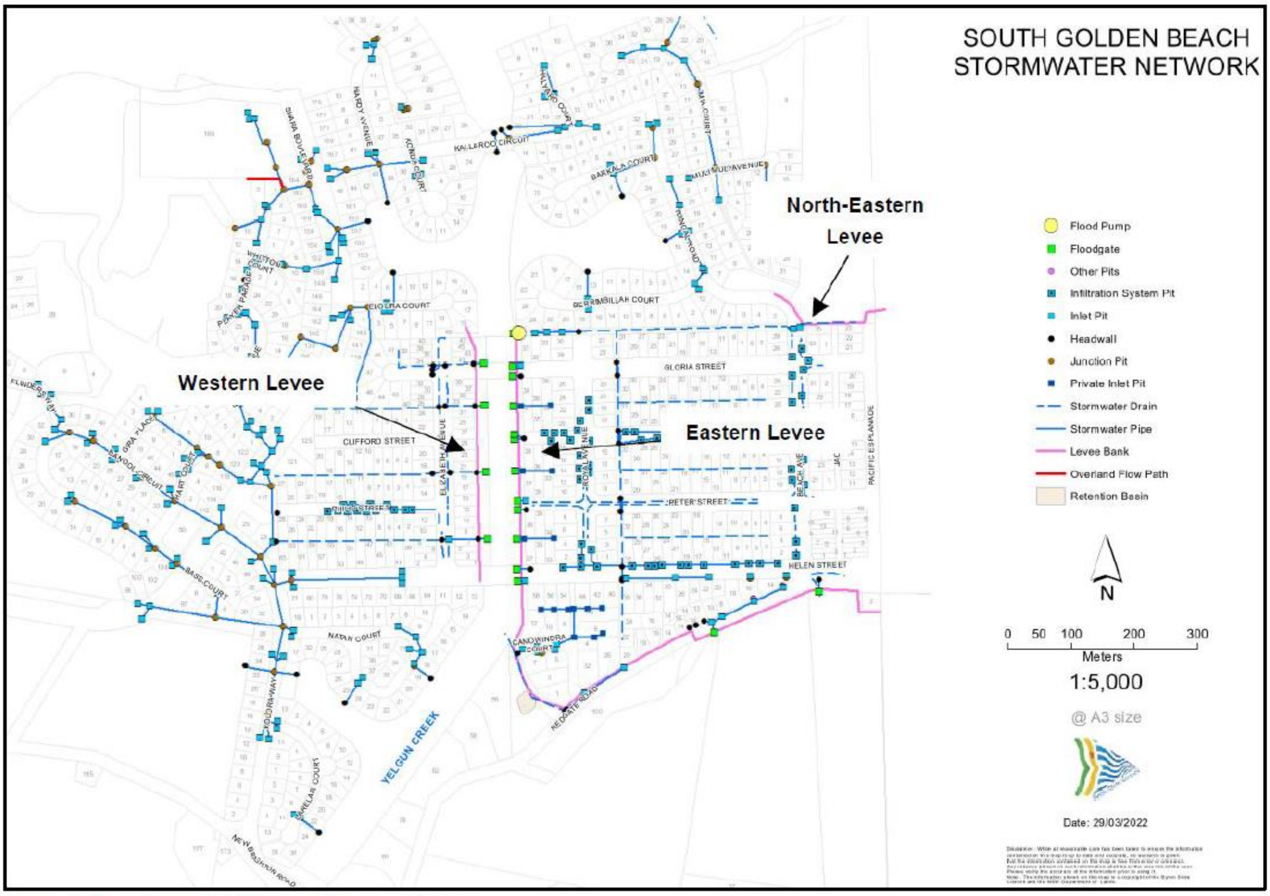


__Figure 1:__ Location of SGB levee (Engeny, 2022)

Current Flood Immunity

NSW Public Works undertook a levee survey in February 2023 which found that the eastern and western levee crests both fluctuate around the design level of RL 3.2 m AHD. The lowest crest levels, which determine flood immunity, are RL 3.01mAHD on the western levee and RL 3.08 on the eastern levee. The current 1% AEP flood level in the Capricornia Canal is 2.9mAHD, lower than both these crest levels. Therefore, the levee provides protection for the 1% AEP event with a freeboard of 110mm on the western side and 180mm on the eastern side, less than the design freeboard of 300mm.

It is recommended to review the survey and fill any areas where the levee crest elevation is less than RL 3.2mAHD. The 1% AEP protection level is considered good for the Northern Rivers area, matching the highest protection provided by any local levees, shown in table below.

Levee	Flood Immunity (AEP)	Council
Murwillumbah – Main St	1.25%	Tweed Shire council
Murwillumbah – South	20%	Tweed Shire council
Murwillumbah – East	1%	Tweed Shire council
Murwillumbah – Dorothy/Williams St's	1%	Tweed Shire council
Tweed Heads South	5%	Tweed Shire council
Pottsville – Seabreeze Estate	1%	Tweed Shire council
Lismore City	10%	Lismore City Council

Key issues

The investigation identified several constraints that will significantly impact the cost of raising the levee. These include:

1. The need to move, reconfigure, or reconstruct existing infrastructure such as foot bridges, footpaths, pump stations, driveways, roads, and fences.
2. The removal of many large trees along both levees for structural integrity, requiring substantial reconstruction of these levee sections.
3. Limited machinery access due to the levee's proximity to private properties and dense vegetation, potentially necessitating costly barge use.
4. The need for steep batters or retaining walls due to the levee's proximity to property boundaries, roads, and the Capricornia Canal, which may also require unpopular pedestrian barrier fences due to the respective safety requirements.
5. A complex approval process due to the disturbance of large mangrove areas, requiring NSW Fisheries permits.

Options

The flood levels of the 0.2% and 0.05% AEP events are not reported in the North Byron Floodplain Risk Management Study and Plan (FRMSP) prepared by WMA Water - 2020, however the Probable Maximum Flood (PMF) is reported as RL 5.2mAHD, significantly above the crest of the existing levee (3.2mAHD) and both proposed raising heights (3.5mAHD and 3.8mAHD). Therefore, the benefits of raising the levee will increase the flood immunity from 1% AEP to an event larger than the 1% AEP but less than the PMF, i.e. potentially 0.2% AEP or 0.05% AEP of the events modelled in the FRMSP.

The Average Annual Damage (AAD) approach, as outlined in the Flood Risk Management Manual (DPE, 2023), can be used to assess the benefits of the levee raising. This method estimates potential flood damage caused by a range of storm magnitudes (Annual Exceedance Probability - AEP), translates them into monetary values, calculates an average annual damage, and compares the AAD with and without the levee. The difference represents the levee's annual economic benefit. A cost-benefit analysis then determines if the levee investment is justified. Rare events, for example >1% AEP floods, generally don't significantly impact the AAD because they occur infrequently. Lower magnitude, more frequent events generally have a bigger baring on AAD over time and contribute more significantly to the expected annual damages. Therefore, although this exercise has not been undertaken for this study, the benefits of increasing the levee's flood immunity to 0.2% or 0.05% are expected to be small relative to the costs of construction, which is expected to be large due to the constraints identified above.

Levee Raising Recommendations

Summarising the information presented above in the Levee Raising Assessment Section of the report (attachment 1)

- The current levee has a flood immunity greater than the 1% AEP event, which compared to other levees in the Northern Rivers is high.
- Raising the levee is not expected to have a significant impact on the AAD of the area, as it will only increase flood immunity for rare occurrence flood events.
- Significant constraints have been identified as part of the initial constraints study, indicating the cost and complexity of raising the levee would be high relative to the expected benefits.
- Due to the reasons stated above the cost-benefit ratio of the levee is expected to be low.

Based on the reasons identified above, it is recommended that raising the levee by either 300mm or 600mm is **not** undertaken.

Recommended actions

Levee Repair and Maintenance Works

After the 2022 floods, Engeny inspected the levee for Byron Shire Council, finding it in good condition with no structural integrity loss. They made 20 recommendations to maintain this condition: 2 high-priority items needing immediate action, 9 medium-priority items for action within a year, and 9 low-priority items for ongoing maintenance. The recommended actions, cost estimates provided by WEC, and funding sources are detailed in the report. Funding is based on the NSW Public Works Flood Levee Repair and Maintenance Program covering levee assessment, condition recording, repair planning, resilience improvements, and reliability evaluation. General maintenance costs are the Council's responsibility.

The table summarising recommended levee works, including costings and proposed funding source, have been extracted from the South Golden Beach - Levee Maintenance and Raising Investigation (WEC, 2024) and are presented below.

Table 1: *Recommended levee works including costings and proposed funding source*

No.	Recommendation	Recommendation Type	Priority
Engeny 2022			
General			
1 EOC: $1,000/mth Funding source: Council	Commence undertaking routine inspections (i.e. monthly) of the Levees	Levee Safety	Low
North- Eastern Levee			
2 EOC: $1,150 Funding source: NSW PW Grant	Repair the existing crest sinkhole by backfilling the hole with low permeability clay. Modify the surrounding crest surface levels with gravel sheeting to promote free draining conditions to the upstream side of the crest to prevent ponding of water on the crest. Any works undertaken should not lower the existing crest levels. Continue to monitor the area following the repair works, including inspecting the upstream batter and downstream batter / toe in this area, for any signs of internal erosion / sinkholes.	Levee Safety	High
3 EOC: $4,600/yr Funding source: Council	Poison and cut small trees / saplings / shrubs with trunks < 100 mm diameter	Maintenance	Low
4 EOC: $2,300/yr Funding source: Council	Remove debris downstream from drainage channel to reinstate free draining condition to allow water to drain away from the downstream toe and minimise saturation of the levee foundations.	Maintenance	Low

Eastern Levee			
5 EOC: $2,000/mth Funding source: Council	Mow grass on the embankment where possible, to allow for improved observation of levee embankment condition.	Maintenance	Low
6 EOC: $4,600/yr Funding source: Council	Poison and cut small trees / saplings / shrubs with trunks < 100 mm diameter	Maintenance	Low
7 EOC: $2,300/yr Funding source: Council	Clear / slash dense vegetation immediately upstream and downstream of the flood gates / culvert inlets and outlets	Maintenance	Medium
8 EOC: $1,150/qtr Funding source: Council	Remove debris from drainage channel between Peter and Helen Street to reinstate free draining condition and minimise saturation of the levee foundations.	Maintenance	Low
9 EOC: $10,000^ Funding source: NSW PW Grant	Undertake desktop stability analysis of the levee to determine the sensitivity of factor of safety against instability is to varying crest widths and batter slopes and whether the embankment meets recommended factors of safety.	Levee Safety	Medium
10 EOC: $5,000 Funding source: NSW PW Grant	Undertake detailed ground survey of the levee to determine critical sections for stability analysis.	Levee Safety	Medium
11 EOC: $8,000 (risk audit) Funding source: NSW PW Grant	Undertake a risk audit / qualitative risk assessment on existing structures constructed on the levee to quantify potential impact on levee structural integrity. OR Remove existing structures constructed on the levee and develop remediation design to reinstate levee as per the original design intent.	Levee Safety	Medium
12 EOC: Included in Item 1 Funding source: -	Monitor existing retaining walls as part of monthly routine inspections. If condition of retaining walls further deteriorates develop remediation design.	Maintenance	Medium
13 EOC: Included in Item 1 Funding source: -	Monitor existing culvert inlet / outlet cracking and spalling as part of a monthly routine inspections. Repair if cracking exceeds 5mm or condition continues to significantly deteriorate.	Maintenance	Low
14 EOC: $1,500 Funding source: NSW PW Grant	Repair damaged flood gate near the Southern Golden Beach Skate Park	Maintenance	High

Western Levee			
15 EOC: $2,000/mth Funding source: Council	Mow grass on the embankment where possible, to allow for improved observation of levee embankment condition.	Maintenance	Low
16 EOC: $4,600/yr Funding source: Council	Poison and cut small trees / saplings / shrubs with trunks < 100 mm diameter	Maintenance	Low
17 EOC: $2,300/yr Funding source: Council	Clear / slash dense vegetation immediately upstream and downstream of the flood gates / culvert inlets and outlets	Maintenance	Medium
18 EOC: $10,000^ Funding source: NSW PW Grant	Undertake desktop stability analysis of the levee to determine the factor of safety against instability and whether the embankment meets recommended factors of safety	Levee Safety	Medium
19 EOC: $5,000 Funding source: NSW PW Grant	Undertake detailed ground survey of the levee to determine critical section for stability analysis.	Levee Safety	Medium
20 EOC: $16,000 (risk audit) Funding source: NSW PW Grant	Undertake a risk audit / qualitative risk assessment on existing structures constructed on the levee to quantify potential impact on levee structural integrity. OR Remove existing structures constructed on the levee and develop remediation design to reinstate levee as per the original design intent.	Levee Safety	Medium

21 EOC: $1,150 Funding source: Council	Clear the debris and sediment blocking the northern most open flap valve on the eastern levee (refer Figure 2). It is recommended that the Mangroves growing around the flap valve are also cleared to allow for a free flowing, unimpeded outlet, and to reduce the risk of future re-blockage. It is noted that machinery access to the outlet is impeded by vegetation and steep banks and the works will likely require manual (hand) excavation and clearing. It is also noted that the clearing of mangroves will likely require a permit from Fisheries NSW unless the works fall under Councils existing stormwater maintenance permit. Confirmation should be sought prior to undertaking the works.	Maintenance	High
22 EOC: $4,600 Funding source: NSW PW Grant	Reinstate all locations where the levee crest elevation is less than RL 3.2mAHD back to the design level, as per the Feb 2023 NSW Public Works survey (Attachment 2)	Levee Safety	Medium

^ Cost of undertaking desktop stability analysis per levee (east and west) is anticipated to reduce to $15,000 if undertaken as a single project.
* EOC = Estimated Opinion of Cost

Strategic Considerations

Community Strategic Plan and Operational Plan

This investigation and report indirectly connect to the Drainage Upgrade OP activity for South Golden Beach as identified below.

CSP Objective	CSP Strategy	DP Action	Code	OP Activity
5: Connected Infrastructure	**5.5: Provide continuous and sustainable water and sewerage management**	**5.5.3: Storm-water - Provide stormwater infrastructure to manage flood mitigation and improve social and environmental outcomes**	**5.5.3.8**	**Continue to progress South Golden Beach drainage upgrade program**

Recent Resolutions

Legal/Statutory/Policy Considerations

Not Applicable

Financial Considerations

The estimated annual cost for Council-funded maintenance actions is $85,300. An additional one-off cost of $1,150 is needed for clearing a blocked flood gate. The NSW Public Works Flood Levee Repair and Maintenance Program can fund recommended levee actions totalling a one-off cost of $59,250.

Consultation and Engagement

Given this is a preliminary feasibility study, no consultation or engagement has been undertaken.

23 Apr 2024

Byron Shire Council
70 – 90 Station Street, Mullumbimby, NSW, 2482
PO Box 219, Mullumbimby, NSW, 2482

Attention: **Steve Twohill**

RE: **South Golden Beach - Levee Maintenance and Raising Investigation**

Introduction and Background

As a result of the unprecedented flood events which took place in early 2022 across the NSW North Coast Region, funding for urban flood levees has been announced by the NSW and Australian Governments under Category D of the Disaster Recovery Funding Arrangements (DRFA). The program aims to fund the assessment, repair, and practical betterment of levees throughout 13 LGAs on the NSW Mid and North Coast, including Byron Shire, and will be jointly delivered by Public Works (DRNSW) in partnership with the Department of Planning and Environment, Environment and Heritage Group and the various local councils.

Byron Shire Council (Council) are considering how this funding might be used in repairing and improving the SGB flood levee. The levee protects the urban areas on along the eastern and western sections of Capricornia Canal. A schematic depicting the levee alignment is presented in Figure 1.

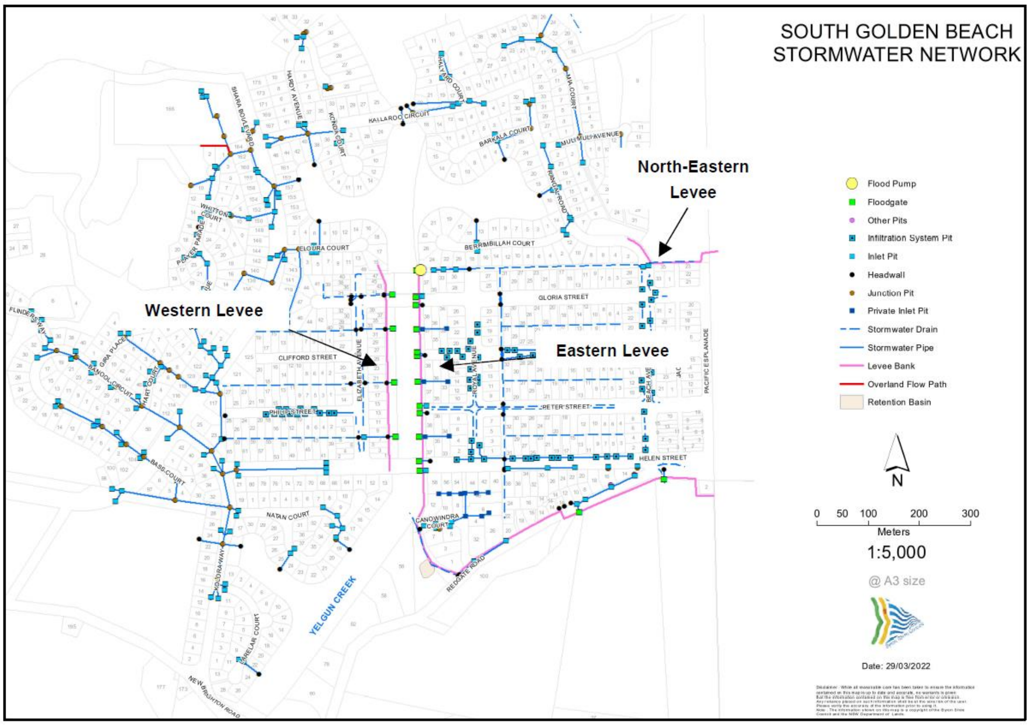


__Figure 1:__ Location of SGB levee (Engeny, 2022)

The urban area to the east is not able to gravity drain when the water level in Capricornia Canal is sufficiently high, so in 2006 a flood pump station was installed to pump these overland flows into the canal. An investigation into the feasibility of constructing a similar pump arrangement on the western side is currently being investigated by Council.

Council have engaged WEC to undertake a constraints and feasibility assessment to improve the levee flood protection by raising the levee and to prepare high level costings to repair and remediate the levee in accordance with a recent levee audit (Engeny, 2022).

Levee Repair and Maintenance Works

Following the large flood events of 2022, Engeny was engaged by Council to undertake visual inspection of the levee to identify structural defects / levee safety issues and provide recommendations for any investigations, engineering assessments and / or remedial works design considered necessary to address identified defects. The investigation is documented in a letter to council titled *South Golden Beach Levee Inspection* (Engeny 2022 – Attachment 4) and found the levee to be in good condition with no visual evidence of loss of structural integrity. The study made 20 recommendations to ensure the levees good condition is maintained:

- 2 items requiring immediate action (High Priority),
- 9 items requiring action within the next 12 months (Medium Priority); and,
- 9 non-critical items which require ongoing maintenance (Low Priority).

Further to the items identified by Engeny, WEC has identified 2 additional required actions as part of this study:

1. Based on survey provided by Council, undertaken in February 2023 (NSW Public Works), the crest of both the eastern and western portions of the levee generally fluctuates around the design level of RL 3.2 mAHD. However, as a levees flood immunity is only as high as its lowest crest elevation, the lowest crest levels have been identified from the survey. The lowest level surveyed on the western levee is RL 3.01mAHD (chainage 369.64m), while the lowest on the eastern levee is RL 3.08 (chainage 1541.86m). The North Byron Floodplain Risk Management Study and Plan (WMA, 2020) specifies the current day 1% Annual Exceedance Probability (AEP) flood level in the Capricornia Canal as 2.9mAHD (Table 6 of the study). This level is below the lowest crest elevations identified in the NSW Public Works survey of the levee (Feb 2023). The levee therefore currently provides protection for the 1% AEP event with a freeboard of 110mm on the western side and 180mm on the eastern side. This is less than the 300mm freeboard adopted for the design of the levee (design crest = RL 3.2mAHD). It is recommended that the survey be reviewed and any locations which the levee crest elevation is less than RL 3.2mAHD are filled back to the design level.
2. A site inspection carried out on the 9/11/23 found that debris build up and sediment deposition has rendered the northern most flap gate on the western levee unable to close, as depicted in Figure 2. It is recommended clearing of this flap gate be undertaken as a matter of urgency as it effectively provides a breach in the levee and may have contributed to the deep flooding experienced on the downstream side of the levee during the February 2022 flood event.

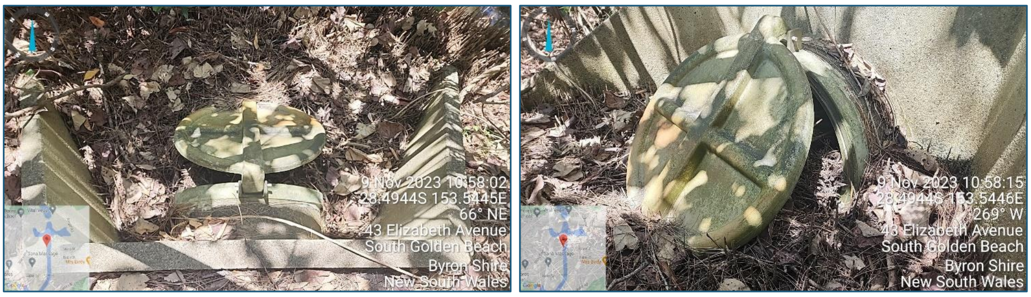


Figure 2: *Open flap valve at northern end of western levee*

Council requires cost estimates of undertaking these recommendations and establishment as to how they will be funded, that is, whether they fit into the government funding agreement or require Council funding. This is included in the scope of this report.

The recommended actions table has been extracted from the Engeny report and is presented below, alongside high-level opinion of costs (EOC) to undertake the works, the EOC calculations are presented in Attachment 1. Also presented is the recommended funding source.

The identified funding sources are based on the NSW Public Works Flood Levee Repair and Maintenance Program letter. The letter states the funding is for:

- Assess and understand physical and environmental characteristics of levees.
- Record and confirm current levee conditions, including damage and causes.
- Develop a prioritised repair plan with cost estimates for flood-related damages.
- Identify and implement improvements for urban area levee resilience.
- Evaluate the reliability of levees for potential future flood events.

It is understood that general maintenance activities are Councils responsibility to fund.

Table 1: *Recommended levee works including costings and proposed funding source*

No.	Recommendation	Recommendation Type	Priority
Engeny 2022			
General			
1 EOC: $1,000/mth Funding source: Council	Commence undertaking routine inspections (i.e. monthly) of the Levees	Levee Safety	Low
North- Eastern Levee			
2 EOC: $1,150 Funding source: NSW PW Grant	Repair the existing crest sinkhole by backfilling the hole with low permeability clay. Modify the surrounding crest surface levels with gravel sheeting to promote free draining conditions to the upstream side of the crest to prevent ponding of water on the crest. Any works undertaken should not lower the existing crest levels. Continue to monitor the area following the repair works, including inspecting the upstream batter and downstream batter / toe in this area, for any signs of internal erosion / sinkholes.	Levee Safety	High
3 EOC: $4,600/yr Funding source: Council	Poison and cut small trees / saplings / shrubs with trunks < 100 mm diameter	Maintenance	Low
4 EOC: $2,300/yr Funding source: Council	Remove debris downstream from drainage channel to reinstate free draining condition to allow water to drain away from the downstream toe and minimise saturation of the levee foundations.	Maintenance	Low

No.	Recommendation	Recommendation Type	Priority
Eastern Levee			
5 EOC: $2,000/mth Funding source: Council	Mow grass on the embankment where possible, to allow for improved observation of levee embankment condition.	Maintenance	Low
6 EOC: $4,600/yr Funding source: Council	Poison and cut small trees / saplings / shrubs with trunks < 100 mm diameter	Maintenance	Low
7 EOC: $2,300/yr Funding source: Council	Clear / slash dense vegetation immediately upstream and downstream of the flood gates / culvert inlets and outlets	Maintenance	Medium
8 EOC: $1,150/qtr Funding source: Council	Remove debris from drainage channel between Peter and Helen Street to reinstate free draining condition and minimise saturation of the levee foundations.	Maintenance	Low
9 EOC: $10,000^ Funding source: NSW PW Grant	Undertake desktop stability analysis of the levee to determine the sensitivity of factor of safety against instability is to varying crest widths and batter slopes and whether the embankment meets recommended factors of safety.	Levee Safety	Medium
10 EOC: $5,000 Funding source: NSW PW Grant	Undertake detailed ground survey of the levee to determine critical sections for stability analysis.	Levee Safety	Medium
11 EOC: $8,000 (risk audit) Funding source: NSW PW Grant	Undertake a risk audit / qualitative risk assessment on existing structures constructed on the levee to quantify potential impact on levee structural integrity. OR Remove existing structures constructed on the levee and develop remediation design to reinstate levee as per the original design intent.	Levee Safety	Medium
12 EOC: Included in Item 1 Funding source: -	Monitor existing retaining walls as part of monthly routine inspections. If condition of retaining walls further deteriorates develop remediation design.	Maintenance	Medium

No.	Recommendation	Recommendation Type	Priority
13 EOC: Included in Item 1 Funding source: -	Monitor existing culvert inlet / outlet cracking and spalling as part of a monthly routine inspections. Repair if cracking exceeds 5mm or condition continues to significantly deteriorate.	Maintenance	Low
14 EOC: $1,500 Funding source: NSW PW Grant	Repair damaged flood gate near the Southern Golden Beach Skate Park	Maintenance	High
Western Levee			
15 EOC: $2,000/mth Funding source: Council	Mow grass on the embankment where possible, to allow for improved observation of levee embankment condition.	Maintenance	Low
16 EOC: $4,600/yr Funding source: Council	Poison and cut small trees / saplings / shrubs with trunks < 100 mm diameter	Maintenance	Low
17 EOC: $2,300/yr Funding source: Council	Clear / slash dense vegetation immediately upstream and downstream of the flood gates / culvert inlets and outlets	Maintenance	Medium
18 EOC: $10,000^ Funding source: NSW PW Grant	Undertake desktop stability analysis of the levee to determine the factor of safety against instability and whether the embankment meets recommended factors of safety	Levee Safety	Medium
19 EOC: $5,000 Funding source: NSW PW Grant	Undertake detailed ground survey of the levee to determine critical section for stability analysis.	Levee Safety	Medium
20 EOC: $16,000 (risk audit) Funding source: NSW PW Grant	Undertake a risk audit / qualitative risk assessment on existing structures constructed on the levee to quantify potential impact on levee structural integrity. OR Remove existing structures constructed on the levee and develop remediation design to reinstate levee as per the original design intent.	Levee Safety	Medium

No.	Recommendation	Recommendation Type	Priority
Wilde Engineering Consulting			
21 EOC: $1,150 Funding source: Council	Clear the debris and sediment blocking the northern most open flap valve on the eastern levee (refer Figure 2). It is recommended that the Mangroves growing around the flap valve are also cleared to allow for a free flowing, unimpeded outlet, and to reduce the risk of future re-blockage. It is noted that machinery access to the outlet is impeded by vegetation and steep banks and the works will likely require manual (hand) excavation and clearing. It is also noted that the clearing of mangroves will likely require a permit from Fisheries NSW unless the works fall under Councils existing stormwater maintenance permit. Confirmation should be sought prior to undertaking the works.	Maintenance	High
22 EOC: $4,600 Funding source: NSW PW Grant	Reinstate all locations where the levee crest elevation is less than RL 3.2mAHD back to the design level, as per the Feb 2023 NSW Public Works survey (Attachment 2)	Levee Safety	Medium

^ Cost of undertaking desktop stability analysis per levee (east and west) is anticipated to reduce to $15,000 if undertaken as a single project.
* EOC = Estimated Opinion of Cost

Levee Raising Assessment

Council wishes to undertake an assessment into the costs and benefits of raising the SGB flood levee. Two nominal height increases have been identified by Council for this analysis: 300mm and 600mm. As discussed above, the current design height of the levee is RL 3.2mAHD, so the proposed works would bring the levee height to RL 3.5mAHD and RL 3.8mAHd respectively.

Constraints

A site inspection of the levee was carried out on the 9/11/23 to inform a preliminary constraints study of the levee raising works. This study identified several significant constraints which will all have substantial impact on the cost of constructing the levee raising. These constraints include:

- **Existing infrastructure** would require moving, reconfiguration or reconstruction to allow for the levee raising. Existing infrastructure includes the foot bridge and associated footpaths, the stormwater pump station, sewer pump stations, multiple driveways, Redgate Rd, Canowindra Ct and many private property fences. The road raisings will need to tie into existing driveways and adjacent roads, which may impose the need to regrade private driveways and blocks, potentially impacting dwellings.
- **Large trees** (>500mm diam, 15-20m tall) along both the eastern and western levees which would require removal to raise the levee. To ensure structural integrity and longevity of the levee the tree root balls would require removal. This would necessitate reconstructing large sections of the existing levee.
- **Constructability** – Due to the levee's proximity to private blocks and the dense vegetation in the vicinity there is very limited machinery access from land to undertake the raising works. A barge could be employed to grant greater access to the levee; however, this would add considerable cost to the construction project.
- Raising of the levee would require **steep batters or retaining walls** throughout the extents due to levees vicinity to property boundaries, roads, and Capricornia Canal. These will again add significant expense, but also likely require the installation of pedestrian barrier fence, which is anticipated to be unpopular among residents.
- The site will have a complex approval pathway as large areas of mangroves will require disturbance, which will necessitate NSW Fisheries permits.

Photos exemplifying the constraints identified above are presented in Attachment 3.

Current Flood Immunity

As stated above, the North Byron FRMSP (WMA, 2020) specifies the current day 1% AEP flood level in the Capricornia Canal as 2.9mAHD (Table 6 of the study). Considering the design crest level of the levee or RL 3.2mAHD (which requires reinstatement in areas (refer item 22 in Table 1), this allows for 300mm freeboard during the 1% AEP flood, which is considered an appropriate design freeboard. It is also noted that considering the lowest elevations on the eastern and western levee, identified in the NSW Public Works survey (Feb 2023), the levee still provides 1% AEP flood immunity with a freeboard of 110mm on the western side and 180mm on the eastern side.

In terms of levee protection in the Northern Rivers area, 1% AEP is a relatively good level of protection, equalling the highest level of protection given by any levees in the area.

Levee	Flood Immunity (AEP)	Council
Murwillumbah – Main St	1.25%	Tweed Shire council
Murwillumbah – South	20%	Tweed Shire council
Murwillumbah – East	1%	Tweed Shire council
Murwillumbah – Dorothy/Williams St's	1%	Tweed Shire council
Tweed Heads South	5%	Tweed Shire council
Pottsville – Seabreeze Estate	1%	Tweed Shire council
Lismore City	10%	Lismore City Council

Discussion on Potential Benefits of Raisins Levee

The flood levels of the 0.2% and 0.05% AEP events are not reported in the North Byron FRMSP (WMA, 2020), however the PMF is reported as RL 5.2mAHD, significantly above the crest of the existing levee and both proposed raising heights. Therefore, the benefits of raising the levee will increase the flood immunity from 1% AEP to an event larger than the 1% AEP but less than the PMF, i.e. potentially 0.2% AEP or 0.05% AEP of the events modelled in the FRMSP.

The NSW Department of Planning and Environment - Flood Risk Management Guideline MM01 (DPE, Aug 2023) outlines the Average Annual Damage (AAD) approach as a key method for assessing the benefits of flood mitigation measures, such as a flood levee. The AAD approach is a quantitative method used to evaluate the potential annual economic damage from flooding in a specific area.

A summary of how the AAD approach is used in the context of raising SGB levee is given below:

1. **Flood Damage Estimation**: The AAD method involves estimating the potential damage caused by floods of different magnitudes (i.e. AEPs). This estimation is based on various factors like property values, land use, and the vulnerability of structures and assets in the floodplain.
2. **Economic Analysis**: The estimated damages are then translated into monetary values. This step considers both direct damages (like property and infrastructure damage) and indirect damages (such as business interruptions).
3. **Average Annual Damage Calculation**: The AAD is calculated by integrating the damage estimates over a range of flood events, weighted by their probability of occurrence. This gives an average value of expected annual damage due to flooding.
4. **Assessment of Levee Benefits**: The AAD without the levee is compared to the AAD with the levee in place. The difference between these two values represents the annual economic benefits provided by the levee in terms of reduced flood damage.

5. **Cost-Benefit Analysis**: Finally, the cost of constructing and maintaining the levee is compared to the benefits of reduced flood damage. This analysis helps determine whether the investment in the levee is economically justified.
6. **Decision Making**: The results of the AAD approach, combined with other considerations like construction constraints, environmental impacts, community preferences, inform decision-making regarding floodplain management and the construction of flood mitigation structures.

The Average Annual Damage (AAD) minimises the impact of rare, high-damage flood events in its calculations due to their low probability of occurrence (see point 3 above), focusing instead on the more frequent, less severe events which, over time, contribute more significantly to the annual expected damages. Therefore, the benefits gained by increasing the flood immunity of the levee to 0.2% or even 0.05% is expected to be small relative to the costs of construction, which is expected to be large due to the constraints identified above.

Conclusion

Summarising the information presented above in the Levee Raising Assessment Section of this report:

- The current levee has a flood immunity greater than the 1% AEP event, which compared to other levees in the Northern Rivers is high.
- Raising the levee is not expected to have a significant impact on the AAD of the area, as it will only increase flood immunity for rare occurrence flood events.
- Significant constraints have been identified as part of the initial constraints study, indicating the cost and complexity of raising the levee would be high relative to the expected benefits.
- Due to the reasons stated above the cost-benefit ratio of the levee is expected to be low.

Based on the reasons identified above, it is recommended that raising the levee by either 300mm or 600mm is not undertaken.

Yours sincerely

J. Wilde

Josh Wilde

Director | Principal Engineer

Wilde – Engineering Consulting Pty. Ltd.

Ph: 0492850181

Email: josh.wilde@wildeec.com

Attachments:

1. High-Level Opinion of Costs of Levee Inspection Recommended Actions
2. NSW Public Works Survey of SGB Levee (Feb 2023)
3. Photos Exemplifying Identified Constraints
4. South Golden Beach Levee Inspection (Engeny 2022)

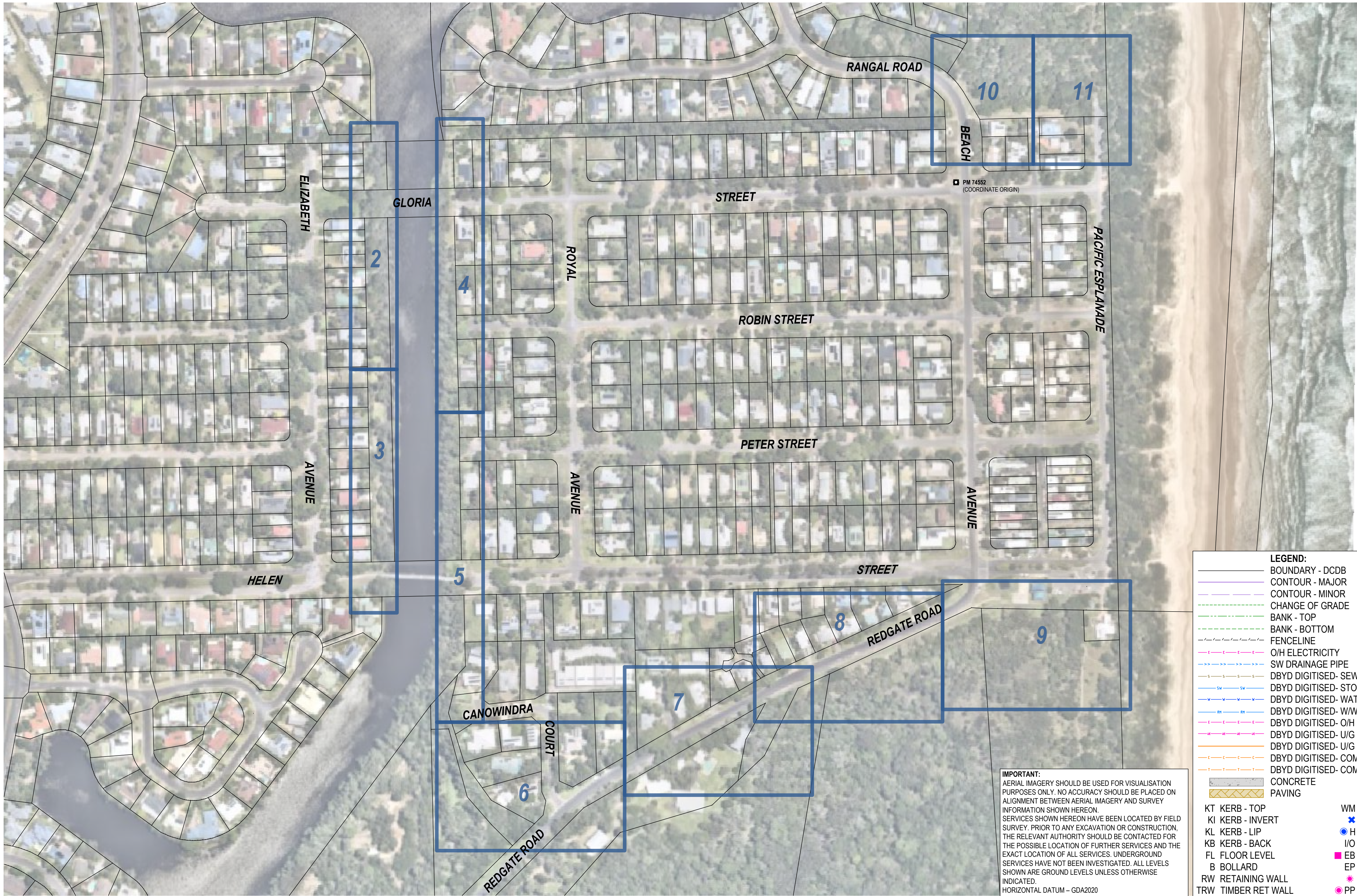
ATTACHMENT 1 HIGH-LEVEL COST ESTIMATES OF LEVEE INSPECTION RECOMMENDED ACTIONS

Item #	Recommendation type	Funding source	Unit	Quantity	Rate	Amount	Notes
1	Levee safety	Council	Day	1	$1,000	$ 1,000.00	Based on 2 Council staff on $120,000 p.a
2	Levee safety	Grant	Day	0.50	$ 2,300.00	$ 1,150.00	Based on Council weekly crew rate of $11,500.
3	Maintenance	Council	Week	2.00	$ 2,300.00	$ 4,600.00	Based on Council weekly crew rate of $11,500.
4	Maintenance	Council	Week	1.00	$ 2,300.00	$ 2,300.00	- Ongoing at 1 time per year (assumed) - Based on concil weekly crew rate of $11,500
5	Maintenance	Council	Day	1.00	$ 2,000.00	$ 2,000.00	- Ongoing, monthly (assumed) - Based on Council daily mawing rate of $2,000.
6	Maintenance	Council	Day	2.00	$ 2,300.00	$ 4,600.00	- Ongoing at 1 time per year (assumed) - Based on concil weekly crew rate of $11,500
7	Maintenance	Council	Day	1.00	$ 2,300.00	$ 2,300.00	- Ongoing at 1 time per year (assumed) - Based on concil weekly crew rate of $11,500
8	Maintenance	Council	Day	0.50	$ 2,300.00	$ 1,150.00	- Ongoing at 1 time per 3 months (assumed) - Based on concil weekly crew rate of $11,500
9	Levee safety	Grant	Item	1.00	$ 10,000.00	$ 10,000.00	Reduced to $7,500 if undertakewn in conjunction with item 18
10	Levee safety	Grant	Item	1.00	$ 5,000.00	$ 5,000.00	
11	Levee safety	Grant	Item	1.00	$ 8,000.00	$ 8,000.00	$2,000 per outlet assumed
12	Maintenance	-	-	-	-	-	Included in item 1
13	Maintenance	-	-	-	-	-	Included in item 1
14	Maintenance	Grant	Day	1	$1,500	$ 1,500.00	Based on 2 Council staff on $120,000 p.a and $500 of materials
15	Maintenance	Council	Day	1.00	$ 2,000.00	$ 2,000.00	- Ongoing, monthly (assumed) - Based on Council daily mawing rate of $2,000.
16	Maintenance	Council	Day	2.00	$ 2,300.00	$ 4,600.00	- Ongoing at 1 time per year (assumed) - Based on concil weekly crew rate of $11,500
17	Levee safety	Council	Day	1.00	$ 2,300.00	$ 2,300.00	- Ongoing at 1 time per year (assumed) - Based on concil weekly crew rate of $11,500
18	Levee safety	Grant	Item	1.00	$ 8,000.00	$ 8,000.00	Reduced to $7,500 if undertakewn in conjunction with item 9
19	Levee safety	Grant	Item	1.00	$ 5,000.00	$ 5,000.00	$2,000 per outlet assumed
20	Levee safety	Grant	Item	1.00	$ 16,000.00	$ 16,000.00	
21	Maintenance	Council	Day	0.50	$ 2,300.00	$ 1,150.00	Based on Council weekly crew rate of $11,500.
22	Levee safety	Grant	Day	2.00	$ 2,300.00	$ 4,600.00	Based on Council weekly crew rate of $11,500.

Legend

Low Priority
Medium Priority
High Priority

ATTACHMENT 2 NSW PUBLIC WORKS SURVEY OF SGB LEVEE (FEB 2023)



LEGEND:

- BOUNDARY - DCDB
- CONTOUR - MAJOR
- CONTOUR - MINOR
- CHANGE OF GRADE
- BANK - TOP
- BANK - BOTTOM
- FENCELINE
- O/H ELECTRICITY
- SW DRAINAGE PIPE
- DBYD DIGITISED- SEWER
- DBYD DIGITISED- STORMWATER
- DBYD DIGITISED- WATER
- DBYD DIGITISED- W/WATER RISING MAIN
- DBYD DIGITISED- O/H ELECTRICITY
- DBYD DIGITISED- U/G HIGH VOLTAGE
- DBYD DIGITISED- U/G COMMS - NBN
- DBYD DIGITISED- COMMS
- DBYD DIGITISED- COMMS MAINS
- CONCRETE
- PAVING

KT	KERB - TOP	WM	WATER METER
KI	KERB - INVERT		STOP VALVE
KL	KERB - LIP	H	HYDRANT
KB	KERB - BACK	I/O	SEWER I/O
FL	FLOOR LEVEL	EB	ELEC PILLAR BOX
B	BOLLARD	EP	ELECTRICITY PIT
RW	RETAINING WALL		STREET LIGHT
TRW	TIMBER RET WALL	PP	POWER POLE
BRW	CONC BLOCK RET WALL		COMMS PIT
ST	STAIRS		TREE

IMPORTANT:
AERIAL IMAGERY SHOULD BE USED FOR VISUALISATION PURPOSES ONLY. NO ACCURACY SHOULD BE PLACED ON ALIGNMENT BETWEEN AERIAL IMAGERY AND SURVEY INFORMATION SHOWN HEREON.
SERVICES SHOWN HEREON HAVE BEEN LOCATED BY FIELD SURVEY. PRIOR TO ANY EXCAVATION OR CONSTRUCTION, THE RELEVANT AUTHORITY SHOULD BE CONTACTED FOR THE POSSIBLE LOCATION OF FURTHER SERVICES AND THE EXACT LOCATION OF ALL SERVICES. UNDERGROUND SERVICES HAVE NOT BEEN INVESTIGATED. ALL LEVELS SHOWN ARE GROUND LEVELS UNLESS OTHERWISE INDICATED.
HORIZONTAL DATUM – GDA2020
MAP PROJECTION – MGA 2020(ZONE 56)
ORIGIN: PM74552 (E: 553 787. 218 N: 6 847 918. 658)
SF: 0.999629 **GRID DISTANCES SHOWN.**
VERTICAL DATUM – AHD (AUSGEOID2020)

0 60m

ISSUE	DATE	REVISION
A	17/02/23	FIRST RELEASE

Tony Hart REGISTERED SURVEYOR

BARKER RYAN STEWART

SYDNEY P: 02 9659 0005
CENTRAL COAST P: 02 4325 5255
HUNTER P: 02 4966 8388
COFFS HARBOUR P: 02 5642 4222
NORTHERN RIVERS P: 02 6681 6696
www.brs.com.au
mail@brs.com.au

PLANS ISSUED BY BRS NORTHERN RIVERS (ABN 41 657 245 317) PART OF THE BARKER RYAN STEWART GROUP

SCALE:	1:1500 (A1)	CONTOURS:	0.5m INTERVAL	CLIENT:	NSW PUBLIC WORKS
SURVEYOR:	PF RB	DATUM:	AHD	PROJECT:	DETAIL
DRAWN:	ED	ORIGIN:	PM74552		
DATE:	FEB '23	RL:	2.672	LGA:	BYRON
CAD REF:	221040-01			SOURCE:	AERIAL: NEARMAP (DECEMBER 2022)

PLAN OF FLOOD LEVEE SURVEY

SOUTH GOLDEN BEACH

(THIS PLAN MAY NOT BE THE LATEST ISSUE) SHEET 1 OF 11 SHEETS | ISSUE: A

LEGEND:

- BOUNDARY - DCDB
- CONTOUR - MAJOR
- CONTOUR - MINOR
- CHANGE OF GRADE
- BANK - TOP
- BANK - BOTTOM
- FENCELINE
- O/H ELECTRICITY
- SW DRAINAGE PIPE
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- DBYD DIGITISED- W/WATER RISING MAIN
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- DBYD DIGITISED- U/G HIGH VOLTAGE
- DBYD DIGITISED- U/G COMMS - NBN
- DBYD DIGITISED- COMMS
- DBYD DIGITISED- COMMS MAINS
- CONCRETE
- PAVING

KT	KERB - TOP	WM	WATER METER
KI	KERB - INVERT		STOP VALVE
KL	KERB - LIP	H	HYDRANT
KB	KERB - BACK	I/O	SEWER I/O
FL	FLOOR LEVEL	EB	ELEC PILLAR BOX
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BRW	CONC BLOCK RET WALL		COMMS PIT
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SF: 0.999629 **GRID DISTANCES SHOWN.**
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0 8m

ISSUE	DATE	REVISION
A	17/02/23	FIRST RELEASE

Tony Hart REGISTERED SURVEYOR

BARKER RYAN STEWART

SYDNEY P: 02 9659 0005
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PLANS ISSUED BY BRS NORTHERN RIVERS (ABN 41 657 245 317) PART OF THE BARKER RYAN STEWART GROUP

SCALE:	1:200 (A1)
SURVEYOR:	PF RB
DRAWN:	ED
DATE:	FEB '23
CAD REF:	221040-01

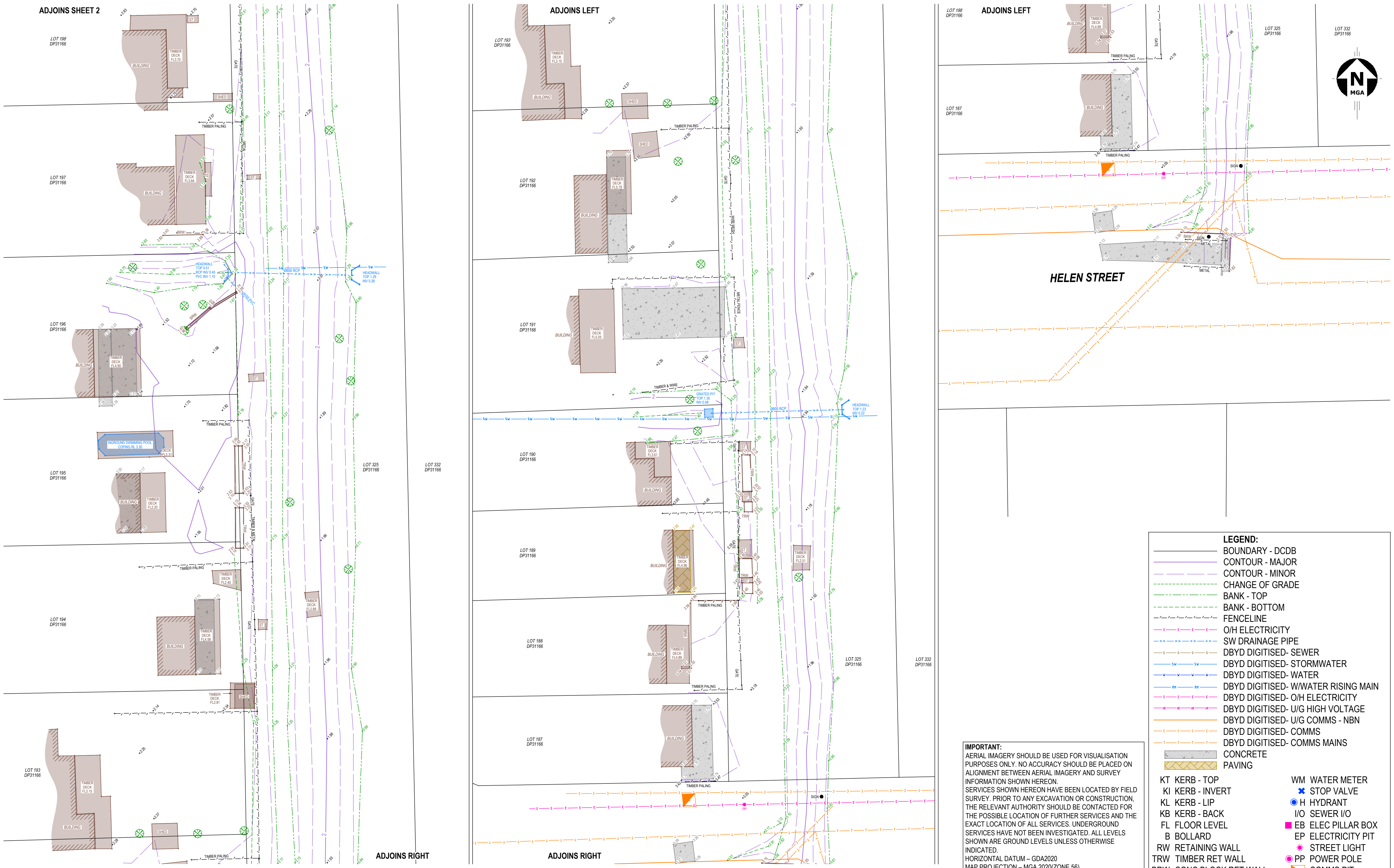
CONTOURS:	0.5m INTERVAL
DATUM:	AHD
ORIGIN:	PM74552
RL:	2.672

CLIENT:	NSW PUBLIC WORKS
PROJECT:	DETAIL
LGA:	BYRON
SOURCE:	AERIAL: NEARMAP (DECEMBER 2022)

PLAN OF FLOOD LEVEE SURVEY

SOUTH GOLDEN BEACH

(THIS PLAN MAY NOT BE THE LATEST ISSUE) **SHEET 2 OF 11 SHEETS | ISSUE: A**



LEGEND:

- BOUNDARY - DCDB
- CONTOUR - MAJOR
- CONTOUR - MINOR
- CHANGE OF GRADE
- BANK - TOP
- BANK - BOTTOM
- FENCELINE
- O/H ELECTRICITY
- SW DRAINAGE PIPE
- DBYD DIGITISED- SEWER
- DBYD DIGITISED- STORMWATER
- DBYD DIGITISED- WATER
- DBYD DIGITISED- W/WATER RISING MAIN
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- DBYD DIGITISED- U/G HIGH VOLTAGE
- DBYD DIGITISED- U/G COMMS - NBN
- DBYD DIGITISED- COMMS
- DBYD DIGITISED- COMMS MAINS
- CONCRETE
- PAVING

KT	KERB - TOP	WM	WATER METER
KI	KERB - INVERT		STOP VALVE
KL	KERB - LIP	H	HYDRANT
KB	KERB - BACK	I/O	SEWER I/O
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B	BOLLARD	EP	ELECTRICITY PIT
RW	RETAINING WALL		STREET LIGHT
TRW	TIMBER RET WALL	PP	POWER POLE
BRW	CONC BLOCK RET WALL		COMMS PIT
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HORIZONTAL DATUM – GDA2020
MAP PROJECTION – MGA 2020(ZONE 56)
ORIGIN: PM74552 (E: 553 787. 218 N: 6 847 918. 658)
SF: 0.999629 **GRID DISTANCES SHOWN.**
VERTICAL DATUM – AHD (AUSGEOID2020)

0 8m

ISSUE	DATE	REVISION
A	17/02/23	FIRST RELEASE

Tony Hart REGISTERED SURVEYOR

BARKER RYAN STEWART

SYDNEY P: 02 9659 0005
CENTRAL COAST P: 02 4325 5255
HUNTER P: 02 4966 8388
COFFS HARBOUR P: 02 5642 4222
NORTHERN RIVERS P: 02 6681 6696
www.brs.com.au
mail@brs.com.au

PLANS ISSUED BY BRS NORTHERN RIVERS (ABN 41 657 245 317) PART OF THE BARKER RYAN STEWART GROUP

SCALE: 1:200 (A1)
SURVEYOR: PF RB
DRAWN: ED
DATE: FEB '23
CAD REF: 221040-01

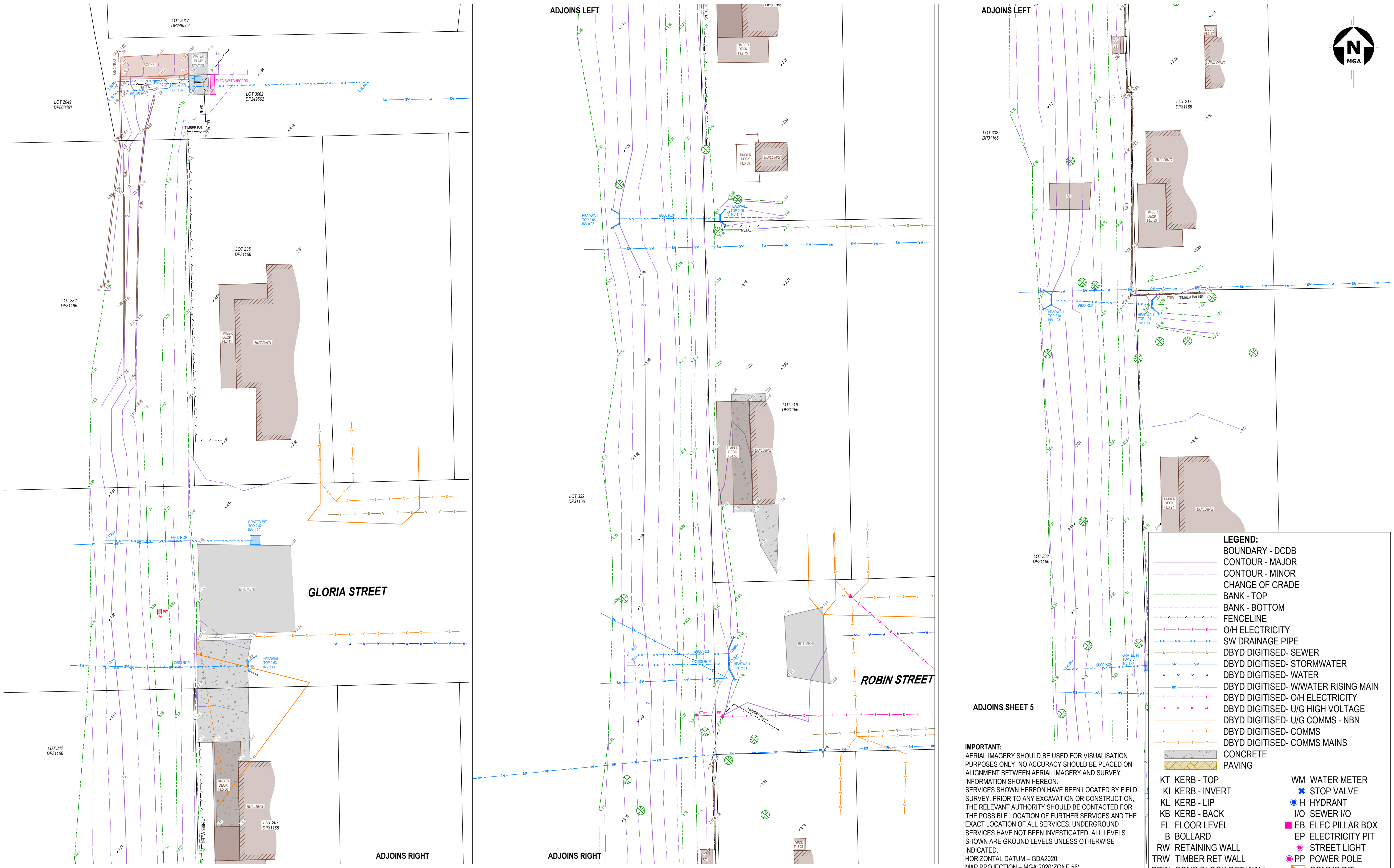
CONTOURS: 0.5m INTERVAL
DATUM: AHD
ORIGIN: PM74552
RL: 2.672

CLIENT: NSW PUBLIC WORKS
PROJECT: DETAIL
LGA: BYRON
SOURCE: AERIAL: NEARMAP (DECEMBER 2022)

PLAN OF FLOOD LEVEE SURVEY

SOUTH GOLDEN BEACH

(THIS PLAN MAY NOT BE THE LATEST ISSUE) SHEET 3 OF 11 SHEETS | ISSUE: A



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SCALE:	1:200 (A1)	CONTOURS:	0.5m INTERVAL	CLIENT:	NSW PUBLIC WORKS
SURVEYOR:	PF RB	DATUM:	AHD	PROJECT:	DETAIL
DRAWN:	ED	ORIGIN:	PM74552		
DATE:	FEB '23	RL:	2.672	LGA:	BYRON
CAD REF:	221040-01			SOURCE:	AERIAL: NEARMAP (DECEMBER 2022)

PLAN OF FLOOD LEVEE SURVEY

SOUTH GOLDEN BEACH

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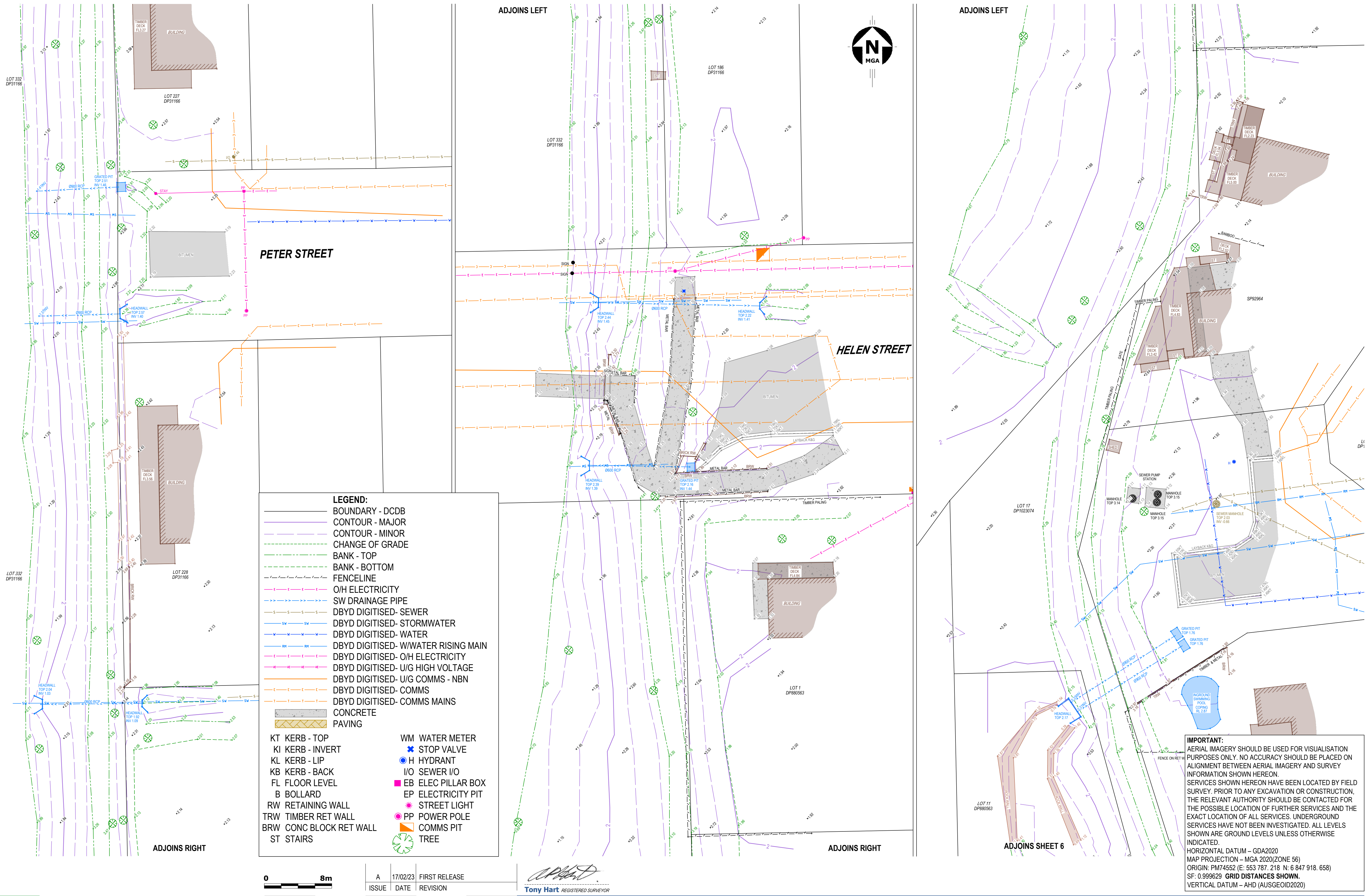

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PLAN OF FLOOD LEVEE SURVEY

SOUTH GOLDEN BEACH

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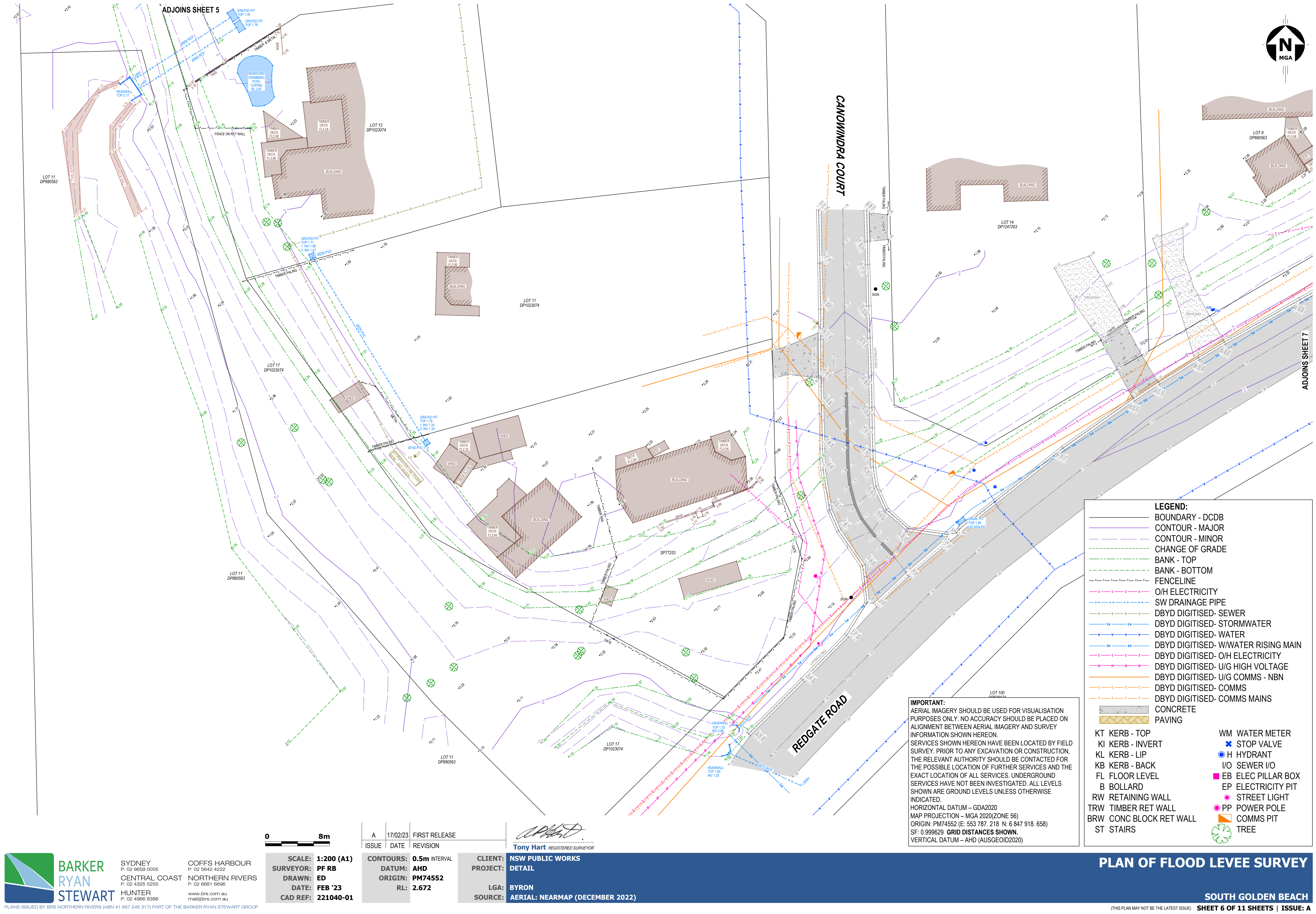
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ADJOINS SHEET 7
CANOWINDRA COURT
REDGATE ROAD
N
MGA
LOT 11 DP880563
LOT 13 DP1023074
LOT 11 DP1023074
LOT 17 DP1023074
LOT 14 DP1247263
LOT 8 DP880563
SP77253
LEGEND:
BOUNDARY - DCDB
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CONTOUR - MINOR
CHANGE OF GRADE
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PLAN OF FLOOD LEVEE SURVEY
SOUTH GOLDEN BEACH
(THIS PLAN MAY NOT BE THE LATEST ISSUE)
SHEET 6 OF 11 SHEETS | ISSUE: A

LEGEND:

BOUNDARY - DCDB
CONTOUR - MAJOR
CONTOUR - MINOR
CHANGE OF GRADE
BANK - TOP
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FENCELINE
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PLAN OF FLOOD LEVEE SURVEY

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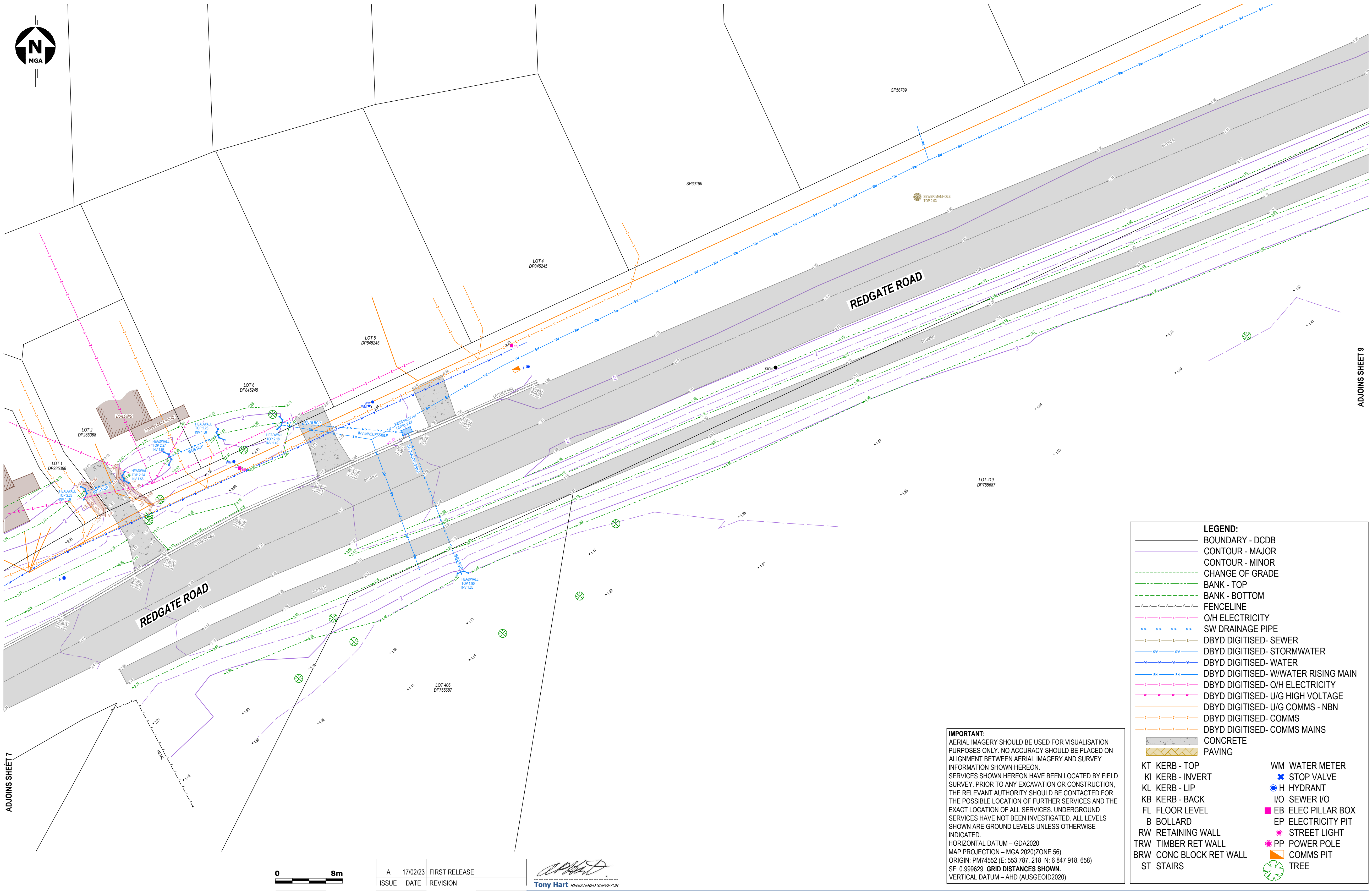

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PLAN OF FLOOD LEVEE SURVEY

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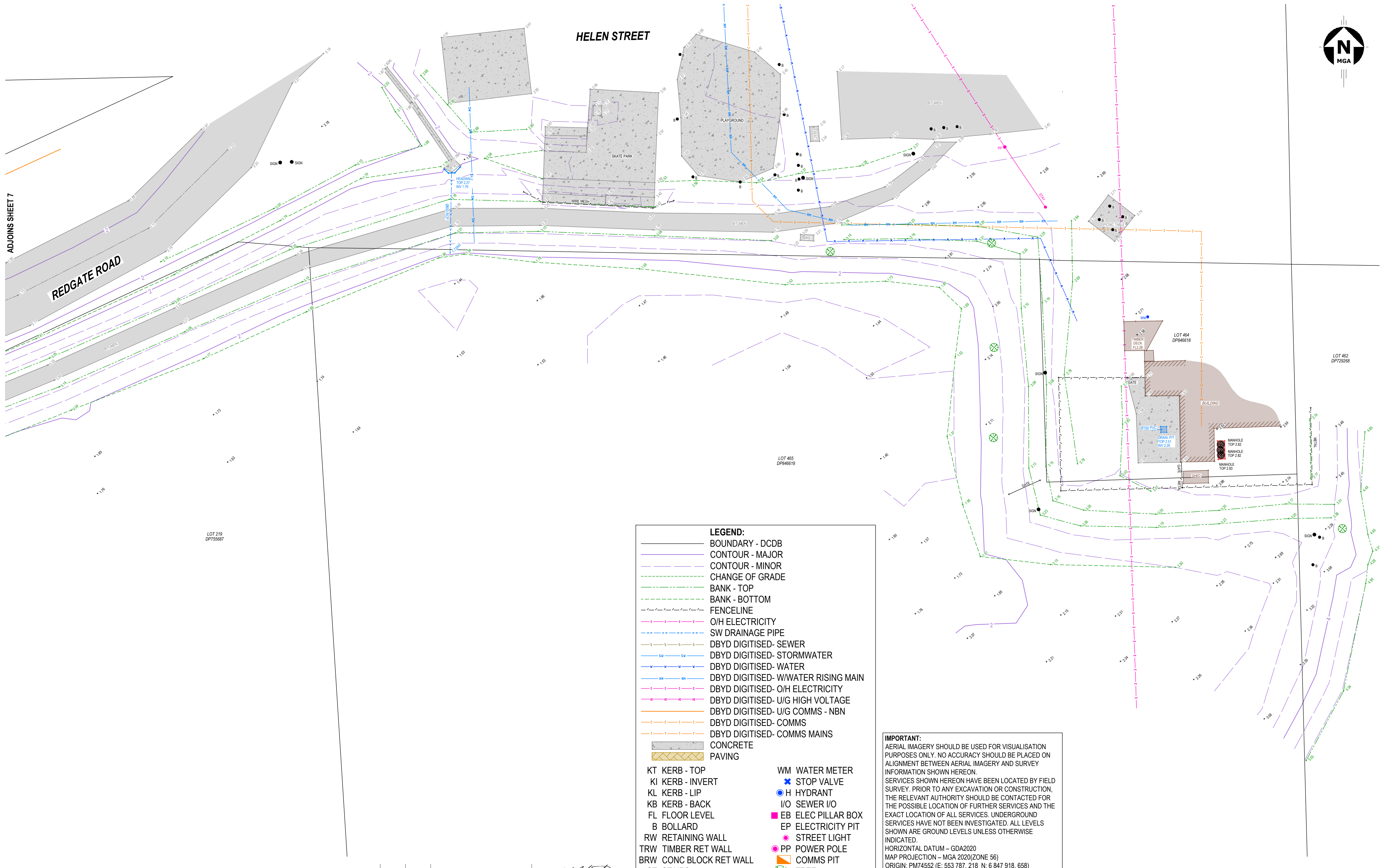

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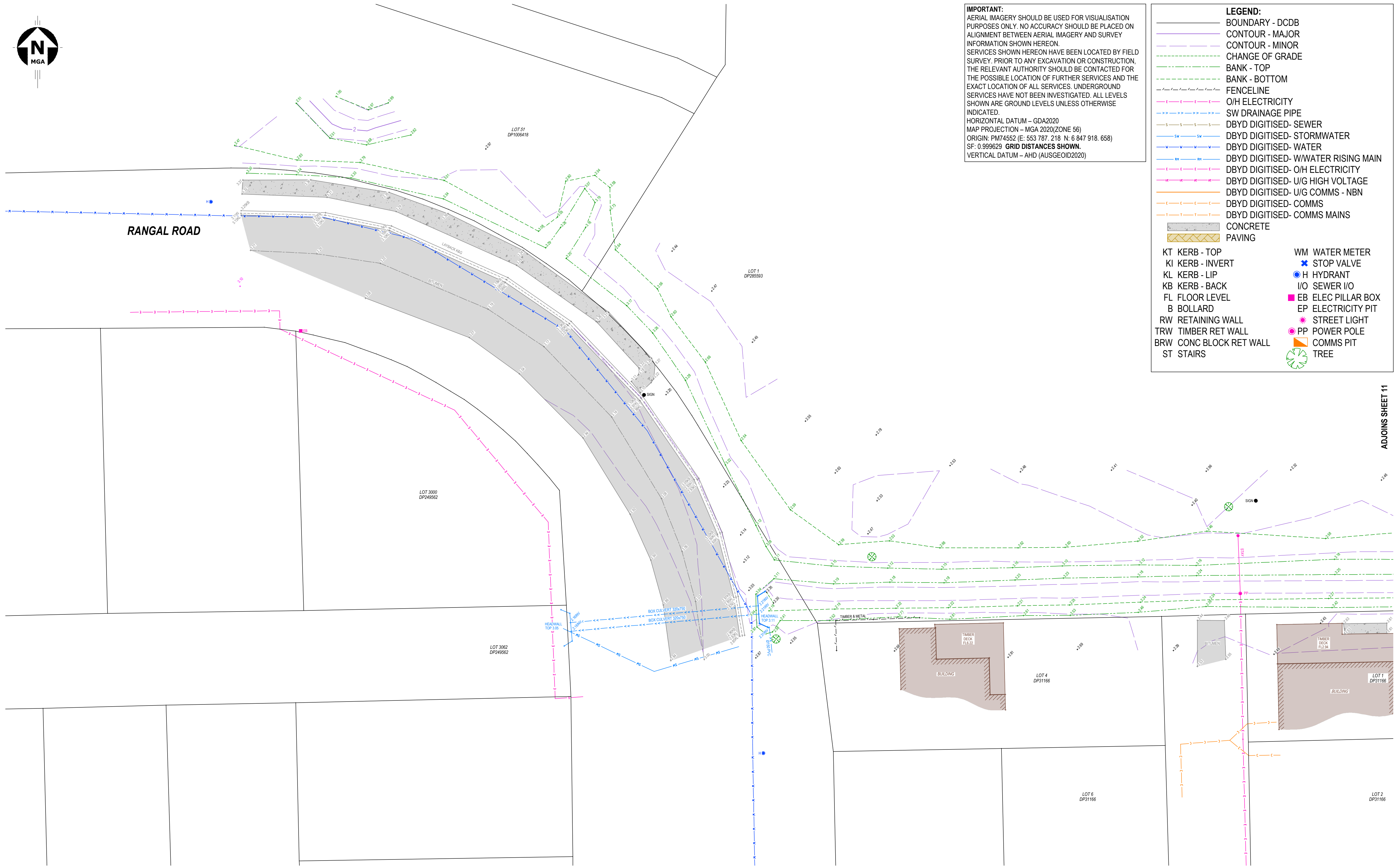

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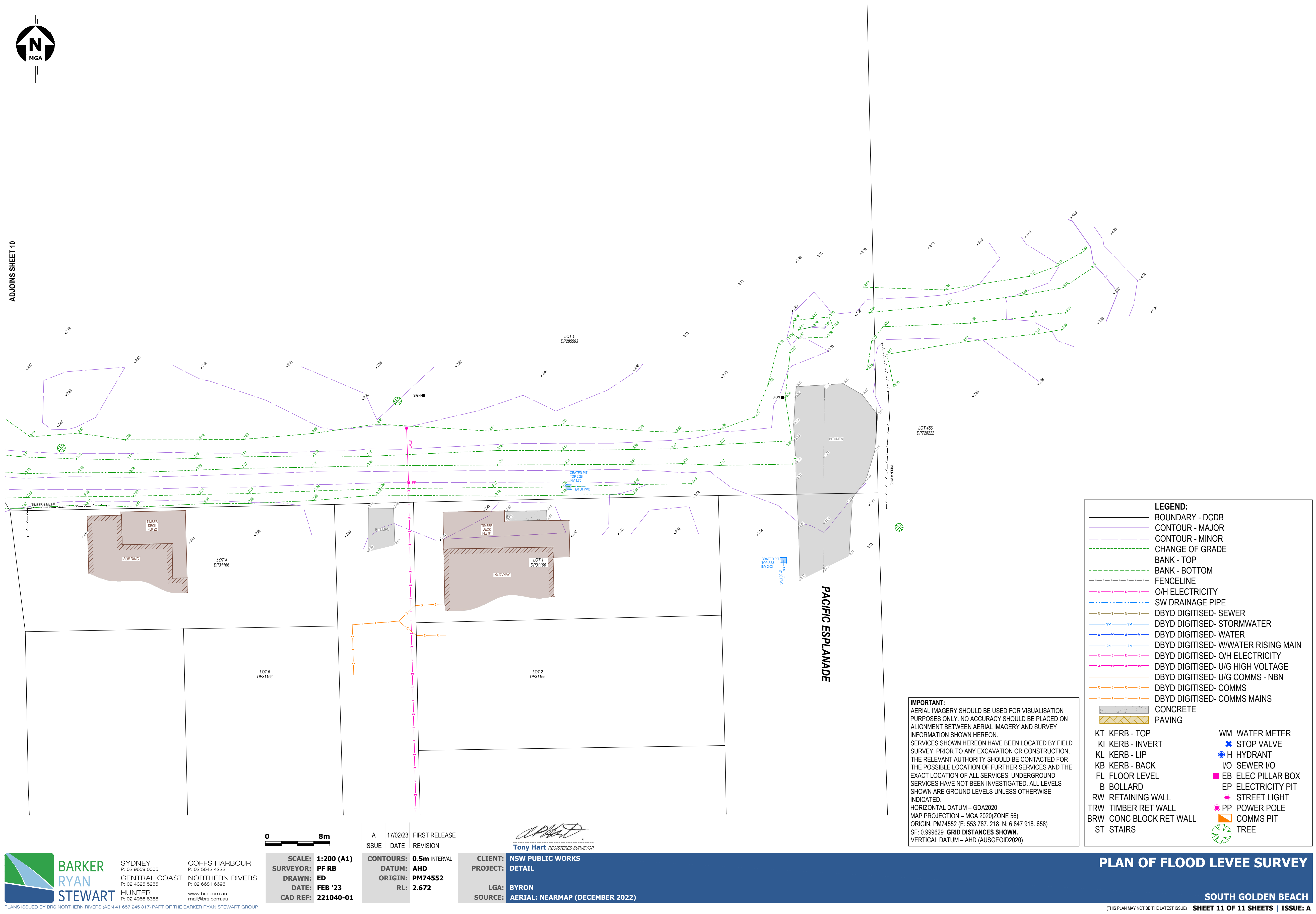
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MGA
ADJOINS SHEET 10
LOT 1
DP285593
LOT 456
DP728222
LOT 4
DP31166
LOT 1
DP31166
LOT 6
DP31166
LOT 2
DP31166
BUILDING
BITUMEN
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LEGEND:
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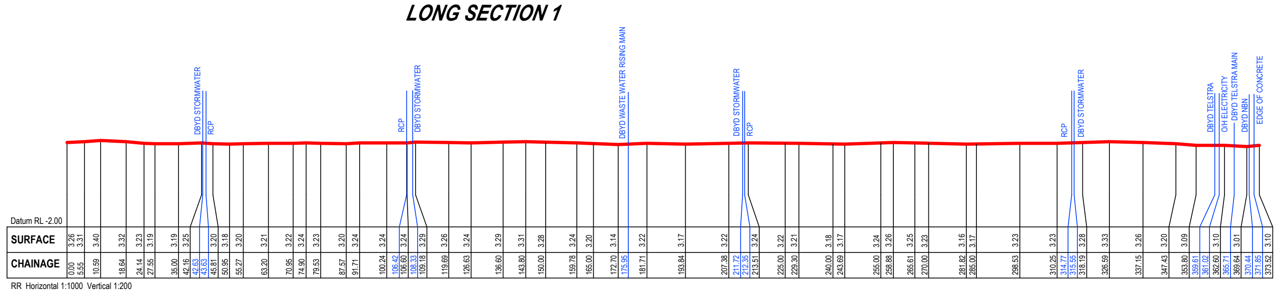
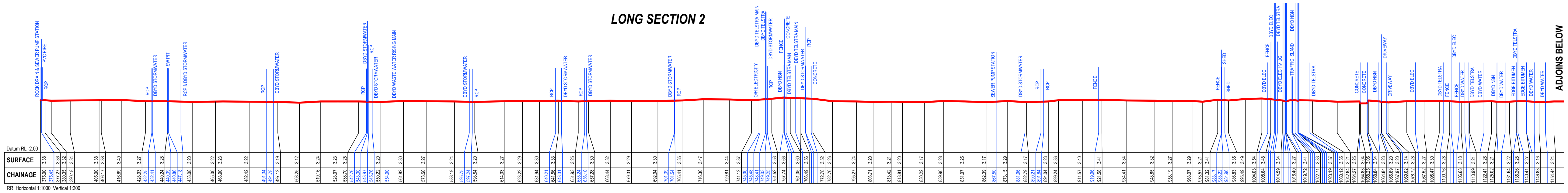
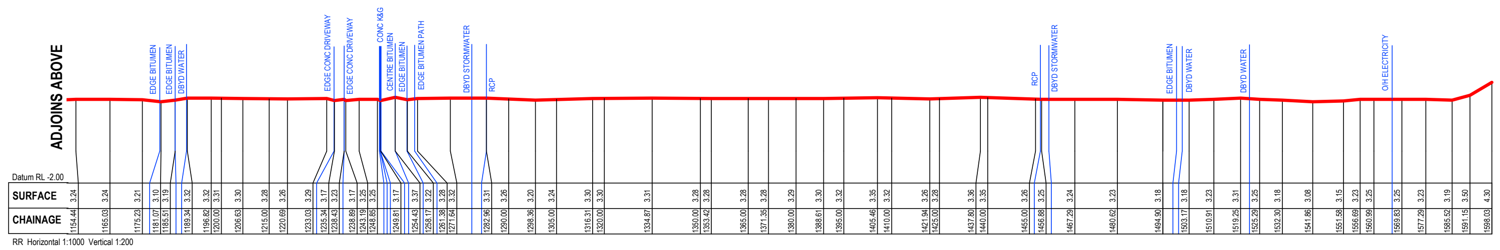
BRW CONC BLOCK RET WALL
ST STAIRS
WM WATER METER
STOP VALVE
H HYDRANT
I/O SEWER I/O
EB ELEC PILLAR BOX
EP ELECTRICITY PIT
STREET LIGHT
PP POWER POLE
COMMS PIT
TREE
IMPORTANT:
AERIAL IMAGERY SHOULD BE USED FOR VISUALISATION PURPOSES ONLY. NO ACCURACY SHOULD BE PLACED ON ALIGNMENT BETWEEN AERIAL IMAGERY AND SURVEY INFORMATION SHOWN HEREON.
SERVICES SHOWN HEREON HAVE BEEN LOCATED BY FIELD SURVEY. PRIOR TO ANY EXCAVATION OR CONSTRUCTION, THE RELEVANT AUTHORITY SHOULD BE CONTACTED FOR THE POSSIBLE LOCATION OF FURTHER SERVICES AND THE EXACT LOCATION OF ALL SERVICES. UNDERGROUND SERVICES HAVE NOT BEEN INVESTIGATED. ALL LEVELS SHOWN ARE GROUND LEVELS UNLESS OTHERWISE INDICATED.
HORIZONTAL DATUM – GDA2020
MAP PROJECTION – MGA 2020(ZONE 56)
ORIGIN: PM74552 (E: 553 787. 218 N: 6 847 918. 658)
SF: 0.999629 GRID DISTANCES SHOWN.
VERTICAL DATUM – AHD (AUSGEOID2020)
0 8m
A 17/02/23 FIRST RELEASE
ISSUE DATE REVISION
Tony Hart REGISTERED SURVEYOR
BARKER RYAN STEWART
SYDNEY P: 02 9659 0005
CENTRAL COAST P: 02 4325 5255
HUNTER P: 02 4966 8388
COFFS HARBOUR P: 02 5642 4222
NORTHERN RIVERS P: 02 6681 6696
www.brs.com.au
mail@brs.com.au
PLANS ISSUED BY BRS NORTHERN RIVERS (ABN 41 657 245 317) PART OF THE BARKER RYAN STEWART GROUP
SCALE: 1:200 (A1)
SURVEYOR: PF RB
DRAWN: ED
DATE: FEB '23
CAD REF: 221040-01
CONTOURS: 0.5m INTERVAL
DATUM: AHD
ORIGIN: PM74552
RL: 2.672
CLIENT: NSW PUBLIC WORKS
PROJECT: DETAIL
LGA: BYRON
SOURCE: AERIAL: NEARMAP (DECEMBER 2022)
PLAN OF FLOOD LEVEE SURVEY
SOUTH GOLDEN BEACH
(THIS PLAN MAY NOT BE THE LATEST ISSUE) SHEET 11 OF 11 SHEETS | ISSUE: A

LONG SECTION 1

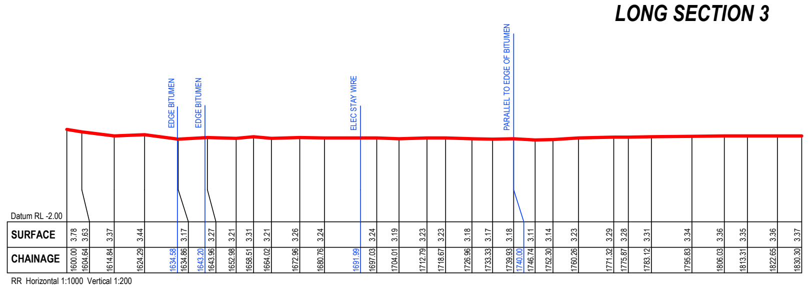


LONG SECTION 2





LONG SECTION 3



0 40m

ISSUE	DATE	REVISION
A	17/02/23	FIRST RELEASE

Tony Hart REGISTERED SURVEYOR

BARKER RYAN STEWART

SYDNEY P: 02 9659 0005
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PLANS ISSUED BY BRS NORTHERN RIVERS (ABN 41 657 245 317) PART OF THE BARKER RYAN STEWART GROUP

SCALE:	AS SHOWN	CONTOURS:	N/A INTERVAL	CLIENT:	NSW PUBLIC WORKS
SURVEYOR:	RB PF	DATUM:	AHD	PROJECT:	DETAIL
DRAWN:	ED	ORIGIN:	PM74552		
DATE:	FEB '23	RL:	2.672	LGA:	BYRON
CAD REF:	221040-02			SOURCE:	AERIAL: N/A

PLAN OF FLOOD LEVEE SURVEY
LONG SECTIONS

SOUTH GOLDEN BEACH

(THIS PLAN MAY NOT BE THE LATEST ISSUE) SHEET 1 OF 1 SHEETS | ISSUE: A

ATTACHMENT 3 PHOTOS EXEMPLIFYING IDENTIFIED CONSTRAINTS

Photo (taken 9/11/23)	Comment
	Large trees on downstream side of eastern bank amongst smaller trees and shrubs. Would require removal and reconstruction of levee in the event of levee raising.
	Existing retaining 3 walls at northern end of eastern levee, one forming the boundary of a private property.
	Stormwater pump station and spillway on easter levee, would require reconstruction in the event of levee raising.
	Stormwater pump station on easter levee, would require reconstruction in the event of levee raising.

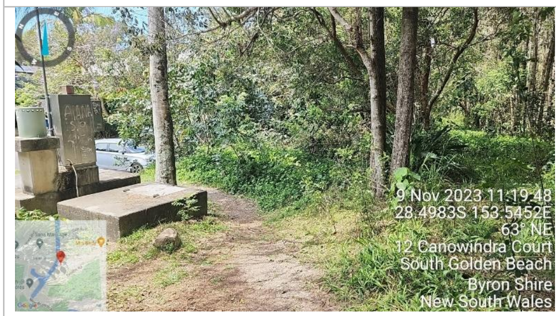
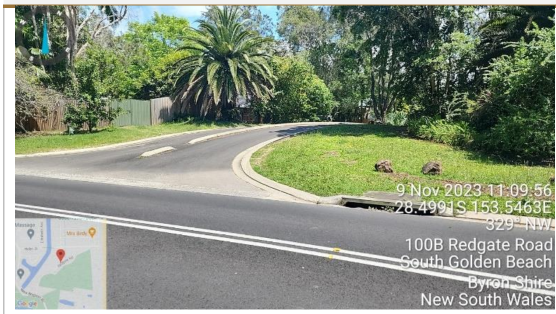
Photo (taken 9/11/23)	Comment
	Due to proximity to road and stormwater headwall, retaining walls and or steep batters would be required to maintain functionality of existing infrastructure.
	Existing footbridge and associated paths would require reconstruction / reconfiguration on bother eastern and western levees to be compatible with the new levee heights.
	Sewer pump station on eastern levee would require consideration and potential reconstructions in the event of levee raising.
	Densely wooded area at southern end of eastern levee would require significant clearing works and levee reconstruction in the event of levee raising.

Photo (taken 9/11/23)	Comment
	Redgate Rd and Canowindra Ct would require demolition, regrading and reconstruction in the event of levee raising. Adjacent driveways, private blocks and verges may also require regrading to ensure compatibility with new road vertical alignment.
	Retaining walls or steep batters would be required to ensure that existing infrastructure is not impacted by levee raising. This would induce the need for pedestrian barrier fencing in areas.
	The footpath along Redgate Rd would require reconstruction and some vegetation removal on the downstream side of the levee.
	Example of driveway which would require reconstruction to meet new levee crest elevation.

ATTACHMENT 4 SOUTH GOLDEN BEACH LEVEE INSPECTION (ENGENY 2022)

ENGENY
WATER MANAGEMENT

Level 2, 500 Queen Street, Brisbane QLD 4000
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E: admin@engeny.com.au

20 April 2022

Byron Shire Council
70 Station Street
Mullumbimby NSW 2482

Attention: Scott Moffett

Dear Scott,

RE: South Golden Beach Levee Inspection

INTRODUCTION

Engeny was engaged by Byron Shire Council to undertake structural integrity inspections of three flood protection levees within the town of South Golden Beach in Northern New South Wales. The inspection was requested by Council following significant rainfall events where the levees overtopped in several locations, causing widespread flooding within the South Golden Beach community.

The general layout of the flood protection levees is illustrated in Figure 1 below.

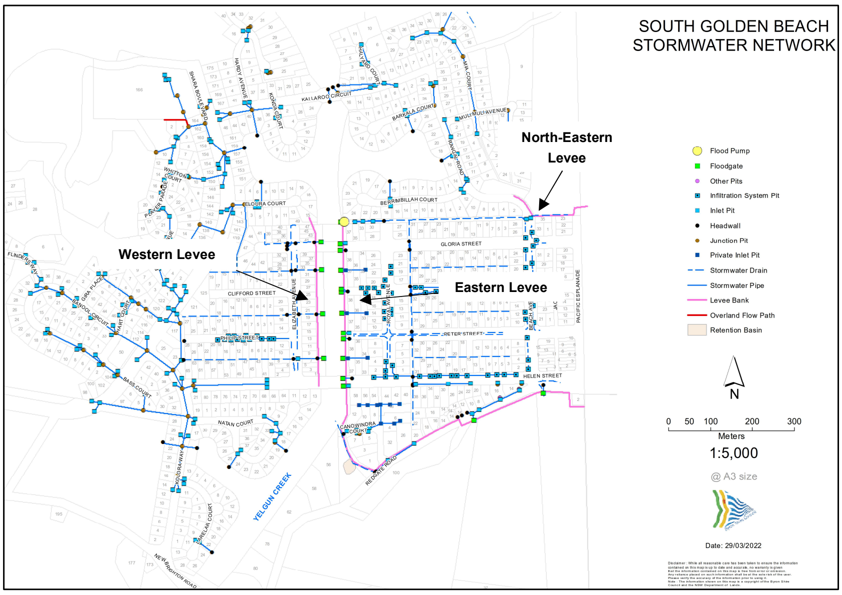

Figure 1 South Golden Beach Levees – General Arrangement

ENGENY WATER MANAGEMENT

BACKGROUND

The community at South Golden Beach is currently protected from flooding by levees along the eastern and western sections of Capricornia Canal. The levees were constructed in 1989, with pumps later installed in 2006 to reduce flooding behind the levee. The levee is currently set at RL3.2 m AHD to protect South Golden Beach properties from a 1% AEP flood event.

PURPOSE OF REPORT

This letter report summarises the key findings of the Engeny site inspection of the South Golden Beach Levees including the following:

- Observed structural defects / levee safety issues.
- Recommendations for any investigations, engineering assessments and / or remedial works design considered necessary to address any defects or safety issues identified during the inspection.

INSPECTION AND REPORTING LIMITATIONS

Visual assessments are limited to accessibility and visibility at the time of the site visit. Certain restrictions including but not limited to accessibility, visibility due to vegetative cover, water levels, weather conditions such as rainfall, timing and once-off nature of visual inspections may prevent all issues from being identified.

A proper assessment of the condition of structures can only be gained over an extended period of data collection and interpretation and regular and further detailed field inspections. No engineering assessments or analysis have been undertaken as part of the inspection and this inspection is not intended to be a substitute for a detailed Levee inspection audit.

The advice tendered in this report is not warranted with respect to any conditions that either reveal subsequent to this inspection or were not able to be observed during the inspection.

Observations made in this report are limited to the structural / geotechnical defects and deficiencies and do not include commentary on the hydraulic performance of the levees and associated drainage structures (i.e. flood immunity / culvert flow capacity).

INSPECTION FINDINGS

A visual inspection of the structures was undertaken and focussed on the identification of structural / geotechnical defects and deficiencies that could inhibit the levee to perform its required function.

The inspection was carried out by Miles Tremlett-Johnstone & Bennett Hume on April 1, 2022.

The inspections included visual assessment of the condition and adequacy of all components of the structures against relevant levee safety deficiency indicators recommended in industry standard guidelines. The inspection covered the following components and levee safety deficiency indicators (where applicable):

- Crest:
  - Cracking.
  - Subsidence.
  - Sinkholes.
  - Surface treatment defects.
- Upstream and downstream embankment slope and toe (where visible):

- – Cracking.
  – Slips.
  – Bulging.
  – Erosion.
  – Trees.
  – Seepage.
  – Soaks.
- Abutments (where levee ties into natural ground):
  – Erosion.
- Inlet / Outlet Works.
- Other appurtenant structures.

The visual inspection was limited to areas that were accessible during the time of the inspection.

INACCESSIBLE AREAS

The following locations had restricted access or were completely inaccessible during the field inspection:

- High water levels on the upstream side of the levee prevented detailed inspection of parts of the upstream batter, majority of the upstream toe and partially or fully submerged flood gates.
- Significant portions of the levee were densely vegetated which made inspection of the embankment condition difficult.
- Residents' property boundaries encompass a portion of the levee's downstream batter and toe restricting the observation of potential deficiency indicators.

NORTH-EASTERN LEVEE

Field observations including deficiencies or defects for the North-Eastern Levee are summarised below.

Remedial actions and recommendations required to address identified defects and deficiencies are summarised in Table 2 of this report. Photographs, with coordinates, illustrating the general condition of the structure together with observed deficiencies or defects are included in Attachment 1 – North-Eastern Levee Photographs

- Upstream Batter:
  – Good grass coverage is present on the upstream batter over the entire length of the levee.
  – Isolated large trees are growing within upstream batter.
  – No clear sign of structural integrity issues or defects were present on the upstream batter.
- Crest:
  – Good grass coverage is present on embankment crest over the entire length of the levee.
  – Isolated large trees growing in embankment crest towards the eastern extremities of the structure.
  – Cross-fall appears to be consistently grading toward the upstream batter.
  – Single sinkhole, 300mm deep, 300mm diameter located on the downstream edge of the crest. No evidence of a 'pipe' entry on the upstream batter or exit on the downstream batter.
- Downstream Batter
  – Good grass coverage is present on the downstream batter over the entire length of the levee.
  – Power pole has been installed through the downstream batter.
  – No clear sign of structural integrity issues or defects were present on the downstream batter.
- Upstream Toe:
  – Water ponded on the upstream toe preventing detailed inspection.
- Downstream Toe

- – Water ponded within downstream toe drain and unable to escape due to culvert / downstream drainage channel blockage.
- – Conversations with locals at the time of the inspection identified that the source of the water was from levee overtopping rather than seepage through the levee embankment and / or foundations.
- – No clear sign of structural integrity issues or defects were present on the downstream toe.

- Ancillary / Drainage infrastructure
  - – Existing culvert blocked / inundated with water preventing a detailed culvert inspection.

EASTERN LEVEE

Field observations including deficiencies or defects for Eastern Levee are summarised below.

Remedial actions and recommendations required to address identified defects and deficiencies are summarised in Table 2 of this report.

Photographs, with coordinates, illustrating the general condition of the structure together with observed deficiencies or defects are included in Attachment 2.

- Upstream Batter:
  - – Upstream batter can generally be characterised by dense grass coverage together with frequent small to large trees.
  - – The dense vegetation coverage on the upstream batter significantly restricted the observation of potential defects and deficiency indicators.
  - – Some isolated areas of sparse vegetation were present on the upstream batter and generally showed no clear sign of structural integrity issues or defects.
  - – Minor erosion / loss of material (~50mm) was observed at retaining wall abutments / tie-in points.
  - – The stone / brick retaining wall on the upper bench appeared to be in good condition with no clear sign of structural integrity issues or defects.
  - – The timber retaining wall on the lower bench was observed to be skewed approximately 10 degrees, giving evidence to suggest overturning.
  - – Steepness of the upstream batter is inconsistent and generally varies from 1V:1H to 1V:4H.
  - – A terrace has been constructed (presumably by the local resident) on the upstream batter of the levee near Robin Street. No construction information is available for the structure, as such its impact on the structural integrity of the levee is unknown. There were no clear signs of structural integrity issues or defects associated with the terrace at the time of the inspection.
- Crest:
  - – Good grass coverage is present on embankment crest over most of the levee.
  - – Some bare areas where no vegetation exist at isolated locations along the crest. No evidence of desiccation cracking was observed at these bare areas; however, the surface of the levee was saturated at time of the inspection.
  - – Small to large trees are present over a significant portion of the embankment crest.
  - – Tree roots appear to daylight through the crest at several locations.
  - – Asphalt / pavement present on crest between where the levee crosses to the southern side of Redgate Road and the South Golden Beach Skate Park.
  - – Cross-fall of the levee crest is inconsistent and varies over the length of the structure; however, it generally falls toward the upstream batter.
  - – The crest width generally varies between 2 – 3 m.
  - – Property fences have been constructed on the embankment crest of the levee at several locations. There were no clear signs of structural integrity issues or defects associated with the presence of fencing along the embankment crest at the time of the inspection.
- Downstream Batter:

- – Residents' property boundaries encompass majority of the levee downstream batter, restricting the observation of potential deficiency indicators.
  – Downstream batter can generally be characterised by dense grass coverage together with frequent small to large trees, further restricting the observation of potential deficiency indicators.
  – Areas of the downstream batter that could be adequately inspected showed no clear sign of structural integrity issues or defects.
  – Various structures / landscaping features have been constructed (by the residents) on the downstream batter of the embankment. No construction information is available for the structures, as such their impact on the structural integrity of the levee is unknown. It is noted that there were no clear signs of structural integrity issues or defects associated with the structures and landscaping features at the time of the inspection.

- Upstream Toe:
  – High water levels within Capricornia Canal prevented detailed inspection of the upstream toe.
  – Frequent small to large trees present at embankment toe.
- Downstream Toe:
  – Residents' property boundaries encompassed majority of the levee downstream toe, restricting the observation of potential deficiency indicators.
  – The downstream toe can generally be characterised by dense grass coverage together with frequent small to large trees, further restricting the observation of potential deficiency indicators.
  – Areas of the downstream toe that could be adequately inspected showed no clear sign of structural integrity issues or defects.
- Ancillary / drainage infrastructure:
  – A significant build-up of debris has accumulated within the drainage channel between Peter and Helen Street.
  – Majority of flood gates and culvert inlets / outlets were partially obstructed by dense vegetation or debris.
  – Some floodgates / culvert outlets were either fully or partially submerged at the time of inspection, as such a detailed assessment of structural integrity could not be undertaken.
  – The floodgate at the South Golden Beach Skate Park is damaged and requires rectification. The floodgate has snapped at the hinge and is currently only being held together by a makeshift hinge constructed from a piece of metal fastened to the pipe and flood gate.

WESTERN LEVEE

Field observations including deficiencies or defects for Western Levee are summarised below.

Remedial actions and recommendations required to address identified defects and deficiencies are summarised in Table 2 of this report.

- Upstream Batter:
  – Upstream batter can generally be characterised by dense grass coverage together with frequent small to large trees, restricting the observation of potential deficiency indicators.
  – Steepness of upstream batter was consistent and generally 1V:3H.
  – Multiple terrace structures have been constructed (presumably by the local resident(s)) on the upstream batter of the levee. No construction information is available for the structures, as such its impact on the structural integrity of the levee is unknown. There were no clear signs of structural integrity issues or defects associated with the terraces at the time of the inspection.
- Crest:
  – Good grass coverage is present on embankment crest of the levee.
  – Occasional small to large trees are present on the embankment crest.
  – Tree roots appear to daylight through the crest at several locations.

ENGENY WATER MANAGEMENT

  - Cross-fall of the levee crest appeared to be generally consistent and falls toward the upstream batter.
  - The crest width generally consistent at approximately 2 m.
- Downstream Batter:
  - Residents' property boundaries encompass majority of the levee downstream batter, restricting the observation of potential deficiency indicators.
  - Downstream batter can generally be characterised by dense grass coverage together with frequent small to large trees, further restricting the observation of potential deficiency indicators.
- Upstream Toe:
  - High water levels within Capricornia Canal preventing detailed inspection of upstream toe and associated flood infrastructure.
  - Frequent small to large trees present at embankment toe.
- Downstream Toe:
  - Residents' property boundaries encompassed majority of the levee downstream toe, restricting the observation of potential deficiency indicators.
  - The downstream toe can generally be characterised by dense grass coverage together with frequent small to large trees, further restricting the observation of potential deficiency indicators.
  - Areas of the downstream toe that could be adequately inspected showed no clear sign of structural integrity issues or defects.
  - Various structures / landscaping features have been constructed (by the residents) on the downstream toe of the embankment. No construction information is available for the structure, as such their impact on the structural integrity of the levee is unknown. It is noted that there were no clear signs of structural integrity issues or defects associated with the structures and landscaping features at the time of the inspection.
- Ancillary / drainage infrastructure:
  - All floodgates / culvert inlets and outlets were either fully or partially submerges at the time of inspection and such a detailed assessment of structural integrity could not be undertaken.

Photographs, with coordinates, illustrating the general condition of the structure together with observed deficiencies or defects are included in Attachment 3 – Western Levee Photographs.

PRIORITY RANKINGS

The recommendations for each structure have been made to mitigate further deterioration of the structure (which if left untreated will ultimately lead to loss of structural integrity) or address issues pertaining to levee safety.

Action priority rankings have been provided in Table 1 based on consideration of the following:

- Defect severity.
- Rate of assumed defect propagation.
- Criticality relative to operational and the likelihood of the defect leading to a serious or catastrophic failure.
- The likelihood of defect propagation going unobserved.
- General engineering judgement based on similar observations.

The action priority ranking categories and corresponding response times are summarised below in Table 1.

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Table 1 Action Priority and Corresponding Response Times

Priority	Response Time
High	Immediate action required.
Medium	Acton required in the next 12 months.
Low	Ongoing maintenance.

RECOMMENDATIONS

The following recommendations are made to mitigate further deterioration of the structure (existing defects which if left untreated could ultimately lead to loss of structural integrity) or address issues pertaining to levee safety or operational performance.

In summary, the South Golden Beach Levee's were observed to be in good condition with no visual evidence of loss of structural integrity. The structure is considered suitable for continued use as a flood protection structure, with a number of recommendations to address observed defects and deficiencies.

Levee recommendations are summarised below inTable 2.

Table 2 Recommendations

No.	Dam	Recommendation	Recommendation Type	Priority
1	General	Commence undertaking routine inspections (i.e. monthly) of the Levees	Levee Safety	Low
2	North-Eastern Levee	Repair the existing crest sinkhole by backfilling the hole with low permeability clay. Modify the surrounding crest surface levels with gravel sheeting to promote free draining conditions to the upstream side of the crest to prevent ponding of water on the crest. Any works undertaken should not lower the existing crest levels. Continue to monitor the area following the repair works, including inspecting the upstream batter and downstream batter / toe in this area, for any signs of internal erosion / sinkholes.	Levee Safety	High
3		Poison and cut small trees / saplings / shrubs with trunks < 100 mm diameter	Maintenance	Low
4		Remove debris downstream from drainage channel to reinstate free draining condition to allow water to drain away from the downstream toe and minimise saturation of the levee foundations.	Maintenance	Low
5	Eastern Levee	Mow grass on the embankment where possible, to allow for improved observation of levee embankment condition.	Maintenance	Low
6		Poison and cut small trees / saplings / shrubs with trunks < 100 mm diameter	Maintenance	Low
7		Clear / slash dense vegetation immediately upstream and downstream of the flood gates / culvert inlets and outlets	Maintenance	Medium
8		Remove debris from drainage channel between Peter and Helen Street to reinstate free draining condition and minimise saturation of the levee foundations.	Maintenance	Low
9		Undertake desktop stability analysis of the levee to determine the sensitivity of factor of safety against instability is to varying crest widths and batter slopes and whether the embankment meets recommended factors of safety.	Levee Safety	Medium
10		Undertake detailed ground survey of the levee to determine critical sections for stability analysis.	Levee Safety	Medium

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No.	Dam	Recommendation	Recommendation Type	Priority
11		Undertake a risk audit / qualitative risk assessment on existing structures constructed on the levee to quantify potential impact on levee structural integrity. OR Remove existing structures constructed on the levee and develop remediation design to reinstate levee as per the original design intent.	Levee Safety	Medium
12		Monitor existing retaining walls as part of of monthly routine inspections. If condition of retaining walls further deteriorates develop remediation design.	Maintenance	Medium
13		Monitor existing culvert inlet / outlet cracking and spalling as part of a monthly routine inspections. Repair if cracking exceeds 5mm or condition continues to significantly deteriorate.	Maintenance	Low
14		Repair damaged flood gate near the Southern Golden Beach Skate Park	Maintenance	High
15	Western Levee	Mow grass on the embankment where possible, to allow for improved observation of levee embankment condition.	Maintenance	Low
16		Poison and cut small trees / saplings / shrubs with trunks < 100 mm diameter	Maintenance	Low
17		Clear / slash dense vegetation immediately upstream and downstream of the flood gates / culvert inlets and outlets	Maintenance	Medium
18		Undertake desktop stability analysis of the levee to determine the factor of safety against instability and whether the embankment meets recommended factors of safety	Levee Safety	Medium
19		Undertake detailed ground survey of the levee to determine critical section for stability analysis.	Levee Safety	Medium
20		Undertake a risk audit / qualitative risk assessment on existing structures constructed on the levee to quantify potential impact on levee structural integrity. OR Remove existing structures constructed on the levee and develop remediation design to reinstate levee as per the original design intent.	Levee Safety	Medium

Regards,

M.Tremlett-Johnstone

Miles Tremlett-Johnstone

Senior Geotechnical & Dams Engineer

ATTACHMENT 1 – NORTH-EASTERN LEVEE PHOTOGRAPHS

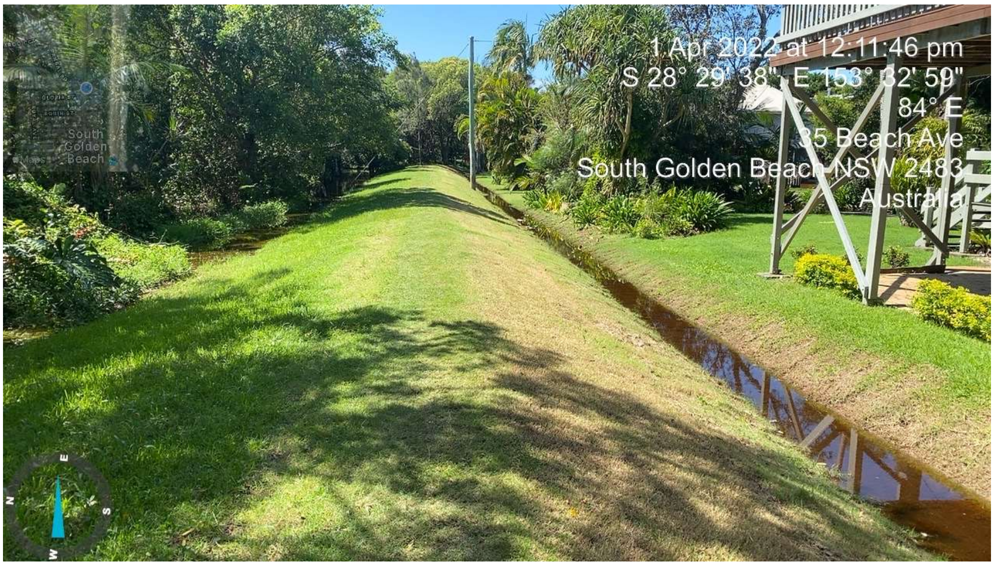

Figure 2 North-eastern levee crest looking east. Power pole present at downstream toe.

Figure 3 North-eastern levee crest sinkhole.

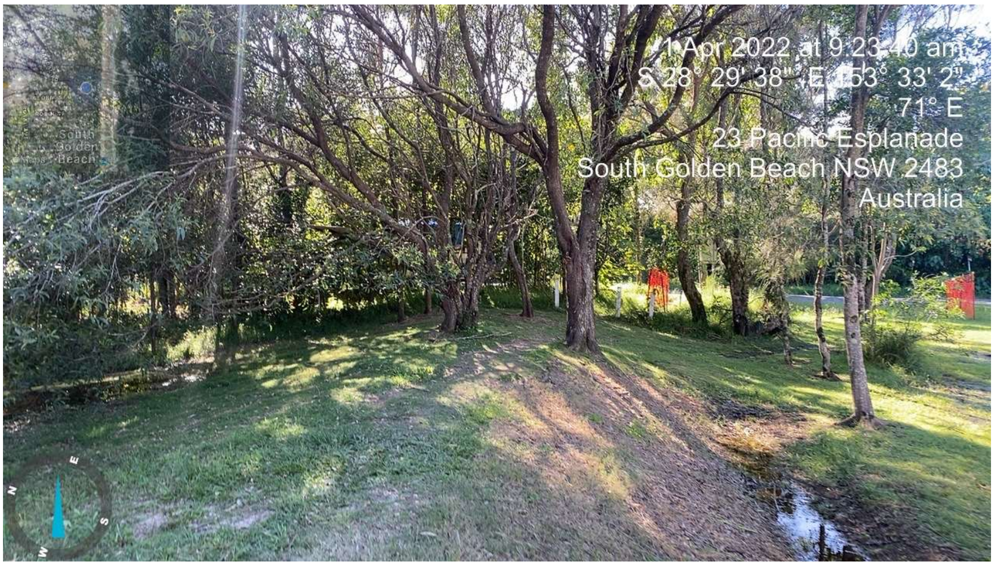

Figure 4 Large trees growing within embankment crest.

Figure 5 Culvert blocked preventing water ponding at downstream toe from free draining.

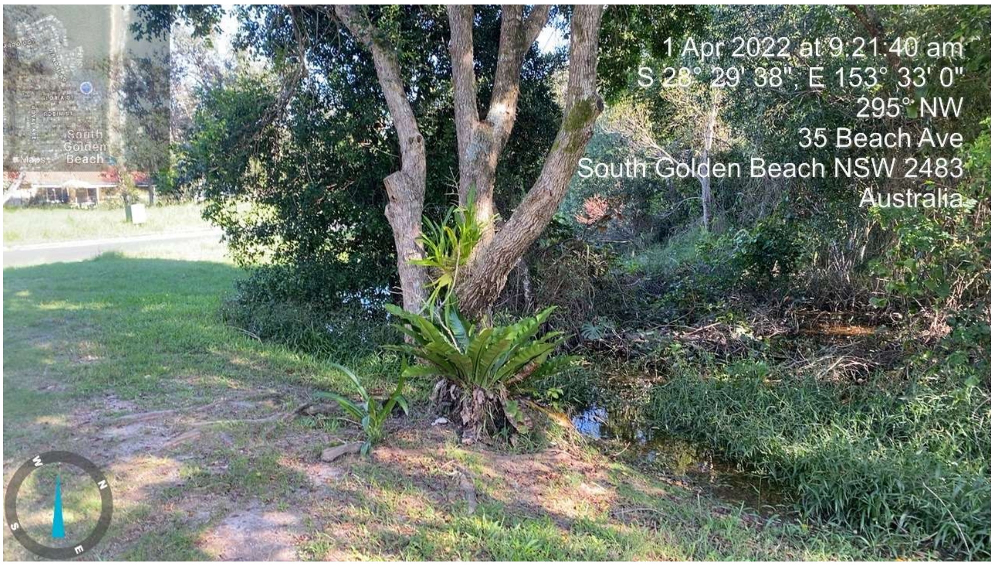

Figure 6 Large tree growing on upstream batter.

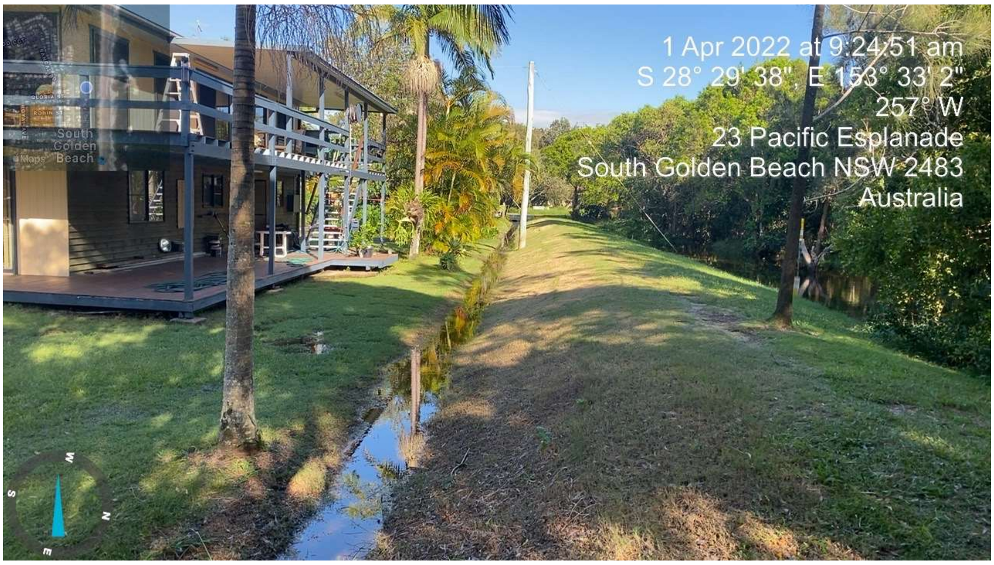

Figure 7 Water ponding at downstream toe.

Figure 8 Water ponding at upstream toe.

Figure 9 Section of levee along Rangal Road.

ATTACHMENT 2 – EASTERN LEVEE PHOTOGRAPHS

Figure 10 Eastern levee crest looking south (North of Gloria Street).

Figure 11 Submerged floodgate (North of Gloria Street).

Figure 12 Minor loss of material around retaining wall tie-ins (North of Gloria Street).

Figure 13 Minor loss of material around retaining wall tie-ins (North of Gloria Street).

Figure 14 Masonry retaining wall in good condition.

Figure 15 Evidence of timber retaining wall overturning on upstream batter.

Figure 16 Gloria Street flood gate in good condition, minor build of debris preventing full closure.

Figure 17 Trees growing on upstream batter and at upstream toe (near Gloria Street).

Figure 18 Garden bed constructed on levee downstream batter (near Gloria Street).

Figure 19 Partially submerged flood gate. Debris appears to be preventing full closure of flood gate.

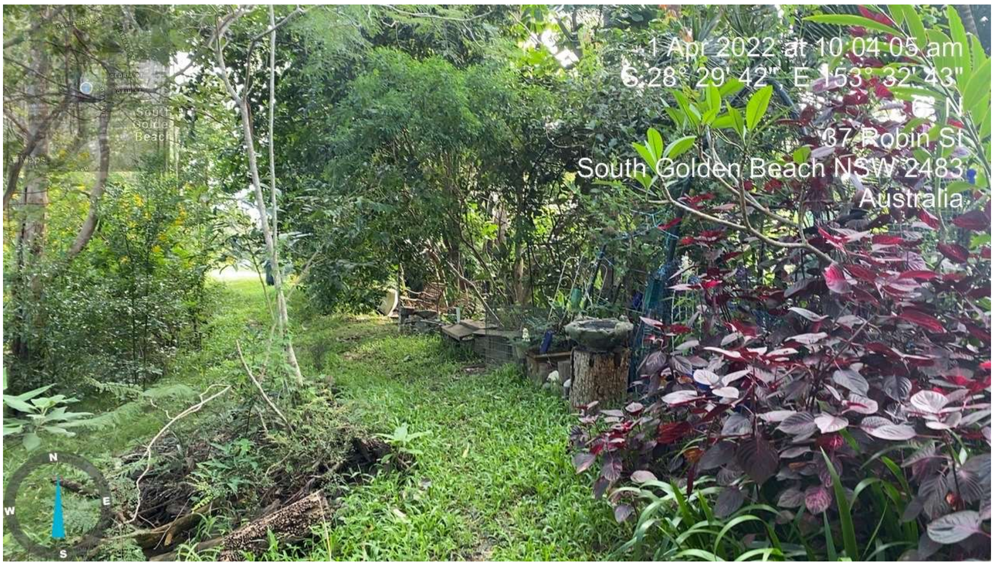

Figure 20 Resident's Garden bed appear to be constructed on downstream batter and encroaching on crest.

Figure 21 Densely vegetated upstream batter.

Figure 22 Concrete spalling around RCP inlet at Robin Street.

Figure 23 flood gates at Robin Street, generally good condition. Debris appears to be prevented full closure of northern gate.

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Figure 24 Northern batter and toe.

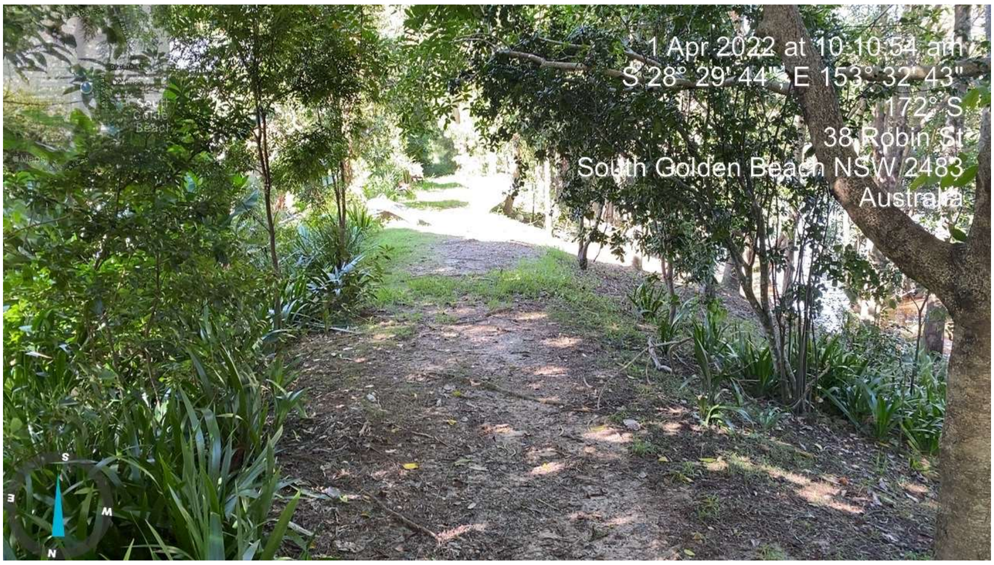


Figure 25 Isolated bare areas on crest. Presence of tree roots growing through crest.

Figure 26 Terrace constructed on upstream batter of levee.

Figure 27 Flood gate in good condition.

Figure 28 Significant vegetation coverage on downstream batter, crest and upstream batter.

Figure 29 Significant vegetation coverage on upstream batter.

Figure 30 Concrete cracking / spalling (<5mm) at culvert inlet on Peter Street.

Figure 31 Significant debris accumulation within drainage channel between Peter Street and Helen Street.

Figure 32 Significant debris accumulation within drainage channel between Peter Street and Helen Street.

Figure 33 Partially submerged flood gate. Good condition.

Figure 34 Concrete cracking / spalling (<5mm) at culvert inlet on Helen Street.

Figure 35 Helen Street flood gate.

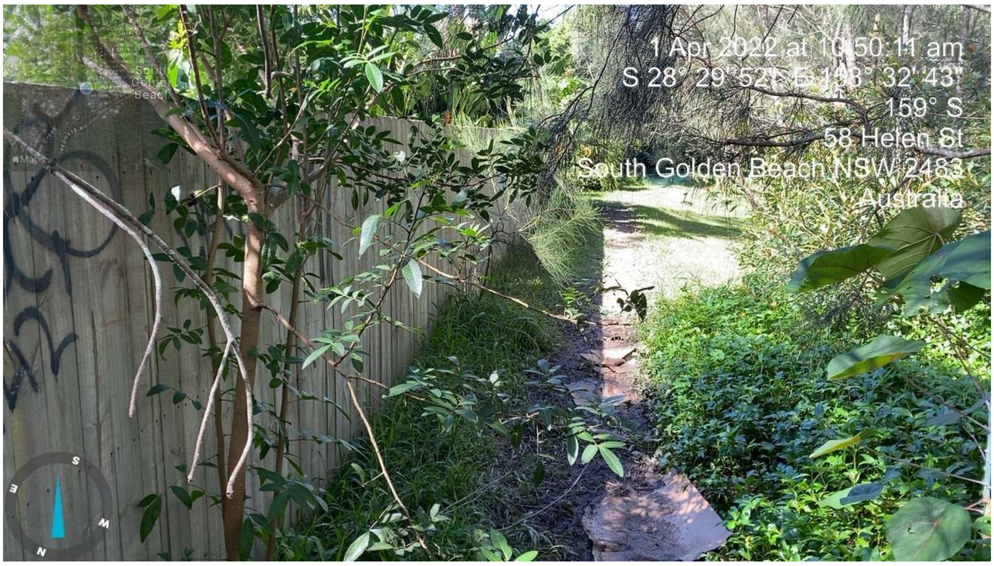


Figure 36 Fencing constructed on downstream edge of crest.

Figure 37 Structure constructed on downstream batter.

Figure 38 Levee crest along Redgate Road (North of Road).

Figure 39 Downstream batter along Redgate Road (South of Road).

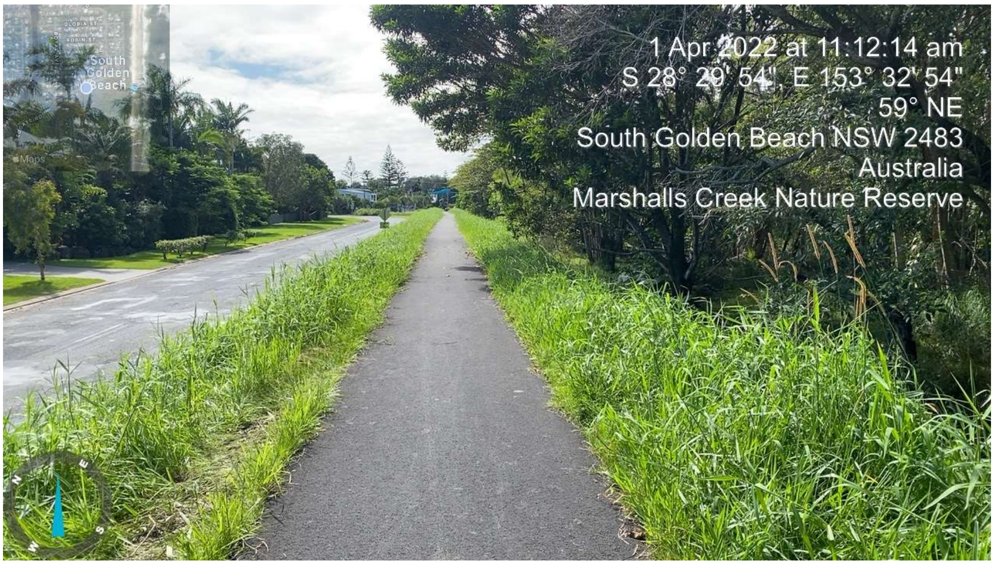


Figure 40 Crest along Redgate Road (South of Road).

Figure 41 Damaged flood gate near South Golden Beach Skate Park.

ATTACHMENT 3 – WESTERN LEVEE PHOTOGRAPHS

Figure 42 Dense vegetation coverage of levee at southern tie-in.

Figure 43 Significant vegetation coverage at southern end of levee alignment.

Figure 44 Crest and upstream batter with small to large size trees at toe of upstream batter.

Figure 45 Terraced upstream batter constructed of timber.

Figure 46 Culvert Inlet fully submerged.

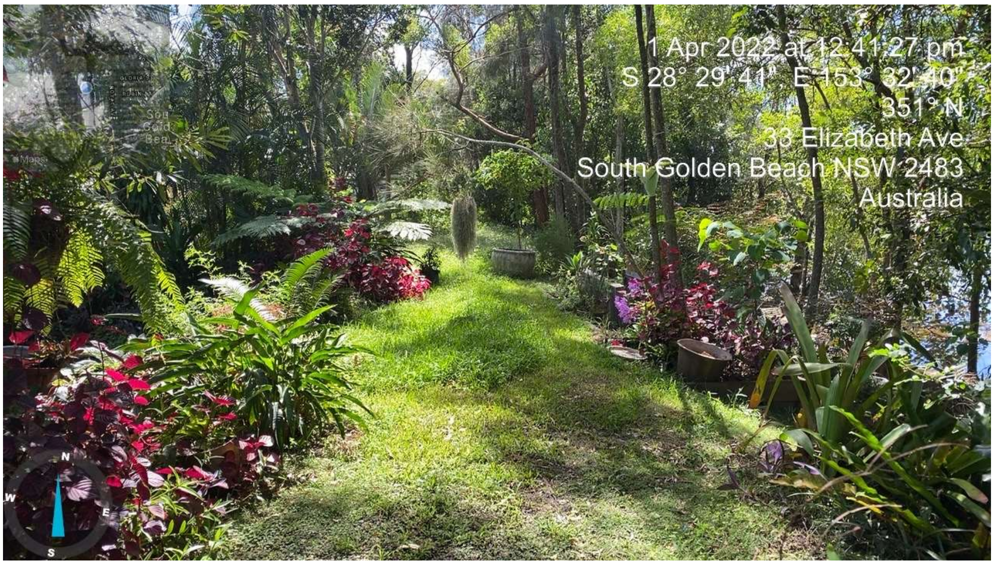


Figure 47 Siginifcant vegetation and tree growth on upstream and downstream levee batters.

Figure 48 Culvert Inlet fully submerged.

Figure 49 Culvert Outlet / Flood gate fully submerged.

Figure 50 Terraced upstream batter constructed of timber retaining walls.

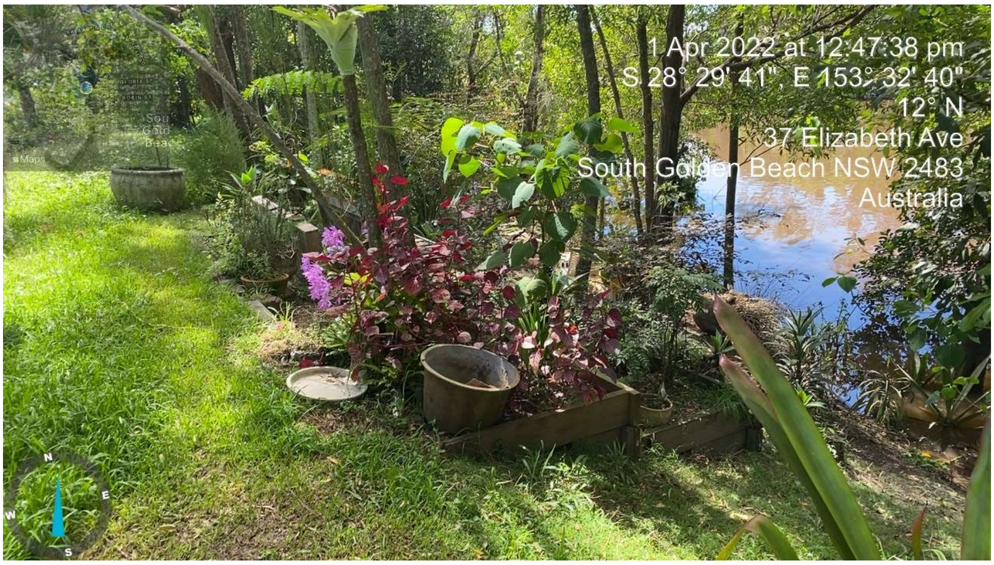


Figure 51 Landscaping features on crest and terraced into upstream batter.

Report No. 4.3 Flood Gate Upgrade Options Investigation - South Golden Beach

Directorate: Infrastructure Services

Report Author: Isabella Avelino Gianelli, Project Engineer

File No: I2024/164

Summary:

JB Pacific was commissioned by Byron Shire Council staff to investigate potential upgrade options for floodgates at South Golden Beach NSW. The project scope includes twelve gates on the east bank, four gates along the west bank of Yelgun Creek and two along Redgate Road. The aim is to improve flood resilience of the area by investigating into the most effective upgrade options.

RECOMMENDATION:

1. **That the Committee notes the Floodgate Upgrade Options Investigation prepared by JB Pacific March 2024– Attachment 1 (E2024/47404). In particular, the recommendations contained in Section 4.2 and 5 of the report.**

Attachments:

1 Report_SGB_Floodgates_upgrade_options_investigation_JBPacific, E2024/47404 , page 145⇩

Report

The project location and extent has been shown in Figure 1-1.

Figure 1-1: Project site

In order to improve the floodgates, it is critical to understand the pros and cons of the current systems. Site inspection, made by JB Pacific, has revealed that floodgates with the following features have demonstrated notable effectiveness:

- Floodgates with grated pit upstream show significantly less debris accumulation inside of the pipes.
- Floodgates with upstream swale grassed (not planted with vegetation) show significantly less debris accumulation inside of the pipes.

Key issues

The main issues with the existing systems are:

1. Stagnant water rear of levee:
   - Flood risk: the closure or difficulty to discharge water into Yelgun Creek may lead to increase in water level during flood events and result in water damage to residential properties.
   - Hygiene, odour and aesthetic concerns: Stagnant water can be breeding ground for mosquitoes and attract various vectors which can transmit diseases to humans.
2. Flap gates unable to seal:
   - Flood risk: the flap gates are supposed to be one-way systems allowing drainage into the creek only. As many of them are constantly open, they become two-way systems and would allow creek water to come over the levee and flood land behind.
   - Flood risk: The flap gates unable to open.

The issues could exist simultaneously or even be of influence of each other, however, they are listed separately to facilitate proposal of solutions/options. Based on the present issues, the flap gates can be further grouped in Table 2-1, potentially requiring improvement in similar aspects.

The groups are:

- A - Water ponding rear of levee
- B - Large amount of debris coming through system, blockage at flap gate, unable to seal
- C - Large amount of debris on apron, flap gate unable to open
- D - No access due to overgrow
- E - No pressing issue.

Group D and E are advised to be monitored and no further options will be necessary until any issue with them become clear. Further options will be proposed for Group A to C. Further options will be proposed for Group A to C.

Table 2-1: Asset categorisation based on issue. (extract from attachment 1)

Asset ID	Condition / issues	Group
17923	Rock chute with minor defects (missing mortar and loss of rocks). Floodgate had remediation works done to it. Unknown issue.	E
17924	No water at rear of levee during high tide.	B
17925	No access.	D
17926	Pond of water rear of levee	A
17927	Pond of water rear of levee	A
17928	Overgrow of weed	D
17929	Overgrow of weed	D
17930	Flap gate closed at time of inspection. Flap gate invert level above creek water level for majority of time. Large amount of debris/deposition on apron, may prevent the flap gate from opening.	B
17931	Flap gate open (50mm at bottom) at time of inspection. Flap gate invert level above water level for majority of time. No signs of scour, concrete apron intact.	B
17932	Flap gate open (100mm at base). Heavy blockage. Debris inside of pipe and on apron. Concrete spalling and exposure of reinforcement at outlet headwall. Large amount of debris/deposition on apron, may prevent the flap gate from opening.	B
17933	No debris in flap gate. Delamination of fibre reinforced polymer flap gate. Large amount of debris/deposition on apron, may prevent the flap gate from opening.	C
17934	Inlet headwall scoured resulting in concrete partially unsupported. Overgrow of weed, poor access to outlet. Large amount of debris/deposition on apron, may prevent the flap gate from opening.	C
17935	Nil	E
17936	Flap gate not closed properly. Vegetation growth and debris inside of flap gate.	B
17937	Heavy debris at inlet. Flap gate not closed properly.	B
17938	Rubber ring degradation and displacement. Flap gate not sealed.	B
17939	Inlet and outlet are dry	D
17940	Inlet and outlet are dry	D

Group A - Stagnant water rear of levee

This has been observed along the west bank of Yelgun Creek and is considered likely to be the result of the following factors:

- Flap gates unable to seal due to rubber ring degradation.
- Flap gates unable to seal as they are jammed by debris.
- Flap gates unable to open as thick siltation and debris accumulating on the apron.
- Waterhead too small to flush debris out as longitudinal grade being too flat.
- Waterhead too small to flush debris out as insufficient maintenance and large volume of debris accumulation acting as natural log jams.

To avoid the ponding, upgrade options shall consider achieve at least one of the following:

- Ensure flap gates seal properly.
- Replace flap gates with another type of valve that seals properly with presence of debris.
- Increase waterhead.

Group B – blockage at flap gate

This has been observed at seven gates along the Yelgun Creek and is considered likely to be the result of the following factors:

- Dense vegetation growth in swales and on levee. Foliage, twigs and branches are main component of debris observed on site. Trees growing on the levee could compromise stability of the levee through their extensive root system. Piping could occur after mortality of trees and shrinkage of died root systems. Trees growing inside of swales are considered worsening the blockage.
- Lack of public awareness at locations. Residents utilise the swale as storage for green waste or compost.
- Absence of any sieve/grates at inlets.
- Waterhead too small or flap gates too heavy to be flushed open, resulting in water slowly drain out of a small opening and debris accumulating inside of the gates.

The blockage is considered a combined result of the above. Therefore, upgrade options shall consider achieve at least one of the following:

- Reduction in debris input into the systems.
- Replace flap gates with another type of valve that seals properly with presence of debris and allows water to drain freely during low tide times.

Group C - flap gate unable to open

This is a concern for nine gates which include gates experiencing blockage at flap gates. Large amount of debris accumulated at concrete aprons could make the opening of flap gates even more difficult resulting in loss of water head. Resolving the issues of Group B is expected to improve this issue at the same time. Apart from the above causes in Section 2.3, this is considered likely to be the result of the following factors:

- Outlet location experiences no flush from creek. Their locations are retrieved on riverbank and behind mangroves which further reduce flow.

The blockage is considered a combined result of the above. Therefore, upgrade options shall consider achieve at least one of the following:

- Reduction in debris input into the systems.
- Replace flap gates with another type of valve that seals properly with presence of debris and allows water to drain freely during low tide times.
- Extend outlets into the creek for flushing of concrete aprons.

Group D – no access and Group E – no pressing issue
No issues have been identified for seven gates which fall into Group D and E, either due to no access or flap gates are working properly.

Options

This section considers potential options for improvements for groups of outlets. Issues observed on site can be of the same cause as analysed above and same options will be proposed in such a case.

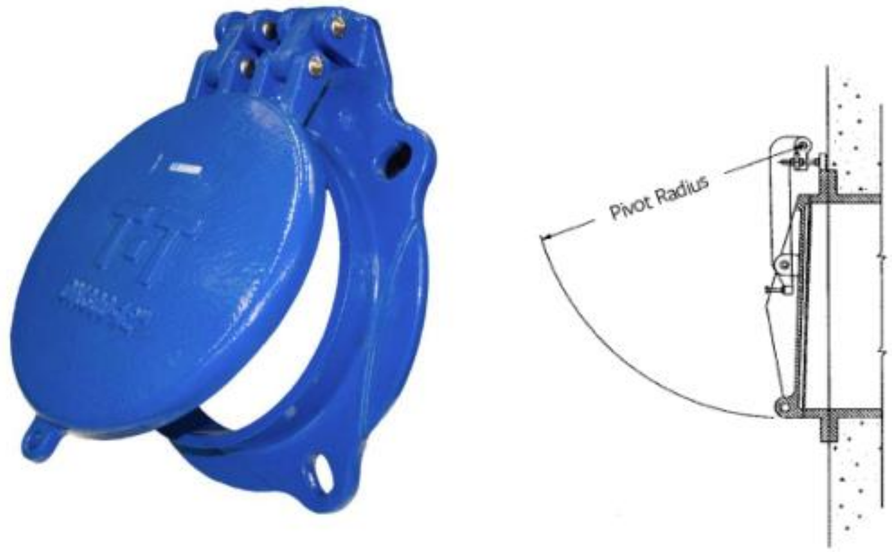
Option 1 – Maintenance work on existing system

The current systems have been in a good to fair condition after being in service for 50 years. The performance is reduced mainly due to lack of maintenance. Regular maintenance works are therefore worth considering, such as replacing degraded rubber ring, raking the pipes to remove excess debris, lubricating hinges for easier operation of flaps, pressure wash aprons and remove excessive debris etc. This option has minimum capital expenditure but requires long-term and continuous investment into maintenance. The maintenance level is considered medium to set a base-line case for this study.

Option 2 - Improving flap gates Option

2.1 – New flap gates: many improvements have been made to flap gates over the past 50 years. Replacing the existing gates with new designs will reduce head loss resulting in better drainage and seal. Comparing with the single hinge flap gates on site, double hung hinge flap gates have the benefit of less likelihood for sticking gates and reduction in head loss. Examples below shows a simple double hung flap gate and a Mueller hydro gate with an adjustable pivot lug. The latter can be adjusted for more sensitivity (less water to crack the gate open) which can result in less debris accumulating inside of the gates. Mounting new flap gates will only trigger a small amount of expense but it is likely they need to be imported from overseas. Locally in Australia, flap gates of lighter material are available such as High-Density Polyethylene (HDPE) which will be more sensitive than the current glass fibre reinforced polymer gates. This option also comes with a medium level or slightly lighter maintenance need.

At the same time, the current pipes seem to have a flush end, then connecting to a flap gate. This would result in flap gates to remain slightly open due to gravity. A schematisation of the situation is in Figure 3-2. This is considered a design defect or poor construction quality and should be remediated if confirmed through detailed geometry check of the flap gates.



Left: T-T pumps (UK) product. Right: Hydro gate (US) product.
Figure 3-1: Example of double hung flap gates.

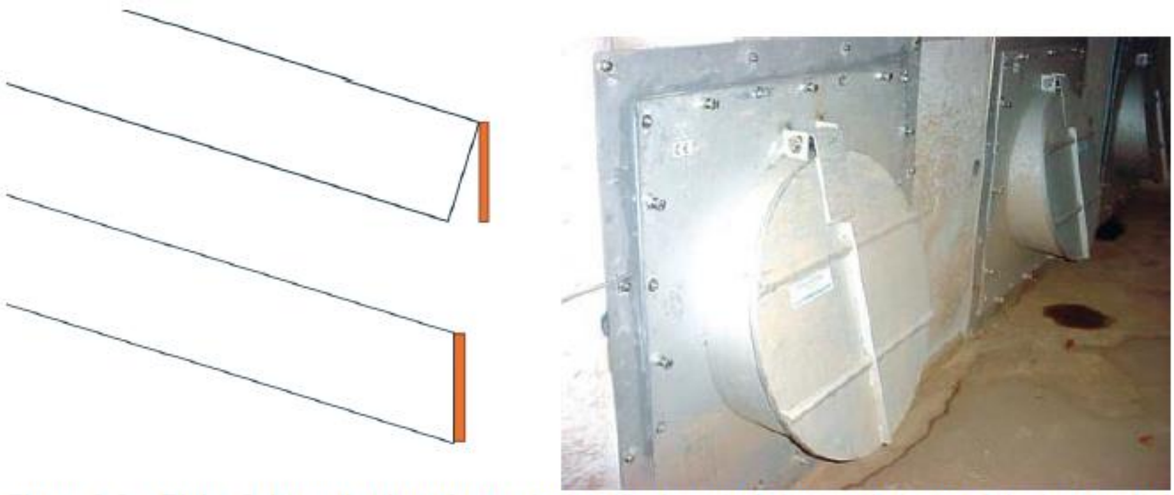


Figure 3-2: Right: Schematisation of poor design (flush end of pipe, top) vs. good design (end of pipe at an angle, bottom). Left: Good design in real life.

Option 2.2 - Automated flap gates: automate the operation of flap gates to fully open and close can reduce head loss. This increases the likelihood of flushing debris out of the system, but requires establishment of new power supply, actuators and staff overwatching the operation which suggests a medium size capital expenditure and maintenance cost. The automated flap gates still require maintenance due to blockage by twigs and branches but is expected of less frequent due to less loss of water head. The actuators can be hydraulically or electrically operated. However, many gates at this site sits above tidal range suggesting the hydraulic operation is not available unless they are extended out into the creek, while electrical actuators need to be positioned above flood levels to avoid submergence. As these gates are customised, their fabrication price remains unknown. Existing flap gates cannot be recycled, and new gates are needed for automation.

Option 2.3 – New flushing system: a flushing system (likely consists of a hose, a water pump and a switch) can be incorporated inside of the pipe near its inlet to flush debris out and potentially clearing the concrete apron given enough pressure. This can largely reduce maintenance frequency, ensures the seal of flap gates at most times and reduce maintenance difficulty comparing with raking individual pipes. However, the flushing system requires new power supply, and water source. Its operation can be manually turned on by council staff (no telemetry required) or fully automated (with telemetry). Such system will be custom made which suggests a medium size capital expenditure but small maintenance fee on going.

Option 3 - Improving swales

Clearing out and restoring the swales to grass swales can significantly reduce the amount of debris going through the system. This includes clear out vegetations and reprofile swales for a 1% to 4% longitudinal grade. The system still requires maintenance but is expected of less frequent due to less debris coming through and greater waterhead to flush out them. A small capital expenditure and maintenance investment are expected, given the survey confirms the grade of existing swales are insufficient.

Option 4 - Replacing flap gates

Removing and replacing the existing flap gates with alternative one-way valves can improve performance and reduce maintenance requirements. Different valves are considered here.

Option 4.1 – Automated vertical rising gates: removing existing flap gates and replacing them with automated sluice gates (or knife gates, to retrofit onto existing pipes) that seals tight with minor leave debris present. Knife and sluice gates are vertical rising valves need to be lifted open through powered mechanic arms. Electrical actuators have been considered the most economic for our case by flap valve suppliers JBP approached.

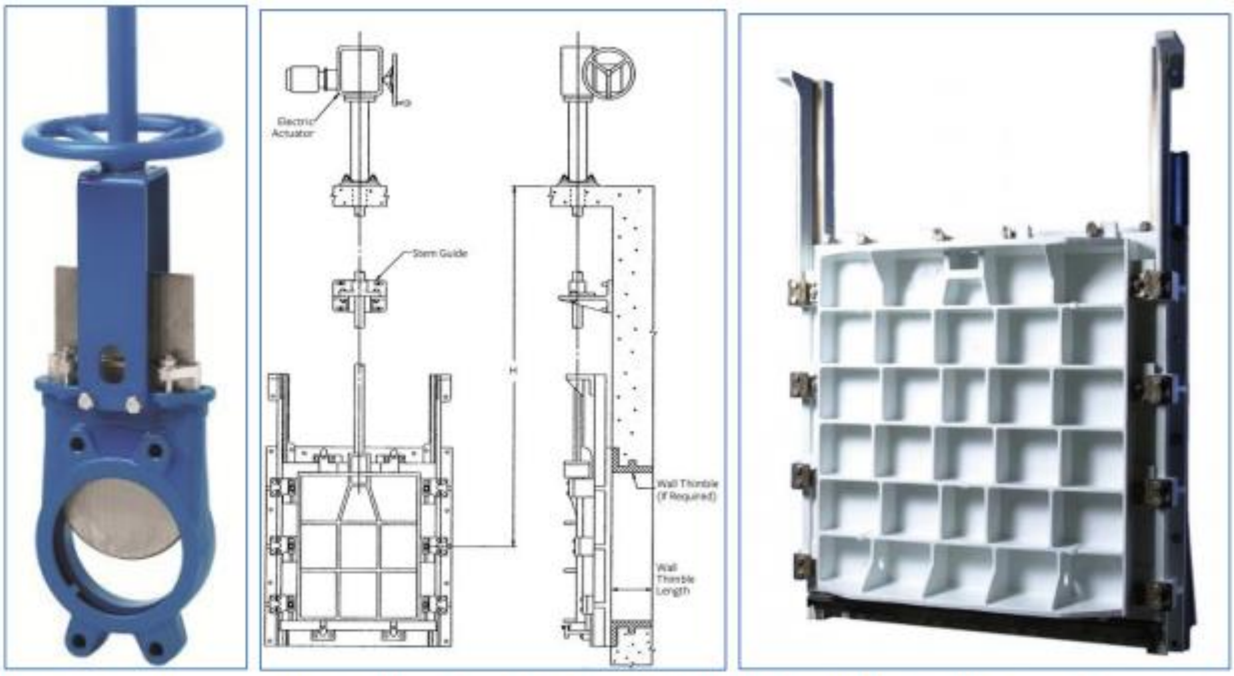


Figure 3-3: Left: Example of knife valves of AVK Industrial. Middle and Right: Automated sluice gate of Muller (US)

The valves are off-shelf products, but the automation requires new power supply (with flood immunity) and actuators and operators as discussed before. The supplier has suggested the knife valves requires similar degree of maintenance as flap valves because they are unable to cut through twigs and branches.

Also note the knife valves require support from both sides therefore cannot be directly fitted on to the existing pipes. Likely works include cutting the concrete pipe; install the knife valve; rejoin the concrete pipe at both ends to provide stability for the valve. This is therefore high in capital and maintenance expenditure. Sluice gates can be mounted onto existing pipes (single side support) which saves on modification of concrete pipes.

With automation, a new risk to public safety will need to be managed by council by controlling unauthorised access to these valves. Closing of the knife valves could lead to death and serious injury of any person inside of the pipe. Full isolation of the system during maintenance works is also highly recommended for the safety of council staff.

Option 4.2 – Alternative one-way valves: there are other non-return valves available on the market that relies on hydrostatic pressure to operate. They eliminate the need for power supply and telemetry system which significantly reduce upgrade cost. Some examples include scissor gates, duckbill valves and in-line check valves.

Scissor gates rely on buoyance to open and close and can handle foliage debris. However, twigs and branches will still prevent it from sealing. The design is customised by HydroSlide (UK). The gate is of metal, which will have corrosion issue in our site and requires careful selection of material and corrosion prevention measures such as painting.

Duckbill valves have higher tolerance to debris comparing with flap gates, and are usually made of rubber. They are safer for fish and are claimed to be maintenance free (no moving mechanical parts), if given enough water head. More information on catchment area, longitudinal grade of each outlet would be required to determine if water head is sufficient to open them as they usually require higher head than flap gates.

In-line check valves can also seal better with minor foliage debris than flap gates but requires higher water head to open. They can be made of rubber and shares many pros and cons with the duckbill valves. Their application can result in a small to large capital expenditure, depending on how much work is required to increase water head to a satisfactory level. Based on observation on site, it is likely to require earthwork and replacing concrete pipes at a greater grade for this option to perform as intended. This suggests a large capital expenditure. However improved systems are expected to have less maintenance requirements.

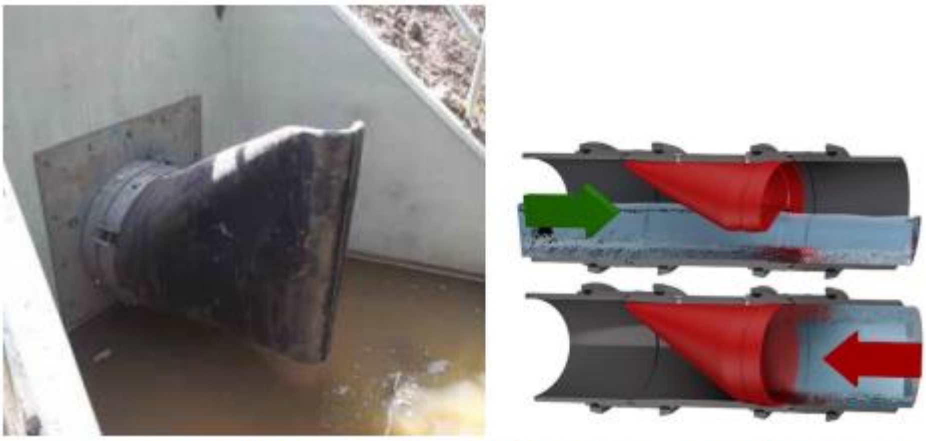


Figure 3-4: Left: Scissor valves. Middle: Duckbill valves. Right: In-line check valves.

Group B – blockage at flap gate, unable to seal

Option 3 and 4 discussed in Section 3.1.4 and 3.1.5 have been discussed above for Group A and are applicable to Group B with the same pros and cons. Hence it is not further discussed here.

Option 5 – Screens at inlet

Reduction in debris coming through the system reduces likelihood of blockage at flap gates. This can be achieved by installing screens/sieves/grates at inlets. The screens can prevent natural and man-made (plastic bags, cans) debris entering the creek and accumulate at locations that are easy to access and clear out. This is a value-add on cleaning the creek and allow safe removal of debris. There are many designs available depending on target debris size. Alignment of the screen can also vary from being perpendicular to the approach flow (susceptible to blockage but easy construction with off-shelf products) to being at an oblique angle to the approach flow to increase its effective area and reduce likelihood of blockage.

Without clearing of the swales, the debris are not removed from the system but simply accumulated upstream with less influence on seal of flap gates. However, the screens will change the hydraulic of the swale and suitability and design details should be confirmed through numerical modelling. The build-up requires clearing prior and after flood season to ensure minimum rise of water level in the swale and no increase in flood risk upstream.

The screens are easy to install, and swales are of good foot access. Therefore, this option has a small capital expenditure and a medium maintenance fee in long-run.

Figure 3-5: Left: Oblique screen. Right: Right angle screen.

Group C – flap gate unable to open

The restriction on gate's ability to open due to sedimentation on aprons can be resolved through:

- Careful design of Option 2 - Improving flap gates with sufficient clearance.
- Reducing debris load through Option 3 - Improving swales and Option 5 – Screens at inlet.
- Change of valve opening mechanism through Option 4 - Replacing flap gates. Duckbill valves have higher tolerance to debris and requires higher water head/ flow rate to open. Its design will not be blocked by accumulation of debris outside of the valve, and its release of water will have more volume hence better chance at flushing apron clean.

Multi Criteria Assessment

Methodology

Each option has been reviewed to establish their relative merits against a set of project objectives via a Multi-Criteria Analysis (MCA). The purpose of the MCA is to help determine the preferred options in a systematic way. It uses Technical, Environmental, Social and Economic categories, including several sub-categories to develop a scoring system. Table 4-1 MCA scoring criteria and results are presented in attachment 1.

Next steps

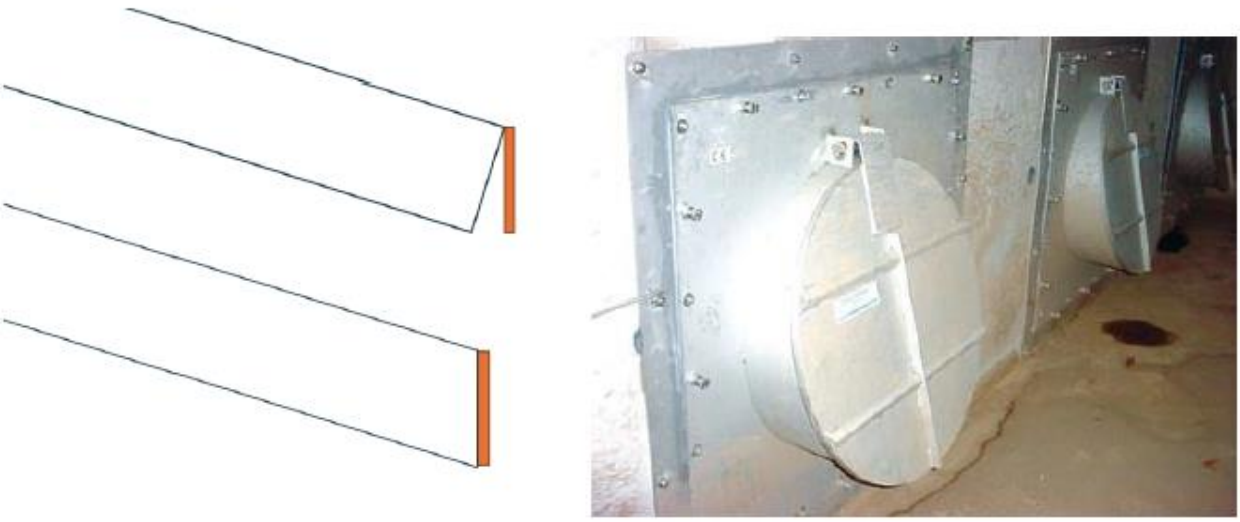
Exploring options to reduce maintenance frequency and difficulty reveals that automation, while initially appealing, adds complexity. It introduces additional electronic or mechanical components and specialized services along the levee. Automation may decrease outlet maintenance demand but requires regular upkeep by personnel with specific skills due to involvement with electricity, moving parts, and computer algorithms. O utsourcing this maintenance is an option but increases the maintenance budget. Moreover, in a marine environment with flood risk, electrical automation systems may necessitate monthly maintenance. Automation does not eliminate the need for regular maintenance tasks such as clearing swales, removing debris, and inspecting outlets, as automated systems may struggle with handling woody debris. Therefore, automation isn't recommended.

Upon review of available products and areas of improvements, a mechanical system relying on gravity/hydrostatic pressure just as the current flap gates remains council's best choice for easy maintenance and low capital cost. However, improvements can certainly be made on the existing system.

JBP recommends taking the following measures:

1. Enhance seal/ water tightness: Consider adopting an improved design allows flap gates to close fully under gravity by extending the bottom of pipe to meet the gate as illustrated in Figure 3-2. Importing double hung hinged flap gates or bespoken flap gate design for Group A and B. Upgrade/ remediation priority will be on the gates along the western bank, 17924 to 17927, as the inlet invert is lower than the spring tide level, during high tide water will flow from the creek to inland.

Figure 3-2



2. Increase water head

Clear out swales of vegetation other than grass and re-grade them to ensure a good longitudinal profile, applicable to gates connected to swales. There are gates connected to open grass land which do not require further clearance.

3. Reduce debris coming into the system

(a) Install grates at inlets to further reduce debris coming into pipes. This may not be necessary if the swales are clear of debris. It is recommended to monitor the systems after clearing the swales before installing grates for gates without screens. If swales cannot to be cleared for any reason, priority should be given to floodgates that has dense vegetation or deciduous trees within 20m upstream of the inlet, and then gradually roll out to all inlets.

(b) Educate residents on the importance of maintaining the swales clear of foreign objects and avoid planting in or on the swale banks.

The measures are not listed in order of priorities but are recommended to be actioned at once to achieve the best outcome.

Yearly maintenance programme

Following CIRIA C7861 guidance and combining with specific site observations, a generic maintenance programme is developed to follow remediation works proposed above to further improve flood resilience of the site.

5.1 Activity

Expected maintenance activities for the remediated floodgates are:

1. Inspection. Council staff to inspect floodgates for abnormalities and identify triggers of further maintenance activities as below.

2. Removing sediment and debris from pipes through high-pressure jetting. This eliminates the need to feed a rake through the pipes and the need for personnel to enter the systems. The pressure should not be damaging to the concrete pipes but sufficient to flush debris directly out or at least to outlet points for easy removal.

3. Clearing debris from screens. Screens tend to block with debris and regular cleaning is needed to maintain hydraulic performance of them. As the floodgates in interest do not experience large head of water, manual raking is considered suitable. This activity should only be carried out in good sunny weather when the systems are dry. The debris should be removed from the site.

4. Maintaining flap gates. Flap gates operation relies on rubber rings and hinges. These parts should be examined and replaced timely. Lubrication of hinges should be conducted regularly to facilitate open and close of gates.

5. Controlling vegetation upstream. Swales feeding into the flap gates are to be cleared of debris and unnecessary vegetation that contributes to blockage.

5.2 Frequency

As the design/construction of these gates are not ideal, the below frequencies are recommended as a minimum:

- Inspection – Quarterly for any year. Recommended times are late October, late January, late April, and August based on ‘wet season’ from November to April.

- Activity 2, 3, and 5 – Biannually at late October (before start of wet season) and late April (drier time for easy access).
- Activity 4 – Likely to be every year but depends on manufacturer's guidance.

Strategic Considerations

Community Strategic Plan and Operational Plan

CSP Objective	CSP Strategy	DP Action	Code	OP Activity
5: Connected Infrastructure	**5.5: Provide continuous and sustainable water and sewerage management**	**5.5.3: Storm-water - Provide stormwater infrastructure to manage flood mitigation and improve social and environmental outcomes**	**5.5.3.8**	**Continue to progress South Golden Beach drainage upgrade program**

Recent Resolutions

-

Legal/Statutory/Policy Considerations

Not applicable

Financial Considerations

This project has been funded under funding source - NRRRP Stream 1 - Increasing flood risk awareness. CSIRO ID NP10.

Indicative costs for construction works recommended in Section 4.2 have been developed as a guidance.

Proposed work	Rate	Unit	Item	Cost	Assumptions
Site mobilisation	$ 2,000	/Item	1	$ 2,000	
SS or fibre reinforced flap gates	$ 8,000	/Item	18	$ 144,000	
Installation of flap gates	$ 300	/hr	36	$ 10,800	No modification to concrete pipe or headwall required. Two hours per gate
Swale clearing with excavator	$ 1,600	/day	9	$ 14,400	Two swales per day
Disposal of green waste	$ 120	/m3	54	$ 6,480	3m3 of green waste from each swale
Disposal of construction waste	$ 200	/m3	18	$ 3,600	
Aluminium screens	$ 2,000	/Item	14	$ 28,000	
Installation of screens	$ 300	/hr	56	$ 16,800	Four hours per grate
Sum:				$ 226,080	

Yearly maintenance cost

Based on the frequency and activities proposed in Section 5, indicative costs for maintenance are as below.

Table 6-2: Indicative maintenance cost per year (extract from attachment 1)

Maintenance	Rate	Unit	Item	Cost	Assumption
Inspection	$ 200	/time	4	$ 800	By council staff
Remove debris from pipes	$ 400	/hr	27	$ 10,800	With high pressure jetting, 1.5 hr per pipe
Clearing screens	$ 150	/hr	18	$ 2,700	Manual clearing, 1 hr per screen
Maintenance on flap gates	$ 220	/item	18	$ 3,960	$50 for rubber ring and $20 for lubrication
Sum:				$ 18,260	

Council do have an existing Maintenance Budget allowance for this area under the “North – Urban Drainage Maintenance” component of the Draft Operation Plan 2024/2025. Any upgrade items outlined in Section 4.2 and 5 and costs in Section 6 of this report would need to be reviewed and rationalised against the other priorities within that funding allowance.

Consultation and Engagement

Given this is an investigation study, no consultation or engagement has been undertaken.

NOTE TO FILE

JBA Project Code	2024s0342
Contract	Floodgate upgrade options investigation
Client	Byron Shire Council
Day, Date and Time	23/04/2024
Author	C.Yang
Subject	South Golden Beach floodgates upgrade options

1 Introduction

JB Pacific was commissioned by Byron Shire Council (BSC) to investigate potential upgrade options for floodgates at South Golden Beach NSW. The project scope includes twelve gates on the east bank, four gates along the west bank of Yelgun Creek and two along Redgate Road. BSC aims to improve flood resilience of the area by investigating into the most effective upgrade options.

The project location and extent has been shown in Figure 1-1 with floodgate locations marked with asset ID.

Figure 1-1: Project site

1.1 Background and available data

The floodgates are council owned and managed assets. Council record shows they were installed in between 1970 to 1976, with one exception, gate 19738 was built in 1985. This suggests they have been in service for 48 to 54 years. The last record of condition inspection was in year 2019 and all of them were considered in condition 2 (BSC internal rating system) but has no additional description on defects, maintenance program nor records of remediation works.

Table 1-1 presents critical information on the floodgates provided by BSC. The location of each is expressed in terms of easting and northing, using coordinate reference system MGA94 zone 56.

NOTE TO FILE

JBA Project Code	2024s0342
Contract	Floodgate upgrade options investigation
Client	Byron Shire Council
Day, Date and Time	23/04/2024
Author	C.Yang
Subject	South Golden Beach floodgates upgrade options

Table 1-1: Extract of council supplied information

Asset ID	Easting	Northing	Diameter (mm)	Construction year
17923	553347.06	6847957.89	900	1976
17924	553306.35	6847636.549	600	1975
17925	553303.52	6847740.90	600	1975
17926	553301.28	6847845.14	600	1975
17927	553300.21	6847910.94	600	1975
17928	553352.38	6847588.89	600	1970
17929	553353.30	6847569.65	600	1970
17930	553345.38	6847906.84	900	1976
17931	553345.89	6847891.33	900	1976
17932	553346.76	6847843.64	600	1976
17933	553348.99	6847792.54	900	1976
17934	553349.29	6847742.29	600	1970
17935	553353.80	6847695.13	900	1970
17936	553353.62	6847681.89	900	1970
17937	553351.99	6847636.02	600	1970
17938	553348.57	6847800.08	900	1985
17939	553829.96	6847553.89	600	1976
17940	553665.01	6847489.82	450	1970

1.2 Inspection

JBP engineers visited site on 11/03/2024 at a high tide. Observations have been summarised in Table 1-2. It is noted that some floodgates have clearly been cleaned and this means issues of such floodgates may not be observed. Some inlets and outlets have been covered under vegetation and debris and JBP were unable to access them. General comments are:

- All floodgates consist of open swale, inlets of concrete headwall or grated pits on land side of levee, outlets of concrete headwalls with flap gates on the creek side of the levee.
- The pipe sizes observed on site are consistent with council provided record.
- The condition of outlets and inlets are generally fair, unless mentioned otherwise in the table below. The durability of materials (fibre reinforced polymer flap gates and concrete headwalls with apron and wing walls) over approximately 50 years of service is proven to be good.
- The outlets on the east bank of Yelgun Creek are mostly above high tide level.
- The outlets on the west bank of Yelgun Creek are submerged under high tide.

BSC advised the floodgates fails to prevent backflow from the tidal Yelgun Creek into open swales running between residential lots, allowing water going behind the South Golden Beach Levee. The suspected reason is that they are constantly jammed by debris and fails to seal.

Photos records can be found in Table 1-3.

NOTE TO FILE

JBA Project Code	2024s0342
Contract	Floodgate upgrade options investigation
Client	Byron Shire Council
Day, Date and Time	23/04/2024
Author	C.Yang
Subject	South Golden Beach floodgates upgrade options

Table 1-2: Site inspection notes

Asset ID	Inlet condition	Outlet Description	Condition / issues
17923	Clean open swale with three grated detention pits. Further upstream of swale is a concrete channel with double grates.	Flap gate submerged. Steel reinforcement of unknown purpose can be seen mounting on the gate.	Nil
17924	Heavily vegetated swale with a lot of debris covering the inlet. Appears to be a compost area set up by residents. Inlet suspected to be dry most of the time.	Flap gate not sealed, submerged.	No water at rear of levee during high tide.
17925	No access. Dense vegetation.	Flap gate not sealed, submerged.	Nil
17926	No access. Open channel with stagnant water and overgrow of weed.	Flap gate not sealed, submerged.	Pond of water rear of levee
17927	No access. Open channel with stagnant water and overgrow of weed.	Difficult access. Flap gate not sealed, submerged.	Pond of water rear of levee
17928	Concrete headwall with no grates. Minimum debris.	Flap gate of 800mm.	Overgrow of weed
17929	Grated pit covered under debris.	Overgrow of weed. No access	Nil
17930	Grated pit of 1080 x 1100, minor debris such as leaves	Flap gate of 1100mm. Debris inside of flap gate, mainly of leaves and rubbish, minor vegetation growth inside of pipe	Flap gate closed at time of inspection. Flap gate invert level above creek water level for majority of time. Large amount of debris/deposition on apron, may prevent the flap gate from opening.
17931	Concrete headwall with no grates	Flap gate of 1100mm. Debris inside of flap gate, mainly of leaves and twigs.	Flap gate open (50mm at bottom) at time of inspection. Flap gate invert level above water level for majority of time. No signs of scour, concrete apron intact.
17932	Dense vegetation establishment in open swale. Concrete headwall with no grates.	Flap gate of 800mm. Debris inside of flap gate, mainly of leaves, twigs and branches.	Flap gate open (100mm at base). Heavy blockage. Debris inside of pipe and on apron. Concrete spalling and exposure of reinforcement at outlet headwall. Large amount of

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Asset ID	Inlet condition	Outlet Description	Condition / issues
			debris/deposition on apron, may prevent the flap gate from opening.
17933	One of a twin cell culvert with no grate. Reinforcement exposed.	Flap gate of 1100mm.	No debris in flap gate. Delamination of fibre reinforced polymer flap gate. Large amount of debris/deposition on apron, may prevent the flap gate from opening.
17934	Concrete headwall with no grates.	Flap gate of 800mm. Good seal.	Inlet headwall scoured resulting in concrete partially unsupported. Overgrow of weed, poor access to outlet. Large amount of debris/deposition on apron, may prevent the flap gate from opening.
17935	Grated pit of 1080 x 1100, covered in large debris.	Flap gate of 900mm. Good seal, minimum debris trapped inside	Nil
17936	Concrete headwall with no grates. Vegetation growth into the inlet suggesting minimum discharge and mostly dry.	Flap gate of 1100mm.	Flap gate not closed properly. Vegetation growth and debris inside of flap gate.
17937	Concrete headwall with no grates.	Flap gate of 800mm.	Heavy debris at inlet. Flap gate not closed properly.
17938	One of a twin cell culvert with no grate. Reinforcement exposed.	Flap gate of 1100mm. Small amount of aggregates inside of flap gate.	Rubber ring degradation and displacement. Flap gate not sealed.
17939	Concrete headwall with no grates. Overgrow of weed and vegetation.	Flap gate of 800mm. Difficult access due to over grow	Inlet and outlet are dry
17940	Concrete headwall with no grates. Minor debris accumulation.	Difficult access. Overgrow of weed.	Inlet and outlet are dry

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Table 1-3: Photo record

Asset ID	Inlet condition	Outlet Description
17923		
17924		
17925	No access	

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Asset ID	Inlet condition	Outlet Description
17926		
17927		
17928		

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Asset ID	Inlet condition	Outlet Description
17929		No access
17930		
17931		

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Asset ID	Inlet condition	Outlet Description
17932		
17933		
17934		

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Asset ID	Inlet condition	Outlet Description
17935		
17936		
17937		

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Asset ID	Inlet condition	Outlet Description
17938		
17939		
17940		

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2 Issue identification

In order to improve the floodgates, it is critical to understand the pros and cons of the current systems. Site inspection has revealed that floodgates with the following features have demonstrated notable effectiveness:

- Floodgates with grated pit upstream show significantly less debris accumulation inside of the pipes.
- Floodgates with upstream swale grassed (not planted with vegetation) show significantly less debris accumulation inside of the pipes.

The main issues with the existing systems are:

- Stagnant water rear of levee:
  - Flood risk: Difficulty to discharge water into Yelgun Creek may lead to increase in water level during flood events and result in water damage to residential properties.
  - Hygiene, odour and aesthetic concerns: Stagnant water can be breeding ground for mosquitoes and attract various vectors which can transmit diseases to humans.
- Flap gates unable to seal:
  - Flood risk: The flap gates are supposed to be one-way systems allowing drainage into the creek only. As many of them are constantly open, they become two-way systems and would allow creek water to come over the levee and has the potential of flooding land behind.
  - Flood risk: The flap gates unable to open due to debris accumulated on outlet apron. Large amour of debris was observed on the apron, but the flap gates were still able to open at time of inspection. This issue was raised by residents. Overall, it is still a risk, and it is a good practice to minimise accumulation of debris on the apron.

The issues could exist simultaneously or even be of influence of each other, however, they are listed separately to facilitate proposal of solutions/options. Based on the present issues, the flap gates can be further grouped in Table 2-1, requiring improvement in similar aspects. The groups are:

A. Water ponding rear of levee
B. Large amount of debris coming through system, blockage at flap gate, unable to seal
C. Large amount of debris on apron, flap gate unable to open
D. No access due to overgrow
E. No pressing issue observed.

In which JBP advise to monitor Group E and no further options will be necessary until any issue with them become clear. For Group D it is advised to clear them and monitor performance. Further options will be proposed for Group A to C.

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Table 2-1: Asset categorisation based on issue.

Asset ID	Condition / issues	Group
17923	Rock chute with minor defects (missing mortar and loss of rocks). Floodgate had remediation works done to it. Unknown issue.	E
17924	No water at rear of levee during high tide	B
17925	No access	D
17926	Pond of water rear of levee	A
17927	Pond of water rear of levee	A
17928	Overgrow of weed	D
17929	Overgrow of weed	D
17930	Flap gate closed at time of inspection. Flap gate invert level above creek water level for majority of time. Large amount of debris/deposition on apron, may prevent the flap gate from opening.	B
17931	Flap gate open (50mm at bottom) at time of inspection. Flap gate invert level above water level for majority of time. No signs of scour, concrete apron intact.	B
17932	Flap gate open (100mm at base). Heavy blockage. Debris inside of pipe and on apron. Concrete spalling and exposure of reinforcement at outlet headwall. Large amount of debris/deposition on apron, may prevent the flap gate from opening.	B
17933	No debris in flap gate. Delamination of fibre reinforced polymer flap gate. Large amount of debris/deposition on apron, may prevent the flap gate from opening.	C
17934	Inlet headwall scoured resulting in concrete partially unsupported. Overgrow of weed, poor access to outlet. Large amount of debris/deposition on apron, may prevent the flap gate from opening.	C
17935	Nil	E
17936	Flap gate not closed properly. Vegetation growth and debris inside of flap gate.	B
17937	Heavy debris at inlet. Flap gate not closed properly.	B
17938	Rubber ring degradation and displacement. Flap gate not sealed.	B
17939	Inlet and outlet are dry	D
17940	Inlet and outlet are dry	D

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2.1 Survey information

A topographic survey done in 2023 has been provided by BSC in pdf format. The extent covers all the inlets and outlets but do not provide a full view for swales and areas under water (including ponding water). A preliminary assessment on the grades of pipes reveals that 11 pipes have a gradient of less than 1% with two pipes having negative grades from the survey. This discrepancy suggests potential inaccuracies in the survey, or issues related to construction quality. It is widely acknowledged that the minimum grade for stormwater drainage should be 1% and with a flap gate at the end, a steeper grade will be beneficial.

It is plausible that the design of the stormwater systems has adopted a larger pipe size for a design flow to accommodate the minimal grades dictated by the topography. However, such an approach implies that during normal operations, there may not be sufficient flow to effectively flush the pipes.

No calculations or modelling have been undertaken to delve deeper into this potential issue. Nevertheless, it is evident that such designs cannot be relied upon for self-cleaning and will require more frequent maintenance than standard stormwater drainage systems, to ensures optimal system performance during regular operations.

Table 2-2: Grade of concrete pipes.

Asset ID	Inlet (mAHD)	Outlet (mAHD)	Pipe length (m)	Pipe grade*	Water head (m)
17923	0.30	0.32	29.53	-0.07%	-0.020
17924	0.48	0.22	15.49	1.68%	0.260
17925	0.45	0.28	14.75	1.15%	0.170
17926	0.46	0.28	14.35	1.25%	0.180
17927	0.51	0.37	14.45	0.97%	0.140
17928	1.41	1.45	19.43	-0.21%	-0.040
17929	1.44	1.39	12	0.42%	0.050
17930	1.29	1.16	17	0.76%	0.130
17931	1.47	1.37	16.86	0.59%	0.100
17932	1.18	0.98	12	1.67%	0.200
17933	1.37	1.33	12	0.33%	0.040
17934	1.13	1.03	12	0.83%	0.100
17935	1.46	1.41	9.73	0.51%	0.050
17936	1.40	1.37	9.74	0.31%	0.030
17937	1.09	1.03	12	0.50%	0.060
17938	1.36	1.33	12	0.25%	0.030
17939	1.76	1.72	9.49	0.42%	0.040
17940	1.38	1.26	17.92	0.67%	0.120
*: Positive grade suggests flow direction towards creek.					

2.2 Group A - Stagnant water rear of levee

This has been observed along the west bank of Yelgun Creek and is considered likely to be the result of the following factors:

- Flap gates unable to seal due to rubber ring degradation.
- Flap gates unable to seal as they are jammed by debris.
- Flap gates unable to open as thick siltation and debris accumulating on the apron.
- Waterhead too small to flush debris out as longitudinal grade being too flat.

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- Waterhead too small to flush debris out as insufficient maintenance and large volume of debris accumulation acting as natural log jams.

The main cause may be identified with more confidence with support from the council maintenance team. Without further information, to avoid the ponding, upgrade options shall consider achieve at least one of the following:

- Ensure flap gates seal properly.
- Replace flap gates with another type of valve that seals properly with presence of debris.
- Increase waterhead.

2.3 Group B – blockage at flap gate

This has been observed of at seven gates along the Yelgun Creek and is considered likely to be the result of the following factors:

- Dense vegetation growth in swales and on levee. Foliage, twigs and branches are main component of debris observed on site. Trees growing on the levee could compromise stability of the levee through their extensive root system. Piping could occur after mortality of trees and shrinkage of died root systems. Trees growing inside of swales are considered contributing to the blockage.
- Lack of public awareness at locations. Residents utilise the swales as storage for green waste or compost or use for aesthetic/ landscaping through planting of vegetation other than grass.
- Absence of any sieve/grates at inlets.
- Waterhead too small or flap gates too heavy to be flushed open, resulting in water slowly drain out of a small opening and debris accumulating inside of the gates.

The blockage is considered a combined result of the above. Therefore, upgrade options shall consider achieve at least one of the following:

- Reduction in debris input into the systems.
- Replace flap gates with another type of valve that seals properly with presence of debris and allows water to drain freely during low tides.

2.4 Group C - flap gate unable to open

This is a concern for nine gates which include gates experiencing blockage at flap gates. Large amount of debris accumulated at concrete aprons could make the opening of flap gates even more difficult resulting in loss of water head. Resolving the issues of Group B is expected to improve this issue at the same time. Apart from the above causes in Section 2.3, this is considered likely to be the result of the following factors:

- Outlet location experiences no flush from creek. Their locations are retrieved on riverbank and behind mangroves which further reduce flow.

The blockage is considered a combined result of the above. Therefore, upgrade options shall consider achieve at least one of the following:

- Reduction in debris input into the systems.
- Replace flap gates with another type of valve that seals properly with presence of debris and allows water to drain freely during low tide times.
- Extend outlets into the creek for flushing of concrete aprons.

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2.5 Group D – no access and Group E – no pressing issue

No issues have been identified for seven gates fall into Group D and E either due to no access or flap gates are working properly.

Where there is no access to the assets, it is recommended to provide access through maintenance and clearing of swales (further discussion below in Section 3.1.4).

As the issue identification is based on one site visit, there may have been maintenance works done to the outlets that have temporarily resolved an issue or the issue was not obvious at the time of visit. Without further information from council, no further investigation will be conducted into these gates in this project. Due to the proximity of the gates and considering their service life, the preferred option identified in this project are considered applicable to gates in these groups to maximise value of site mobilisation cost.

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3 Options and actions identification

This section considers potential options for improvements for groups of outlets. These options are generally long-term unless noted otherwise and will be fed into a Multi Criteria Assessment (MCA) to gain a better understanding of suitability.

3.1 Group A – stagnant water

3.1.1 Immediate action

Five potential causes are identified previously. It is recommended to conduct a topographic survey of swales feeding into flap gates 17926 and 17927 to confirm the invert line of the swales and efficiency of remediation works such as regrading and stabilising the swale to provide sufficient waterhead.

3.1.2 Option 1 – Maintenance work on existing system

The current systems have been in a good to fair condition after being in service for 50 years. The performance is reduced mainly due to lack of maintenance. Regular maintenance works are therefore worth considering, such as replacing degraded rubber ring, raking the pipes to remove excess debris, lubricating hinges for easier operation of flaps, pressure wash aprons and remove excessive debris etc. This option has minimum capital expenditure but requires long-term and continuous investment into maintenance. The maintenance level is considered medium to set a base-line case for this study.

3.1.3 Option 2 - Improving flap gates

Option 2.1 – New flap gates

Many improvements have been made to flap gates over the past 50 years. Replacing the existing gates with new designs will reduce head loss resulting in better drainage and seal. Comparing with the single hinge flap gates on site, double hung hinge flap gates have the benefit of less likelihood for sticking gates and reduction in head loss. Examples below shows a simple double hung flap gate and a Mueller hydro gate with an adjustable pivot lug. The latter can be adjusted for more sensitivity (less water to crack the gate open) which can result in less debris accumulating inside of the gates. Mounting new flap gates will only trigger a small amount of expense but it is likely they need to be imported from overseas. Locally in Australia, flap gates of lighter material are available such as High-Density Polyethylene (HDPE) which will be more sensitive than the current glass fibre reinforced polymer gates. This option also comes with a medium level or slightly lighter maintenance need.

At the same time, the current pipes seem to have a flush end, then connecting to a flap gate. This would result in flap gates to remain slightly open due to gravity. A schematisation of the situation is in Figure 3-2. This is considered a design defect or poor construction quality and should be remediated if confirmed through detailed geometry check of the flap gates.

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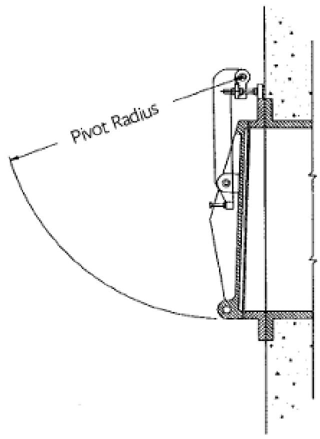

Left: T-T pumps (UK) product. Right: Hydro gate (US) product.

Figure 3-1: Example of double hung flap gates.

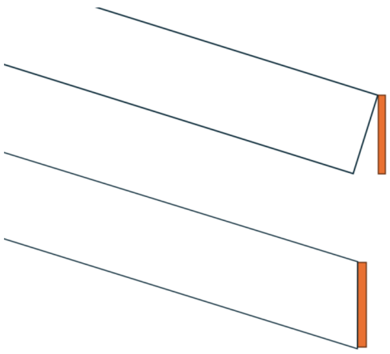

Figure 3-2: Right: Schematisation of poor design (flush end of pipe, top) vs. good design (end of pipe at an angle, bottom). Left: Good design in real life.

Option 2.2 - Automated flap gates

Automate the operation of flap gates to fully open and close can reduce head loss. This increases the likelihood of flushing debris out of the system, but requires establishment of new power supply, actuators and staff overwatching the operation which suggests a medium size capital expenditure and maintenance cost. The automated flap gates still require maintenance due to blockage by twigs and branches but is expected of less frequent due to less loss of water head. The actuators can be hydraulically or electrically operated. However, many gates at this site sits above tidal range suggesting the hydraulic operation is not available unless they are extended out into the creek, while electrical actuators need to be positioned above flood levels to avoid submergence. This will be reviewed in detail if automated flap gates are considered suitable in MCA. As these gates are customised, their fabrication price remains unknown. Existing flap gates cannot be recycled, and new gates are needed for automation.

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Option 2.3 – New flushing system

A flushing system (likely consists of a hose, a water pump and a switch) can be incorporated inside of the pipe near its inlet to flush debris out and potentially clearing the concrete apron given enough pressure. This can largely reduce maintenance frequency, ensures the seal of flap gates at most times and reduce maintenance difficulty comparing with raking individual pipes. However, the flushing system requires new power supply, and water source. Its operation can be manually turned on by council staff (no telemetry required) or fully automated (with telemetry). Such system will be custom made which suggests a medium size capital expenditure but small maintenance fee on going.

3.1.4 Option 3 - Improving swales

Clearing out and restoring the swales to grass swales can significantly reduce the amount of debris going through the system. This include clear out vegetations and reprofile swales for a 1% to 4% longitudinal grade. The system still requires maintenance but is expected of less frequent due to less debris coming through and greater waterhead to flush out them. A small capital expenditure and maintenance investment are expected, given the survey confirms the grade of existing swales are insufficient.

Figure 3-3: Comparison between a well-maintained grass swale versus a densely vegetated swale.

3.1.5 Option 4 - Replacing flap gates

Removing and replacing the existing flap gates with alternative one-way valves can improve performance and reduce maintenance requirements. Different valves are considered here.

Option 4.1 – Automated vertical rising gates

Removing existing flap gates and replacing them with automated sluice gates (or knife gates, to retrofit onto existing pipes) that seals tight with minor leave debris present. Knife and sluice gates are vertical rising valves need to be lifted open through powered mechanic arms. Electrical actuators have been considered the most economic for our case by flap valve suppliers JBP approached.

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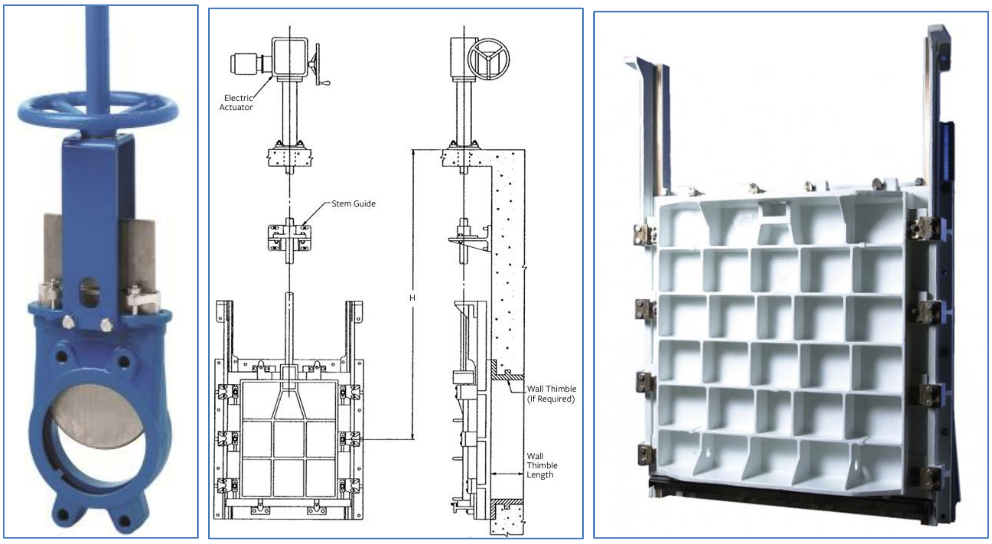

Figure 3-4: Left: Example of knife valves of AVK Industrial. Middle and Right: Automated sluice gate of Muller (US)

The valves are off-shelf products, but the automation requires new power supply (with flood immunity) and actuators and operators as discussed before. The supplier has suggested the knife valves requires similar degree of maintenance as flap valves because they are unable to cut through twigs and branches.

Also note the knife valves require support from both sides therefore cannot be directly fitted on to the existing pipes. Likely works include cutting the concrete pipe; install the knife valve; rejoin the concrete pipe at both ends to provide stability for the valve. This is therefore high in capital and maintenance expenditure. Sluice gates can be mounted onto existing pipes (single side support) which saves on modification of concrete pipes.

With automation, a new risk to public safety will need to be managed by council by controlling unauthorised access to these valves. Closing of the knife valves could lead to death and serious injury of any person inside of the pipe. Full isolation of the system during maintenance works is also highly recommended for the safety of council staff.

Option 4.2 – Alternative one-way valves

There are other non-return valves available on the market that relies on hydrostatic pressure to operate. They eliminate the need for power supply and telemetry system which significantly reduce upgrade cost. Some examples include scissor gates, duckbill valves and in-line check valves.

Scissor gates rely on buoyance to open and close and can handle foliage debris. However, twigs and branches will still prevent it from sealing. The design is customised by HydroSlide (UK). The gate is of metal, which will have corrosion issue in our site and requires careful selection of material and corrosion prevention measures such as painting.

Duckbill valves have higher tolerance to debris comparing with flap gates and are usually made of rubber. They are safer for fishes and are claimed to be maintenance free (no moving mechanical parts), if given enough water head. More information on catchment area, longitudinal grade of each outlet would be required to determine if water head is sufficient to open them as they usually require higher head than flap gates.

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In-line check valves can also seal better with minor foliage debris than flap gates but requires higher water head to open. They can be made of rubber and shares many pros and cons with the duckbill valves. Their application can result in a small to large capital expenditure, depending on how much work is required to increase water head to a satisfactory level. Based on observation on site, it is likely to require earthwork and replacing concrete pipes at a greater grade for this option to perform as intended. This suggests a large capital expenditure. However the improved system is expected to have less maintenance requirements.

Figure 3-5: Left: Scissor valves. Middle: Duckbill valves. Right: In-line check valves.

3.2 Group B – blockage at flap gate, unable to seal

Option 3 and 4 discussed in Section 3.1.4 and 3.1.5 have been discussed above for Group A and are applicable to Group B with the same pros and cons. Hence it is not further discussed here.

3.2.1 Option 5 – Screens at inlet

Reduction in debris coming through the system reduces likelihood of blockage at flap gates. This can be achieved by installing screens/sieves/grates at inlets. The screens can prevent natural and man-made (plastic bags, cans) debris entering the creek and accumulate at locations that are easy to access and clear out. This is a value-add on cleaning the creek and allow safe removal of debris. There are many designs available depending on target debris size. Alignment of the screen can also vary from being perpendicular to the approach flow (susceptible to blockage but easy construction with off-shelf products) to being at an oblique angle to the approach flow to increase its effective area and reduce likelihood of blockage.

Without clearing of the swales, the debris are not removed from the system but simply accumulated upstream with less influence on seal of flap gates. However, the screens will change the hydraulic of the swale and suitability and design details should be confirmed through numerical modelling. The build-up requires clearing prior and after flood season to ensure minimum rise of water level in the swale and no increase in flood risk upstream.

The screens are easy to install, and swales are of good foot access. Therefore, this option has a small capital expenditure and a medium maintenance fee in long run.

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Figure 3-6: Left: Oblique screen. Right: Right angle screen.

3.3 Group C – flap gate unable to open

The restriction on gate's ability to open due to sedimentation on aprons can be resolved through:

- Careful design of Option 2 - Improving flap gates with sufficient clearance.
- Reducing debris load through Option 3 - Improving swales and Option 5 – Screens at inlet.
- Change of valve opening mechanism through Option 4 - Replacing flap gates. Duckbill valves have higher tolerance to debris and requires higher water head/ flow rate to open. Its design will not be blocked by accumulation of debris outside of the valve, and its release of water will have more volume hence better chance at flushing apron clean.

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4 Multi Criteria Assessment

4.1 Methodology

Each option has been reviewed to establish their relative merits against a set of project objectives via a Multi-Criteria Analysis (MCA). The purpose of the MCA is to help determine the preferred options in a systematic way. It uses Technical, Environmental, Social and Economic categories, including several sub-categories to develop a scoring system.

Table 4-1: MCA scoring criteria

Category	Considerations	Descriptions
Financial	Construction cost	Material cost, surcharge due to difficulty in construction, labour intensity and workmanship requirement
	Maintenance cost	Difficulty and frequency in maintenance
Constructability	Design cost	Complexity and scale of design
	Material availability	Volume and scarcity of material
	Complexity of construction	Variety and difficulty of required construction activities
Social	Public safety	Likelihood and consequence of unauthorised access
	Service life	Around 10 years (score 1), to 50 years and more (score 5)
Environmental	Carbon footprint	Amount of waste and new material required

The MCA process has been undertaken by designers, ranking options to identify the options with the best overall scores. The result is a color-coded MCA matrix with green indicating a more preferrable response and red suggesting poor performance (see Table 4-2).

Table 4-2: MCA scoring standard

Scoring	Color code	Description
5		Best
4		Good
3		Neutral
2		Bad
1		Worst

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Contract	Floodgate upgrade options investigation
Client	Byron Shire Council
Day, Date and Time	27/03/2024
Author	C.Yang
Subject	Floodgates issue identification

Table 4-3: MCA results

	Options							
Considerations	1 - Maintenance	2.1 - New flap gate	2.2 - Automated flap gates	2.3 - Flushing	3 - Swale work	4.1 - Automated vertical gates	4.2 - Alternative valves	5 - Screen
Construction cost	5	4	1	2	4	1	4	4
Maintenance cost	1	3	2	2	1	2	3	4
Design cost	5	4	1	2	5	1	3	3
Material availability	5	5	2	2	5	2	5	5
Complexity of construction	5	4	2	2	4	1	4	5
Public safety	5	5	2	4	5	1	5	5
Service life/ durability	1	5	3	3	2	3	5	4
Carbon footprint	5	3	2	2	4	2	3	3
Sum	32	33	15	19	30	13	32	33

NOTE TO FILE

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4.2 Recommendation

It is understood BSC wants to investigate options reducing the maintenance frequency or difficulty by means of semi and fully automation. However, any degree of automation comes with additional electronic or mechanical parts and additional services running along the levee. Automation will reduce maintenance demand of outlets but at the same time, itself requires regular maintenance by staff of special skills due to the need of working with electricity, moving parts, and computer algorithms. These needs can be outsourced but it will add into maintenance budget. The frequency of maintenance of an electrical automation system can be monthly in such a marine environment with flood risk. At the same time automation will not eliminate the need for regular maintenance such as clearing of swale and access, removal of debris, inspection of outlets etc as the automated systems will still have difficulties in handling woody debris. Therefore, automation is not recommended.

On the other hand, the site visit observations reveal the unsatisfactory performance are likely to be result of suboptimal design (water head too small), outdated elements (heavy flap gates requiring high water head) and lack of maintenance (missing rubber rings and accumulation of debris).

Upon review of available products and areas of improvements, a mechanical system relying on gravity/hydrostatic pressure just as the current flap gates remains council's best choice for easy maintenance and low capital cost. However, improvements can certainly be made on the existing system. JBP recommends taking the following measures:

1. Enhance seal/ water tightness

   Consider adopting an improved design allows flap gates to close fully under gravity by extending the bottom of pipe to meet the gate as illustrated in Figure 3-2. Importing double hung hinged flap gates or bespoken flap gate design for Group A and B. Upgrade/ remediation priority will be on the gates along the western bank, 17924 to 17927, as the inlet invert is lower than the spring tide level, during high tide water will flow from the creek to inland.

2. Increase water head

   Clear out swales of vegetation other than grass and re-grade them to ensure a good longitudinal profile, applicable to gates connected to swales. There are gates connected to open grass land which do not require further clearance.

3. Reduce debris coming into the system

   (a) Install grates at inlets to further reduce debris coming into pipes. This may not be necessary if the swales are clear of debris. It is recommended to monitor the systems after clearing the swales before installing grates for gates without screens. If swales cannot to be cleared for any reason, priority should be given to floodgates that has dense vegetation or deciduous trees within 20m upstream of the inlet, and then gradually roll out to all inlets.

   (b) Educate residents on the importance of maintaining the swales clear of foreign objects and avoid planting in or on the swale banks.

The measures are not listed in order of priorities but are recommended to be actioned at once to achieve the best outcome. Note the above recommendations assume that BSC intends to upgrade the current systems and avoid complete rebuild if possible.

NOTE TO FILE

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5 Yearly maintenance programme

Following CIRIA C786[1] guidance and combining with specific site observations, a generic maintenance programme is developed to follow remediation works proposed above to further improve flood resilience of the site.

5.1 Activity

Expected maintenance activities for the remediated floodgates are:

1. Inspection. Council staff to inspect floodgates for abnormalities and identify triggers of further maintenance activities as below.
2. Removing sediment and debris from pipes through high-pressure jetting. This eliminates the need to feed a rake through the pipes and the need for personnel to enter the systems. The pressure should not be damaging to the concrete pipes but sufficient to flush debris directly out or at least to outlet points for easy removal.
3. Clearing debris from screens. Screens tend to block with debris and regular cleaning is needed to maintain hydraulic performance of them. As the floodgates in interest do not experience large head of water, manual raking is considered suitable. This activity should only be carried out in good sunny weather when the systems are dry. The debris should be removed from the site.
4. Maintaining flap gates. Flap gates operation relies on rubber rings and hinges. These parts should be examined and replaced timely. Lubrication of hinges should be conducted regularly to facilitate open and close of gates.
5. Controlling vegetation upstream. Swales feeding into the flap gates are to be cleared of debris and unnecessary vegetation that contributes to blockage.

5.2 Frequency

BSC can conduct maintenance activities per their standard maintenance programme for council assets but as the design/construction of these gates are not ideal, the below frequencies are recommended as a minimum:

- Inspection – Quarterly for any year. Recommended times are late October, late January, late April, and August based on 'wet season' from November to April.
- Activity 2, 3, and 5 – Biannually at late October (before start of wet season) and late April (drier time for easy access).
- Activity 4 – Likely to be every year but depends on manufacturer's guidance.

[1] CIRIA, 2019. CIRIA 786 Culvert, screen, and outfall manual. London.

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6 Indicative cost

6.1 Capital expenditure

Indicative costs for construction works recommended in Section 4.2 have been developed as a guidance.

Table 6-1: Indicative construction cost

Proposed work	Rate	Unit	Item	Cost	Assumptions
Site mobilisation	$ 2,000	/Item	1	$ 2,000	
SS or fibre reinforced flap gates	$ 8,000	/Item	18	$ 144,000	
Installation of flap gates	$ 300	/hr	36	$ 10,800	No modification to concrete pipe or headwall required. Two hours per gate
Swale clearing with excavator	$ 1,600	/day	9	$ 14,400	Two swales per day
Disposal of green waste	$ 120	/m3	54	$ 6,480	3m3 of green waste from each swale
Disposal of construction waste	$ 200	/m3	18	$ 3,600	
Aluminium screens	$ 2,000	/Item	14	$ 28,000	
Installation of screens	$ 300	/hr	56	$ 16,800	Four hours per grate
Sum:				$ 226,080	

6.2 Yearly maintenance cost

Based on the frequency and activities proposed in Section 5, indicative costs for maintenance are as below.

Table 6-2: Indicative maintenance cost per year

Maintenance	Rate	Unit	Item	Cost	Assumption
Inspection	$ 200	/time	4	$ 800	By council staff
Remove debris from pipes	$ 400	/hr	27	$ 10,800	With high pressure jetting, 1.5 hr per pipe
Clearing screens	$ 150	/hr	18	$ 2,700	Manual clearing, 1 hr per screen
Maintenance on flap gates	$ 220	/item	18	$ 3,960	$50 for rubber ring and $20 for lubrication
Sum:				$ 18,260	

Report No. 4.4 Post 2022 Event Flood Behaviour Analysis - Brunswick River , Belongil Creek and Tallow Creek - NSW Department of Planning & Environment

Directorate: Infrastructure Services

Report Author: Steve Twohill, Flood and Drainage Engineer

File No: I2024/676

Summary:

The NSW Department of Planning & Environment (DPE) – now rebranded to NSW Department of Climate Change, Energy, the Environment and Water (DCCEEW) have finalised and published Post 2022 Flood Analysis Assessments for the three (3) main catchments contained within Byron Shire Council.

These reports have been uploaded to the NSW State of Emergency Service – NSW Flood Data Portal. All these reports are available to be viewed and downloaded.

These assessment reports are outlined as:-

“Post 2022 Event Flood Behaviour Analysis - Brunswick River – Final Report – February 2024” – WMA Water - (E2024/51340). Download link at Post 2022 Event Flood Behaviour Analysis - Brunswick River Report - Datasets - NSW Flood Data Portal

“Post Event Flood Behaviour Analysis of the March 2022 Event – Belongil Creek – Final Report – 19 April 2024” – BMT - (E2024/51531). Download link at Post Event Flood Behaviour Analysis of the March 2022 Event - Belongil Creek Report - Datasets - NSW Flood Data Portal

“Post Event Flood Behaviour Analysis of the March 2022 Event – Tallow Creek – Final Report – 19 April 2024” – BMT - (E2024/51533). Download link at Post Event Flood Behaviour Analysis of the March 2022 Event - Tallow Creek Report - Datasets - NSW Flood Data Portal

Links to these reports have been included on the Byron Shire Council website.

In response to requests from the Committee, DCCEEW have provided an animation of the 2022 flood event for the North Byron catchment – refer document E2024/51367

RECOMMENDATION:

1. That the Floodplain Management Advisory Committee notes that the Department of Climate Change, Energy, the Environment and Water (DCCEEW) have finalised and published Post 2022 Flood Analysis Assessments for the three (3) main catchments contained within Byron Shire Council. These include the North Byron/Brunswick River, Belongil Creek and Tallow Creek catchments.

Attachments:

1 BSC Flood Mitigation Program, E2022/52007 , page 176⇩

Report

The NSW Department of Planning & Environment (DPE) – now rebranded to NSW Department of Climate Change, Energy, the Environment and Water (DCCEEW) have finalised and published Post 2022 Flood Analysis Assessments for the three (3) main catchments contained within Byron Shire Council.

These reports have been uploaded to the NSW State of Emergency Service – NSW Flood Data Portal. All these reports are available to be viewed and downloaded.

These assessment reports are outlined as:-

"Post 2022 Event Flood Behaviour Analysis - Brunswick River – Final Report – February 2024" – WMA Water - (E2024/51340). Download link at Post 2022 Event Flood Behaviour Analysis - Brunswick River Report - Datasets - NSW Flood Data Portal

"Post Event Flood Behaviour Analysis of the March 2022 Event – Belongil Creek – Final Report – 19 April 2024" – BMT - (E2024/51531). Download link at Post Event Flood Behaviour Analysis of the March 2022 Event - Belongil Creek Report - Datasets - NSW Flood Data Portal

"Post Event Flood Behaviour Analysis of the March 2022 Event – Tallow Creek – Final Report – 19 April 2024" – BMT - (E2024/51533). Download link at Post Event Flood Behaviour Analysis of the March 2022 Event - Tallow Creek Report - Datasets - NSW Flood Data Portal

Links to these reports have been included on the Byron Shire Council website.

These reports aim to understand the areas impacted by the recent 2022 flood event and determine the current approved flood model's ability to replicate the event. The common recommendation and finding from the analysis were that the existing Flood Studies have reached their use by date due to advances in modelling technology and techniques gained over the past five (5) years. Updates to all current flood studies are recommended.

While the Report's findings provide various recommendation that Byron Shire Council support, we will not be making any changes to our planning instruments at this stage. To do this, we would need our own updated Floodplain Management Study and Plan/s for each of the catchments in the Shire. This would require updates to all Flood Models to then inform the Flood Risk Study and Plan process. That would include review of Development Controls, Fill Exclusion zones as examples. This approach is consistent with the mandated processes under the NSW Flood Risk Management Manual 2023 that Council shall comply with.

To support this approach in respect to updated development controls, the Brunswick River report compared the actual 2022 event to the adopted 2100 development flood controls that include 1% AEP, sea level rise and 20% increased rainfall intensity. It found that the 2022 event was either consistent or lower that these design controls.

In respect to the northern region of the shire, DCCEEW have provided an animation of the 2022 flood event for the North Byron / Brunswick River catchment – refer document E2024/51367.

There is an anomaly with the recreation of the flood pattern in the South Golden Beach area on the western side of the canal system. Flooding was experienced from the north in a manner not predicted by the design model. The post flood review raised concerns with the flood model limitation at the Kallaroo Bund Interface and interface with the Coastal Creeks of Tweed Shire.

In terms of updated flood studies, Council has been awarded DCCEEW grant funds to undertake the Belongil and Tallow Creek/s, works have been tendered with contract engagement expected to be issued by end of May 2024. Works were put on hold awaiting the updated the Light Detention and Ranging Survey (LIDAR) being undertaken by the CSIRO. To date no updated LIDAR data has been issued by the CSIRO. This project will also include updates to the Floodplain Risk Management Study and Plan/s for both catchments.

In respect to the North Byron Flood Study and associated Risk Management Study and Plan no budget has been allocated within the draft Operational Plan 2024/25 by Council for this work. Applications for the 2024-25 Floodplain Management Program close on 16 May 2024. This is a reoccurring annual grant; Council will seek funding to support an application in the 2025/2026 round.

Key issues

Not applicable

Strategic Considerations

Community Strategic Plan and Operational Plan

CSP Objective	CSP Strategy	DP Action	Code	OP Activity
3: Nurtured Environment	3.3: Protect the health of coastline, estuaries, waterways, and catchments	3.3.2: Floodplain management - Mitigate the impact of flooding on private and public property	3.3.2.3	Floodplain Risk Management Committee coordination

Recent Resolutions

- 23-271, 23-094, 22-606, 22-352, 23-654

Legal/Statutory/Policy Considerations

The updated Floodplain Development Manual 2023 supports the policy and guides councils through the floodplain risk management process. The manual helps councils develop and implement local floodplain risk management plans and outlines the technical assistance provided by the NSW Government.

The manual details the roles and responsibilities of various NSW agencies and includes information on:

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

The manual was originally gazetted in 2005 with a new updated manual being gazetted in 2023. It is the manual relating to the development of flood-liable land for the purposes of section 733 of the Local Government Act 1993.

Financial Considerations

There are no financial considerations in this instance as the report is being commissioned by NSW DCCEEW.

Consultation and Engagement

NSW DCCEEW have provided draft copies of the reports and briefing sessions to the committee in late 2023. The adopted reports are now publicly available with links on the Byron Shire Council website.

Byron Shire Council - 2022 - Whole Flood Mitigation Program' (E2022/52007)

	Floodplain Management Plan	Proposed Mitigation Action	Priority	Responsibility	Approx Value	Comments
1	North Byron	Flood Planning Levels revised based on the recommendations of the FRMS.	Complete	Complete	Staff Time	Complete
2	North Byron	Section 10.7 (5) certificates to provide further detail of flood behaviour. Consideration to providing property-level flood information via an online GIS platform	Complete	Complete	Staff Time	Complete
3	North Byron	Byron Shire Council and SES to consider the findings and recommendations of the FRMS in the development of the Flood Warning Network for North Byron.	Complete	Complete	Staff Time	Complete
4	North Byron	Identify key roads and implement automatic warning signs and depth indicators.	High	BSC - IPT	$100,000	Grant being invstigated
5	North Byron	Council consider updating the DCP to incorporate the recommendations detailed in the FRMS; Provide more detailed guidance on the principles of wet proofing, appropriate design and materials, with direct reference to available guideliness; include a requirement for an assessment of property level protection as part of the DCP2014 planning matrix criteria FL4; Implement the recommendations regarding appropriate fill areas in the DCP2014	Partially complete	BSC - SEE / IPT	Staff Time	To be discussed with SEE
6	North Byron	Development a whole of catchment drainage model and overland flow path investigation.	High Priority	BSC - IPT	$250,000	2:1 grant submitted May 22
7	North Byron	Undertake more detailed assessment of properties which may benefit from property level protection	High	BSC - IPT	$50,000	Will form part of the scope of Shire overland flow path study
8	North Byron	Implement debris control measures for Federation Bridge and Billinudgel Railway Bridge.	Design underway	BSC - IPT	$100,000	Grant funded for design phase only
9	North Byron	Undertake an Evacuation Assessment for Mullumbimby.	High Priority	SES (tech intel from IPT)	Staff Time	Underway by SES
10	North Byron	Changes to land use zoning should consider flood compatibility based on the recommendations of the FRMS.	Complete	Complete	Staff Time	Complete
11	North Byron	Further investigate raising eligible residential properties to reduce flood damages.	Moderate	BSC - IPT	Staff Time (pending Council decision on VHR Council/State contribution	Underway as part of VHR/VHP scheme
12	North Byron	Further detailed assessment of Saltwater Creek upgrade assessment and mitigation options for Mullumbimby.	Moderate	BSC - IPT	Refer to item 6	Will form part of the scope of Shire overland flow path study
13	North Byron	Form a committee, comprising council, state, emergency services and community member representatives to oversee the implementation of the FRMP	Complete	Complete	Complete	Complete
14	North Byron	Council and the SES to update the Local Flood Plan based on findings of the FRMS.	Moderate	SES (tech intel from IPT)	Staff Time	Underway by SES
15	North Byron	Revise the Flood Planning Area based on the recommendations of the FRMS.	Complete	Complete	Staff Time	Complete
16	North Byron	Engage with the community to prepare an ongoing flood education program, with appropriate evaluation by Council and SES following implementation.	Moderate	SES/BSC - IPT / Comms	$20,000	Funding to be sought
17	North Byron	Further consideration of Avocado Court drainage modification.	Moderate	BSC - IPT	Refer to item 6	Will form part of the scope of Shire overland flow path study
18	North Byron	Byron Shire Council compliance team investigate illegal builds south of North Heads Road.	Ongoing	BSC - SEE	Staff Time	To be discussed with SEE
19	North Byron	Develop a sediment transport model to investigate modification to the rock walls, as part of the Coastal Management Program for the Brunswick Estuary.	Moderate	BSC - SEE / IPT	$150,000	Being considered as part Coastal Management Plan
20	North Byron	Further consideration of Billinudgel infrastructure improvements.	Moderate	BSC - IPT	Refer to item 6	Will form part of the scope of Shire overland flow path study
21	North Byron	Develop guidance on the design and installation of fencing traversing waterways and channels.	Moderate	BSC - IPT	$15,000	Funding to be sought

22	North Byron	Consider establishing a Voluntary House Purchase scheme for eligible properties.	Complete	BSC - IPT	Staff Time (pending Council decision on VHR Council/State contribution	Grant submitted May 22
23	North Byron	More detailed assessment of potential raising of River Street to provide improved flood immunity and evacuation.	Low	BSC - IPT	Refer to item 6	Will form part of the scope of Shire overland flow path study
24	North Byron	Implement the recommendations of the South Golden Beach levee audit.	Low	BSC - IPT	$200,000	Funding to be sought
25	North Byron	Further consider viable options to implement the recommendations of the New City Road drainage assessment.	Low	BSC - IPT	Refer to item 6	Will form part of the scope of Shire overland flow path study
26	Tallow Creek	New Byron Local Environment Plan to more robustly protect existing development from increased flooding impacts resulting from future development and update to be in line with NSW Floodplain Development Manual (2005)	Complete	Complete	Staff Time	Complete
27	Tallow Creek	Commence undertaking to rezone the land identified as high flood hazard for the 1 in 100 year ARI flood to preclude these areas from future development	Complete	Complete	Staff Time	Complete
28	Tallow Creek	Adopt FPLs as part of the DCP 2002 as the extent of flood prone land in the Tallow Creek catchment that consider climate change conditions (Scenario 4)	Complete	Complete	Staff Time	Complete
29	Tallow Creek	Implementation of design measures and evacuation plans to minimise impacts on future planned community uses as identified in the DCP No. 9	Medium Priority	BSC - SEE	Staff Time	To be discussed with SEE
30	Tallow Creek	Adopt prescribed areas of fill exclusion.	Complete	Complete	Staff Time	Complete
31	Tallow Creek	Ensure future developments within the catchment utilise on-site stormwater detention measures to maintain pre-development peak runoff characteristics.	Complete	Complete	Staff Time	Already part of BSC DCP
32	Tallow Creek	Prepare a section contribution plan for all civil works in this plan.	Complete	Complete	$20,000	Wasn't supported or adopted by Council
33	Tallow Creek	Update 149 certificates and any lots with additional controls over them, including add 1495 certificates for lots effected by PMF and not within the FPL.	Complete	Complete	Staff Time	Complete
34	Tallow Creek	Adopt new version of the hydraulic model to allow for assessment of all proposed development	Complete	Complete	Staff Time	Complete
35	Tallow Creek	Establish relationship between flood return period, sand bar levels and flooding conditions in Tallow Lake to assist in SES flood evacuation planning	Underway	BSC - IPT	$15,000	Contract awarded.
36	Tallow Creek	Support SES in inclusion of Suffolk Park in Flood Response Plan	Complete	SES (tech intel from BSC)	Staff Time	To be discussed with SES
37	Tallow Creek	Install flood gauge at Broken Head Road culvert showing example flood levels	Underway	BSC - IPT	$500	To be completed in June 2022
38	Tallow Creek	Install lake level and rainfall monitoring station on Tallow Lake and connect to Council's flood warning system	Complete	Complete	$25,000	Complete
39	Tallow Creek	Upgrade Broken Head Road Crossing of South Tallow Creek	Medium Priority	BSC - IPT	$355,000	2009 price - needs to be increased to current day value
40	Tallow Creek	Upgrade Coogera Circuit Detention	Medium Priority	BSC - IPT	$380,000	2010 price - needs to be increased to current day value
41	Tallow Creek	Raise footpath at Tallow Lake footbridge to ensure trafficable up to a lake level of 2.5mAHD.	Complete	Complete	$44,000	Complete
42	Tallow Creek	Develop and implement asset management and maintenance plan	Complete	Complete	$20,000	Complete
43	Tallow Creek	Implement interim management plan through water level and quality monitoring	Complete	Complete	$100,000	Complete
44	Tallow Creek	Develop data collection program for variables such as sand bar and lake stored level, to support development of long-term management plan.	Complete	Complete	Staff Time	Complete
45	Tallow Creek	Inspect the sand bar and record its level every year prior to the onset of the rainfall season	Complete	Complete	Staff Time	Complete
46	Tallow Creek	Monitor the level of the opening during the rainfall season and undertake maintenance earthworks to restore the level as per the accepted Interim Sandbar Management Strategy.	Complete	Complete	Staff Time	Complete
47	Tallow Creek	Update Council Geographic Information Systems (GIS) to include outputs of this plan and update any lots with additional controls over them.	Complete	Complete	Staff Time	Complete
48	Tallow Creek	Ensure authority uses the GIS layers to prepare property reports.	Complete	Complete	Staff Time	Complete
49	Tallow Creek	Add adopted document to Council's website, plus additional A1 pdf of FPL	Complete	Complete	Staff Time	Complete

50	Belongil Creek	Preferred Byron Drainage Strategy	Immediate Priority	BSC - IPT	$1,300,000	Grant awarded for design phase only. Contract award by August 22
51	Belongil Creek	Preferred Byron Drainage Strategy Construction	High Priority	BSC - IPT	$15,000,000	Grant awarded for design phase only. Contract award by August 23. Construction phase grant application required.
52	Belongil Creek	Development Controls	Complete	Complete	Staff Time	Complete
53	Belongil Creek	Community Flood Awareness	Immediate Priority	BSC - IPT / Comms	$10,000	Funding to be sought
54	Belongil Creek	Emergency Planning (SMS Messaging)	Complete	Complete	$220,000	As part of flood warning network and emergency dashboard
55	Belongil Creek	Flood Information Dataset	Complete	Complete	$220,000	As part of flood warning network and emergency dashboard
56	Belongil Creek	Belongil Creek Entrance Strategy	Complete	Complete	$125,000	Complete
57	Belongil Creek	Flood Gauges	Complete	Complete	$75,000	This is always ongoing, upgrading gauges/telemetry etc
58	Belongil Creek	Drainage Infrastructure Maintenance	High Priority	BSC - Operations	$1,092,400	One of clean of main drains in Byron Bay
59	Belongil Creek	Voluntary House Raising Scheme	Medium Priority	BSC - IPT	$8,550,000	Grant submitted May 22 for 2/3 funding for upto 2 houses. Total Scheme is 57 houses at $150 per house.
60	Staff Recommended Not Supported By A Plan	SGB Flood Pump Generator	Funded	BSC - IPT	$140,000	Protection from power failures.
61	Staff Recommended Not Supported By A Plan	Investigate Options for SGB Flood Gate Upgrades	High Priority	BSC - IPT	$30,000	Better solutions? No pipes? flood gates with automated knife valves for full closure?
62	Staff Recommended Not Supported By A Plan	Design SGB and Fern Beach Flood Levy Upgrades	High Priority	BSC - IPT	$100,000	Levy over topped in 2022. Propose to raise Levy.
63	Staff Recommended Not Supported By A Plan	Investigate Flood Levey for Western SGB	Medium Priority	BSC - IPT	$30,000	Post 2022 flood, investigate the benefits of a levy for west of Capricornia Canal.
				Total Program Value	**$27,587,900**	

Report No. 4.5 Community Education Strategy and Review of Flood Options / North Byron Flood Investigations - Projects Update

Directorate: Infrastructure Services

Report Author: Steve Twohill, Flood and Drainage Engineer

File No: I2024/677

Summary:

This report provides an update to the Floodplain Advisory Committee requested in their recommendation of Report 4.2 tabled at the Friday 8 December 2023 committee meeting. This recommendation has not been ratified with a council resolution. However, Council staff provide this report in good faith to keep the committee informed of the responses to these matters acknowledging that the Committee will end in September under this current Council term.

The list of items is as follows and is discussed in this report: -

1. **That the Floodplain Management Advisory Committee receive a further update on the ‘Community Education Strategy and Review of Flood Options’ project and a briefing on ways of further engaging community, for example with animations from existing and future flood models.**

Consultants JBP have progressed this assessment and project since the public meeting held on 6 December 2023 and the ensuing Christmas holiday period. Council staff have met with the Consultant JBP in late December 2023 and February 2024 to discuss ways of further engaging the community in relation to improved flood awareness to this region.

In addition, Council sought permission from the NSW Department of Planning & Environment (DPE) to provide and release the confidential 2022 Flood event review report that was presented to the committee late last year. DPE have agreed to that request in late December 2023, this information has been provided to JBP.

This project has budgetary constraints that are already committed with an agreed scope. Staff have negotiated with the consultant JBP to undertake a review of the DPE 2022 flood event review report and integrate outcomes where appropriate in this assessment. The report is well underway however too premature to release for this committee meeting.

Animation and graphical recreation of the flood event are supported, however that aspect is not included in the scope for this project. Given that DPE has commissioned this review by WMA Water and the fact that it is their report and work, we recommend that DPE commission animation graphic models of the 2022 flood event and provide to Council to assist in future community engagement for this project.

We anticipate that the Final report will be presented to the committee at the next scheduled meeting in May 2024.

RECOMMENDATION:

That the Floodplain Management Advisory Committee:-

1. **Note the update on the 'Community Education Strategy and Review of Flood Options' project which focusses on the Northern Byron Shire communities; and**

2. **Recommend that the NSW Department of Planning & Environment (DPE) be requested to commission animation graphic models of the 2022 flood event and provide to Council to assist in future community engagement.**

Attachments:

1 JBP-Review Of Flood Studies North Byron Study Region - Draft Report - Feb 2024, E2024/47658 , page 184⇩

2 JBP-Executive Summary-Review Of Flood Studies North Byron Region - Draft - March 2024, E2024/47660 , page 198⇩

Report

This report provides an update to the Floodplain Advisory Committee requested in their recommendation of Report 4.2 tabled at the Friday 8 December 2023 committee meeting.

This recommendation has not been ratified with a council resolution. However, Council staff provide this report in good faith to keep the committee informed of the responses to these matters acknowledging that the Committee will end in September under this current Council term.

Background to this project is contained in the previous report table at the 8 December 2023 meeting – refer File I2023/1607.

Consultants JBP have progressed this assessment and project since the public meeting held on 6 December 2023 and the ensuing Christmas holiday period. Council staff have met with the Consultant JBP in late December 2023 and February 2024 to discuss ways of further engaging the community in relation to improved flood awareness to this region.

Attachments 1 & 2 are provided for the committee's information.

In addition, Council sought permission from the NSW Department of Planning & Environment (DPE) to provide and release the confidential 2022 Flood event review report that was presented to the committee late last year. DPE have agreed to that request in late December 2023, this information has been provided to JBP.

This project has budgetary constraints that are already committed with an agreed scope. Staff have negotiated with the consultant JBP to undertake a review of the DPE 2022 flood event review report and integrate outcomes where appropriate in this assessment. The report is well underway however too premature to release for this committee meeting.

Animation and graphical recreation of the flood event are supported, however that aspect is not included in the scope for this project. Given that DPE has commissioned this review by WMA Water and the fact that it is their report and work, we recommend that DPE commission animation graphic models of the 2022 flood event and provide to Council to assist in future community engagement for this project.

There are eight (8) interrelated flood related investigations in this study area that will be nearing completion. These other projects include: -

PM22_30091 - AGRN1012 - Local Government Recovery Grant Program

PM22_1486 - Flood Warning Systems (Gauges) Upgrade - Shire Wide

PM23_1513 - Flood Pump Generator Power Supply - South Golden Beach

PM23_1514 - Rear Drainage Easements Upgrade - South Golden Beach

PM23_1516 - Flood Pump Investigation for Western Levee - South Golden Beach

PM23_1517 - Drainage Easement Maintenance Access Upgrade - Narooma Drive

PM23_1519 - Flood Gate Upgrade Options Investigation - South Golden Beach

PM23_##### - Sky Pump Feasibility Investigation - South Golden Beach Canal system

Once all these investigations are complete, there is an opportunity to report all of these projects in a consolidated and integrated manner to the community June/July 2024.

Next steps

The Floodplain Advisory Management Committee will be updated as the project progresses. Committee members will be provided an opportunity to be further involved during the later stage of the project at an options workshop (date not yet confirmed).

Strategic Considerations

Community Strategic Plan and Operational Plan

CSP Objective	CSP Strategy	DP Action	Code	OP Activity
3: Nurtured Environment	3.3: Protect the health of coastline, estuaries, waterways, and catchments	3.3.2: Floodplain management - Mitigate the impact of flooding on private and public property	3.3.2.3	Floodplain Risk Management Committee coordination

Legal/Statutory/Policy Considerations

The study will align with the framework established by the NSW Floodplain Development Manual and national best practice as outlined in the Australian Institute for Disaster Resilience Handbook 7: Managing the floodplain: best practice in flood risk management in Australia (AIDR, 2017).

Financial Considerations

This is a grant funded project comprising consultancy fees only of $37,940 (excl. GST).

Consultation and Engagement

A Community and Stakeholder Engagement Plan (CSEP) has been developed for the project for implementation. The CSEP aims to collate community and stakeholder concerns and ideas and address all concerns after reviewing management options and data. The CSEP considers different approaches to communications and engagement, following the IAP2 Public Participation Spectrum. The key outcomes of the project is improved community and stakeholder understanding and education on flood risk and flood risk management, as such the below is proposed:

- Council Staff/DPE representatives are given a steering role (Empowered).
- Council's Advisory Committees are *Involved*
- The community is *Involved* within the project. This is deliberately not at a level that would allow their request for new mitigation scenarios to be tested without checks from flood engineers to ensure they are viable; however, it will ensure they are a focus on this project.

Review of Flood Studies for the North Byron Study Region Summary

Draft

8 March 2024

Prepared for:
Byron Shire Council

www.jbpacific.com.au

Document Status

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Prepared by	Callan Schonrock BEng Graduate Engineer
Reviewed by	Eoghain O'Hanlon BSc, MPhil Flooding Technical Director
Authorised by	Daniel Rodger BSc, MEng, PGDip, GIS, PGCert Coastal Eng, CPEng Director

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Contract

JBP Project Manager	Eoghain O'Hanlon
Address	Suite 46, 477 Boundary Street, Spring Hill, Brisbane, QLD 4000
JBP Project Code	2023s0843

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FRMS	Flood Risk Management Study
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2022 Flood Event: 25th February - 5th of March 2022 Major Flood.

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Falling Limb: The tail end of a hydrograph typically following a flood peak, depicting duration of flooding

Flood Behaviour: The characteristics and properties of a flood in a catchment, being out of bank flow, flood wave progression/attenuation, rapid flood response or prolonged flooding .

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Hydrodynamic Model: Typically, a numerical model to estimate hydraulic dispersion/conveyance used to define flood extents/depths/velocities.

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Northern Rivers Region: The North Coast of New South Wales.

Hydraulic Roughness: A bed "friction" to hinder conveyance of flow.

Stakeholders: People, groups of people or organizations that have a vested interest in a project, plan or decision

Temporal Pattern: The pattern or distribution of a parameter over time, associated with rainfall over time.

Validation: The process to justify existing flood simulations to be representative of real-world

Executive Summary

Byron Shire Council (BSC) engaged JB Pacific (JBP) to undertake a review of the previous flood studies, flood risk management plans, estuary and coastal studies and all the flood management options that were contained and assessed within them, that are applicable for the North Byron villages of New Brighton, Billinudgel, Ocean Shores and South Golden Beach. This report summarizes these assessments and their findings to support the Byron Shire Council's Community Education Strategy and Flood Review project.

The latest flood study the North Byron Floodplain Risk Management Study and Plan (WMA, 2020) has been the basis for Byron Shire Council's adopted flood risk management plan, from which several management actions have been progressed to varying stages of completion, including submission of grants, design development, construction or implementation underway or already completed.

The findings of this review will be used to confirm the accuracy and completeness previous flood management options assessments and/or identify new and revised options where further analysis may be warranted. The Community and Stakeholder involvement is planned to understand prioritise their concerns and management options, that their either are in favour of implementing and/or further investigation and those which they are not in favour of which should not progress to the next stage analysis or implementation.

This report also summarises investigation gaps for the North Byron flooding behaviour, outlined as in the North Byron Floodplain Risk Management Study and Plan (WMA, 2020).

1 Introduction

Byron Shire Council (BSC) engaged JB Pacific (JBP) to undertake a review of the previously assessed flood mitigation options that are applicable for the North Byron villages of New Brighton, Billinudgel, Ocean Shores and South Golden Beach. This report summarises the works and findings undertaken of the existing flood, estuary and coastal studies for the region, to support the Byron Shire Council Community Education and Flood Review project.

The North Byron region has been subject to several flood risk and flood management studies that have assessed various flood mitigation options. The latest flood study, the North Byron Floodplain Risk Management Study and Plan (WMA, 2020) has been the basis for Byron Shire Council's adopted flood risk management plan, from which several management actions have been progressed to varying stages of completion, including submission of grants, design development, construction or implementation underway or already completed.

The findings of this review, in conjunction with community and stakeholder engagement and education activities, will be used to confirm the accuracy and completeness of previous management/mitigation options assessments and/or identify options where further analysis and/or refinement may be warranted. The Community and Stakeholder involvement is planned to understand their priority concerns and suggested management options. This will include their review of what they are in favour of implementing and their assessment of other options they do not want to progress to the next stage.

2 Flooding in North Byron

2.1 Riverine Flood Risk

The 2022 flood event was estimated to render 837 properties with above floor flooding, and resulted in total tangible damages estimate of $47 Million. Following this significant flooding, community concern has risen for the Northern Byron Community regarding their existing flood risk, concerns of local hydrology, and ongoing plans and works to reduce flood risk for the region. The North Byron community is built within the Marshalls Creek floodplain, with the creek having significant storage and "bathtub" behaviour during a storm event from the constricted Marshalls Creek drainage at the confluence with Brunswick River. This flood behaviour is observed to inundate significant area including parts of:

- Ocean Shores
- New Brighton
- Back Water causing elevated water levels at South Golden Beach

Billinudgel experiences predominant flood risk from riverine flooding, with significant constriction of Marshalls Creek at Billinudgel Bridge and the Pacific Motorway, however protection of Billinudgel from Marshalls Creek has been previously observed to still exhibit inundation from local overland flow.

2.2 Overland Flow Flood Risk

Further flood risk exists in the north Byron region from stormwater overland flow, particularly South Golden Beach and Ocean Shores.

South Golden Beach is protected from a levee up to the 1% AEP canal water level. However, from community consultation the South Golden Beach community experience significant local rainfall observed to inundate parts of the community. While a flood pump services the Western Side of South Golden Beach, to limit risk of elevated water levels within the South Golden Beach Canals preventing effective drainage, East South Golden Beach does not have this functionality. Ocean Shores is susceptible to coincident overland flow, and riverine flood risk. Several community members have testified of flooding from Water Lily Park, and elevated water levels within Marshalls Creek.

From community consultation these communities are extremely susceptible to stormwater network blockage.

3 Reviewed Flood Studies

3.1 Overview

Several significant flood studies have been identified and reviewed as part of this detailed review including:

- North Byron Sky Pumps Study (JBPacific, 2024)
- Post 2022 Event Flood Behaviour Analysis - Brunswick River (WMAwater, 2024)
- Characterisation of the 2022 Floods in the Northern Rivers Region (CSIRO, 2022)
- North Byron Floodplain Risk Management Study and Plan (WMAwater, 2020)
- North Byron Flood Study (BMT, 2016)
- Tweed Byron Coastal Creeks Flood Study (BMT, 2010)
- Marshalls Creek Floodplain Management Plan (Paterson Consultants, 1997)
- Brunswick River Flood Study (WMAwater, 1986)
- Brunswick Valley Flood Plain Management Study Hydrology Report (WMAwater 1984)

Other previous flood studies were identified from the latest North Byron Floodplain Risk Management Study and Plan (WMAwater, 2020). Several of these studies were summarized by the 2020 North Byron FRMS&P including:

- Marshalls Creek Flood Study (1986)
- Flood mitigation Options for Billinudgel (1988)
- Brunswick River Floodplain Management Investigation (1989)
- Proposed Levees and South Golden Beach (1989)
- Report on Feasibility of an EIS for North Ocean Shores Flood Outlet (1992)
- Mullumbimby Floodplain Management Plan (1993)

Additional reports were identified to exist; however, they are not summarized by the FRMS&P or this flood study review. These include:

- Brunswick River Tidal Data Collection (2008)
- Kallaroo Circuit Bund Culver Amplification Hydraulic Impact Assessment (1996)
- Marshalls Creek Dredging Investigations Stage 1 Report (1992)
- Mullumbimby Floodplain Management Study Re-evaluation of Options (1992)

3.2 Limitations

In 2020, flood risk management experts at WMAwater released the latest Flood Risk Management Study and Plan (FRMS&P) for the North Byron region, building on top of the 2016 BMT study. This study investigated the flood risk for the North Byron community by undertaking numerical modelling of simulated river and creek flood events. Notably this study had key limitations including:

- It did not simulate overland flow flooding caused by intense rainfall across land.
- It builds upon and adopts dated industry modelling methodologies.

The existing study additionally utilized community consultation to provide several recommendations for drainage improvements where the modelling results were not practical for drainage assessment. Following the study, as an intermediate intervention, the Byron Shire Council has undertaken several works projects and plans to maintain and improve drainage in the North Byron community. However there remains a high-level of residual community concern about inadequate stormwater drainage and maintenance, which needs better planned and communicated to the community, along with undertaking a catchment wide overland flow path study to better understand the areas of concern.

Several mitigation options have been considered by the FRMS&P and Council to reduce the bathtub effect of Marshalls Creek including but not limited to:

- Marshalls Creek Ocean Outfalls
  - Simulated by carving coastal dunes out of the existing model, shown to reduce the 1-in-100 year peak flood level by 0.1m at Ocean Shores. Not greatly reducing flood risk for Marshalls Creek.
  - Ocean Outfalls are limited in their effectiveness by sizing (width) and through minimizing the risk of elevated ocean levels and waves flowing into Marshalls Creek. Additionally, they require significant clearing to construct and maintenance to ensure their conveyance capacity when needed.
- Pumping floodwater to the Ocean
  - This has been shown to be effective at reducing local and widespread peak flood levels, however there is limited technology to pump the required flow rates. This has also been used to provide a better understanding of the flow rate required for the ocean outfalls.
- Brunswick Heads Rock Wall Removal
  - Simulated by removing the Marshalls Creek Rock Walls out of the existing model, shown to not greatly reduce the 1-in-100 year peak flood level.
  - A limitation of this investigation is the increased tidal flushing of Marshalls Creek believed to increase sediment transport and reduce siltation in Marshalls Creek, having a similar but permanent effect that dredging provides.
  - The 1-in-100 year event was seen to significantly overtop the rock walls, however during more frequent events, the creek conveyance is believed to be a greater portion of total flow.
  - While this option could improve drainage of catchment dominated events, ocean dominated events are believed to propagate further upstream including wave setup, storm surge and peak tide levels. Low lying communities such as New Brighton and South Golden Beach and portions of Ocean Shores, would have to be investigated further for this option to be considered further.
- Brunswick Heads Training Walls Removal

- Simulated by removing the Marshalls Creek Rock Walls out of the existing model, shown to not greatly reduce the 1-in-100 year peak flood level
- Marshalls Creek Dredging
  - Simulated by removing the Marshalls Creek Rock Walls out of the model, shown to not greatly reduce the 1-in-100 year peak flood level
- Billinudgel Levee
  - Simulated to assist keeping Marshalls Creek floodwaters out of the Billinudgel township, however Billinudgel was still observed to be flood affected from local catchment overland flow.
- South Golden Beach Levee Modifications
  - Following an audit several recommendations were made for South Golden Beach Levee modifications
- House Raising
  - Proposed as part of the Voluntary House Raising Scheme
- House Purchasing Scheme
  - Proposed as part of the Voluntary House Raising Scheme
- Kallaroo Circuit Bund Modification
  - Not simulated independently however modelled simultaneous to Dredging, dune openings, rock wall modifications, with lowering of the bund by 1m to -0.025mAHD. Simultaneous modelling indicated a reduction of 0.15m at South Golden Beach.

It was further identified that little previous studies have considered flood mitigation options for Water Lily Park and surrounds at Ocean Shores.

While the options assessment modelling to date, has not been able to exhibit great benefits in flood reduction for the region, Byron Shire Council has undertaken further community consultation of residents, seeking their opinions on the issues and potential mitigation that they are likely to support. It was identified at the latest community consultation that the support for particular mitigation options (ocean outfalls) varies across the region, with those who are potentially closest and likely to benefit the most, being against there installation.

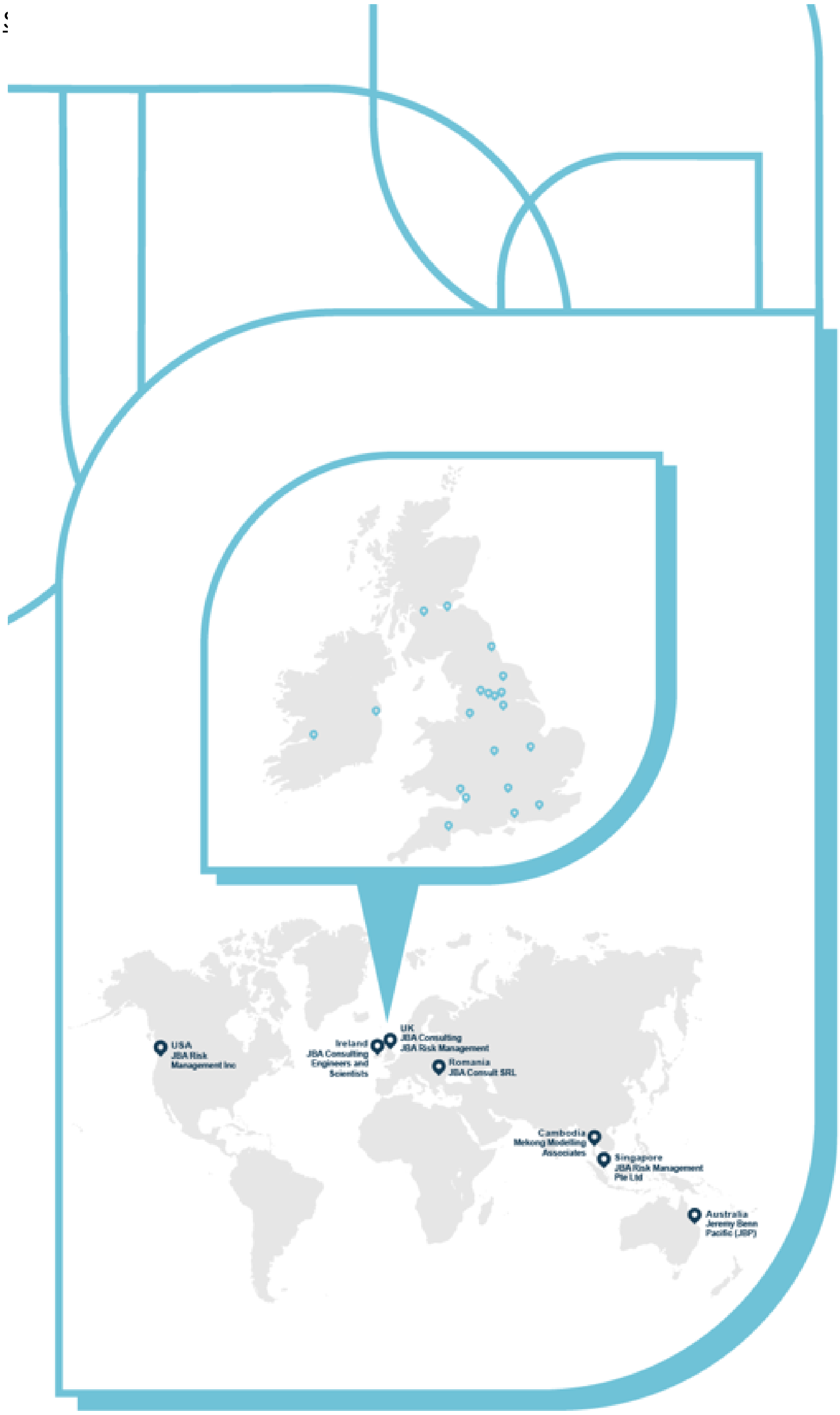
4 Summary

This review has identified several different mitigation options that have been assessed for their effectiveness and their cost to benefit ratio. Mitigation measures that have been suggested range from structural such as levees, dune openings, stormwater drainage upgrades and channel diversions, voluntary resumptions, planning scheme amendments and flood planning levels, to forecasting, flood warning and community education programs.

Council has implemented and is in the process of implementing several of the recommended measures. Measures that Council has already implemented include drainage and maintenance programs, flood forecasting and a flood forecasting and warning system, updates to the planning scheme and the flood planning levels, portal for individual property flood risk information.

Stormwater drainage has been identified as a major consideration for flood risk in the North Byron region it is recommended that future investigations consider flood risk sensitivity to near 100% structural blockage of stormwater infrastructure, siltation blockage of bridges (Orana Road, and Billinudgel Bridge), and alternatives/priority maintenance to be undertaken regularly to avoid blockage induced flood risk. It is expected that this will be assessed as part of the overland flow assessment.

Many of the major structural options were observed to reduce peak water level but were not found to be cost effective and/or resulted in impacts to other areas. However, strong community support for further investigation and to implement mitigation options has been observed at the several previous community consultations and during this study, particularly for ocean outfalls. It was however noted that community support is not unanimous for any mitigation option, with some people who would most benefit being the strongest opposed to the option. It is recommended that further investigation considers flood mitigation effectiveness for events more frequent than the 1% AEP.



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JBP scientists and engineers

Review of Flood Studies for the North Byron Study Region

Draft

8 February 2024

Prepared for:
Byron Shire Council

www.jbpacific.com.au

Byron Shire Council

Document Status

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Prepared by	Callan Schonrock BEng Graduate Engineer
Reviewed by	Eoghain O'Hanlon BSc, MPhil Flooding Technical Director
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The latest flood study the North Byron Floodplain Risk Management Study and Plan (WMA, 2020) has been the basis for Byron Shire Council's adopted flood risk management plan, from which several management actions have been progressed to varying stages of completion, including submission of grants, design development, construction or implementation underway or already completed. Further investigation has been undertaken on the sedimentation of Marshalls Creek to inform future estuary management decisions and monitoring.

The findings of this review are used to confirm the accuracy and completeness previous flood management options assessments and/or identify new and revised options where further analysis may be warranted. The Community and Stakeholder involvement was undertaken to prioritise their concerns and management options, that their either are in favour of implementing and/or further investigation and those which they are not in favour of which should not progress to the next stage analysis or implementation.

Community engagement both undertaken historically and as part of this study, identified that there is strong community support to:

- Alleviate the bath tubbing effect of Marshalls Creek with increasing the capacity of ocean outfalls through new high flow openings and/or the removal of Brunswick Heads rock walls or increasing its capacity.
- Improvement of stormwater drainage networks (Particularly South Golden Beach and Ocean Shores) combined with increased maintenance of the networks.

Support of particular options can be varying depending on the location of the residents in relation to the option, particularly the ocean outfall. With residents who live upstream and away from the actual outfall locations being more supportive than residents who live nearer to the outfalls. The residents who level nearest to the outfalls are the residents that are most likely to receive the greatest amount of benefit from the improved outfall capacity.

However, historical modelling results combined with cost benefit analyses, indicated that there was limited benefit from ocean outfalls and/or the removal of Brunswick Heads rock walls. As a result, this study recommends future studies consider flood mitigation benefit for more frequent events than the 1% AEP event. This study also recommends future studies consider sensitivity to stormwater network blockage to aid council maintenance priorities.

1 Introduction

Byron Shire Council (BSC) engaged JB Pacific (JBP) to undertake a review of the previously assessed flood mitigation options that are applicable for the North Byron villages of New Brighton, Billinudgel, Ocean Shores and South Golden Beach. This report summarises the works and findings undertaken during the existing flood, estuary and coastal studies for the region, to support the Byron Shire Council Community Education and Flood Review project.

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Further investigation has been undertaken on the sedimentation of Marshalls Creek to inform future estuary management decisions and monitoring.

2 Reviewed Flood Studies

2.1 Overview

Several significant flood studies have been identified and reviewed as part of this detailed review including:

- Post 2022 Event Flood Behaviour Analysis - Brunswick River (WMAwater, 2024)
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- Marshalls Creek Dredging Investigations Stage 1 Report (1992)
- Mullumbimby Floodplain Management Study Re-evaluation of Options (1992)

2.2 Brunswick Valley Flood Plain Management Study Hydrology Report (WMAwater Formerly Webb, McKeown & Associates, 1984)

2.2.1 Overview

This study was undertaken by WMAwater on behalf of Byron Shire Council. The scope of the study was limited to defining the hydrologic input parameters of the 20-year, 100-year and extreme floods within the Brunswick Valley for later use in hydraulic model development. A key limitation of this study included its timing. The study want conducted almost 30 years ago, meaning it was conducted with less sophisticated industry standards resulting in limited storm pattern modelling, but also less available rainfall data for design rainfall estimation and now outdated modelling software.

2.2.2 Modelling Methodology

2.2.2.1 Hydrology Model

This study undertook development of a Boyd Hydrologic rainfall runoff model, similar to WBNM. Estimates of design rainfall depths were derived from ARR1977. "Extreme rainfall depths" were also provided by BoM for consideration in this study.

2.2.2.2 Calibration and validation

The hydrologic model was calibrated to several events. Calibration efforts included variation of "C" value for the Boyd Model to best fit historical events. IL and CL were identified from the rainfall and runoff volumes. The model parameters for each event identified are as shown in Table 2-1, where the 1972 event could not be accurately represented by available data and it is believed to be a localised event. Figure 2-1 and Figure 2-2 represent the hydrograph comparisons between the modelled and the recorded flood events for the March 1974 and March 1978 flood events respectively.

Table 2-1: Brunswick Valley FMS (1984) Calibration parameters

Event	"C" Parameter	IL	CL	Modelled Peak (m^3/s)	Observed Peak (m^3/s)	Comparison
October 1972	-	-	-	-	-	-
March 1974	2.2	0	4	296	299	Figure 2-1
March 1978	2.2	0	4	285	279	Figure 2-2

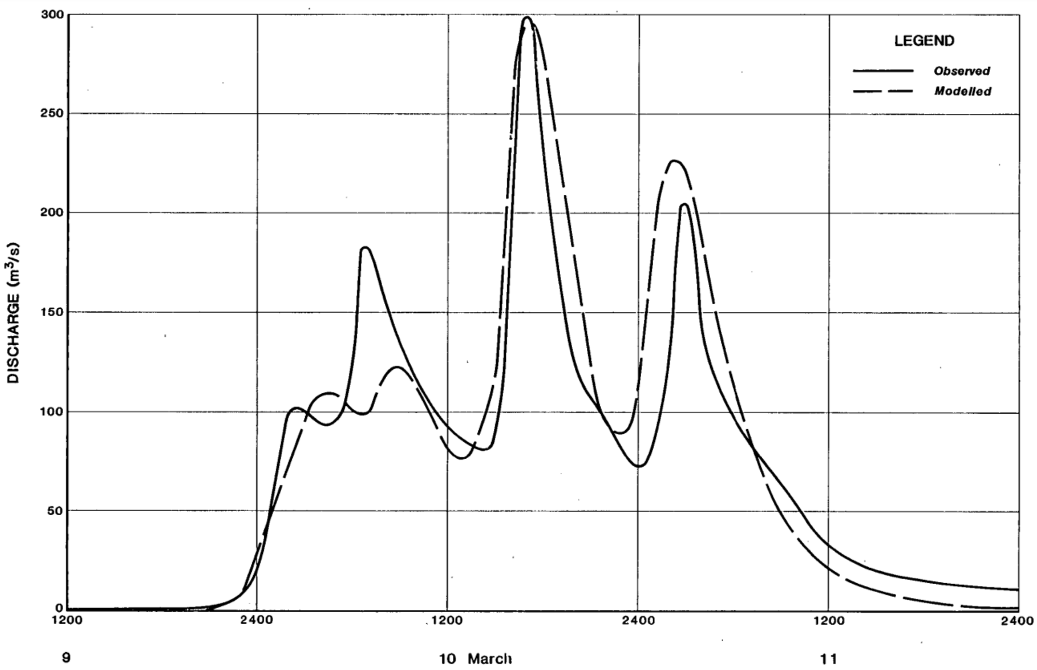

Figure 2-1: Brunswick Valley FMS (1984) 1974 Event Calibration Comparison at Durrumbul

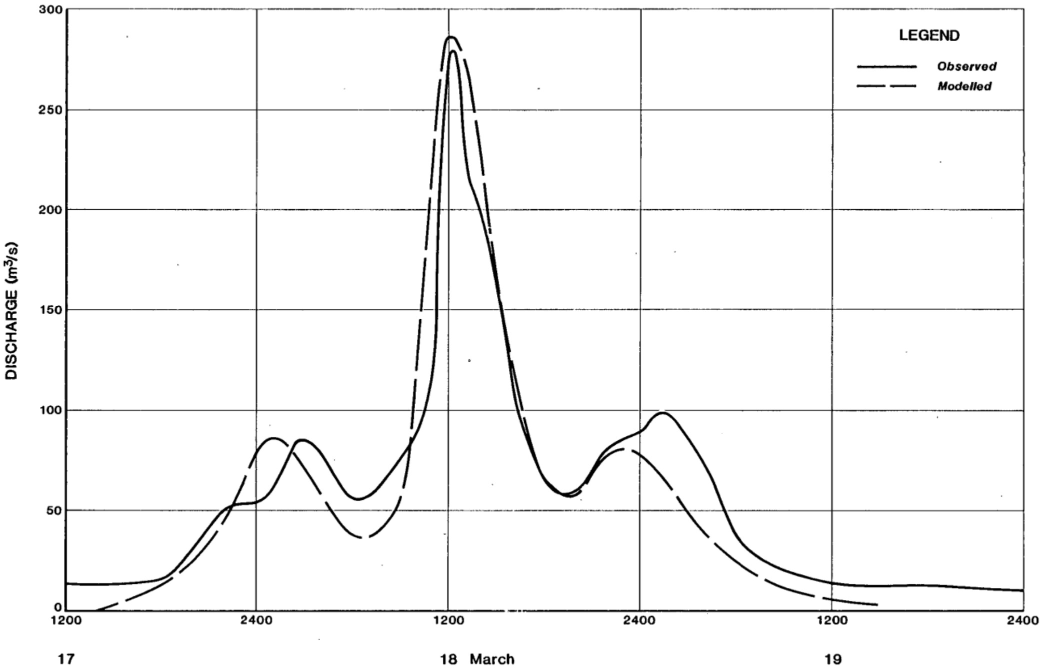

Figure 2-2: Brunswick Valley FMS (1984) 1978 Event Calibration Comparison at Durrumbul

The parameters derived from the calibration were then validated for the 1976 event and achieved a reasonable comparison to the 1976 flood hydrograph at Durrumbul, shown in Table 2-2 and Figure 2-3. The modelled results, however, appear to have missed the initial peak and has the major peak lining up with the third peak, which was the second largest peak for the observed event and occurred several hours after the major observed peak.

Table 2-2: Brunswick Valley FMS (1984) Parameter validation to the 1976 flood

	Observed	Modelled	Percentage Difference
Volume (ML)	6300	5650	-10%
Peak (m^3/s)	144	170	+18%

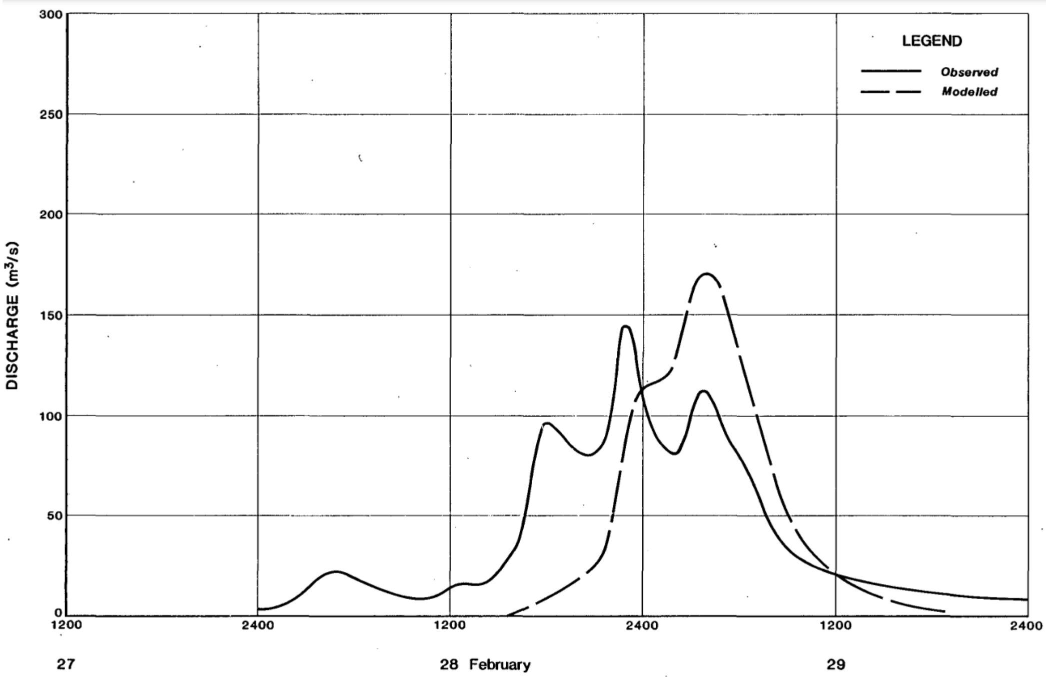

Figure 2-3: Brunswick Valley FMS (1984) Validation Results

2.2.2.3 Design Scenarios and Events

Rainfall depths were derived from local gauge analysis after identifying significant differences to generalised IFDs. A critical duration of 12 hours was identified for the study and a design temporal pattern was produced from observed storm behaviours. Following this the design hydrographs were produced for the 20, 100, and extreme events for the 12-hour critical duration. Resulting hydrographs for the 4.9%, 1% and "extreme" events are presented in Figure 2-4 to Figure 2-6

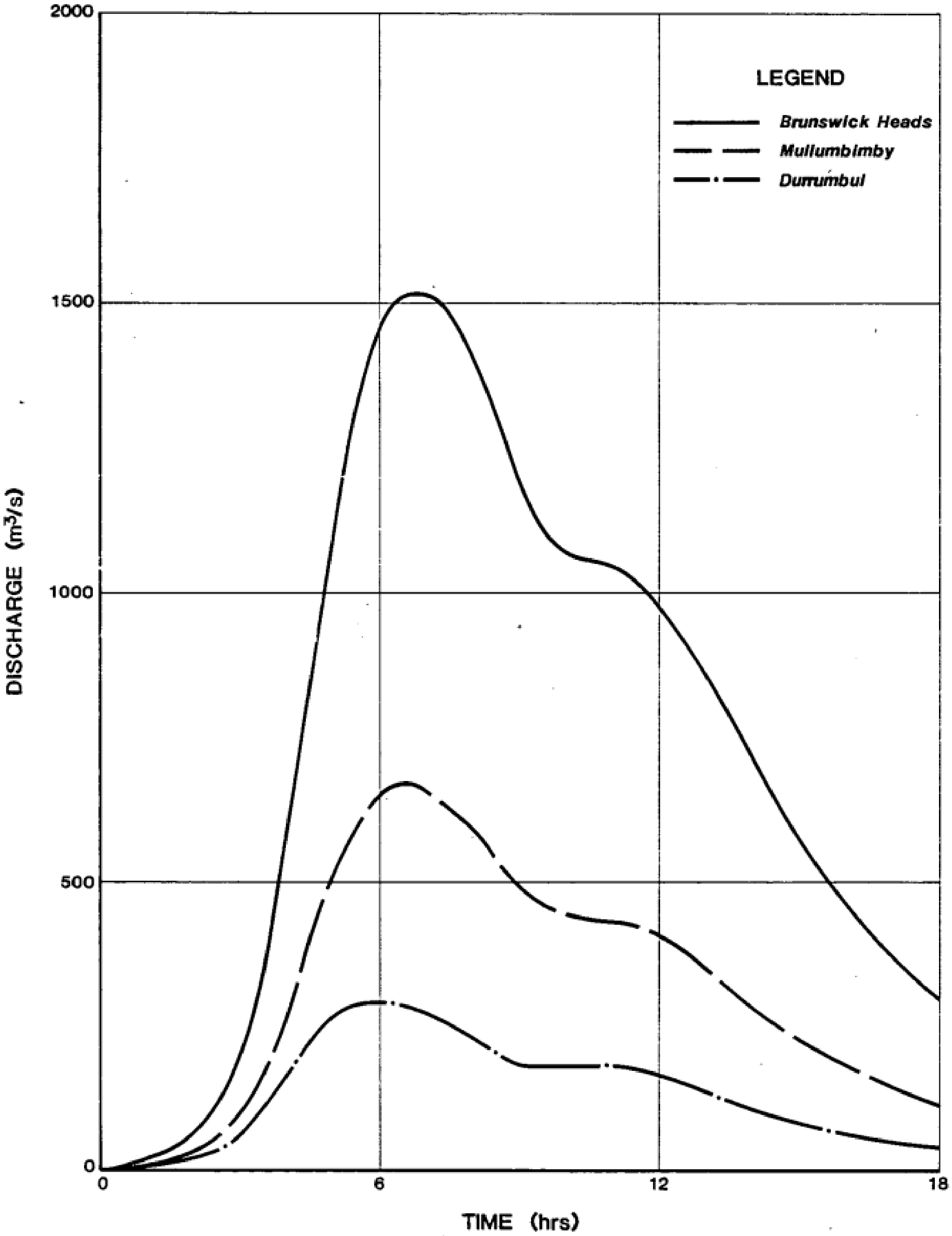

Figure 2-4: Brunswick Valley FMS (1984) Modelled 4.9% AEP Design Discharge

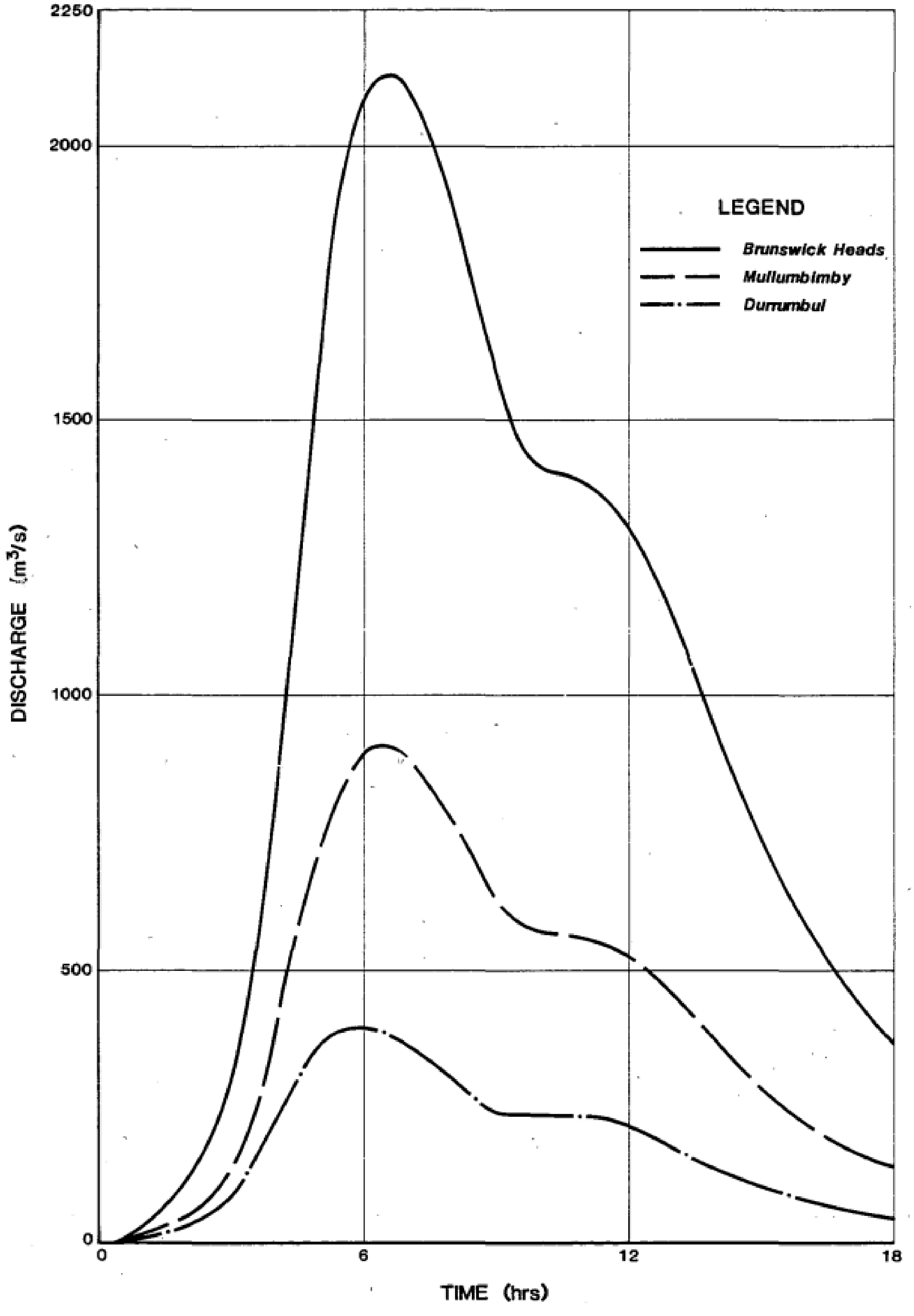

Figure 2-5: Brunswick Valley FMS (1984) Modelled 1% AEP Design Discharge

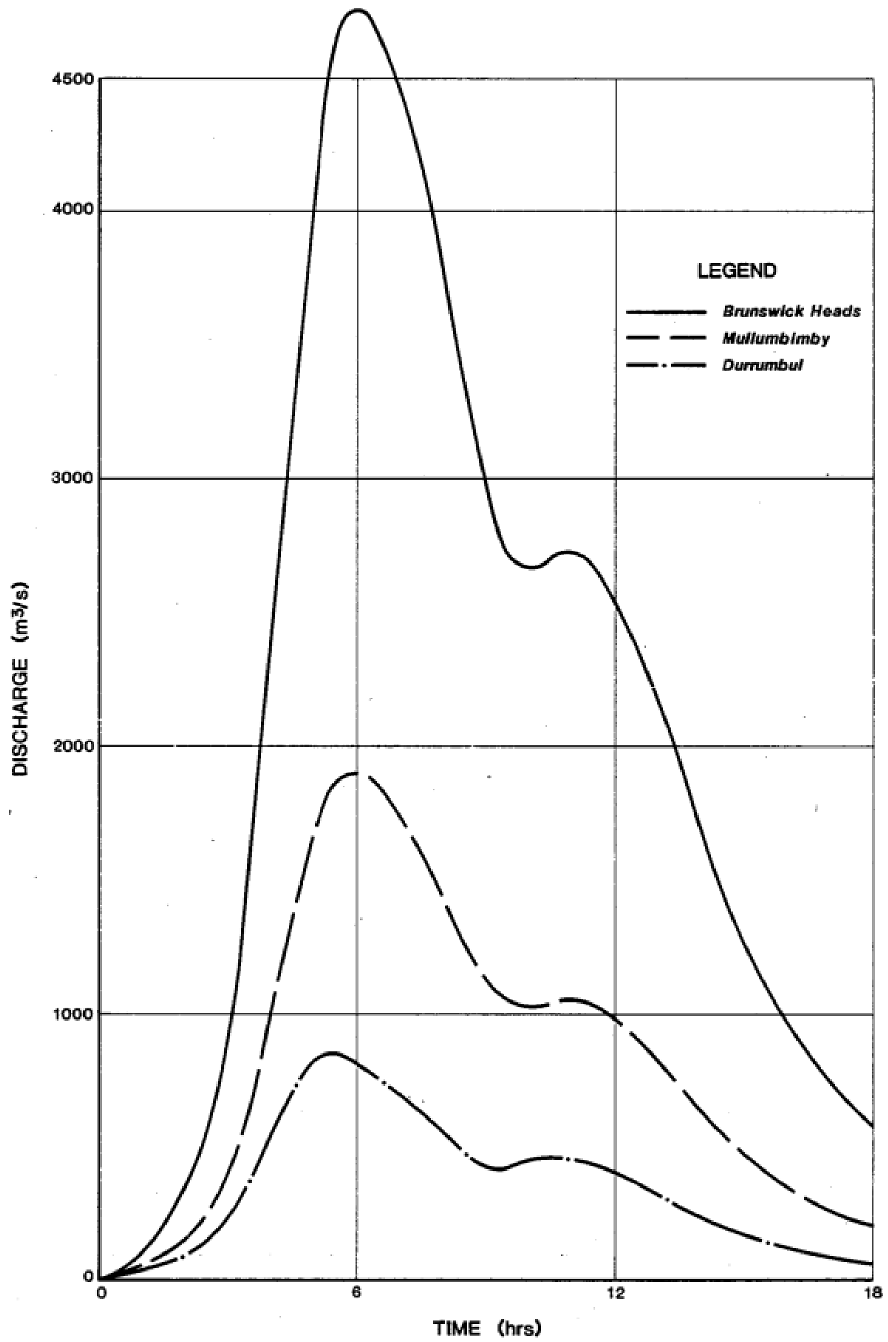

Figure 2-6: Brunswick Valley FMS (1984) Modelled "Extreme" Design Discharge

2.3 Brunswick River Flood Study (WMAwater Formerly Webb, McKeown & Associates, 1986)

2.3.1 Overview

This study was undertaken by WMAwater on behalf of Byron Shire Council. The scope of the study was limited to determining flood behaviour in the Brunswick River and adjacent floodplain from the mouth at Brunswick Heads to a point approximately 3km upstream of Mullumbimby. Peak flood levels were also obtained in the main southern tributary, Simpsons Creek. Key limitations of this study included limited established industry standards, quasi-two-dimensional (one dimensional) hydraulic model.

2.3.2 Modelling Methodology

2.3.2.1 Hydrologic Inflows

This study adopted hydrologic inflows produced by the Brunswick Valley FMS Hydrology study (WMAwater,1984).

2.3.2.2 Hydrodynamic Model

This study undertook development of a quasi-two-dimensional hydraulic model, consisting of four sources of hydrographic and topographic data of varying quality, as follows:

- 1:4000 orthophoto maps derived from photogrammetry
- Hydrographic survey (PWD, 1983)
  - A contour plan of the riverbed from the entrance to the Pacific Highway bridge
    - 50 Cross-sections on the Brunswick River between the Highway bridge and a point upstream of Mullumbimby
    - 27 cross-sections on Marshalls Creek
    - 18 cross-sections on Simpsons Creek
    - 6 cross-sections on Kings Creek
- A survey of the floodplain carried out by Council in 1983, specifically for this study.
- An additional survey carried out by Council in 1984, which defined areas in and to the south of Mullumbimby in more detail.

2.3.2.3 Calibration/Validation/Sensitivity

The hydrodynamic model was calibrated to the 1978 flood event. Calibration efforts included variation of manning's roughness. This resulted in adopting roughness by cross section, ranging from 0.020 - 0.130 Mannings 'n' values. Calibration efforts resulting in fair model calibration from the timing of the study, with results generally falling within ± 0.2m difference to observed flood markers.

2.3.2.4 Scenarios and Events

Similarly, to the hydrology study, the 5%, 1% and "extreme" design storm events were modelled, these were paired with the 5% and 1% design ocean levels of 2.3mAHD and 2.6mAHD, from previous investigations. This produced peak water level contours and Brunswick River peak water level profiles shown in Figure 2-7.

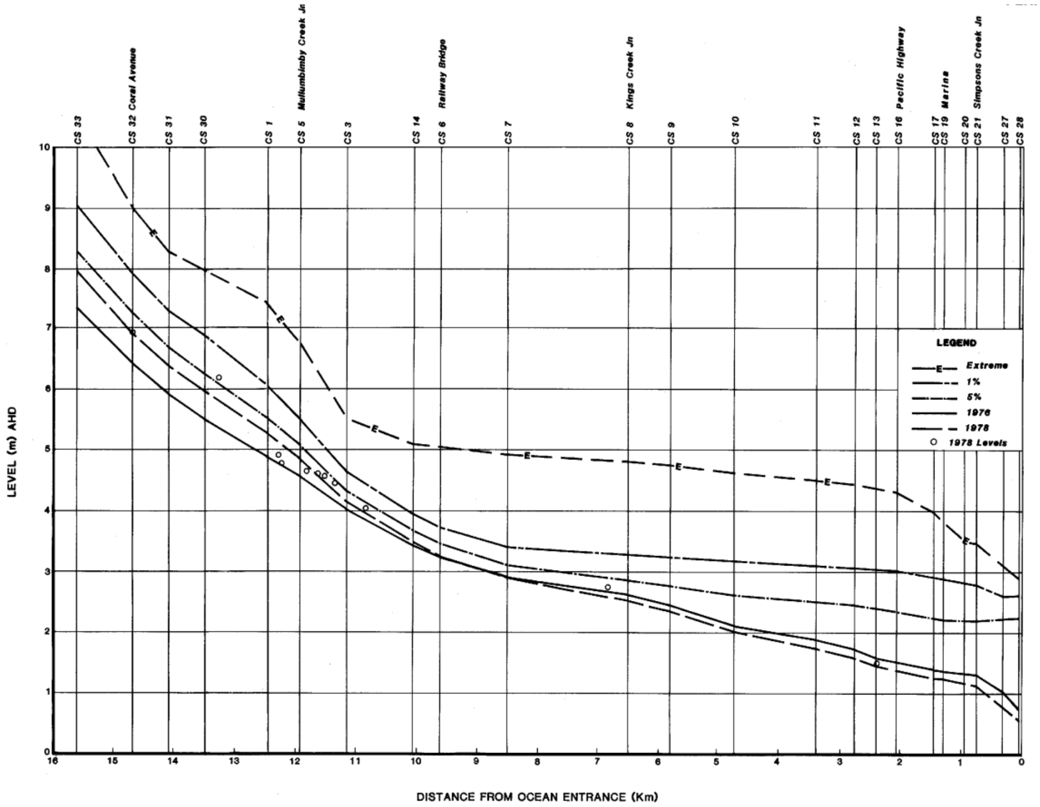

Figure 2-7: Brunswick River FS (1986) Brunswick River Design Peak Level contours

2.4 Tweed-Byron Coastal Creeks Flood Study (BMT, 2009)

2.4.1 Overview

This study was undertaken by BMT on behalf of Tweed Shire Council, and due to the interactions of Yelgun/Marshalls Creek with Mooball Creek, Byron Shire Council took the opportunity to update Marshalls Creek Floodplain Management Plan as part of the study.

The primary objective of the study was to define flood behaviour of several coastal creeks, including the two creeks within the Byron Shire Council LGA, Yelgun Creek and Marshalls Creek. Key limitations of this study included the adoption of ARR87 methodology, outdated land-use, and limited data availability.

2.4.2 Modelling Methodology

2.4.2.1 Hydrology Model

This study undertook refinement of previously developed XP-RAFTS model developed by SMEC in 2006 for the Assessment of Flooding Behaviour in the Marshalls Creek Catchment Study. The hydrologic model extended over several local tributaries including, Burringbar, Sheens, Crabbes, Yelgun and Marshalls Creeks.

2.4.2.2 Hydrodynamic Model

This study undertook development of the Marshalls Creek TUFLOW hydraulic model. A two-dimensional model using a 15 metre grid resolution was adopted to represent the Marshalls Creek floodplain. The TUFLOW FV morphological model was utilized in the study to estimate bathymetry conditions at creek mouths.

2.4.2.3 Calibration/Validation/Sensitivity

The hydrodynamic and hydrologic models were calibrated to the June 2005 event and validated against the May 1987 event.

The calibration effort included the survey of several flood marks, undertaken by Council to provide peak water levels across the catchment, with the modelled peak water levels generally falling within 0.15m of the observed for the June 2005 event. Several recorded flood marks were located outside of the creek at relatively low levels such as 2.2mAHD at New Brighton, 2.6mAHD at Ocean Shores, and 3.9mAHD at Billinudgel, with the peak downstream level peaking at above 1.5mAHD catchment conditions are believed to account for only a portion of the resulting water levels. However, the available peak flood markers do generally support the peak flood levels observed.

A validation of the model was undertaken using the May 1987 event which had several flood markers, with the modelled results generally within 0.2m of the observed peak flood level.

The June 2005 event, had recorded water levels available for Billinudgel Gauge, and periodic recordings at Kallaroo Circuit culverts, the modelled results for the event are shown in Figure 2-8 and Figure 2-9. These indicate a fair calibration to flood peak level at Billinudgel, however falling limb indicates a misrepresentation of low storage-discharge relationships. Recorded water levels at the Kallaroo Circuit culverts were recorded at irregular and sparse intervals and are believed to not capture the timing of the peak, limiting the value of recorded results, however a comparison can be made to the progression of the flood wave, which indicates a fair validation for the falling limb.

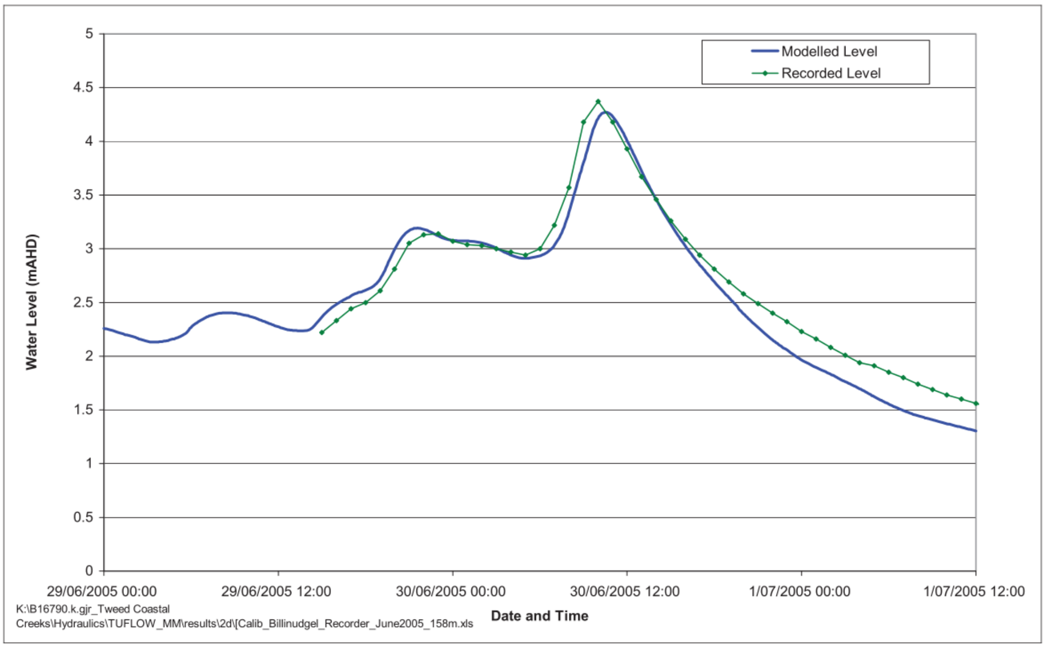

Figure 2-8: Tweed-Byron Coastal Creeks FS June 2005 Event Calibration at Billinudgel gauge

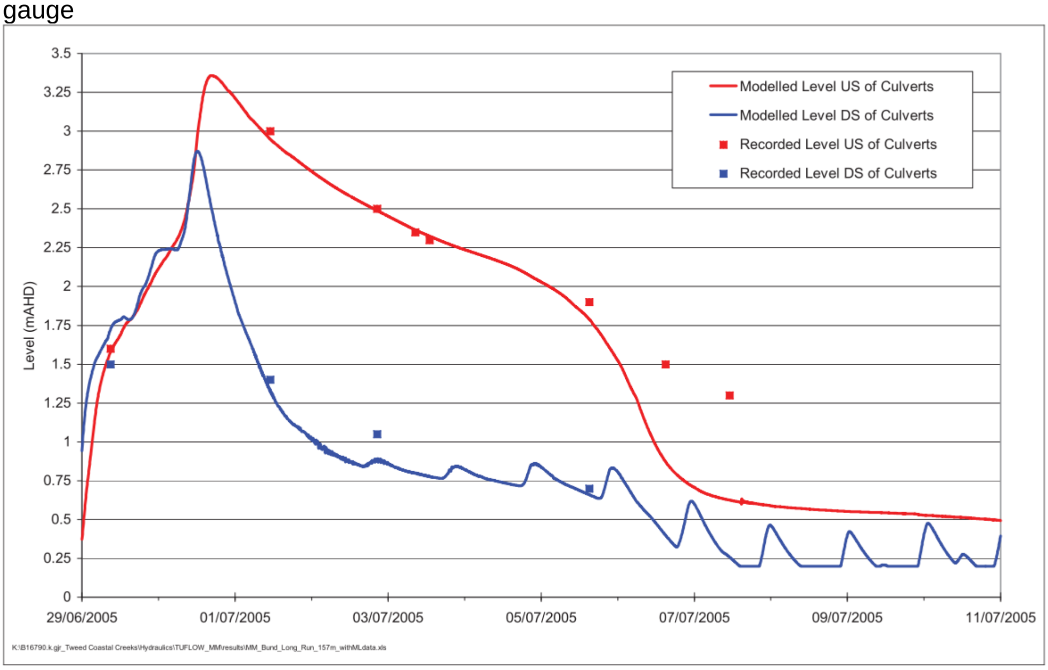

Figure 2-9: Tweed-Byron Coastal Creeks FS June 2005 Event Calibration at Kallaroo Circuit Culverts

2.4.2.4 Scenarios and Events

Several scenarios and events were modelled and have been summarized in Table 2-3.

Table 2-3: Tweed-Byron FS Modelled Scenarios and Events

Design Event	Catchment Inflow Rainfall Event	Ocean Boundary Storm Surge Event	Ocean Boundary Peak Tailwater Level (mAHD)
5 year ARI	5 year ARI	5 year ARI	0.8
10 year ARI	10 year ARI	10 year ARI	1.5
20 year ARI (envelope)	20 year ARI	10 year ARI	1.5
	10 year ARI	20 year ARI	2.2
50 year ARI (envelope)	50 year ARI	10 year ARI	1.5
	10 year ARI	50 year ARI	2.4
100 year ARI (envelope)	100 year ARI	20 year ARI	2.2
	10 year ARI	100 year ARI	2.6
500 year ARI	500 year ARI	100 year ARI	2.6
PMF	PMF	100 year ARI	2.6

2.4.3 Mitigation Measures

The report provided several recommendations to be assessed in the floodplain risk management plan, which was to be completed at a later stage. These recommendations included:

- Update Flood Planning Levels based on the results of this Flood Study, as well as Local Environmental Plans and Development Control Plans as appropriate.
- Update Councils GIS systems with the flood mapping from the Flood Study.
- Update S149 certificates for properties affected by flooding.
- Proceed to the preparation of the Floodplain Risk Management Study, to determine options to manage and/or reduce the flood risk taking into consideration social, ecological, and economic factors.
- The flooding interactions between Marshalls Creek and the Brunswick River should be considered prior to undertaking the Floodplain Risk Management Study for the area. The results of the Coastal Creeks Flood Study didn't consider coincident Brunswick River and Marshalls Creek flooding nor storm surge propagation.
- It was noted that the Floodplain Risk Management Study could be undertaken separately by each Council for their respective area. However, both Councils

should ensure that management and mitigation options do not adversely impact on flooding behaviour where the floodplains are connected.

- On completion of the Floodplain Risk Management Study, a list of preferred options that were recommended by each Council would be presented in an overall Floodplain Risk Management Plan to be publicly exhibited for comment by the community and subsequently approved and implemented by Council.

2.5 Marshalls Creek Floodplain Management Plan (Paterson Consultants, 1997)

2.5.1 Overview

This study was undertaken by Paterson Consultants on behalf of Byron Shire Council. The scope of the study was limited to the development of the floodplain management plan for Marshalls Creek, and tributaries of Yelgun Creek and Billinudgel Creek, and did not undertake any modelling, at the timing of the study Council had adopted the Brunswick River Flood Study (Webb, McKeown & Associates, 1986). Key limitations of this study include the timing of the study as several new developments and changes in land use have occurred since the timing of the study, however many of the recommendations remain valid and are similar to present day council adopted floodplain risk management plans.

2.5.2 Identified Hazards/Risks

2.5.3 Mitigation Measures

Several floodplain management objectives were identified for this study including:

- Alerting the community to the extent and hazard of flood prone land in the Marshalls Creek area.
- Informing the community of Council's policies in relation to the development and use of flood prone land.
- Definition of a flood standard to be used for planning purposes.
- Reduction of the risk to human life and damage to property caused by flooding by appropriate works and measures and by controlling development on flood prone land.
- Adoption of requirements for development and for the use of land which is compatible with the land's flood hazard.
- Reduction of the impact of flooding on existing development by a series of works and measures.
- Prevention of flood losses in future development areas by application of effective planning and development controls.
- Provision of controls regarding flooding such that applications for development (including sub-division, rezoning development and building applications) can be assessed both consistently and on merit in accordance with the NSW Floodplain Development Manual (published by NSW Government, 1986)

- Incorporation of plan provisions into planning policy provisions

The study proposed several general mitigation measures which are summarised in Table 2-4, as well as local mitigation measures summarised in Table 2-5.

Table 2-4: Marshalls Creek FMP General Flood Mitigation Controls

Category	Controls
New sub-divisions of Flood-liable Lands	A moratorium for development of flood-liable land and filling of flood liable lands.
Development of Existing Lots and existing sub-divisions	A building application process
	Effluent disposal mounds where appropriate shall be located to provide minimal obstruction to local drainage and flood flows
Public Information and Education Programs	Byron Council and the SES should monitor the distribution of public information
	Public information should be reviewed after each major flood and amended where necessary
Flood Warning	Improvements to the warning system be investigated principally covering water level gauges to provide public information use of local area "Wardens" to assist in distribution of warnings
	Review of the Flood Plan be undertaken to ensure the consistency of damage and risk areas between all documents and the flood evacuation centres are located on flood free sites
	Investigation if established computer models can be used to improve flood prediction systems downstream of Billinudgel
	Funding to be sought to improve SES capacity to manage flood emergencies
Individual Lot Landscaping provisions	Building and development application provisions to be modified to promote open fencing and prevent traditional high "closed" style fencing
	Building and development controls such that flood protection measures on any particular block do not adversely affect the drainage and flooding characteristics on the surrounding blocks
Trunk Drainage Operations	A trunk drainage plan through the study area is required to identify works and measures to improve the efficiency of the system and to improve water quality
	Council's building and development conditions be reviewed to ensure they require and enforce the provision of overland flow

Category	Controls
	paths for safe discharge of runoff if the trunk drainage system should become blocked
Infrastructure Crossings	Byron Council should develop a set procedure for assessing the impacts of infrastructure crossings of the floodplain
	The established procedure should be applied to all works including those undertaken by Council
	Byron Council should notify the various government bodies authorities and construction groups of the intention to apply the principles of the Floodplain Management Plan to all land within the study area.
Integrated Catchment Management	Applications for development approval or change in land use shall be required to demonstrate that such development or change in land use will not increase runoff flowrates or pollution loadings within the Plan Area.

Table 2-5: Marshalls Creek FMP Local Flood Mitigation Controls

Region	Controls
Billinudgel	Building controls allowing setting of minimum floor levels for new buildings, infill development and building extensions
	The storage of all toxic or hazardous substances or other products which in the opinion of Council may be hazardous or polluted flood waters, must be a minimum of 0.5m above designated flood level
	Development controls to allow filling of existing sub-divisions within the village
	Prohibition of further sub-division of flood liable land adjacent to the existing village boundaries
South Golden Beach and Ocean Shores North	Building controls allowing setting of minimum habitable floor levels for new buildings, infill development and major building extensions at RL 3.6m AHD
New Brighton	Building controls to be developed to
	Landscaping directions to be developed regarding fencing, flood access indicators, effluent disposal mounds

	An interim measure was proposed to adopt the building material and detail guidelines in Appendix F of the NSW floodplain development manual
Ocean Shores	Building controls to set minimum floor levels flood compatible building materials and design of buildings to promote flood compatibility
	Prohibit subdivision or filling of undeveloped "High Hazard" areas.
Ocean Shores North/South Golden Beach/New Brighton Non-Urban Area	Prohibit non-compatible development of "High Hazard - Flood Storage classed land
	Prohibition of further fill or sub-division of the area
Yelgun/Wooyung Area	Building Controls to set minimum floor levels, Flood compatible building restraints, design of buildings to provide flood compatibility flood mounds to provide adequate flood refuge area

2.5.4 Other Findings

The study identified 28 houses in New Brighton and 1 house in Ocean Shores that would be suitable for house raising and a further 21 houses in New Brighton and 95 houses in Ocean Shores which would be appropriate for flood proofing. The study identified funding for house raising through joint Federal, State Governments and Council funded Flood Mitigation Programme to cover the full cost of house raising. The study estimated potential costs at the timing of the study for these works being:

- **House-raising (29 Houses) $ 1,015,000**
- **Flood Proofing (116 houses) $ 342,000**

There is some difference between number of houses suggested for flood proofing in the text and in the tables and summary.

2.6 North Byron Flood Study (BMT, 2016)

2.6.1 Overview

This study was undertaken by BMT on behalf of Byron Shire Council. It included the development of detailed hydrological and hydraulic models for Brunswick River to investigate flood risk for the catchment, for use in subsequent floodplain risk management studies.

The scope of the study was limited to the Brunswick River, Simpsons Creek, and Marshalls Creek Catchments. Key limitations of this study included the poor calibration results to catchment response and the use of the ARR87 methodology.

2.6.2 Modelling Methodology

2.6.2.1 Hydrologic Model

This study undertook the development of an XP-RAFTS hydrological model for Brunswick River, Simpsons Creek, Marshalls Creek and Yelgun Creek. The XP-RAFTS model included several sub catchments to represent each of the major catchments, Brunswick River, Marshalls Creek, Simpson Creek and Yelgun Creek. Upstream sub catchments utilized an external routing methodology with no attenuation of peak flow and specification of travel time in attempt to minimize steep catchment's peak flow attenuation, remaining sub catchments utilized XP-RAFTS Muskingum routing methodology.

2.6.2.2 Hydrodynamic Model

This study undertook development of detailed TUFLOW hydrodynamic models that covered Ocean Shores, Brunswick Heads, Mullumbimby, and Brunswick River Estuary. In the upper areas of the floodplain a significant portion of major creeks and rivers were represented as one dimensional network, as shown in Figure 2-10. The Mannings' roughness values adopted for the design event modelling are presented in Table 2-6. Some of these roughness values are considered to be in the lower end of the range for roughness for typical the land use/vegetation types, however they are considered within reason.

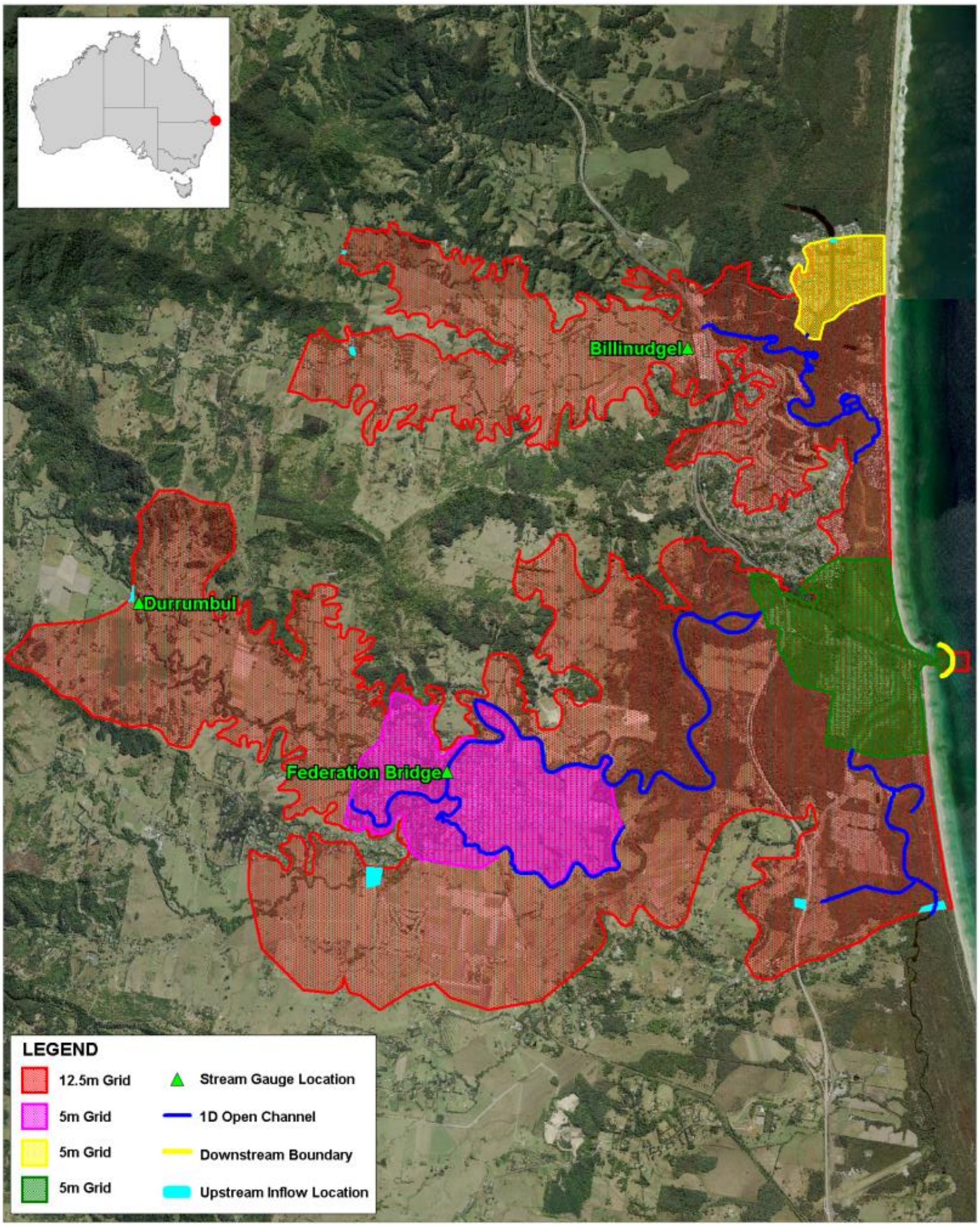

Figure 2-10: North Byron Flood Study (BMT, 2016) Model Schematization

Table 2-6: North Byron Flood Study (BMT, 2016) Roughness Values

Land Use Type	Mannings' n Value
Pasture / Grass	0.04
Scattered Trees	0.05
Medium Trees	0.07
Thick Trees / Forest	0.09
Sandy River Bed	0.03
River Bed	0.04
Dams	0.07
Rock Walls	0.04
Urban Block	0.1
Golf Course	0.04
Sugar Cane	0.2
Bitumen Road	0.02
Gravel Road	0.025
Large Building Footprints	1.00

2.6.2.3 Calibration and Validation Overview

The hydrodynamic and hydrologic models were calibrated to the June 2005 and January 2012 flood events. Calibration efforts included hydrologic and hydrodynamic model calibration. Hydrologic model calibration included variation of; storm losses (IL and CL), roughness, and lag time for upstream sub catchments routing methodology as described in 2.6.2.1. Hydrodynamic model calibration included variation of roughness and structure losses. The calibration efforts results in a varying accuracy in the representation of the events throughout the catchment, the study identified that some of the discrepancies between the observed and the modelled results could be attributed to ever-changing catchment characteristics (including the Pacific Highway Upgrade) and data availability and accuracy, structure blockages and sub-daily rainfall data. Several observations were made on review of the resulting calibration comparisons.

2.6.2.4 Calibration results at Durrumbul

Model results of the Brunswick River Upstream of Durrumbul indicates that there is a misrepresentation of catchment response and falling hydrograph limbs, which is indicative of lower lag or attenuation and misrepresentative of storage - discharge relationships. Examples taken from the report of these comparisons of recorded data at Durrumbul to modelled data are provided in Figure 2-11, Figure 2-12, Figure 2-13, Figure 2-14.

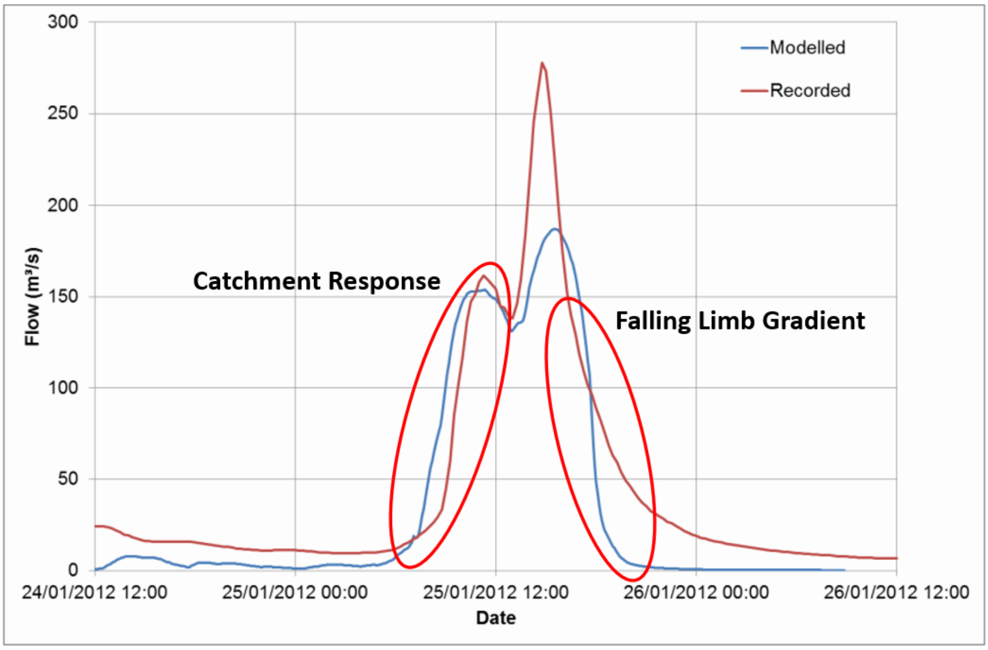

Figure 2-11: January 2012 Calibration Results at Durrumbul

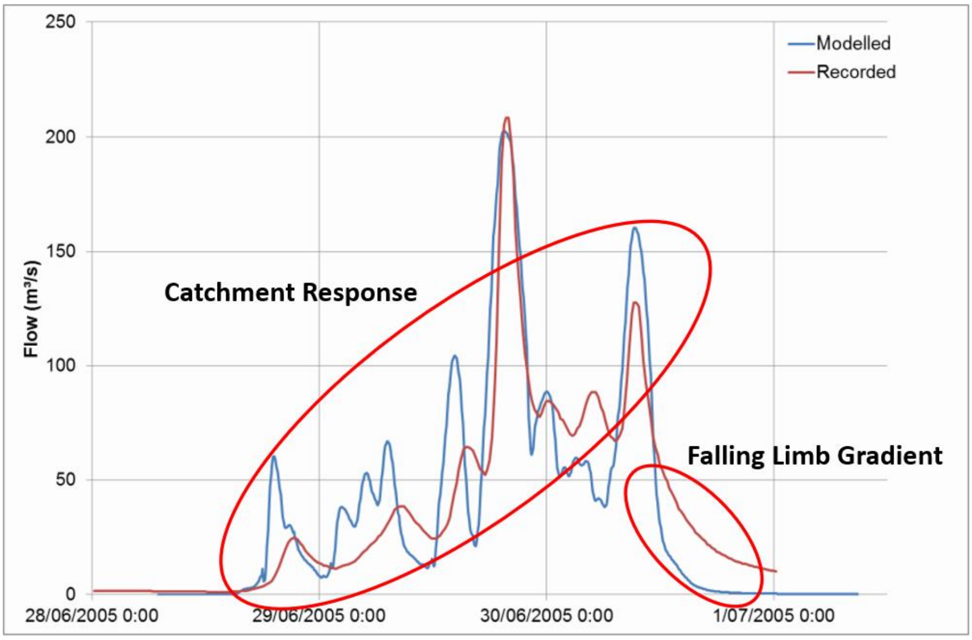

Figure 2-12: June 2005 Calibration Results at Durrumbul

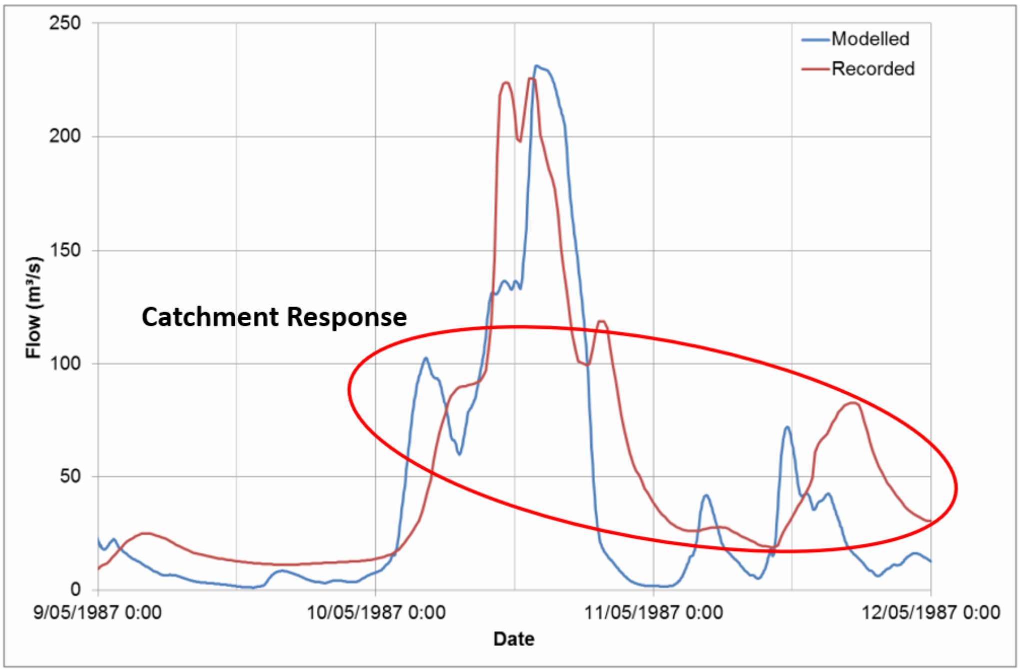

Figure 2-13: May 1987 Calibration Results at Durrumbul

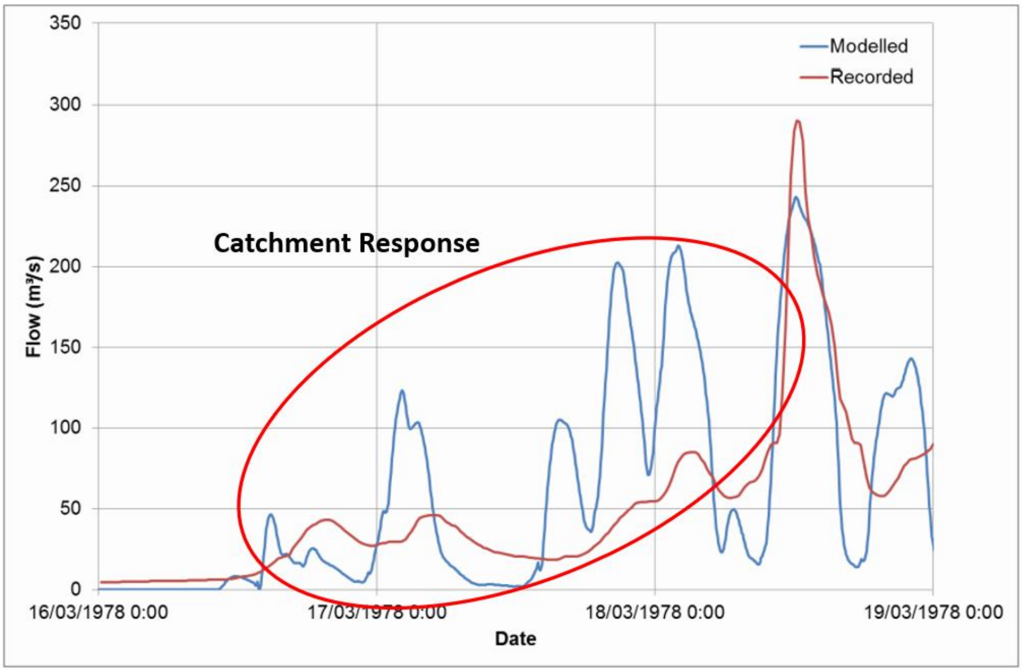

Figure 2-14: March 1978 Calibration Results at Durrumbul

2.6.2.5 Calibration Results at Billinudgel

The hydraulic modelling results at Billinudgel gauge resulted in fair peak level comparisons, however a minor discrepancy was observed to the falling limb of the hydrograph shown in Figure 2-15. This discrepancy is relevant in assessing duration of inundation, which may be important to cropping lands or duration of closure to inundated roads.

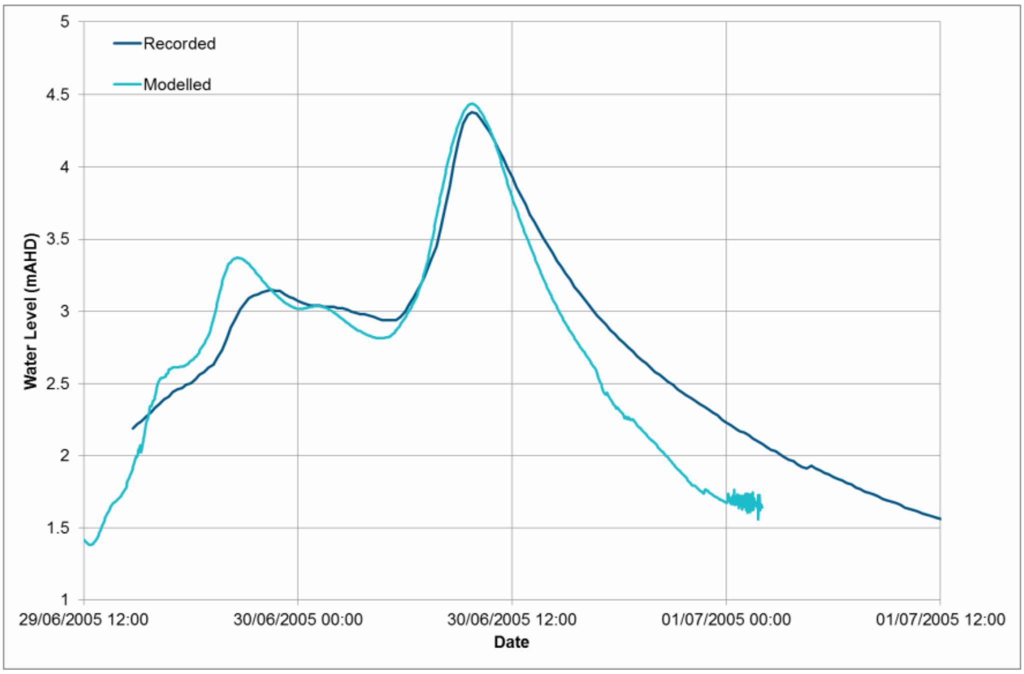

Figure 2-15: North Byron Flood Study (BMT, 2016) Billinudgel Falling Limb

2.6.2.6 Calibration Results at Federation Bridge

Federation Bridge hydraulic model results indicate an overestimation of catchment volumetric response; however, the study believed a significant portion of the observed differences could be due to the data limitation of the sub-daily rainfall. Comparisons are shown in Figure 2-16 and Figure 2-17.

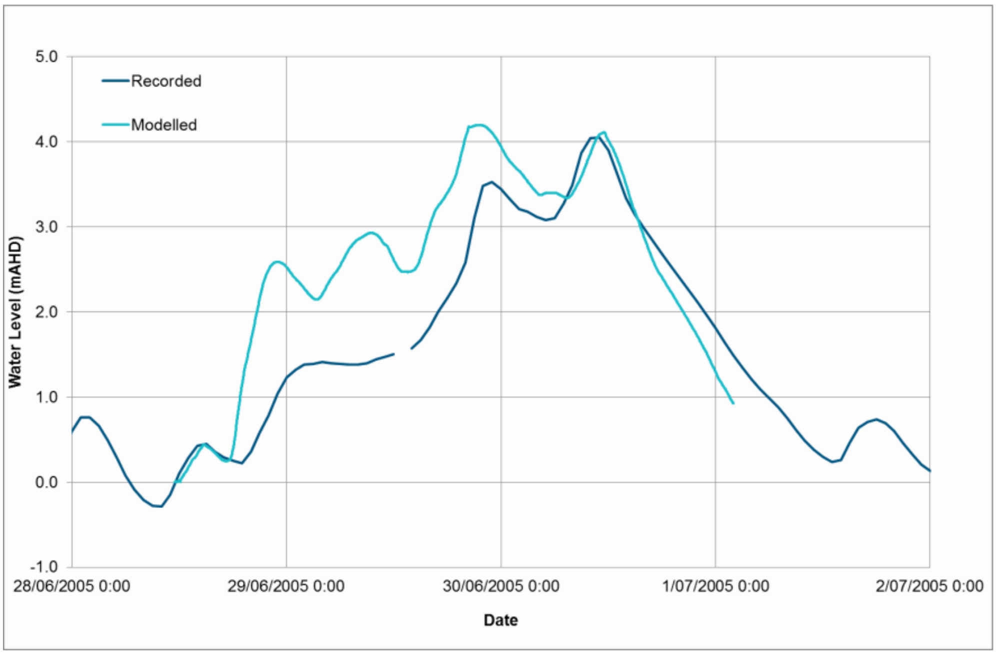

Figure 2-16: North Byron Flood Study (BMT, 2016) 2005 Event Comparison at Federation Bridge

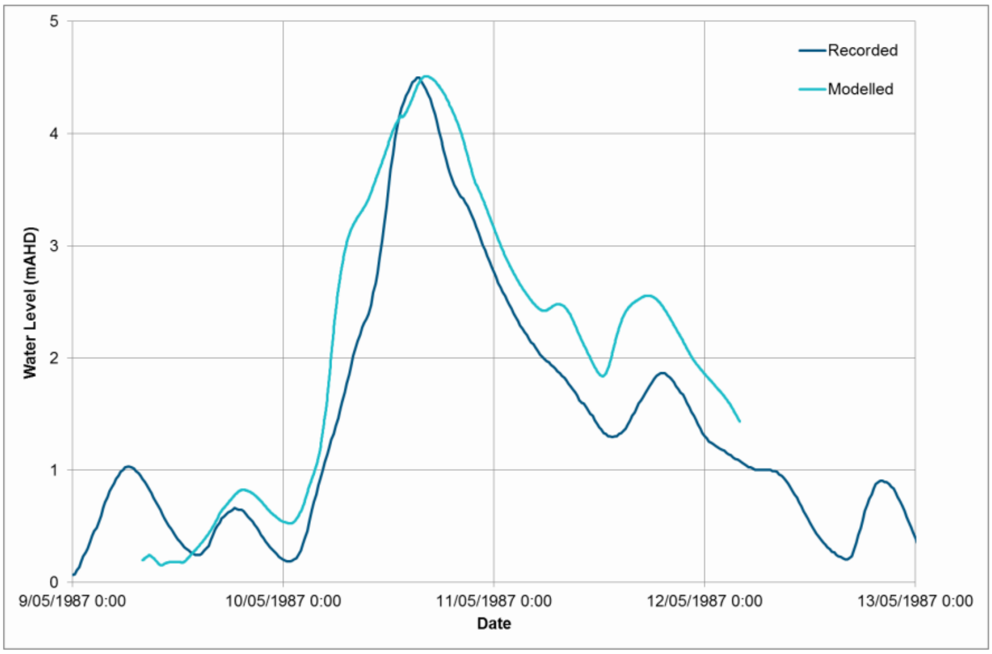

Figure 2-17: North Byron Flood Study (BMT, 2016) 1987 Event Comparison at Federation Bridge

2.6.2.7 Flood marks validation

Recorded flood marks are considered to generally align with model results, with relatively small absolute differences as shown in Figure 2-18 supporting the model calibration. However, it is believed that several recorded flood marks are believed to be located in shallow/sheet flow areas, which generally result in minor absolute differences and are not well related to the main flood flows, limiting the conclusions that can be drawn from these flood marks. It is noted that there is an approximately 1m difference between the recoded and the modelled for a flood mark near Mullumbimby.

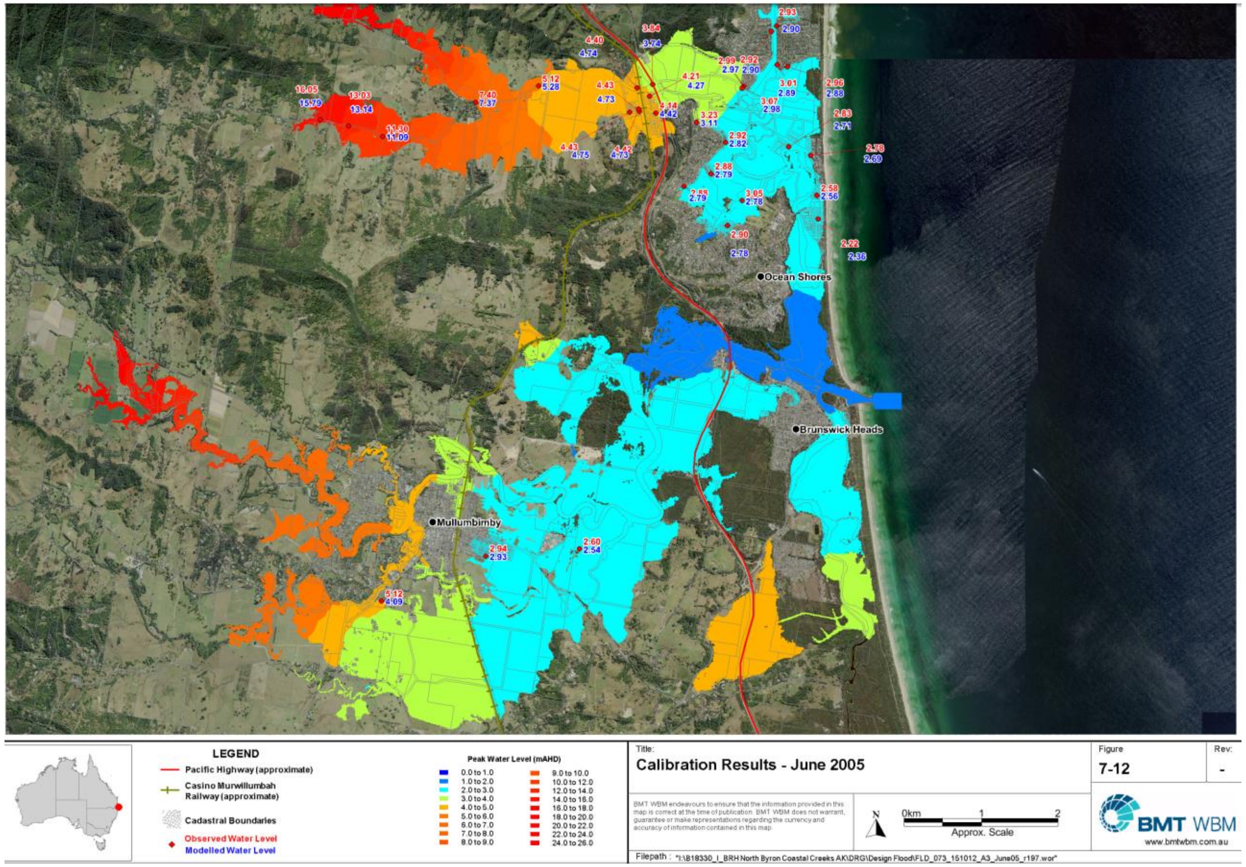

Figure 2-18: North Byron Flood Study (BMT, 2016) 2005 Event Flood Marks Comparisons

2.6.2.8 Scenarios and Events

Several scenarios and events were modelled, including both rainfall and ocean storm surge dominated flood events, for the 5, 10, 20, 50, 100, and 500 year Average Recurrence Interval (ARI), and the PMF events. In addition, climate change sensitivity scenarios were modelled which included, sea level rise and increased rainfall intensity.

2.6.3 Identified Hazards

The flood study undertook community engagement in aims to quantify hazards and concerns facing the community. Results from the community engagement are presented in Figure 2-19 and Figure 2-20

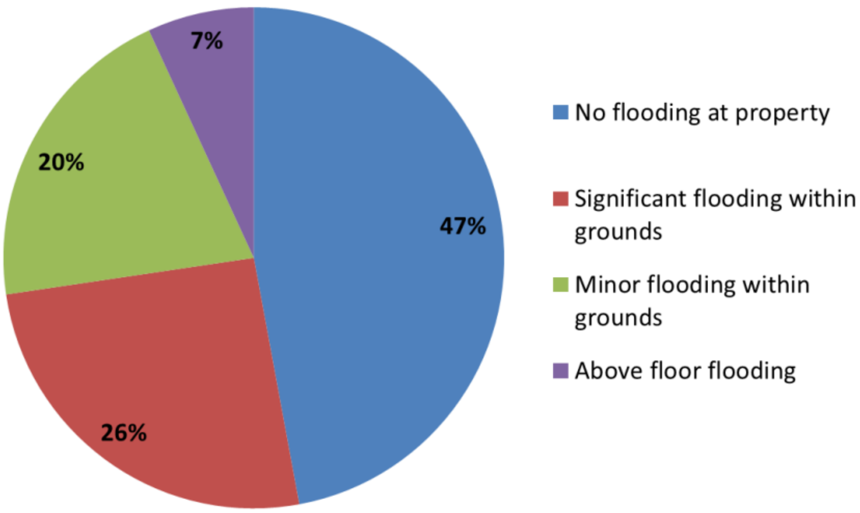

Figure 2-19: North Byron Flood Study (BMT, 2016) Community Identified Degree of Flooding

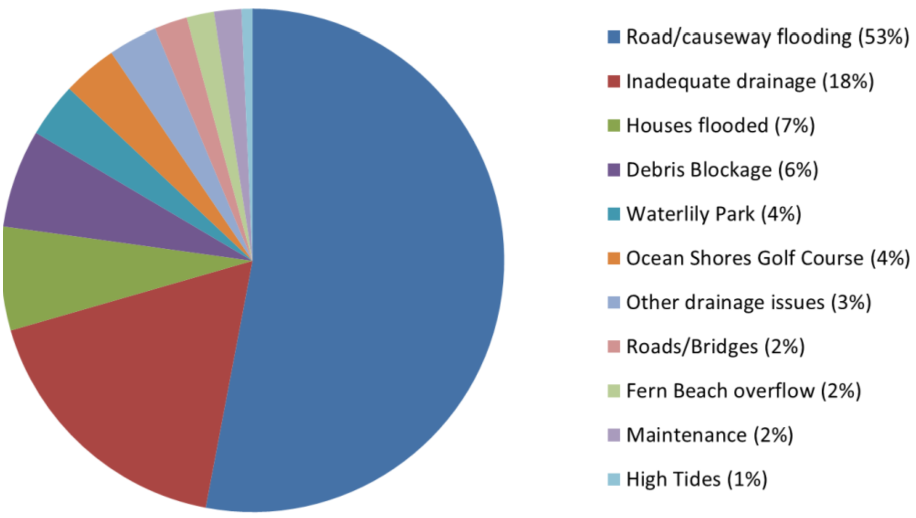

Figure 2-20: North Byron Flood Study (BMT, 2016) Community identified flood hazards

2.6.4 Flood Risk Management Measures

From the conducted community engagement survey several flood risk management options were proposed by the community, presented in Table 2-7. From the community responses a significant portion of management options proposed were attributed to:

- Improve Road Drainage (26%)
- Increase maintenance (23%)
- Dredge creeks and river (19%)
- Remove vegetation/debris/silt (11%)

Similarly, responses to "Flooding issues that should be considered" were largely attributed to:

- Dredge river (25%)
- Restrict / Regulate development in floodplain (21%)
- Storm water drainage (12%)
- Brunswick River Mouth (10%)
- Clean and maintain drainage (7%)

Table 2-7: North Byron Flood Study (BMT, 2016) Community Management Options

Ideas to Improve Flooding		Flooding Issues that Should be Considered	
Improve road drainage	26%	Dredge river	25%
Increase maintenance	23%	Restrict / regulate development in floodplain	21%
Dredge creeks and river	19%	Storm water drainage	12%
Remove vegetation/debris/silt	11%	Brunswick River mouth	10%
Open ocean outlets	3%	Clean and maintain drainage	7%
Levees / bunds	3%	Better flood warning / education	4%
Modify road/rail structures	3%	Modify road / rail structures	3%
Look at Marshalls Creek confluence with Brunswick River	2%	Other	3%
House Raising	2%	Substation at Waterlily Park	2%
Modify Waterlily Lake	2%	Tsunami alerts	1%
Raise causeways/keep clear of debris	2%	Increase in mosquitos	1%
Raise / monitor easements	1%	Sewage in Brunswick River	1%
Remove rock wall	1%	Climate change	1%
Fern Beach resulted in flooding of South Golden Beach	1%	Height of causeway on Main Arm Road	1%
Use wetland areas for mitigation	1%	Insurance	1%
Open flood gates on Golf Course	1%	Sand bar in Marshalls Creek	1%
Traffic management during flood	0%	Traffic management	1%
		Extra span in bridge	1%

Several actions were recommended following the adoption of this flood study including:

- Update the flood planning levels inclusive of the local environmental plans and DCP.
- Update Council's GIS systems with the flood mapping outputs from the flood study.
- Update S149 certificates for the properties affected by flooding.
- Undertake a condition survey of the gauge at Federation Bridge.
- Prepare a drainage strategy to reduce storm water flooding in Mullumbimby.
- Prepare a drainage strategy to reduce storm water flooding in Brunswick Heads.
- Proceed to the preparation of the Floodplain Risk Management Study and Plan to determine options to manage and/or reduce flood risk, taking into consideration social ecological and economic factors. This should consider the following:
  - The flood risk and hazard for extreme events.

- The implications of the sensitivity tests on Flood Planning Levels and whether Council should change its current policy.
- Identification of areas in the floodplain that should not be 'filled' for the purpose of development.
- Review of past and potential future ocean outlets and the implications for flood mitigation. Such investigations should include:
  - Collaboration with Tweed Shire Council - some outlets may have been within Tweed Shire.
  - Each historic ocean outlet should be modelled in unison and in combination with current catchment conditions.
  - A cost-benefit analysis to quantify the economic benefit that the ocean outlets may provide.
- Changes to the rock walls and the implications for flood mitigation. This investigation should include an assessment of removal of vegetation from the Readings Bay rock walls and cost-benefit analyses for the potential works.
- Model the dredging of each of the three creeks individually and in combination for the current catchment conditions. Assess the reduction in flooding these works provide, if any, and prepare a cost benefit analysis for the dredging works.

2.6.5 Other Findings

2.6.5.1 ARR87 Methodology

Due to the timing of the study the ARR87 methodology was adopted, which included ARR87 temporal patterns and the ARR87 IFD estimations. While the IFD estimations were investigated for validity, the quality of available data was not considered viable to support the adoption of locally derived IFD estimations.

2.6.5.2 Marshalls Creek Coastal Break Outs

The study found that there was supporting evidence through historic satellite imagery, of several breakout locations along Marshalls Creek. While no evidence was provided for the cause it was believed to be due to sand mining operations and subdivision works over several years. Flood level and inundation sensitivity due to these blocked outlets was not investigated in this study.

2.7 North Byron Floodplain Risk Management Study and Plan (WMA, 2020)

2.7.1 Overview

This study was undertaken by WMAwater on behalf of Byron Shire Council. This study included an investigation of:

- Flood behaviour including hydraulic and hazard categorisation.
- Future development scenarios
- Review of potential climate change impacts on the flood behaviour and risks
- Flood damages assessment
- Emergency management

This study built on the North Byron Flood Study delivered in 2016. With the previous flood study using ARR87 methodologies, significant changes were made to this study by adopting of the ARR2019 update. The scope of this study was limited to the townships of Mullumbimby, Brunswick Heads, Ocean Shores, and villages of New Brighton, South Golden Beach and Billinudgel, and covers an approximate area of 55km^2. Key limitations of this study include resulting misrepresentation of catchment response from calibration.

2.7.2 Previous Study Overviews

The North Byron Flood Risk Management Study and Plan (WMA, 2020) included reviews of the following studies. These studies

2.7.2.1 Flood Mitigation Options for Billinudgel (Ray Sargent and Associates, 1988)

This report focused on flood mitigation options for Billinudgel. The 1987 Brunswick Valley Floodplain Management study showed minimal impacts on flood levels from filling. However, this report notes that increases in flood levels of 50mm could impact on existing properties and inundate previously dry properties, As the impact from filling land is very low, the report concludes the levees are likely to have minimal impact but while noting this, it does not continue to investigate this option further. To reduce the risk of flooding and prevent a deterioration of the flood problem, the following actions were recommended:

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

2.7.2.2 Brunswick River Floodplain Management Investigations (WMA, 1989)

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

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

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

- To mitigate the impacts from the proposed development, a combination of flood mitigation works would be required and would need to include either the dredging of Marshall Creek or the North Ocean Shores flood outlet/opening.
- A levee around South Golden Beach would increase flood levels at new Brighton and would require a levee on the northern boundary.
- It is expected a levee around New Brighton without additional flood mitigation works would have impacts on upstream flood levels. For New Brighton, flood proofing measures were suggested.
- Should part of the development on Mr Mangleson's land proceed independently of the remainder of the proposal, a section of the floodway proposed opposite the land should be constructed.
- Development on Site B of the Mangelson land may have significant hydraulic impacts as the land is low-lying and forms part of the floodway. These impacts would not be easily mitigated.

2.7.2.3 Mullumbimby Floodplain Management Study (1989)

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

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

- A diversion of floodwaters down Saltwater Creek provides no flood mitigation benefits and would have adverse impacts on other properties.
- Raising of houses or additional local flood protection would be not viable due to the number of houses affected and the cost. In combination with other options, house raising may be viable.

- A flood warning system could reduce flood damages however, due to the short response time of the catchment was not considered a solution.
- Dredging of the Brunswick River would not eliminate the flood problem but in combination with other options could be more effective.
- Lowering or removal of the railway line would reduce flood levels on the upstream side of the railway line, as the line restricts flow across the floodplain at Mullumbimby. However, lowering of the line would increase flood levels on the downstream side and increase flow velocities at Station Street.
- Improved drainage through the railway line by adding culverts under the line would have a similar effect as the lowering of the line. A significant number of culverts (approx. 70) would be necessary to have a significant impact on flood levels upstream.
- A levee bank around the western part of the town would protect 30% of the flood prone properties but would have a negative impact on flood levels upstream of the levee. Associated drainage required with this option includes 4 culverts under the railway line and some additional culverts through the levee. Negative impacts caused by the levee could be mitigated by dredging of the Brunswick River, or stream clearing near the railway bridges to the south of Mullumbimby.
- Development of the proposed Industrial Estate located on Football Club Road would significantly increase flood levels downstream of the railway line. However partial development of the site may be possible.
- A levee bank around the eastern part of the town would protect 56% of the flood prone properties. While there were found to be no negative impacts on flood levels upstream of the railway line, a levee bank would cause a 10mm increase in flood levels downstream of the line. This option would require raising parts of Argyle Street and the construction of a 16-hectare storage basin inside the levee.
- Widening of the Main Road 524 bridge on Kings Creek by over double and lowering of Main Road 524 to ground level would reduce the 1% AEP flood levels by up to 20mm and 50mm respectively. Lowering of MR524 is expected to have impacts to trafficability during flood events. The report concludes neither option is cost efficient.

2.7.2.4 Proposed Levees around South Golden Beach (WMA, 1989)

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

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

2.7.2.5 Report on Feasibility of an EIS for North Ocean Shores Flood Outlet (WMA, 1992)

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

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

2.7.2.6 Draft Mullumbimby Floodplain Management Plan (BSC, 1993)

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

Recommendations made in the plan were:

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

Recommended development Controls within floodways:

- Maintain floodways ability to pass water

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

Recommendations for the eastern Mullumbimby floodplain:

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

Recommendations for Western Mullumbimby/Saltwater Creek Floodplain:

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

2.7.3 Modelling Methodology

2.7.3.1 Hydrology Model

This study adopted of the previously developed XP-RAFTS hydrologic model developed from the 2016 study. However, several refinements were made to the existing XP-RAFTS model including:

- Catchments Slope Review
- Revised manning's roughness
- ARR2019 Storm Losses Applied
- Removal of sub-catchment storage factors
- Removal of Williams Bridge Basin

2.7.3.2 Hydrodynamic Model

This study adopted the TUFLOW hydrodynamic model developed for the 2016 study. However, several refinements were made to the existing TUFLOW model including:

- Inclusion of several significant hydraulic structures
- Topography amendments for recent developments:

  - Tallow Wood Estate Stage 4
  - Waterlily Park survey
  - Shara Boulevard Sports field
  - Orchid Place
  - Rajad Road Subdivision
- River Bathymetry Update using bathymetric survey from November 2017
- Extended model extent
- Higher resolution of urban areas

2.7.3.3 Calibration/Validation/Sensitivity

The hydrodynamic and hydrologic models were calibrated to the March 2017 event, which was caused by ex-Tropical Cyclone Debbie. Calibration was to the recorded stream gauge data at five locations, for flood levels and for recorded streamflow, all modelled flows are believed to underestimate catchment and/or channel lags, with the model results showing all falling and rising limbs having faster runoff responses. While the study claimed a better representation was achieved the associated report figures indicate that a similar lag underestimation was encountered. The significance of the effect on floodplain estimation from the lag misrepresentation was not discussed. It does however have an impact on disaster response decisions and impacts on inundation timings (both time to inundation and duration of inundation. It is believed to be an underestimation of catchment roughness, affecting either channel or catchment lag, as the tidal gauges and catchment streamflow gauges both observe the discrepancy.

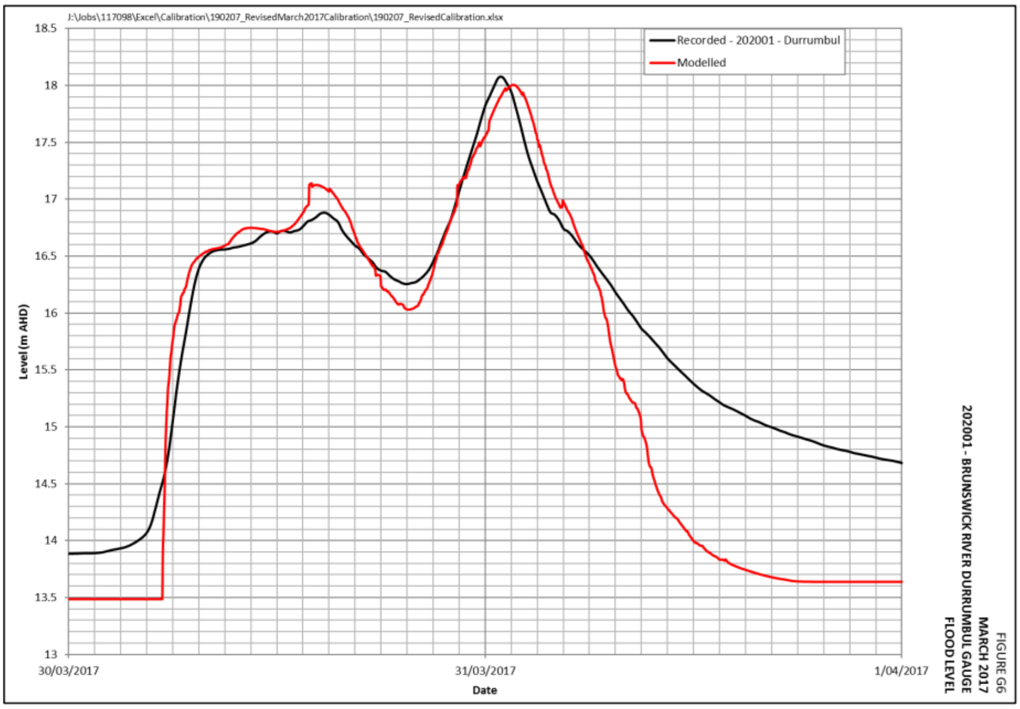

Figure 2-21: North Byron FRMS March 2017 Level Calibration Brunswick River at Durrumbul Gauge

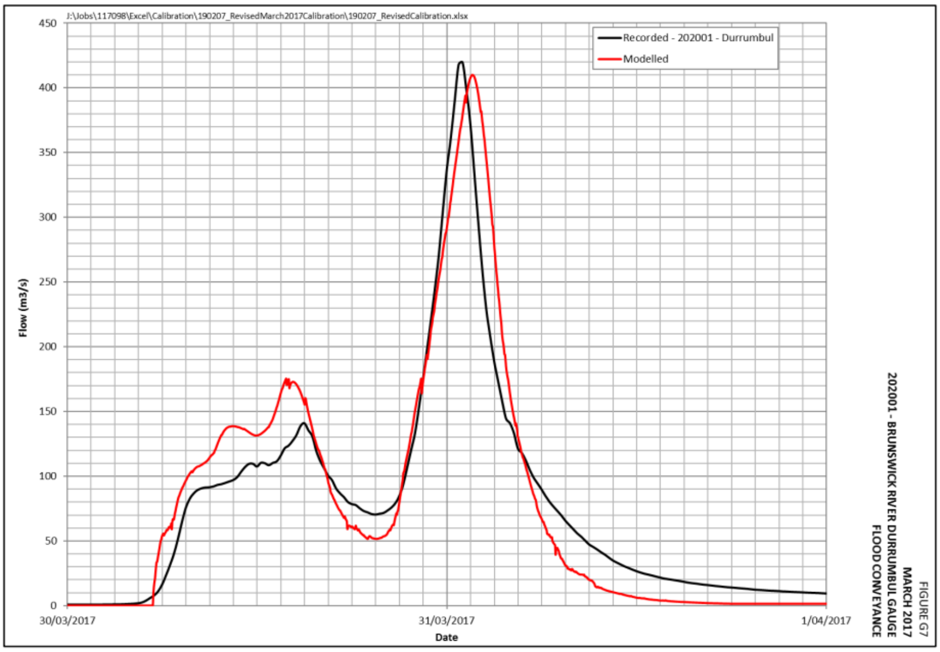

Figure 2-22: North Byron FRMS March 2017 Flow Calibration Brunswick River at Durrumbul Gauge

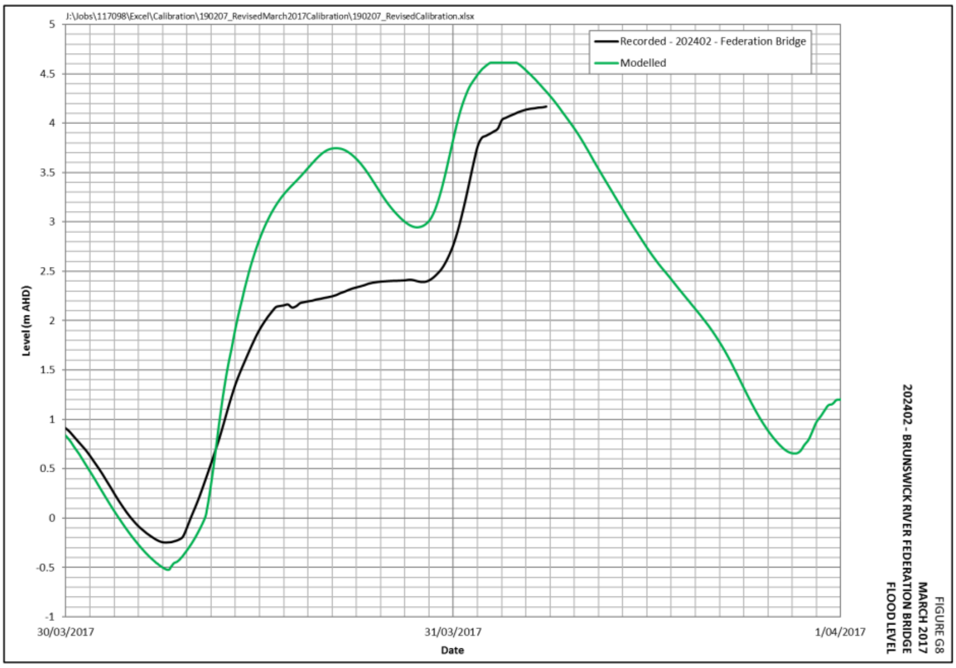

Figure 2-23: North Byron FRMS March 2017 Level Calibration Brunswick River at

Federation Bridge

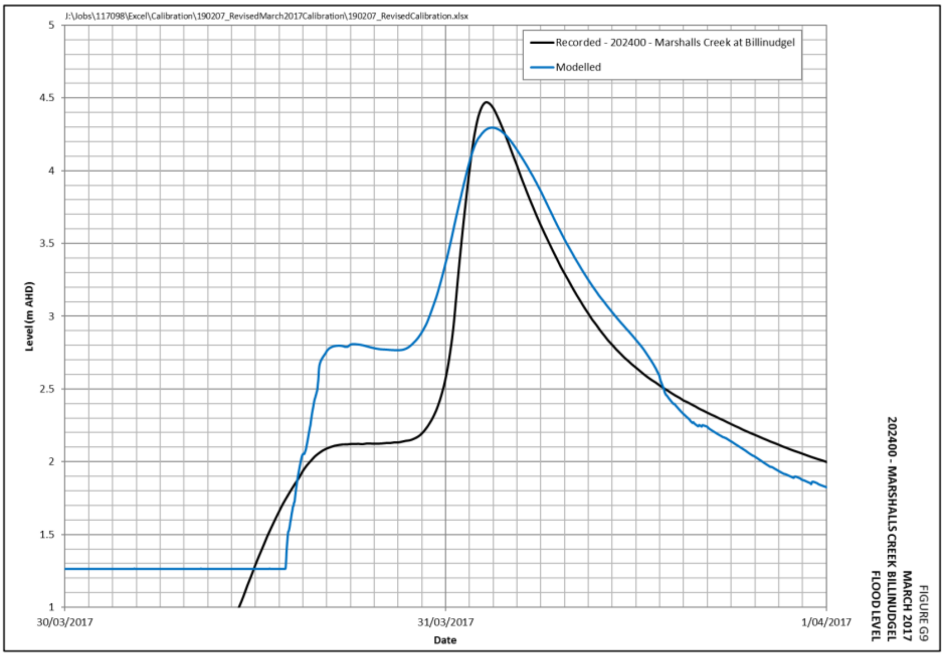

Figure 2-24: North Byron FRMS March 2017 Level Calibration Marshalls Creek at Billinudgel

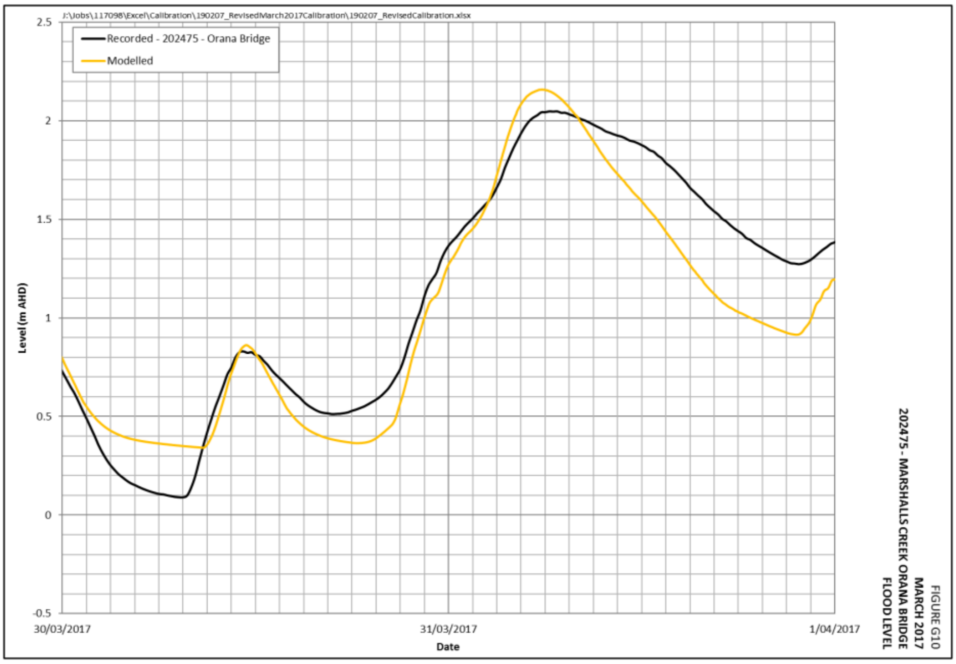

Figure 2-25: North Byron FRMS March 2017 Level Calibration Marshalls Creek at Orana Bridge

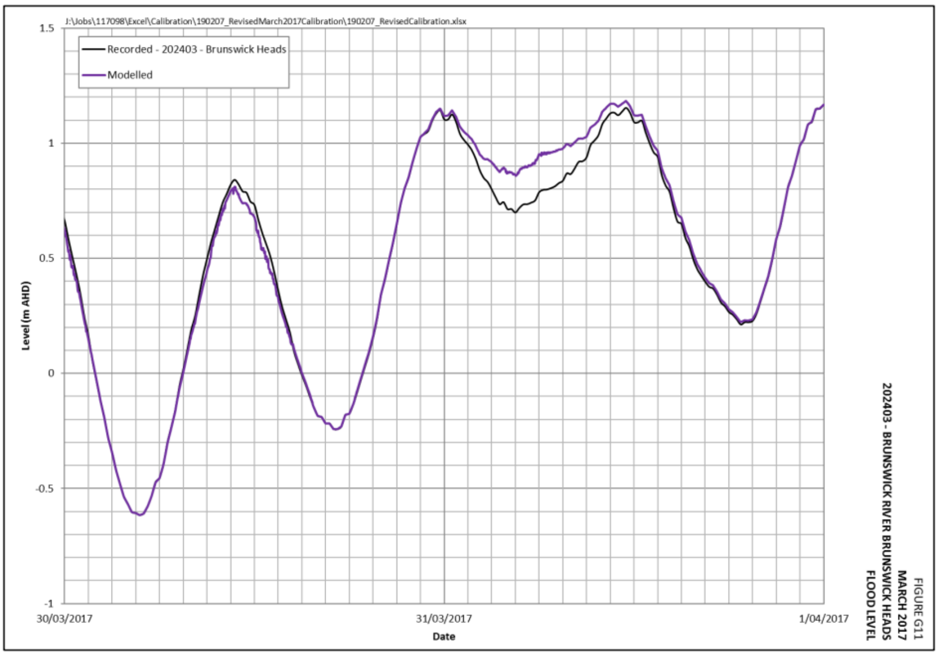

Figure 2-26: North Byron FRMS March 2017 Level Calibration Brunswick River at Brunswick Heads

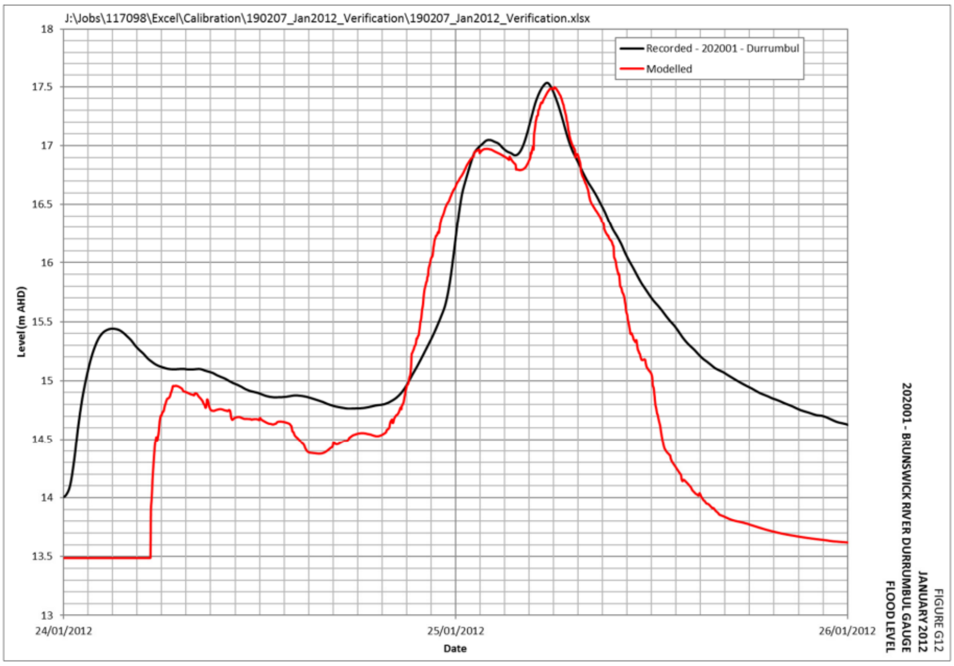

Figure 2-27: North Byron FRMS January 2012 Level Calibration Brunswick River at Durrumbul Gauge

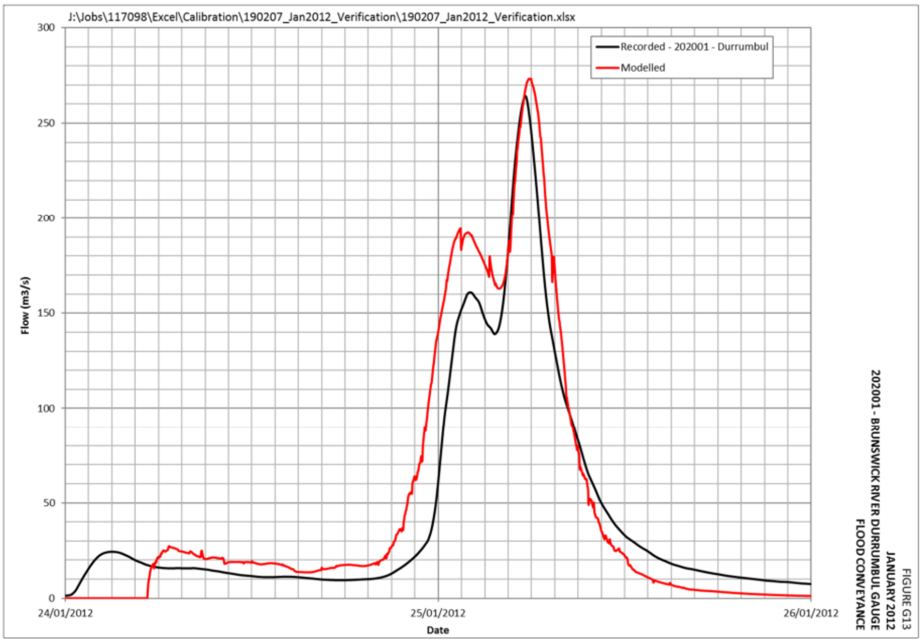

Figure 2-28: North Byron FRMS January 2012 Flow Calibration Brunswick River at Durrumbul Gauge

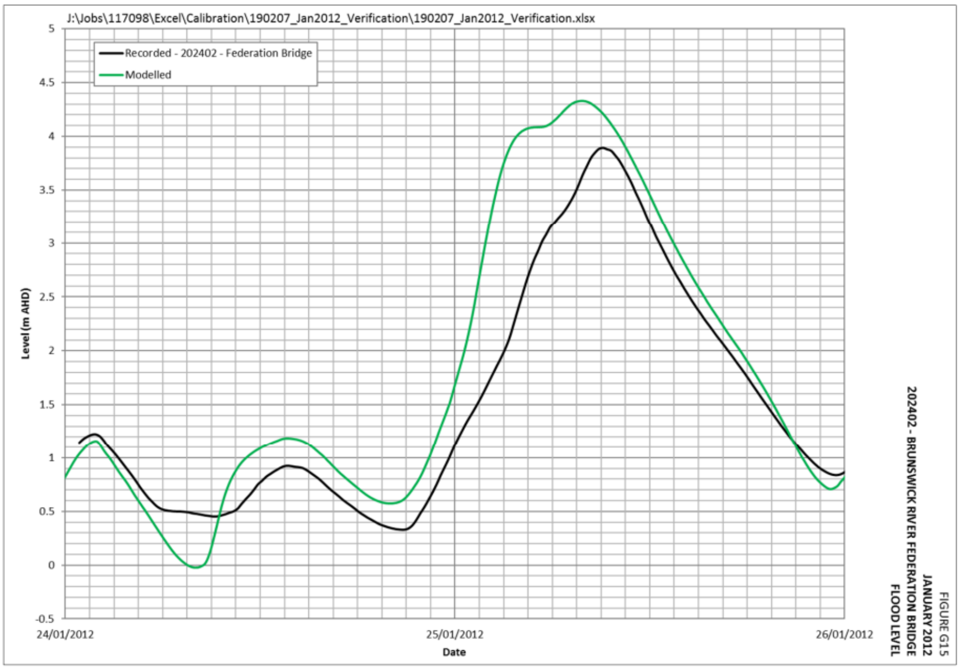

Figure 2-29: North Byron FRMS January 2012 Level Calibration Brunswick River at Federation Bridge

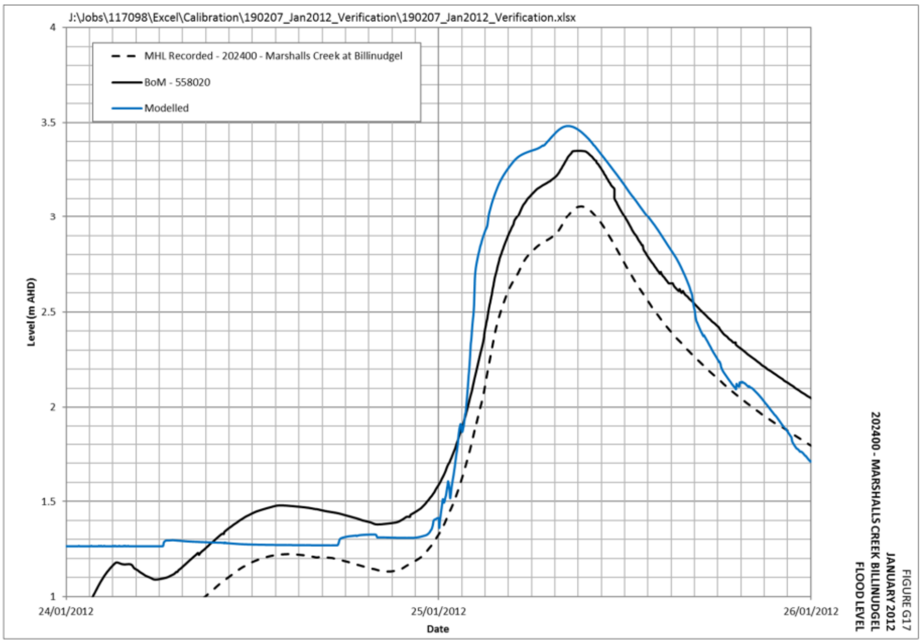

Figure 2-30: North Byron FRMS January 2012 Level Calibration Marshalls Creek at Billinudgel

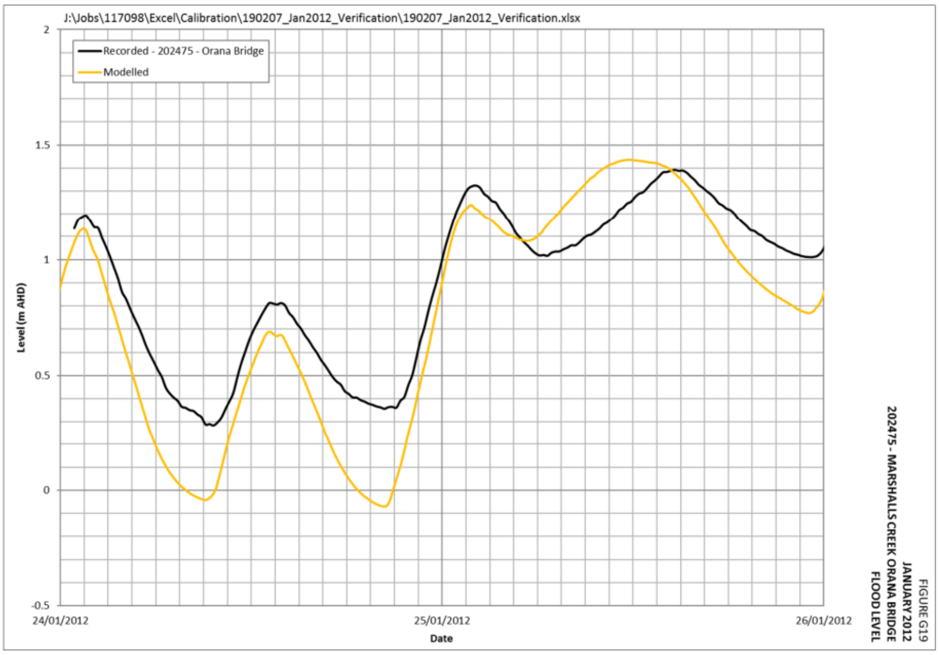

Figure 2-31: North Byron FRMS January 2012 Level Calibration Marshalls Creek at Orana Bridge

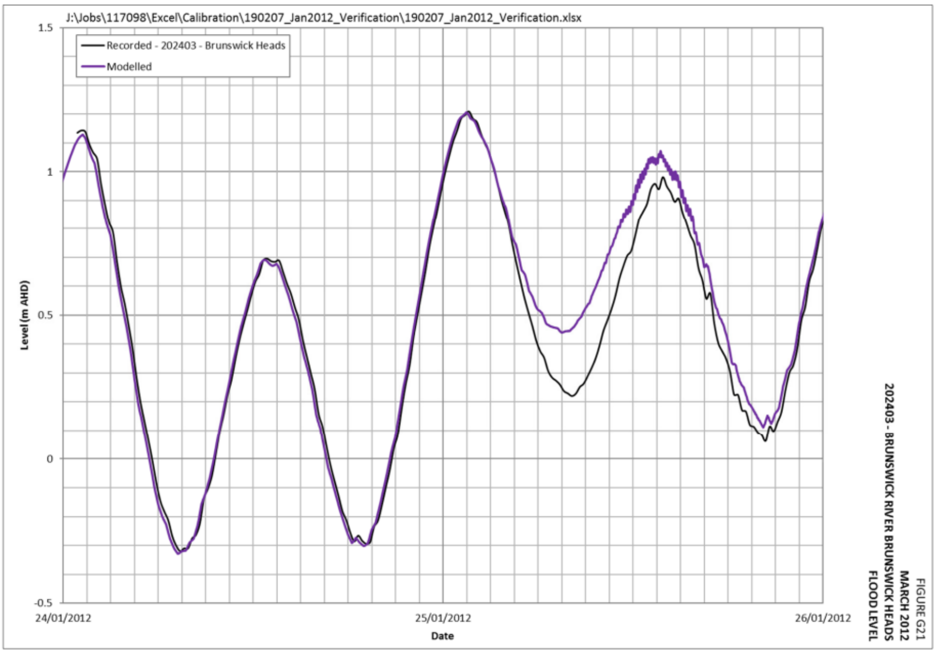

Figure 2-32: North Byron FRMS March 2012 Level Calibration Brunswick River at Brunswick Heads

2.7.3.4 Scenarios and Events

Several oceanic and catchment scenarios were modelled and are summarized in Table 2-8. On review of the listed scenarios, events more common than the 1% AEP design event are thought to be conservative estimates from using join return periods for oceanic and catchment conditions.

Table 2-8: North Byron FRM Study (2020) Scenarios and Events

Design Event	Oceanic Inundation	Catchment Inundation	
		Scenario	Duration
0.2EY	HHWS*	5 year ARI	12hr
			24hr
			36hr
10% AEP	HHWS	10% AEP	12hr
			24hr
			36hr
5% AEP	5% AEP Ocean Level	5% AEP	12hr
			24hr
			36hr
2% AEP	2% AEP Ocean Level	2% AEP	12hr
			24hr
			36hr
1% AEP	5% AEP Ocean Level	1% AEP	12hr
			24hr
			36hr
	1% AEP Ocean Level	5% AEP	12hr
			24hr
			36hr
	ISLW**	1% AEP	12hr
			24hr
			36hr
0.5% AEP	1% AEP Ocean Level	5% AEP	12hr
			24hr
			36hr
0.2% AEP	1% AEP Ocean Level	0.2%	12hr
			24hr
			36hr
PMF Event	1% AEP Ocean Level	PMF	12hr
			24hr
			36hr

2.7.4 Identified Risks

Several risks were identified from community engagement, the top three concerns among the community consultation were:

- Community Safety during floods
- Cost of floods
- Management options disadvantaging other parts of the community.

Several flood hazards were identified from the study that were used to assess flood risk including which were assessed for weighting specific to North Byron and are summarized in Table 2-9.

Table 2-9: North Byron Flood Study Identified Flood Hazards

Criteria	Weight	Comment
Size of flood	3	While some residential properties are in unsafe areas for people / vehicles most properties are located in lower hazard areas for all events excluding the PMF.
Flood Awareness of the community	2	Recent flooding from Ex-Tropical Cyclone Debbie has elevated communities' awareness of flooding.
Depth and Velocity of flood waters	3	Already accounted for in the provisional hazard
Effective Warning and Evacuation Times	3	While the time available for flood warning varies across the North Byron Study area, a large proportion of the residents are located downstream, closer to the outlet (e.g. Mullumbimby and Brunswick Heads) providing opportunity for effective warning
Evacuation Difficulties	4	There are some identified pockets of the floodplain where evacuation routes are cut early, meaning residents may be trapped. Several residential areas were identified by the study as Low Flood Islands including Mullumbimby and a small area of Brunswick Heads.
Rate of Rise of floodwaters	2	While March 2017 exhibited characteristics similar to flash flooding and also showed the variable nature of flood events, flooding in North Byron typically progresses slowly provided people time to prepare
Duration of flooding	2	Duration of flooding varies across the catchment with Mullumbimby experiencing shorter durations of flooding than New Brighton and Billinudgel. However, these areas

Criteria	Weight	Comment
		are not expected to be isolated or flooded for substantial durations of time (e.g. longer than a day).
Effective Flood Access	4	Flood access is a concern for the catchment with several evacuation routes inundated in frequent flood events leaving some areas trapped.

In addition to this the study used modelling results to identify potentially isolated houses, the summary of number of isolated houses is shown in Table 2-10. The results indicate a significant proportion of the isolated houses are in Mullumbimby and may be sensitive to duration of inundation estimated from model results. It is noteworthy that the study indicates a decrease in isolated houses for events rarer than the 5% AEP event, this is believed to be due to a significant number of the isolated houses becoming inundated. Flood hazards, flood levels, and flow velocities were used to identified hotspot locations that were particularly vulnerable to flood risk, these included Mullumbimby, Riverside Crescent (Brunswick Heads), New Brighton, and Billinudgel.

Table 2-10: North Byron FRMS isolated houses

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

2.7.5 Mitigation Measures

2.7.5.1 Existing Mitigation Measures

A levee exists along the eastern and western section of Capricornia Canal protecting the community at South Golden Beach, shown in Figure 2-33, which was constructed in 1989, with pumps installed in 2006 to reduce flooding behind the levee. The levee crest is currently set at a level of 3.2mAHD designed to protect South Golden Beach properties from the 1% AEP flood event. If the levee fails, during a 1% AEP event, an additional 272 properties were modelled to be impacted by flooding.

Figure 2-33: South Golden Beach Levee Location

2.7.5.2 Management Options

The study categorizes flood management measures into three general categories: Flood modification measures, response modification measures and property modification measures. Several mitigation measures were analysed for their viability and recommended for more detailed assessment. This includes several mitigation options recommended by community, previously identified mitigation measures and other identified potential mitigation options. A summary of the options is provided in Table 2-11 and a spatial representation as in Figure 2-34, Figure 2-35, and Figure 2-36.

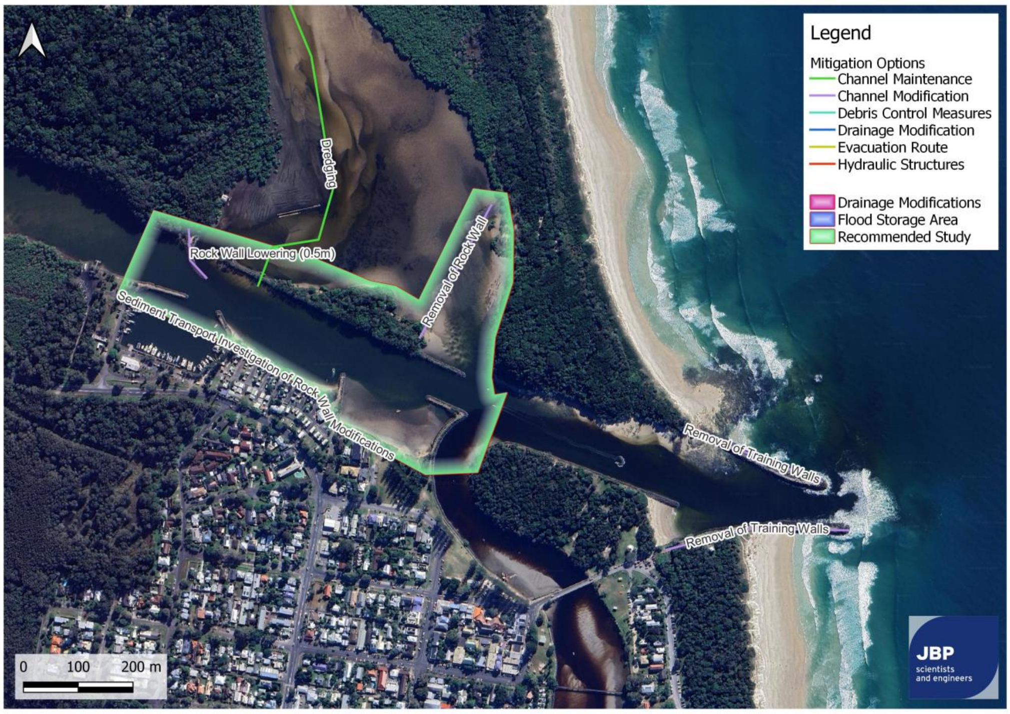

Figure 2-34: Mitigation Options at Brunswick River Opening

Figure 2-35: Mitigation Options at Billinudgel

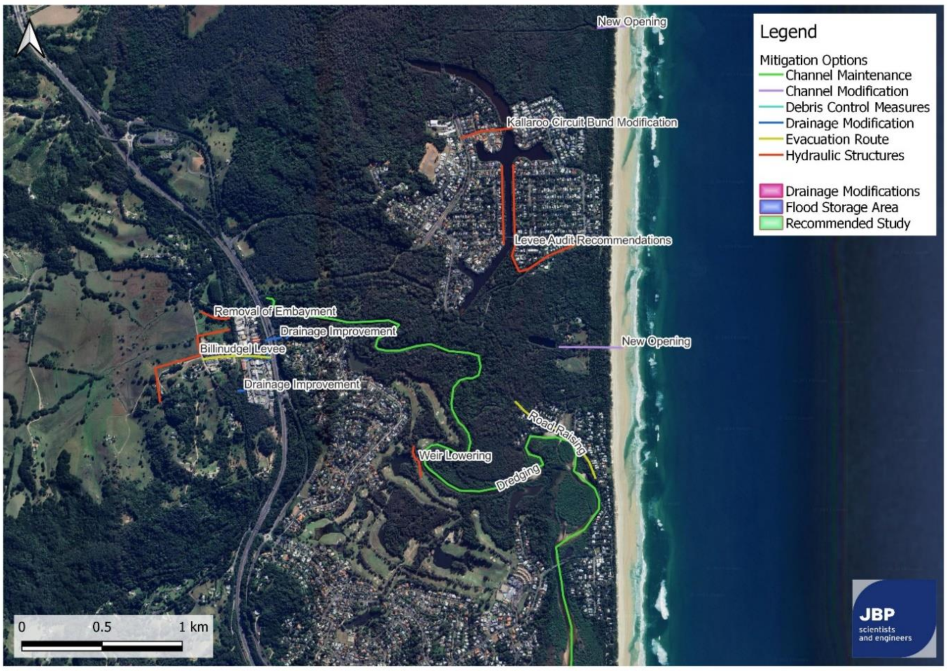

Figure 2-36: Mitigation Options at Northern Beaches

Table 2-11: North Byron Floodplain Risk Management Study potential mitigation measures

Category	Option	ID	Description	Recommended / Progress	Reasoning
Flood Modification Measures	Levee	BL	Billinudgel Levee	Yes	This option was investigated through modelling a levee 650m in length running from west to east along Gerald Street and O'Donnells Lane just south of Marshalls Creek. The levee level was set to 4.7mAHD (0.2-0.3m above 1% AEP peak flood level). The study claims a general reduction in flood levels of up to 0.38m, and existing increases are minor (~0.05m)
		SGBA	South Golden Beach Levee Audit Recommendations	Yes - Funding to be Sought	Several recommendations were made in the South Golden Beach Levee Audit
	Channel Modification	BP01	Kings Creek Bypass Floodway	No	This option was investigated through modelling an excavated 5m wide channel, 1m deeper than the existing Kings Creek, roughly 15,000m^3 of creek bed material. From considerable economic and environmental constraints and concerns for minor reduction of 0.08m in peak flood level this option was not recommended for further investigation.
		BP02	Saltwater Creek Upgrade	Yes - Part of Overland Flow Path Study	This option was investigated through modelling an excavated 5-10m wide channel, 1m deeper than the existing Kings Creek, roughly 20,000m^3 of creek bed material. This option also investigated increasing the capacity of the Jubilee and Myokum culverts for this scenario by lowering the invert level by 1m. While limited flood mitigation benefit was observed from modelling (0.05m lower peak flood level) other modifications options within Saltwater Creek were believed to have the potential for more significant benefits
		DO	Dune Openings	No	This option was investigated through modelling of four additional ocean outlets 20m wide by lowering the dune crest to the adjacent levels at each side of the dune (approximately 1.5mAHD), at Wooyung, North of South Golden Beach, South Golden Beach/New Brighton and South New Brighton. While widespread benefits were observed for catchment dominated events, the benefit was only minor (0.05 - 0.1m peak flood level reduction). It is believed that this mitigation option would result in different Ocean flooding behaviour and have several environmental considerations. From these findings this option is not recommended to be considered further.
		RW	Rock Wall Modifications	No	This option was investigated through modelling the lowering of the Western Brunswick River rock wall by 0.5m and the Marshalls Creek rock wall removal, and while the rock wall modifications were not recommended as a flood mitigation strategy, as the rock walls are significantly submerged in the 1% event, it was recommended that they be investigated for the potential to improve sediment transport
		TW	Removal of Brunswick River Training Wall	No	This option was investigated through modelling the removal of the training walls to the bed level. The resulting decrease in flood levels was observed to be minor (up to 0.1m at Brunswick Heads) but widespread, with the significance diminishing further upstream.
	Channel Maintenance	BRM01	Brunswick River Dredging at Mullumbimby	No	This option was investigated through modelling dredging a 3km stretch of Brunswick River at Mullumbimby by 0.5m depth across 20-30m width. This resulted in minor (0.05m) reduction in peak flood levels at Mullumbimby from this minor impact and significant economic considerations this option is not recommended to be considered further.
		BRM02	Brunswick River and Tributaries	No	This option was investigated through modelling an extended version of BRM01, extending into Mullumbimby and Saltwater Creeks. Results indicated a maximum decrease in flood levels of 0.12m at the Mullumbimby Community Garden an minor (0.05m) reduction in peak flood levels. From the limited impact on flood behaviour and considerable economic and environmental impacts this option is not recommended to be considered further,

Category	Option	ID	Description	Recommended / Progress	Reasoning
		MC	Marshalls Creek Dredging at Ocean Shores	No	This option was investigated through modelling the dredging of a 7.5km stretch of Marshalls Creek to lower the riverbed by 0.5m at widths of between 10m-30m. Modelling results indicated minor (0.05m) reduction in peak flood levels were observed at Ocean Shores and New Brighton. Due to this limited reduction in peak flood levels this option is not recommended to be considered further.
	Drainage Modification	AC	Avocado Court	Yes - Part of Overland Flow Study	This option was investigated through DRAINS modelling of a formal flow path from the residential development along the Yoga Bera Gully pipeline to the Chinbible Avenue swale, as a 1m wide channel with a 0.5% slope. While modelling results of the 1% AEP event indicated low reduction of flood level (0.04m) it is believed other options could have the potential to reduce peak flood levels more significantly.
		NCD	Options identified in New City Road drainage assessment	Yes - Part of Overland Flow Study	The New City Road drainage assessment recommended several drainage modifications this was later considered to be a low priority mitigation measure
		CDM	Catchment wide drainage and overland flow model	Yes - Grant Submitted	Considerable community concern of effective drainage in the area has led to the recommendation to assess the Catchment wide drainage and overland flow.
	Drainage Maintenance	FDC	Debris Control Measures for Federation bridge and the Billinudgel Railway Bridge	Yes - Grant for design phase	While modelling results of 25% blockage sensitivity resulted in a minor increase on the peak flood levels (0.05m) substantial community concerns of maintenance and drainage led to the recommendation for further consideration
	Hydraulic Structures	GCW	Ocean Shores Golf Course Weir Lowering	No	This option was investigated by modelling a 1m lowering of the Gold Course Weir at Ocean Shores. Model results indicate negligible impact to peak flood levels (Up to a 0.01m reduction). From the negligible results it was not recommended to be considered further.
		BM	Billinudgel Infrastructure Improvements	Yes - Part of Overland Flow Study	This option was investigated by modelling of several drainage modifications for Billinudgel. Significant culvert capacity was added, and the 5m widening of the railway bridge north of Billinudgel. This was recommended for consideration in conjunction with Option BL, as minor reductions of peak water levels are observed in preliminary results for independent modelling (maximum of 0.22m at Wilfred Street), however it is believed that optimisation with the BL could result in more significant reduction in peak water levels.
	Flood Storage Areas	SW	Saltwater Creek Flood Storage Area	No	The current area adjacent to the railway line identified as a potential flood storage area is at approximately 3mAHD on the northern side of the wetland and 2-2.5mAHD on the southern side. The ground level was reduced to 2mAHD to investigate this option for flood mitigation. Results indicate minor reductions in flood level, however it may warrant further investigation as part of the Lot 22 assessment for water quality and storm water management
	Combined Option	CB01	Marshalls Creek Dredging (MC), Dune Openings (OO), Rock wall modification (RW) and Kallaroo Circuit Bund modification	No	These options were investigated by simultaneous modelling of previous options, MC, OO, RW and a lowering of the culvert at the Kallaroo Circuit bund to -0.025mAHD. Results indicate reductions in the peak flood levels are largely in areas with very few properties, however a reduction of 0.15m was observed in South Golden Beach, 0.06m at Ocean Shores, up to 0.08m in New Brighton, and 0.04m in Brunswick Heads.
		CB02	Billinudgel Infrastructure (BM) and Billinudgel Levee (BL)	No	These options were investigated by simultaneous modelling of previous options BM and BL. The combination of these options resulted in protection of properties behind the levee with a reduction of flood levels for the 1% AEP flood event up to approximately 0.5m. Some areas observed minor water level increases ranging from 0.02 to 0.05m. However detailed assessment estimated a resulting benefit cost ratio of 0.58.

Category	Option	ID	Description	Recommended / Progress	Reasoning
	Fencing across waterways	WFG	Develop guidance on the design and installation of fencing traversing waterways and channels	Yes	Fencing in agricultural areas are known to having the potential to obstruct flow. While no modelling was undertaken to investigate floodplain sensitivity fencing blockages. Ensuring fencing is designed to not obstruct flood flow will generally improve the conveyance of the system.
Response Modification Options	Emergency Planning	RM01	Update Local Flood Plan based on outcomes of this report and collaboration between Council and the SES	Yes - Underway by SES	It is recommended to update the flood management plan with the findings of the study
	Flood Warning	RM02	Byron Shire Council and SES to consider learnings and recommendations from this FRMS in the development of the Flood Warning Network for North Byron	Yes - Complete	The development of a flood warning network system was recommended.
	Improving road access	RM03	Raising River Street to provide 1% AEP flood immunity and investigating a location for a new Evacuation Centre near Gaggin Street or Terrace Street	Yes - Part of Overland Flow Study	While this flood risk measure increases the peak flood level by up to 0.2m in New Brighton, there is a substantial risk to life for the properties trapped in the vicinity of Casons Road and River Street, with 13 properties experiencing above floor flooding with River Street being the only evacuation route available.
		RM04	Raising Wilfred Street to provide 1%AEP flood immunity	No	While it is not recommended as a standalone measure, if included in conjunction with other flood mitigation options in the area it could be considered for re-assessment
	Road Closures	RM05	Identify key roads and implement automatic warning signs and depth indicators	Yes - Grant being Investigated	The investigation recommended the inclusion of automatic warning signs and depth indicators for Pocket Road, Sherry's Bridge on Main Arm Road, Myocum Road, Coolamon Scenic Drive, Wilsons Creek Road, Gulgan Road, and Left Bank Road
	Community Education and Awareness	RM06	Community engagement to prepare an ongoing flood education program (and appropriate evaluation system)	Yes - Funding to be sought	Several recommendations for raising community awareness and education were suggested, such as historical flood markers, online flood awareness mapping (Now available), community action team group, letter/certificate/pamphlet from Council, information packs for new residents, school project, media releases, library displays, mobile displays, distribution of NSW SES FloodSafe Guide, NSW SES Business FloodSafe Breakfast, Council stall events, flood information signage at key locations, targeted evacuation planning education, South Golden Beach local drainage education.
	Mullumbimby Evacuation Assessment	RM07	Undertake a detailed evacuation assessment for the Mullumbimby township for a range of design events.	Yes - Underway by SES	Mullumbimby was identified as being particularly vulnerable to flood risk, and that evacuation was identified as a major concern. Development of an evacuation management plan for a range of design events was recommended.
Property Modification Options	Voluntary House Raising	PM01	Assess raising eligible residential properties to reduce flood damages.	Yes - Grant submitted	A well-defined criteria that identifies eligible properties is believed to satisfy grant funding, available from the NSW Flood Program, which makes house raising a viable program to reduce flood damages in North Byron.
	Voluntary House Purchase	PM02	Assesses purchasing eligible residential properties to remove residents from high flood risk areas and reduce floodway obstruction.	Yes - Grant Submitted	Similarly, to PM01, a buy back schemes is believed that to be a viable program to reduce flood risk in North Byron, with developing appropriate criteria identify eligible properties that are susceptible to flood risk.

Category	Option	ID	Description	Recommended / Progress	Reasoning
	Land Use Zoning	PM03	Changes to land use zoning should consider flood compatibility using outcomes from this report. Update flood hazard overlay based on the findings of this study	Yes - Complete	Flood hazard is a principal factor for planning land use zoning. It is recommended to update flood hazard overlay to reduce future development in high hazard areas.
	Flood Planning Levels	PM04	Revise Flood Planning Levels based on the findings of this study	Yes - Complete	The Byron Shire Council use several design event flood levels to define flood planning levels including, Present day 10%, 1%, and the 2050 and 2100 1% AEP peak flood levels. It is recommended to use the latest study's findings for flood levels to update the flood planning levels for more representative flood planning levels.
	Flood Planning Area	PM05	Updated FPA based on the findings of this study	Yes - Complete	The Flood planning areas are used to identify land prone to flooding. This study recommends defining the flood planning areas with conservative estimations of the 1% AEP event with 0.9m sea level rise, 20% increased rainfall and 500mm freeboard as defined from this study, this is recommended to increase understanding of flood prone areas, to help reduce development and increase mitigation strategies in these areas.
	Changes to Development Control Plan	PM06	DCP updated based on recommendations of this FRMS	Yes - Partially Complete	A review of the existing Byron Shire Council DCP (2014) by the study, identified some suggestions where further refinement may support the objectives of the intention of a DCP and the useability of the document by applicants.
	Flood Proofing	PM07	Provide more detailed guidance on the principles of wet proofing appropriate designs and materials with direct reference to available guidelines	Yes - Partially Complete	The purpose of flood proofing is to provide a permanent measure, which can be either wet proofing, to minimize damages from choice of materials or other measures or dry proofing, to exclude flood waters entering the building. Flood proofing is recommended for future investigation to reduce flood damages to the area.
	Property Level Protection	PM08	Undertake more detailed assessment of properties which may benefit from property level protection	Yes - Partially Complete	It is believed to be an alternative to retrofitting permanent flood proofing measures to existing properties, property level protection including temporary flood barriers like sandbags, plastic sheeting and other smaller barriers deployed before the onset of flooding could be considered as an effective, non-invasive flood damage control measure.
	S10.7 Certificates	PM09	Provide flooding info on Council's website, include up to date flooding info on future s10.7 (2) and (5) certificates requested	Yes - Complete	Several suggests have been made to improve flooding information available on the Council Website, it is believed that this could increase the understanding of flood risk for home and business owners in the region.
	Future Development Controls	PM10	Further investigation into appropriate controls to manage impacts from future development	Yes	It is believed that enforcing restrictions on future development effectively ensures the community's continuing flood resilience.

A multicriteria assessment was undertaken to rank the mitigation options for North Byron, with the results of this assessment provided in Table 2-12:

Table 2-12: North Byron FRMS (WMA, 2020) Ranked Priority Flood Mitigation Options

ID	Option	Total Score	Overall Rank
PM04	Flood Planning Levels revised based on the recommendations of the FRMS	20	1
PM09	Section 10.7 (5) certificates to provide further detail of flood behaviour. Consideration to providing property-level flood information via an online GIS platform	18	2
RM02	Byron Shire Council and SES to consider the findings and recommendations of the FRMS in the development of the Flood Warning Network for North Byron	18	2
RM05	Identify key roads and implement automatic warning signs and depth indicators	16	4
PM07, PM07, PM08 (part), PM10	Council to consider updating the DCP to incorporate the recommendations detailed in the FRMS; Provide more detailed guidance on the principles of wet proofing, appropriate designs and materials, with direct reference to available guidelines; include a requirement for an assessment to property level protection as part of the DCP2014 planning matrix criteria FL4; Implement the recommendations regarding appropriate fill areas in the DCP2014	16	4
CDM	Development of a whole of catchment drainage model and overland flow path investigation	16	4
PM08 (part)	Undertake more detailed assessment of properties which may benefit from property level protection	16	4
FDC	Implement debris control measures for Federation Bridge and Billinudgel Railway Bridge.	16	4
RM07	Undertake an Evacuation Assessment for Mullumbimby	16	4
PM03	Changes to land use zoning should consider flood compatibility based on the recommendations of the FRMS	16	4
PM01	Further investigate the raising eligibility of residential properties to reduce flood damages	15	11
SC	Further detailed assessments of Saltwater Creek mitigation options for Mullumbimby	15	11

ID	Option	Total Score	Overall Rank
IC	Form a committee, comprising council, state, emergency services and community member representatives to oversee the implementation of the FRMP	15	11
RM01	Council and the SES to update the Local Flood Plan based on findings of the FRMS	15	11
PM05	Revise the Flood Planning Area based on the recommendations of the FRMS	14	15
RM06	Engage with the community to prepare an ongoing flood education program with appropriate evaluation by Council and SES following implementation	14	15
AC	Further consideration of Avocado Court drainage modification	14	15
PM11	Byron Shire Council compliance team investigate illegal builds south of North Heads Road	14	15
RW02	Develop a sediment transport model to investigate modification to the rock walls as part of the Coastal Management Program for the Brunswick Estuary	14	15
BM	Further consideration of Billinudgel infrastructure improvements	13	20
WFG	Develop guidance on the design and installation of fencing traversing waterways and channels	13	20
PM02	Consider establishing a Voluntary House Purchase scheme for eligible properties	13	20
RM03	More detailed assessment of potential raising of River Street to provide improved flood immunity and evacuation	11	23
SGBA	Implement the recommendations of the South Golden Beach levee audit	7	24
NCD	Further consider viable options to implement the recommendations of the New City Road drainage assessment	4	25

2.7.5.3 Community Engagement

The community engagement resulted in the community ranking several structural mitigation options. The top three structural mitigation options identified by the community were:

- Stormwater Pipes gutters and drain upgrades.
- Landscape management
- Dredging

Several other mitigation options were proposed by the community including:

- Significant concern over drain blockages
- Respondents are generally supportive of alterations to the Marshalls Creek rock walls provided appropriate investigation is carried out prior.
- There is significant support for the consideration of openings through the dunes.
- Several respondents reported neighbours helping in past flood events.
- The community trust local knowledge and would look to key community members during events.
- Respondents are concerned about increasing insurance prices in the area.
- 12% of respondents would never evacuate their home.
- 63% of respondents have received conflicting information during an event in the past, with several comments from people who did not receive any information at all.
- 54% of respondents want flood information as early as possible and 81% of respondents would like this information via emergency SMS. Several comments requested accurate and timely information during a flood event.
- In addition to assistance during flood events, respondents have indicated they require the assistance to continue after the flood even has passed.
- Respondents want to see appropriate development within the floodplain there were a little under 50 comments relating to land use planning decision, with several comments specifically about the potential development of Lot 22.

This study included community consultation on Draft FRMS which resulted in several responses, priority concerns of the community were as follows:

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

Following this study, Byron Shire Council has subsequently undertaken works to improve local drainage including drainage upgrades and maintenance.

2.7.6 Other Findings

2.7.6.1 Update to ARR2019

An assessment of sensitivity to ARR2019 methodology was undertaken for the study. It considered several significant changes in industry best practice of ARR2019 in comparison to guidelines from ARR87. The study considered that a full update in accordance with ARR2019 would not greatly assist in understanding flood risk in the catchment, however the report indicates that updates were made, but it is unclear in the report which ARR2019 methodologies were adopted over the developed ARR87 methodologies, other than an update of initial and continuing losses. IFD comparisons were undertaken for the 2016 IFDs, which indicated that the ARR87 estimations were observed to be higher and could be considered a conservative approach, but with the available reporting, which was Appendix C of the report, it is unclear whether the 2016 IFDS were adopted.

2.7.6.2 Legacy Model

Several modelling methodologies used for the development of the Hydrodynamic and Hydrologic model have become dated or inefficient, with usage of 1D river networks, no sub grid sampling, bridges not modelled as layered flow constrictions and no quadtree. Significance of effect to model results, and definition of flood planning levels was not undertaken as a part of this study.

2.7.6.3 Sandbag Blockages underneath railway line opposite Mill Street

Community comments were received that sandbags were placed in culverts underneath the railway line opposite Mill Street. This study modelled the hydraulic structure blockage sensitivity, however the 1% AEP scenario modelling indicated practically no impact for the 50% blocked scenario and impacts were restricted to a property when 100% blocked scenario.

2.7.6.4 Flow Constriction Hotspots

On review of the model results identification of major flow constrictions, causing increased water levels, were observed at several areas including areas at Billinudgel, Orana Bridge, and the junction of Marshalls Creek and Brunswick River.

The modelling indicated that there is a significant constriction at Billinudgel shown in Figure 2-37, where several hydraulic structures are observed to impede flow conveyance. The principle hydraulic structure observed in the modelling results is the railway embankment and bridge, where a greater than 1m head loss is observed across the railway embankment North of Mullumbimby. This is a resultant of the railway embankment being approximately 3m higher than the surrounding ground level. Several modelling methodologies were adopted to represent hydraulic controls at Billinudgel, which could misrepresent flood behaviour, if not representative of real-world conditions. A summary of hydraulic controls at Billinudgel are provided in Table 2-13.

An additional constriction is located downstream at Orana Bridge is observed where a layered flow constriction is modelled with a pier blockage of 4.1 and a form loss coefficient of 0.07, which is standard losses for a typical bridge of this sizing, however the invert level of the deck is modelled at 2.218mAHD with a deck depth of 1.575m, it is believed this is a conservative estimate for the bridge deck invert, which significantly blocks the creek conveyance capacity by 40%.

Table 2-13: North Byron FRMS&P Hydraulic Controls at Billinudgel

Location	Method	Description	Blockage
Rail Embankment	Raised Crest Line	Heights Vary from 4.085 - 4.82 from North of Pacific Highway gully drainage at Billinudgel to Billinudgel	
Gully rail embankment cross drainage, 220m North of Marshall Creek	One-dimensional rectangular culvert	One 2x2m pipe with (US Invert Level higher than elevation data)	50%
Railway Bridge at Billinudgel/Marshalls Creek	One-dimensional form loss and increased Mannings Roughness, along with a one-dimensional Weir	The Weir is set to 3.801mAHD with 20m width, and the bridge is modelled with a Mannings 'n' roughness of 1.00, and a form loss coefficient of 1.75. This modelling approach results in a 0.45m head loss. However, following this bridge several one-dimensional river sections are modelled with a Mannings 'n' roughness factor of 2.677, Which results in a further head loss of 0.5m where channel storage is not used, and half the section leading up to the Pacific Motorway has a form loss coefficient of 0.4.	0%

Road Embankments at Billinudgel	Raised Crest Lines	Several road embankments were used to represent the road levels at Billinudgel. Several roads were raised including Wilfred Street, Mogo Place, Lucky Lane and Bonanza Drive at varying heights typically between 3.2mAHD and 3.8mAHD, except for western Wilfred Street lowering to 2.0mAHD. Additionally, a smaller raised embankment was observed at a subsection of O'Donnells Lane continuing from Wilfred Street at 2.0mAHD to 9.39mAHD. These road embankments were identified to only cause conveyance issues along Wilfred Street, draining East, across the Pacific Motorway.	

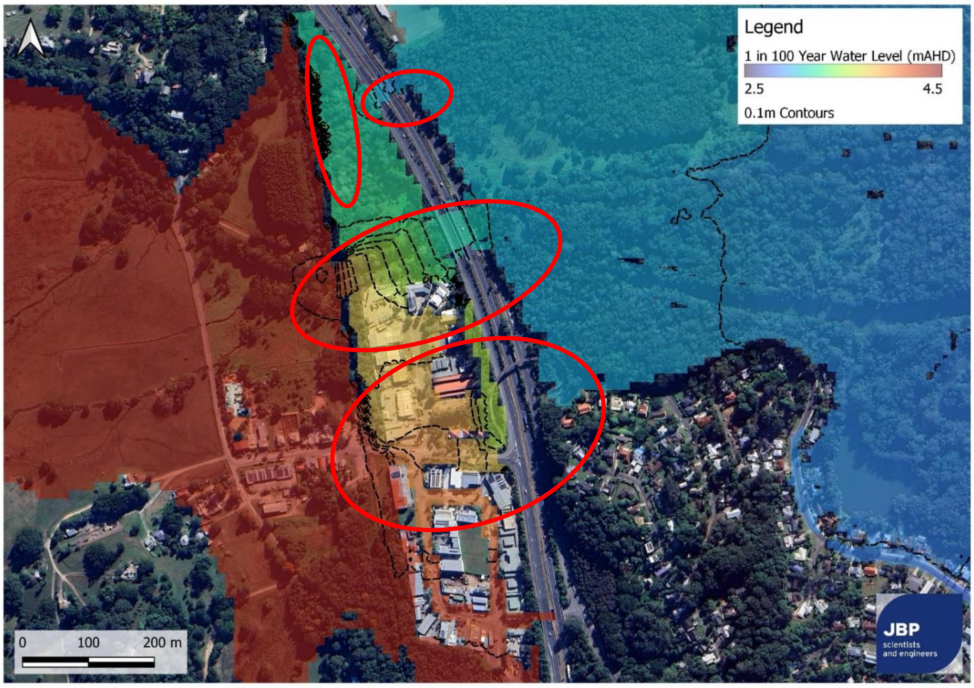

Figure 2-37: North Byron FRMS&P Flood Behaviour at Billinudgel

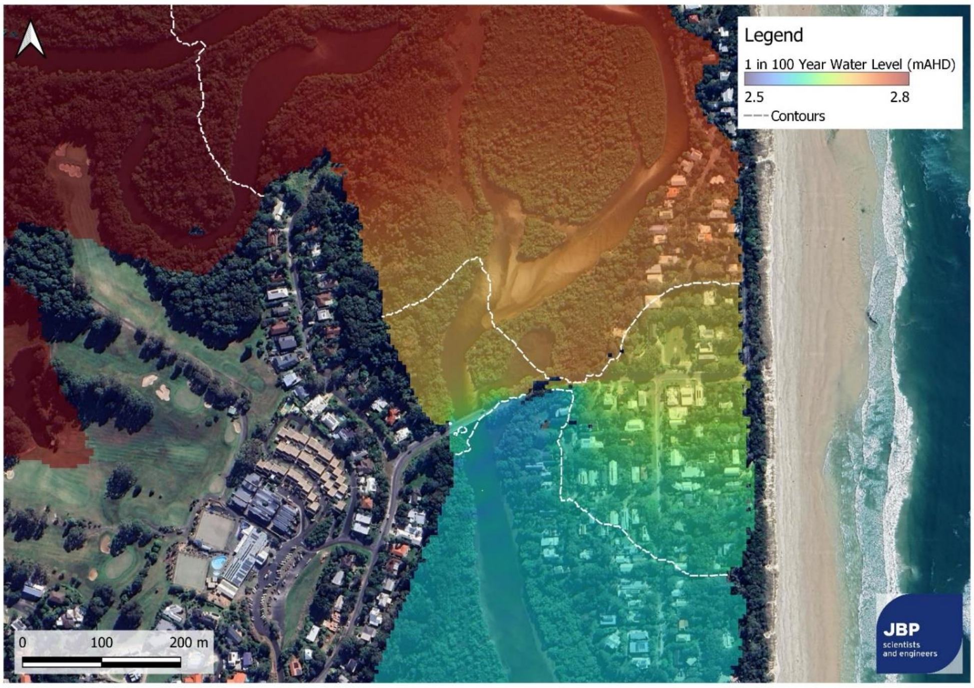

Figure 2-38: North Byron FRMS&P Flood Behaviour at New Brighton

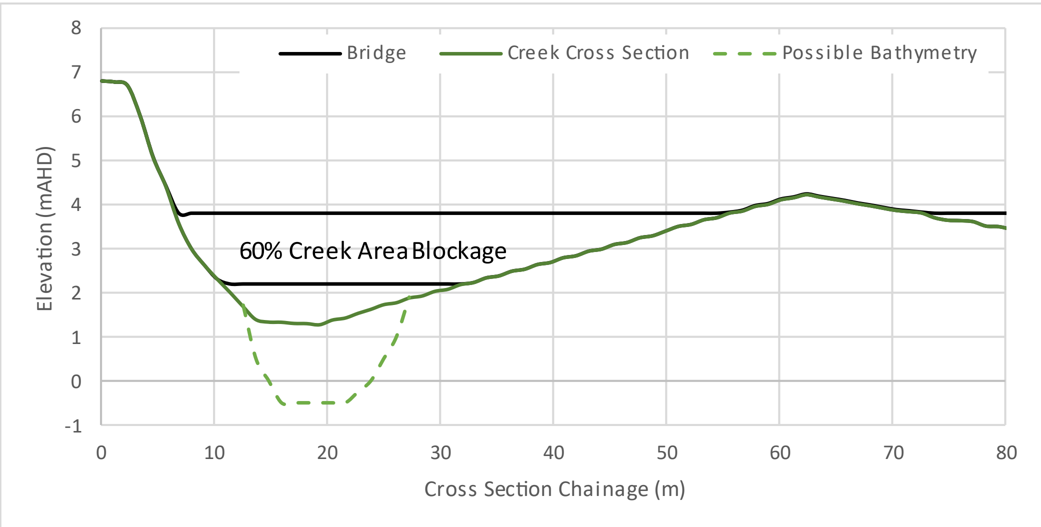

Figure 2-39: North Byron FRMS&P Modelled Bridge Structure Deck

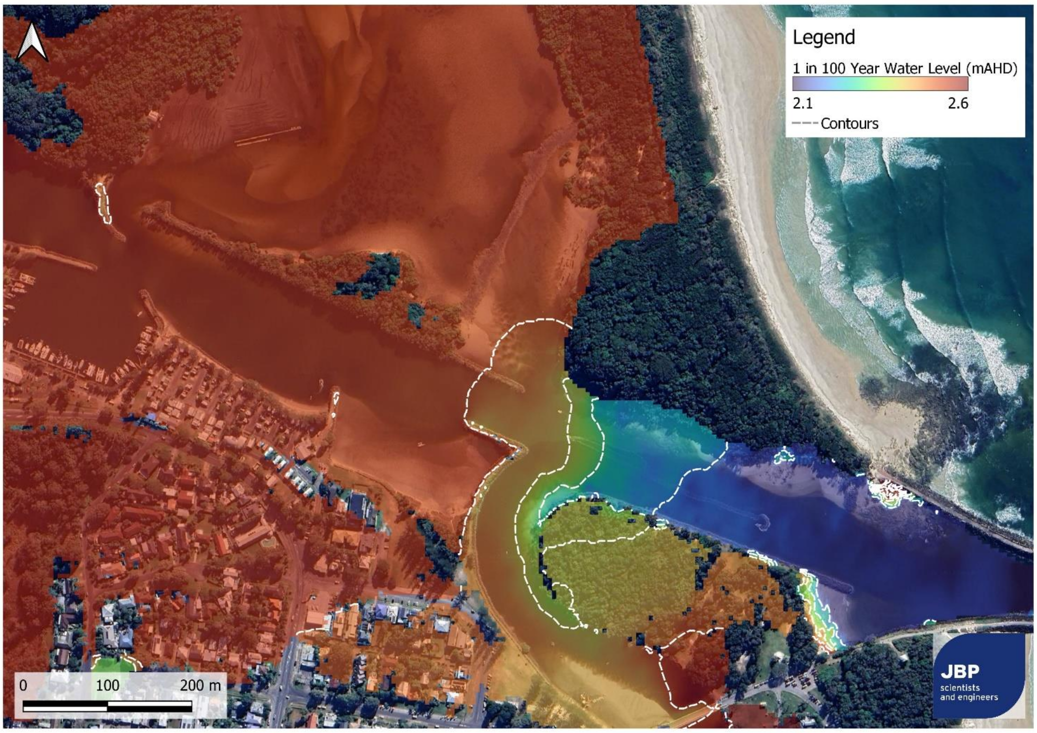

Figure 2-40: North Byron FRMS&P Flood Behaviour at Brunswick Heads

2.8 Post Flood Discussion With South Golden Beach Community Members West of Capricornia Canal (BSC, 2022)

A Post-Flood discussion with South Golden Beach Community Members was undertaken to investigate and flooding concerns and comments from community. In total nine concerns were raised for the region including:

- Overland flow from catchment to the west (Palmer Avenue)
- Backyard Easements Project Revitalization
- Flap Gate Maintenance
- An additional flood pump serving the area West of Capriconia Canal under Elizabeth Street and a flood lifter pump stationed on the Council land opposite Gloria Street
- Collapsed Stormwater Inlet on Shara Boulevard near Palmer Avenue.
- Sewage Pump Failure near #13 Elizabeth Street during heavy rainfall
- Long Term stagnant water on the corner of Elizabeth and Clifford Street.
- Streets as overland flow paths for stormwater

- And two area-wide issues - Drainage from Palmer Avenue and backwater from Marshalls Creek

2.9 MAYDAY Community Flood Debrief and Disaster Preparedness Event Report (2022)

The MAYDAY flood debrief was undertaken to involve the community into collating experiences and proposal of possible solutions. A large portion of solutions proposed targeted response modifications. The list of issues and suggested solutions raised by the community is presented in Table 2-14.

Table 2-14: MAYDAY Community Suggested Solutions

Key Area	Issue	Freq.	Suggested Solutions
Community Hub	Need for community led resilience network	3	- Develop the Community Resilience network throughout SGB, NB, OS - via street and neighbourhood areas and also maintain the CRT 'Key Area Working Groups' - Volunteer training and incentive program (including CRT, Active Listening, trauma informed, volunteer ethics) - Improve communications of community disaster preparedness network through the following: • Facebook group (Adapt Flood Aftermath) • Posters in key locations • Echo • Newsletter • Email Database • New Brighton Market Announcements/stall Street focal points

	Who do we get support from?	1	- Geographic groups/focal points needed for times of trauma/disaster -Community Resilience Team - the CRT will be made up of the Team "Leaders" (Currently Bec and Bron), the key working groups (appoint a "leader" of each group) and the street/neighbourhood focal points/rep - Rescue boat (SES/Marine Rescue) to check on residents - Volunteer expenses reimbursed when stood up (e.g. SLSC, Marine Rescue) - Community liaison person linking to broader government/recovery hub support options - Powers delegated to resilience teams and clarity of roles, e.g. evacuation centres - Need for multiple evacuation centres due to inability of SGB/NOS and some NB to reach OSCC
	Need templates and systems based on organic way resilience mob	1	- Develop electronic and hard copy forms including: • Sensitive (vulnerable people) list - to check on • Spreadsheet of people needing support (Name, Address, contact, issues, needs, people allocated, comments) • List of tradespeople • Volunteer timetable • Daily log • Equipment Register
	No support from enterprise businesses, old systems forgotten/ignored	1	- Improved relationships, self-sufficiency - Make contact with OSCC and link to OSSDA - Understand what skills we have in our community - build the skills and knowledge matrix through the CRT network
Preparedness Plan	Crisis Management plan ineffective	5	- Active community plan - where to go, how to get there, immediate support

Key Area	Issue	Freq.	Suggested Solutions
	minimal visibility of it, minimal understanding of it Who do we listen to? What's the hierarchy of control / instruction / warnings? Who has what role after disasters? Need to confirm roles. Who does what? How to reach them? Not knowing how and when to leave. No community plan.		options, understanding vulnerable people - Need to confirm roles - Planning so that community awareness is developed ahead of time - Need to prioritise actions - Personal plan (Radio/cash/toilet paper/canned foods/When to leave/Switching power off) - Forum to support and assist individuals in making personal emergency plans Register of each street with a focal point who knows who the vulnerable people are - Holiday letting action plan (Holiday houses let by real estates, Stayz, AirBNB) provided localised info packs to keep at the property for guests to understand evacuation and preparedness procedures. - Protect the house beforehand (sandbag sourcing, council support, information flow, what is needed) - Kayaks available and in place - Community Resilience Team 'Newbie pack' for new residents to understand disaster preparedness in the local area.
	Evacuation centre coordination (who's in charge? Who's coordinating Resources)	1	- SES evacuation points predetermined and known - Getting community up to date on an evacuation plan
	People hoarding scarce resources, no incoming supplies (Food/Fuel)	1	- Community based preparedness resources (Shipping container with resourced (at the school/church?) with procedures and how-to info - Personal plan (e.g. radio/cash/toilet paper/canned foods and knowing when to leave)

Key Area	Issue	Freq.	Suggested Solutions
Governance	Role and function of Council (obligations)	1	- Duty of care for residents/rate payers - Compassionate responses from Byron Shire Council and other flood services when residents present with concerns - Town planners and water management people should get ideas from residents - Stop particular communities gaining help first and needy groups being forgotten - Waste management post flood (hazardous waste; salvage and repair)
	Lack of response from government services / emergency services capacity	3	- Improve emergency services capacity - Powers given to people of the ground to act in the minute > single department, full autonomy (decentralisation of power)
	Development decisions	1	- Development moratorium for flood prone areas - Review of "1 in 100 year" terminology as it relates to planning requirements (e.g. building heights, ban new slab on ground builds in floodplain, ban inappropriate fill on floodplain e.g. 1 Kallaroo Cct) - Stop removing vegetation and building on top of the watersheds - DA team capacity (upskill understanding good passive and resilient design) and timeframes need improving
	SGB/NB/OS not considered priorities in Byron Shire - lack of response from council, authorities,	1	- Remediation protocols and communication (post flooding) - Improve relationship with ECHO to ensure greater coverage post flooding) - Councillors to engage across different

Key Area	Issue	Freq.	Suggested Solutions
	media coverage		community organisation and volunteer hubs to be holistic issues and context of area - Council disaster staff worked with volunteer hub during recovery - continue relationship with them and other relevant staff - Engage Councillors proactively in community events.
	Lack of master plan for SGB/NB/OS	1	-Advocacy required
Communications	SES SMS Alerts - How to receive? Not early enough, mixed messages	2	- Instruction to turn on radio - to hear alerts - Local community member on SES team - Build relationships with SES to agree better notice - Warning system with more nuanced messages, not repeated messages - Map information flows (Community members, SES, resilience network, etc.) so that the right information is shared in both directions
	Need for appropriate communication and warnings (Worried about "crying wolf" SMS.	1	- Local community member on SES team - Build relationships with SES to agree better notice - Community communication networks / Street focal points - Timely geographic pre-warning (during/post) - Communicate early; don't leave to too late to reach people (prioritise daylight) - Systematic door-to-door checks for preparedness (street focal points?)
	Localised	3	- Connecting the community - sign

Key Area	Issue	Freq.	Suggested Solutions
	communication back up (radio was only way)		boards to promote messages e.g. bad weather, signage directions to safety (see pics as example) - Short wave radios - UHF/VHF units (also mesh network) - UHF/CB radio - needs planning coordination) - Emergency Channel at a local level - Use community buildings to host infrastructure or become hub / meeting point
	Lack of communication due to mobile, NBN, power out (people with dire needs unable to call for emergency/medical help	6	Starlink/Sprint unit for emergencies - Provider co-op telcos - Mesh Wi-Fi network - Government grants to fund infrastructure needs - Exploration of Community Solar Project

2.10 Characterisation of the 2022 floods in the Northern Rivers region (CSIRO, 2022)

2.10.1 Overview

After the flood event at the end of February and beginning of March 2022, many catchments in the Northern Rivers region saw rainfall totals and water levels exceed historical records significantly in several parts of the region. The Northern Rivers region consists of several Local Government Areas including, Clarence Valley Council, Kyogle Council, Richmond Valley Council, Lismore City Council, Tweed Shire Council, Byron Shire Council, and Ballina Shire Council. This study identified that the daily rainfall totals experienced in the Brunswick basin was the highest on record and was subsequently investigated for greater understanding of the flood event. This study did not undertake any hydrological or hydrodynamic modelling as part of the investigation, as it solely investigated the real-world observed flood behaviour.

2.10.2 Previous Events

This study summarized several major historical events for the Northern Rivers Region. The events are summarized in

Table 2-15.

Table 2-15: List of Major flood events in the Northern Rivers region

Date	Event Maximum Daily Rainfall (mm/day)	Tropical Cyclone	Comment
February 1954	253	TC137	Reference flood for all basins. Often cited as the largest flood on record prior to the 2022 event
June 1967	109		Major Flood in the Clarence River
March 1974	243	Zoe	Major flood in the Clarence River, Richmond Basin including at Lismore and Tweed Basin
February 1976	202		Largest flood for most parts of the Clarence Basin and for the Wilsons River Upstream of Lismore. Significant flood in the Western part of the Richmond Basin. Major flood in Lismore.
March 1978	174		Major Flood in Lismore, Tweed and Brunswick Basin
April 1989	195		Major flood in the Clarence River, Lismore, and Tweed Basin
May 1996	129		Major flood in the Clarence River and Richmond River.
February 2001	314		Major flood in the Clarence River and Richmond basins including Kyogle and Lismore.
March 2001	92		Major flood on the Clarence
January 2008	130		Large flood affecting the Clarence and Richmond basins
May 2009	166		Major flood in the Clarence River and Richmond basins including at Lismore
January 2012	114		Large flood affecting the Brunswick and Tweed basins
January 2013	226	Oswald	Largest flood on record in the Lower Clarence
June 2016	246		Major flood in the Tweed Basin
April 2017	300	Debbie	Significant flood in the Richmond, Tweed and Brunswick basins. Major flood in Lismore.

Date	Event Maximum Daily Rainfall (mm/day)	Tropical Cyclone	Comment
			Levee overtopped.
February 2022	482		Largest flood on record for most parts of Richmond Tweed and Brunswick basins. Major flood in Grafton and along the Clarence River further downstream
April 2022	165		Major flood in Lismore. Levee overtopped

2.10.3 2022 Floods

This study investigated the conditions and flood behaviour of the Feb/Mar 2022 flood event. This included investigation of antecedent conditions, rainfall conditions, frequency analysis, and river levels and flows.

2.10.3.1 Antecedent conditions

Several indicators are used to assess antecedent conditions. This study undertook rainfall conditions, water level analysis and AWRA-L simulations. The month leading up to the Feb/Mar 2022 flood event, experienced wet climate conditions. AWRA-L simulations have several antecedent conditions for several events provided as a comparison in Figure 2-41, with the root zone soil moisture available in Figure 2-42.

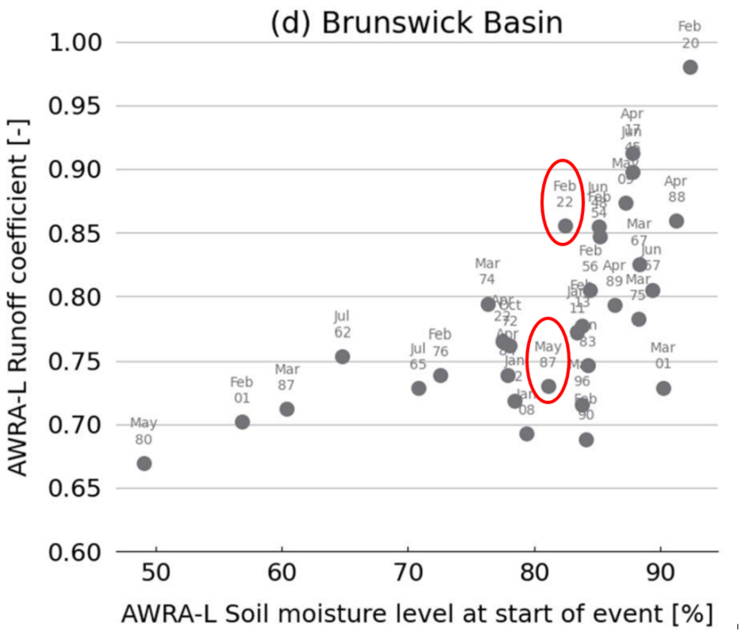

Figure 2-41: AWRA-L event antecedent conditions

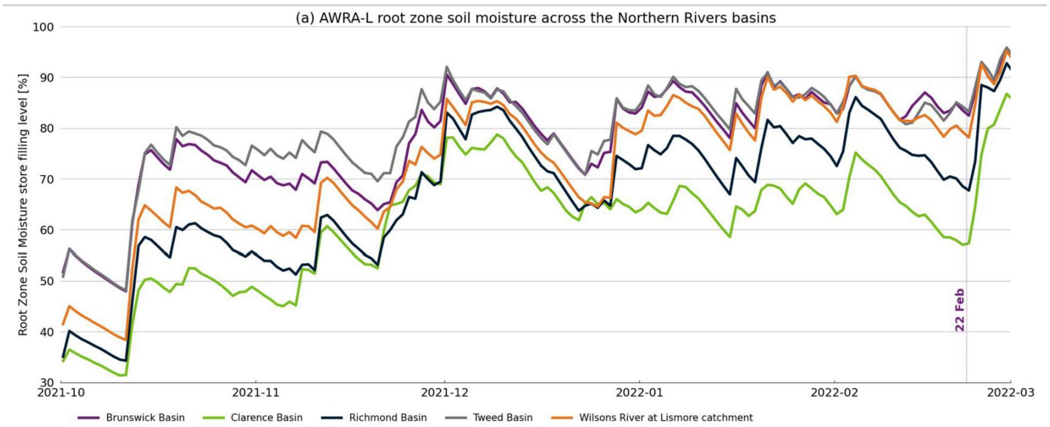

Figure 2-42: 2022 Event Root Zone Soil Moisture store filling level (%)

2.10.3.2 Rainfall Conditions and Frequency Analysis

The study undertook rainfall analysis using several gauges in the region, provided rainfall totals, daily rainfall maximums and date of daily rainfall maximums on record, in Figure 2-43 with associated Annual exceedance probability in Figure 2-44. While this is a good indicator for event size of larger catchments it is expected that the Brunswick River and Marshalls Creek experience shorter critical durations, than 24 hours from the sizing of the catchments. The rainfall gauge Brunswick River at Durrumbul (202001) provides rainfall data for the 2022 event, the gauge recorded a 24-Hour maximum of 696.5mm and a 72-Hour maximum of 1124.9mm, with the CSIRO study estimated these observed rainfall depths of having an equivalent frequency of a 0.1% AEP.

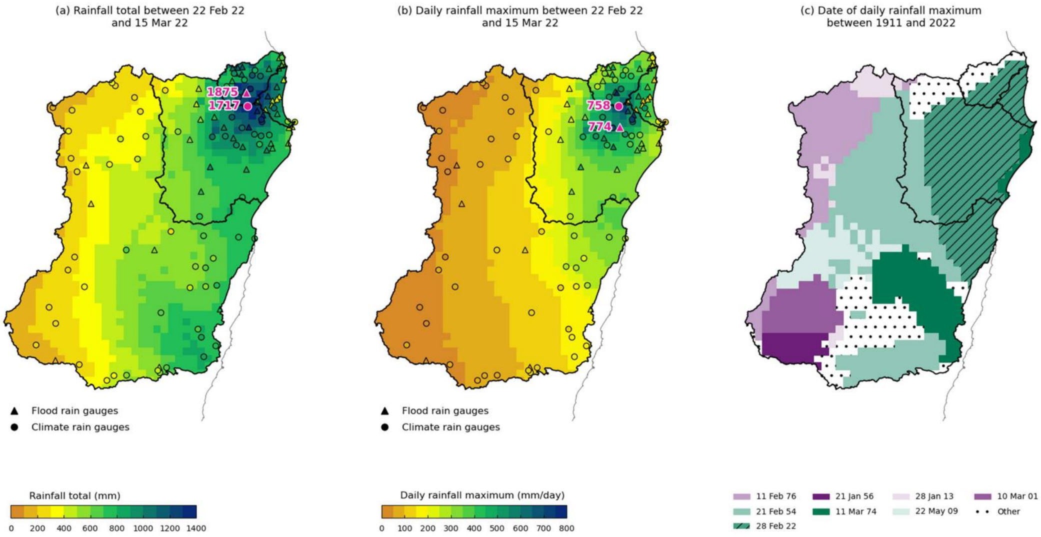

Figure 2-43: CSIRO 2022 Rainfall Analysis

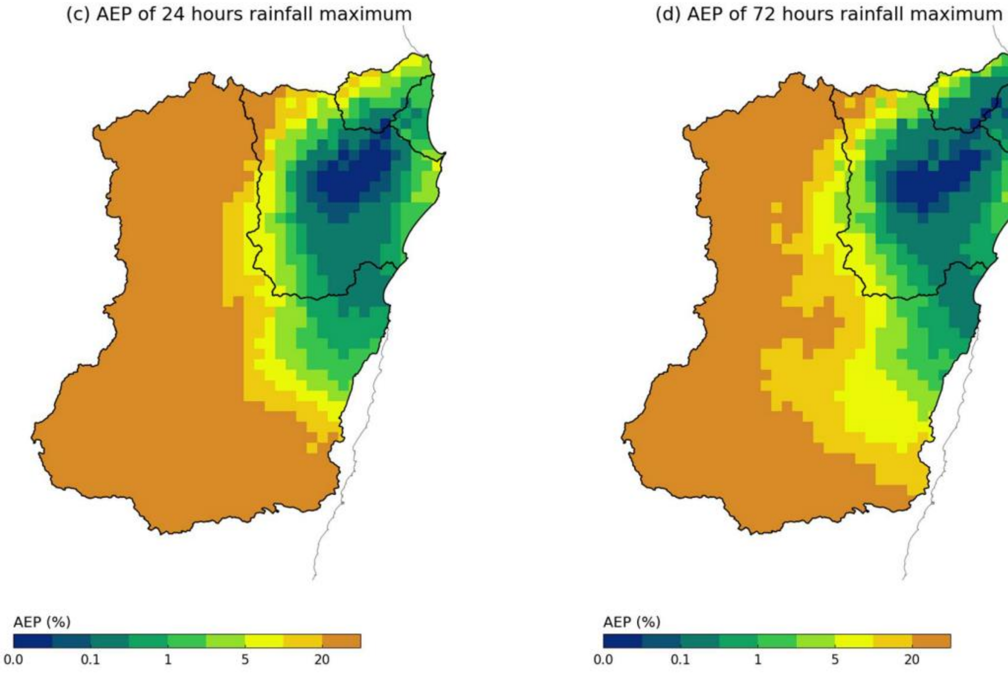

Figure 2-44: CSIRO 2022 flood event rainfall Annual Exceedance Probability

2.10.3.3 Water Level and Frequency Analysis

Three gauges were used for water level analysis for the Brunswick River basin, including Durrumbul (202001), Mullumbimby (202402), and Brunswick Heads (H558063). The levels for the flood event are provided in Figure 2-45. While the water level gauge at Mullumbimby recorded a period of water levels exceeding the defined "Major Flood Level", no information was collected for flood level indication for Marshalls Creek, or its tributaries. Further analysis was undertaken for water levels at Brunswick Heads, the provided historical data is presented in Figure 2-46, which was observed to exceed the historical maximum water level, well exceeding the 95th percentile.

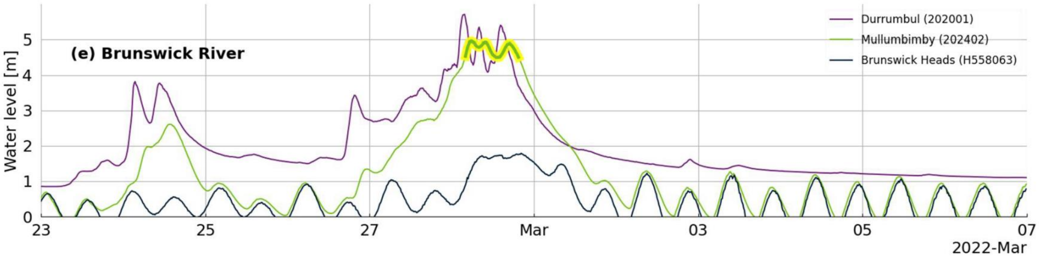

Figure 2-45: Water Levels for Brunswick River

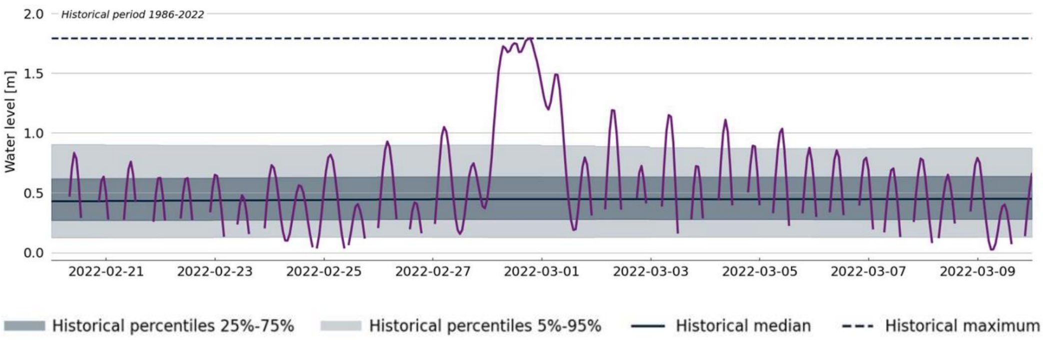

Figure 2-46: 2022 Water Levels against historic water levels at Brunswick Heads

2.11 Post 2022 Event Flood Behaviour Analysis - Brunswick River (WMAwater, 2024)

2.11.1 Overview

Following the 2022 flood event WMAwater undertook review of the resulting flood behaviour experienced in the Brunswick River Catchment. The objectives of the study included:

- Collecting sufficient flood debris information
- Conduct a rapid infrastructure damage assessment
- Model the 2022 Flood Event
    - Determine Magnitude of event
    - Describe flood behaviour
    - Extent of flooding
- Flood Damages Assessment

- Conclusions and Recommendations on the performance of the current modelling systems

2.11.2 2022 Flood Event

The flooding experienced on the 28th of February was widespread over the Brunswick River catchment, with significantly spatially varying observed rainfall with the peak water level observed to overtop the levee in South Golden Beach. Total tangible flood damages were estimated at $47,000,000 with 837 properties estimated to experience above flood flooding. Several resulting surveyed flood peaks presented in Table 2-16. The recorded flood levels in comparison with surveyed flood levels generally indicate a fair comparison, however a 0.5m difference was observed within South Golden Beach, with a recorded peak of 3.6mAHD and a modelled peak of 3.1mAHD, with a significant real-world difference of levee overtopping (3.2mAHD).

Table 2-16: 2022 Flood Event Peak Levels

Gauge	Recorded Peak Level (mAHD)	TUFLOW Modelled Peak Level (mAHD)	Difference (m)
Durrumbul	18.76	19.8	0.04
Federation Bridge	4.96	5.56	0.61
Yelgun Creek (Helen Street Bridge)	3.6	3.1	-0.5
Billinudgel	4.3	4.0	-0.3
Brunswick Heads	1.8	1.6	-0.2
Orana Bridge	2.8	2.6	-0.2

2.11.3 Modelling Methodology

The 2022 event was modelled from the developed hydrologic and hydrodynamic model as part of the North Byron FRMS&P (2020). While the hydrologic model was observed to over-attenuate flows a fair comparison was made for Brunswick River, however, some limitations of the modelling methodology were highlighted by this study such as:

- Over complication between hydraulic models at Ocean Shores, and South Golden beach. In these areas neither model performed well without feedback loops.
- Outdated hydrologic modelling methods such as adoption of ARR87, and XP-RAFTs.
- No accounting for hydraulic linkage of the Tweed Shire Coastal Creeks
- One-Dimensional approaches to riverine modelling

2.11.4 Rainfall Flood Frequency Analysis

This study undertook FFA of at site IFD comparisons and stream gauge FFA. The report claims that BoM 2016 IFD estimates may be under-estimating the rainfall in some locations for longer duration, less frequent events. Although not stated in the report this appears to be from the findings of empirical AMS comparisons to BoM IFDs. Rainfall FFA was undertaken by comparison to 2016 BoM IFDs for Yelgun Creek at Helen St Bridge (558112), estimating up to 1 in 20-year rainfall conditions up to the 100-Hour duration, however at several other locations in the Brunswick River catchment, it was observed to exceed the 0.2% AEP IFD estimations, indicating that BoM rainfall estimations are potentially underestimating some design rainfall durations.

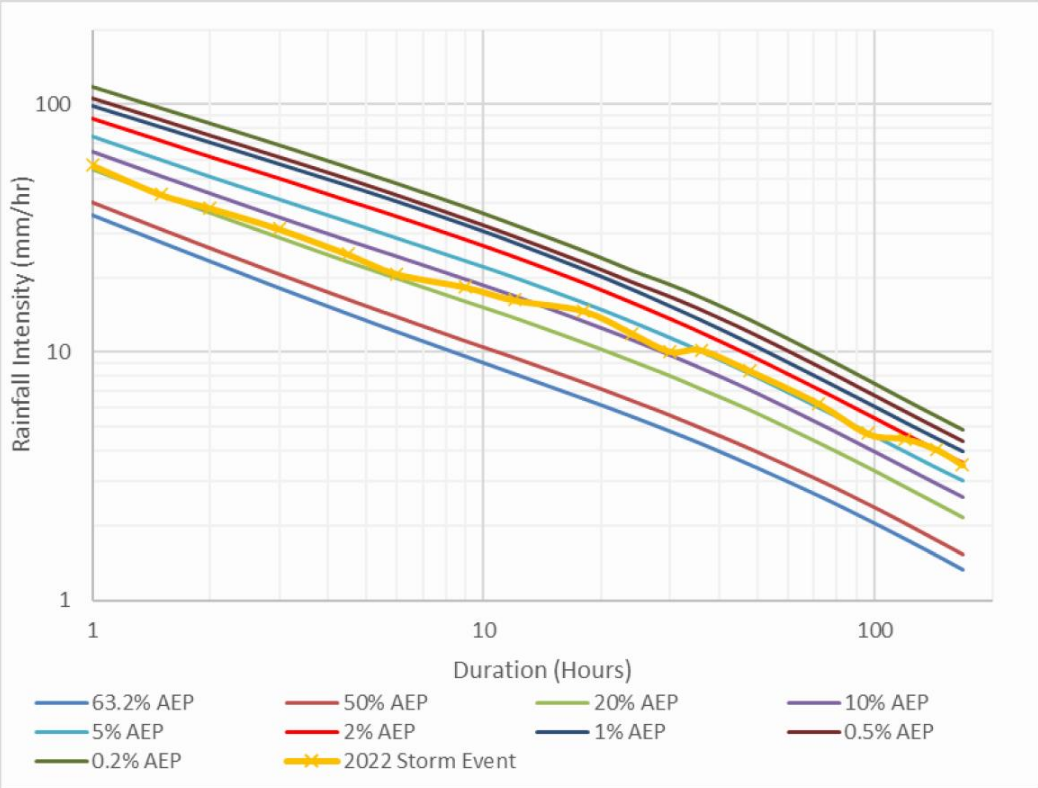

Figure 2-47: Yelgun Creek at Helen St Bridge (558112) - IFD Analysis

2.11.5 Stream Flood Frequency Analysis

From modelling undertaken as part of the study, several peak flows are compared are reported as in Table 2-17. While the 2022 event reports more frequent event than the 5% AEP at St Helen Bridge, all other location estimates range from 2% to 1% AEP. The levee at South Golden Beach was designed to withstand the 1% AEP peak water level, however the 2022 event was observed to overtop the levee, it is believed a localised storm could account for the discrepancy between the observed and model results, the study also identified limitations of the modelling methodology to represent the South Golden Beach, with the hydraulic model extending to the Kallaroo circuit bund.

Table 2-17: Comparison of Design Flows at Locations with 2022 Event Flows

Location	10% AEP	5% AEP	2% AEP	1% AEP	0.2% AEP	2022 Event
Brunswick Heads	911	1,193	1,441	1,782	2,000	1,797
Orana Bridge	249	328	393	472	560	423
St Helen Bridge	68	91	107	129	150	86
Billinudgel	163	215	259	312	370	358

2.12 North Byron Sky Pumps Study (JBPacific, 2024)

2.12.1 Overview

With previous studies finding limited benefit of flood mitigation options for Marshalls Creek, such as ocean outfalls, Rockwall removal and dredging, and residual community support for ocean outfalls, a need was identified to quantify the volume of floodwater extraction required for the following different levels of floodplain benefit:

- 1% AEP event peak water level reduction of 200mm
- 1% AEP event peak water level reduction of 400mm
- 1% AEP event peak water level reduction of 600mm

This resulted in the undertaking modelling of "Sky Pumps" as a flood mitigation option, where floodwater is extracted out of the system. While installing flood pumps were identified to likely be unrealistic for cost-benefits, this study was undertaken to identify flow rates required at the three locations, North of South Golden Beach, immediately South of South Golden Beach, and immediately North of New Brighton shown in Figure 2-48 to remove flood waters through ocean outfalls to achieve the same benefit.

Figure 2-48: Sky Pumps Configuration

2.12.2 Modelling Methodology

This study adopted the existing North Byron flood model developed by the North Byron Floodplain Risk Management Study and Plan (WMA 2020), with minor modifications. The existing model configuration extended up to the Kallaroo Circuit Bund Culverts, so the model domain was extended upstream so that the pump North of South Golden Beach could be modelled.

2.12.3 Sky Pump Extraction Volume Rates

From an iterative modelling process the following required pump operational rates were required. A summary of configuration flood behaviour is provided as below, and are presented in Figure 2-50, Figure 2-51, and Figure 2-52.

- 200mm
  The modelling results indicated that there would be widespread reductions to the North of South Golden Beach, upstream of Kallaroo Circuit Bund of 150-200mm, downstream of this location it appears to be impacted by backflow. The two pumps located immediately South of South Golden Beach and immediately North of New Brighton appear to have coincident effects of Marshalls Creek flood behaviour. Widespread reductions in peak water level of the range of 150-200mm were shown to extend the entire length of the Southern Levee at South Golden Beach and some of the Northern end of New Brighton. New Brighton, Ocean Shores and South Golden Beach were shown to have a reduction of peak water levels between 100-150mm. With minor reductions shown downstream of Ocean Shores, with the exception of Brunswick Heads Nature Reserve with a significant reduction of water overtopping of Tweed Street.
- 400mm
  Widespread reduction was shown to the North of South Golden Beach, upstream of Kallaroo Circuit Bund indicated a reduction of 380mm, downstream of this location was observed to have backflow dominated water levels. The two pumps located immediately South of South Golden Beach and immediately North of New Brighton are shown to result in peak level reductions immediately adjacent to the pump location, resulting in a reduction of peak water levels near 250mm at Ocean Shores, 150-300mm at New Brighton and 180mm within South Golden Beach. Minor reductions in peak water level were shown to occur at Brunswick River at Brunswick Heads of up to 80mm, with Brunswick Heads Nature Reserve benefiting with up to 180mm reduction in peak water level.
- 600mm
  Widespread reduction was observed North of South Golden Beach, upstream of Kallaroo Circuit Bund to 550mm, downstream of this location was shown to be impacted by backflowing water levels. The two pumps located immediately South of South Golden Beach and immediately North of New Brighton were shown to have immediate reduction in water level near to the pump location, resulting in a reduction of peak water levels of 300mm at Ocean Shores, 150-300mm at New Brighton and 220mm within South Golden Beach. Minor reductions in peak water level were shown at Brunswick River at Brunswick Heads of up to 80mm, with Brunswick Heads Nature Reserve benefiting with up to 180mm reduction in peak water level.

Table 2-18: Required Operational Pump Rates (Cumecs)

Pump operational below 1% AEP peak water level	Pump Immediately North of New Brighton	Pump Immediately South of South Golden Beach	Pump Immediately North of South Golden Beach
200mm	75	50	25
400mm	120	55	40
600mm	130	60	40

2.12.4 Conclusions

The modelling results indicated that widespread peak water level reductions for Ocean Shores, New Brighton, and South Golden Beach, with some alleviation on peak water levels for Brunswick Heads for each of the sky pumps scenarios. While the bath tubbing affect observed in Marshalls Creek is not eliminated, it is believed that the reduction in peak water level could be significantly impact in areas currently experiencing drainage issues exacerbated by elevated riverine water levels, particularly in South Golden Beach, which is protected by a levee. It is recommended that future overland flow studies consider the flooding benefit of well-maintained stormwater drainage networks.

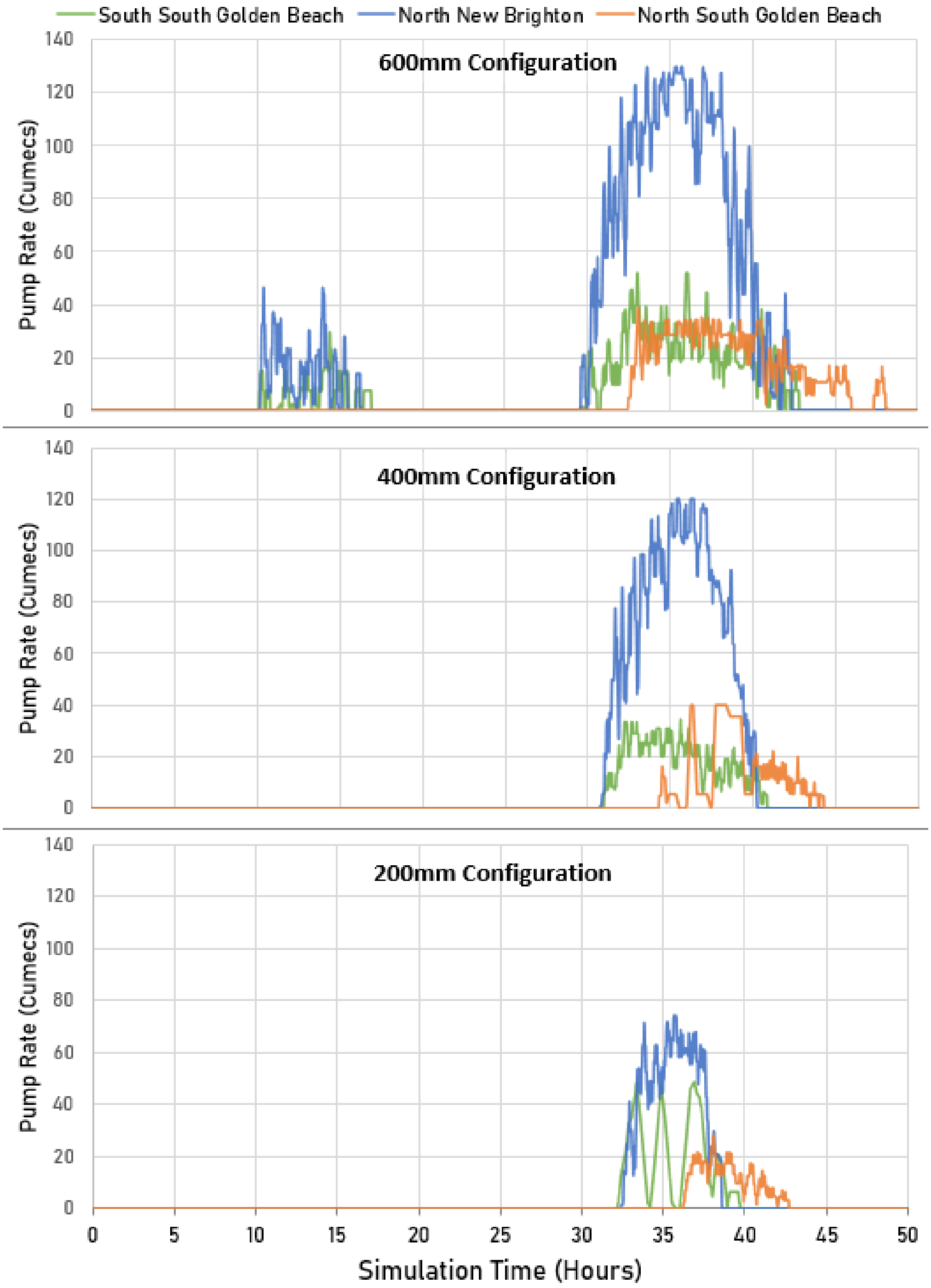

Figure 2-49: Sky Pumps 1% AEP Required Extraction Rates

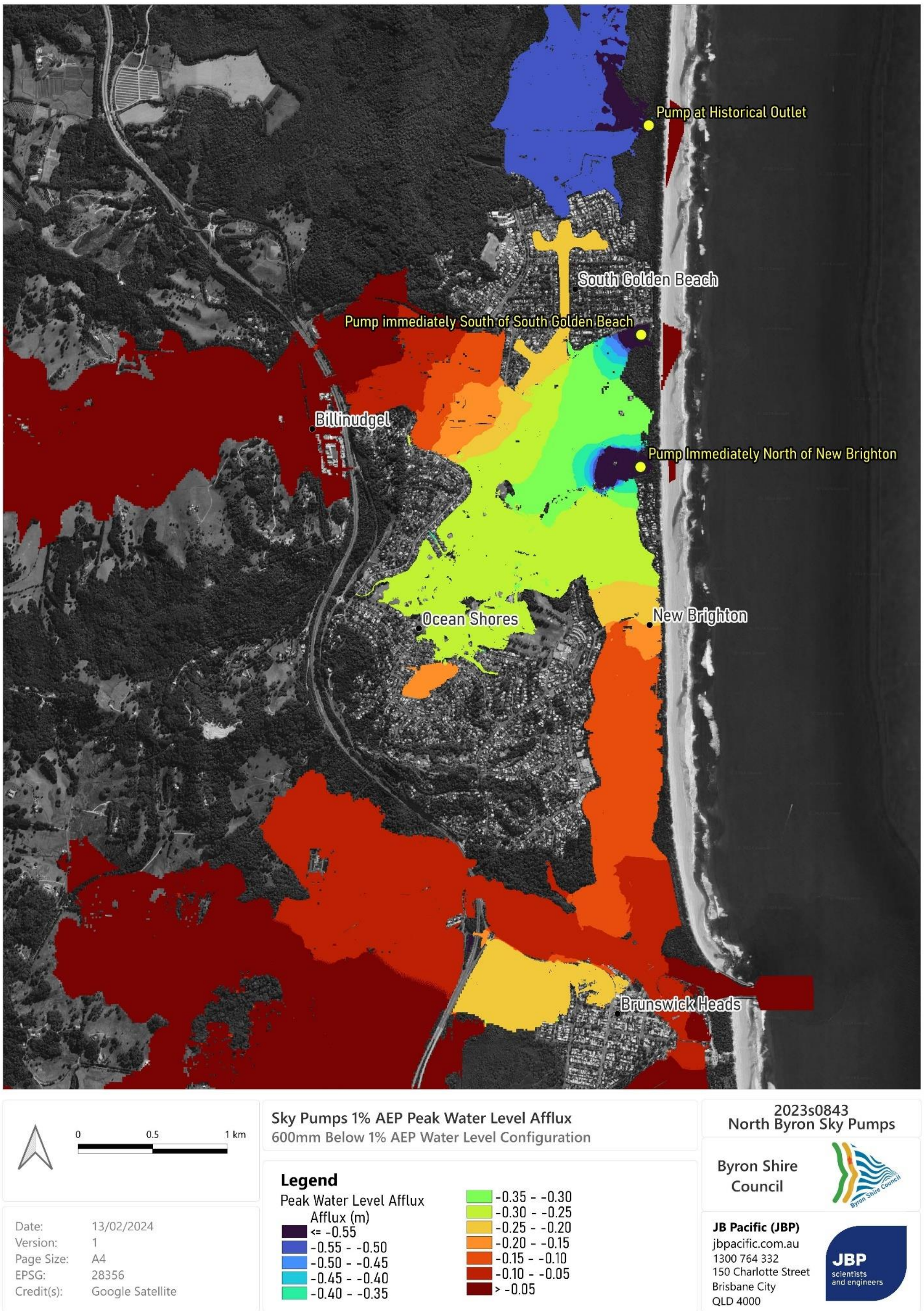

Figure 2-50: 1%AEP Afflux 600mm Sky Pump Configuration

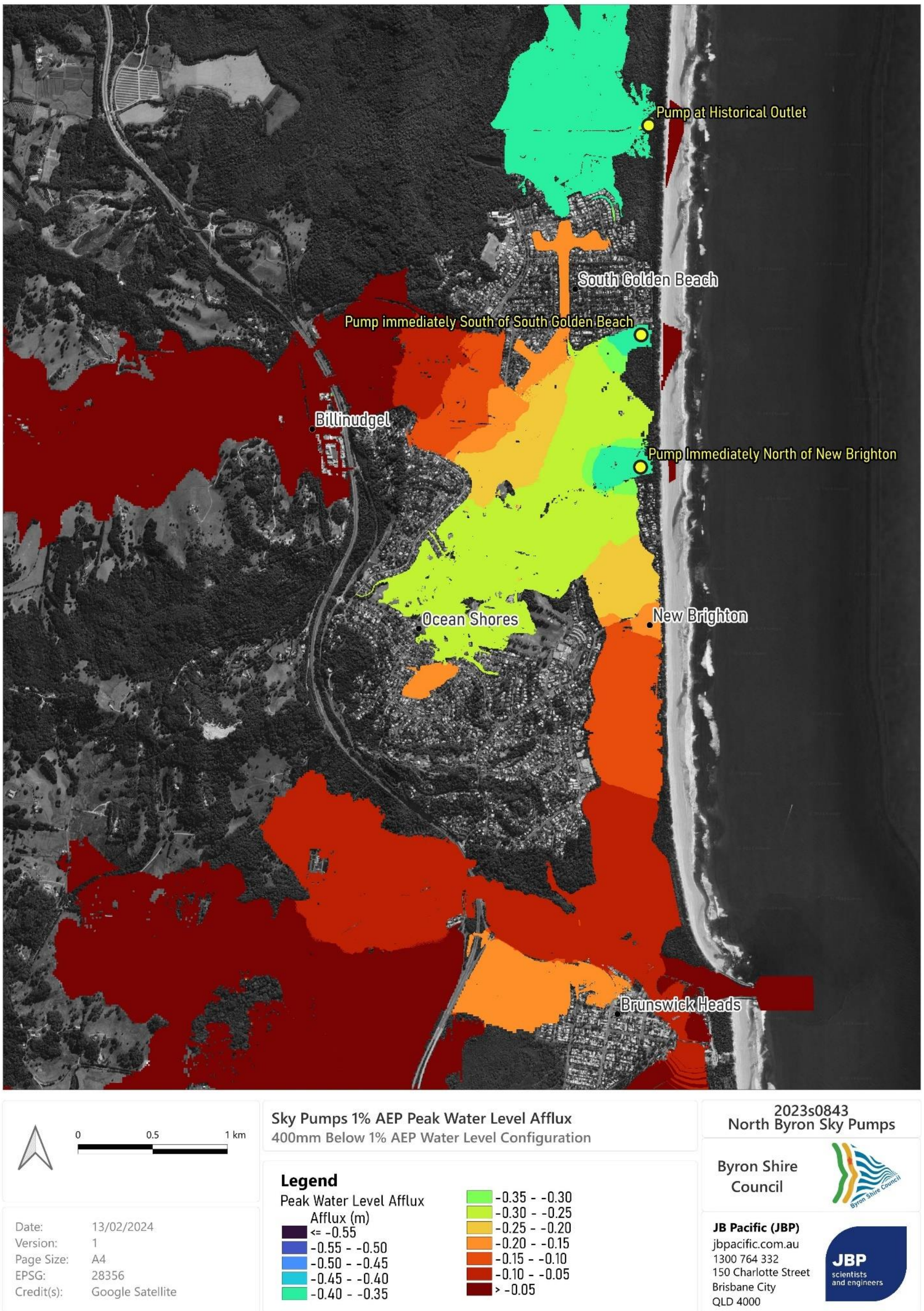

Figure 2-51: 1% AEP Afflux 400mm Sky Pump Configuration

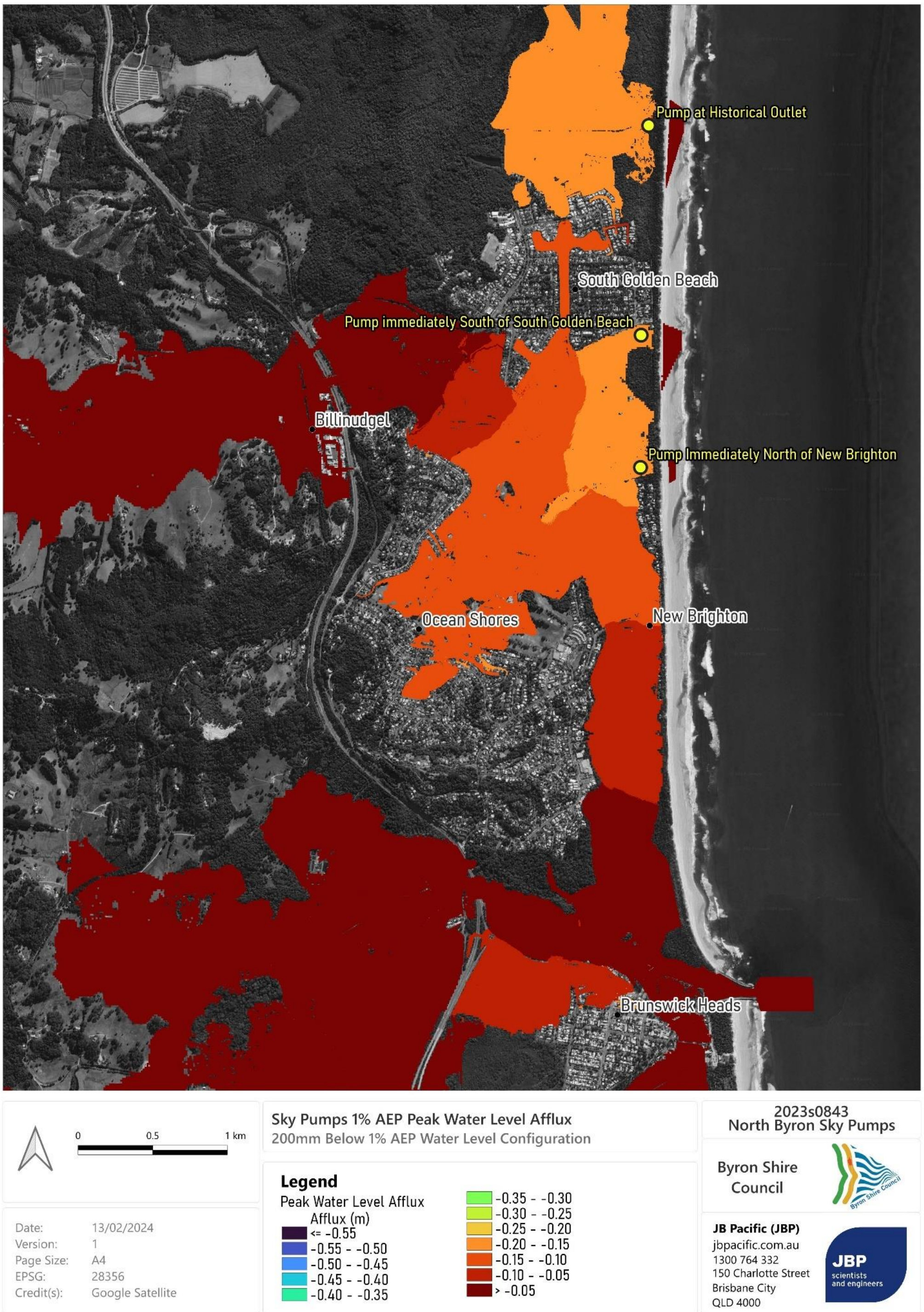

Figure 2-52: 1% AEP Afflux 200mm Sky Pump Configuration

3 Reviewed Estuary Studies

3.1 Overview

Several estuary studies have been identified for review for this project, as they included potential mitigation options and community consultation engagements, the reviewed studies included:

- Marshalls Creek Dredging Investigation (1992)
- Brunswick River Estuary Study (2002)
- Brunswick Estuary Management Study and Plan (2007)
- Brunswick Estuary Management Plan (2008)
  - Brunswick River Estuary Study Public Exhibition Report

3.2 Marshalls Creek Dredging Investigation (Planning Workshop and Web McKeown Associates, 1992)

3.2.1 Scope

This study was undertaken to prepare an Environmental Impact Statement (EIS) for the dredging of Marshalls Creek for flood mitigation purposes. As it was believed that the Marshalls Creek Floodplain potentially provides the greatest relief to all flood prone properties and could be undertaken at minimal cost to Council. While the study did not undertake any numerical modelling or flood estimation assessment many ecological considerations were provided for five distinct dredging options.

3.2.2 Dredging Options

1. Dredging would extend from 1km upstream of the Marshalls Creek training walls to about 0.3km downstream of the confluence with Yelgun Creek. The volume of sediment removed would be 330, 000m^3. Options 1a-1c accommodate a setback from both sides of the creek bank over length of the creek proposed for dredging of 5m, 10m, or 15m, respectively. The amounts of sand removed would be 280,000m^3, 175,000m^3, and 100,000m^3 for options 1a, b, and c, respectively.
2. Dredging would extend from about 2.3km upstream of the training walls. It would avoid dredging adjacent to seagrasses which fringe the edge of the creek and are located about 0.6km downstream of Orana Bridge. Some 220,000m^3 of sand would be removed under this option.
3. This option is similar to the previous one, except that no dredging would occur near to seagrass beds located 0.5km upstream of Orana Bridge. Moreover, a 5m offset would be taken from both creek banks over the length of the dredged portion. The volume of sand removed under this option would be 135,000m^3.
4. This option is similar to Option 3, but the upstream extent of dredging would be reduced by 1.4km to a point about 0.6km upstream of Casons Road. As with the

previous option a 5m offset would be employed. The volume of sand removed would be 90,000m^3

5. Dredging would extend from 1km upstream of the Marshalls Creek training walls to about 0.3 km downstream of the confluence with Yelgun Creek. It would occur to a maximum depth of -2.5mAHD with 1:5 batters. Measures would be incorporated to maintain bank stability and protect biological resources in designated areas, in all other areas the dredge batter would start from the edge of the creek. The volume of sediment which would be extracted would be 130,000m^3.

3.2.3 Constraints

The study identified several ecological constraint considerations for dredging Marshalls Creek. The NSW Fisheries guidelines, provides guidelines relevant to the dredging of Marshalls Creek including:

- Buffer Zones must be maintained around oyster leases, seagrass beds, saltmarshes and mangrove stands.
- Settlement ponds adjacent to the waterway must be constructed above the mean high-water mark and secure from 1 in 10 year flood levels to ensure that entrained silt from dredging operations is not returned to the waterway.
- Silt curtains must be used where high turbidity levels are likely as result of dredging or reclamation.
- Dredging in shallow areas generally must not exceed a depth of 2m at mean low water to facilitate mixing and ensure that the substratum remains in the euphotic zone. The bottom must be even, battered to a slope of 1 in 7 and free of holes (which allow build up of stagnant waters).
- The applicant must undertake to pay compensation to oyster farmers if investigations by responsible authorities establish that operations carried out during dredging have adversely affected oyster leases due to siltation or any deterioration in water quality.
- Existing public access to the estuary foreshore must be maintained or, where possible, enhanced.
- Existing flora and fauna must be maintained in their natural undisturbed states in areas which are not designated for dredging and in areas adjacent to the dredging. In particular, this applies to vegetated foreshore, saltmarsh, mangrove and seagrass areas.

3.3 Brunswick River Estuary Study (MHL, 2002)

3.3.1 Scope

This study undertook investigation of Brunswick River Estuary, including the main arm of the Brunswick River, Marshalls Creek and Simpsons Creek, to support the Byron Shire Council in development of the estuary management plan.

3.3.2 Identified Issues of Concern

Several primary issues of concern were identified from this study including Ecological Health, Erosion, sedimentation, protection of aquatic habitat, riparian vegetation, acid sulphate soils, flooding, fishing, alteration to natural flows, waterway usage, and development.

3.3.3 Flooding

This study identified the primary sources of flooding in the Brunswick River Estuary as east-coast lows and tropical cyclones, typically associated with longer duration storms in comparison to frontal convective storms. It was also identified that the Capricornia Canal and Marshalls Creek are affected by the ocean levels including the spring/neap range and flow constrictions within the canals at Kallaroo Circuit. It was identified that the spring and neap cycles peak levels range between 0.70mAHD and 1.23mAHD at the entrance, 0.68mAHD and 1.16mAHD at Mullumbimby and the tidal limit extends to the Coral Avenue ford. Along Marshalls Creek at New Brighton the range was identified as 0.23mAHD and 0.37mAHD while upstream of the Kallaroo Circuit resulted in a negligible 0.01m difference. The tidal prism for the estuary varies between about 1,200 and 4,000 ML between the spring and neap tides, which was identified as marginally larger than the 1,300ML estuary volume.

3.3.4 Recommendations

The study recommended that floodplain management should be integrated with recommended estuary management strategies recommended from this study including implementation of planning controls on flood prone land.

3.4 Brunswick Estuary Management Study and Plan (Patterson Britton, 2007)

3.4.1 Scope

This study was undertaken to develop an estuary management strategy and plan for the Brunswick River Estuary including the Marshall Creek and Simpsons Creek Estuaries. This study builds upon the findings of the Brunswick River Estuary Study (MHL, 2002).

3.4.2 Identified Issues of Concern

Several primary issues of concern were identified from this study including water quality management, wastewater management, estuarine sediment quality management, acid sulfate soil management, estuarine flushing, estuarine sedimentation and Erosion, catchment management, terrestrial vegetation management, aquatic habitat management, ecological health, fishery management, waterway usage, cultural values and tourism. This study identified flood risk as a lower priority concern for the estuary and did not adopt flood mitigation as a priority management objective for the Brunswick Estuary.

3.4.3 Community and Stakeholder Engagement

Three committee workshops were undertaken, where the first targeted whether the findings of the Brunswick River Estuary Study reflected the current concerns of the community. The second workshop was held with members of the Brunswick Estuary Management Committee at the Byron Shire Council to discuss the outcomes of the first workshop and to establish an agreed list of management objectives and strategies for the Brunswick Estuary, A list of potential management strategies and works was provided to council with council feedback being given before the third workshop where the preferred management strategies were presented to the Committee. A public exhibition of the draft estuary management plan was presented for 3 months seeking feedback from community and key stakeholders.

The first committee workshop delivered a rank-ordered list of key issues shown in Table 3-1. Where the concern of flooding was ranked last from the committee out of all 31 key issues within the estuary, notably even losing out to "Reduced Estuary navigability", at rank 29. As the latest major flood before the study was undertaken had occurred in 1987 (some 20-years), which was known as the "Mother's Day Flood", and that no major floods had occurred close to the timing of the study could have affected the perceived relevance of flood risk to the community. The study also claims that concern for flooding was reduced in the community due to the draft floodplain management plan for Mullumbimby being released at the timing of the study.

Table 3-1: Ranking of key issues from committee member responses

Ranking	Key Issue
1	Water quality - sewer overflows and effluent
2	Riparian Vegetation - loss of habitats
3	Protection and rehabilitation of riparian vegetation

Ranking	Key Issue
4	Protection of aquatic habitat
5	Fishing - fauna and habitat
6	Water quality - pollutants
7	Water quality - agricultural runoff
8	Education - Improve awareness
9	Development - infrastructure development
10	Cultural values - Aboriginal sites
11	Development - Urban expansion
12	Tourism - maintaining a balance
13	Foreshore access - pedestrian and cycle pathway on public land
14	Water Quality - accidental spillage
15	Sediment quality - nutrients and trace metals
16	Fish Kills
17	Fish stocks
18	Bank erosion - failure of remedial measures
19	Sedimentation - fisheries habitat
20	Effect of pollution incidents on aquatic habitat
21	Increased bank erosion
22	Waterway usage - boating impacts
23	Waterway usage - conflicts between users
24	Waterway usage - facilities
25	Acid Sulfate soils - acid runoff
26	Alteration to natural flows - training walls and breakwaters
27	Sedimentation - navigation
28	Water quality - low estuarine flushing
29	Waterway usage - reduced navigability
30	Sedimentation - tidal exchange
31	Flooding - flooding behaviour

3.4.4 Flooding

The study recommended the undertaking of several studies, including the preparation of floodplain management plans for Brunswick Heads, and Mullumbimby and a review of the existing Marshalls Creek Floodplain Management Plan, and to incorporate climate change investigation into these studies and plans.

3.5 Brunswick Estuary Management Plan (Byron Shire Council, 2008)

This Brunswick Estuary Management Plan built upon the Brunswick Estuary Management Study and Plan (Patterson Consultants, 2007), to produce an estuary management plan for adoption of council. It included several estuary management options which were ranked in priority, including several flood risk mitigation options adopted from the Brunswick Estuary Management Study and Plan (Patterson Consultants, 2007).

4 Reviewed Coastal Studies

4.1 Overview

Similar to the estuary management studies and plans Coastal studies were reviewed to assess any flood management options, activities, planning and community consultation outcomes. Studies that were reviewed included:

- Byron Shire Coastline Hazards Assessment Update (BMT, 2013)
- Coastal Zone Management Plan (BSC, 2018)
- Byron Shire Coastal Hazards Assessment (2022) - ONGOING

4.2 Byron Shire Coastal Hazards Assessment Update (BMT, 2013)

This study builds on top of Byron Coastline Hazard Definition study (WBM Oceanics Australia, 2000), in accordance with updates to the Coastal Protection Act, 1979 and new guidelines from "Guidance for preparing Coastal Zone Management Plans" in 2010, including new planning horizons of 2050 and 2100. This study investigated several coastal processes including oceanic inundation from storm tide and sea level rise. Several extents of oceanic inundation are available for the North Byron region and are presented within the study. From the report it is unclear which approach was undertaken to result in the inundation extents from either bathtub or numerical modelling approaches.

4.3 Coastal Zone Management Plan for the Brunswick Estuary (Byron Shire Council, 2018)

4.3.1 Purpose

This study and its associated report investigated several coastal zone management options for the Brunswick Estuary.

Some recommendations were made for further investigation into flood mitigation including:

- Incorporation of climate change impacts in the North Byron Coastal Creeks Flood Study and Marshalls Creek Flood Study
- Preparation of a water-sensitive urban design policy for the Byron Shire
- Undertake drain mapping of the North and South of Brunswick River and Marshalls Creek
- Control and manage development.

5 Marshalls Creek Sedimentation

5.1 Introduction

JB Pacific have been commissioned by Byron Shire Council to undertake an analysis of sedimentation in Marshalls Creek.The sediment analysis includes a range of historic and contemporary sources, including:

- Available aerial imagery/photogrammetry
- Available data (LiDAR, Bathymetry, Sonar, sediment sampling etc)
- Previous studies

5.1.1 Background

Marshalls Creek originates approximately 1.5 km east of the village of Main Arm, situated in the northeastern part of the state of New South Wales. It flows in an eastward direction, meandering through a valley that is bound by ridges to the north and south. The creek covers a total distance of 23 km before it joins the Brunswick River.

Lacks Creek is a significant tributary that joins Marshalls Creek upstream of Billinudgel. Other contributing water sources include Strike-a-Light Creek and a large modified tidal lake near Balemo Drive. In addition, there is the Capricornia Canal, constructed in 1974, is a large artificial canal that facilitates drainage from elevated terrain within the Ocean Shores and low-lying areas, directing water into Marshalls Creek.

The lower part of Marhsall Creek from the Pacific Highway bridge to Brunswick Heads is tidal in nature. The hydrology of Marshalls Creek, NSW, has undergone significant changes over the decades, influenced by various factors:

- **Urbanization and Runoff:** The adjacent urban landscape has expanded, leading to increased runoff into Marshalls Creek. Urban development contributes to higher volumes of stormwater discharge, carrying sediment and pollutants into the watercourse.
- **Land Use Changes:** Changing catchment conditions, including deforestation, farming practices, and ongoing urban development, have likely increased runoff and suspended sediment loads. The alteration of land use patterns affects the natural hydrological balance of the creek.
- **Infrastructure Development:** The construction of extensive drainage canals and levees near the reserve, dating back to the 1920s and 1930s, has been a notable factor. These structures were designed to drain wetland areas and enhance the viability of the land for agricultural and residential uses. The development of such infrastructure has altered the natural flow patterns and groundwater levels, impacting the creek's hydrology.
- **Structural Interventions:** The addition of training walls at the entrance of Marshalls Creek, implemented since the late 1960s, has influenced sand accretion in the lower estuary. The original purpose of these walls was to prevent

Brunswick River from silting up, ensuring a deep channel for the fishing fleet to access the ocean. Capricornia Canal was constructed in the early 1970s, linking Yelgun Creek to Marshalls Creek.

- **Natural Events:** Natural storm events have contributed to changes in channel conditions. These include alterations to the creek's course, sediment deposition, and erosion, all of which impact the overall hydrological dynamics. Marshalls Creek has experienced several significant flood events, including notable occurrences in May 1987 (commonly known as "the Mothers Day Flood"), March 1974, June 2005, March 2017 and March 2022.

5.1.2 Available Data

A range of datasets are available at a regional scale as well as specific to the study area.

5.1.2.1 Height datums

All height data is relative to Australian Height Datum (AHD), unless otherwise specified.

5.1.2.2 Elevation data

Topographic data has been sourced from the ELVIS (Elevation Information System) data portal[1]:

- 1m NSW LiDAR data (2010): High resolution (1m) LiDAR survey of the Byron shire region. This data is available in 1km-by-1km tiles.
- 5m Coastal marine topographic and bathymetric data (2018): Medium resolution (5m) LiDAR and bathymetric survey of Point Danger to Cape Byron.

5.1.2.3 Aerial and satellite imagery

Historical aerial imagery was downloaded from NSW Government Spatial Services website and georeferenced in QGIS. There were 7 dates in total: 1958, 1966, 1971, 1987, 1991 and 1997. In addition, this has been supplemented by satellite imagery from Google Earth and Sentinel Hub. Selected examples are shown in Figure 5-1. High temporal Setinel-2 imagery covering 2016 to 2024 has been assessed to identify broad-scale post-flood changes in creek morphology.

1 **https://elevation.fsdf.org.au/**

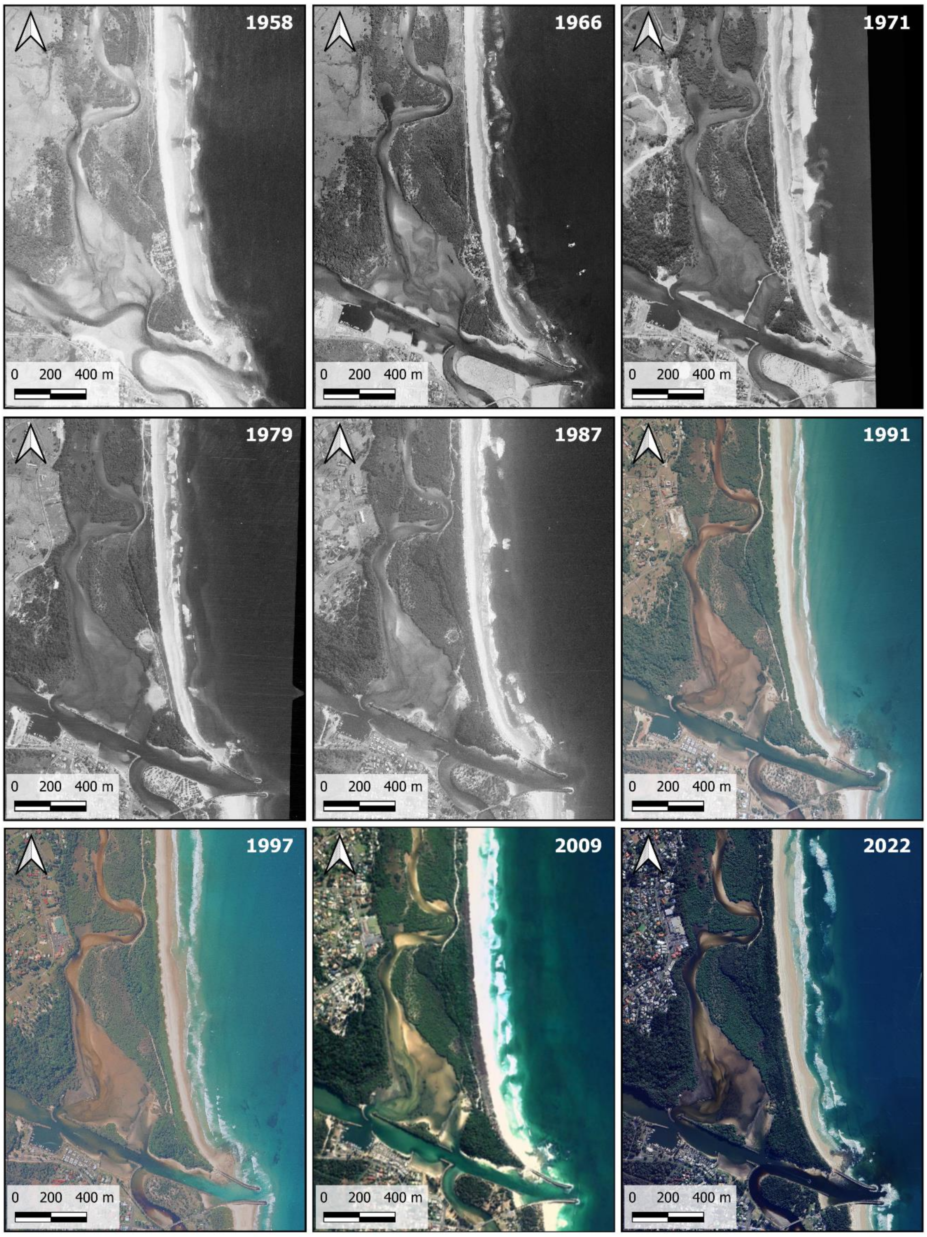

Figure 5-1: Selected historical aerial and satellite imagery. Historical images 1958-1997 available on **https://portal.spatial.nsw.gov.au/**. Satellite images 2009-2022 available from Google Earth.

5.1.2.4 Published literature

- Marshalls Creek near Brunswick Heads, Northern New South Wales: A preliminary study of bed sediments and stability (Warner, 1988)
- Marshalls Creek Floodplain Management Plan. (Paterson Consultants, 1997)
- Brunswick River Estuary Study (2002). Appendix E – Physical Processes
- North Byron Floodplain Risk Management Study and Draft Plan (2019)

5.2 Sediment Dynamics

5.2.1 Sources of bed material

Marshall Creek has been the subject of several studies over the years. A previous investigation by Warner (1988)[2], which included sediment sampling, suggested three sources of channel bed material in the lower tidally influenced part of Marshalls Creek; fluvial sediments, reworked coastal sands and marine sands.

Warner found that the upper part of the estuary, between the Pacific Highway bridge at Billinudgel and lake entrance at Ocean Shores Golf Club, comprised predominately fluvial sediments. Downstream from the lake to about Orana Bridge, Warner described the bed material as reworked coastal sands of mainly fine- to medium-grain size which have been well rounded and well sorted by marine processes. This material is believed to have been derived from eroded barrier systems and dunes formed during the Holocene period after sea level rise. From Orana Bridge to the training walls, Warner found the bed material comprised predominately of marine sands, having been deposited in a flood-tide delta environment. Marine sand and reworked sand are very similar in terms of composition, distribution, shape and sorting, the main discerning traits being marine sand is pale orange (iron staining) and contains more shell fragments.

5.2.2 Channel morphology

The reaches of Marshalls Creek vary from the wide, shoaled region of Readings Bay at the confluence of the Brunswick River, to more meandering further upstream towards New Brighton.

5.2.3 Historical changes in creek morphology

The aerial imagery of 1958, prior to the construction of the training walls, shows extensive shoaling in the lower estuary and Readings Bay (Figure 5-1) formed by sand transported in on the flood tide.

Although the 1988 study by Warner suggested much of the marine sand had been introduced since the near closure of the estuary by the training walls in the 1960s. As noted

2 Warner, R. 1988. Marshalls Creek near Brunswick Heads, Northern New South Wales: A preliminary study of bed sediments and stability.

in the 1997 Marshalls Creek Floodplain Management Plan3 and 2002 Brunswick River Estuary Study, historical oblique photographs of the estuary show siltation of the Readings Bay pre-dated training wall construction (Figure 5-2).

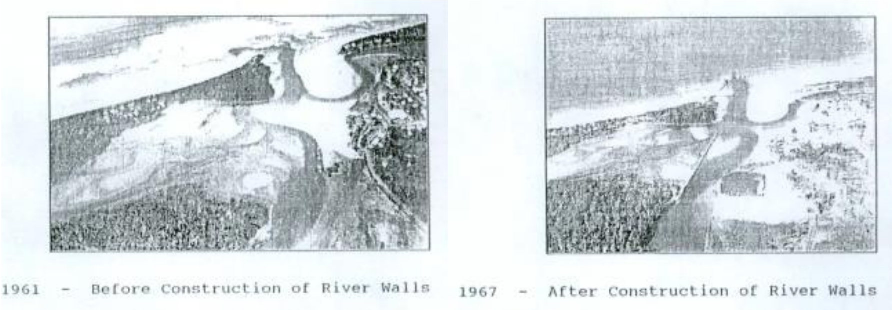

Figure 5-2: Oblique photographs of Marshalls Creek entrance pre- and post-training wall construction (source: 1997 Marshalls Creek Floodplain Management Plan).

In most tide-dominated estuaries, the peak tidal current is generally stronger during flood than during ebb; this promotes import of marine sediment in periods of low or medium river runoff. Historical conditions in the early to mid-1900s, marked by a drier Marshalls Creek catchment with fewer floods, likely facilitated the introduction of a significant amount of marine sand during that period[2]. Aerial imagery shows a large sand shoal on the eastern side of Readings Bay with Marshalls Creek forming a number of braided channels.

The east-west training wall across the entrance to Marshalls Creek was built in the early 1960s. It originally has an opening at the eastern end only (see 1966 image in Figure 5-1). Between 1967 and 1971 modifications were made to the training walls. The channel to the boat harbour kept silting up so a second opening was made at the western end, a wall was constructed perpendicular to the original training wall cutting off the eastern opening built, and a curved spur constructed projecting into the main Brunswick River channel (see 1971 image in Figure 5-1). The perpendicular wall was lowered in 1973 after concerns about its effects on flooding. The eastern opening is 42 m wide, however, the north-east rock wall at an elevation of circa 0.4 m AHD limits its operability to large, infrequent events. The western opening is 37 m wide and is free flowing.

The training walls have trapped sand in the Readings Bay with aerial imagery highlighting the rapid accumulation of sediment on the northern side of the wall soon after construction. By 1979, vegetation had started colonising this accumulation above high-water levels. Calculations of the surface area of this accumulation, as depicted in

Figure 5-3, demonstrate a general increase over time, with some fluctuations, and a recent trend suggesting stabilization. Bathymetric data exists for 2018, however, no newer data is available to allow volumetric comparisons within the bay.

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3 Paterson Consultants. 1997. Marshalls Creek Floodplain Management Plan. Byron Shire Council.

Since construction of the training walls tidal flow in Readings Bay has been constrained to a single deep channel.

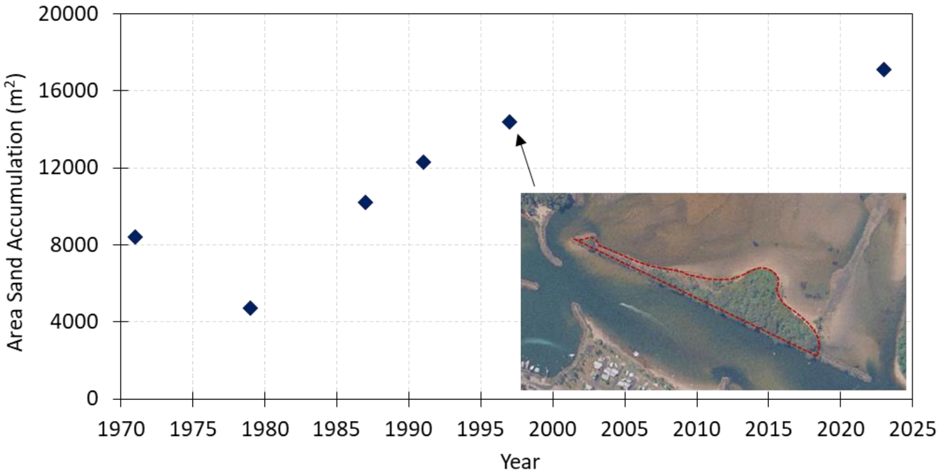


Figure 5-3: Timeseries plot showing surface area of sand accumulation on the northern side of the training wall.

Further upstream, there is also evidence for natural channel changes in the recent past. A cutoff meander is discernible in the wetlands of New Brighton (Figure 5-4), exemplifying the typical evolution of meandering rivers where a curved section is abandoned in favour of a more direct route. South of New Brighton, the ongoing evolution of meandering is evident through the erosion of bank material on the outer bends, where the flow is swifter, and the deposition of sediment on the inner bends. Figure 5-5 shows the evolution of this meander through recent aerial and satellite imagery. Bank erosion along this stretch of the creek is measured at a rate of approximately 1 metre per year. This meander is anticipated to progress towards a more sinusoidal form until a cutoff event eventually transpires. These observations underscore the dynamic nature of Marshalls Creek and emphasize the importance of continued monitoring and adaptive management strategies to address its evolving geomorphology.

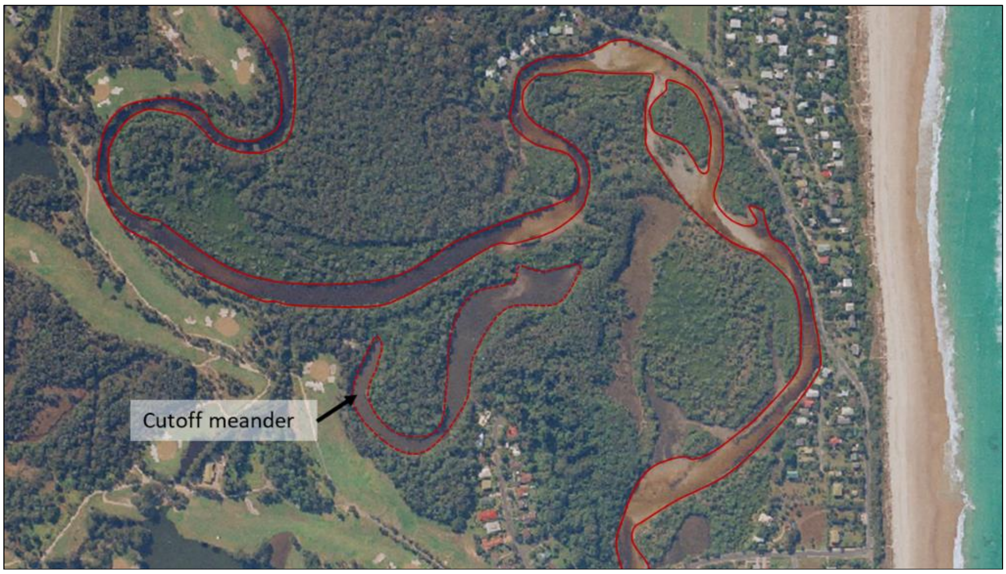


Figure 5-4: Cutoff meander in New Brighton (1997 NSW historical imagery).

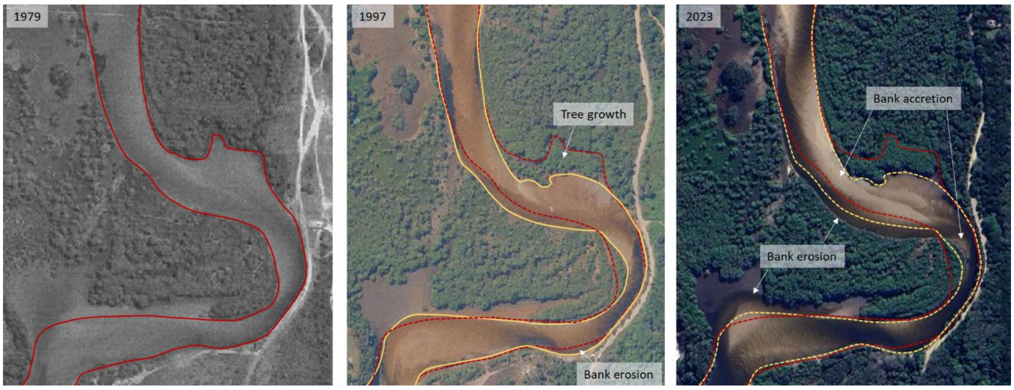


Figure 5-5: Evolution of meander south of New Brighton (NSW historical imagery).

The 2002 Brunswick Estuary Study compared cross sections in Marshalls Creek from 1983 and 1991 finding a general accretion of the creek bed upstream of the Orana Bridge. The study found that downstream of Orana Bridge increases in depth of up to 0.5 m were documented while upstream of Orana Bridge a decrease of 0.5 m was documented.

5.2.4 Bedload changes

The movement of sediment in the study area is affected by tides and river discharges which can cause notable changes over relatively short periods, such as during a storm. These processes mobilise sand from the bed and transport it from one area to another, resulting in areas of erosion and accretion.

Much of the sand in the lower part of the estuary, even up to New Brighton is very mobile in the upper layers, as is evident from low amplitude, ebb-dominated shoals/dunes with secondary bedforms (i.e. ripples and mega-ripples) partially superimposed on the larger dunes. The dunes retain their shape and asymmetry for extended periods of time while secondary bedforms appear to reverse in response to the changing flow direction. Tidal flows have also formed ebb and flood barbs along the lower reaches as shown in Figure 5-6.

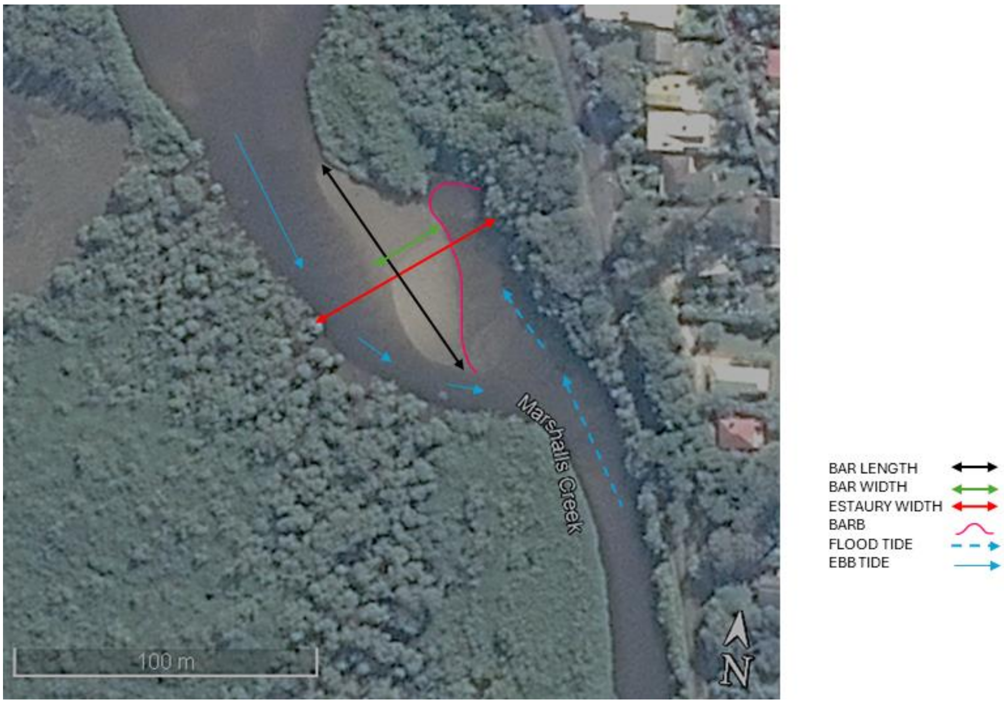


Figure 5-6: Tidal flows have formed ebb and flood barbs.

Timeseries of satellite images show the differential migration and merging of dunes. Tracing the crests of dunes between successive satellite imagery makes it possible to estimate average migration rates of ebb-dominated dunes. It is surprisingly difficult to characterise this downstream movement, partly because the bed forms change their profiles with time but also because any given bed form has a finite lifetime. When imagery was more than a year apart it was difficult to track individual

Figure 5-7 shows migration of bedload sediment upstream of Orana Bridge following the March 2022 floods. Five crests can be tracked between June 2022 and March 2023 with those crests migrating at circa 30-40 m/year in a downstream direction.

Figure 5-8 shows the evolution of shoals in Readings Bay between June 2021 and 2022. The eastern side of Reading Bay appears relatively immobile. Along the western side, dunes migrate downstream at circa 20-30 m/year. It is not clear what occurs as the shoals get closer to the creek entrance. Imagery suggests some sediment can migrate through the entrance; the rest likely gets reworked during larger flood tides.

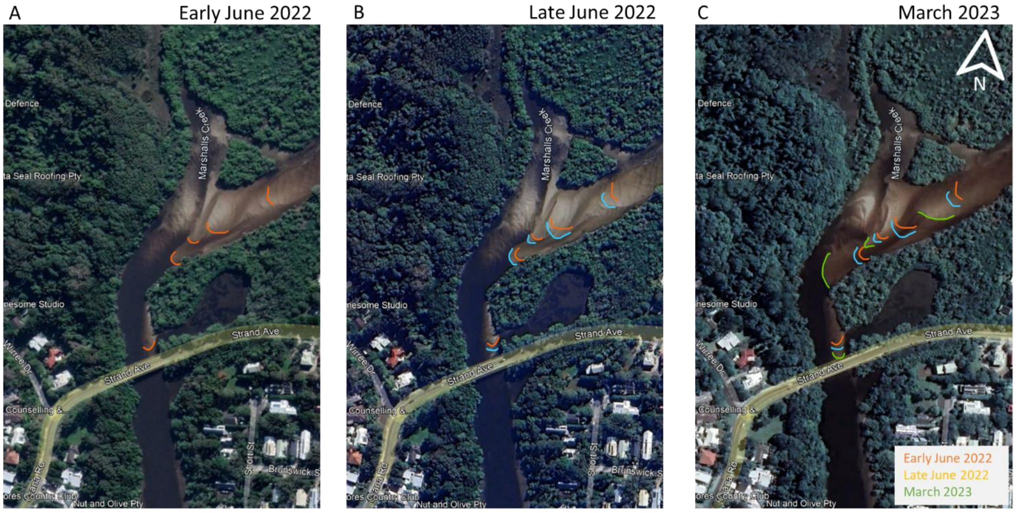


Figure 5-7: Migration of ebb-dominated dunes in New Brighton.

Figure 5-8: Migration of ebb-dominated dunes in Reading Bay.

5.2.5 Influence of Storms

During storms, soil and debris are washed off the land into the river turning it brown and transported to the ocean. This is typical of most large rain events in the Marshalls Creek catchment. Figure 5-9 shows the changes in Marshalls Creek pre and post a storm event on the 29-30 March 2022 where circa 295 mm of rain was recorded at Mullumbimby. The images show it takes several days for the suspended sediment to clear with most of the fine sediment transported to the ocean.

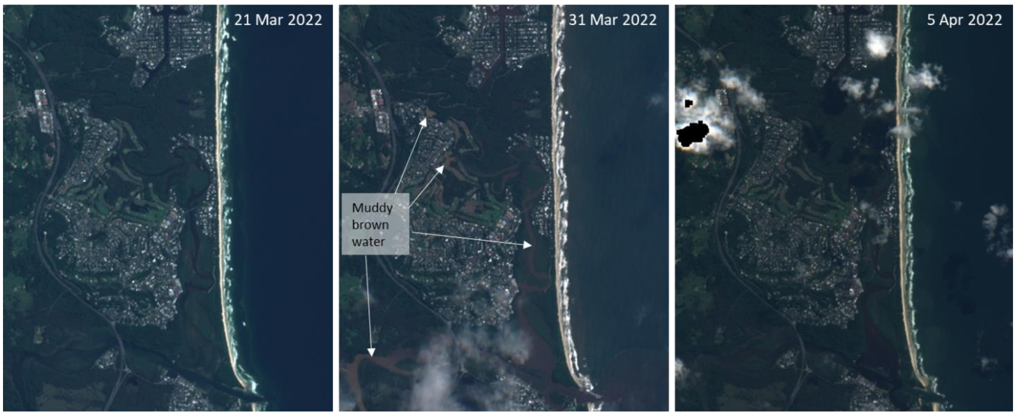


Figure 5-9: Impact of 29-30 March 2022 rainfall event on water quality (Sentienl-2 imagery).

The interplay between storm surges and increase river flows due to rainfall create a complex dynamic in a tidal river such as Marshalls Creek. Following storm events, bedload and dune patterns suggest both downstream pulses of sand and upstream entrainment of sand with the flood tide. The low resolution of Senitenl-2 imagery and temporal gaps in available high-resolution satellite imagery makes it difficult to identify storm-induced changes.

5.3 Summary

Previous studies identified three sources of channel bed material: fluvial sediments, reworked coastal sands, and marine sands.

Historical imagery indicates that Marshalls Creek entrance had a high volume of sedimentation with significant shoaling prior to the construction of the training walls in the 1960s. Following construction, the Brunswick River was straightened, and siltation increased on the north side of the Marshalls Creek entrance training wall. This accumulation appears to be stabilising in recent years suggesting the majority of sediment in Readings Bay is immobile. It is evident from historical imagery that around Ocean Shores and New Brighton, there are ongoing natural channel changes and meander evolution of the creek, with ~1 m/year of bank erosion occurring on the outside of meander beds and deposition of sand on the inside.

Tidal flows and river discharges influence sediment movement, causing erosion, accretion, and migration of sandy shoals. Larger dunes are ebb-dominant and migrate downstream at 30-40 m/year with storm events potentially exacerbating these processes. The high frequency of events and low temporal resolution of imagery mean it is difficult to track dune migration over several years. Storm events significantly affect sediment transport and water quality in Marshalls Creek, leading to changes in bedload dynamics and dune migration patterns. There is also evidence of sediment reworking during flood tides with occasional upstream movement of shoals.

Marshalls Creek experiences dynamic sedimentation influenced by various factors, including human interventions and natural processes. Continued monitoring using available data sources is recommended for informed decision-making and sustainable environmental management.

6 Identified Investigation Gaps

The North Byron Floodplain Risk Management Study (WMA, 2020) identified several potential gaps in assessing flood management and mitigation options, which it recommended for further investigation, including:

- A review of Simpsons Creek Sedimentation Study
- Catchment Drainage Model
- Undertake a Mullumbimby Evacuation Assessment
- Dredging assessments were done for Brunswick River and Marshalls Creek in isolation however a recommendation was that it also be done in combination.
- Further detailed modelling assessments of Saltwater Creek mitigation options for Mullumbimby.
- Undertake more detailed assessments of properties, which may benefit from property level protection.
- Further investigate the eligibility of raising residential properties to reduce flood damages.
- More detailed assessment of potentially raising River Street to provide improved flood immunity and evacuation:
  - This was modelled in the study but was recommended that further detailed investigation be undertaken to better understand the impacts and benefits of this option.

Additional alternative modification approaches to flood mitigation options were identified on review of the adopted modelling approaches in the North Byron FRMS (WMA, 2020), including:

- Dredging/Channel Modification: Flow path widening, connecting South Golden Beach canals with Marshalls Creek, in addition to dredging extent modification. The reporting for the Marshalls Creek Dredging suggests that the dredging extended to the West end of the Marshalls Creek junction with Brunswick River, it is thought that with the rock wall removal at the Eastern end of the junction that flow conveyance will improve further, increasing the drainage from Marshalls Creek out to the ocean. Additionally, as part of this FRMS&P only the 1% AEP event was modelled to assess the flood mitigation impact of dredging where the creek banks were observed to overtop significantly, it is believed more frequent events, or shorter duration events would have a larger portion of flood water flow within the creek banks increasing the effectiveness as a flood mitigation option.

- Rock Wall modification: While preliminary modelling was undertaken as part of the North Byron FRMS, the investigation only modelled the 1% AEP event, which was observed to submerge the existing rock wall structure resulting in minimal flood mitigation. It could be investigated for flood mitigation impact to more frequent events where the creek blockage would be more significant. Additionally, it was also noted that while the enforcement of the hydraulic structure existed in the model, few sections of the hydraulic enforcement were believed to incorrectly represent the maximum rock wall crest and could be improved, however it is believed to result in minimal modelling impact.

- Dune Openings Modelling Modification
    - While this was modelled as a flood mitigation option in the North Byron FRMS&P, further lowering of the dune crest lower than the modelled (~1.5mAHD) at the South Golden Beach Openings is expected to potentially increase catchment release. However, lower dune crest levels have potential to result in oceanic backflow due to high tides and/or storm surge.
    - Dune openings were modelled with a 20m width, however with significantly flood water extent widths, a wider modelled channel has the potential to increase flow conveyance, as the estuary area enclosed by South Golden Beach, Ocean Shores and New Brighton, are observed to bathtub inundate from limited outflow drainage.
    - An alternative dune opening is suggested to be investigated for viability 100m North of New Brighton Beach. This alternative location would be subject to investigation of disruption to either indigenous heritage sites and dune and environmental health.
    - An additional opening immediately south of New Brighton was identified that could be investigated to improve Marshalls Creek immediate drainage before the junction with Brunswick River, consideration of possible increased sedimentation at the Marshalls Creek junction with Brunswick River must be considered if not in conjunction with dredging.
    - The preliminary modelling undertaken did not investigate impacts of tidal inundation/coincidental tidal and catchment conditions.
    - Previous modelling has not considered flood benefit to stormwater drainage systems with lowered tailwater levels.

- Drainage Infrastructure at Billinudgel
    - While several drainage infrastructure improvements were suggested a Billinudgel no infrastructure improvements were identified for improving the rail embankment cross drainage immediately North of Billinudgel

- Drainage Improvement at Strand Avenue
    - A significant constriction is observed at Strand Avenue Bridge, modelled as a 2.218mAHD deck level with a 1.575m depth.

6.1 Community Perception and Communications

It is noted throughout the various studies and community consultation that several options were regularly put forward by the community that were shown to not significantly decrease flood levels and the number of properties that were affected. It may be considered as part of future studies for reconsideration of flood alleviation affects for more frequent events than the 1 in 100-year flood event.

7 Community Consultation

7.1 Community Survey

A community survey was undertaken in November 2023, to gauge community awareness and support for flood mitigation options. The survey asked about the respondent's:

- Supported Mitigation Options
- Priorities for flood mitigation
- And any comments on floodplain management in North Byron

The community survey received 90 responses; a summary of supported mitigation options is shown in Figure 7-1. Where 65 of 90 respondents were in support of the Ocean Outfalls. The magnitude of the support is believed to be sourced from the historical ocean openings and previous investigation of the ocean outfalls as a flood mitigation option.

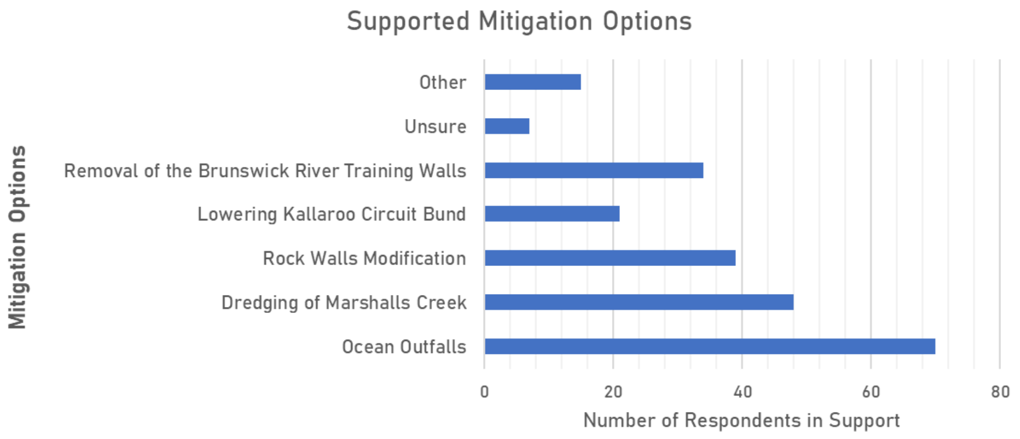


Figure 7-1: Community Survey Supported Mitigation Options (Multiple Choice)

From the responses stormwater was identified a prominent issue mentioned several times by a significant number of respondents. A following summary is provided regarding number of mentions of stormwater concerns, ranked by percentage of mentions from respondents.

1. Maintenance/Improvement of drainage (20% of respondents)
2. Prevention of fill areas with adverse effects (11%)
3. Easement Flow Path Blockage (8%)
4. Kallaroo Circuit Bund Constriction (8%)
5. Flooding from Water Lily Park (5%)
6. Hydraulic Linkage with Tweed-Byron Coastal Creeks (3%)
7. Vegetation Flow Path Blockage (2%)

Responses with attributed locations are provided for Billinudgel, South Golden Beach, Ocean Shores, New Brighton and Brunswick Heads in Figure 7-2, Figure 7-3, Figure 7-4, and Figure 7-5.

Figure 7-2: Billinudgel Community Survey Responses

Figure 7-3: Ocean Shores and New Brighton Community Survey Responses

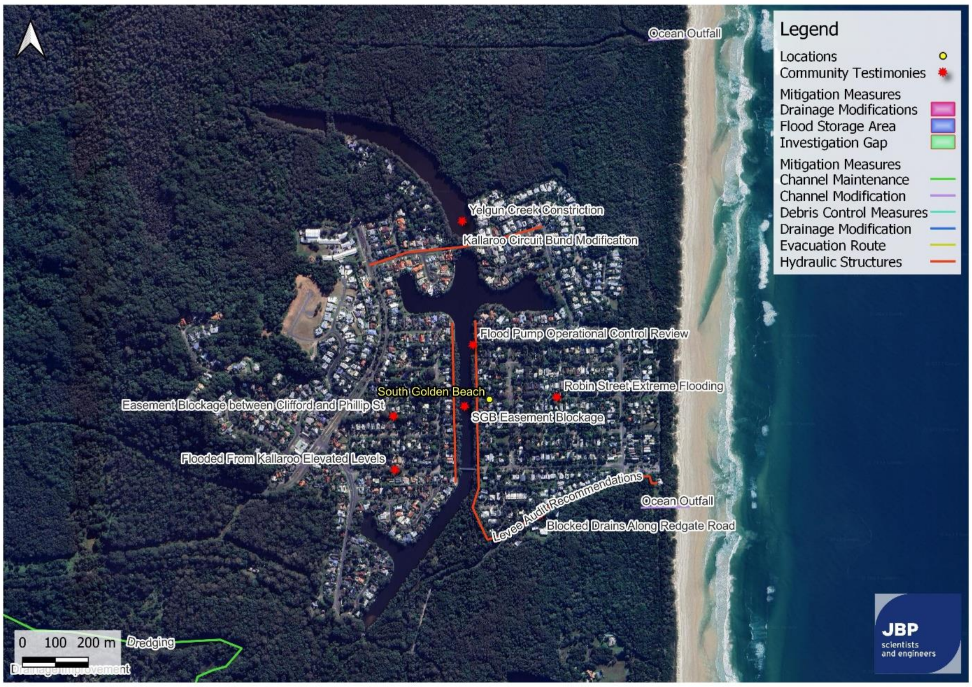


Figure 7-4: South Golden Beach Community Survey Responses

Figure 7-5: Brunswick Heads Community Survey Responses

7.2 Community Workshop

7.2.1 Overview

A community engagement workshop was undertaken to further explore community support for flood mitigation options following the community survey. The workshop identified several considerations for future flood studies and flood modelling. Findings from the workshop, with recommendations for investigation have been broken down by locality below.

7.2.2 South Golden Beach

South Golden Beach has several concerns predominantly regarding stormwater flooding, as South Golden Beach is protected from Yelgun Creek and backwater from Marshalls Creek from a 1% AEP levee level. Concerns raised during the workshop included:

- The development at Palmer Avenue/Player Parade was observed to have inadequate drainage during the 2022 flood event, a local resident testified that a worrying volume of water was flowing down Palmer Avenue and believed to have little stormwater network conveyance. The stormwater network is recommended to be further investigated for adequacy as part of an overland flow flood study.
- Blockage of stormwater pits and kerb inlets, concern was raised for the maintenance of the existing stormwater infrastructure. It is recommended that hydraulic structure blockage sensitivity is to be conducted up to 100% blockage.
- Concerns of easement flow path blockage were raised, including overgrown vegetation. It is recommended that easement roughness sensitivity is to be undertaken as part of future modelling.
- Some uncertainty for cause of flooding was raised, it was believed that flooding for significant portions of South Golden Beach was from inadequate stormwater drainage, however it was unknown if this was due to elevated water levels in the canals, preventing drainage.
- Changes to the floodplain are believed to affect sugar cane agriculture North of South Golden Beach, along with the floodplain in Tweed Shire Council. This concern has been identified from previous studies and it is recommended that mitigation options are to be investigated for impact to the Tweed Shire Council.

7.2.3 Billinudgel

Billinudgel had concerns predominantly regarding Marshalls Creek flood behaviour. Thoughts raised during the workshop included:

- Billinudgel has significant flow path blockage at Billinudgel Bridge (Railway Line) and the Pacific Motorway. Residents expressed concern of siltation in Marshalls Creek, where historically it was deep flowing it is now observed to be shallow flow. It is identified that the debris control measure currently under investigation may improve conveyance capacity.

- From the survey, concern was raised for vegetation blockage of the drainage flow path running parallel to Billinudgel immediately West of the township. It is recommended that this flow path undergoes roughness sensitivity checks as part of future modelling.

7.2.4 Ocean Shores

Varying responses were provided regarding Ocean Shores.

- Some responses regarded flooding sourced from Water Lily Park. It was noted that limited stormwater mitigation options, and investigations have been proposed for Ocean Shores. It is believed that the planned catchment wide overland flow study will provide a foundation for mitigation options. Including stormwater infrastructure upgrades.
- Strong support for ocean outfalls were expressed to increase Ocean Shores flood resilience, however a few community members expressed concern over the considerations of costing, sea level rise and tidal inundation.
- There exists concern of the Ocean Shore's Golf Course impact to flood behaviour due to its significant flood storage. While Ocean Shores Golf Course weir lowering has been modelled before it is suggested to be further investigated for any additional flood alleviation potential.

7.2.5 New Brighton

- A community member raised concern about the existing open drainage channel running along Brunswick Street, claimed to have still water, and during a flood event carries a significant volume of water at a hazardous velocity. It is recommended to investigate an underground stormwater network along Brunswick Street as part of the planned Overland Flow Study.
- Strong support for ocean outfalls were expressed to increase New Brighton's flood resilience.

7.2.6 Brunswick Heads

Brunswick Heads had concerns predominantly regarding Marshalls Creek Constriction at the conjunction with Brunswick River. All mitigation options suggested during the workshop had been investigated by the North Byron Floodplain Risk Management Study (2021), however all the options were observed to have limited alleviation for the North Byron Communities. The options raised for Brunswick Heads included:

- Brunswick Heads Rock Wall Removal / Lowering
- Brunswick Heads Dredging
- Brunswick River Training Wall Removal
- Combination options, with ocean openings, dredging and rock wall removal.

While the previous modelling was discussed several community members insisted further investigation. Key limitations of previous modelling included only the investigation of the 1% AEP event and 20m wide outfalls. It is suggested that further investigation explores flood mitigation benefit for more frequent events, or modification of outfall setup.

8 Options Review

8.1 Overview

From the reviewed of the studies detailed in the previous sections, many flood mitigation options for the North Byron Beaches/Townships have been assessed and are summarised into the below list and detailed in the following subsections:

1. Billinudgel Levee
2. South Golden Beach Levee Audit Recommendations
3. Dune Openings
4. Rock Wall Modifications
5. Removal of Brunswick River Training Wall
6. Marshalls Creek Dredging at Ocean Shores
7. Catchment Wide Drainage and Overland Flow Model
8. Debris Control Measures for Billinudgel Bridge
9. Ocean Shores Golf Course Weir Lowering
10. Billinudgel Infrastructure Improvements
11. Marshalls Creek Dredging, Dune Openings, Rock wall Modification and Kallaroo Circuit Bund Modification
12. Billinudgel Infrastructure and Billinudgel Levee
13. Develop Guidance on the design and installation of fencing traversing waterways and channels
14. Update Local Flood Plan Based on outcomes of the North Byron FRMS&P and collaboration between Council and the SES
15. Byron Shire Council and SES to consider learnings and recommendations from the North Byron FRMS&P (2020) in the development of the Flood Warning Network for North Byron
16. Raising River Street to provide 1% AEP flood Immunity and Investigating a location for a new Evacuation Centre near Gaggin Street or Terrace Street
17. Raising Wilfred Street to provide 1% AEP flood immunity
18. Identify key roads for the implementation of automated warning signs and depth indicators
19. Community engagement to prepare and ongoing flood education program (and appropriate evaluation system)
20. Assess raising eligible residential properties to reduce flood damages
21. Assess purchasing eligible residential properties to remove residents from high flood risk areas and reduce flood way obstruction

22. Changes to land use zoning should consider flood compatibility using outcomes from this report. Update flood hazard overlay based on the findings of the North Byron FRMS&P (WMA, 2020)
23. Revise Flood Planning Levels based on the findings of this study
24. Updated FPA based on the findings of the North Byron FRMS&P (WMA, 2020)
25. DCP updated based on recommendations of the North Byron FRMS&P (WMA, 2020)
26. Provide flooding info on Council's website, include up to date flooding info on future s10.7 (2) and (5) certificates requested
27. South Golden Beach Flood Pump Generator
28. South Golden Beach Flood Gate Upgrade
29. South Golden Beach and Fern Beach Flood Levee Upgrade
30. Investigate Flood Levee for Western South Golden Beach
31. Post Event Shire-wide Flood Planning Levels Review
32. Formation of a committee to oversee the completion of the FRMP
33. Investigation of illegal builds south of North Heads Road

8.2 Detailed Option Assessment

8.2.1 Billinudgel Levee

Item	Findings
Synopsis	This option proposes a Levee protecting the township of Billinudgel with several buildings currently at risk of flooding.
Potential Impacts	While Levees can be an effective flood mitigation option to protect a township, the design and construction often has considerable economic consideration. Additionally, while levees may render portions of townships flood free, levees typically elevate flood waters within the creek adjacent to the levee and potentially increasing water levels upstream due to the restriction in flow.
Coastal Impacts	This option is believed to have minimal effect outside flood events and any coastal impacts were considered negligible.
Key Constraints	The North Byron Floodplain Risk Management Study (2021) identified risks of residual overland flow flooding with modelling of a preliminary Levee design, this would have to be investigated further to assess drainage options for Billinudgel.
Potential Approval Pathways and barriers	While the North Byron Floodplain Risk Management Study (2021) indicated that the community are generally neutral about building flood levees in the North Byron catchment, it is believed that the construction and maintenance costs would be substantial.

Flood mitigation Effectiveness	The North Byron Floodplain Risk Management Study (2021), undertook the modelling of a Levee, the results indicated widespread reductions of peak flood levels of up to 0.38m in the area behind the levee with increases of water level up to approximately 0.05m within the waterway. However, flooding remained in that area due to overland flow from the southern catchment tributary.

8.2.2 South Golden Beach Levee Audit Recommendations

Item	Findings
Synopsis	In 2014 the NSW Department of Works undertook a visual audit of the South Golden Beach levee; this audit identified several recommendations for implementation which were predominantly linked to vegetation management and ongoing maintenance.
Potential Impacts	The recommendations to come out of the audit are believed not to cause immediate hazards for South Golden Beach, rather long-term deterioration of the levee.
Coastal Impacts	The maintenance of the South Golden Beach Levee is believed to have minimal coastal impacts
Key Constraints	While the North Byron Floodplain Risk Management Study recommended for these suggestions to be implemented, funding remains to be sought.
Potential Approval Pathways and barriers	Levees typically have low maintenance costs after implementation if properly and regularly maintained, it is not expected to be a substantial cost to implement the Audit Recommendations.
Flood mitigation Effectiveness	The items identified from the Audit are believed to have no immediate impact to flood hazard.

8.2.3 Dune Openings

Item	Findings
Synopsis	The North Byron Beaches have historically had dune openings, since the dune closures, several floods have occurred, and the flood mitigation options assessing dune opening/s have been subsequently investigated to relieve catchment flows upstream of Brunswick River.
Potential Impacts	While dune openings do relieve downstream catchment flows there are environmental and ecological considerations to consider, biodiversity impacts due to increased salinity, tidal inundation, and possible increase in siltation.

Item	Findings
Coastal Impacts	Dune openings have potential to cause significant short term coastline erosion over catchment events, and effects to longitudinal shoreline recession.
Key Constraints	Significant concerns of community include disruption to the community, ecological concerns and increased tidal propagation within the estuary. There are significant regulatory concerns and requirements in relation to clearing and works undertaken in a marine zone. All these concerns would have to be addressed before implementation.
Potential Approval Pathways and barriers	Further evidence through Sky Pumps investigations provide evidence of widespread potentially impactful benefit. Through further investigation as part of future overland flow path studies it is recommended to be investigated for impact to drainage networks.
Flood mitigation Effectiveness	Existing pre-liminary modelling has been undertaken by the North Byron Floodplain Risk Management study and plan, indicating limited reduction in peak water levels of approximately 0.05m at Brunswick Heads and 0.1m at Ocean Shores. However further options have been identified for consideration for catchment flood mitigation and further investigation of tidal inundation.

8.2.4 Rock Wall Modifications

Item	Findings
Synopsis	Major rock wall structures exist at the Brunswick River opening and at the Marshalls Creek Brunswick River junction. The rock walls are a hydraulic structure built up across a section of Marshalls Creek, which limits flow conveyance. A modification of these rock walls has been considered as a potential option to reduce flood risk.
Potential Impacts	By increasing conveyance into Brunswick River and immediately discharging catchment flows through the ocean outlet, it is believed to lower water levels at the rock walls and upstream of the rock walls. Coincident flooding from Brunswick River and Marshalls Creek may cause increased water levels and water velocity at Brunswick Heads, this would also need to be considered before implementation.
Coastal Impacts	Modification/Reduction of structure flow path blockage is believed to have an impact to sediment transport within Marshalls Creek, with expected higher velocities immediately upstream of the Rock Walls. It is also believed to have increased saline intrusion as coastal dominated events are expected to have improved conveyance as well, impacts to risks of breakthroughs is not considered as part of this

Item	Findings
	review.
Key Constraints	Rock wall modifications are expected to have significant financial considerations, ecological considerations as well as potentially significant community concerns. Modification of the rock walls will also have to consider Marine Estate legislation due to the increase in flow velocities into the opposite Brunswick Heads Boat Harbour.
Potential Approval Pathways and barriers	Potential approval could be sought through demonstration of improved flood mitigation from previously modelled scenarios. This could include improved rock wall DEM enforcement in the model, modelling of more frequent events, or modification of combined mitigation options, predominately modification of dredging options.
Flood mitigation Effectiveness	Preliminary modelling of rock wall modifications was undertaken by the North Byron Floodplain Risk Management Study and Plan (2020), however only the 1% AEP event was assessed, and it observed the rock walls were significantly overtopped during this event. More frequent events are expected to show a more significant flood risk mitigation due to the proportion of blockage compared to the flow conveyance.

8.2.5 Removal of Brunswick River Training Walls

Item	Findings
Synopsis	The removal of the Brunswick River Training Walls was proposed to better convey catchment flows.
Potential Impacts	As a flood mitigation option, the removal of the Brunswick River Training Walls is expected to increase conveyance of catchment through the river mouth. This has the potential to change outlet morphology and shoaling.
Coastal Impacts	Increased shoaling and morphological changes could result in an unexpected reduction of catchment discharge, which would also result in an increase in wave propagation into the estuary increasing the estimated wave setup height.
Key Constraints	Removal of the Brunswick River training walls is expected to have significant economic and community usage implications importantly the navigability, this is a major concern with a small Boat Harbour located immediately upstream. Additionally key fish habitat and marine estate legislation would have to be considered before implementation.
Potential Approval	Approval for the removal of the Brunswick River training walls is expected to be challenging with the limited flood mitigation benefit,

Item	Findings
Pathways and barriers	potentially increased tidal inundation risk and significant impact to navigability and morphology. These would all have to be addressed prior to the seeking approval.
Flood mitigation Effectiveness	The North Byron FRMS&P (2020) undertook preliminary modelling investigating the potential flood mitigation. Results indicated a minor reduction of catchment peak flood water levels. The study did not undertake a detailed assessment of tidal inundation, nor the changes of morphology on flood behaviour.

8.2.6 Marshalls Creek Dredging at Ocean Shores

Item	Findings
Synopsis	The dredging of Marshalls Creek was proposed to improve flow conveyance through Marshalls Creek extending from Billinudgel to Brunswick River
Potential Impacts	Dredging increases the flow conveyance of in bank flows, potentially reducing out of bank inundation.
Coastal Impacts	No identified coastal impacts were identified from the dredging of Marshalls Creek
Key Constraints	Upstream Marshalls creek, at Billinudgel, exists a bridge believed to hinder accessibility for dredging this is suggested to be investigated further if a modification to the proposed dredging option is considered.
Potential Approval Pathways and barriers	Approval for the Marshalls creek dredging option could be sought through demonstration of improved flood mitigation through modification of the modelling dredging approach or through demonstration of improved flood resilience through more frequent events.
Flood mitigation Effectiveness	While preliminary modelling was undertaken by the FRMS&P (2020), this modelling only undertook the modelling of the 1%AEP event, where the flood waters overtopped the creek banks significantly, resulting in minimal reduction in peak water levels of 0.05m. The flood mitigation effectiveness for more frequent events is unknown.

8.2.7 Catchment Wide Drainage and Overland Flow Model

Item	Findings
Synopsis	A large community concern was identified for North Byron of drainage and overland flow. The development of a catchment wide drainage and overland flow model is proposed and is currently pending grant approval.
Potential Impacts	The development of a detailed hydraulic model will improve understanding of overland flow behaviour at North Byron identifying hotspots for which further investigation can be undertaken. The development of the detailed hydraulic model also would allow further usage of the model to investigate other flood mitigation options.
Coastal Impacts	The development of this detailed hydraulic model would allow further investigation of tidal impacts, with increased wave setup into the estuary, which could be further used to assess mitigation options.
Key Constraints	The usage and adoption of this hydraulic model would be subject to validation and calibration results, as two recent comparable hydraulic models would exist, so substantial evidence would have to be supplied for reasoning of Council adoption.
Potential Approval Pathways and barriers	There are a number of grant opportunities for the region as a result of the flooding that occurred in 2022. Potential issues with assessing the overland flow is that residents may not appreciate their properties being identified as being within an overland flow path as it may result in increased insurance premiums and reduction in the viable uses of their property, which may reduce its value.
Flood mitigation Effectiveness	Community feedback indicates that the North Byron community experiences significant overland flow flood risk. Definition of the communities' overland flow flood risk would aid mitigation options appraisal and approval pathways.

8.2.8 Debris Control Measures for Billinudgel Bridge

Item	Findings
Synopsis	Billinudgel modelling results indicate a significant head loss experienced at the constriction of Billinudgel Bridge, leading to the proposal of debris control measures as a flood mitigation option. This option has a current grant for design phase.
Potential Impacts	This option would improve flow conveyance through Billinudgel believed to reduce peak water levels experienced at Billinudgel.

Item	Findings
Coastal Impacts	This flood mitigation option was not identified to have any significant coastal impact
Key Constraints	While debris control measures would increase flow conveyance the Billinudgel bridge piers block a portion of the creek cross section, so it is believed there will be consistent head loss at Billinudgel Bridge.
Potential Approval Pathways and barriers	A grant has already been approved for design phase; however further investigation of flood mitigation affects should be investigated.
Flood mitigation Effectiveness	While the North Byron FRMS&P undertook preliminary modelling of Billinudgel Bridge sensitivity to blockage, modelling results indicated a minor increase in flood levels (0.05). Several concerns were raised on review of the modelling methodology at Billinudgel, however as discussed in section 5, limiting the interoperability of the modelling results. Real world flood mitigation for blockage controls is unknown and is recommended to be investigated further.

8.2.9 Ocean Shores Golf Course Weir Lowering

Item	Findings
Synopsis	The option of the Ocean Shores Golf Course Weir Lowering was proposed to reduce peak flood levels
Potential Impacts	The lowering of the Golf Course weir was believed to have the potential to lower the peak flood levels by changing the flood behaviour at Ocean Shores.
Coastal Impacts	No coastal impacts were identified for this flood mitigation option
Key Constraints	The Golf Course Weir acts a dam for an upstream pond of the golf course, this would require approval for modification of private property.
Potential Approval Pathways and barriers	The lowering of the Ocean Shores Golf Course Weir is expected to be challenging due to the negligible modelled impact.
Flood mitigation Effectiveness	The North Byron FRMS&P undertook preliminary modelling of the Ocean Shores golf course weir lowering, results indicate a negligible impact to flood levels experienced at ocean shores with a reduction of 0.01m

8.2.10 Billinudgel Infrastructure Improvements

Item	Findings
Synopsis	Billinudgel infrastructure improvements was proposed to reduce flooding observed at Billinudgel. These improvements are aimed to be considered as part of the development of the Overland Flow Study.
Potential Impacts	Infrastructure improvements such as improved cross drainage and stormwater networks could result in a reduction of overland flood risk.
Coastal Impacts	No coastal impacts were identified for this flood mitigation option.
Key Constraints	Existing hydraulic structures at Billinudgel would either have to be replaced or improved for improved drainage infrastructure.
Potential Approval Pathways and barriers	Approval for Billinudgel Infrastructure improvements could be sought through detailed hydrodynamic modelling undertaken as part of the Overland Flow Study.
Flood mitigation Effectiveness	The North Byron FRMS&P undertook preliminary modelling of infrastructure improvements at Billinudgel indicating minor reduction of peak water levels with a maximum of 0.22m lowering at Wilfred Street. Flooding at Billinudgel experiences is sourced from major constriction caused from the Railway embankment and bridge, with the 1% AEP event overtopping the creek banks, infrastructure improvements at creek cross drainage are not observed to greatly improve flow conveyance.

8.2.11 Marshalls Creek Dredging, Dune Openings, Rock wall Modification and Kallaroo Circuit Bund Modification

Item	Findings
Synopsis	A combination of options were proposed as flood risk management options including dune openings rock wall modification and Kallaroo Circuit bund.
Potential Impacts	These options in combination have potential to increase conveyance through Marshalls Creek, reducing peak water levels
Coastal Impacts	This option has greatest coastal impact from dune openings, having potential to cause significant short term coastline erosion over catchment events, and effects to longitudinal shoreline recession.

Item	Findings
Key Constraints	Similarly, to the Dune openings option there is a significant concern of community disruption, ecological concerns and increased tidal propagation within the estuary. All these concerns and others related to the combination of flood mitigation would have to be addressed before implementation.
Potential Approval Pathways and barriers	While individual approval pathways could be sought for each mitigation option this could take a significant amount of time, a coincidental combination of mitigation options could be investigated for effectiveness and cost-benefit. A coincidental investigation like dredging and rock wall modification are believed to magnify flood mitigation effectiveness. Additionally, more frequent events could demonstrate that the out of bank inundation could be conveyed by the in-bank flow capacity with a combination of these mitigation options as the 1% AEP event well overtops the creek banks.
Flood mitigation Effectiveness	Preliminary modelling was undertaken of these of flood mitigation events, resulting in widespread flood mitigation benefit up to 0.15m at South Golden Beach, 0.06m at Ocean Shores and up to 0.08m in New Brighton, however only the 1% AEP event was modelled, which significantly overtops the creek banks. It is believed a more significant reduction of inundation extent could be observed for more frequent events.

8.2.12 Billinudgel Infrastructure and Billinudgel Levee

Item	Findings
Synopsis	A combination of the flood mitigation options including the Billinudgel Levee and Billinudgel Infrastructure upgrades were proposed to mitigate the overland flow flood risk for the areas behind the Billinudgel Levee.
Potential Impacts	While the Billinudgel Levee solely resulted in residual overland flow flooding, a combination of improved Billinudgel stormwater infrastructure was proposed to drain the overland flow and protect the township.
Coastal Impacts	No coastal impacts were identified for this mitigation option
Key Constraints	The Pacific Motorway as well as the residential area East and downstream of Billinudgel limit the drainage options for Billinudgel, as any options is to not adversely impact downstream or other urban areas.
Potential	The North Byron FRMS&P investigated the viability of these flood

Item	Findings
Approval Pathways and barriers	mitigation options, while the levee and infrastructure protected the buildings of Billinudgel, a more detailed investigation estimated that the option would result in a CBR of 0.58.
Flood mitigation Effectiveness	The North Byron FRMS&P undertook modelling of the Billinudgel Levee and infrastructure as a flood mitigation option, a widespread reduction of flooding in Billinudgel was observed with minor increases in flood levels ranging from 0.02-0.05 in Marshalls Creek. However, there are concerns of modelling methodology, see Section 2.7.6.

8.2.13 Develop Guidance on the design and installation of fencing traversing waterways and channels

Item	Findings
Synopsis	Fencing that traverses' waterways and channels are known to cause blockage, the development of guidance for the design and installation was proposed as a flood mitigation option.
Potential Impacts	Providing advice on fencing that traverses' waterways that results minimal blockage, allows greater flow to convey through channels.
Coastal Impacts	No coastal impacts were identified from this flood mitigation option.
Key Constraints	As this would be development of guidance and not policy, difficulty in enforcement or removal of inappropriate fencing would be a constraint.
Potential Approval Pathways and barriers	Identification of properties with fencing traversing waterways would assist in identifying of potentially interest properties which council could target to provide explanation and guidance on suitable fencing, sensitivity modelling could be undertaken for key properties to aid explanation of effects to property owners.
Flood mitigation Effectiveness	No modelling was identified as being undertaken it is suggested that sensitivity modelling runs could be undertaken as part of the Overland Flow Study.

8.2.14 Update Local Flood Plan Based on outcomes of the North Byron FRMS&P (2020) and collaboration between Council and the SES

Item	Findings
Synopsis	Recommendations were given for flood mitigation options in the North Byron FRMS&P, it was proposed for these options to be considered further for adoption by the Council and SES. These have subsequently been adopted with minimal modifications as part of Council's FRMP
Potential Impacts	Further investigations into mitigation options have been recommended by the study, as well as providing the best practice flood risk estimation for the North Byron Community as of present day.
Coastal Impacts	The existing coastal structures have been assessed for modification by this study as well as other coastal mitigation options including Dune openings.
Key Constraints	While this study undertook detailed modelling, it was not within the scope of the project to assess overland flow drainage and flooding. Some concerns of modelling methodology are discussed in Section 2.7.6.4
Potential Approval Pathways and barriers	While minimal hard structural mitigation options were recommended for further investigation, the study summarised a list of many mitigation options regardless of their effectiveness. The findings of this study can be used as evidence to educate the community that some of their preferred options aren't effective, whilst alternatives more effective and viable mitigation measures.
Flood mitigation Effectiveness	This flood study undertook widespread mitigation measures catchment wide. While improvements could be made to the investigations, the preliminary modelling undertaken has exhibited either flood mitigation effectiveness or inefficiencies, for many options during the 1% AEP event.

8.2.15 Byron Shire Council and SES to consider learnings and recommendations from the North Byron FRMS&P (2020) in the development of the Flood Warning Network for North Byron

Item	Findings
Synopsis	As the townships in North Byron are in lower portion of the catchment, it is believed that a flood warning network could be an effective response measure and is proposed as a mitigation option.
Potential Impacts	A flood warning network could reduce property and vehicular flood damages and population at risk during flood events.
Coastal Impacts	No coastal impacts were identified for this mitigation option

Item	Findings
Key Constraints	Flood warnings provided from the findings of the North Byron FRMS&P (2020) would be limited to the quality of the modelling in the flood study, as some concerns were raised over catchment lag in the hydrologic model, which a flood warning network is heavily reliant on.
Potential Approval Pathways and barriers	The development of the flood warning network was completed for North Byron as per the recommendation of the North Byron FRMS&P (2020)
Flood mitigation Effectiveness	As a great majority of buildings in the North Byron Community are located lower portion of the catchment and could potentially benefit significantly from a properly implemented flood warning network.

8.2.16 Raising River Street to provide 1% AEP flood Immunity and Investigating a location for a new Evacuation Centre near Gaggin Street or Terrace Street

Item	Findings
Synopsis	River Street was identified as an evacuation route for the township of New Brighton. Due to this the raising of River Street to provide 1% AEP flood immunity was proposed.
Potential Impacts	The raising of River Street for flood immunity would provide the residents of New Brighton an evacuation route to reduce risk of loss of life.
Coastal Impacts	No coastal impacts were identified for this flood mitigation option
Key Constraints	The North Byron FRMS&P (2020) modelling results indicate that the raising of River Street would result in localised increases of peak water levels.
Potential Approval Pathways and barriers	It is proposed that these impacts and design options be further investigated as part of the Overland Flow Study, and potential control measures to minimize impact.
Flood mitigation Effectiveness	While this flood mitigation option is estimated to raise local water levels at New Brighton, 13 properties were identified to experience above floor flooding with River Street being their only evacuation route.

8.2.17 Raising Wilfred Street to provide 1% AEP flood immunity

Item	Findings
Synopsis	With other mitigation options potentially changing the flood behaviour at Billinudgel, the raising Wilfred Street to provide the road with 1% AEP flood immunity was considered as a flood mitigation option to further increase resilience at Billinudgel.
Potential Impacts	While raising roads can hinder conveyance of overland flow increasing water levels, with adequate cross drainage, this mitigation option can result in a flood free evacuation route.
Coastal Impacts	No coastal impacts were identified for this flood mitigation option
Key Constraints	Raising Wilfred Street holds back overland flow drainage and is only recommended as a flood mitigation option in conjunction with other flood mitigation options. The existing drainage for overland flow runs North to Marshalls Creek immediately adjacent to Billinudgel, the raising of Wilfred Street is expected to exacerbate the overland flow inundation.
Potential Approval Pathways and barriers	Similar to the raising of River Street, this option could be considered in conjunction with other mitigation options such as the Billinudgel Levee, and drainage infrastructure improvements
Flood mitigation Effectiveness	The North Byron FRMS&P undertook preliminary modelling investigating the impacts of raising Wilfred Street, involving raising of Wilfred Street by 0.5m, while this did not provide 1% AEP flood immunity, the raising of 0.5m increased time available for evacuation during a flood event. This modelling resulted in widespread impacts of 0.05m and up to 0.2m increased water levels. This modelling did not incorporate improved drainage infrastructure to facilitate the raising, and it is believed improved drainage infrastructure would provide additional benefits for evacuation of Billinudgel.

8.2.18 Identify key roads for the implementation of automated warning signs and depth indicators

Item	Findings
Synopsis	North Byron experiences several flooded roads, which present a risk to life for motorists and pedestrians. It is recommended that the usage of road closures early notifications and creek crossing deterrents are used to discourage the crossing of floodwaters.
Potential Impacts	While this option does not improve flood behaviour several flooded roads were identified, where deterrents could be used to reduce attempts of crossing floodwaters.
Coastal Impacts	No coastal impacts were identified for this flood mitigation option.
Key Constraints	Two options were presented from the North Byron FRMS&P including automatic road closures/boom gates and automatic warning signs and depth indicators.
Potential Approval Pathways and barriers	The North Byron FRMS&P (2020) identified some key road crossing locations for consideration, where this mitigation option could be employed, a significant majority of these locations were for Mullumbimby, a few locations were identified for the Northern Beaches community including Orana Road, Shara Boulevard, Red Gate Road, New Brighton Road, Brunswick Street and The Pocket Road.
Flood mitigation Effectiveness	Floodwater crossing deterrents and indicators typically reduce risk to population, with identification of at-risk roads and crossings in North Byron this implementation could reduce flood risk in North Byron.

8.2.19 Community engagement to prepare and ongoing flood education program (and appropriate evaluation system)

Item	Findings
Synopsis	The North Byron community have indicated concern of the lack in local knowledge and understanding of flood risk. This was identified in many of the previous study surveys regarding drainage upgrades/maintenance and channel modification. A plan for community engagement and ongoing flood education program was suggested as an outlet for the community to express concerns of flooding in the local area, while also being educated on the potential options for flood mitigation in North Byron and the findings of previous studies.

Item	Findings
Potential Impacts	This mitigation option has several benefits including community awareness and preparedness for flooding, but also for increased opportunity for community expression and subsequent Council evaluation of options for further consideration.
Coastal Impacts	This mitigation option is expected to result in several community comments and feedback on coastal mitigation options.
Key Constraints	Many attempts at community engagement have been undertaken before including the North Byron Flood Study (2016) and the North Byron Flood Risk Management Study and Plan (2020), each of which indicating high community concern and lack in the level of understanding of mitigation option investigations, and the impacts.
Potential Approval Pathways and barriers	A community and stakeholder engagement plan is underway as part of this project.
Flood mitigation Effectiveness	Many potential outcomes are possible because of the community engagement plan including identification of investigation gaps, increased community flood risk understanding, increased flood preparedness and potential support for future flood mitigation options.

8.2.20 Assess the raising of eligible residential properties to reduce flood damages

Item	Findings
Synopsis	Many houses experience above floor flooding in North Byron, raising the floor level to above defined flood level was proposed to potentially reduce flood damages.
Potential Impacts	This mitigation option would result increasing flood resilience of many at risk properties adjacent to Marshalls Creek.
Coastal Impacts	No coastal impacts were identified for this mitigation option
Key Constraints	Many instances exists where house raising may not be viable, including, cost of house raising in comparison to relocation or building a new house, and community willingness.
Potential Approval Pathways and barriers	Further detailed assessment of properties viable for house raising can be undertaken to investigate approval pathways. Council has proposed this option as a part of the VHR/VHP scheme.

Item	Findings
Flood mitigation Effectiveness	House raising eligible properties would likely consist of properties adjacent creeks/major flow paths, whilst house raising for 1% AEP flood immunity results in a decrease of damages for events up to the 1% AEP. It results in a substantial increase for rarer events, or climate change considerations could be a residual risk to these properties. 20 properties were identified as potentially eligible for house raising in New Brighton, with an additional building in Billinudgel. It is recommended these properties be considered for detailed investigation of raising eligibility.

8.2.21 Assess purchasing eligible residential properties to remove residents from high flood risk areas and reduce flood way obstruction

Item	Findings
Synopsis	Many properties may be not viable for house raising due to extreme water levels, velocities, or material of building. Voluntary purchases involving the acquisition of high-risk flood affected properties was proposed to reduce the flood risk of these properties.
Potential Impacts	Voluntary house purchasing removes these properties from flood risk if the property is also rezoned to a use that can't be developed. It does however remove housing stock. Properties need to be fairly and consistently selected. Can lead to neighbourhoods having a gappy appearance as the uptake is voluntary.
Coastal Impacts	Some of these properties could be located adjacent to the coast, and the house purchasing of these properties could reduce coastal risk for North Byron simultaneously or provide further reasoning for voluntary house purchasing.
Key Constraints	As the house purchasing is voluntary a significant community education program would have to be pursued targeted to eligible properties of their flood/coastal risk. Significant funds required to purchase and remove buildings.
Potential Approval Pathways and barriers	The Byron Shire Council has indicated that this plan has had a Grant Submitted in May 2022, for further investigation of this program.
Flood mitigation Effectiveness	This mitigation option immediately removes properties from high flood risk areas, in attempt to relocate residents to lower risk areas and repurposes land use for North Byron to increase the communities flood resilience.

8.2.22 Revise Flood Planning Levels based on the findings of the North Byron FRMS&P (WBM 2020)

Item	Findings
Synopsis	Flood planning levels are used extensively for development and flood risk assessments. It was proposed that council update FPL to the recommendations of the North Byron FRMS&P.
Potential Impacts	As a result of the adoption of the new flood levels future development would be based on the revised flood planning levels. Decreasing overdesign and potentially increasing flood resilience of new developments.
Coastal Impacts	No coastal impacts were identified as part of this mitigation option.
Key Constraints	The updated flood planning levels are only used to control new developments, it is not within the scope of the DCP to control existing developments.
Potential Approval Pathways and barriers	Byron Shire Council has indicated that the flood planning levels have been updated to those recommended in the North Byron FRMS&P (WBM, 2020).
Flood mitigation Effectiveness	Development controls for new developments, provide resilient future developments and control impact to neighbouring and existing properties with best practices.

8.2.23 Changes to land use zoning should consider flood compatibility using outcomes from this report. Update flood hazard overlay based on the findings of the North Byron FRMS&P (WBM, 2020)

Item	Findings
Synopsis	The flood hazard zoning in North Byron was improved by the North Byron FRMS&P, changing defined flood levels for flood hazard overlays for the North Byron developers and community. This mitigation option was proposed to re-evaluate land use areas to aide development areas, and property purchase schemes.
Potential Impacts	Re-zoning land to land-uses that are appropriate for the flood classification provides the benefit that future development minimises additional people being placed in at risk areas.
Coastal Impacts	Flood planning areas in North Byron can be adjacent to coastal areas, changes to land use at coastal areas could result in potential changes for coastal hazards.

Item	Findings
Key Constraints	Changes to land use zoning, including community relocation have high community involvement and considerations. May include compensation to those affected by the changes (devaluing the property/reducing usage)
Potential Approval Pathways and barriers	The Byron Shire Council has indicated that the Land Use Zoning has been updated for flood compatibility in North Byron. Considerations for future studies including the planned Overland Flow Study, or implementation of flood mitigation options may result in changes to flood planning areas.
Flood mitigation Effectiveness	This flood mitigation measure exists primarily as a preventative measure for future developments, but also for consideration for existing developments.

8.2.24 Updated FPA based on the findings of the North Byron FRMS&P (WBM, 2020)

Item	Findings
Synopsis	The North Byron FRMS&P undertook review and improvement of the existing flood model developed by BMT in 2016, changing North Byron's design flood estimates. It was proposed that the council update flood planning areas based on the findings of the North Byron FRMS&P (2020).
Potential Impacts	Improvements to flood estimation and the resultant flood planning areas would assist in prioritising mitigation strategies and planning for priority areas.
Coastal Impacts	Changes to flood planning areas can coincide with coastal hazard areas, and potentially increase coastal hazards.
Key Constraints	The flood planning areas identified in the North Byron FRMS&P exclude coastal inundation modelling and might not represent all mechanics of inundation (Coastal, Catchment and Coincidental flooding). The North Byron region and specifically Marshalls Creek are coastal adjacent estuaries and could be sensitive to tidal conditions.
Potential Approval Pathways and barriers	The Byron Shire Council has indicated that the Flood Planning Areas have been updated in North Byron. Considerations for future studies including the planned Overland Flow Study, or implementation of flood mitigation options may result in change to flood planning areas.
Flood mitigation Effectiveness	The improved flood risk estimation further increases understanding of flood behaviour in North Byron, leading to greater confidence in designating planning zones and the design and assessment of mitigation options.

8.2.25 DCP updated based on recommendations of this North Byron FRMS&P (WBM, 2020)

Item	Findings
Synopsis	The Development Control Plan (DCP) provides guidelines to support the planning controls in the Local Environmental Plan developed by council. It was proposed to update the local DCP based on the findings of the review of the existing DCP within the North Byron FRMS&P (WBM, 2020). Suggested amendments included more detailed guidance on the principles of wet proofing, appropriate design and materials, with direct reference to available guidelines, a requirement for an assessment of property level protection as part of the DCP2014 planning matrix criteria and implement the recommendations regarding appropriate fil areas in the DCP2014.
Potential Impacts	The amendments proposed for the Byron Shire Council DCP, are aimed to improve community flood resilience, through guidance for new developments.
Coastal Impacts	No coastal impacts were identified for this mitigation option.
Key Constraints	While the suggested amendments improve flood resilience for future developments, it does not reduce flood risk for existing structures.
Potential Approval Pathways and barriers	Byron Shire Council indicates that the proposed amendments are partially complete and still ongoing.
Flood mitigation Effectiveness	The review of the DCP by (WBM, 2020) generally found the existing DCP consistent with current best practice, with the proposed amendments suggesting minor improvements to increase flood resilience and improve useability and guidance of the DCP.

8.2.26 Provide flooding info on Council's website, include up to date flooding info on future s10.7 (2) and (5) certificates requested

Item	Findings
Synopsis	Flooding impacts are widespread in the North Byron region, with several properties experiencing different and varying levels of flooding. It was proposed that council provide further detailed information regarding flood behaviour as property level flood information via an online, easy to access, GIS platform.
Potential Impacts	As flood behaviour varies property to property this platform would provide residents and home/business owners guidance of their flood risk specific to their property.

Item	Findings
Coastal Impacts	The implemented GIS platform provides catchment inundation for events up to the PMF extent, no mapping is provided for tidal inundation.
Key Constraints	This property level information is currently available for "flood prone areas" this information is provided as PMF inundation extents. While this is a conservative estimation of flood risk, it may benefit properties near the fringe of the PMF extent to observe more frequent events. Additionally, it is further recommended to assess community knowledge of this flood information portal.
Potential Approval Pathways and barriers	The Byron Shire Council have finished developing the online GIS platform for property level flood risk.
Flood mitigation Effectiveness	The mapping portal has provided property owners/dwellers a method to assess their flood risk, which may improve residents support for mitigation options, such as voluntary house raising/purchasing scheme. Additionally, for properties within the flood risk zone, residents become more aware of their flood risk potentially increasing the community's preparedness.

8.2.27 South Golden Beach Flood Pump Generator

Item	Findings
Synopsis	Residents west of Capricornia Canal are aware of the flood pump serving the area East of the Canal. It was proposed that a flood pump for the Residents on the West side of Capricornia Canal could benefit from an additional flood pump under Elizabeth Street.
Potential Impacts	Flood pumps provide improved floodwater drainage, however they would not protect West South Golden Beach from creek flooding from Marshalls Creek.
Coastal Impacts	No coastal impacts were identified as part of this mitigation option.
Key Constraints	The existing pump on the East side of Capricornia canal has a large drain used for the collection of stormwater directing a substantial volume to the central pump. The East of Capricornia canal has a smaller catchment of overland flow, and is expected to have reduced effectiveness.
Potential Approval	Further investigation of capability and storm water flood risk for residents West of Capricornia Canal could be undertaken to further

Item	Findings
Pathways and barriers	justify an additional flood pump. It is proposed to be investigated as part of the planned Overland Flow Study.
Flood mitigation Effectiveness	While a flood pump would reduce the risk of overland flow inundation, it could be investigated in conjunction with the Western South Golden Beach Levee investigation to provide additional flood risk immunity for the residents.

8.2.28 South Golden Beach Flood Gate Upgrades

Item	Findings
Synopsis	South Golden Beach experiences overland flow drainage to the Capricornia Canal. It was proposed that alternate solutions like flood gates with automated knife valve for full closure would increase the flood resilience of South Golden Beach.
Potential Impacts	An automated system for the flood gates could further ensure the protection of South Golden Beach from back water while maintaining overland flow drainage systems.
Coastal Impacts	No coastal impacts were identified from this mitigation option.
Key Constraints	No existing hydraulic model exists for identifying South Golden Beach's capacity for drainage and susceptibility for back water flooding
Potential Approval Pathways and barriers	It is recommended to use the findings of the planned overland flow study to help guide cost-benefit analysis due to the existing flood gates at South Golden Beach.
Flood mitigation Effectiveness	While no modelling has been undertaken to investigate potential operational controls, it is believed that operational controls could increase the resilience of the South Golden Beach township.

8.2.29 South Golden Beach and Fern Beach Flood Levee Upgrades

Item	Findings
Synopsis	It was identified that the levy was overtopped in the 2022 flood event. Subsequently it was proposed that a raising of this levee would be warranted.
Potential Impacts	Raising the levee could result in the protection of several properties behind the Levee in South Golden Beach, however it is known that levees typically increase water levels within the channel.
Coastal Impacts	No coastal impacts were identified as part of this mitigation option.

Item	Findings
Key Constraints	Raising this flood levee further would be a considerable financial cost, it is estimated that the existing level provides protection up to the 1% AEP event. While the levee provides protection for riverine flooding, it does not provide protection for overland flow.
Potential Approval Pathways and barriers	Byron Shire Council has indicated that it is currently under investigation by Public Works. Raising the flood levee to provide further protection beyond the 1% AEP event could be justified through a cost benefit analysis.
Flood mitigation Effectiveness	While raising the flood levee would provide further protection beyond the current design, similarly, increasing the design capacity overland flow drainage infrastructure to improve the flood immunity of the township.

8.2.30 Investigate Flood Levee for Western South Golden Beach

Item	Findings
Synopsis	A flood levee exists for the Capricornia Canal protecting residents east of the canal. However, it is observed that significant flood waters travel to the western side of the canal, and it was proposed a Flood Levee for Western South Golden Beach could reduce flood risk for the township.
Potential Impacts	A flood levee designed to provide flood immunity for flood events protects properties behind the levee, however levees often increase the flood waters in front of the levee. The inclusion of the western levee may reduce the level of protection that the existing eastern levee provides.
Coastal Impacts	No coastal impacts were identified as a part of this study.
Key Constraints	Flood levees are associated with a considerable financial cost, where few properties are currently observed to be impacted by the 100 year flood event from the modelling results developed by the North Byron FRMS&P (WMA, 2020).
Potential Approval Pathways and barriers	Modelling to be undertaken by the Catchment Wide overland flow study could result in different flood levels potentially further justifying the investigation of a flood levee for West South Golden Beach.

Item	Findings
Flood mitigation Effectiveness	As very few properties are observed to be impacted by the 1% AEP event is expected to have limited effect on the protection of properties for Western South Golden Beach, as it is unknown if the residents West of South Golden Beach experience significant overland flow flooding.

8.2.31 Post Event Shire-wide Flood Planning Level Review

Item	Findings
Synopsis	The CSIRO undertook post-event analysis for the Northern Rivers Region in the "Characterisation of the 2022 floods in the Northern Rivers Region. It was proposed to use the findings of this study, along with the MAYDAY Flood debrief held on 15th May 2022, with any additional region-specific information to review flood planning levels with the observed flood event.
Potential Impacts	By undertaking a post-event review of the unprecedented floods in 2022 and comparison to the flood planning levels, discrepancies could be identified and reviewed for observed rare flood behaviour and estimated design event rare flood behaviour.
Coastal Impacts	Identification of any extreme short-term erosion during the observed event could be an indication of erosion risks.
Key Constraints	As a significant time has passed since the event, flood markers and debris markers to indicate flood levels would be scarce. Community testimonials with supporting evidence of photographs could be a valid alternative. However, timing is a critical constraint to this option as community interest will dissipate over time.
Potential Approval Pathways and barriers	Understanding of the 2022 flood event could result in greater understanding of flood behaviour and increase potential for validation/calibration efforts for the development of the planned Catchment Wide overland flow study, and it recommended to be undertaken as part of the study.
Flood mitigation Effectiveness	An improved representation of extreme flood events by future flood studies from having well characterized event behaviour of the 2022 flood event could increase accuracy/confidence of future model results and any mitigation assessments.

8.2.32 Formation of a committee to oversee the implementation of the FRMP

Item	Findings
Synopsis	Many recommendations were made from the North Byron FRMS&P (WMA, 2020). It was proposed that a formation of a committee would better ensure progression and quality of works undertaken towards implementation of the recommendations.
Potential Impacts	Ensuring the progression of recommended mitigation options could result in improved timeliness of completion and comprehensive evaluation of works undertaken.
Coastal Impacts	Flood mitigations with potential of coastal impact could be further assessed from mitigation option implementation as part of this committee obligations.
Key Constraints	Further investigations are planned and are likely to result in further recommendations for flood mitigation options, notably the planned Catchment Wide overland flow study, the findings of this study could result in contradiction or identification of more effective flood mitigation options.
Potential Approval Pathways and barriers	Byron Shire Council has indicated that this has been completed.
Flood mitigation Effectiveness	The North Byron FRMS&P (WMA, 2020) undertook preliminary modelling to investigate many of these flood mitigation options, however, the preliminary modelling undertaken was limited to the 1% AEP event. Further modelling may be undertaken as part of the planned Catchment Wide Overland Flow Study to assess flood mitigation effectiveness.

8.2.33 Investigation of illegal builds south of North Heads Road

Item	Findings
Synopsis	Illegal builds were identified south of North Heads Road, further investigation of these builds is proposed to assess impact to flood behaviour.
Potential Impacts	Private builds typically go through development assessments, to raise any issues of flood behaviour impact including levees and fill pads.
Coastal Impacts	No coastal impacts were identified as part of this mitigation option.
Key Constraints	Further investigation of the illegal builds and their effect on flood behaviour will have to be investigated to identify constraints.

Item	Findings
Potential Approval Pathways and barriers	The removal of illegal builds is expected to have push back from the property owner, as the builds may increase flood resilience for the single property but may worsen downstream water levels.
Flood mitigation Effectiveness	The developments can be further investigated for flood mitigation by identification if the developments are outside the flood planning area, or above the flood planning level.

9 Summary

This review has identified several different mitigation options that have been assessed for their effectiveness and their cost to benefit ratios. Mitigation measures that have been suggested range from structural such as levees, dune openings, flood pumps, stormwater drainage upgrades and channel diversions, voluntary resumptions, planning scheme amendments and flood planning levels, to forecasting, flood warning and community education programs.

Council has implemented and is in the process of implementing several of the recommended measures. Measures that Council has already implemented include drainage and maintenance programs, flood forecasting and warning systems, updates to the planning scheme and the flood planning levels portal for individual property flood risk information.

Stormwater drainage has been identified as a major concern for flood risk in the North Byron region, it is recommended that future investigations consider flood risk sensitivity to near structural blockage of stormwater infrastructure, siltation blockage of bridges (Orana Road, and Billinudgel Bridge), to assist in developing priority maintenance plans for regular maintenance to avoid blockage induced flooding.

Many of the major capital works options which although were seen to be effective at mitigating flooding were not found to be cost effective and/or resulted in impacts to other areas. Numerous options were seen to reduce flooding from creek flooding but resulted in impacts due to overland flooding. Strong community support for further investigation/implementation has been observed from several previous community consultations and as that undertaken as part of this study, particularly for ocean outfalls. Further investigation through the North Byron Sky Pumps study has further quantified the localised impact for flood level alleviation and is recommended to be used to assist in community consultation. The Sky Pumps have been used to quantify the flow rates required to by potential ocean outfalls to reduce peak flood level by the designated amounts.

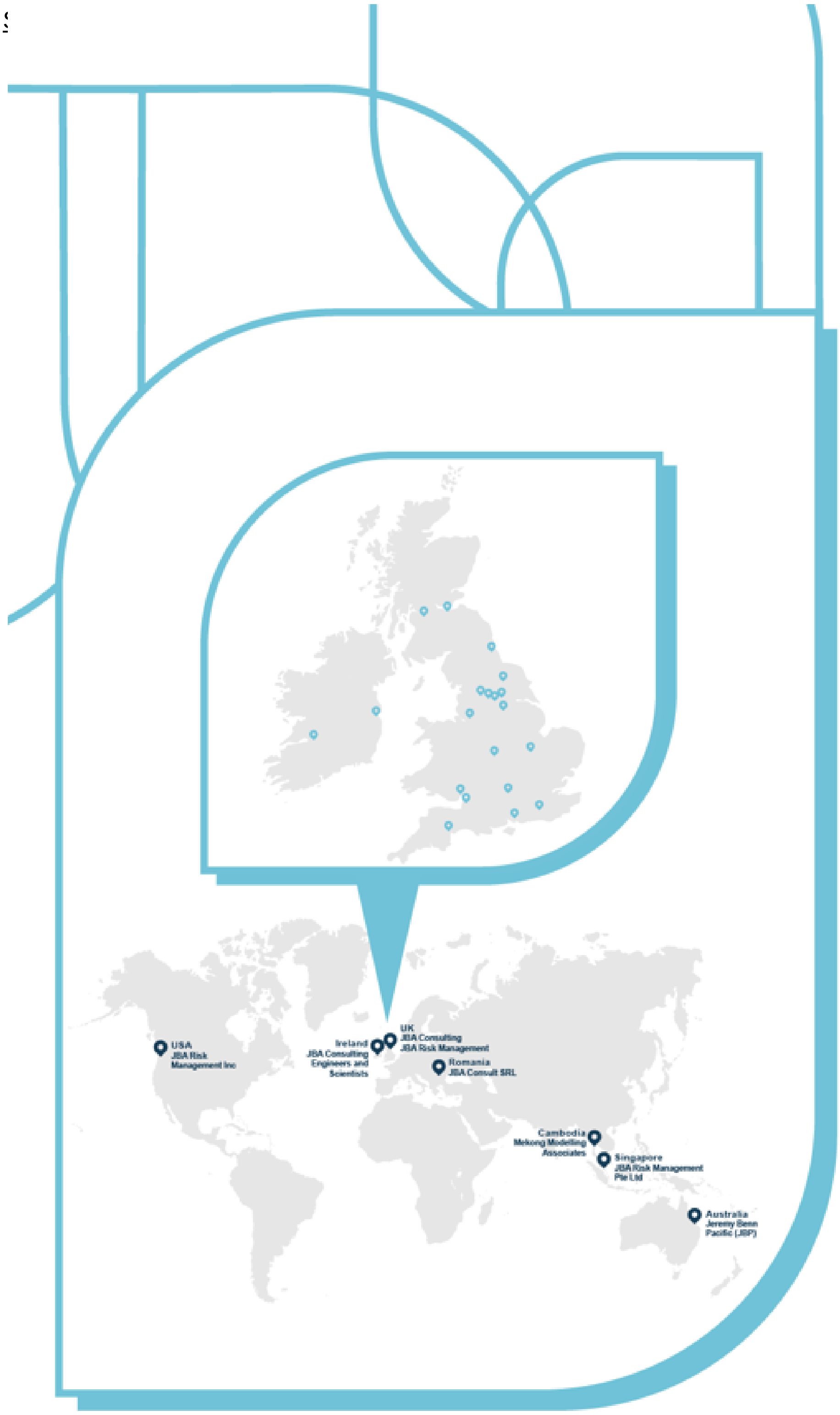
It is noted that any structural option that is found to provide a reduction to flooding is going to be subject to significant regulatory approval due to the environment that it will need to be constructed, as most of the North Byron region is nature reserve.

As has been identified during several studies the community has some awareness of flood mitigation and potential options, however technical understanding of the mechanisms and reasons why the options may or may not work and their effectiveness remains a challenge for the North Byron Community. As part of this project simplified examples and explanations of the key concepts needs to be provided to the community to improve their understanding and to enable them to relinquish their desire for measures that have been shown in the past to provide little to no effective reduction in flood risk. Many of the major structural options were observed to reduce peak water level but were not found to be cost effective and/or resulted in impacts to other areas.

There is strong community support for further mitigation option investigation and implementation, particularly for ocean outfalls, it is recommended for re-consideration for more frequent events than the 1% AEP subject to community tolerability.

The community has a strong desire to fix/alleviate nuisance flooding. This type of flooding occurs frequently and is regularly in the community's perspective. This can mostly be alleviated through improved drainage and maintenance of stormwater drainage systems.

It is noted that support for different structural mitigation measures can be varying across the region with certain areas being strongly for the mitigation and other areas being strongly against. The outfalls option was strongly suggested and recommended by parts of the community, while at the same time residents who lived nearest to the proposed outfall locations were seen to be against the option. Having a community that is significantly divided on whether a option should go ahead will likely mean that there will be significant rejection of the option even if it is shown to provide a benefit to the community.



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