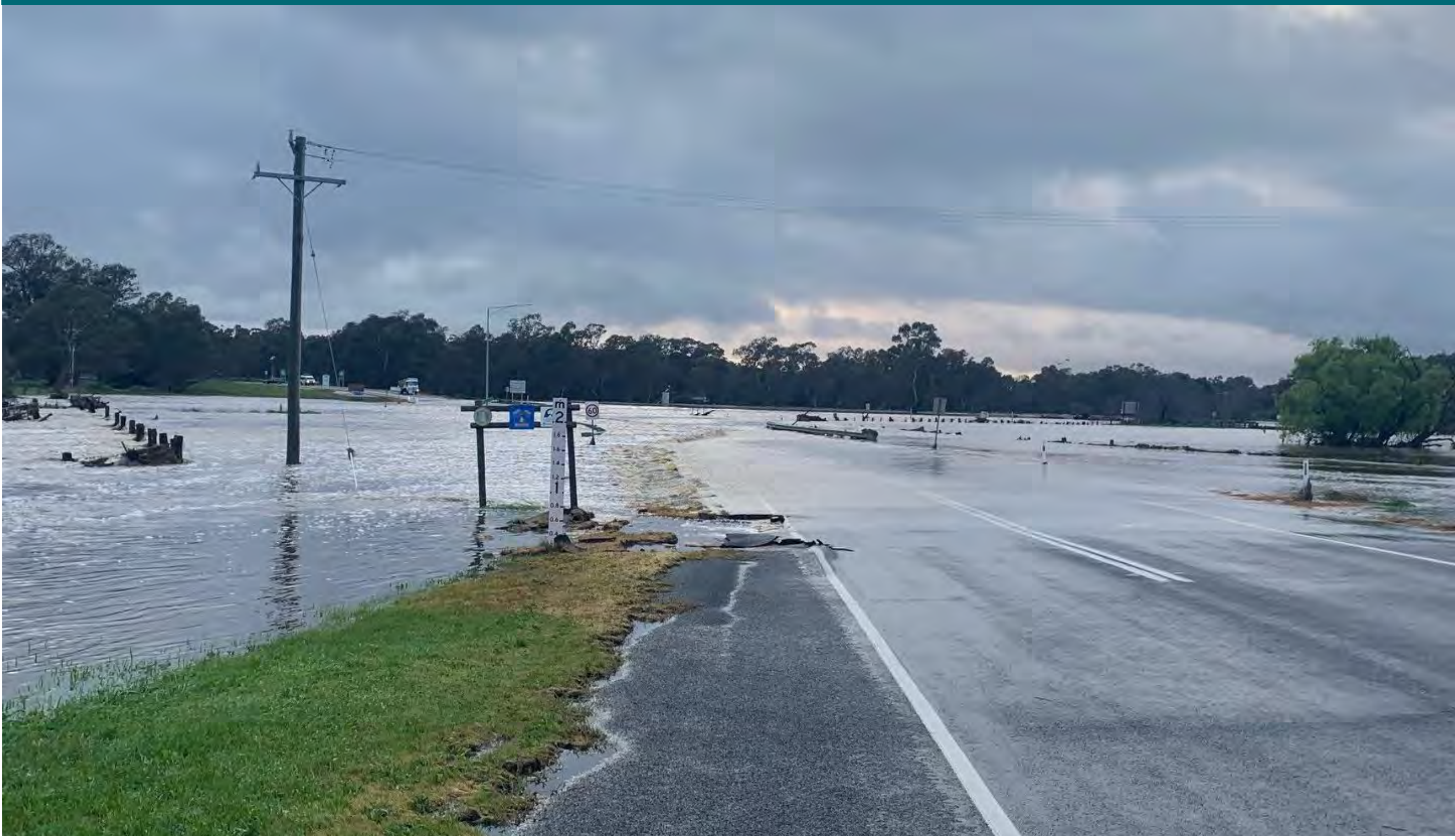
Attachment 9.4.2.1

Community Consultation Summary

Newstead Flood Study and Mitigation Strategy 2025



Project overview

Newstead has a history of flooding. Most recently, the town experienced flood events in 2000, 2010, 2011, 2016 and 2022. Therefore, Council is working with consultants Water Technology to carry out a flood study and develop a flood mitigation strategy for Newstead.

Newstead has an earthen levee that protects against flooding events similar to the size of the 2022 flood, however the characteristics of the levee are unknown, and no formal management arrangement of the levee exists, and future floods could breach the existing levee. In July 2025 Water Technology simplified the potential solutions and presented them to community as five mitigation options.

SHAPE Mount Alexander

Acknowledgement of Country

Mount Alexander Shire Council acknowledges that the traditional custodians of this land, the Dja Dja Wurrung and Taungurung peoples, proudly survive. We acknowledge their continued practice of custom and their close cultural, spiritual, physical, social, historical and economic relationship with the land and waters that make up their Country, which includes Mount Alexander Shire.

Council recognises the Victorian Government's Recognition and Settlement Agreements with both the Dja Dja Wurrung Clans Aboriginal Corporation and the Taungurung Land and Waters Council.

Engagement overview

The July - August 2025 Stage 2 community consultation received more than triple the engagement that the Stage 1 engagement received in 2024, showing an increase in community understanding of the Flood Study and a readiness to give input on the to the proposed mitigation options.

We did the following to engage the community:

We launched a Shape page which received 131 visits and 185 views. We ran an online survey, which received five responses over two weeks. We also presented to 36 community members at a community engagement session at Newstead Community Centre on Monday, 28 July 2025 (6pm-8pm).

We raised awareness of the project and the engagement activities in the following ways:

- letterbox drop to potentially flood-impacted Newstead residents
- text messages to previously registered flood-impacted Newstead residents
- vulnerable residents were approached directly with information and a flyer during a visit from Council's Home Support Program team
- ads in local newspapers and newsletters and social media posts
- posters and flyers in key locations in Newstead

> Five mitigation options were developed by consultants Water Technology and presented to the community.

Community Conversation

The Community Conversation was designed to be open, inclusive, and educative. The project consultants Water Technology presented a background on the flood study and the five options for mitigation.

A diverse group of residents took part, with the majority aged between 35 and 65 years old. Most participants were local to Newstead or the surrounding area, reflecting strong local interest and investment in the issue.

What we presented

- Information about the flood study and the five mitigation options
- Updated flood mapping following a 2024 community consultation
- A Q&A with Council staff, Water Technology staff and the North Central Catchment Management Authority

Flood mitigation options:

1. Vegetation removal
2. Raising the Newstead levee
3. Raising and extending the levee
4. Removing the Pyrenees Highway Bridge
5. Raising and extending the Newstead levee and vegetation removal

What we asked

- What are your ideas on how we can collectively reduce the impact of floods in Newstead?
- Which flood mitigation option do you think we should prioritise?
- What are your flood-related observations of this region?

Key themes

The following pages capture our community's ideas and hopes for the mitigation options. We have grouped the community feedback into key themes that emerged from the conversation, six areas of issues and opportunities, and five community priorities for consideration.

Key themes arising from the community discussion and online submissions

Option five (extending the levee and vegetation removal) was the most popular choice, however some concerns were raised:

- **Flooding risk to northern properties**: This option may increase flood risk for homes north of the current levee.
- **Access issues with option five:** Residents on Wyndham Street express concern about being cut off by the proposed levee extension.
- **Community-wide impact**: While option five is seen as the lowest risk for most of Newstead, it may disproportionately affect a few northern residents.

Alternative levee design and routing:

- **Lower-profile levee preference**: Residents north of Newstead-Maldon Rd request levees that are effective but not visually or physically dominating.
- **Modified levee alignment**: Suggestions include rerouting the levee along Hilliers Street (a paper road) and Council-owned gullies to avoid isolating properties.
- **Use of existing infrastructure**: Proposals to enhance the existing "mini levee" and explore cost-effective extensions using natural or council-built features.

Bridge and infrastructure modifications:

- **Bridge-induced flooding**: The 1990 bridge replacement is cited as a key factor in worsening flood conditions due to a "dam effect."
- **Proposed rectifications**:
  - Install culverts to restore original riverbank levels
  - Remove excess fill under the bridge to improve water flow
  - Upgrade the Muckleford bridge to maintain access to Castlemaine during floods

Key themes continued

Hydrological observations and historical context:

- **Vegetation removal**: Long-term residents note that clearing vegetation has led to erosion and faster, shallower water flows.

- **Climate change considerations**: Concerns that past flood modelling underestimated future flow increases due to climate change.

Evacuation and emergency access:

- **Transport continuity**: Suggestions to upgrade Green Gully Creek and install culverts along Pyrenees Highway to prevent pooling and maintain access to Maryborough.

- **Evacuation planning**: Calls for a designated assembly and helipad point for emergency response.

Cost and feasibility considerations:

- **Cost-effective alternatives**: Residents propose levee designs that reduce the need for service realignment and infrastructure changes.

- **Community-led proposals**: Emphasis on locally informed solutions that balance personal protection with broader town benefits.

> “From a whole community perspective, it appears that the least-risk option for the most people in Newstead lies with Option 5.”

Issues and opportunities

Levee design and property access:

Proposed levee extensions (especially Option 5) risk isolating homes and businesses, particularly at the north end of Wyndham Street and near the Newstead-Maldon Road.

Concerns about levee height being overly dominant and disruptive to landscape and access.

Community-informed levee alternatives:

Residents propose rerouting levees along Council-owned gullies and paper roads (e.g. Hilliers Street) to protect more properties and reduce costs.

Enhancing existing "mini levees" could offer targeted protection without major infrastructure changes.

Bridge and floodwater flow restrictions:

The 1990 bridge replacement has created a throttling effect, contributing to faster and higher floodwaters.

Accumulated fill and lack of culverts under the bridge exacerbate flooding, especially on the west side.

Bridge rectification and flow restoration:

Installing culverts and removing excess fill could restore natural riverbank levels and improve floodwater release.

These changes may reduce west-side flooding and align with earlier engineering recommendations.

Inadequate floodwater release and drainage:

Existing levee and bridge structures trap floodwater, creating a dam-like effect.

Poor drainage from Green Gully Creek and surrounding areas leads to pooling and transport disruption.

Integrated emergency access planning:

Upgrading key crossings (e.g. Muckleford Bridge) and improving drainage along Pyrenees Highway could maintain access to Maryborough and Castlemaine.

Designating safe assembly and helipad points could strengthen community resilience during flooding.

Community priorities

If we combine the key feedback themes with the issues and opportunities identified, some distinct community priorities emerge. These will help guide the project team and Council as they consider next steps.

1 **Protect northern properties without isolation.**
Residents north of Newstead-Maldon Road and Wyndham Street prioritise flood protection that does not isolate homes or businesses. They advocate for levee designs that maintain access and avoid cutting off communities.

2 **Model and consider community-proposed levee alternatives.**
There is strong interest in having Council formally model alternative levee routes proposed by residents - especially those using existing mini levees and Council-owned gullies - to assess their viability and cost-effectiveness.

3 **Rectify bridge infrastructure to improve water flow.**
Community members consistently call for culverts or similar modifications to the 1990 bridge structure to reduce the throttling effect and allow floodwaters to disperse more naturally, especially on the west side.

4 **Ensure emergency access and evacuation routes.**
Maintaining reliable transport routes during floods is a key priority. Suggestions include upgrading the Muckleford Bridge, improving drainage near Pyrenees Highway, and identifying safe assembly and helipad zones.

5 **Integrate environmental and historical insights into planning.**
Residents emphasise the importance of factoring in long-term observations - such as erosion from vegetation removal and underestimated climate impacts - into future flood modelling and levee design.

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Mount Alexander
Shire Council

Attachment 9.4.2.2

MOUNT ALEXANDER SHIRE COUNCIL

Gender Impact Assessment - Toolkit

Document Control

Date: 10 January 2024

Business Unit: Engineering

Name of Policy, Program or Service: Newstead Flood Study and Mitigation Strategy

GIA Version: 1.0

Authors Name: Arafat Hossain

TRIM No: DOC/24/1853

Arafat Hossain

Table of Contents

Part A - Context

Background

VICTORIAN GENDER EQUALITY ACT 2020

In 2020 the Victorian Government enacted the Gender Equality Act, the first of its kind in Australia. The Act was created out of a response to the 2016 Royal Commission into Family Violence and places a responsibility with the public sector such as Local Councils to promote and improve workplace gender equality.

The Act promotes gender equality by:

- Requiring the public sector, local councils and universities to take positive action towards achieving workplace gender equality.
- Requiring these organisations to consider and promote gender equality in their policies, programs and services.
- Establishing the Public Sector Gender Equality Commissioner to provide education, support implementation and enforce compliance.

REPORTING OBLIGATIONS UNDER THE ACT

The purpose of the Act is to encourage defined entities to apply a whole organisational approach to working towards gender equality.

There are three essential obligations under the Act, one obligation is to conduct gender impact assessments (GIA's) on policy, programs and services for the purpose of understanding, influencing and advancing gender equality.

GIA's seek to understand the external impact of an organisation by applying a comprehensive gender lens to policies, programs or services which have a direct and significant impact on the public that are in development or in review.

Objectives of the Gender Equality Act

- Promote, encourage and facilitate the achievement of gender equality and improvement in the status of women; and
- Support the identification and elimination of systemic causes of gender inequality in policy, programs and delivery of services in workplaces and communities; and
- Recognise that gender inequality may be compounded by other forms of disadvantage or discrimination that a person may experience on the basis of Aboriginality, age, disability, ethnicity, gender identity, race, religion, sexual orientation and other attributes; and
- Redress disadvantage, address stigma, stereotyping, prejudice and violence, and accommodate persons of different genders by way of structural change; and
- Enhance economic and social participation by persons of different genders; and
- Further promote the right to equality set out in the Charter of Human Rights and Responsibilities and the Convention on the Elimination of All Forms of Discrimination against Women.

Gender Impact Assessments

Who is this toolkit for?

The purpose of this framework is to help guide you through:

- Understanding what a GIA is and why they are important
- Understanding whether GIA's will be applicable in your role
- Determining whether a policy, program or service will have a direct and significant impact on the public
- Following the step-by-step guide to conducting a GIA

WHAT IS A GIA?

Gender Impact Assessment is a process of critical reflection, to analyse and assess how proposed policies, programs and services might be experienced, or affect women, men and gender-diverse people differently.

Mount Alexander Shire Council (MASC) is included as a defined entity under the Act, and is therefore responsible for meeting the reporting obligations stipulated within the legislation.

As a key part of the reporting obligations, MASC is required to incorporate GIA's into the regular process for developing and reviewing policies, programs and services.

Gender Impact Assessments seek to:

- Assess the effects that the policy, program or service may have on people of different genders.
- Explain how the policy, program or service will be changed to better support people of all genders and promote gender equality.

Intersectionality

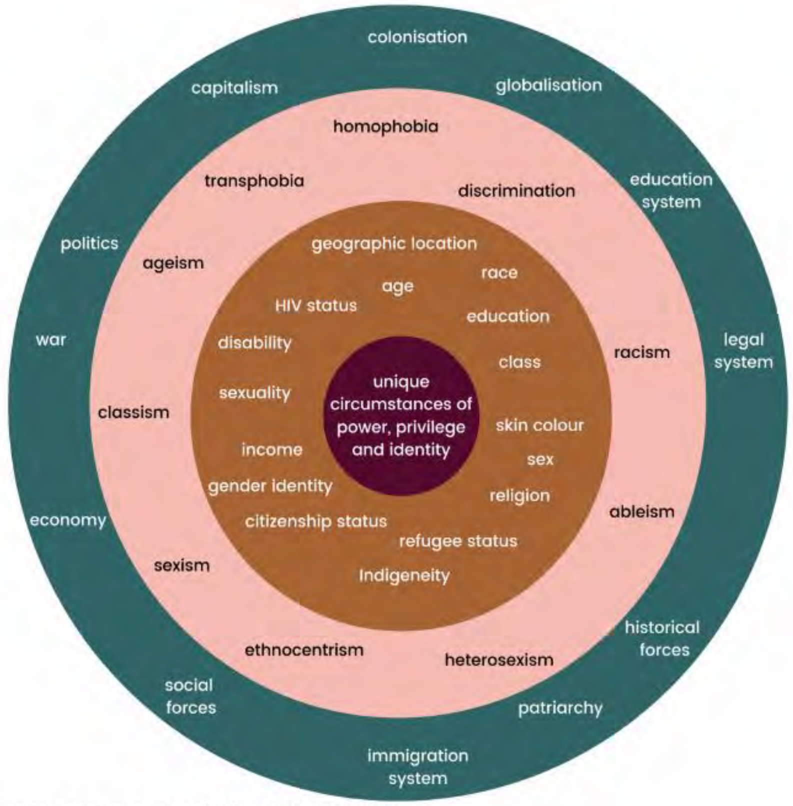
The *Victorian Gender Equality Act 2020* incorporates the concept of intersectionality in its consideration of gender equality. This reflects the reality that for many Victorians, gender inequality may be compounded by other forms of discrimination and cultural and structural oppression that a person may experience due to other characteristics. These characteristics include:

- Race
- Aboriginality and Torres Strait Islander
- Religion
- Ethnicity
- Disability
- Age
- Sexual orientation
- Gender identity

The Act requires organisations to consider these when developing strategies and measures to promote gender equality.

- Where practical, apply an intersectional approach to consider how gender inequality can be compounded by disadvantage or discrimination that a person may experience on the basis of other factors such as age, disability, gender, sexual orientation, geographical location, socio-economic background, cultural background or identify as Aboriginal or Torres Strait Islander.

This diagram shows how different factors that make up a person's life intersect with each other; one is not exclusive to each other.



Adapted from Intersectionality Wheel - Simpson 2009.

Part B – conducting GIA'S

GIA – Pre-screening

Use this section to determine:

- Whether you are likely to need to conduct GIA's regularly as part of your role AND;
- How to determine the overall impact on the public, and therefore needs to undergo a GIA.

DO YOU NEED TO CONSIDER GENDER IMPACT ASSESSMENT IN YOUR ROLE?

GIA's are applicable to any policy, program or service that may have a direct and significant impact on the public. You will need to consider conducting GIA's if you are responsible for:

a) Drafting internal policies, procedures and guidelines or programs where the primary focus of the policy, program or service is the public.

b) Responsible for developing, coordinating or delivering a council run program with the wider community i.e. Community Wellbeing's Social Support programs, Community Partnerships MONDO Lounge programs.

c) Delivering a service where the primary focus is the public i.e. Local Laws, animal registration services

DETERMING WHETHER THE IMPACT ON THE PUBLIC IS 'DIRECT AND SIGNIFICANT'?

Use the Matrix below to determine whether a selected policy, program or service has a direct and significant impact on the public. Based on your understanding of the policy, program or service, you will assign a score of 1, 2 or 3 to each factor to reflect the degree to which the public are impacted.

Refer to the Gender Equality Commission website and the 'Determining whether a GIA is required Guidance Note' for further explanation of the terminology 'Direct and Significant'.

FACTOR		Score		
		1	**2**	**3**
i. Target Audience	Will this policy, program or service indirectly or directly impact the wider community? (1= no impact, 3 = direct impact)			Y
ii. Number of people affected	How many people do you estimate will be impacted by this policy, program or service? (1 = 0-5, 3 = 50+)			Y
iii. Cost	What is the cost involved in implementing this policy, program or service? (1 = $0-$1,000, 3 = $50,000+)			Y
iv. Duration/time	What is the total duration of this policy, program or service? (1= one off/less than a day, 3 = ongoing)	Y		
	Total (out of 12)	10		

Based on the matrix above, you will have a total final score between 4 and 12:

TOTAL SCORE	GENDER IMPACT ASSESSMENT REQUIRED?	RECOMMENDATION
4 – 5	NO	Policy, program or service has an indirect and low impact on the community. No GIA is required.
6 – 9	Recommended	Policy, program or service has a direct and significant impact on the community. GIA is required.
10 – 12	YES	Policy, program or service has a direct and significant impact on the community. GIA is required.

Once you've completed the pre-screening matrix above, you'll be able to follow the step-by-step guide on the following pages to complete a GIA.

Conducting a GIA

Use the guide below to conduct a GIA of your selected policy, program or service. If you need any additional information or guidance at any point in the process, please contact People and Culture @mountalexander.vic.gov.au

The Gender Impact Assessment Template follow four key steps:

Step 1. Define the issues and challenge assumptions

Think about how women, men and gender-diverse people will be effected by the policy, program or service (PPS). Brainstorm the questions, discuss in a group to gain diverse ideas and views. Explore the issues, it can be open ended, it's a process to get you thinking.

- Important topics include the needs, preferences, perceptions and experiences of women and men, as well as differences in access, owing to cost, transport, safety, child-care and other matters.
- You may also consider the influence of age, ability, Indigenous status, culture, religion or other characteristics, as you might in planning any program.
- Finally, consider what evidence may be required to investigate these possibilities, including how women will be consulted in this process.

Discuss, ideally with your team:

- What is the purpose and objectives of the PPS?
- What is the issue the policy, program or service is trying to address?
- Who is the target audience, the 'end user'?

Think about how gender, and other inequalities, might shape the PPS.

- Consider how other factors influence and/or act as a barrier in the way people live.

Step 2. Understand your context

Collect evidence to understand how gender shapes the context. This step helps you undertake additional research on your GIA focus and gather evidence for any proposed changes to the policy, program or service.

Refer to pages 16-17 of the Gender Equality Commission templates and resources for a list of Victorian and National data sources.

Step 3. Options analysis

Develop an option for your policy, program or service and weigh up the gendered impact. *Is there a better way to do it that will benefit more people or meet a need not previously been met?*

Step 4. Make a recommendation

Make a recommendation based on the evidence collected and the analysis conducted that would improve the policy, program or service. *We need to do a, b, c, to achieve a greater outcome.*

Appendix 1

Gender Impact Assessment

STEP ONE: DEFINING THE ISSUES AND CHALLENGE ASSUMPTIONS

Question		Response
Title of policy/program/service:		Newstead Flood Study and Mitigation Strategy
Business Unit:		Engineering
Duration of policy/program/service:		16 Months
Purpose and Objectives	What is the purpose of this particular policy, program or service? Why is it needed?	Newstead has a history of riverine flooding. There is a complex relationship between multiple streams that requires detailed investigation to understand the potential risks and the different scenarios that may contribute to flooding at Newstead. This project will include a full flood study and assessment of mitigation options for Newstead.
	Who is the target group/end user, for this policy, program or service?	Newstead community and particularly currently impacted residents.
	Who will be impacted by this policy, program or service beyond the target group?	Stakeholders Including: • NCCMA • Djarra • DEECA • GMW • BOM • DTP • VIC SES • Coliban Water • Mount Alexander Shire Council
	How have those who are impacted (directly and indirectly) by the policy, program or service been included in the design or decision making?	A Project Steering Committee (PSC) has been formed to oversee the project which includes representatives from all stakeholders. The community will have multiple input opportunities provided at different stages of the project to gain feedback from the local community and directly impacted residents.

	What barriers might limit women, men, gender-diverse people from accessing, benefitting and using this policy, program or service?	The major barrier is ensuring all members of the community have an opportunity to contribute and comment on the outputs and actions from the study. In previous studies there has been limited representation or only the highly vocal members Emergency access/egress needs maybe a barrier considered The outcomes and options from the study will also need to accommodate the needs of the impacted community.
	What actions could be taken to remove those barriers?	The community engagement plan needs to ensure
	How will this policy, program or service impact those who are gender diverse?	There flood study program will not impact gender diverse people. The study will provide the same benefits for all in the community.
Considering Intersectionality	How will this policy, program or service impact those who identify as Aboriginal or Torres Strait Islander?	There is no different impact on Aboriginal or Torres Strait Islander people from this flood study project. A cultural heritage assessment will be undertaken if any structural improvement/ relocation of the levee is required to be done as part of the flood mitigation process. If required a Cultural Heritage Management Plan will also be completed, this will manage any cultural heritage impacts.
	How will this policy, program or service impact those who might have disabilities, are from different cultural identities, ages, sexual orientations or religion?	Rescue of people with disabilities and people of some age groups are always challenging during any flood event. Implementation of mitigation options found through this study will mitigate the impact of flooding on such vulnerable group of people.
	How will this policy, program or service impact people who live in the urban environment (in town) compared to living remotely or are isolated?	Improved flood mitigation strategy will provide greater benefits/impacts for the overall Newstead community. Improvement of flood levee structure will provide better protection for the urban community in Newstead.
	Considering intersectionality, what additional needs might there be for people who experience gender inequality alongside other forms of discrimination?	No additional needs are identified for these groups.
	What action can be taken to address these needs?	No actions required.

Focus Area	**What will you focus on in your assessment to support a more gender equitable outcome for the end user and community?**	The focus will be on ensuring the project outcomes meet all standards and are appropriate for the location.

STEP TWO: RESEARCH AND CONSULTATION

Question	**Response**
What information is available to help you understand the above issues in more depth?	Previous Investigation Report, Risk Assessment, Design Report, Councillor Briefing, Survey data, historical flood events, Customer complaints and Grant Funding Agreements.
What did the internal data, desktop research, consultation and engagement tell you?	A comprehensive flood study and research on flood mitigation options is required.
Have you consulted with the affected target groups? (If not, please explain why not).	Multiple consultation will be undertaken during the flood study project. However, the community members are informed about the project and also invited to participate in the Project Steering Committee (PSC).

STEP THREE: OPTIONS ANALYSIS

Question	**Response**
Based on the information in Step One and Two, what are your options for helping mitigate, or reduce the gendered and/or intersectional impacts of the policy, program or service?	No issues have been highlighted and no mitigation options are required.
What are the benefits associated with this particular option?	Not applicable
What are the costs (if any) associated with this particular option?	The flood study and mitigation research work will cost $170,000
Overall gender impact Score your option using the guide below to determine if the option has a positive, neutral or negative overall gender impact.	2 This project aims at improved and sustainable flood management strategy for overall Newstead community.

-5 -4 -3 -2 -1 0 1 2 3 4 5

NEGATIVE GENDER IMPACT

Reinforces traditional gender roles/norms

Reinforces privilege to genders already privileged in this area

Doesn't level the playing field

Doesn't create any new opportunities for access and inclusion

Doesn't consider gender inequality alongside other forms

NEUTRAL GENDER IMPACT

Does not appear to support gender inequality/equality

POSITIVE GENDER IMPACT

Considers the different needs of different genders and diverse groups to support a more fair and inclusive community.

Works to remove barriers to gender equality and deliberately tries to level the playing field.

Actively promotes equality for those experiencing gender

STEP FOUR: RECOMMENDATIONS

Question	Response
Based on the steps above, what is your final recommendation?	The flood study and mitigation option assessment to be completed as part of the strategy to make Newstead safer during coming flood events.

Final Checklist

Once a complete GIA has been applied to your policy, program or service, complete the checklist below and then please send a copy of your completed GIA to People and Culture @mountalexander.vic.gov.au with the subject format: GIA – policy/program/service title – Unit:

Have you:	Yes	No	Comment
Challenged your own assumptions and identified gaps in gender knowledge? (Step One)	✖	☐	Helped to identify the factors that might have impacts on different genders.
Worked with your team to identify who is likely to be impacted by this policy, program or service and what gendered factors might influence the way different community members are impacted? (Step One)	✖	☐	Inputs taken from team members
Conducted desktop research and analysed gender disaggregated statistics to investigate how issues of gender, cultural identity, ability, sexual orientation, gender identity, age or religion might shape how your policy, program or service is implemented or experienced? (Step Two)	✖	☐	Conducted
Undertaken collaborative approaches to consultation and engagement to understand access to, and experience of the policy, program or service and/or co-design a solution? (Step Two)	✖	☐	Undertaken
Develop an option or options for your proposed policy, program or service that improves the gender-related benefits and costs? (Step Three)	✖	☐	Options developed
Made a recommendation with rationale for your approach which considers how your recommendation meets the needs of people of different genders; addresses gender inequality; and promotes gender equality? (Step Four)	✖	☐	Recommendation provided
Do you recommend any further work to be undertaken in steps one, two or three? If so, what?	☐	✖	
Do you support the recommendation made?	✖	☐	To improve gender impact of this project

Name of Unit: Engineering

Name of lead officer: Arafat Hossain

Names of other officers involved in GIA: Kerrie Eldridge, Paul Diss

GIA completion date: 12/01/2024

Appendix 2

GLOSSARY OF KEY GENDER TERMS AND CONCEPTS

The following section contains key terms and concepts you may come across in conducting a GIA, or seeking to gain a more nuanced understanding of gender equality.

We acknowledge that Gender Terms and Concepts are constantly evolving and the key terms outlined here are not exhaustive.

Source: *Safe and Strong*, A Victorian Gender Equality Strategy, Safe and Strong Victorian Gender Equality Definitions and *Educating for Equality – Glossary of Terms and definitions* , Our Watch, Educating for Equality – Glossary of Terms and definitions

Gender: The socially-constructed differences between men and women, as distinct from 'sex', which refers to their biological differences.

Gender-based violence – Violence that is used against someone because of their gender. It describes violence rooted in gender-based power inequalities and gender-based discrimination. While people of all genders can experience gender-based violence, the term is most often used to describe violence against women and girls, because the majority of cases of gender-based violence are perpetrated by men against women.

Gender diverse – People who are gender diverse are those whose gender expression differs from what is socially expected. This includes individuals who identify as agender (having no gender), as bigender (both woman and man) or as non-binary (neither woman nor man). There is a diverse range of non-binary gender identities such as gender-queer, gender neutral, gender fluid and third gendered. Language in this space is still evolving and people may have their own preferred gender identities that are not listed here, and these preferences should be respected.

Gender equality: The equal rights, responsibilities and opportunities of women, men and trans and gender-diverse people. Equality does not mean that women, men and trans and gender diverse people will become the same but that their rights, responsibilities and opportunities will not depend on their gender.

Gender equity: Entails the provision of fairness and justice in the distribution of benefits and responsibilities on the basis of gender. The concept recognises that people may have different needs and power related to their gender and that these differences should be identified and addressed in a manner that rectifies gender related imbalances.

Gender inequality – The unequal distribution of power, resources, opportunity, and value between people of different genders and sexualities, due to prevailing gendered norms and structures.

Gender identity – A person's innate, deeply felt psychological identification of their gender, which may or may not correspond to the person's designated sex at birth. Many terms may be used to self-describe gender identity (see LGBTIQ+ and gender diverse). A person's gender identity may be different from their biological and physiological sex or sexual orientation and may change over their lifetime.

Gender norms and structures: Ideas about how people should be and act according to the gender they are assigned or identify with. We internalise and learn these 'rules' early in life. This sets up a life-cycle of gender socialisation and stereotyping.

Gender roles – Functions and responsibilities expected to be fulfilled by women and men, boys and girls within society or culture.

Gender stereotypes: Simplistic generalisations about the gender attributes, differences and roles.

Intersectionality: A methodology of studying the overlapping or intersecting social identities and related systems of oppression, domination, or discrimination.

Intersex: This refers to the diversity of physical characteristics between the stereotypical male and female characteristics. Intersex people have reproductive organs, chromosomes or other physical sex characteristics that are neither wholly female nor wholly male. Intersex is a description of biological diversity and may or may not be the identity used by an intersex person.

LGBTIQ+ – An acronym used to describe members of the lesbian, gay, bisexual, trans, intersex, queer or questioning community. It is sometimes used to include allies or supporters of the LGBTIQ+ community. Other acronyms used to describe this community include LGBTIQ, or LGBTIQA+.

Sexual harassment – Unwelcome sexual advances, requests for sexual favours or other unwelcome conduct of a sexual nature that makes a person feed offended, humiliated or intimidated. Sexual harassment can be physical, verbal or written. It is not consensual interaction, flirtation or friendship, or behaviour that is mutually agreed upon. Under the Sex Discrimination Act 1984 (Cth), sexual harassment in Australia is unlawful.

Sex – The biological and physical characteristics typically used to define humans as male or female. A person's sex does not mean they have a particular gender identity or sexual orientation.

Sex and gender discrimination – Treating, or proposing to treat, someone unfairly because of their sex or gender. In Australia, it is against the law to treat people unfairly on the basis of their sex, sexual orientation, gender identity, intersex status, marital or relationship status, pregnancy and breastfeeding, and caring responsibilities.

Sexism – Discrimination based on gender, and the attitudes, stereotypes and cultural elements that promote this discrimination. Sexism refers to the language, attitudes, behaviours, and conditions that create, support or reinforce gender inequality. Sexism can take many forms, such as jokes or comments, sexual harassment, or sex discrimination. It can be perpetrated by individuals or embedded within the structures and systems of institutions and organisations.

Sexual violence – Any sexual activity that occurs without free and informed consent. It refers to a broad range of sexual behaviours that make a person feel uncomfortable, intimidated, frightened, or threatened. It includes any time a person is forced, coerced or manipulated into any unwanted sexual activity, such as touching, sexual harassment and intimidation; forced marriage; trafficking for the purpose of sexual exploitation; image-based abuse; sexual assault and rape.

Sexual harassment can include: •comments about a person's private life or the way they look • sexually suggestive behaviour, such as leering or staring • brushing up against someone, touching, fondling or hugging • sexually suggestive comments or jokes • displaying offensive screen savers, photos, calendars or objects • repeated requests to go out, requests for sex, sexually explicit emails, text messages or posts on social networking sites, and • sexual assault.

Sexual orientation – A person's sexual or emotional attraction to others. People express their sexuality in different ways. A person's sex or gender does not mean they have a particular sexual orientation, and vice versa.

• A lesbian woman is attracted to other women.
• A gay person is attracted to people of the same gender as themselves.
• A *bisexual* person is attracted to people of their own gender and other genders.
• A *heterosexual* or 'straight' person is attracted to people of the opposite gender to themselves.
• An *asexual* person does not experience sexual attraction, but may experience romantic attraction towards others.
• A *pansexual* person is attracted to people of all genders, binary or non-binary.
• *Queer* is an umbrella term for diverse gender or sexualities. In the past, queer was used as a discriminatory term and can be offensive to some people, particularly older LGBTIQ+ people. The term has been reclaimed in recent years and is increasingly used by people to describe themselves in an empowering way.
• *Questioning* is used as an umbrella term for people who are still exploring or questioning their gender or sexual orientation. People may not want to have other labels applied to them yet but may want to be clear that they are non-binary or non-heterosexual.

Transgender — An umbrella term referring to people whose gender identity and/or expression is different from cultural expectations based on the sex they were assigned at birth. A transgender person may identify specifically as transgender or as male or female, or outside of these categories. Being transgender does not imply any specific sexual orientation. Transgender people may identify as heterosexual, gay, lesbian, bisexual, pansexual, queer, or in other ways. Also often abbreviated to 'trans'.

Quotas: Quota systems have been viewed as one of the most effective special measures or affirmative actions for increasing gender equality in participation. There are now 77 countries with constitutional, electoral or political party quotas for women. In countries where women's issues had always been relegated to the lowest priority, increases in the number of women in decision-making positions help move women's agendas up to a higher priority level.

Attachment 9.4.2.3

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Newstead Flood Intelligence Documentation

Newstead Flood Study and Mitigation Strategy (M1751-2023)

Mount Alexander Shire Council

5 December 2025

Document Status

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V01	Draft	Lachlan Inglis	Lachlan Inglis	08/05/2025
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Project Details

Project Name	Newstead Flood Study and Mitigation Strategy (M1751-2023)
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ACKNOWLEDGEMENT OF COUNTRY

The Board and employees of Water Technology acknowledge and respect the Aboriginal and Torres Strait Islander Peoples as the Traditional Custodians of Country throughout Australia. We specifically acknowledge the Traditional Custodians of the land on which our offices reside and where we undertake our work. In particular, we recognise the Dja Dja Wurrung People as the Traditional Custodians of the waters and lands on which this project is based.

We respect the knowledge, skills and lived experiences of Aboriginal and Torres Strait Islander Peoples, who we continue to learn from and collaborate with. We also extend our respect to all First Nations Peoples, their cultures and to their Elders, past and present.

Artwork by Maurice Goolagong 2023. This piece was commissioned by Water Technology and visualises the important connections we have to water, and the cultural significance of journeys taken by traditional custodians of our land to meeting places, where communities connect with each other around waterways.

The symbolism in the artwork includes:

- *Seven circles representing each of the States and Territories in Australia where we do our work*
- *Blue dots between each circle representing the waterways that connect us*
- *The animals that rely on healthy waterways for their home*
- *Black and white dots representing all the different communities that we visit in our work*
- *Hands that are for the people we help on our journey*

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GLOSSARY

Annual Exceedance Probability (AEP)	Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded; it would occur quite often and would likely be relatively small magnitude. A 1% AEP flood has a low probability of occurrence or being exceeded; it would be fairly rare but it would likely be of extreme magnitude.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Recurrence Interval (ARI)	Refers to the average time interval between a given flood magnitude occurring or being exceeded. A 10 year ARI flood is expected to be exceeded on average once every 10 years. A 100 year ARI flood is expected to be exceeded on average once every 100 years. The AEP is the ARI expressed as a percentage.
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Design flood	A design flood is a probabilistic or statistical estimate, being generally based on some form of probability analysis of flood or rainfall data. An average recurrence interval or exceedance probability is attributed to the estimate.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from elevated sea levels and/or waves overtopping coastline defences.
Flood frequency analysis	A statistical analysis of observed flood magnitudes to determine the probability of a given flood magnitude.
Flood hazard	Potential risk to life caused by flooding. Flood hazard combines the flood depth and velocity.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Flood storages	Those parts of the floodplain that are important for the temporary storage, of floodwaters during the passage of a flood.

Geographical information systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Intensity frequency duration (IFD) analysis	Statistical analysis of rainfall, describing the rainfall intensity (mm/hr), frequency (probability measured by the AEP), duration (hrs). This analysis is used to generate design rainfall estimates.
LiDAR	Spot land surface heights collected via aerial light detection and ranging (LiDAR) survey. The spot heights are converted to a gridded digital elevation model dataset for use in modelling and mapping.
Peak flow	The maximum discharge occurring during a flood event.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Average Recurrence Interval.
Probable Maximum Flood	The flood that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in a particular drainage area.
RORB	A hydrological modelling tool used in this study to calculate the runoff generated from historic and design rainfall events.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.
Topography	A surface which defines the ground level of a chosen area.
TUFLOW	A hydraulic modelling software package used to undertake modelling using hydrological modelling inputs.

1 INTRODUCTION

1.1 Overview

Water Technology was commissioned by Mount Alexander Shire Council (MASC) to undertake the Newstead Flood Study and Mitigation Strategy. The project is funded by the Disaster Ready Fund and the Victorian Government. The investigation covers the study area presented in Figure 1-1.

Newstead is a small township in Victoria, located 15 km west of Castlemaine on the banks of the Loddon River. Located within MASC and the North Central Catchment Management Authority (NCCMA) management area, Newstead was established in the mid-19th century as a river crossing point and today hosts a population of approximately 800 people.

The Loddon River catchment upstream of Cairn Curran Reservoir was included in a RORB hydrology model prepared as part of the Cairn Curran Dam Hydrology report[1] prepared by SKM. This model was refined for the catchment upstream of Guildford during the NCCMA Rapid Flood Risk Assessment[2]. The SKM model was calibrated to three events from 2010 and 2011. Given the age of the SKM model and that the Guildford model only covers part of the catchment upstream of Newstead, a new hydrology model was produced for the current study. However, parameters adopted for the previous models were considered for model validation. This study will produce flood intelligence information for use in emergency management, assess the current flood impact/exposure in terms of annual average damages caused by flooding in Newstead, investigate structural and non-structural mitigation options and make recommendations for establishing a flood warning system for the town.

This report is one of a series documenting the outcomes for the Newstead Flood Study. Each reporting stage is shown below:

R01 – Data Review and Validation Report – Final version published 20 August 2024

R02 – Hydrology Report **–** Final version published 31 October 2024

R03 - Draft Hydraulic Modelling Report – Final version published 13 December 2024

R04 – Final Hydraulic Modelling Report – Final version published 3 April 2025

R05 - Design Modelling and Mapping Outputs – Final version published 3 April 2025

R06 – Flood Intelligence Documentation – This report

R07 – Flood Damage and Structural Mitigation Options – Final version published 5 December 2025

R08 – Final Project Report – Final version published 5 December 2025

This report details the hydraulic model build and calibration process undertaken as part of the study.

1.2 Objectives and outputs

The Newstead Flood Study and Mitigation Strategy outputs are required to meet several floodplain management objectives as highlighted in the project brief prepared by MASC. The objectives of the investigation are described below:

[1] SKM, 2012 Cairn Curran Dam: Flood Hydrology Update
[2] HARC, 2020 Guildford Rapid Flood Risk Assessment - North Central CMA Region, prepared for North Central CMA

- Undertake hydrologic and hydraulic modelling to determine flood levels and flood extents for the full range of flood events up to and including the Probable Maximum Flood (PMF).
- Calibrate models to historic flood events including the October 2022 flood event.
- Investigate modelling of climate change scenarios.
- Assess the feasibility of a range of potential mitigation options including understanding of the level of protection provided by the existing levee and information to inform necessary upgrades to this levee.
- Analyse the feasibility of establishing effective flood warning, accounting for time available between rainfall and the township flooding, in the context of a total flood warning system.
- Update flood intelligence to be incorporated into the Municipal Flood Emergency Plan.
- Provide recommendations to update the Planning Scheme and ensure it is informed by the best available flood information.

1.3 Study area

The main flood risk in Newstead is posed by the Loddon River, a levee was constructed in the 1920's that is still protecting the eastern portion of the township from Loddon River flooding. However, a number of smaller catchments generate runoff towards Newstead directly or indirectly, resulting in complex hydrologic and hydraulic conditions to address in planning and emergency response. These catchments include Mia Mia Creek, Muckleford Creek, Larni Barramal Yaluk, Green Gully and Green Gully Creek as shown in Figure 1-1. Additionally, there are several tributaries joining the Loddon River near Newstead further impacting river levels.

Newstead most recently experienced flooding in October 2022, causing flooding to parts of the township located on the western side of the Loddon River. Flooding in Newstead has historically caused levee breaches which were mitigated by sandbagging during the flood event. Flooding of the Loddon River also leads to the town being isolated when major traffic routes are cut off. The Loddon River at Newstead has been subject to considerable physical and ecological modifications due to extensive historic mining activities and other anthropogenic influences since European settlement. In recent years, bank erosion has been an issue for landholders adjacent to the Loddon River.

1.4 Flood intelligence and MFEP deliverables

The tender document sets out the following flood intelligence and warning products to be delivered as part of the Flood Intelligence and Warning Report:

- Flood/No flood tool – rainfall intensity and flooding indicator.
- Flood peak calculator – river gauge level correlations.
- Flood peak travel time calculator/warning time available.
- Modelled/calibrated hydrographs at gauging stations.
- Prepare draft documentation for insertion into the Mount Alexander Flood and Storm Emergency Plan (MFSEP), this includes:
  - Flood intelligence card
  - Property and road inundation tables, mapping and data (inundation depth and time) for all properties and roads impacted by flooding.
  - Proposed updates to other outdated information in the MASC MFEP relating to Newstead (Appendix A, B and C)

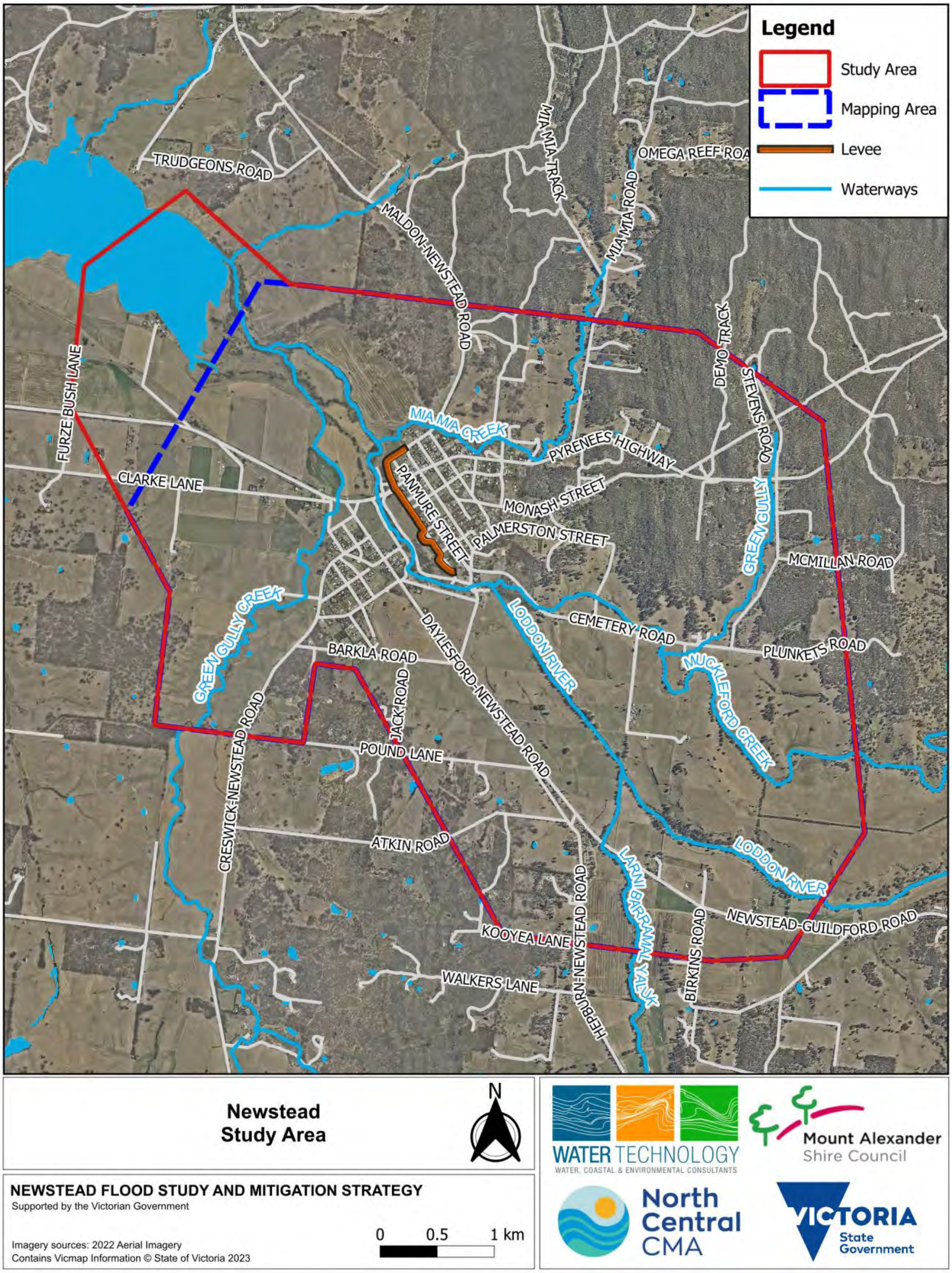


Figure 1-1 Newstead study area

2 CATCHMENT AND FLOOD BEHAVIOUR

2.1 Flood behaviour

The Loddon River originates in the Great Dividing Range within the Hepburn and Mount Alexander shires, flowing north until Vaughan where it turns in a westerly direction towards the township of Newstead. Upstream of Newstead, the Loddon River is joined by several tributaries including Campbells Creek, Larni Barramal Yaluk, Muckleford Creek, Green Gully, Green Gully Creek and Mia Mia Creek. Flooding in Newstead is primarily caused by the Loddon River, but localised flood events can cause flooding along any of the tributaries. The eastern portion of the Newstead township is located behind a levee bank.

When the Loddon River floods, widespread breakouts from the river channel and tributaries are observed in the 20% AEP event inundating farmland upstream and downstream of the township and the Pyrenees Highway is overtopped by Green Gully Creek. The flood behaviour is similar in the 10% AEP event.

The Newstead levee is overtopped in the 5% AEP event, with flood levels up to 0.5 m observed inside the levee. For the 2% AEP event, the flooding behind the levee causes flooding above floor at 80 properties and large areas of Newstead become isolated/inaccessible.

Note that all intelligence data presented in this report has been produced based on the near-term climate change considerations for the year 2030 (based on the Shared Social Pathway SSP5 scenario).

2.2 Rainfall and streamflow gauges

2.2.1 Streamflow gauge monitoring network

Four active streamflow gauges are located within the Upper Loddon Catchment with water level and streamflow data available to the present date. The four streamflow gauges information is displayed in Table 2-1 and shown in Figure 2-1. The streamflow gauges located upstream of Newstead may be useful in predicting flooding at Newstead, however it is noted that they are located relatively close to Newstead and that there are a number of ungauged catchments which contribute to flooding in Newstead, including Mia Mia Creek and Green Gully Creek. The Bureau of Meteorology (BoM) do not provide a quantitative level of service at the Newstead gauge. Any warning information is likely to be qualitative or general in nature and may reference the Flood Class Levels at the site.

Table 2-1 Streamflow gauges in the Upper Loddon catchment

Station Name	Distance From Newstead	Station No.	Period of Record
Loddon River at Newstead	0.0 km	407215	1973 - current
Loddon River at Vaughan DS Fryers Creek	14.4 km E	407217	1967 - current
Muckleford Creek at Muckleford	12.6 km N	407300	1993 - current
Larni Barramal Yaluk at Yandoit	11.4 km S	407221	1973 - current

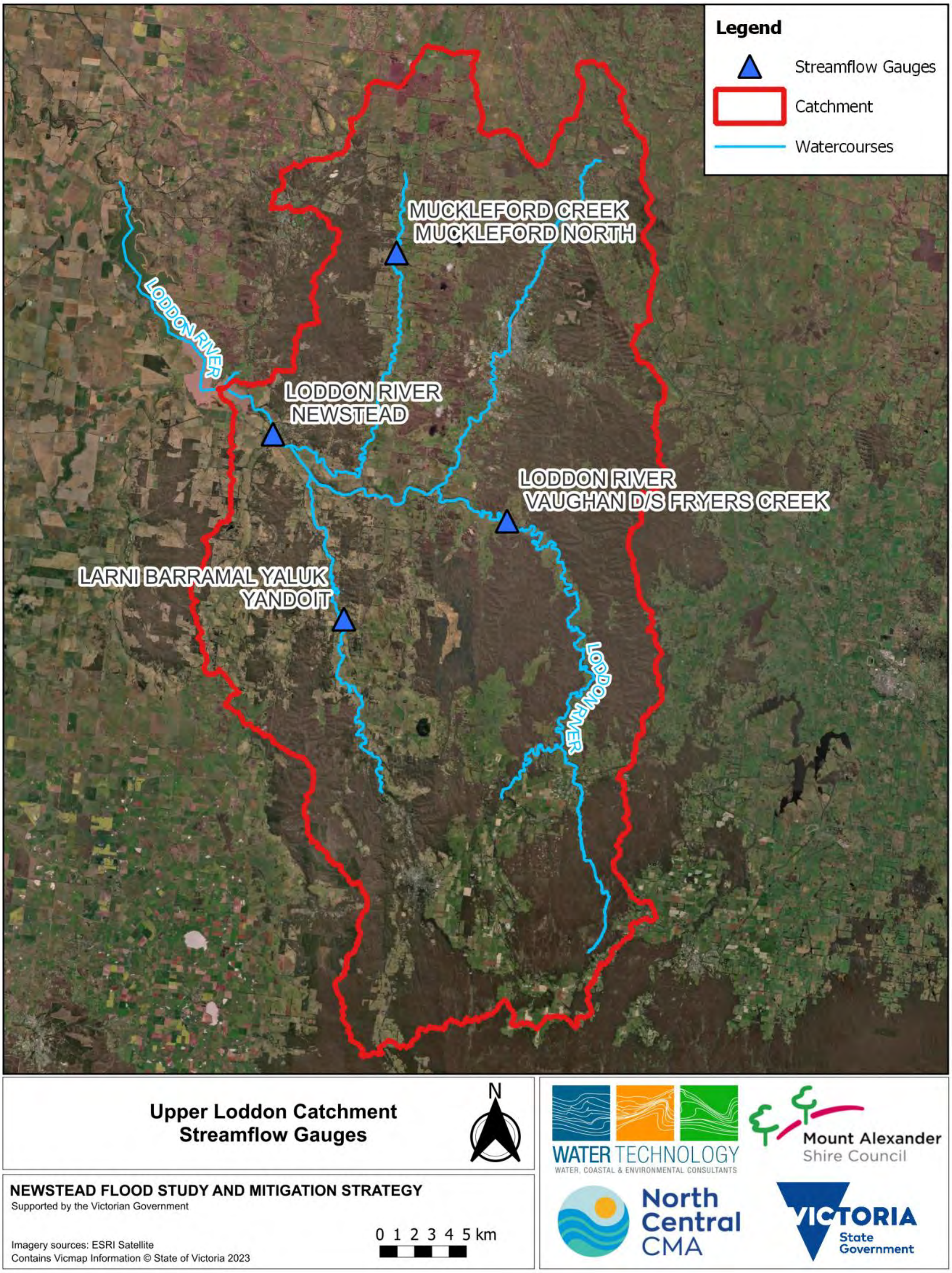


Figure 2-1 Streamflow gauges in the Upper Loddon catchment

2.2.2 Rainfall gauge monitoring network

Given the proximity of the streamflow gauges to Newstead and subsequently, the limited travel time from the upstream gauges, and the presence of ungauged catchments upstream of Newstead, predicting the likely magnitude of flooding in Newstead is reliant on the real time rainfall gauge network and rainfall forecasts. In some events, warning times may be too short for monitoring of streamflow to be of any use as a means of issuing early flood warning.

The currently active rainfall gauges within and in proximity to the Loddon River catchment upstream of Newstead are shown in Figure 2-2. These gauges are useful for predicting floods in Newstead and are summarised in Table 2-2. Three (3) of the available daily gauges, also record sub daily rainfall, typically every 6 minutes. These are the Bendigo Airport, Ballarat Aerodrome and Redesdale weather stations. These gauges are also highlighted in Figure 2-2.

Table 2-2 Active rainfall station information

Station Name	Dist. From Newstead	Station No.	Start
Newstead	0.6 km NE	088048	1897
Joyce Creek	6.1 km NW	088032	1907
Eberys	10.7 km SW	088021	1913
Maldon (Stump Rd)	13.6 N	088161	2005
Vaughan	14.0 km SE	088108	1958
Cairn Curran Reservoir	15.4 km NW	088009	1949
Castlemaine Prison	16.1 km E	088110	1966
Smeaton (Blampied (Bardia))	26.1 km SW	088113	1968
Daylesford	27.2 km SE	088020	1867
Malmsbury Reservoir	29.3 km SE	088042	1872
Creswick	37.6 km SW	088019	1949
Woodstock-On-Loddon	38.3 km N	081100	1970
Redesdale (sub-daily)	40.3 km NE	088051	1903
Glen Park (White Swan Reservoir)	46.9 km S	089048	1953
Bendigo Airport (sub-daily)	47.4 km NE	081123	1991
Ballarat Aerodrome (sub-daily)	50.6 km SE	089002	1960
Eppalock Reservoir	50.9 km NE	081083	1965

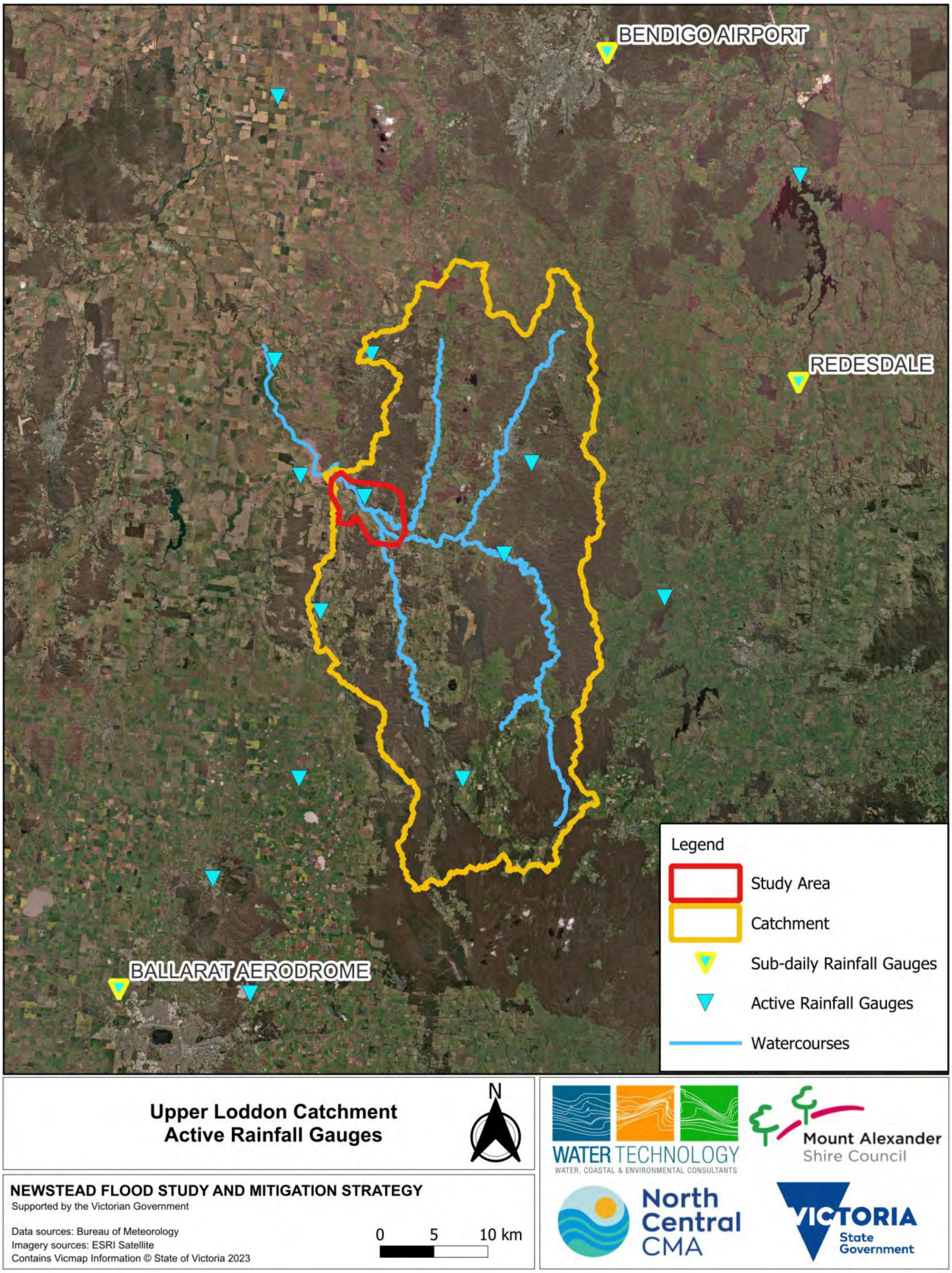


Figure 2-2 Daily and sub-daily rainfall stations near the study area

2.3 Historic floods

Newstead has a long history of flooding since European settlement in the 1850s. The current Newstead Local Flood Guide (developed by the SES) lists records of historic floods occurring in 1890, 1909 and 1934. Additionally, investigations of historic news articles identified significant flood events in Newstead in 1870, and 1916.

More recently, Newstead experienced significant flood events in 2000, 2010, 2011, 2016 and 2022. The recent flood event in 2022 is well documented and noted as the largest flood on record at the Loddon River at Newstead gauge. Table 2-3 details the total storm rainfall and duration at the Newstead rainfall gauge and the recorded flood level at the Loddon River gauge, together with an estimated flood magnitude.

Table 2-3 Total rainfall, peak flood level and associated flood event

Flood Event	Rainfall (Newstead)		Peak Flood Level (Loddon River at Newstead)	Approximate Flood AEP
	Rainfall (mm)	Duration (days)		
November 2010	123.6	4	5.60	20% - 10%
January 2011	180	6	5.90	10% - 5%
September 2016	124.2	10	5.70	20% - 10%
October 2022	68.8	3	6.12	5% - 2%

Several photographs taken during the 2010, 2011, 2016 and 2022 events collected by NCCMA, council and community members were used as of the calibration process, with a selection presented in Figure 2-3 to Figure 2-6 to highlight key roads and areas of the town which may be impacted in a flood event.

Figure 2-3 Pyrenees Highway west of the Loddon River, facing west, 1535 hours on 13 October 2022.

Figure 2-4 Brandt St/Hepburn-Newstead Rd intersection, captured at around 1400 hours on 14 September 2016.

Figure 2-5 Newstead residents sandbagging the Loddon River, January 2011

Figure 2-6 Intersection of Hepburn-Newstead Road and Pyrenees Highway, September 2010

2.4 Flood peak travel time

Definitive information on the time it takes for flooding to develop (i.e. to arrive at a location) following the onset of heavy rain and the time it takes for the flood peak to be reached is highly variable. The magnitude and timing of a flood is dependent on several factors including the attributes of the rainfall/storm event and antecedent conditions. Flood peak timing for all gauges within the Upper Loddon River catchment was assessed against existing gauge data to identify the time from the onset of heavy rainfall to develop an understanding of lag times from rainfall to gauge rise and catchment travel times.

Table 2-4 shows the typical travel time along the Loddon River and its tributaries, based on the flood events in 2022, 2016, 2011 and 2010. The rainfall temporal pattern and storm duration or the combination of both can impact the magnitude of flooding at Newstead. The table highlights that reliance on upstream gauges provides limited warning time, and that more warning time can be provided by monitoring rainfall gauges within the catchment.

Table 2-4 Timing of peak flow at Newstead

From	To	Typical travel time
Start of rainfall (catchment)	Start of Loddon River rising in Newstead	11 hours to 4 days
Start of Loddon River rising in Newstead	Peak Loddon River level at Newstead	11 to 54 hours
Peak Loddon River level at Vaughan	Peak Loddon River level at Newstead	0 to 5 hours
Peak Muckleford Creek level at Muckleford	Peak Loddon River level at Newstead	2 to 5 hours
Peak Larni Barramal Yaluk level at Yandoit	Peak Loddon River level at Newstead	0 to 6 hours

Additionally to analysing gauge data from historic events, the calibrated hydrology model developed as part of this study was utilised to estimate typical flood peak travel times. The modelled hydrographs at the Loddon River at Newstead gauge for the 1% AEP and 10% AEP rainfall events are shown in Figure 2-7 and Figure 2-8. The graphs show all modelled AEP events for durations between 12 hours and 168 hours for all ten temporal patterns, A total of 100 hydrographs were produced for each AEP. Also shown on the graphs is the critical duration and median temporal pattern peak flow at this location, selected in accordance with the recommendations of ARR.

The graphs show a significant range in peak flows and timing produced by rainfall depths of a specified AEP when that rain falls over different durations and temporal patterns within the duration. This illustrates the difficulty in accurately predicting flood peaks and timing from rainfall alone.

The graphs show that the modelled flood peaks can manifest around **10 to 20 hours** from the start of intense rainfall, with the majority of events peaking between 12 hours and 3 days from the start of the rainfall burst. Some events peak beyond 3 days from the start of rainfall, however these become rarer and may contain "embedded bursts" where rainfall intensity within an event increases for a short period of time.

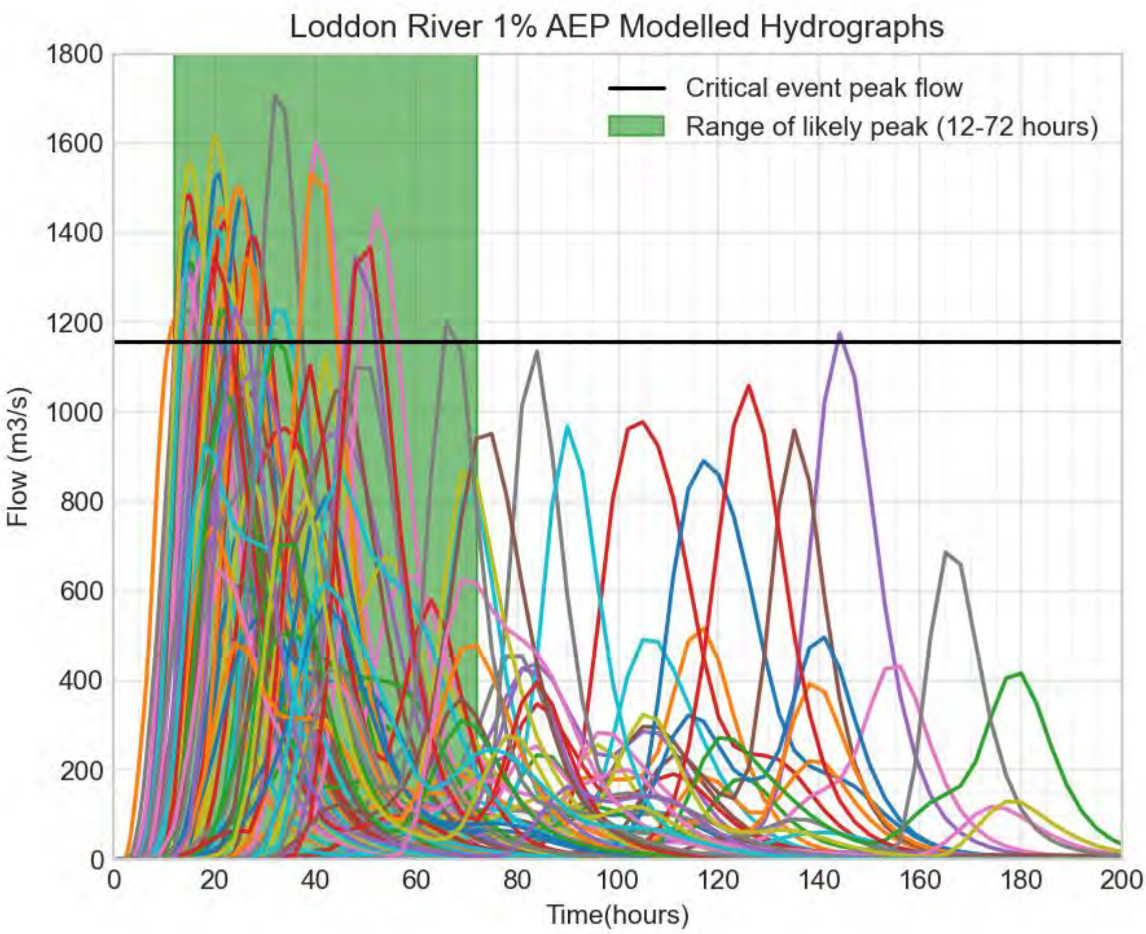


Figure 2-7 1% AEP hydrograph for all modelled rainfall events at Newstead

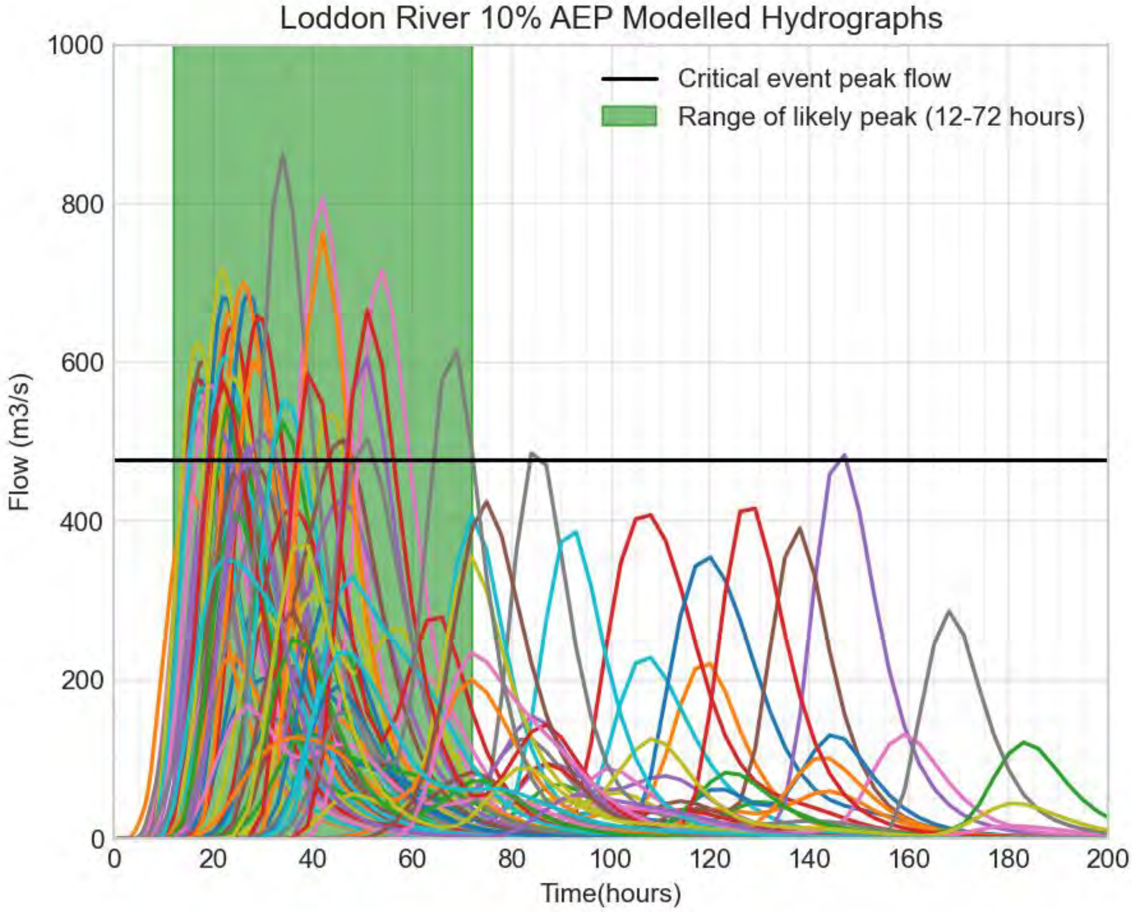


Figure 2-8 **10% AEP hydrograph for all modelled rainfall events at Newstead**

The lack of sub-daily rainfall gauges within the catchment increases the difficulty to estimate rainfall-runoff response times. However, the sub-daily rainfall stations located close to the catchment shown in Figure 2-2 can be monitored as an indicator to direct flood response activities.

The speed a flood travels along a waterway is largely dependent on antecedent conditions and the magnitude of the flood. A flood on a 'dry' watercourse will generally travel more slowly than a flood on a 'wet' watercourse (e.g. the first flood after a dry period will travel more slowly than the second flood in a series of floods).

In large floods, often water levels will rise reasonably quickly initially as flow predominately travels along the channel. The flood peak travels through the catchment a little slower as flow now spreads out on to the floodplain.

A range of factors including recent flood history, soil moisture and forecast weather conditions should be considered when using the following information to direct flood response activities.

The reality that a community at risk can be inundated before the peak of the flood should not be overlooked. In the past, efforts have concentrated on estimating and forecasting the time of the peak, however this can sometimes be detrimental. Messaging should focus on the expected extent and timing of inundation with respect to upstream areas and the broader floodplain. Flood warning messaging can focus on rainfall monitoring and forecasting ensuring predicting the likelihood of a flood, (i.e. a more general message).

2.5 Flood/No flood tool

The Intensity Frequency Duration (IFD) design rainfall data can be utilised along with forecast and observed rainfall data as an early flood warning tool. The data can be used to identify the likely magnitude of flooding and resulting consequences based on the predicted rainfall and rainfall which has occurred during an event. The Flood/No Flood tool in Figure 2-9 provides a graphical representation of the Intensity-Frequency-Duration relationships for various AEP events as presented in the Final Hydraulic Modelling Report (R04).

To use the table, plot the total rainfall depth against elapsed time since the start of the event. Exclude very light rain when determining the event start point. Plotting of rainfall data should occur periodically as the event progresses. The likelihood and potential severity of flooding can be estimated by checking the rainfall and adopting the nearest curve AEP event as being likely. The table displays intensity-frequency-duration data developed using statistical analysis of sub daily rainfall gauges, relevant gauges at Newstead being Bendigo Airport (81123), Ballarat Aerodrome (89002) and Redesdale (88051). The Flood/No Flood tool can be used in combination with these gauges and/or rainfall observed within the Loddon River catchment and at Newstead in particular.

It may be appropriate to step up or down a level depending on catchment antecedent conditions, for example if the rainfall for a 12 hour duration indicates a 5% AEP event will occur, but the catchment is dry with most farm dams empty, it may be appropriate to “step down” to a 10% AEP event or even lower. Similarly a very wet catchment will produce a greater response and may justify a “step up” in estimated AEP for response purposes.

The tool can provide a quick estimate as to whether there will be a flood and how severe that flood may be; however, it must be stressed that the tool cannot provide accurate flood predictions and should not be relied upon entirely. Should life or property be in danger a cautious approach should be taken.

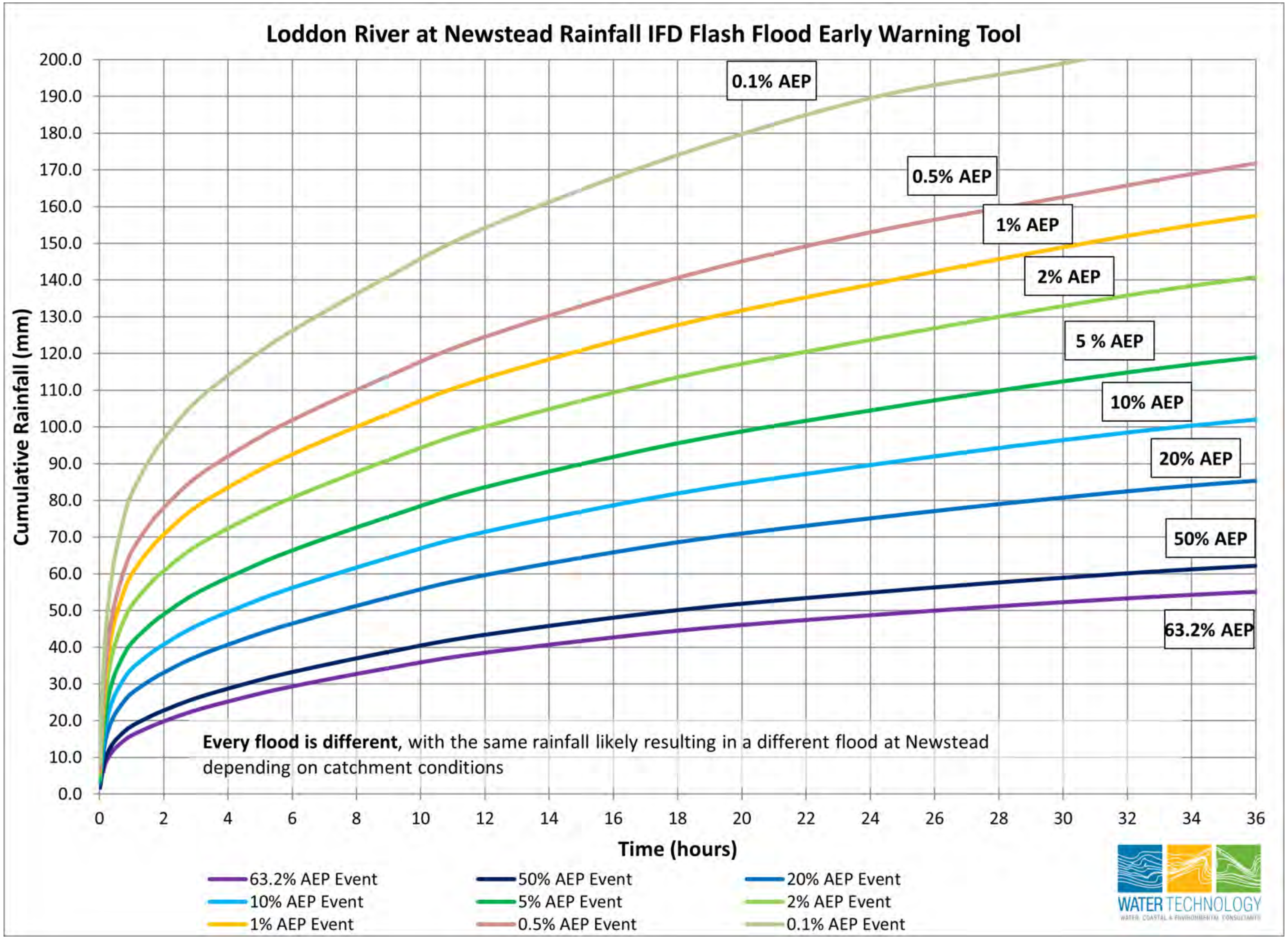


Figure 2-9 Loddon River at Newstead Flood/No flood tool

2.6 Flood class levels

Defined Flood Class Levels (FCLs) are available for the Loddon River at Newstead gauge and are detailed in Table 2-5. Flood mapping for the FLCs are presented in Appendix D. The Bureau of Meteorology's definitions of FCLs are presented below:[3]

Minor flooding

If the water level reaches the minor flood level, it causes inconvenience. Low-lying areas next to water courses are inundated. Minor roads may be closed and low-level bridges submerged. In urban areas flooding may affect some backyards and buildings below floor level as well as bicycle and pedestrian paths. In rural areas removal of livestock and equipment may be required.

Moderate flooding

If the water level reaches the moderate flood level, the area of inundation is larger. Main traffic routes may be affected. Some buildings may be affected above floor level. Evacuation may be required. In rural areas removal of livestock is necessary.

Major flooding

If the water level reaches the major flood level large areas are inundated. Many buildings may be affected above floor level. Properties and towns are likely to be isolated and major rail and traffic routes closed. Evacuation may be required. Utility services may be affected.

Table 2-5 Current Flood Class Levels for Newstead

Flood Class	Level at Loddon River at Newstead gauge (m)	Level at Loddon River at Newstead gauge (mAHD)	Description
Minor	3	210.937	The minor flood level is well below the 20% AEP level at Newstead (5.49 m). Minor out of bank flooding from the Loddon River is observed upstream of Punt Road. Mia Mia Creek floods onto farmland north of Newstead and shallow outbreaks are observed along Green Gully Creek.
Moderate	4.5	212.437	The moderate flood level is also well below the 20% AEP level at Newstead (5.49 m).Out of bank flooding is observed along the Loddon River and Green Gully Creek in most of the study area, with the Pyrenees Highway overtopped by Green Gully Creek.
Major	5.6	213.537	The major flood level is in between the 20% and 10% AEP level at Newstead (5.49 m and 5.80 m respectively). Widespread out of bank flooding is expected along all waterways entering Newstead, with impacts to the Pyrenees Highway and Hepburn-Newstead Road as well as some residential streets. No properties are impacted above floor level.

[3] http://www.bom.gov.au/australia/flood/knowledge-centre/about-warning-service.shtml

3 MUNICPAL FLOOD AND STORM EMERGENCY PLAN (APPENDIX C) DOCUMENTATION

3.1 Warning time

Flooding at Newstead is caused by overbank flows from Loddon River and its tributaries near Newstead. The critical storm duration for the Loddon River, Muckleford Creek and Larni Barramal Yaluk ranges from 12 to 18 hours (for example, for a 1% AEP flood over an 18 hour storm duration, approximately 128 mm of rainfall would be observed), with shorter critical duration expected for the smaller tributaries Green Gully Creek, Mia Mia Creek and Green Gully (1.5 to 9 hours). Timing of peak flooding in the Newstead township is however likely to be within 12 hours to 3 days.

3.2 Roads affected

The main access roads to and from the township of Newstead include the Pyrenees Highway, Hepburn - Newstead Road, Creswick-Newstead Road and Maldon-Newstead Road. Table 3-1 outlines the roads where maximum depths exceed 0.3 m and the flood hazard classification becomes 'unsafe' for vehicles. These roads are shown in Appendix B with the comparison to the 1% AEP flood extent.

It should be noted that all access roads into Newstead become inundated, with Creswick-Newstead Road providing access the longest, up until the 2% AEP event.

Table 3-1 Roads with 'unsafe' inundation depth for each AEP (m)

Roads inundated	Design flood AEP (%)								
	20	10	5	2	1	0.5	0.2	0.1	0.05
Adair Street			0.47	2.05	2.38	2.49	2.61	2.71	2.83
Barkla Road									0.48
Bodles Road					0.36	0.42	0.57	0.62	0.67
Brandt Street		0.44	1.02	1.63	2.02	2.23	2.56	2.79	2.99
Cameron Road	1.30	1.39	1.51	1.76	1.92	2.00	2.11	2.20	2.27
Canrobert Street				1.66	2.24	2.47	2.76	2.93	3.11
Cemetery Road	1.73	2.49	3.02	3.52	3.85	4.03	4.32	4.52	4.70
Church Street			0.31	0.73	1.11	1.33	1.68	1.91	2.12
Clarke Lane	0.87	1.19	1.47	1.73	1.91	2.03	2.29	2.51	2.72
Clyde Street	0.44	0.52	0.63	0.83	0.96	1.03	1.13	1.21	1.28
Codrington Street			0.16	0.36	0.41	0.43	0.46	0.48	0.49
Creek Road	1.58	1.93	2.23	2.52	2.71	2.84	3.10	3.31	3.51
Creswick - Newstead Road					0.41	0.51	0.75	0.94	1.12
Daylesford - Newstead Road		0.36	0.94	1.55	1.94	2.15	2.49	2.71	2.91
Dundas Street	0.79	1.13	1.47	1.77	1.93	2.04	2.25	2.41	2.57
Fitzroy Street				0.53	1.25	1.52	1.85	2.05	2.24
Hepburn - Newstead Road	0.71	1.17	1.74	2.33	2.72	2.94	3.28	3.50	3.71
Hilliers Street				0.66	1.22	1.45	1.72	1.89	2.06

Roads inundated	Design flood AEP (%)								
	20	10	5	2	1	0.5	0.2	0.1	0.05
Layard Street	2.61	3.14	3.55	3.94	4.20	4.35	4.62	4.82	5.01
Maclaren Road	0.72	0.83	0.97	1.22	1.39	1.47	1.58	1.66	1.74
Maldon - Newstead Road				0.81	1.06	1.15	1.35	1.51	1.67
Mcnabb Road		0.96	1.49	1.89	2.27	2.48	2.82	3.05	3.25
Mia Mia Road								0.33	0.38
Newstead - Guildford Road					0.38	0.47	0.71	5.98	6.10
Palmerston Street	2.77	3.49	4.02	4.52	4.86	5.04	5.34	5.55	5.73
Panmure Street			0.54	2.12	2.47	2.58	2.71	2.80	2.95
Petersens Road	0.48	0.63	1.00	1.47	1.80	1.97	2.26	2.46	2.65
Punt Road	3.54	4.19	4.65	5.07	5.35	5.51	5.78	5.96	6.14
Pyrenees Highway	0.57	0.49	0.89	1.40	1.90	2.10	2.33	2.49	2.65
Recreation Avenue				1.03	1.66	1.88	2.15	2.32	2.49
Ruskis Place			0.45	2.14	2.71	2.94	3.22	3.40	3.57
Simpson Street	0.70	1.06	1.38	1.66	1.85	1.97	2.22	2.42	2.62
Tivey Street	0.44	0.79	1.09	1.38	1.57	1.70	1.96	2.16	2.36
Wyndham Street				0.38	0.54	0.61	0.67	0.80	0.98

3.3 Isolated areas

A number of areas are at risk of isolation due to access roads being inundated. The following list outlines these areas and the associated AEP:

- From the 20% AEP event, properties along the northern end of Simpson Street become inaccessible due to road depths above 0.3 m.
- From the 10% AEP event, the Pyrenees Highway begins to become inundated to unsafe levels (above 0.3 m) with parts of Newstead now isolated, but other access roads remain open. Properties on Brandt Street, 35 Campbell Street and 56 Punt Road become inaccessible.
- From the 2% AEP event, floodwater becomes deeper around the Newstead township. Many areas of central Newstead including along Layard Street, Recreation Avenue, Panmure Street, Canrobert Street, Ruskis Place, Hillier Street, Lyons Street and Maldon-Newstead Road become isolated, as well as the properties on Wyndham Street north of Maldon-Newstead Road.
- From the 1% AEP event, almost all properties in central Newstead both east and west of the levee bank are inaccessible due to road depths.

Creswick-Newstead Road and Maldon-Newstead Road provide access to the edge of the township in events rarer than the 1% AEP, however all properties within Newstead are isolated from accessing the dry areas of these roads.

3.4 Property inundation

Floor level survey of 148 buildings was captured within the study area, including 24 commercial and 124 residential buildings. These buildings were selected for floor level survey based on the preliminary flood modelling undertaken during this study. It should be noted that there were minor limitations within the floor level survey data captured, in that only the main residential dwelling or commercial building was captured for each property, outbuildings were not surveyed. The number of properties flooded below floor indicates a property with a residential dwelling or commercial building on it. This does not include parcels of land which are flooded but do not have an associated building i.e. vacant lots, farm paddocks etc.

To classify the flood risk at a property scale, two categories were used, these were:

- Property flooded below floor.
  - This indicates the property is within the flood extent, however the flood level is below the surveyed floor level.
- Property flooded above floor.
  - This indicates the property is within the flood extent and the flood level is above the surveyed floor level.

The existing conditions 1% AEP flood extent and the properties flooded above floor during the range of modelled design events are shown in Figure 3-1 and Figure 3-2. The table provided in Appendix C outlines the properties flooded above and below floor, a summary can be found in Table 3-2. The values in the tables were obtained using flood level minus surveyed floor level for each modelled event. Therefore, a positive value indicates the property is flooded above floor, while a negative value refers to property flooded below floor.

Table 3-2 Summary of property inundation

Design flood event AEP	No. of properties flooded below floor - residential	No. of properties flooded above floor - residential	No. of properties flooded below floor - commercial	No. of properties flooded above floor - commercial
20%	2	0	0	0
10%	6	0	0	0
5%	32	2	1	0
2%	24	67	1	17
1%	21	81	3	18
0.5%	27	86	3	18
0.2%	24	98	5	19
0.1%	20	103	5	19
0.05%	18	106	4	20
PMF	0	124	0	24

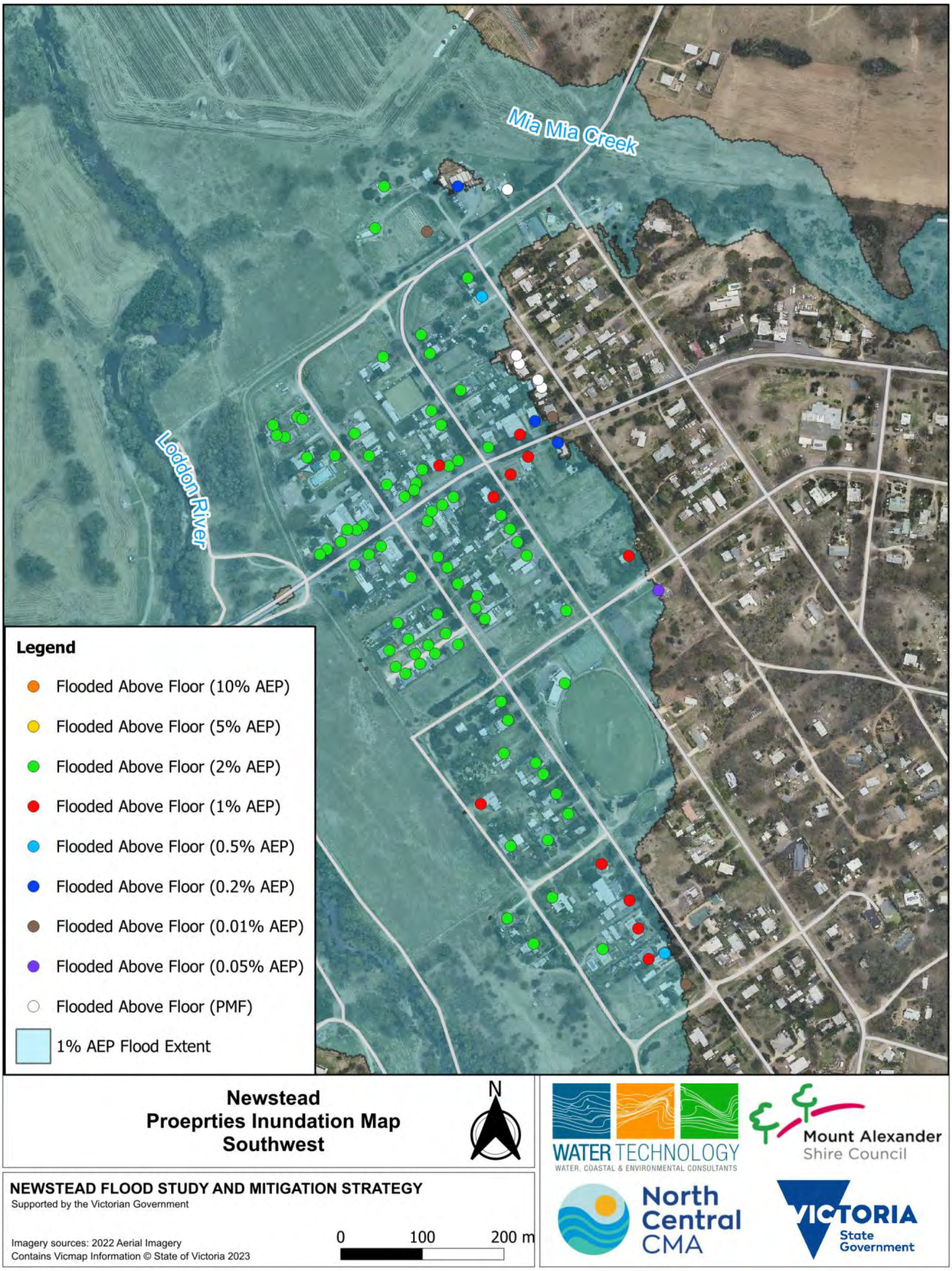


Figure 3-1 Properties flooded above floor – Northeast Newstead

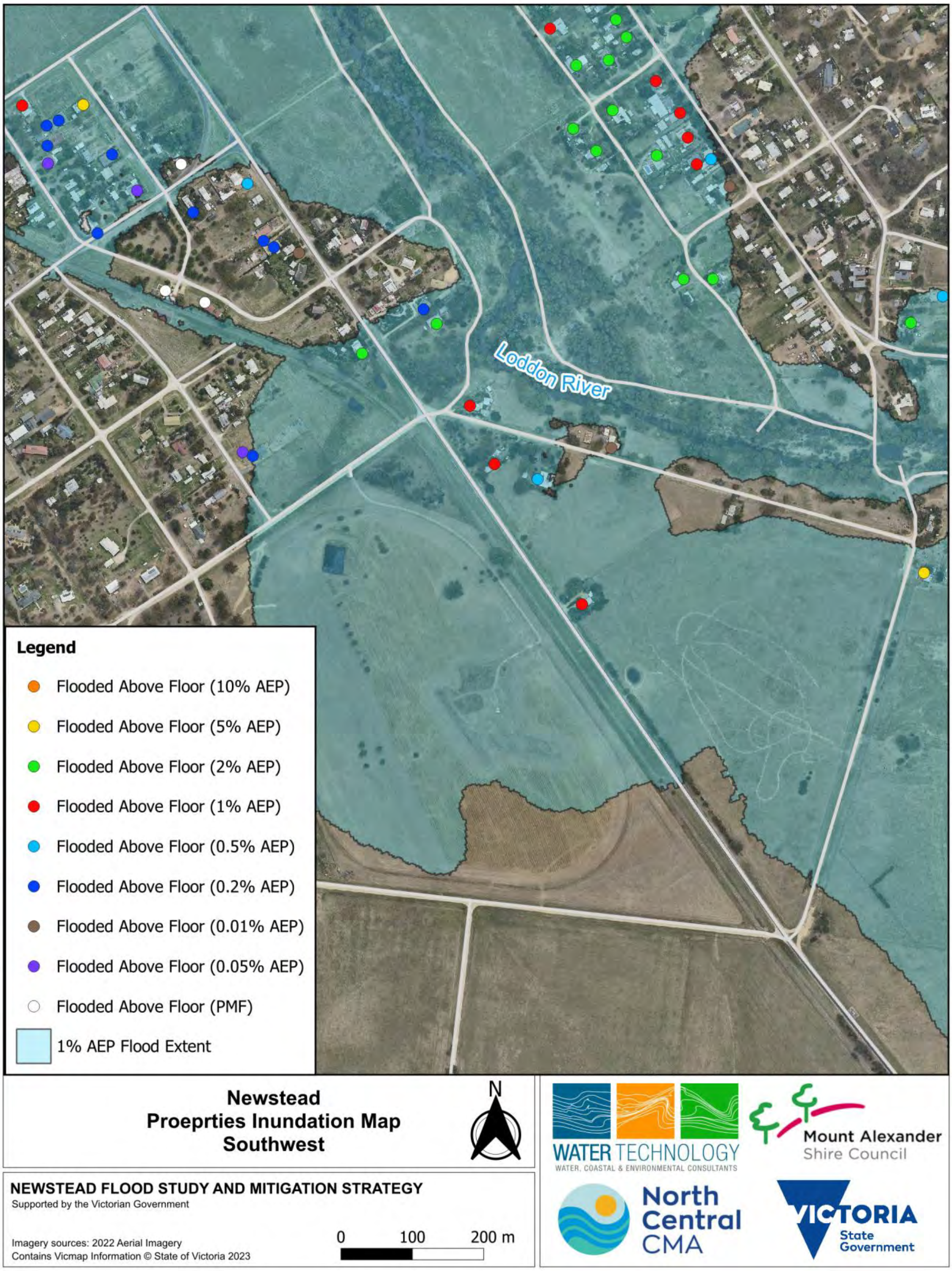


Figure 3-2 Properties flooded above floor – Southwest Newstead

3.5 Flood Intelligence Card

The flood mapping was produced to identify the consequences of flooding for various design events. Combined with the flood/no flood forecasting procedure described in Section 2.5, the flood consequence table allows emergency services and Council to quickly understand the likely impacts of flooding and plan accordingly. The Flood Intelligence Card below describes the key flooding consequences across the study area for each design event.

The table was developed to be read from top to bottom, with each subsequent larger magnitude event reporting on the incremental changes in consequences. For example, if the reader wants to understand the consequences of a 1% AEP event, then the flood characteristics should be read for the 20%, 10%, 5%, 2% and 1% AEP events in succession. It is also recommended that the reader refer to the PDF maps provided with this study. There is a separate map for each modelled design event, providing peak flood depths, extents and water surface elevations for each flood event.

While flood intelligence cards provide guidance on the relationship between flood magnitude and flood consequences, flood intelligence records are approximations. This is because no two floods at a location, even if they peak at the same height, will have identical impacts. Further, the hydrologic and hydraulic modelling that underpins much of the intelligence detailed below is informed by several assumptions and approximations that are unlikely to be replicated exactly during a flood event. Actual impacts under similar rainfall conditions are therefore expected to be similar but may not be exactly the same: there are likely to be some differences. More details about flood intelligence and its use can be found in the Australian Emergency Management Manuals flood series at https://knowledge.aidr.org.au/resources/manual-series/ and in particular in Manual 21 “Flood Warning”.

A guidance on sandbagging document published by VICSES is available in the SES sandbagging guide here detailed in Appendix A.

FLOOD INTELLIGENCE CARD – Loddon River at Newstead GAUGE, Newstead

Version 2 -December 2025

Note: flood intelligence records are approximations. This is because no two floods at a location, even if they peak at the same height, will have identical impacts. Flood intelligence cards detail the relationship between flood magnitude and flood consequences. More details about flood intelligence and its use can be found in the Australian Emergency Management Manuals flood series.

This Flood Intelligence Card publication is presented by the Victoria State Emergency Service for the purpose of disseminating emergency management information. The contents of the information have not been independently verified by the Victoria State Emergency Service. No liability is accepted for any damage, loss or injury caused by errors or omissions in this information or for any action taken by any person in reliance upon it. ***Scan the QR code for the current levels for this gauge.***

Insert QR Code of URL for current level of gauge and remove this box

SES

LOCATION:	*Newstead*
CURRENT LEVEL:	*http://www.bom.gov.au/fwo/IDV67207/IDV67207.588004.plt.shtml*
STREAM:	**Loddon River**
GAUGE NUMBER:	**588004 (BoM) 407215 (VIC)**
GAUGE ZERO:	**207.937 mAHD**
GAUGE TYPE:	**Telemetered**

MAP REFERENCE:	
MINOR FLOOD LEVEL:	**3.0**
MODERATE FLOOD LEVEL:	**4.5**
MAJOR FLOOD LEVEL:	**5.6**
LEVEE HEIGHT:	**6.5**
HIGHEST RECORDED FLOOD:	**6.12 (October 2022)**

River Height (m)	Annual Exceedance Probability (% AEP)	Expected Inundation and Consequences	Actions
3.00	**Minor Flood Level**  	**Properties likely Impacted** • No property likely impacted above or below floor **Community Infrastructure Likely Impacted** • No community infrastructure likely impacted **Essential Infrastructure Likely Impacted** • No essential infrastructure likely impacted **Tourism / Recreation Likely Impacted** • No tourism/recreation likely impacted **Roads Flooded** • Clarke Lane, Clyde Street, Maclaren Road, Tivey Street **Roads flooded above 0.3m** • Cameron Road, Cemetery Road, Creek Road, Layard Street, Palmerston Street, Punt Road	• Continue to monitor rainfall and water levels.
4.50	**Moderate Flood Level**  	**Properties likely Impacted** • No property likely impacted above or below floor **Community Infrastructure Likely Impacted** • No community infrastructure likely impacted **Essential Infrastructure Likely Impacted** • No essential infrastructure likely impacted **Tourism / Recreation Likely Impacted** • No tourism/recreation likely impacted **Roads Flooded** • Roads included in the events above and Bodles Road, Pyrenees Highway, Clarke Lane, Dundas Street, Hepburn - Newstead Road **Roads flooded above 0.3m** • Roads included in the events above. • Clyde Street, Maclaren Road	• Continue to monitor rainfall and water levels. • Consider early evacuation of vulnerable residents in areas likely to be inundates/isolated. • If further inundation likely, implement evacuation plan and / or removal of furniture etc from buildings likely to be flooded over-floor in the Major event and / or sandbagging buildings. • Place 'water over road' signs on Pyrenees Highway and Hepburn - Newstead Road

5.49	**20% AEP Flood Level**	**Properties likely Impacted (Refer to property table in this appendix for more detail)** **2 Properties in Total** • 2 properties flooded below floor (2 Simpson Street and 2 Palmerston Street) and 0 commercial properties. • Properties along the northern end of Simpson Street become isolated due to road depths above 0.3 m. **Community Infrastructure Likely Impacted** • No community infrastructure likely impacted **Essential Infrastructure Likely Impacted** • No essential infrastructure likely impacted **Tourism / Recreation Likely Impacted** • No tourism/recreation likely impacted **Roads Flooded (Roads in red are DTP operated roads) (Refer to roads table in this appendix for more detail)** • Cameron Road, Cemetery Road, Clarke Lane, Clyde Street, Creek Road, Dundas Street, Hepburn - Newstead Road, Layard Street, Maclaren Road, Palmerston Street, Petersens Road, Punt Road, Pyrenees Highway (0.57m), Simpson Street, Tivey Street. Flood depth on these roads is above 0.3m	• Continue to monitor rainfall and water levels. • Consider early evacuation of vulnerable residents in areas likely to be inundates/isolated. • If further inundation likely, implement evacuation plan and / or removal of furniture etc from buildings likely to be flooded over-floor in the 10% AEP event and / or sandbagging buildings. • Close Pyrenees Highway and Hepburn - Newstead Road.
5.60	**Major Flood Level**  	**Properties likely Impacted** • 4 residential properties flooded below floor (2 Simpson Street, 2 Palmerston Street, 2C Wyndham Street and 13 Campbell Street) and 0 commercial properties. • Properties along the northern end of Simpson Street become isolated due to road depths above 0.3 m. **Community Infrastructure Likely Impacted** • No community infrastructure likely impacted **Essential Infrastructure Likely Impacted** • No essential infrastructure likely impacted **Tourism / Recreation Likely Impacted** • No tourism/recreation likely impacted **Roads Flooded** • Roads included in the events above. • Daylesford - Newstead Road **Roads flooded above 0.3m** • Roads included in the events above. Brandt Street, Mcnabb Road, Petersens Road, Pyrenees Highway, Simpson Street, Tivey Street	• Continue to monitor rainfall and water levels. • Consider early evacuation of vulnerable residents in areas likely to be inundates/isolated. • If further inundation likely, implement evacuation plan and / or removal of furniture etc from buildings likely to be flooded over-floor in larger events and / or sandbagging buildings. • Place 'water over road' signs on Daylesford - Newstead Road • Close Pyrenees Highway and Hepburn - Newstead Road.
5.70	**September 2016 Flood Level Peak**	2 residential dwellings located within flood extent	

5.80	**10% AEP Flood Level**	**Properties likely Impacted (Refer to property table in this appendix for more detail)** **6 Properties in Total** • Properties included above • 2 additional properties are flooded below floor including 2 residential properties (35 Campbell Street, 1A Tivey Street) and 0 commercial properties • Properties on Brandt Street, 35 Campbell Street and 56 Punt Road become inaccessible. • Pyrenees Highway begins to become inundated to unsafe levels (above 0.3 m) with parts of Newstead now isolated **Community Infrastructure Likely Impacted** • No community infrastructure likely impacted **Essential Infrastructure Likely Impacted** • No essential infrastructure likely impacted **Tourism / Recreation Likely Impacted** • No tourism/recreation likely impacted **Roads Flooded (Roads in red are DTP operated roads) (Refer to roads table in this appendix for more detail)** • Roads included in the events above. • Roads are isolated and flood depth on the street is above 0.3m: Brandt Street, Daylesford - Newstead Road (0.36m), McNabb Road	• Continue to monitor rainfall and water levels. • Consider early evacuation of vulnerable residents in areas likely to be inundates/isolated • If further inundation likely, implement evacuation plan and / or removal of furniture etc from buildings likely to be flooded over-floor in the 5% AEP event and / or sandbagging buildings. • Close Daylesford-Newstead Road. Previously closed roads to remain closed.
6.10	**5% AEP Flood Level**	**Properties likely Impacted (Refer to property table in this appendix for more detail)** **35 Properties in Total** • Properties included above • 2 properties flooded above floor: 2 Simpson Street and 56 Punt Road • 28 additional properties are flooded below floor including 27 residential properties: 1, 2A Brandt Street, 1,4 Layard Street, 1, 3 Tivey Street, 11, 13, 14, 15, 17, 18, 19, 28, 30, 32, 34, 40A Panmure Street, 18 Campbell Street, 1A, 2 Recreation Avenue, 2, 3, 4, 5 Ruskis Place, 2B Wyndham Street • and 1 additional commercial property (2 Panmure Street) **Community Infrastructure Likely Impacted** • No community infrastructure likely impacted **Essential Infrastructure Likely Impacted** • No essential infrastructure likely impacted **Tourism / Recreation Likely Impacted** • No tourism/recreation likely impacted **Roads Flooded (Roads in red are DTP operated roads) (Refer to roads table in this appendix for more detail)** • Roads included in the events above. • Roads are isolated and flood depth on the street is above 0.3m: Adair Street, Ruskis Place	• Continue to monitor rainfall and water levels. • Consider early evacuation of vulnerable residents in areas likely to be inundates/isolated • If further inundation likely, implement evacuation plan and / or removal of furniture etc from buildings likely to be flooded over-floor in the 2% AEP event and / or sandbagging buildings. • Plan for the event of the Newstead CFA Fire Station being isolated and/or inundated. • “Water over road” signs should be in place on Creswick-Newstead Road, and Newstead-Guildford Road.

6.12	**October 2022 Flood Level Peak**	• The Maldon Newstead Road bridge across Mia Mia Creek was the only road into Newstead not impacted by flood waters – this includes flooding outside the Newstead area • Sandbagging of the levee prevented levee from overtopping • 11 residential dwellings located within flood extent	
6.38	**2% AEP Flood Level**	**Properties likely Impacted (Refer to property table in this appendix for more detail)** **109 Properties in Total** • Properties included above • 1 additional commercial property is flooded below floor (29 Lyons Street) • 17 additional commercial properties are flooded above floor (14, 22 Hilliers Street and 27 Lyons Street, 4, 5, 6, 8, 9, 11, 12, 13, 14, 23-25 Lyons Street, 2, 21A Panmure Street) • 17 additional residential properties are flooded below floor (1 Simpson Street, 13 Adair Street, 14 Hillier Street, 18, 18A, 21 Lyons Street, 2A Wyndham Street, 38, 38A, 42 Panmure Street, 5 Canrobert Street, 3, 5, 8 Tivey Street, 11A Campbell Street, 3 Codrington Street, 2A Palmerston Street, 4 Recreation Avenue) • 65 additional residential properties are flooded above floor (13, 18 Campbell Street, 1 Canrobert Street, 1, 3, 4, 9, 10, 12, 16, 20, 20A Hilliers Street, 1, 3, 10, 15, 17, 19, 23-25 Lyons Street, 1, 2, 3, 4, 5, 6, 8 Ruskis Place, 2, 5, 7, 8, 9, 9A, 11,12, 13, 14, 14A, 14B, 15, 17, 18, 19, 24, 24A, 26, 28, 30, 32, 34, 40A Panmure Street, 1, 2, 4, 6, 7 Layard Street, 1A, 2 Recreation Avenue, 2, 2B, 2C Wyndham Street, 2 Palmerston Street) • Many areas of central Newstead including along Layard Street, Recreation Avenue, Panmure Street, Canrobert Street, Ruskis Place, Hilliers Street, Lyons Street and Maldon-Newstead Road become isolated, as well as the properties on Wyndham Street north of Maldon-Newstead Road. **Community Infrastructure Likely Impacted** • Newstead CFA Fire Station is flooded above floor, flood depth is 0.7m • Community Hall is flooded above floor, flood depth is 1.1m • Mechanics Institute is flooded above floor, flood depth is 1.0m **Essential Infrastructure Likely Impacted** • No essential infrastructure likely impacted **Tourism / Recreation Likely Impacted** • Newstead Cricket Club is flooded above floor, flood depth is 0.7m • Crown Hotel is flooded above floor; flood depth is 1.1m **Roads Flooded (Roads in red are DTP operated roads) (Refer to roads table in this appendix for more detail)** • Roads included in the events above. • Roads are isolated and flood depth on the street is above 0.3m: Canrobert Street, Codrington Street, Fitzroy Street, Maldon - Newstead Road (0.81m), Recreation Avenue, Wyndham Street	• Continue to monitor rainfall and water levels. • Consider early evacuation of vulnerable residents in areas likely to be inundates/isolated • If further inundation likely, implement evacuation plan and / or removal of furniture etc from buildings likely to be flooded over-floor in the 1% AEP event and / or sandbagging buildings. • Water over road" signs should be in place on Creswick-Newstead Road, and Newstead-Guildford Road • Close Maldon - Newstead Road.

<table>
<tr><td>6.54</td><td>1% AEP
Flood Level</td><td>Properties likely Impacted (Refer to property table in this appendix for more detail)
123 Properties in Total
• Properties included above
• 3 additional commercial properties flooded below floor (2 Canrobert Street, 6 Tivey Street, 6 Creswick-Newstead Road)
• 1 additional commercial property flooded above floor (29 Lyons Street)
• 10 additional residential properties are flooded below floor (2 Brandt Street, 20-22, 31 Lyons Street, 4 Creswick-Newstead Road, 4 Wyndham Street, 40, 44 Panmure Street, 9 Church Street, 6A, 9, 11Tivey Street)
• 14 additional residential properties are flooded above floor (1, 2A Brandt Street, 35 Campbell Street, 5 Canrobert Street, 14 Hillier Street, 18, 18A, 21 Lyons Street, 38, 38A, 40, 42 Panmure Street, 4 Recreation Avenue, 1 Tivey Street)
Community Infrastructure Likely Impacted
• Newstead CFA Fire Station is flooded above floor, flood depth is 1.23m
• Community Hall is flooded above floor, flood depth is 1.57m
• Mechanics Institute is flooded above floor, flood depth is 1.54m
Essential Infrastructure Likely Impacted
• No essential infrastructure likely impacted
Tourism / Recreation Likely Impacted
• Newstead Cricket Club is flooded above floor, flood depth is 1.31 m
• Crown Hotel is flooded above floor; flood depth is 1.6m
Roads Flooded (Roads in red are DTP operated roads) (Refer to roads table in this appendix for more detail)
• Roads included in the events above.
• Roads are isolated and flood depth on the street is above 0.3m: Bodles Road, Creswick - Newstead Road (0.41m), Newstead - Guildford Road (0.38m).</td><td>• Continue to monitor rainfall and water levels.
• Consider early evacuation of vulnerable residents in areas likely to be inundates/isolated
• If further inundation likely, implement evacuation plan and / or removal of furniture etc from buildings likely to be flooded over-floor in the 0.5% AEP event and / or sandbagging buildings.
• Close Creswick - Newstead Road and Newstead-Guildford Road. Previously closed roads to remain closed.</td></tr>
<tr><td>6.65</td><td>0.5% AEP
Flood Level</td><td>Properties likely Impacted (Refer to property table in this appendix for more detail)
134 Properties in Total
• Properties included above
• 10 additional residential properties are flooded below floor (10 Wyndham Street, 33 Lyons Street, 46 Panmure Street, 6, 8,10, 12, 14 Campbell Street, 1, 3 Creswick-Newstead Road)
• 5 additional residential properties are flooded above floor (2 Brandt Street, 44 Panmure Street, 4 Wyndham street, 2A Palmerston Street, 2 Campbell Street)
Community Infrastructure Likely Impacted
• Newstead CFA Fire Station is flooded above floor, flood depth is 1.45m
• Community Hall is flooded above floor, flood depth is 1.76m
• Mechanics Institute is flooded above floor, flood depth is 1.74m
Essential Infrastructure Likely Impacted
• No essential infrastructure likely impacted
Tourism / Recreation Likely Impacted
• Newstead Cricket Club is flooded above floor, flood depth is 1.55 m
• Crown Hotel is flooded above floor; flood depth is 1.8m
Roads Flooded (Roads in red are DTP operated roads) (Refer to roads table in this appendix for more detail)
• Roads included in the events above.</td><td>• Continue to monitor rainfall and water levels.
• Consider early evacuation of vulnerable residents in areas likely to be inundates/isolated
• If further inundation likely, implement evacuation plan and / or removal of furniture etc from buildings likely to be flooded over-floor in the 0.2% AEP event and / or sandbagging buildings.
• Previously closed roads to remain closed.</td></tr>
</table>

		• Roads are isolated and flood depth on the street is above 0.3m: Barkla Road	
6.87	**0.2% AEP Flood Level**	**Properties likely Impacted (Refer to property table in this appendix for more detail)** **146 Properties in Total** • Properties included above • 3 additional commercial property flooded below floor (2, 8A Tivey Street, 16 Simpson Street) • 1 additional commercial property flooded above floor (6 Creswick-Newstead Road) • 8 additional residential properties are flooded below floor (10 Tivey Street, 12,14, 16 Wyndham Street, 2 Creswick-Newstead Road, 3-7 Brandt Street, 3 Dundas Street, 1 Clyde Street) • 10 additional residential properties flooded above floor (1 Simpson Street, 1 Creswick-Newstead Road, 8, 10, 11A Campbell Street, 11 Adair Street, 9 Church Street, 20-22, 31 Lyons Street, 1A Tivey Street) **Community Infrastructure Likely Impacted** • Newstead CFA Fire Station is flooded above floor, flood depth is 1.7m • Community Hall is flooded above floor, flood depth is 2.0m • Mechanics Institute is flooded above floor, flood depth is 2.0m **Essential Infrastructure Likely Impacted** • No essential infrastructure likely impacted **Tourism / Recreation Likely Impacted** • Newstead Cricket Club is flooded above floor, flood depth is 1.8 m • Crown Hotel is flooded above floor; flood depth is 2.0m • Newstead Railway Arts Hub is flooded below floor **Roads Flooded (Roads in red are DTP operated roads) (Refer to roads table in this appendix for more detail)** • Roads included in the events above.	• Continue to monitor rainfall and water levels. • Consider early evacuation of vulnerable residents in areas likely to be inundates/isolated • If further inundation likely, implement evacuation plan and / or removal of furniture etc from buildings likely to be flooded over-floor in the 0.1% AEP event and / or sandbagging buildings. • Previously closed roads to remain closed.
7.04	**0.1% AEP Flood Level**	**Properties likely Impacted (Refer to property table in this appendix for more detail)** **147 Properties in Total** • Properties included above • 1 additional residential property flooded below floor (48 Panmure Street) • 5 additional residential properties are flooded above floor (12 Campbell Street, 3-7 Brandt Street, 33 Lyons Street, 46 Panmure Street, 2A Wyndham Street) **Community Infrastructure Likely Impacted** • Newstead CFA Fire Station is flooded above floor, flood depth is 1.9m • Community Hall is flooded above floor, flood depth is 2.2m • Mechanics Institute is flooded above floor, flood depth is 2.1m **Essential Infrastructure Likely Impacted** • No essential infrastructure likely impacted **Tourism / Recreation Likely Impacted** • Newstead Cricket Club is flooded above floor, flood depth is 1.9 m • Crown Hotel is flooded above floor; flood depth is 2.2m • Newstead Railway Arts Hub is flooded below floor **Roads Flooded (Roads in red are DTP operated roads) (Refer to roads table in this appendix for more detail)**	• Continue to monitor rainfall and water levels. • Consider early evacuation of vulnerable residents in areas likely to be inundates/isolated • If further inundation likely, implement evacuation plan and / or removal of furniture etc from buildings likely to be flooded over-floor in the 0.05% AEP event and / or sandbagging buildings. • Previously closed roads to remain closed.

		• Roads included in the events above.	
7.22	**0.05% AEP Flood Level**	**Properties likely Impacted (Refer to property table in this appendix for more detail)** **148 Properties in Total** • Properties included above • 1 additional commercial property is flooded above floor (2 Canrobert Street) • 3 additional residential properties are flooded above floor (4 Creswick-Newstead Road, 7 Church Street, 5 Tivey Street) **Community Infrastructure Likely Impacted** • Newstead CFA Fire Station is flooded above floor, flood depth is 2.1m • Community Hall is flooded above floor, flood depth is 2.3m • Mechanics Institute is flooded above floor, flood depth is 2.3m **Essential Infrastructure Likely Impacted** • No essential infrastructure likely impacted **Tourism / Recreation Likely Impacted** • Newstead Cricket Club is flooded above floor, flood depth is 2.1 m • Crown Hotel is flooded above floor; flood depth is 2.4m • Newstead Railway Arts Hub is flooded below floor **Roads Flooded (Roads in red are DTP operated roads) (Refer to roads table in this appendix for more detail)** Roads included in the events above.	

4 SUMMARY

Several flood intelligence products have been developed to improve flood response capability for Newstead and the Loddon River, including a flood impact summary table, flood peak timing estimates and the development of a quick “Flood/No Flood” tool designed to estimate the magnitude of flooding based on observed rainfall. The report should be used as a reference document during flood events to confirm flood response actions required.

Much of the flood intelligence information contained in this report will be included in a draft revision of the MASC MFSEP for SES and Council approval. It is recommended the flood intelligence information is incorporated into council and/or SES community education programs to improve flood awarenes

APPENDIX A
VICSES SANDBAGGING GUIDE

Sandbagging

Protecting your home

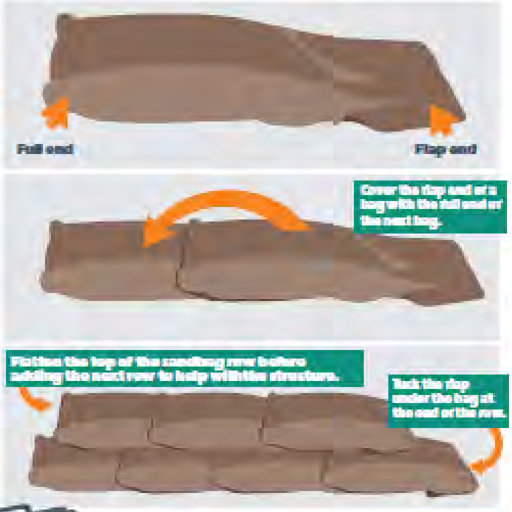
Sandbags won't stop the water completely, but can reduce the amount of water entering your home.

How do I fill a sandbag?

- Only use sand to fill hessian bags. Do not use dirt.
- Only fill sandbag two-thirds full.
- Do not over fill the sandbag as it will be too heavy to carry.
- Do not tie the top of the sandbag.
- Take care when filling and lifting the sandbag, to avoid injury.

How do I lay sandbags?

- Lay sandbags like brickwork. Stagger rows so that the joins do not line up.
- Start at one end and work to the other end.
- Ensure the unfilled part of the bag is covered by the next bag.
- Tuck flap under the bag at the end of the row.
- If the sandbag wall is going to be more than five (5) bags high, you will need to lay two (2) rows wide.



Where do I place the sandbags?

- Place sandbags in plastic bags to cover drainage holes in home (e.g. showers, toilets, sinks) to stop back flow of water.
- Place a small wall across doorways, at least the height of the expected water level. Be careful not to trap yourself inside.
- If available, plastic sheeting may be used under sandbags to reduce the seepage.

What do I do once I have finished with the sandbags?

- Sturdy gloves should be worn when handling wet sandbags as they can contain chemicals, waste and diseases.
- Sandbags that have been in contact with floodwater need to be thrown away.
- Contact your local council to find out how to dispose of your sandbags safely.

Sandbags and sand

SES

Preparing your home

Having sandbag supplies ready can assist you before a flooding emergency occurs.

What supplies do I need to sandbag my home?

- Sandbags
- Sand
- Plastic sheeting
- Gloves and safety goggles
- Shovel or hand scoop

Where can I purchase these supplies?

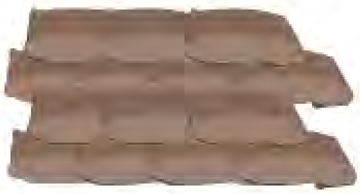
- Many sandbag supplies can be purchased from hardware stores or garden centers.
- VICSES do not routinely supply sandbags to households.
- During floods, sandbag distribution points may be established in flood-affected areas.

How many sandbags will I need and how much sand?

- Most homes can be protected by less than 25 sandbags.
- The number of sandbags will depend on your local flood risk and availability.
- Sandbags are filled 2/3 full which requires around 15-20kgs of sand per bag.

How do I store my sand and sandbags?

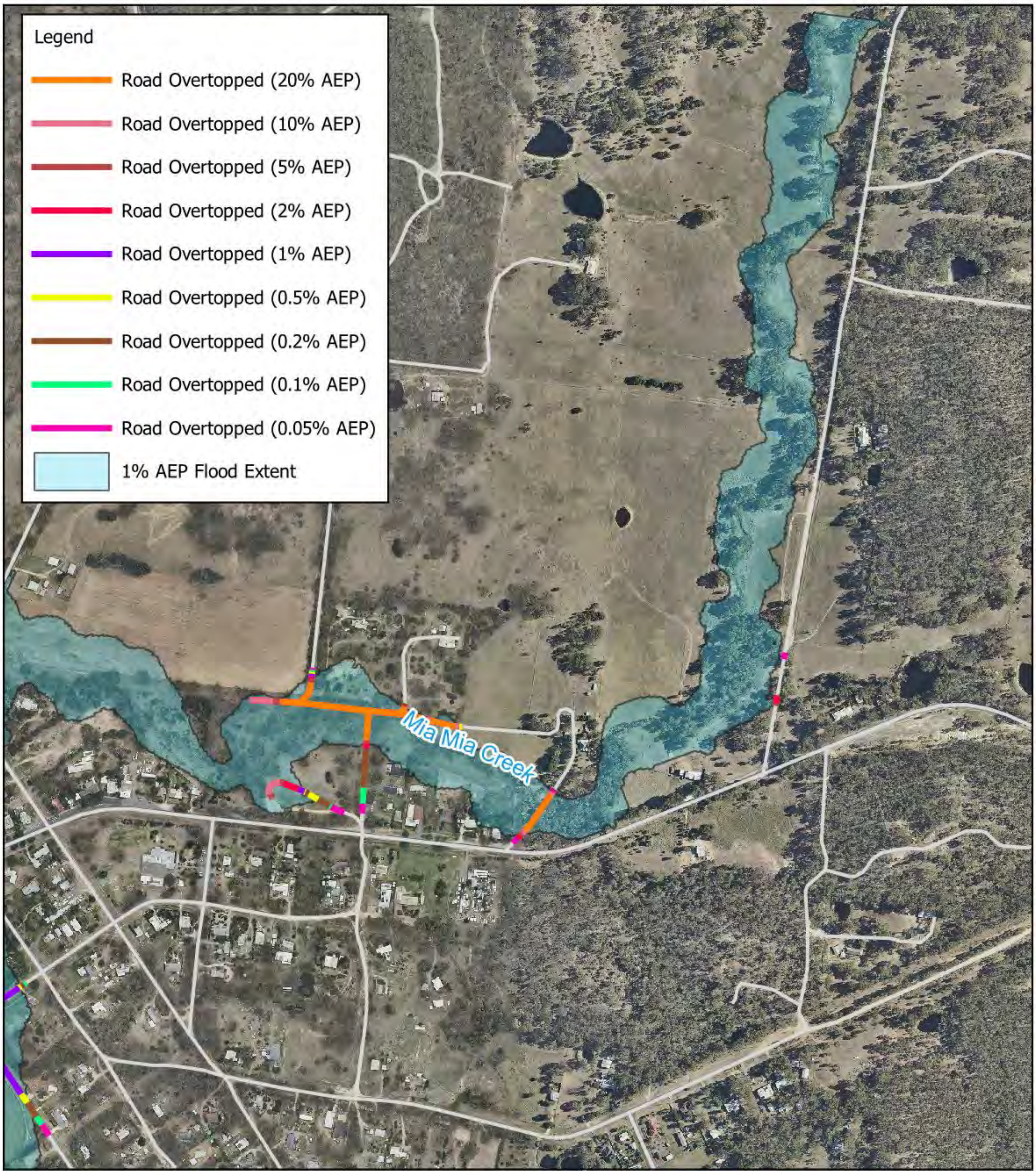
- Filled sandbags only have a short shelf life.
- It is recommended to store sandbags empty.
- Sandbags should be stored in a cool dry area away from UV light.
- Sand should be kept dry and can be stored in water-resistant containers or under a tarp.
- Sand is heavy - ensure it is stored so it can be moved safely.



When should I sandbag my home?

- **You** are best placed to decide if there is a need to sandbag your home, based on local knowledge and past flood events.
- Monitor your local conditions. Stay up-to-date with weather forecasts and warnings by downloading the **BOM Weather** and **VicEmegency** apps, or call the VicEmergency Hotline on 1800 226 226.
- If you think you are at risk, do not wait for an official warning to act.

APPENDIX B
ROAD INUNDATION MAPPING



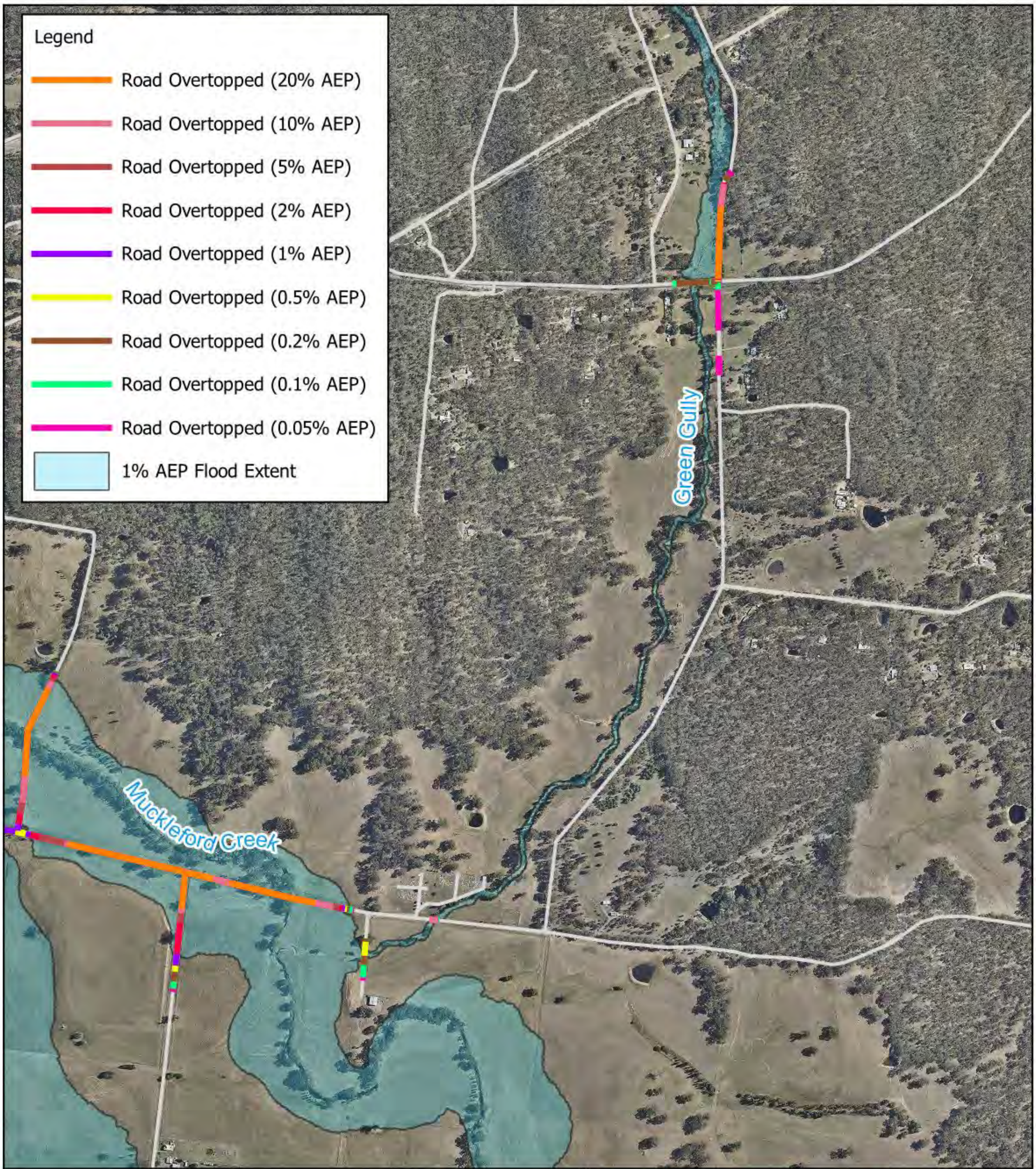
Newstead
Roads Inundation Map 1

N

NEWSTEAD FLOOD STUDY AND MITIGATION STRATEGY
Supported by the Victorian Government

Data sources:
Imagery sources: 2022 Aerial Imagery
Contains Vicmap Information © State of Victoria 2023

0 100 200 m



Newstead
Roads Inundation Map 2

NEWSTEAD FLOOD STUDY AND MITIGATION STRATEGY
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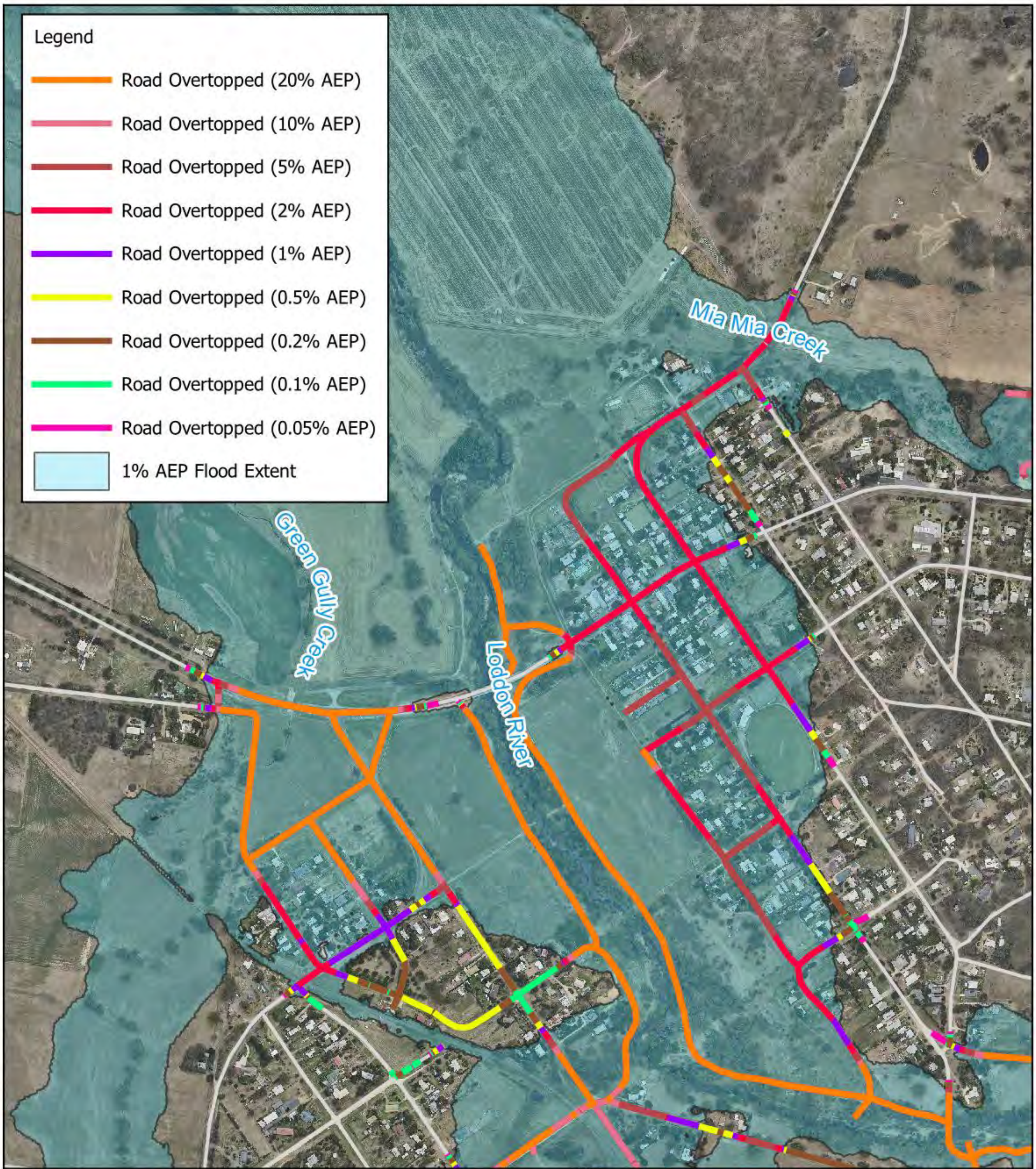

Newstead
Roads Inundation Map 3

NEWSTEAD FLOOD STUDY AND MITIGATION STRATEGY
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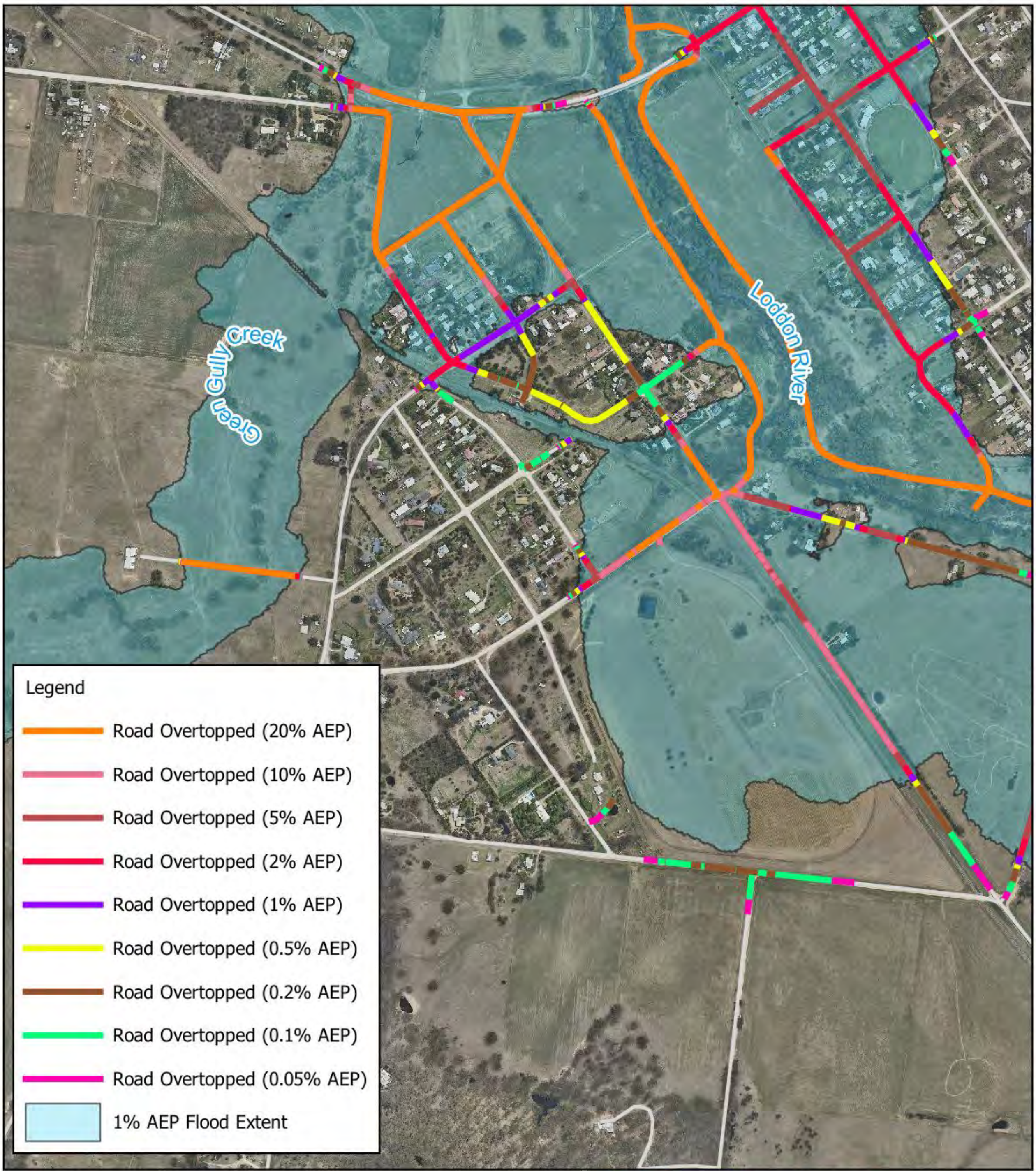

Newstead
Roads Inundation Map 4

N

NEWSTEAD FLOOD STUDY AND MITIGATION STRATEGY
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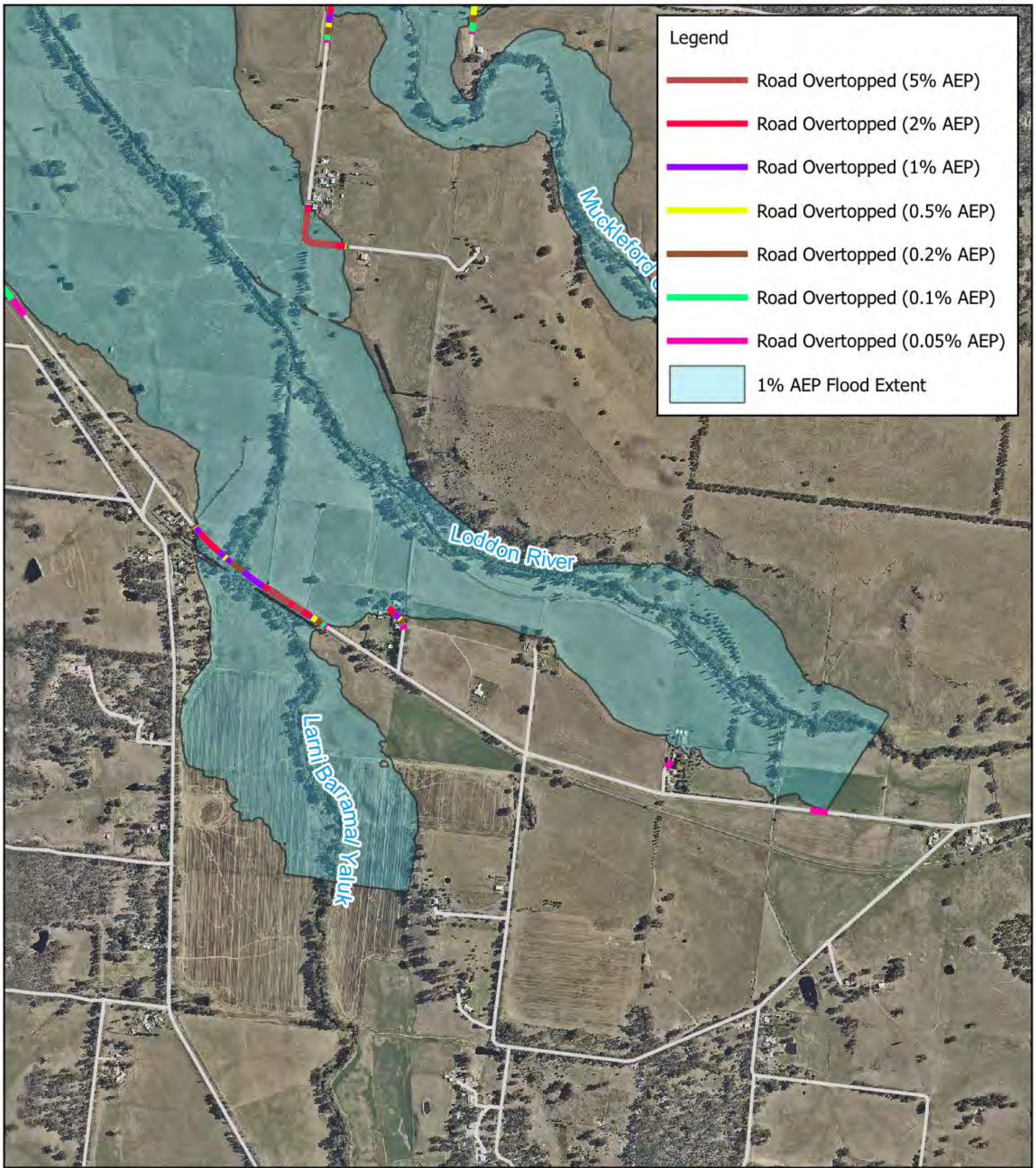
0 100 200 m

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS
Mount Alexander Shire Council
North Central CMA
VICTORIA State Government



Newstead
Roads Inundation Map 5

NEWSTEAD FLOOD STUDY AND MITIGATION STRATEGY
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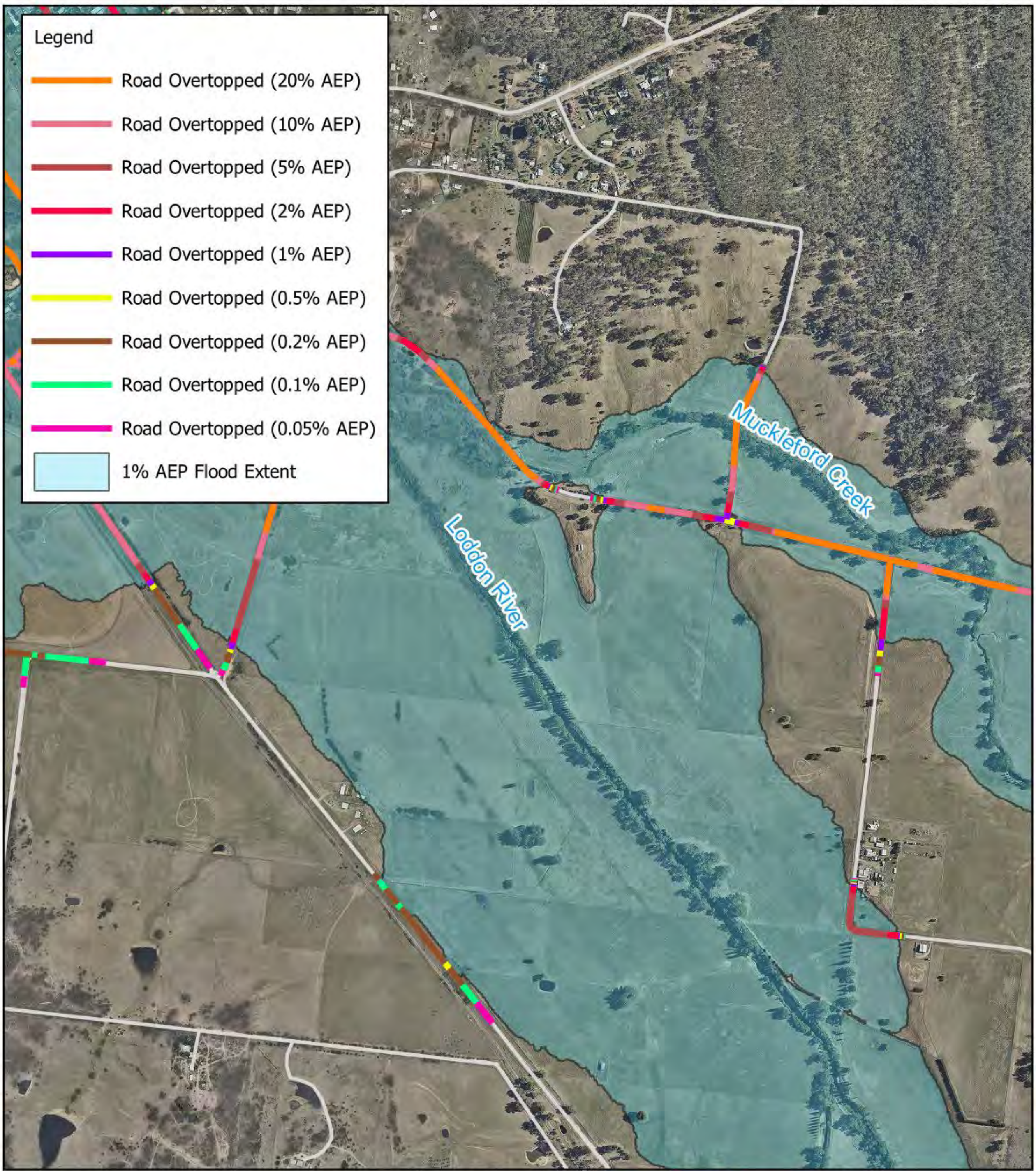
Mount Alexander Shire Council
North Central CMA
VICTORIA State Government



Newstead
Roads Inundation Map 6

NEWSTEAD FLOOD STUDY AND MITIGATION STRATEGY
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APPENDIX C
ROAD AND PROPERTY INUNDATION TABLES

APPENDIX D
FLOOD CLASS LEVEL MAPPING

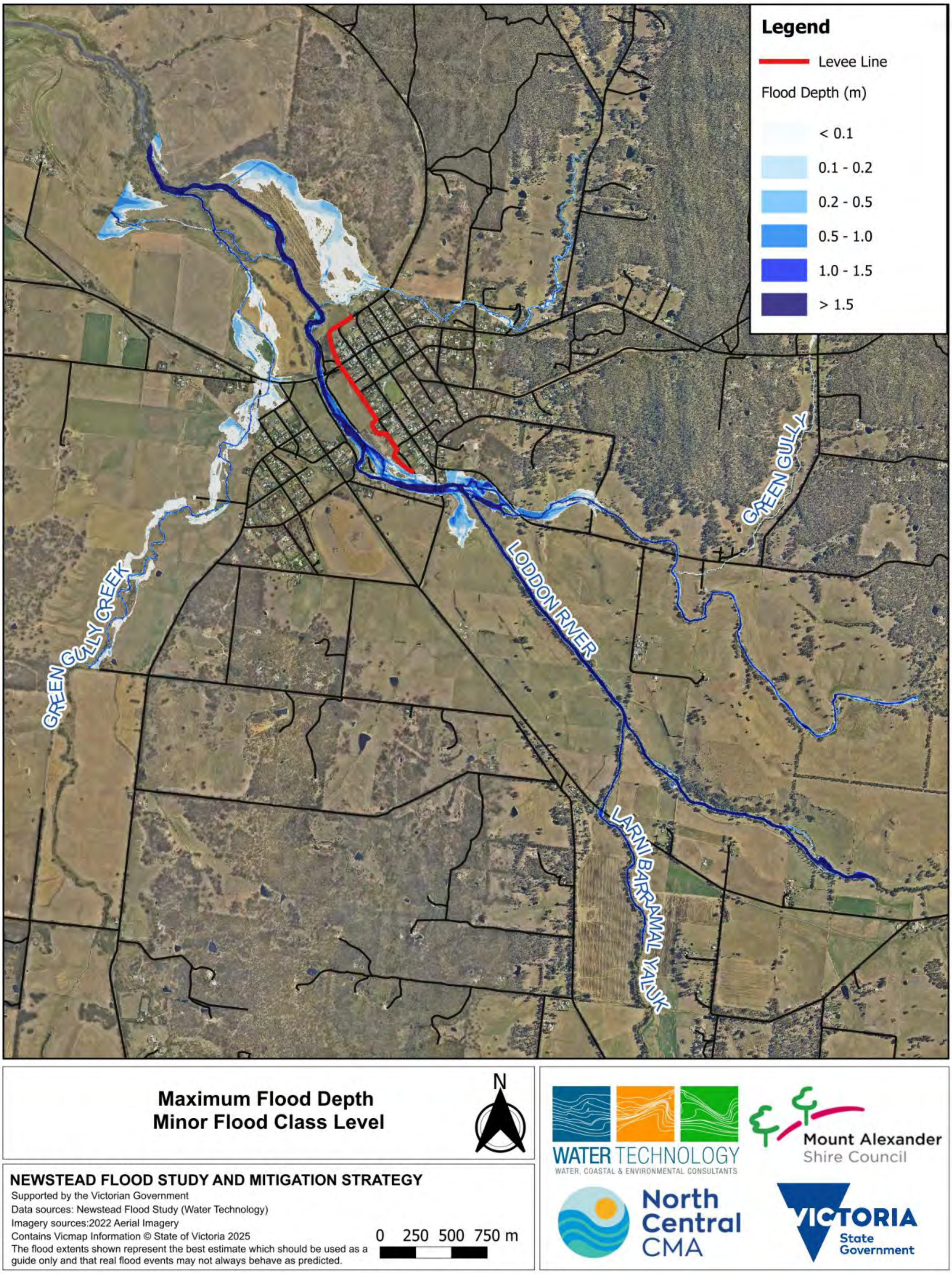

Figure 4-1 Minor Flood Maximum Depth

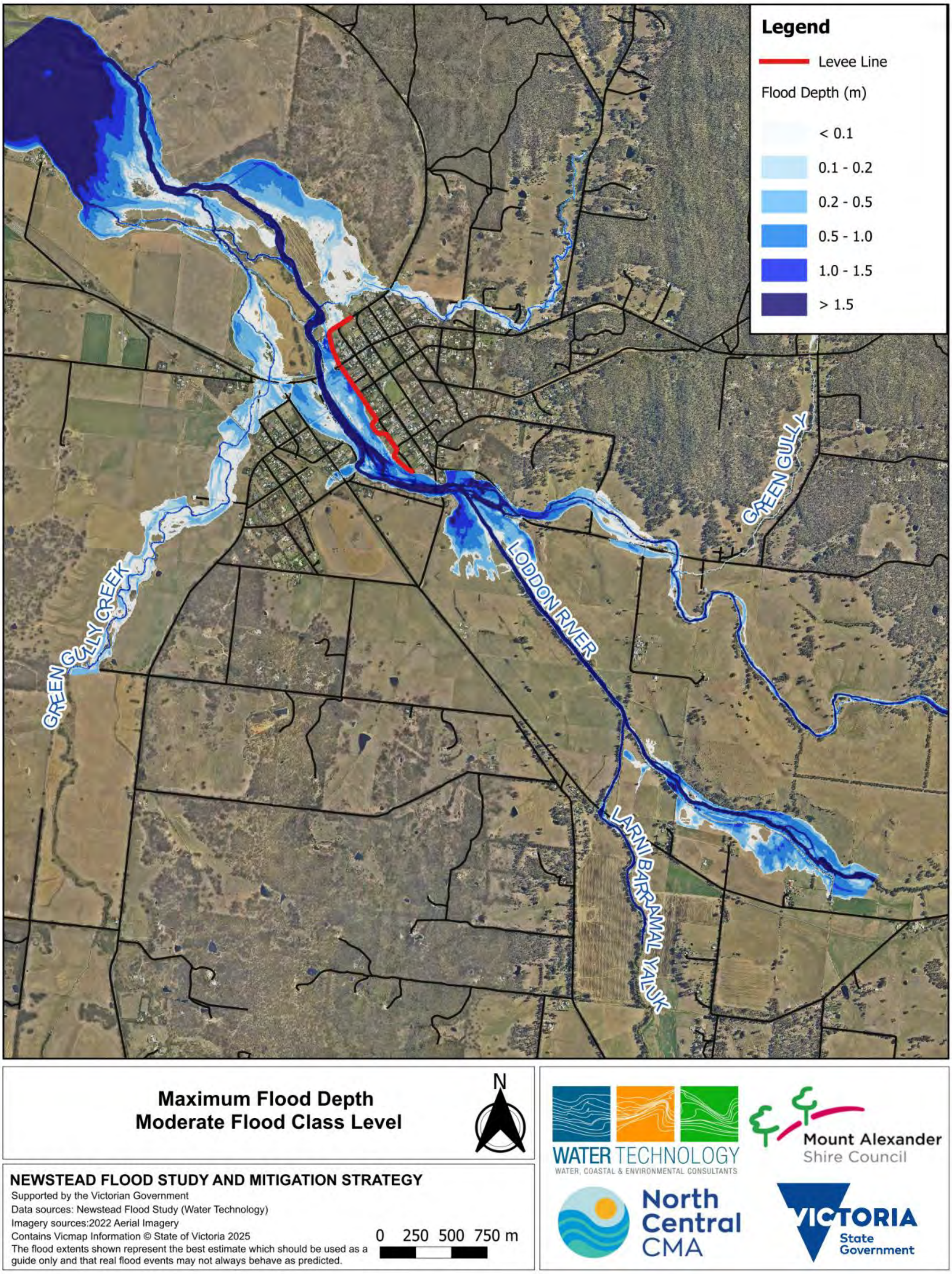

Figure 4-2 Moderate Flood Maximum Depth

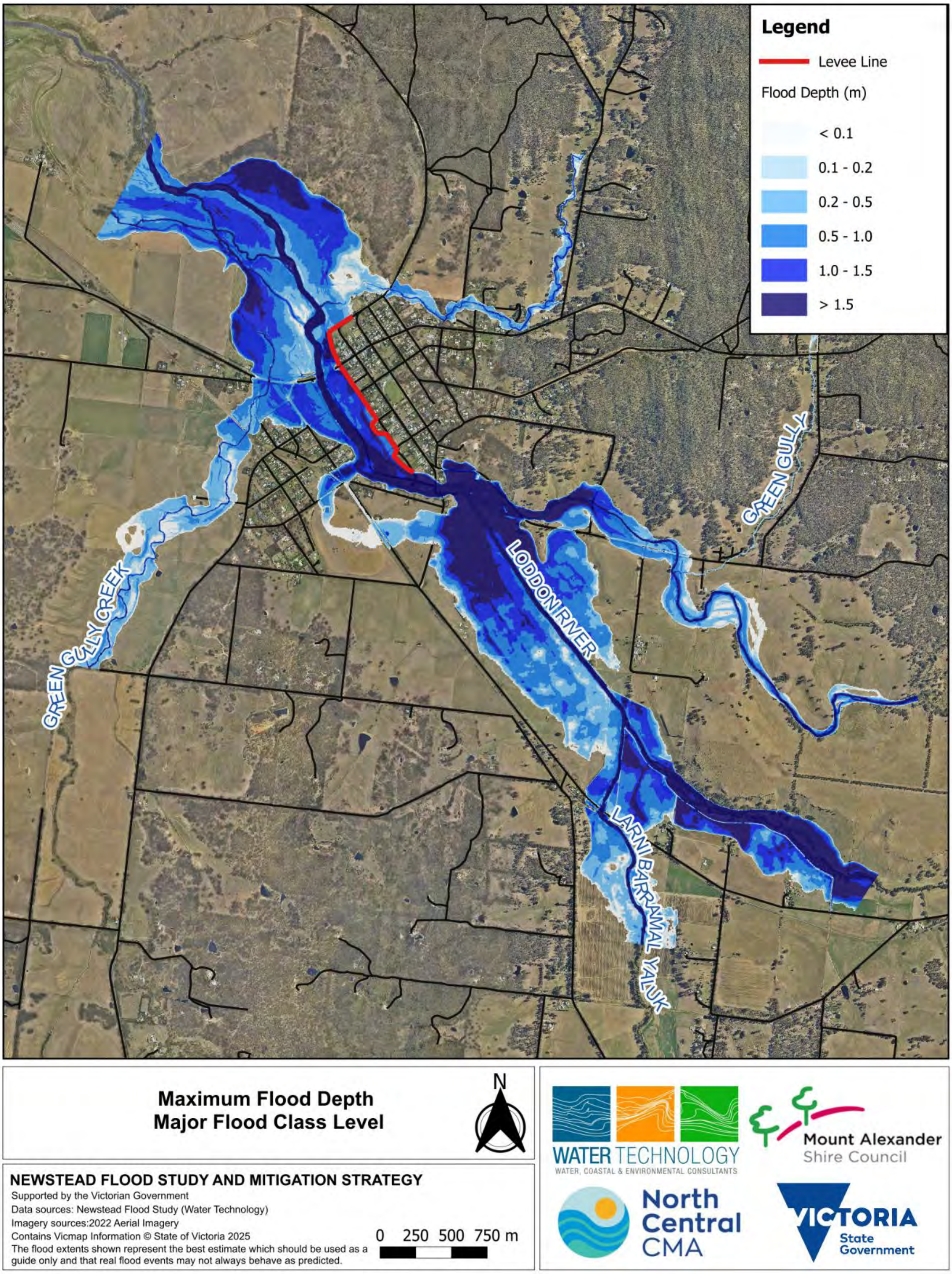

Figure 4-3 Major Flood Maximum Depth

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Melbourne
15 Business Park Drive
Notting Hill VIC 3168

Brisbane
Level 5, 43 Peel Street
South Brisbane QLD 4101

Perth
Level 1, 21 Adelaide Street
Fremantle WA 6160

Wangaratta
First Floor, 40 Rowan Street
Wangaratta VIC 3677

Wimmera
597 Joel South Road
Stawell VIC 3380

Darwin
5/5 Goyder Road
Parap NT 0820

Sydney
Suite 3, Level 1, 20 Wentworth Street
Parramatta NSW 2150

Adelaide
1/198 Greenhill Road
Eastwood SA 5063

New Zealand
7/3 Empire Street
Cambridge New Zealand 3434

Geelong
51 Little Fyans Street
Geelong VIC 3220

Gold Coast
Suite 37, Level 4, 194 Varsity Parade
Varsity Lakes QLD 4227

Sunshine Coast
Office #4 of the Regatta 1 Business Centre
2 Innovation Parkway
Birtinya QLD 4575

1300 198 413

watertech.com.au

MEMORANDUM

To	Rana Punam | Mount Alexander Shire Council Nick Butler | North Central CMA
From	Lachlan Inglis | Water Technology
Date	5 December 2025
Subject	Newstead Flood Study and Mitigation Strategy - Planning Scheme Overlays
Our ref	24010317_M07V02.docx

1 OVERVIEW

The North Central CMA and Mount Alexander Shire Council have a responsibility to assess and if possible, manage flood risk. In some cases, flood risk is unable to be reduced or eliminated by structural means. The results from the Newstead Flood Study and Mitigation Strategy indicates a widely spread flooding risk which is difficult and costly to manage with structural mitigation measures. Where residual risk remains, planning and building controls provide an important role in ensuring that development within areas known to be at risk is appropriately managed and measures are taken to ensure potential damage and loss of life mitigated.

The Victoria Planning Provisions (VPPs) contain a number of controls that can be employed to provide guidance for the use and development of land that is affected by inundation from floodwaters. These controls include the Floodway Overlay (FO), the Land Subject to Inundation Overlay (LSIO), the Special Building Overlay (SBO), the Urban Floodway Zone (UFZ) and the Environmental Significance Overlay (ESO).

Section 6(e) of the Planning and Environment Act 1987 enables planning schemes to 'regulate or prohibit any use or development in hazardous areas, or likely to be hazardous'. As a result, planning schemes contain State planning policy for floodplain management requiring, among other things, that flood risk be considered in the preparation of planning schemes and in land use decisions.

Guidance for applying flood controls to Planning Schemes is available from the Department of Energy, Environment and Climate Action (DEECA, formerly DELWP) Practice Note on Applying Flood Controls in Planning Schemes and The Victorian Floodplain Management Strategy, released by DELWP in 2015. The objective of the state planning policy framework1 for floodplain management is to assist in the protection of:

- Life, property and community infrastructure from flood hazard.
- The natural flood-carrying capacity of rivers, streams and floodways.
- The flood storage function of floodplains and waterways.
- Floodplain areas of environmental significance or of importance to river health.

2 PROPOSED OVERLAYS

In considering the appropriateness of controls within Newstead and how potential future flood impacts can be reduced, updating the local planning scheme to reflect the flood intelligence produced by the Newstead Flood Study and Mitigation Strategy (this study) is considered the most practical and beneficial outcome.

As presented in R06 – MFEP Documentation and R07 - Flood Damage and Structural Mitigation Options Report, a large number of dwellings are shown to be impacted by inundation in central Newstead. By implementing planning controls, the level of existing risk can be maintained.

Draft planning scheme mapping has been produced in line with the project brief and discussions with North Central CMA. The draft flood related overlays have been developed based on two climate change scenarios: the 1% behaviour for the year 2100, as projected under Shared Socioeconomic Pathways SSP3 and SSP5 respectively. Flood modelling of the scenarios was undertaken in line with Australian Rainfall and Runoff 2019 (V4.2) and is detailed in R04 – Final Hydraulic Modelling Report. The most appropriate controls considered for application in Newstead include the Land Subject to Inundation Overlay (LSIO), the Floodway Overlay (FO) and the Special Building Overlay (SBO).

- **Land Subject to Inundation Overlay (LSIO)** – defines the floodplain fringe and lower hazard areas within the 1% AEP flood extent

Purpose: Land Subject to Inundation Overlays are planning scheme controls that apply to land affected by flooding associated with waterways, natural flow paths and drains. Such areas are commonly known as floodplains. The LSIO is used to identify flood fringe areas of the floodplain where flooding depths and velocities are typically lower.

- **Floodway Overlay (FO)** – defines the high hazard portion of the floodplain

Purpose: Floodway Overlays apply to land that's identified as carrying active flood flows associated with waterways, natural flow paths and drains. The overlay is characterised by areas impacted by deep and or fast flowing floodwaters during the 1% AEP flood event.

- **Special Building Overlay (SBO)** – defines the portion of the floodplain within the Newstead Township that is located inside the levee

Purpose: Special Building Overlays are to ensure that future developments allow the free passage of floodwaters, minimise flood damage, and are safe with flood hazard and local drainage conditions.

The flood related overlay layers have been developed in line with the North Central CMA criteria, as shown below:

- LSIO – area inundated in a 1% AEP flood extent.
- FO – area inundated meeting the following criteria:
  - Land where the 1% AEP flood depth is likely to reach or exceed 0.5 metres, and/or
  - Land where the 1% AEP flood hazard factor (the produce of depth and velocity) is likely to reach or exceed 0.4 m^2/s.
- SBO - area inundated in a 1% AEP flood extent located inside the Newstead Township levee.

Currently there is no LSIO, FO or SBO available for the study area, thus planning overlays should be developed as direct outcomes from this study.

3 PLANNING SCHEME MAPPING

Two sets of draft flood related overlays have been developed based on two climate change scenarios:

The 1% behaviour for the year 2100, as projected under Shared Socioeconomic Pathways SSP3 and

The 1% behaviour for the year 2100, as projected under Shared Socioeconomic Pathways SSP5.

Figure 1 shows the draft LSIO, FO and SBO extents developed using the SSP5 - 8.5, year 2100 inundation scenario. Figure 2 shows the draft LSIO and FO extents developed using the SSP3 – 7.0, year 2100 inundation scenario.

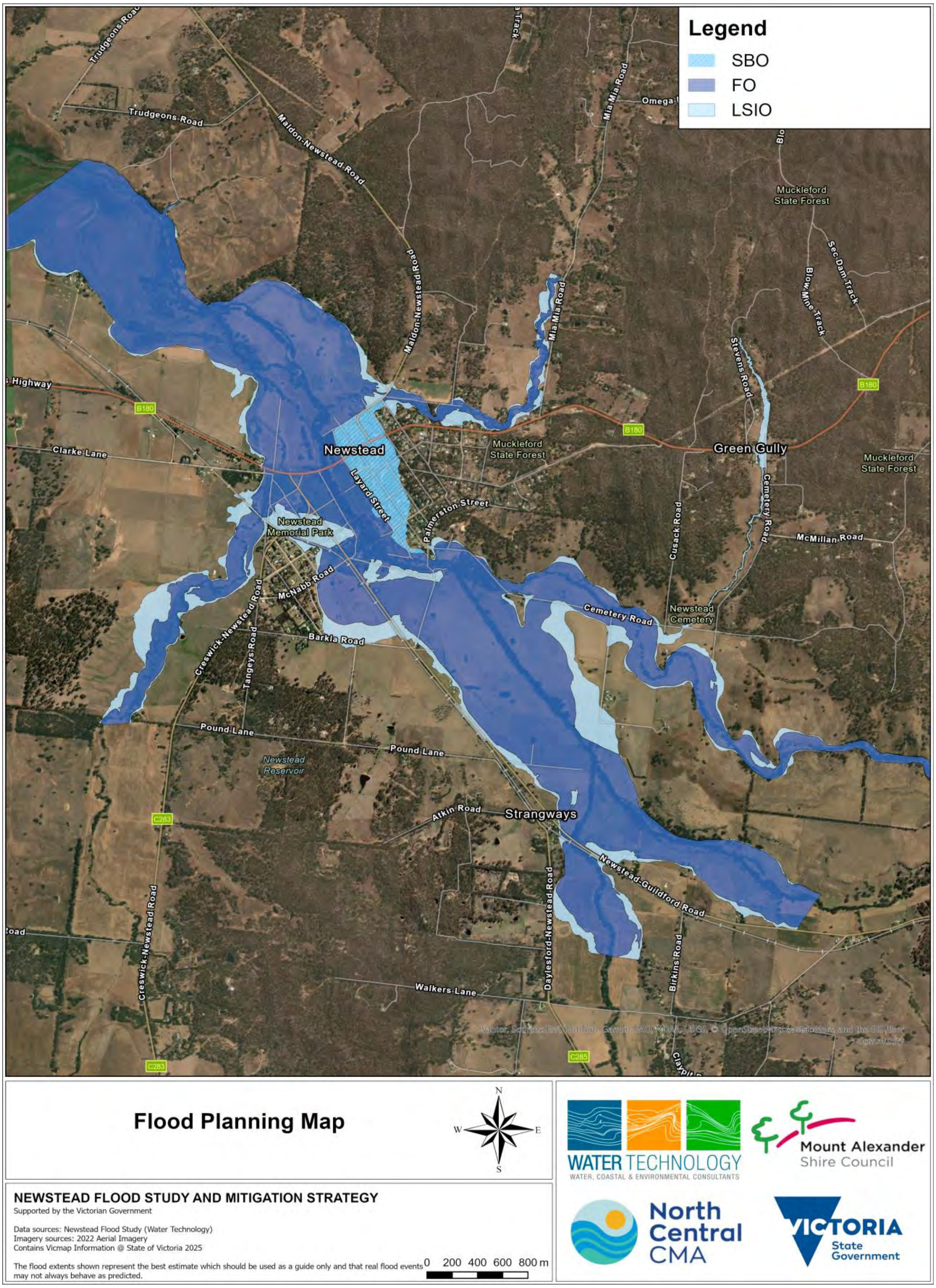

Figure 1 Draft Flood Related Planning Overlays developed using the 2100 SSP5 event

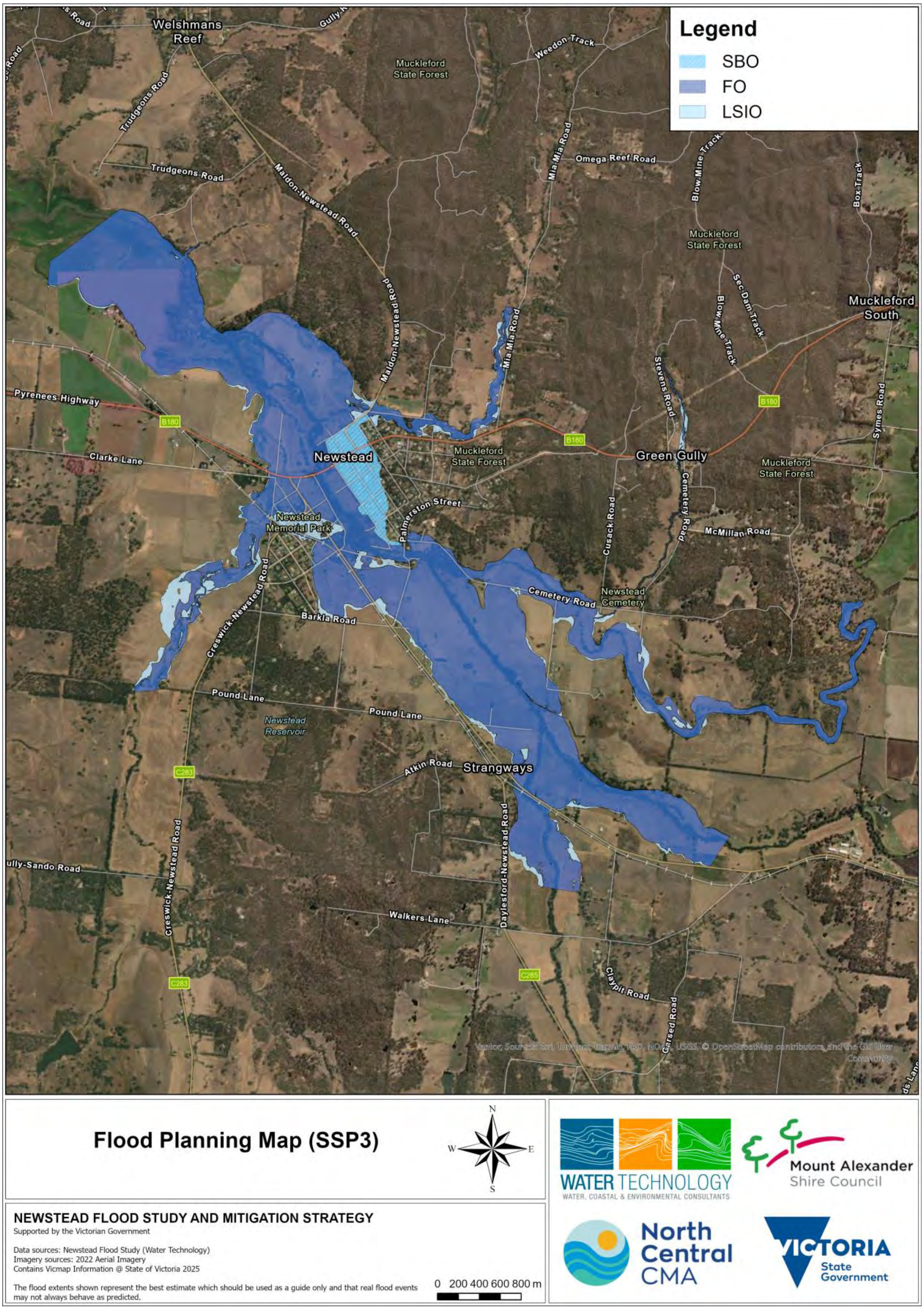

Figure 2 LSIO and FO developed using the 2100 SSP3 event

Summary Report

Newstead Flood Study and Mitigation Strategy (M1751-2023)

Mount Alexander Shire Council

9 December 2025

Document Status

Version	Doc type	Reviewed by	Approved by	Date issued
V01	Draft	Lachlan Inglis	Lachlan Inglis	28/10/2025
V02	Draft	Lachlan Inglis	Lachlan Inglis	30/10/2025
V03	Draft	Lachlan Inglis	Lachlan Inglis	09/12/2025

Project Details

Project Name	Newstead Flood Study and Mitigation Strategy (M1751-2023)
Client	Mount Alexander Shire Council
Client Project Manager	Rana Punam
Water Technology Project Manager	Elin Olsson
Water Technology Project Director	Lachlan Inglis
Authors	Lachlan Inglis and Nadeeka Parana Manage
Document Number	24010317_Final_Summary_Report_R08V03.docx

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ABN 60 093 377 283

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GLOSSARY

Annual Exceedance Probability (AEP)	Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded; it would occur quite often and would likely be relatively small magnitude. A 1% AEP flood has a low probability of occurrence or being exceeded; it would be fairly rare but it would likely be of extreme magnitude.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Recurrence Interval (ARI)	Refers to the average time interval between a given flood magnitude occurring or being exceeded. A 10 year ARI flood is expected to be exceeded on average once every 10 years. A 100 year ARI flood is expected to be exceeded on average once every 100 years. The AEP is the ARI expressed as a percentage.
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Design flood	A design flood is a probabilistic or statistical estimate, being generally based on some form of probability analysis of flood or rainfall data. An average recurrence interval or exceedance probability is attributed to the estimate.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from elevated sea levels and/or waves overtopping coastline defences.
Flood frequency analysis	A statistical analysis of observed flood magnitudes to determine the probability of a given flood magnitude.
Flood hazard	Potential risk to life caused by flooding. Flood hazard combines the flood depth and velocity.

Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Flood storages	Those parts of the floodplain that are important for the temporary storage, of floodwaters during the passage of a flood.
Geographical information systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Intensity frequency duration (IFD) analysis	Statistical analysis of rainfall, describing the rainfall intensity (mm/hr), frequency (probability measured by the AEP), duration (hrs). This analysis is used to generate design rainfall estimates.
LiDAR	Spot land surface heights collected via aerial light detection and ranging (LiDAR) survey. The spot heights are converted to a gridded digital elevation model dataset for use in modelling and mapping.
Peak flow	The maximum discharge occurring during a flood event.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Average Recurrence Interval.
Probable Maximum Flood	The flood that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in a particular drainage area.
RORB	A hydrological modelling tool used in this study to calculate the runoff generated from historic and design rainfall events.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.
Topography	A surface which defines the ground level of a chosen area.
TUFLOW	A hydraulic modelling software package used to undertake modelling using hydrological modelling inputs.

1 INTRODUCTION

1.1 Overview

Water Technology was commissioned by Mount Alexander Shire Council (MASC) to undertake the Newstead Flood Study and Mitigation Strategy. The project is funded by the Disaster Ready Fund and the Victorian Government. The investigation covers the study area presented in Figure 1-1.

Newstead is a small township in Victoria, located 15 km west of Castlemaine on the banks of the Loddon River. Located within MASC and the North Central Catchment Management Authority (NCCMA) management area, Newstead was established in the mid-19th century as a river crossing point and today hosts a population of approximately 800 people.

The Loddon River catchment upstream of Cairn Curran Reservoir was included in a RORB hydrology model prepared as part of the Cairn Curran Dam Hydrology report[1] prepared by SKM. This model was refined for the catchment upstream of Guildford during the NCCMA Rapid Flood Risk Assessment[2]. The SKM model was calibrated to three events from 2010 and 2011. Given the age of the SKM model and that the Guildford model only covers part of the catchment upstream of Newstead, a new hydrology model was produced for the current study. However, parameters adopted for the previous models were considered for model validation. This study will produce flood intelligence information for use in emergency management, assess the current flood impact/exposure in terms of annual average damages caused by flooding in Newstead, investigate structural and non-structural mitigation options and make recommendations for establishing a flood warning system for the town.

This report is one of a series documenting the outcomes for the Newstead Flood Study. Each reporting stage is shown below:

R01 – Data Review and Validation Report – Final version published 20 August 2024

R02 – Hydrology Report – Final version published 31 October 2024

R03 - Draft Hydraulic Modelling Report – Final version published 13 December 2024

R04 – Final Hydraulic Modelling Report – Final version published 3 April 2025

R05 - Design Modelling and Mapping Outputs – Final version published 3 April 2025

R06 – Municipal Flood Emergency Plan (MFEP) Documentation – Draft published 8 May 2025

R07 – Flood Damage and Structural Mitigation Options – Draft published 28 October 2025

R05 – Final Summary Report – This report

1.2 Objectives and outputs

The Newstead Flood Study and Mitigation Strategy outputs are required to meet several floodplain management objectives as highlighted in the project brief prepared by MASC. The objectives of the investigation are described below:

[1] SKM, 2012 Cairn Curran Dam: Flood Hydrology Update
[2] HARC, 2020 Guildford Rapid Flood Risk Assessment - North Central CMA Region, prepared for North Central CMA

- Undertake hydrologic and hydraulic modelling to determine flood levels and flood extents for the full range of flood events up to and including the Probable Maximum Flood (PMF).
- Calibrate models to historic flood events including the October 2022 flood event.
- Investigate modelling of climate change scenarios.
- Assess the feasibility of a range of potential mitigation options including understanding of the level of protection provided by the existing levee and information to inform necessary upgrades to this levee.
- Analyse the feasibility of establishing effective flood warning, accounting for time available between rainfall and the township flooding, in the context of a total flood warning system.
- Update flood intelligence to be incorporated into the Municipal Flood Emergency Plan.
- Provide recommendations to update the Planning Scheme and ensure it is informed by the best available flood information.

1.3 Study area

The main flood risk in Newstead is posed by the Loddon River, a levee was constructed in the 1920's that is still protecting the eastern portion of the township from Loddon River flooding. However, a number of smaller catchments generate runoff towards Newstead directly or indirectly, resulting in complex hydrologic and hydraulic conditions to address in planning and emergency response. These catchments include Mia Mia Creek, Muckleford Creek, Larni Barramal Yaluk, Green Gully and Green Gully Creek as shown in Figure 1-1. Additionally, there are several tributaries joining the Loddon River near Newstead further impacting river levels.

Newstead most recently experienced flooding in October 2022, causing flooding to parts of the township located on the western side of the Loddon River. Flooding in Newstead has historically caused levee breaches which were mitigated by sandbagging during the flood event. Flooding of the Loddon River also leads to the town being isolated when major traffic routes are cut off. The Loddon River at Newstead has been subject to considerable physical and ecological modifications due to extensive historic mining activities and other anthropogenic influences since European settlement. In recent years, bank erosion has been an issue for landholders adjacent to the Loddon River.

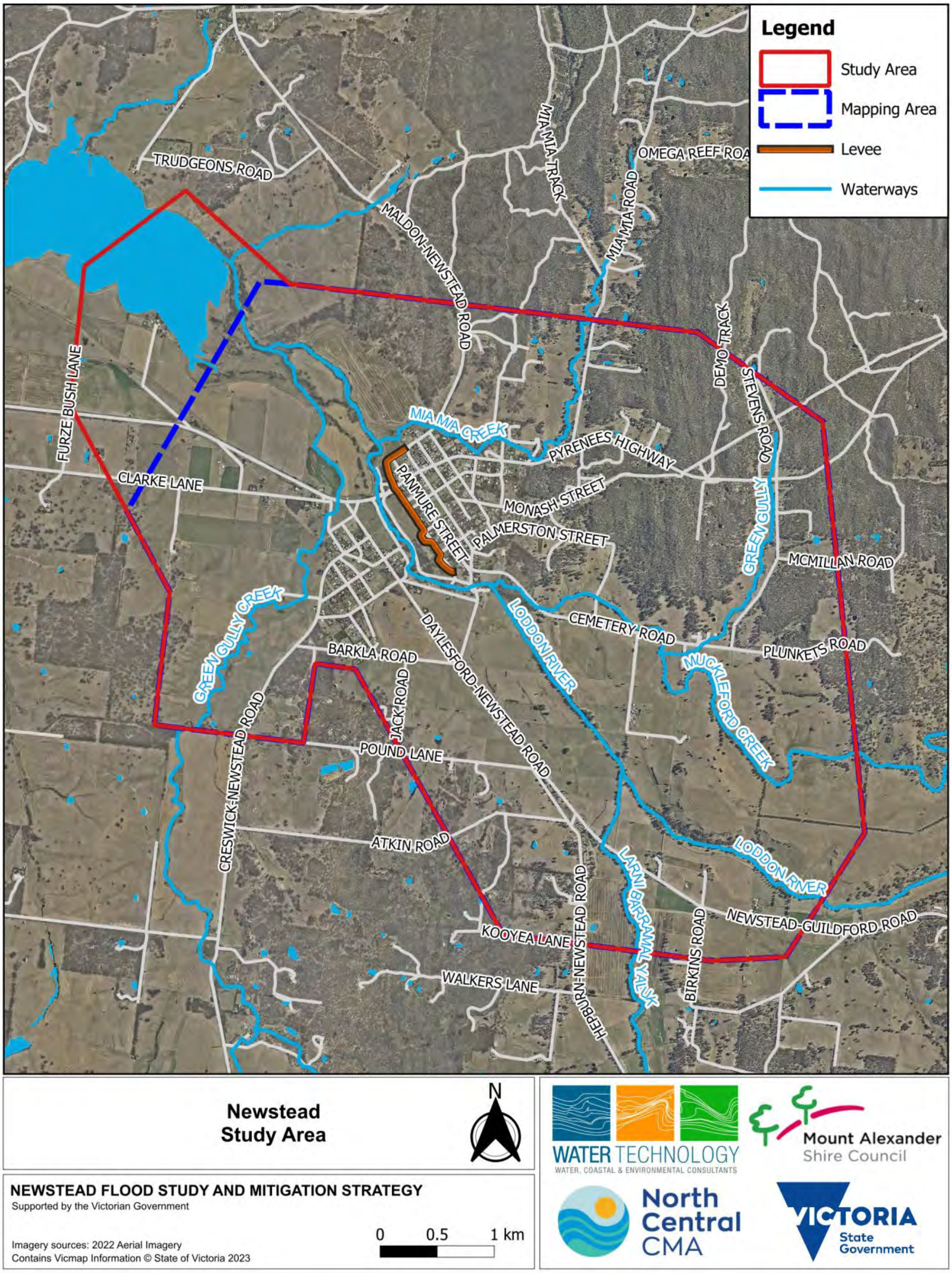


Figure 1-1 Newstead study area

1.4 Flood behaviour

The Loddon River originates in the Great Dividing Range within the Hepburn and Mount Alexander shires, flowing north until Vaughan where it turns in a westerly direction towards the township of Newstead. Upstream of Newstead, the Loddon River is joined by several tributaries including Campbells Creek, Larni Barramal Yaluk, Muckleford Creek, Green Gully, Green Gully Creek and Mia Mia Creek. Flooding in Newstead is primarily caused by the Loddon River, but localised flood events can cause flooding along any of the tributaries. The eastern portion of the Newstead township is located behind a levee bank.

When the Loddon River floods, widespread breakouts from the river channel and tributaries are observed in the 20% AEP event inundating farmland upstream and downstream of the township and the Pyrenees Highway is overtopped by Green Gully Creek. The flood behaviour is similar in the 10% AEP event.

The Newstead levee is overtopped in the 5% AEP event, with flood levels up to 0.5 m observed inside the levee. For the 2% AEP event, the flooding behind the levee causes flooding above floor at 80 properties and large areas of Newstead become isolated/inaccessible.

Note that all intelligence data presented in this report has been produced based on the near-term climate change considerations for the year 2030 (based on the Shared Social Pathway SSP5 scenario).

2 DATA REVIEW AND VALIDATION

The first stage of the project included the collation and review of available data relevant to flooding in Newstead. This included the following:

- Previous flood studies and reports

There was no flood study of Newstead nor any previous hydrologic model covering the upper reaches of the Loddon River have been undertaken before this study. During the data collation and review process the following studies were identified as relevant:

  - Newstead Erosion Control – Loddon River Investigation and Design
  - Newstead Levee Investigation Report
  - Risk Assessment – Newstead Levee
  - Newstead Levee Alignment – Modelling Assessment
  - Mia Mia Creek Flood Impact Assessment
  - North Central CMA Erosion Assessment and Works Prioritisation Project

- Historical flood events and accompanying anecdotal evidence
  - The Newstead Local Flood Guide (developed by the SES) lists records of historic flood levels and impacts for the 1890, 1909, October 1934, October 2000, January 2011, October 2016 and October 2022 flood events
  - Evidence was gathered for the 1870, 1916, 1934, 2010, 2011 and 2022 flood events. The hydraulic model calibration focused on the October 2022 event, the largest flood on record at Newstead.
  - Surveyed water levels from the events in 2000, 2010 and 2022, a total of 63 flood marks were provided by the NCCMA.
  - Anecdotal evidence was obtained during the community consultation session conducted in June 2024.
- Recorded streamflow

Following four (4) active streamflow gauges within the study area have data available with water level and streamflow data available to the present date.

  - Loddon River @ Newstead (407215)
  - Larni Barramal Yaluk @ Yandoit (407221)
  - Loddon River @ Vaughan D/S Fryers Creek (407217)
  - Muckleford Creek @ Muckleford North (407300)

- Recorded rainfall
  - Daily and sub-daily rainfall data provided by the Bureau of Meteorology were used in this study.
  - A total of 23 daily rain gauges have been in use, with records covering various periods since 1867. Of these, 5 gauges remain operational. The Newstead gauge, which is the nearest active gauge within the township, has a long-standing record from 1897 to the present day.
  - Bendigo Airport, Redesdale, and Ballarat Aerodrome gauges capture sub-daily rainfall measurements.
- Storages

There are several storages within the study area, including:

  - Cairn Curran Reservoir, located downstream of the Newstead Township, and
  - Several water storage dams in open space (e.g., Newstead Racecourse).
- Levees
  - The Newstead levee located on the east side of the Loddon River stretching from the southern end of Layard Street to the northern end of Panmure Street, with a length of about 1.5 km.
  - Additional levees have been identified through the latest LiDAR along the Loddon River and Larni Barramal Yaluk, located in the upper portions of the study area.
- Road and drainage infrastructure
  - The road and related infrastructure have been identified using aerial imagery, topographic data, Department of Transport (DoT) records, and council asset information. Further detail for these structures has been gathered through topographic surveys and site inspections.
- Topographic data
  - The 2022 Department of Transport Digital Twin Project LiDAR was the only available high-resolution dataset covering the entire study area.
  - The dataset was verified against survey data provided by Price Merrett for the current project, as described in R01 – Data Review and Validation Report. Based on the verification, the LiDAR dataset showed a high degree of accuracy and was considered suitable for use in the hydraulic model.
  - The LiDAR captured a water level in the Loddon River, and hence was not accurately representing the river bathymetry below the water level. Surveyed cross-sections for the Loddon River from 2012 were provided by ALS, covering a small area upstream and downstream the Loddon River at Newstead gauge. The data was used to enhance bathymetry of the Loddon River in this area.
  - Survey data for the Newstead Levee was included in the model in favour of the LiDAR to accurately represent the levee crest. The LiDAR was further supplemented with breaklines to represent minor levees and some roads acting as hydraulic controls, ensuring flow could not overtop these structures until it reached the crest level (as determined by sampling the 1m LiDAR DEM).

3 MODEL DEVELOPMENT AND CALIBRATION MODELLING

3.1 Overview

The Hydrology Report (R02) describes in detail the hydrologic (RORB) model build and parameter selection adopted for the study. The report also details the calibration and validation modelling of the historic events (November 2010, January 2011, September 2016 and October 2022).

The Hydraulic Modelling Report (R03) describes the hydraulic (TUFLOW) model built, and calibration and validation process in detail. Model performance and alignment with the anecdotal evidence was utilised to determine the hydraulic roughness. Other parameters were selected based on consideration of adopted values from nearby flood studies and regional approximations in the absence of local calibration data.

3.2 General Methodology

The hydrologic assessment of the Newstead flood study followed the following steps:

- Development of a catchment wide RORB rainfall runoff model.
- Calibration of the RORB model to the historic events (November 2010, January 2011, September 2016 and October 2022).
- Completion of a flood frequency analysis (FFA) for the Loddon River at Newstead (407215).
- Adopting routing parameters based on calibration for design event modelling.
- Design event modelling and reconciliation of design event peak flows at the Loddon River at Newstead Gauge with expected quantiles as informed by the FFA.

3.3 Rating Curve Review

At the beginning of the project a detailed review of the Loddon River at Newstead streamflow Gauge rating table was required due flows over 20,500 ML/day are extrapolated. Given that all the significant events at Newstead are larger than this, it was crucial to understand the accuracy of the rating curve for high flows.

A thorough investigation into the gauge was conducted, with the following steps undertaken:

1. A TUFLOW hydraulic model of the gauge site was developed to create a modelled rating curve for a range of steady state flows.
2. The rating table of the Loddon River at Newstead gauge was compared to results of hydraulic modelling of the gauge site to achieve a close match for high flows above gaugings (within the extrapolated region of the rating table). The rating curve review is detailed in the Data Review and Validation Report R01.
3. Several calibration events including the October 2022 flood event, were modelled and showed a suitable agreement with observed gauging. The October 2022 flood event is the largest recorded event on the Loddon River within the period of continuous recording of river heights, with the Loddon River at Newstead gauge recording a peak height of 6.12 metres (214.06 mAHD).

3.4 Flood Frequency Analysis

A flood frequency analysis (FFA) was completed for the Loddon River at Newstead (407215). The analysis considered all available complete calendar years of data, from 1976 to 2023. The analysis was completed in the software package FLIKE, as recommended by ARR2019. The annual series used data as published by DEECA on Victoria's Water Measurement Information System (WMIS). The raw data was considered fit for purpose based on the rating curve review undertaken during the data review phase of the Newstead Flood Study.

The following distributions were tested, with the Log Pearson III distribution providing the best fit to the observed data:

- Log Pearson III
- Generalised Extreme Value
- Log Natural
- Generalised Pareto

The adopted FFA quantiles are shown in Table 3-1.

Table 3-1 Adopted FFA quantiles for Loddon River at Newstead (407215)

AEP	Peak Design Flow (ML/day)		
	Log Pearson III	LPIII 5% Limit	LPIII 95% Limit
20%	20,638	14,452	29,102
10%	36,025	26,191	49,919
5%	53,705	39,186	79,116
2%	79,173	55,276	137,209
1%	99,160	65,095	201,266
0.5%	119,188	72,681	283,411
0.2%	145,076	79,561	419,829
0.1%	163,859	83,142	552,890
0.05%	181,745	85,822	717,537

A graph of Log Pearson III distribution and the observed values is shown in Figure 3-1.

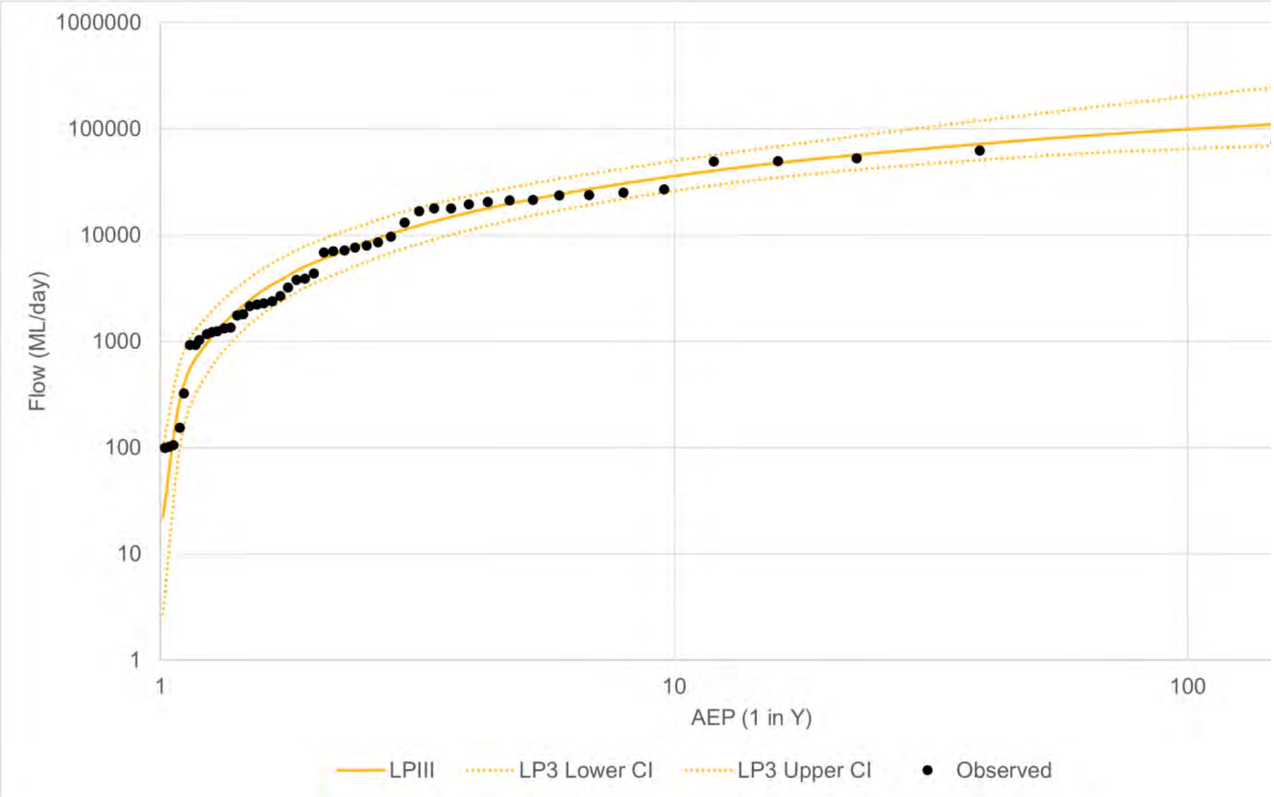


Figure 3-1 FFA: Log Pearson III Distribution

The five largest flood events since records began were compared against the design FFA distribution to assign an approximate AEP (as defined by the FFA) to each event in Table 3-2 below.

Table 3-2 Approximate AEP of 5 largest recorded events (based on FFA)

Year	Gauge Height (m)	Flow (ML/day)	Approximate AEP
October 2022	6.12	74,986	Between 2% and 5%
January 2011	5.89	62,251	Between 2% and 5%
September 2016	5.70	52,836	Between 5% and 10%
November 2010	5.63	49,759	Between 5% and 10%
October 2000	5.64	49,335	Between 5% and 10%

3.5 RORB summary

3.5.1 Model build

A hydrologic model of the Upper Loddon River catchment to the outfall in Cairn Curran Reservoir was developed for this study. Modelling utilised RORB, a rainfall-runoff modelling software package to determine flow hydrographs at specific locations within the catchment (i.e. gauges) and at the upstream extent of the hydraulic model.

The final RORB model included 201 sub-catchments encompassing a total catchment area of approximately 1103 km^2, with the hydraulic study area located in the western end of the catchment, see Figure 3-2. The reaches were all defined as Type 1 'natural' and impervious fractions ranged from 0.05 to 0.7. Interstation areas were placed at the gauge locations throughout the catchment. By using interstation areas, it was possible to apply varying Kc values to each catchment individually during the model's calibration phase.

3.5.2 Model parameters

The hydrologic (RORB) model was calibrated using several streamflow gauges, including the Loddon River at Newstead gauge (407215). Where possible, additional gauges were incorporated during calibration to ensure a representative fit across the wider catchment.

The RORB model was calibrated using an initial loss/continuing loss method. The m routing parameter adopted the recommended value of 0.8 in line with the RORB manual. The model adopted a single m across the full catchment but varied the value of k_c at each interstation area, with loss parameters adjusted to reach a level of agreement with the recorded peak flows at the streamflow gauges. K_c values were adjusted to match the shape and timing of the hydrograph at Newstead as closely as possible.

The calibration was completed for 2010, 2011, 2016 and 2022 events. The modelling agrees with recorded flows at a number of streamflow gauges throughout the catchment and shows close match to peak flow, peak timing and volume error. Table 3-3 shows a summary of the RORB parameters adopted for the calibration events.

Table 3-3 Summary of values for calibration events

Interstation Area/Gauge	K_c	m	IL (all bursts) mm	CL (all bursts) mm/hr
407217 Loddon River at Vaughan (d/s Fryers Ck)	18.00	0.8	18 - 55	0.25 – 3.00
407221 Larni Barramal Yaluk at Yandoit	21.98		18 - 45	0.25 – 2.25
407300 Muckleford Creek at Muckleford North	10.00 -12.46		15 - 40	0.75 – 3.00
Green Gully interstation	3.12		18 - 45	0.75 – 3.00
407215 Loddon River at Newstead	19.51		20 - 45	0.50 – 3.00
Mia Mia Creek interstation	4.32		18 - 45	0.75 – 3.00
Catchment outlet	17.47		18 - 45	0.75 – 3.00

The calibration process is detailed in the Hydrology Report R02.

Given the satisfactory performance of the RORB model at the Newstead gauge in the calibration events, the calibration routing parameters were adopted for design. While the calibration events adopted varying losses across the catchment/interstation areas, design modelling adopted a single IL and CL for the whole model based on the reconciliation of modelled flows with FFA. The adopted design parameters are shown in Table 3-4 below.

Table 3-4 Design RORB kc values by interstation area

Interstation Area/Gauge	K_c	D_{av} (km)	K_c/D_{av}	m	Initial Loss (mm)	Continuing Loss (mm/hr)
407217 Loddon River at Vaughan (d/s Fryers Creek)	18	27.99	0.64	0.8	21	1.75
407221 Larni Barramal Yaluk at Yandoit	21.98	22.9	0.96			
407300 Muckleford Creek at Muckleford North	12.46	9.97	1.25			
Green Gully interstation	3.12	2.5	1.25			
407215 Loddon River at Newstead	19.51	24.91	0.78			
Mia Mia Creek interstation	4.32	4.98	0.87			
Catchment outlet	17.47	13.98	1.25			

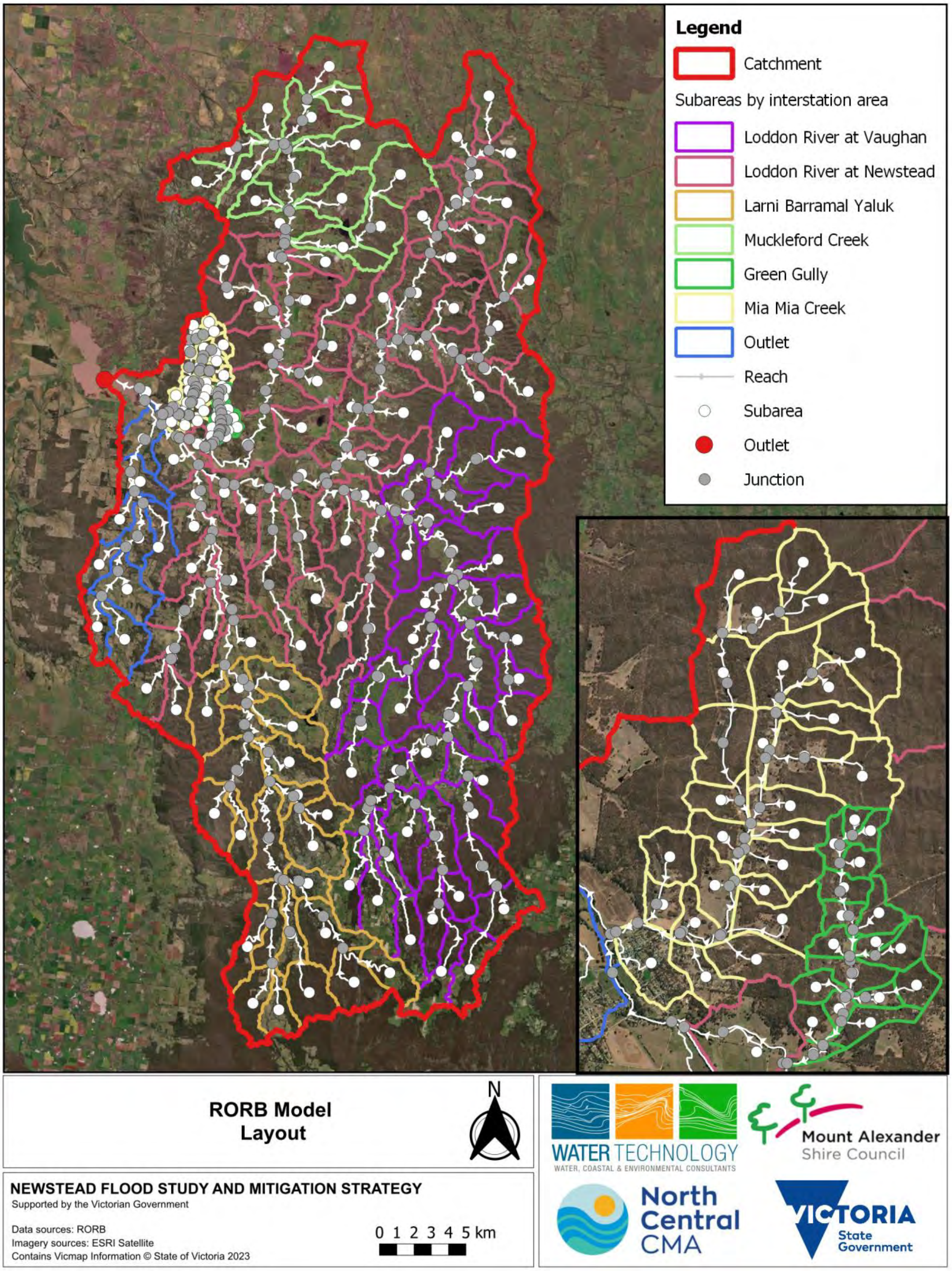


Figure 3-2 RORB model layout

3.5.3 Rainfall

3.5.3.1 Historic events

The RORB model was run for the 2010, 2011, 2016 and 2022 flood events. Daily rainfall totals were summed over the duration of the events and a spatial distribution of total rainfall created by interpolating the rainfall totals with an inverse distance weighted distribution. The average rainfall over each subarea of the RORB model was then applied to that subarea. Temporal distributions were derived from sub-daily records for the events and each subarea in the model was modelled with the temporal distribution of the closest sub-daily station.

3.5.3.2 Design Rainfall

Design rainfall depths were obtained from the Bureau of Meteorology Design Rainfall Data System[3]. Initially, the baseline IFD data was utilised in order to enable reconciliation with FFA. Climate change factors were then adopted by scaling the design rainfall to provide consideration of the near-term (2030) and long-term (2100) changes to baseline IFDs from when they were developed (2016).

Rainfall depths were obtained in ascii grid format to enable spatial variation of rainfall to be considered in line with the recommendations of ARR2019 for catchments exceeding 20km^2. Areal reduction factor (ARF) parameters and temporal patterns were obtained from the ARR Datahub[4].

- *Temporal patterns* for the catchment were adopted from the Murray Basin region. Due to the size of the catchment, areal temporal patterns are recommended for use by ARR2019. Areal temporal patterns are available for storms 12 hours in duration and longer. Given the critical duration was shown to be longer than 12 hours, point temporal patterns were not considered for design rainfall distribution.
- *Spatial Variation* was applied in RORB using an Intensity-Frequency-Duration (IFD) data file. GIS tools were used to assign a point rainfall (taken as the average of rainfall grid cells that intersect a subarea) to each subarea. The weighted average rainfall for the catchment and the percentage of the weighted average to be applied to each subarea was then calculated in a spreadsheet for each duration and magnitude of event as per the methodology described in Book 2, Chapter 6 of ARR2019.
- *Median Pre-bursts* rainfall depth was subtracted from the storm Initial Loss to obtain the burst Initial Losses applicable for this study. The burst initial losses were then applied to the design burst rainfall depths. The ARR datahub provides pre-burst depths for storms between 1 hour and 72 hours only, and for AEPs up to the 1% event only. All long duration storms had no associated pre-burst, and it was assumed that this would carry forward to storms longer than 72 hours. For events rarer than the 1% AEP, the pre-burst depths from the 1% AEP were applied.
- *Embedded bursts* are bursts within a design temporal pattern which, when multiplied by the design rainfall depth, create a shorter duration storm of lower frequency (i.e. higher magnitude) than the intended design burst. RORB has a built in feature to filter embedded bursts which spreads troublesome timestep peaks across other time increments, thus removing the embedded burst but maintaining the general temporal pattern as supplied. Temporal pattern filtering was used in the design modelling.

[3] http://www.bom.gov.au/water/designRainfalls/revised-ifd/
[4] https://data.arr-software.org/

3.6 TUFLOW summary

3.6.1 Model parameters and design

A hydraulic model of Newstead was built using the TUFLOW modelling package. The TUFLOW model design and parameter selection is described in detail in R03 – Draft Hydraulic Modelling Report . A short summary of the modelling logic and selected parameters is provided below however readers wishing to know more about the model build should refer to the full report.

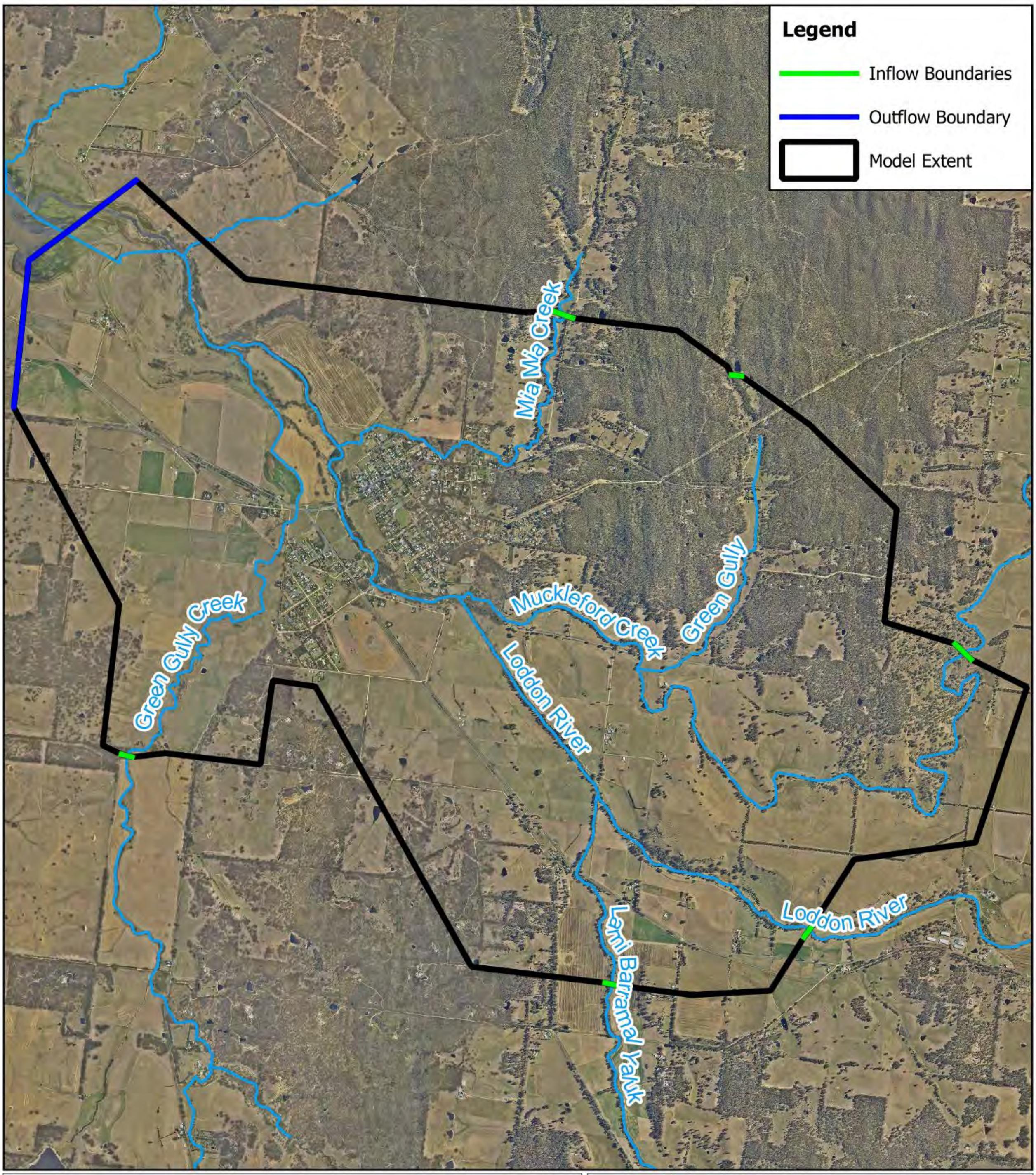
The key TUFLOW model parameters, along with the design approach for key components of the model, are shown in Table 3-5. The TUFLOW model extent and boundary areas are shown in Figure 3-3.

Table 3-5 Key TUFLOW model parameters

Parameter	Value
Model Build	2023-03-AE-iSP-w64
Model Precision	Single Precision
Grid Cell Size	3 metres
Model Orientation	Along Loddon River orientation at Newstead
Sub Grid Sampling	Sample frequency 5, sample distance 0.75 metre
Solution Scheme	HPC
Inflows	RORB hydrographs at 6 inflow locations
Outflow	Height-Flow boundary with a slope of 0.1%
Hydraulic Roughness	Manning's 'n', varies with land use
1-Dimensional elements	Culverts and pipes linked to 2-D domain (note bridges modelled as 2-D bridge flow constrictions)

Table 3-6 Hydraulic roughness

Land use / Topographic description	Roughness coefficient (Manning's n)
Open space, minimal vegetation	0.0375
Open space, moderate vegetation	0.080
Open space, heavy vegetation	0.120
Built-up and residential areas – high density (buildings modelled separately)	0.100
Built-up and residential areas – low density (buildings modelled separately)	0.050
Building footprints	0.400
Industrial, commercial or large buildings	0.300
Waterbodies	0.020
Waterways	0.030
Roads	0.020



Hydraulic Model Extent and Boundaries

N

NEWSTEAD FLOOD STUDY AND MITIGATION STRATEGY
Supported by the Victorian Government

Imagery sources:2022 Aerial Imagery
Contains Vicmap Information © State of Victoria 2023

0 500 1,000 m

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Mount Alexander Shire Council

North Central CMA

VICTORIA State Government

Figure 3-3 Hydraulic model extent and boundaries

3.7 Calibration modelling results

The results of the calibration modelling were used to ensure the models were performing as expected, reproducing depths and extent from the flooding experienced in large flood events.

The hydrology calibration shows that the RORB model developed for the study is suitable to replicate a range of flood events including large floods such as the January 2011 and October 2022 events. The modelling agrees with recorded flows at a number of streamflow gauges throughout the catchment and shows close match to peak flow, peak timing and volume error.

The hydraulic model calibration focused on the October 2022 event, the largest flood on record at Newstead. The September 2016 event was also modelled as a validation event as it represents a longer duration storm event. The modelled calibration results were compared to anecdotal evidence obtained during the community consultation session conducted in June 2024.

The following calibration data sources were available.

- The Newstead Local Flood Guide (developed by the SES) listing records of historic flood levels and impacts for the 1890, 1909, October 1934, October 2000, January 2011, October 2016 and October 2022 flood events
- Photo evidence gathered for the 1870, 1916, 1934, 2010, 2011 and 2022 flood events.
- Surveyed water levels from the events in 2000, 2010 and 2022, a total of 63 flood marks were provided by the NCCMA.
- Anecdotal evidence obtained during the community consultation session conducted in June 2024.

More detail around the calibration data is presented in the Model Calibration Reports (R02 and R03). Figure 3-4 and Figure 3-5 show the modelled flood depth for the October 2022 and September 2016 events, respectively.

Modelling of the two calibration/validation events has shown an acceptable match to the available calibration data sources, including stream gauge data, flood marks, anecdotal records and photos, indicating the hydraulic model is suitable for design modelling of riverine inundation in Newstead.

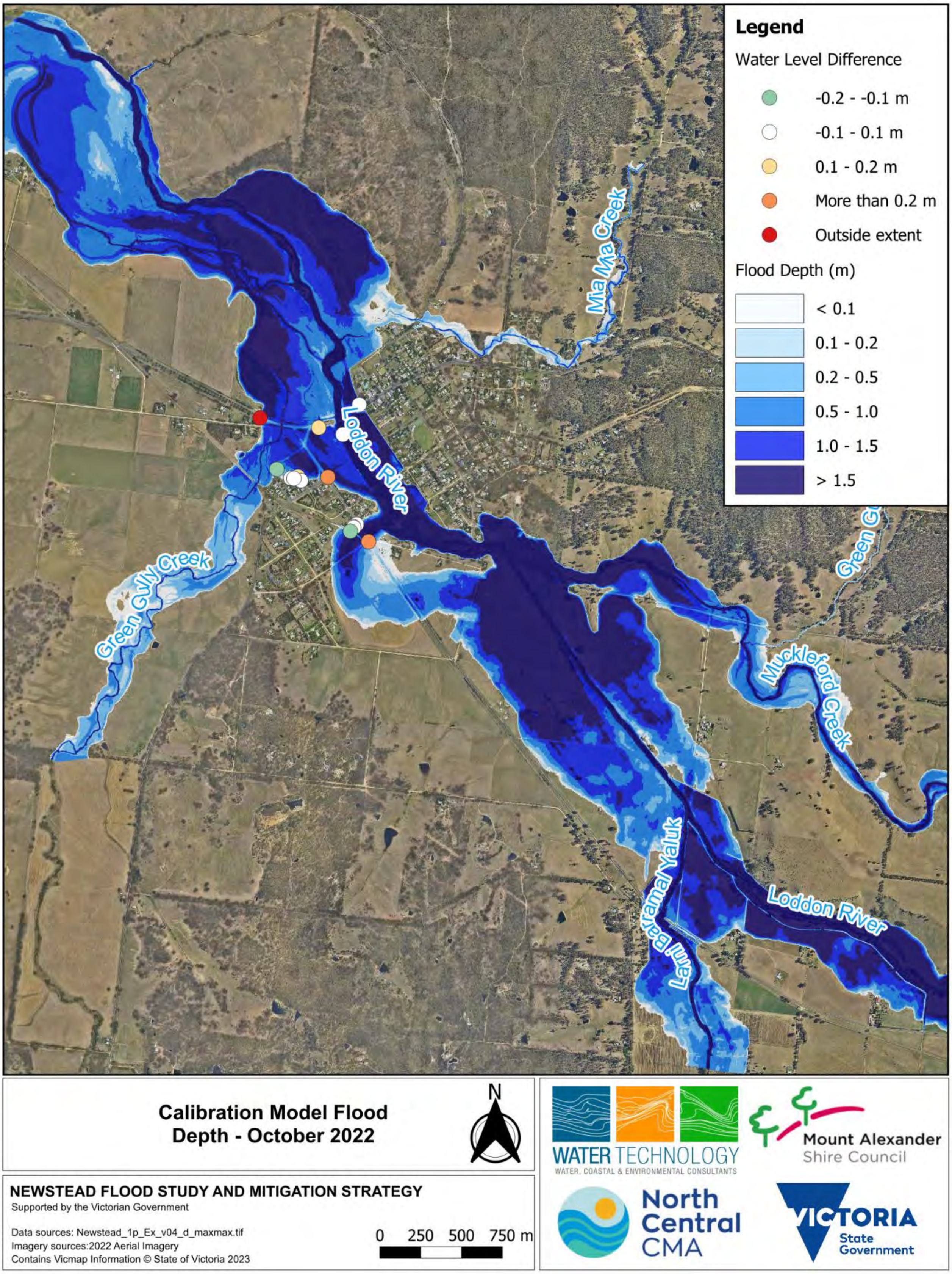


Figure 3-4 Calibration model flood depth – October 2022

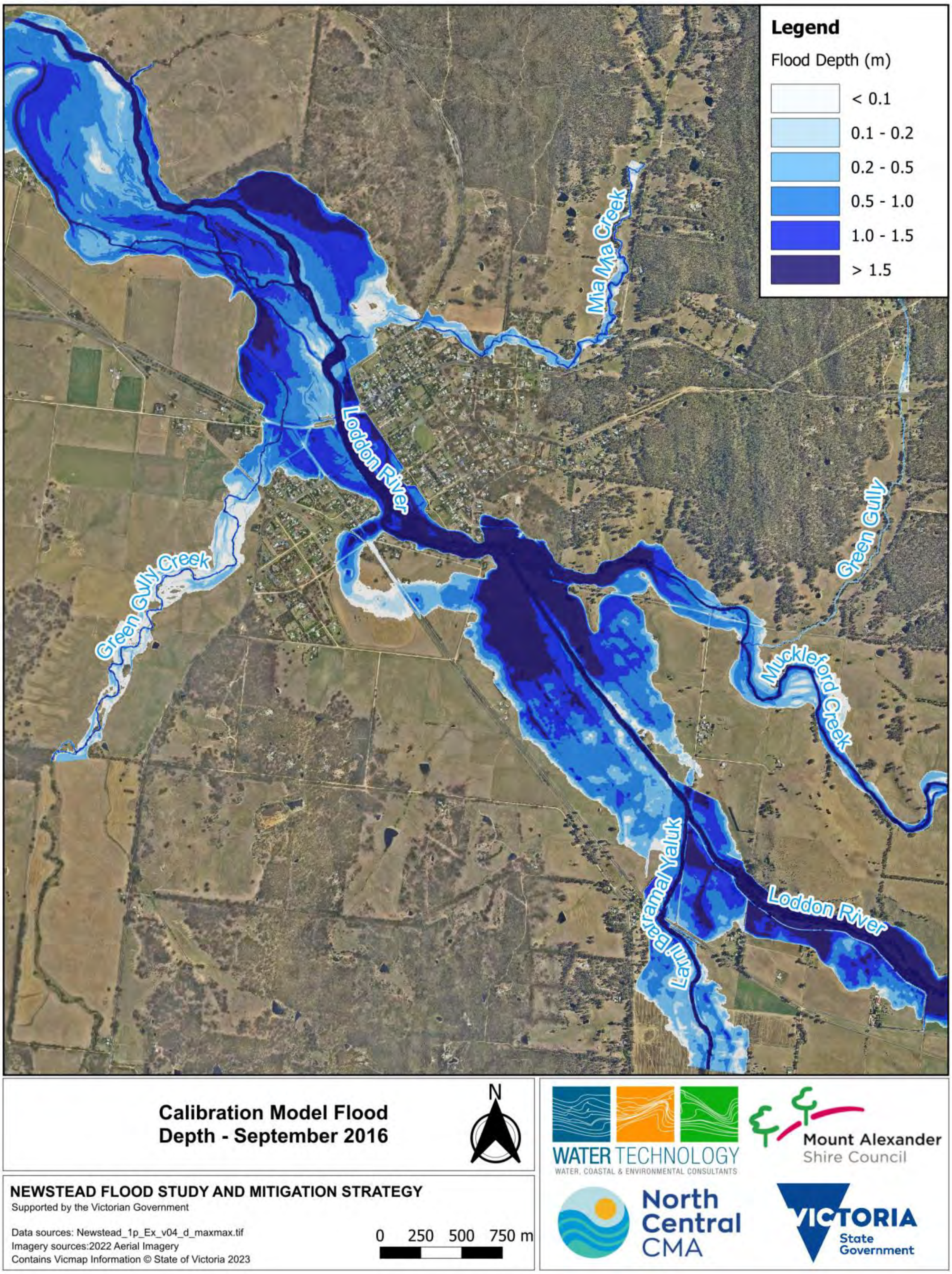


Figure 3-5 Calibration model flood depth – September 2016

4 DESIGN MODELLING

4.1 Hydrology

The RORB hydrologic model was run for a range of design flow events. The design flows at the Newstead gauge, along with the FFA results and confidence limits, are shown in Table 4-1.

Table 4-1 Design Flows, critical durations and representative temporal patterns

AEP	Loddon River at Newstead Peak Flow (m^3/s)	Critical Duration	Representative Temporal Pattern	FFA 5% Confidence Limit (m^3/s)	FFA Expected Quantile (m^3/s)	FFA 95% Confidence Limit (m^3/s)
20%	307.4	18 hour	TP09	167.3	238.9	336.8
10%	477.4	18 hour	TP09	303.1	417.0	577.8
5%	677.2	18 hour	TP09	453.5	621.6	915.7
2%	945.1	18 hour	TP09	639.8	916.4	1,588.1
1%	1,156.8	18 hour	TP09	753.4	1,147.7	2,329.5
0.5%	1,331.3	18 hour	TP09	841.2	1,379.5	3,280.2
0.2%	1,594.2	18 hour	TP09	920.8	1,679.1	4,859.1
0.1%	1,794.4	18 hour	TP09	962.3	1,896.5	6,399.2
0.05%	2,000.9	18 hour	TP09	993.3	2,103.5	8,304.8

4.1.1 Climate Change

The impact of increased rainfall intensity associated with climate change was investigated, with current day scenario design modelling based on the near-term climate change considerations for 2030 (SSP5 – 8.5).

- The model was run for a range of design flow events and the resultant flows at the Newstead Gauge for the near-term climate change scenario is shown in

Table 4-2.

Several additional scenarios have modelled for the 1% AEP event to assess the potential impacts:

The following two scenarios were also considered.

- Projected flows to 2100 under SSP5 – 8.5
- Projected flows to 2100 under SSP3 – 7.0 (1% AEP and 10% AEP only)

The results of the Long-term modelling for the two SSP scenarios are provided in Table 4-3 and Table 4-4.

Table 4-2 Design flows, critical durations and representative temporal patterns for near-term (2030) climate change scenario

AEP	Loddon River at Newstead Peak Flow (m^3/s)	Critical Duration	Representative Temporal Pattern
20%	399.9	18 hour	TP09
10%	606.5	18 hour	TP09

AEP	Loddon River at Newstead Peak Flow (m^3/s)	Critical Duration	Representative Temporal Pattern
5%	842.6	18 hour	TP09
2%	1155.7	18 hour	TP09
1%	1403.8	18 hour	TP09
0.5%	1618.3	18 hour	TP09
0.2%	1929.6	18 hour	TP09
0.1%	2163.6	18 hour	TP09
0.05%	2405.1	18 hour	TP09

The resultant flows at the Newstead Gauge for the long-term climate change scenario is shown in .

Table 4-3.

Table 4-3 Design flows, critical durations and representative temporal patterns for long-term (2100) climate change scenario (SSP5 – 8.5).

AEP	Loddon River at Newstead Peak Flow (m^3/s)	% Increase compared to 2030	Critical Duration	Representative Temporal Pattern	Approximate near-term (2030) AEP
20%	621.5	55	18 hour	TP09	Just larger than 10%
10%	918.2	51	18 hour	TP09	Between 5% and 2%, closer to 5%
5%	1219.8	45	18 hour	TP09	Just larger than 2%
2%	1631.2	41	12 hour	TP09	Just larger than 0.5%
1%	1985.8	41	12 hour	TP09	Between 0.2% and 0.1%, closer to 0.2%
0.5%	2272.3	40	12 hour	TP09	Between 0.1% and 0.05%
0.2%	2685.9	39	12 hour	TP09	Larger than 0.05%
0.1%	3013.9	39	12 hour	TP09	Larger than 0.05%
0.05%	3346.8	39	12 hour	TP09	Larger than 0.05%

Table 4-4 Design flows, critical durations and representative temporal patterns for long-term (2100) climate change scenario (SSP3– 7.0).

AEP	Loddon River at Newstead Peak Flow (m^3/s)	% Increase compared to 2030 SSP5	Critical Duration	Representative Temporal Pattern	Approximate near-term (2030) AEP
10%	821.6	29	18 hour	TP09	Just smaller than 5%
1%	1804.9	35	18 hour	TP09	Between 0.5% and 0.2%,

4.2 Hydraulics

Design flows in the waterways entering the hydraulic model were determined using a hydrology model (RORB) as described in the Hydrology Report (R02).

The flood extents for the full range of modelled AEP events for each catchment area are shown in Figure 4-1, and the 1% AEP maximum depth results are shown in Figure 4-2.

Flood depth maps for the full range of AEPs and the PMF event are provided in Appendix A of the Final Hydraulic Modelling Report (R04). Flood depths for the 2100 1% AEP under SSP5-8.5 is shown in Figure 4-3.

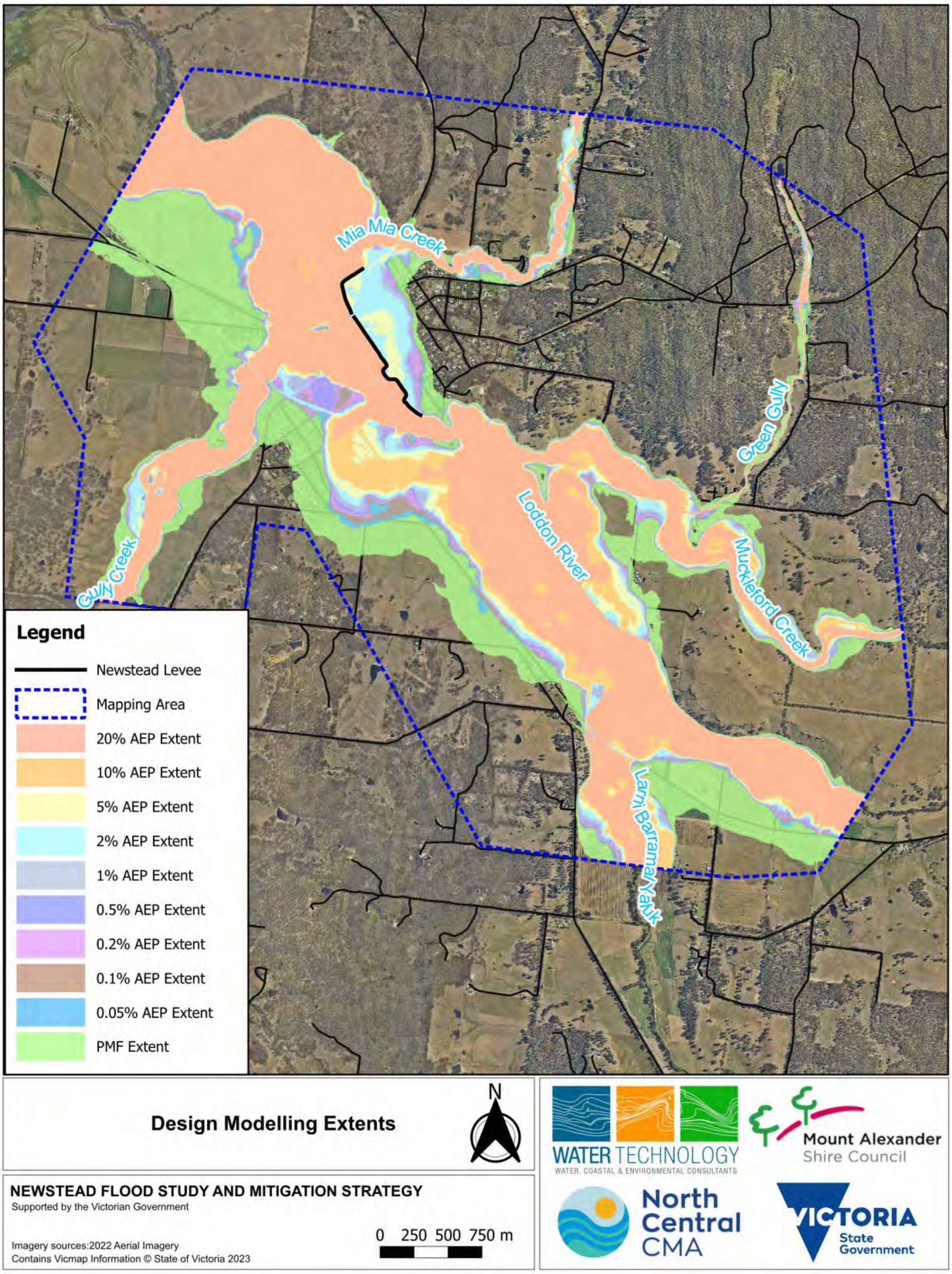


Figure 4-1 Design modelling flood extents

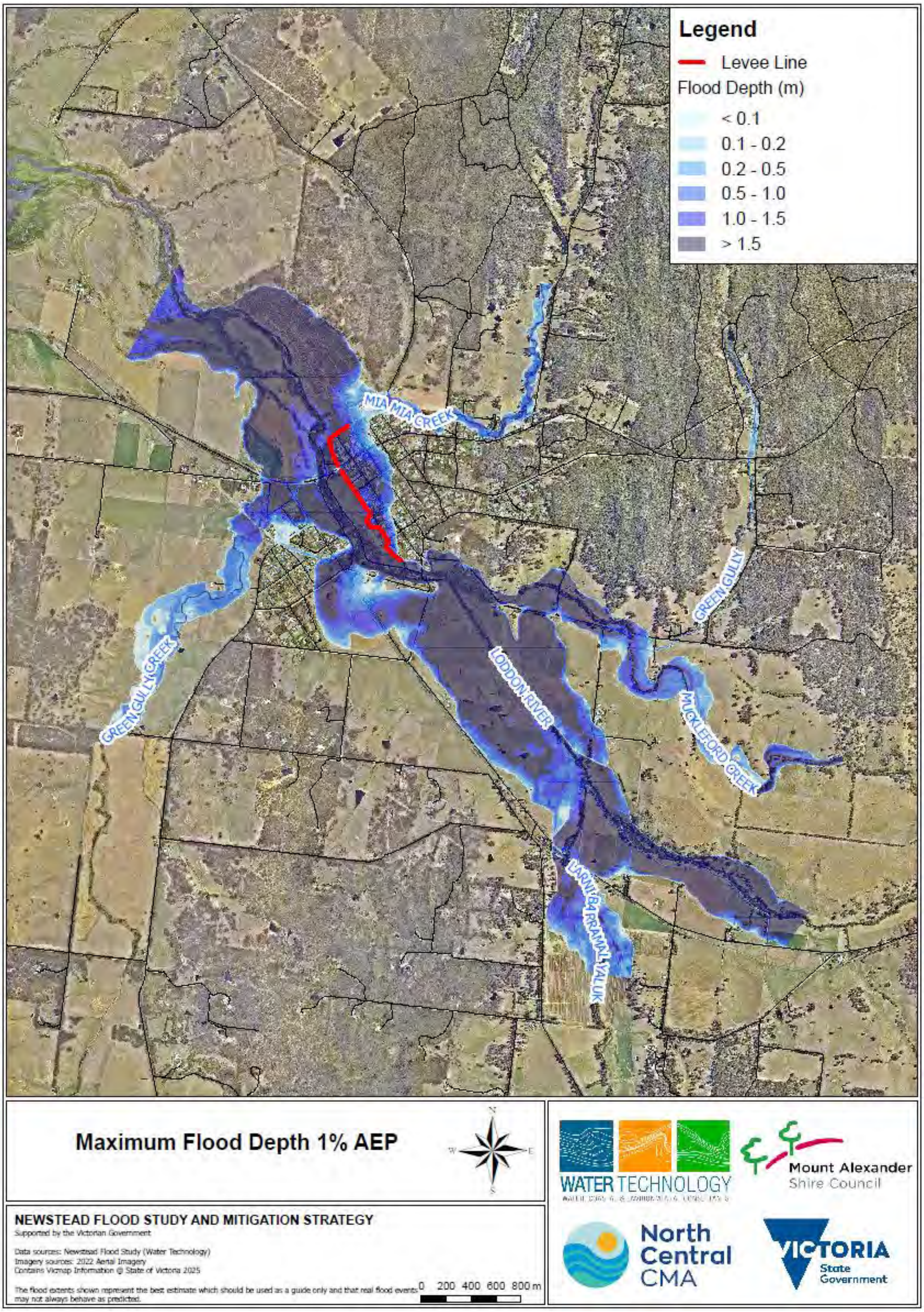


Figure 4-2 1% AEP flood depth

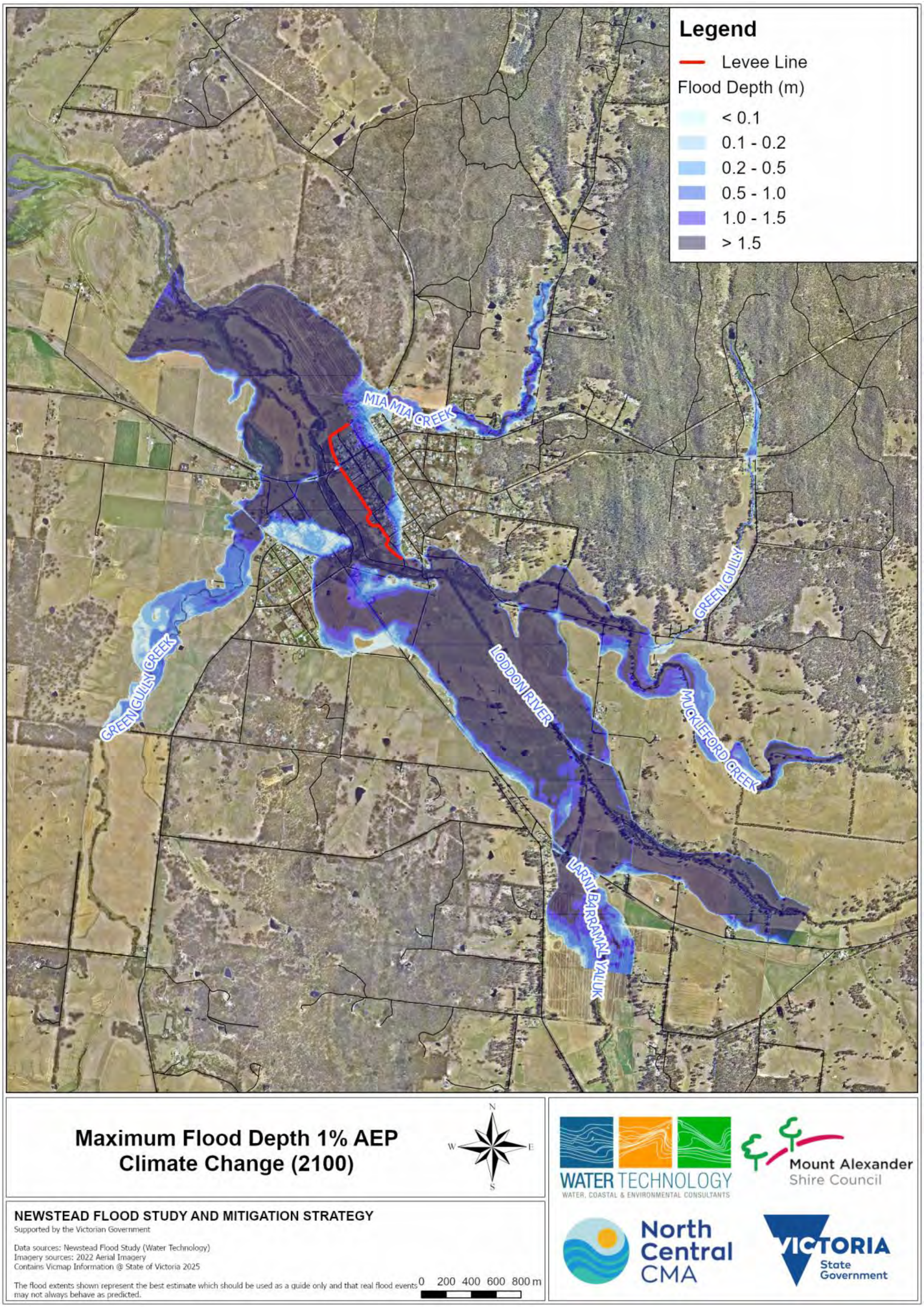


Figure 4-3 1% AEP SSP 5 – 8.5 2100 depth

4.3 Sensitivity testing

Sensitivity testing of the model was undertaken for hydraulic roughness coefficients, blockage of the hydraulic structures and the downstream boundary condition. Sensitivity testing was completed for the 1% AEP event 12-hour duration only, since this is the critical duration at Newstead.

The sensitivity analysis shows that the hydraulic model is somewhat sensitive to hydraulic roughness parameters adopted. For the 1% AEP event, structure blockage and boundary conditions were not shown to have a significant impact on results in the township aside from localised increases upstream of blocked culverts and the model boundary. The details of the sensitivity testings are described in the Hydraulic Modelling Report (R04).

5 FLOOD DAMAGES AND MITIGATION

5.1 Overview

Detail associated with the flood damage and mitigation potential in Newstead is documented in the Flood Damages and Structural Mitigation Options Report (R07).

Flooding in Newstead is primarily caused by the Loddon River, but localised flood events can cause flooding along any of the tributaries. The eastern portion of the Newstead township is located behind a levee bank. When the Loddon River floods, widespread breakouts from the river channel and tributaries are observed in the 20% AEP event inundating farmland upstream and downstream of the township and the Pyrenees Highway is overtopped by Green Gully Creek. The flood behaviour is similar in the 10% AEP event.

The Newstead levee is overtopped in the 5% AEP event, with flood levels up to 0.5 m observed inside the levee. For the 2% AEP event, the flooding behind the levee causes flooding above floor at 80 properties and large areas of Newstead become isolated/inaccessible.

To classify the impact of flooding and risk to the Newstead community, hydraulic flood model results were used to determine the properties and assets likely to be inundated during a range of design events.

5.2 Road inundation

During major flood events the road network is most commonly inundated. There is risk associated with travelling through floodwaters of any depth. Flood water can often unknowingly exceed safe vehicle fording depths and velocities. This presents a risk to community who may become isolated and seek to evacuate and to operational staff and emergency services.

Flood mapping shows several roads within the mapped area can become impacted by flood water during relatively frequent flood events (i.e. 20% AEP). The extent of road inundation for all modelled events is show in Figure 5-1 and Figure 5-2. Consideration should be given to this information in planning for suitable evacuation routes.

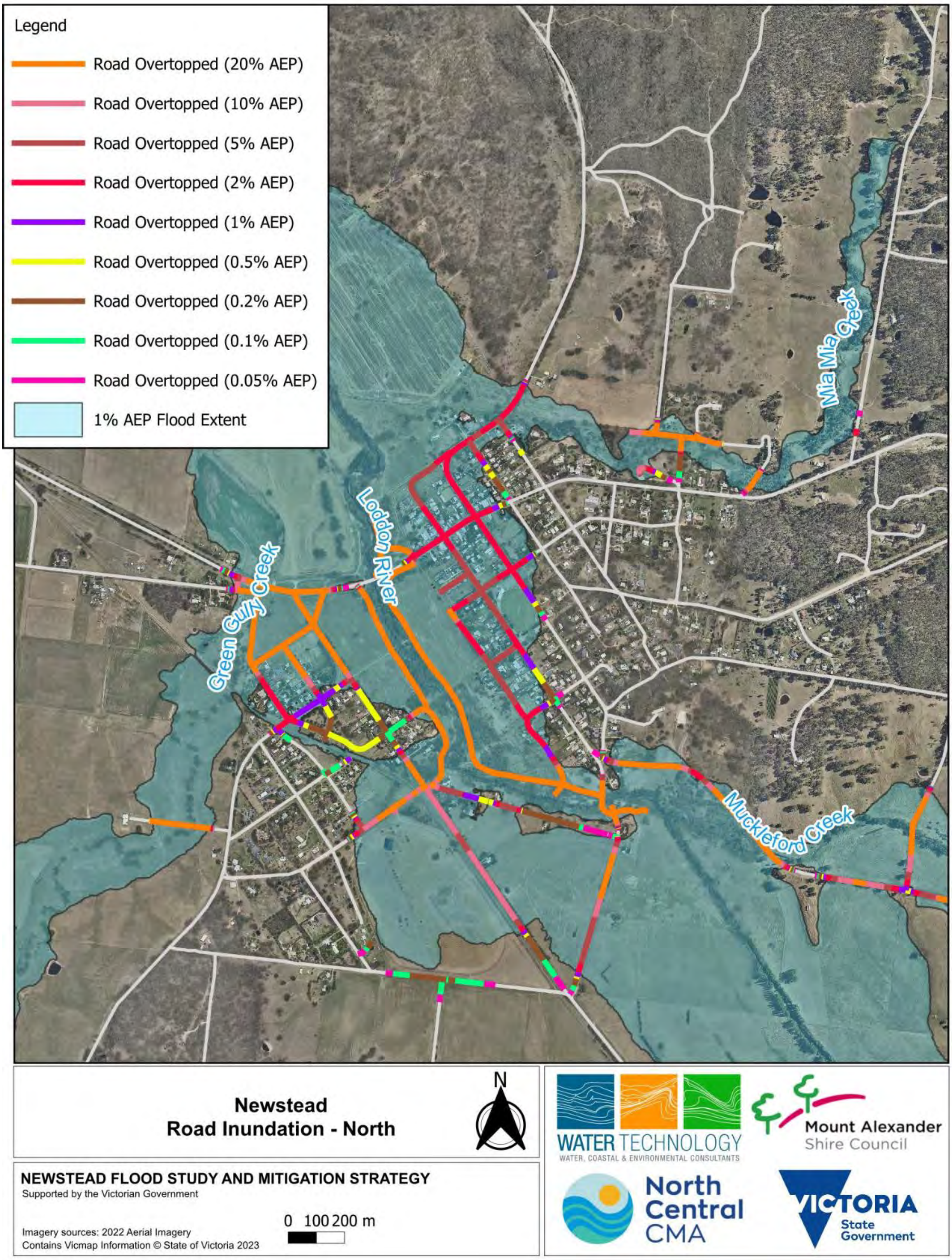


Figure 5-1 Road Inundation - North

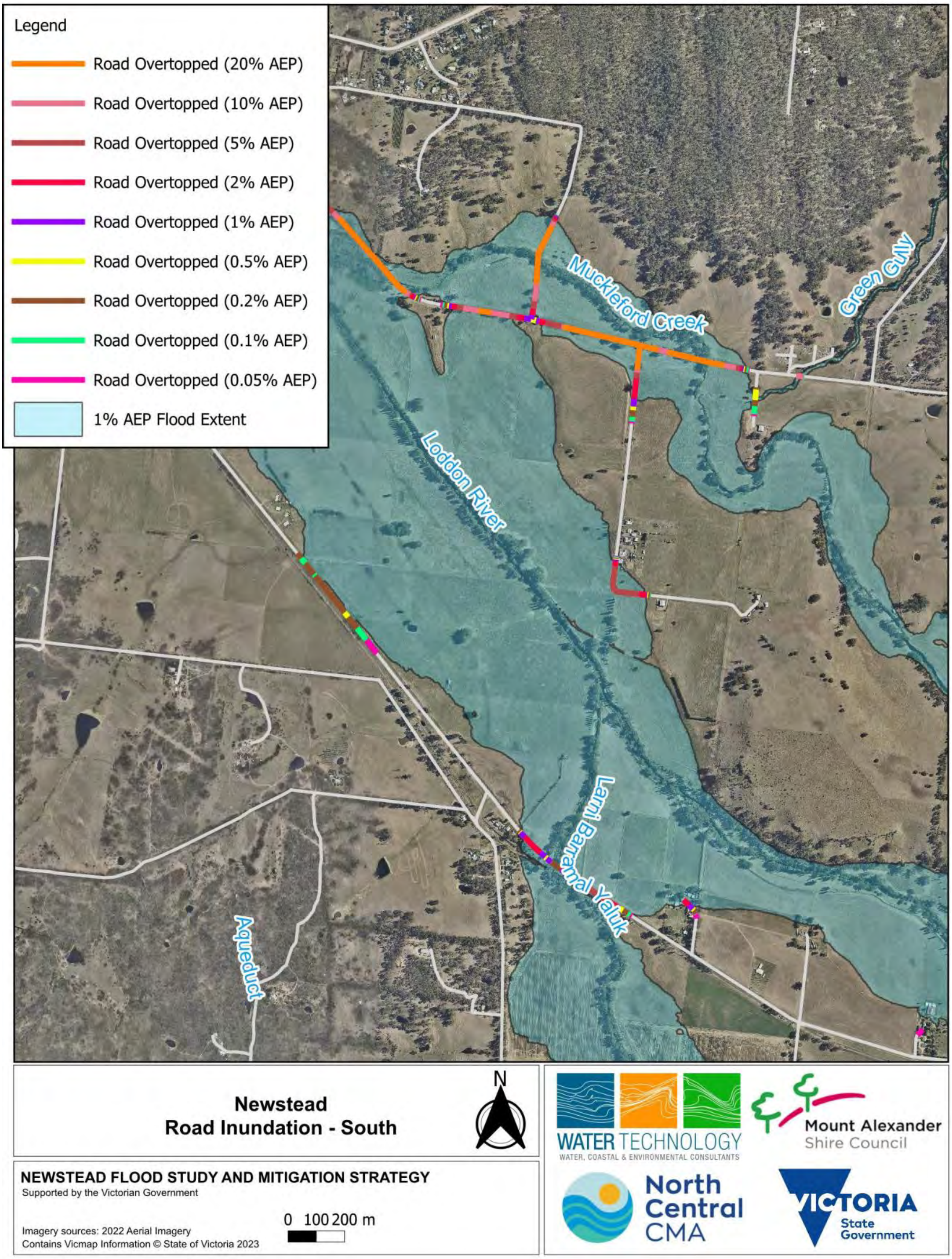


Figure 5-2 Road Inundation - South

5.3 Property inundation

Floor level survey of 148 buildings was captured within the study area, including 24 commercial and 124 residential buildings. These buildings were selected for floor level survey based on the preliminary flood modelling undertaken during this study. It should be noted that there were minor limitations within the floor level survey data captured, in that only the main residential dwelling or commercial building was captured for each property, outbuildings were not surveyed. The number of properties flooded below floor indicates a property with a residential dwelling or commercial building on it. This does not include parcels of land which are flooded but do not have an associated building i.e. vacant lots, farm paddocks etc.

To classify the flood risk at a property scale, two categories were used, these were:

- Property flooded below floor.
  - This indicates the property is within the flood extent, however the flood level is below the surveyed floor level.
- Property flooded above floor.
  - This indicates the property is within the flood extent and the flood level is above the surveyed floor level.

The 1% AEP flood extent and the properties flooded above floor during the range of modelled design events are shown in Figure 5-3. Figure 5-4 outlines the properties which are shown to be flooded above and below floor. The values in those tables were obtained using the difference between flood level and surveyed floor level for each modelled event. Noting that a positive value (shown in red) indicates the property is flooded above floor, while a negative value refers to property flooded below floor.

The existing conditions 1% AEP flood extent and the properties flooded above floor during the range of modelled design events are shown in Figure 5-3 and Figure 5-4. A summary can be found in Table 5-1.

Table 5-1 Summary of property inundation

Design flood event AEP	No. of properties flooded below floor - residential	No. of properties flooded above floor - residential	No. of properties flooded below floor - commercial	No. of properties flooded above floor - commercial
20%	2	0	0	0
10%	6	0	0	0
5%	32	2	1	0
2%	24	67	1	17
1%	21	81	3	18
0.5%	27	86	3	18
0.2%	24	98	5	19
0.1%	20	103	5	19
0.05%	18	106	4	20
PMF	0	124	0	24

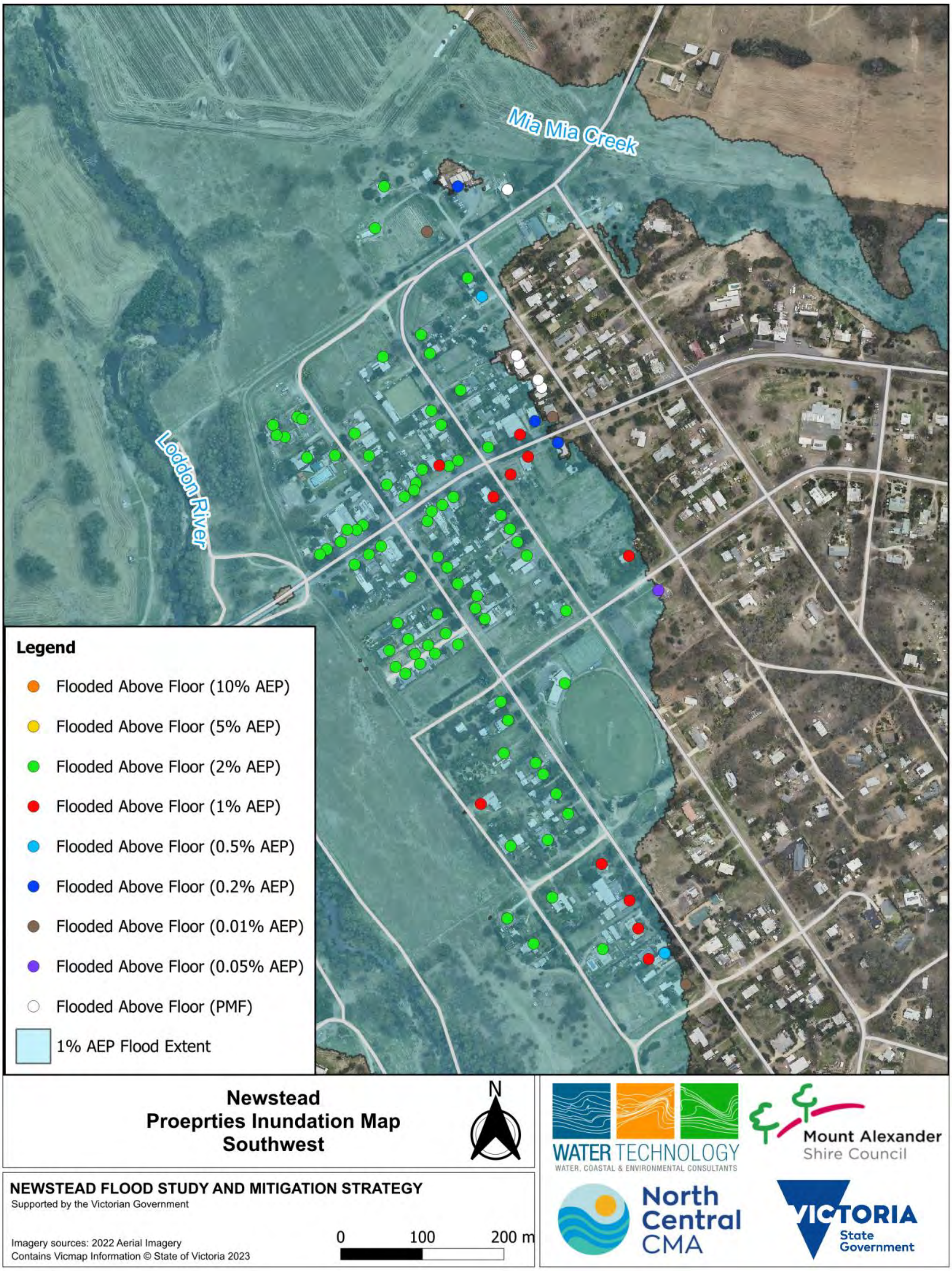


Figure 5-3 Properties flooded above floor – Northeast Newstead

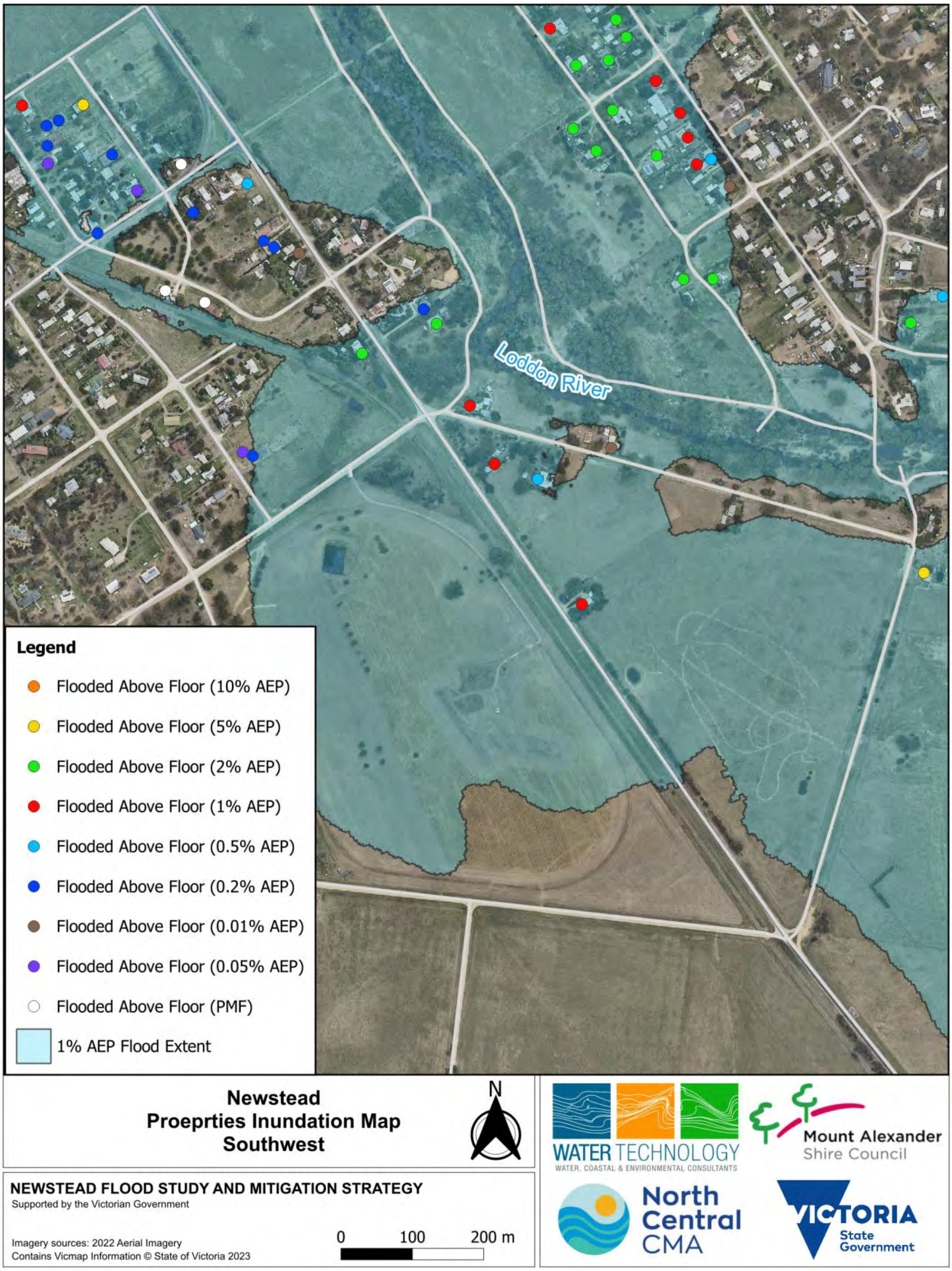


Figure 5-4 Properties flooded above floor – Southwest Newstead

5.4 Damage assessment

Floor level survey was available for 124 residential and 24 commercial buildings. Flood model results for the range of existing conditions events were processed to calculate the Average Annual Damages (AAD) for Newstead, which totals $951,241. The damages figure considers flooding of roads, properties and buildings. The damages assessment table is shown in Figure 5-5.

	AEP									
	PMF	**0.05%**	**0.10%**	**0.20%**	**0.50%**	**1%**	**2%**	**5%**	**10%**	**20%**
Residential Buildings Flooded Above Floor	124	106	103	98	86	81	67	2	0	0
Commercial Buildings Flooded Above Floor	24	20	19	19	18	18	17	0	0	0
Properties Flooded Below Floor	689	517	511	503	493	475	461	430	357	340
Total Properties Flooded	**837**	**643**	**633**	**620**	**597**	**574**	**545**	**432**	**357**	**340**
Direct Potential External Damage Cost	$9,929,312	$6,389,510	$6,225,264	$6,060,100	$5,803,102	$5,638,070	$5,308,640	$4,314,070	$3,803,182	$3,305,974
Direct Potential Residential Damage Cost	$17,118,766	$11,965,081	$11,362,391	$10,490,362	$9,087,556	$8,298,899	$6,051,423	$151,691	$0	$0
Direct Potential Commercial Damage Cost	$2,600,015	$1,686,619	$1,630,404	$1,567,636	$1,435,526	$1,317,542	$874,880	$0	$0	$0
Total Direct Potential Damage Cost	**$29,648,093**	**$20,041,210**	**$19,218,059**	**$18,118,098**	**$16,326,184**	**$15,254,511**	**$12,234,943**	**$4,465,761**	**$3,803,182**	**$3,305,974**
Total Actual Damage Cost *(0.8*Potential)*	**$23,718,474**	**$16,032,968**	**$15,374,447**	**$14,494,478**	**$13,060,947**	**$12,203,609**	**$9,787,954**	**$3,572,609**	**$3,042,546**	**$2,644,779**
Infrastructure Damage Cost	**$1,174,464**	**$692,519**	**$662,133**	**$611,301**	**$541,752**	**$513,084**	**$469,729**	**$293,092**	**$220,982**	**$161,052**
Rural Cost	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
Total Cost	**$24,892,938**	**$16,725,487**	**$16,036,581**	**$15,105,779**	**$13,602,699**	**$12,716,693**	**$10,257,683**	**$3,865,700**	**$3,263,528**	**$2,805,831**
Average Annual Damage (AAD)	**$951,241**									

Figure 5-5 Existing conditions Average Annual Damage (AAD)

5.5 Structural Mitigation Options

5.5.1 Overview

Several structural mitigation options were assessed during this study, focusing on the areas of Newstead impacted by inundation in the 1% AEP flood event. The mitigation options were hydraulically assessed using the 1% AEP design flood event.

The mitigation options assessed in this study are summarised as follows:

- Mitigation Option 1 - Vegetation clearance by reducing the land use roughness in an area covering the riverbed and banks in the vicinity of the Pyrenees Highway bridge.
- Mitigation Option 2 – Raising of the existing levee above the 1% AEP flood level.
- Mitigation Option 3 – Extending the raised levee from option 2 at the northern and southern ends to tie into the existing topography and create a flood barrier for eastern Newstead.
- Mitigation Option 4 – Removal of the Pyrenees Highway bridge and flattening the topography of the bridge abutments to the surrounding ground level.
- Mitigation Option 5 - Combination of vegetation removal option (Mitigation Option 1 above) and raising and extension of existing levee (Mitigation Option 3 above).

The above five options were presented at the community consultation session. Mitigation Option 5 was the preferred option from the community receiving 10 of 13 votes. Feedback from community members regarding the alignment was taken on board as well as a desire to understand the change in impacts on the western side of town as a result of the proposed options. As a result, an additional two options were investigated, and further floor level survey (24 properties) was undertaken.

- Mitigation Option 6 - Raising, extension and realignment of existing levee at two locations to keep the levee on public land and to include properties on the northern end of Wyndham Street within the levee.
- Mitigation Option 7 - Green Gully Creek culvert assessment (A desktop assessment only).

The options were investigated separately and are discussed below. *Not all mitigation options were modelled for all durations. Specifically mitigation options 1, 4 and 5 were only modelled for the 12-hour duration event which is the critical duration along the Loddon River at Newstead but not the critical duration for the smaller tributaries.*

5.5.2 Mitigation Option 1: Vegetation Clearance

This option was represented in the model as a wholesale change in the land use (removal of all vegetation) to identify the maximum reduction in flood levels achievable. Vegetation clearance was modelled by reducing the land use roughness in an area covering the riverbed and banks in the vicinity of the Pyrenees Highway bridge. A flood level difference map for the 1% AEP event is presented in Figure 5-6, comparing the mitigation option to the existing conditions.

This option showed a reduction in flood depth inside the levee of 150mm in the 12-hour event, however no significant reduction in extent. Reductions in flood depth along the western side of town are in the order ~150mm. When comparing the properties flooded above floor, there is a reduction of 5 properties.

This option is not likely to be supported by the CMA due to waterway health impacts. A targeted vegetation removal along the waterway would result in a far smaller impact (reduction in flood levels).

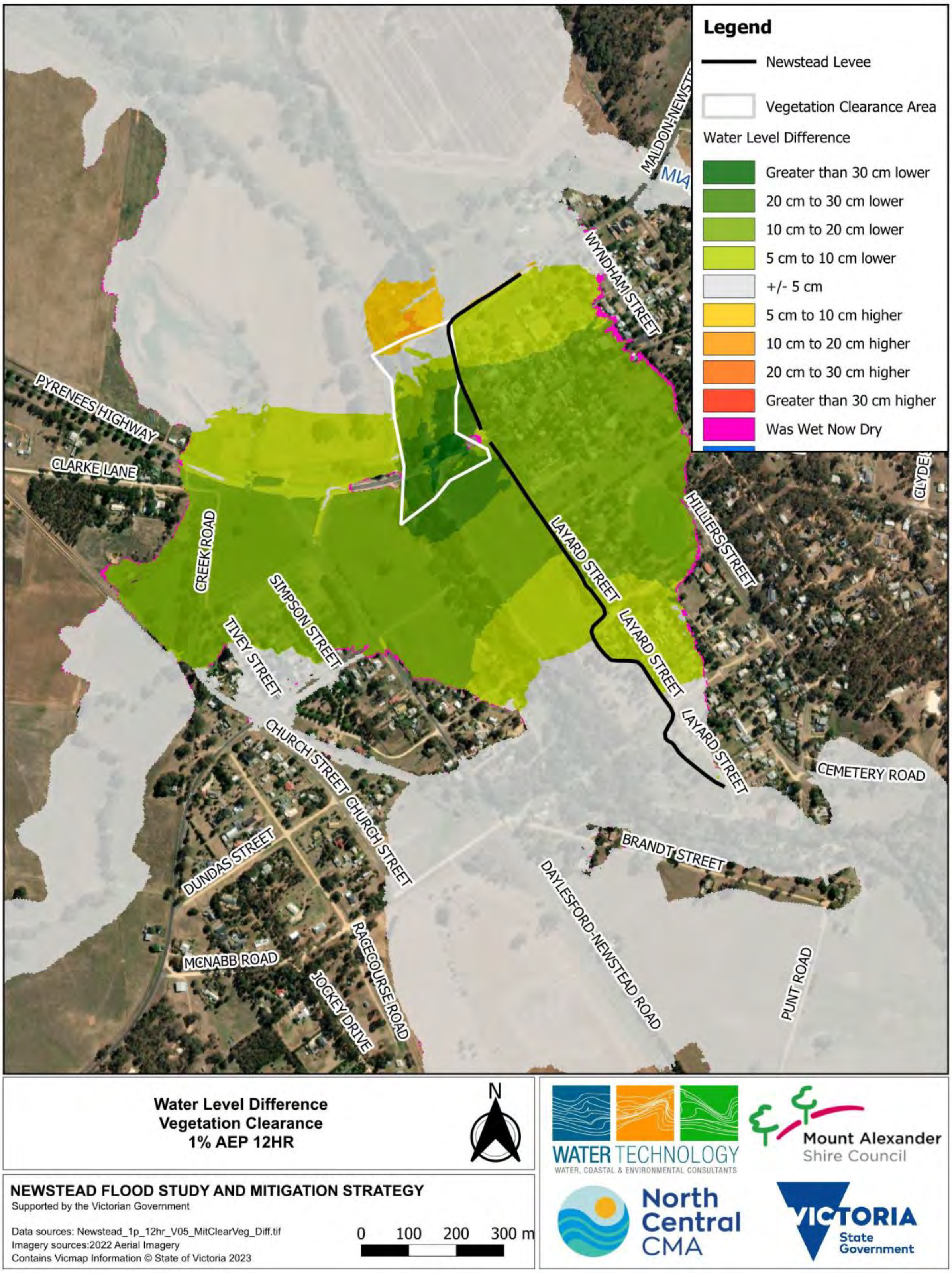


Figure 5-6 1% AEP flood level difference – Vegetation clearance

5.5.3 Mitigation Option 2: Raised Levee

This option assessed raising of the current levee to above the 1% AEP flood level. A flood level difference map for the 1% AEP event is presented in Figure 5-7, comparing the mitigation option to the existing conditions.

The 1% AEP flood shows a reduction in above floor flooding of 33 properties and upto 300mm reduction in depth inside the levee, however flooding still occurs inside the levee above floor level as the levee is outflanked and flooding from the Loddon River and Mia Mia Creek. Increases in flood levels on the western side of town of around 150mm are shown across properties in Simpson Street, Creek Road and Tivey Street. There is minimal increase in flood extent.

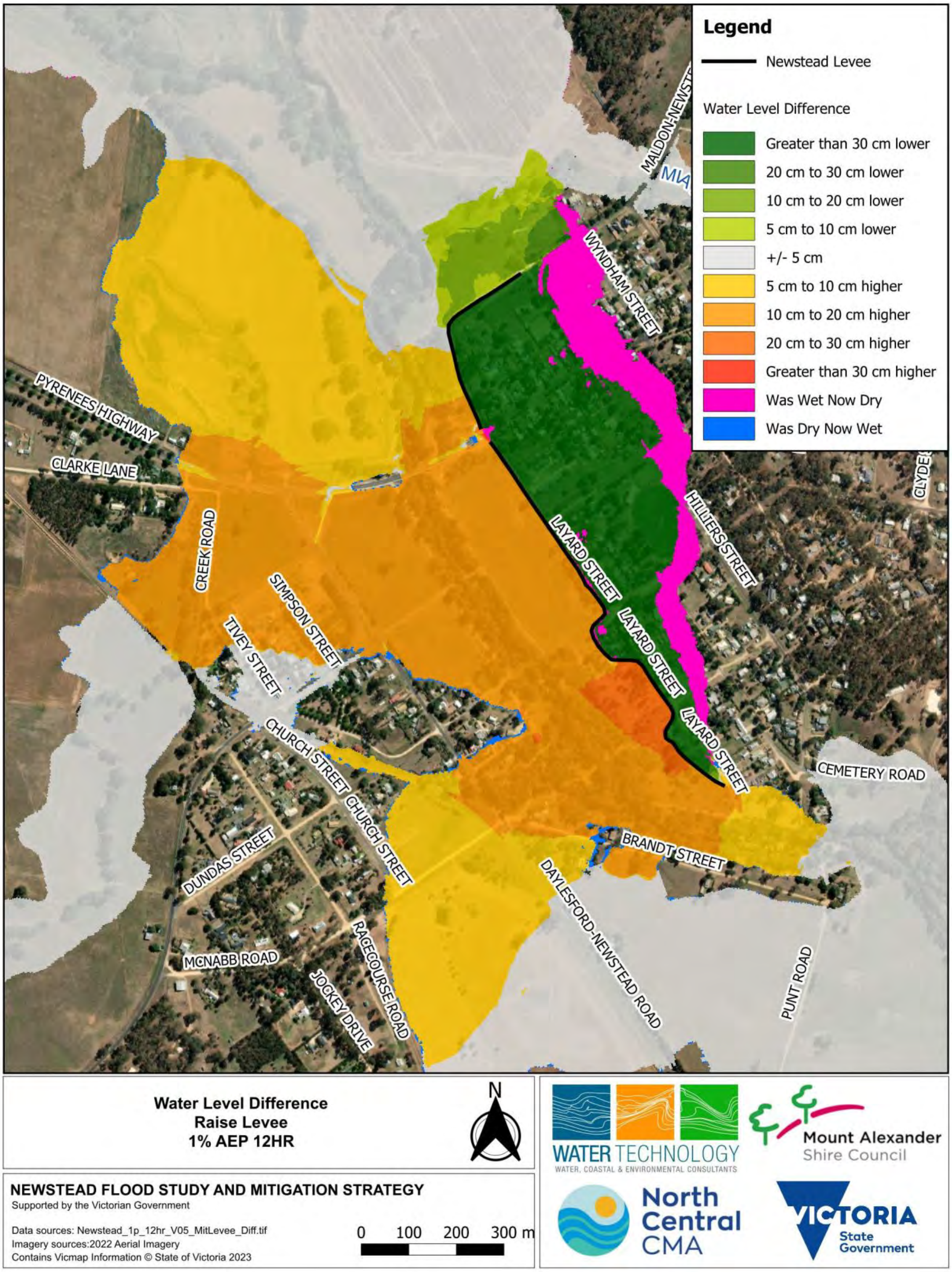


Figure 5-7 1% AEP flood level difference – Raised levee

5.5.4 Mitigation Option 3: Raised and Extended Levee

The raised levee from option 2 was extended at the northern and southern ends to tie into the existing topography and create a flood barrier for eastern Newstead. A flood level difference map for the 1% AEP event is presented in Figure 5-8, comparing the mitigation option to the existing conditions.

The extension of the levee to stop the outflanking from the Loddon River shows a larger reduction in extent compared to Mitigation Option 2. There are reductions in depth upto 300mm depths inside the levee, however above floor flooding still occurs inside the levee as a result of overtopping from Mia Mia Creek. This option shows a reduction in above floor flooding of 67 properties in the 1% AEP event. Increases in flood levels on the western side of town of around 150mm are shown across properties in Simpson Street, Creek Road and Tivey Street as well as an increase in flood extent.

In the 1% AEP flood event, 19 dwellings have an increase in flood level, however there are no properties which show a change from below floor to above floor inundation in this event.

In the 2% AEP flood event, 17 dwellings have an increase in flood level, however there are no properties which show a change from below floor to above floor inundation in this event.

In the 5% AEP flood event, one dwelling changes from below to above floor flooding, however the change in flood level is less than 15mm.

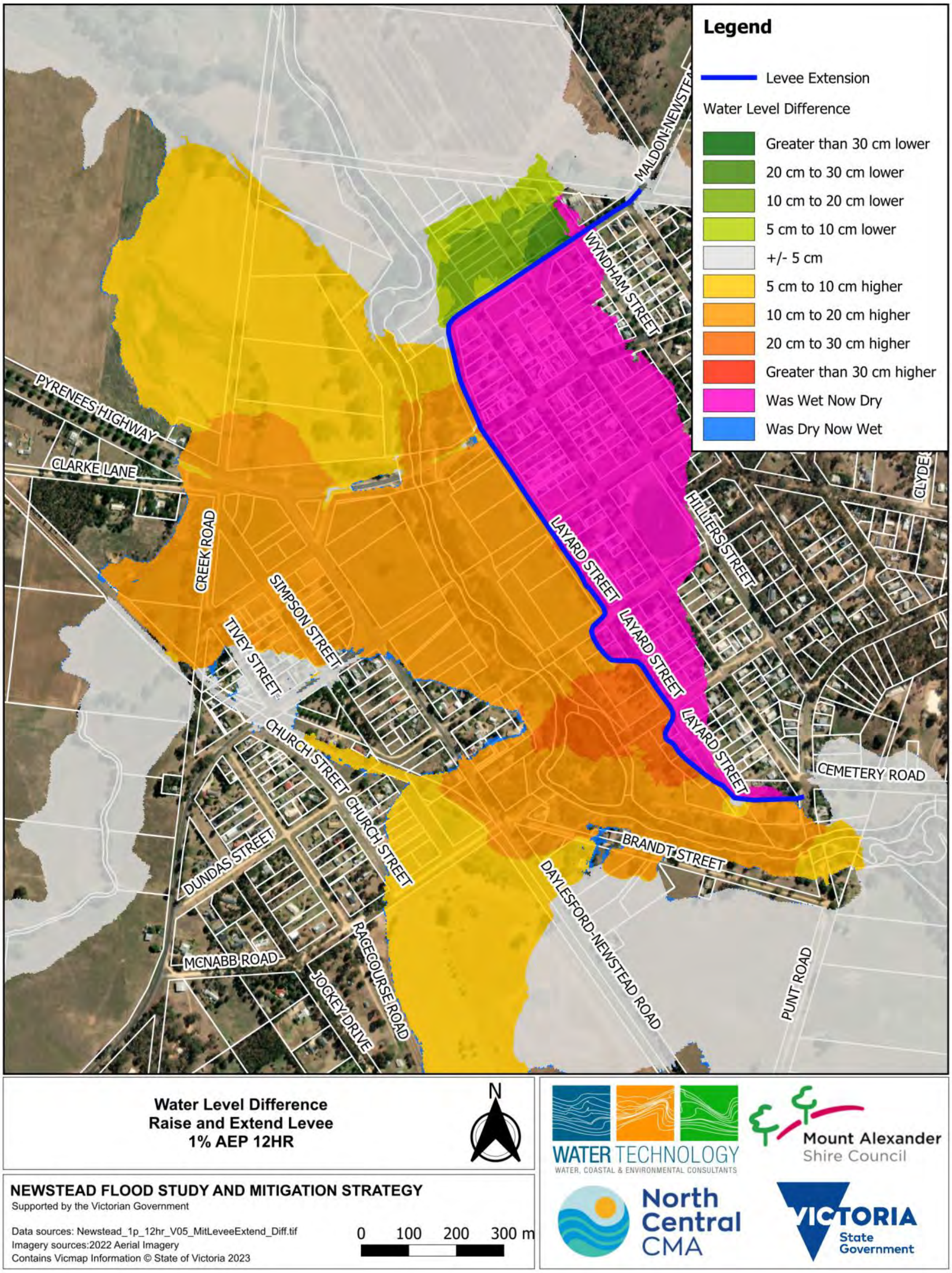


Figure 5-8 1% AEP flood level difference – Raised and extended levee

5.5.5 Mitigation Option 4: Bridge Removed (Pyrenees Highway Bridge)

Removal of the Pyrenees Highway bridge was modelled by removing the bridge structure and flattening the topography of the bridge abutments to the surrounding ground level. A flood level difference map for the 1% AEP event is presented in Figure 5-9, comparing the mitigation option to the existing conditions.

Removing the Pyrenees highway bridge and abutments reduces the flood level by up to 150 mm inside the levee and up to 300 mm outside the levee including through the western side of town, however does not significantly reduce the 1% AEP flood extent. The reduction in flood level results in 5 less properties flooded above floor (in a 1% AEP event) compared to existing conditions. The impacts are similar to those observed for the vegetation clearance option (Mitigation Option 1). There is a minor increase immediately downstream of the bridge. While this shows that the bridge does have some impacts on upstream flood levels, it has no impacts on the flood extent and removing the bridge would provide limited benefits in terms of property inundation.

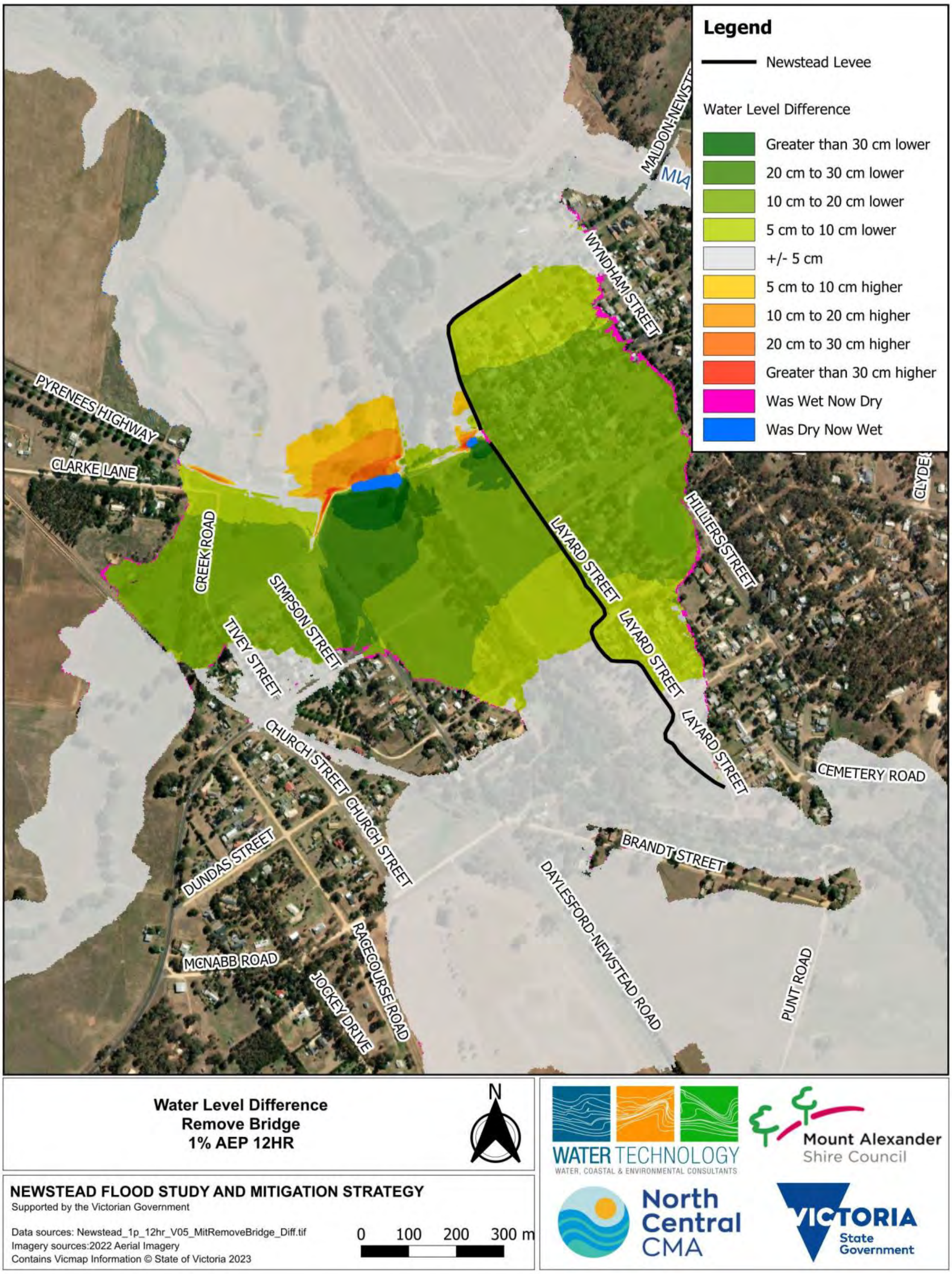


Figure 5-9 1% AEP flood level difference – Bridge removed

5.5.6 Mitigation Option 5: Raised and Extended Levee + Vegetation Clearance

Mitigation options 1 and 3 were combined to assess if vegetation removal can counter for some of the impacts created by raising the levee. A flood level difference map for the 1% AEP event is presented in Figure 5-10, comparing the mitigation option to the existing conditions.

Combining options 1 and 3 reduces the flood extent inside the levee, while flood levels outside the levee are still increased (up to 250 mm) but to smaller magnitude than Option 3. There are 67 less properties flooded above floor compared to existing conditions, with no additional properties flooded above floor outside of the levee. The impacts of flood extent and property inundation are similar to those observed for option 3. The area of increased flood levels outside the levee (through the western side of town) is significantly reduced. There are still similar to Option 3 (upto 150mm) around Brandt Street.

This option which involves extensive removal of vegetation to achieve the reduction in flood levels is not likely to be supported by the CMA due to waterway health impacts. A targeted vegetation removal along the waterway would result in a far smaller impact (reduction in flood levels) outside of the levee.

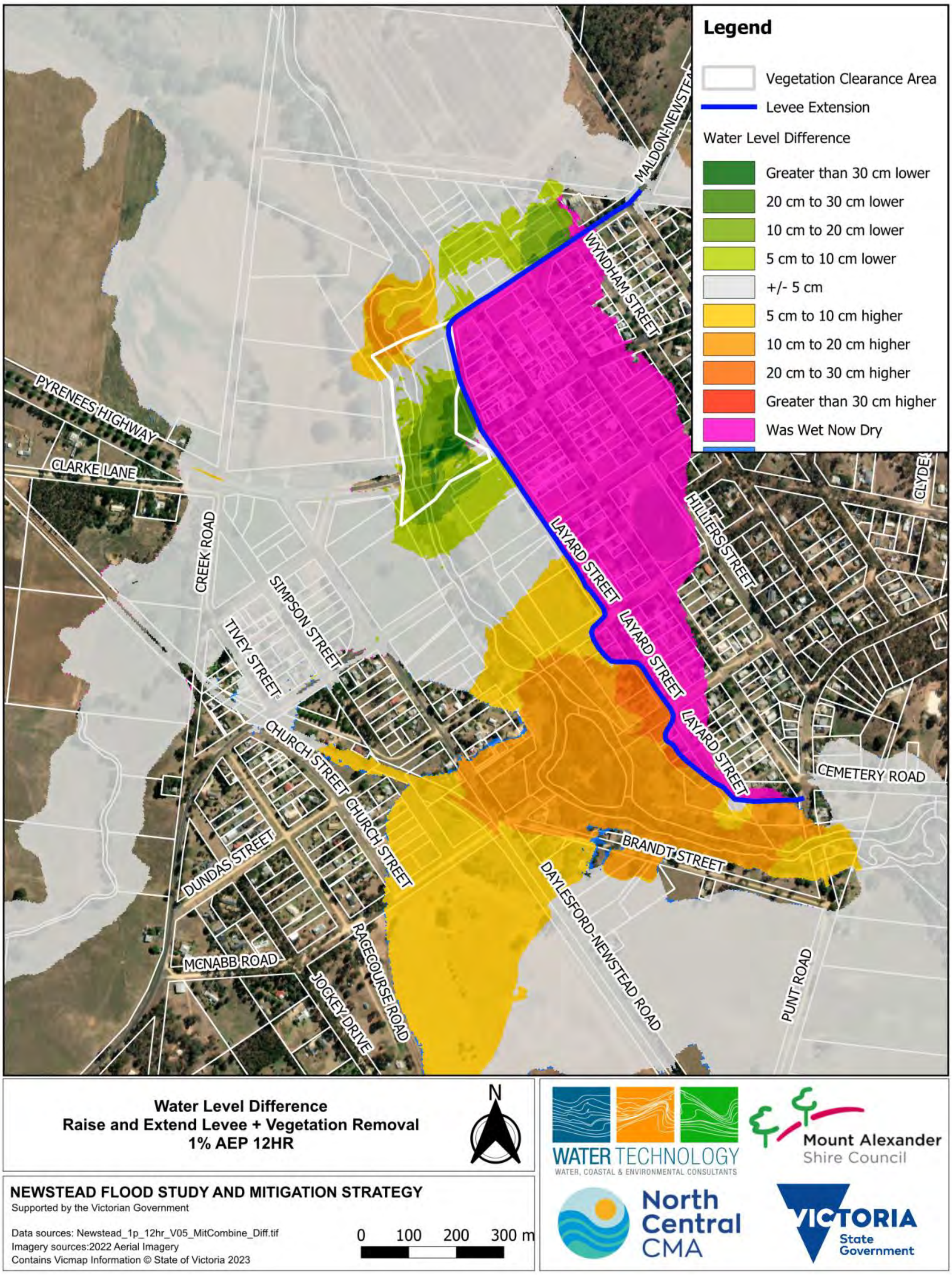


Figure 5-10 1% AEP flood level difference – Raised and extended levee with vegetation clearance

5.5.8 Community Consultation

The above five options were presented at the community consultation session. Mitigation Option 5 was the preferred option from the community receiving 10 of 13 votes. Feedback from community members regarding the alignment was taken on board as well as a desire to understand the change in impacts on the western side of town as a result of the proposed options. As a result, an additional two options were investigated, and further floor level survey (24 properties) was undertaken.

5.5.9 Mitigation Option 6: Raised, Extended and Realigned Levee

The raised and extended levee from Mitigation Option 3 was realigned at two locations to keep the levee on public land and to include properties on the northern end of Wyndham Street within the levee.

- The revised alignment at the northern end of the levee runs closer to Mia Mia Creek rather than the existing alignment which followed the Maldon-Newstead Road. This alignment provides flood protection for an additional five dwellings in the area.
- The alignment at the southern end of the levee was modified to where possible minimise the extent of levee on private land, additionally the alignment was moved slightly closer to the Loddon River to offset the distance from existing dwellings.
- A final section along Mia Mia Creek has two options, to either follow Codrington Road or sit closer to Mia Mia Creek and provides protection to the town from Mia Mia Creek flooding.

A flood level difference map for the 1% AEP event is presented in Figure 5-11, comparing the mitigation option to the existing conditions.

The updated and raised levee alignment completely removes the flood extent inside the levee, while increasing flood levels outside the levee by up to 400 mm. This option results in a reduction of above floor flooding at 87 properties in the 1% AEP flood event.

Impacts outside the levee are similar to Option 3 but show larger increases in flood levels on the western side of the Loddon River. Again there are increased flood levels showing the breakout of flows from the railway cutting at Dundas Street. This leads to 14 additional; properties being inundated between Creswick–Newstead Road, Campbell Street and the railway line in a 1% AEP event. The flood mapping shows the breakout of flow is shallow through these properties flood depths less than 50 mm.

In the 1% AEP flood event, 32 dwellings have an increase in flood level, two properties show a change from below floor to above floor inundation in this event.

In the 2% AEP flood event, 17 dwellings have an increase in flood level, three properties show a change from below floor to above floor inundation in this event.

In the 5% AEP flood event, one dwelling changes from below to above floor flooding.

The larger increases in flood level on the western side of the Loddon River when compared to Mitigation Option 3 indicate the realignment of the levee closer to the river reduces the flow capacity. This option also requires significantly more volume of fill to create the levee as the levee is now placed in deeper sections of the floodplain.

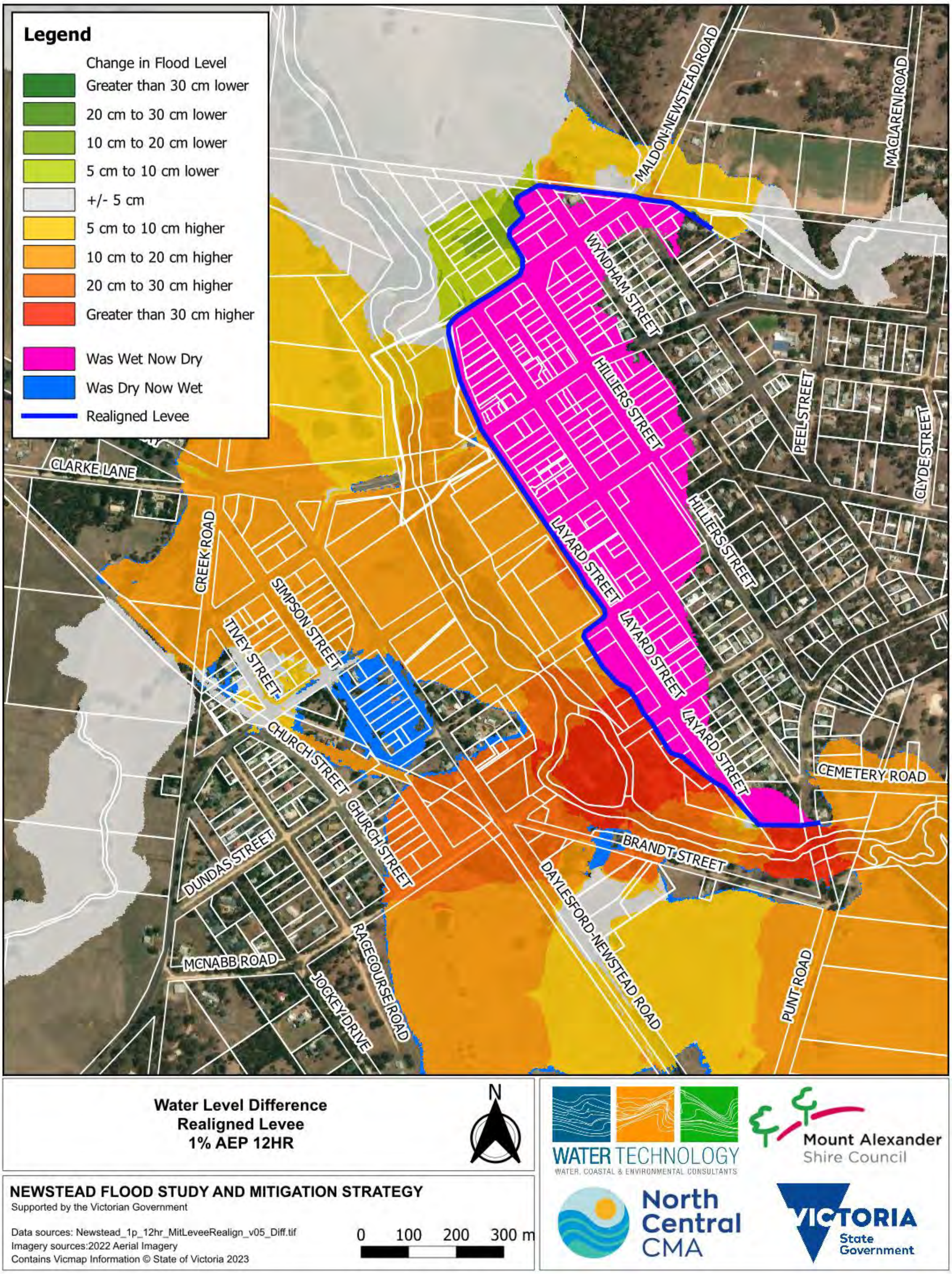


Figure 5-11 1% AEP flood level difference – Raised, extended and realigned levee

5.5.10 Mitigation Option 7: Green Gully Creek culvert assessment

Flood modelling and anecdotal evidence from past flood events identified The Pyrenees Highway being overtopped at Green Gully Creek. Hydraulic modelling of existing conditions shows the road becomes impassable at events greater than a 10% AEP and is overtopped in more regular events.

In considering this option, a desktop assessment was undertaken to estimate the capacity of the existing crossing at Green Gully Creek. The assessment indicated that the current culvert arrangement can convey around 25 m³/s. Total flow from the upstream Green Gully Creek catchment during the 20% and 10% AEP events are presented in Figure 5-12.

The effectiveness of the option is limited in extreme flood events, however it does offer the ability to maintain access from Newstead west towards Maryborough in events upto a 10% AEP or extends the time the road is trafficable in rarer events by several hours. Further investigation and consultation with DTP would be required to identify the impacts of increased culverts or raising the road profile on the flood behaviour upstream and downstream of the road.

Any raising the Highway road profile is likely to result in increased levels on properties upstream, and a comprehensive assessment would be needed to understand the extent of these effects.

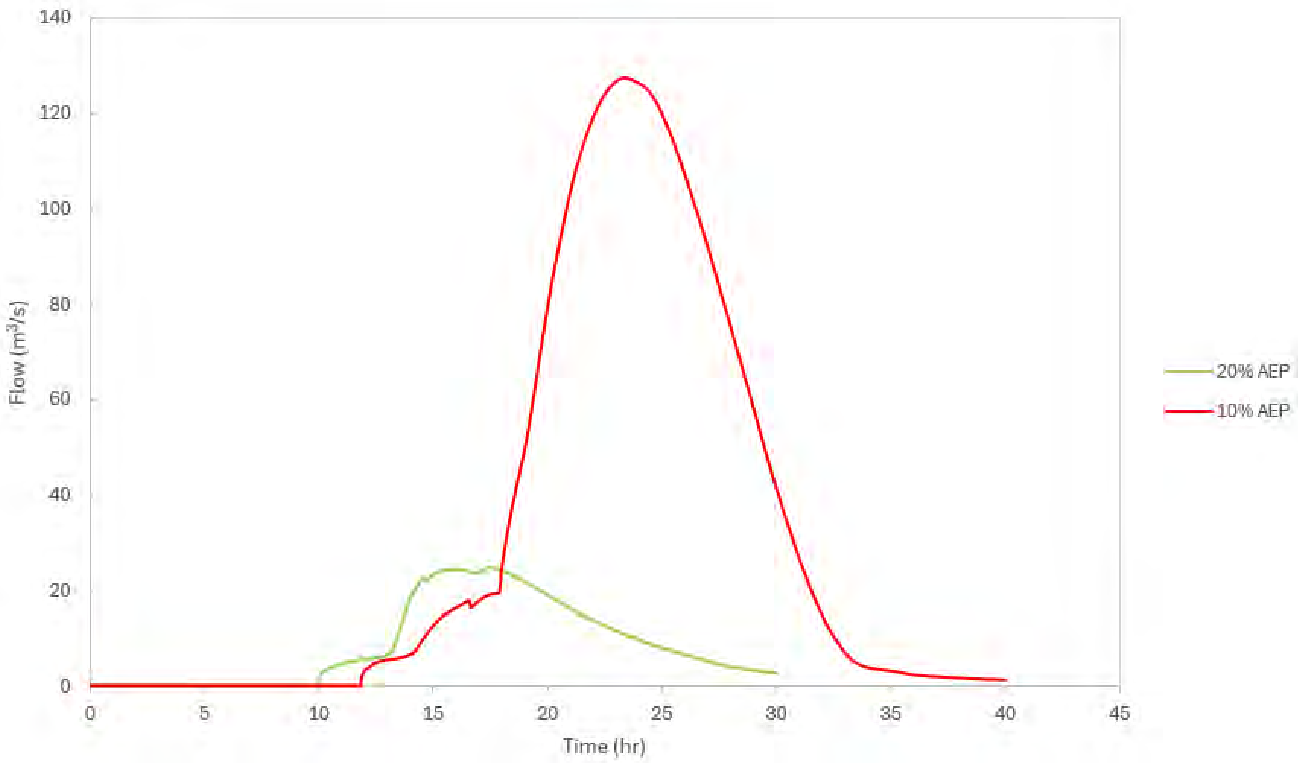


Figure 5-12 Total flow upstream of Green Gully Creek culvert crossing

5.5.11 Mitigation Impacts

A summary of the impacts of each option considered are presented in Table 5-2.

Table 5-2 Summary of the impacts

Option	Reduction in above floor flooding	Impacts on western side of town	Notes
1	5	Reduction in flood levels (150mm)	Not likely to be achievable to the extent modelled due to environment/waterway health considerations.
2	33	100-150mm increase	Levee is outflanked at several locations.
3	67	150mm increase + increased extent. 19 dwellings with increased flood levels in 1% AEP event.	Flooding above floor inside levee occurs from Mia Mia Creek
4	5	Reductions in flood level 150-300mm	Entire removal of bridge and approach embankments.
5	67	Generally less than 50mm. Far less than Option 3.	Flooding above floor inside levee from Mia Mia Creek still occurs. As per Option 1,Not likely to be achievable to the extent modelled due to environment/waterway health considerations.
6	87	200-300mm increase + increased extent. 32 dwellings with increased flood levels in 1% AEP event.	Full protection inside the levee but greater impacts on western side. Significant increase in cost compared to Option 3
7	N/A	Likely to be isolated to around the roadway	Has not been modelled. Does provide additional evacuation/access route time towards Maryborough in events up to 10% AEP of several hours. Provides minimal to no benefit in 1% AEP events

5.6 Mitigation Damages

Simar to the existing conditions, a flood damage assessment was undertaken for the following three options:

- Mitigation Option 2: Raised Levee.
- Mitigation Option 3: Raised and Extended Levee.
- Mitigation Option 6: Raised, Extended and Realigned Levee.

The flood damage assessment determined the monetary flood damage for the range of modelled design events (i.e. 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2%, 0.1% and 0.05% AEP events and the PMF floods).The damage occurring in each of the modelled events has been used to calculate an AAD for the study area. A summary of the flood damage assessment in a 1% AEP event for the three options is shown in .

The expected damage in a 1% AEP event for Option 2 is $8,739,227, compared to $12,716,693 under existing conditions a reduction of $3,977,466.

The expected damage in a 1% AEP event for Option 3 is $6,337,102, a reduction of $6,379,591.

The expected damage in a 1% AEP event for Option 6 is $4,895,810, a reduction of $7,820,883.

Table 5-3 Mitigation Options 1% AEP Average Annual Damages (AAD) Summary

	1% AEP			
	Existing	**Option 2**	**Option 3**	**Option 6**
Residential Buildings Flooded Above Floor	81	52	27	11
Commercial Buildings Flooded Above Floor	18	14	5	0
Properties Flooded Below Floor	475	518	475	411
Total Properties Flooded	**574**	**584**	**507**	**422**
Direct Potential External Damage Cost	$5,638,070	$5,628,762	$5,209,727	$4,667,417
Direct Potential Residential Damage Cost	$8,298,899	$4,244,124	$2,075,687	$963,571
Direct Potential Commercial Damage Cost	$1,317,542	$398,305	$47,979	$0
Total Direct Potential Damage Cost	**$15,254,511**	**$10,271,191**	**$7,333,393**	**$5,630,988**
Total Actual Damage Cost *(0.8*Potential)*	**$12,203,609**	**$8,216,953**	**$5,866,714**	**$4,504,790**
Infrastructure Damage Cost	**$513,084**	**$522,275**	**$470,388**	**$391,019**
Rural Cost	N/A	N/A	N/A	N/A
Total Cost	**$12,716,693**	**$8,739,227**	**$6,337,102**	**$4,895,810**

5.6.1 Cost-benefit analysis

Based on the modelling presented above and discussions with MASC, it was determined to assess a cost-benefit analysis for the three options; The selected options were Option 2: Raised Levee, Option 3: Raised and Extended Levee and Option 6 Raised, Extended and Realigned Levee.

The resultant AAD for Option 2 was $836,934 per year, providing an annual reduction of $114,307. The resultant AAD for Option 3 was $764,965 per year, providing an annual reduction of $$218,261. The resultant AAD for option 6 was $707,385 per year, providing an annual reduction of $243,856. The reduction in AAD is a result of fewer properties being inundated above floor in almost all events.

For Mitigation Option 6, there are in total 87 less properties flooded above floor in the 1% AEP event. There is also a reduction in properties flooded below floor in most of the analysed events, and a significant reduction in costs associated with infrastructure damage for all events except for the PMF event.

A high-level cost estimate was developed based on cost estimates developed by Price Merrett. A 30% contingency was included in the total cost estimates for each option to account for unforeseen contingencies, along with a 10% Engineering Fee and 12% Administration Fee. Other assessments including Cultural and Heritage, Environmental, Flood Impact and Geotechnical Report fee estimates have been lumped together. The cost/benefit was assessed in terms of the net present value of the option. A 50-year project timeline was adopted with a discount rate of 6% and an annual maintenance fee of $4,000.

5.6.2 Summary

Several mitigation options were tested in the Newstead hydraulic model, focusing on reducing damage and hazard associated with the flooding from the Loddon River impacting central Newstead. Impacts of each mitigation option were demonstrated, with raising, extending and realigning the levee deemed as the option which provides the greatest protection to the township.

Flood damages, in the form of Average Annual Damages (AAD), were assessed for Newstead based on flood modelling of three options undertaken as part of the Study. Construction cost estimates were assessed against the reduction in AAD from the existing case to inform net present value analysis.

- Mitigation Option 2: Raised Levee was the cheapest option but has the smallest reduction in damages and above floor flooding.
- Mitigation Option 3: Raised and Extended Levee reduced above floor flooding by 67 properties but still has above floor flooding inside the levee (from Mia Mia Creek) but has some increased flood levels on the western side of the town.
- Mitigation Option 6: Raised, Extended and Realigned Levee reduced above floor flooding by 88 properties but was the most expensive option and results in larger increases to the western side of the town.

The report recommends that a Mitigation Option 6 be explored further as the preferred option. This would include opportunities to reconfigure the alignment in the southern end of the levee to where possible reduce the volume of fill material required as well as investigate opportunities to reduce the increased flood levels on the western side of the town.

5.7 Planning scheme mapping

The Victoria Planning Provisions (VPPs) contain several controls that can be employed to provide guidance for the use and development of land that is affected by inundation from floodwaters. These controls include the Floodway Overlay (FO), the Land Subject to Inundation Overlay (LSIO), the Special Building Overlay (SBO), the Urban Floodway Zone (UFZ) and the Environmental Significance Overlay (ESO). Inclusion of flood mapping in the planning scheme is a key non-structural mitigation measure to prevent flood risk from increasing into the future.

Currently there are no flood-related planning overlays in Newstead. Flood-related planning overlays should be developed as direct outcomes from this study. Updating the planning scheme mapping allows development applications within the floodplain to be assessed in line with current national, state, regional and local policies. The ultimate effect of this will be to discourage inappropriate development within the floodplain, reducing the number of future buildings and occupants exposed to flood risk.

Draft planning scheme mapping has been produced in line with the project brief and discussions with North Central CMA. The draft flood related overlays have been developed based on two climate change scenarios: the 1% behaviour for the year 2100, as projected under Shared Socioeconomic Pathways SSP3 and SSP5 respectively. Flood modelling of the scenarios was undertaken in line with Australian Rainfall and Runoff 2019 (V4.2) and is detailed in R04 – Final Hydraulic Modelling Report. The most appropriate controls considered for application in Newstead include the Land Subject to Inundation Overlay (LSIO), the Floodway Overlay (FO) and the Special Building Overlay (SBO).

- **Land Subject to Inundation Overlay (LSIO)** – defines the floodplain fringe and lower hazard areas within the 1% AEP flood extent

Purpose: Land Subject to Inundation Overlays are planning scheme controls that apply to land affected by flooding associated with waterways, natural flow paths and drains. Such areas are commonly known as floodplains. The LSIO is used to identify flood fringe areas of the floodplain where flooding depths and velocities are typically lower.

- **Floodway Overlay (FO)** – defines the high hazard portion of the floodplain

Purpose: Floodway Overlays apply to land that's identified as carrying active flood flows associated with waterways, natural flow paths and drains. The overlay is characterised by areas impacted by deep and or fast flowing floodwaters during the 1% AEP flood event.

- **Special Building Overlay (SBO)** – defines the portion of the floodplain within the Newstead Township that is located inside the levee

Purpose: Special Building Overlays are to ensure that future developments allow the free passage of floodwaters, minimise flood damage, and are safe with flood hazard and local drainage conditions.

The LSIO and FO layers have been developed in line with the North Central CMA criteria, as shown below:

- LSIO – area inundated in a 1% AEP flood extent.
- FO – area inundated meeting the following criteria:
  - Land where the 1% AEP flood depth is likely to reach or exceed 0.5 metres, and/or
  - Land where the 1% AEP flood hazard factor (the produce of depth and velocity) is likely to reach or exceed 0.4 m^2/s.
- SBO - area inundated in a 1% AEP flood extent located inside the Newstead Township levee.

Two draft maps of the proposed overlays are shown in Figure 5-13 and Figure 5-14.

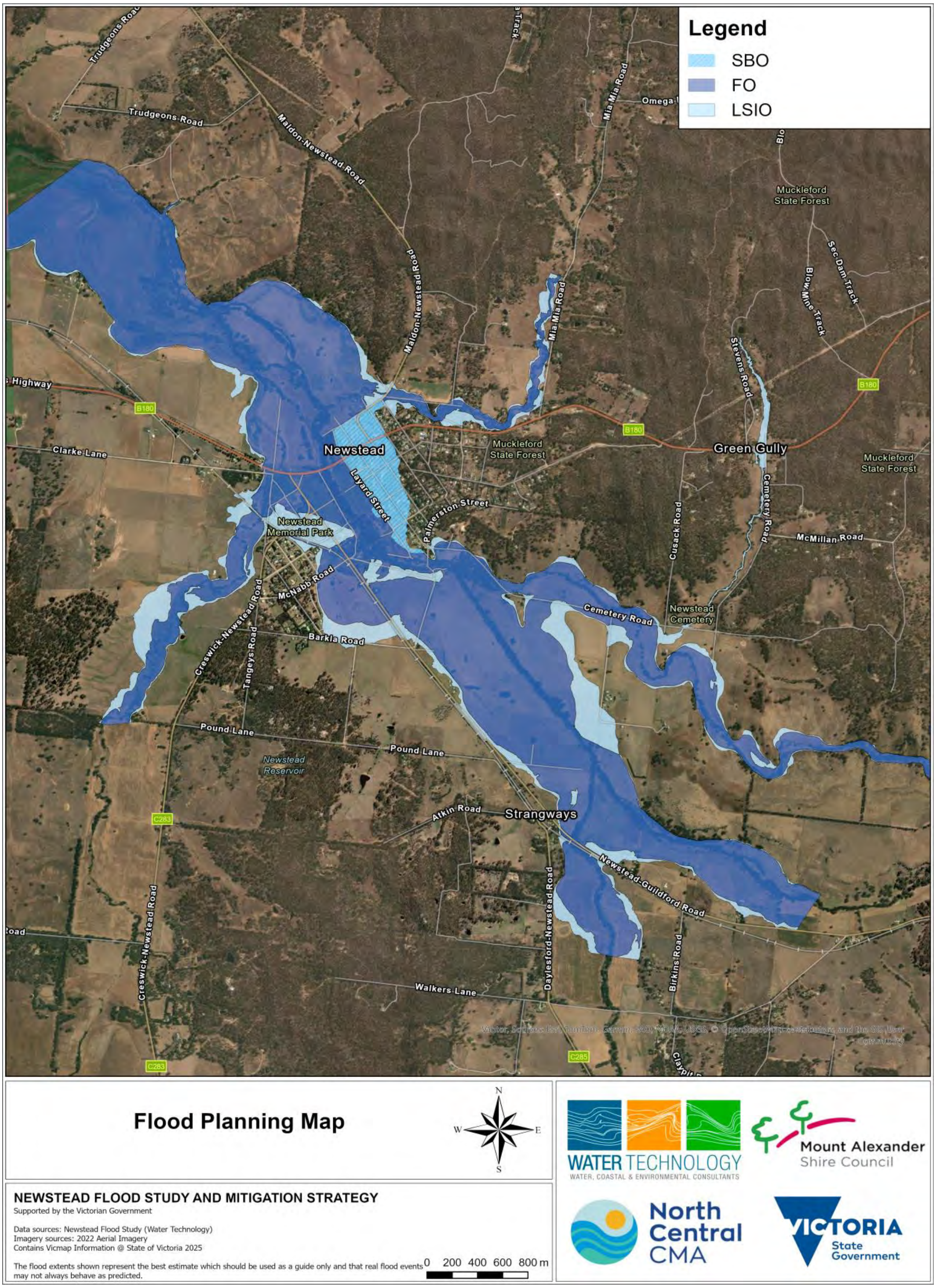


Figure 5-13 Draft Flood Related Planning Overlays developed using the 2100 SSP5 event

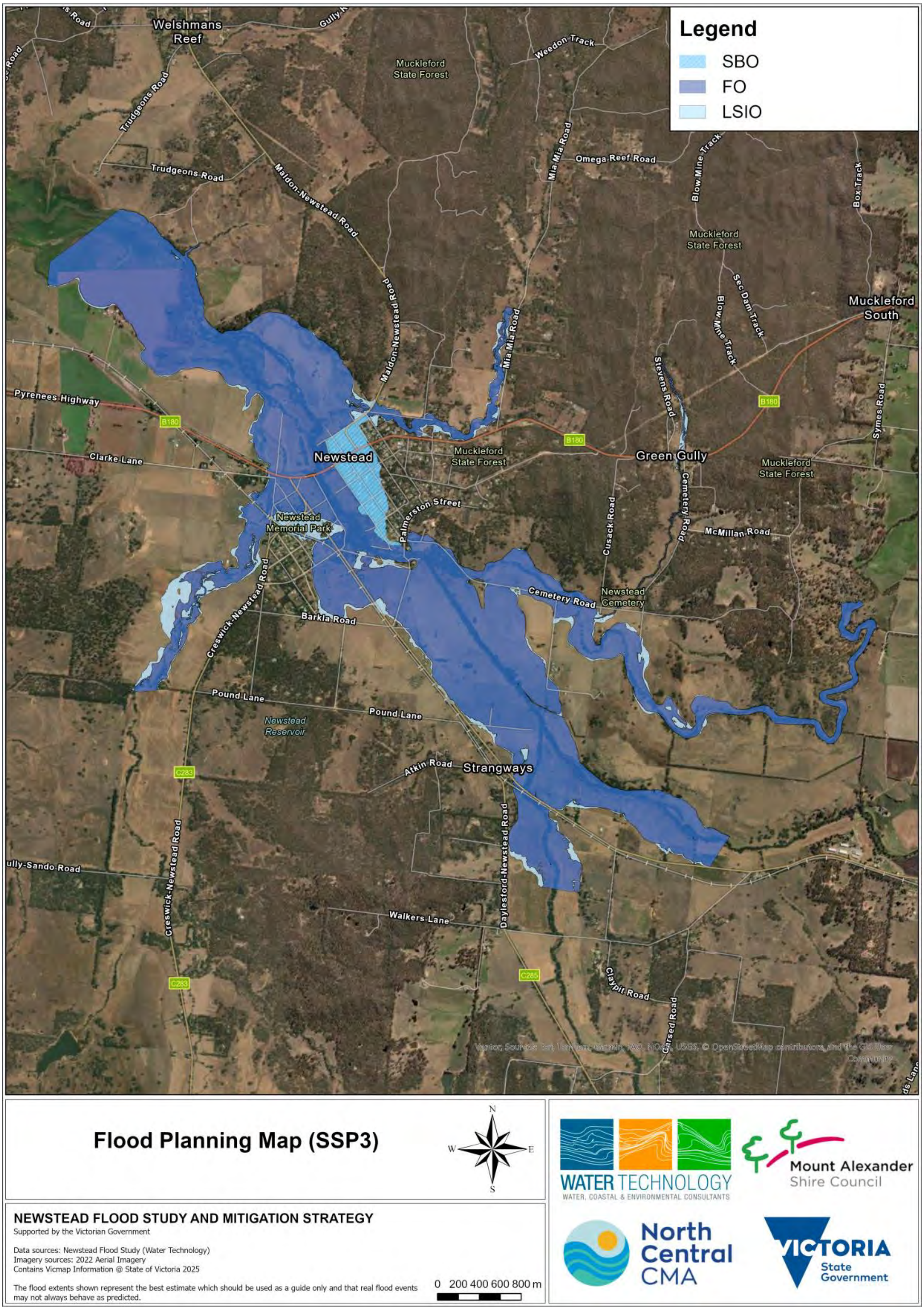


Figure 5-14 Draft Flood Related Planning Overlays developed using the 2100 SSP3 event

6 FLOOD INTELLIGENCE AND WARNING

6.1 Overview

Flood intelligence and flood warning outputs utilise the 1% AEP + climate change under SSP5 for 2030. This was considered the most appropriate scenario given the date of the study and current climate change advice, determined in consultation with the project technical reference group.

In line with the project brief, the following flood intelligence products were produced:

- Flood/No flood tool – rainfall intensity and flooding indicator.
- Flood peak calculator – river gauge level correlations.
- Flood peak travel time calculator/warning time available.
- Modelled/calibrated hydrographs at gauging stations.
- Prepare draft documentation for insertion into the Mount Alexander Flood Emergency Plan (MFEP), this includes:
  - Flood intelligence card
  - Property and road inundation tables, mapping and data (inundation depth and time) for all properties and roads impacted by flooding.
  - Proposed updates to other outdated information in the MASC MFEP relating to Newstead (Appendix A, B and C)

6.2 Flood peak travel time

Definitive information on the time it takes for flooding to develop (i.e. to arrive at a location) following the onset of heavy rain and the time it takes for the flood peak to be reached is highly variable. The magnitude and timing of a flood is dependent on several factors including the attributes of the rainfall/storm event and antecedent conditions. **Timing of flooding in the Newstead township is however likely to be within 11 to 54 hours.**

Table 6-1 Flood peak travel timing

From	To	Typical travel time
Start of rainfall (catchment)	Start of Loddon River rising in Newstead	11 hours to 4 days
Start of Loddon River rising in Newstead	Peak Loddon River level at Newstead	11 to 54 hours
Peak Loddon River level at Vaughan	Peak Loddon River level at Newstead	0 to 5 hours
Peak Muckleford Creek level at Muckleford	Peak Loddon River level at Newstead	2 to 5 hours
Peak Larni Barramal Yaluk level at Yandoit	Peak Loddon River level at Newstead	0 to 6 hours

6.3 Flood/No Flood tool

The Intensity Frequency Duration (IFD) design rainfall data used in the development of Mount Alexander Flood Emergency Plan (MFEP) can be utilised along with forecast and observed rainfall data as an early warning tool. The data can be used to identify the likely magnitude of flooding and resulting consequences based on the predicted rainfall depths of an event. The flood/no flood tool is presented in Figure 6-1 and discussed in detail in the Municipal Flood Emergency Plan (MFEP) Documentation (R06).

6.4 Municipal Flood and Storm Emergency Plan Flood Intelligence Table

A set of summary tables were developed for Newstead, to be read from top to bottom, with each subsequent larger magnitude event reporting on the incremental changes in consequences across different regions of the study area. This is presented in the Newstead Flood Intelligence Documentation.

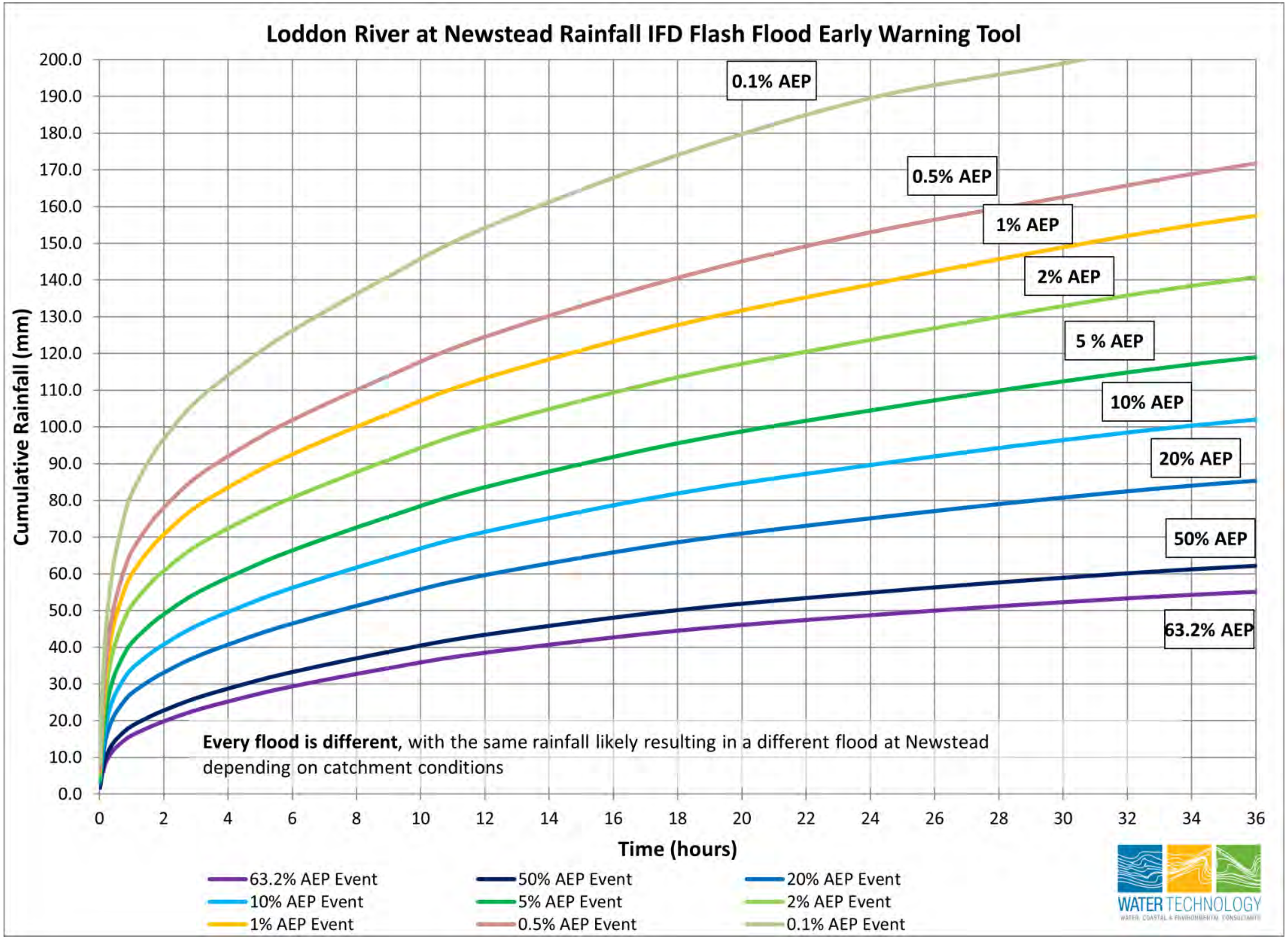


Figure 6-1 Loddon River at Newstead Flood/No flood tool

7 SUMMARY

The Newstead Flood Study has produced detailed flood modelling of Loddon River upstream of Newstead and its tributaries. The mapping produced by this study is fit for the purposes of flood emergency planning and response alongside statutory and strategic planning in the town. The study has also investigated the current flood impacts in terms of average annual damages and the potential for structural mitigation to reduce those damages. Flood intelligence products have been produced for insertion into the Mount Alexander Flood Emergency Plan (MFEP), these are detailed in the MFEP Documentation Report.
Recommendations from the Newstead Flood Study have been separated into the agencies responsible:

- Mount Alexander Shire Council
  - Endorse the flood study with the aim of adopting the flood study recommendations.
  - Share mapping and findings of the current study with the Newstead community including newcomers.
  - Undertake a planning scheme amendment to update the flood related planning overlays to reflect the flood risk mapping produced by this project.
  - Review the information within the Flood Intelligence and Flood Warning Report to undertake an update of the Mount Alexander Shire Council MFEP.
  - Investigate opportunities install a level gauge with historic flood levels near the Newstead levee to provide a robust reference for communications during emergencies.
  - Investigate funding mechanisms of the preferred mitigation option including detailed design and consideration of an alternative alignment to reduce the construction cost.
  - Undertake a review of the current response, maintenance and operations documentation with Council staff.
- North Central Catchment Management Authority
  - Endorse the flood study and use the flood mapping data to inform floodplain risk management decisions.
  - Upload the Victoria Flood Database mapping data and the excel spreadsheet of property inundation to FloodZoom.
  - Investigate opportunities to install telemetered rainfall gauges within the catchment and stream gauges at Castlemaine and the Mia Mia Creek and Green Gully Creek catchments.
  - Discuss with BoM to review the current Flood Class Levels at Newstead.
- Victoria State Emergency Service:
  - Continue to engage the community through flood awareness programs such as FloodSafe.
  - Update the Newstead Local Flood Guide and assist Council in updating the MFEP.
- VicRoads
  - Investigate opportunities to reduce the frequency of overtopping the Pyrenees Highway at Green Gully Creek
  - Add “Floodway” signs on major roads susceptible to flooding, particularly Pyrenees Highway with depth markers where appropriate.

Future flood events in Newstead should be monitored carefully and compared to the results of this study, with flood levels marked and surveyed where possible. Where flood behaviour appears to disagree with the findings of the study, the reason for the discrepancy should be investigated and an update to the study should be considered.

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Attachment 9.4.2.6

WATER TECHNOLOGY
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Flood Warning Assessment Report

Newstead Flood Study and Mitigation Strategy(M1751-2023)

Mount Alexander Shire Council

5 December 2025

Document Status

Version	Doc type	Reviewed by	Approved by	Date issued
V01	Draft	Lachlan Inglis	Lachlan Inglis	21/10/2025
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Project Details

Project Name	Newstead Flood Study and Mitigation Strategy(M1751-2023)
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ACKNOWLEDGEMENT OF COUNTRY

The Board and employees of Water Technology acknowledge and respect the Aboriginal and Torres Strait Islander Peoples as the Traditional Custodians of Country throughout Australia. We specifically acknowledge the Traditional Custodians of the land on which our offices reside and where we undertake our work. In particular, we recognise the Dja Dja Wurrung People as the Traditional Custodians of the waters and lands on which this project is based.

We respect the knowledge, skills and lived experiences of Aboriginal and Torres Strait Islander Peoples, who we continue to learn from and collaborate with. We also extend our respect to all First Nations Peoples, their cultures and to their Elders, past and present. In particular, we recognise the Dja Dja Wurrung People as the Traditional Custodians of the waters and lands on which this project is based.

Artwork by Maurice Goolagong 2023. This piece was commissioned by Water Technology and visualises the important connections we have to water, and the cultural significance of journeys taken by traditional custodians of our land to meeting places, where communities connect with each other around waterways.

The symbolism in the artwork includes:

- *Seven circles representing each of the States and Territories in Australia where we do our work*
- *Blue dots between each circle representing the waterways that connect us*
- *The animals that rely on healthy waterways for their home*
- *Black and white dots representing all the different communities that we visit in our work*
- *Hands that are for the people we help on our journey*

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GLOSSARY

Annual Exceedance Probability (AEP)	Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded; it would occur quite often and would likely be relatively small magnitude. A 1% AEP flood has a low probability of occurrence or being exceeded; it would be fairly rare but it would likely be of extreme magnitude.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Recurrence Interval (ARI)	Refers to the average time interval between a given flood magnitude occurring or being exceeded. A 10 year ARI flood is expected to be exceeded on average once every 10 years. A 100 year ARI flood is expected to be exceeded on average once every 100 years. The AEP is the ARI expressed as a percentage.
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Design flood	A design flood is a probabilistic or statistical estimate, being generally based on some form of probability analysis of flood or rainfall data. An average recurrence interval or exceedance probability is attributed to the estimate.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from elevated sea levels and/or waves overtopping coastline defences.
Flood frequency analysis	A statistical analysis of observed flood magnitudes to determine the probability of a given flood magnitude.
Flood hazard	Potential risk to life caused by flooding. Flood hazard combines the flood depth and velocity.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Flood storages	Those parts of the floodplain that are important for the temporary storage, of floodwaters during the passage of a flood.

Geographical information systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Incident Control Centre (ICC)	A facility established by VicSES to manage and coordinate a response to an emergency incident.
Intensity frequency duration (IFD) analysis	Statistical analysis of rainfall, describing the rainfall intensity (mm/hr), frequency (probability measured by the AEP), duration (hrs). This analysis is used to generate design rainfall estimates.
LiDAR	Spot land surface heights collected via aerial light detection and ranging (LiDAR) survey. The spot heights are converted to a gridded digital elevation model dataset for use in modelling and mapping.
Peak flow	The maximum discharge occurring during a flood event.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Average Recurrence Interval.
Probable Maximum Flood	The flood that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in a particular drainage area.
RORB	A hydrological modelling tool used in this study to calculate the runoff generated from historic and design rainfall events.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.
Topography	A surface which defines the ground level of a chosen area.
TUFLOW	A hydraulic modelling software package used to undertake modelling using hydrological modelling inputs.

1 INTRODUCTION

1.1 Overview

Water Technology was commissioned by Mount Alexander Shire Council (MASC) to undertake the Newstead Flood Study and Mitigation Strategy. The project is funded by the Disaster Ready Fund and the Victorian Government. The investigation covers the study area presented in Figure 1-1.

Newstead is a small township in Victoria, located 15 km west of Castlemaine on the banks of the Loddon River. Located within MASC and the North Central Catchment Management Authority (NCCMA) management area, Newstead was established in the mid-19th century as a river crossing point and today hosts a population of approximately 800 people.

The Loddon River catchment upstream of Cairn Curran Reservoir was included in a RORB hydrology model prepared as part of the Cairn Curran Dam Hydrology report[1] prepared by SKM. This model was refined for the catchment upstream of Guildford during the NCCMA Rapid Flood Risk Assessment[2]. The SKM model was calibrated to three events from 2010 and 2011. Given the age of the SKM model and that the Guildford model only covers part of the catchment upstream of Newstead, a new hydrology model was produced for the current study. However, parameters adopted for the previous models were considered for model validation. This study will produce flood intelligence information for use in emergency management, assess the current flood impact/exposure in terms of annual average damages caused by flooding in Newstead, investigate structural and non-structural mitigation options and make recommendations for establishing a flood warning system for the town.

This report is one of a series documenting the outcomes for the Newstead Flood Study. Each reporting stage is shown below:

R01 – Data Review and Validation Report – Final version published 20 August 2024

R02 – Hydrology Report – Final version published 31 October 2024

R03 - Draft Hydraulic Modelling Report – Final version published 13 December 2024

R04 – Final Hydraulic Modelling Report – Final version published 3 April 2025

R05 - Design Modelling and Mapping Outputs – Final version published 3 April 2025

R06 – Municipal Flood Emergency Plan (MFEP) Documentation – Draft published 8 May 2025

R07 – Flood Damage and Structural Mitigation Options – TBC

R08 – Final Project Report – TBC

R09 - Flood Warning Assessment Report – This report

This report provides an assessment of the flood warning components currently in place for Newstead, with recommendations for further improvement to the flood warning system

[1] SKM, 2012 Cairn Curran Dam: Flood Hydrology Update

[2] HARC, 2020 Guildford Rapid Flood Risk Assessment - North Central CMA Region, prepared for North Central CMA

1.2 Objectives and outputs

The Newstead Flood Study and Mitigation Strategy outputs are required to meet several floodplain management objectives as highlighted in the project brief prepared by MASC. The objectives of the investigation are described below:

- Undertake hydrologic and hydraulic modelling to determine flood levels and flood extents for the full range of flood events up to and including the Probable Maximum Flood (PMF).
- Calibrate models to historic flood events including the October 2022 flood event.
- Investigate modelling of climate change scenarios.
- Assess the feasibility of a range of potential mitigation options including understanding of the level of protection provided by the existing levee and information to inform necessary upgrades to this levee.
- Analyse the feasibility of establishing effective flood warning, accounting for time available between rainfall and the township flooding, in the context of a total flood warning system.
- Update flood intelligence to be incorporated into the Municipal Flood Emergency Plan.
- Provide recommendations to update the Planning Scheme and ensure it is informed by the best available flood information.

1.3 Study area

The main flood risk in Newstead is posed by the Loddon River, a levee was constructed in the 1920's that is still protecting the eastern portion of the township from Loddon River flooding. However, a number of smaller catchments generate runoff towards Newstead directly or indirectly, resulting in complex hydrologic and hydraulic conditions to address in planning and emergency response. These catchments include Mia Mia Creek, Muckleford Creek, Larni Barramal Yaluk, Green Gully and Green Gully Creek as shown in Figure 1-1. Additionally, there are several tributaries joining the Loddon River near Newstead further impacting river levels.

Newstead most recently experienced flooding in October 2022, causing flooding to parts of the township located on the western side of the Loddon River. Flooding in Newstead has historically caused levee breaches which were mitigated by sandbagging during the flood event. Flooding of the Loddon River also leads to the town being isolated when major traffic routes are cut off. The Loddon River at Newstead has been subject to considerable physical and ecological modifications due to extensive historic mining activities and other anthropogenic influences since European settlement. In recent years, bank erosion has been an issue for landholders adjacent to the Loddon River.

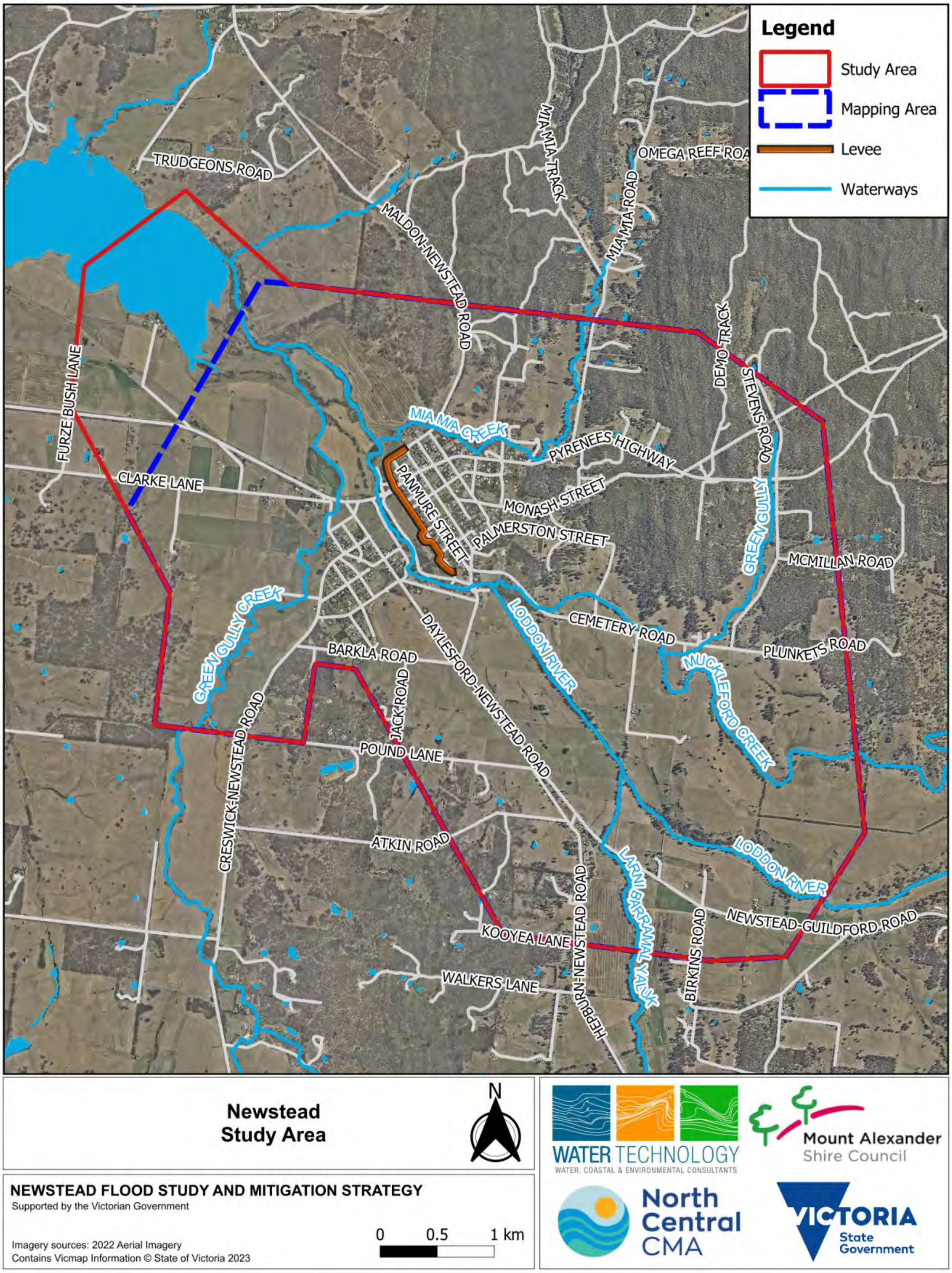

Figure 1-1 Newstead study area

1.4 Flood warning improvement deliverables

The tender brief sets out the following flood warning assessments to be delivered as part of the Newstead Flood Study and Mitigation Strategy:

- Estimates of effective flood warning time for flood magnitudes likely to result in damage to the township.
- Assessment of the capacity of the community and emergency services (including CFA and SES) to implement effective actions within the estimated flood warning times.
- Identification of potential gauge sites for flood warning, and development of theoretical relationships between appropriate measures and flooding in the township for future implementation of permanent or mobile gauging systems.

2 BACKGROUND: TOTAL FLOOD WARNING SYSTEM

Water Technology is currently undertaking the Loddon Total Flood Warning System Review[3], which includes an assessment of flood risk, flood history, flood warning lead times and the existing flood warning systems for a number of communities, including Newstead, located in the Loddon River catchment. This study has also sought to identify possible total flood warning system (TFWS) component gaps and TFWS improvements for each community. This report builds on the work undertaken as part of both the Loddon Total Flood Warning System Review and previous reporting from the Newstead Flood Study and Mitigation Strategy (the current study).

The Australian Government has provided guidance to assess and design robust flood warning systems. It introduced the concept of the 'total flood warning system' to describe the full range of elements that must be developed if flood warning services are to be provided effectively.

Guidelines for the assessment and development of a TFWS are provided by the Australian Government in its document: Application of the Total Warning System to Flood[4]. A schematic of the components of the TFWS promoted by this document is provided in Figure 2-1.

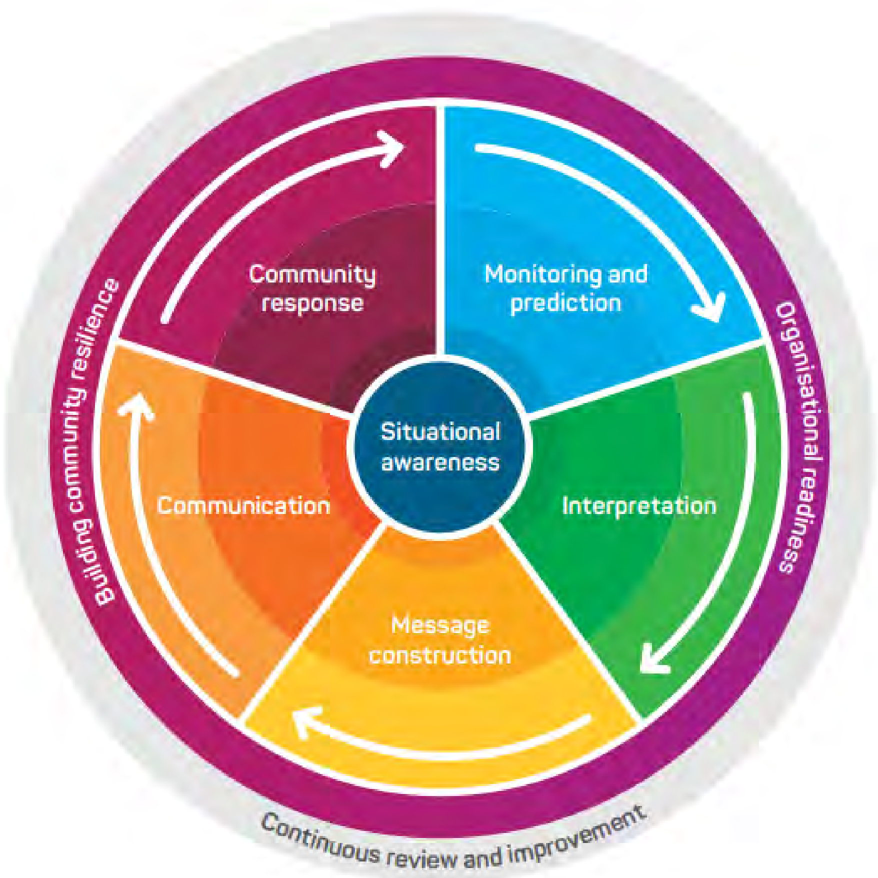

Figure 2-1 Australian Components of the Total Flood Warning System[4]

[3] Water Technology, 2025 *Loddon Total Flood Warning System Review*, report prepared for the North Central Catchment Management Authority
[4] AIDR, 2022 *Application of the Total Warning System to Flood.* Australian Institute for Disaster Resilience

The information produced by a flood investigation generally relates to the “monitoring and prediction” and “interpretation” elements. Flood mapping, damages and intelligence produced by the study will be valuable in interpreting incoming data. Some of the elements of the study (for example the “Flood/No Flood” tool produced in the Municipal Flood Emergency Plan) can aid with prediction.

Emergency message construction, communication, and community response are outside the scope of a flood investigation however would generally be completed from within an Incident Control Centre (if one has been set up) and the applicable Incident Management Team controlling the incident. Formal flood warning messages in Victoria fall within the remit of the Bureau of Meteorology and fall within two classes: Flood Watches and Flood Warnings.

Flood Watches are general warnings covering a large area and are not specific to particular waterways or townships. They can be delivered well before flooding is expected to arise and are often based on forecast rainfalls.

Flood Warnings, on the other hand, are specific to a location and will predict how high the water will peak at that location. Flood Warnings are often related to Flood Class Levels (see Section 5).

Review of available information should take place after any flood event, or any other discovery of new flood information as appropriate. Historic events should be added to the available information, particularly the MFEP, as they occur.

Monitoring, in the context of flooding, generally refers to monitoring rainfall and stream levels but may include other aspects such as storage levels and catchment conditions to name a few. Locations to monitor will depend on the available data sources and the catchment of interest.

The following sections will discuss the current and potential monitoring capability for the Loddon River and tributaries upstream of Newstead, flood travel times and flood class levels at Newstead to assist in future data collection and prediction.

3 CURRENT FLOOD WARNING SYSTEM

A TFWS assessment framework[5] was used to review the existing flood warning system for Newstead and identify potential improvements in the system. This framework builds on that promoted by the Australian Government and the Australian Institute for Disaster Resilience[6,7] and is similar to that outlined in the Application of the Total Warning System to Flood Handbook[4]. The framework involves 12 components of the TFWS:

- Understanding flood risk
- Emergency management planning
- Community flood engagement and education
- Data collection
- Prediction
- Interpretation
- Warning message construction
- Warning message communication
- Response
- Review
- Community participation
- Integration of the TFWS components

Figure 3-1 provides a schematic representation of the TFWS assessment framework used in the Loddon Total Flood Warning System Review[3].

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[5] Molino, S., Dufty, N., Crapper, G. & Karwaj, A., 2011 *Are warnings working? Achievements and challenges in getting communities to respond*, paper presented to the Floodplain Management Association Conference, Tamworth NSW, February 2011

[6] *Australian Disaster Resilience Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (AIDR 2017).

[7] *Public Information and Warnings* (AIDR 2021).

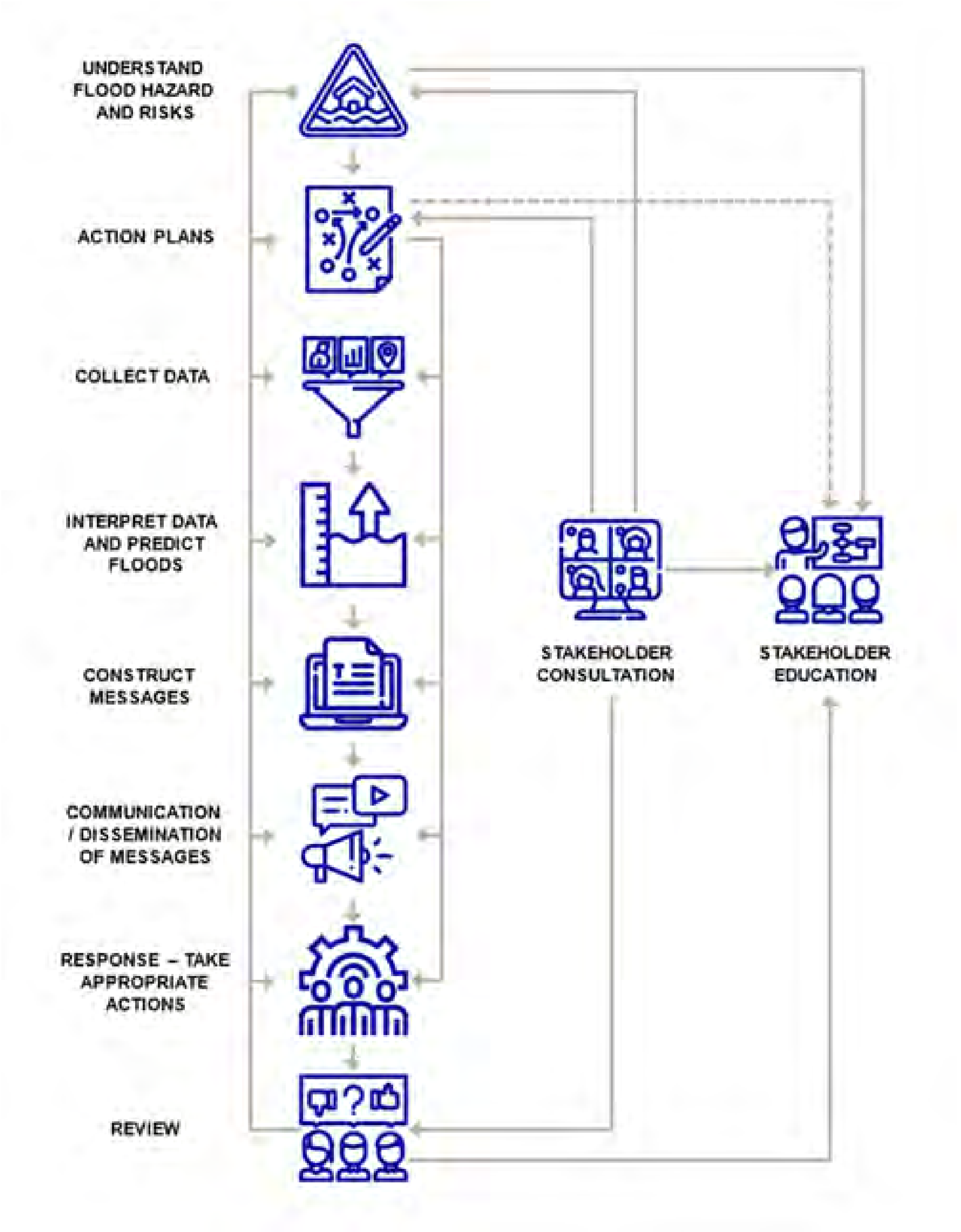

Figure 3-1 TFWS assessment framework[5]

An assessment of the existing flood warning system in Newstead in relation to the 12 TFWS components is provided in Table 3-1. Further refinement of the assessment was provided through community and stakeholder engagement.

Table 3-1 Assessment of the existing flood warning system for Newstead

TFWS Component	Assessment of the existing flood warning system
Understanding flood risk	The current study has provided details of flood impacts for different events (R04 – Final Hydraulic Modelling Report) and possible flood risk mitigation options (R07 – Flood Damage and Structural Mitigation Options). Recent flood experience enables the local community to understand flood risk and have realistic flood perceptions. Levee overtopping is a significant concern to the local community. Impacts of flash flooding from overland flows should also be considered in the TFWS. There are newcomers to the town that may be unaware of flood risk.
Emergency management planning	The Municipal Flood Emergency Planning Committee (MFEPC) is currently reviewing the Mount Alexander Shire Council Municipal Flood Emergency Plan (MFEP). It was last updated July 2019. In relation to flood warning, the MFEP should include the flood intelligence products produced as part of the current study (R06 – Municipal Flood Emergency Plan Documentation) as well as the updated MFEP template. The MFEP also includes details about flood warning arrangements (e.g. roles of emergency agencies). Evacuation routes and appropriate emergency relief centres should be checked and are understood to be under review as part of the ongoing work that Mount Alexander Shire is undertaking through regular MEMPC committee meetings.
Community flood engagement and education	The Newstead Local Flood Guide (LFG) provides public information about the flood risk, flood levels, flood warnings, emergency kits and an emergency plan - https://dev.ses.vic.gov.au/plan-and-stay-safe/flood-guides/mount-alexander-shire-council. The LFG is being updated based on the flood study.
Data collection	There are several telemetered rainfall gauges within the catchment upstream of Newstead. The closest rain gauges that record sub-daily rainfalls and report to the BoM's website are outside of the catchment and include the Ballarat Airport AWS (6 minute recording, displayed at 1-hour intervals on BoM and approximately 10 minutes on Flood Zoom), Redesdale and Bendigo Airport. Four active streamflow gauges are located within the Upper Loddon Catchment with water level and streamflow data available to the present date at: ■ Loddon River at Vaughan ■ Loddon River at Newstead ■ Larni Barramal Yaluk at Yandoit ■ Muckleford Creek at Muckleford The streamflow gauges located upstream of Newstead may be useful in predicting flooding at Newstead however it is noted that they are located relatively close to Newstead and that there are a number of ungauged catchments which contribute to flooding in Newstead, including Mia Mia Creek and Green Gully Creek. The Bureau of Meteorology (BoM) does not provide a quantitative level of service at the Newstead gauge. Any warning information is likely to be general in nature.

TFWS Component	Assessment of the existing flood warning system
	A Flood Watch or Warning for Newstead is predicted from information at the streamflow gauges listed above. The warning times from rainfall to flooding will be affected by the predicted rainfall totals, catchment conditions, and the amount of time rain takes to fall. The information provided in a Flood Watch or Warning may be very general in nature. Newstead would benefit from a specific warning product. GMW track around 65% of inflows into Cairn Curran and then look at how much the dam has risen each hour to decide on releases. Lack of rain gauges in the upstream catchment hinders the prediction service. Given the proximity of the existing streamflow gauges to Newstead and subsequently, the limited travel time from the upstream gauges, and the presence of ungauged catchments upstream of Newstead, predicting the likely magnitude of flooding in Newstead is reliant on the real time rainfall gauge network and rainfall forecasts. In some events, warning times may be too short for monitoring of streamflow to be of any use as a means of issuing early flood warning. This is further assessed in Section 4.
Prediction	Newstead could benefit from a predictive service. GMW is able to provide predicted inflow and outflow from Cairn Curran (downstream of Newstead) but cannot precisely predict what flow will occur at Newstead. Based on previous significant flood events, the flood peak at Newstead is occurring well after 6-hours from the onset of rainfall within the catchment. Modelled flood peaks can manifest around 10 to 20 hours from the start of intense rainfall, with the majority of events peaking between 12 hours and 3 days from the start of the rainfall burst, This is discussed further in Section 4 and Section 6.
Interpretation	Interaction with the town levee is a key impact that has been assessed as part of the design modelling (R04 – Final Hydraulic Modelling Report) and flood intelligence assessment (R06 – Municipal Flood Emergency Plan Documentation). A river level gauge exists in town that flood emergency mapping has been linked to for interpretation in an Incident Control Centre (ICC) and with local emergency managers. The current flood class levels at the Loddon River at Newstead Gauge are as follows: ■ Minor Flood Level 3.00m ■ Moderate Flood Level 4.50m ■ Major Flood Level 5.60m Compared to the design modelling levels from the current study, the flood class levels are low, this is further discussed in Section 5.

TFWS Component	Assessment of the existing flood warning system
Warning message construction	Generic messaging is currently limited to flood watch, regional flood warnings and severe weather warnings for the Loddon catchment. Riverine flooding warnings presently issued on advice of BoM, VICSES reviews and adds consequence information (MFEP), polygons catchment/sub-catchment based. The establishment of Newstead as a forecast location quantitative prediction appears worth pursuing.
Warning message communication	Warning group in ICC can tailor area within the message, however this is not overly specific without input from G-MW on expected flows into Cairn Curran.
Response	Newstead becomes isolated which can hinder response efforts. The levee being close to overtopped/overtopping in 2011 and 2022 has led to trauma within the community. Feedback from the community indicates the Current warnings are not specific enough - community finds that really confronting, increasing anxiety. There is an older population (mean age 51 years[8]). Only 5.5% of community require assistance in a flood and there are high levels of volunteerism (27.3%) indicating strong social connectedness. There are relatively few renters (9.2%) in town demonstrating low transience. No land uses with vulnerable people at risk (i.e. aged care, hospitals, pre-schools, caravan parks, schools etc.)
Review	There was no evidence that the existing flood warning system for Newstead was being reviewed regularly (e.g. through a system monitoring and evaluation process).
Community participation	High level of volunteerism shows the potential for community participation in emergency management including flood warning. There is an active CFA Brigade in the town https://newsteadcfa.org/ and the closest SES unit is based in Castlemaine.
Integration of the TFWS components	There was no strong evidence (e.g. in the MFEP) found that the linkages across the components of the TFWS were well understood for the study area.

[8] Australian Bureau of Statistics, Census Data 2021, https://abs.gov.au/census/find-census-data/quickstats/2021/SAL21936

4 FLOOD PEAK TRAVEL TIME

4.1 Overview

Definitive information on the time it takes for flooding to develop (i.e. to arrive at a location) following the onset of heavy rain and the time it takes for the flood peak to be reached is highly variable. The magnitude and timing of a flood is dependent on several factors including the attributes of the rainfall/storm event and antecedent catchment conditions. The flood peak travel time assessment from R06 – Municipal Flood Emergency Plan (MFEP) Documentation is repeated below in more detail.

4.2 Historic events

4.2.1 Gauged flows

Flood peak timing for all gauges within the Upper Loddon River catchment was assessed against existing gauge data to identify the time from the onset of heavy rainfall to develop an understanding of lag times from rainfall to gauge rise and catchment travel times.

Table 4-1 shows the typical travel time along the Loddon River and its tributaries, based on the flood events in 2022, 2016, 2011 and 2010. Figure 4-1 shows the location of the streamflow gauges. The rainfall temporal pattern and storm duration or the combination of both can impact the magnitude of flooding at Newstead. The table highlights that reliance on upstream gauges provides limited warning time, and that more warning time can be provided by monitoring rainfall gauges within the catchment.

Table 4-1 Timing of peak flow at Newstead

From	To	Typical travel time
Start of rainfall (catchment)	Start of Loddon River rising in Newstead	11 hours to 4 days
Start of Loddon River rising in Newstead	Peak Loddon River flow at Newstead	11 to 54 hours
Peak Loddon River flow at Vaughan	Peak Loddon River flow at Newstead	3.5 to 4.75 hours
Peak Muckleford Creek flow at Muckleford	Peak Loddon River flow at Newstead	2 to 5 hours
Peak Larni Barramal Yaluk flow at Yandoit	Peak Loddon River flow at Newstead	0 to 6 hours
End of heavy rainfall (catchment)	Peak Loddon River flow at Newstead	0 to 7 hours

Recorded rainfall and streamflow during the 2022, 2016, 2011 and 2010 event are shown in Figure 4-2 to Figure 4-5, showing rainfall totals recorded at the Bendigo Airport, Redesdale and Ballarat Aerodrome sub-daily rainfall stations and streamflow at each existing streamflow gauge location. The estimated lag time between the onset of heavy rain in the upper catchment to a rise at the Newstead streamflow gauge was between 11 hours and 4 days. The Newstead gauge peaked between 0 to 7 hours after the end of the rainfall. The flood peak travel time between the Vaughan and Newstead gauges was between 3.5 and 4.75 hours.

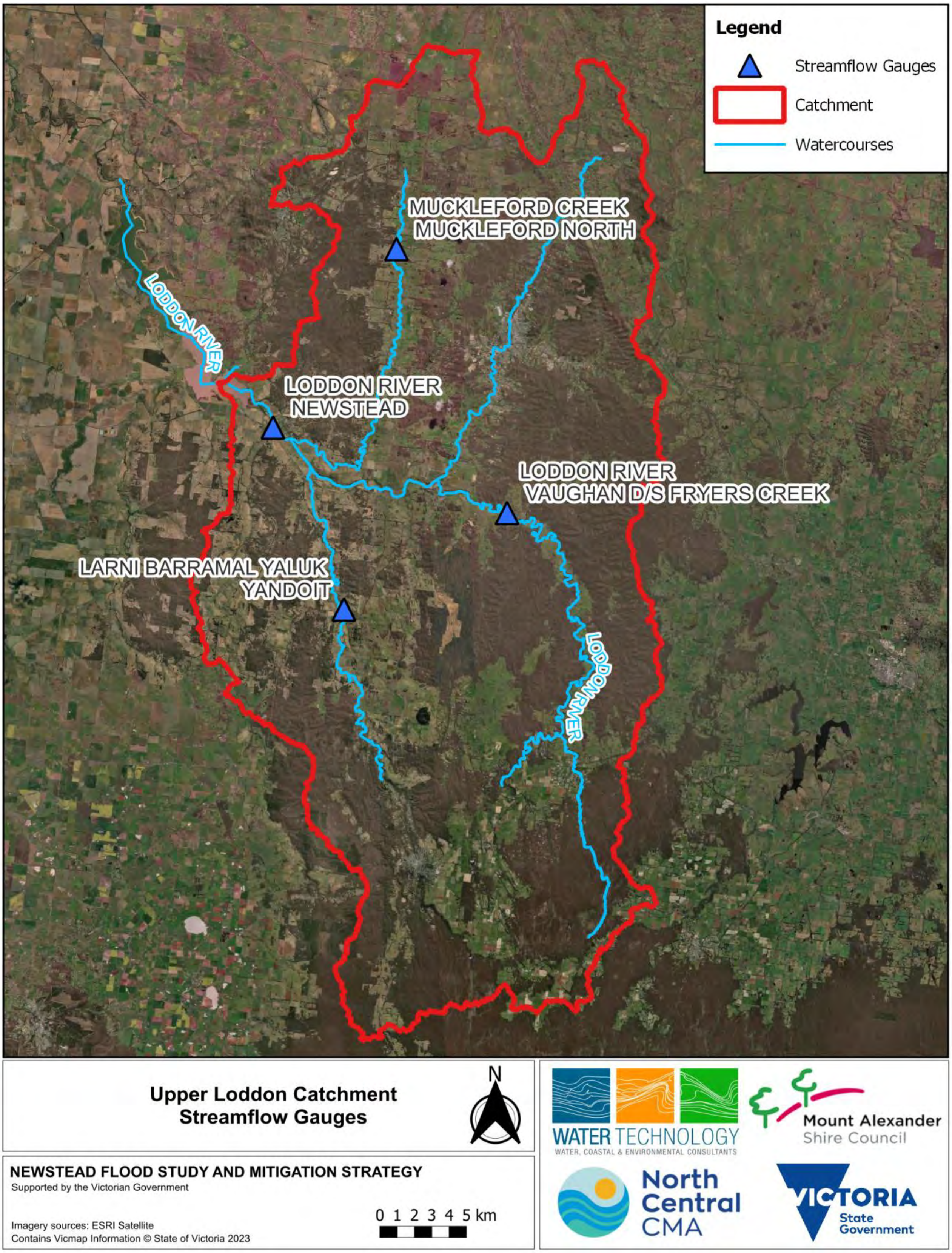

Figure 4-1 Streamflow gauge locations

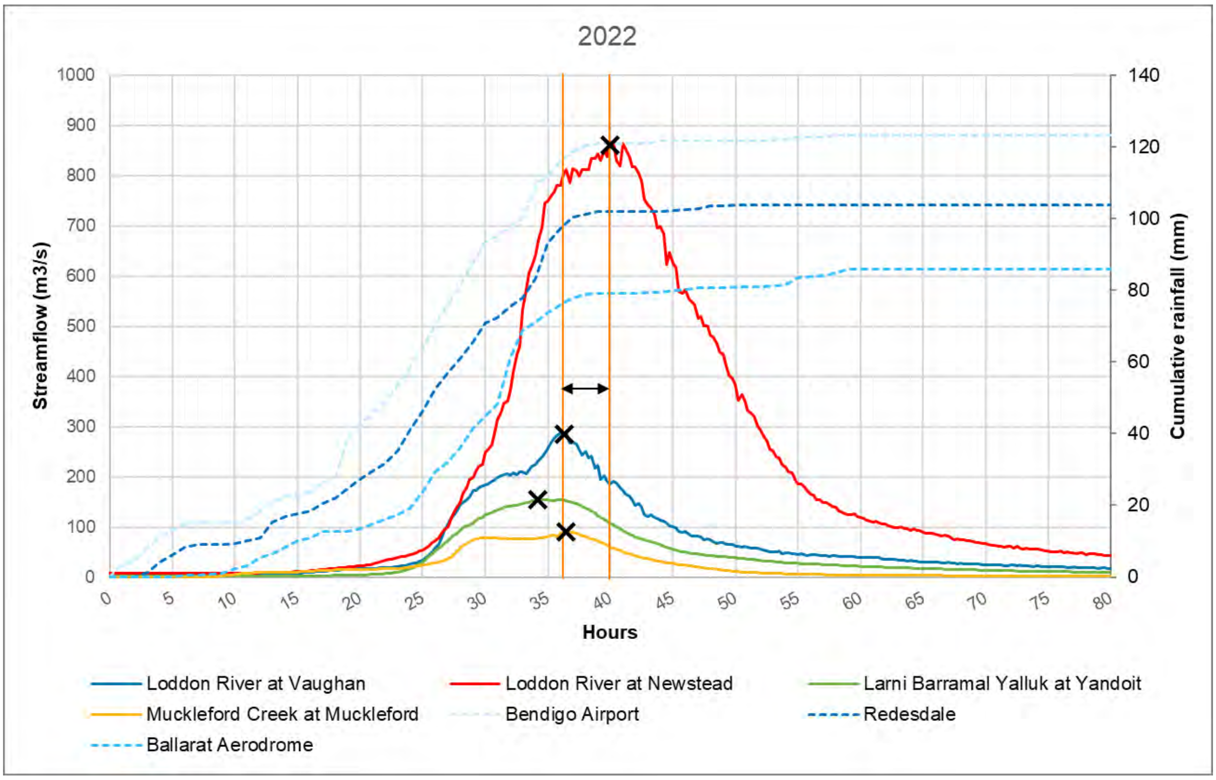

Figure 4-2 Gauged travel time between gauging stations during October 2022

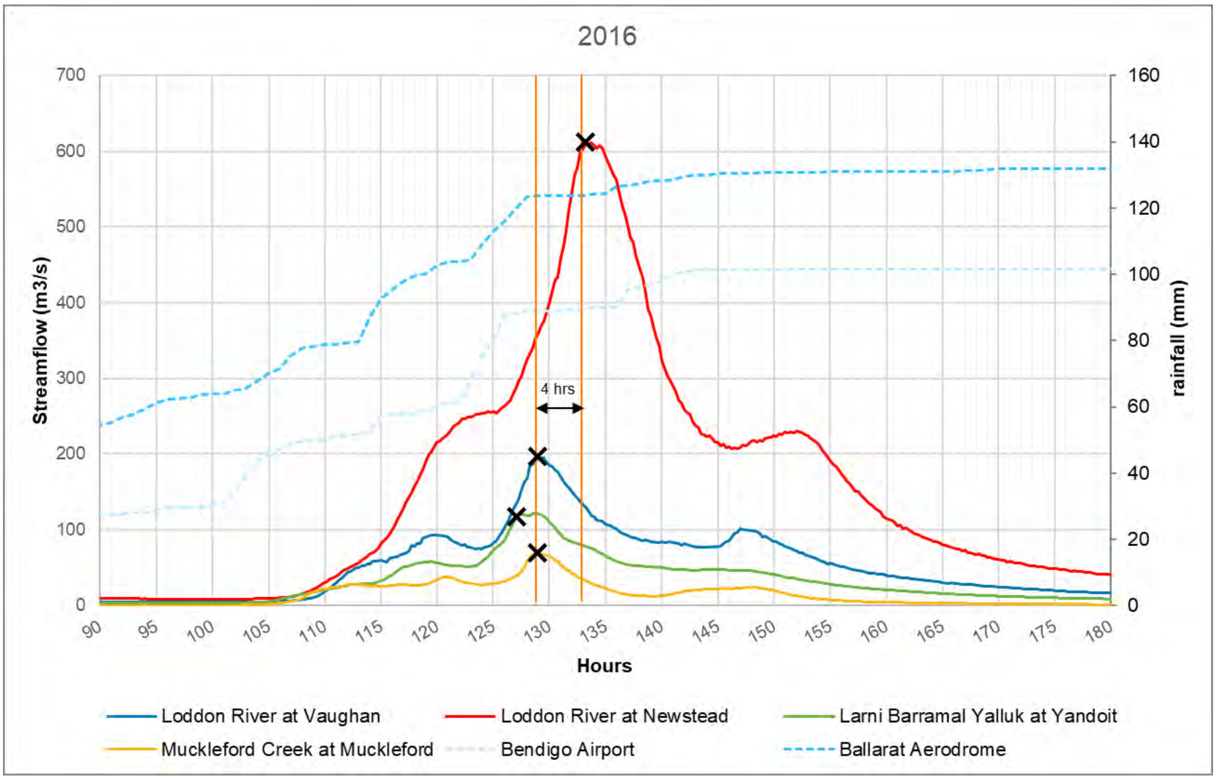

Figure 4-3 Gauged travel time between gauging stations during September 2016

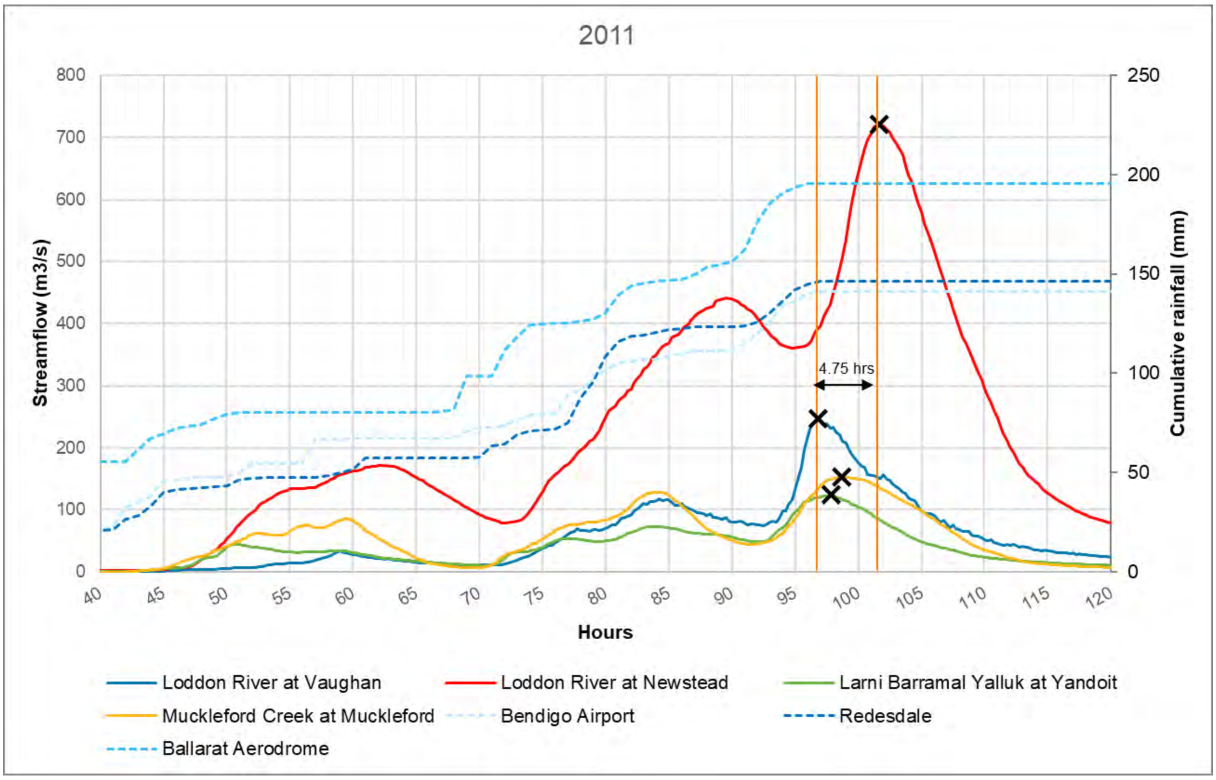

Figure 4-4 Gauged travel time between gauging stations during January 2011

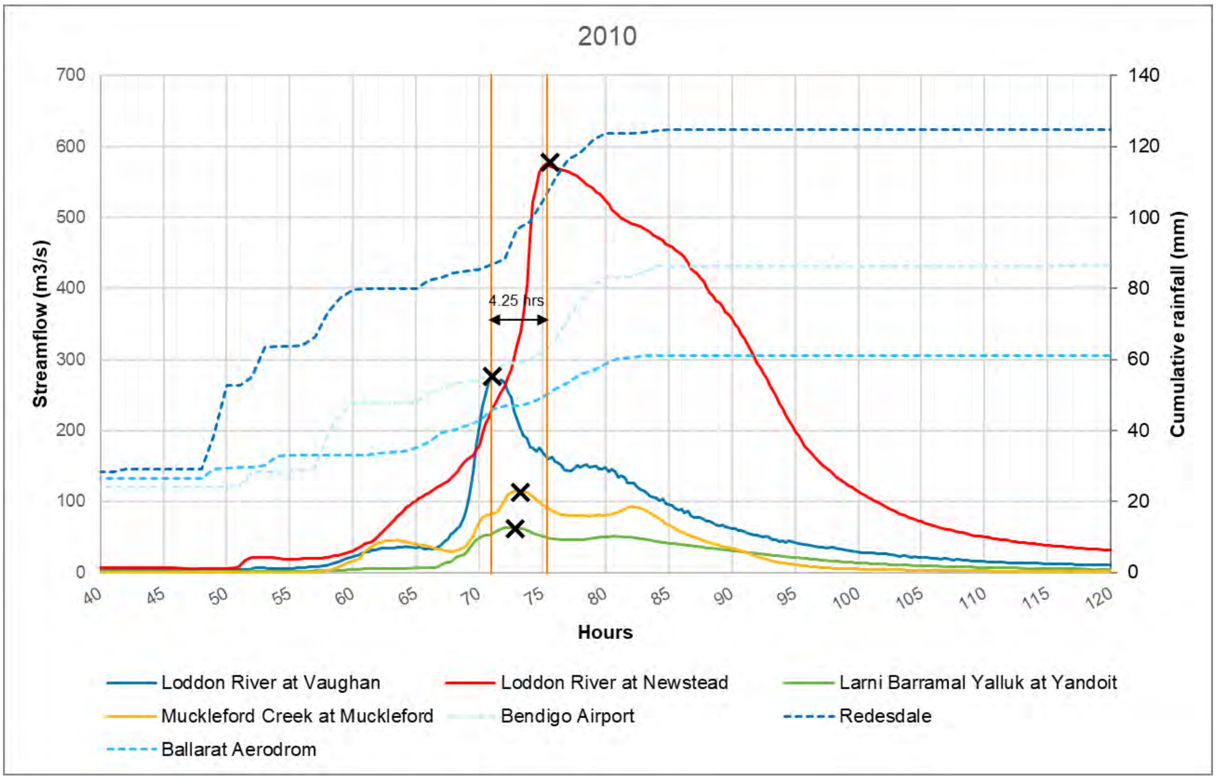

Figure 4-5 Gauged travel time between gauging stations during November 2010

4.2.2 Modelled flows

The flood peak timing analysis was repeated using the hydrology model results to enable assessment of potential additional gauge locations. Artificial gauge stations were added at three locations (see Figure 4-6):

- Loddon River at Vaughan Springs Road – to assess the benefit of a streamflow gauge further upstream in the Loddon River catchment
- Campbells Creek at Castlemaine – to assess the benefit of a streamflow gauge on a major ungauged catchment contributing to Loddon River flooding
- Green Gully Creek at Sandon – to assess the benefit of a streamflow gauge within an ungauged catchment that causes flood impacts in Newstead
- Mia Mia Creek at Mia Mia Track – to assess the benefit of a streamflow gauge within an ungauged catchment that causes flood impacts in Newstead

Recorded rainfalls at the sub-daily rainfall stations and modelled streamflows at each potential streamflow gauge location are shown in Figure 4-7 to Figure 4-10 for the 2022, 2016, 2011 and 2010 events The plots also include modelled flows at existing stations on the Loddon River for comparison. Table 4-2 shows and overview of the modelled flood peak travel times.

Table 4-2 Timing of modelled flows at potential gauging stations

From	To	Typical travel time
Peak Loddon River flow at Vaughan Springs Rd	Peak Loddon River flow at Newstead	2 to 6 hours
Peak Loddon River flow at Vaughan	Peak Loddon River flow at Newstead	1 to 5 hours
Peak Campbells Creek flow at Castlemaine	Peak Loddon River flow at Newstead	2 to 5 hours
Peak Mia Mia Creek flow at Mia Mia Track	Peak Mia Mia Creek flow at Newstead	0 to 2 hours
Peak Green Gully Creek flow at Sandon	Peak Green Gully Creek flow at Newstead	2 to 6 hours (2016 - 24 hours, outlier)

The results show that an additional gauge upstream of Vaughan only provides up to two hours of additional warning time, with the Loddon River at Newstead flood peak occurring within 2 to 6 hours of the peak at Vaughan Springs Road. Additionally, the placement of a gauge far upstream means many of the tributaries contributing to flooding at Newstead are not accounted for by this gauge meaning a gauge at this location would not be a reliable indicator of flooding at Newstead.

Similar travel times are shown at the remaining proposed gauge sites, indicating none of them would provide much value in predicting a flood event at Newstead.

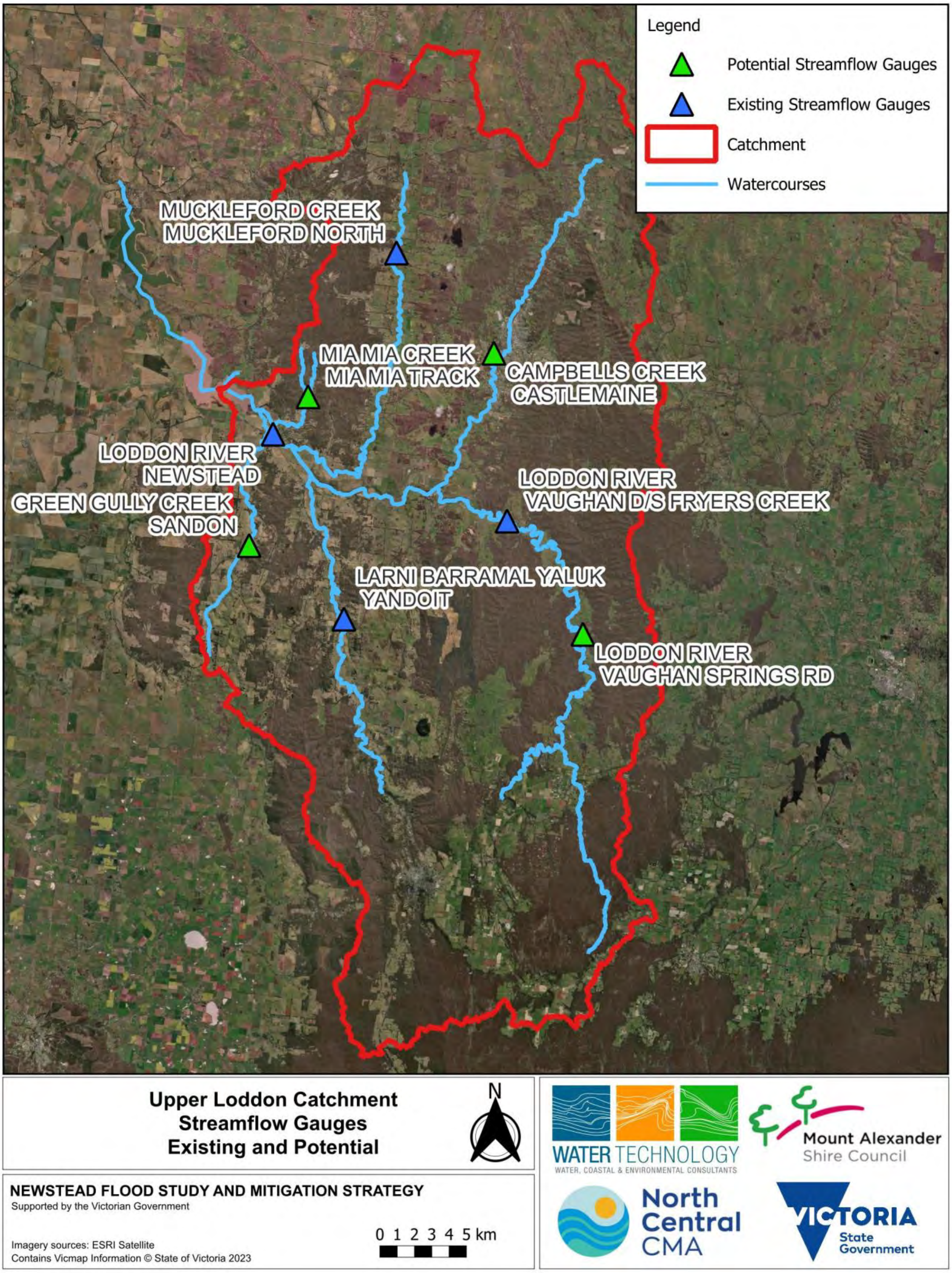

Figure 4-6 Potential streamflow gauge locations

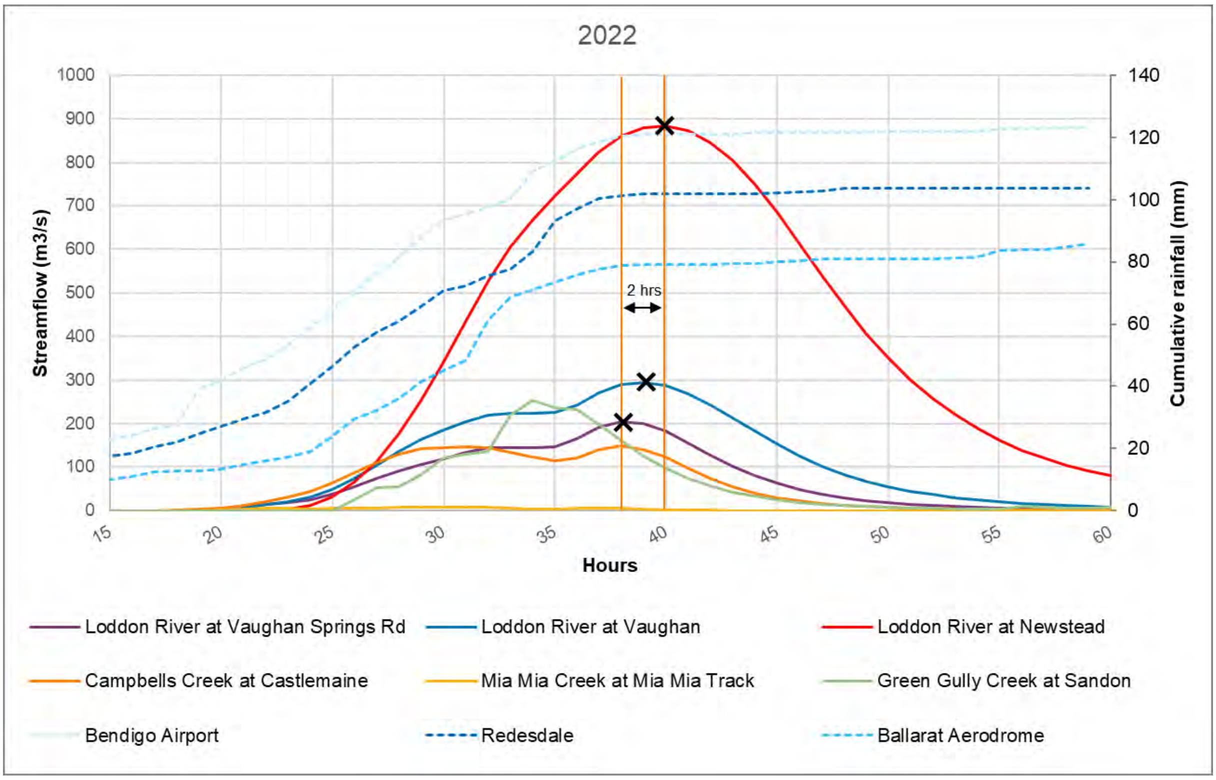

Figure 4-7 Modelled travel time between gauging stations during October 2022

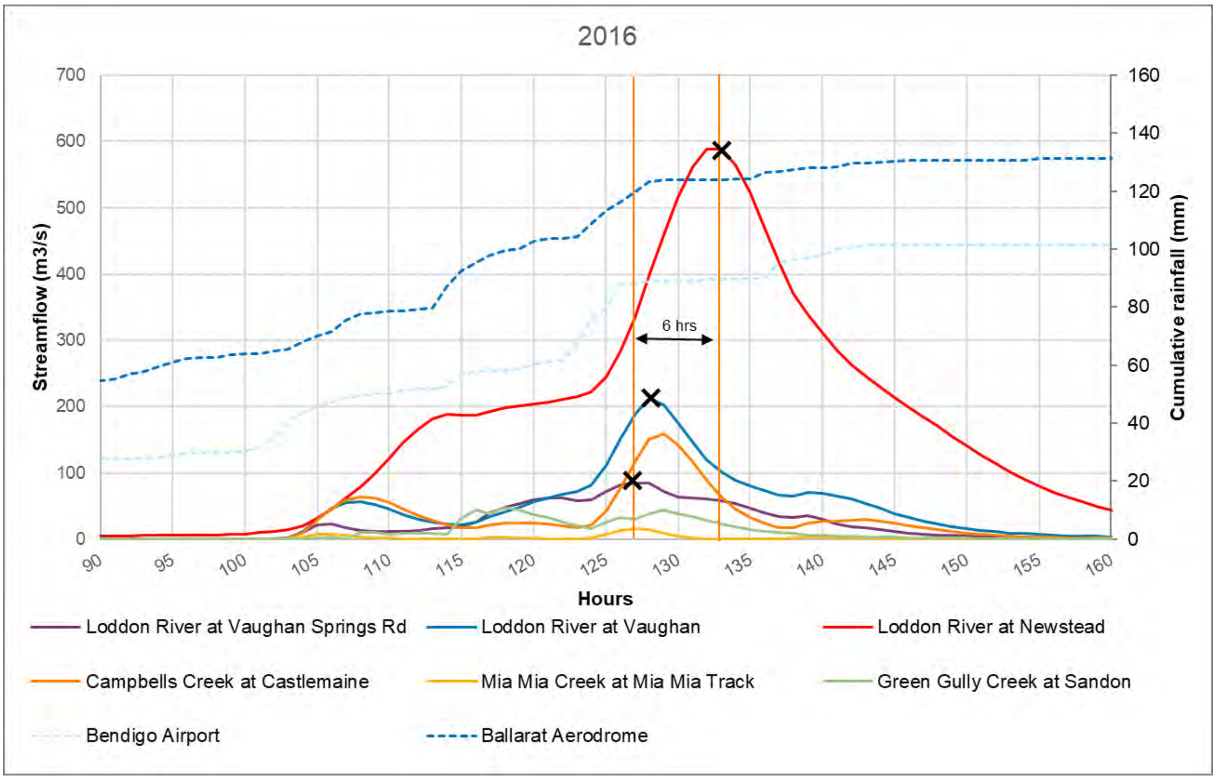

Figure 4-8 Modelled travel time between gauging stations during September 2016

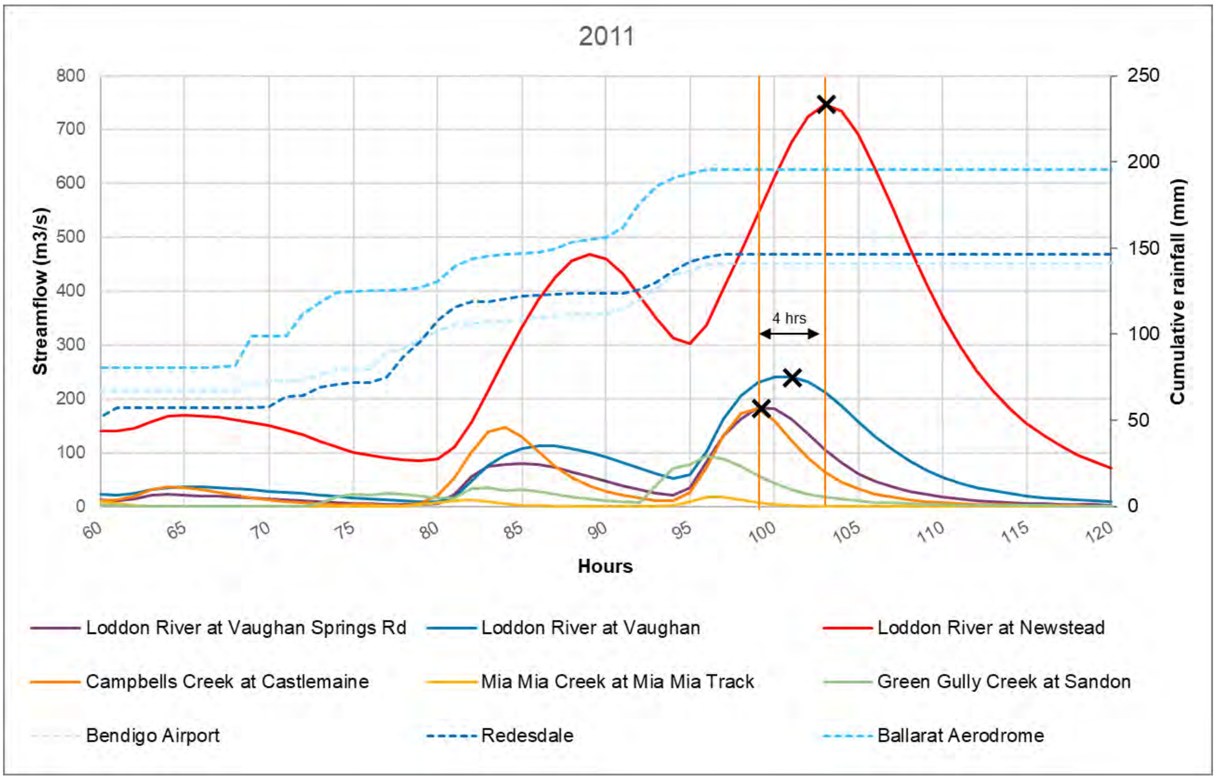

Figure 4-9 Modelled travel time between gauging stations during January 2011

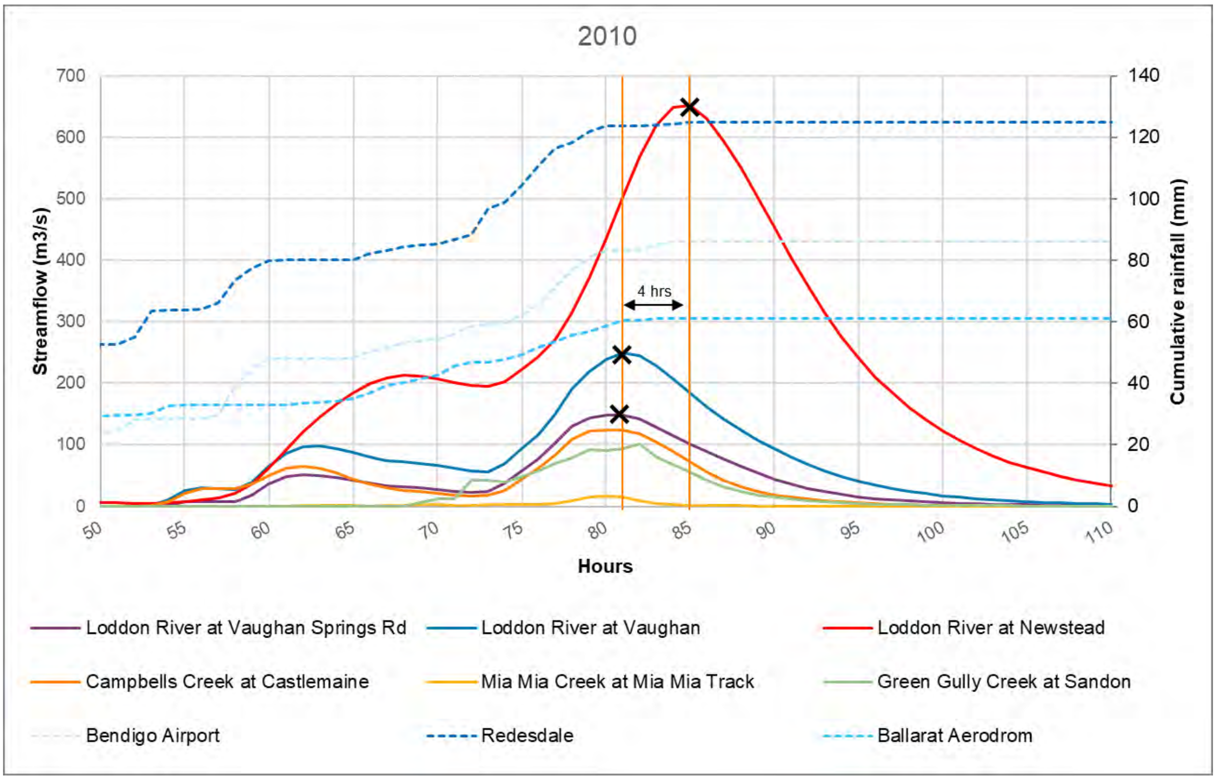

Figure 4-10 Modelled travel time between gauging stations during November 2010

4.3 Design flood peak travel times

Additional to analysing historic events, the calibrated hydrology model developed as part of this study was utilised to estimate typical flood peak travel times for a range of storms. The modelled hydrographs at the Loddon River at Newstead gauge for the 1% AEP and 10% AEP rainfall events are shown in Figure 4-11 and Figure 4-12. The graphs show all modelled AEP events for durations between 12 hours and 168 hours for all ten temporal patterns, A total of 100 hydrographs were produced for each AEP. Also shown on the graphs is the critical duration and median temporal pattern peak flow at this location, selected in accordance with the recommendations of ARR.

The graphs show a significant range in peak flows and timing produced by rainfall depths of a specified AEP when that rain falls over different durations and temporal patterns within the duration. This illustrates the difficulty in accurately predicting flood peaks and timing from rainfall alone.

The graphs show that the modelled flood peaks can manifest around **10 to 20 hours** from the start of intense rainfall, with the majority of events peaking between 12 hours and 3 days from the start of the rainfall burst. Some events peak beyond 3 days from the start of rainfall, however these become rarer and may contain "embedded bursts" where rainfall intensity within an event increases for a short period of time.

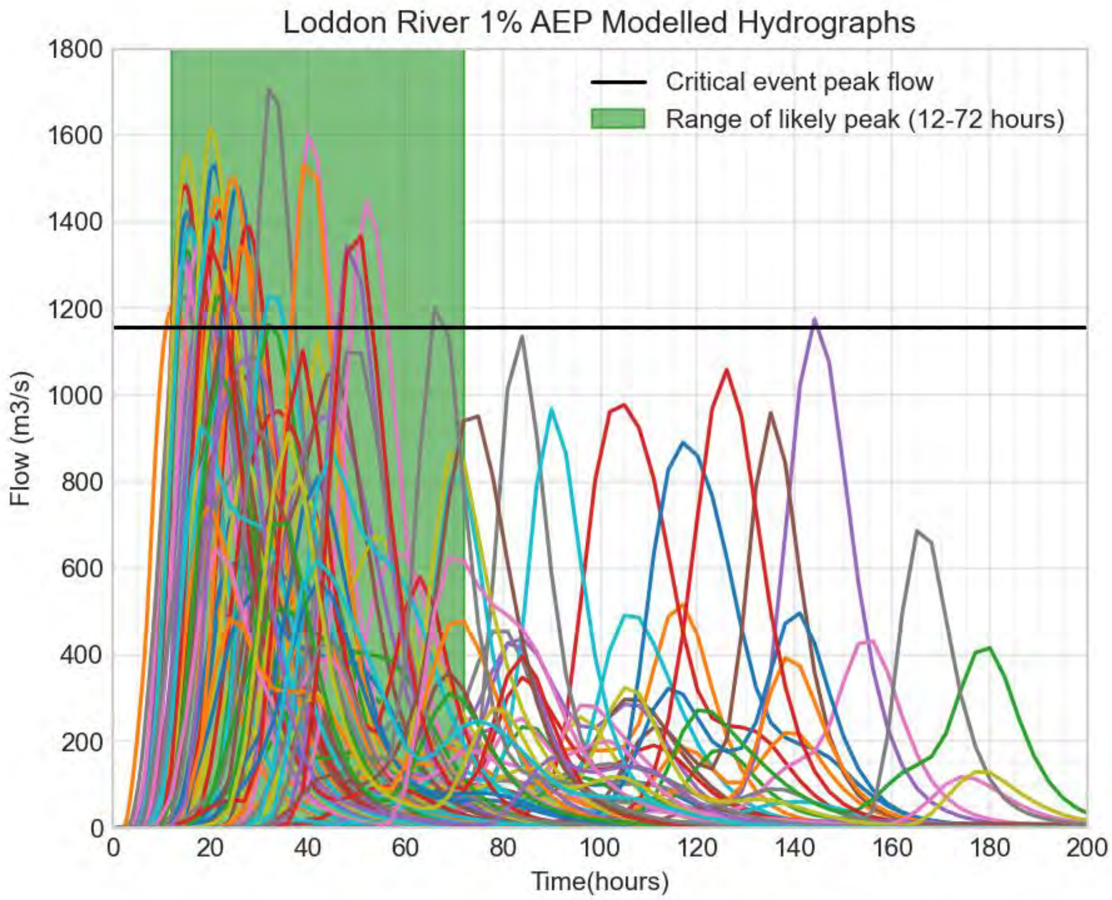

Figure 4-11 1% AEP hydrograph for all modelled rainfall events at Newstead

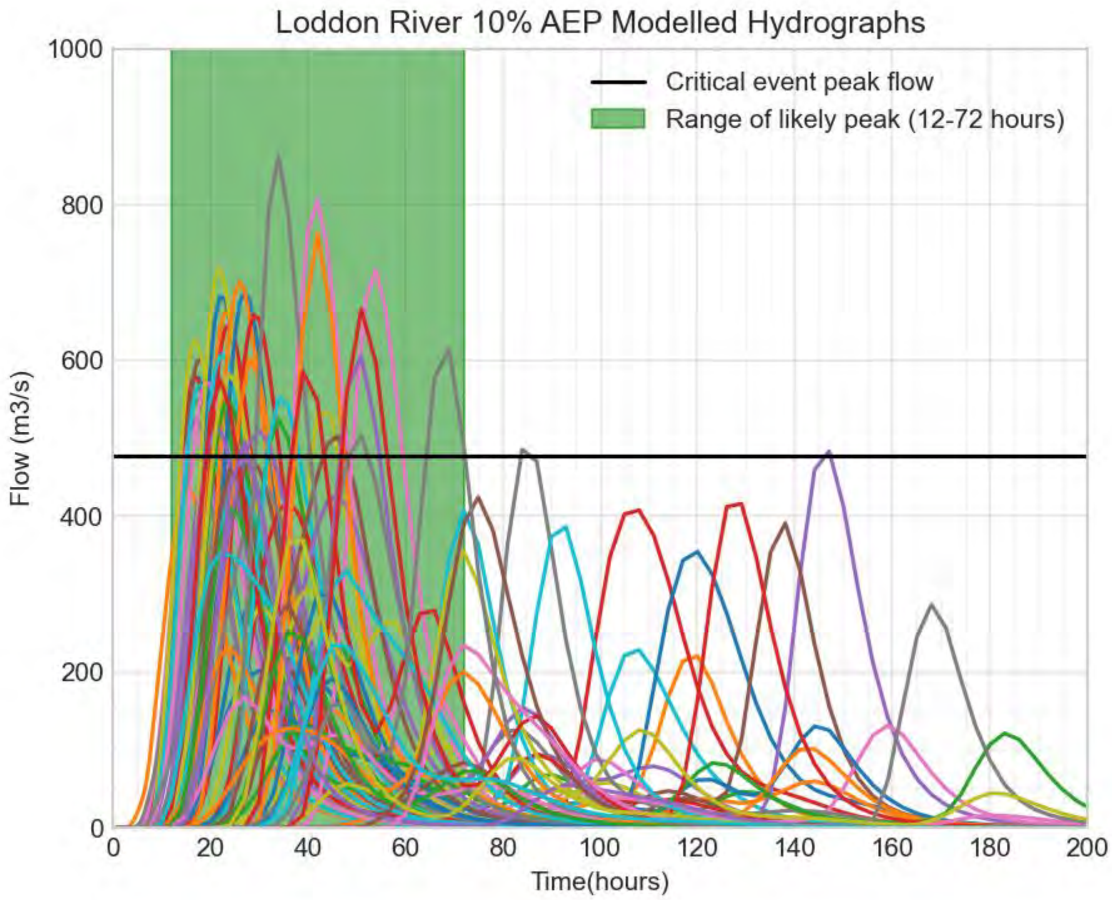

Figure 4-12 10% AEP hydrograph for all modelled rainfall events at Newstead

5 FLOOD CLASS LEVELS

Defined Flood Class Levels (FCLs) are available for the Loddon River at Newstead gauge and are detailed in Table 5-1.

Table 5-1 Current Flood Class Levels for Newstead

Flood Class	Gauge level at Loddon River at Newstead gauge (m)	Flood Level at Loddon River at Newstead gauge (mAHD)	Description
Minor	3.0	210.937	The minor flood level is well below the 20% AEP level at Newstead (5.49 m). Minor out of bank flooding from the Loddon River is observed upstream of Punt Road. Mia Mia Creek floods onto farmland north of Newstead and shallow outbreaks are observed along Green Gully Creek.
Moderate	4.5	212.437	The moderate flood level is also well below the 20% AEP level at Newstead (5.49 m). Out of bank flooding is observed along the Loddon River and Green Gully Creek in most of the study area, with the Pyrenees Highway overtopped by Green Gully Creek.
Major	5.6	213.537	The major flood level is in between the 20% and 10% AEP level at Newstead (5.49 m and 5.80 m respectively). Widespread out of bank flooding is expected along all waterways entering Newstead, with impacts to the Pyrenees Highway and Hepburn-Newstead Road as well as some residential streets.

The Bureau of Meteorology's definitions of FCLs are presented below:[9]

Minor flooding

If the water level reaches the minor flood level, it causes inconvenience. Low-lying areas next to water courses are inundated. Minor roads may be closed and low-level bridges submerged. In urban areas flooding may affect some backyards and buildings below floor level as well as bicycle and pedestrian paths. In rural areas removal of livestock and equipment may be required.

Moderate flooding

If the water level reaches the moderate flood level, the area of inundation is larger. Main traffic routes may be affected. Some buildings may be affected above floor level. Evacuation may be required. In rural areas removal of livestock is necessary.

Major flooding

If the water level reaches the major flood level large areas are inundated. Many buildings may be affected above floor level. Properties and towns are likely to be isolated and major rail and traffic routes closed. Evacuation may be required. Utility services may be affected.

[9] http://www.bom.gov.au/australia/flood/knowledge-centre/about-warning-service.shtml

Based on the Bureau of Meteorology definitions, the existing flood class levels at Newstead appear to be slightly low. Table 5-2 details proposed flood class levels based on the design modelling undertaken for the current project.

Table 5-2 Proposed Flood Class Levels for Newstead

Flood Class	Level at Loddon River at Newstead gauge (m)	Level at Loddon River at Newstead gauge (mAHD)	Description
Minor	4.5	212.437	Propose to adopt the current moderate flood level as the minor flood level. Out of bank flooding is observed along the Loddon River and Green Gully Creek in most of the study area, causing inconvenience with the Pyrenees Highway overtopped by Green Gully Creek but at a shallow level.
Moderate	5.5	213.427	Propose to adopt the 20 % AEP flood level (5.49m gauge height) as the moderate flood level. Widespread out of bank flooding is expected along all waterways entering Newstead, with road closures on the Pyrenees Highway and Hepburn-Newstead Road as well as some residential streets. No property is flooded above floor, but 1 property is flooded below floor with over 30 parcels inundated away from the main building.
Major	5.8	213.737	Propose to adopt the 10% AEP flood level as the major flood level. Widespread out of bank flooding is expected along all waterways entering Newstead, with road closures on the Pyrenees Highway, Hepburn-Newstead Road and Daylesford-Newstead Road as well as some residential streets. The water level is still below the Newstead levee crest. No property is flooded above floor, but 3 properties are flooded below floor with over 30 parcels inundated away from the main building, and areas of Newstead are isolated.

6 FLOOD WARNING IMPROVEMENTS

6.1 Existing capability

Currently, there is no formal flood warning system in place that is specific to Newstead. As described in Table 3-1, the flood warning system at Newstead consists of generic messaging limited to flood watch, regional flood warnings and severe weather warnings for the Loddon catchment. Additionally, there are several ungauged catchments and the streamflow gauges upstream of Newstead are located too close to provide sufficient warning time alone. Currently, official flood warning capability for the catchment and township is limited to the issue of a Flood Watch for the Loddon River. Note a flood watch is not necessarily guaranteed to be issued prior to flooding.

There are no sub-daily rainfall gauges within the Upper Loddon catchment upstream of Newstead, therefore rainfall estimates in the catchment upstream of Newstead are not well captured. Currently estimates of rainfall within the catchment relies on rainfall gauges outside of the catchment.

6.2 Ideal (Potential) capability

The Loddon Total Flood Warning System Review[3] has identified possible improvements to the flood warning system specifically for Newstead, see Table 6-1.

Table 6-1 Possible improvements to the flood warning system at Newstead

TFWS Component	Potential Actions	Rationale
Understanding flood risk	Share mapping and findings of the current study with the Newstead community including newcomers.	Newstead Flood Study and Mitigation Strategy will provide details of flood impacts for different events and possible flood risk mitigation options. Levee overtopping is a concern to the local community. There are newcomers to the town that may be unaware of flood risk.
Emergency management planning	Update the Mount Alexander Shire Council MFEP in the light of the Newstead Flood Study and Mitigation Strategy, specifically R06 – Municipal Flood Emergency Plan (MFEP) Documentation and de-briefs from recent flood events.	The Municipal Flood Emergency Planning Committee (MFEPC) is currently reviewing the Mount Alexander Shire Council Municipal Flood Emergency Plan (MFEP). It was last updated July 2019.
Community flood engagement and education	Update the Newstead Local Flood Guide (LFG) in line with the MFEP update.	The Newstead Local Flood Guide (LFG) provides public information about the flood risk, flood levels, flood warnings, emergency kits and an emergency plan - The LFG needs to be updated based on the flood study.
Community flood engagement and education	Install a gauge board with historic flood levels near the Newstead levee to provide a robust reference for communications during emergencies	Levee overtopping is critical to emergency response including sandbagging and possible evacuation.

TFWS Component	Potential Actions	Rationale
Data collection	Install telemetered stream gauges in Mia Mia Creek and Green Gully Creek catchments. Section 4.2.2 details an assessment of potential new gauging sites, this is further discussed below.	Four active streamflow gauges are located within the Upper Loddon Catchment with water level and streamflow data available to the present date. The streamflow gauges located upstream of Newstead may be useful in predicting flooding at Newstead, however it is noted that they are located relatively close to Newstead and that there are a number of ungauged catchments which contribute to flooding in Newstead, including Mia Mia Creek and Green Gully Creek.
Prediction	Explore the possibility of a quantitative level of flood warning service at Newstead with BoM	Currently, the information provided in a Flood Watch or Warning may be very general in nature. The assessment of the onset of flooding/flood peak timing from the beginning of rainfall within this report suggests sufficient warning time meet the BoM requirements for a quantitative level of service. G-MW currently predict inflows into Cairn Curran Reservoir.
Interpretation	Use the Flood/No Flood tool provided in R06 – Municipal Flood Emergency Plan (MFEP) Documentation to assist in flood decision-making along with the Flood Intelligence Cards to assist emergency decision-making and to develop warning advice to the Newstead community.	Given the proximity of the streamflow gauges to Newstead and subsequently, the limited travel time from the upstream gauges, and the presence of ungauged catchments upstream of Newstead, predicting the likely magnitude of flooding in Newstead is reliant on the real time rainfall gauge network and rainfall forecasts. In some events, warning times may be too short for monitoring of streamflow to be of any use as a means of issuing early flood warning.

6.3 Additional monitoring infrastructure

Flood data monitoring for the catchments upstream of Newstead would benefit from the placement of a sub-daily rainfall gauge in the upper catchment. There are no existing gauges in the upper catchment. The nearby gauges at Ballarat, Bendigo and Redesale may not reflect rainfall in the catchment nor in the immediate vicinity of the township.

A sub-daily rain gauge within the Upper Loddon catchment would therefore improve the monitoring capability for the township and broader catchment. A rain gauge within Newstead itself would provide the additional benefit of allowing for monitoring of flash flooding conditions within the township, which is known to have caused issues recently, based on feedback received during community consultation sessions for this project.

Analysis presented in Section 4 indicates that the benefit from providing additional streamflow gauges in the Upper Loddon, Campbells Creek, Mia Mia Creek and Green Gully Creek is relatively limited for predicting flooding at Newstead, however may provide additional benefits at locations such as Castlemaine and Campbells Creek for establishing a quantitative flood history.

In summary,

- Discussions on the ability for BoM to provide a quantitative level of service at Newstead should be undertaken. Involvement with G-MW on their current prediction of flow into Cairn Curran may aid in the discussions.
- A rainfall gauge in the Upper Loddon catchment would improve monitoring capabilities in Newstead. The gauge would play a direct role in warning of impending floods.
- An additional streamflow gauge within the Campbells Creek, Mia Mia Creek or Green Gully Creek catchments would provide some (but limited) benefit to estimating flows at Newstead/Cairn Curran but may provide other benefits including improved flow estimation for Cairn Curran inflows or benefits for other towns.

7 SUMMARY AND RECOMMENDATIONS

The Newstead Flood Study and Mitigation Strategy has produced detailed flood modelling of the Loddon River and other tributaries for the catchment upstream of Newstead. Flood modelling has underpinned the basis of this investigation with the mapping produced to be used for flood emergency planning and response alongside flood intelligence, statutory and strategic planning in the town.

A summary of the flood warning findings has identified:

Preferred monitoring capability and infrastructure to support a Total Flood Warning System for Newstead has been discussed, with a sub-daily rain gauge recommended in the Upper Loddon catchment would provide Newstead with improved monitoring for flood conditions in the town. This may allow for a quantitative level of flood warning service to be discussed with both G-MW, who currently predict inflows into Cairn Curran Reservoir and the Bureau.

Updated Flood Class Levels have been proposed based off the Bureau of Meteorology's definitions and flood mapping completed for Newstead. The Flood Class Levels utilise the existing stream gauge in Newstead, which could be accompanied by a gauge board for manual reading. It is noted that insufficient lead time for a flood would mean that the implementation of flood class levels and a qualitative warning system would not be achievable.

A number of Flood Warning recommendations from the Newstead Flood Study have been separated into the agencies responsible for their fulfilment. This report should be read in conjunction with the Loddon Total Flood Warning System Review[3] report to understand the broader Loddon River flood warning context.

The flood warning recommendations include:

  - Review the information within the Flood Intelligence and Flood Warning Report to undertake an update of the Mount Alexander Shire Council MFEP.
  - Undertake a review of the current response, maintenance and operations documentation with Council staff.
  - Upload the Victoria Flood Database mapping data and the excel spreadsheet of property inundation to FloodZoom.
- In conjunction with the NCCMA
  - Discuss with the BoM requirements for a quantitative level of service at Newstead. This should also involve G-MW who currently predict inflows into Cairn Curran Reservoir.
  - Investigate opportunities to install telemetered rainfall gauges within the catchment and to a lesser extent, stream gauges at Castlemaine/Campbells Creek and the Mia Mia Creek and Green Gully Creek catchments.
  - Investigate opportunities install a level gauge with historic flood levels near the Newstead levee to provide a robust reference for communications during emergencies.
  - Discuss with BoM to review the current Flood Class Levels at Newstead.
- In conjunction with VicSES
  - Continue to engage the community through regular flood awareness programs such as the VICSES FloodSafe program.
  - Update the Newstead Local Flood Guide.

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