Wagga Wagga City Council

# Tarcutta, Ladysmith and Uranquinty Floodplain Risk Management Studies and Plans

## Final Report

June 2021

grc HYDRO

## Acknowledgement

Wagga Wagga City Council has prepared this document with financial assistance from the NSW and Commonwealth Governments through the Natural Disaster Resilience Program. This document does not necessarily represent the opinions of the NSW or Commonwealth Governments.

**Tarcutta, Ladysmith & Uranquinty Floodplain Risk Management Studies and Plans**

Draft Report

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| 3-Jun-2021 | 3 | Updated post Public Exhibition |

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# Executive Summary

## The Floodplain Risk Management Program

Wagga Wagga City Council (Council) has, with the financial support of the NSW Government via the Floodplain Risk Management Program, commissioned GRC Hydro to undertake Floodplain Risk Management Studies and Plans for the townships of Tarcutta, Ladysmith and Uranquinty.

This study comprises stages 3 to 4 in the five-stage process outlined in the NSW Government's Floodplain Development Manual (FDM, 2005) (DIPNR, 2007). These works include:

1. **Data collection** – collection of all applicable data to be used for the ensuing stages of the studies;
2. **Flood Study** – a comprehensive technical investigation of flood behaviour that provides the main technical foundation for the development of a robust floodplain risk management plan;
3. **Floodplain Risk Management Study (FRMS)** – assess the impacts of floods on the existing and future community and allows the identification of management measures to treat flood risk;
4. **Floodplain Risk Management Plan (FRMP)** – outlines a range of measures, for future implementation, to manage existing, future and residual flood risk effectively and efficiently; and
5. **Plan Implementation** – once the management plan is adopted, an implementation strategy (devised in Stage 4) is followed to stage components dependent on funding availability.

Following the completion of the FRMP Council will begin implementing its recommended measures and will review the plan periodically.

## Report Overview

This report describes the data collection, model update, flood risk assessment and mitigation measures assessment of the Tarcutta, Ladysmith & Uranquinty Floodplain Risk Management Studies and Plans (FRMS&P). The study, which has been undertaken by GRC Hydro on behalf of Wagga Wagga City Council, follows on from the Tarcutta, Ladysmith and Uranquinty Flood Studies, completed in late 2014, which themselves were in response to the significant flood events of 2010 and 2012. The FRMS&P investigates flood risk in the three towns, and will inform the Council flood planning processes, and recommend a number of flood risk mitigation measures in the Floodplain Risk Management Plan. The Plan is presented as a table in this executive summary. The report contains the following sections:

- **Background** – description of the three study areas, overview of relevant policies and legislation and available data.
- **Overview of Flood Behaviour** – methodology and results of Australian Rainfall and Runoff 2019 (ARR2019) model updates.
- **Flood Risk Assessment** – Separate section for each town including flood hazard, hydraulic categories, levee function, flooding hotspots, flood warning and emergency response
- **Flood Risk Mitigation Measures** – description of the approach to flood mitigation and assessment of options in each town.
- **Community consultation** undertaken during the project

Model Update Results

The current study has updated the modelling approach used in the flood study to be consistent with ARR2019, which has significantly affected design flood levels. The approach, which involves updates to the design rainfall, losses, temporal patterns and other model parameters, was confirmed with Council and DPIE after preliminary results that showed issues with the prescribed losses values. Losses were then updated in accordance with DPIE guidelines updated in early 2019. The methodology is described in Section 3.1.

This report presents the updated flood behaviour for each town for the range of design events in Section 3.2, which incorporates mainstream and overland flooding. The results show that areas of mainstream flooding are around 0.1 to 0.3 m higher than previously adopted, while overland flooding is largely unchanged. This corresponds to an increase in flood hazard and other post-processed model outputs.

Flood Risk Assessment

An assessment of each town's flood behaviour has been carried out to determine specific areas of flood risk across a range of metrics, including flood hazard, hydraulic categories, the existing levees, the economic impact of flooding and the flood warning available. The risk assessment for each town is presented in Section 4 (Tarcutta), Section 5 (Ladysmith) and Section 6 (Uranquinty), with sections for each of the metrics. The risk assessment found that:

- **Tarcutta** has severe flood affectation in parts of the town, due to Tarcutta Creek flooding for floods of 5 % AEP and greater, when inundation occurs on Sydney Street and Centenary Avenue. Several properties are flooded above floor in such flood events and the main road (Sydney Street) is cut-off in the 20% AEP event. The existing levee is overtopped in approximately the 2% AEP event which causes high velocity flow into Centenary Avenue properties. The levee can also cause flooding when it's cross-drainage structures either block overland flow draining to the creek, or allow creek flow into the town area. The majority of the town is not flooded by mainstream flooding and there is evacuation access for most flooded properties. There are two main overland flowpaths in the town that cause flooding of yards and roads. Refer to Figure A 5 for the location of these features.
- **Ladysmith** has minimal flood affectation due to flooding of Kyeamba Creek for events up to and including the 0.5% AEP, with the floodplain generally separate to the urban area. Above floor flooding due to mainstream flooding only occurs for the 0.2% and PMF event. There is no levee in the town. There are 3 overland flowpaths that cause flooding of yards and roads in frequent flood events (20% AEP and greater). Refer to Figure B 5 for the location of these features.
- **Uranquinty** is severely affected by Sandy Creek flooding for floods of 5% AEP and greater, when inundation occurs via overtopping of Deane Street via a breakout of Sandy Creek. To the north, an overland flowpath overtops the Connorton Street levee and floods many properties, with mostly below floor flooding. When local catchment flooding coincides with flooding of Sandy Creek (as it did in recent floods), the two flowpaths generally coincide to cause severe flooding of the southern portion of town and the western portion near Ryan and King Streets. The main levee section, which runs from the south end of Deane Street to Uranquinty Cross Road, is overtopped on several locations in the 0.2% AEP. The levee has a lower section close to Baker Street, where it already overtops in a 10% AEP event. There is generally evacuation access during flood events. Refer to Figure C 5 for the location of these features.

Flood Risk Mitigation Measures

A range of flood risk mitigation measures have been assessed for each town based on assessment of the flood risk, and consultation with Council and the community. The types of measures have been categorised as flood modification, property modification or response modification, in accordance with the NSW Floodplain Development Manual (DIPNR, 2007). Flood modification measures have focussed on upgrading the existing levee systems and their drainage, and various other measures. Where appropriate measures have been modelled using one or multiple design flood events. Property modification options include a Flood Planning Area for each town, and adapting measures recently proposed in the LGA by other FRMS&Ps. Response modification measures include improving the warning system for Tarcutta and Uranquinty, and increased flood awareness. A full list of assessed measures is set out in Section 8 and the recommended measures are summarised below.

*Table 1: Draft Floodplain Risk Management Plan*

| Option and report reference | Description | Responsibility | Priority |
|---|---|---|---|
| Flood Planning Area and Level for each town (PM01) | A designated area in each town where Council planning controls, including minimum floor levels, apply to development. | Wagga Wagga City Council (WWCC) | High |
| Updated information in the Local Environment Plan (PM02) | Revision of the LEP text to improve functionality and separate overland and mainstream flood risk. | WWCC | Medium |
| Adoption of matrix-style Development Control Plan and related DCP changes (PM03) | Revision of the current planning controls to improve their clarity and prescribe specific controls on development based on its type and the flood risk present. | WWCC | Medium |
| Inclusion of Flood Risk Information on Section 10.7 (2) & (5) Planning Certificates (PM04) | Provision of detailed information on a site's flood risk via the existing planning certificates. | WWCC | Medium |
| Update the Wagga Wagga Local Flood Plan section for each town (RM01, RM04, RM06) | Incorporate the consequences of flooding observed in the 2010 and 2012 floods in the Local Flood Plan, as well as flood risk information from the FRMS. | SES | High |
| Update Flood Intelligence Cards for each town (RM02, RM05, RM08) | Updated information will list consequences of flooding in each town in relation to particular creek depths. | SES | High |
| Install an automatic water level recorder on Umbango Creek (RM03) | Improve the warning system for flooding at Tarcutta by including the Umbango Creek catchment, which currently has no gauge. | WWCC in consultation with SES and BOM | High |
| Install a telemetered pluviometer in the Sandy Creek catchment (RM07) | Improve the warning system for flooding at Uranquinty by installing a new rain gauge in the Sandy Creek catchment (currently none exists). | WWCC in consultation with SES and BOM | Medium |
| Requirement for Site Specific Flood Emergency Plans (RM09) | For development in areas of high flood risk, require a site specific plan be prepared that details flood risk and evacuation. | WWCC | Medium |
| Community Flood Education (RM10) | Undertake various activities aimed at raising and maintaining public awareness of flooding. | WWCC | High |

| Option and report reference | Description | Responsibility | Priority |
|---|---|---|---|
| Maintenance for Levee Cross-drainage for Tarcutta (TD01) | Undertake regular maintenance of the cross-drainage structures including clearing vegetation and sediment. SES own and maintain mobile pumps for use during a flood. | WWCC and SES | High |
| Upgrade Existing Tarcutta Levee (TL04) | Upgrade the levee by raising it to protect against the 1% AEP flood. | WWCC | Low |
| Improved drainage on Cunningdroo Street (LK01) | Construct a kerb-gutter system at the end of Cunningdroo St, Ladysmith, to reduce ponding on the road area. | WWCC | Medium |
| Uranquinty Levee System Upgrade (UL01) | Upgrade the levee by raising it to protect against the 1% AEP flood. | WWCC | High |
| Sandy Creek Regular Clearing of Sedimentation (S06) | Regularly remove built-up sediment from the creek bed to prevent blockage of the channel. | WWCC | High |
| Maintenance for Levee Cross-Drainage for Uranquinty (UD01) | Undertake regular maintenance of the cross-drainage structures including clearing vegetation and sediment. SES own and maintain mobile pumps for use during a flood. | WWCC | High |

Public exhibition of the draft study and plan was held from 1 April to 5 May 2021. The exhibition period was aimed at informing residents and other stakeholders of the draft study and plan and inviting feedback, which can then be incorporated into the final report. The following consultation activities were used during the exhibition period:

- Public notices including notification of the information sessions;
- A website with an overview of the study and plan, as well as a link to the draft report and a feedback form, and booking system for the information sessions; and
- Information sessions on 20th and 21st of April, consisting of a group meeting in Uranquinty and a series of one-on-one meetings with interested residents in each town.

A summary of the submissions received during the public exhibition is presented in Appendix D.

Submissions tended to be very specific and focus on current and future concerns of residents that pertained to development and drainage. Particularly residents of both Ladysmith and Uranquinty were concerned about ongoing and future development and how it might impact existing flood liability.

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# 1. INTRODUCTION

The Tarcutta, Ladysmith and Uranquinty Floodplain Risk Management Studies and Plans (FRMS&P) have been prepared for the three towns to investigate and manage flood risk. The studies, which are being undertaken by GRC Hydro on behalf of Wagga Wagga City Council (Council), follow on from the Tarcutta, Ladysmith and Uranquinty Flood Studies (Lyall & Associates on behalf of Wagga Wagga City Council, 2014).

The FRMS&P updates the flood study results considering the recommendations by Australian Rainfall and Runoff 2019 (ARR2019), evaluates flood risks in the three towns, informs Council flood planning processes, and recommends flood risk mitigation measures in the Floodplain Risk Management Plan. The report contains the following sections:

- **Background** – description of the three study areas, overview of relevant policies and legislation and available data.
- **Overview of Flood Behaviour** – methodology and results of Australian Rainfall and Runoff 2019 (ARR2019) model updates.
- **Flood Risk Assessment** – Separate section for each town including flood hazard, hydraulic categories, levee function, flooding hotspots, flood warning and emergency response
- **Flood Risk Mitigation Measures** – description of the approach to flood mitigation and assessment of options in each town.
- **Community consultation** undertaken to date

# 2. BACKGROUND

## 2.1 Study Areas

The three study areas are the townships of Tarcutta, Ladysmith and Uranquinty, and their surrounds. The study areas, which are located in the Wagga Wagga City Council Local Government Area (LGA), are shown in Figures 1-3. Descriptions for each study area are given below.

### 2.1.1 Tarcutta

The township of Tarcutta (study area defined in Figure 1) has an area of approximately 23 $km^2$. Tarcutta has a population of 213 (2016 census) and is located approximately 40 km south-east of Wagga Wagga, on the Hume Highway. The town is located approximately halfway between Sydney and Melbourne, which led to its historical function as a rest stop, and more recently, as a stopping and changeover point for truck drivers. The town consists of a main road (Sydney Street) with several shops, surrounded by a series of residential streets. The town has a police station, an RSL, a post office and a primary school. The town and the wider LGA are located on the traditional lands of the Wiradjuri people. The Murrumbidgee River, downstream of the town, is from the Wiradjuri name ‘Murrumbidjeri’, literally translated as “big water”.

The town is located on the east bank of Tarcutta Creek, which flows generally south to north through the study area. Keajura Creek joins Tarcutta Creek approximately 1 km upstream of the town, while Umbango Creek joins Tarcutta Creek about 30 km upstream of the town. The total catchment area upstream of the town is 1,341 $km^2$, of which 575 $km^2$ is Tarcutta Creek, 588 $km^2$ is Umbango Creek and 178 $km^2$ is Keajura Creek. Within the township, ground level elevations range from approximately 260 m AHD in the south-east to 220 m AHD in the south-west. Tarcutta Creek has a gradient of approximately 0.1% through the study area. The majority of the study area is cleared land, with limited pockets of vegetation along the two creeks, and on some properties.

Tarcutta has been flooded relatively recently, with significant events occurring in October 2010 and March 2012. The October 2010 creek level was approximately 0.5 m higher than March 2012 at the town, and was close to a 2% AEP event. There was significant above-floor flooding of property, and the highway was cut. There is a levee in the town that was overtopped in the 2010 flood and provides limited protection to low-lying areas. Further information is provided in the flood study (Lyall & Associates on behalf of Wagga Wagga City Council, 2014) and in Section 4.6. Other significant rainfall events occurred in March and December 2010, 1974, 1983 and 1992.

### 2.1.2 Ladysmith

The Ladysmith township (study areas defined in Figure 2) has an area of approximately 10 $km^2$. Ladysmith has a population of 208 (2016 census) and is located approximately 17 km south-east of Wagga Wagga, 5 km south of the Sturt Highway. The town has a combined petrol station, post office and general store on the main road (Tumbarumba Road) and a community hall (Ladysmith Memorial Hall). The town has several streets of residential properties, and a primary school on Tywong Street. The town is a stop on the defunct Tumbarumba railway line, which connected Wagga Wagga to Tumbarumba and also included Tarcutta.

The town is located on the east bank of Kyeamba Creek, which flows generally south to north through the study area. Tywong Creek joins Kyeamba Creek immediately upstream of the town, while Obriens Creek joins Kyeamba Creek approximately 4 km south of the town. Kyeamba Creek has a total catchment area of 530 $km^2$ upstream of Ladysmith. The township of Ladysmith ranges in ground elevation from approximately 240 m AHD in the east to 200 m AHD in the west. Kyeamba Creek has a gradient of approximately 0.1% through the study area.

Kyeamba Creek has flooded relatively recently, with the March and October 2010 floods the largest on record near Ladysmith. While there was not significant flooding of the town during these events, many roads were cut and properties outside of the town were inundated. Other floods are recorded as occurring in August 1983, 1939 and 1974.

### 2.1.3 Uranquinty

The Uranquinty study area, defined in Figure 3, has an area of approximately 16 $km^2$. The town has a population of 909 (2016 census) and is located approximately 14 km south-west of Wagga Wagga, on the Olympic Highway. The town has a petrol station, various shops and a primary school. As with Ladysmith and Tarcutta, the town traversed by a main road (Morgan Street/Olympic Highway) with low-density residential streets on either side. There is an area of new residential development towards the north-west end of the town, near Connorton and Guttler Streets. The Main Southern Railway line, which runs from Sydney to Albury, passes through the centre of town, although passenger trains no longer stop in the town.

The town is located on the east bank of Sandy Creek, which flows generally south to north through the study area, joining the Murrumbidgee approximately 10 km north of the town. Coloboralli Creek and its tributaries meet Sandy Creek approximately 4 km upstream of Uranquinty near Oxley Bridge Road. At Uranquinty, Sandy Creek has an upstream catchment area of 128 $km^2$ and a creek gradient of approximately 0.2% through the township. The town area itself is approximately 1.2 $km^2$. Ground level elevations within Uranquinty range from approximately 210 m AHD in the east to 195 m AHD in the west. There are two embankments on the floodplain where the railway and highway cross Sandy Creek, which run generally perpendicular to the flow direction. There is also a levee system that separates the town from Sandy Creek. During a flood, the levee system and the two embankments force all flow beneath the bridges, or in large events, into the town past the levee system.

Uranquinty has been flooded relatively recently, with significant events occurring in October 2010 and March 2012. The 2010 flood was around 0.2 m higher than in 2012, and caused significant flow over Deane Street into the town, whereas the road was only just overtopped in 2012. Other flood events occurred in 1939, March and October 1974, January 1995, and March 2010. Further information on the recent floods is provided in the flood study (Lyall & Associates on behalf of Wagga Wagga City Council, 2014).

*Figure 1: Study Area Tarcutta*

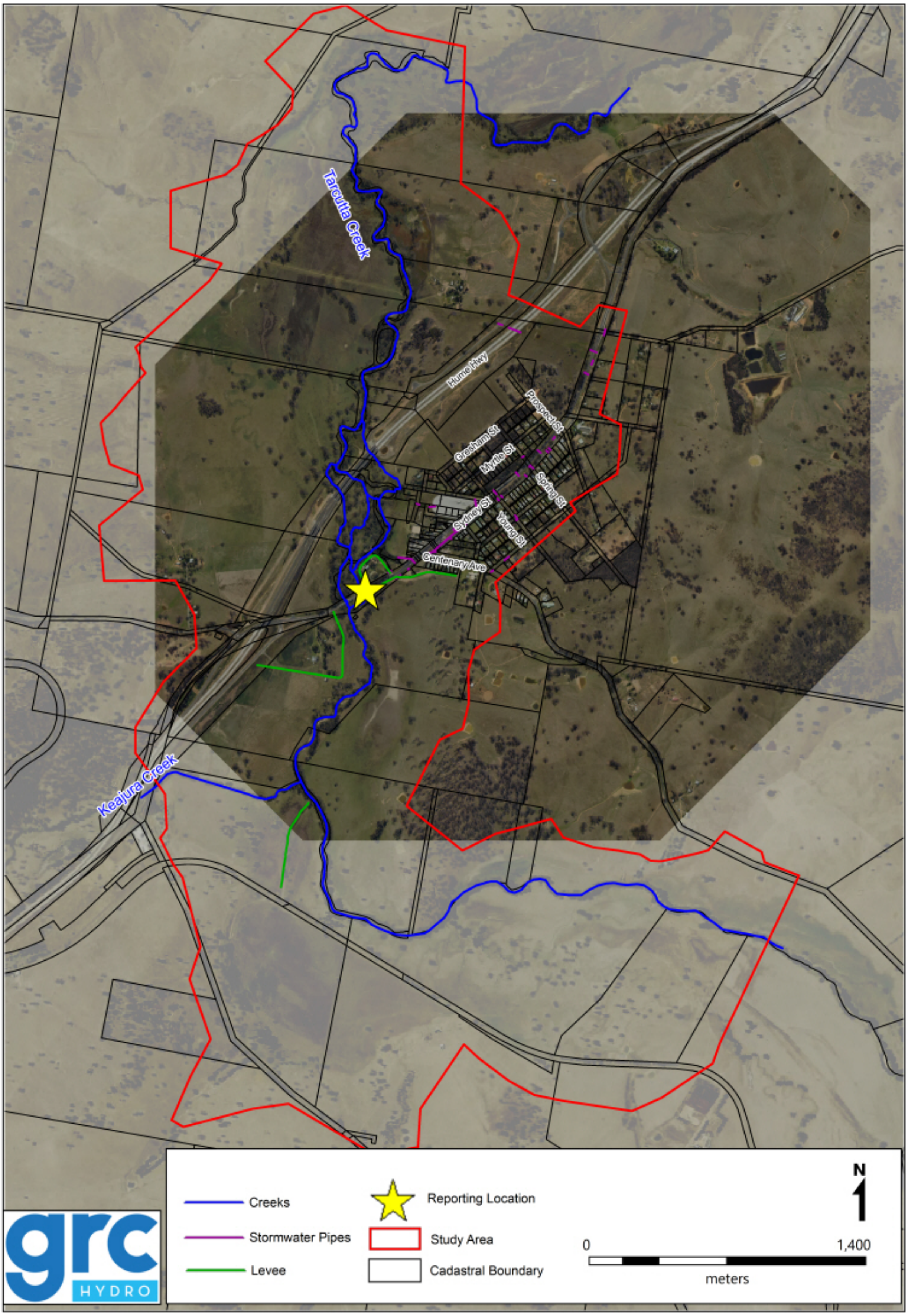


*Figure 2: Study Area Ladysmith*

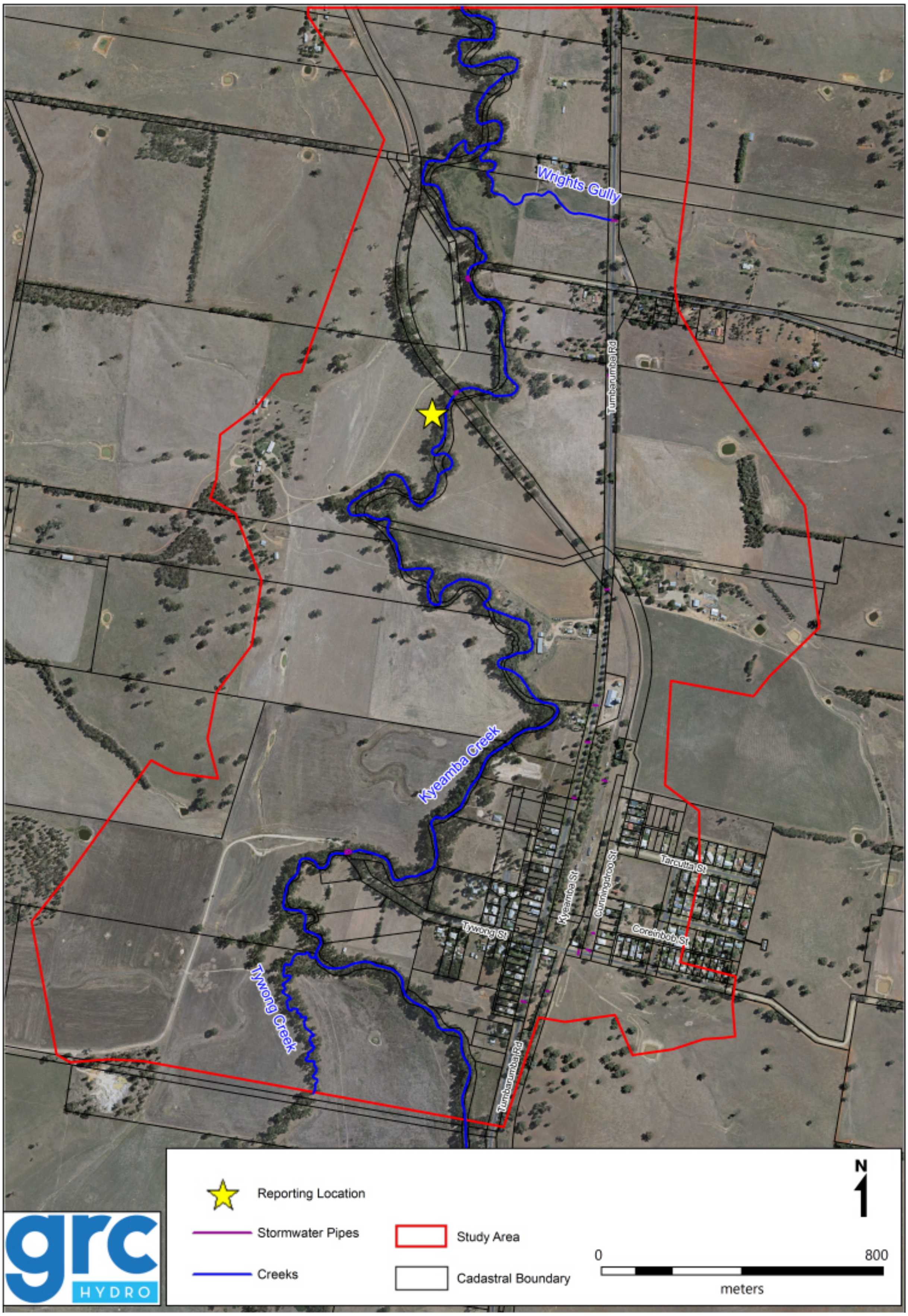


*Figure 3: Study Area Uranquinty*

## 2.2 Flood Mechanisms

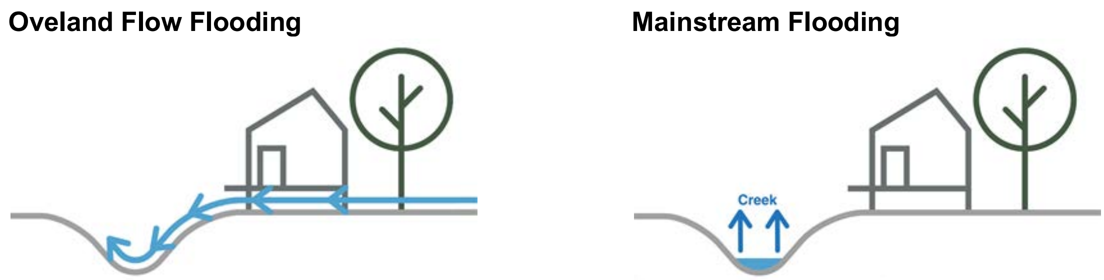
The current study assesses two key flood mechanisms that can occur in each of these three townships; overland flow flooding and mainstream flooding. Typically, these two mechanisms occur independently however they can occur simultaneously.

Overland flow flooding occurs when rainfall in the vicinity of the towns causes flooding as water flows toward the creeks. This type of flooding is often referred to as “flash flooding” due to short warning times. Typically, this type of flooding rises and recedes over a short period of time and the floodwaters are usually relatively shallow and fast moving. In Tarcutta and Ladysmith, there are two main overland flowpaths, while in Uranquinty they originate to the west and north-west of the town. Image 1 (left hand side) depicts this mechanism.

Mainstream flooding occurs from rising water on a defined watercourse causing the watercourse to break its banks, spread over the floodplain and inundate areas that are usually dry. Watercourses such as Tarcutta Creek, Kyeamba Creek and Sandy Creek can cause flooding in Tarcutta, Ladysmith and Uranquinty respectively. This mechanism typically occurs over a long period of time and typically results in deep, slow moving floodwaters. Image 1 (right hand side) depicts this mechanism.

More information on overland flow and mainstream flooding for each town is described in their respective flood risk report sections (Sections 4, 5 and 6)

*Image 1: Flood Mechanisms affecting Tarcutta, Ladysmith and Uranquinty*




## 2.3 Policies, Legislation and Plans

The study makes use of several policies, legislation and guidance relevant to management of flood risk in the Wagga Wagga LGA. These are summarised below.

### 2.3.1 Wagga Wagga Local Environmental Plan 2010

The LEP contains standard provisions in Clause 7.2 for flood planning in the LGA. The objectives of the clause are to:

a) minimise flood risk to life and property,
b) allow development that is compatible with a site’s flood hazard, including the risks associated with climate change; and
c) to avoid adverse impacts on flood behaviour and the environment.

The clause applies to land in the “Flood Planning Area” on the Flood Planning Map, or other land at or below the flood planning level. The Flood Planning Map was not published in 2010 with the rest of the LEP and does not exist (publicly, at least) at the time of the current report. Unlike some other LEPs in NSW, the clause explicitly defines the FPL as “a 1:100 ARI (average recurrent interval) flood event plus 0.5 m freeboard”.

### 2.3.2 Wagga Wagga Development Control Plan 2010

The Development Control Plan (DCP) contains provisions for development in flood prone land in the LGA. Specifically, Section 4.2 of the DCP describes the objectives as to:

a) minimise the public and private costs of flood damage,
b) minimise the risk of [sic] life during floods by encouraging construction and development that is “flood proofed” and compatible with the flood risk of the area,
c) ensure development is compatible with the flood hazard; and
d) require compatibility with the Floodplain Development Manual (NSW, 2005) as relevant.

Specific flood controls in the section include:

- Essential community services (defined as emergency services facilities, health services and facilities involved in flood warning and evacuation) are to be located outside of the PMF extent, in the flood precincts defined by the 2009 Wagga Wagga Floodplain Risk Management Study.
- Similarly, critical utilities (defined as childcare and other education facilities, seniors living and certain critical infrastructure) are to be located outside of the PMF, based on the same flood precincts.
- Specific controls for development within the various flood risk precincts in the vicinity of Wagga Wagga, are defined by the Wagga Wagga Floodplain Risk Management Study. Controls are set for various types of development, including critical utilities, low impact commercial, industrial and high impact commercial, recreation and agriculture, and residential development.

The section does not contain particular controls or restrictions on development in Ladysmith, Tarcutta or Uranquinty, although the objectives of the section state it applies to land that is identified as flood prone.

Section 6 of the DCP contains descriptions of each of the towns in the LGA (referred to as villages in the section) including brief reference to the towns’ flood affectation. Section 6.2 gives three objectives for development of the towns, which do not specifically relate to flood risk. There is also a ‘village plan’ for each town consisting of an annotated map. The features of note on each map are:

- The Ladysmith map shows a potential subdivision area on the north-east corner of the town, north of the houses at the east end of Tarcutta Street.
- For Tarcutta, it’s noted that the eastern side of the town is suited to smaller lots, provided stormwater can be managed without constructing formal kerb and guttering, while the western side (closer to the creek) is ‘not suitable for close settlement due to topography, servicing constraints and existing vegetation’. A second map for Tarcutta recommends landscaped swales along a widened verge on Centenary Avenue.
- For Uranquinty, an area centred on Ben Street, near the creek, is noted as not suitable for small lots/closer settlement, and to avoid further kerb and gutter. An area to the north-east, at the north end of Gutler Street, has the note ‘continue urban extension of village in this area only’.

### 2.3.3 Wagga Wagga Spatial Plan 2013/2043

The Spatial Plan sets out strategic directions for the development of Wagga Wagga LGA in response to forecast population growth of around 24% by 2031. The strategy is based on desktop investigation into various constraints, including flooding. The document states that it does not seek to rezone land that is flood prone land. The plan describes the area's natural hazards, including flooding, and notes flooding as a significant constraint to development in the City of Wagga Wagga (the section does not reference the various towns in the LGA or the recently completed flood studies). The document does contain three 'actions' in regard to flood risk:

- "Council to work with State Government in progressing legislation to address overland flow flooding" (medium term).
- "Review impact of overland flow flooding on development" (ongoing).
- "Review development control plan controls to ensure adequate controls are in place for flood prone land in line with hazard categories identified in the flood study" (short term). [unclear which flood study is being referred to].

The document contains a map of Ladysmith with an area to the north-west of the town identified as potential urban land – the map is reproduced below in Figure 4. The land is between Tumbarumba Road and Kyeamba Creek, to the north-west of the town centre. The area is located partly within the Flood Planning Area determined by this study (see Section 7).

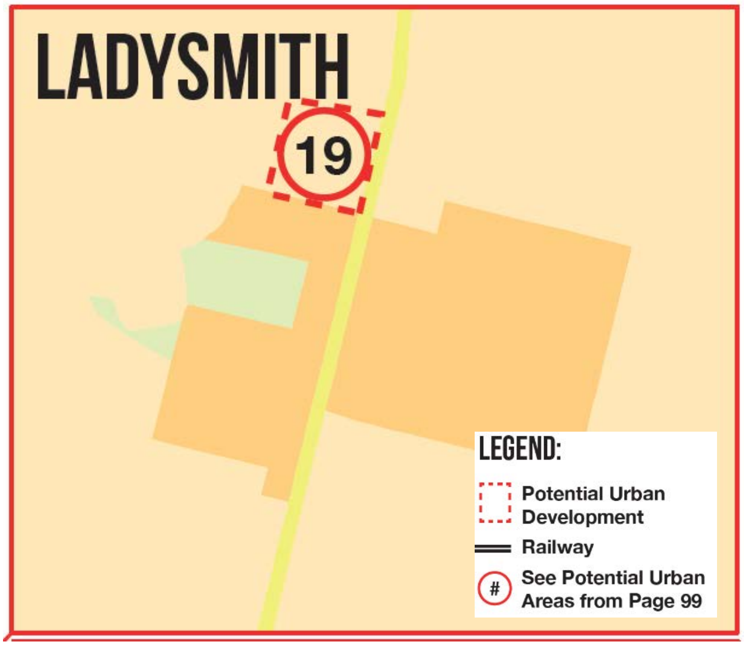



*Figure 4: Excerpt of Wagga Wagga Spatial Plan 2013/2043*

### 2.3.4 Wagga Wagga Local Flood Plan

This emergency response plan contains flood intelligence and response procedures and responsibilities for the Wagga Wagga LGA. The plan, which is a sub-plan of the Wagga Wagga Local Disaster Plan and published in January 2006, has specific sections for Tarcutta, Ladysmith and Uranquinty. The plan sets out 30 different entities that have specific responsibility for emergency response, beginning with the Wagga Wagga SES Local Flood Controller. Information specific to each towns consists of:

- **Tarcutta** has a levee that protects it up to a level of 3.7 m at the Tarcutta Gauge, and the levee has no freeboard. Overtopping of the levee will inundate approximately 10 properties, and require evacuation of about 40 people. There is no formal warning system, and flooding of the highway may strand motorists travelling between Sydney and Melbourne (it should be noted that this may have changed since the bypass construction).

Annex I states that evacuations will be required if the Tarcutta gauge level is anticipated to reach 3.7 m, and Tarcutta RSL and Citizens Club can be used for evacuation

- **Ladysmith** has low-lying areas that are flooded relatively often, and require movement of equipment and livestock. Major floods affect the western ends of Tywong Road and Keajura Street and up to eight houses may require evacuation. Annex K states the evacuation trigger will be based on reconnaissance and evaluation during a flood, and that Ladysmith Memorial Hall can be used for evacuation.
- **Uranquinty** has a levee that protects its south side from flooding from Sandy Creek, which was designed for the 1% AEP flood (although the flood intelligence reports (Bewsher Consulting, 2012; Dr. Stephen Yeo, 2013) state Council indicated that it was actually 2% AEP). There are three residences frequently flooded south of the levee, and overtopping of the levee would require evacuation of at least 60 residences. Flooding can occur inside the levee due to overland flooding, and flooding can cause closure of the Olympic Highway through the town. Annex J states the evacuation trigger will be based on reconnaissance and evaluation during a flood, and that Uranquinty Public School can be used for evacuation.

### 2.3.5 Wagga Wagga Revised Murrumbidgee River Floodplain Risk Management Plan

The plan covers the city of Wagga Wagga and contains recommended measures relevant to the current study, following its adoption by Council in 2018. Specifically, the Floodplain Risk Management Plan includes:

- Update the recently completed Vegetation Management Plan to consider new state biodiversity legislation instruments, then draft Standard Operation Procedures for selected recommended activities. (Priority: High)
- Flood Emergency Management Planning, specifically to review and update current Council and SES emergency flood response documents, drawing from latest modelling and recent floods. (Priority: High)
- Move Flood Planning Area mapping into the Wagga Wagga DCP, whilst retaining the definition of the Flood Planning Area and Flood Planning Level in the LEP. (Priority: High)
- Reformat DCP to Matrix style document The Development Control Plan (DCP) is currently a long, wordy and cumbersome document. Reverting to a matrix style format will make it easier for Council and the public to apply and understand. (Priority: High)
- Add clause to LEP to control critical facilities and vulnerable land uses between the FPA and PMF extent. (Priority: High)
- Flood Risk Info on the Section 10.7 Planning Certificates (formerly known as Section 10.7) (Priority: High)

These measures, while prepared for the Murrumbidgee River floodplain of the LGA, are closely integrated with Council policies and plans, and therefore have implications for other towns in the LGA. They have been considered during assessment of flood risk management measures in this report and through discussion with Council.

### 2.3.6 State and National Plans and Policies

Management of flood risk in the three towns is also guided by various state-wide and national policies related to floodplain management in Australia. These have been listed below, including their relevance to the current study:

- Australian Rainfall and Runoff 2019 – sets out hydrological data and procedures to be used for hydrological and hydraulic modelling of flooding in Australia.

- Building Code of Australia - provides a standard for the design and construction of new buildings in Flood Hazard Areas (FHA) with the aim of reducing risk to building occupants.
- NSW Environmental Planning and Assessment Act 1979 – Is the overarching state legislation for local legislation. The Act provides the framework for regulating and protecting the environment and controlling development. Pursuant to Section 9.1 of the EP&A Act, councils have the responsibility to facilitate the implementation of the NSW Government's Flood Prone Land Policy. It specifies how councils' LEPs manage flooding.
- NSW Local Government Act 1993, Section 733 – this section of the Act describes the exemptions that NSW councils have from liability relating to flood liable land. It states that councils do not incur any liability regarding advice they give in good faith, regarding the likelihood, nature or extent of flooding.
- NSW Flood Prone Land Policy - aims to reduce the impact of flooding and flood liability on individual landowners and occupiers of flood prone property and to reduce private and public losses resulting from floods via economically positive methods where possible. The NSW Floodplain Development Manual supports the policy.
- NSW Government's Floodplain Development Manual (2005) – Defines the assessment of flood risk in NSW, including flood hazard, hydraulic categories and other variables. More broadly it sets out the objectives for floodplain development in the state, including description of types of mitigation measure.
- State Environmental Planning Policy (Exempt and Complying Development Codes) (2008) - are environmental planning tools used to address planning issues within NSW. In a flooding context, the SEPP for Exempt and Complying Development Codes 2008 is key for defining:
    - Exempt developments, where development can occur without the need for development consent; and
    - Complying development, where development must be carried out in accordance with a complying development certificate.

  The policy describes where and development of flood-prone land should occur.
- NSW DPIE guidelines relating to flooding. Various guidelines have been published by DPIE for specific aspects of flood risk assessment in NSW. Some specifically related to the study are:
    - Floodway Definition (2007)
    - Practical Consideration of Climate Change (2007)
    - Incorporating 2016 Australian Rainfall and Runoff in studies (2019)
    - Residential Flood Damages (2007)
    - Drainage Behind and Through Levees (2007)
    - SES Requirements from the FRM Process (2007)

## 2.4 Available Data

### 2.4.1 Previous Studies

A number of studies related to flooding in Tarcutta, Ladysmith and Uranquinty have been undertaken. The most relevant to the current study are the Tarcutta, Ladysmith and Uranquinty Flood Studies, prepared by Lyall & Associates on behalf of Council, with the final report published March 2014. There are limited other studies – two studies examined flooding at Tarcutta as part of the highway bypass works, and a 1987 report on the Murrumbidgee River included flooding at Uranquinty. The following sections summarise the previous studies.

#### 2.4.1.1 *Tarcutta, Ladysmith and Uranquinty Flood Studies (Lyall & Associates, 2014)*

The study was undertaken by Lyall & Associates, on behalf of Council, as part of Council's Floodplain Risk Management Program for the LGA. As per the NSW Floodplain Development Manual, the flood study covers the first and second stages in the program and prepares Council and the community for the current study, which covers the third and fourth stages of the program. The key outputs of the flood study were:

- description of the flood behaviour and its effects experienced during the floods in 2010 and 2012.
- design flood information for a range of flood events, including basic information (peak flood depth, level and velocity) and processed outputs (provisional hydraulic hazard and hydraulic classification).
- a set of calibrated hydrologic and hydraulic models that cover overland and mainstream flooding across the three towns. These models, which used the RAFTS and DRAINS software for the hydrologic assessment, and TUFLOW for the hydraulic model, were updated as part of the current study (see Section 3.1).
- establishment of consultation channels with the community and other stakeholders, that have raised awareness of the nature and location of flooding in the LGA, and of the flood study's function and relation to the current study.

Table 2 summarises the approach and results of the flood study.

*Table 2: Summary of 2014 Flood Study*

| Feature | Description | Relevance to FRMS (current study) |
|---|---|---|
| ***Data collection*** | The following data was collected for the study:<br>• LiDAR data surveyed in 2009 by surveying firm Fugro<br>• Council GIS data including aerial photos, LEP layers, cadastral and road data.<br>• Pit and pipe, culvert and bridge crossing, creek cross-sections and floor level data provided by Council and survey during the study.<br>• Bureau of Meteorology design rainfall data, and rainfall data from 5 pluviometers and 12 daily read stations.<br>• Previous studies (2 in Tarcutta, 1 in Uranquinty)<br>• Questionnaire responses and newspaper description of historical floods, as well as the post-event data collection report for the 2010/12 floods. | The LiDAR, design rainfall, stormwater assets and aerial photos from the flood study have been used in the current study, see Section 2.4.2. |
| ***Hydrologic Model*** | A RAFTS model was established for each town's upstream catchment, while each also had a DRAINS model for overland flow in the urban area. Both RAFTS and DRAINS were run from within the DRAINS software, which allows simulation of RAFTS model type. Hydrological schematisation, including losses and Areal Reduction Factors, were based on ARR1987. The hydrograph generated at the downstream of each RAFTS model was applied to the upstream boundary of each hydraulic model.<br>There was also a flood frequency analysis of the Old Borambola gauge downstream of Tarcutta, but it did not closely fit historical events and was not used in subsequent design event analysis. | Hydrologic models were adopted for use in the current study and updated for ARR2019 (see Section 3.1). |
| ***Hydraulic Model*** | A 1D-2D TUFLOW model was established for each town. The main creek channels were schematised in 1D and the sub- | The overall hydraulic modelling approach |

| Feature | Description | Relevance to FRMS (current study) |
|---|---|---|
| | surface stormwater network was included as a 1D model embedded in the model grid. Fenced properties were represented with high hydraulic roughness (0.1), while buildings themselves had very high roughness (10). Cross-drainage pipes in the Tarcutta and Uranquinty levees were modelled as 1D elements with a one-way flow restriction, to represent the flap gates. The models did not adopt a particular creek level for the overland flow events, rather a variety of storm durations were applied to the whole catchment and then the peak flood level enveloped.<br>The models were calibrated using data from the October 2010 and March 2012 flood events. | was adopted for use in the current study. Areas of update are described in Section 4. |
| ***Design Flood Information*** | The following results were produced by the study:<br>• Peak flood level, depth and flow for 20%, 10%, 5% 2%, 1%, 0.5% and 0.2% AEP [1], and PMF<br>• Provisional hydraulic hazard and hydraulic classification for the 1% AEP<br>• Sensitivity of 1% AEP flood to climate change scenarios - rainfall increase of 10% and 30%<br>• Interim Flood Planning Area for each town, for mainstream flooding<br>• Sensitivity of Tarcutta and Uranquinty to levee failure in the 1% AEP (the Uranquinty levee has a 2% AEP design height). | The current study updates the modelling approach and produce new design flood information, which will supersede that produced by the flood study. The study also produces final hydraulic hazard and hydraulic classification. |
| ***Community Consultation*** | The study involved distribution of a newsletter and questionnaire to residents and business owners in each of the towns (exact number not specified). There were also a series of information sessions during the exhibition phase in March 2015. | The current study continues the consultation. See Section 9 for more detail. |

#### *2.4.1.2 Flood Investigations for Hume Highway Bypass of Tarcutta*

Two flood investigations were undertaken as part of design of the Hume Highway bypass of Tarcutta. Parsons Brinkerhoff completed a flood study as part of the Environmental Assessment for Hume Highway Bypass of Tarcutta (2009) that used a WBNM hydrologic and a 10 m TUFLOW hydraulic model. The models were calibrated to four events that occurred prior to the large floods of 2010 and 2012. Then in 2010 the Tarcutta Hume Alliance carried out further assessment of the flood behaviour in the vicinity of the highway bypass.

#### *2.4.1.3 NSW Inland Rivers Floodplain Management Studies – Murrumbidgee Valley*

This study was undertaken by Sinclair Knight and Partners in 1987 and included description of the flood behaviour in Uranquinty and recommended measures. The study recommended conveyance improvements to the creek sections, and a levee scheme for the town. The study was followed by Council's construction of the town's levee, which was designed to protect against a 50 year ARI flood.

[1] The flood study used ARI terminology. The events listed have been converted to AEP.

## 2.4.2 Model Build Data

### *2.4.2.1 LiDAR Data*

LiDAR data used for the study is unchanged from that used in the flood study. Metadata indicates the data sets were collected with LiDAR scanning from plane flyovers of the towns. Details of the data set are given below:

- The data was captured by Fugro Spatial Solutions in March 2009 and titled 'J221527 NSW DECC Central Wetlands LiDAR'.
- The data has vertical accuracy of ± 0.06 m (1$^{st}$ confidence interval) and horizontal accuracy of 0.13 m (1$^{st}$ confidence interval).
- The raw data consists of a series of point elevations, which were filtered for non-ground strikes and then used to produce a Triangular Irregular Network (TIN), from which a gridded Digital Elevation Model (DEM) is sampled.
- It was reported that the LiDAR for Tarcutta was re-processed during the flood study, due to the remoteness of the calibration ground control points, which reportedly rectified the original issue.

### *2.4.2.2 Design Rainfall*

Design rainfall data is used to model design flood events and has been collected for the current study from 2016 Intensity-Frequency-Duration (IFD) data. IFD data describes rainfall depths (mm) for the full array of design flood events over a range of durations (1 minute to 168 hours), for any location in Australia. The data is provided online on the Bureau of Meteorology (BOM) website. This data can be obtained in various formats. Both spatially varying and point rainfall data has been utilised in the current study for mainstream and overland flooding respectively.

2016 IFD design rainfall depths for each design event for various durations were obtained from the BOM website and are presented in Table 3, for the 1% and 5% AEP for Ladysmith (Uranquinty and Tarcutta show similar trends). The table also presents the equivalent rainfall depths from ARR1987 for comparison against the 2016 IFD rainfall depths.

*Table 3: 2016 IFD rainfall depths compared against ARR1987 depths for Ladysmith*

| | 5% AEP, total rainfall depth (mm) | | 1% AEP, total rainfall depth (mm) | |
|---|---|---|---|---|
| **Duration** | **IFD 2016** | **ARR1987** | **IFD 2016** | **ARR1987** |
| **1 hour** | 39 | 37 | 52 | 51 |
| **1.5 hour** | 44 | 42 | 59 | 57 |
| **2 hour** | 47 | 46 | 63 | 62 |
| **3 hour** | 52 | 51 | 69 | 68 |
| **4.5 hour** | 58 | 57 | 76 | 75 |
| **6 hour** | 62 | 62 | 82 | 81 |
| **9 hour** | 69 | 69 | 90 | 89 |
| **12 hour** | 74 | 74 | 97 | 96 |
| **18 hour** | 82 | 83 | 108 | 107 |
| **24 hour** | 88 | 89 | 116 | 115 |
| **36 hour** | 98 | 98 | 128 | 127 |

As shown in the table, the 2016 IFD design rainfall depths are quite similar to ARR1987, across all durations. For the durations of 9 to 24 hours (critical storm duration range), the total rainfall depths are very slightly smaller for the 5% AEP and slightly larger for the 1% AEP.

#### 2.4.2.3 Floor Level Survey

Floor level survey is used to estimate buildings' level of exposure to the range of design flood events. Survey typically describes properties' lowest habitable floor level, which is then compared to a flood level adjacent to the building, giving an estimate of the depth of flooding in each design event. For a flood study or FRMS, floor level survey is collected for a subset of properties that are estimated to be affected by flooding. Properties outside this subset are either not affected, or only affected in a very rare floods (e.g. >1% AEP), so an estimate of the floor level is made, based on the LiDAR or other ground survey.

The flood study included survey of 70 properties' floor levels across the three towns, with six in Ladysmith, 14 in Tarcutta and 50 in Uranquinty. Additional survey was undertaken by the current study for all properties within the 0.5% AEP flood extent, to complement the existing floor level survey. This process was undertaken by estimating the height between the ground level and the lowest habitable floor level, using Google Street View and LiDAR. The ground level for each property was determined using LiDAR data. The floor level was determined by adding the LiDAR ground level to the estimated height from ground to floor level. A site visit was undertaken to verify existing floor level estimates and obtain ground to floor estimates for properties that were unable to be seen from Google StreetView.

#### 2.4.2.4 Stormwater Network

The stormwater network data collected by the flood study is also utilised for the current study. The data, which consists of the pit/pipe network and culvert crossings, is contained within the hydraulic model layers of the stormwater network and is shown on Figures 1-3. No updates have been made to the data used in the flood study.

#### 2.4.2.5 Council GIS Data

The latest Council GIS (geographical information system) data was provided at the commencement of this study. The dataset covers a range of GIS information including aerial imagery of each town, cadastre for the wider LGA and survey of bridges, culverts and floor levels undertaken as part of the flood study.

# 3. OVERVIEW OF FLOOD BEHAVIOUR

This section of the report describes the modelling approach used and presents the design flood depths and levels, which have been updated from the Flood Study. The hydrologic and hydraulic models were updated to apply the latest Australian Rainfall and Runoff methodology ('ARR2019') which produced a new estimate of the 1% AEP event and other design floods. The updated methodology is presented in Section 3.1 and the updated results are presented in Section 3.2. Sections 4, 5 and 6 then presents a flood risk assessment for each town, including processed outputs (flood hazard, hydraulic categories), economic impact of flooding, function of the levees, emergency response and description of flooding hotspots.

## 3.1 Model Review and Update

The flood study (Lyall & Associates on behalf of Wagga Wagga City Council, 2014) established a series of hydrologic and hydraulic models, using DRAINS, RAFTS and TUFLOW software. The models were calibrated to historical flood events in 2010 and 2012, and used to produce design flood behaviour for each of the study areas. The hydraulic models included all relevant features, including levee structures, channel bathymetry, buildings and stormwater pipes, and included both overland and mainstream flooding. More information on the models is given in Table 2 in Section 2.4.1.1.

Following data collection, the hydraulic and hydrologic models have been reviewed and updated to reflect the best available data and methodology. The models were found to suitably represent the current state of each catchment and study area, however required update to the latest Australian Rainfall and Runoff (ARR2019) rainfall data and modelling approach, and minor changes to the hydraulic roughness and gutter representation (see Section 3.1.5). The update was made for each of the three towns and the results were compared to the flood study results. The updated methodology is presented in Section 3.1.1 and an overview of the results in Section 3.2 for the range of design flood events. The 1% AEP is the event primarily used for planning purposes and is of primary interest to Council.

It is important to note that the methodology for determining the Probable Maximum Flood (PMF) has not changed with the release of ARR2019. As such, the PMF estimate derived in the Flood Study has been adopted in the current study.

### 3.1.1 ARR2019 Methodology

The hydrologic and hydraulic models were updated to the methodology prescribed by ARR2019. ARR2019 is based on a series of research projects that aims to provide more accurate techniques for analysis of flood behaviour across Australia. Alongside the updated methods of analysis, it uses a dataset of rainfall and streamflow gauge data that is significantly expanded, spatially and temporally, from ARR1987. A summary of the main changes in the ARR2019 methodology, when compared to ARR1987, are as follows:

- Design rainfall data (i.e. intensity-frequency-duration data) across Australia has been updated due to the availability of three more decades of data;
- Where previously a single temporal pattern was used for a particular design event and duration, now an ensemble of 10 temporal patterns is modelled per storm duration;
- Use of the pre-burst rainfall incorporated prior to the design storm burst;
- Update to the Initial and Continuing Loss values which better reflect local conditions; and
- Update to the calculation of the Aerial Reduction Factor (ARF) based on Australian conditions.

As discussed in Section 2.2, the three study areas are each affected by two flood mechanisms; mainstream flooding and overland flow flooding. Each of these mechanisms require a different ARR2019 methodology and as such, they have been discussed separately in the following sections; Section 3.1.2 Mainstream Flooding and Section 3.1.3 Overland Flow Flooding.

## 3.1.2 Mainstream Flood Estimation

### *3.1.2.1 Design Rainfall*

Spatially varying design rainfall data (see Section 2.4.2.2) was applied to each sub-catchment centroid within the mainstream hydrologic models to account for any rainfall gradients across the catchments. This data is provided online, in ASCII format, on the BOM website.

### *3.1.2.2 Areal Reduction Factor*

Design rainfall (see Section 3.1.2.1), provided from the BOM, relates to rainfall at a specific point within a catchment rather than rainfall for across an entire catchment area. Typically, rainfall at a point is not characteristic of rainfall average rainfall intensity across the catchment and as such, an Areal Reduction Factor (ARF) is applied to the catchment rainfall to account for this discrepancy. The ARR Data Hub placed the study area within the “Southern Temperate” ARF region and the ARF for the catchments were based on these calculations. The ARF applied varied between 0.83 and 0.87 for Tarcutta, 0.84 and 0.88 for Ladysmith and 0.90 and 0.93 for Uranquinty.

For comparison with the Flood Study, the ARF was derived based on the catchment area to each study areas respective reporting location; Tarcutta Creek and Old Borambola Stream Gauge, Kyeamba Creek and Ladysmith Stream Gauge and Sandy Creek adjacent to Uranquinty township.

For application in the TUFLOW hydraulic model the ARF was derived based on the upstream inflow location.

### *3.1.2.3 Rainfall Losses*

Rainfall losses for design events were modified from those recommended by ARR2019. The ARR2019 losses, which consist of an initial loss (mm) and a continuing loss (mm/hour), are available via the ARR ‘datahub’ website. A sample of these losses, for durations of interest in Tarcutta for the 1% AEP, is shown in Table 4. The table also includes the rainfall losses used in the flood study for the mainstream flood estimate.

*Table 4: ARR2019 recommended Rainfall losses, 1% AEP, Tarcutta (mainstream only)*

| | Initial Loss (mm) | | Continuing Loss (mm/hour) | |
|---|---|---|---|---|
| **Duration** | **ARR2019** | **Flood Study** | **ARR2019** | **Flood Study** |
| **12 hour** | 19.1 | 15 | 4.9 | 2.5 |
| **18 hour** | 21 | 15 | 4.9 | 2.5 |
| **24 hour** | 25.8 | 15 | 4.9 | 2.5 |
| **36 hour** | 27.8 | 15 | 4.9 | 2.5 |

The significantly higher losses recommended by ARR2019 were found to greatly reduce the peak flow estimates for each town in the 1% AEP. For example, the 1% AEP flow for Tarcutta was reduced from 1,035 $m^3$/s (flood study result) to 639 $m^3$/s. While this reduction was also influenced by factors such as the IFD data and the revised temporal patterns, subsequent model testing found that the results were sensitive to the reduction in losses. The Department of Industry, Planning and Environment (DPIE, formerly OEH) subsequently recommended application of their guidelines for use of ARR2019 in NSW[2]. These guidelines recommend use of "*the average calibration losses from the actual study on the catchment if available*" as the preferred approach along with a calculated initial loss burst based on Equation 1 (shown below).

**Equation 1**

$$IL_{B\ for\ design} = IL_{S\ calibrated\ or\ transformed} \times \left(\frac{IL_{Bdatahub}}{IL_{Sdatahub}}\right)$$

The Flood Study calibrated an initial loss of 15 mm and continuing loss of 2.5 mm/hr for the 1% AEP event, for each catchment. As such, the calibrated losses adopted in the Flood Study were input into the hydrological model (less the initial loss burst) and the ARR2019 methodology was applied. Adopted losses are outlined in Table 5 (below)

*Table 5: 1% AEP event adopted losses for durations of interest (mainstream flooding)*

| Catchment | Loss | 1% AEP Losses | | | |
|---|---|---|---|---|---|
| | | 12 hour | 18 hour | 24 hour | 36 hour |
| **Tarcutta** | Initial loss (less preburst) (mm) | 10.23 | 11.25 | 13.82 | 14.89 |
| | Continuing loss (mm/hour) | 2.5 | | | |
| **Ladysmith** | Initial loss (less preburst) (mm) | 10.34 | 12.00 | 14.26 | 15 |
| | Continuing loss (mm/hour) | 2.5 | | | |
| **Uranquinty** | Initial loss (less preburst) (mm) | 12.17 | 12.98 | 14.37 | 15 |
| | Continuing loss (mm/hour) | 2.5 | | | |

The adopted losses were agreed with Council and DPIE in February 2019.

### *3.1.2.4 Temporal Patterns*

Temporal patterns were updated to those recommended by ARR2019, also available via the 'datahub' website. ARR2019 requires use of ten temporal patterns for each combination of AEP and duration. The temporal patterns for the three towns fall within the 'Murray Basin' geographic area.

ARR2019 recommends that catchments greater than 75 km$^2$ in area use areal temporal patterns, and smaller catchments use point temporal patterns. The mainstream catchments of interest are 1,341 km$^2$ (Tarcutta), 530 km$^2$ (Ladysmith) and 128 km$^2$ (Uranquinty). However, areal temporal patterns are only available for durations of 12 hours or longer. For reference, the flood study estimated Tarcutta to have a critical duration of 18 hours, Ladysmith 6 hours and Uranquinty 6 hours. Both areal and point temporal patterns were investigated for their resulting design discharges and it was concluded areal temporal patterns should be used for all three towns.

Initial investigations found that the application of point temporal patterns for Uranquinty would produce the greatest 1% AEP estimate however in the context of the design events (undertaken using both point and areal temporal patterns) it was found that the areal temporal patterns would produce a more appropriate estimate. For reference, the peak 1% AEP flow derived for the critical 6 hour event using point temporal patterns was 190 m$^3$/s compared to the critical 1% AEP 12 hour flow of 184 m$^3$/s using areal temporal patterns. Since the difference between these flows is minimal and both estimates exceed the 1% AEP estimate derived in the Flood Study using ARR1987, it was determined that the application areal temporal patterns for the 1% AEP 12 hour event would produce the best estimate.

[2] NSW OEH Floodplain Risk Management Guide – Incorporating 2016 Australian Rainfall and Runoff in studies 01/2019

#### 3.1.2.5 *Critical Duration Assessment*

The ensemble of temporal patterns was modelled in the hydrologic model. The methodology for determining the critical duration for mainstream flooding was as follows:

1. The spatially varying design rainfall, losses and temporal patterns were applied to the RAFTS/DRAINS hydrologic model for each catchment, for a range of 1% AEP design storm events. The following durations were used:
   a. 12, 18, 24 and 36 hours for Tarcutta,
   b. 12, 18 and 24 hours for Ladysmith; and
   c. 12, 18 and 24 hours for Uranquinty.
2. For each duration, 10 temporal patterns were used. This resulted in 40 design storms for Tarcutta, 30 for Ladysmith and 30 for Uranquinty.
3. From the model results, the peak flow for each town[3] was extracted and for each duration, the mean flow was determined. Each duration's mean flow was then compared and the duration with the highest mean flow is determined as the critical duration.
4. As advised in ARR2019, for the critical duration, the design storm with a peak flow above the mean is selected to be run in the hydraulic model (TUFLOW). The results from the hydrologic model for this event were applied to the hydraulic model as inflows, and the model produced the peak depth, level and velocity across the study area.
5. For non-1% AEP design events (20%, 10%, 5%, 2% and 0.5% AEP) the same approach is used, with each having a designated design storm based on the hydrological model results that is used to simulate flood behaviour in the hydraulic model.

The results of the first 3 steps of the above methodology are presented in Charts 1 to 3 below. The charts, which represent the peak flows for the ensemble of ten temporal patterns as a blue cross per storm duration, the mean flow as a blue square and the flood study results as a green circle. These results show that the critical duration is 18 hours (1080 min) for Tarcutta, 12 hours (720 min) for Ladysmith and 12 hours (720 min) for Uranquinty. The longer durations have some storms that produce higher individual peak flows than the critical duration, but the average of these durations' flows is lower.

[3] The reporting locations were: Tarcutta Creek at the old highway (now Sydney Street) depth gauge, Kyeamba Creek and Ladysmith Stream Gauge and Sandy Creek adjacent to Uranquinty township. Their location is shown as a yellow star on Figure 1 to Figure 3.

*Chart 1: Tarcutta 1% AEP Peak Flows*

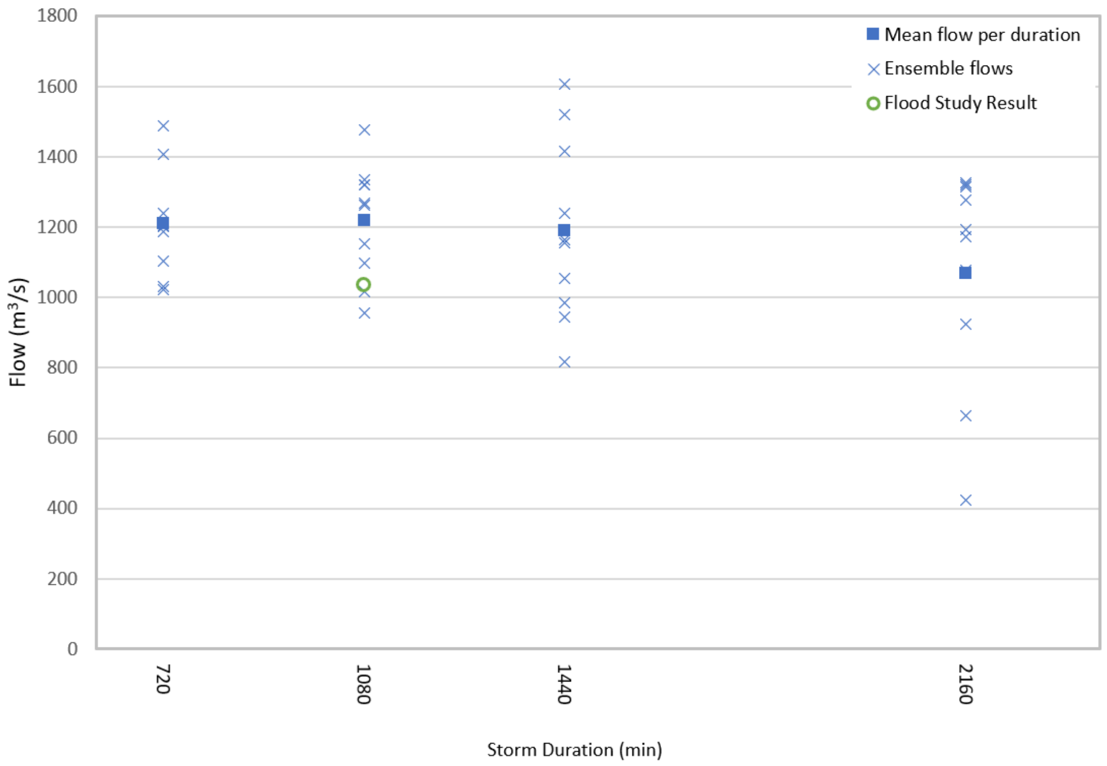



*Chart 2: Ladysmith 1% AEP Peak Flows*

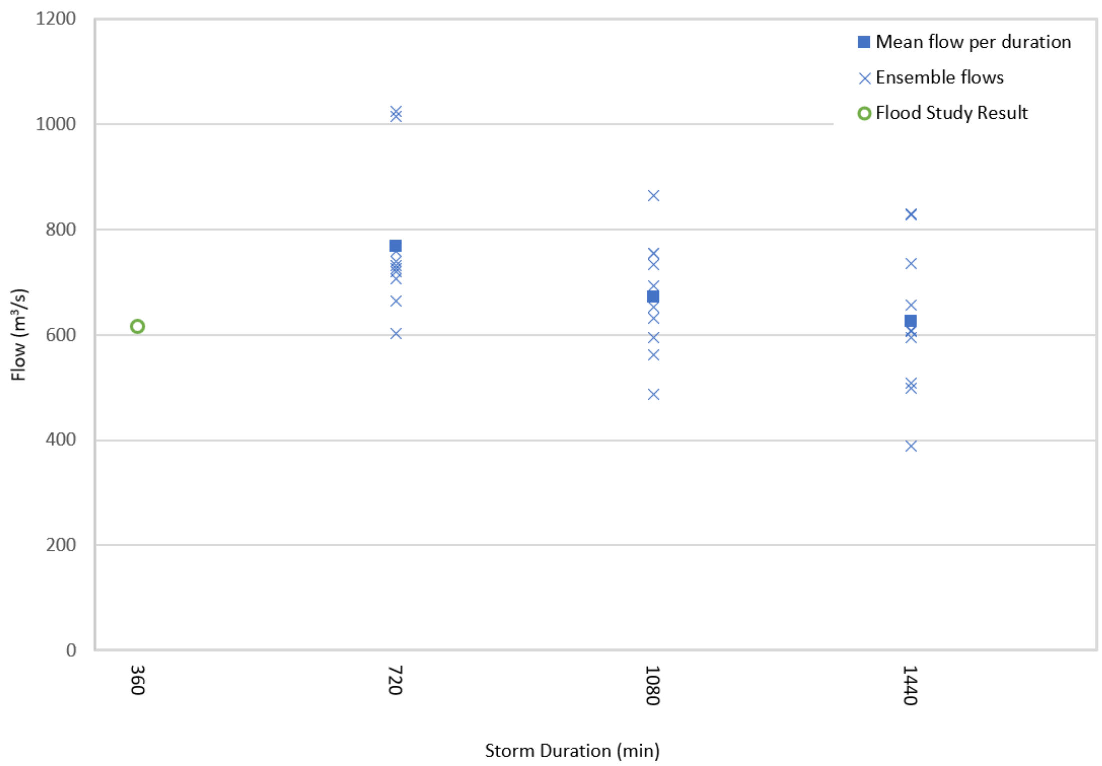
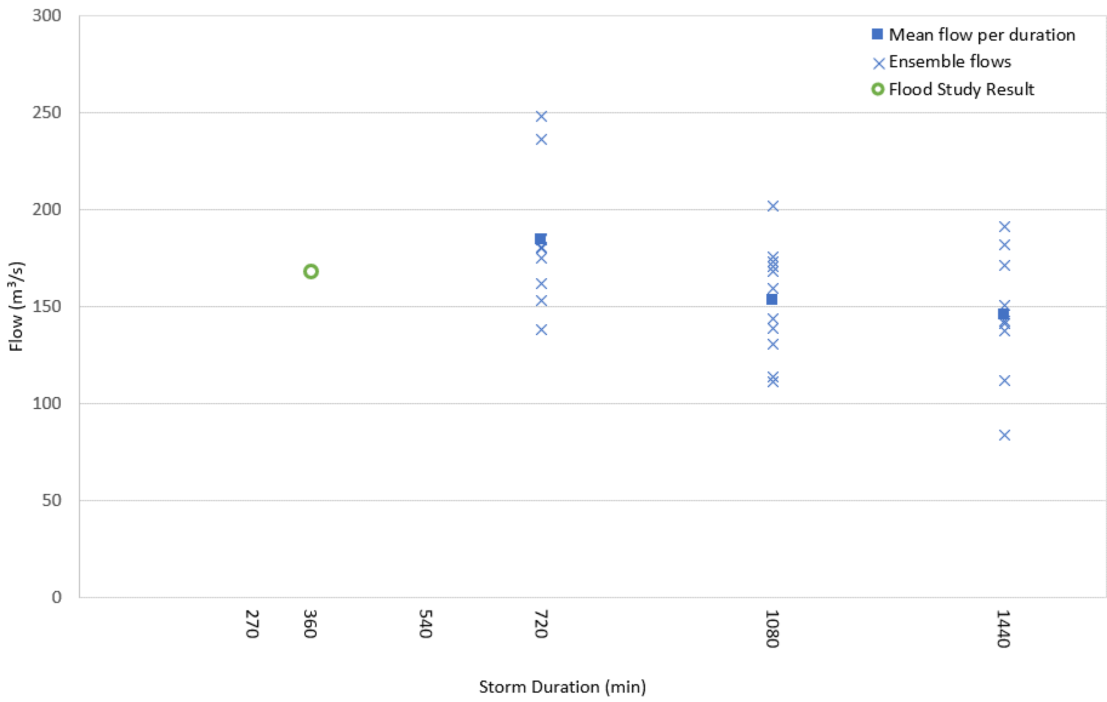


*Chart 3: Uranquinty 1% AEP Peak Flows*




#### *3.1.2.6 Mainstream Hydrologic Model Results*

Table 6 presents mainstream peak flows for the full range of design flood events at each of the study areas.

*Table 6: Mainstream Hydrologic Model Results*

| AEP | Mainstream Design Flows | | | | | |
|---|---|---|---|---|---|---|
| | Tarcutta (18 hr) | | Ladysmith (12hr) | | Uranquinty (12hr) | |
| | Critical Storm Pattern No. | Peak Flow ($m^3/s$) | Critical Storm Pattern No. | Peak Flow ($m^3/s$) | Critical Storm Pattern No. | Peak Flow ($m^3/s$) |
| **20%** | 6 | 316 | 7 | 199 | 7 | 48 |
| **10%** | 4 | 524 | 7 | 325 | 1 | 79 |
| **5%** | 4 | 713 | 1 | 438 | 2 | 107 |
| **2%** | 2 | 1,031 | 1 | 632 | 1 | 154 |
| **1%** | 2 | 1,262 | 1 | 759 | 1 | 184 |
| **0.5%** | 2 | 1,527 | 1 | 892 | 1 | 219 |
| **0.2%** | 2 | 1,865 | 1 | 1,066 | 1 | 264 |

### 3.1.3 Overland Flow Flood Estimation

#### *3.1.3.1 Design Rainfall*

2016 IFD design rainfall depths were extracted from the BOM website for each township and applied to the overland flow hydrologic models as point rainfall. These rainfall depths are presented in Table 7. It is important to note that the critical duration in overland flow catchments is typically much less than that of mainstream catchments and as such, shorter durations are presented in Table 7.

*Table 7: Overland Flow Design Rainfall Depths*

| AEP | Rainfall Depth (mm) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tarcutta | | | | Ladysmith | | | Uranquinty | | | |
| | 45 min | 60 min | 90 min | 120 min | 60 min | 90 min | 120 min | 60 min | 90 min | 120 min | 180 min |
| **20%** | 24.7 | 27.1 | 30.7 | 33.5 | 28.6 | 32.2 | 34.9 | 28.5 | 31.9 | 34.4 | 38 |
| **10%** | 29.4 | 32.3 | 36.6 | 39.8 | 34.2 | 38.5 | 41.6 | 34.2 | 38.2 | 41.1 | 45.3 |
| **5%** | 34.2 | 37.6 | 42.5 | 46.2 | 39.8 | 44.7 | 48.3 | 39.9 | 44.5 | 47.8 | 52.6 |
| **2%** | 40.8 | 44.8 | 50.7 | 55 | 47.4 | 53.2 | 57.4 | 47.7 | 53.1 | 56.9 | 62.4 |
| **1%** | 46.1 | 50.6 | 57.2 | 62.1 | 53.4 | 59.9 | 64.6 | 53.8 | 59.8 | 64 | 70.1 |
| **0.5%** | 51.8 | 56.8 | 64.2 | 69.8 | 59.6 | 66.9 | 72.2 | 60.6 | 67.3 | 72 | 79 |
| **0.2%** | 59 | 64.7 | 73.1 | 79.5 | 67.9 | 76.1 | 82.2 | 69.1 | 76.8 | 82.2 | 90.2 |

#### *3.1.3.2 Areal Reduction Factor*

ARR2019 specifies that for catchments less than or equal to 1 km$^2$ an ARF of 1 can be applied. As such, this conservative approach was adopted for the assessment of overland flow catchments in each of the three study areas, which all cover an area less than 1km$^2$.

#### *3.1.3.3 Rainfall Losses*

As was applied for mainstream flood estimation, rainfall losses for overland flow were adopted using the NSW OEH Floodplain Risk Management Guide (2019) for application of ARR2019. As previously described, this guide recommends a hierarchical approach to estimation of rainfall losses, depending on the available information. In summary, the approach is to use (1) the loss values determined via calibration of a hydrologic/hydraulic model, and if these are not available, then to use (2) 'Probability neutral burst loss' from ARR Data Hub for initial loss and NSW Flood Frequency Analysis-reconciled continuing losses (also from ARR Data Hub, which were available for similar catchments to the three of interest here).

The choice of approach (1) or (2) required some judgement and further analysis as the Flood Study losses for each town's catchment appear to not have been calibrated for the overland section of the town, but rather chosen based on experience of similar catchments. The loss values for areas of overland flow applied in the study are given in Table 8.

*Table 8: Flood Study Overland Flow Rainfall Losses (all towns)*

| | Urban subcatchments – ILSAX model with soil no. 3 | | 'Rural' subcatchments |
|---|---|---|---|
| | **Unpaved portion** | **Paved portion** | |
| **All AEP** | 2 mm | 10 mm | 15 mm IL, 2.5 mm/h CL |

Loss values for each of the towns and AEP were derived from Table 8 for approach (1) using the previously described 'Equation 1'. Similarly, the recommended losses for approach (2) were derived based on the nearby FFA for 'Ladysmith – 410048' gauge, which estimated a continuing loss of 1.57 mm/hr, and the probability neutral loss available via the Data Hub. The hydrologic and hydraulic model were then used to test the flow estimates based on the two approaches. It was found that both approaches produced reasonable estimates of the overland flow in a variety of AEP, which is expected as they apply quite similar losses values. Approach (1) was chosen based on the following reasoning:

- While approach (2) reasonably estimates overland flow, it would result in a higher mainstream flow estimate, as it further decreases the losses values. Given the flow has been increased since the flood study, this is not preferable as it leads to discontinuity between the studies, for residents and other stakeholders.
- Approach (1), while not strictly applicable due to the absence of 'calibrated' losses, is consistent with the approach used for modelling of mainstream flooding.
- Approach (2) is a more generalised derivation of losses at a regional scale, and therefore is lower down on the Guide's hierarchy. The Guide emphasises use of previous studies and nuanced understanding of a catchment's flood behaviour, over application of regional values.

The approach (1) losses are shown in Table 9, Table 10 and Table 11. The durations shown in each table are the durations found to be critical (see Section 3.1.3.5). It should be noted that the flood study's use of the ILSAX losses model has not been used by the current study, but the pervious and impervious percentages of each subcatchment are unchanged. The 'BX' parameter for subarea storage multiplier was unchanged from the flood study (0.9 for Uranquinty and Ladysmith, 1.0 for Tarcutta). The percentage of pervious / impervious areas is dependent on the subcatchment type. While for rural catchments an imperviousness of 0% is used, the impervious area for urban catchments differs between 10-30% for Tarcutta, 10-40% for Ladysmith and 10-50% for Uranquinty.

*Table 9: Adopted losses for overland flow - Tarcutta*

| AEP | Initial loss (mm) | | | | | | | | Continuing Loss (mm/h) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Rural sub-catchments and pervious sections of urban sub-catchments | | | | Impervious sections of urban sub-catchments | | | | Rural and pervious sections | Impervious sections |
| | 45 min | 60 min | 90 min | 120 min | 45 min | 60 min | 90 min | 120 min | | |
| 20% | 14.4 | 14.4 | 14.3 | 13.7 | 1.9 | 1.9 | 1.9 | 1.8 | 2.5 | 0 |
| 10% | 14.6 | 14.6 | 14.5 | 14.0 | 1.9 | 1.9 | 1.9 | 1.9 | 2.5 | 0 |
| 5% | 14.7 | 14.7 | 14.6 | 14.4 | 2.0 | 2.0 | 2.0 | 1.9 | 2.5 | 0 |
| 2% | 14.7 | 14.7 | 14.7 | 14.7 | 2.0 | 2.0 | 2.0 | 2.0 | 2.5 | 0 |
| 1% | 14.7 | 14.7 | 14.7 | 15.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.5 | 0 |
| 0.5 % | 14.7 | 14.7 | 14.7 | 15.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.5 | 0 |
| 0.2 % | 14.7 | 14.7 | 14.7 | 15.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.5 | 0 |

*Table 10: Adopted losses for overland flow – Ladysmith*

| AEP | Initial loss (mm) | | | | | | Continuing Loss (mm/h) | |
|---|---|---|---|---|---|---|---|---|
| | Rural sub-catchments and pervious sections of urban sub-catchments | | | Impervious sections of urban sub-catchments | | | Rural and pervious sections | Impervious sections |
| | 60 min | 90 min | 120 min | 60 min | 90 min | 120 min | | |

| | | | | | | | section s | |
|---|---|---|---|---|---|---|---|---|
| **20%** | 14.3 | 14.1 | 13.5 | 1.9 | 1.9 | 1.8 | 2.5 | 0 |
| **10%** | 14.4 | 14.3 | 13.7 | 1.9 | 1.9 | 1.8 | 2.5 | 0 |
| **5%** | 14.5 | 14.5 | 14.0 | 1.9 | 1.9 | 1.9 | 2.5 | 0 |
| **2%** | 14.6 | 14.6 | 14.6 | 2.0 | 2.0 | 1.9 | 2.5 | 0 |
| **1%** | 14.7 | 14.8 | 15.0 | 2.0 | 2.0 | 2.0 | 2.5 | 0 |
| **0.5 %** | 14.7 | 14.8 | 15.0 | 2.0 | 2.0 | 2.0 | 2.5 | 0 |
| **0.2 %** | 14.7 | 14.8 | 15.0 | 2.0 | 2.0 | 2.0 | 2.5 | 0 |

*Table 11: Adopted losses for overland flow – Uranquinty*

| AEP | Initial loss (mm) | | | | | | | | Continuing Loss (mm/h) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Rural sub-catchments and pervious sections of urban sub-catchments | | | | Impervious sections of urban sub-catchments | | | | Rural and pervious sections | Impervious sections |
| | 45 min | 60 min | 90 min | 120 min | 45 min | 60 min | 90 min | 120 min | | |
| **20%** | 14.1 | 14.0 | 13.2 | 13.0 | 1.9 | 1.9 | 1.8 | 1.7 | 2.5 | 0 |
| **10%** | 14.3 | 14.2 | 13.5 | 12.9 | 1.9 | 1.9 | 1.8 | 1.7 | 2.5 | 0 |
| **5%** | 14.4 | 14.4 | 13.9 | 12.8 | 1.9 | 1.9 | 1.9 | 1.7 | 2.5 | 0 |
| **2%** | 14.5 | 14.6 | 14.5 | 13.7 | 1.9 | 2.0 | 1.9 | 1.8 | 2.5 | 0 |
| **1%** | 14.7 | 14.8 | 14.9 | 14.4 | 2.0 | 2.0 | 2.0 | 1.9 | 2.5 | 0 |
| **0.5 %** | 14.7 | 14.8 | 14.9 | 14.4 | 2.0 | 2.0 | 2.0 | 1.9 | 2.5 | 0 |
| **0.2 %** | 14.7 | 14.8 | 14.9 | 14.4 | 2.0 | 2.0 | 2.0 | 1.9 | 2.5 | 0 |

#### *3.1.3.4 Temporal Patterns*

As recommended in ARR2019, catchments less than 75 $km^2$ utilise point temporal patterns for design flood estimation. Since the overland flow catchments at each township are below this threshold, point temporal patterns were adopted in the overland flow hydrologic/hydraulic models.

#### *3.1.3.5 Critical Duration Assessment*

Since the nature of overland flow flooding in a catchment is typically dispersed, determining the critical storm and duration for each design event can be difficult and inaccurate using the hydrologic model. As such, the ensemble of temporal patterns for a range of durations were modelled in both the hydrologic model and hydraulic model.

The critical storm for each duration was selected based on the temporal pattern that produced the median peak flood level in the hydraulic model. This is calculated using a grid analysis of the peak water level grids and the grid that is closest, across all grid cells, to the median flood level grid. These critical storms were then compared against a range of durations, using a similar grid analysis. The storm duration that produced the peak flood level for the selected median storms was then selected as critical.

The critical duration for each town's overland flow is shown in Table 12. The table also lists the storm number that was found to be critical. As shown in the table, the duration varied for each town, with 1-2 hour generally found to be critical in most AEP with exceptions of 0.5% AEP in Tarcutta (45 minutes) and 20% AEP in Uranquinty (3 hour).

*Table 12: Overland Flow Critical Storm/duration*

| AEP | Tarcutta | | Ladysmith | | Uranquinty | |
|---|---|---|---|---|---|---|
| | Critical Storm Pattern No. | Critical Duration (mins) | Critical Storm Pattern No. | Critical Duration (mins) | Critical Storm Pattern No. | Critical Duration (mins) |
| **20%** | 7 | 120 | 7 | 120 | 6 | 180 |
| **10%** | 3 | 120 | 6 | 120 | 9 | 120 |
| **5%** | 2 | 90 | 8 | 90 | 2 | 120 |
| **2%** | 2 | 60 | 3 | 90 | 8 | 90 |
| **1%** | 6 | 60 | 1 | 90 | 1 | 90 |
| **0.5%** | 1 | 45 | 1 | 90 | 8 | 90 |
| **0.2%** | 7 | 120 | 6 | 60 | 6 | 120 |

### 3.1.4 Use of Overland and Mainstream Results

As presented in the previous two sections, the estimation of overland and mainstream flooding follow slightly different approaches, resulting from the different upstream catchment sizes. The catchment size also produce different critical durations: 1-2 hours for overland flooding, depending on event AEP, and 12 hours (or 18 in Tarcutta) for mainstream flooding. For ease of use, the design flood behaviour is 'enveloped' for the purpose of subsequent reporting. This refers to two model result grids, one from the overland critical duration and the other from mainstream critical duration, being combined to take the maximum value in each grid cell. This means that reference to, for example, the 1% AEP flood depth, refers to the depth in the enveloped results grid.

For understanding of the flood behaviour of the two mechanisms, the separate results have been presented for the 5% AEP and 1% AEP in Figure A 24 and Figure A 25 (Tarcutta), Figure B 24 and Figure B 25 (Ladysmith) and Figure C 24 and Figure C 25 (Uranquinty).

### 3.1.5 Review and Update of Hydraulic Models

Review of the hydraulic models found that each town and its catchment were accurately schematised, but that minor changes were warranted in the models' representation of kerb and gutter systems, and of the hydraulic roughness in Tarcutta. An overview of the hydraulic model approach is provided in Table 2.

#### *3.1.5.1 Kerb and Gutter Representation*

The kerb and gutter system is the main drainage mechanism for urban areas with shallow overland flow, as it conveys runoff that would otherwise be on the adjacent footpath or possibly through properties. The three towns have varying extents of kerb/gutter, with Uranquinty mostly all covered and Ladysmith and Tarcutta less so. After review of the hydraulic models found that the kerb and gutter system was not explicitly schematised, it was added as a model layer to each TUFLOW model. This layer consists of polylines that 'stamp' in a small depression in the model surface along each gutter, one model cell wide, to the depth of the gutter (as estimated from the DEM). This is standard practice in models of hydraulic models of urban areas across NSW.

The model update was found to have negligible impact on the overall flow magnitude and depth, but gave more realistic representation of flow paths through urban areas by formation of more contiguous and direct flow paths.

##### *3.1.5.2 Hydraulic Roughness on Tarcutta Creek*

The hydraulic roughness or Manning's 'n' was updated in the vicinity of Tarcutta Creek and the old highway to better reflect observed floodplain vegetation. The changed area is the vegetated area that extends from the old highway (now Sydney Street) bridge over Tarcutta Creek, to just downstream of the highway bypass. Outside of the main channel (which is modelled in 1D), the vegetated area used a manning's 'n' of 0.2. It should be noted that a lower value of 0.08 was used to calibrate the 2010 flood in the flood study, and 0.2 was used only for the 2012 event, based on the calibration process and of aerial photographs showing denser vegetation. This was then adopted for design flood modelling as 2012 was the most recent flood event.

Site visit showed this area to have a mix of grassed clearings, small trees and shrubs, and some pockets of dense trees adjacent to the channel. Based on these observations the roughness was reduced to 0.09 (equivalent to 'trees and scrub' in the existing roughness categories for the model, as 0.2[4] was considered too high for the current conditions; however, it is acknowledged that this denser vegetation may occur again in the future. This change reduced the peak flood level in this area by approximately 0.4 m in the 1% AEP. The large decrease reflects the very high roughness previously applied (0.2) based on the 2012 event and the need to maintain the current amount of vegetation in the area.

## 3.2 Design Flood Behaviour

The results for the updated modelling approach incorporating ARR2019 are presented in the following sections. These results will supersede the previously adopted flood study results upon adoption of the Floodplain Risk Management Study.

With the update to ARR2019, design flows for mainstream flooding have generally increased. As a result of this, flood levels have increased in most areas affected by mainstream flooding. Typically, overland flow flood levels have remained similar in most areas. The following sections present the updated design flood results, while Sections 4, 5 and 6 then describes the flood risk assessment undertaken for each town.

### 3.2.1 Tarcutta

Updated peak flood depths and levels for the range of design flood events are shown in Figure A 1 to Figure A 8 in Appendix A. Table 13 provides the peak flood depths at key locations throughout the Tarcutta township, for all design events, and a comparison to the Flood Study, which used ARR87 (with generally lower design flows) and denser vegetation on the creek, which increased flood levels in the town. The reporting locations are shown on Figure A 1. The ground level is also given so that the flood level (mAHD) can be calculated at each point.

*Table 13: Updated design flood depths - Tarcutta*

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[4] Based on the seminal Manning's 'n' estimates developed by Chow, 0.2 is the upper limit of a vegetated floodplain, only applying to a floodplain with vegetation equivalent to dense willow trees in summer. All other types of vegetation, including scrub and trees, have an upper limit of between 0.06 and 0.16, and an average value of 0.05 and 0.12.

| ID | Location (see Figure A1) | Ground level (mAHD) | 20% AEP | 10% AEP | 5% AEP | 2% AEP | 1% AEP | 0.5% AEP | 0.2% AEP | PMF | Flood Study 1% AEP (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Peak Flood Depth (m) per design event | | | | | | | | |
| 1 | Cricket Oval | 227.05 | 0.10 | 0.45 | 0.74 | 1.13 | 1.45 | 1.75 | 2.08 | 8.59 | 1.54 |
| 2 | Sydney St near Spring St (overland flow only in 1% AEP) | 244.41 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 | 0.03 | 0.11 | 0.02 |
| 3 | Creek side of the levee | 228.04 | 0.20 | 0.77 | 1.18 | 1.76 | 2.00 | 2.19 | 2.38 | 8.13 | 1.92 |
| 4 | Centenary Ave/Sydney St | 227.95 | - | - | - | 0.35 | 0.76 | 1.14 | 1.51 | 8.07 | 0.83 |
| 5 | 4 Centenary Ave | 227.15 | 0.12 | 0.45 | 0.73 | 1.16 | 1.58 | 1.97 | 2.35 | 8.99 | 1.65 |
| 6 | Cynthia St/Bent St (overland flow only in 1% AEP) | 236.04 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.08 | 0.02 |

Full description of the flood behaviour in Tarcutta is given in Section 4.

### 3.2.2 Ladysmith

Updated peak flood depths and levels for the range of design flood events are shown in Figure B 1 to Figure B 8 in Appendix B. Table 14 provides the peak flood depths at key locations throughout the Ladysmith township, for all design events. The reporting locations are shown on Figure B 1. The ground level is also given so that the flood level (mAHD) can be calculated at each point.

*Table 14: Updated design flood depths - Ladysmith*

| ID | Location (see Figure B1) | Ground level (mAHD) | 20% AEP | 10% AEP | 5% AEP | 2% AEP | 1% AEP | 0.5% AEP | 0.2% AEP | PMF | Flood Study 1% AEP (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Peak Flood Depth (m) per design event | | | | | | | | |
| 1 | Kyeamba St/Tywong St | 208.03 | 0.08 | 0.09 | 0.09 | 0.10 | 0.10 | 0.11 | 0.12 | 0.33 | 0.10 |
| 2 | Tumbarumba Rd | 205.14 | - | - | - | 0.07 | 0.08 | 0.08 | 0.09 | 2.22 | 0.07 |
| 3 | Humula St/Kyeamba St | 206.17 | 0.05 | 0.07 | 0.08 | 0.11 | 0.13 | 0.13 | 0.14 | 1.14 | 0.11 |
| 4 | Tywong St/Cunningdroo St | 210.40 | - | - | - | 0.06 | 0.07 | 0.08 | 0.11 | 0.34 | 0.07 |
| 5 | Tarcutta St/Cunningdroo St | 208.49 | 0.09 | 0.13 | 0.09 | 0.10 | 0.10 | 0.1 | 0.13 | 0.40 | 0.13 |
| 6 | Condon Cl | 205.50 | 0.22 | 0.22 | 0.22 | 0.22 | 0.23 | 0.23 | 0.27 | 2.17 | 0.29 |
| 7 | Tywong St | 202.85 | 0.56 | 0.77 | 0.92 | 1.15 | 1.27 | 1.40 | 1.54 | 5.41 | 1.11 |
| 8 | Tumbarumba Rd | 205.80 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 1.07 | 0.01 |
| 9 | Cricket Oval | 202.54 | 0.01 | 0.08 | 0.22 | 0.39 | 0.50 | 0.59 | 0.73 | 4.81 | 0.35 |

Note: all locations are only affected by overland flow in the 1% AEP, except for 7 (Tywong St) and 9 (Cricket Oval).

Full description of the flood behaviour in Ladysmith is given in Section 5.

### 3.2.3 Uranquinty

Updated peak flood depths and levels for the range of design flood events are shown in Figure C 1 to Figure C 8 in Appendix C. Table 14 provides the peak flood depths at key locations throughout the Ladysmith township, for all design events. The reporting locations are shown on Figure C 1. The ground level is also given so that the flood level (mAHD) can be calculated at each point.

*Table 15: Updated design flood depths - Uranquinty*

| ID | Location (see Figure C1) | Ground level (mAHD) | Peak Flood Depth (m) per design event 20% AEP | 10% AEP | 5% AEP | 2% AEP | 1% AEP | 0.5% AEP | 0.2% AEP | PMF | Flood Study 1% AEP (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Cutler Ln/Read St | 199.47 | 0.80 | 1.02 | 1.13 | 1.24 | 1.31 | 1.40 | 1.51 | 4.20 | 1.27 |
| 2 | Olympic Hwy/Uranquinty St | 202.16 | - | - | 0.05 | 0.08 | 0.09 | 0.12 | 0.14 | 0.76 | 0.08 |
| 3 | Olympic Hwy/Yarragundry St | 200.17 | - | 0.31 | 0.38 | 0.49 | 0.55 | 0.61 | 0.68 | 1.68 | 0.52 |
| 4 | Olympic Hwy | 199.21 | - | - | 0.17 | 0.78 | 0.92 | 1.00 | 1.09 | 3.05 | 0.93 |
| 5 | Ryan St/Connorton St | 202.29 | 0.58 | 0.62 | 0.73 | 0.80 | 0.84 | 0.87 | 0.90 | 2.63 | 0.82 |
| 6 | King St | 195.96 | 0.23 | 0.31 | 0.40 | 0.40 | 0.64 | 0.87 | 1.14 | 3.32 | 0.60 |
| 7 | Ben St/O'Connor St | 199.18 | - | 0.00 | 0.16 | 0.79 | 0.94 | 1.03 | 1.15 | 4.09 | 0.95 |
| 8 | O'Connor St/Yarrangundry St | 201.16 | 0.10 | 0.19 | 0.22 | 0.26 | 0.29 | 0.31 | 0.34 | 1.42 | 0.25 |
| 9 | Read St/Bridge St | 199.43 | - | - | 0.11 | 0.45 | 0.61 | 0.70 | 0.83 | 4.03 | 0.63 |

Note: Locations 2,3,5 and 8 are only affected by overland flow in the 1% AEP, not mainstream flooding.

Full description of the flood behaviour in Ladysmith is given in Section 6.

# 4. FLOOD RISK ASSESSMENT - TARCUTTA

## 4.1 Overview

Flooding in Tarcutta occurs from two mechanisms; localised rainfall causing overland flow that originates to the east and north-east of the town, and rainfall over the Tarcutta Creek catchment to the south of town causing flooding of Tarcutta Creek, which flows south to north along the town's western boundary. The latter, which is referred to as mainstream flooding, consists of a large floodplain of up to 500 metre width, with most areas in excess of 1 m depth of flow. In contrast, overland flooding involves a series of flow-paths in urban areas, with most several metres wide and with depth of less than 0.3 m. The two flooding mechanisms can occur simultaneously or separately. The variation in depth and velocity of floodwaters, and the hydraulic function of different sections of the floodplain, are described in **Sections 4.2** and **4.3**, respectively.

The levee in Tarcutta influences flood affectation of people and property in the town. The levee, which is on the south boundary of the town between Sydney Street and the school, blocks creek flow from entering the town in some but not all flood events. There are also two other levees, that are not owned or maintained by Council, closer to Tarcutta Creek. The function of the levees is described in detail in **Section 4.4**.

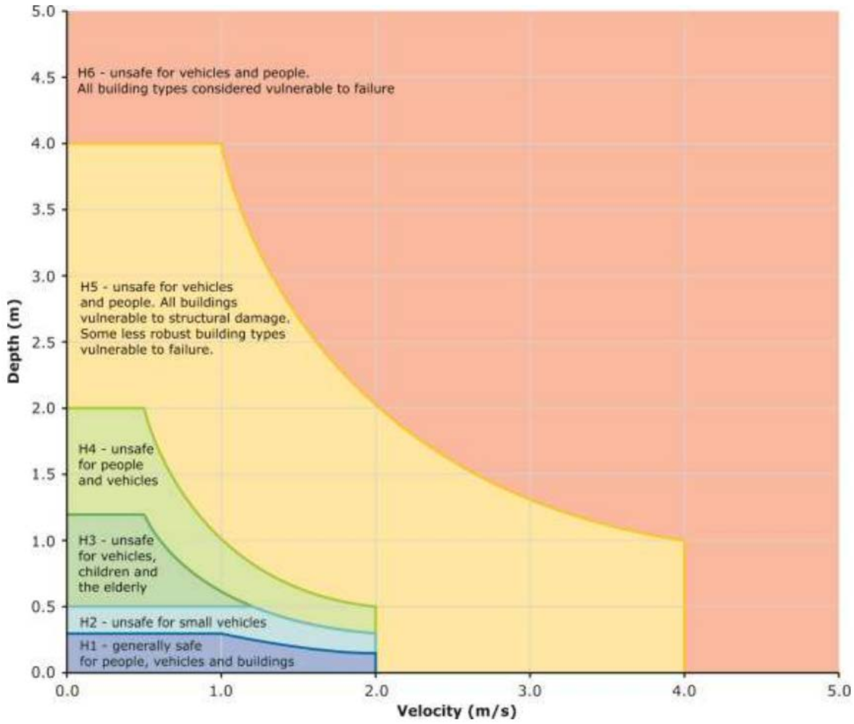
Areas of concentrated flood risk are referred to as flooding hotspots and are defined in **Section 4.5**. These areas consist of a road or pedestrian thoroughfare that is inundated in flood events, or a collection of properties that are flooded. The report describes the flood mechanism at each hotspot, the flood behaviour across the range of possible floods and the type of flood risk.

Finally, the flood warning available in Tarcutta and the emergency response arrangements are described in **Section 4.6** and the economic impact of flooding, based on a flood damages assessment, is presented in **Section 4.7.**

## 4.2 Flood Hazard

### 4.2.1 Background

Flood hazard is defined as the threat that a particular type of flooding will pose to human activity. It is initially calculated based on the flood's depth and velocity in each model grid cell, as part of the flood study stage. It is finalised during the floodplain risk management stage by considering other factors not covered by the depth-velocity calculation. The calculation is based on the Australian Emergency Management Handbook 7 guideline (Australian Institute for Disaster Resilience, 2017), which considers the threat to types of people (children, adult) and activity (pedestrian, vehicle and within a building). The calculation is presented in the below chart.




The chart divides a particular flood event into six categories of hazard, specifically:

- H1 – Generally safe for people, vehicles and buildings (corresponding to very shallow and slow flow)
- H2 – Unsafe for small vehicles
- H3 – Unsafe for vehicles, children and the elderly
- H4 – Unsafe for people and vehicles
- H5 – Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure.
- H6 – Unsafe for vehicles and people. All building types considered vulnerable to failure (corresponding to very deep and fast flow)

### 4.2.2 Flood Hazard in Tarcutta

Hazard categories for Tarcutta are presented in Figure A 17 to Figure A 19, for the 5% and 1% AEP, as well as the PMF. The figures show the following areas of hazard:

- In the 5% AEP, areas of H6 are confined to Tarcutta Creek and its anabranch channels downstream of Sydney Street. The remainder of the creek floodplain is largely H4 and H5, with areas of H3 on the fringes, including the oval and near the pub. The south side of Centenary Avenue is a mix of H3 to the west where water ponds and H1 and H2 to the east of this. The remainder of the town is largely H1.
- In the 1% AEP, areas of H6 are largely confined to Tarcutta Creek and its anabranch channels downstream of Sydney Street. The remainder of the creek floodplain is largely H5, including the oval, flooding near the pub and on the town side of the levee. Houses and roads in this vicinity of Sydney Street and Centenary Avenue are otherwise affected by H3 and H4 hazard, while the remainder of the town is largely H1 and H2.

- In the PMF, the majority of the floodplain is H6, including a section covering a large section of Sydney Street and the majority of Centenary Avenue. There are areas of H4 and H5 bordering this, affecting tens of properties. The two main overland flowpaths in the town affect properties on Young, Toonga and Sydney streets with H5 flow. Large areas of the town would be devastated were a PMF event to occur, via destruction of buildings and other structures.

## 4.3 Hydraulic Categories

### 4.3.1 Background

Hydraulic Categories are a processed model output that classify floodwaters into floodway, flood storage or flood fringe. These categories describe the function of flow in a particular area of the floodplain, and are commonly used by town planners to understand flood behaviour in an area of potential development. According to the Australian Emergency Management Handbook 7 (Australian Institute for Disaster Resilience, 2017), these three categories can be defined as:

- Floodway – the areas where a significant proportion of the floodwaters flow and typically align with defined channels. If these areas are blocked or developed, there will be significant redistribution of flow and increased flood levels across the floodplain. Generally, the floodway is areas of deep and/or fast-moving floodwaters. The handbook refers to floodway as flow conveyance (the terms are interchangeable);
- Flood Storage – areas where, during a flood, a significant proportion of floodwaters extend into, water is stored and then recedes after a flood. Filling or development in these areas may increase flood levels nearby.
- Flood Fringe – areas that make up the remainder of the flood extent. Development in these areas are unlikely to alter flood behaviour in the surrounding area.

There is no prescribed methodology for deriving each category and as such categorisation is typically determined based on experience and knowledge of the study area. As per the study brief, the hydraulic categories for mainstream flooding have been derived using three methods. This is also consistent with other studies in the LGA including the Wagga Wagga Revised Murrumbidgee FRMS&P (WMAwater on behalf of Wagga Wagga City Council, 2017). The general approach uses the following steps for mainstream flow:

1. For the 1% AEP design event, derive an estimate of the hydraulic categories in accordance with Howells et al, 2003 (Howells et al, 2003), which uses thresholds for the velocity-depth product, velocity and depth to define each category.
2. For isolated areas of flood storage or flood fringe that are surrounded by floodway, convert them to floodway if they are less than 0.3 ha in area. Similarly, if a particular channel or flowpath of floodway is discontinuous at a point due to a localised man-made change, convert the area to floodway if necessary to achieve correct impact in the next step.
3. Model the effect of fully developing the non-floodway area by blocking out all non-floodway areas of the model so they are impermeable to flow. Measure the change in peak flood levels that results from the reduced flow area. If the increase is around 0.1 m, the categories are considered reasonable, if a larger increase is recorded, increase the floodway area by changing the thresholds in step 1, or decrease the area if the impact is too low.
4. Once a reasonable estimate of the hydraulic categories is found, confirm their delineation by measuring the percentage of flow in areas of floodway compared to total flow. The floodway is expected to have approximately 80-90% of total flow.

5. Once the thresholds of velocity-depth product, velocity and depth are determined for the 1% AEP event, apply the same criteria for deriving the 5% AEP and PMF hydraulic categories.

The dispersed and shallow nature of overland flooding means that the same process cannot be used to delineate hydraulic categories for overland flow. Rather, the velocity/depth thresholds are applied without calculating the afflux of developing the flood storage area or measuring the percentage of flow. The adopted thresholds for overland flow are:

- Floodway – peak value of velocity multiplied by depth (V × D) > $0.15 m^2/s$ and peak velocity > 0.25m/s, or peak velocity > 1.0m/s and peak depth > 0.15m;
- Flood storage – catchment area outside floodway where peak depth > 0.5m; and
- Flood fringe – catchment area outside floodway where peak depth < 0.5m.

### 4.3.2 Hydraulic Categories in Tarcutta

The hydraulic categories of floodway, flood storage and flood fringe have been derived for the 5% AEP, 1% AEP and PMF events and are shown in Figure A 20 to Figure A 22. As described in the previous section, the categories are used by town planners and other stakeholders to understand flood risk. Areas of floodway are generally incompatible with development aside from parks or recreational facilities, while areas of flood storage can generally be developed, if the loss of storage or other impacts are managed. Flood fringe is areas of shallow flooding that, if developed, have minimal effect on the overall function of the floodplain.

The figures show that in the 1% AEP, the majority of the mainstream flood extent is floodway, with small areas of flood storage and fringe on the periphery. The floodway extends into the town where the main levee is overtopped near Centenary Avenue, and at properties on Sydney Street. There is also a floodway on one overland flowpath through the town. The rest of the town is mostly flood fringe.

In the 5% AEP, the floodway again occupies the majority of the floodplain, while flooded areas around Sydney Street and Centenary Avenue are a mix of flood storage and flood fringe. In the PMF, the majority of all flooded areas are floodway, with minimal flood storage and flood fringe limited to parts of the town with shallow flooding.

The velocity (v), depth (d) and velocity*depth (v*d) thresholds determined for mainstream flooding in Tarcutta are:

- Upstream of the Sydney Street bridge, floodway where v*d > 0.25 $m^2/s$ and v > 0.25 m/s
- Downstream of the Sydney Street bridge, floodway where v*d > 0.5 $m^2/s$ and v > 0.5 m/s
- For all areas outside the floodway, flood storage where d > 0.5 m, otherwise flood fringe.

The results of the assessment are shown in Figure 5, which shows the afflux from blocking the adopted mainstream flood storage area, as well as a breakdown of the flow percentage for the mainstream flow, comparing the floodway and non-floodway area. The figure shows that the adopted thresholds achieve the 0.1 m afflux for most areas (see yellow areas of impact) and the floodway flow is between 70 and 95%.

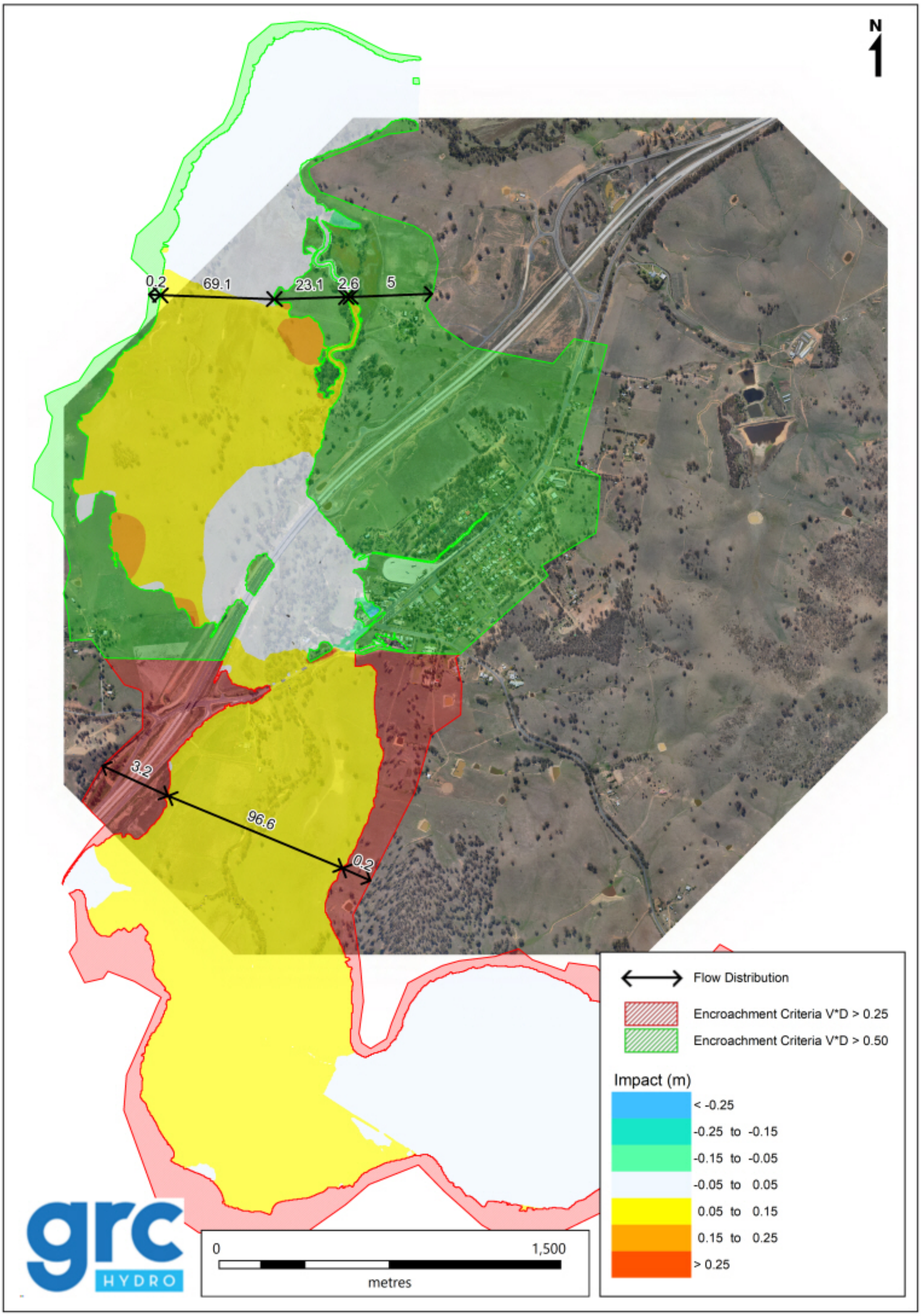



*Figure 5: Results of determination of 1% AEP hydraulic categories for Tarcutta*

## 4.4 Levee Function

Tarcutta's levees protect parts of the town from small flood events while being overtopped or circumvented by floodwaters in larger events. There are three levees of note in or adjacent to the town, as shown on Figure 1 and described below:

- The earth embankment levee on the south boundary of the town, approximately 400 m long extending from near the school, parallel to Centenary Avenue and then along the south side of Sydney Street. This levee is owned by Council and, as the main flood protection levee, is referred to as the Tarcutta levee. It is believed to have been built by the then Department of Main Roads in 1969 (Bewsher Consulting, 2012) and was then raised by the Roads and Traffic Authority in 1995 to 229.6 mAHD, which was at the time estimated to be 0.6 m above the 1 in 100 year flood level. It is now between 229.6 and 229.9 mAHD, with some localised low points down to 229.4 mAHD (see following section).
- The earth embankment levee that, combined with a section of Sydney Street, forms a ring levee around the Old Tarcutta Inn property. The levee is approximately 350 m long and is referred to as the Old Tarcutta Inn levee. It is on private property and not maintained by Council.
- Similarly, the Hambledon property approximately 1 km south-west of the town centre has an earth embankment levee that, along with Sydney Street, forms a ring levee around the property. The levee is approximately 750 m long and is referred to as the Hambledon levee. It is also on private property and not maintained by Council.

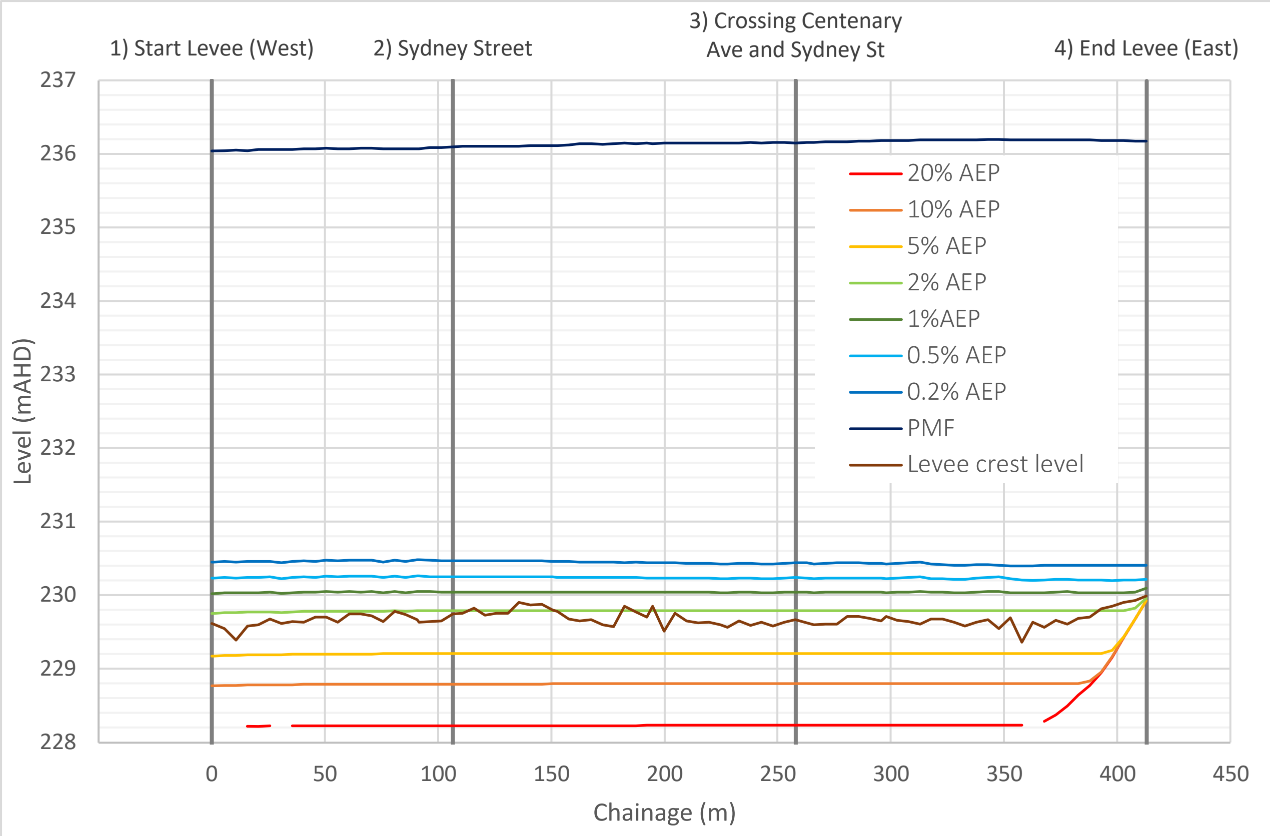
A levee's level of protection refers to the smallest design flood event that the levee protects against. For example, a 1% AEP level of protection will not protect against any events larger than the 1% AEP flood. Assuming the alignment of the levee is sufficient to protect the areas behind it, the level of protection is a comparison of the design flood level, the levee crest level and the levee freeboard, with the crest level minus the freeboard equal to the highest design flood level the levee will protect against.

Freeboard is a function of several local factors including factors not accounted for in the flood level estimate (e.g. wind and wave setup), uncertainty in the design flood estimate (a function of the modelling approach used) and assumed changes to the levee height (e.g. settlement in an earth levee). Levee freeboard can be as low as 0.2-0.3 m but is typically 0.5-0.7 m and can be over 1 m. For reference, North Wagga Wagga levee originally used a 0.3 m before being revised to 0.75 m, while the Wagga Wagga CBD levee uses 0.9 m.

The three levees in Tarcutta do not have a designated freeboard value. This does not mean the freeboard is 0 m, rather, it has not been explicitly stated. The flood study assumed a freeboard of 0.5 m for use in preliminary assessment of levee failure and level of protection. This freeboard is generally suitable for flood risk assessment although a full analysis as was undertaken at Wagga Wagga may be undertaken if the levee is considered for upgrade.

Based on this freeboard, the levee crest level compared to the range of design flood levels is presented in Figure 6. The figure shows that the levee is overtopped at a 229.6 mAHD, or 229.4 mAHD if the localised low points are not sandbagged or otherwise raised. The overtopping at 229.6 mAHD occurs in a 2% AEP, or in a 5% AEP event if the levee is assumed to have 0.5 m freeboard. The 1% AEP level is 230.05 mAHD and so is likely to overtop with between 0.5 to 1 m depth. The PMF level is 236 mAHD. The figure shows the flood level is generally constant against the levee.

*Figure 6: Design flood levels compared to Tarcutta levee crest level*



1) Start Levee (West)
2) Sydney Street
3) Crossing Centenary Ave and Sydney St
4) End Levee (East)
Level (mAHD)
237
236
235
234
233
232
231
230
229
228
0
50
100
150
200
250
300
350
400
450
Chainage (m)
20% AEP
10% AEP
5% AEP
2% AEP
1%AEP
0.5% AEP
0.2% AEP
PMF
Levee crest level

Overtopping of the Tarcutta levee must be considered in conjunction with the potential for its protected area to be inundated by mainstream flow originating from the direction of the oval and the petrol station/pub, as this occurred in the October 2010 event. Bewsher Consulting (2012) reports that flow came past the pub and over Sydney Street (west to east), flooding Centenary Avenue properties prior to the levee being overtopped. The report also states that previous modelling indicated the Hume Highway bypass construction, which was ongoing during the flood, would worsen flooding[5] in the vicinity of the pub, and so this may have been a contributing factor to the observed flooding. The relative timing of the inundation is shown in Figure 7, which shows the 1% AEP event (note this is a larger event with a different storm duration to the 2010 event).

As shown on the figure, in large floods the town can be flooded from the direction of the oval, before the levee is overtopped. Once the levee is overtopped, the flow tends to create a wide flowpath moving north over Sydney Street, moving parallel to the creek flow. The timing and risk are further described in flooding hotspots reporting (Section 4.5). Note that the flood modelling shown in Figure 7 models the levee with its current crest level and does not subtract the levee freeboard in the model.

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[5] Bewsher Consulting, 2012 notes that modelling pertained to the construction phase and that the completed highway was modelled to have lower impacts on flooding.

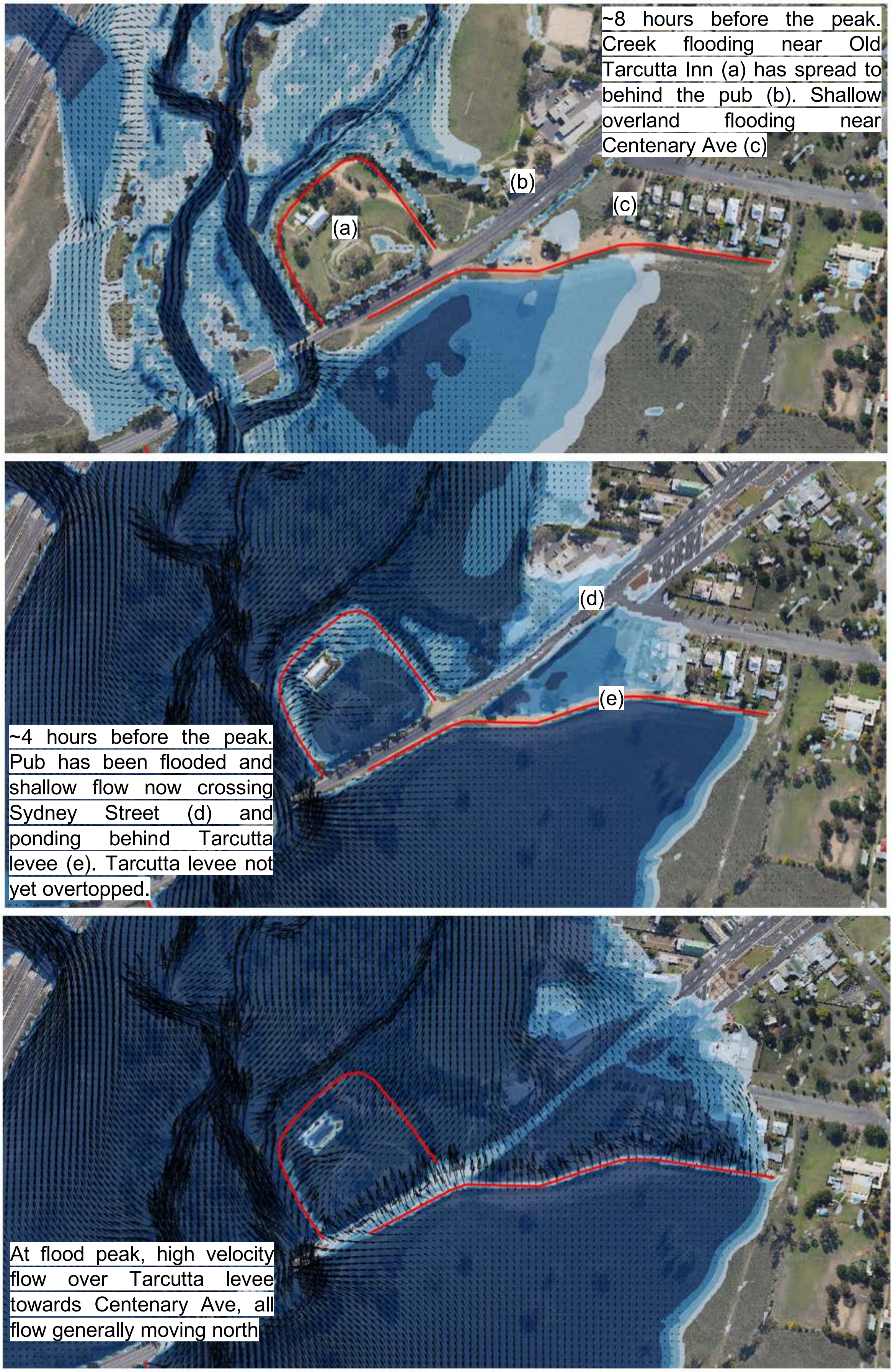



*Figure 7: 1% AEP flooding at Tarcutta levee*

### 4.4.1 Levee Cross-drainage

Levee cross-drainage refers to drains that pass through or underneath the levee structure. They are designed to convey overland flow that builds up on the town side of the levee, through to the creek. A second feature is that the cross-drainage must block flow from entering the protected area during flooding of the creek. This is achieved either by a hinged floodgate on the creek side of the levee, which is held closed by floodwaters, or a manual or automated vertical flood gate that is closed and opened depending on the creek level. If there is risk of overland flow coinciding with creek flooding, a pump system can also be incorporated to pump overland flow over the levee. While possible designs are quite varied, all require maintenance and upkeep to ensure the dual function of the drainage is met (draining overland flow and blocking creek flow).

*The Tarcutta levee has one cross-drain just east of where the levee meets Sydney Street, adjacent to the Riverina Water treatment plant. It is a 0.75m diameter pipe with a hinged floodgate on the creek side and a concrete headwall. The upstream side is overgrown with long grass and likely partially blocked with siltation (see Image 2). It is reported that the gate was stuck open in the March 2012 flood and this led to flooding of the water treatment plant. It is therefore likely that in its current state it has impaired functioning in both draining overland flow and blocking Tarcutta Creek flow. The levee cross-drainage location is shown on*

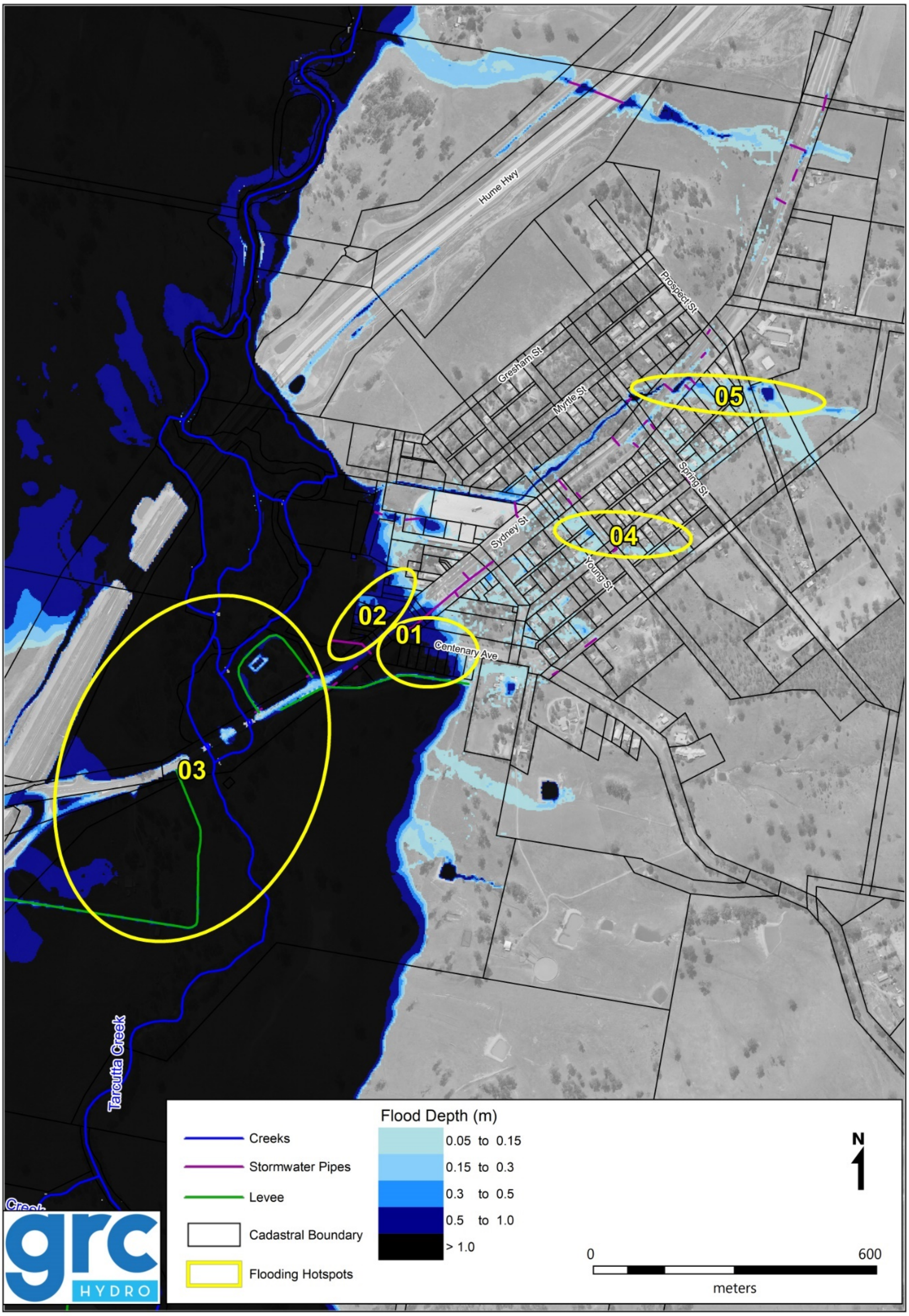



Figure 8, where the stormwater pipe (purple line) crosses the levee (green line) in between hotspots 1, 2 and 3.

Image 2: Levee drain upstream inlet (Source: SES) and downstream headwall (red arrow)

Improvements to the levee cross-drainage are described in Section 8.2.1.5.

## 4.5 Flooding Hotspots

*Tarcutta contains several areas of concentrated flood risk, due to a combination of road and property flooding. These are referred to as flooding hotspots and include Centenary Avenue (1), Sydney Street near Centenary Avenue (2), and the two properties with levees (Hambledon and Old Tarcutta Inn) (3). There are also two significant overland flowpaths in the town, one near Young Street (4) and the other near Toonga Street (5). Each hotspot has been described with regards to properties and roads inundated, and the depth and hazard of floodwaters in a range of events. An overview of the hotspots is shown on*

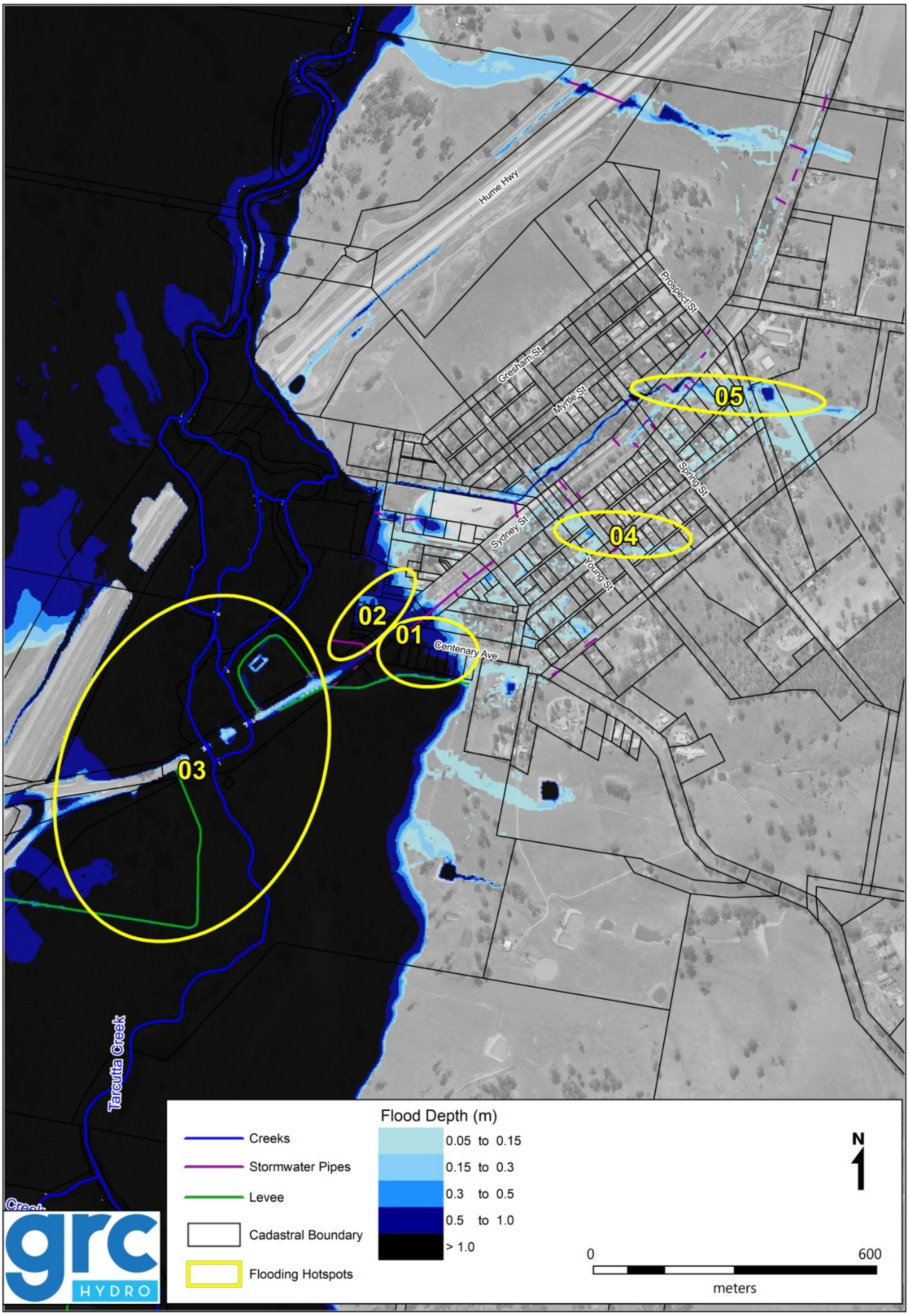
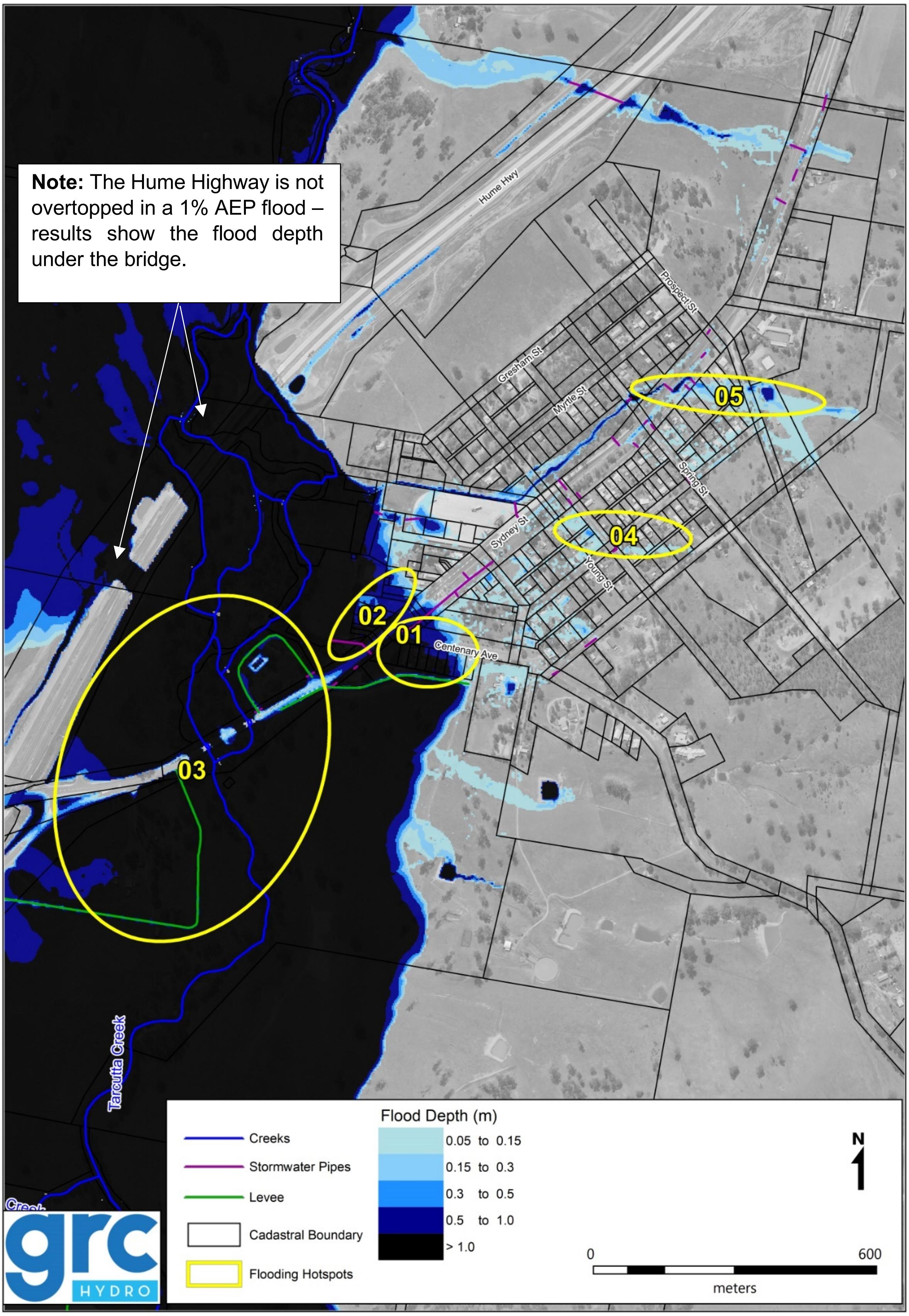



Figure 8 below.



Note: The Hume Highway is not overtopped in a 1% AEP flood – results show the flood depth under the bridge.
Hume Hwy
Prospect St
Gresham St
Myrtle St
Spring St
Sydney St
Young St
Centenary Ave
Tarcutta Creek
01
02
03
04
05
Creeks
Stormwater Pipes
Levee
Cadastral Boundary
Flooding Hotspots
Flood Depth (m)
0.05 to 0.15
0.15 to 0.3
0.3 to 0.5
0.5 to 1.0
> 1.0
N
0
600
meters
grc HYDRO

*Figure 8: Tarcutta Hotspots with 1% AEP Flood Depth*

### 4.5.1 Centenary Avenue (Hotspot 1)

The western end of Centenary Avenue is inundated when the Tarcutta levee is overtopped, when creek flow backs up from behind the pub and crosses Sydney Street, or when overland flooding accumulates behind the levee and is not efficiently drained. This means it can be flooded during a creek flood, during a localised rainfall event, or a combination of both. The flooded area consists of 7 houses on the south side of the street, a police station to the north and Riverina Water assets to the west. The local school is further up the hill to the east and is flooded in the PMF event. The area naturally drains to the west in the direction of Tarcutta Creek, but the Tarcutta levee and Sydney Street (formerly the Hume Highway) are raised above the natural ground level and impede flow. There is now a topographic depression where the levee meets the road, which is drained by a culvert that passes through the levee. At the time of writing the area was overgrown and residents have noted the need to maintain the levee drainage.

Table 16 describes the area's flood behaviour and flood risk.

*Table 16: Centenary Avenue Hotspot Description*

| Flood Risk Characteristic | Description |
|---|---|
| **Depth of flooding** | • In 5% AEP, up to 0.5 m at west end of Centenary Avenue, most properties flooded by 0.1-0.2 m<br>• In 1% AEP, 1.5 m at west end of Centenary Avenue, gradually decreasing to 0 m at school. |
| **Flood Hazard** | • In 5% AEP, majority of property and road area H1, some H2.<br>• In 1% AEP, H6 at rear of some properties where high velocity overtopping of levee. Rest of property and road mix of H4 and H5. |
| **Properties flooded above ground** | • 9 in 5% AEP<br>• 10 in 1% AEP |
| **Properties flooded above floor (approx.)** | • 2 in 5% AEP (shed and back office, from overland flooding)<br>• 7 in 1% AEP (5 houses).<br>• Police station flooded above floor in 0.5% AEP |
| **Evacuation** | There is rising road access to the west on Centenary Avenue |
| **Duration** | Depending on the length of the storm event and drainage of the area, flooding likely to last several hours. Shallow inundation may be trapped for several days after a flood. |
| **Additional Risk Factors** | The area is in close proximity to the Tarcutta Levee which will cause high velocity, high hazard flow when overtopped in large flood events. The levee has an uneven crest level and so may overtop unpredictably. There is some risk of levee collapse or overtopping causing rapid erosion of the structure in large floods. The levee does not appear to have a designated spillway. |
| **Gauge levels** | The Tarcutta Levee is overtopped at a gauge level of between 3.9 m (estimated from 2010 flood) and 4.1 m (estimated from model results). Creek flow over Sydney Street heading towards Centenary Ave occurs at a gauge depth of 4.06m, at which point flooding of Centenary Ave properties starts to occur. Note there is some uncertainty in these gauge estimates, see Section 8.2.2.2 for more information) |

### 4.5.2 Sydney Street near Centenary Avenue (Hotspot 2)

Inundation at Sydney Street near Centenary Avenue is mainly caused by mainstream flow from the north-west in smaller floods, and from the south-east via overtopping of the levee in larger floods. Flooding is related to creek flooding and not overland flow. Sydney Street is the main thoroughfare through Tarcutta and connects to Westbrook Road (via Centenary Avenue) which leads to rural properties south-east of town. Several properties and the road itself are inundated due to flooding of Tarcutta Creek. The multiple sources of flooding (from the north-west and then the south-east) are described in Section 4.4, including Figure 7 which shows how the flooding occurs. In a 5% AEP flood event approximately two properties are flooded above floor at the Sydney Street/Centenary Avenue intersection, while around 5 are inundated in a 1% AEP event.

Table 17 describes the area's flood behaviour and flood risk.

*Table 17: Sydney Street near Centenary Avenue Hotspot Description*

| Flood Risk Characteristic | Description |
|---|---|
| **Depth of flooding** | • In 5% AEP, up to 1 m depth at Riverina Water treatment plant, some properties flooded by 0.1-0.3 m (above floor level). Centre of Sydney Street has <0.05 m depth, up to 1 m depth on side of road.<br>• In 1% AEP, up to 2 m at Riverina Water and 0.5-1 m depth at Sydney Street and adjacent properties. |
| **Flood Hazard** | • In 5% AEP, property areas are H1-H3 while Sydney Street is H1.<br>• In 1% AEP, property areas are H1-H4, while Sydney Street is H3-H4 |
| **Properties flooded above ground** | • 3 in 5% AEP<br>• 5 in 1% AEP |
| **Properties flooded above floor (approx.)** | • 2 in 5% AEP<br>• 5 in 1% AEP |
| **Evacuation** | During 5% AEP Sydney Street is accessible from the north-east with rising road access. The road is cut-off by floodwaters in the 1% AEP but still has rising road access. |
| **Duration** | Depending on the length of the storm event and drainage of the area, flooding likely to last several hours. Shallow inundation may be trapped for several days after a flood. |
| **Additional Risk Factors** | • The properties on the north side of Sydney Street are close to the creek channel and therefore localised high velocities can occur during large flood events.<br>• The depth and velocity of inundation over Sydney Street may be underestimated by motorists.<br>• The Riverina Water treatment plant is located close to the Tarcutta Levee which will cause high velocity, high hazard flow when overtopped in large flood events. The levee has an uneven crest level and so may overtop unpredictably. There is some risk of levee collapse or overtopping causing rapid erosion of the structure in large floods. |
| **Gauge levels** | Creek flow over Sydney Street heading towards Centenary Ave occurs at a gauge depth of 4.06m, at which point flooding of Centenary Ave properties starts to occur. Note there is some uncertainty in these gauge estimates, see Section 8.2.2.2 for more information) |

## 4.5.3 Hambledon and Old Tarcutta Inn (Hotspot 3)

There are two properties with levees, 'Hambledon' and 'Old Tarcutta Inn'. The Hambledon property is severely flooded during the 2% AEP event, when the levee is overtopped and flood depths up to 3 m are reached on the east side of the property, and between 1 m and 2 m at the property's buildings. Flooding is related to creek flooding and not overland flow. The levee of the Old Tarcutta Inn overtops during the 10% AEP event, but the building is not flooded until the 1% AEP event, due to a concrete block wall around the house. At both locations, estimation of levee overtopping is approximate due to uncertainties regarding freeboard. Local effects such as wind and wave setup may cause overtopping in more frequent events

Table 18 describes the area's flood behaviour and flood risk for the hotspot.

*Table 18: Hambledon and Old Tarcutta Inn Hotspot Description*

| Flood Risk Characteristic | Description |
|---|---|
| **Depth of flooding** | • 5% AEP: no flooding at 'Hambledon', 'Old Tarcutta Inn' property flooded by up to 3 m.<br>• 1% AEP: depths up to 2-3 m at 'Hambledon', 'Old Tarcutta Inn' flooded above floor by 0.9 m. |
| **Flood Hazard** | • 5% AEP: 'Hambledon' not flooded, H1-H5 at 'Old Tarcutta Inn'.<br>• 1% AEP: H4, surrounding areas H5 at Hambledon. H3 at building, H4-H6 on surrounding areas at 'Old Tarcutta Inn'. |
| **Properties flooded above ground** | 'Hambledon' first flooded in 2% AEP, 'Old Tarcutta Inn' first flooded in 20% AEP. |
| **Properties flooded above floor** | 'Hambledon' first flooded above floor in 2% AEP, 'Old Tarcutta Inn' first flooded in 1% AEP. |
| **Evacuation** | Once the Hambledon levee is overtopped there is isolation of the building as floodwaters cover the property. Once Sydney Street is reached (approx.. 170 m from buildings) there is rising road access.<br>There is high likelihood of isolation of Old Tarcutta Inn building. Before levee is overtopped, there is shallow flooding of the property and evacuation would be on to Sydney Street. In larger floods the access to Sydney Street is cut-off and once Sydney Street reached, sections to the east and west may be flooded. |
| **Duration** | Depending on the length of the storm event and drainage of the area, flooding likely to last several hours. Inundation within each levee may be trapped for several days after a flood. |
| **Additional Risk Factors** | Both properties are inside levees that can be overtopped in a flood event. The location of overtopping may depend on local hydraulic effects as there is not a designated spillway. Risk of high velocity flow impacting the property and access road is greater at the Old Tarcutta Inn. The second levee at Old Tarcutta Inn surrounding the building may also overtop unpredictably and may encourage occupation of the property during a flood, which would present high risk to the occupants. |
| **Gauge levels** | Hambledon levee is overtopped at a gauge level of 4.00 m, Old Tarcutta Inn levee is overtopped at 3.27 m. |

## 4.5.4 Tarcutta Overland Flowpaths (Hotspot 4)

There are two significant overland flowpaths in Tarcutta, one near Young Street and the other near Toonga Street. These are concentrations of runoff from rainfall occurring in or the north or west of the town. This means flooding can occur when the creek has a normal (non-flood) flow rate. They have variable depth and velocity but in most sections would be considered safe to cross in a vehicle as most are H1 hazard (safe to cross) with smaller areas of H2/H3 hazard (unsafe to cross). Several properties are flooded in their front/back yards by shallow flow, but above-floor flooding is estimated to be negligible in the 1% AEP event.

Table 19 describes the area's flood behaviour and flood risk for the area.

*Table 19: Overland Flowpaths Hotspot Description*

| Flood Risk Characteristic | Description |
|---|---|
| **Depth of flooding** | • 5% AEP: 0.35m adjacent to Young Street, up to 0.6m adjacent to Toonga Street<br>• 1% AEP: 0.4m adjacent to Young Street, 0.68m adjacent to Toonga Street |
| **Flood Hazard** | • 5% AEP: mainly H1, small areas H2 close to properties (Young Street); mainly H1, small areas H2-H3 (Toonga Street) |

| Flood Risk Characteristic | Description |
|---|---|
| | • 1% AEP: mainly H1, small areas H2 close to properties (Young Street); mainly H1, small areas H2-H4 (Toonga Street) |
| **Properties flooded above ground** | • 6 in 5% AEP<br>• 8 in 1% AEP |
| **Properties flooded above floor (approx..)** | • 1 in 5% AEP<br>• 1 in 1% AEP |
| **Evacuation** | Rising road access at each location as flowpaths are localised. Evacuation would only be warranted in very large floods. |
| **Duration** | Depending on the length of the storm event and drainage of the area, flooding may last <1 hour or up to several hours. Yards and blocked drains may be waterlogged for several days. |
| **Additional Risk Factors** | - |
| **Gauge levels** | Overland flow catchments are too small to use flow or level gauges. |

## 4.6 Flood Warning and Emergency Response

### 4.6.1 Existing Systems

Tarcutta has a basic existing flood warning system based on a series of rainfall and stream gauges in the Tarcutta Creek catchment. The creek has three separate subcatchments or tributaries, being Tarcutta Creek, Umbango Creek and Keajura Creek, with the latter a relatively small tributary joining the main creek just upstream of the town. There are two stream gauges across the three subcatchments, both on Tarcutta Creek (also referred to as Oberne Creek) at Westbrook and Belmore Bridge, approximately 25 km and 33 km south of Tarcutta, respectively. There is also a manually-read gauge on the downstream side of Sydney Street near the Old Tarcutta Inn. Telemetered rainfall gauges in the area include Tarcutta Post Office, Humula, Carabost and those in neighbouring catchments. The town is also 25 km south-east of the rainfall radar at Wagga Wagga Airport.

Flood intelligence relating specific gauge readings to flood levels and consequences is limited to the manual creek gauge in Tarcutta, which is linked to the effects of flooding following the 2010 and 2012 floods. The flood intelligence reports (Bewsher Consulting, 2012; Dr. Stephen Yeo, 2013) collected for those reports recommended the following information for the gauge:

- **3.37 m gauge height:** 1 March 2012 peak height. Floodwater in beer garden and cellar at Tarcutta Hotel. Floodwater in Riverina Water treatment plant yard but not over floor of main building.
- **3.85 m gauge height**: 9 December 2010 peak height. Main Tarcutta levee not quite overtopped (but this was reinforced by sandbags). Hotel cellar flooded.
- **(TBC) 3.90 m gauge height:** Crest height of the main Tarcutta levee, this levee has no freeboard. If this levee is overtopped, the Riverina Water treatment plant, Tarcutta Hotel, Caltex service station and up to six residences would be inundated, and Sydney Street (Old Hume Hwy) near the Tarcutta Creek Bridge would be inundated.
- **4.49 m gauge height:** 15 October 2010 peak height. Probable record flood at Tarcutta. Refer to property register in Bewsher Consulting (2012) report for detailed listing of consequences. Main Tarcutta levee, Hambledon levee and Old Tarcutta Inn levee all overtopped. Four houses in Centenary Ave flooded. Hambledon and Old Tarcutta Inn residences flooded. Hotel flooded to depth of 50 cm. Service station flooded. Water treatment plant flooded to depth of about 1.2m. Hume Highway closed for about 13 hours.

Flood-related warnings are issued by the Bureau of Meteorology and the SES. The Bureau of Meteorology (BOM) generally does not issue predictions for specific flood levels (and the corresponding effects) for catchments with flash flooding. However, they do issue more general warnings include Flood Watch (covering a wide area), Severe Weather Warnings and Severe Thunderstorm Warnings. The SES do not issue automated notices based on rainfall or creek levels in the catchment but can issue warnings in conjunction with BOM warnings and when information is available for the Tarcutta gauge. SES warnings via media release or similar appear to not have been issued in the 2010 or 2012 floods due to insufficient automated readings. The flood intelligence reports for those events noted the need for a larger stream gauge network if the warning system is to be upgraded.

### 4.6.2 Recommendations

Recommendation for the emergency response and warning network are presented in Section 8 of this report – Sections 8.2.2, 8.3.2, 8.4.2 have measures specific to each town, and Section 8.5 has general measures. The measures include updating the Local Flood Plan and flood intelligence cards, installation of a new stream gauge and rainfall gauge (both telemetered), and flood education.

## 4.7 Economic Impact of Flooding

### 4.7.1 Background

A flood damages assessment is used to quantify the economic impact of flooding on the community. Generally, a flood damages assessment aggregates the following:

- Direct costs to individual properties such as structural damages or damage to contents;
- Indirect costs to individual properties such as clean-up, disposal or loss of income; and
- Cost of damage to infrastructure.

These costs are categorised as tangible flood damages, while social and environmental impacts, categorised as intangible flood damages, are not covered by the economic impact assessment.

The flood damages assessment for the current study has been completed in accordance with guidance for estimating residential flood damages from the (then) NSW Department of Environment and Climate Change (Department of Environment and Climate Change, NSW, 2007). This guideline uses the depth of flooding above ground and floor level to estimate the variation of damage to structures and yards. The absolute flood damages flood value are used solely for the purpose of calculating benefit-cost ratios for proposed mitigation measures and by the state government in prioritising resources. It should also be noted that the same assessment methodology is used for all locations in NSW and has not been modified for this study.

The flood damages assessment entails comparison of design flood levels to the floor level and ground level at each property. Based on this comparison, a site-specific level of flood affectation is derived. This informs the residential flood damages calculation, whereby a monetary value is applied to each property based on the level of property damage over a range of design flood events. The flood damages for a town or suburb is typically summarised using the Average Annual Damages (AAD), which is an estimate of the average financial cost of flooding due to property damage in any year. The AAD is calculated by scaling down the cost of a flood event based on the likelihood it will happen in a given year. For reference, the recent Murrumbidgee FRMS (WMAwater on behalf of Wagga Wagga City Council, 2017) estimated an AAD of $5.6 million for its study area, while the Holbrook FRMS estimated an AAD of $0.5 million. The default parameter values have largely been used in the flood damages spreadsheet, with the typical house size adjusted slightly for each town. The estimated duration of immersion is 1 hour and the earnings adjustment is 1.81 based on February 2019 data from the ABS.

### 4.7.2 Tarcutta Flood Damages

The flood damages assessment for Tarcutta estimated an Average Annual Damage of $307,376. The results of the assessment, including properties flooded above floor per design event, and corresponding cost, is presented in Table 20.

*Table 20: Tarcutta Flood Damages Summary*

| Event | No. Properties Affected | No. Flooded Above Floor Level | Total Damages for Event | % Contribution to AAD | Avg. Damage Per Flood Affected Properties ($) |
|---|---|---|---|---|---|
| **20% AEP** | 47 | 0 | $703,958 | 34% | $14,978 |
| **10% AEP** | 51 | 1 | $824,230 | 25% | $16,161 |
| **5% AEP** | 52 | 6 | $1,095,168 | 15% | $21,061 |
| **2% AEP** | 56 | 12 | $1,424,598 | 12% | $25,439 |
| **1% AEP** | 57 | 17 | $1,904,752 | 5% | $33,417 |
| **0.5% AEP** | 59 | 23 | $2,293,875 | 3% | $38,879 |
| **0.2% AEP** | 59 | 23 | $2,434,080 | 2% | $41,256 |
| **PMF** | 59 | 48 | $5,368,966 | 3% | $90,999 |
| **Average Annual Damages (AAD)** | | | **$307,376** | | **$3,421** |

The table shows that few properties in Tarcutta are flooded above floor in frequent floods (i.e. 20%-5% AEP), while approximately 50 properties are affected by flooding in most flood events. Flood affectation includes properties with shallow overland flow that is below floor level, which may not be registered as flooding by some residents, depending on the location, depth and duration of flow. The standard flood damages estimation includes a cost of around $10,000 for below-floor flooding, which results in large damages for frequent events (e.g. $703k in 20% AEP). In rarer events, the number flooded above floor level increases to around 20 properties, and there is a corresponding increase in the event damages, with $1.9 million in the 1% AEP.

# 5. FLOOD RISK ASSESSMENT – LADYSMITH

## 5.1 Overview

Flooding in Ladysmith occurs from two mechanisms; localised rainfall causing overland flow that originates to the east and south-east of the town, and rainfall over the Kyeamba Creek, O'Briens Creek and Tywong Creeks' catchments to the south of town causing flooding of Kyeamba Creek, which flows south to north along the town's western boundary. The latter, which is referred to as mainstream flooding, consists of a wide floodplain of up to 600 metres, with most areas in excess of 1 m depth of flow. In contrast, overland flooding involves a series of flow-paths in urban areas, with most several metres wide and with depth of less than 0.3 m. The two flooding mechanisms can occur simultaneously or separately. Figure 10 in this section shows an overview of features while more detailed figures in Appendix B show the range of design flood behaviour. The variation in depth and velocity of floodwaters, and the hydraulic function of different sections of the floodplain, are described in **Sections 5.2** and **5.3**, respectively.

Areas of concentrated flood risk are referred to as flooding hotspots and are defined in **Section 5.4**. These areas consist of a road or pedestrian thoroughfare that is inundated in flood events, or a collection of properties that are flooded. The report describes the flood mechanism at each hotspot, the flood behaviour across the range of possible floods and the type of flood risk.

Finally, the flood warning available in Ladysmith and the emergency response arrangements are described in **Section 5.5** and the economic impact of flooding, based on a flood damages assessment, is presented in **Section 5.6.**

## 5.2 Flood Hazard

An introduction to the concept and derivation of flood hazard is given in Section 4.2.1.

Hazard categories for Ladysmith are presented in Figure B 17 to Figure B 19, for the 5% and 1% AEP, as well as the PMF. The figures show the following areas of hazard:

- In the 5% AEP, areas of H6 are confined to Kyeamba Creek. The remainder of the creek floodplain is largely H3, H4 and H5, with areas of H2 and H1 adjacent to the creek between the main areas of flow. The town of Ladysmith is mostly H1, with H2 in some gutter flowpaths. The public school is H1 except for an area of H2 near its western boundary.
- In the 1% AEP, areas of H6 are confined to Kyeamba Creek and few isolated anabranch channels. The remainder of the creek floodplain is largely H4 and H5, including the large floodway that runs in parallel to the creek (see north-south H5/yellow band on Figure B 18). The town is mostly H1, with H2 in some gutter flowpaths. The public school is H1 except for H3 on its western half (a grassed play-area). One property on Tywong Street has areas of H2 and H3.
- In the PMF, the majority of the floodplain is H6, with a 1km width of H6 flow from the west of the town across the creek. Two overland flowpaths in the town are comprised of H5 and H4 flow, on Tywong Street and Tarcutta Street. The school and other properties on the west side of town are affected by H5 and H6 flow.

## 5.3 Hydraulic Categories

An introduction to the concept and derivation of hydraulic categories is given in Section 4.3.1.

The hydraulic categories of floodway, flood storage and flood fringe have been derived for the 5% AEP, 1% AEP and PMF events and are shown in Figure B 20 to Figure B 22. As described previously, the categories are used by town planners and other stakeholders to understand flood risk. Areas of floodway are generally incompatible with development aside from parks or recreational facilities, while areas of flood storage can generally be developed, if the loss of storage or other impacts are managed. Flood fringe is areas of shallow flooding that, if developed, have minimal effect on the overall function of the floodplain.

The figures show that in the 1% AEP, the majority of the mainstream flood extent is floodway, with small areas of flood storage and fringe on the periphery. There is a large natural floodway west of the creek's main channel near the town. The floodway does not extend into the town save for a part of the school and another property on Tywong Street. There are discontinuous sections of floodway on the town's overland flowpaths. The rest of the town is mostly flood fringe.

In the 5% AEP, the floodway occupies less of the floodplain, with large areas of flood storage particularly east of the wide natural floodway. In the PMF, the majority of all flooded areas are floodway, with minimal flood storage and flood fringe limited to parts of the town with shallow flooding.

The velocity (v), depth (d) and velocity*depth (v*d) thresholds determined for mainstream flooding in Ladysmith are:

- Upstream of the railway embankment (north of town), floodway where v*d > 0.35 $m^2$/s and v > 0.35 m/s
- Downstream of the railway embankment, floodway where v*d > 0.5 $m^2$/s and v > 0.5 m/s
- For all areas outside the floodway, flood storage where d > 0.5 m, otherwise flood fringe.

The results of the assessment are shown in Figure 9, which shows the afflux from blocking the adopted mainstream flood storage area, as well as a breakdown of the flow percentage for the mainstream flow, comparing the floodway and non-floodway area. The figure shows that the adopted thresholds achieve the 0.1 m afflux for most areas (see yellow areas of impact) and the floodway flow is between 93 and 98% of total flow. Although the flow in the floodway is higher than the 80-90% originally targeted, the results achieve the best fit to the afflux criteria of the 7 different threshold combinations tested.

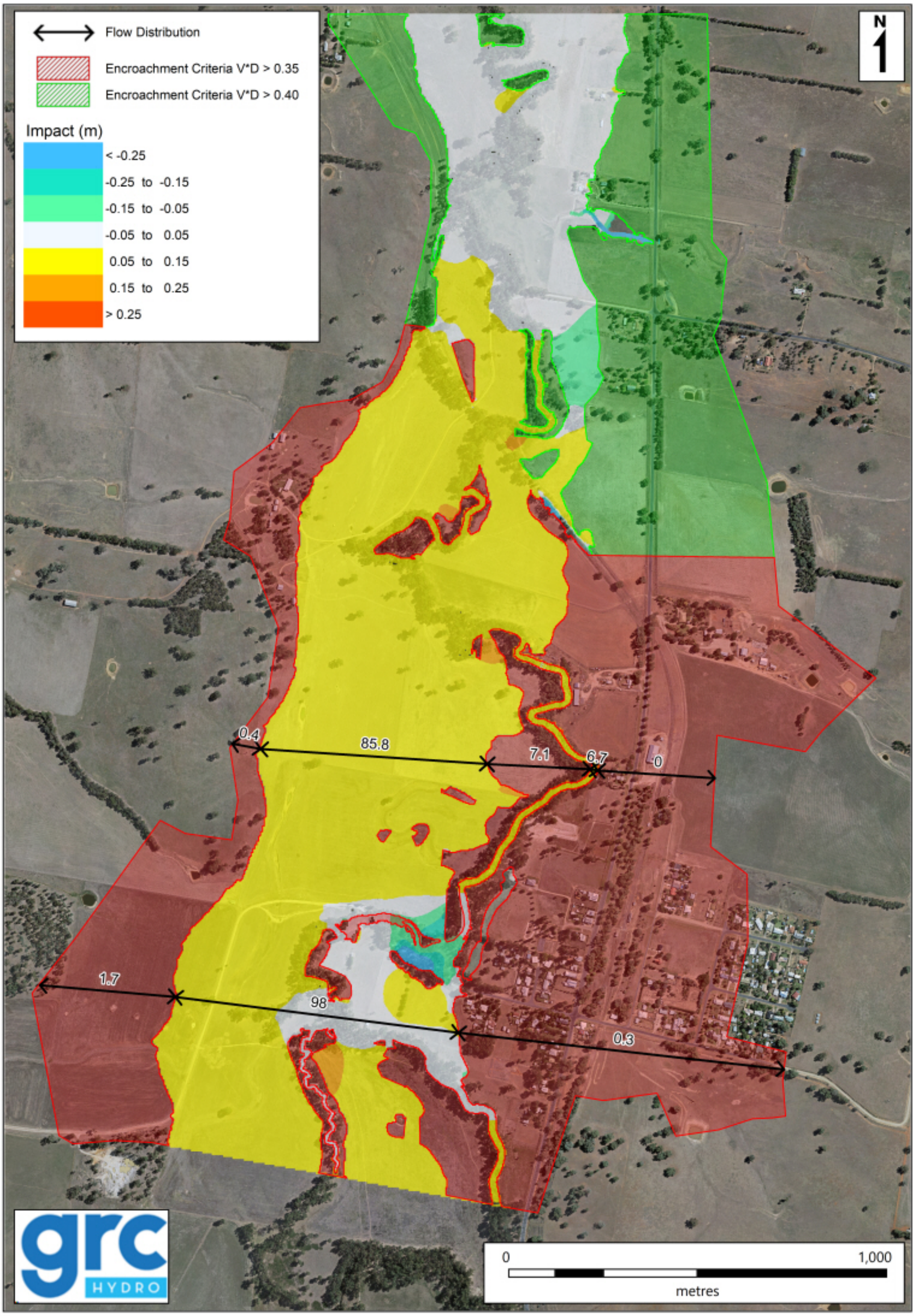



*Figure 9: Results of determination of 1% AEP hydraulic categories for Ladysmith*

## 5.4 Flooding Hotspots

Ladysmith contains few areas of concentrated flood risk with most flood events causing inundation of roads and properties outside the town itself (for example location 2 on Figure 10). One hotspot in the town is the west end of Tywong Street (location 1). Each hotspot has been described with regards to properties and roads inundated, and the depth and hazard of floodwaters in a range of events. An overview of the hotspots is shown on Figure 10 below.

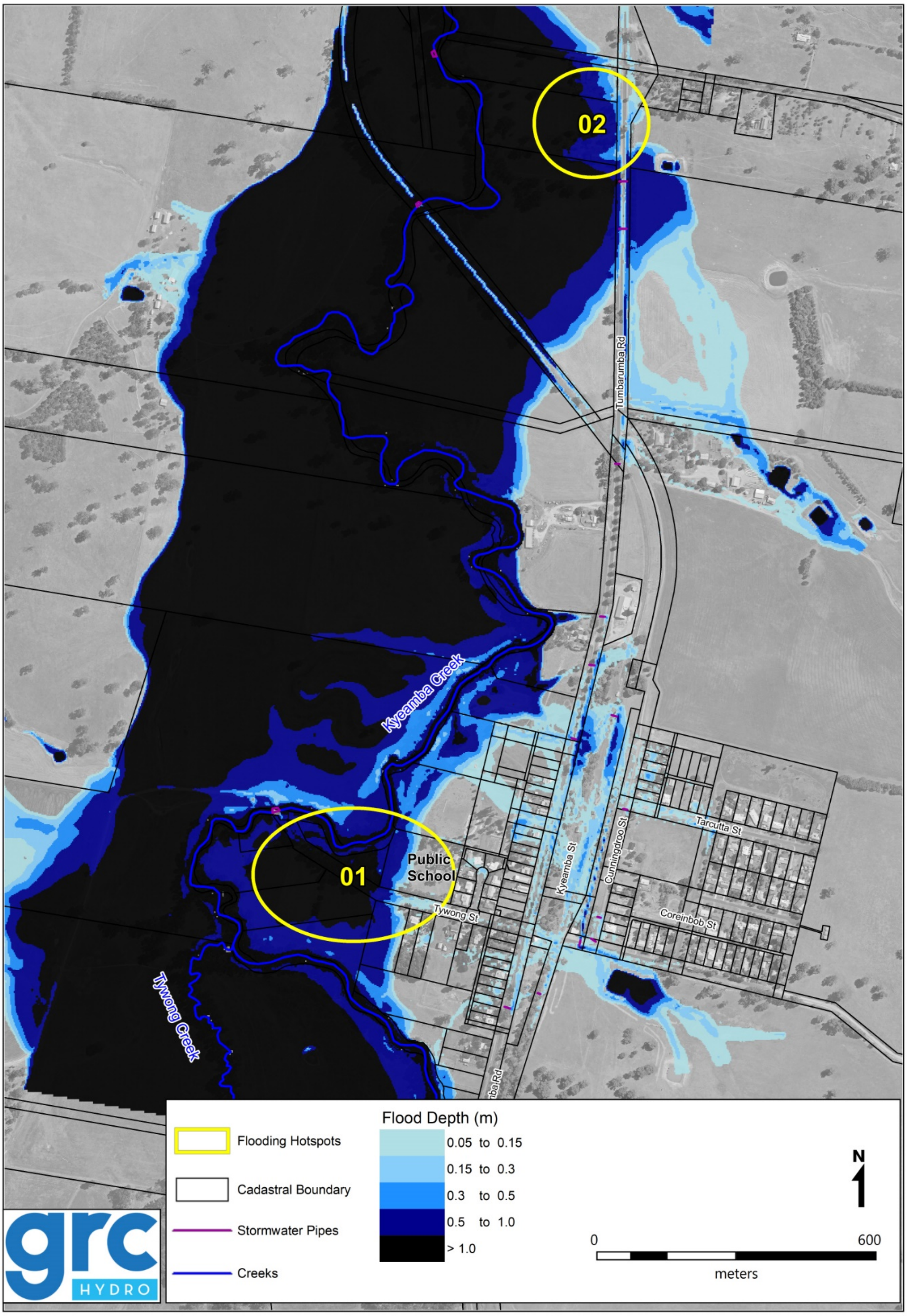



*Figure 10: Ladysmith Hotspots with 1% AEP Flood Depth*

### 5.4.1 Properties Outside Ladysmith township (Hotspot 1)

The Flood Intelligence Report for the 2010 flood (Bewsher Consulting, 2012) reported on 8 properties in or near Ladysmith that were flooded, based on questionnaire responses, while one property is reported on in the 2012 event (Dr. Stephen Yeo, 2013). Most of these are located outside of the study area and modelled flood behaviour is not available. There are two properties within the study area that were reported as flooded: 9080 Tumbarumba Road and 7 Mona Vale Road. The properties are adjacent and are located ~1.7 km north of town, and both are affected by flooding of Kyeamba Creek. The west sides of the properties are affected in the 20% AEP event and larger, while floodwaters reach the buildings in the 10% AEP event (7 Mona Vale Road) and the 20% AEP event (9080 Tumbarumba Road). There is evacuation access via Tumbarumba Road but in large floods there is risk of isolation as parts of Tumbarumba Road can be cut by overland flow.

### 5.4.2 West end of Tywong Street (Hotspot 2)

The west end of Tywong Street is inundated by mainstream flooding during large flood events. Above floor inundation of buildings is only estimated to occur in the 0.2% AEP event and larger, however yards are flooded in the 10% AEP event. The property and buildings of Ladysmith Public School are affected by severe flooding during the PMF event with depths up to 3-4m. The school has significant flooding in the 1% AEP event on its western half closer to the creek, away from the school buildings.

Table 21 describes the area’s flood behaviour and flood risk.

*Table 21: West End of Tywong Street Hotspot Description*

| Flood Risk Characteristic | Description |
|---|---|
| **Depth of flooding** | • In 5% AEP, 0.1-0.25m<br>• In 1% AEP, 0.1-0.45m |
| **Flood Hazard** | • In 5% AEP, mainly H1<br>• In 1% AEP, mainly H1, areas of H2 and H3 |
| **Properties flooded above ground** | • 1 in 5% AEP<br>• 3 in 1% AEP |
| **Properties flooded above floor** | • 0 in 5% AEP<br>• 0 in 1% AEP |
| **Evacuation** | Rising road access on Tywong Street heading east. |
| **Duration** | Depending on the length of the storm event and drainage of the area, flooding likely to last several hours. Shallow inundation may be trapped for several days after a flood. |
| **Additional Risk Factors** | As a school, Ladysmith Public School has higher risk of injury or loss of life than other properties. |
| **Gauge levels** | The western edge of the school is first flooded at a gauge depth of 4.87 m and the east end of the lot (at the building) is approximately 1.2 m higher. |

## 5.5 Flood Warning and Emergency Response

### 5.5.1 Existing Systems

Ladysmith has a basic existing flood warning system based on a series of rainfall and stream gauges in the three upstream creeks. The creek has three separate subcatchments or tributaries, being Kyeamba Creek, O'Briens Creek and Tywong Creek, with the three combining 2-4 km upstream of the town. There is one stream gauge across the three subcatchments, at 'Book Book', approximately 16 km south of Ladysmith. There is also a stream gauge near Mona Vale road approximately 1.3 km north of town. There is telemetered rainfall gauge, also at Book Book, and those in neighbouring catchments. The town is also 6 km south-east of the rainfall radar at Wagga Wagga Airport.

Flood intelligence relating specific gauge readings to flood levels and consequences is limited to the automatic gauge downstream of Ladysmith on Kyeamba Creek, which is linked to the effects of flooding following the 2010 and 2012 floods. The flood intelligence reports (Bewsher Consulting, 2012; Dr. Stephen Yeo, 2013) collected for those reports recommended the following information for the gauge:

- **5.75 m gauge height:** 26 August 1983 peak height. No buildings known to be affected.
- **5.85 m gauge height**: 7 March 2010 peak height. 'Trevella' (9080 Tumbarumba Road) flooded to depth of 0.3m above floor.
- **6.13 m gauge height:** 4 March 2012 peak height. 'Trevella' (9080 Tumbarumba Road) flooded over floor.
- **6.67 m gauge height:** 15 October 2010 peak height. Possible record flood at Ladysmith. Refer to property register in Bewsher Consulting (2012) report for detailed listing of consequences. 'Trevella' (9080 Tumbarumba Road) flooded to depth of 0.5m above floor. 'Pinneena' and 'Nabbilla' threatened.
- Travel times between Book Book and Ladysmith gauges (approximately 17 km apart) are reported for each recent flood, with most peaks taking 5-10 hours to travel, with a minimum of 2 hours 45 minutes and a maximum of 12 hours 15 minutes.

Flood-related warnings are issued by the Bureau of Meteorology and the SES. The Bureau of Meteorology (BOM) generally does not issue predictions for specific flood levels (and the corresponding effects) for catchments with flash flooding. However, they do issue more general warnings include Flood Watch (covering a wide area), Severe Weather Warnings and Severe Thunderstorm Warnings. The SES do not issue automated notices based on rainfall or creek levels in the catchment but can issue warnings in conjunction with BOM warnings and when information is available for the Tarcutta gauge. SES warnings via media release or similar appear to not have been issued in the 2010 or 2012 floods due to insufficient automated readings. The flood intelligence reports for those events noted the need for a larger stream gauge network if the warning system is to be upgraded.

### 5.5.2 Recommendations

Recommendation for the emergency response and warning network are presented in Section 8 of this report – Sections 8.2.2, 8.3.2, 8.4.2 have measures specific to each town, and Section 8.5 has general measures. The measures include updating the Local Flood Plan and flood intelligence cards, installation of a new stream gauge and rainfall gauge (both telemetered), and flood education.

## 5.6 Economic Impact of Flooding

Section 4.7.1 describes the key concepts in how the economic impact of flooding has been estimated.

The flood damages assessment for Ladysmith estimated an Average Annual Damage of $145,332. The results of the assessment, including properties flooded above floor per design event, and corresponding cost, is presented in Table 22.

*Table 22: Ladysmith Flood Damages Summary*

| Event | No. Properties Affected | No. Flooded Above Floor Level | Total Damages for Event | % Contribution to AAD | Avg. Damage Per Flood Affected Properties ($) |
|---|---|---|---|---|---|
| **20% AEP** | 19 | 0 | $314,495 | 32% | $16,552 |
| **10% AEP** | 23 | 2 | $451,054 | 26% | $19,611 |
| **5% AEP** | 26 | 2 | $493,391 | 16% | $18,977 |
| **2% AEP** | 32 | 3 | $684,857 | 12% | $21,402 |
| **1% AEP** | 35 | 5 | $812,148 | 5% | $23,204 |
| **0.5% AEP** | 35 | 5 | $850,470 | 3% | $24,299 |
| **0.2% AEP** | 35 | 8 | $931,805 | 2% | $26,623 |
| **PMF** | 42 | 35 | $3,370,184 | 3% | $80,242 |
| **Average Annual Damages (AAD)** | | | **$145,332** | | **$3,460** |

The table shows that few properties in Ladysmith are flooded above floor in all floods save for the very rare events, while approximately 30 properties are affected by flooding in most flood events. Flood affectation includes properties with shallow overland flow that is below floor level, which may not be registered as flooding by some residents, depending on the location, depth and duration of flow. The standard flood damages estimation includes a cost of around $10,000 for below-floor flooding, which results in large damages for frequent events (e.g. $314k in 20% AEP). Flood damages in Ladysmith are estimated as being lower than Tarcutta and Uranquinty, largely due to the absence of creek flooding in most of the town for most flood events.

# 6. FLOOD RISK ASSESSMENT – URANQUINTY

## 6.1 Overview

Flooding in Uranquinty occurs from two mechanisms; localised rainfall causing overland flow that originates to the west and north of the town, and rainfall over the Sandy Creek catchment to the south of town causing flooding of Sandy Creek, which flows south to north along the town's western boundary. The latter, which is referred to as mainstream flooding, consists of a wide floodplain of up to 700 metres, with most areas in excess of 0.5 m depth of flow. In contrast, overland flooding involves a series of flow-paths in urban areas, with most several metres wide and with depth of less than 0.3 m. The two flooding mechanisms can occur simultaneously or separately. Figure 14 in this section shows an overview of features while more detailed figures in Appendix C show the range of design flood behaviour. The variation in depth and velocity of floodwaters, and the hydraulic function of different sections of the floodplain, are described in **Sections 6.2 and 6.3**, respectively.

The levee system in Uranquinty has a large influence on the extent of flood affectation of people and property in the town. The levee is made up of a levee along the Sandy Creek floodplain on the west and south sides of the town, and secondary levees on Connorton Street and near Churches Plains Road. The parts of the levee have been separated as follows, in accordance with the flood study:

- Connorton Street drain and levee – from Connorton Street to the north end of Deane Street
- Town levee (south) – from the south end of Deane Street to the highway bridge
- Town levee (north) – from the highway bridge to Uranquinty Cross Road
- Churches Plain Road Levee – to the north of the town

The levee sections are shown in Figure 3 and on Figure 12 in **Section 6.4.** The system blocks creek flooding and overland flow from entering the town in some but not all flood events. The function of the levees is described in detail in **Section 6.4**.

Areas of concentrated flood risk are referred to as flooding hotspots and are defined in **Section 6.5**. These areas consist of a road or pedestrian thoroughfare that is inundated in flood events, or a collection of properties that are flooded. The report describes the flood mechanism at each hotspot, the flood behaviour across the range of possible floods and the type of flood risk.

Finally, the flood warning available in Uranquinty and the emergency response arrangements are described in **Section 6.6** and the economic impact of flooding, based on a flood damages assessment, is presented in **Section 6.7.**

## 6.2 Flood Hazard

An introduction to the concept and derivation of flood hazard is given in Section 4.2.1.

Hazard categories for Uranquinty are presented in Figure C 17 to Figure C 19 for the 5% and 1% AEP, as well as the PMF. The figures show the following areas of hazard:

- In the 5% AEP, areas of H6 are confined to sections of Sandy Creek. The remainder of the creek floodplain outside of the levee system is H1, H2 and H3, with some smaller areas of H4 and H5. Inside the levee, there is an area of H3 along the southern end of

Morgan Street and another between the highway and railway. There is another area of H3 near the levee low point near King Street. The remainder of the town is a combination of H1 and H2.

- In the 1% AEP, areas of H6 are confined to sections of Sandy Creek. The remainder of the creek floodplain outside of the levee system is H1, H2 and H3, with some smaller areas of H4 and H5 (similar to the 5% AEP). Inside the levee, there is a large area of H3 and H4 in a southern portion of the town near O'Connor Street that affects tens of properties and several roads, and another smaller area near King Street to the west. The remainder of the town is a combination of H1 and H2.
- In the PMF, the majority of the town is affected by H5 and H6 flow, as the levees are overtopped and major flowpaths form on many of the streets, particularly in the southern portion of town. The north-east part of the town is slightly less affected with a combination of H1 to H5 flow.

## 6.3 Hydraulic Categories

An introduction to the concept and derivation of hydraulic categories is given in Section 4.3.1.

The hydraulic categories of floodway, flood storage and flood fringe have been derived for the 5% AEP, 1% AEP and PMF events and are shown in Figure C 20 to Figure C 22. As described in the previous section, the categories are used by town planners and other stakeholders to understand flood risk. Areas of floodway are generally incompatible with development aside from parks or recreational facilities, while areas of flood storage can generally be developed, if the loss of storage or other impacts are managed. Flood fringe is areas of shallow flooding that, if developed, have minimal effect on the overall function of the floodplain.

The figures show that in the 1% AEP, the majority of the floodplain upstream of the town is floodway, while downstream of the town there are also large areas of flood fringe. The town itself has a large section of floodway generally connecting the overtopping of Deane Street to the discharge through the Ryan/Baker Street area. There is a flood storage area around Bridge and Morgan Street, while the majority of the rest of the town is flood fringe.

In the 5% AEP, the floodplain is primarily floodway with large areas of flood fringe and minimal flood storage. Floodway within the town is mostly limited to the kerb-gutter on some streets. In the PMF, the majority of the town and the floodplain is floodway, save for parts of the town towards the north-east with flood fringe.

The velocity (v), depth (d) and velocity*depth (v*d) thresholds determined for mainstream flooding in Uranquinty are:

- Upstream of the railway/highway bridges, floodway where v*d > 0.25 $m^2/s$ and v > 0.25 m/s
- Downstream of the railway/highway bridges, floodway where v*d > 0.35 $m^2/s$ and v > 0.35 m/s
- Inside of the town's levees, floodway where v*d > 0.20 $m^2/s$ and v > 0.20 m/s
- For all areas outside the floodway, flood storage where d > 0.5 m, otherwise flood fringe.

The results of the assessment are shown in Figure 11, which shows the afflux from blocking the adopted mainstream flood storage area, as well as a breakdown of the flow percentage for the mainstream flow, comparing the floodway and non-floodway area. The figure shows that the adopted thresholds achieve the 0.1 m afflux for some areas (see yellow areas of impact) and the floodway flow is between 96 and 99%. Although not entirely satisfying the original objectives for defining floodway, the floodway presented is the result of modelling 10 different combinations of threshold values for the different areas, each with varied v*d and v threshold and areas of high flow manually added in or subtracted based on the afflux results.

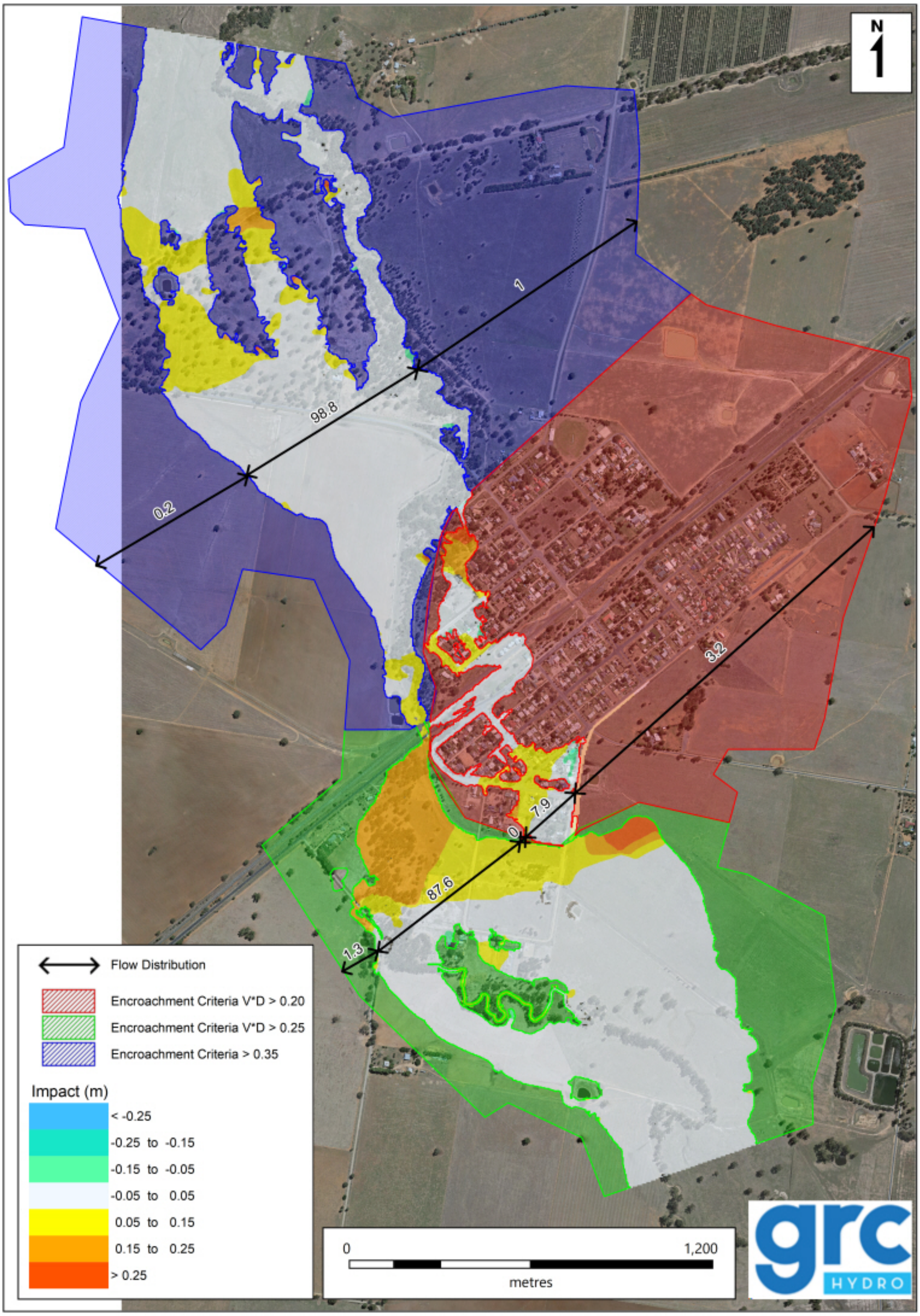


*Figure 11: Results of determination of 1% AEP hydraulic categories for Uranquinty*

## 6.4 Levee Function

Uranquinty's levees protect parts of the town from small flood events while being overtopped or circumvented by floodwaters in larger events. There are four levees of note in or adjacent to the town, as shown on Figure 3 and described below:

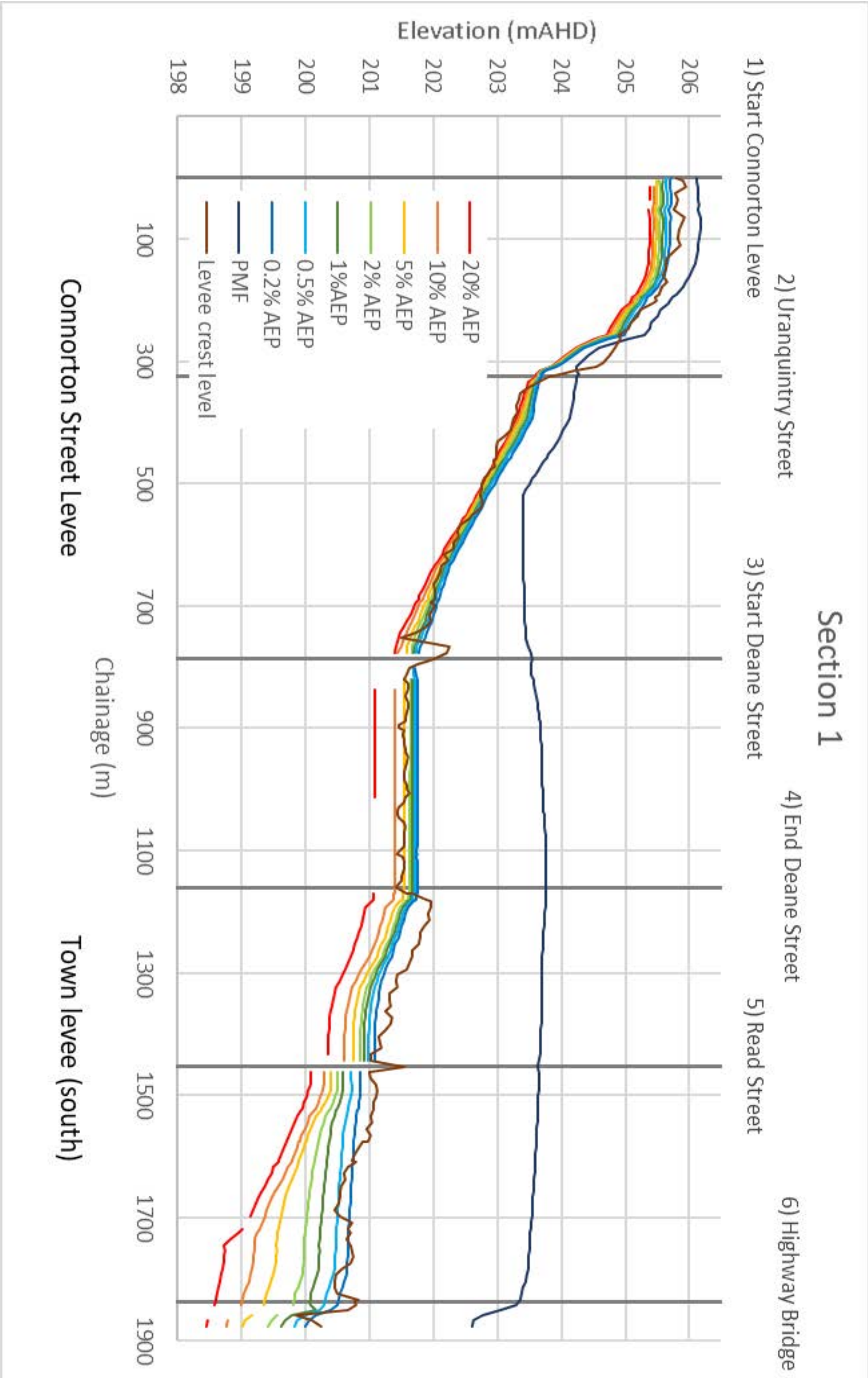
- Town levee (south). The town levee, also referred to as the Sandy Creek levee, is made up of 'south' and 'north' sections, with the south section from the south end of Deane Street to the highway bridge. The south section is 0.7 km long. The levee is owned by Council and protects the town from flooding of Sandy Creek (also referred to as mainstream flooding) in some but not all flood events. It was built in 1982-1988 as part of a wider scheme for the town (see Bryant, 1980). At the time of its construction it was estimated to protect against the 2% AEP flood. The current crest level is between 202.0 and 200.5 mAHD.
- Town levee (north). The north part of the levee is from the highway bridge, past the railway bridge and then along the creek up to Uranquinty Cross Road. It is part of the same levee as described above but has an elevation from 200.8 and 197.1 mAHD, with a spillway that is as low as 195.9 mAHD at the north end.
- Connorton Street drain and levee. The overland flow earth embankment levee along Connorton Street starting north of the neighbourhood centre and ending at Ryan Street, which is approximately 1.0 km long. The road crest of Deane Street connects this levee to the town levees, and so is described as being part of the same levee. The combined system is owned by Council and was designed to protect the town from overland flooding originating east of Connorton Street, as well as Sandy Creek flooding that spreads to Deane Street. It was designed and built alongside the Sandy Creek levee although there were constraints with the design that prevented the design crest level being achieved. Today, the levee is less than 30 cm high in most parts, with a crest level between 205.9 and 201.4 mAHD (see following section).
- The Churches Plains Road levee on the north side of town, which is also a low earth embankment and approximately 0.8 km long. The levee is designed to divert overland flow towards Sandy Creek, north of town. The origin of the levee is unknown, and it now has a crest level between 198.7 and 211.6 mAHD.

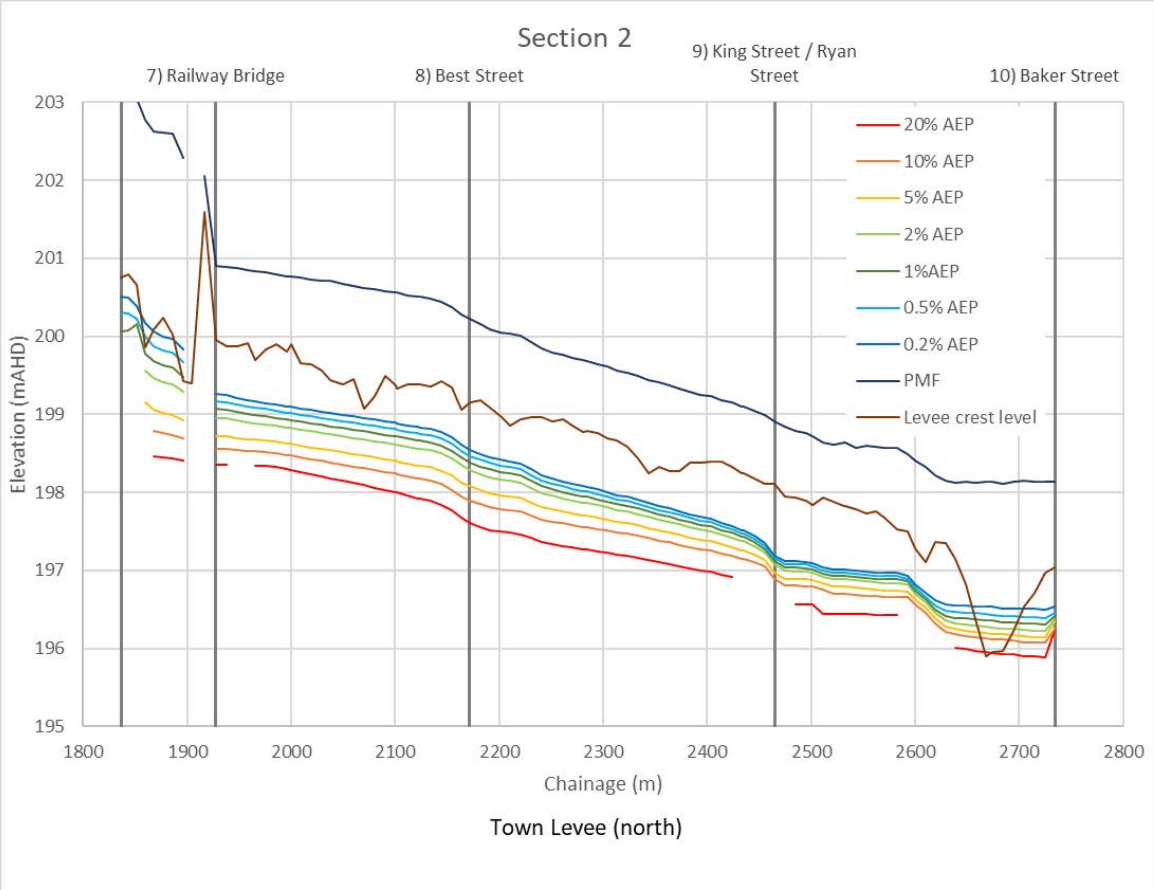
For a description of the concepts of level of protection and freeboard Section 4.4. In modelling and analysing design flood behaviour, the levees have all been modelled to include their current crest heights, that is, the freeboard has not been subtracted in the model.

The freeboard for the town levee (south and north) in Uranquinty is not known and the other levees were intended to have 300 mm freeboard, although it appears this height was not reached for the Connorton Street levee. The flood study assumed a freeboard of 0.5 m for the town levee for use in preliminary assessment of levee failure and level of protection. These freeboards (0.5 m for Sandy Creek, 0.3 m for overland flow) are generally suitable for flood risk assessment although a full analysis may be undertaken if the levee is considered for upgrade. It should be noted that Deane Street can be overtopped by Sandy Creek flooding, overland flow or a mixture of both.

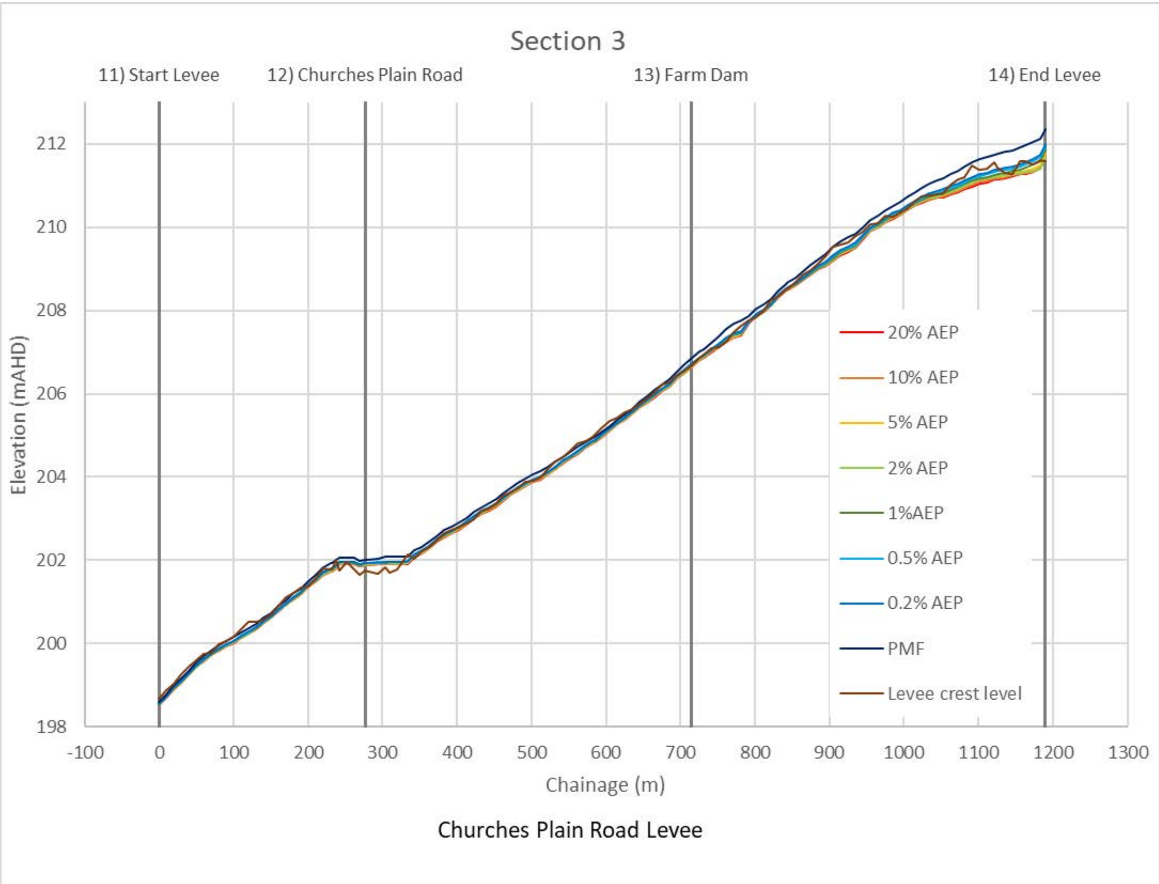
Based on these freeboards, the levees' crest levels compared to the range of design flood levels is presented in Figure 12. The figure separates the levees into the Connorton Street town levee (south) sections, and then the railway to Uranquinty Cross Road section. The figure shows the following:

- The Connorton Street section is overtopped by overland flow in all design floods modelled, particularly in the section just west of the neighbourhood centre at Uranquinty Street.
- If a 0.5 m freeboard is assumed, Deane Street is overtopped by the 20% AEP and larger events. The section between Deane Street and the highway bridge is overtopped by the 10% AEP event just upstream of Read Street. If low-points are sandbagged, it will protect against a 2% AEP event. Without raising, the levee would be overtopped by up to 0.4 m in the 1% AEP.
- If a 0.5 m freeboard is assumed, a low point ~150 m downstream of the railway bridge is overtopped in the 2% AEP event, and all design events modelled will overtop the section near Baker Street. The majority of this section will protect against floods up to the 0.2% AEP (equivalent to 1 in 500 year ARI).
- The Churches Plains Road levee is overtopped in various points, particularly at Churches Plain Road, starting in a 20% AEP event.

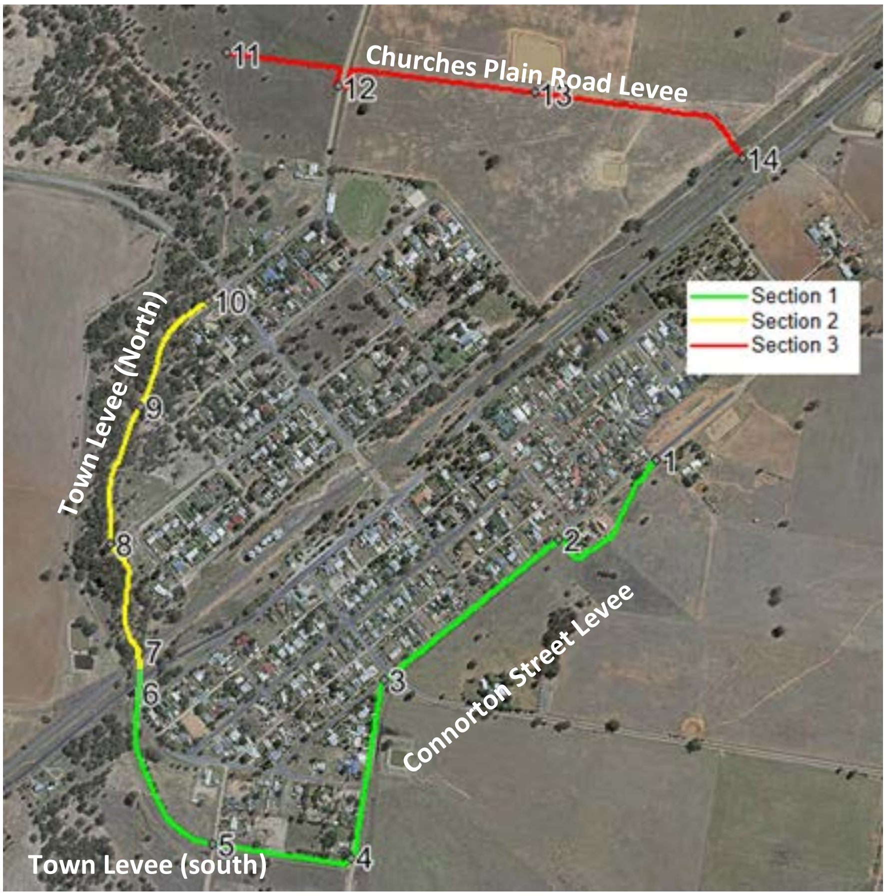

Section 1
Elevation (mAHD)
198
199
200
201
202
203
204
205
206
100
300
500
700
900
1100
1300
1500
1700
1900
Chainage (m)
1) Start Connorton Levee
2) Uranquintry Street
3) Start Deane Street
4) End Deane Street
5) Read Street
6) Highway Bridge
20% AEP
10% AEP
5% AEP
2% AEP
1%AEP
0.5% AEP
0.2% AEP
PMF
Levee crest level
Connorton Street Levee
Town levee (south)



Section 2
7) Railway Bridge
8) Best Street
9) King Street / Ryan Street
10) Baker Street
20% AEP
10% AEP
5% AEP
2% AEP
1%AEP
0.5% AEP
0.2% AEP
PMF
Levee crest level
Elevation (mAHD)
Chainage (m)
203
202
201
200
199
198
197
196
195
1800
1900
2000
2100
2200
2300
2400
2500
2600
2700
2800
Town Levee (north)

Section 3
11) Start Levee
12) Churches Plain Road
13) Farm Dam
14) End Levee
20% AEP
10% AEP
5% AEP
2% AEP
1%AEP
0.5% AEP
0.2% AEP
PMF
Levee crest level
Elevation (mAHD)
Chainage (m)
212
210
208
206
204
202
200
198
-100
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
Churches Plain Road Levee




Each section corresponds to a chart above. Numbers labelled (1, 2, 3, etc) correspond to the labelled chainages on each chart. Note there is no levee structure on Deane Street (points 3 and 4) with the road crest level acting as a levee.

*Figure 12: Design flood levels compared to Uranquinty levees crest level*

Overall, localised low points reduce the level of protection against Sandy Creek flooding to around the 20% AEP event, but if these were slightly raised and a section built along Deane Street, the levee could have 1% AEP protection. More extensive works are needed to improve the overland flow levees, but a raised levee would not be large structure (e.g. around 0.5 m including 0.2 m freeboard).

### 6.4.1 Levee Cross-drainage

Levee cross-drainage refers to drains that pass through or underneath the levee structure. They are designed to convey overland flow that builds up on the town side of the levee, through to the creek. A second feature is that the cross-drainage must block flow from entering the protected area during flooding of the creek. This is achieved either by a hinged floodgate on the creek side of the levee, which is held closed by floodwaters, or a manual or automated vertical flood gate that is closed and opened depending on the creek level. If there is risk of overland flow coinciding with creek flooding, a pump system can also be incorporated to pump overland flow over the levee. While possible designs are quite varied, all require maintenance and upkeep to ensure the dual function of the drainage is met (draining overland flow and blocking creek flow).

Levee cross-drainage in Uranquinty consists of culverts at 5 locations, as shown on Figure 13. Their dimensions and inverts are listed in Table 23. All locations drain overland flowpaths in the town, with location 2 connected to an open channel in the town and no. 4 to the subsurface stormwater drainage in the southern portion of town. As shown on the figure, the drains have a mix of hinged and manual flood gates. In the 2010 and 2012 floods, overland flooding ponded on the town side due to a high creek level that prevented opening of the gates at locations 3, 4 and 5 (manually or automatically), and pumps were used by the SES in the 2012 event. Ponding was also reported to the north (near locations 1 and 2) in the 2012 flood. The manual flood gates at location 3 were built after the 2012 flood, as it was observed that the hinged floodgates on the downstream side could be kept open (or closed) by vegetation.

Improvements to the levee cross-drainage are described in Section 8.4.1.7.

*Table 23: Dimensions of Levee Cross-drainage in Uranquinty*

| No. on Figure 13 | Length (m) | Diameter (m) and no. of pipes | Upstream Invert (mAHD) | Downstream Invert (mAHD) | Closest Creek Invert Level (mAHD) | Levee section | Closing Mechanism |
|---|---|---|---|---|---|---|---|
| **1** | 14.2 | 0.9 (1) | 195.15 | 194.16 | 192.70 | Town levee (north) | Manual |
| **2** | 18.6 | 0.9 (1) | 194.93 | 194.89 | 193.21 | Town levee (north) | Automatic (hinged flap gate) |
| **3** | 17.8 | 0.9 (2) | 196.54 | 196.30 | 195.50 | Town levee (south) | Manual on upstream, automatic (hinged) on creek side |
| **4** | 118.9 | 0.9 (1) | 197.40 | 197.05 | 195.78 | Town levee (south) | Automatic (hinged flap gate) |
| **5** | 14.7 | 0.9 (1) | 197.79 | 197.67 | 195.12 | Town levee (north) | Automatic (hinged flap gate) |


*Figure 13: Uranquinty Levee Cross-drainage*

## 6.5 Flooding Hotspots

Uranquinty contains several areas of concentrated flood risk, due to a combination of road and property flooding. These are referred to as flooding hotspots and include Bridge and Morgan Streets (1), the Olympic Highway near Sandy Creek (2), Ryan and King Streets (3) and Connorton and O'Connor Streets (4). Each hotspot has been described with regards to properties and roads inundated, and the depth and hazard of floodwaters in a range of events. An overview of the hotspots is shown on Figure 14 below.

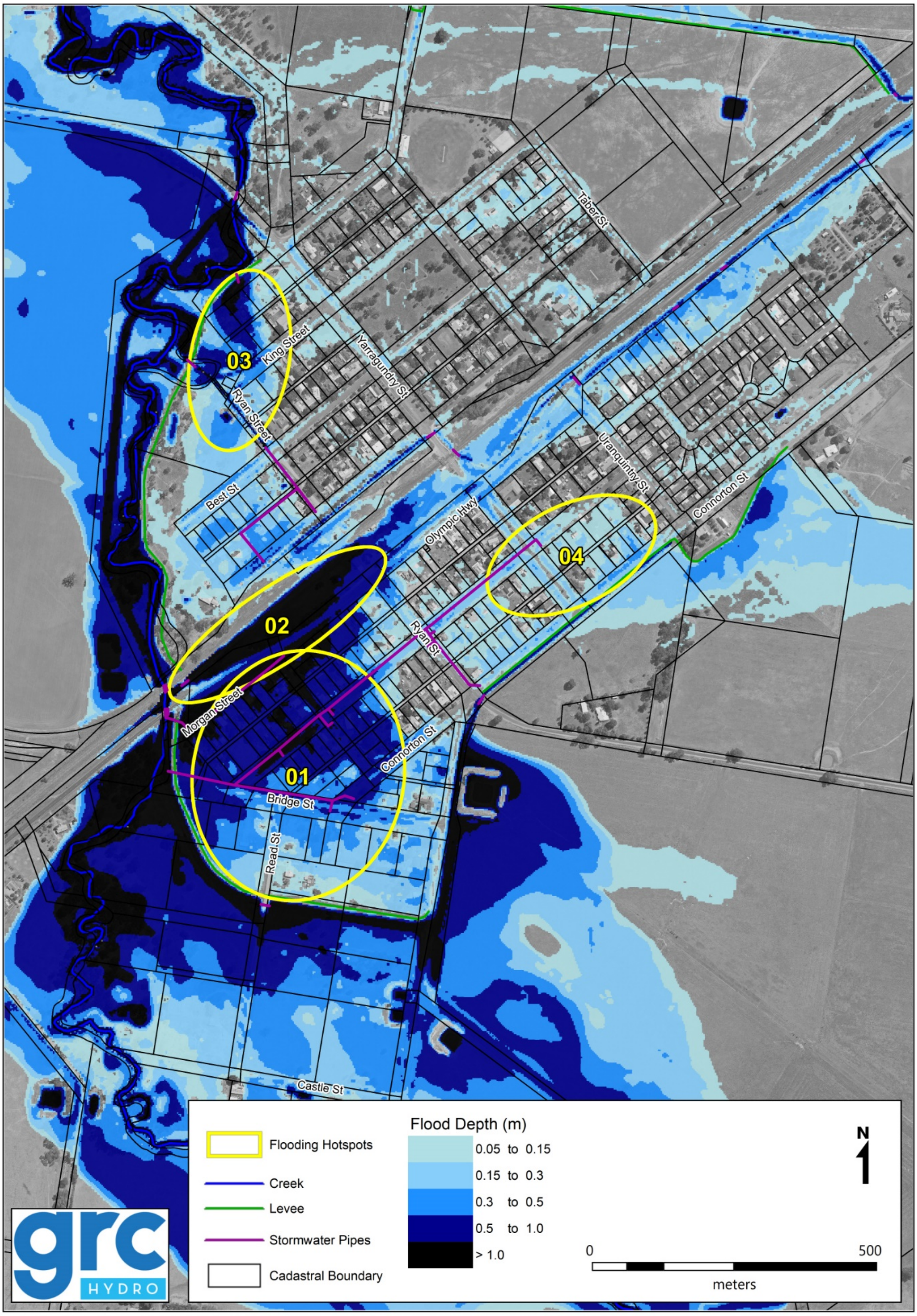



*Figure 14: Uranquinty Hotspots with 1% AEP Flood Depth*

### 6.5.1 Area near Bridge Street and Morgan Street (Hotspot 1)

The southern area of town near Bridge Street and Morgan Street is inundated by a combination of mainstream and overland flow. It can be inundated by either mechanism or by a combination of both. Overland flow typically originates from flow over the Connorton Street levee, while Sandy Creek flooding inundates the area via overtopping of Deane Street and then the town levee (south) in larger events. Flow from Connorton Street tends to flow south via O'Connor Street and the highway, with ponding then occurring on Morgan Street and the southern end of O'Connor Street. In mainstream flooding, the area is first inundated by flow from Deane Street coming as a wide flowpath the width of Deane Street, and then via overtopping of the levee between Read Street and the highway bridge. The area is drained via two mechanisms: the levee cross-drainage (see Section 6.4.1), and an overland flowpath heading north-west past the railway silos when sufficient runoff accumulates in the area and the railway line is overtopped. Flood risk in the area consists of flooding of a major road (Olympic Highway), residential streets, and numerous commercial and residential properties.

Table 24 describes the area's flood behaviour and flood risk.

*Table 24: Area near Bridge Street and Morgan Street Hotspot Description*

| Flood Risk Characteristic | Description |
|---|---|
| **Depth of flooding** | • In 5% AEP up to 0.8 m adjacent to Morgan Street, and several streets and properties with around 0.3 m depth.<br>• In 1% AEP up to 1.5 m adjacent to Morgan Street, Morgan Street, Ben Street and Bridge Street with over a 1 m depth, and adjacent properties between 0.5 m and 1.5 m flood depth. |
| **Flood Hazard** | • Mix of H1, H2 and H3 in 5% AEP<br>• Mix of H3 and H4 in 1% AEP |
| **Properties flooded above ground** | • Approximately 15 in 5% AEP<br>• Approximately 40 in 1% AEP |
| **Properties flooded above floor (approx.)** | • 1 in 5% AEP<br>• 9 in 1% AEP |
| **Evacuation** | Generally, there is rising road access towards the north-west via O'Connor Street. However, in large events (e.g. 1% AEP) the Olympic Highway is inundated and large sections of O'Connor Street and Connorton Street are significantly flooded, which inhibits evacuation. |
| **Duration** | Depending on the length of the storm event and drainage of the area, flooding likely to last several hours. Inundation behind the levee may be trapped for several days after a flood. |
| **Additional Risk Factors** | Parts of the area are in close proximity to the town levee (south) and Deane Street which will cause high velocity, high hazard flow when overtopped in large flood events. There is some risk of levee collapse or overtopping causing rapid erosion of the structure in large floods. Malfunction of the levee drainage may exacerbate flooding by either preventing drainage of the area, or allowing creek flow into the area. |
| **Gauge levels** | There is no gauge in Uranquinty. The timing of flood consequences at two hypothetical gauges is described in Section 8.4.2.3. |

### 6.5.2 Olympic Highway (Hotspot 2)

The Olympic Highway connects Wagga Wagga to Albury as well as Uranquinty and other towns to these regional centres. The highway passes directly through Uranquinty including a bridge over Sandy Creek. The highway can be cut-off by Sandy Creek floodwaters originating from of Deane Street, or by overland flow from the west and north-west of town which flow through the town before joining Sandy Creek. Flooding of the road will result in temporary closure of the highway in both directions.

Table 25 describes the road's flood behaviour and flood risk.

*Table 25: Olympic Highway Hotspot Description*

| Flood Risk Characteristic | Description |
|---|---|
| **Depth of flooding** | • In 5% AEP up to 0.2 m for a section between Ryan Street and Ben Street, and 0.1-0.2 m near Yarragundry Street from overland flow.<br>• In 1% AEP approximately 1 km of the highway is inundated, from the town side of the Sandy Creek bridge up to Uranquinty Street. In the north half of this section, the depths are around 0.2 m, while south of Ryan Street there is 0.5-1 m of flow. |
| **Flood Hazard** | • In 5% AEP, H1-H2<br>• In 1% AEP, H1-H3 |
| **Properties flooded above ground** | Not applicable |
| **Properties flooded above floor** | Not applicable |
| **Evacuation** | There is rising road access to the north-east and the south-west leading out of Uranquinty. |
| **Duration** | Depending on the length of the storm event and drainage of the area, flooding likely to last several hours. Shallow inundation may be trapped for several days after a flood. |
| **Additional Risk Factors** | Olympic Highway is the main road through Uranquinty and is also used by other towns for access to Wagga Wagga. The depth and velocity of flooding may be underestimated by motorists and would require presence of SES or local police to turn back vehicles. |
| **Gauge levels** | There is no gauge in Uranquinty. The timing of flood consequences at two hypothetical gauges is described in Section 8.4.2.3. |

### 6.5.3 Area near Ryan Street and King Street (Hotspot 3)

The area near Ryan Street and King Street on the west side of Uranquinty experiences flooding when flow from south of the highway accumulates in the area, before discharging to Sandy Creek. Flow generally originates from the drainage channel along the highway, which drains the small catchment to the north-east of town, and the overland flow from Connorton and Deane Streets (see previous sections). Flooding occurs when the drainage structures through the town levee (north) have their capacity exceeded, or a high flow in Sandy Creek prevents discharge. The structures are near the end of Ryan Street and near Uranquinty Cross Road, in large floods the lower section of the levee near Uranquinty Cross Road is overtopped by flow exiting the town. There is also risk of the town levee (north) being overtopped by Sandy Creek flooding in large events.

Table 26 describes the area's flood behaviour and flood risk.

*Table 26: Area near Ryan Street and King Street Hotspot Description*

| Flood Risk Characteristic | Description |
|---|---|
| **Depth of flooding** | • In 5% AEP up to 1 m<br>• In 1% AEP up to 1.5 m |
| **Flood Hazard** | • In 5% AEP mainly H1, areas of H2-H4<br>• In 1% AEP H1-H4 |
| **Properties flooded above ground** | • 6 in 5% AEP<br>• 10 in 1% AEP |

| | |
|---|---|
| **Properties flooded above floor (approx..)** | • 2 in 5% AEP<br>• 6 in 1% AEP |
| **Evacuation** | There is generally rising road access out of the affected area, e.g. Yarragundry Street. However, many streets will have shallow flooding during severe overland flooding. |
| **Duration** | Depending on the length of the storm event and drainage of the area, flooding likely to last several hours. Shallow inundation may be trapped for several days after a flood. |
| **Additional Risk Factors** | The area is close to the levee which will cause high velocity, high hazard flow when overtopped in large flood events. There is some risk of levee collapse or overtopping causing rapid erosion of the structure in large floods.<br>Malfunction of the levee drainage may exacerbate flooding by either preventing drainage of the area, or allowing creek flow into the area. |
| **Gauge levels** | There is no gauge in Uranquinty. The timing of flood consequences at two hypothetical gauges is described in Section 8.4.2.3. |

### 6.5.4 Area near Connorton Street and O'Connor Street (Hotspot 4)

There is a significant overland flowpath that enters the town along Connorton Street. The flowpath is generally wide (e.g. ~300 m in 1% AEP event) with shallow depths of 0.1-0.4 m. In most flood events the flowpath overtops the Connorton Street levee, causing inundation on properties of Connorton Street, O'Connor Street and the surrounding streets. The flow then drains to the Bridge/Morgan Street area, towards the highway, or in large events over the highway/railway towards Ryan/King Street area.

Table 27 describes the area's flood behaviour and flood risk.

*Table 27: Area near Connorton Street and O'Connor Street Hotspot Description*

| Flood Risk Characteristic | Description |
|---|---|
| **Depth of flooding** | • In 5% AEP up to 0.2 m, most areas 0.1 m.<br>• In 1% AEP up to 0.4 m, most areas 0.1-0.2 m. |
| **Flood Hazard** | • In 5% AEP majority is H1, small areas of H2 in kerb/gutter<br>• In 1% AEP majority is H1, small areas of H2 in kerb/gutter |
| **Properties flooded above ground** | • 17 in 5% AEP<br>• 29 in 1% AEP |
| **Properties flooded above floor (approx.)** | • 3 in 5% AEP<br>• 6 in 1% AEP |
| **Evacuation** | Generally rising road access to the north-east. Evacuation may not be required for most properties as shallow/short duration flooding. |
| **Duration** | Depending on the length of the storm event and drainage of the area, flooding likely to last one or several hours. Shallow inundation may be trapped for several days after a flood. |
| **Additional Risk Factors** | There is minimal risk of high hazard overtopping of Connorton Street levee as it is currently a low levee, however this may change if the levee is raised. |
| **Gauge levels** | Overland flow catchments are too small to use flow or level gauges. |

## 6.6 Flood Warning and Emergency Response

### 6.6.1 Existing Systems

Uranquinty currently has a limited flood warning system with information only available from rainfall gauges in neighbouring catchments. There are no official rainfall or stream gauges in the Sandy Creek catchment. Warnings for the town are therefore based on observing flooding as it occurs, high rainfall in nearby gauges (e.g. The Rock and Wagga Wagga, between 10 and 15 km from the catchment), and the rainfall radar at Wagga Wagga airport (~25 km north-west). There is no flood intelligence card as there is not a stream gauge near the town to relate the observed level in Sandy Creek to particular consequences of flooding.

Flood-related warnings are issued by the Bureau of Meteorology and the SES. The Bureau of Meteorology (BOM) generally does not issue predictions for specific flood levels (and the corresponding effects) for catchments with flash flooding. However, they do issue more general warnings include Flood Watch (covering a wide area), Severe Weather Warnings and Severe Thunderstorm Warnings. The flood intelligence reports for the 2010 and 2012 events noted the need to investigate a flood forecasting tool using a new pluviometer in the Sandy Creek catchment.

### 6.6.2 Recommendations

Recommendation for the emergency response and warning network are presented in Section 8 of this report – Sections 8.2.2, 8.3.2, 8.4.2 have measures specific to each town, and Section 8.5 has general measures. The measures include updating the Local Flood Plan and flood intelligence cards, installation of a new stream gauge and rainfall gauge (both telemetered), and flood education.

## 6.7 Economic Impact of Flooding

Section 4.7.1 describes the key concepts in how the economic impact of flooding has been estimated.

The flood damages assessment for Uranquinty estimated an Average Annual Damage of $396,861. The results of the assessment, including properties flooded above floor per design event, and corresponding cost, is presented in Table 28.

*Table 28: Uranquinty Flood Damages Summary*

| Event | No. Properties Affected | No. Flooded Above Floor Level | Total Damages for Event | % Contribution to AAD | Avg. Damage Per Flood Affected Properties ($) |
|---|---|---|---|---|---|
| **20% AEP** | 95 | 0 | $1,522,396 | 27% | $16,025 |
| **10% AEP** | 122 | 12 | $2,200,633 | 22% | $18,038 |
| **5% AEP** | 160 | 16 | $3,080,900 | 16% | $19,256 |
| **2% AEP** | 206 | 57 | $5,604,709 | 15% | $27,207 |
| **1% AEP** | 231 | 73 | $7,090,848 | 8% | $30,696 |
| **0.5% AEP** | 246 | 96 | $8,452,955 | 5% | $34,362 |
| **0.2% AEP** | 257 | 115 | $9,732,640 | 3% | $37,870 |
| **PMF** | 281 | 250 | $24,977,964 | 4% | $88,890 |
| **Average Annual Damages (AAD)** | | | **$840,988** | | **$2,993** |

The table shows that few properties in Uranquinty are flooded above floor in frequent floods (i.e. 20%-5% AEP), while around 100-150 properties are affected by flooding in these events. Flood affectation includes properties with shallow overland flow that is below floor level, which may not be registered as flooding by some residents, depending on the location, depth and duration of flow. The standard flood damages estimation includes a cost of around $10,000 for below-floor flooding, which results in large damages for frequent events (e.g. $1.5 million in 20% AEP).

In rarer events, the number flooded above floor level increases substantially, with 57 in the 2% AEP and 96 in the 0.5% AEP. There is a corresponding increase in the event damages, with $7.1 million in the 1% AEP. This is due to widespread flooding of the town due to overtopping Deane Street, Connorton Street levee, and the town levee (north and south) in rarer events. The higher

AAD in Uranquinty relative to Tarcutta and Ladysmith corresponds to the town's impacts of flooding in the 2010/2012 events.

# 7. FLOOD PLANNING AREA AND LEVEL (PM01)

The Flood Planning Area (FPA) defines properties that are subject to flood related development controls. The FPA is a key planning tool for managing and mitigating flood risk in an LGA.

The process of deriving the FPA varies depending on the dominant flood mechanism in a study area, with areas of creek flooding (also referred to as mainstream flooding) using a different approach to areas of overland flow. The Floodplain Development Manual (DIPNR, 2007) recommends the FPA be derived from the 1% AEP flood level plus 0.5 m freeboard level. This methodology has been used elsewhere in the LGA (see WMAwater on behalf of Wagga Wagga City Council, 2017) and is suitable for use in Tarcutta, Ladysmith and Uranquinty for defining the FPA in areas of mainstream flooding.

For areas affected by overland flow, the FPA is defined by the 1% AEP flood extent, with areas of minor flooding removed. Specifically, the 1% AEP flood extent is trimmed by removing areas with depth of less than 0.15 m, except for where these areas contain H5 or H6 hazard (i.e. shallow but very fast-moving and therefore hazardous flow). This extent only applies to areas outside of the mainstream flooding extent. The method was chosen to be consistent with the Wagga Wagga Major Overland Flow FRMS&P.

In summary, the FPA is an area defined by a combination of two methods:

- <u>Areas with Mainstream Flooding:</u> The 1% AEP peak flood level within the creek plus 0.5 m freeboard. This area is determined by expanding the flood extent until it is equivalent to the 1% AEP plus 0.5 m, using the ground surface data in GIS software.
- <u>Overland Flow Flooding:</u> Areas of 1% AEP flooding outside the mainstream flood extent, that have greater than 0.15 m depth, and all areas of H5 and H6 hazard, regardless of depth.

The Flood Planning Level (FPL) is then the 1% AEP level at the area of interest, plus 0.5 m. For lots affected solely by overland flooding, the FPL may be lower, depending on what is set in Council's legislation (i.e. LEP and DCP).

The FPA for Tarcutta is shown in Figure A 23, for Ladysmith in Figure B 23 and for Uranquinty in Figure C 23. For Tarcutta and Uranquinty, there are portions of the town within the mainstream FPA. This is due to the levees in both towns having less than 1% AEP level of protection. If the levees are raised to the 1% AEP level of protection, the FPA will be revised and these areas removed.

The FPA/FPL constitutes floodplain risk management measure PM01 and is referred to in the following section in the context of other property modification measures.

# 8. FLOOD RISK MITIGATION MEASURES

## 8.1 Background

Assessment of flood risk mitigation measures is one of the two key outputs of the current study, along with assessment of the villages' flood risk. Flood risk mitigation measures are broadly defined as interventions that Council or other stakeholders can implement that will reduce, or otherwise manage, the risk of flooding in each town. There is a wide range of measures that can be used to manage flood risk, from large-scale structural works (e.g. a new levee) to non-structural interventions (e.g. planning control for new development). To determine which are best suited to a particular area, the range of measures is considered and evaluated against the nature of the flood risk. Measures that are considered to have potential to reduce flood risk are then investigated further, including hydraulic and/or hydrologic modelling if appropriate. The investigation then determines whether a measure is feasible and ranks the feasible measures for implementation priority. The recommended measures are summarised in the Floodplain Risk Management Plan, including timing, responsibility and indicative costing. Costings have been based on unit rates in the 2019 Rawlinsons Construction Handbook.

Mitigation measures are chosen from three categories set out in the NSW Floodplain Development Manual (2005), as follows:

1. **Property Modification Measures** are those that modify existing properties to manage their flood risk. This includes planning-related measures such as minimum floor levels and zoning based on a locality's flood risk. They also include house raising, and in cases of high flood risk, voluntary purchase schemes.
2. **Response Modification Measures** are those that improve the ability of people to plan for and react to flood events. They often involve emergency services and can be targeted at different phases of a flood, e.g. preparation, response and recovery.
3. **Flood Modification Measures** are those that change the depth, level, flow or velocity of floodwaters, via structural measures. They are often used to exclude flow from an area (e.g. a levee bank) or to reduce the peak flow (e.g. detention basin).

All measures will have different effects for different sizes of flood. For example, measures that give benefit in the 10% AEP flood may have negligible benefit in the 1% AEP event.

Table 29 gives an overview of typical measures in each category and their advantages and disadvantages, based on the NSW Floodplain Development Manual.

*Table 29: Overview of mitigation measure types*

| | Measure | Areas of Application | Advantages | Disadvantages |
|---|---|---|---|---|
| **Property Modification** | **Land-use Planning** | Can be used in any area of development on flood-prone land but is particularly effective where new areas of development are planned. | In areas of new development, can avoid large-scale flood risk by incorporating flood risk mitigation into the development process. | Limited use when development is not planned as controls or zoning are not enforced. In such cases the measure will only be effective in the long term. Stringent controls on development may not be accepted by community. |
| | **Voluntary Purchase** | Where residential properties are exposed to high hazard flow that poses risk to life or high financial cost. | Can significantly reduce flood risk by removing people from high risk flooding. | Expensive relative to other options and requires consent of each residence. |
| | **Voluntary House Raising** | Where residential properties are exposed to low hazard and localised flow that can be avoided with higher floor levels. | Can significantly reduce cost of flooding in an area by reducing above-floor flooding. Avoids relocation of people. | Generally only suitable for low hazard flow. Not all house types are suitable for raising. |
| | **Flood Access** | Where isolation during a flood event is considered hazardous. | Can reduce risk to life by provision of access routes out of a flooded area. | Does not reduce damage to built assets. Limited to areas with isolation and access issues. |
| **Response Modification** | **Flood Education, community readiness** | Where a community's knowledge of flooding can be improved in order to reduce their flood risk. | Can equip community with best response/recovery plan for flooding, often cost-effective | Hard to ensure 100% of community is reached, limited benefit in particularly high hazard areas. |
| | **Flood Prediction and Warning** | Where rainfall and flooding in a catchment can be forecast or measured and warning sent to downstream areas. | Can be used to initiate complete evacuation or other preparation measures. | Limited use in small catchments, warnings may be misinterpreted, does not reduce risk to fixed assets (e.g. houses). |
| | **Recovery Planning** | Where recovery from a flood can be significantly improved | Designate responsibilities between agencies involved including Council, SES, community and insurers. | Focuses on the aftermath of a flood event so generally used in conjunction with other measures. |
| **Flood Modification** | **Flood Mitigation Dams** | Where a larger creek or river has available land to detain flood flow. | Can completely remove instance of common floods. | Often severe environmental impacts, requires large areas of land. |
| | **Retarding Basins** | Where an overland flowpath or small creek can be detained before it enters an urban area. | Reduces the flood peak and therefore flood levels in urban areas. | Requires large area of land, can be hazardous during a flood if a multi-use space. |
| | **Levees** | Where a creek or river can be blocked from a developed area. | Can protect against a range of floods, can be straightforward design and construction | Level of protection often overestimated, can be overtopped and fail. Often impacts properties outside the levee. |
| | **Bypass Floodways** | Where there is land available with suitable topography to create a bypass channel for a creek or river | Can reduce flooding in an urban area by diverting flow during a flood. | Requires large area of land and only suited to some floodplain topographies. May impact areas downstream. |
| | **Channel Modifications** | Where a creek or river is particularly constricted or otherwise inefficient in conveying floodwaters | Can reduce peak flood level by improving conveyance along a section of channel | Often significant impacts on environment and natural amenity. May impact areas downstream. |

As described previously, all measures have a common disadvantage of having limited benefit in extreme floods, or in floods larger than their design event. Similarly, all measures must be maintained, either physically in the case of built measures, or renewed and updated in the case of flood education, planning controls and other interventions.

Flood modification and response modification measures are presented for each town in Sections 8.2 to 8.4, while property modification options common to the three towns are presented in Section 8.6.

## 8.2 Tarcutta Flood Risk Mitigation Measures

Flood risk mitigation measures were developed based on assessment of the town's flood risk (see Section 4) as well as via community consultation and discussion with Council. Areas of high flood risk in Tarcutta are where the creek flow impacts properties. This is generally on Sydney Street near Centenary Avenue and along Centenary Avenue. The existing levee already offers some protection against flooding for these areas, so its upgrade has been suggested by Council and community members. If found to be feasible, the residual risk associated with floods greater than the levee design flood can then be treated with non-structural measures. There are also issues associated with overland flow in the town and measures for these have been investigated separately.

### 8.2.1 Tarcutta Flood Modification Measures

#### *8.2.1.1 Upgrade Existing Tarcutta Levee (TL04)*

The mitigation measure consists of upgrading and raising the existing Tarcutta levee to give protection against the 1% AEP flood event. The levee is currently overtopped in the 1% AEP event and inundates a number of properties as well as Centenary Avenue and Sydney Street – see sections 4.4 and 4.5.1 for more information. This inundation and associated flood risk warrants investigation of the costs, benefits and feasibility of upgradinging the levee. The levee is an earth embankment structure with land available on the creek side and so raising the crest level and footprint is generally feasible from a technical viewpoint. The existing levee crest varies between 229.36-230.0 mAHD and would be raised to approximately 230.8 mAHD to provide 1% AEP protection (exact height to be determined based on freeboard assessment).

The option has been assessed via model simulation of the 1% AEP event with the levee upgraded. The alignment of the raised levee and the impact on the 1% AEP flood level is shown in Figure 15.

The figure shows that upgrading and raising of the levee has a significant effect on flood affectation, with the greatest benefit at Centenary Avenue properties and a widespread adverse impact of 0.1-0.2 m in the upstream area. The upgraded levee prevents overtopping in the 1% AEP event, which results in a reduction of between 0.2 and 0.9 m in the peak flood level at Centenary Avenue properties, and 0.1-0.2 m for Sydney Street properties near the pub. The properties are not flood free due to the flooding originating behind the pub on Sydney Street (see Section 4.5.1).

The adverse impacts, which are a result of flow that previously overtopped the levee now being confined to the vicinity of the creek, are between 0.1 and 0.2 m for a large area that extends approximately 4 km upstream (not shown on the figure). The area of greatest increase (darker orange on Figure 15) does not affect any properties except for one property ('Hambledon') with impact of 0.1-0.2 m in the upstream area. Other properties in the area of impact do not have buildings in the 1% AEP flood extent.

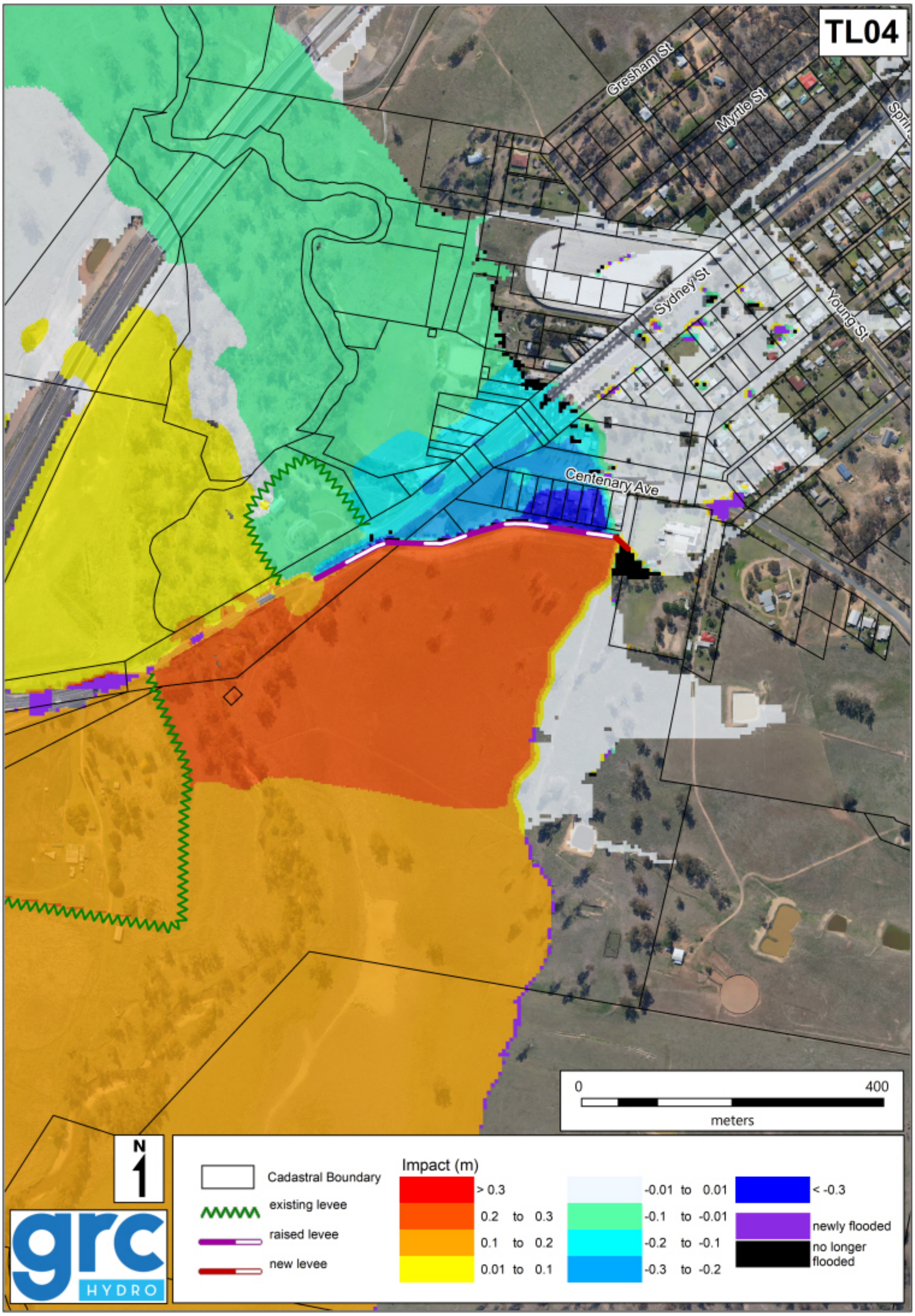



*Figure 15: 1% AEP Impact - Option TL04*

There are some very localised areas of impact (adverse and beneficial) between Sydney Street and Young Street. These are model artifacts and do not have any bearing on the option assessed.

**Further Analysis**

Based on the assessment presented above, the option warranted further analysis including its benefit in a range of floods, the impacts on visual amenity and overall flood risk, and preliminary costing and cost. The option was simulated for each design flood event and the results are presented in Table 30 below. The table shows that the option has limited benefit in common events (as the current levee is not overtopped) and extreme events (as the raised levee is still overtopped). The greatest benefit is in the 1% and 0.5% AEP events, when around 5 properties are no longer flooded above floor and there is a saving of approximately $290,000 in flood damages. The reduction in AAD ($4,610) is small relative to other levee projects of this scale

*Table 30: Option TL04, Reduction in Damages and Above-Floor Flooding*

| Event | Reduction in Properties Flooded Above Floor | Reduction in Event Damages |
|---|---|---|
| 20% AEP | 0 | - |
| 10% AEP | 0 | - |
| 5% AEP | 0 | - |
| 2% AEP | 1 | $42,483 |
| 1% AEP | 5 | $222,863 |
| 0.5% AEP | 4 | $292,175 |
| 0.2% AEP | 2 | $287,443 |
| PMF | 2 | $204,101 |
| | **Average Annual Damage Reduction** | $4,610 |

The impact on visual amenity is estimated to be significant but not a major constraint in raising the levee. As described, the levee would be approximately 0.8-1.0 m higher than its current height (assuming a freeboard of 0.5 m – actual freeboard would depend on detailed assessment). The levee currently obstructs the view of the properties on Centenary Avenue and this view would be further reduced with a raised levee. Feedback on the option will be sought from residents during public exhibition of this study. The option does not have significant social or environmental impacts as it involves modification to an existing structure and will have no impact on the normal functioning of the creek. A typical cross-section and a visualisation of an upgraded section is presented in Figure 16 below.

East end (left) and west end (right) of levee with crest in yellow and approximate additional height in yellow dashed

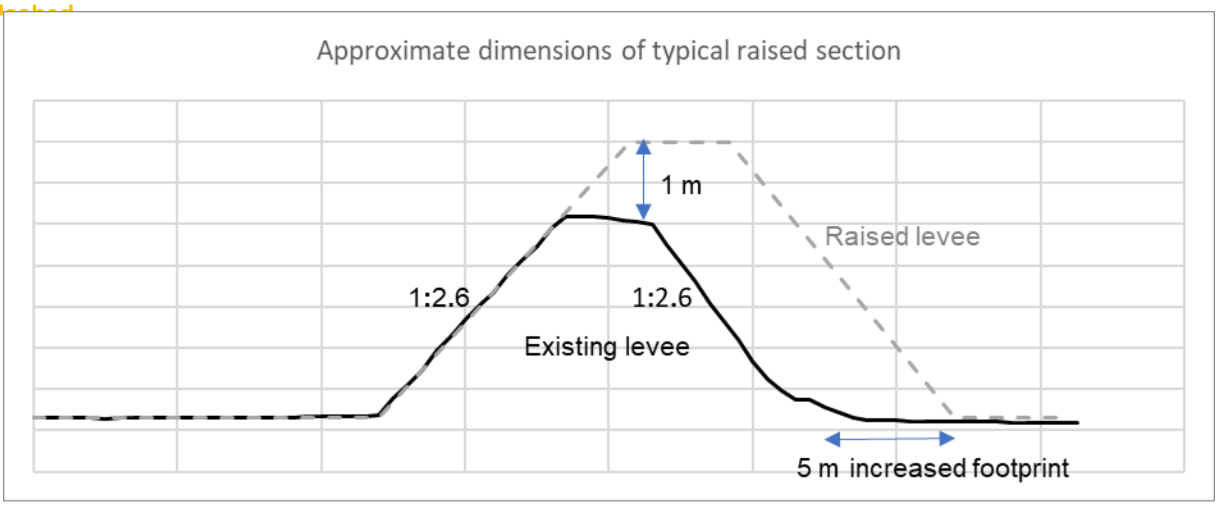



*Figure 16: Approximate TL04 Levee Height and Cross-Section*

A preliminary cost estimate for the option is presented in Table 31 and the detailed costing is in Appendix E.

*Table 31: Option TL04 Cost Estimate*

| Item | Cost Estimate |
|---|---|
| Detailed Survey and design | $105,000 |
| Contractor setup and project management | $25,000 |
| Excavation and compaction of fill | $130,546 |
| **Total (inc. GST)** | $276,601 |
| Cost estimate is only approximate, for the purposes of economic analysis of the option. It is based on approximately 413 m of levee raised by an average of 0.83 m. | |

The option's reduction in Average Annual Damages, the Net Present Value (NPV) of this reduction (assuming 50 year design life and 7% discount rate) and the benefit-cost ratio are presented below.

- Average Annual Damage Reduction: $4,610
- NPV of reduction: $68,076
- Cost estimate of option: $276,601
- Benefit-cost ratio: 0.2

The benefit-cost ratio is 0.2, meaning its cost is around five times the value of its expected benefit and it is not justified on economic grounds alone. Overall, the option does not have significant technical constraints, but it provides limited benefit in the design event (1% AEP) as it does not prevent flooding of the area from the direction of Sydney Road. It is therefore only worth consideration if a larger levee (see following option) is found to not be feasible. It involves adverse impact at one upstream dwelling and hence the option is dependent on successful negotiation with the landowner. The overall comparison of the Tarcutta options is presented in Section 8.7.

#### *8.2.1.2 Upgrade Existing Tarcutta Levee and New Oval Levee (TL06)*

The mitigation measure consists of upgrading and raising the existing Tarcutta levee and construction of a second section of levee on the east side of the oval. As described in Section 4.4, the Tarcutta levee currently offers reduced protection as Centenary Avenue is also flooded from the direction of Sydney Street. This issue was found to still be present when the existing levee is raised (see previous section). Besides Centenary Avenue, an additional levee section would also potentially benefit properties along Sydney Street and the inundation of the road itself.

The levee would likely be an earth embankment structure, but the structure type and precise alignment have not been assessed. The existing levee crest varies between 229.36-230.0 mAHD and would be raised to approximately 230.8 mAHD to provide 1% AEP protection (exact height to be determined based on freeboard assessment) and the section of new levee would be 0.8-2.1 m above existing ground (assuming 0.5 m freeboard).

The option has been assessed via model simulation of the 1% AEP event with the existing levee raised and the new section included. The alignment of the two sections and the impact on the 1% AEP flood level is shown in Figure 17.

The figure shows that raising of the levee combined with a new levee has a significant effect on flood affectation, with a large, widespread benefit from Centenary Avenue and across Sydney Street to the service station area. The properties are effectively flood free save for shallow overland flooding (hence the figure not showing the area as ‘No Longer Flooded’), as the levees block all creek flooding from entering the town. This is a reduction of 0.5-1.2 m in the town’s flood depth in the 1% AEP and corresponds to a large reduction in above-floor property flooding.

As with the previous measure (TL04), the adverse impacts, which are a result of flow that previously overtopped the levee now being confined to the vicinity of the creek, are between 0.1 and 0.2 m for a large area that extends approximately 4 km upstream (not shown on the figure). The area of greatest increase (darker orange on Figure 17) does not affect any properties but there is 1 property (‘Hambledon’) with impact of 0.1-0.2 m in the upstream area. Other properties in the area of impact do not have buildings in the 1% AEP flood extent.

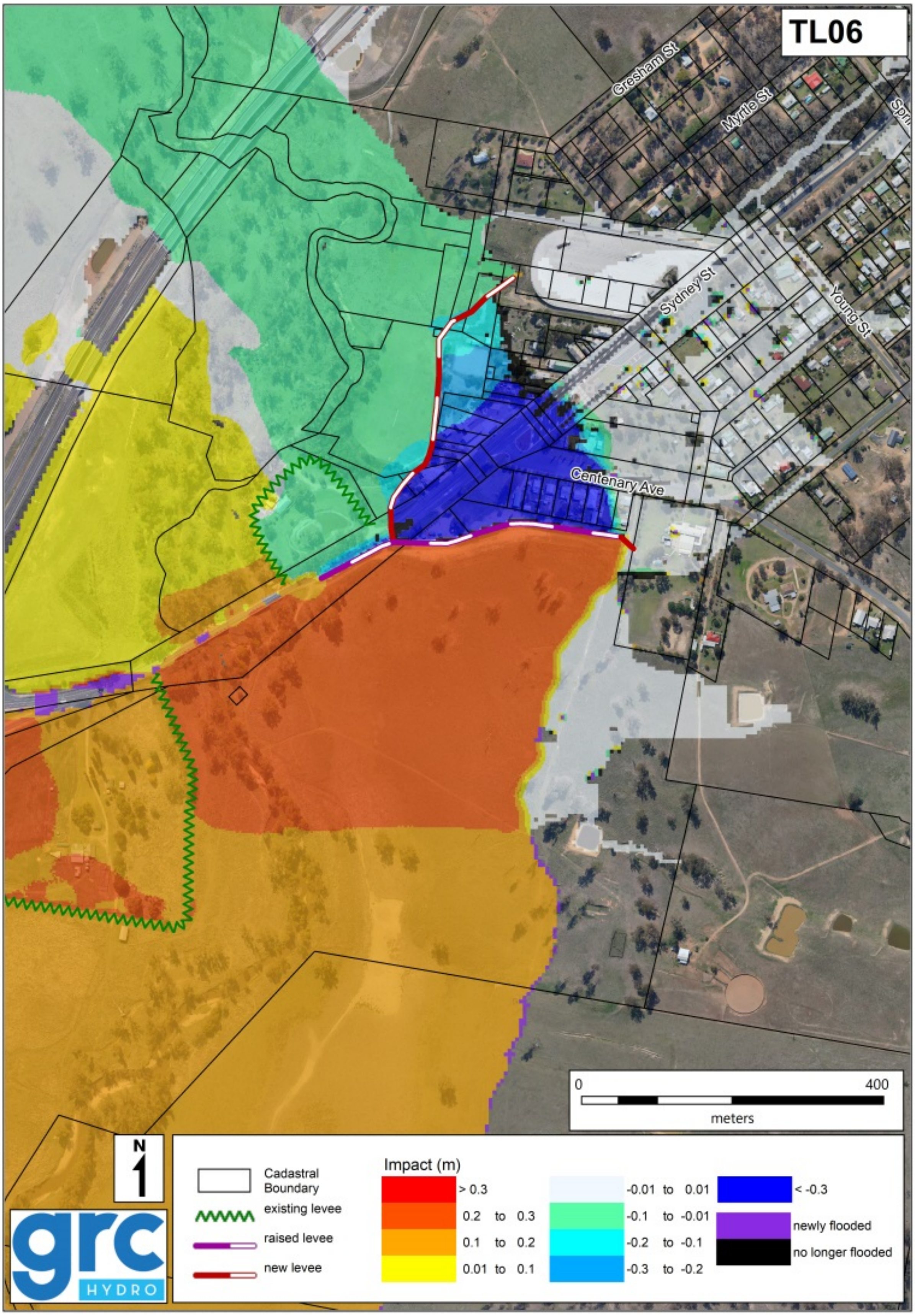



*Figure 17: 1% AEP Impact - Option TL04*

**Further Analysis**

Based on the assessment presented above, the option warranted further analysis including its benefit in a range of floods, the impacts on visual amenity and overall flood risk, and preliminary costing and cost. The option was simulated for each design flood event and the results are presented in Table 30 below. The table shows that the option has limited benefit in common events (as the current levee is not overtopped) and extreme events (as the raised levee is still overtopped). The greatest benefit is in the 1% AEP event, when around 5 properties are no longer flooded above floor and there is a saving of approximately $360,000 in flood damages. The reduction in AAD ($8,016) is small relative to other levee projects of this scale.

It is worth comparing the option to TL04, which has a similar effect. The most notable difference is that it has less benefit in events greater than 1% AEP, compared to TL04 (raising the existing levee). This is because the area the levee protects becomes a significant flow area of the floodplain in very large floods, and having two large structures obstructing this flow (which are both overtopped) leads to higher flood levels than a single structure (i.e. the existing levee).

*Table 32: Option TL06, Reduction in Damages and Above-Floor Flooding*

| Event | Reduction in Properties Flooded Above Floor | Reduction in Event Damages |
|---|---|---|
| 20% AEP | 0 | - |
| 10% AEP | 0 | - |
| 5% AEP | 1 | $41,587 |
| 2% AEP | 3 | $108,141 |
| 1% AEP | 6 | $361,416 |
| 0.5% AEP | 2 | $228,468 |
| 0.2% AEP | 0 | $145,247 |
| PMF | 2 | $204,101 |
| | **Average Annual Damage Reduction** | $8,016 |

The impact on visual amenity is estimated to be significant and may possibly be a major constraint in building the levee. As described, the levee would be approximately 0.8-2.1 m higher than the existing ground level (assuming a freeboard of 0.5 m – actual freeboard would depend on detailed assessment). The visual impact of raising the existing levee is discussed in the previous option. For the new section, the oval and creek area would no longer be visible from some locations, and access would be impeded.  A section of the levee could use a sliding gate to maintain road/pedestrian access. There may be community opposition to a new levee for these reasons and as such feedback should be sought during public exhibition.  A typical cross-section and a visualisation of a raised area is presented in Figure 16 below.

Potential siting and indicative height (in red) of new levee section adjacent to the oval.

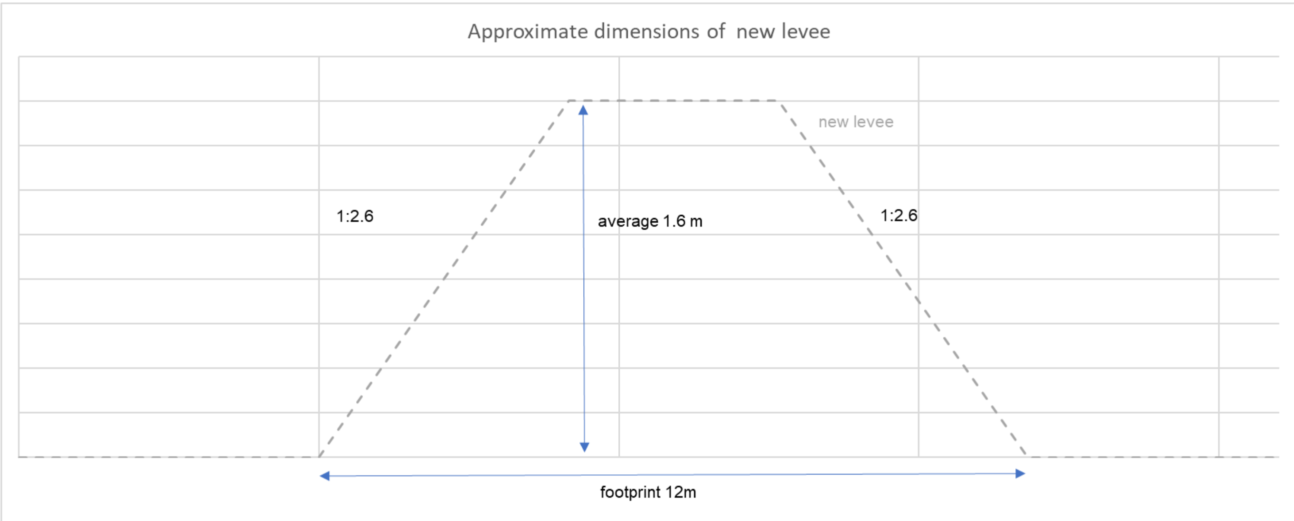



*Figure 18: Approximate TL06 Levee Height and Cross-Section*

A preliminary cost estimate for the option is presented in Table 33 and the detailed costing is in Appendix E.

*Table 33: Option TL06 Cost Estimate*

| Item | Cost Estimate |
|---|---|
| Detailed Survey and detailed design study | $110,000 |
| Contractor setup and project management | $35,000 |
| Construction (Excavation and compaction of fill, drainage pipes) | $353,053 |
| **Total (inc. GST)** | $536,839 |
| Cost estimate is only approximate, for the purposes of economic analysis of the option. It is based on approximately 850 m of levee raised by an average of 1.3 m. | |

The option's reduction in Average Annual Damages, the Net Present Value (NPV) of this reduction (assuming 50 year design life and 7% discount rate) and the benefit-cost ratio are presented below.

- Average Annual Damage Reduction: $8,016
- NPV of reduction: $118,374
- Cost estimate of option: $536,839
- Benefit-cost ratio: 0.2

The benefit-cost ratio is 0.2, meaning its cost is around five times the value of its expected benefit and it is not justified on economic grounds alone. Overall, the option does not have significant technical constraints, but relative to the size of the levee structure (~1 km) there are relatively few properties benefited (around 14). There is also limited benefit in events larger than the 1% AEP when the levee is overtopped.

In the context of the previous option (upgrade of existing levee only), the levee is slightly less feasible on economic grounds, and it has a substantially higher cost estimate. As with the previous option, a new levee involves adverse impact at one upstream dwelling and hence the option is dependent on successful negotiation with the landowner. Despite these drawbacks, these are the only two levee measures that can provide protection to the area, so if neither are adopted then the area will rely on planning and response modification measures. At this stage it is not recommended to build either levee, however, this can be revised based on Council feedback and if there is significant political and community support for a levee.

#### *8.2.1.3 Reduction in Hambledon Levee Extent (TL02)*

The mitigation measure consists of reducing the footprint of the existing Hambledon levee. As described in Section 4.5.3, the Hambledon levee currently protects the Hambledon property and is a private levee. Modelling of design events indicates the levee restricts flow on a large portion of the floodplain and the flood affectation of nearby properties may potentially be improved if the levee is reduced in size.

The option has been assessed via model simulation of the 1% AEP event with the current Hambledon levee removed and a new, smaller levee built. The removed levee and new levee, as well as the impact on the 1% AEP flood level, is shown in Figure 19.

The figure shows that there is minimal reduction in the peak 1% AEP flood level as a result of reducing the levee's extent. Areas of reduction that are of benefit to the town's flooding are confined to the Sydney Street/Centenary Avenue area, where the flood level is 0.01-0.1 m lower compared to the existing case. There is a small reduction in the flood level across the rest of the floodplain but it is less than 0.01 m. This indicates the Hambledon property acts largely as flood storage and so impeding its conveyance has minimal effect on the floodplain's function.

The figure does not indicate the increased flood risk at the Hambledon property as a result of the reduce levee. The larger footprint of the existing levee is considered to have generally lower risk than a more localised levee around only the residential buildings, due to evacuation constraints and potential effects of failure of the levee. This increase in flood risk is unlikely to be considered as worth the trade-off of marginally improved flood affectation at Centenary Ave/Sydney St.

**Recommendation:** The option is not pursued further due to minimal benefit in the 1% AEP event and increased flood risk at the Hambledon property.

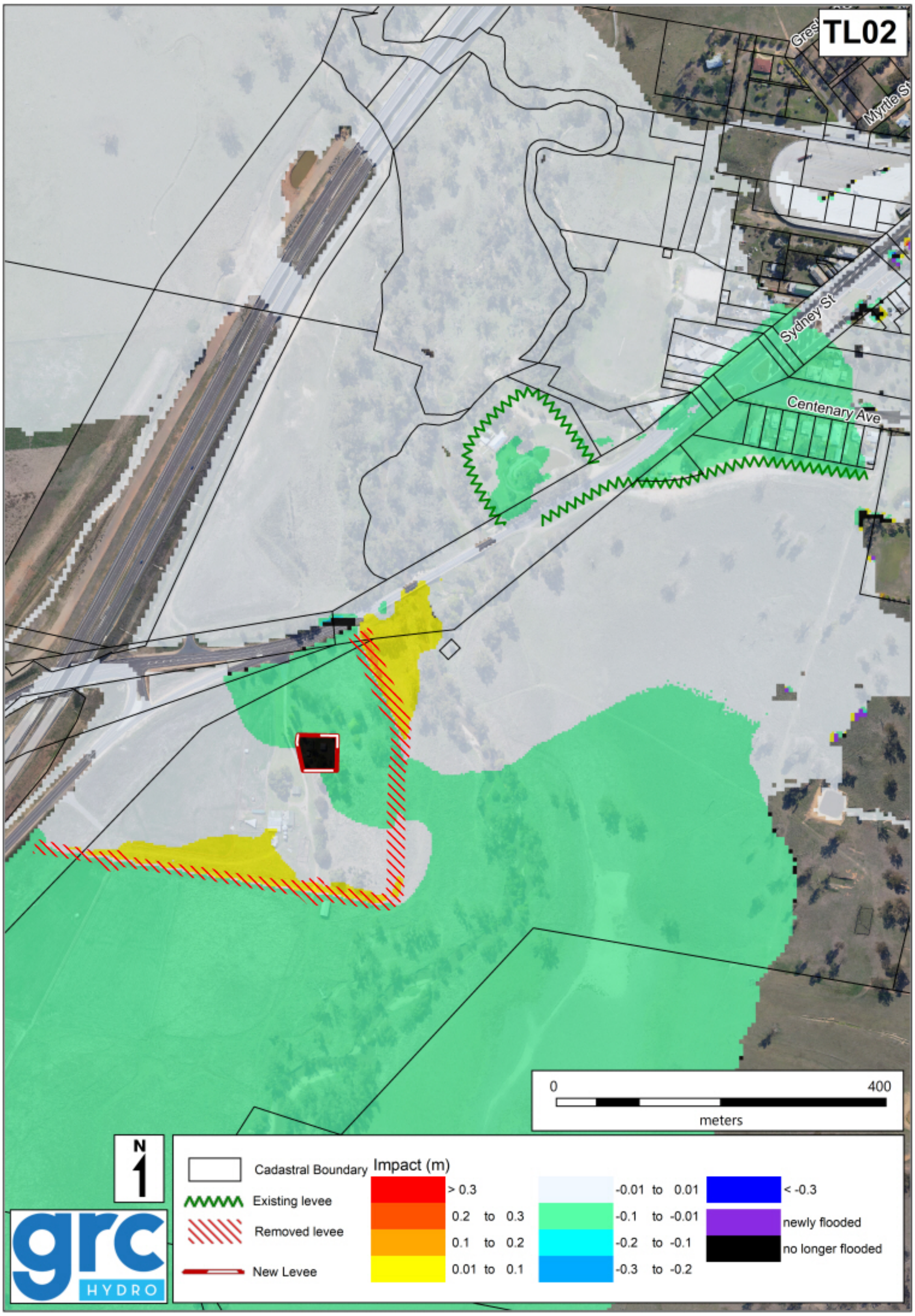



*Figure 19: 1% AEP Impact - Option TL02*

#### 8.2.1.4 Improved Drainage near Young Street (TK01)

The mitigation measure consists of a kerb/gutter on the laneway between Argent and Cynthia Streets in Tarcutta, near Young Street. There is an overland flowpath that flows west from Argent Street towards the intersection of Cynthia and Young Streets, which has caused erosion and flooding of Cynthia Street properties in heavy rainfall events. Fencing along the laneway has been amended to try to divert the flow towards Young Street, to limited success. Modelling indicates the flowpath has a peak flow of 0.2 $m^3/s$ in the 20% AEP.

The option has been assessed via model simulation of the 20% AEP event with a large gutter in the laneway, approximately 0.3 m deep and 0.5 m wide. The model resolution is not suited to fine-scale stormwater features and so flow was also obstructed from entering the lots. The location of the gutter, as well as the impact on the 20% AEP flood level, is shown in Figure 20.

The figure shows that while the flowpath can be diverted towards Young Street, there is significant adverse impacts in the downstream areas (yellow and purple areas on Figure 20). The lack of well-defined flowpath through this area of Tarcutta means that a slight re-distribution of flow (0.2 $m^3/s$ in this case) can easily create newly flooded areas. Streets are generally not aligned with the natural flow direction and so this means the kerb-gutter system does not convey the majority of flow in a flooding event.

The option cannot be recommended due to the adverse impacts. It is recommended local drainage improvements on private property be considered, for example a lined swale along the current flowpath. This type of works is not included in the scope of the current study or the floodplain risk management program.

**Recommendation:** The option is not recommended in the Floodplain Risk Management Plan due to adverse impacts in downstream areas.

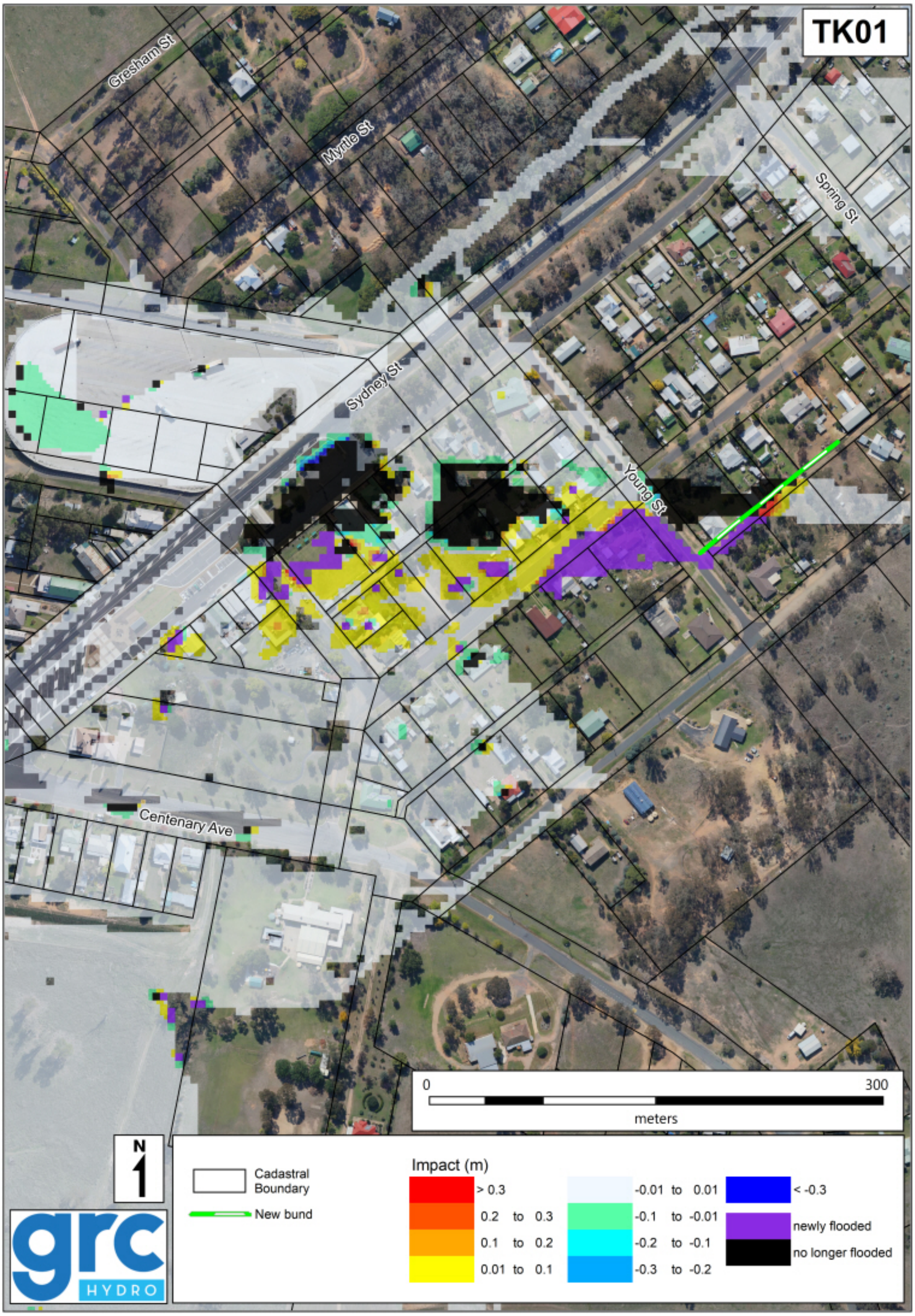



*Figure 20: 20% AEP Impact - Option TK01*

#### 8.2.1.5 Maintenance of Levee Cross-Drainage for Tarcutta (TD01)

This mitigation measure consists of improving the cross-drainage structure in the Tarcutta levee. In recent floods the hinged floodgate has been stuck open which lead to flooding near Centenary Avenue. There is also a risk of overland flooding ponding and prevented from discharging due to blockage of the culvert or a high creek level.

It is recommended that Council oversee a maintenance program where the long grass at either end of the culvert is cut back periodically, and the culvert is cleared of sediment or other blockage. The hinge structure on the downstream end should also be tested periodically. To plan for the incidence of coincident overland flow and Tarcutta Creek flooding, the SES should own and maintain a collection of mobile pumps that can be used in flood events.

The option has not been modelled as the design flood modelling assumes the cross-drainage is functioning. However, from recent floods it is well-understood that if the drainage malfunctions significant flooding can occur on Centenary Avenue, beginning at the water treatment plan. The cost of a maintenance program is expected to be significantly less than its expected benefit

**Recommendation**: The option is recommended via the draft Floodplain Risk Management Plan.

### 8.2.2 Tarcutta Response Modification Measures

There is potential to improve the response during and after a flood in Tarcutta, by drawing on lessons from the 2010 and 2012 flood events, and the design flood event modelling produced by the current study. The existing flood warning system is described in detail in Section 4.6.1, and the response during the two recent floods is described in Bewsher Consulting, 2012 and Yeo, 2013. Response measures are set out in the following section and then further measures that are applicable to all three towns are described in Section 8.5.

#### 8.2.2.1 Update the Tarcutta section of the Wagga Wagga Local Flood Plan (RM01)

The Wagga Wagga Local Flood Plan is the primary record of the consequences of different sized floods in Tarcutta and of the responsibilities and actions corresponding to the effects of flooding. The information it currently contains for Tarcutta and the other two towns is summarised in Section 2.3.4. It is recommended that information from the recent floods in 2010 and 2012, and the findings of the current study, be used to update the Tarcutta section. The following updates are recommended:

1. Update the Plan with the recommended changes from the 2010 event's Flood Intelligence Collection and Review (Bewsher Consulting, 2012), which were subsequently drafted for the Local Flood Plan following the 2012 flood event. Volume 2 of the "Flood Intelligence Collection and Review for 24 Towns and Villages in the Murray and Murrumbidgee Regions" (Dr. Stephen Yeo, 2013) contains the new draft Plan contents. The proposed updates are to Annex A (The Flood Threat), Annex B (Effects of Flooding on the Community), Annex C (Gauges Monitored) and Annex I (Tarcutta Sector Evacuation).
2. In addition to those changes, incorporate findings from the current study and the flood study. In Annex A, describe the level of protection of the various levees based on information presented in Section 4.4 of this report. In the same section and in Annex B, add description of the areas of hazardous flooding, and the number of properties flooded, in the flooding hotspots described in Section 4.5 of this report. The information in Table 16 to Table 19 summarises the key information for each hotspot and relevant parts can be copied into the Local Flood Plan.

#### 8.2.2.2 Update the Intelligence Card for the Tarcutta Creek manual gauge at the town (RM02)

There is a flood intelligence card for the Tarcutta Creek manual gauge at the town that is recommended to be updated with information from the current study and from the 2010 and 2012 events. Being located within the town, readings at the gauge itself give negligible advance warning of mainstream flooding. However, it provides information on what flood consequences occur at different gauge heights, and when linked to the height at upstream gauges, provides warning for these consequences.

The observed consequences of the 2010 and 2012 floods should be added to the card (if they aren't already so). These changes to the card have been drafted by Dr. Stephen Yeo (2013) (see page 19-15 of that document, pdf page 108 of Volume 1, part 3). **It is noted that the model results differ slightly to the observed gauge height at which levee overtopping occurs.** Dr. Stephen Yeo (2013) states that the 2012 flood peaked at 3.86 m at the gauge, and the levee was observed as being very close to overtopped, hence the levee crest was stated to be equivalent to a gauge level of 3.90 m. The model results indicate the levee is overtopped at 4.10 m (0.2 m higher). There is not a clear explanation for the difference, but a likely cause is that Sydney Street bridge experienced blockage or other effect that increased the structure losses. Notwithstanding the above it is not recommended to supersede the levee overtopping level on the flood intelligence card.

Additional information that can be added to the card, based on the current study modelling of design flood events, is as follows:

*Table 34: Information for Tarcutta Flood Intelligence Card*

| Class | Height (m) | Consequences |
|---|---|---|
| | 3.12 | 20% AEP flood event |
| | 3.62 | 10% AEP flood event |
| | 4.02 | 5% AEP flood event |
| | 4.42 | 2% AEP flood event |
| | 4.62 | 1% AEP flood event |
| | 4.72 | 0.5% AEP flood event |
| | 5.02 | 0.2% AEP flood event |
| | 11.12 | Probable Maximum Flood (PMF) |
| | 3.27 | Old Tarcutta Inn levee first overtopped |
| | 4.01 | 'Hambledon' levee first overtopped. |
| | 4.06 | Sydney Road first overtopped from pub side with flow in the direction of Centenary Avenue |

#### *8.2.2.3 Install an automatic water level recorder on Umbango Creek (RM03)*

Reporting of the 2010 and 2012 floods refers to the need for improved warning for flooding at Tarcutta, via installation of an automatic water level recorder on Umbango Creek. As per Bewsher Consulting, 2012, flooding at Tarcutta can occur due to flooding from one or more of the upstream subcatchments of Oberne, Umbango and Keajura Creeks, and this means there is not a strong correlation between the Belmore Bridge gauge (on Oberne Creek) and the Tarcutta depth marker. Dr. Stephen Yeo (2013) also refers to the Belmore Bridge peak flood level occurring after the peak at Tarcutta, limiting its use as a warning system in some events. Given the large size of the Umbango catchment (586 $km^2$ versus 604 $km^2$ for Oberne Creek), a water level recorder on Umbango Creek would significantly improve the warning system. It would be incorporated into the Bureau of Meteorology's Murrumbidgee flood warning system. To provide a similar warning time and upstream catchment area as the Belmore Bridge gauge, the new gauge should be located between the town of Humula and the creek's confluence with Murraguldrie Creek (see Figure 21).

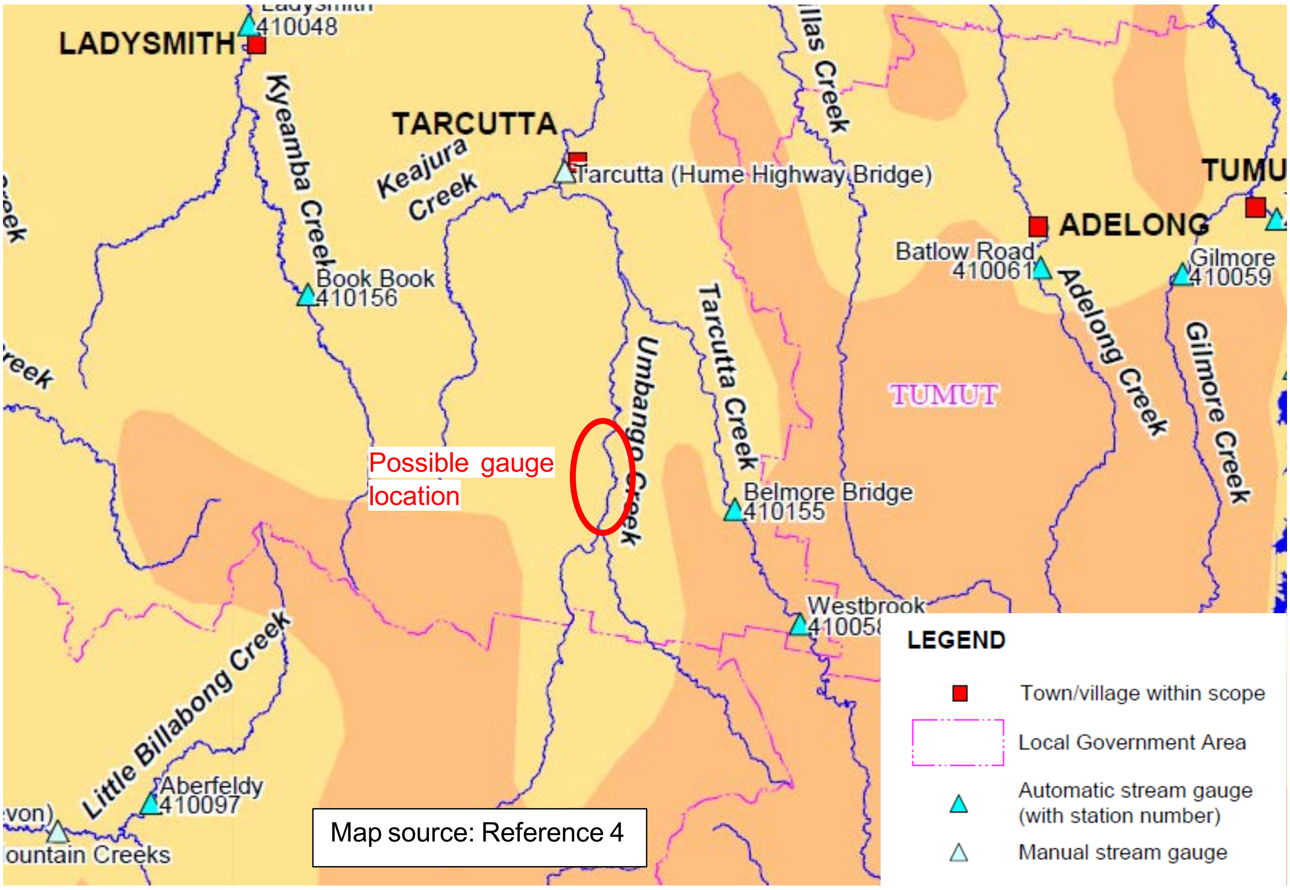



*Figure 21: Approximate location new gauge*

## 8.3 Ladysmith Flood Risk Mitigation Measures

Flood risk mitigation measures were developed based on assessment of the town's flood risk (see Section 5) as well as via community consultation and discussion with Council. There are limited areas of high flood risk in most flood events in Ladysmith. Recent floods in 2010 and 2012 mainly affected roads and properties outside of the town. Mitigation measures have not been investigated for individual properties outside of town. There are also issues associated with overland flow in the town and one measure has been assessed in relation to this.

### 8.3.1 Ladysmith Flood Modification Measures

#### *8.3.1.1 Improved Drainage on Cunningdroo Street (LK01)*

The mitigation measure consists of a small swale (or kerb/gutter) on the north end of Cunningdroo Street in Ladysmith. There is an overland flowpath that flows towards Cunningdroo Street from Tarcutta Street, and which has been reported to cause ponding of flow on the north end of Cunningdroo Street in heavy rainfall events. The open space north and west of the Cunningdroo cul-de-sac provide an opportunity to improve drainage from the cul-de-sac.

The option has been assessed via model simulation of the 20% AEP event with a new gutter on either side of the street, approximately 0.3 m deep and 0.5 m wide (similar to other gutters). The location of the gutter, as well as the impact on the 20% AEP flood level, is shown in Figure 22.

The figure shows that there is significant improvement to the area's drainage in the 20% AEP flood. The figure shows a localised reduction of ~0.1 m and an area that is no longer flooded adjacent to the gutters. Although the flow drained to the north results in a small adverse impact of less than 0.1 m, this is considered acceptable as no assets or property are affected.

The option does not have any apparent disadvantages and should be implemented by Council in the short-term. It does not warrant further investigation as the change in flood behaviour is minor and the option cannot be justified via cost-benefit analysis (as there is minor quantifiable damage in the existing case).

**Recommendation**: The option is recommended via the draft Floodplain Risk Management Plan.

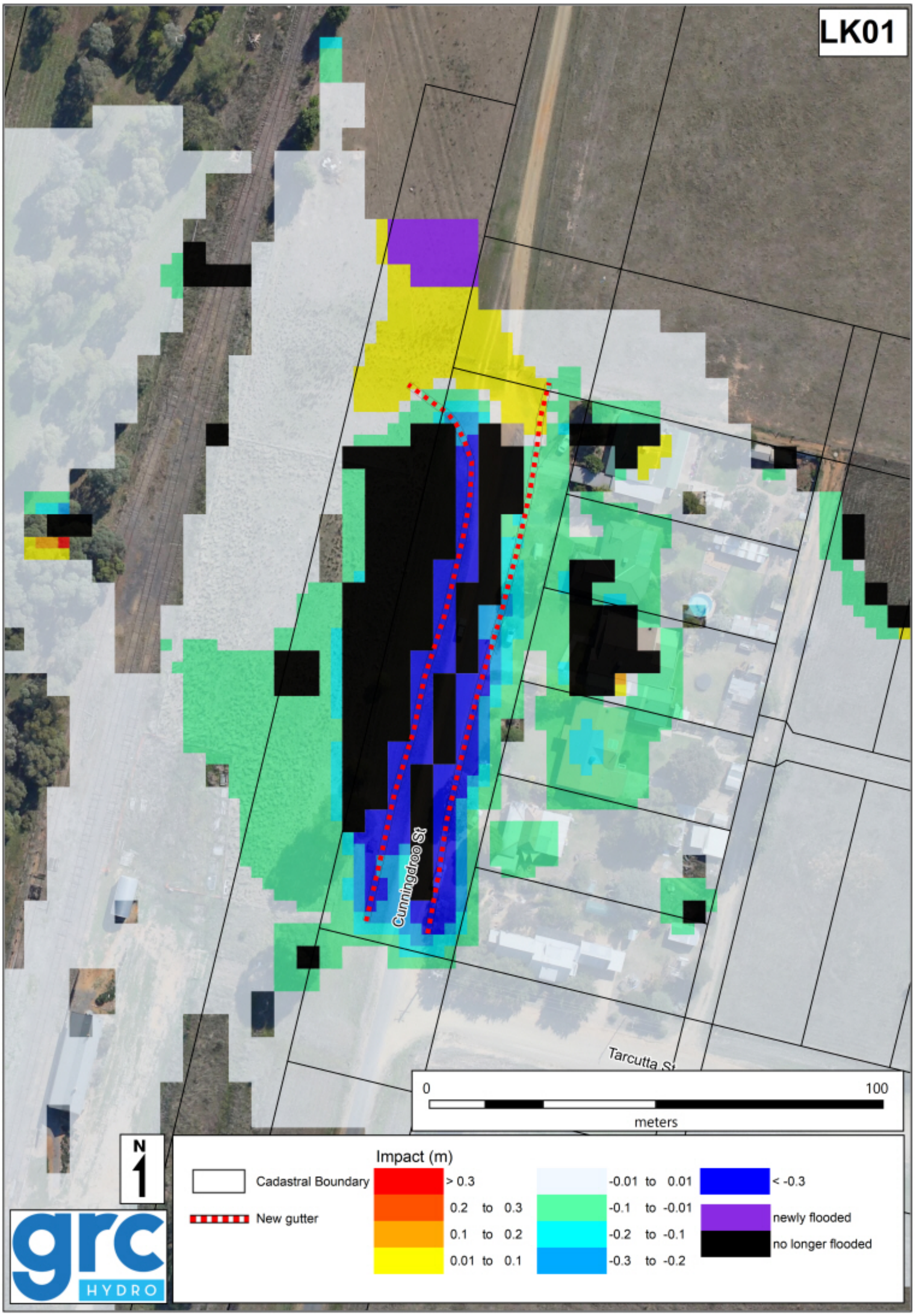



*Figure 22: 20% AEP Impact - Option LK01*

## 8.3.2 Ladysmith Response Modification Measures

There is limited potential to improve the response during and after a flood in the town of Ladysmith, as limited flooding occurs in most events in the town. However, the experience from recent flood events can be used to update the relevant sections of the Local Flood Plan and the Flood Intelligence Card, as well as from design event modelling and the findings of this study. Response measures are set out in the following section and then further measures that are applicable to all three towns are described in Section 8.5.

### *8.3.2.1 Update the Ladysmith section of the Wagga Wagga Local Flood Plan (RM04)*

The Wagga Wagga Local Flood Plan is the primary record of the consequences of different sized floods in Ladysmith. The information it currently contains for Ladysmith and the other two towns is summarised in Section 2.3.4. It is recommended that information from the recent floods in 2010 and 2012, and the findings of the current study, be used to update the Ladysmith section. Most information pertains to flooding outside the town and this report's study area. The following updates are recommended:

1. Update the Plan with the recommended changes from the 2010 event's Flood Intelligence Collection and Review (Bewsher Consulting, 2012), which were subsequently drafted for the Local Flood Plan following the 2012 flood event. Volume 2 of the "Flood Intelligence Collection and Review for 24 Towns and Villages in the Murray and Murrumbidgee Regions" (Dr. Stephen Yeo, 2013) contains the new draft Plan contents. The proposed updates are to Annex A (The Flood Threat), Annex B (Effects of Flooding on the Community), Annex C (Gauges Monitored) and Annex K (Ladysmith Sector Evacuation).
2. In addition to those changes, incorporate findings from the current study and the flood study. In Annex B, add description of the areas of hazardous flooding, and the number of properties flooded, in the flooding hotspots described in Section 5.4 of this report. The information in Table 21 summarises the key information for the Ladysmith hotspot and relevant parts can be copied into the Local Flood Plan.

### *8.3.2.2 Update the Intelligence Card for the Kyeamba Creek at Ladysmith gauge (RM05)*

There is a flood intelligence card for the Kyeamba Creek at Ladysmith gauge at the town that is recommended to be updated with information from the current study and from the 2010 and 2012 events. Observed consequences from the previous floods have been drafted by Dr. Stephen Yeo (2013) (see page 20-8 of that document, pdf page 117 of Volume 1, part 3).

Additional information that can be added to the card, based on the current study modelling of design flood events, as follows:

*Table 35: Information for Ladysmith Flood Intelligence Card*

| Class | Height (m) | Consequences |
|---|---|---|
| | 5.70 | 20% AEP flood event |
| | 6.20 | 10% AEP flood event – Western portion of the school site flooded (approx. 20% of site). |
| | 6.59 | 5% AEP flood event |
| | 7.02 | 2% AEP flood event - Western portion of the school site flooded (approx. 30% of site). |
| | 7.17 | 1% AEP flood event – most of school site flooded, including buildings. |
| | 7.31 | 0.5% AEP flood event |
| | 7.46 | 0.2% AEP flood event |
| | 11.41 | Probable Maximum Flood (PMF) - Most of town that is west of the railway is severely flooded |

## 8.4 Uranquinty Flood Risk Mitigation Measures

Flood risk mitigation measures were developed based on assessment of the town's flood risk (see Section 6) as well as via community consultation and discussion with Council. Areas of high flood risk in Uranquinty are where the creek flow enters the town in the southern portion of town, and the overland flowpath that crosses Connorton Street and eventually drains through the levee near Ryan and King streets (town levee, north). The existing town levee (north and south) already offers some protection against flooding for these areas, and its upgrade has been suggested by Council and community members. If found to be feasible, the residual risk associated with floods greater than the levee design flood can then be treated with non-structural measures. The bypass floodway built to complement the levee system has also been investigated for upgrade. The efficiency of the creek channel near the highway/railway crossing has also been investigated, as has cross-drainage in the levee.

### 8.4.1 Uranquinty Flood Modification Measures

#### *8.4.1.1 Uranquinty Levee System Upgrade (UL01)*

The mitigation measure consists of upgrading and raising all sections of the existing Uranquinty levee, from Connorton Street around to Uranquinty Cross Road, as well as Churches Plain Road levee, to give protection against the 1% AEP flood event. The levee is currently overtopped in the 1% AEP event at a number of points and inundates a number of properties – see section 6.4 for more information. This inundation and associated flood risk warrants investigation of the costs, benefits and feasibility of upgrading and raising the levee.

The levee is an earth embankment structure with land available on the creek side, and east of Connorton Street, and so raising the crest level and footprint is generally feasible from a technical viewpoint. The existing levee crest varies between 197.0-211.6 mAHD and would be raised with 0.1-1.7m to provide 1% AEP protection (exact height to be determined based on freeboard assessment).

The option has been assessed via model simulation of the 1% AEP event with the levee raised. The alignment of the raised levee and the impact on the 1% AEP flood level is shown in Figure 23 for creek flooding and Figure 24 for overland flow.

The figure shows that raising of the levee has a significant effect on flood affectation, with the greatest benefit across the southern half of Uranquinty and a widespread adverse impact of 0.1-0.2 m in the upstream area. The upgraded levee prevents overtopping in the 1% AEP event, including the Connorton Street and Deane Street sections which were overtopped in recent floods, and this results in large areas of the town being no longer flooded. Parts of the town are still flooded due to shallow overland flow from within the town and to the north-east.

The adverse impacts, which are a result of flow that previously overtopped the levee now being confined to the creek's floodplain, are between 0.1 and 0.2 m for a large area that extends approximately 500 m upstream. The area of greatest increase (orange on Figure 23 and Figure 24) affects one property's buildings on Olympic Highway. The building is on the very edge of the flood extent and so the option has been modelled with a small levee at that location, which would require feedback from the property owner. Other properties in the area of impact do not have buildings in the 1% AEP flood extent.

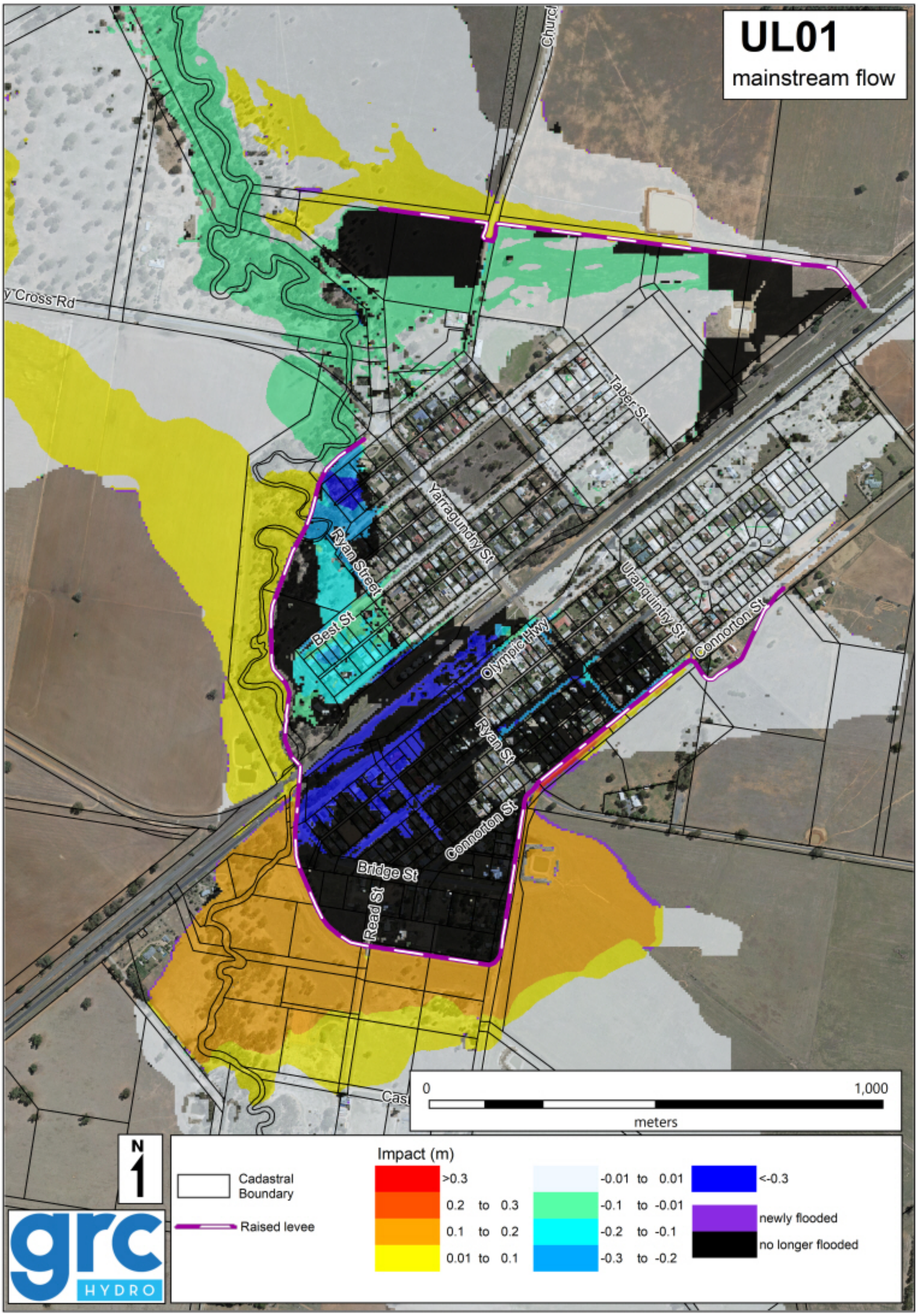



*Figure 23: 1% AEP Impact - Option UL01 - Mainstream Flooding*

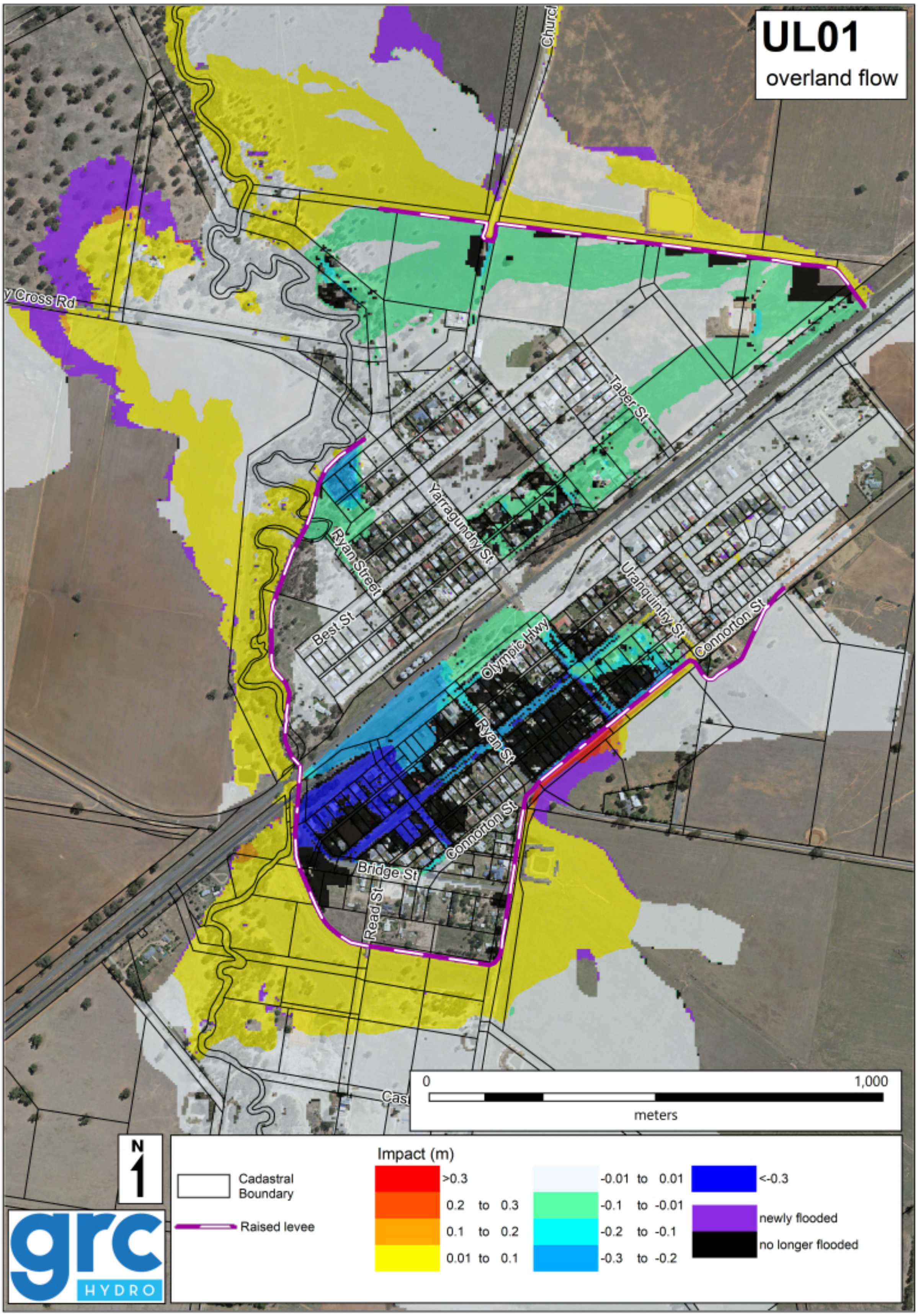



*Figure 24: 1% AEP Impact - Option UL01 - Overland Flow*

Based on the assessment presented above, the option warranted further analysis including its benefit in a range of floods, the impacts on visual amenity and overall flood risk, and preliminary costing and cost. The option was simulated for each design flood event and the results are presented in Table 36 below. The table shows that the option has significant benefit in a range of design flood events, as it removes the Connorton Street overland flowpath. The greatest benefit is in the 2%, 1% and 0.5% AEP events, when around 40-50 properties are no longer flooded above floor and there is a saving of approximately $3.5m in flood damages. There is a significant reduction in AAD ($242,511).

*Table 36: Option UL01, Reduction in Damages and Above-Floor Flooding*

| Event | Reduction in Properties Flooded Above Floor | Reduction in Event Damages |
|---|---|---|
| 20% AEP | 0 | $208,949 |
| 10% AEP | 3 | $517,025 |
| 5% AEP | 6 | $1,079,512 |
| 2% AEP | 42 | $3,421,436 |
| 1% AEP | 56 | $4,484,283 |
| 0.5% AEP | 41 | $3,221,371 |
| 0.2% AEP | 23 | $1,541,604 |
| PMF | 1 | -$28,339 |
| | **Average Annual Damage Reduction** | $242,511 |

The impact on visual amenity is estimated to be significant but not a major constraint in raising the levee. The additional height required is varied along the length – along Sandy Creek around 0.3 m is needed, south of the two bridges it is around 0.4 m and adjacent to Deane Street around 1.3 m. The Connorton Street levee is only to protect against overland flow and would be around 0.5 m higher than what currently exists. Similarly Churches Plain Road levee would only be to protect against overland flow and would be around 0.6 m higher than existing. All heights are dependent on freeboard assessment (0.5 m assumed for mainstream, 0.3 m for overland). The levee currently obstructs the view of various properties and this view would be further reduced with a raised levee. Feedback on the option will be sought from residents during public exhibition of this study. The option does not have significant social or environmental impacts as it involves modification to an existing structure and will have no impact on the normal functioning of the creek. A typical cross-section and a visualisation of a raised area is presented in Figure 25 below.

Town levee (north) (left) and Connorton Street levee (right) with crest in yellow and approximate additional height in **yellow dashed**

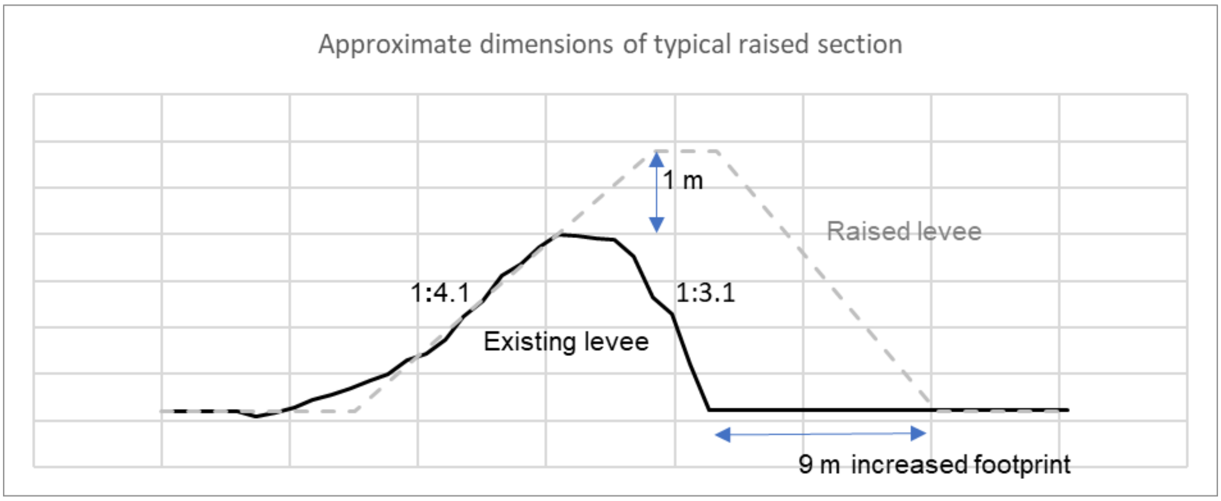



*Figure 25: Approximate UL01 Levee Height and Cross-Section*

A preliminary cost estimate for the option is presented in Table 31 and the detailed costing is in Appendix E.

*Table 37: Option UL01 Cost Estimate*

| Item | Cost Estimate |
|---|---|
| Detailed Survey, Geotechnical Assessment and Detailed Design Study | $135,000 |
| Contractor setup and project management | $25,000 |
| Excavation and earthworks including drainage | $767,910 |
| **Total (inc. GST)** | $1,020,701 |
| Cost estimate is only approximate, for the purposes of economic analysis of the option. It is based on approximately 3176 m of levee raised by an average of 0.64 m. | |

The option's reduction in Average Annual Damages, the Net Present Value (NPV) of this reduction (assuming 50 year design life and 7% discount rate) and the benefit-cost ratio are presented below.

- Average Annual Damage Reduction: $242,511
- NPV of reduction: $3,581,118

- Cost estimate of option: $1,020,701
- Benefit-cost ratio: 3.5

The benefit-cost ratio is 3.5, meaning its benefit is around four times the value of its estimated cost and it is strongly justified on economic grounds. The ratio is quite high because there is a large number of properties currently flooded by both mainstream and overland flooding. A significant portion of the benefit comes from a levee at Deane Street where much of the overtopping occurred in recent floods.

Overall, the option does not have significant technical constraints, and it provides significant benefit in the design event (1% AEP) and other flood events. Based on the assessment, it is strongly recommended to be implemented in the short term. It involves adverse impact at one property building, which can be offset with a small bund/levee at that property, but which will require feedback from the property owner. The overall comparison of the Uranquinty options is presented in Section 8.7.

#### *8.4.1.2 Deane and Connorton Levee Raised with Channel Improvement (UL04)*

The mitigation measure consists of raising the existing Uranquinty levee along Connorton Street, construction of a new levee along Deane Street, and increasing the capacity of the channel/ditch that runs parallel to the levee, to give protection against the 1% AEP flood event. The levee is currently overtopped in the 1% AEP event by overland flow on the Connorton Street section and a mix of overland and mainstream flooding on Deane Street, and this inundates a number of properties – see section 6.4 for more information. This inundation and associated flood risk warrants investigation of the costs, benefits and feasibility of raising the levee. The option is essentially reinstatement of part of the scheme originally planned for Uranquinty (Bryant, 1980), based on the latest design flood behaviour.

The levee is a low earth embankment structure with land available east of Connorton and Deane Streets and so raising the crest level and footprint is generally feasible from a technical viewpoint. The existing levee crest varies between 201.4-205.8 mAHD and would be raised to approximately 201.8-206.1 mAHD to provide 1% AEP protection (exact height to be determined based on freeboard assessment). Sample cross-sections of the enlarged channel are shown on Figure 26.

The option has been assessed via model simulation of the 1% AEP event overland flow event. The alignment of the raised levee, the modified channel and the impact on the 1% AEP flood level is shown in Figure 26.

The figure shows that raising of the levee, combined with the channel enhancement, has a significant effect on flood affectation, with the greatest benefit across the southern half of Uranquinty and a widespread adverse impact of 0.1 m in the downstream area. The upgraded levee/channel prevents overtopping and inundation along Connorton and Deane Streets in the 1% AEP event, and this results in large areas of the town being no longer flooded. Parts of the town are still flooded due to shallow overland flow from within the town and to the north-east.

The adverse impacts, which are a result of flow that previously overtopped the levee now being directed to the floodplain downstream, are around 0.1 m for a large area, largely downstream of the railway bridge along Sandy Creek. The area of greatest increase affects the house on one property off of Uranquinty Cross Road and another dwelling south of the highway bridge. The former cannot have its impact mitigated by a bund or other feature, while the latter can. Other properties in the area of impact do not have buildings in the 1% AEP flood extent. The mitigation measure also raises the flood level against the main levee, which reduces its level of protection.

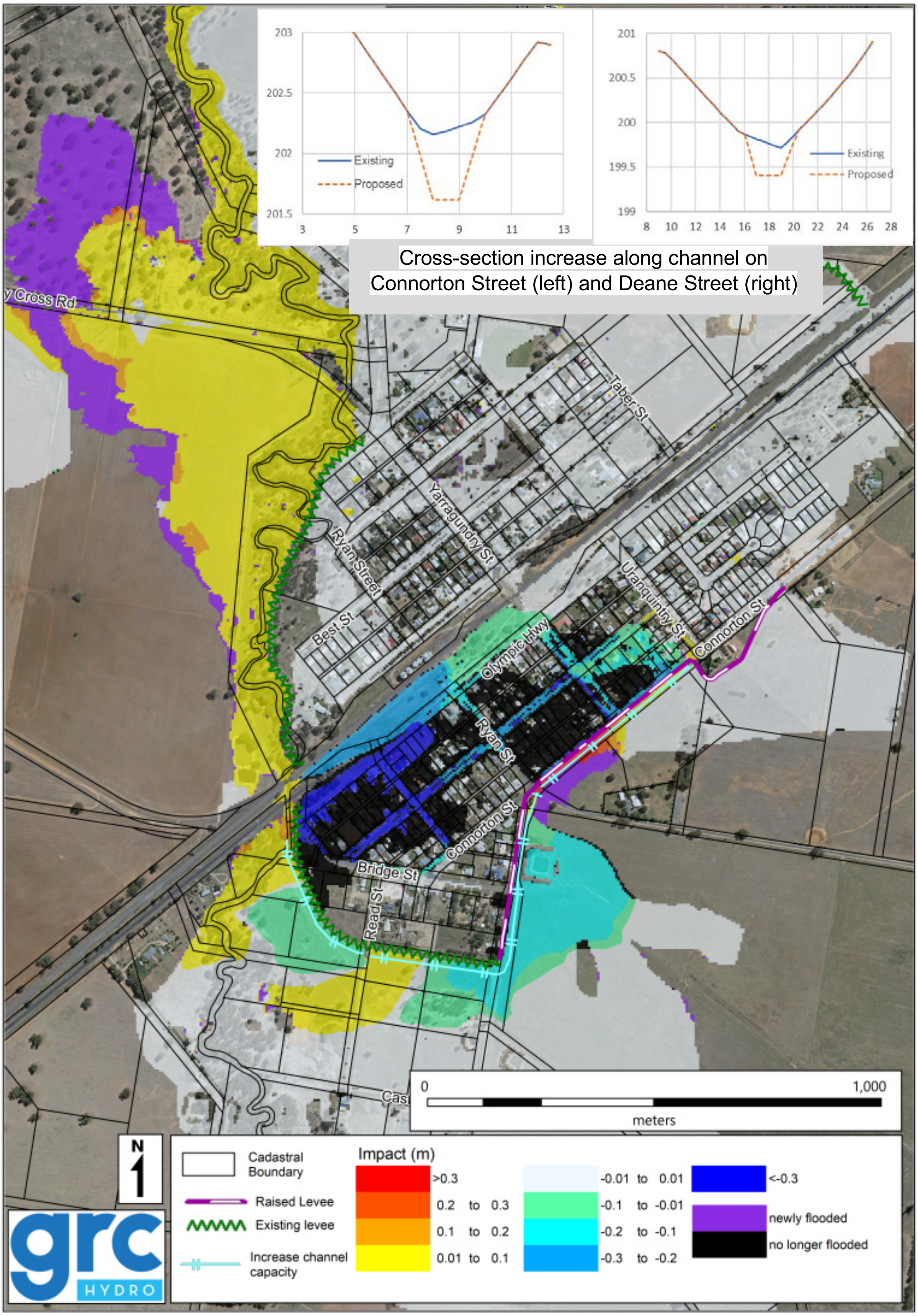



*Figure 26: 1% AEP Impact - Option UL04 - Overland Flow*

Based on the assessment presented above, the option warranted further analysis including its benefit in a range of floods, the impacts on visual amenity and overall flood risk, and preliminary costing. The option was simulated for each design flood event and the results are presented in Table 38 below. The table shows that the option has significant benefit in a range of design flood events, as like the previous option, it removes the Connorton Street overland flowpath. Unlike the previous option, it does not prevent flooding at properties currently affected by mainstream flooding. The greatest benefit is in the 2%, 1% and 0.5% AEP events, when around 40 properties are no longer flooded above floor and there is a saving of approximately $3.5m in flood damages. There is a significant reduction in AAD ($231,925), which is slightly less than option UL01.

*Table 38: Option UL04, Reduction in Damages and Above-Floor Flooding*

| Event | Reduction in Properties Flooded Above Floor | Reduction in Event Damages |
|---|---|---|
| 20% AEP | 0 | $208,949 |
| 10% AEP | 2 | $504,891 |
| 5% AEP | 6 | $1,079,512 |
| 2% AEP | 43 | $3,366,499 |
| 1% AEP | 45 | $3,695,761 |
| 0.5% AEP | 36 | $2,614,835 |
| 0.2% AEP | 22 | $1,438,303 |
| PMF | 0 | -$7,691 |
| | **Average Annual Damage Reduction** | $231,925 |

The impact on visual amenity is estimated to be significant but not a major constraint in raising the levee. The additional height required is varied along the length – with the section adjacent to Deane Street around 1.3 m higher than the existing road. The Connorton Street levee is only to protect against overland flow and would be around 0.5 m higher than what currently exists, depending on freeboard assessment (0.3 m freeboard assumed). The levee currently obstructs the view of various properties and this view would be further reduced with a raised levee. Feedback on the option will be sought from residents during public exhibition of this study. The option does not have significant social or environmental impacts as it involves modification of an existing structure and will have no impact on the normal functioning of the creek. The drainage channel excavation would need to be carried out to ensure the channel does not erode and lead to increased sediment in the creek. A typical cross-section and a visualisation of the raised levee is presented in Figure 27 below.

Two sections of Connorton Street levee with crest in yellow and approximate additional height in **yellow dashed**

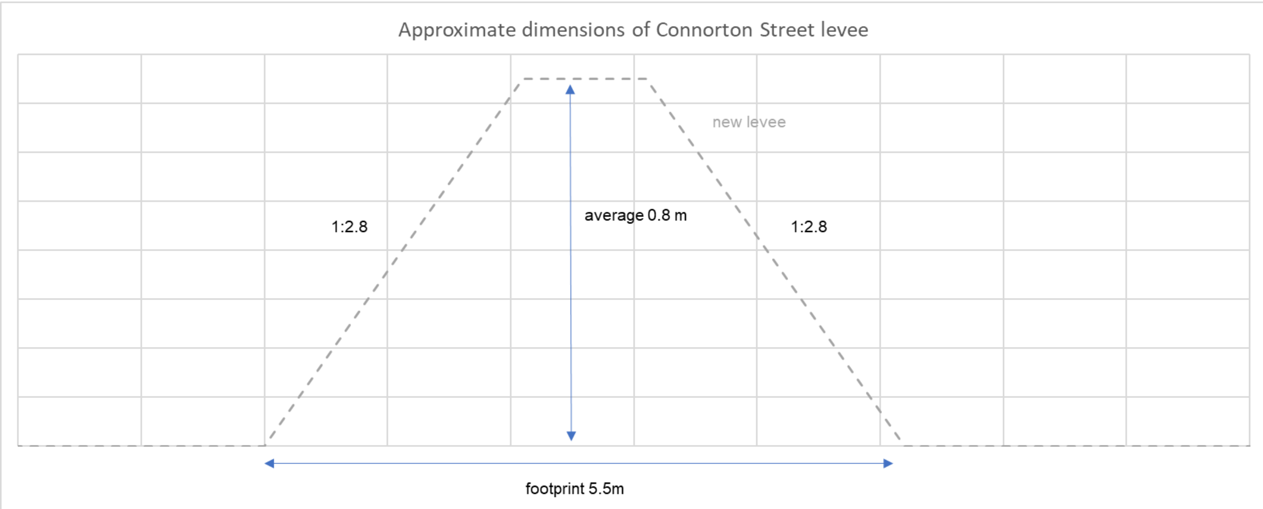



*Figure 27: Approximate UL04 Levee Height and Cross-Section*

A preliminary cost estimate for the option is presented in Table 39 and the detailed costing is in Appendix E.

*Table 39: Option UL04 Cost Estimate*

| **Item** | **Cost Estimate** |
|---|---|
| Detailed Survey and Detailed Design Study | $135,000 |
| Contractor setup and project management | $25,000 |
| Excavation and earthworks including drainage and retractable barrier at Key Street | $356,983 |
| **Total (inc. GST)** | $568,681 |
| Cost estimate is only approximate, for the purposes of economic analysis of the option. It is based on approximately 1180 m of levee raised by an average of 0.8 m. | |

The option's reduction in Average Annual Damages, the Net Present Value (NPV) of this reduction (assuming 50 year design life and 7% discount rate) and the benefit-cost ratio are presented below.

- Average Annual Damage Reduction: $231,925
- NPV of reduction: $3,424,797
- Cost estimate of option: $568,681

- Benefit-cost ratio: 6.0

The benefit-cost ratio is 6.0, meaning its benefit is around six times the value of its estimated cost and it is strongly justified on economic grounds. The ratio is very high relative to most flood mitigation works and is related to the large number of houses that can be protected by the option. The ratio is much higher than UL01 as it is more focussed on the area of the most damaging overtopping (Deane Street and to a lesser degree, Connorton Street).

Overall, the option does not have significant technical constraints, and it provides significant benefit in the design event (1% AEP) and other flood events. It involves adverse impact at two properties' buildings, only one of which can be offset (pending consent). The location of the adverse impacts means the option is slightly less preferable to UL01, to which it is very similar. The overall comparison of the Uranquinty options is presented in Section 8.7.

#### *8.4.1.3 Levee System Raised with Bypass Channel Improvements (UL05)*

The mitigation measure consists of raising the existing Uranquinty levee as in UL01, combined with increased capacity of the drainage channel from Connorton Street up to Uranquinty Cross Road. The option is designed to give protection against the 1% AEP flood event and consists of reinstatement of the scheme originally planned for Uranquinty (Bryant, 1980), based on the latest design flood behaviour. As described for the previous two options, the levee raising is technically feasible with regards to available land. It is noted that the drainage channel intersects at several points with the creek and so it's upgrade would have to incorporate and manage potential impacts on vegetation and stability of the creek banks.

The option has been assessed via model simulation of the 1% AEP event. The alignment of the raised levee and enlarged channel, and the impact on the 1% AEP flood level is shown in Figure 28 for creek flooding and Figure 29 for overland flow. Sample cross sections for the east side of system are shown on the previous figure (Figure 26) and for the section along the creek on Figure 28.

The figure shows that raising of the levee has a significant effect on flood affectation, with the greatest benefit across the southern half of Uranquinty and a widespread adverse impact of 0.1-0.2 m in two separate areas. The mitigation measure has the same benefit of UL01 in the town, as both block the creek/overland flow from entering the town. While UL01 caused an adverse impact south of the town, this impact has been reduced in UL05 but there is a large area of increase around Uranquinty Cross Road and further downstream along the creek, of 0.1-0.3 m. This impacts the house on one property off of Uranquinty Cross Road by 0.1 m, and other properties that do not have buildings in the flood extent. The figure also shows that there is a reduction in flood level along Sandy Creek next to the town of around 0.2 m, which reduces the amount the levee would need to be raised.

The impact on the property downstream was found to not be mitigated via flood protection works on the property. The adverse impact is over a wide area and the additional flow cannot be diverted from the area. While there are more complicated measures that may offset the impact, the adverse impact and the difficulty of upgrading the channel where it crosses the creek channel means the option is generally not feasible, especially when other similar options are available.

**Recommendation:** The option is not recommended in the Floodplain Risk Management Plan.

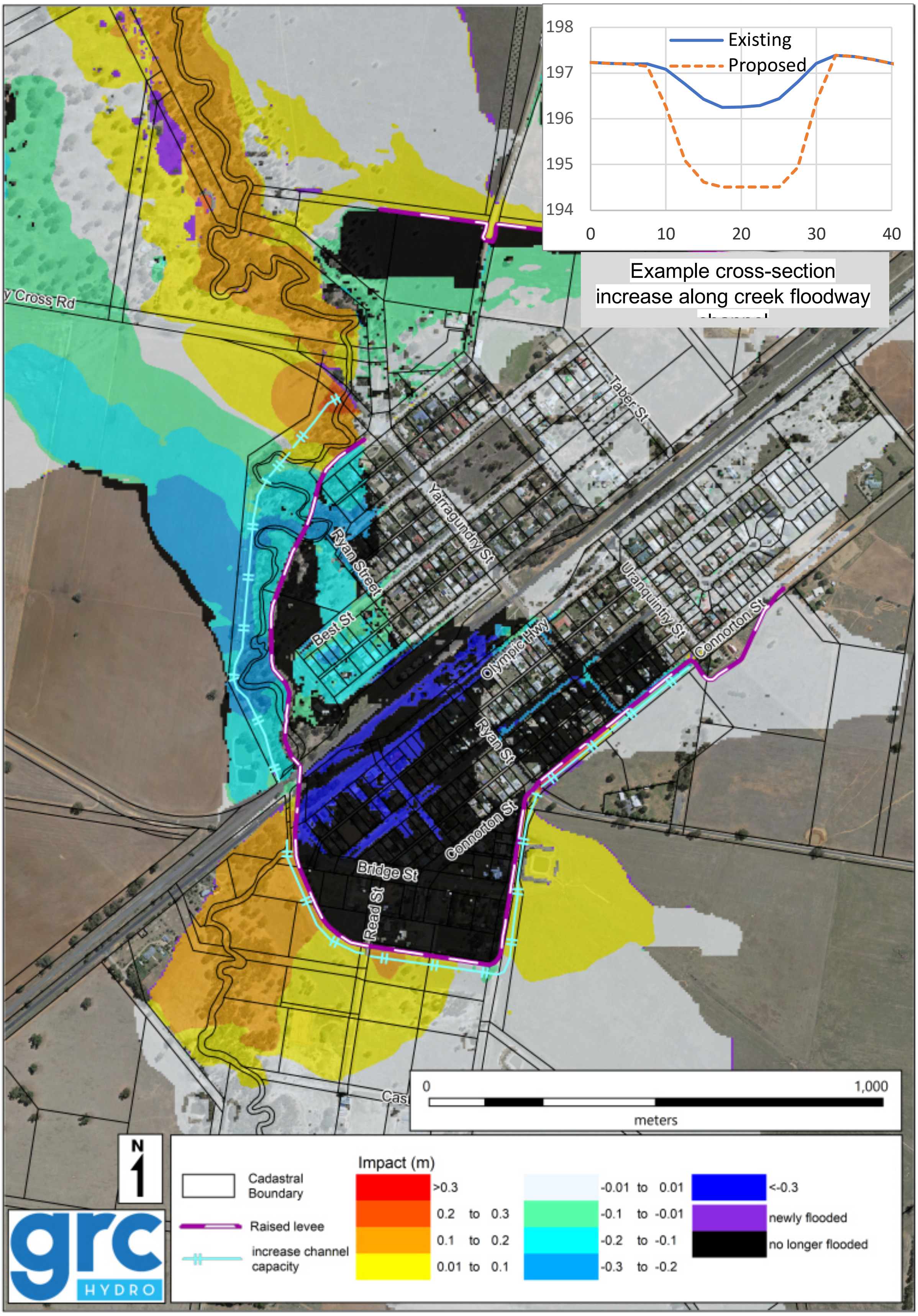



*Figure 28: 1% AEP Impact - Option UL05 - Mainstream Flooding*

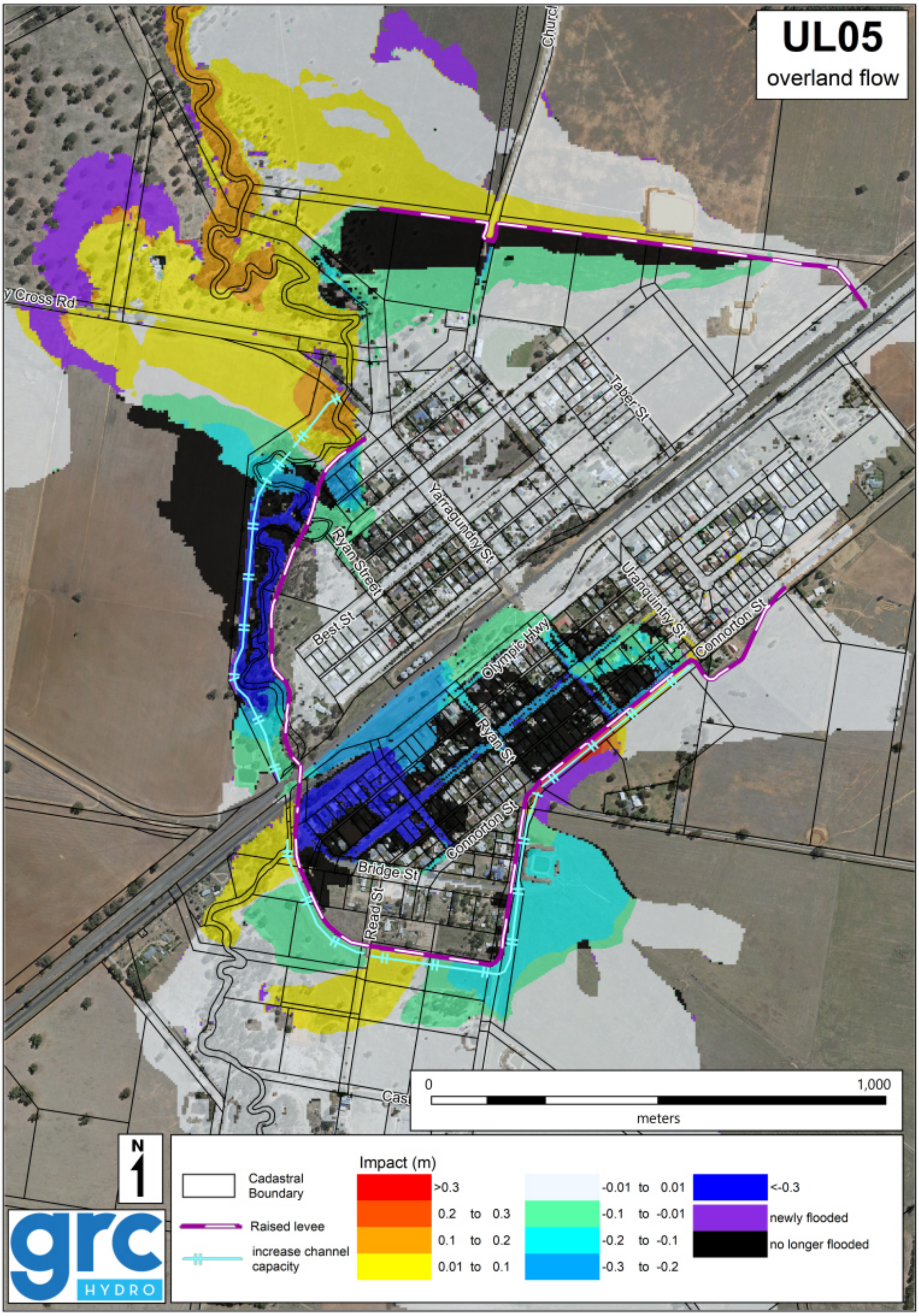



*Figure 29: 1% AEP Impact - Option UL05 - Overland Flow*

#### *8.4.1.4 Upgraded Culverts at Uranquinty Cross Road (UC01)*

The mitigation measure consists of increasing the capacity of the culverts where Sandy Creek passes under Uranquinty Cross Road, to reduce possible backwater effects in the 1% AEP flood event. The culverts have been reported to experience blockage and may contribute to raised flood levels in the area upstream. The road itself is not flooded in the 1% AEP event at the culverts' location, but is overtopped further to the west. The sensitivity of the 1% AEP flood behaviour to the capacity of the culverts has been assessed by doubling their capacity – from two 2 m x 2.95 m culverts to four culverts.

The option has been assessed via model simulation of the mainstream 1% AEP event with the culvert capacity doubled. The location of the culverts and the impact on the 1% AEP flood level is shown in Figure 30.

The figure shows that upgrading the culvert capacity has a moderate effect on flood affectation, with similar sized areas of increase and decrease in peak flood level. The culverts' peak flow increases from 49.3 $m^3$/s in the existing case to 80.5 $m^3$/s. This increase indicates the creek is constrained in flow area through the culverts in the existing case, leading to a backwater effect upstream. The increased flow results in a decrease of up to 0.2 m in the upstream area, which increases the levee's level of protection, and an increase of 0.1 to 0.3 m in the downstream area. The increase affects several properties but not any houses or other buildings.

The option is not particularly beneficial to either road access, as the road is still flooded to the west, nor to property affectation, as there is only one building the in the reduced area. The benefit from the decrease in flood level against the levee could more easily be achieved by slightly raising the levee in that area.

**Recommendation:** The option is not recommended via the draft Floodplain Risk Management Plan. The option can be reconsidered in the future if the road is being upgraded.

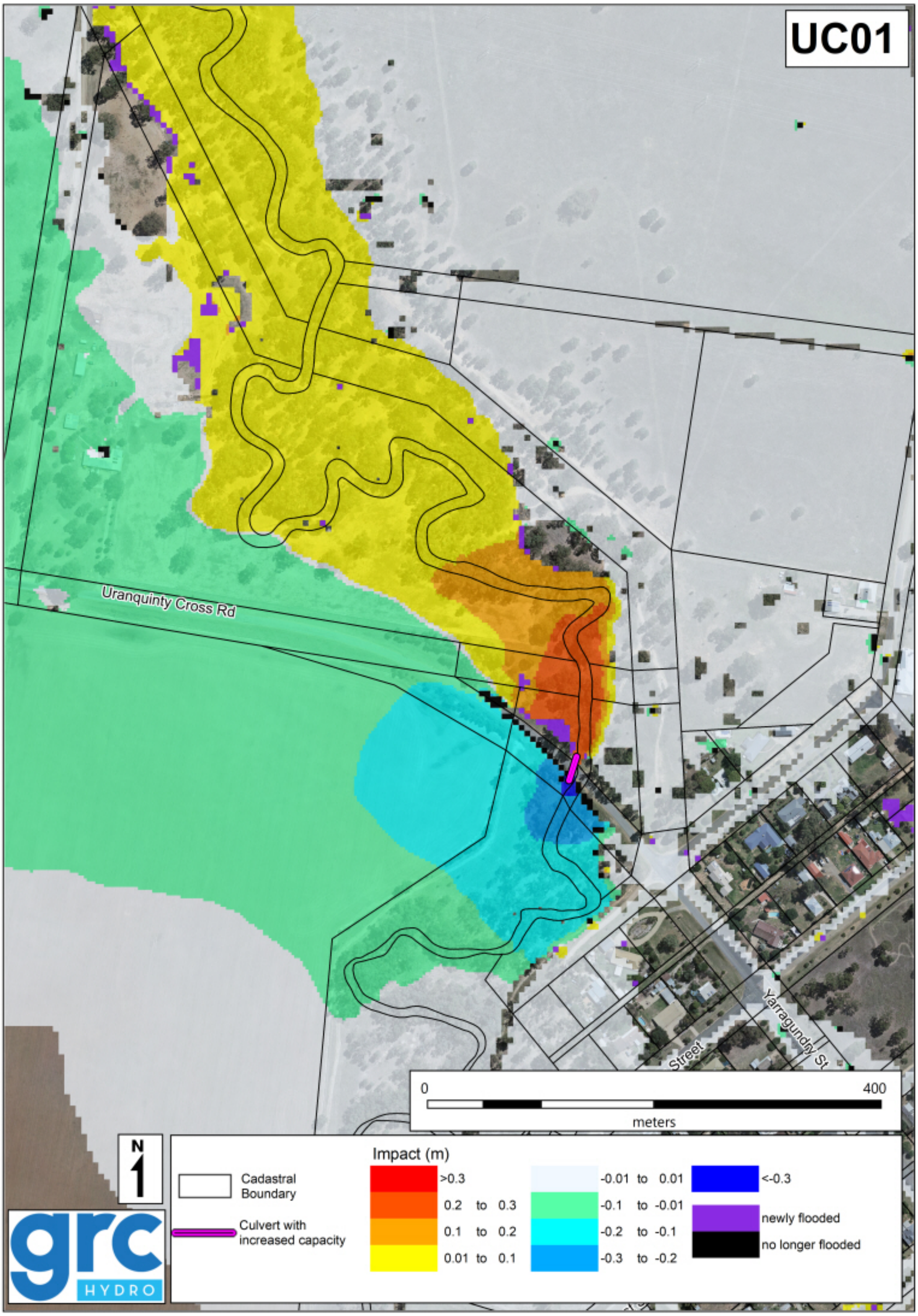



*Figure 30: 1% AEP Impact - Option UC01 - Mainstream Flooding*

#### *8.4.1.5 Concrete Channel Section in Sandy Creek (UV02)*

The mitigation measure consists of large-scale modifications to a 250 m section of Sandy Creek near the highway and railway bridges. The section would be converted to a concrete channel with more regular cross-sections and likely removal of large trees along the creek (as they lie in or immediately adjacent to the creek bed). The option does not involve modifying the shape of cross-sections beneath the road or railway, as such works would be problematic to stability of these structures.

The option has been assessed via model simulation of the mainstream 1% AEP event with the channel concreted and its cross-sections made more regular in shape. The location of the section and the impact on the 1% AEP flood level is shown in Figure 31 and Figure 32 shows a sample of the modified cross-sections Figure 30.

The figure shows that converting the creek to a concrete channel has a significant effect on flood affectation, with a decrease of up to 0.4 m in the peak flood level against the levee, and by 0.1 in the southern portion of town. The channel results in a lower flood level due to the reduced hydraulic roughness than a natural channel and the increased flow area. Remarkably, the increased flow does not result in adverse impact in the downstream area. This is likely due to the additional flow being able to distribute itself across the unconstrained floodplain downstream. In regard to the reduced flood level and the lack of adverse impact, the measure is considered to have high merit.

A further two model simulations were tested to check the sensitivity of the various changes. Firstly a wall was inserted to block expansion of flow between the two bridges towards the south-west, which has been observed to cause turbulence. The results showed negligible effect on peak flood level in the 1% AEP event. Secondly the flow area was increased by ~25% through the two bridge cross-sections, which possibly act as a bottleneck on flow. The results showed minimal increase in flow and a minimal decrease in peak flood level, due to cross-section beneath the bridges having a larger flow area than the creek upstream and downstream. Lastly, the sensitivity of a raised bed level (which occurs due to high volumes of sand sediment along the creek) was tested and presented in the following section (option 'S06').

The option would have potential adverse environmental impacts due to removal of vegetation and natural habitat, and potential erosion of the creek bed at the transition from concrete to natural creek bed at the downstream end. The natural amenity of the creek may also be impacted, and the option may have low community support relative to other options. These risks are significant and would require further assessment as part of this study and during a concept design stage. Further modelling may also reveal alternative designs, such as a concrete channel beginning at the two bridges, provides the same benefit.

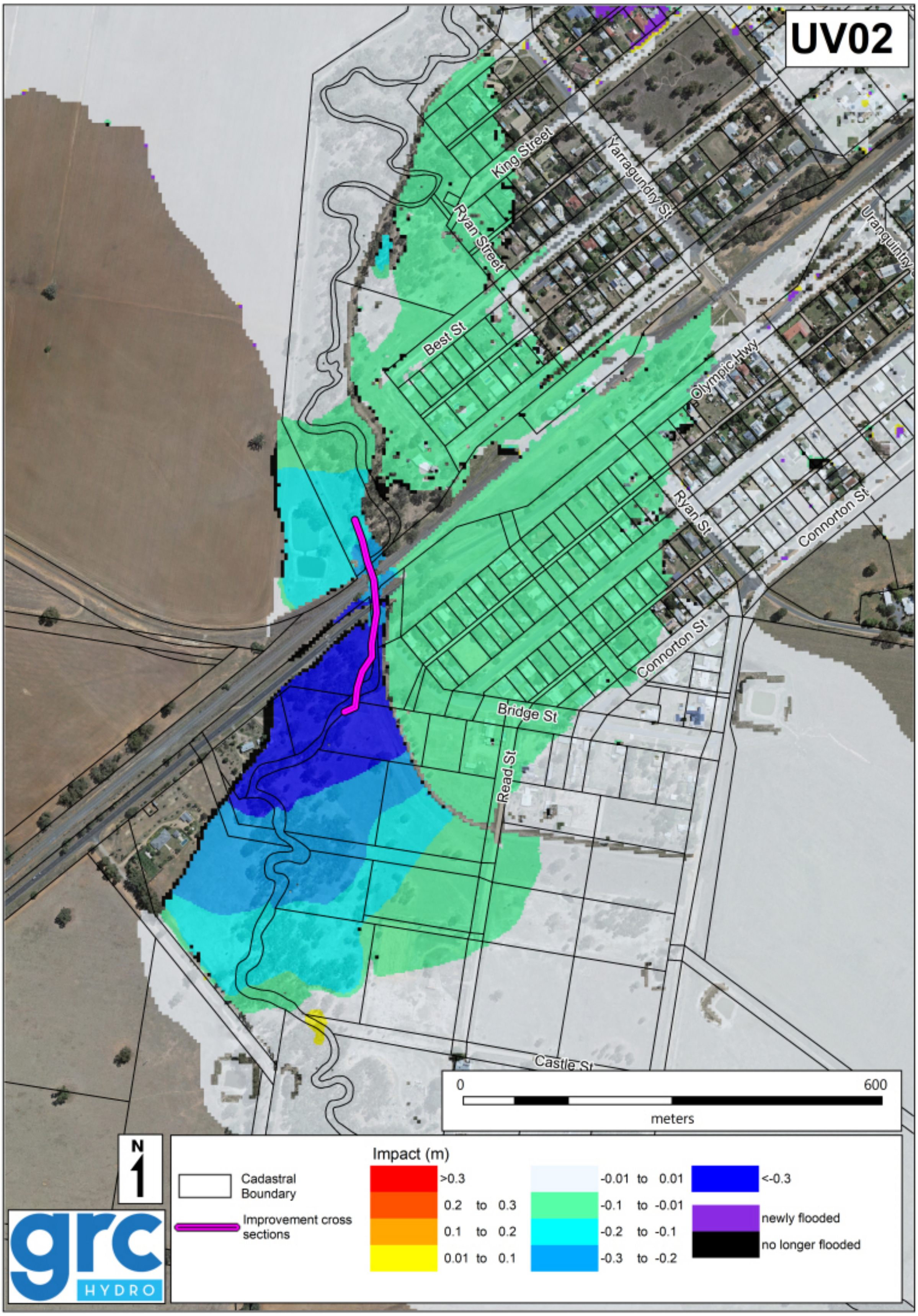



*Figure 31: 1% AEP Impact - Option UV02 - Mainstream Flooding*

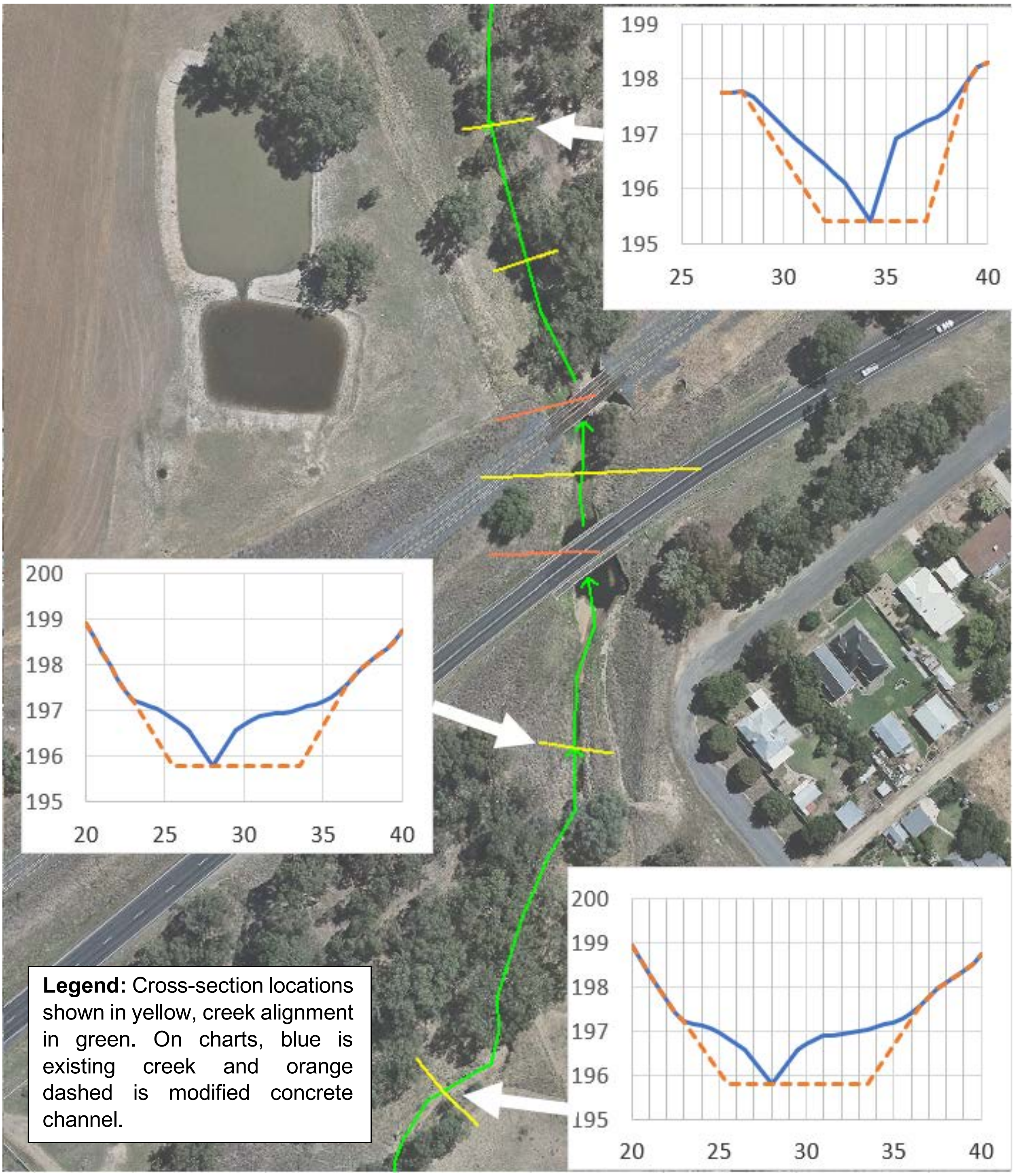



*Figure 32: Sample of modified cross-sections under UV02*

Based on the assessment presented above, the option warranted further analysis including its benefit in a range of floods, the impacts on visual amenity and overall flood risk, and preliminary costing and cost. The option was simulated for each design flood event and the results are presented in Table 40 below. The table shows that the option has some benefit in a range of design flood events, as it leads to reduced flow overtopping the levee system. The greatest benefit is in the 5%, 0.5% and 0.2% AEP events, when around 3-6 properties are no longer flooded above floor and there is a saving of approximately $200,000 in flood damages. There is a small reduction in AAD ($14,928).

*Table 40: Option UV02, Reduction in Damages and Above-Floor Flooding*

| Event | Reduction in Properties Flooded Above Floor | Reduction in Event Damages |
|---|---|---|
| 20% AEP | 0 | $- |
| 10% AEP | 0 | $- |
| 5% AEP | 2 | $216,522 |
| 2% AEP | 5 | $182,147 |
| 1% AEP | 3 | $109,060 |
| 0.5% AEP | 0 | $209,983 |
| 0.2% AEP | 6 | $371,918 |
| PMF | 0 | $38,369 |
| | **Average Annual Damage Reduction** | $14,928 |

As described previously, the option will have significant environmental impacts and removal of trees will impact on the natural amenity of the area.

A preliminary cost estimate for the option is presented in Table 41 and the detailed costing is in Appendix E.

*Table 41: Option UV02 Cost Estimate*

| Item | Cost Estimate |
|---|---|
| Detailed Survey and Detailed Design Study | $15,000 |
| Contractor setup and project management | $25,000 |
| Excavation and earthworks, laying of concrete slab along channel, tree removal | $765,680 |
| **Total (inc. GST)** | $886,248 |
| Cost estimate is only approximate, for the purposes of economic analysis of the option. It is based on excavation of 3,730 $m^3$ of creek and concreting of 4,780 $m^2$ | |

The option's reduction in Average Annual Damages, the Net Present Value (NPV) of this reduction (assuming 50 year design life and 7% discount rate) and the benefit-cost ratio are presented below.

- Average Annual Damage Reduction: $14,928
- NPV of reduction: $220,436
- Cost estimate of option: $886,248
- Benefit-cost ratio: 0.3

The benefit-cost ratio is 0.3, meaning its estimated cost is around three times the value of its benefit and it would not be justified on economic grounds alone. Overall, the option has significant constraints, especially with regards to potential social and environmental impacts, and it provides limited benefit in design flood events. The option would only be considered for recommendation were there no other option available for the area. The overall comparison of the Uranquinty options is presented in Section 8.7.

#### *8.4.1.6 Sandy Creek Regular Clearing of Sedimentation (S06)*

The mitigation measure consists of regular maintenance of Sandy Creek near the railway/road bridges, to reduce possible backwater effects in the 1% AEP flood event. The section of creek through and upstream of the two bridges has been reported to have a variable bed level, with high sediment loads building up the creek bed level. Along with overgrown weeds and grasses, this may contribute to raised flood levels in the area upstream. The sensitivity of the 1% AEP flood behaviour to the capacity of the culverts has been assessed by increasing the bed level by an average of 1.5 m from the existing case. The level of sediment at the railway was estimated to be as high as 1.8 m above a 'cleaned out' creek level, in reality.

The option has been assessed via model simulation of the mainstream 1% AEP event. The location of the section with raised bed level and the impact on the 1% AEP flood level is shown in Figure 34. The 'increased blockage' creek section shown on the figure in bright green indicates where the creek bed has been raised by around 1.5 m (the sides of the creek are unchanged, above this level). There are two caveats regarding this mitigation measures. Firstly, the estimate of 1.8 m increase in bed level due to sediment loads is based on discussion with residents and the actual amount that occurs may be more or less. Based on a comparison of photos, it is estimated the existing case modelled, which has an invert of 195.1 mAHD under the railway bridge, is equivalent to a low bed level. Secondly, the modelled option is not a measure that is to be carried out. Rather, it is a measure of the sensitivity to a 'worst case' of sedimentation and overgrown vegetation. This means that increases in flood level in the figure indicate the measure is worth implementing, the opposite of previous measures.

The figure shows that sedimentation and overgrown vegetation has a significant effect on flood affectation, with a large area of increase upstream and downstream of the bridge crossings. The impact upstream is up to 0.4 m and a large portion of the town experiences an increase of 0.1 to 0.2 m in flood level, as a result. This increase indicates that natural build-up of sediment, which can occur gradually during regular flow, or suddenly during high flow, should be avoided, and vegetation should be maintained. A photo below from April 2019 from under the railway bridge indicates what is estimated as moderate sediment build-up and well-maintained vegetation.

Figure 33 shows a flow comparison of the 1% AEP creek hydrograph for the base case versus the S06 option (regular sedimentation clearing) and UV02 (a concrete channel in the creek). As can be seen, the concrete channel does not markedly change the flow, as the concrete channel simply produces a lower flood level for the same flow. In comparison, S06 reduces the peak flow by around 20 $m^3/s$, a significant reduction that re-emphasises the sensitivity of the creek to sediment build-up.

*Image 3: Sandy Creek at Railway Bridge*

Based on the assessment presented above, the option warranted further analysis including its benefit in a range of floods and preliminary costing and cost. The option was simulated for each design flood event and the results are presented in Table 42 below. The table shows that the option has the greatest benefit in rare events (1% AEP and larger) with a saving of around $500,000 in each event. There is a small reduction in AAD ($18,675).

*Table 42: Option S06, Reduction in Damages and Above-Floor Flooding*

| Event | Reduction in Properties Flooded Above Floor | Reduction in Event Damages |
|---|---|---|
| 20% AEP | 0 | $- |
| 10% AEP | 0 | $12,134 |
| 5% AEP | 3 | $126,512 |
| 2% AEP | 0 | $271,238 |
| 1% AEP | 11 | $514,654 |
| 0.5% AEP | 7 | $436,863 |
| 0.2% AEP | 9 | $628,348 |
| PMF | 1 | $105,622 |
| | **Average Annual Damage Reduction** | $18,675 |

The option is not expected to have potential environmental impacts as it essentially maintaining the current level of sediment in the creek. It is understood that the creek naturally has a high sediment load which naturally varies with the rate of discharge on the creek. Council have also undertaken the maintenance recently and it is believed to be relatively straightforward.

A preliminary cost estimate for the option is estimated to be $20,000 as an annual cost. The option's reduction in Average Annual Damages, the Net Present Value (NPV) of this reduction (assuming 50 year design life and 7% discount rate) and the benefit-cost ratio are presented below. The average annual damage is compared to the annual cost to calculate the ratio.

- Average Annual Damage Reduction: $18,675
- NPV of reduction: $275,777
- Cost estimate of option: $10,000 annually
- Benefit-cost ratio: 1.8

The benefit-cost ratio is 1.8, meaning its estimated annual benefit is approximately twice its annual benefit. Overall, the option has significant benefits and is a continuation of a recent Council practice, which means it is relatively straightforward to implement. Based on the assessment, the option is recommended for implementation. The overall comparison of the Uranquinty options is presented in Section 8.7.

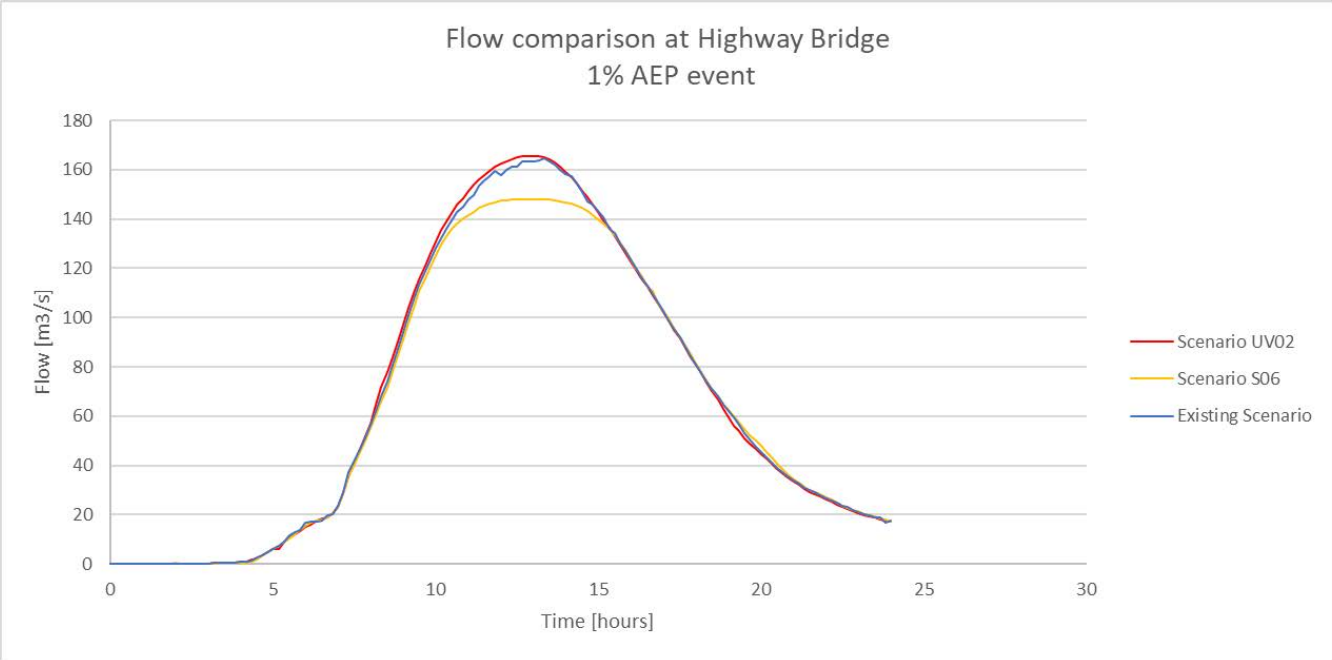



*Figure 33: Flow Comparison at Highway bridge, 1% AEP event, Existing scenario, S06 and UV02 scenario*

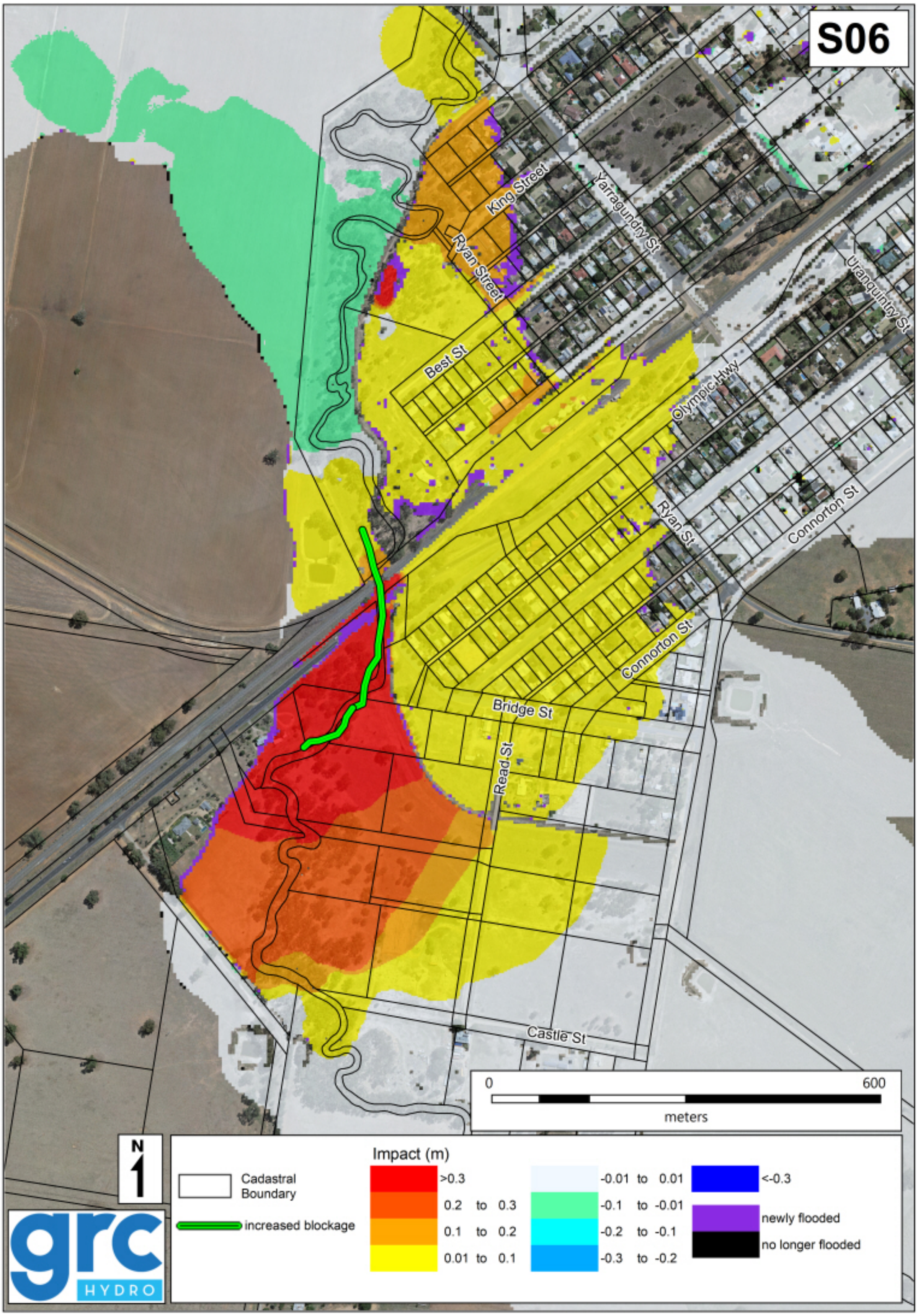



*Figure 34: 1% AEP Impact - Option S01 - Mainstream Flooding*

#### *8.4.1.7 Maintenance of Levee Cross-Drainage for Uranquinty (UD01)*

This mitigation measure consists of improving the cross-drainage structure in the Uranquinty levee. In recent floods overland flooding has been prevented from discharging due to a high creek level and the levee spillway was overtopped near Uranquinty Cross Road (see Section 4.4.1 for more information).

It is recommended that Council oversee a maintenance program involving periodic clearing of grass and other low vegetation at the upstream and downstream end of each cross-drain, as well as clearing of any obstructions or sedimentation in each drain. The hinge structures and manual gates should also be tested periodically. To plan for the incidence of coincident overland flow and Tarcutta Creek flooding, the SES should own and maintain a collection of mobile pumps that can be used in flood events.

It is noted that the need for pumping overland flow will be significantly reduced if the levee is raised along Deane Street and Connorton Street.

The option has not been modelled as the design flood modelling assumes the cross-drainage is functioning. However, from recent floods it is well-understood that if the drainage malfunctions significant flooding can occur near Morgan Street and King Street. The cost of a maintenance program is expected to be significantly less than its expected benefit

**Recommendation**: The option is recommended via the draft Floodplain Risk Management Plan.

### 8.4.2 Uranquinty Response Modification Measures

As with Tarcutta, there is potential to improve the response during and after a flood in Uranquinty, by drawing on lessons from the 2010 and 2012 flood events, and the design flood event modelling produced by the current study. The existing flood warning system is described in detail in Section 4.6.1, and the response during the two recent floods is described in Bewsher Consulting, 2012 and Yeo, 2013. Response measures are set out in the following section and then further measures that are applicable to all three towns are described in Section 8.5.

#### *8.4.2.1 Update the Uranquinty section of the Wagga Wagga Local Flood Plan (RM06)*

The Wagga Wagga Local Flood Plan is the primary record of the consequences of different sized floods in Uranquinty and of the responsibilities and actions corresponding to the effects of flooding. The information it currently contains for Uranquinty and the other two towns is summarised in Section 2.3.4. It is recommended that information from the recent floods in 2010 and 2012, and the findings of the current study, be used to update the Uranquinty section. The following updates are recommended:

3. Update the Plan with the recommended changes from the 2010 event’s Flood Intelligence Collection and Review (Bewsher Consulting, 2012), which were subsequently drafted for the Local Flood Plan following the 2012 flood event. Volume 2 of the “Flood Intelligence Collection and Review for 24 Towns and Villages in the Murray and Murrumbidgee Regions” (Dr. Stephen Yeo, 2013) contains the new draft Plan contents. The proposed updates are to Annex A (The Flood Threat), Annex B (Effects of Flooding on the Community) and Annex J (Uranquinty Sector Evacuation).
4. In addition to those changes, incorporate findings from the current study and the flood study. In Annex A, describe the level of protection of the Uranquinty levee based on information presented in Section 6.4 of this report. In the same section and in Annex B, add description of the areas of hazardous flooding, and the number of properties flooded, in the flooding hotspots described in Section 6.5 of this report. The information in Table 24 to Table 27 summarises the key information for each hotspot and relevant parts can be copied into the Local Flood Plan.

#### 8.4.2.2 Install a telemetered pluviometer in the Sandy Creek catchment (RM07)

There is currently no warning system in Uranquinty that uses observed data (rainfall or creek level) within the catchment. Bewsher Consulting, 2012 states there is low appetite for a gauge in the catchment, and that the small catchment size means there would be little warning time were one to be installed. Previous reporting also indicated the occurrence of significant variation in rainfall within each catchment of those investigated, which means observed rainfall at the closest gauges ('Wagga Wagga Research Centre' and Wagga Wagga AWS) may not be representative of rainfall in the Sandy Creek catchment. It is therefore recommended to install a telemetered pluviometer in the southern portion of the Sandy Creek catchment, to better inform warnings issued by the Bureau of Meteorology for possible flooding.

Bewsher Consulting, 2012 also recommends consideration of a table or graph linking observed rainfall depths and durations to particular flood levels at Uranquinty. This kind of information can give a prediction of the flood level if, for example, 100 mm of rainfall occurs over a 2-hour period. Based on review of where this is applied in NSW, and recent analysis of a similar application in Cooma, there is likely to be limited utility of a very detailed prediction tool. Currently there are four locations in NSW where a warning is issued based on a specific rainfall depth occurring. From 'Provision of and Requirements for Flood Warning' (SES, 2018), they are:

- Parramatta River (depth not specified)
- Orange: >70 mm rainfall in 6 hours triggers a warning with a target lead time of 1 hour
- Stockinbingal: >50 mm rainfall in 6 hours triggers a warning with a target lead time of 1 hour
- Cootamundra: >50 mm rainfall in 6 hours triggers a warning with a target lead time of 1 hour

It is understood that the rainfall depth can use a combination of observed and forecast rainfall. The analysis for Cooma, which looked at a greater range of depth/duration combinations, and different levels of warning triggered, found that while relationships can be derived, any prediction is heavily dependent on what rainfall losses are assumed. Given rainfall losses vary significant between events, and can only be coarsely estimated before an event occurs, this means a predicted or forecast flood level cannot be accurately estimated. Nevertheless, a large observed rainfall depth at a hypothetical rainfall gauge in the Sandy Creek catchment can provide a strong indication that some level of flooding will occur.

#### 8.4.2.3 Creek Depth Marker and Flood Intelligence Card for Uranquinty (RM08)

As described in the previous option, there is currently no gauge, and therefore no flood intelligence card, for Uranquinty. However, there is some utility in establishing a depth marker in Uranquinty which can serve as a reference point for the relative height of historical and design flood levels. Such a depth marker, while not providing any advanced warning of flooding, would facilitate direction of emergency resources and evacuation during a flood, and can inform the local community and the SES on the potential for larger floods than recently observed.

Two possible locations have been tested for a depth marker: immediately downstream of the railway bridge, on the town side of the creek (location 1) and on the creek, immediately upstream of Uranquinty Cross Road (Location 2). Any location on the creek will be difficult to access in a very large flood, while locations further away will not be flooded in small to moderate sized floods. Information on the consequences of different flood events in shown in Table 43. Flood levels are provided in mAHD but these would be converted to gauge depths by subtracting the gauge zero height (also mAHD) of the gauge, if it is installed.

*Table 43: Flood intelligence for two hypothetical gauge locations*

| Gauge Location 1 | Gauge Location 2 | Consequences |
|---|---|---|
| 198.35 | 195.74 | 20% AEP flood event |

| | | |
|---|---|---|
| 198.56 | 195.95 | 10% AEP flood event |
| 198.72 | 196.03 | 5% AEP flood event |
| 198.95 | 196.12 | 2% AEP flood event |
| 199.07 | 196.21 | 1% AEP flood event |
| 199.17 | 196.30 | 0.5% AEP flood event |
| 199.26 | 196.41 | 0.2% AEP flood event |
| 200.89 | 197.93 | Probable Maximum Flood (PMF) |
| 198 | 196 | March 2012 flood (estimate) |
| 199 | 196.5 | October 2010 flood (estimate) |
| 198.37 | 195.71 | Levee overtopped approximately 100 m upstream of Uranquinty Cross Road |
| 198.60 | 195.99 | Deane Street overtopped |
| 199.15 | 196.27 | Levee overtopped at Bridge Street between Morgan and O'Connor Street |

## 8.5 Response Modification Measures – All Towns

Besides those assessed for each town, there are general response modification measures that can improve flood risk across the three towns. As with the property modification measures, there are measures recommended by the other recent studies in the LGA that would be equally suited to the current study. These include requiring flood emergency plans for development in areas of high hazard flooding, and community flood education. If Council are implementing these measures in Wagga Wagga, expanding their coverage to the three towns will be relatively straightforward.

### 8.5.1 Requirement for Site Specific Flood Emergency Plans (RM09)

This measure was recommended by the Wagga Wagga Revised Murrumbidgee River Floodplain Risk Management Study and Plan. It involves requiring a Flood Emergency Plan to form part of a development application for any lot in area with high hazard flooding. The Plan will ensure that development in these areas includes planning for evacuation (including access routes) and other preparation (e.g. responsibilities and warning systems). The towns of Ladysmith, Tarcutta and Uranquinty are less likely to have such development than Wagga Wagga, which has a very large floodplain, but there may be some instances where a plan is warranted. The option does not specify the threshold for when a plan is required. In general, it should be where the lot has significant areas of high hazard (e.g. H4-H6 flow) or evacuation constraints (e.g. not flooded but isolated).

### 8.5.2 Community Flood Education (RM10)

Community flood education was recommended by the recent Wagga Wagga Revised Murrumbidgee River FRMS&P (WMAwater on behalf of Wagga Wagga City Council, 2017) and any programs or events in Wagga Wagga could be expanded and adapted to the three towns. WMAwater on behalf of Wagga Wagga City Council, 2017 gives a detailed description of all 12 different awareness/education activities that can be similarly used in the three towns, except for the guided walking tour for which there may be insufficient interest in the three towns. It should also be noted that Uranquinty has an active Uranquinty Community Safety Group that already conducts awareness initiatives and which should be consulted with by Council prior to any education/awareness activities.

The primary source of education materials should be the photos, data and written descriptions from the recent March 2012 and December 2010 floods. Two comprehensive reports were written on these floods (Bewsher Consulting, 2012; Dr. Stephen Yeo, 2013). Where appropriate, this data can be supplemented with information from the current study, including maps of design flood events and description of the levees' level of protection.

In general, there appears to be good awareness of flooding in each town, due to the relatively recent flood events. However, it will soon be 10 years since the last significant flood occurred (2012) and awareness tends to decrease over time. The focus should therefore be on either regular awareness activities, or permanent markers, that ensure each town, and particularly those in the flooding hotspots identified in this report, are aware of the range of floods that can occur, their consequences, and how to increase the community's resilience to flooding.

Awareness raising should be tailored to local demographic data, where possible. Tarcutta and Ladysmith have a slightly older population (average age: 46) compared to Uranquinty and Wagga Wagga (average age: 36-38), which would indicate there may be slightly lower mobility, on average. The most effective means of communication and alerts (e.g. email, sms, telephone call, in person) may be tailored to each area, based on the SES and Council experience. Across the three towns, there are 21 households reported as speaking a language other than English at home, with the most common being Thai and Swedish. Information and alerts can be made in other languages if these households can not read English.

## 8.6 Property Modification Measures – All Towns

Property modification measures are those that modify existing properties, or future development in the area, to manage the area's flood risk. These measures tend to be either interventions for specific properties with high flood risk, such as house raising or voluntary purchase, or broader policy changes that gradually reduce flood risk as development occurs. An overview of the types of measures available is presented at the start of this section in Table 29.

The current study is being undertaken in the context of two recent studies in the LGA that also assessed property modification, and these can be utilised by the current study. The Wagga Wagga Revised Murrumbidgee FRMS&P (WMAwater on behalf of Wagga Wagga City Council, 2017) and the Major Overland Flow FRMS&P (not yet on public exhibition at time of writing), assess planning measures that manage both mainstream (i.e. creeks and rivers) and overland flooding, via changes to Council's Development Control Plan (DCP) and Local Environment Plan (LEP). Where suitable, these measures can also be used in Tarcutta, Ladysmith and Uranquinty, which share the same local government planning documents. It should be noted that these measures will apply to the three towns, regardless of the findings of the current study, as the DCP and LEP apply to the whole LGA.

There are three categories of existing measures that have been determined to be suitable for application to the current study, and one further measure, which is adoption of a Flood Planning Level and Area for each town, that requires tailoring to each town. The FPA and FPL are described in Section 7 and referred to as option 'PM01', while the other three measures are described below.

### 8.6.1 Updated information in the Local Environment Plan (PM02)

It is recommended that flood-related clauses in the Local Environment Plan (LEP) be updated to improve the definition of flooding in the LGA, and to update the objectives for its management. The actual measure is described in the two FRMS&P (WMAwater on behalf of Wagga Wagga City Council, 2017 and the MOF FRMS&P, with the latter not on public exhibition at the time of writing). A paraphrased summary of the measure from WMAwater on behalf of Wagga Wagga City Council, 2017 is provided below:

*Summary of Option PL1 from* WMAwater on behalf of Wagga Wagga City Council, 2017: The measure involves removing the flood maps showing the Flood Planning Area from the LEP so that the map can be updated more easily as new data and revised modelling results become available. This will be achieved by removing references in the LEP to the Flood Planning Area and the Flood Planning Map and replacing them with reference to the Flood Planning Level. The FPL in the LEP's dictionary is also proposed to be updated, to allow for freeboards other than 0.5 m.

*Summary of Option PL3 from* WMAwater on behalf of Wagga Wagga City Council, 2017: The measure entails updating the LEP flood clause to set controls on sensitive land uses between the Flood Planning Area and the Probable Maximum Flood extent. Sensitive land uses and critical facilities built in this area, which would not otherwise be subject to flood-related controls, would have appropriate controls applied to them. Critical facilities as described in the Floodplain Development Manual (DIPNR, 2007) include fire, ambulance and police stations, hospitals and nursing homes, schools, water and electricity supply installations, interstate highways, the bus station and chemical plants.

Further changes to the LEP as recommended by the MOFS FRMS&P, which will cover overland flow in Wagga Wagga, are likely to be applicable to overland flow in Tarcutta, Ladysmith and Uranquinty. Once available, these proposed changes should be reviewed to ensure their appropriateness for the three towns. Given they are likely to be suitable, separate LEP changes will not be proposed by the current study, at this stage.

### 8.6.2 Adoption of matrix-style Development Control Plan and related DCP changes (PM03)

It is recommended that Council's Development Control Plan (DCP) be updated to set controls on development of flood-prone land that take into account both the level of flood risk and the type of development. The actual measures are described in the FRMS&P (WMAwater on behalf of Wagga Wagga City Council, 2017 and the MOF FRMS&P, with the latter not on public exhibition at the time of writing). A paraphrased summary of the measures from WMAwater on behalf of Wagga Wagga City Council, 2017 is provided below:

*Summary of Option PL2 from* WMAwater on behalf of Wagga Wagga City Council, 2017: The measure involves updating Section 4.2 of the DCP with a matrix that lists controls that vary based on the sensitivity of each land use to flooding, the severity of the flood hazard at the site, and the hydraulic category of flooding at the site. These three variables would set the controls for a particular site, and would replace the flood risk precincts previously used. As for the actual controls, it is proposed that Council consolidate their existing controls, with reference given to an example set of controls from Liverpool DCP 2008. It is recommended to reword any controls to remove ambiguity in their wording.

*Summary of Option PL7 from* WMAwater on behalf of Wagga Wagga City Council, 2017: As part of the matrix-style DCP section described by Option PL2, Option PL7 involves specific controls in the DCP flood proofing of non-residential buildings. The measure does not specify the exact degree of flood proofing but states that dry or wet proofing could both be appropriate.

*Summary of Option PL8 from* WMAwater on behalf of Wagga Wagga City Council, 2017: As part of the matrix-style DCP section described by Option PL2, Option PL8 involves ensuring that a recent building standard (Australian Building Codes Board's 'Construction of Buildings in Flood Hazard Areas'), is used to support Council controls on building construction in flood hazard areas. The standard is aimed at preventing collapse or other structural damage to buildings when moderately flooded, with specifications for building materials, and electrical, plumbing and drainage installation.

*Summary of Option PL9 and PL10 from* WMAwater on behalf of Wagga Wagga City Council, 2017: Options PL9 and PL10 refer to controls that may be included in the DCP or another policy. PL9 describes a requirement for flood impact assessment to be carried out for development in areas with significant flood flow. PL10 describes possible controls on building design for flood-prone properties that are redeveloped over time. Discussion with Council is needed to check details regarding the adoption of these measures. In general, both are suitable for the three towns in the current study.

Further changes to the DCP as recommended by the MOFS FRMS&P, which will cover overland flow in Wagga Wagga, are likely to be applicable to overland flow in Tarcutta, Ladysmith and Uranquinty. Once available, these proposed changes should be reviewed to ensure their appropriateness for the three towns. Given they are likely to be suitable, separate DCP changes will not be proposed by the current study, at this stage.

### 8.6.3 Inclusion of Flood Risk Information on Section 10.7 (2) & (5) Planning Certificates (PM04)

It is recommended that Council provide additional information on Section 10.7 (2) and (5) planning certificates describing a site's flood risk, so as to better inform stakeholders and facilitate improved response during a flood event. The actual measure is described in the FRMS&P (WMAwater on behalf of Wagga Wagga City Council, 2017 and the MOF FRMS&P, with the latter not on public exhibition at the time of writing). A paraphrased summary of the measure from WMAwater on behalf of Wagga Wagga City Council, 2017 is provided below:

*Summary of Option PL5:* The measure consists of expanding the amount of information on flooding on Section 10.7 (2) and (5) certificates. Council currently provides information on S10.7 (2) certificates regarding development controls for properties in the FPA, with no additional information on the (5). Additional information to be provided on the certificates consists of GIS-based map showing design flood behaviour. Suggested information, specific to both certificate types, is provided, including:

- Whether the land is within the FPA and flood related development controls apply, (2);
- Design flood levels/depths specific to the property for the 1% AEP, 5% AEP and PMF
- events, (5);
- Percentages of lots affected by the FPA if not 100%, (5);
- Likelihood of flooding and mechanism (riverine/ overland flow/ both) (5);
- Flood hazard (5);
- Hydraulic categorisation (e.g. floodway) (5);
- Evacuation routes/ constraints (5); and
- Associated Mapping for the above items (5).

Further changes to the S10.7 (2)/(5) certificates as recommended by the MOFS FRMS&P, which will cover overland flow in Wagga Wagga, are likely to be applicable to overland flow in Tarcutta, Ladysmith and Uranquinty. Once available, these proposed changes should be reviewed to ensure their appropriateness for the three towns. Given they are likely to be suitable, separate S10.7 changes will not be proposed by the current study, at this stage.

### 8.6.4 Voluntary Purchase or Voluntary House Raising (VP/VHR) (PM05)

VP and VHR are used to remove a dwelling from the floodplain completely (VP) or to raise it to reduce its flood risk (VHR). Both options have multiple drawbacks, mainly relating to social impacts, and so they are only used in areas where certain criteria have been met. Specifically, dwellings eligible for VP are those that experience regular, high hazard flooding where there is a risk to life and no other measures are available. VHR has a slightly looser eligibility criteria but can only be applied to certain construction types, and it must be economically feasible.

For VP, the investigation of various structural and non-structural measures strongly indicates that flood risk can be managed in the three towns without resorting to purchase. For VHR, there are around 20 dwellings in Uranquinty and 7 in Tarcutta with relatively high flood damages where it may be justified. In Uranquinty, a relatively modest upgrade of the levee system would protect these lots in a large flood (i.e. 1% AEP). In Tarcutta, VHR could be investigated further if no levee upgrade goes ahead. At this stage, neither measure is recommended.

## 8.7 Multi-criteria Analysis of Measures

The assessment of various flood modification, property modification and response modification measures has been presented in this section, and measures that are both feasible and significantly reduce flood risk have been recommended. In this section, these criteria and others are scored, across the recommended options, in order to compare their relative advantages and disadvantages. This enables particular options to be prioritised and is a useful tool for decision-makers and other stakeholders. It should be noted that scoring and ranking is only used for an indicative comparison and is not intended to act as a final verdict on the options. Also note that the scoring and ranking may be updated following the public exhibition period, especially in regard to community acceptance.

The results of the analysis are presented in Table 44. Each criteria corresponds to a column and has been scored between -3 (lowest score) and 3 (highest score).

*Table 44: Multi-criteria Assessment*

| Reference | Mitigation Measure | Impact on road flooding | Impact on property flooding | Impact on risk to life | Technical Feasibility | Community Acceptance | Economic Value (B/C ratio) | Cost and available funding | Environmental Impact | Impact on SES | Political Feasibility | Total Score | Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PM01 | Flood Planning Area and Level for each town | 0 | 3 | 1 | 3 | 2 | 3 | 0 | 0 | 2 | 2 | 16 | 8 |
| PM02 | Updated information in the Local Environment Plan | 0 | 2 | 1 | 3 | 2 | 3 | 0 | 0 | 2 | 2 | 15 | 9 |
| PM03 | Adoption of matrix-style Development Control Plan and related DCP changes | 0 | 2 | 1 | 1 | 1 | 2 | 0 | 0 | 1 | 2 | 10 | 14 |
| PM04 | Inclusion of Flood Risk Information on s10.7 (2) & (5) Planning Certificates | 0 | 1 | 1 | 1 | 0 | 2 | 0 | 0 | 1 | 1 | 7 | 16 |
| RM01/4/6 | Update the Wagga Wagga Local Flood Plan section for each town | 1 | 1 | 2 | 3 | 3 | 3 | 2 | 0 | 3 | 3 | 21 | 1 |
| RM02/5/8 | Update Flood Intelligence Cards for each town | 1 | 1 | 2 | 3 | 3 | 3 | 2 | 0 | 3 | 3 | 21 | 1 |
| RM03 | Install an automatic water level recorder on Umbango Creek | 1 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 2 | 2 | 15 | 9 |
| RM07 | Install a telemetered pluviometer in the Sandy Creek catchment | 1 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 2 | 2 | 15 | 9 |
| RM09 | Requirement for Site Specific Flood Emergency Plans | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 0 | 1 | 1 | 13 | 12 |
| RM10 | Community Flood Education | 2 | 2 | 2 | 3 | 2 | 3 | 2 | 0 | 2 | 2 | 20 | 4 |
| TD01 | Maintenance of Levee Cross-drainage for Tarcutta | 1 | 2 | 1 | 2 | 2 | 3 | 2 | 0 | 2 | 2 | 17 | 6 |
| TL04 | Upgrade Existing Tarcutta Levee | 1 | 1 | 1 | 3 | 1 | -2 | 0 | 0 | 1 | 0 | 6 | 18 |
| LK01 | Improved drainage on Cunningdroo Street | 1 | 0 | 0 | 3 | 3 | 1 | 1 | 0 | 0 | 2 | 11 | 13 |
| TL06 | Raise Existing Tarcutta Levee and New Oval Levee | 2 | 2 | 2 | 3 | 0 | -3 | 0 | 0 | 2 | -1 | 7 | 16 |
| S06 | Sandy Creek Regular Clearing of Sedimentation | 1 | 1 | 1 | 2 | 0 | 1 | 2 | -1 | 1 | 1 | 9 | 15 |
| UD01 | Maintenance of Levee Cross-Drainage for Uranquinty | 1 | 2 | 1 | 2 | 2 | 3 | 2 | 0 | 2 | 2 | 17 | 6 |
| UL01 | Uranquinty Levee System Upgrade | 3 | 3 | 3 | 2 | 1 | 3 | 1 | 0 | 3 | 2 | 21 | 1 |
| UL04 | Deane and Connorton Levee Raised with Channel Improvement | 3 | 3 | 3 | 2 | 1 | 3 | 1 | 0 | 2 | 2 | 20 | 4 |
| UV02 | Concrete Channel Section in Sandy Creek | 1 | 1 | 1 | 0 | -1 | -1 | 1 | -2 | 1 | -1 | 0 | 19 |

The table shows that the highest ranked measures are updating the Local Flood Plan and Flood Intelligence Cards, along with raising the Uranquinty Levee system raising (UL01). These measures have widespread benefit to both road and property flooding, and risk to life, while having no significant drawbacks. Other high scoring measures are Community Flood Education, Maintenance of Levee Cross-Drainage in both Tarcutta and Uranquinty, and UL04, however, it's noted that if UL01 is built that would obviate the need for UL04. DCP and LEP updates also score well, as does RM03 and RM07 (additional flood warning equipment). The two levee options in Tarcutta score decently for reduced flood risk but have low economic benefit and are generally expensive. Some options score relatively low but are straightforward and will provide overall benefit, for example S06 and PM04.

The results of the assessment were used to inform the draft Plan in the executive summary of this document, including the priority of each recommended measure.

# 9. COMMUNITY CONSULTATION

Community consultation was undertaken during the study to inform residents of the study's findings and to seek feedback on the findings of the report. There were broadly two channels of communication: community representatives were consulted on the study's findings progressively throughout the project, and the wider community was consulted at the beginning of the study and then during public exhibition. Community representatives were sought from each town, to attend the Flood Risk Management Advisory Committee (FRMAC) meetings at council chambers and be in regular contact with the consultants, but unfortunately only two from Uranquinty were available.

The following section describes the newsletter and questionnaire at the study outset and during public exhibition, and the information sessions held.

## 9.1 Newsletter and Questionnaire – February 2019

A newsletter and questionnaire were sent out in February 2019 to inform residents of the study and request feedback on potential mitigation measures. The mailout consisted of a 2 page newsletter and 2 page questionnaire, with a different version used for each town. The mailout was accompanied by a webpage (on Council's existing 'Flood Futures' website) which contained the same information as the newsletters and a link to an online version of the questionnaire. An example of the newsletter and questionnaire from Tarcutta is provided in Appendix D. The mailout was to all households and businesses in each of the three towns. Statistics for the mailout are summarised in Table 45 and in Figure 35. The results from each town are presented in the following sections.

*Table 45: Community Consultation Response Summary*

| Town | Number Mailed Out* | Questionnaire Responses Received (inc. online) | Response Rate |
|---|---|---|---|
| **Tarcutta** | 260 | 9 | 3% |
| **Ladysmith** | 179 | 7 | 4% |
| **Uranquinty** | 512 | 29 | 6% |

*Note that questionnaires were mailed to both residents and property owners, which increased the number sent out and while ensuring a more complete consultation, also likely resulted in a lower response rate.

### 9.1.1 Tarcutta Questionnaire Responses

The nine questionnaire responses from Tarcutta indicate residents favour structural works for flood mitigation. Five responses supported use of levee repair/increases and modifying sections of creek channel, while seven favoured improved overland flowpaths. Responses proposed a number of measures for further investigation, including improved conveyance under Tarcutta Creek Bridge, raising the levee and improvement/maintenance of drainage paths within the town. These measures will be tabulated along with the options outlined in the flood study for discussion with Council.

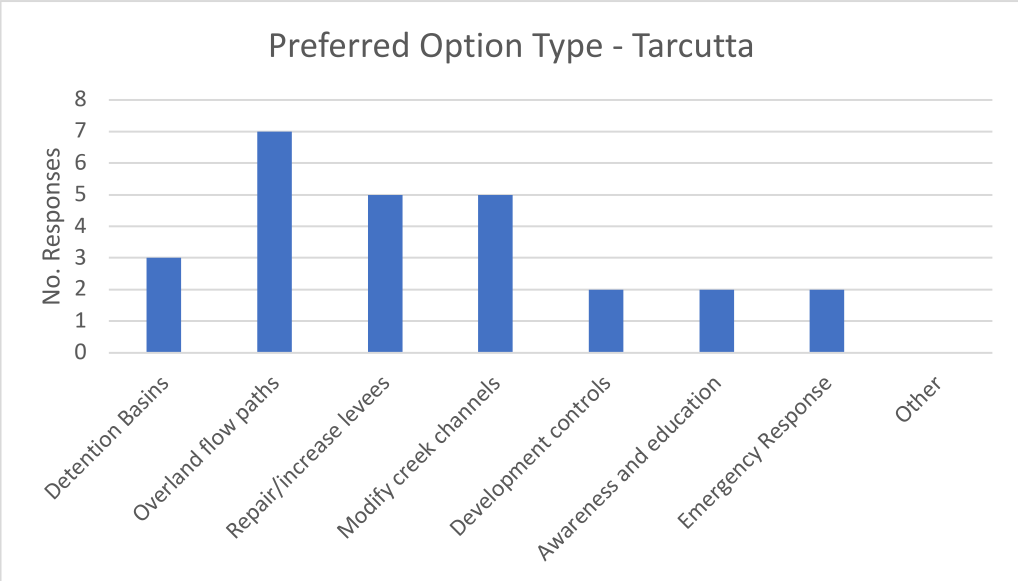
Support for non-structural measures was relatively low, with two favouring planning controls, two awareness and education and two emergency response improvements. No particular measures were proposed in regard to planning controls.

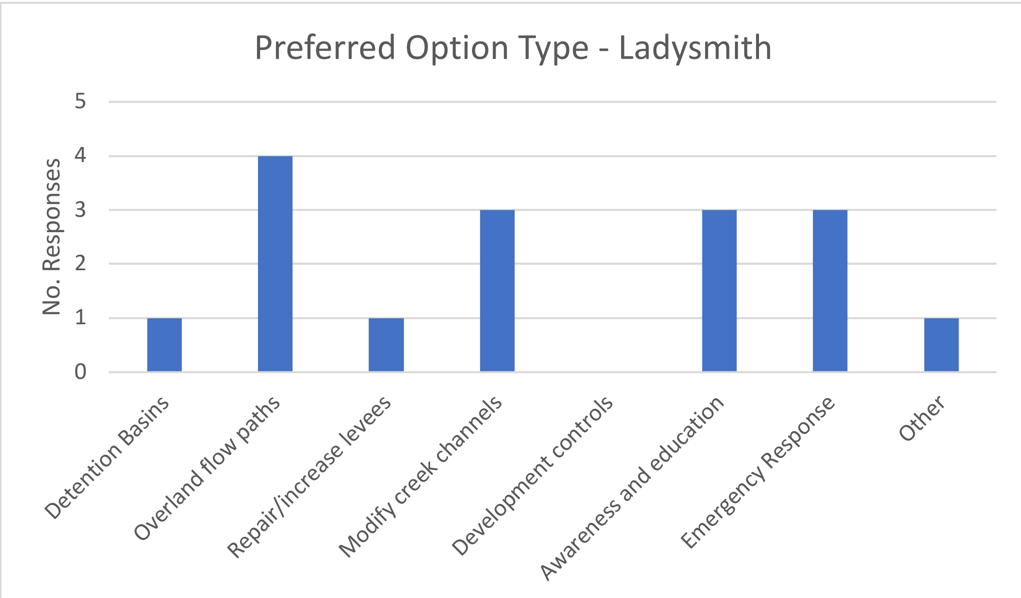
### 9.1.2 Ladysmith Questionnaire Responses

The seven questionnaire responses from Ladysmith indicate residents, on average, do not strongly favour particular types of mitigation option. The highest support by residents was for improved overland flowpaths (4 responses) which corresponded with issues described (almost all responses pertained to local overland flooding). Specific measures proposed included addressing a build-up of soil on Mona Vale Road, and better real-time monitoring of flood events. These measures will be tabulated along with the options outlined in the flood study for discussion with Council.

### 9.1.3 Uranquinty Questionnaire Responses

Uranquinty had the highest number of responses of the three towns and there was a high level of engagement with a range of types of mitigation measure. From the 29 responses, there was very high support for three types of structural option (overland flowpaths, levees, and modifying creek channels) with approximately 80% support for each. Many potential measures were discussed related to levee improvements, drainage upgrades and the effect of recent development in the town. There was lower support for planning controls (14%), flood awareness and education (21%) and emergency response improvements (17%). All of the proposed measures will be tabulated along with the options outlined in the flood study for discussion with Council.



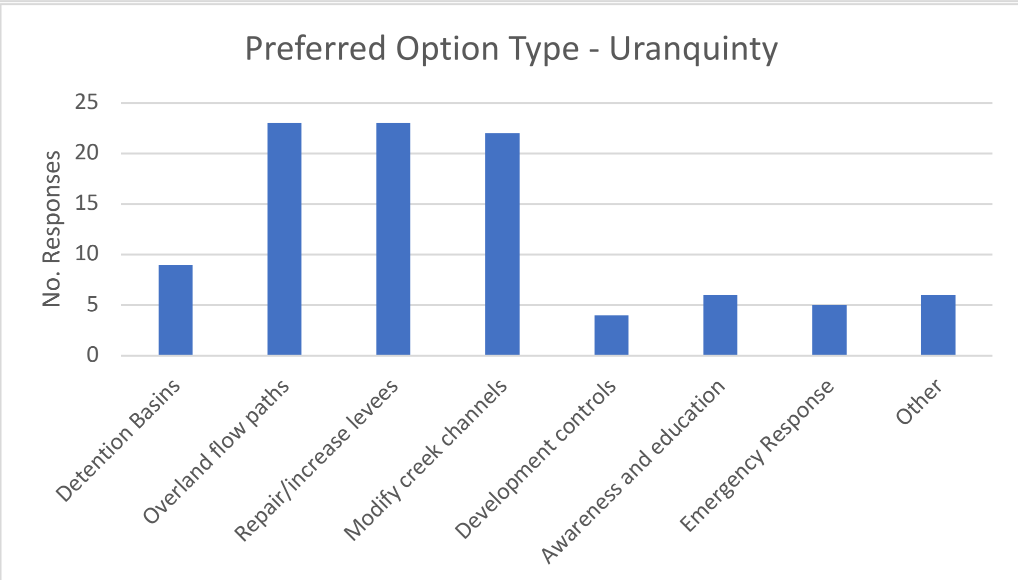




*Figure 35: Questionnaire Results - Preferred Options*

## 9.2 Public Exhibition

Public exhibition of the draft study and plan was held from 1 April to 5 May 2021. The exhibition period was aimed at informing residents and other stakeholders of the draft study and plan and inviting feedback, which can then be incorporated into the final report. The following consultation activities were used during the exhibition period:

- Public notices including notification of the information sessions;
- A website with an overview of the study and plan, as well as a link to the draft report and a feedback form, and booking system for the information sessions; and
- Information sessions on 20th and 21st of April, consisting of a group meeting in Uranquinty and a series of one-on-one meetings with interested residents in each town.

The submissions and feedback received during the public exhibition are summarised in Appendix D.

Broadly speaking feedback supported the findings of the study and was mainly centred around emphasising specific issues that community members believed should be prioritised. An issue that was consistently raised in Ladysmith and Uranquinty alike was the potential impact of ongoing and future development on existing flood issues.

# 10. REFERENCES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6. Flood Mitigation of Uranquinty, **1980, M.J. Bryant**
7. Wagga Wagga Local Flood Plan, **2006, SES**
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10. Managing the Floodplain Handbook, **2017, Australian Institute for Disaster Resilience, developed by National Flood Risk Advisory Group**
11. Floodplain Risk Management Guideline – Residential Flood Damages, **2007, Department of Environment and Climate Change, NSW**

# APPENDIX A – TARCUTTA DESIGN FLOOD MAPS

# APPENDIX B – LADYSMITH DESIGN FLOOD MAPS

# APPENDIX C – URANQUINTY DESIGN FLOOD MAPS

# APPENDIX D – COMMUNITY CONSULTATION

# PUBLIC EXHIBITION SUBMISSIONS

This sections presents summarised feedback received during the public exhibition period in April and May 2021. Feedback was invited as part of the consultation period with stakeholders able to email feedback, submit it via the contact form on Council's website, or in person during the information sessions held in each town. Feedback given in person was counted as a submission.

On May 2021 GRC Hydro representatives met the residents of the villages of Tarcutta, Ladysmith and Uranquinty to allow residents to express their concerns. While a general concern was raised regarding development flood impacts and the need for effective and timely maintenance of the existing drainage assets, case-specific issues were also noted. What follows is a summary of the comments, complaints and recommendations gathered from the residents.

## Tarcutta

Issues raised by residents of Tarcutta mainly pertain to the poor maintenance of several infrastructure items, to wit:

- The lack of maintenance of a manmade creek near the Tarcutta Hotel has cut off access to the Old Tarcutta Inn at 4514 Hume Hwy.
- The blockage of a stormwater pipe near the Tarcutta Hotel has gone unnoticed by Council.
- Council have ceased to monitor a stormwater flap valve at the gate sitting behind the hotel, which has allowed waters from creek to flow in. This gate also poses a major hazard to a public football field.
- Residents also expressed disappointment of the exclusion of their houses from the levee bank.

One residence only attended the Public Meeting with other submissions received via mail.

## Ladysmith

At Ladysmith there was concurrence that creek flooding is not the issue and instead the issue is drainage at specific locations. Particularly the possibility of impacts due to new development were highlighted as an issue residents are concerned about.

Residents at southern end of town indicated there is a persistent drainage issue with water coming off of Tumbarumba Road and draining into property at this location (flowing west toward creek).

Several drainage works have been carried on by Council over the years which include the filling of a dam near Tywong Street and Cunningdroo Street and the installation of culverts under the road embankment of Kyeamba Street. The latter intervention helped manage overland flows, as praised by residents at 52 Kyeamba Street who has not experienced flooding since. On the reverse side potentially such works may have altered flow regimes for others.

Pre-existing issues remain along Cunningdroo Street, where runoff tends to flow from a subdivision located on higher ground and inundate the properties facing Cunningdroo Street via the rear. Further, lack of maintenance of local drainage is an issue raised consistently.

## Uranquinty

At Uranquinty `the participation level was highest and numerous submissions with significant detail have been made. Further this community was key to informing the studies progress at Uranquinty and many measures tested were put forward by Uranquinty community itself.

Rather than repeat submission here a summary is made. Whilst it is acknowledged a summary will omit details, it is also more readily digested and if nothing else those submitting during the Public Exhibition phase are seeking to have their message heard.

In summary issues are:

- Existing level of flood liability in town and what can be done to mitigate it including closing Deane/Connorton St levee (inclusive of upper catchment areas) and installation of a pump at Deane St;
- Development impacts on existing flood liability. Development south of the highway is perceived to add substantially to the situation at Deane St and it was evident that community members find this unwelcome. Similarly development north of the highway was a concern for residents who feel that unless existing drainage infrastructure is improved, such development might be expected to worsen their situation; and
- Infrastructure optimisation. Existing levees, gates and other drainage structures require maintenance and/or alterations in order to best serve the community.

Regularly clearing internal drains within the town should be undertaken.


# Have your say: Tarcutta, Ladysmith & Uranquinty Floodplain Risk Management Studies & Plans

On behalf of Wagga Wagga City Council, GRC Hydro are undertaking Floodplain Risk Management Studies and Plans for Tarcutta, Ladysmith and Uranquinty.

We would like to hear your experiences of flooding to better understand how flooding occurs in your area and what measures may improve the current flood situation.

These studies and plans will identify and recommend appropriate actions to manage flooding in your area. This study will be used by Council to manage flood risks in your area.

## What is the Floodplain Risk Management Program?

The Floodplain Risk Management Program is run by the NSW Government.

This program helps councils make informed decisions about managing flood risk, implementing management plans to reduce flood risk and to provide essential information to the SES to deal with flood emergency response.

This program consists of five stages and the current study will undertake the third and fourth stages of this process; Floodplain Risk Management Study and Plan. This follows on from the Flood Study that was completed in 2014.

The stages of the Floodplain Risk Management Program are presented below:


This current study deals with these two stages.

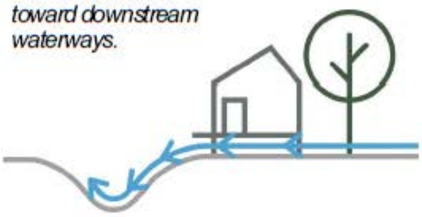
## Flooding in Tarcutta

Flooding in Tarcutta is caused by heavy rainfall in the catchment of Tarcutta Creek causing it to break its banks and spread over its floodplain.

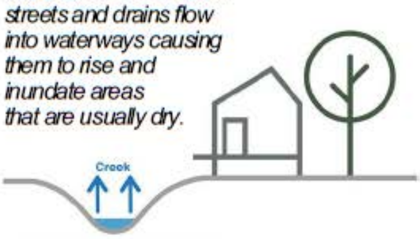
There is a second source of flooding, referred to as overland flow flooding.

This occurs when rainfall in the vicinity of the town causes flooding as it flows towards the creek. Mainstream and overland flow flooding can occur simultaneously, or separately.

*Overland flow flooding occurs as rainfall runoff moves toward downstream waterways.*



*Mainstream flooding occurs when runoff from streets and drains flow into waterways causing them to rise and inundate areas that are usually dry.*




## What is a floodplain risk management study and plan?

A floodplain risk management study and plan (FRMS&P) follows a flood study.

A flood study is a comprehensive technical investigation of flood behaviour which defines the nature of flood risk in the LGA by providing information on the extent, level and velocity of floodwaters for a full range of flood magnitudes.

A FRMS&P draws on the results of the flood study to identify, assess and compare various flood risk management options and opportunities aimed at improving the existing flood situation in the LGA.

It provides information and tools to allow considered assessment of flood impacts of management options and provides a strategic plan for implementation.

Management options are typically categorised as property modification measures, response modification measures and flood modification measures.

GRC Hydro: Water Engineers and Hydrologists

wagga.nsw.gov.au/floodfutures


## What is a FRMS&P used for?

A FRMS&P provides key information for Council, the SES and the community for effectively managing and mitigating flood risk.

For Council, FRMS&P's are primarily a planning tool for future development in the LGA and implementing flood mitigation measures for existing development areas. Examples of applications for Council are listed below:

- Examination of Council's local flood risk management policies, strategies and planning instruments; and
- Identification and assessment of floodplain risk management measures for existing development areas aimed at reducing social, environmental and economic loss of flooding on development and the community.

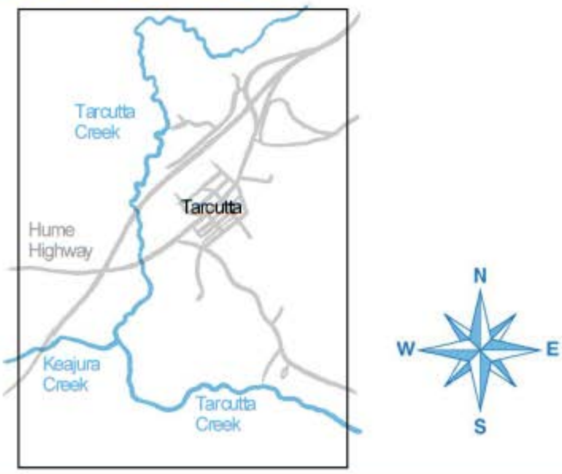
Information from the FRMS&P will assist the SES in its evacuation and logistics planning. The outcomes of the study will provide the SES with:

- a clear description of flood behaviour in the study area for a full range of flood events;
- a description of flood warning times for the LGA; and
- identification of critical evacuation issues in the LGA such as locations where road access is cut and the warning time before road access is cut.

## The study area

The Tarcutta, Ladysmith and Uranquinty Flood Studies were completed in late 2014 and outcomes from the flood studies have formed the basis of the current study.

Tarcutta was severely impacted by flooding in October 2010, with floodwaters overtopping the levee banks, eight properties flooded and residents evacuated to the RSL. Flooding in March 2012 also caused property inundation but was generally less severe than 2010.




## Have your say

Your feedback is important in helping us get a complete picture of the communities knowledge of potential mitigation measures in Tarcutta.
There are a variety of ways you can share your experiences and knowledge with us:

- Fill out the questionnaire included with this letter and send it back using the self-addressed envelope provided or email it to floodfutures@wagga.nsw.gov.au
- Fill out the questionnaire online at wagga.nsw.gov.au/floodfutures

**Please return your questionnaire by XX XXXX to ensure your feedback is included.**

## Why your feedback is important

GRC Hydro will use computer models developed in the flood studies to assess flood mitigation measures.
This process involves identifying areas that are significantly flood affected and assessing flood modification measures to relieve the flood risk at these locations. Community input and knowledge of measures that might mitigate flooding in the Local Government Area is invaluable to this study.

## What happens next

GRC Hydro will assess flood modification measures and will present draft findings to Council's Floodplain Risk Management Advisory Committee. Following further discussion, the draft report containing recommended measures will be placed on public exhibition in 2019.

## More information

If you have any further questions regarding the study or any further flood information/photos please attach them to your questionnaire or contact a member of the project team:

- Felix Taaffe: Senior Engineer, GRC Hydro
  tarcutta@grchydro.com.au
  02 9030 0342
- Shaula Siregar: Lead Engineer – Water and Waste Assets, Wagga Wagga City Council
  floodfutures@wagga.nsw.gov.au
  1300 292 442

GRC Hydro: Water Engineers and Hydrologists wagga.nsw.gov.au/floodfutures


## Contact Details

Name

Address:

Phone Number:

Email:

Can we contact you for more information? ◯ Yes ◯ No

## Your Property

What building type is your property?

◯ Residential ◯ Industrial

◯ Commercial

Business Name:

How long have you lived or worked at this property? ____ Years ____ Months

## Flood Management Options

The current study is assessing a range of measures aimed at managing the current flood risk. The study is looking for input from residents to better understand local preferences for floodplain management.

Which of the following options do you prefer for managing flood risk? (tick box based on preference)

- ◯ Upgrade detention basins to reduce peak flood flow rates
- ◯ Improve overland flow paths to increase their capacity
- ◯ Repair and/or increase the size of existing levee banks
- ◯ Modify creek channels to increase their capacity
- ◯ Impose greater flood-related development controls and increase strategic flood planning
- ◯ Increase flood awareness and education in the community
- ◯ Upgrade flood warning, evacuation planning and emergency response measures
- ◯ Other suggestions (describe below)

GRC Hydro: Water Engineers and Hydrologists wagga.nsw.gov.au/floodfutures


## Further Information

For any of the options ticked, please provide any further information or feedback you may have. This may include the location, length or alignment of any civil works, or ideas for planning and emergency response-related measures. If you have photos, maps or other materials, you can send them to floodfutures@wagga.nsw.gov.au along with your contact details.

______________________________________________

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______________________________________________

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## Other Comments

If you have other comments which could assist us in the development of the Tarcutta, Ladysmith and Uranquinty Floodplain Risk Management Study & Plan, please write them in the space below.

______________________________________________

______________________________________________

______________________________________________

______________________________________________

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Please return your questionnaire by XX XXXXXX 2019 to ensure your feedback is included/that it is counted. If your information does not fit in the space provided, please email it to **floodfutures@wagga.nsw.gov.au**

GRC Hydro: Water Engineers and Hydrologists | wagga.nsw.gov.au/floodfutures

# Appendix E – PRELIMINARY COSTINGS

| Costing Estimate - Raise Existing Tarcutta Levee (TL04) | | | | | |
|---|---|---|---|---|---|
| **No.** | **Item** | **Unit rate ($)** | **Amount** | **Units** | **Cost** |
| 1 | **Pre-construction Costs** | | | | |
| 1.1 | Detailed Survey | 5000 | 1 | | $ 5,000.00 |
| 1.2 | Contractor setup including WHS | 15000 | 1 | | $ 15,000.00 |
| 1.3 | Project Management | 10000 | 1 | | $ 10,000.00 |
| 1.4 | Detailed Design Study inc. Geotechnical Assessment | 100000 | 1 | | $ 100,000.00 |
| 2 | **Excavation and Earthworks** | | | | |
| 2.1 | Clear site of light vegetation and cart away | 0.38 | 5756.0 | m2 | $ 2,187.28 |
| 2.2 | Excavate from borrow pit and deposit as fill within 1km including compaction to 90% (light soil) | 10.25 | 5756.0 | m3 | $ 58,999.00 |
| 2.3 | Compaction of level and grade surface | 4 | 5397.7 | m2 | $ 21,590.85 |
| 2.4 | Top soil placement and seeding | 8.85 | 5397.7 | m2 | $ 47,769.76 |
| | | | | Subtotal | $ 260,546.89 |
| | | | | GST | $ 26,054.69 |
| | | | | Total | $ 286,601.58 |

Map below indicates the modelled levee height (1% AEP). Height does not include freeboard.

| Costing Estimate - Raise Existing Tarcutta Levee & New Levee (TL06) | | | | | |
|---|---|---|---|---|---|
| **No.** | **Item** | **Unit rate ($)** | **Amount** | **Units** | **Cost** |
| 1 | **Pre-construction Costs** | | | | |
| 1.1 | Detailed Survey | 10000 | 1 | | $ 10,000.00 |
| 1.2 | Contractor setup including WHS | 15000 | 1 | | $ 15,000.00 |
| 1.3 | Project Management | 10000 | 1 | | $ 10,000.00 |
| 1.4 | Detailed Design Study inc. Geotechnical Assessment | 100000 | 1 | | $ 100,000.00 |
| 2 | **Excavation and Earthworks** | | | | |
| 2.1 | Clear site of light vegetation and cart away | 0.38 | 14986.7 | m2 | $ 5,694.96 |
| 2.2 | Excavate from borrow pit and deposit as fill within 1km including compaction to 90% (light soil) | 10.25 | 14986.7 | m3 | $ 153,614.04 |
| 2.3 | Compaction of level and grade surface | 4 | 12188.4 | m2 | $ 48,753.75 |
| 2.4 | Top soil placement and seeding | 8.85 | 12188.4 | m2 | $ 107,867.68 |
| 2.5 | Purchase and installation of drainage pipes (1200mm) | 1050 | 30.1 | m | $ 31,605.00 |
| 2.6 | Purchase and installation of headwalls | 1375 | 4 | | $ 5,500.00 |
| | | | | Subtotal | $ 488,035.43 |
| | | | | GST | $ 48,803.54 |
| | | | | Total | $ 536,838.97 |

The map below indicates the modelled levee height (1% AEP). Height does not include freeboard.

| Costing Estimate - Raise Existing Uranquinty Levee (UL01) | | | | | |
|---|---|---|---|---|---|
| **No.** | **Item** | **Unit rate ($)** | **Amount** | **Units** | **Cost** |
| 1 | **Pre-construction Costs** | | | | |
| 1.1 | Detailed Survey | 10000 | 1 | | $ 10,000.00 |
| 1.2 | Contractor setup including WHS | 15000 | 1 | | $ 15,000.00 |
| 1.3 | Project Management | 10000 | 1 | | $ 10,000.00 |
| 1.4 | Detailed Design Study inc. Geotechnical Assessment | 125000 | 1 | | $ 125,000.00 |
| 2 | **Excavation and Earthworks** | | | | |
| 2.1 | Clear site of light vegetation and cart away | 0.38 | 20980.5 | m2 | $ 7,972.59 |
| 2.2 | Excavate from borrow pit and deposit as fill within 1km including compaction to 90% (light soil) | 10.25 | 20980.5 | m3 | $ 215,050.05 |
| 2.3 | Compaction of level and grade surface | 4 | 31088.5 | m2 | $ 124,354.04 |
| 2.4 | Top soil placement and seeding | 8.85 | 31088.5 | m2 | $ 275,133.31 |
| 2.5 | Purchase and installation of drainage pipes (1500mm) | 1680 | 80.0 | m | $ 134,400.00 |
| 2.6 | Purchase and installation of headwalls | 1375 | 8 | | $ 11,000.00 |
| | | | | Subtotal | $ 927,909.99 |
| | | | | GST | $ 92,791.00 |
| | | | | Total | $ 1,020,700.99 |

Map below indicates the modelled levee height (1% AEP level). Height does not include freeboard.

| Costing Estimate - Raise Existing Levee increase channel (UL04) | | | | | |
|---|---|---|---|---|---|
| **No.** | **Item** | **Unit rate ($)** | **Amount** | **Units** | **Cost** |
| 1 | **Pre-construction Costs** | | | | |
| 1.1 | Detailed Survey | 10000 | 1 | | $ 10,000.00 |
| 1.2 | Contractor setup including WHS | 15000 | 1 | | $ 15,000.00 |
| 1.3 | Project Management | 10000 | 1 | | $ 10,000.00 |
| 1.4 | Detailed Design Study inc. Geotechnical Assessment | 125000 | 1 | | $ 125,000.00 |
| 2 | **Excavation and Earthworks** | | | | |
| 2.1 | Clear site of light vegetation and cart away | 0.38 | 3688.5 | m2 | $ 1,401.61 |
| 2.2 | Excavate from borrow pit (channel area) and deposit as fill within 1km including compaction to 90% (light soil) | 10.25 | 3688.5 | m3 | $ 37,806.70 |
| 2.3 | Compaction of level and grade surface | 4 | 6769.1 | m2 | $ 27,076.32 |
| 2.4 | Top soil placement and seeding | 8.85 | 6769.1 | m2 | $ 59,906.36 |
| 2.5 | Excavate trenches 1.00/2.00m deep in light soil | 58 | 3931.5 | m3 | $ 228,029.42 |
| 2.6 | Hydro mulch, sprayed grass seed compound | 3250 | 0.9 | ha | $ 2,762.50 |
| | | | | | |
| | | | | Subtotal | $ 516,982.91 |
| | | | | GST | $ 51,698.29 |
| | | | | Total | $ 568,681.20 |

Map below indicates the modelled levee height (1% AEP). Height does not include freeboard.

| Costing Estimate – Concrete Channel Section in Sandy Creek (UV02) | | | | | |
|---|---|---|---|---|---|
| **No.** | **Item** | **Unit rate ($)** | **Amount** | **Units** | **Cost** |
| 1 | **Pre-construction Costs** | | | | |
| 1.1 | Detailed Survey | 5000 | 1 | | $ 5,000.00 |
| 1.2 | Contractor setup including WHS | 15000 | 1 | | $ 15,000.00 |
| 1.3 | Project Management | 10000 | 1 | | $ 10,000.00 |
| 1.4 | Detailed Design Study | 10000 | 1 | | $ 10,000.00 |
| 2 | **Excavation and Earthworks** | | | | |
| 2.1 | Excavation and Earthworks | 58 | 3730.0 | m3 | $ 216,340.00 |
| 2.2 | concrete slab 150mm | 109 | 4780.0 | m2 | $ 521,020.00 |
| 2.3 | Cut down tree, grub up stump, roots and cart away or burn on site (2000/3000mm girth) | 944 | 30.0 | | $ 28,320.00 |
| | | | | | |
| | | | | Subtotal | $ 805,680.00 |
| | | | | GST | $ 80,568.00 |
| | | | | Total | $ 886,248.00 |

Sample cross-sections and alignment of modified creek section are shown on Figure 31