1. NARROMINE TOWN FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Author	Director Infrastructure and Engineering Services
Responsible Officer	Director Infrastructure and Engineering Services
Link to Strategic Plans	CSP – 3.1.2 Resolve issues surrounding the flood levee and impacts on residential development

Executive Summary

The purpose of this report is to present feedback from public exhibition and seek Council's endorsement to adopt the Narromine Town Floodplain Risk Management Study and Plan Update.

Report

At Council's Ordinary Meeting held on 16 June 2021, it was resolved that the draft Narromine Town Floodplain Risk Management Study and Plan Update that was presented to the Narromine Floodplain Management Committee be accepted and placed on public exhibition for a period of 28 days (*Resolution 2021/108*)

The draft Narromine Town Floodplain Risk Management Study and Plan Update was subsequently placed on Council's website and Facebook, as well as hard copies distributed to 4 locations within the Shire for public viewing. Closing date for written submissions was 16 July 2021. The document was also distributed to members of the Local Emergency Management Committee as well as Inland Rail for comment.

One written submission was received regarding the impact of flooding along River Drive for the Option B alignment. A copy of the submission is provided to Councillors under separate cover.

1. NARROMINE TOWN FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE CONT'D.

Issue	Detail of Concern Raised	Staff Comment
Impact of flooding of properties along River Drive for Option B	The modelling shows that construction of the levee would increase the depth of flooding of properties along River Drive by 2 to 10cm thus increasing any damage. When assessing the costs, no mention is made of the adverse effects of the levee on areas it does not protect. However, when calculating the cost of the levee, no account is taken of increased damage due to the levee for residents along River Drive, and many people on the northern side of the river.	While Levee Option B by itself would increase peak flood levels along River Drive, the inclusion of the upgraded railway culverts at Webb's Siding in the Preferred Flood Mitigation Scheme (PFMS) will mitigate these impacts. Therefore, the adoption of the PFMS by Council will ensure that flooding conditions along the River Drive Properties would not be exacerbated for all floods up to the 1:100-year event as a result of the proposed works. (Referred to as a 1% AEP flood event in the document) Future concept and detailed design studies of the levee will include detailed engineered estimates of probable costs.

Financial Implications

Adoption of the Study and Plan Update will enable Council to apply to relevant funding bodies for the next stage of the Narromine Levee Project being concept design and relevant feasibility studies.

Legal and Regulatory Compliance

Compliance with LEP
Compliance with DCP
Protection of the Environment Operations Act, 1997
NSW Floodplain Development Manual

Risk Management Issues

The study meets the technical requirements as per the NSW Floodplain Development Manual and it has been prepared adhering to the best flood risk management practices.

1. NARROMINE TOWN FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE (CONT'D)

Internal/External Consultation

Consultation has been undertaken with the Narromine community, Floodplain Management Committee, Inland Rail and with the Local Emergency Management Committee.

Further consultation may be required for specialist studies such as (but not limited to) detailed design, environmental and geotechnical studies.

Attachments

- Narromine Town Floodplain Risk Management Study and Plan Update (***see Attachment No 1***)

RECOMMENDATION

That Council adopt the Narromine Town Floodplain Risk Management Study and Plan Update.

André Pretorius
Director Infrastructure and Engineering Services

NARROMINE SHIRE COUNCIL

NARROMINE TOWN FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

VOLUME 1 – REPORT

JULY 2021

Aerial photograph taken looking south during the February 1955 flood, with the Macquarie River in the foreground.

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FOREWORD

NSW Government's Flood Policy

The NSW Government's Flood Prone Land Policy is directed at providing solutions to existing flooding problems in developed areas and to ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the Policy, the management of flood liable land remains the responsibility of local government. The State subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist councils in the discharge of their floodplain management responsibilities. The Policy provides for technical and financial support by the State through the following four sequential stages:

1.	Data Collection and Flood Study	Collects flood related data and undertakes an investigation to determine the nature and extent of flooding.
2.	Floodplain Risk Management Study	Evaluates management options for the floodplain in respect of both existing and proposed development.
3.	Floodplain Risk Management Plan	Involves formal adoption by Council of a plan of management for the floodplain.
4.	Implementation of the Plan	Construction of flood mitigation works to protect existing development. Use of Local Environmental Plans to ensure new development is compatible with the flood hazard. . Improvements to flood emergency management procedures.

Presentation of Study Results

The results of flood modelling which has been undertaken as part of the present study using contemporaneous computer modelling techniques are presented in this report (***Updated Flood Study***). Both the *Updated Flood Study* and the *Floodplain Risk Management Study* have been prepared under the guidance of the Floodplain Risk Management Committee comprising representatives from Narromine Shire Council, the NSW Department of Planning, Industry and Environment, the NSW State Emergency Service and community representatives.

ACKNOWLEDGEMENT

Narromine Shire Council has prepared this document with financial assistance from the NSW Government through its Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the Department of Planning, Industry and Environment.

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ABBREVIATIONS

AEP	Annual Exceedance Probability (%)
AHD	Australian Height Datum
ARI	Average Recurrence Interval (years)
ARR 1987	Australian Rainfall and Runoff (1987 Edition)
ARR 2019	Australian Rainfall and Runoff (2019 Edition)
BoM	Bureau of Meteorology
Council	Narromine Shire Council
DECC	Department of Environment and Climate Change
DPIE	Department of Planning, Industry and Environment
FDM	Floodplain Development Manual, 2005
FRMC	Floodplain Risk Management Committee
FPL	Flood Planning Level
FPA	Flood Planning Area
FRMS	Floodplain Risk Management Study
FRMP	Floodplain Risk Management Plan
FRMS&P	Floodplain Risk Management Study and Plan
LEP	Local Environmental Plan
LiDAR	Light Detection and Ranging (survey)
MHFL	Minimum Habitable Floor Level
NSWG	New South Wales Government
NSW SES	New South Wales State Emergency Service
PMF	Probable Maximum Flood

SUMMARY

S1 Study Objectives

Narromine Shire Council (**Council**) commissioned the update of *Narromine Floodplain Risk Management Study* and the *Narromine Floodplain Risk Management Plan*, both of which were prepared by Lyall & Associates in 2009 (respectively referred to herein as "***FRMS 2009***" and "***FRMP 2009***").

The overall objectives of the present study were to review the two aforementioned documents, refine the definition of flooding at Narromine using contemporaneous computer modelling techniques, reassess the impacts of flooding on the community, review existing Council policies as they relate to development of land in flood liable areas, consider options for the management of flood affected land and to develop a contemporaneous *Floodplain Risk Management Plan* for the town *(**Narromine Town FRMP 2021**)* which:

i) Proposes modifications to existing Council policies to ensure that the development of flood affected land is undertaken so as to be compatible with the flood hazard and risk.

ii) Proposes *Flood Planning Levels* for the various land uses in the floodplain.

iii) Sets out the recommended program of works and measures aimed at reducing over time, the social, environmental and economic impacts of flooding.

iv) Provides a program for implementation of the proposed works and measures.

While the present study principally deals with **Main Stream Flooding** from the Macquarie River, inundation resulting from **Major Overland Flow** in the absence of riverine type flooding has also been assessed.

S2 Study Activities

The activities undertaken as part of the present study, details of which are documented in this *Floodplain Risk Management Study* (***Narromine Town FRMS 2021***) report included:

1. Undertaking a consultation program to ensure that residents and business owners in Narromine were informed of the objectives, progress and outcomes over the course of the study (**Appendix A**).
2. Review of flooding patterns at Narromine for flood events up to the Extreme Flood, as determined by a new set of flood models which were developed as part of the present study (denoted herein as the *"**Updated Flood Study**"*) (**Chapter 2**).
3. Assessment of the economic impacts of flooding, including the numbers of affected properties and estimation of damages (**Chapter 2** and **Appendix B**).
4. Review of current flood related planning controls for Narromine and their compatibility with flooding conditions (**Chapter 2**).
5. Review of existing flood warning and preparedness (**Chapter 2**).
6. Strategic review of potential floodplain management works and measures aimed at reducing flood damages, including an economic assessment of the most promising measures and the preparation of suggested wording for inclusion in the *Narromine Shire Council Development Control Plan* which are aimed at guiding future development in flood prone areas (**Chapter 3** and **Appendices C** and **D**).
7. Ranking of works and measures using a multi-objective scoring system which took into account economic, financial, environmental and planning considerations (**Chapter 4**).
8. Preparation of *Narromine Town FRMP 2021* (**Chapter 5**).

S3 Summary of Flood Impacts

Figures 2.9, **2.10**, **2.11**, **2.13** and **2.15** show the indicative extent and depth of inundation design flood events with Annual Exceedance Probabilities (**AEPs**) of 5%, 2%, 1%, 0.5%, as well as the Extreme Flood, while **Figures 2.12** and **2.14** show maximum flow velocities on the Macquarie River floodplain for the 1% (1 in 100) and 0.5% (1 in 200) AEP floods. **Figure 2.16** shows design water surface profiles along the Macquarie River at Narromine.

While floodwater would break out of the Macquarie River and cross Warren Road to the north of Bowen Fletcher Drive in Skypark during a 2% (1 in 50) AEP flood event (refer **Figure 2.10**), it would generally be confined to the river and its immediate overbank area during floods up to about 1.25% (1 in 80) AEP in magnitude.

At the 1% (1 in 100) AEP level of flooding, 449 dwellings, 72 commercial/industrial buildings and seven public buildings are subjected to above-floor inundation. The total flood damages in Narromine amounts to about $50 Million in the event of a 1% (1 in 100) AEP flood, increasing to about $417 Million in an Extreme Flood. If freeboard is added to the nominal flood levels, then the estimated flood damages in Narromine increase to about $103 Million and $456 Million for the 1% (1 in 100) AEP and Extreme Flood, respectively.

The "*Present Worth Value*" of damages resulting from all floods up to the magnitude of the Extreme Flood assuming a seven per cent discount rate and an economic life of 50 year is about $22.5 Million, increasing to about $35.8 Million when freeboard is taken into account.

S4 Flood Risk and Development Controls

An updated approach which uses contemporaneous concepts of *flood hazard* and *hydraulic categorisation* has been recommended for incorporation in *Narromine Shire Development Control Plan 2011* (***Narromine Shire DCP 2011***). The delineation of Flood Planning Constraint Categories (**FPCCs**) is based on the proximity to flow paths, depths and velocities of flow, the rate of rise of floodwaters and ease of evacuation from the floodplain in the event of a flood emergency.

Figure D1.1 in **Appendix D** is an extract from the *Flood Planning Map* relating to the township of Narromine. The extent of the Flood Planning Area (**FPA**) (the area where proposed residential and commercial/industrial type development would be subject to flood related development controls) has been defined as the extent of land that lies at or below the 1% (1 in 100) AEP plus 0.5 m

Minimum Habitable Floor Level (**MHFL**) requirements would be imposed on future development in properties that are identified as lying either partially or wholly within the extent of the FPA shown on the *Flood Planning Map*. The MHFLs for all land use types are the same as are currently set out in *Narromine DCP 2011*, those being:

- at or above the 1% (1 in 100) AEP plus 0.5 m freeboard in the case of residential type development;
- as close as practical to the 1% (1 in 100) AEP plus 0.5 m but no lower than the 2% (1 in 50) AEP plus 0.5 m freeboard in the case of commercial/industrial type development; and
- at or above the 0.5% (1 in 200) AEP plus 0.5 m freeboard in the case of flood vulnerable residential type development, essential community facilities and critical utilities.

S5 Narromine Town Floodplain Risk Management Plan 2021

Narromine Town FRMP 2021 showing recommended flood management measures for the study area is presented in **Chapter 5**, with the recommended works and measures summarised in **Table S1** at the end of this Summary. The recommended works and measures have been given a provisional priority ranking, confirmed by the Floodplain Risk Management Committee, according to a range of economic, social, environmental and other criteria set out in **Table 4.1** of the report.

Narromine Town FRMP 2021 comprises four "non-structural" management measures which could be implemented by Council with the assistance of NSW SES, using existing data and without requiring Government funding. The measures are as follows:

- **Measure 1** – Inclusion of a new special flood considerations clause in the *Narromine Local Environmental Plan 2011 (**Narromine LEP 2011**)* which would apply to land identified as Outer Floodplain (i.e. to land which lies between the FPA and the extent of the Extreme Flood), noting that the wording in clause 6.2 titled *Flood planning* will be automatically updated by the NSW Government on 14 July 2021. The changes to *Narromine LEP 2011* will provide flexibility in defining the Flood Planning Level (**FPL**) in areas subject to different types of flooding across the whole of the local government area and for ease of implementing **Measure 2**.
- **Measure 2** - The application of a graded set of planning controls for future development that recognise the location of the development within the floodplain; to be applied through an update of the wording in *Narromine Shire Development Control Plan 2011* (***Narromine Shire DCP 2011***). Recommended wording for inclusion in *Narromine Shire DCP 2011* is set out in **Appendix D**.
- **Measures 3** - Improvements in the NSW State Emergency Service's (**NSW SES's**) emergency planning, including use of the flood related information contained in this study to update the *Narromine Shire Local Flood Plan*. Information in this present report which would be of assistance to NSW SES includes more detailed information on the nature and extent of flooding at Narromine.
- **Measure 4** - Council should take advantage of the information on flooding presented in this report, including the flood mapping, to inform occupiers of the floodplain of the flood risk. This could be achieved through the preparation of a *Flood Information Brochure* which could be prepared by Council with the assistance of NSW SES containing both general and site specific data and distributed with rate notices.

In addition to the above measures, *Narromine FRMP 2021* includes the following two "structural" measures which would require Government funding:

- **Measure 5** - The detailed design and construction of a levee along the southern bank of the Macquarie River in combination with the upgrade of the existing railway culverts at Webbs Siding (denoted herein as the "**Preferred Flood Mitigation Scheme**"). The scheme also includes the design and implementation of flood proofing measures for an existing homestead that is located on the Backwater Cowal where peak flood levels would be increased as a result of the scheme. **Measure 5** includes the update of the flood modelling for post-Preferred Flood Mitigation Scheme conditions, as well as the flood planning related aspects of *Narromine Shire DCP 2011*.

- **Measure 6** – The development and implementation of a *Vegetation Management Plan* which is aimed at managing the density of understorey vegetation on the banks of the Macquarie River at Narromine, as well as the removal of flood debris from the same area follow major flood events.

S6 Timing and Funding of FRMP Measures

The total estimated cost to implement *Narromine Town FRMP 2021* is **$22.3 Million**, exclusive of Council and NSW SES staff costs. The timing of the measures will depend on Council's overall budgetary commitments and the availability of both Local and State Government funds.

Assistance for funding qualifying projects included in the *Narromine Town FRMP 2021* may be available upon application under the Commonwealth and State funded floodplain management programs, currently administered by NSW Department of Planning, Industry and Environment.

S7 Council Action Plan

1. Council to update *Narromine Town LEP 2011* and *Narromine Shire DCP 2011*, the latter by incorporating the suggested form of wording set out in **Appendix D** of this report into the existing document (**Measures 1** and **2** of *Narromine Town FRMP 2021*).
2. NSW SES to update the *Narromine Shire Local Flood Plan* using the flooding information set out in this report (**Measure 3** of *Narromine Town FRMP 2021*).
3. Council to inform residents and business owners of the flood risk based on the information presented in *Narromine Town FRMS 2021*. (e.g. displays of flood mapping at Council offices, preparation of *Flood Information Brochure* for distribution with rate notices, etc) (**Measure 4** of *Narromine Town FRMP 2021*).
4. Council to commission the detailed design and construction of the scope of works comprising the Preferred Flood Mitigation Scheme (**Measure 5** of *Narromine Town FRMP 2021*).
5. Council to develop and implement a *Vegetation Management Plan* for the riparian corridor of the Macquarie River at Narromine (**Measure 6** of *Narromine Town FRMP 2021*).

TABLE S1
RECOMMENDED MEASURES FOR INCLUSION IN NARROMINE TOWN FLOODPLAIN RISK MANAGEMENT PLAN

Measure	Required Funding	Features of the Measure	Priority
1. Update of *Narromine LEP 2011*	Council's staff costs	• A new *special flood considerations* clause should be incorporated in *Narromine LEP 2011* which applies to land that lies between the FPA and the Extreme Flood. The new clause relates to development with particular evacuation or emergency response issues (e.g. group homes, residential aged care facilities, etc). It is also aimed at protecting the operational capacity of emergency response facilities and critical infrastructure during extreme flood events. • It is noted that the wording in clause 6.2 of *Narromine LEP 2011* titled *Flood planning* will be automatically updated by the NSW Government on 14 July 2021 as part its recent reform of the *NSW Flood Prone Land Package*.	**High Priority**: this measure is designed to mitigate the flood risk to future development and has a high priority for inclusion in the *Narromine Town FRMP 2021*. It does not require Government funding.
2. Incorporate contemporaneous approach to managing future development on flood prone land in *Narromine Shire DCP 2011*.	(Council's staff costs)	▪ Graded set of flood controls based on the type of development and their location within the floodplain, defined as land inundated by the Extreme Flood. ▪ Floodplain divided into four zones based on the assessed flood hazard and hydraulic categorisation. ▪ Similar to the current approach adopted by Council, the minimum habitable floor level varies depending on land use type.	**High Priority**: this measure is designed to mitigate the flood risk to future development and has a high priority for inclusion in the *Narromine Town FRMP 2021*. It does not require Government funding.
3. Ensure flood data in the *Narromine Town FRMS 2021* are available to the NSW SES for improvement of flood emergency planning.	NSW SES costs	• NSW SES should update the *Narromine Shire Local Flood Plan* using more detailed information on the nature and extent of Main Stream Flooding.	**High Priority**: this measure would improve emergency response procedures and has a high priority. It does not require Government funding.
4. Implement flood awareness and education program	Council staff costs	• Council to inform residents of the flood risk, based on the information presented in the *Narromine Town FRMS 2021*. (e.g. displays of flood mapping at Council offices, preparation of *Flood Information Brochure* for distribution with rate notices, etc).	**High Priority**: this measure would improve the flood awareness of the community and has a high priority. It does not require Government funding.
5. Detailed design and construction of Preferred Flood Mitigation Scheme, as well as updating flood related aspects of *Narromine Shire DCP 2011*	$22 Million	▪ Prepare submission for Government funding for detailed design and construction. ▪ Underground utilities search. ▪ Geotechnical investigation to assess foundation conditions (extra over work undertaken as part of SMEC, 2019). ▪ Liaison with Australian Rail Track Corporation to determine requirements for the upgrade of the existing railway culverts at Webbs Siding. ▪ Prepare detailed design and cost estimate. ▪ Update flood modelling based on post-Preferred Flood Mitigation Scheme conditions, as well as flood planning related aspects of *Narromine Shire DCP 2011*. ▪ Construct Preferred Flood Mitigation Scheme.	**High Priority**: this measure would significantly reduce the impact that major flooding has on the community and remove a major constraint on future development in Narromine, that being the present need to set the MHFL well above natural surface levels in parts of Narromine.
6. Develop and implement *Vegetation Management Plan* for the Macquarie River at Narromine.	$0.3 Million	• The *Vegetation Management Plan* will identify the steps which need to be undertaken to manage the density of understorey vegetation along the banks of the Macquarie River at Narromine, as well as the removal of debris following a flood event. • The required funding would permit the development of the *Vegetation Management Plan*, the removal of dense understorey vegetation from the banks of the river and the implementation of a regular maintenance program over a five year period.	**Low Priority**: this measure would reduce the risk of a blockage being experienced at the various road crossings, as well as reduce the frequency of nuisance flooding.
Total Estimated Cost	**$22.3 Million**		

1 INTRODUCTION

1.1 Study Background

This report provides an update to the *Narromine Floodplain Risk Management Study* and the *Narromine Floodplain Risk Management Plan*, both of which were prepared by Lyall & Associates in 2009 (respectively referred to herein as "***FRMS 2009***" and "***FRMP 2009***").

The present study *(**Narromine Town FRMS 2021**)* updated baseline flooding conditions using contemporaneous computer modelling techniques (***Updated Flood Study***). It included an updated assessment of the economic impacts of flooding and the feasibility of potential measures aimed at reducing the impact of flooding on both existing and future development. This process allowed the formulation of a contemporaneous *Floodplain Risk Management Plan* for the township of Narromine (***Narromine Town FRMP 2021***).

While *Narromine Town FRMS 2021* principally deals with the impact that floodwater originating from the Macquarie River has on the community (**Main Stream Flooding**), it also takes into consideration the impact that local catchment runoff (**Major Overland Flow**) would have on existing and future development following the construction of a levee along the southern bank of the Macquarie River. **Figure 1.1** is a location plan showing the extent of the Macquarie River system upstream of Narromine.

1.2 Background Information

The following documents were used in the preparation of this report.

- *Narromine Flood Behaviour Study* (Bewsher Consulting, 1998)
- *Floodplain Development Manual* (New South Wales Government (NSW Government, 2005)
- *Macquarie River (Narromine to Oxley Station) Floodplain Risk Management Study* (SKM, 2008)
- *Narromine Flood Study* (Lyall & Associates, 2009a)
- *Narromine Floodplain Risk Management Study and Plan* (Lyall & Associates, 2009b)
- *Narromine Local Environmental Plan 2011*
- *Narromine Shire Development Control Plan 2011*
- *Narromine River Bank Levee Feasibility Study [Draft Report] (Lyall & Associates, 2012)*
- *Narromine River Bank Levee Feasibility Study* (Lyall & Associates, 2013)
- *Narromine Shire Local Flood Plan* (NSW State Emergency Service (**NSW SES**), 2014)
- *Review of Narromine Flood Studies* (BMT WBM, 2018)
- *Narromine Town Levee Concept Design* (SMEC, 2019)

1.3 Overview of Narromine Town FRMS 2021 Report

The findings of *Narromine Town FRMS 2021*, as well as *Narromine Town FRMP 2021* are set out in this report. The contents of each Chapter of the report are briefly outlined below:

- **Chapter 2**, **Baseline Flooding Conditions**. This Chapter includes a description of the drainage system and a review of existing flood behaviour at Narromine. The Chapter also summarises the economic impacts of flooding on existing urban development, reviews Narromine Shire Council's (**Council's**) flood planning controls and management measures and the NSW SES's flood emergency planning.
- **Chapter 3**, **Potential Floodplain Management Measures**. This Chapter reviews the feasibility of floodplain management options for their possible inclusion in *Narromine Town FRMP 2021.* The list of measures considered is based on input from the Community Consultation process, which sought the views of residents and business owners in Narromine on the range of measures which are set out in *FRMP 2009*, as well as other potential flood management measures which could be included in *Narromine Town FRMP 2021*. The measures are investigated at the strategic level of detail, including indicative cost estimates of the most promising measures and a benefit/cost analysis.
- **Chapter 4**, **Selection of Floodplain Management Measures**. This Chapter assesses the feasibility of potential floodplain management strategies using a multi-objective scoring procedure which was developed in consultation with the Floodplain Risk Management Committee (**FRMC**) and outlines the preferred strategy.
- **Chapter 5** presents *Narromine Town FRMP 2021* which comprises a number of structural and non-structural measures which are aimed at increasing the flood awareness of the community and ensuring that future development is undertaken in accordance with the local flood risk. A number of investigations are recommended, along with the design and construction of flood modification measures which are aimed at mitigating the impact of Main Stream Flooding on existing development.
- **Chapter 6** contains a glossary of terms used in the study.
- **Chapter 7** contains a list of References.

Four technical appendices provide further information on the study results:

Appendix A – Community Consultation summarises residents' and business owners' views on potential flood management measures which could be incorporated in *Narromine Town FRMP 2021*.

Appendix B – **Flood Damages** is an assessment of the economic impacts of flooding to existing residential, commercial and industrial development, as well as public buildings in Narromine. The damages have been assessed using the hydraulic models that were developed as part of the present study, as well as the property database that was first developed as part of *FRMS 2009* and subsequently expanded as part of the present study.

Appendix C - Potential Flood Modification Measures comprises a series of figures which show the impact a range of potential flood modifications measures would have on the behaviour of Main Stream Flooding at Narromine. The figures comprising **Appendix C** are bound in **Volume 2** of the report.

Appendix D – **Suggested Wording for Inclusion in Narromine Shire Development Control Plan** presents guidelines for the control of future urban development in flood prone areas in the Narromine local government area. The guidelines cater for both Main Stream Flooding and Major Overland Flow.

1.4 Community Consultation

Following the Inception Meeting of the FRMC, a *Community Newsletter* was prepared by the Consultants and distributed to residents and business owners by Council. A *Community Questionnaire* was also distributed by Council seeking details from residents and business owners regarding their attitudes toward potential floodplain management measures. Council distributed approximately 1,672 *Community Newsletters and Questionnaires* to residents and business owners in April 2020.

A total of 143 responses were received (a response rate of about 9 per cent), 133 were residents, several of whom also run businesses in Narromine. Community responses are summarised in **Chapter 3** of this report, with supporting information in **Appendix A**. The views of the community on potential flood management measures to be considered in the study were also taken into account in the assessment presented in **Chapter 3** of this report.

The FMRC reviewed the potential flood management measures developed in **Chapter 3** and assessed the measures using the proposed scoring system of **Chapter 4**. *Narromine Town FRMS 2021* and accompanying *Narromine Town FRMP 2021* were also reviewed by the FRMC and amended prior to the preparation of the public exhibition report.

The draft *Narromine Town FRMS 2021* and *Narromine Town FRMP 2021* were placed on public exhibition for a 28 day period ending 16 July 2021. Only one submission was received from a resident who was concerned that the construction of a levee along the southern bank of the Macquarie River would exacerbate flooding conditions in existing residential development that is located along River Drive. Council responded to the submission advising that the inclusion of the railways culvert upgrade at Webbs Siding would ensure that the construction of the riverbank levee would not exacerbate flooding conditions in existing development that is located along River Drive for all floods up to 1% (1 in 100) AEP in magnitude.

1.5 Flood Frequency and Terminology

In this report, the frequency of floods is referred to in terms of their Annual Exceedance Probability (**AEP**). The frequency of floods may also be referred to in terms of their Average Recurrence Interval (**ARI**). The approximate correspondence between these two systems is:

Annual Exceedance Probability (AEP) – %	Average Recurrence Interval (ARI) – years
0.2	500
0.5	200
1	100
10	10
20	5

The AEP of a flood represents the percentage chance of its being equalled or exceeded in any one year. Thus a 1% (1 in 100) AEP flood, which is equivalent to a 100 year ARI, has a 1% chance of being equalled or exceeded in any one year and would be experienced, on the average, once in 100 years; similarly, a 20 year ARI flood has a 5% chance of exceedance, and so on.

In *Updated Flood Study*, flooding patterns on the Macquarie River floodplain were assessed for design floods ranging between a 5% (1 in 20) AEP event and the Extreme Flood, noting that the Extreme Flood was assumed to have a peak flow equal to 5 times the 1% (1 in 100) AEP event. The definition of Major Overland Flow in the urban parts of Narromine was also defined for a 1% (1 in 100) AEP storm event.

2 BASELINE FLOODING CONDITIONS

2.1 Physical Setting

The town of Narromine is located on the Macquarie River in the north-west of NSW, about 450 km from Sydney and 40 km downstream of the regional centre of Dubbo. The town has a population of about 3,500 and includes about 1,680 residential type properties. Most of the urban development including the main business and commercial area is located in flood prone land on the southern bank of the river.

The Macquarie River at Narromine has a catchment area of 26,000 km^2. **Figure 1.1** shows the drainage system of the Macquarie River catchment upstream of the town. There are two major water storages upstream of Narromine. Burrendong Dam, which was completed in 1967, is located at the confluence of the Macquarie and Cudgegong Rivers and is approximately 120 km upstream of Narromine, while Windamere Dam, which was completed in 1984, is situated on the Cudgegong River about 100 km upstream of Burrendong Dam.

Windamere Dam has a total storage capacity of 368 GL and controls a catchment area of 1,070 km^2. The reservoir has no reserved storage capacity or operating rules designed to reduce flood flows. The small proportion of the catchment controlled by the dam, together with the absence of flood mitigation storage, results in the dam having no significant effect on flood flows on the Macquarie River.

Burrendong Dam has a total catchment area of 13,900 km^2, approximately 50% of the catchment at Narromine. The dam has a total storage volume of 1,678 GL of which 489 GL is allocated to flood mitigation. The flood mitigation volume represents approximately half the volume of runoff which passed the dam site in the February 1955 flood. That flood resulted in the highest recorded flood level on the Macquarie River and inundated most of the urban area of Narromine.

The Bell, Little and Talbragar Rivers join the Macquarie River downstream of Burrendong Dam and generally comprise the remainder of the catchment at Narromine. Inflows from these three river systems, especially the Talbragar River can result in rapid rises in river levels at the urban centres of Dubbo and Narromine.

2.2 Drainage System at Narromine

2.2.1 Macquarie River Floodplain

Narromine is bounded on the northern side by the Macquarie River and on the south side by the Backwater Cowal, which forms part of the Bogan River system (refer **Figure 2.1**, sheet 1). The Backwater Cowal is fed by a local catchment that extends to the south-west of Narromine and can also be fed from a breakout that occurs from the Macquarie River upstream of Narromine at a location called Webbs Siding.

While an area of high ground separates the Backwater Cowal from the town, flood modelling undertaken as part of the present study shows there is the potential for floodwater which breaks out of the Macquarie River at Webbs Siding to enter the southern limits of the town near the intersection of Tomingley Road and Gainsborough Road during a flood similar to that which occurred in February 1955.

The main channel of the Macquarie River and its immediate southern overbank has a large conveyance capacity where it runs to the north of the town. As a result, surcharge of the southern bank of the river at Narromine only occurs on a relatively infrequent basis. That said,

there are a number of existing low points that are located along the southern bank of the Macquarie River which allow floodwater to prematurely enter the town. While the main breakout has been blocked by the construction of an earthen levee which runs between Manildra Street and the extension of Dandaloo Street on the northern side of Culling Street (denoted herein as the "**Town Levee**"), there are a number of other natural low points that are located to its east and west which allow floodwater to enter the town during floods larger than about 1.25% (1 in 80) AEP.

One of the abovementioned low points is located on the Town Cowal which leaves the Macquarie River approximately midway between the eastern end of Crossley Drive and the western end of River Drive. The Town Cowal meanders in a westerly direction through the urbanised parts of Narromine, crossing the Main Western Railway on three occasions. While multi-cell box culvert arrangements are located on the Town Cowal at its eastern and western crossings of the Main Western Railway, only a single 750 mm diameter pipe is located at the central crossing.

Section 2.5 of this report provides further description of flood behaviour in Narromine for both historic and design flood events.

2.2.2 Local Stormwater Drainage System

Figures 2.1, sheet 2 shows the layout of the existing stormwater drainage system at Narromine. The majority of the stormwater drainage system at Narromine comprises short sections of pipe that are located at road intersections. Runoff from the northern portion of the town is generally controlled by six individual piped stormwater drainage lines which discharge to the southern bank of the Macquarie River, while runoff from the southern portion of the town generally flows overland to a series of natural depressions and man-made ponds that are located immediately to the west and south of the urbanised area.

While local catchment runoff discharging to the Town Cowal typically ponds at several location along its length, during intense storm events it would generally follow the line of the natural depression in a westerly direction where it would ultimately discharge to the Backwater Cowal.

2.3 Flood History

Table 2.1 over summarises the timeline of historic flooding at Narromine, while **Table 2.2** summarises the flood history at Narromine based on peak flood levels that were recorded at one of the three stream gauges that have been in operation at Narromine, the locations of which are shown on **Figure 2.1**, sheet 1 (denoted herein individually as the "**Town Gauge**, "**Bridge Gauge**" and **Weir Gauge**" and collectively as the "**Narromine Stream Gauges**").[1]

Figure 2.2 is an aerial photograph showing the extent of flooding that occurred near the peak of a flood that occurred in December 2010. Also shown on **Figure 2.2** are the location and elevation of historic flood marks which were provided by NSW SES, as well as the alignment of natural surface levels which formed the long sections referred to in **Section 2.5** of this report. **Figure 2.3** shows the water level and discharge data that were recorded by the *Macquarie River at Baroona* stream gauge (GS 421127) (**Baroona stream gauge**) which is located a short distance upstream of Narromine (refer **Figure 2.1**, sheet 1 for location) for floods that occurred in August 1990 and December 2010, as well as the rate of rise and fall of floodwater for the most recent of the two flood events.

[1] Note that the Bridge Gauge is currently in operation at Narromine.

TABLE 2.1
TIMELINE OF FLOODING AT NARROMINE

Period	Flood History
Pre-1950	• Large floods occurred in 1920 and 1926. Based on data presented in Bewsher, 1998, both these floods are believed to have been similar in magnitude to the August 1990 and December 2010 events. • Large floods are also said to have occurred on the Macquarie River in 1867 and 1870.
1950-1959	• Four floods were experienced in parts of the Macquarie Valley in the 1950's, the largest of which occurred in February 1955. • Several floods occurred in 1950, the largest of which occurred in November 1950 when parts of Narromine were inundated. This flood triggered the construction of an early form of the Town Levee.(1) This flood reached 14.86 m on the Town Gauge.(2) WC&IC hydrographers recorded a peak flow in the river of 2,550 m^3/s at a height of 14.54 m on the Town Gauge. • The second flood occurred in 1952 and reached 13.23 m on the Town Gauge. • The large flood of 1955 overtopped the Town Levee and inundated most of Narromine. The section of railway embankment at Webbs Siding was also washed out. The water level reached 15.66 m on the Town Gauge.(2) • The fourth flood occurred in March 1956 and surcharged the southern bank of the Macquarie River in the vicinity of what is now Crossley Drive. This flood reached 15.14 m on the Town Gauge(2). WC&IC hydrographers recorded a peak flow of 1,470 m^3/s in the river at a height of 13.56 m on the Town Gauge. • The Town Levee was reconstructed and raised following the March 1956 flood.(3)
1960-1989	• Construction on Burrendong Dam, which incorporates flood mitigation storage, was completed in 1967. • The largest flood over this period occurred in February 1971 and reached 13.08 m on the Bridge Gauge. A peak flow of 1,500 m^3/s was recorded in the river at a height of 12.87 m on the Bridge Gauge.
1990-2009	• Three floods were experienced in parts of the Macquarie Valley in 1990, the largest of which occurred in the month of August. • The August 1990 flood reached 13.48 m on the Bridge Gauge, with a peak flow 2,078 m^3/s recorded at the Baroona stream gauge. • Floodwater did not surcharge the southern bank of the Macquarie River during this flood event.
2010 to date	• Major flooding was experienced in parts of the Macquarie Valley in December 2010, with record flood levels recorded along the Talbragar and Little Rivers downstream of Burrendong Dam. The December 2010 event was the first major flood to be experienced in the Macquarie Valley since 1990. • Whilst the peak flow in the river was similar to that recorded during the August 1990 event (2,200 m^3/s in December 2010 versus 2,078 m^3/s in August 1990), the peak height recorded at the Bridge Gauge was about 600 mm higher (14.07 m in December 2010 versus 13.48 m in August 1990).

1. WC&IC drawings entitled "*Flood Prevention Plans and Section"* and dated December 1956 show the presence of a low levee bank running along the eastern side of Manildra Street extending south as far as the Mitchel l Highway. It is assumed that this section of the river bank levee was constructed in response to the 1950 flood.
2. Source: BMT WBM, 2018
3. Source: Bewsher Consulting, 1998

TABLE 2.2
HISTORIC AND DESIGN GAUGE HEIGHTS[1,2]
NARROMINE STREAM GAUGES

Flood Event	Height on Narromine Stream Gauges (m)[3]
Extreme Flood	16.37
0.2% AEP	15.58
0.5% AEP	15.30
1% AEP	15.10
February 1955	15.05[4] *15.66 [Town Gauge][4]*
March 1956	14.66[5,6] *15.14 [Town Gauge][4]*
2% AEP	14.59
November 1950	14.25[4] *14.86 [Town Gauge][4]*
December 2010[7]	14.07
Major Flood[8]	13.70
August 1990[5]	13.44
5% AEP	13.16
10% AEP	11.15
20% AEP	9.18
Moderate Flood[8]	9.10
Minor Flood[8]	4.00

1. Design peak flood levels relate to the findings of the *Updated Flood Study*
2. Unless otherwise noted, gauges heights relate to the current Bridge Gauge
3. Gauge zero on Bridge Gauge = 224.01 m AHD, while gauge zero on the Town Gauge and Weir Gauge is estimated to be 224.75 m AHD and 223.12 m AHD, respectively (refer **Section 2.5.2** of this report for details).
4. Source: BMT WBM, 2018
5. Source: Bewsher Consulting, 1998
6. Source: Pinneena
7. NSW SES
8. Source: *Narromine Shire Local Flood Plan*

2.4 Rate of Rise and Duration of Flooding at Narromine

The construction of Burrendong Dam has resulted in a reduction in peak flood levels and an attenuation of the flood wave in downstream areas. The shape of the hydrograph at Narromine can also be influenced by the magnitude and relative timing of flood flows in the Talbragar River, which joins the Macquarie River at Dubbo. However, in general, the stage hydrograph at Narromine is characterised by a slow time of rise lasting from 2 to 4 days, followed by maintenance of flows near the peak for several days and a recession time lasting up to several weeks.

Flood peaks take between 2 to 4 days to traverse the reach of river from Burrendong Dam to Narromine. Flood waves sometimes exhibit a double peak, for example in February 1971, due to the early arrival of flows from the Talbragar River. Contributions to flow from the Talbragar River can augment downstream flooding in the Macquarie River, but flows from this catchment in isolation are not sufficient to result in significant flood events at Narromine.

2.5 Definition of Historic and Design Flood Behaviour

2.5.1 Background to Hydraulic Model Development and Update

The hydraulic model used in *FRMS 2009* was originally developed as part of Bewsher Consulting, 1998 and later updated as part of Lyall & Associates, 2009a. It used the MIKE 11 one-dimensional software which was based on a geometric model comprising cross-sections of the channel of the Macquarie River and its floodplain. While the updated MIKE 11 model was used in the preparation of Lyall & Associates, 2012, it was a recommendation of that study to develop a two-dimensional (in plan) hydraulic model of the Macquarie River floodplain using the available Light Direction and Ranging (**LiDAR**) survey data.

As the coverage of the available LiDAR survey data upon which the two-dimensional hydraulic model was to be based did not encompass all of the floodplain, additional field survey was required both to the north and south of Narromine along the Macquarie River and Backwater Cowal, respectively. This gap in the data was filled by the survey of several cross-sections of the channel and floodplain.

Following a review of the preliminary hydraulic model results, the Department of Planning, Industry and Environment (**DPIE**) requested that a bathymetric survey of the Macquarie River be undertaken to check whether there had been a change in waterway area below the standing water level in the river[2] since 1996 (i.e. the date of the original survey upon which the original MIKE 11 hydraulic model was based). The locations of the cross-sections comprising the bathymetric survey matched those of the original survey. In accordance with one of the recommendations of Lyall & Associates, 2012, survey of the existing stormwater drainage system in Narromine was also undertaken.

The TUFLOW two-dimensional (in plan) hydraulic modelling software was used as part of Lyall & Associates, 2013 to more accurately define flooding patterns at Narromine. The key features of the TUFLOW hydraulic model that was developed as part of Lyall & Associates, 2013 were as follows:

- The two-dimensional model domain comprised a 10 m grid spacing, ground levels for which were sampled from a digital elevation model that was generated from the LiDAR survey.
- Modelling of the waterway area below the standing water level in the river, as well as the steep sections of river bank, as a one-dimensional element. Cross-sections used to define this element of the model were compiled using the LiDAR survey, as well as the bathymetric survey data.
- Extension of the hydraulic model a distance of about 7.5 km downstream of the limit of the two-dimensional model domain using a number of cross-sections that were extracted from the MIKE 11 model that was developed as part of SKM, 2008, supplemented by the land and bathymetric survey that was undertaken as part of Lyall & Associates, 2013.

[2] The standing water level in the Macquarie River of about RL 226.4 m AHD is controlled by the low level weir which is located downstream of the Narromine-Eumungerie Road bridge.

- Modelling of the Backwater Cowal channel and its left (southern) overbank as a one-dimensional element. Cross-sections surveyed as part of Lyall & Associates, 2013 were used for this purpose.
- Modelling of the stormwater drainage system in Narromine as a series of one-dimensional elements. Details of the pit and pipe system surveyed as part of Lyall & Associates, 2013 were used for this purpose.
- An upstream boundary centred on the Macquarie River comprising a discharge hydrograph.
- Free draining outlets comprising conceptual weirs with sufficient capacity to convey the modelled flow in the river system.

The TUFLOW hydraulic model was calibrated to the floods that occurred in August 1990 and December 2010. It was found that Manning's n values in the river downstream of the Narromine-Eumungerie Road Bridge needed to be reduced by 20 per cent compared to those that provided correspondence to the December 2010 flood data in order to achieve close correspondence with the recorded peak gauge height of 13.48 m for the August 1990 flood. **Table 2.3** sets out the Manning's n values that provided correspondence between recorded and modelled flood levels for the August 1990 and December 2010 floods.

TABLE 2.3
CALIBRATED HYDRAULIC ROUGHNESS VALUES
DERIVED FOR THE MACQUARIE RIVER AT NARROMINE

Surface Treatment	Manning's n Set No. 1 (Hydraulically Smooth Condition) (August 1990 Flood)		Manning's n Set No. 2 (Hydraulically Rough Condition) (December 2010 Flood)	
	Upstream of Narromine-Eumungerie Road Bridge	Downstream of Narromine-Eumungerie Road Bridge	Upstream of Narromine-Eumungerie Road Bridge	Downstream of Narromine-Eumungerie Road Bridge
Road and Railway	0.02		0.02	
Grassed Floodplain	0.05		0.05	
River Bed	0.06	**0.044**	0.06	**0.055**
Sparsely Treed Areas	0.08		0.08	
Tree Lined River Bank	0.35	**0.24**	0.35	**0.30**
Allotments	1.0		1.0	

The reduction in hydraulic roughness is attributed to the fact that the August 1990 event was the third flood in that year leading to a possible reduction in the amount of woody debris conveyed by the floodwater, combined with a reduced density of riparian vegetation compared with the December 2010 event which occurred after an extended dry period.

As part of *Narromine Town FRMS 2021*, the TUFLOW hydraulic model was extended to the east, south and west of Narromine using LiDAR survey data that were captured as part of the proposed Inland Rail project (***Narromine Town FRMS 2021 TUFLOW Model***). The blocking effects of individual buildings within Narromine were also built into the *Narromine Town FRMS 2021 TUFLOW Model*.

2.5.2 Hydraulic Model Calibration

The *Narromine Town FRMS 2021 TUFLOW Model* was recalibrated to flood marks that were recorded during the August 1990 and December 2010 flood events. The *Narromine Town FRMS 2021 TUFLOW Model* was also run for conditions that are thought to be representative of those at the time of the February 1955 flood (e.g. a peak flow of 5,600 m^3/s, the Main Western Railway lowered by 300 mm and the river in its "hydraulically smooth" condition).

Figures 2.4, **2.5** and **2.6** show the indicative extent and depth of the February 1955, August 1990 and December 2010 floods as derived by the *Narromine Town FRMS 2021 TUFLOW Model*, respectively while **Figure 2.7** shows the water surface profiles along the Macquarie River for the three historic floods. Included on **Figure 2.7** is the Town, Weir and Bridge gauges, noting that the gauge zero on the two historic gauges has been derived based on information contained in Pinneena and the *Water Datum*, the conversion to Australian Height Datum for which is as follows:[3]

Gauge Zero (m AHD) = (Gauge Zero (feet/inches) + 1.7') x 0.3048 – 0.05

Table 2.4 over the page provides a comparison of recorded versus modelled peak flood levels for the February 1955, August 1990 and December 2010 floods. The key findings of the model calibration process were as follows:

i. Computed peak flood levels for the February 1955 flood are broadly in agreement with the recorded flood levels, noting there are a number of exceptions where the computed level is measurably higher or lower than the recorded level. These large differences are attributed to the time which had elapsed between the occurrence of the flood and when Bewsher Consulting, 1998 collected the historic flood level data, noting that there are obvious errors in the historic record given the discrepancies between adjacent flood levels.

ii. The computed peak February 1955 flood heights on the Bridge Gauge for the Macquarie River in its hydraulically smooth and hydraulic rough condition are 15.18 m and 15.30 m, respectively, noting the results presented in **Table 2.4** and on **Figure 2.4** are for the river in its hydraulic smooth condition.

iii. A good match was generally achieved with the flood marks that were recorded along the Macquarie River for the August 1990 and December 2010 using the two sets of Manning's n values. While the hydraulic model did not reproduce the peak flood levels that were recorded at FM_2010.4, FM_2010.5 and FM_2010.11 for the December 2010 flood, there are obvious errors in the historic record given the discrepancies between adjacent flood levels.

Based on the above findings, the *Narromine Town FRMS 2021 TUFLOW Model* is considered to provide a good match with historic flood behaviour when adjusted for conditions which were current at the time of the event. Given recent flood experience and land management practices along the Macquarie River, it is recommended that the nature of design floods be defined based on the Macquarie River in its hydraulically rough condition.

[3] WaterNSW attempted to identify the correct datum conversion as the information contained on Pinneena states that the datum in 1907 was surveyed to "WCDatum" (which is assumed to mean *Water Conservation Datum*) and in 1949 to "NWWCD" (which is understood to mean *North-West Water Conservation Datum*). By inspection of the modelled water surface profile for the February 1955 flood it would appear that the adopted *Water Datum* may be the same or similar to the *Water Conservation Datum* and *North-West Conservation Datum* as the modelled February 1955 flood level is close to the official gauge reading of 15.66 m on the Town Gauge.

TABLE 2.4
COMPARISON OF RECORDED VERSUS MODELLED PEAK FLOOD LEVELS

Flood Event	Flood Mark Identifier	Source	Recorded Flood Level (m AHD)	Modelled Flood Level (m AHD)	Difference[3] (m)
February 1955[2]	FM_1955.1	Bewsher Consulting, 1998	238.60	239.05	0.45
	FM_1955.2		239.77	239.09	-0.68
	FM_1955.3		239.11	239.08	-0.03
	FM_1955.4		239.50	239.57	0.07
	FM_1955.5		239.78	239.49	-0.29
	FM_1955.6		240.60	240.15	-0.45
	FM_1955.7		239.40	239.38	-0.02
	FM_1955.8		239.50	239.49	-0.01
	FM_1955.9		239.35	239.43	0.08
	FM_1955.10		239.50	239.71	0.21
	FM_1955.11		239.60	239.52	-0.08
	FM_1955.12		239.10	239.22	0.12
	FM_1955.13		239.40	239.45	0.05
	FM_1955.14		239.05	239.95	0.90
	FM_1955.15		240.05	239.94	-0.11
	FM_1955.16		239.10	239.11	0.01
	FM_1955.17		239.99	239.92	-0.07
	FM_1955.18		240.03	239.92	-0.11
	FM_1955.19		239.44	239.50	0.06
	FM_1955.20		239.07	239.10	0.03
	FM_1955.21		239.30	239.05	-0.25
	FM_1955.22		239.39	239.11	-0.28
	FM_1955.23		238.72	239.14	0.42
	FM_1955.24		238.90	239.12	0.22
	FM_1955.25		238.90	239.14	0.24
	FM_1955.26		238.88	239.24	0.36
	FM_1955.27		239.25	239.26	0.01
	FM_1955.28		239.80	239.92	0.12
	FM_1955.29		239.10	239.37	0.27
	FM_1955.30		237.70	236.69	-1.01
	FM_1955.31		242.42	243.25	0.83
	FM_1955.32		238.93	239.03	0.10
	FM_1955.33		239.02	238.99	-0.03
	FM_1955.34		238.90	238.87	-0.03
	FM_1955.35		242.79	243.26	0.47
	FM_1955.36		242.96	243.29	0.33
	FM_1955.37	Community Questionnaire	239.30[5]	239.19	-0.11
	FM_1955.38		239.90[5]	240.27	0.37
	FM_1955.39		239.40[5]	239.26	-0.14
	FM_1955.40		240.16[5]	239.65	-0.51
	FM_1955.41		239.85[5]	239.76	-0.09
	FM_1955.42		239.20[5]	239.07	-0.13
	FM_1955.43		238.60[5]	239.07	0.47

Cont'd Over

TABLE 2.4 (Cont'd)
COMPARISON OF RECORDED VERSUS MODELLED PEAK FLOOD LEVELS

Flood Event	Flood Mark Identifier	Source	Recorded Flood Level (m AHD)	Modelled Flood Level (m AHD)	Difference[3] (m)
August 1990[3]	FM_1990.1	Bewsher Consulting, 1998	239.16	239.16	0.00
	FM_1990.2		239.30	239.47	0.17
	FM_1990.3		237.02	237.00	-0.02
December 2010[4]	FM_2010.1	NSW SES	239.78	239.64	-0.14
	FM_2010.2		239.71	239.66	-0.05
	FM_2010.3		239.71	239.84	0.13
	FM_2010.4		239.48	239.89	0.41
	FM_2010.5		238.40	238.79	0.39
	FM_2010.6		238.64	238.78	0.14
	FM_2010.7		238.84	238.78	-0.06
	FM_2010.8		239.55	239.64	0.09
	FM_2010.9		238.38	238.38	0.00
	FM_2010.10		237.54	237.56	0.02
	FM_2010.11		237.18	237.55	0.37

1. A positive value indicates that the modelled peak flood level is higher, and conversely a negative value indicates that the modelled peak flood level is lower than the recorded peak flood level.
2. Refer **Figure 2.4** which shows the plan location of the flood mark.
3. Refer **Figure 2.5** which shows the plan location of the flood mark.
4. Refer **Figure 2.6** which shows the plan location of the flood mark.
5. Recorded flood level derived by assuming floor level of dwelling is located 0.3 m above natural surface level.

2.5.3 Updated Flood Frequency Analysis

The flood frequency analysis that was undertaken as part of Lyall & Associates, 2013 was updated to include an additional seven years of peak flow data. The latest approach to undertaking flood frequency analyses was implemented, with the result that information relating to the two large floods that occurred in 1955 and 1956 (i.e. prior to the construction of Burrendong Dam) were able to be taken into account.

Figure 2.8 shows the lines of best fit that were fitted to the available stream flow record, while **Table 2.5** over the page provides a comparison of design peak flows that were derived for Narromine as part of previous studies, as well as the present study. The key finding of the updated flood frequency analysis was that the design peak flow estimates for Narromine are largely unchanged to those derived as part of Lyall & Associates, 2013.

2.5.4 Updated Design Flood Modelling

The *Narromine Town FRMS 2021 TUFLOW Model* was run in its hydraulically rough condition for floods with AEPs of 5% (1 in 20), 2% (1 in 50), 1% (1 in 100) and 0.5% (1 in 200), as well as the Extreme Flood which was assumed to have a peak flow five (5) times the peak 1% AEP flood event (i.e. 5 x 3,900 = 19,500 m^3/s).

Figures 2.9, **2.10**, **2.11**, **2.13** and **2.15** show the indicative extent and depth of inundation for the five modelled design flood events, while **Figures 2.12** and **2.14** show maximum flow velocities on the Macquarie River floodplain for the 1% (1 in 100) AEP and 0.5% (1 in 200) AEP floods. **Figure 2.16** shows design water surface profiles along the Macquarie River at Narromine.

TABLE 2.5
FLOOD FREQUENCY DERIVED DESIGN PEAK FLOW ESTIMATES AT NARROMINE(1)
(m^3/s)

Annual Exceedance Probability (% AEP)	Bewsher Consulting, 1998	Lyall & Associates, 2013	*Narromine Town FRMS 2021*
20	-	-	600
10	1,000	-	1,000
5	1,500	1,600	1,600
2	2,600	2,700	2,700
1	3,800	3,900	3,900
0.5	5,600	5,800	5,600
0.2	-	-	9,000

1. Values have been rounded to the nearest 100 m^3/s.

The key features of Main Stream Flooding at Narromine for design floods of varying magnitude are as follows:

- Floodwater would be confined to the Macquarie River and its immediate overbank where it runs to the north of Narromine for all floods up to 5% (1 in 20) AEP.
- Floodwater would surcharge the western bank of the Macquarie River downstream of the Narromine-Eumungerie Road bridge during a 2% (1 in 50) AEP flood where it would flow in a westerly direction through several residential properties before entering the Narromine Aerodrome. The existing flood runner which is located on the northern side of the river opposite the Town Levee would also operate during a 2% (1 in 50) AEP.
- Based on a review of the TUFLOW model results and by comparison with the flood frequency analysis, floodwater would commence to enter Narromine via the existing low points that are located along the southern bank of the Macquarie River during a flood with an AEP of about 1.25% (1 in 80) AEP.
- During a 1% (1 in 100) AEP flood, floodwater would enter Narromine via the Town Cowal, as well as a result of a general overtopping of the southern river bank further to its west. Minor overtopping would also occur at the location of the saddle in River Drive, east of its intersection with High Park Road. The majority of development that is located on the northern side of the Main Western Railway would be impacted by floodwater, while the presence of the single 750 mm diameter pipe at the location where the Town Cowal crosses the Main Western Railway would result in floodwater discharging in a westerly direction through existing residential development that is located to the south of the rail corridor.
- Major overtopping would occur along the southern bank of the Macquarie River during a 0.5% (1 in 200) AEP flood event, with the majority of development in Narromine impacted by floodwater. A significant volume of floodwater would surcharge the Macquarie River at Webbs Siding where it would discharge to the Backwater Cowal. The raised nature of Tomingley Road results in floodwater from the Backwater Cowal combining with

floodwater which ponds near the southern limits of Narromine. The raised nature of an existing irrigation canal embankment which runs in a north-south direction to the west of Narromine would also result in elevated flood levels being experienced in parts of the town.

- All development within Narromine would be inundated with the exception of a few rural residential type dwellings that are located along High Park Road during an Extreme Flood.

In order to gain an understanding of the impact that the construction of a levee bank along the southern bank of the Macquarie River would have on patterns of Major Overland Flow in Narromine, a second TUFLOW model was developed as part of Lyall & Associates, 2013 (***Narromine Town MOF TUFLOW Model***). The *Narromine Town MOF TUFLOW Model* was used to assess the areas that would be impacted by local catchment runoff should a 1% (1 in 100) AEP storm occur directly over Narromine in the absence of elevated water levels in the Macquarie River. **Figure 2.17** shows the indicative extent and depth of Major Overland Flow in Narromine for a 1% (1 in 100) AEP storm event, the key features of which are as follows:

- major ponding would occur along the Town Cowal upstream of the Main Western Railway, inundating the Narromine Christian School grounds, as well as a number of existing residential and commercial properties that are located immediately to the south of Terangion Street between its intersection with Algalah Street and A'Beckett Street;

- increased depths of inundation would be experienced in existing residential properties that are located in the area bounded by Terangion Street to the north, A'Beckett Street to the east, Cathundril Street to the south and Third Avenue to the west; and

- parts of the Narromine Public School and Narromine High School would be inundated to a depth of up to 0.8 m.

Both the *Narromine Town FRMS 2021 TUFLOW Model* and the *Narromine Town MOF TUFLOW Model* have been used to assess the impact that a range of potential flood modification measures would have on both Main Stream Flooding and Major Overland Flow, details of which are set out in **Chapter 3** of this report.

2.6 Existing Flood Mitigation Measures

Apart from the existing Town Levee, there are no other formal flood mitigation measures in Narromine.

2.7 Economic Impacts of Flooding

The economic consequences of floods are discussed in **Appendix B** of this report, which assesses flood damages to residential, commercial and industrial property and public buildings in areas affected by Main Stream Flooding. There were only limited data provided by respondents to the *Community Questionnaire* on historic flood damages to the urban parts of the study area. Accordingly, it was necessary to use data on damages experienced as a result of historic flooding in other urban centres. The residential flood damages were based on the publication *Floodplain Risk Management Guideline No. 4, 2007* (**Guideline No. 4**) published by the Department of Environment and Climate Change (now DPIE). Damages to industrial and commercial development, as well as public buildings were evaluated using data from previous floodplain risk management investigations in NSW.

It is to be noted that the principal objectives of the damages assessment were to gauge the severity of urban flooding likely to be experienced at Narromine and also to provide data to allow the comparative economic benefits of various flood modification measures to be evaluated in **Chapter 3** of the report. As explained in **Appendix B**, it is not the intention to determine the depths of inundation or the damages accruing to *individual properties*, but rather to obtain a reasonable estimate of damages experienced over the extent of the urban area in the town for the various design flood events. The estimation of damages using *Guideline No. 4* (in lieu of site specific data determined by a loss adjustor) also allows a uniform approach to be adopted by Government when assessing the relative merits of measures competing for financial assistance in flood prone centres in NSW.

Damages were estimated for the design flood levels determined from the hydraulic modelling undertaken as part of the present study. The elevations of 1,886 building floors levels were based on surveyed floor levels for those properties that are located along the southern bank of the Macquarie River and a nominal 0.3 m height of floor above a representative natural surface within the allotment (as estimated by visual inspection) to the natural surface elevation determined from LiDAR survey for the remainder of the properties in Narromine. The number of properties predicted to experience "above-floor" inundation in Narromine, together with estimated flood damages is listed in **Table 2.6** over the page.

While the threshold of above-floor flooding for residential type development is a 2% (1 in 50) AEP flood, large-scale flood damages are not experienced in Narromine until the southern bank of the river is overtopped during floods larger than about 1.25% (1 in 80) AEP.

The maximum depth of above-floor inundation in the worst affected properties would increase from about 1.3 m during a 1% (1 in 100) AEP flood event, to about 4 m in the Extreme Flood.

The design flood levels used for computing the economic impacts shown in **Table 2.6** do not allow for increased levels resulting from wave action, debris build-up and other local hydraulic effects. These factors are usually taken into account by adding a factor of safety (freeboard) to the nominal flood level when assessing the true "level of protection" of a particular property against flooding. Freeboard is related to the fetch length and velocity of flow, which is itself dependent on the bed slope and hydraulic roughness of the drainage system. Fetch length and flow velocities tend to increase with peak flow and therefore increasing the freeboard with increase in flood magnitude could be justified. For the present analysis, a 500 mm freeboard allowance was adopted for assessing damages for the 1% (1 in 100) AEP and greater floods, reducing to 300 mm for the 2% (1 in 50) AEP and 5% (1 in 20) AEP floods. No freeboard was assumed for the 10% (1 in 10) and 20% (1 in 5) AEP floods given their inbank nature.

For a discount rate of 7% pa and economic life of 50 years, the *Present Worth Value* of damages for all flood events up to the Extreme Flood is about $22.5 Million for the nominal flood level case, increasing to about $35.8 Million when freeboard is taken into account. Therefore one or more schemes costing up to this amount could be economically justified if they eliminated damages in Narromine for all flood events up to this level. While schemes costing more than this value would have a benefit/cost ratio less than 1, they may still be justified according to a multi-objective approach which considers other criteria in addition to economic feasibility. Flood management measures are considered on a multi-objective basis in **Chapter 4**.

TABLE 2.6
FLOOD DAMAGES IN NARROMINE

Design Flood Event (% AEP)	Residential			Commercial/ Industrial			Public			Total Damages ($ Million)
	Number of Properties		Damages ($ Million)	Number of Properties		Damages ($ Million)	Number of Properties		Damages ($ Million)	
	Flood Affected	Flooded Above Floor Level		Flood Affected	Flooded Above Floor Level		Flood Affected	Flooded Above Floor Level		
20%	0	0	0	0	0	0	0	0	0	0
10%	0	0	0	0	0	0	0	0	0	0
5%	0	0	0	0	0	0	0	0	0	0
2%	10	2	0.27	0	0	0	0	0	0	0.27
1%	747	449	43.32	111	72	3.30	10	7	3.07	49.69
0.5%	1310	1126	108.31	153	138	11.93	24	17	5.71	125.95
0.2%	1512	1446	201.94	168	159	30.10	26	26	12.25	244.29
Extreme	1659	1655	314.53	176	175	78.46	27	27	23.77	416.76

2.8 Impact of Flooding on Vulnerable Development and Critical Infrastructure

Figure 2.18 shows the location of vulnerable development and critical infrastructure relative to the extent of inundation resulting from the assessed flood events, while **Table 2.7** over the page sets out the frequency of floods which would impact this type of development/infrastructure.[4]

Community Assets

While the northern portion of the Narromine Aerodrome would be subject to relatively shallow inundation during a 2% (1 in 50) AEP flood event on the Macquarie River, the depth and extent of inundation within the aerodrome increases significantly during larger flood events.

Seven of the nine existing sewage pumping stations would be impacted by floodwater during a 1% (1 in 100) AEP flood, while the remaining two (SS7 and SS3) would be impacted by a 0.5% (1 in 200) AEP flood event. The sewage waste facility (SS10) which is located to the south of Narromine would only be impacted during an Extreme Flood.

The land upon which the raw water storage reservoir (Nymagee) (WS1) and water storage reservoir (Duffy) (WS3) are located would be inundated during a 1% (1 in 100) AEP flood event, while the land upon which the potable storage reservoir (Nymagee) (WS2) is located would be inundated during a 0.5% (1 in 200) AEP flood event.

All of the major road crossings would be impacted by floodwater during events which surcharge the southern bank of the Macquarie River (during floods less frequent than about 1.25% (1 in 80) AEP).

Emergency Services

The Ambulance, Fire & Rescue NSW, Police, Rural Fire Service and NSW SES Local Unit stations are all located on land that would be inundated during a 1% (1 in 100) AEP flood event, while the evacuation centres located at the Narromine United Serviceman's Club and the showground would be impacted by floodwater during a 1% AEP and Extreme Flood, respectively.

Vulnerable Development

The Wesley Units (AC1) and Derribong Villas (AC2) aged care facilities are located on land that is impacted by a 0.5% (1 in 200) AEP flood, while the Timbrebongie House (AC3) aged care facility is only impacted by an Extreme Flood. Narromine Pre-School Kindergarten Inc. child care facility (CC3) is located on land that is impacted by a 1% (1 in 100) AEP flood, while the Rivergum Childcare Centre (CC1) and Cherrygum Daycare Centre (CC2) are impacted by 0.5% (1 in 200) AEP and Extreme Flood events, respectively.

The three educational facilities in Narromine (i.e. Narromine Christian School (EF1), Narromine High School (EF2) and St Augustines Parish School (EF3)) are all located on land which would be impacted by floodwater during a 1% (1 in 100) AEP flood event.

While the Narromine Shire Medial Centre (HC1) would only be impacted by an Extreme Flood, the Narromine Hospital & Community health Centre (HC2) would be impacted by a 0.5% (1 in 200) AEP flood event.

Both the Narromine Rockwell Tourist Park (CP1) and the Narromine Tourist Park (CP2) would be impacted by floodwater during a 1% (1 in 100) AEP flood event.

[4] Critical infrastructure has been split into two categories; community assets and emergency services.

TABLE 2.7
IMPACT OF FLOODING ON VULNERABLE DEVELOPMENT AND CRITICAL INFRASTRUCTURE LOCATED IN THE STUDY AREA(1)

Type	Development/Structure	Location Identifier(1)	Design Flood Event				
			5% AEP	2% AEP	1% AEP	0.5% AEP	Extreme Flood
Community Assets	Narromine Aerodrome	-	O	X	X	X	X
	Major Road Crossing (Town Cowal At Burraway Street)	MC1	O	O	X	X	X
	Major Road Crossing (Town Cowal At Warren Road)	MC2	O	O	X	X	X
	Major Road Crossing (Town Cowal At Mitchell Highway)	MC3	O	O	X	X	X
	Major Road Crossing (Town Cowal At Narromine Road)	MC4	O	O	X	X	X
	Sewage System (Sewer Pumping Station 1)	SS1	O	O	X	X	X
	Sewage System (Sewer Pumping Station 2)	SS2	O	O	X	X	X
	Sewage System (Sewer Pumping Station 3)	SS3	O	O	O	X	X
	Sewage System (Sewer Pumping Station 4)	SS4	O	O	X	X	X
	Sewage System (Sewer Pumping Station 5)	SS5	O	O	X	X	X
	Sewage System (Sewer Pumping Station 6)	SS6	O	O	X	X	X
	Sewage System (Sewer Pumping Station 7)	SS7	O	O	O	X	X
	Sewage System (Sewer Pumping Station 8)	SS8	O	O	X	X	X
	Sewage System (Sewer Pumping Station 9)	SS9	O	O	X	X	X
	Sewage System (Narromine Waste Facility)	SS10	O	O	O	O	X
	Water Supply (Raw Water Storage Reservoir (Nymagee))	WS1	O	O	X	X	X
	Water Supply (Potable Storage Reservoir (Nymagee))	WS2	O	O	O	X	X
	Water Supply (Water Storage Reservoir (Duffy))	WS3	O	O	X	X	X

Cont'd Over

TABLE 2.7
IMPACT OF FLOODING ON VULNERABLE DEVELOPMENT AND CRITICAL INFRASTRUCTURE LOCATED IN THE STUDY AREA(1)

Type	Development/Structure	Location Identifier(1)	Design Flood Event				
			5% AEP	2% AEP	1% AEP	0.5% AEP	Extreme Flood
Emergency Services	Ambulance Facility	-	O	O	X	X	X
	Evacuation Centre (Narromine United Servicemen's Club)	EC1	O	O	X	X	X
	Evacuation Centre (Narromine Showgrounds)	EC2	O	O	O	O	X
	F&R NSW Station	-	O	O	X	X	X
	Police Station	-	O	O	X	X	X
	RFS Station	-	O	O	X	X	X
	SES Station (NSW SES - Narromine Unit)	-	O	O	X	X	X
Vulnerable Development	Aged Care Facility (Wesley Units)	AC1	O	O	O	X	X
	Aged Care Facility (Derribong Villas)	AC2	O	O	O	X	X
	Aged Care Facility (Timbrebongie House)	AC3	O	O	O	O	X
	Child Care Facility (Rivergum Childcare Centre)	CC1	O	O	O	X	X
	Child Care Facility (Cherrygum Daycare)	CC2	O	O	O	O	X
	Child Care Facility (Narromine Pre-School Kindergarten Inc.)	CC3	O	O	X	X	X
	Educational Facility (Narromine Christian School)	EF1	O	O	X	X	X
	Educational Facility (Narromine Public School)	EF2	O	O	X	X	X
	Educational Facility (Narromine High School)	EF3	O	O	X	X	X
	Educational Facility (St Augustines Parish School)	EF4	O	O	X	X	X
	Hospital (Narromine Shire Medical Centre)	HC1	O	O	O	O	X
	Hospital (Narromine Hospital & Community Health)	HC2	O	O	O	X	X
	Caravan Park (Narromine Rockwall Tourist Park)	CP1	O	O	X	X	X
	Caravan Park (Narromine Tourist Park)	CP2	O	O	X	X	X

1. Refer **Figure 2.18** for location of vulnerable development and critical infrastructure.

"O" = Infrastructure not impacted by flooding.
"X" = Infrastructure impacted by flooding.

2.9 Hydrologic Standard of Existing Road Network

Floodwater which surcharges the southern bank of the Macquarie River during floods larger than about 1.25% (1 in 80) AEP would cut the Mitchell Highway at Webbs Siding and also where it crosses the Town Cowal. Floodwater would also inundate the highway to the west of the aerodrome. While the local road network would also be impacted by floodwater which surcharges the southern bank of the river during floods larger than about 1.25% (1 in 80) AEP, it is noted that a short section of Warren Road to the north of Bowden Fletcher Drive in Skypark would be inundated by floodwater during a 2% (1 in 50) AEP flood event.

2.10 Potential Impacts of a Change in Hydraulic Roughness

An analysis was undertaken to assess the sensitivity of flood behaviour to potential changes in hydraulic roughness. **Figure 2.19** (2 sheets) shows the impact that a 20% increase in the "best estimate" hydraulic roughness values would have on flood behaviour for a 1% (1 in 100) AEP flood event.

The analysis showed that peak 1% (1 in 100) AEP flood levels on the northern side of the Main Western Railway would typically be increased by up to 0.15 m, with a maximum of about 0.3 m shown to occur in the residential properties that are located along the northern side of River Drive. Due to the ponding nature of the flow south of the Main Western Railway, peak 1% (1 in 100) AEP flood levels in existing development would generally be increased in the range 0.3 - 0.5 m.

While the above finding would indicate that the adoption of a 0.5 m freeboard for setting minimum floor levels in future development would cater for any potential increases in peak 1% (1 in 100) AEP flood levels associated with changes in hydraulic roughness, further consideration of the freeboard requirements for future development which takes these potential impacts into account is presented in **Section 3.5.1.2** of this report.

2.11 Potential Impacts of a Partial Blockage of Hydraulic Structures

The mechanism and geometrical characteristics of blockages in hydraulic structures and piped drainage systems are difficult to quantify due to a lack of recorded data and would no doubt be different for each system and also vary with flood events. Realistic scenarios would be limited to waterway openings becoming partially blocked during a flood event (no quantitative data are available on instances of blockage of the drainage systems which may have occurred during historic flood events).

The potential for a partial blockage of the existing transverse drainage structures that are located along the Main Western Railway was assessed as part of the present study. Based on the procedures set out in the 2019 edition of *Australian Rainfall and Runoff* (Geoscience Australia, 2019) (**ARR 2019**), blockage factors of between 10% and 50% were applied to these structures.

Figure 2.20 (2 sheets) shows the afflux for a 1% (1 in 100) AEP flood resulting from a partial blockage of the aforementioned hydraulic structures. The analysis showed that a partial blockage of major hydraulic structures would not have a significant impact on peak 1% (1 in 100) AEP at Narromine.

While the above finding would indicate that the adoption of a 0.5 m freeboard for setting minimum floor levels in future development would generally cater for any potential increases in peak 1% (1 in 100) AEP flood levels associated with a partial blockage of hydraulic structures, further consideration of the freeboard requirements for future development which is subject to flooding from the Macquarie River is presented in **Section 3.5.1.2** of this report.

2.12 Potential Impacts of Future Climate Change

DPIE recommends that its guideline *Practical Consideration of Climate Change, 2007* be used as the basis for examining climate change in projects undertaken under the State Floodplain Management program and the *FDM, 2005*. The guideline recommends that until more work is completed in relation to the climate change impacts on rainfall intensities, sensitivity analyses should be undertaken based on increases in rainfall intensities ranging between 10 and 30 per cent.

On current projections the increase in rainfalls within the service life of developments or flood management measures is likely to be around 10 per cent, with the higher value of 30 per cent representing an upper limit which may apply near the end of the century. Under present day climatic conditions, increasing the 1% (1 in 100) AEP design rainfall intensities by 10 per cent would produce about a 0.5% (1 in 200) AEP flood; and increasing those rainfalls by 30 per cent would produce about a 0.2% (1 in 500) AEP event.

For the purpose of the present study, the impact a 10% increase in design rainfall intensities would have on flooding behaviour was assessed by comparing the peak flood levels which were derived from the flood modelling for design events with AEPs of 1 and 0.5 per cent.

Figure 2.21 (2 sheets) shows the impact that a 10% increase in 1% (1 in 100) AEP design rainfall intensities would have on flood behaviour at Narromine.

The analysis showed that peak 1% (1 in 100) AEP flood levels on the northern side of the Main Western Railway would typically be increased in the range 0.3 - 0.5 m, with a maximum of about 0.7 m shown to occur in the residential properties that are located along the northern side of River Drive. Due to the ponding nature of the flow south of the Main Western Railway, peak 1% (1 in 100) AEP flood levels in existing development would generally be increased in the range 0.5 - 0.7 m.

While the above finding would indicate that the adoption of a 0.5 m freeboard for setting minimum floor levels in future development would not necessarily cater for increases in peak 1% (1 in 100) AEP flood levels associated with future climate change, further consideration of the freeboard requirements for future development which takes these potential impacts into account is presented in **Section 3.5.1.2** of this report.

2.13 Flood Hazard Vulnerability and Hydraulic Categorisation of the Floodplain

2.13.1 General

According to Appendix L of *NSWG, 2005*, in order to achieve effective and responsible floodplain risk management, it is necessary to divide the floodplain into areas that reflect:

1. The impact of flooding on existing and future development and people. To examine this impact it is necessary to divide the floodplain into *"flood hazard vulnerability"* categories, which are provisionally assessed on the basis of the velocity and depth of flow. This task was undertaken as part of the present study where the floodplain was divided into six flood hazard vulnerability zones. **Section 2.13.2** below provides details of the adopted procedure.
2. The impact of future development activity on flood behaviour. Development in active flow paths (i.e. *"floodways"*) has the potential to adversely re-direct flows towards adjacent properties. Examination of this impact requires the division of flood prone land into various *"hydraulic categories"* to assess those parts which are effective for the conveyance of flow, where development may affect local flooding patterns. While the hydraulic categorisation of the floodplain was undertaken as part of *FRMS 2009*, it was updated as part of the present study. **Section 2.13.3** below summarises the adopted procedure.

2.13.2 Flood Hazard Vulnerability Categorisation

Flood hazard categories may be assigned to flood affected areas in accordance with the definitions contained in the publication entitled "*Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia*" (Australian Institute for Disaster Resilience (**AIDR**), 2017). Flood prone areas may be classified into six hazard categories based on the depth of inundation and velocity of flow that relate to the vulnerability of the community when interacting with floodwater, as shown in the illustration over which has been taken from AIDR, 2017:

Figure 2.22 (2 sheets) shows the *Flood Hazard Vulnerability Classification* based on the procedures set out in AIDR, 2017 for the 1% (1 in 100) AEP flood event.

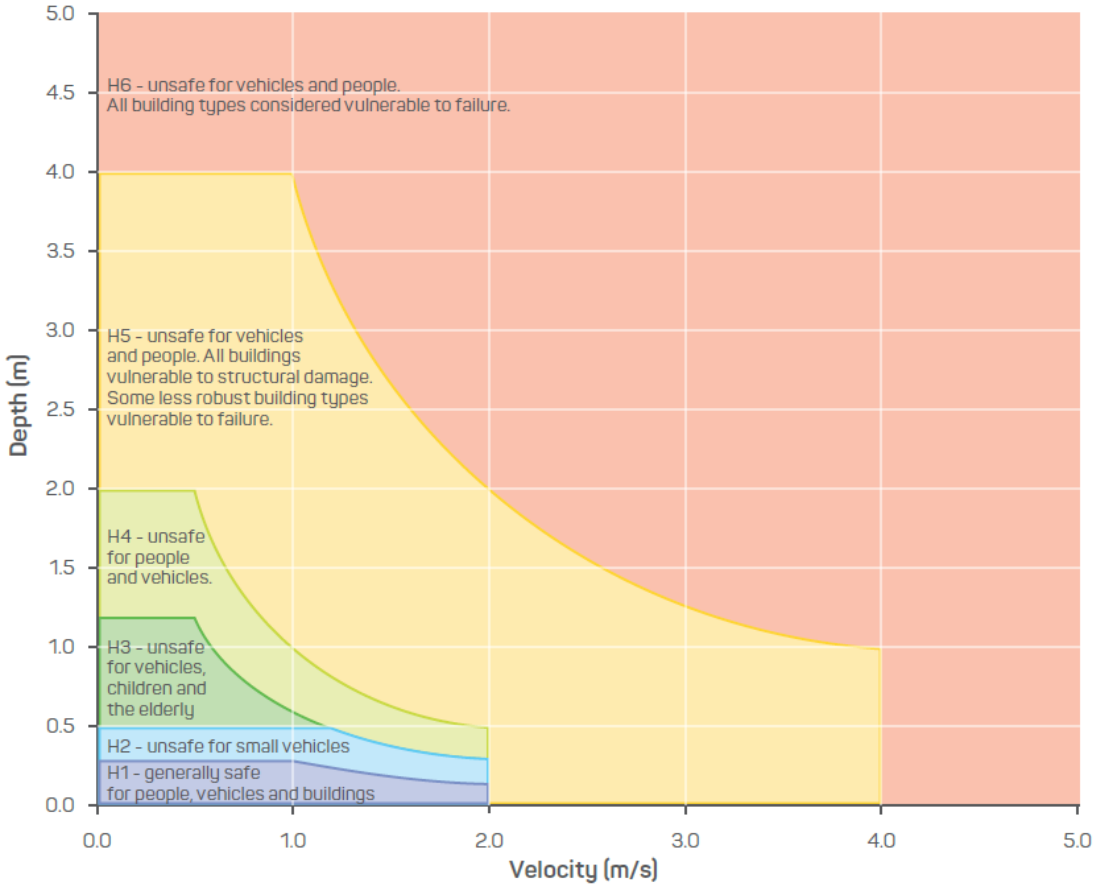
Areas classified as H5 and H6 are generally limited to the Macquarie River and its immediate overbank area, while flooding along the line of the Town Cowal downstream of the extension of Morgan Street is classified as H4 in a 1%(1 in 100) AEP flood event. While the majority of the urbanised parts of Narromine that are inundated during a 1% (1 in 100) AEP flood are classified as either H1 or H2, there are several large pockets of existing development where the flooding is classified as H3.

2.13.3 Hydraulic Categorisation of the Floodplain

According to the *FDM*, the floodplain may be subdivided into the following three hydraulic categories:

- Floodways;
- Flood storage; and
- Flood fringe.

Floodways are those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with obvious naturally defined channels. Floodways are the areas that, even if only partially blocked, would cause a significant re-distribution of flow, or a significant increase in flood level which may in turn adversely affect other areas. They are often, but not necessarily, areas with deeper flow or areas where higher velocities occur.



Flood storage areas are those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. If the capacity of a flood storage area is substantially reduced by, for example, the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased. Substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.

Flood fringe is the remaining area of land affected by flooding, after floodway and flood storage areas have been defined. Development in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.

Floodplain Risk Management Guideline No. 2 Floodway Definition, offers guidance in relation to two alternative procedures for identifying floodways. They are:

- **Approach A**. Using a *qualitative approach* which is based on the judgement of an experienced hydraulic engineer. In assessing whether or not the area under consideration was a floodway, the qualitative approach would need to consider; whether obstruction would divert water to other existing flow paths; or would have a significant impact on upstream flood levels during major flood events; or would adversely re-direct flows towards existing development.
- **Approach B**. Using the hydraulic model, in this case TUFLOW, to define the floodway based on *quantitative experiments* where flows are restricted or the conveyance capacity of the flow path reduced, until there was a significant effect on upstream flood levels and/or a diversion of flows to existing or new flow paths.

One quantitative experimental procedure commonly used is to progressively encroach across either floodplain towards the channel until the designated flood level has increased by a significant amount (for example 0.1 m) above the existing (un-encroached) flood levels. This indicates the limits of the hydraulic floodway since any further encroachment will intrude into that part of the floodplain necessary for the free flow of flood waters – that is, into the floodway.

The *quantitative assessment* associated with **Approach B** is technically difficult to implement. Restricting the flow to achieve the 0.1 m increase in flood levels can result in contradictory results, especially in unsteady flow modelling, with the restriction actually causing reductions in computed levels in some areas due to changes in the distribution of flows along the main drainage line.

Accordingly the *qualitative approach* associated with **Approach A** was adopted, together with consideration of the portion of the floodplain which conveys approximately 80% of the total flow and also the findings of *Howells et al, 2004* who defined the floodway based on velocity of flow and depth. Based on the findings of a trial and error process, the following criteria were adopted for identifying those areas which operate as a "floodway" in a 1% AEP event, noting that manual adjustments were made to the extent of the resulting floodway area to ensure continuity of the various flow paths:

- Velocity x Depth greater than 0.25 m^2/s **and** Velocity greater than 0.25 m/s; or
- Velocity greater than 1 m/s.

Flood storage areas were identified as those areas which do not operate as floodways in a 1% AEP event but where the depth of inundation exceeds 1 m. The remainder of the flood affected area was classified as flood fringe.

Figure 2.23 shows the division of the floodplain into floodway, flood storage and flood fringe areas for the 1% (1 in 100) AEP flood event.

While floodway areas are generally confined to the Macquarie River and its immediate overbank area, in addition to the Town Cowal, the eastern end of Nymagee Street also acts as a floodway during a 1% (1 in 100) AEP flood event. The remainder of the flood affected area is generally classified as flood fringe with isolated pockets of flood storage areas.

2.14 Environmental Considerations

The majority of the floodplain within the town of Narromine has been developed for agriculture or urban purposes. The only remaining "natural" areas lie within the river banks, particularly along the Macquarie River.

The Macquarie River has a stable V shaped channel along much of its length through Narromine. The channel is generally 15 m deep and most of the floodwater is contained within its banks. The main river channel contains remnant vegetation including some large eucalypts but has also been subject to invasion by exotic species such as willows and weed species from domestic gardens. The invasion of exotic species along the river bank has the potential to increase the hydraulic roughness and raise flood levels. There does not appear to be any evidence that this has occurred yet, but monitoring of the vegetation along the Macquarie River would be warranted to ensure that exotic species did not produce a significant increase in hydraulic roughness.

2.15 Council's Existing Planning Instruments and Policies

2.15.1 General

The *Narromine Local Environmental Plan, 2011* (***Narromine LEP 2011***) is the principal statutory planning document used by Council for controlling development by defining zoning provisions, establishing permissibility of land use and regulating the extent of development in the Narromine Shire local government area.

The *Narromine Shire Development Control Plan 2011* (***Narromine Shire DCP 2011***) supplements *the Narromine LEP 2011* by providing general information and detailed guidelines and controls which relate to the decision making process.

2.15.2 Land Use Zoning – Narromine LEP 2011

Figure 2.24 shows the zonings that are incorporated in *Narromine LEP 2011* for the study area. The study area comprises a mixture of *General Residential (R1)* and *Large Lot Residential (R2)* zoned areas, as well as *Local Centre (B2)*, *General Industrial (IN1), Public Recreation (RE1), Private Recreation (RE2), Special Activities (SP1)* and *Infrastructure (SP2)* zoned areas.

2.15.3 Flood Provisions – Narromine LEP 2011

Clause 6.2 of *Narromine LEP 2011* entitled "Flood planning" outlines its objectives in regard to development of land that is at or below the FPL. It is similar to the standard Flood Planning Clause used in recently adopted LEPs in other NSW country centres and applies to land at or below the FPL.

The FPL currently referred to is the 1:100 ARI (or 1% AEP) flood plus an allowance for freeboard of 0.5 m. The area encompassed by the FPL (i.e. the FPA) denotes the area subject to flood related development controls, such as locating development outside high hazard areas and setting minimum floor levels for future residential development. It is now standard practice for the residential FPL to be based on the 1% (1 in 100) AEP flood plus an appropriate freeboard unless exceptional circumstances apply.

It is noted that the NSW Government will be automatically updating the wording in clause 6.2 on 14 July 2021 as part of recent reforms that it has introduced to its *NSW Flood Prone Land Package*. As a result of the update, Council will need to nominate the FPLs that it wishes to use to define the FPA, and make alternative arrangements for making flood planning maps publicly available where previously solely reliant on LEP flood overlay maps

While clause 6.2 will be automatically updated by the NSW Government on 14 July 2021, it is recommended that the *special flood considerations* clause which forms part of the updated *NSW Flood Prone Land Package* also be incorporated in *Narromine LEP 2011*. The objectives of the new clause are as follows:

- in relation to development with particular evacuation or emergency response issues (e.g. schools, group homes, residential care facilities, hospitals, etc.) to enable evacuation of land which lies above the FPL; and
- to protect the operational capacity of emergency response facilities and critical infrastructure during extreme flood events.

The new clause would apply to land which lies between the FPL and the level of the Extreme Flood. Suggested wording in relation to this new clause is given in **Section 3.5.1.4**.

2.15.4 Flood Related Development Controls

Chapter 6a of *Narromine Shire DCP 2011* entitled "Flood Policy" sets out the controls that apply to development on the floodplain at Narromine. The objective of the chapter is to 'place development controls on the further development of flood liable land'.

The chapter includes a figure which shows the floodplain divided into the following six zones:

- Macquarie River Floodway
- Town Cowal Floodway
- Manildra Street/ River Drive Precinct
- High Hazard Ponding Area
- Intermediate Floodplain
- Outer Floodplain

A matrix type approach has been adopted for setting out a graded set of planning controls which apply to different types of development in each zone. The policy requires Minimum Habitable Floor Levels (**MHFLs**) to set as follows:

- at or above the 1% (1 in 100) AEP plus 0.5 m freeboard in the case of residential type development;
- as close as practical to the 1% (1 in 100) AEP plus 0.5 m but no lower than the 2% (1 in 50) AEP plus 0.5 m freeboard in the case of commercial/industrial type development; and
- at or above the 0.5% (1 in 100) AEP plus 0.5 m freeboard in the case of flood vulnerable residential type development, essential community facilities and critical utilities.

Special consideration is also to be given to maintaining the conveyance of floodwater in the Manildra Street / River Drive Precinct, as well as in the Skypark development that is located on the western side of Warren Road adjacent to the Narromine Aerodrome.

2.16 Flood Warning and Flood Preparedness

2.16.1 Narromine Shire Local Flood Plan

The NSW SES is nominated as the principal combat and response agency for flood emergencies in NSW. NSW SES is responsible for the issuing of relevant warnings (in collaboration with BoM), as well as ensuring that the community is aware of the flood threat and how to mitigate its impact.

The *Narromine Shire Local Flood Plan* which is dated July 2014 covers preparedness measures, the conduct of response operations and the coordination of immediate recovery measures for all levels of flooding within the Narromine Shire local government area. *Narromine Shire Local Flood Plan* is administered by the Narromine Local Commander who controls flood operations within the Narromine area. NSW SES maintains a local headquarters which is located on the southern side of the Main Western Railway immediately adjacent to the Town Cowal at 103-109 Manildra Street, Narromine.

Volume 1 of *Narromine Shire Local Flood Plan* entitled '*Narromine Shire Flood Emergency Sub Plan*' includes sections on flood preparedness, response and recovery. Volume 1 is divided into the following sections:

- ***Introduction****;* this section of the document identifies the responsibilities of the NSW SES Local Controller and NSW SES members and supporting services such as the Police, BoM, Ambulance, Fire Brigades, State Water Corporation, Council, etc. It also identifies the importance for NSW SES and Council to coordinate the development and implementation of a public education program to advise the population of the flood risk.
- ***Preparedness****;* this section of the document deals with activities required to ensure the *Narromine Shire Local Flood Plan* functions during the occurrence of the flood emergency. The Plan will devote considerable attention to flood alert and emergency response.
- ***Response***; The NSW SES maintains an operation centre at the Local NSW SES Headquarters in Manildra Street. Response operations will commence: on receipt of a BoM Preliminary Flood Warning, Flood Warning, Flood Watch, Severe Thunderstorm Warning or a Severe Weather Warning for flash flooding; on receipt of a dam failure alert; or when other evidence leads to an expectation of flooding within the council area.
- ***Recovery****,* involving measures to ensure the long term welfare for people who have been evacuated, recovery operations to restore services and clean up and de-briefing of emergency management personnel to review the effectiveness of the *Narromine Shire Local Flood Plan.*

Annex A of the *Narromine Shire Local Flood Plan* deals with the flood threat in the Macquarie Valley, with specific reference to the Narromine Shire local government area. **Table 2.8** lists the peak heights for a range of historic flood events as set out in Annex A of the *Narromine Shire Local Flood Plan*. It is noted that the December 2010 flood which reached 14.07 m on the Bridge Gauge and the flow in the river was about 190,000 ML/day (or 2,200 m^3/s) is not included in the data set.

TABLE 2.8
HISTORIC GAUGE HEIGHTS AT NARROMINE(1)

Historic Flood Event	*Gauge Height (m)*	*Peak Flow(2) (ML/day)*	*Assigned AEP (%)*	*Assigned ARI (years)*
1955	*15.65*	*501,100 [5,800]*	*0.5*	*200*
1990	*13.48*	*179,500 [2,080]*	*1.5*	*65*
1971	*13.16*	*158,000 [1,830*	*4.5*	*20*
2000	*11.20*	*99,300 [1,150]*	*7.5*	*15*
1998	*10.29*	*92,300 [1,070]*	*10*	*10*
1976	*8.70*	*67,200 [780]*	*19*	*5*

1. Source: *Narromine Shire Local Flood Plan*
2. Values in [ ] are the corresponding peak flows in m^3/s rounded to the nearest 10 m^3/s.

While Annex A states that the Town Levee was designed to keep out the more frequent, smaller floods up to approximately 14.6 m on the Bridge Gauge, it highlights that this level approximates the 1% (1 in 100) AEP as defined in a draft version of Lyall & Associates, 2009a. Annex A also acknowledges that there is the potential for floodwater to enter Narromine via a number of low points that are located along the southern side of the river upstream of the Town Levee.

Annex B of the *Narromine Shire Local Flood Plan* deals with the effects of flooding on the Narromine community. The document states that five floods have entered the town in the past 130 years, the last in February 1955. It states that the February 1955 flood broke out of the Macquarie River about six kilometres upstream and entered the town from the east, as well as directly from the river adjacent to Culling Street. Floodwater crossed the railway line to both the east and west of the town and inundated the built-up area to depths of 0.3-2.1 m. Only the railway station, part of the railway line and the floors of some buildings remained above water. Virtually all the town's population had to be evacuated. Much of the water came from the east, passing through the railway embankment culvert 1.5 km east of the town and following a depression along the southern side of the railway embankment as far south as Cathundril Street.

3 POTENTIAL FLOODPLAIN MANAGEMENT MEASURES

3.1 Range of Available Measures

A variety of floodplain management measures can be implemented to reduce flood damages. They may be divided into three categories, as follows:

Flood modification measures change the behaviour of floods in regard to discharges and water surface levels to reduce flood risk. This can be done by the construction of levees, detention basins, channel improvements and upgrades of piped drainage systems in urban areas. Such measures are also known as "structural" measures as they involve the construction of engineering works. Vegetation management is also classified as a flood modification measure.

Property modification measures reduce risk to properties through appropriate land use zoning, specifying minimum floor levels for new developments, voluntary purchase of residential property in high hazard and/or floodway areas, or raising existing residences in the less hazardous areas. Such measures are largely planning (i.e. "non-structural") measures, as they are aimed at ensuring that the use of floodplains and the design of buildings are consistent with flood risk. Property modification measures could comprise a mix of structural and non-structural methods of damage minimisation to individual properties.

Response modification measures change the response of flood affected communities to the flood risk by increasing flood awareness, implementation of flood warning and broadcast systems and the development of emergency response plans for property evacuation. These measures are entirely non-structural.

3.2 Previous Studies

Table 3.1 over summarises the flood, property and response modification measures that comprised *FRMP 2009*, including their estimated cost and status in terms of their implementation. The same table was included in the *Community Newsletter* which was disseminated to residents and business owners in Narromine at the commencement of the present study. While the property and response modification measures have been implemented by Council and NSW SES, the only flood modification measure that has been completed is the feasibility study for the river bank levee.

The undertaking of the feasibility study for the river bank levee involved a lengthy process which included the development of a more detailed two-dimensional (in plan) hydraulic model of the Macquarie River at Narromine and the development of concept designs for four potential levee options (denoted "*Levee Options A, B, C and D"* in SMEC, 2019). It also included extensive consultation with the community both in group and one-on-one settings. The image over is taken from SMEC, 2019 showing the alignment of the four assessed levee options.

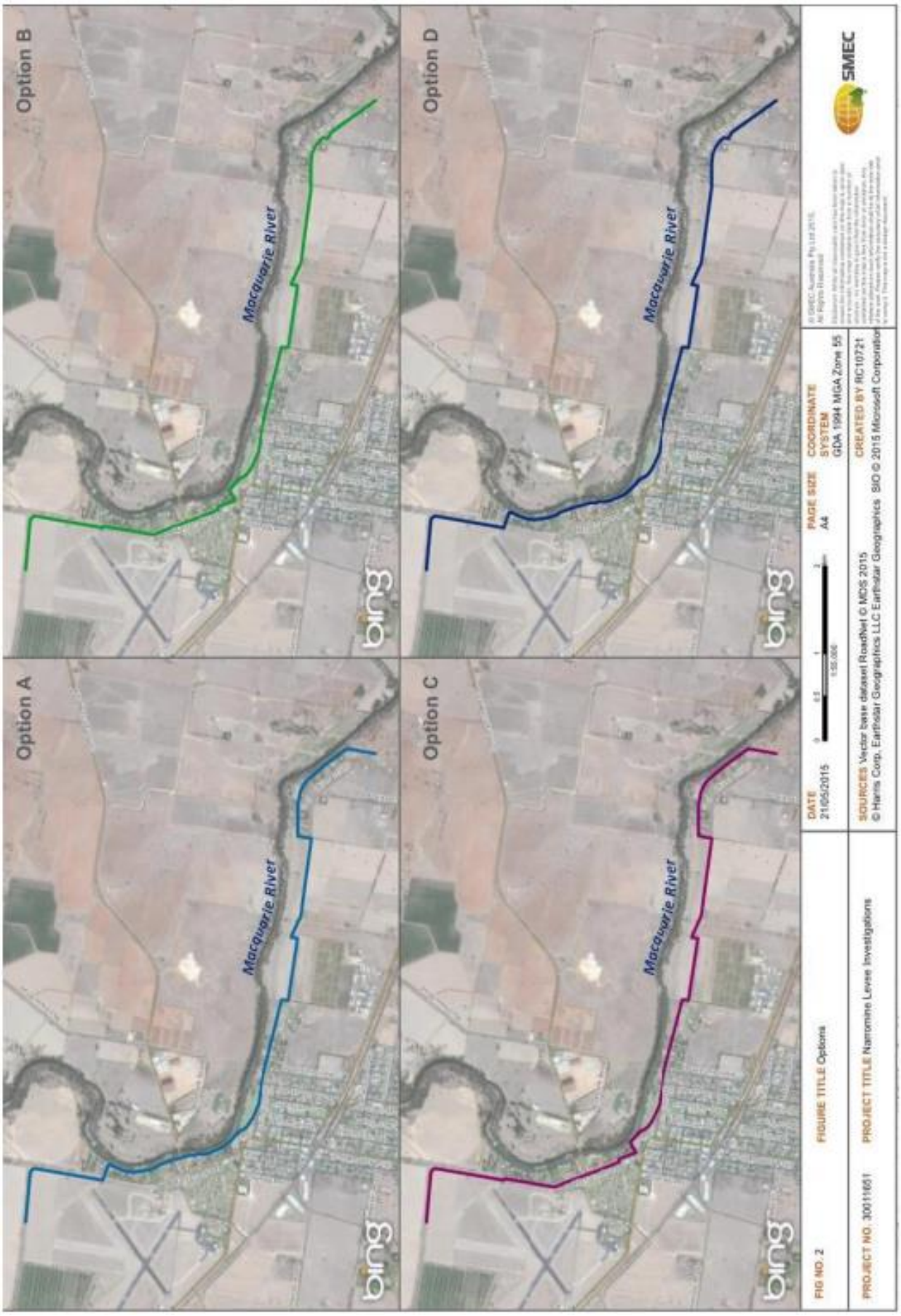
A key outcome of SMEC, 2019 was that Levee Options A, C and D were not feasible given their close proximity to the river bank where they run parallel with River Drive and/or Warren Road. As a result, only Levee Option B was considered to be feasible in terms of its constructability.

A key outcome of the community consultation process that formed part of SMEC, 2019 was that there was still considerable concern within the community with Levee Option B, namely in regards the third party related impacts that it would have on flooding in existing residential development that is located along the eastern side of Warren Road and to a lesser extent River Drive. The Chairman of the *Narromine Irrigation Board of Management* also raised concerns regarding the impact that the change in flow regime would have on its infrastructure.

TABLE 3.1
FLOODPLAIN RISK MANAGEMENT MEASURES COMPRISING FRMP 2009

Measure[1]	Estimated Cost	Priority Assigned to Implementation of Measure	Status of Measure
PM1 – Implement the recommended development controls based on *draft Flood Policy for Narromine*	Council staff's Cost	High	Implemented
RM1 – Ensure flood data in this *Floodplain Risk Management Study and draft Plan* is available to NSW SES for inclusion in flood emergency response	Council and NSW SES Costs	High	Implemented
RM2 – Implement flood awareness and education program for residents and owners of commercial and industrial developments	NSW SES and Property/Business Owner Costs	High	Implemented
FM1 – Feasibility Study of river bank levee	$80,000	High	Completed
FM2 – Preparation of detailed design and construction of levee (dependent on the results of the above study).	$1.6 Million	Medium	Yet to be commenced
FM3 – Feasibility Study of upgrading the hydraulic capacity of culverts beneath the Parkes Narromine Railway	$50,000	Medium	Yet to be commenced
FM4 – Prepare detailed design and construct culvert works (Scheme is dependent on the results of the above study and whether river bank levee scheme is implemented. The river levee would reduce ponding upstream of the railway and possibly reduce the need for improved culverts)	$0.8 Million	Medium	Yet to be commenced
Total Cost of Implementing Flood Modification Measures FM1, FM2, FM3 and FM4	**$2.53 Million**		

1. FM = Flood Modification Option PM = Property Modification Option RM = Response Modification Option


Option B
Macquarie River
Option D
Macquarie River
Option A
Macquarie River
Option C
Macquarie River
bing
FIG NO. 2
FIGURE TITLE Options
DATE
21/05/2015
PAGE SIZE
A4
COORDINATE SYSTEM
GDA 1994 MGA Zone 55
PROJECT NO. 30011651
PROJECT TITLE Narromine Levee Investigations
SOURCES Vector base dataset RoadNet © MDS 2015
© Harris Corp, Earthstar Geographics LLC Earthstar Geographics SIO © 2015 Microsoft Corporation
CREATED BY RC10721
SMEC

Based on the outcomes of SMEC, 2019, a key requirement of *Narromine Town FRMS 2021* was the need to investigate options for mitigating the third party related impacts that are associated with the construction of Levee Option B, details of which are set out in **Section 3.4.2** of this report.

3.3 Community Views

Comments on potential flood management measures were sought from the Narromine community by way of the *Community Questionnaire* which was distributed at the commencement of the present study. The responses are summarised in **Appendix A** of this report. Question 15 in the *Community Questionnaire* outlined a range of potential flood management measures, the responses to which are shown on **Table 3.2** over the page. The measures are discussed in more detail in later sections of this Chapter.

The Community mostly favoured the following measures:

- Improve the stormwater system within the town area
- Provide a Planning Certificate to purchasers in flood prone areas, stating that the property is flood affected
- Improve flood warning and evacuation procedures both before and during a flood
- Removal of floodplain obstructions
- Upgrade of the existing railway culverts

A mostly negative response was given to the widening of watercourses and the construction of permanent levees. Providing subsidies for raising the floor level of properties and the implementation of a residential Voluntary Purchase scheme were also unpopular with the Community.

3.4 Potential Flood Modification Measures

3.4.1 Stormwater Drainage Upgrades

While most of Narromine would be inundated by floodwater during a 1% (1 in 100) AEP flood on the Macquarie River, it is evident from the responses to the *Community Questionnaire* that nuisance flooding due to local catchment runoff is of concern to the Community.

By inspection of **Figure 2.17**, it is clear that parts of Narromine are impacted by Major Overland Flow during intense storm events, especially in development that is located along the line of the Town Cowal.

While upgrading the existing railway culvert that is located in line with Meryula Street on the Town Cowal would reduce the severity of local catchment flooding that is experienced in existing development that is located to the south of the rail corridor, it would increase the depth of inundation that would be experienced in existing development that is located to its north. In order to mitigate these impacts it would be necessary to upgrade the existing stormwater drainage system along the Town Cowal to the north of rail corridor.

TABLE 3.2
COMMUNITY VIEWS ON POTENTIAL FLOOD MANAGEMENT MEASURES

Flood Management Measure	Classification[1]	Respondent's Views	
		Yes	No
Management of riparian vegetation to provide flood mitigation, stability, aesthetic and habitat benefits	FM	76	15
Widening of watercourses	FM	60	36
Removal of floodplain obstructions	FM	91	9
Improve the stormwater system within the town area	FM	116	5
Construction of urban levees	FM	58	40
Upgrade of the existing railway culverts	FM	86	14
Voluntary scheme to purchase residential property in high hazard areas	PM	36	48
Provide funding or subsidies to raise houses above major flood level in low hazard areas	PM	36	63
Specify additional controls on future development in flood-liable areas	PM	67	24
Improve flood warning and evacuation procedures both before and during a flood	RM	93	15
Provide a Planning Certificate to purchasers in flood prone areas, stating that the property is flood affected	PM	100	8

1. FM = Flood Modification Option PM = Property Modification Option RM = Response Modification Option

In order to reduce the depth of inundation that is experienced in existing residential development that is located in the area that is bounded by Terangion Street to the north, A'Beckett Street to the east, Cathundril Street to the south and Third Avenue to the west it would be necessary to upgrade the existing stormwater drainage lines which run in a westerly direction along Backwater Road and in a southerly direction along Temoin Street.

At the time of writing Council had engaged consultants to assess options for upgrading the local stormwater drainage system at Narromine. As a result, a recommendation to undertake such a study has not been included in *Narromine Town FRMP 2021*.

3.4.2 River Bank Levee and Railway Culvert Upgrade

As mentioned, while Levee Option B was considered to be feasible in terms of its constructability, there was still concern within parts of the community regarding the impact that it would have on flood behaviour in properties that are located along Warren Road and to a lesser extent River Drive.

As part of the present study, a total of four variants of Levee Option B were initially assessed which were aimed at reducing the third party related impacts on existing residential development and irrigation type infrastructure (denoted herein as "*Levee Options B1, B1a, B2 and Ha*"). Following a review of the initial study findings by the Technical Working Group (**TWG**) which comprised both Council and DPIE representatives, an additional two variants were also assessed (denoted herein as "*Levee Options B1b and B1c"*). **Figure 3.1** shows the alignment of Levee Option B, as well as the six assessed variants.

Figures C1.1 to **C1.10** in **Appendix C** show the impact that Levee Options B, B1, B1a, B2 and Ha would have on peak flood levels and maximum flow velocities for a 1% (1 in 100) AEP flood event. The initial assessment found that the adoption of Levee Options B1, B1a, B2 and Ha would not mitigate the third party related impacts on existing residential development and irrigation type infrastructure.

Following further discussions with the TWG, the option of reducing the blocking effects of the Main Western Railway where it crosses the Macquarie River floodplain at Webbs Siding was investigated. **Figures C1.11** to **C1.20** in **Appendix C** show the impact that Levee Options B, B1, B1a, B2 and Ha in combination with the upgrade of the existing railway culverts at Webbs Siding would have on peak flood levels and maximum flow velocities for a 1% (1 in 100) AEP flood event. The investigation found that it would be necessary to install a 500 m length of box culverts near the eastern limit of the Webbs Siding breakout in order to mitigate the third party related impacts associated with Levee Options B1 and B1a, while residual impacts remained in existing residential development that is located along Warren Road for Levee Options B, B2 and Ha.

Following a review of the above findings, the TWG selected Levee Option B1a in combination with the upgrade of the railway culverts at Webbs Siding as the preferred option to present to the FRMC. At the subsequent FRMC meeting, it was suggested that a more optimum alignment would be to run the levee south from the western end of River Drive to the Mitchell Highway where it would tie into high ground. Two alternative levee alignments were subsequently investigated, those being Levee Options B1b and B1c.

The investigation found that while the two alternative levee alignment options would not impact flood behaviour during a 1% (1 in 100) AEP flood event (refer **Figures C1.21** and **C1.22** in **Appendix C**), there would be a significant increase in the depth of floodwater ponding along the eastern side of the levee bank where it runs between River Drive and the Mitchell Highway during slightly larger flood events (refer **Figures C1.23** and **C1.24** in **Appendix C**). This would mean that the levee would have a reduced capacity to protect Narromine from being inundated by floodwater during events that are slightly larger than 1% (1 in 100) AEP given the available freeboard to its crest would be greatly reduced.

Based on the above finding, the FRMC determined that Option B1a in combination with the upgrade of the existing railway culverts at Webbs Siding is the preferred option for protecting the urbanised parts of Narromine from Main Stream Flooding (denoted herein as the "**Preferred Flood Mitigation Scheme**").

Figure 3.2 is a long sections along the alignment of Levee Option B1a showing natural surface levels relative to its crest, as well as peak 1% (1 in 100) and 0.5% (1 in 200) AEP flood levels. As per the findings of SMEC, 2019, the crest height of the river bank levee has been set a minimum 0.75 m above peak 1% (1 in 100) AEP flood levels. **Figure 3.2** also includes a long section of the Main Western Railway where its crosses the Macquarie River floodplain at Webbs Siding showing details of the existing and upgraded railway culverts.

Figure 3.3 shows the indicative extent and depth of Main Stream Flooding under post-Preferred Flood Mitigation Scheme conditions for a 1% (1 in 100) AEP flood event. Also shown on **Figure 3.3** are flow velocity vectors, maximum water surface elevation contours and peak flows in the various flow paths. **Figure 3.4** shows the impact that the Preferred Flood Mitigation Scheme would have on the extent and depth of Main Stream Flooding, as well as the distribution of flow on the floodplain, while **Figure 3.5** shows the impact that it would have on maximum flow velocities for a 1% (1 in 100) AEP flood event. Similar information is shown on **Figures 3.6**, **3.7** and **3.8** for a 0.5% (1 in 200) AEP flood event.

The key findings of the investigation in regards the Preferred Flood Mitigation Scheme were as follows:

i. The urbanised parts of Narromine south of the river bank levee would be protected from Main Stream Flooding for floods up to 1% (1 in 100) AEP in magnitude (refer **Figures 3.4** and **3.5**).

ii. Third party related impacts associated with the scheme would be limited to properties that are located along the Backwater Cowal south of Narromine due to the resulting redistribution of flow. While the extent and depth of inundation would be increased along the Backwater Cowal as part of the scheme, only one existing homestead would be adversely impacted as a result of its implementation for floods up to 1% AEP in magnitude (refer "Homestead C" on **Figure 3.4**) and a second homestead at the 0.5% (1 in 200) AEP level of flooding (refer "Homestead B" on **Figure 3.7**).

iii. While the increase in flow along the Backwater Cowal would increase flow velocities in the watercourse, they would generally not exceed 1.0 m/s and 2.0 m/s for floods up to 1% (1 in 100) AEP and 0.5% (1 in 200) AEP, respectively under Post-Preferred Flood Mitigation Scheme conditions (refer maximum flow velocities shown on **Figures 2.12** and **2.14** and the relative increases shown on **Figures 3.6** and **3.8**).

iv. Minor overtopping of the levee would occur in the vicinity of River Drive during a 0.5% (1 in 200) AEP flood event. Floodwater would also inundate parts of Narromine south of the river bank levee due to backwater flooding from the Town Cowal south of the Main Western Railway, as well as flow which surcharges the northern bank of the Backwater Cowal immediately east (upstream) of Tomingley Road during a flood of this magnitude.

While the Preferred Flood Mitigation Scheme would protect most of Narromine from Main Stream Flooding, existing development would still be impacted by Major Overland Flow as a result of rain falling directly over the township. **Figure 3.9** shows the indicate extent and depth of local catchment flooding under post-Preferred Flood Mitigation Scheme conditions, while **Figure 3.10** shows the impact that coincident elevated water levels in the Macquarie River would have on the depth and extent of Major Overland Flow for a 1% (1 in 100) AEP storm event. It would be necessary to update the flood modelling and mapping for Narromine as part of the detailed design of the Preferred Flood Mitigation Scheme as the controls relating to future development within the protected area would generally relate to flood levels associated with Major Overland Flow rather than Main Stream Flooding following its construction.

Based on the capital cost estimate derived for Levee Option B as part of SMEC, 2019, it is estimated that the Preferred Flood Mitigation Scheme would cost about $22 Million to construct. The *present worth value* of flood damages that would be saved by the construction of the Preferred Flood Mitigation Scheme after taking freeboard into account is estimated to be about $18.8 Million, resulting in a benefit cost ratio of about 0.85.

While the construction of the Preferred Flood Mitigation Scheme cannot be justified on economic grounds (i.e. because its benefit cost ratio is less than 1), it would provide the added benefit of removing a major constraint on future development in Narromine, that being the need to set habitable floor levels in some areas over 1 m above natural surface levels. It would also significantly reduce the disruption that would otherwise be experienced by residents and business owners during major flood events on the Macquarie River.

Based on the above findings, the design and construction of the Preferred Flood Mitigation Scheme has been included in *Narromine Town FRMP 2021*, noting that it would also be necessary to update the flood modelling and also the flood planning related aspects of *Narromine Shire DCP 2011* as part of this process.

3.4.3 Preferred Flood Mitigation Scheme in Combination with Inland Rail Project

In the knowledge that the proposed Inland Rail project will cross the Macquarie River floodplain in the vicinity of Webbs Siding, an assessment was undertaken to determine whether its construction would impact the level of protection afforded by the Preferred Flood Mitigation Scheme. The investigation also included an assessment of the impact that the construction of the Preferred Flood Mitigation Scheme would have on flood behaviour in the vicinity of the proposed Inland Rail project.

Inland Rail provided a copy of a TUFLOW model that had been developed as part of the preparation of the Environmental Impact Statement for the project. Details of the project such as the proposed railway embankment and the associated transverse drainage structures were extracted from Inland Rail's TUFLOW model and input to the *Narromine Town FRMS 2021 TUFLOW Model*. The updated TUFLOW model (***Narromine Town FRMS 2021 Inland Rail TUFLOW Model***) was then run for post-Preferred Flood Mitigation Scheme and Inland Rail project conditions for both the 1% (1 in 100) AEP and 0.5% (1 in 200) AEP flood events.

Figure 3.11 shows the indicative extent and depth of Main Stream Flooding under post-Preferred Flood Mitigation Scheme and Inland Rail project conditions for a 1% (1 in 100) AEP flood, while **Figure 3.12** shows that the construction of the Inland Rail project would result in slightly higher peak 1% (1 in 100) AEP flood levels south of the Main Western Railway when compared to conditions that would result from the construction of the Preferred Flood Mitigation Scheme in its absence. **Figures 3.13** and **3.14** show similar information for a 0.5% (1 in 200) AEP flood event.

The redistribution of flow associated with the construction of the Preferred Flood Mitigation Scheme would result in an increase in the magnitude and velocity of flow discharging through the transverse drainage structures that are associated with the Inland Rail project immediately south of the Main Western Railway, a feature which will need to be taken into account by the designers of the rail project.

While the Inland Rail project would not have a significant impact on the distribution of flow under post-Preferred Flood Mitigation Scheme conditions for a 1% (1 in 100) AEP flood event, it would result in a minor reduction in the flow which would discharge south via Webbs Siding during a 0.5% (1 in 200) AEP flood event. The result would be that increases in peak flood levels attributable to the Preferred Flood Mitigation Scheme would be slightly greater along the Macquarie River and slightly less along the Backwater Cowal when compared to present day conditions.

Based on the above findings, the assessment concluded that the construction of the Inland Rail project would not result in a major impact on flood behaviour under post-Preferred Flood Mitigation Scheme conditions and as such would not reduce the level of flood protection afforded by the scheme.

3.4.4 Vegetation Management

Management programs in creeks and rivers typically involve maintenance of batters and the removal of sediment and dense vegetation, as well as the clearance of flood debris after significant flow events. Clearance of debris within the stream corridor reduces the potential for future capture by the flow and blockage of bridges and culverts.

While there is merit in removing flood debris from the banks of the Macquarie River after significant flow events, this would only have a relatively minor impact in terms of reducing peak flood levels in the river given its already large conveyance capacity. That said, the removal of flood debris in combination with the removal of dense understorey vegetation along the banks of the river would assist in reducing the frequency that floodwater surcharges the southern bank of the river at Narromine. As a result, the development and implementation of a *Vegetation Management Plan* for the Macquarie River at Narromine has been included in *Narromine Town FRMP 2021*.

3.5 Property Modification Measures

3.5.1 Controls over Future Development

3.5.1.1 Current Government Policy

The NSW Government has recently finalised reforms of the *NSW Flood Prone Land Package*. As part of the reform, the wording in the flood planning clause of all NSW Councils will be updated on 14 July 2021. As part of the reform, Council will need to nominate the FPL or levels that it wishes to define the FPA and make alternative arrangements for making flood planning maps publicly available where previously solely reliant on LEP flood overlay maps. The reforms also include an optional clause titled *special flood considerations* which applies to land which lies between the FPA and the extent of the Extreme Flood. The adopted form of wording for the flood planning and special flood considerations clauses, the former which will automatically come in effect on the 14 July 2021 and the latter which is recommended for inclusion in *Narromine LEP 2011* is set out in **Section 3.5.1.4** of this report.

3.5.1.2 Considerations for Setting Freeboard Requirements at Narromine

Selection of the FPL for an area is an important and fundamental decision as the standard is the reference point for the preparation of floodplain risk management plans. It is based on the adoption of the peak level reached by a particular flood plus an appropriate allowance for freeboard. It involves balancing social, economic and ecological considerations against the consequences of flooding, with a view to minimising the potential for property damage and the risk to life and limb. If the adopted FPL is too low, new development in areas outside the FPA (particularly where the difference in level is not great) may be inundated relatively frequently and damage to associated public services will be greater. Alternatively, adoption of an excessively high FPL will subject land that is rarely flooded to unwarranted controls.

Councils are responsible for determining the appropriate FPLs within their local government area. *Narromine LEP 2011* currently nominates the "*1:100 ARI (average recurrence interval) flood event plus 0.5 metre freeboard*" as the FPL.

Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Design variables that are typically incorporated in the derivation of freeboard typically comprise the following:

- increases in peak flood levels due to wind and wave action;
- increases in peak flood levels due to local water surge;
- uncertainties in the design flood level estimates due to the confidence limits associated with the design peak flow estimates for Narromine, inaccuracies in the LiDAR survey data and possible variations in key parameters such as hydraulic roughness; and
- increases in peak flood levels due to future climate change.

Table 3.3 provides a summary of a joint probability analysis which was undertaken to assess the freeboard allowance which should be incorporated in the FPL for areas at Narromine that are affected by Main Stream Flooding, noting the methodology for deriving the various components of the freeboard allowance is based on the approach set out in NSW Public Works, 2010.

TABLE 3.3
SUMMARY OF FREEBOARD ANALYSIS
AREAS AFFECTED BY MAIN STREAM FLOODING

Design Variable [A]	Probability of Occurrence [B]	Maximum Allowance (m) [C]	Joint Probability Allowance (m) [D]
Wave Action	50%	0.15	0.08
Inaccuracies in Peak 1% AEP Flood Level Estimate			
- LiDAR survey data	100%	0.15	0.15
- Peak flow estimate	50%	0.20	0.10
- Hydraulic roughness	25%	0.20	0.05
Future Climate Change	50%	0.50	0.25
TOTAL			**0.63**

The maximum allowance for uncertainties in the peak 1% (1 in 100) AEP flood level estimate is comprised of the following

- inaccuracies in the LiDAR survey data (+0.15 m);
- provision for a 10% increase in the best-estimate peak 1% (1 in 100) AEP flow derived by the flood frequency analysis (+0.2 m)
- increase in peak flood levels associated with a possible 20% increase in the best-estimate hydraulic roughness values (generally a maximum of +0.2 m based on the information shown on **Figure 2.19**).

In regards the potential impacts of future climate change on flood behaviour at Narromine, the *ARR Data Hub* gives the following interim climate change factors for Representative Concentration Pathways (**RCPs**) of 4.5 and 8.5 in the years 2050 and 2090:

Year	RCP 4.5	RCP 8.5
2050	7.3%	10.1%
2090	10.8%	22.8%

A flood with an AEP of 0.5% is commonly considered to be analogous to a flood that would result from a 10% increase in 1% (1 in 100) AEP rainfall intensities. By comparison with the interim climate change factors, the adoption of the 0.5% (1 in 200) AEP would provide a reasonable indicator of the potential for future climate change to impact peak 1% (1 in 100) AEP flood levels at Narromine (generally a maximum of +0.5 m based on the information shown on **Figure 2.21**).

While the joint probability analysis set out in **Table 3.3** indicates a freeboard slightly greater than the traditional value of 0.5 m would be appropriate for Narromine, given a larger portion of this relates to the potential impacts of future climate change, the exact nature of which cannot yet be determined, it is considered reasonable to adopt a freeboard of 0.5 m for setting the FPL at Narromine. It is also noted that Council intends to actively pursue the implementation of the Preferred Flood Mitigation Scheme which will protect the majority of development within Narromine from Main Stream Flooding for floods up to 1% (1 in 100) AEP in magnitude.

Figure D1.1 in **Appendix D** is an extract from the *Flood Planning Map* at Narromine. The extent of the FPA is shown in a solid red colour in **Figure D1.1** and has been defined as the area that lies at or below by the 1% (1 in 100) AEP plus 0.5 m freeboard. Also shown in **Figure D1.1** is the extent of the Outer Floodplain, which is the area of land which lies between the extent of the FPA and the Extreme Flood.

3.5.1.3 Proposed Planning Controls for Narromine

While *Narromine Shire DCP 2011* contains a set of flood related development controls, these are linked to flood mapping and peak flood levels which have been superseded by the more detailed flood modelling that has been undertaken as part of the present study. Proposed planning controls for flood prone areas in Narromine, along with suggested wording for inclusion in *Narromine Shire DCP 2011* are presented in **Appendix D**.

It is proposed that properties intersected by the extent of the FPA would be subject to S10.7 flood affectation notification and planning controls graded according to flood hazard and evacuation constraints. NSWG, 2005 suggests wording on S10.7 (2) Planning Certificates along the following lines:

> *"Council considers the land in question to be within the Flood Planning Area and therefore subject to flood related development controls. Information relating to this flood risk may be obtained from Council. Restrictions on development in relation to flooding apply to this land as set out in Council's Flood Policy which is available for inspection at Council offices or website."*

Annexures 2A and **2B** in **Appendix D** set out the graded set of flood related planning controls which apply to development in areas that are affected by Main Stream Flooding and Major Overland Flow, respectively. MHFL requirements would be imposed on future development in properties that are identified as lying either partially or wholly within the extent of the FPA shown on **Figure D1.1**.

The MHFLs for all land use types are the same as are currently set out in *Narromine DCP 2011*, those being:

- at or above the 1% (1 in 100) AEP plus 0.5 m freeboard in the case of residential type development;
- as close as practical to the 1% (1 in 100) AEP plus 0.5 m but no lower than the 2% (1 in 50) AEP plus 0.5 m freeboard in the case of commercial/industrial type development; and
- at or above the 0.5% (1 in 100) AEP plus 0.5 m freeboard in the case of flood vulnerable residential type development, essential community facilities and critical utilities.

Figure D1.2 in **Appendix D** is an extract of the *Flood Planning Constraint Category Map* for the Narromine Shire which shows the subdivision of the floodplain into a number of categories which have been used as the basis for developing the graded set of planning controls. The floodplain has been divided into the following four categories:

- **Flood Planning Constraint Category 1 (FPCC 1)**, which comprises areas where factors such as the depth and velocity of flow, time of rise, and evacuation problems mean that the land is unsuitable for most types of development. The majority of new development types are excluded from this zone due to its potential impact on flood behaviour and the hazardous nature of flooding.
- **Flood Planning Constraint Category 2 (FPCC 2)**, which comprises areas which lie within the extent of the FPA where the existing flood risk warrants careful consideration and the application of significant flood related controls on future development.
- **Flood Planning Constraint Category 3 (FPCC 3)**, which comprises areas which lie within the extent of the FPA but outside areas designated FPCC1 and FPCC2. Areas designated FPCC3 are more suitable for new development and expansion of existing development provided it is carried out in accordance with the controls set out in this document.
- **Flood Planning Constraint Category 4 (FPCC 4)**, which comprises the area which lies between the extent of the FPA and the Extreme Flood. Flood related controls in areas designated FPCC4 are typically limited to flood evacuation and emergency response, although additional controls apply to essential community facilities and utilities that are critical for response and recovery, as well as community hospitals, residential care facilities and group homes.

The derivation of the four FPCCs firstly involved the derivation of a number of sub-regions which were based on the nature of flooding at Narromine, the sub-categories of which are set out in **Table 3.4** over. These sub-regions were then combined, with the resulting extents further refined in order to improve the area over which each FPCC applied.

TABLE 3.4
KEY ELEMENTS COMPRISING FLOOD PLANNING CONSTRAINT CATEGORIES

FPCC	Sub-category	Constraint
1	a	1% AEP Floodway
	b	1% AEP Flood Hazard Vulnerability Classification H6
2	a	1% AEP Flood Storage
	b	1% AEP Flood Hazard Vulnerability Classification H5
3	a	Flood Planning Area
	b	1% AEP Flood Emergency Response Classification (Flooded - Isolated - Submerged)
4	-	Extent of Extreme Flood

3.5.1.4 Revision of Narromine LEP 2011 by Council

Narromine Town FRMS 2021 and *Narromine Town FRMP 2021* have both been developed giving consideration to the following amended form of wording which will automatically come into effect on 14 July 2021:

"6.2 Flood planning

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

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

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

(c) to avoid adverse or cumulative impacts on flood behaviour and the environment,

(d) to enable the safe occupation and efficient evacuation of people in the event of a flood.

(2) Development consent must not be granted to development on land the consent authority considers to be within the flood planning area unless the consent authority is satisfied the development—

(a) is compatible with the flood function and behaviour on the land, and

(b) will not adversely affect flood behaviour in a way that results in detrimental increases in the potential flood affectation of other development or properties, and

(c) will not adversely affect the safe occupation and efficient evacuation of people or exceed the capacity of existing evacuation routes for the surrounding area in the event of a flood, and

(d) incorporates appropriate measures to manage risk to life in the event of a flood, and

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

(3) In deciding whether to grant development consent on land to which this clause applies, the consent authority must consider the following matters—

(a) the impact of the development on projected changes to flood behaviour as a result of climate change,

(b) the intended design and scale of buildings resulting from the development,

(c) whether the development incorporates measures to minimise the risk to life and ensure the safe evacuation of people in the event of a flood,

(d) the potential to modify, relocate or remove buildings resulting from development if the surrounding area is impacted by flooding or coastal erosion.

(4) A word or expression used in this clause has the same meaning as it has in the Considering Flooding in Land Use Planning Guideline unless it is otherwise defined in this clause.

(5) In this clause—

Considering Flooding in Land Use Planning Guideline means the *Considering Flooding in Land Use Planning Guideline* published on the Department's website on 14 July 2021.

flood planning area has the same meaning as it has in the Floodplain Development Manual.

Floodplain Development Manual means the *Floodplain Development Manual* (ISBN 0 7347 5476 0) published by the NSW Government in April 2005.

It is also recommended that the optional new *special flood considerations* clause be added to *Narromine LEP 2011* as follows:

Special flood considerations

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

(a) to enable the safe occupation and evacuation of people subject to flooding,

(b) to ensure development on land is compatible with the land's flood behaviour in the event of a flood,

(c) to avoid adverse or cumulative impacts on flood behaviour,

(d) to protect the operational capacity of emergency response facilities and critical infrastructure during flood events,

(e) to avoid adverse effects of hazardous development on the environment during flood events.

(2) This clause applies to—

(a) for sensitive and hazardous development—land between the flood planning area and the probable maximum flood, and

(b) for development that is not sensitive and hazardous development—land the consent authority considers to be land that, in the event of a flood, may—

(i) cause a particular risk to life, and

(ii) require the evacuation of people or other safety considerations.

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

(a) will not affect the safe occupation and efficient evacuation of people in the event of a flood, and

(b) incorporates appropriate measures to manage risk to life in the event of a flood, and

(c) will not adversely affect the environment in the event of a flood.

(4) A word or expression used in this clause has the same meaning as it has in the Considering Flooding in Land Use Planning Guideline unless it is otherwise defined in this clause.

(5) In this clause—

Considering Flooding in Land Use Planning Guideline*—see clause 5.21(5).*

flood planning area*—see clause 5.21(5).*

Floodplain Development Manual*—see clause 5.21(5).*

probable maximum flood *has the same meaning as it has in the Floodplain Development Manual.*

sensitive and hazardous development *means development for the following purposes—*

[list land uses]

Direction— Only the following land uses are permitted to be included in the list—

(a) boarding houses,

(b) caravan parks,

(c) correctional centres,

(d) early education and care facilities,

(e) eco-tourist facilities,

(f) educational establishments,

(g) emergency services facilities,

(h) group homes,

(i) hazardous industries,

(j) hazardous storage establishments,

(k) hospitals,

(l) hostels,

(m) information and education facilities,

(n) respite day care centres,

(o) seniors housing,

(p) sewerage systems,

(q) tourist and visitor accommodation,

(r) water supply systems

The steps involved in Council amending *Narromine LEP 2011*following the finalisation and adoption of the *FRMS&P 2021* are:

1. Council Planning Staff consider the conclusions of the *FRMS&P 2021* and suggested amendments to *Narromine LEP 2011*.
2. Council resolves to amend *Narromine LEP 2011* in accordance with the *FRMS&P 2021*.
3. Council prepares a Planning Proposal in accordance with NSW Planning and Environment Guidelines. Planning Proposal submitted to NSW Planning and Environment in accordance with section 3.33 of the EP&A Act, 1979.
4. Planning Proposal considered by DPIE and determination made in accordance with section 3.34(2) of the EP&A Act, 1979 as follows:
   (a) whether the matter should proceed (with or without variation),
   (b) whether the matter should be resubmitted for any reason (including for further studies or other information, or for the revision of the planning proposal),
   (c) community consultation required before consideration is given to the making of the proposed instrument (the community consultation requirements),
   (d) any consultation required with State or Commonwealth public authorities that will or may be adversely affected by the proposed instrument,
   (e) whether a public hearing is to be held into the matter by the Planning Assessment Commission or other specified person or body,
   (f) the times within which the various stages of the procedure for the making of the proposed instrument are to be completed.
5. Planning Proposal exhibited for public comment.
6. Planning Proposal reviewed following public submissions and submissions from relevant State and Commonwealth authorities.
7. Final Local Environmental Plan with proposed amendments drafted.
8. Amending Local Environmental Plan made by the Minister and gazetted.

3.5.2 Voluntary Purchase of Residential Properties

Removal of housing from high hazard floodway areas in the floodplain is generally accepted as a cost effective means of correcting previous decisions to build in such areas. The Voluntary Purchase of residential property in hazardous areas has been part of subsidised floodplain risk management programs in NSW for over 20 years.[5] After purchase, land is subsequently cleared and the site re-developed and re-zoned for public open space or some other flood compatible use. A further criterion applied by State Government agencies in assessing eligibility for funding is that the property must be in a high hazard floodway area, that is, in the path of flowing floodwaters where the depth and velocity at the peak of the flood are such that life could be threatened, damage of property is likely and evacuation difficult.

[5] State government funding is only available for properties where the buildings were approved and constructed prior to 1986 when the original Floodplain Development Manual was gazetted. Properties built after this date should have been constructed in accordance with the principles in the manual.

Under a Voluntary Purchase scheme the owner is notified that the body controlling the scheme, Council in the present case, is prepared to purchase the property when the owner is ready to sell. There is no compulsion whatsoever to sell at any time. The price is determined by independent valuers and the Valuer General, and by negotiation between Council and the owners. Valuations are not reduced due to the flood affected nature of the site.

Prior to progressing to the purchase of a property, it would first be necessary to hold discussions with each eligible and agreeable property owner, as well as a detailed assessment of each property to determine a priority order and costing for each.

While there is one existing dwelling that is located in a high hazard floodway where the depth of above-floor inundation would exceed 1 m in a 1% (1 in 100) AEP flood event, Council advised that its date of construction is later than 1986, hence it is not eligible for inclusion in the NSW Government's VP Scheme.

3.5.3 Raising Floor Levels of Residential Properties

The term "house raising" refers to procedures undertaken, usually on a property by property basis, to protect structures from damage by floodwaters. The most common process is to raise the affected house by a convenient amount so that the floor level is at or above the MHFL. For weatherboard and similar buildings this can be achieved by jacking up the house, constructing new supports, stairways and balconies and reconnecting services. Alternatively, where the house contains high ceilings, floor levels can be raised within rooms without actually raising the house. It is usually not practical to raise brick or masonry houses. Most of the costs associated with this measure relate to the disconnection and reconnection of services. Accordingly, houses may be raised a considerable elevation without incurring large incremental costs.

State and Federal Governments have agreed that flood mitigation funds will be available for house raising, subject to the same economic evaluation and subsidy arrangements that apply to other structural and non-structural flood mitigation measures. In accepting schemes for eligibility, the Government has set out the following conditions:

- House raising should be part of the adopted Floodplain Risk Management Plan.
- The scheme should be administered by the local authority.

State government funding is only available for properties where the buildings were approved and constructed prior to 1986 when the original Floodplain Development Manual was gazetted. Properties built after this date should have been constructed in accordance with the principles in the manual. The Government also requires that councils carry out ongoing monitoring in areas where subsidised voluntary house raising has occurred to ensure that redevelopment does not occur to re-establish habitable areas below the design floor level. In addition, it is expected that councils will provide documentation during the conveyancing process so that subsequent owners are made aware of restrictions on development below the design floor level.

Council's principal role in subsidised voluntary house raising would be to:

- Define a habitable floor level, which it will have already done in exercising controls over new house building in the area.
- Guarantee a payment to the builder after satisfactory completion of the agreed work.
- Monitor the area of voluntary house raising to ensure that redevelopment does not occur to re-establish habitable areas below the design floor level.

Prior to progressing to the raising of a dwelling, it would be necessary to hold discussions with each eligible and agreeable property owner, as well as a detailed assessment of each property to determine a priority order and costing for each.

The current cost to raise a medium sized (150 m^2) house is about $100,000 based on recent experience in other centres.

While there are ten (10) existing dwellings that are located in high hazard flood storage areas in Narromine, all ten would be protected from riverine type flooding through the implementation of the Preferred Flood Mitigation Scheme. Because of this, there is no justification for their inclusion in the NSW Government's Voluntary House Raising Scheme.

3.6 Response Modification Measures

3.6.1 Flood Forecasting, Warning and Evacuation Planning

Improvements to the flood warning and response procedures were strongly favoured by the community during the community consultation process. An effective flood warning system has three key components, i.e. a flood forecasting system, a flood warning broadcast system and a response/evacuation plan. All systems need to be underpinned by an appropriate public flood awareness program.

An effective system has been implemented by BoM which monitors meteorologic conditions and is also capable of predicting flood behaviour along the Macquarie River in real time. It forms the first stage of the flood warning/emergency response system for the Macquarie River catchment.

From the information on flooding characteristics presented in **Section 2.4**, the flood response at Narromine to major storms on the Macquarie River catchment is expected to be up to a week (i.e. from the occurrence of the peak rainfall to the occurrence of the peak discharge in the lower reaches of the Macquarie River). As a result, there is sufficient time available to NSW SES to plan and implement emergency response operations at Narromine.

3.6.2 Improved Emergency Planning and Response

As mentioned in **Section 2.15**, the *Narromine Shire Local Flood Plan* provides detailed information regarding preparedness measures, conduct of response operations and coordination of immediate recovery measures for all levels of flooding.

NSW SES should ensure information contained in this report on the impacts of flooding on urban development, as well as recommendations regarding community education are used to update the following Annexes in Volume 2 of the *Narromine Shire Local Flood Plan*:

Annex A – The Flood Threat includes the following sub-sections:

Land Forms and River Systems – ref. **Sections 2.1** and **2.2** of the report for information on these topics.

Characteristics of Flooding – Indicative extents of inundation for historic floods that occurred in February 1955, August 1990 and December 2010 are shown on **Figures 2.4**, **2.5** and **2.6**, while similar information is shown on **Figures 2.9**, **2.10**, **2.11**, **2.13** and **2.15** for design floods ranging between 5% (1 in 20) AEP and the Extreme Flood. The location of vulnerable development and critical infrastructure relative to the flood extents is shown on **Figure 2.18**.

Flood History – The history of flooding at Narromine is discussed in **Section 2.3** of the report.

Design Flood Heights – The design flood heights for the Bridge Gauge should be updated based on the design peak flood levels set out in **Table 2.2** of the report.

Flood Mitigation Systems – Apart from the existing Town Levee, there are no other formal flood mitigation measures in Narromine.

Extreme Flood Events – The Extreme Flood was modelled and the indicative extent and depth of inundation presented on **Figure 2.15**.

Annex B – Effects of Flooding on the Community

Information on the properties affected by the 1% (1 in 100) AEP design flood are included in the flood damages database, a copy of which will be uploaded to the NSW SES's Flood Data Portal at the completion of the present study, noting that the floor level data used in this assessment were based on survey for those properties that are located along the southern bank of the Macquarie River and by adding a nominal 0.3 m height of floor above a representative natural surface within the allotment (as estimated by visual inspection) to the natural surface elevation determined from LiDAR survey for the remainder of the properties in Narromine.

Figure 2.18 shows the location of vulnerable development and critical infrastructure in Narromine relative to the flood extents ranging between 5% (1 in 20) and the Extreme Flood. Refer **Section 2.8** for details of affected infrastructure.

Figures 3.15, 3.16 and **3.17** show the flood emergency response planning classifications for the 5% (1 in 20) AEP, 1% (1 in 100) AEP and Extreme Flood events, respectively, based on the definitions set out in AIDR, 2017.

3.6.3 Public Awareness Programs

Community awareness and appreciation of the existing flood hazards in the floodplain would promote proper land use and development in flood affected areas. A well informed community would be more receptive to requirements for flood proofing of buildings and general building and development controls imposed by Council. Council should also take advantage of the information on flooding presented in this report, including the flood mapping, to inform occupiers of the floodplains of the flood risk.

One aspect of a community's preparedness for flooding is the "flood awareness" of individuals. This includes awareness of the flood threat in their area and how to protect themselves against it. The overall level of flood awareness within the community tends to reduce with time, as memories fade and as residents move into and out of the floodplain. The improvements to flood warning arrangements described above, as well as the process of disseminating this information to the community, would represent a major opportunity for increasing flood awareness in Narromine.

Means by which community awareness of flood risks can be maintained or may be increased include:

- displays at Council offices using the information contained in the present study and photographs of historic flooding in the area; and

- talks by NSW SES officers with participation by Council and longstanding residents with first-hand experience of flooding in the area.
- preparation of a *Flood Information Brochure* which could be prepared by Council with the assistance of NSW SES containing both general and site specific data and distributed with rate notices.

The community should also be made aware that a flood greater than historic levels or the flood planning level can, and will, occur at some time in the future.

4 SELECTION OF FLOODPLAIN MANAGEMENT MEASURES

4.1 Background

NSWG, 2005 requires a Council to develop a Floodplain Risk Management Plan based on balancing the merits of social, economic and environmental considerations which are relevant to the community. This chapter sets out a range of factors which need to be taken into consideration when selecting the mix of works and measures that should be included in the Floodplain Risk Management Plan.

The community will have different priorities and, therefore, each needs to establish its own set of considerations used to assess the merits of different options. The considerations adopted by a community must, however, recognise the NSW Government's requirements for floodplain management as set out in NSWG, 2005 and other relevant policies. A further consideration is that some elements of the Floodplain Risk Management Plan may be eligible for subsidy from State and Federal Government sources and the requirements for such funding must, therefore, be taken into account.

Typically, State and Federal Government funding is given on the basis of merit, as judged by a range of criteria:

- The magnitude of damage to property caused by flooding and the effectiveness of the option in mitigating damage and reducing the flood risk to the community.
- Community involvement in the preparation of the Floodplain Risk Management Plan and acceptance of the option.
- The technical feasibility of the option (relevant to structural works).
- Conformance of the option with Council's planning objectives.
- Impacts of the option on the environment.
- The economic justification, as measured by the benefit/cost ratio of the option.
- The financial feasibility as gauged by Council's ability to meet its commitment to fund its part of the cost.
- The performance of the option in the event of a flood greater than the design event.
- Conformance of the option with Government Policies (e.g. NSWG, 2005 and Catchment Management objectives).

4.2 Ranking of Options

A suggested approach to assessing the merits of various options is to use a subjective scoring system. The chief merits of such a system are that it allows comparisons to be made between alternatives using a common "currency". In addition it makes the assessment of alternatives "transparent" (i.e. all important factors are included in the analysis). The system does not, however, provide an absolute "right" answer as to what should be included in *Narromine Town FRMP 2021* and what should be left out. Rather, it provides a method by which the Council can re-examine its options and if necessary, debate the relative scoring given to aspects of *Narromine Town FRMP 2021*.

Each option is given a score according to how well the option meets the considerations discussed above. In order to keep the scoring simple the following system is proposed:

+2	Option rates very highly
+1	Option rates well
0	Option is neutral
- 1	Option rates poorly
- 2	Option rates very poorly

The scores are added to get a total for each option.

Based on considerations outlined in this chapter, **Table 4.1** presents a suggested scoring matrix for the options reviewed in **Chapter 3** at Narromine. This scoring has been used as the basis for prioritising the components of *Narromine Town FRMP 2021*. **The proposed scoring and weighting shown in Table 4.1 were reviewed by the FRMC as part of the process of finalising *Narromine Town FRMP 2021***.

4.3 Summary

Table 4.1 indicates that there are good reasons to consider including the following elements into *Narromine Town FRMP 2021*:

- An update of the *Narromine LEP 2011* to allow better management of the floodplain
- Improved planning controls through the updating of *Narromine Shire DCP 2011* based on the recommended approach set out in this report
- Incorporation of the catchment specific information on flooding impacts contained in this report in NSW SES Response Planning and Flood Awareness documentation for the study area
- Improved public awareness of flood risk in the community
- Design and construction of the Preferred Flood Mitigation Scheme
- Development and implementation of a *Vegetation Management Plan* for the Macquarie River at Narromine.

TABLE 4.1
ASSESSMENT OF POTENTIAL FLOODPLAIN MANAGEMENT MEASURES FOR INCLUSION IN NARROMINE TOWN FRMP 2021

Option	Impact on Flooding/ Reduction in Flood Risk	Community Acceptance	Technical Feasibility	Planning Objectives	Environ. Impacts	Economic Justification	Financial Feasibility	Extreme Flood	Government Policies and TCM Objectives	Score
Flood Modification										
Stormwater Drainage Upgrades	+1	+2	+2	+1	0	-1	+1	0	0	+6
Preferred Flood Mitigation Scheme	+2	+1	+2	+2	0	-1	+1	0	+1	+8
Vegetation Management Plan	+1	+2	+2	+1	+2	0	+1	0	+2	+11
Property Modification										
Controls over Future Development (via update of *Narromine LEP 2011* and *Narromine Shire DCP 2011*);	+2	+2	+2	+2	0	0	0	+1	+2	+11
Voluntary Purchase of Residential Property	+2	-1	+2	+2	0	-1	-2	+2	-2	+2
Response Modification										
Improved Emergency Planning and Response	+2	+2	+1	+1	0	+1	+1	+1	+1	+10
Public Awareness Programs	+1	+2	0	+1	0	+1	0	+1	+2	+8

5 NARROMINE TOWN FLOODPLAIN RISK MANAGEMENT PLAN 2021

5.1 The Floodplain Risk Management Process

The updating of the *Narromine Floodplain Risk Management Study* (***FRMS 2009***) and the *Narromine Floodplain Risk Management Plan* (***FRMP 2009***) has been undertaken as part of a Government program to mitigate the impacts of major floods and reduce the hazards in the floodplain. The updated Floodplain Risk Management Plan for Narromine (***Narromine Town FRMP 2021***) has been prepared as part of the Floodplain Risk Management Process in accordance with NSW Government's Flood Prone Land Policy.

The first steps in the process of preparing *Narromine Town FRMP 2021* were the collection of flood data and the updating of the definition of flood behaviour at Narromine (***Updated Flood Study***). It also included the review of previous studies and the updating of *FRMS 2009* (***Narromine Town FRMS 2021***).

5.2 Purpose of the Plan

The overall objectives of *Narromine Town FRMS 2021* were to assess the impacts of flooding, review policies and measures for the management of flood affected land and to develop *Narromine Town FRMP 2021* which:

- Sets out the recommended program of works and measures aimed at reducing over time, the social, environmental and economic impacts of flooding and establishes a program and funding mechanism for *Narromine Town FRMP 2021*.
- Proposes amendments to Narromine Shire Council's (**Council's**) existing policies to ensure that the future development of flood affected land in the study area is undertaken so as to be compatible with the flood hazard and risk.
- Ensures *Narromine Town FRMP 2021* is consistent with NSW State Emergency Service's (**NSW SES's**) local emergency response planning procedures.
- Ensures that *Narromine Town FRMP 2021* has the support of the community.

5.3 The Study Area

The study area for *Narromine Town FRMP 2021* generally applies to the urban areas in Narromine that are affected by floodwater which originates from the Macquarie River (denoted herein as "**Main Stream Flooding**"). The nature of flooding which occurs as a result of rain falling directly over Narromine in the absence of Main Stream Flooding has also been defined in order to assist in the assessment process (denoted herein as "**Major Overland Flow**").

Figure 1.1 is a location plan showing the extent of the Macquarie River system upstream of Narromine, while **Figure 2.1** (2 sheets) shows the key features of the existing drainage system at Narromine.

5.4 Community Consultation

The Community Consultation process provided valuable direction over the course of the investigations, bringing together views from key Council staff, other departments and agencies, and importantly, the views of the community gained through:

- the delivery of a *Community Newsletter and Questionnaire* to property occupiers in the study area which allowed the wider community to gain an understanding of the issues being addressed as part of the study;
- meetings of the Technical Working Group and Floodplain Risk Management Committee to discuss results as they became available; and
- public exhibition of the draft *Narromine Town FRMS 2021* and *Narromine Town FRMP 2021* in combination with a community workshop which was held in Narromine.

5.5 Existing Flood Behaviour

While floodwaters have historically inundated parts of Narromine, the last flood to have surcharged the southern bank of the Macquarie River occurred in 1956. While this overtopping event was relatively minor in nature, more major flooding was experienced in Narromine in February 1955 when a large portion of the town was inundated by floodwater.

At the time of the February 1955 flood, the flow in the river was equivalent to a flood with an Annual Exceedance Probability (**AEP**) of about 1% (1 in 100). However, the construction of Burrendong Dam has meant that a flood with an AEP of 0.5% (1 in 200) would now be required to generate a similar flow in the river at Narromine. **Figure 2.4** shows the indicative extent and depth of inundation which is considered to have occurred at Narromine during the February 1955 flood event.

While the floods that occurred in August 1990 and December 2010 did not break out of the Macquarie River at Narromine, the latter did come within 0.7-0.8 m of surcharging its southern bank in the vicinity of both River Drive and Crossley Drive, as well as at the location of the existing earthen levee which runs between Manildra Street and Dandaloo Street on the northern side of Culling Street (denoted herein as the "**Town Levee**"). Both the August 1990 and December 2010 floods had an AEP of about 3.3% (1 in 30).

Figure 2.2 is an aerial photograph showing the extent of inundation that occurred near the peak of the December 2010 flood, while **Figure 2.7** shows the water surface profiles of the February 1955, August 1990 and December 2010 floods relative to the elevation of the southern bank of the Macquarie River at Narromine, noting that the water surface profiles were generated by the hydraulic model that was developed as part of the present study.

While floodwater would break out of the Macquarie River and cross Warren Road to the north of Bowen Fletcher Drive in Skypark during a 2% (1 in 50) AEP flood event (refer **Figure 2.10**), it would generally be confined to the river and its immediate southern overbank area during floods up to about 1.25% (1 in 80) AEP in magnitude.

At the 1% (1 in 100) AEP level of flooding, the majority of existing development that is located on the northern side of the Main Western Railway would be impacted by floodwater, while the minor nature of the transverse drainage structure that is located on the Town Cowal where it crosses the Main Western Railway near Meryula Street results in floodwater discharging in a westerly direction through existing development that is located to the south of the rail corridor. **Figure 2.11** shows the indicative extent and depth of inundation which would result from a 1% (1 in 100) AEP flood at Narromine.

Figure 2.13 shows the indicative extent and depth of inundation which would result from a flood with an AEP of 0.5% (1 in 200), noting that flooding conditions would be slightly worse than those that were experienced at the time of the February 1955 flood due to more recent changes on the floodplain.[6]

The extent of the floodplain at Narromine has been defined by reference to an Extreme Flood which is assumed to have a peak flow five (5) time that of the 1% (1 in 100) AEP flood. **Figure 2.15** shows the indicative extent and depth of inundation which would result from the Extreme Flood, noting that all of Narromine would be inundated as a result of such a flood.

Parts of Narromine are also subject to flooding when intense rain falls directly over the town in the absence of elevated water levels in the Macquarie River. **Figure 2.17** shows the indicative extent and depth of inundation that would result from a localised 1% (1 in 100) AEP storm event. Major ponding would occur in parts of Narromine, especially along the line of the Town Cowal. The Narromine Christian School grounds, as well as parts of the Narromine Public School and Narromine High School would also be inundated by local catchment runoff during a 1% (1 in 100) AEP storm event.

5.6 Existing Flood Mitigation Measures

Apart from the Town Levee there are no other formal flood mitigation measures in Narromine.

5.7 Economic Impacts of Flooding

Table 5.1 over the page shows the number of properties that would be flooded to above-floor level and the damages experienced in residential and commercial/industrial development, as well as public buildings in the study area.

At the 1% (1 in 100) AEP level of flooding, 449 dwellings, 72 commercial/industrial buildings and 7 public buildings are subjected to above-floor inundation. The maximum depth of above-floor inundation in the worst affected residential and commercial property increases from about 1.3 m for a 1% (1 in 100) AEP flood event to about 4 m for the Extreme Flood.

The total flood damages in Narromine based on nominal flood levels amounts to about $50 Million in the event of a 1% (1 in 100) AEP flood, increasing to about $417 Million in an Extreme Flood. For a discount rate of 7% pa and an economic life of 50 years, the *Present Worth Value* of damages for all flood events up to the Extreme Flood is about $22.5 Million. If freeboard is taken into account that the *Present Worth Value* of damages for all flood events up to the Extreme Flood increases to about $35.8 Million

[6] While the flow in the Macquarie River is similar to that which occurred in February 1955, conditions have changed on the floodplain, such as the raising of the Main Western Railway by about 0.3 m. The railway embankment at Webbs Siding also failed during the February 1955 flood which would have permitted more water to flow to the south of Narromine, a feature which was not incorporated in the definition of design flood behaviour.

TABLE 5.1
ECONOMIC IMPACTS OF FLOODING IN STUDY AREA

Design Flood Event (% AEP)	Properties Flooded Above-Floor Level						Total Flood Damages
	Residential		Commercial/Industrial		Public		
	No.	$ Million	No.	$ Million	No.	$ Million	$ Million
20	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0
2	2	0.27	0	0	0	0	0.27
1	449	43.32	72	3.30	7	3.07	49.69
0.5	1126	108.31	138	11.93	17	5.71	125.95
0.2	1446	201.94	159	30.10	26	12.25	244.29
Extreme	1655	314.53	175	78.46	27	23.77	416.76

5.8 Structure of Floodplain Risk Management Plan 2021

A summary of *Narromine Town FRMP 2021* proposed for the study area along with broad funding requirements for the recommended measures are shown in **Table S1** at the commencement of the *Narromine Town FRMS 2021* report. These measures comprise preparation of planning documentation by Council, improvements to emergency response planning and community education on flooding by Council and NSW SES. The measures will over time achieve the objectives of reducing the flood risk to existing and future development for the full range of floods.

Narromine Town FRMP 2021 is based on the following mix of measures which have been given a provisional priority ranking according to a range of economic, social, environmental and other criteria set out in **Table 4.1** of the report:

- **Measure 1** – Update wording in the Narromine Local Environmental Plan 2011 (***Narromine LEP 2011***)
- **Measure 2** – Improvements to planning and development controls for future development in flood prone areas through the update of *Narromine Shire Development Control Plan 2011* (***Narromine Shire DCP 2011***)
- **Measure 3** – Improvements to emergency response planning
- **Measure 4** – Increase public awareness of the risks of flooding in the community
- **Measure 5** – Design and construction of a levee along the southern bank of the Macquarie River in combination with the upgrade of the existing railway culverts at Webbs Siding. **Measure 5** also includes the update of the flood modelling for post-Preferred Flood Mitigation Scheme conditions, as well as the flood planning related aspects of *Narromine Shire DCP 2011***.**
- **Measure 6** – Development and implementation of a *Vegetation Management Plan* for the banks of the Macquarie River at Narromine.

5.9 Planning and Development Controls

The results of *Narromine Town FRMS 2021* indicate that an important measure for Council to adopt is the update of both *Narromine LEP 2011* and *Narromine Shire DCP 2011* to reflect more contemporaneous best-floodplain risk management practices.

5.9.1 Revision of Narromine LEP 2011

Clause 6.2 of *Narromine LEP 2011* entitled "Flood planning" outlines its objectives in regard to development of flood prone land. The Flood Planning Level (**FPL**) referred to is the 1% (1 in 100) AEP flood plus an allowance for freeboard of 0.5 m. The area encompassed by the FPL is known as the Flood Planning Area (**FPA**) and denotes the area subject to flood related development controls, such as locating development outside high hazard areas and setting minimum floor levels for future residential development.

The NSW Government recently finalised reforms of the Flood Prone Land Package which included an update of the flood planning clause in all NSW Council Local Environmental Plans which will come into effect on 14 July 2021. While the wording of the flood planning clause in the Narromine LEP 2011 will be automatically updated on this date, it is recommended that the new special flood considerations clause set out in the Flood Prone Land Package also be incorporated in *Narromine LEP 2011* (**Measure 1**). The objectives of the new clause are as follows:

- in relation to development with particular evacuation or emergency response issues (e.g. group homes, residential care facilities, etc.) to enable evacuation of land subject to flooding in events exceeding the flood planning level; and
- to protect the operational capacity of emergency response facilities and critical infrastructure during extreme flood events.

The new clause would apply to land identified as Outer Floodplain (i.e. land which lies between the FPA and the extent of the Extreme Flood). Wording in relation to this new clause is given in **Section 3.5.1.4**.

5.9.2 Narromine Shire Development Control Plan

The recommended approach to managing future development in the study area uses contemporaneous concepts of *flood hazard* and *hydraulic categorisation* to develop controls for future development in flood prone land (**Measure 2**). **Figure D1.1** in **Appendix D** is an extract from the *Flood Planning Map* relating to the study area. The extent of the FPA has been defined as the 1% (1 in 100) AEP plus 0.5 m freeboard.

It is proposed that properties intersected by the extent of the FPA would be subject to S10.7 flood affectation notification and planning controls graded according to flood hazard and hydraulic categorisation. **Annexures 2A** and **2B** in **Appendix D** set out the graded set of flood related planning controls which apply to development in areas that are affected by Main Stream Flooding and Major Overland Flow, respectively. **Figure D1.1** in **Appendix D** shows the areas where the graded set of flood related planning controls set out in **Annexures 2A** and **2B** apply.

Minimum habitable floor level (**MHFL**) requirements would be imposed on future development in properties that are identified as lying either partially or wholly within the extent of the FPA shown on **Figure D1.1**. The MHFLs for residential land use types is the level of the 1% (1 in 100) AEP flood event plus freeboard, whereas for commercial and industrial land use types the MHFL is to be as close to the 1% AEP flood level plus freeboard as practical, but no lower than the 2% (1 in 20) AEP flood level plus freeboard. In situations where the MHFL for commercial and industrial

land used types is below the 1% (1 in 100) AEP flood level plus freeboard, a mezzanine area equal to 20% of the total habitable floor area or 20 m^2 (whichever is the larger) is to be provided, the elevation of which is to be set no lower than the 1% AEP flood level plus freeboard. The MHFLs for flood vulnerable residential development, critical utilities and uses, and essential community facilities located on the floodplain at Narromine is the 0.5% (1 in 200) AEP flood event plus 0.5 m freeboard

Figure D1.2 in **Appendix D** is an extract of the *Flood Planning Constraint Category Map* for Narromine. The figure shows the subdivision of the floodplain into the following four categories which have been used as the basis for developing the graded set of planning controls:

- **Flood Planning Constraint Category 1 (FPCC 1)**, which comprises areas where factors such as the depth and velocity of flow, time of rise, and evacuation problems mean that the land is unsuitable for most types of development. The majority of new development types are excluded from this zone due to its potential impact on flood behaviour and the hazardous nature of flooding.
- **Flood Planning Constraint Category 2 (FPCC 2)**, which comprises areas which lie within the extent of the FPA where the existing flood risk warrants careful consideration and the application of significant flood related controls on future development.
- **Flood Planning Constraint Category 3 (FPCC 3)**, which comprises areas which lie within the extent of the FPA but outside areas designated FPCC1 and FPCC2. Areas designated FPCC3 are more suitable for new development and expansion of existing development provided it is carried out in accordance with the controls set out in this document.
- **Flood Planning Constraint Category 4 (FPCC 4)**, which comprises the area which lies between the extent of the FPA and the Extreme Flood. Flood related controls in areas designated FPCC4 are typically limited to flood evacuation and emergency response, although additional controls apply to essential community facilities and utilities that are critical for response and recovery, as well as community hospitals, residential care facilities and group homes.

5.10 Improvements to Emergency Response Planning and Community Awareness

Two measures are proposed in *Narromine Town FRMP 2021* to improve emergency response planning and community awareness to the threat posed by flooding.

Measure 3 involves the update by NSW SES of the *Narromine Shire Local Flood Plan* using information on flooding patterns and flood prone areas identified in this report. Figures have been prepared showing indicative extents and depths of inundation for a range of design flood events. Figures have also been prepared showing the flood hazard and hydraulic categorisation of the floodplain for the 1% (1 in 100) AEP flood event. **Section 3.6.2** references the locations of key data within this report.

Council should also take advantage of the information on flooding presented in this report, including the flood mapping, to inform occupiers of the floodplains of the flood risk (included as **Measure 4** of *Narromine Town FRMP 2021*). This information could be included in a *Flood Information Brochure* to be prepared by Council with the assistance of NSW SES containing both general and site specific data and distributed with the rate notices. The community should also be made aware that a flood greater than historic levels or the planning level can, and will, occur at some time in the future.

5.11 Flood Modification Works

While a range of potential flood modification measures were assessed as part of the present study, a preferred approach to mitigating the impacts of flooding on existing development at Narromine has been recommended for inclusion in *Narromine Town FRMP 2021* (denoted herein as the "**Preferred Flood Mitigation Scheme**").

The implementation of the Preferred Flood Mitigation Scheme (**Measure 5**) involves the detailed design and construction of a levee along the southern bank of the Macquarie River in combination with the upgrade of the existing railway culverts at Webbs Siding. The scheme also includes the design and implementation of flood proofing measures for an existing homestead that is located on the Backwater Cowal where peak flood levels would be increased as a result of the scheme.

The design and construction of the Preferred Flood Mitigation Scheme is estimated to cost about $22 Million and will save up to about $18.8 Million in flood damages upon completion, resulting in a benefit cost ratio of about 0.85. While the construction of the Preferred Flood Mitigation Scheme cannot be justified on economic grounds (i.e. because its benefit cost ratio is less than 1), it would provide the added benefit of removing a major constraint on future development, that being the need to set habitable floor levels in parts of Narromine over 1 m above natural surface levels. It would also significantly reduce the disruption that would otherwise be experienced by residents and business owners during major flood events on the Macquarie River.

The assessment undertaken as part of the present study found that the construction of the Inland Rail project would not compromise the level of flood protection afforded by the Preferred Flood Mitigation Scheme. The assessment also found that the construction of the Inland Rail project would result in only a minor increase in the extent and depth of inundation upstream of the future rail corridor when compared to post-Preferred Flood Mitigation Scheme conditions.

Measure 5 includes the updating of the flood modelling to reflect flood behaviour under post-Preferred Flood Mitigation Scheme conditions and the updating of the flood planning related aspects of *Narromine Shire DCP 2011*.

In addition to the above set of works, *Narromine Town FRMS 2021* concluded that there would be merit in Council developing and implementing a *Vegetation Management Plan* which is aimed at managing the density of understorey vegetation along the banks of the Macquarie River at Narromine, as well as the removal of debris that is deposited on the banks of the river following major flood events (**Measure 6**).

5.12 Implementation Program

The steps in progressing the floodplain management process from this point onwards are:

1. Council adopts *Narromine Town FRMP 2021* and submits an application for funding assistance.
2. Assistance for funding qualifying projects included in *Narromine Town FRMP 2021* may be available upon application under the Commonwealth and State funded floodplain management programs, currently administered by the Department of Planning, Industry and Environment.
3. As funds become available from Government agencies and/or Council's own resources, implement the measures in accordance with the established priorities.

Narromine Town FRMP 2021 should be regarded as a dynamic instrument requiring review and modification over time. The catalysts for change could include new flood events and experiences, legislative change, alterations in the availability of funding, reviews of Council's planning strategies and importantly following the construction of the Preferred Flood Mitigation Scheme. In any event, a thorough review every ten years is warranted to ensure the ongoing relevance of *Narromine Town FRMP 2021*.

6 GLOSSARY OF TERMS

Note: For expanded list of definitions, refer to Glossary contained within the NSW Government Floodplain Development Manual, 2005.

TERM	DEFINITION
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, for a flood magnitude having five per cent AEP, there is a five per cent probability that there would be floods of greater magnitude each year.
Australian Height Datum (AHD)	A common national surface level datum corresponding approximately to mean sea level.
Floodplain	Area of land which is subject to inundation by floods up to and including the Extreme Flood event, that is, flood prone land.
Flood Planning Area	The area of land that is shown to be in the Flood Planning Area on the *Flood Planning Map*.
Flood Planning Map	The *Flood Planning Map* shows the extent of land on which flood related development controls apply in a given area, noting that other areas may exist which are not mapped but where flood related development controls apply.
Flood Planning Constraint Category 1 (FPCC 1)	Comprises areas where factors such as the depth and velocity of flow, time of rise, and evacuation problems mean that the land is unsuitable for most types of development. The majority of new development types are excluded from this zone due to its potential impact on flood behaviour and the hazardous nature of flooding
Flood Planning Constraint Category 2 (FPCC 2)	Comprises areas which lie below the *Flood Planning Level* where the existing flood risk warrants careful consideration and the application of significant flood related controls on future development.
Flood Planning Constraint Category 3 (FPCC 3)	Comprises areas which lie below the *Flood Planning Level* but outside areas designated FPCC1 and FPCC2. Areas designated FPCC3 are more suitable for new development and expansion of existing development provided it is carried out in accordance with the controls set out in this document.
Flood Planning Constraint Category 4 (FPCC 4)	Comprises the area which lies above the *Flood Planning Level* but within the extent of the Extreme Flood. Flood related controls in areas designated FPCC4 are typically limited to flood evacuation and emergency response, although additional controls apply to essential community facilities and utilities that are critical for response and recovery, as well as community hospitals, residential care facilities and group homes.
Flood Planning Level (FPL)	Flood levels selected for planning purposes, as determined by the relevant adopted floodplain risk management study and plan, or as part of a site specific study In the absence of an adopted floodplain risk management study and plan for a particular location, the *Flood Planning Level* is defined as the peak 1% AEP flood level plus the addition of a 0.5 m freeboard.

TERM	DEFINITION
Flood Prone/Flood Liable Land	Land susceptible to flooding by the PMF. Flood Prone land is synonymous with Flood Liable land.
Floodway	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
Flood Storage Area	Those parts of the floodplain that may be important for the temporary storage of floodwaters during the passage of a flood. Loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation.
Freeboard	Provides reasonable certainty that the risk exposure selected in deciding a particular flood chosen as the basis for the *Flood Planning Level* is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the *Flood Planning Level*.
Habitable Room	In a residential situation: a living or working area, such as a lounge room, dining room, kitchen, bedroom or workroom. In an industrial or commercial situation: an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
Local Drainage	Land on an overland flow path where the depth of inundation during the 1% AEP storm event is less than 0.1 m.
Main Stream Flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
Major Overland Flow	Where the depth of overland flow during the 1% AEP storm event is greater than 0.1 m.
Extreme Flood	The largest flood that could conceivably occur at a particular location. Generally, it is not physically or economically possible to provide complete protection against this event. The Extreme Flood defines the extent of flood prone land, that is, the floodplain.

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APPENDIX A

COMMUNITY CONSULTATION

TABLE OF CONTENTS

ATTACHMENTS

A1. INTRODUCTION

At the commencement of the *FRMS,* the Consultants prepared a *Community Newsletter* and a *Community Questionnaire*, both of which were distributed by Council to the residents and business owners in Narromine (refer to **Attachment 1**). The questionnaire was also able to be completed online via Council's website.

The purpose of the *Community Newsletter* was to introduce the objectives of the study and set the scene on flooding conditions so that the community would be better able to respond to the *Community Questionnair*e and contribute to the study process.

The *Newsletter* contained the following information:

- A statement of the objectives of the *FRMS&P*; namely the development of a strategy for reducing the flood risk and minimising the long-term impact of flooding on the community.
- A list of the floodplain risk management measures which comprised the *Narromine Floodplain Risk Management Plan 2009.*
- A plan showing the extent of the study area.

The *Community Questionnaire* was structured with the objectives of:

- Determining residents' and business owners' attitudes to controls over future development in flood liable areas.
- Inviting community views on possible flood management options which could be considered for further investigation in the *FRMS* and possible inclusion in the resulting *FRMP*.
- Obtaining feedback on any other flood related issues and concerns which the residents and business owners cared to raise.

This **Appendix** to the *FRMS&P* report discusses the responses to the nine questions that were included in the *Community Questionnaire* and comments made by respondents.

Chapter A2 deals with the residents' and business owners' views on the relative importance of classes of development over which flood-related controls should be imposed by Council.

Chapter A3 identifies residents' and business owners' views on the suitability of the various options which could be considered in more detail in the *FRMS.*

Chapter A4 discusses the best methods by which the community could provide feedback to the consultants over the course of the study.

Chapter A5 summarises the findings of the community consultation process.

A2 RESIDENT PROFILE AND FLOOD AWARENESS

A2.1 General

Residents were requested to complete the *Community Questionnaire* and return it to the Consultants by 15 May 2020. The deadline was extended to include any submissions that were received after this date. The Consultants received 143 responses in total out of the 1,672 that had been distributed.

The Consultants have collated the responses, which are shown in graphical format in **Attachment 2**.

A2.2 Respondent Profile

The first four questions of the *Community Questionnaire* canvassed resident information such as whether the respondent was a resident or business owner, length of time at the property, the type of property (e.g. house, unit/flat).

Of the 143 responses, 133 were residents, several of whom also run businesses in Narromine (**Question 2**).

The majority of respondents occupied residential type property (**Question 3**), which included houses (79 respondents), units/flats/apartments (1), villas/townhouses (2) and vacant lots (2). Nine (9) respondents owned non-residential type property, which included shops/commercial premises (4 respondents), industrial units (2), and warehouse or factory (3). Note that some responses were included in more than one property classification type, while a large number of respondents did not provide a response to this question.

The length of time respondents had been at the address was found to be varied, with approximately 12% of respondents having lived at the residence for between '1-5 years', 41% for '5 to 20 years', and 47% for 'more than 20 years' (**Question 4**).

A2.3 Flood Experience

Twenty-six (26) respondents said they had information of flooding at their property, the sources of which included personal experience (25 respondents), flood levels from Council (3), information from NSW SES (1) and photographs (7) (**Question 5**).

Twenty-one (21) respondents had experienced flooding at their property as a result of floodwater which broke out of the Macquarie River, while another nine had been impacted by major overland flow. Twelve (12) respondents said their property was impacted by the February 1955 flood, while six (6) nominated the August 1990 flood and twelve (12) the December 2010 flood as impacting their property. (**Question 6**)

Twelve (12) respondents said that their property had been above-floor flooded, eleven (11) of which related to the February 1955 flood and one (1) to the August 1990 flood (**Question 7**). Several respondents advised the depth of above-floor flooding that was experienced in the dwelling.

Twenty (20) respondents advised that parts of their dwelling was damaged during the biggest flood that they had experienced, in addition to damage that was experienced elsewhere on the property (**Question 8**).

Thirty-five (35) respondents advised that they had not experienced any problems as a result of the biggest flood, while other advised that they had experienced a loss of trade (5), restricted access (15) and higher insurance premiums (21). Two (2) others advised that they had considered moving as a result of flooding (**Question 9**).

One respondent advised that they had incurred $10,000 of damages as a result of the biggest flood that they had experienced (event not nominated by the respondent), while a second advised that they had incurred $8,500 as a result of the August 1990 flood. Several others advised that they had incurred up to $5,000 of damages as a result of flooding in Narromine (**Question 10**).

During the biggest flood to have been experienced by respondents, most received some form of warning of the approaching flood, with only ten (10) stating that they had not received any warning (**Question 11**).

A2.4 Controls over Development in Flood Prone Areas

The respondents were asked to rank from 1 to 4 the classes of development which they consider should receive protection from flooding (**Question 12**). Rank 1 was the most important and rank 4 the least.

The classes in decreasing order of importance to respondents ranged from:

- essential services (e.g. sewer, water, electricity);
- residential property;
- vulnerable residential (e.g. aged persons accommodation); and
- essential community facilities (e.g. schools, evacuation centres residential property;
- commercial/business type development.

These results gave a guide to the Consultants as to the appropriate location of future development of the various classes within the floodplain. For example, on the basis of community views, essential services would receive the highest level of protection by locating future development of this nature outside the floodplain.

In **Question 13**, respondents were asked what notifications Council should give about the flood affectation of individual properties. The community was strongly in favour of advising existing residents (93) and prospective purchasers (83) of the known potential flood threat, while eighteen (18) respondents favoured only advising those who enquire to Council about the known potential flood risk. Seven (7) respondents favoured not providing any notification.

Respondents were also asked in **Question 14** about the level of control Council should place on new development to minimise flood-related risks. The most popular response was to advise of the flood risk, but allow the individual a choice as to whether they develop or not, provided steps are taken to minimise potential flood risks (73 respondents). The next most favoured response was to prohibit all new development only in those locations that would be extremely hazardous to

persons or property due to the depth and/or velocity of floodwaters, or evacuation difficulties (31 respondents). Twenty-five (25) respondents felt Council should place restrictions on developments to reduce the potential for flood damage (e.g. minimum floor level controls or the use of compatible building materials) and prohibit all development on land with any potential to flood, while seventeen (17) respondents felt that Council should prohibit all new development only in those locations that would be extremely hazardous to persons or property during floods.

A3 POTENTIAL FLOOD MANAGEMENT MEASURES

The respondents were asked for their opinion on potential flood management measures which could be evaluated in the *FRMS* (and if found to be feasible included in the *FRMP*), by ticking a "yes" or "no" to the eleven potential options identified in **Question 15**.

The options comprised a range of *structural flood management measures* (e.g. programs by Council to manage vegetation in the river system to maintain hydraulic capacity; widening of watercourses; removal of floodplain obstructions; improving the stormwater system within the town; levees to contain floodwaters; upgrade of existing railway culverts, as well as various *non-structural management measures* (e.g. voluntary purchase of residential properties in high hazard areas; raising floor levels of houses in low hazard areas; flood related controls over new developments; improvements to flood warning and evacuation procedures; community education on flooding; flood advice certificates). The options were not mutually exclusive, as the adopted *FRMP* could, in theory, include all of the options set out in the *Community Questionnaire*, or indeed, other measures nominated by the respondents or the FRMC.

The most popular structural measures were improvements to the stormwater system within the town area, followed in descending order of preference by the removal of floodplain obstructions, the upgrade of existing railway culverts and management of riparian vegetation.

Of the non-structural measures, provision of a Planning Certificate to purchasers in flood prone areas, improvement of flood warning and evacuation procedures and specifying controls on future development in flood-prone areas.

A mostly negative response was given to the widening of watercourses and the construction of permanent levees. Providing subsidies for raising the floor level of properties and the implementation of a residential Voluntary Purchase scheme were also unpopular.

A4 INPUT TO THE STUDY AND FEEDBACK FROM THE COMMUNITY

In **Question 16,** residents were asked for their view on the best methods of their providing input to the Study and feedback to the Consultants over the course of the investigation. Council's website and social media pages were the most popular methods, followed by articles in the local newspaper. Other suggestions raised by respondents include:

- Circular or newsletter either posted or emailed from Council
- Face-to-face interaction through community meetings.

Thirty (30) respondents advised that they would like Council to contact them in order to provide further information (**Question 17**).

A5 SUMMARY

One-hundred and forty three (143) responses were received to the *Community Questionnaire* which was distributed by Council to residents and business owners in Narromine. The responses amounted to about nine (9) per cent of the total number of questionnaires that were distributed to the community.

The issues identified by the responses to the *Community Questionnaire* support the objectives of the study as nominated in the attached *Community Newsletter,* and the activities nominated in the Study Brief. While over ten percent of the respondents to the questionnaire were in favour of prohibiting all new development on land with any potential to flood, the majority of respondents were in favour of Council advising of the flood risks, but allowing the individual a choice to develop so long as potential flood risks are minimised.

Of the *structural measures* which could be incorporated in the *FRMP*, the most popular were improvements to the stormwater system within the town area and the removal of floodplain obstructions. While the construction of permanent levees was one of the least favoured of the options, a large number of respondents felt it was necessary to either upgrade the existing levee bank or build the new river-bank levee as they believed the degree of flood affectation within the town was holding back development and also leading to increased insurance premiums.

The provision of a Planning Certificate to purchasers in flood prone areas, improvements to flood warning and evacuation procedures, and specifying controls on future development in flood-prone areas were the most popular of the potential *non-structural measures* set out in the *Community Questionnaire*.

ATTACHMENT A1

COMMUNITY NEWSLETTER
AND QUESTIONNAIRE

YOUR ATTITUDES TO COUNCIL'S DEVELOPMENT CONTROLS

12. Please rank the following development types according to which you think are the most important to protect from floods
(1= highest priority to 4= least priority)

Development Type	Rank
Commercial/Business	
Residential	
Vulnerable residential development (e.g. aged persons accommodation)	
Essential community facilities (e.g. schools, evacuation centres)	
Essential services (e.g. sewer, water, electricity etc.)	

13. What notifications do you consider Council should give about the potential flood affectation of individual properties? *(Tick one or more boxes)*

- ☐ Advise every resident and property owner on a regular basis of the known potential flood threat
- ☐ Advise only those who enquire to Council about the known potential flood threat
- ☐ Advise prospective purchasers of property of the known potential flood threat.
- ☐ Provide no notifications
- ☐ Other

14. What level of control do you consider Council should place on new development to minimise flood-related risks? *(Tick only one box)*
(In addition to being favoured by the Community, these options would also need to comply with legislation)

- ☐ Prohibit all new development on land with any potential to flood
- ☐ Prohibit all new development only in those locations that would be extremely hazardous to persons or property due to the depth and/or velocity of floodwaters, or evacuation difficulties
- ☐ Place restrictions on developments which reduce the potential for flood damage (e.g. minimum floor level controls or the use of flood compatible building materials)
- ☐ Advise of the flood risks, but allow the individual a choice as to whether they develop or not, provided steps are taken to minimise potential flood risks
- ☐ Provide no advice regarding the potential flood risks or measures that could minimise those risks

YOUR OPINIONS ON FLOODPLAIN RISK MANAGEMENT MEASURES

15. Below is a list of other possible options that may be looked at to try to minimise the effects of flooding in the study area.
This list is not in any order of importance and there may be other options that you think should be considered. For each of the options listed, please indicate "yes" or "no" to indicate if you favour the option. Please leave blank if undecided.

Option	Yes	No
Management of riparian vegetation to provide flood mitigation, stability, aesthetic and habitat benefits.		
Widening of watercourses.		
Removal of floodplain obstructions.		
Improve the stormwater system within the town area.		
Construction of urban levees		
Upgrade of the existing railway culverts		
Voluntary scheme to purchase residential property in high hazard areas.		
Provide funding or subsidies to raise houses above major flood level in low hazard areas.		
Specify additional controls on future development in flood-liable areas.		
Improve flood warning and evacuation procedures both before and during a flood.		
Provide a Planning Certificate to purchasers in flood prone areas, stating that the property is flood affected.		

OTHER INFORMATION

16. What do you think is the best way for us to get input and feedback from the local community about the results and proposals from this study?
(Tick one or more boxes)

- ☐ Council's website
- ☐ Articles in local newspaper
- ☐ Through Council's Floodplain Management Committee
- ☐ Other

17. If you wish us to contact you so you can provide further information, please provide your details below:

Name:

Phone: Best time to call is

Email:

ADDITIONAL COMMENTS

REVIEW OF THE NARROMINE FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

Narromine SHIRE COUNCIL

TO RESIDENTS & BUSINESS OWNERS OF NARROMINE:

Narromine Shire Council has engaged consultants to undertake a review of the Narromine Floodplain Risk Management Study and Plan which was prepared for the township in 2009. The purpose of the review is to assist Council in refining strategic plans for mitigating and managing the effects of existing flood risk (associated with existing development on flood prone land), future flood risk (associated with any new development on flood prone land) and continuing flood risk (the risk remaining in both existing and future development areas after floodplain risk management measures are implemented).

The review is jointly funded by Council and the NSW Department of Planning, Industry and Environment and aims to build community resilience towards flooding through informing better planning of development, emergency management and community awareness. Council has established a Floodplain Risk Management Committee which is comprised of relevant council members, state government agencies and community representatives.

The review will utilise the results of the Narromine River Bank Levee Feasibility Study which was completed in 2013. Figure 1 overleaf shows the indicative extent of the 1 in 100 year flood on the Macquarie River at Narromine under present day conditions as defined by this study.

A brief summary of the floodplain risk management measures which form the Narromine Floodplain Risk Management Plan (2009), including their estimated cost is provided overleaf, while an electronic copy of the Narromine Floodplain Risk Management Study and Plan (2009) and Narromine River Bank Levee Feasibility Study (2013) can be found on Council's website at www.narromine.nsw.gov.au.

ABOUT THE QUESTIONNAIRE

This Questionnaire is part of the Review of the Narromine Floodplain Risk Management Study and Plan, which is currently being undertaken by Narromine Shire Council with the financial support of the NSW Department of Planning, Industry and Environment. Your responses to the questionnaire will help us determine the flood issues that are important to you.

Please return your completed Questionnaire in the reply paid envelope provided by Friday 15 May 2020. No postage stamp is required. All information provided will remain confidential and for use in this study only. If you have misplaced the supplied envelope or wish to send an additional submission the address is:

Lyall & Associates Consulting Water Engineers
Reply Paid 85163
NORTH SYDNEY NSW 2060

HAVE YOUR SAY

An important first step in the review process is to re-appraise what flood related issues are important to the community. The attached questionnaire has been provided to residents and businesses to assist the Consultants in gathering this important information.

The questionnaire may also be completed online via Council's website at www.narromine.nsw.gov.au.

All information provided will remain confidential and for use in this study only. Please return the completed questionnaire in the reply paid envelope provided by Friday 15 May 2020.

FOR MORE INFORMATION CONTACT

Narromine Shire Council
Sarah Masonwells, Executive Assistant
Infrastructure and Engineering
P: (02) 6889 9999
M: mail@narromine.nsw.gov.au
W: www.narromine.nsw.gov.au

FLOODPLAIN MANAGEMENT MEASURES FORMING THE NARROMINE FLOODPLAIN RISK MANAGEMENT PLAN (2009)

The table below is a brief summary of the floodplain risk management measures which form the Narromine Floodplain Risk Management Plan (2009), including their estimated costs.

Option	Estimated Cost	Priority	Status of Measure
PM1 – Implement the recommended development controls based on draft Flood Policy for Narromine.	Council staff's Cost	High	✓
RM1 – Ensure flood data in this Floodplain Risk Management Study and draft Plan is available to NSW SES for inclusion in flood emergency response.	Council and NSW SES Costs	High	✓
RM2 – Implement flood awareness and education program for residents and owners of commercial and industrial developments.	NSW SES and Property/ Business Owner Costs	High	✓
FM1 – Feasibility Study of river bank levee.(1,2)	$80,000 (1)	High	✓
FM2 – Preparation of detailed design and construction of levee (dependent on the results of the above study).	$1.6 Million (3)	Medium	Yet to commence
FM3 – Feasibility Study of upgrading the hydraulic capacity of culverts beneath the Parkes Narromine Railway.(4)	$50,000 (3)	Medium	Yet to commence
FM4 – Prepare detailed design and construct culvert works (scheme is dependent on the results of the above study and whether river bank levee scheme is implemented. The river levee would reduce ponding upstream of the railway and possibly reduce the need for improved culverts).(4)	$0.8 Million (3)	Medium	Yet to commence
Total Cost of Implementing Flood Mitigation Measures FM1, FM2, FM3 and FM4	$2.53 Million (3)		

1. FM1 was completed in 2013. The results of the study are presented in Narromine River Bank Levee Feasibility Study (2013)
2. Scope of floodplain risk management measure refined as part of Narromine River Bank Levee Feasibility Study (2013) and the Narromine Town Levee Concept Design (2016). Figure 1 shows the currently proposed alignment of the river bank levee.
3. Following the adoption of the revised Plan, Narromine Shire Council can seek funding from the NSW State Government under its Floodplain Management Program to cover the majority of the cost of implementing the recommended set of measures.
4. Refer Figure 1 for location of the proposed upgraded culverts

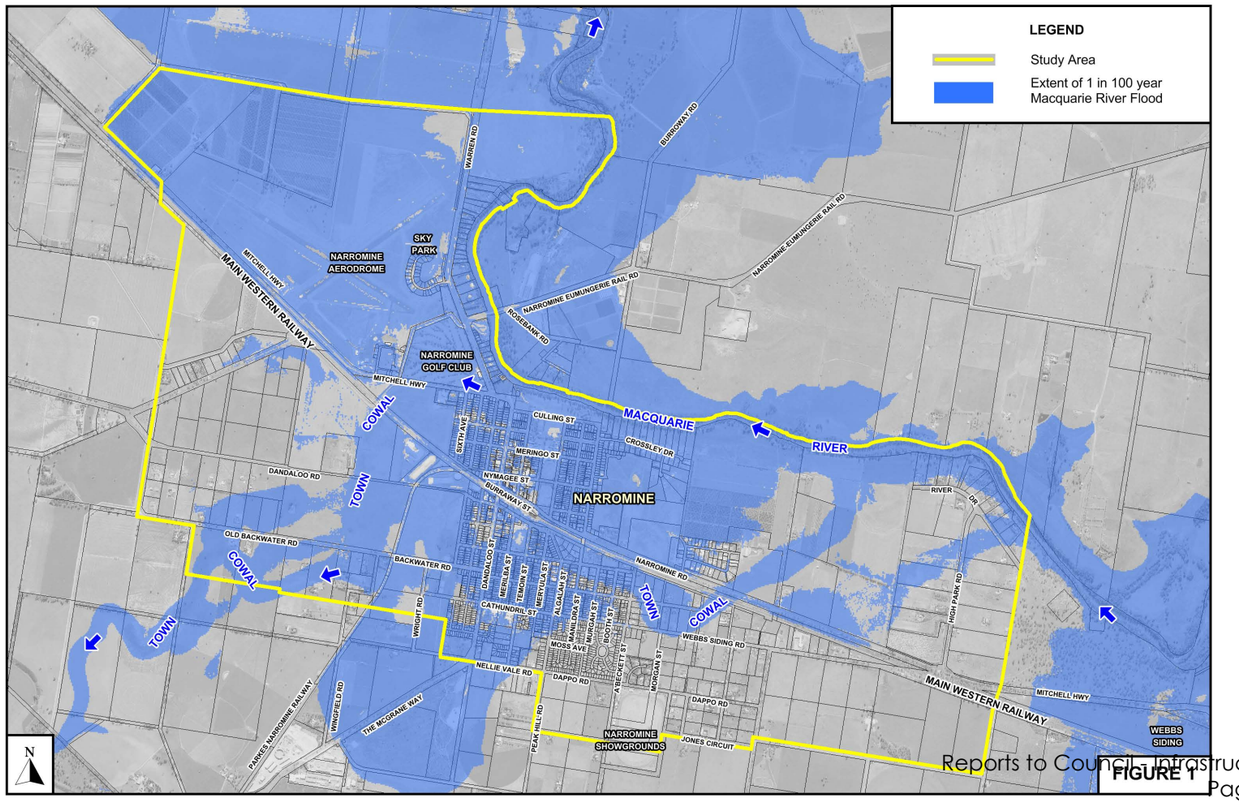


FIGURE 1

COMMUNITY QUESTIONNAIRE

Narromine Shire Council

NSW Government Planning & Environment

Your name (optional): _____

Address: _____

ABOUT YOUR PROPERTY

2. Please tick as appropriate:

- ☐ I am a resident
- ☐ I am a business owner
- ☐ Other _____

3. How long have you been at this address?

- ☐ 1 year to 5 years
- ☐ 5 years to 20 years
- ☐ More than 20 years (_____ years)

4. What is your property?

- ☐ House
- ☐ Villa/Townhouse
- ☐ Unit/Flat/Apartment
- ☐ Vacant land
- ☐ Industrial unit in larger complex
- ☐ Stand alone warehouse or factory
- ☐ Shop
- ☐ Community building
- ☐ Other _____

YOUR FLOOD EXPERIENCE

If flooding has affected your property – Go to Q5

If not, but flooding has affected you in other ways – Go to Q9

If you have not been affected by flooding – Go to Q12

5. Do you have any information about flooding at the property?

☐ Yes ☐ No

If yes, what information do you have?

- ☐ Own experience
- ☐ Flood levels from Council
- ☐ Information from NSW SES
- ☐ Photographs
- ☐ Other _____

6. Have you ever experienced flooding, either as a result of the river breaking its banks or due to shallow overland flow through the property?

☐ Yes - River break out ☐ Yes - Shallow overland flow

☐ No

If yes, which floods?

☐ December 2010 ☐ August 1990

☐ Other _____

7. In the biggest flood you have experienced, was the property flooded above floor level of the main building?

☐ Yes ☐ No ☐ Not applicable

☐ If yes, what was the depth of water over the floor?

_____

What year? _____

8. During the biggest flood, what was damaged by floodwaters?

(Tick one or more boxes)

- ☐ No damage occurred
- ☐ Vehicles
- ☐ Garden, yard, paddocks
- ☐ Garage, shed
- ☐ Electrical equipment, machinery, tools
- ☐ Stock and other goods
- ☐ Carpet, furniture, fittings and/or office equipment
- ☐ Your premises (paint, structurally, etc)
- ☐ Other _____

9. As a result of the biggest flood, did you experience any problems during or after the flood?

(Tick one or more boxes)

- ☐ No problems experienced
- ☐ Loss of business / trade
- ☐ Restricted access / can't get to work
- ☐ Higher insurance premiums
- ☐ Considered selling/moving

10. During the biggest flood, what was the approximate cost to you (at the time) from the damage caused by the flood?

$ _____

11. In this biggest flood, did you receive any warning, and if so, from where?

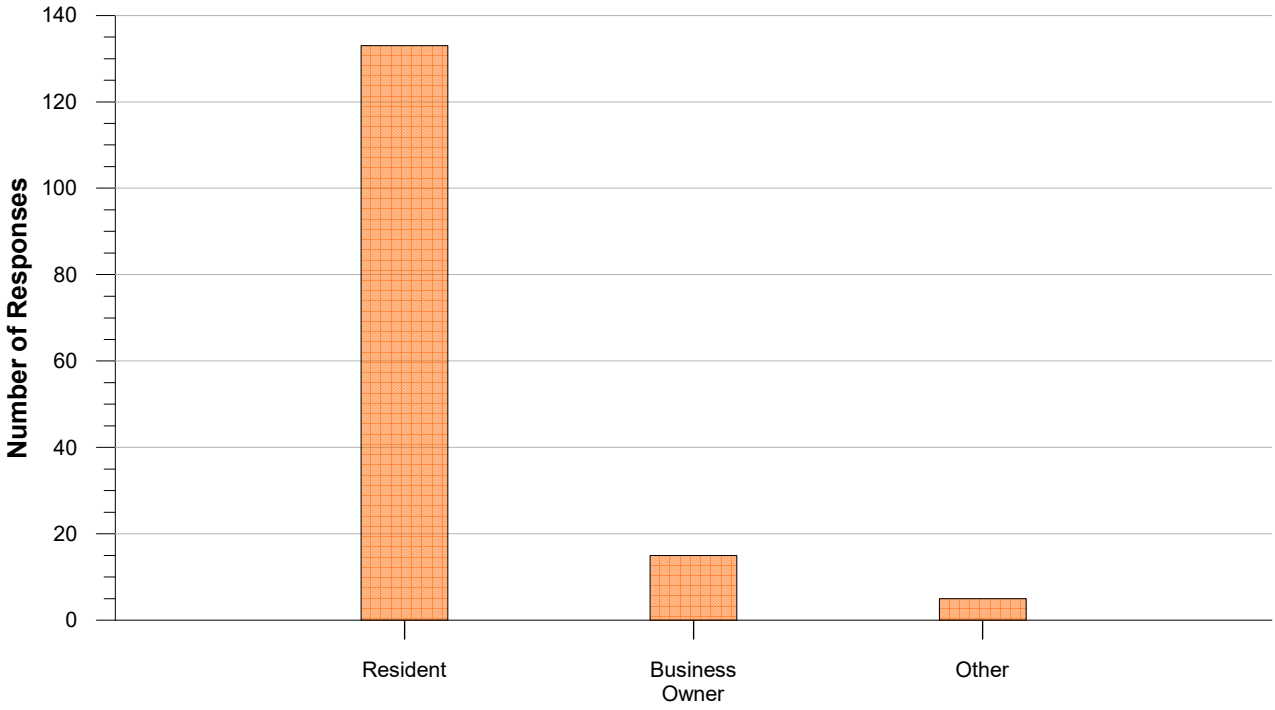
(Tick one or more boxes)

- ☐ No warning whatsoever
- ☐ TV
- ☐ Radio
- ☐ Own observations
- ☐ Police
- ☐ NSW SES
- ☐ Neighbours, relatives or friends
- ☐ Other _____

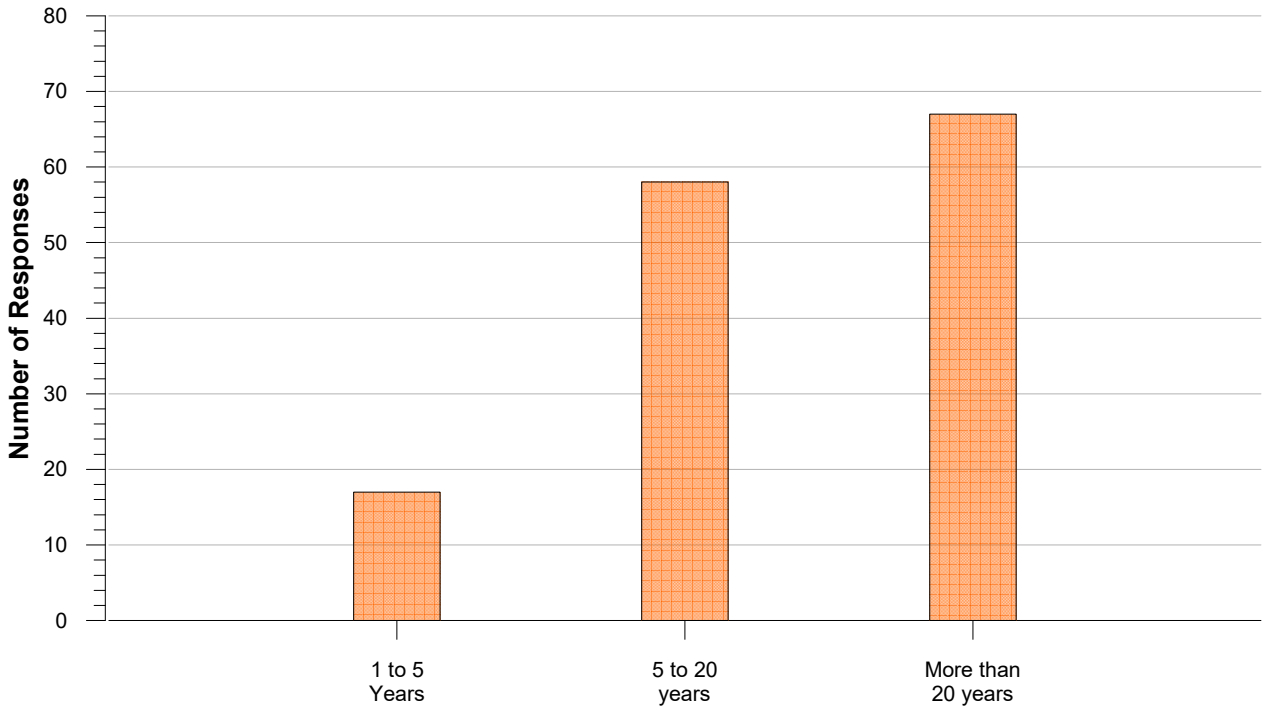
ATTACHMENT A2

RESPONSES TO COMMUNITY QUESTIONNAIRE

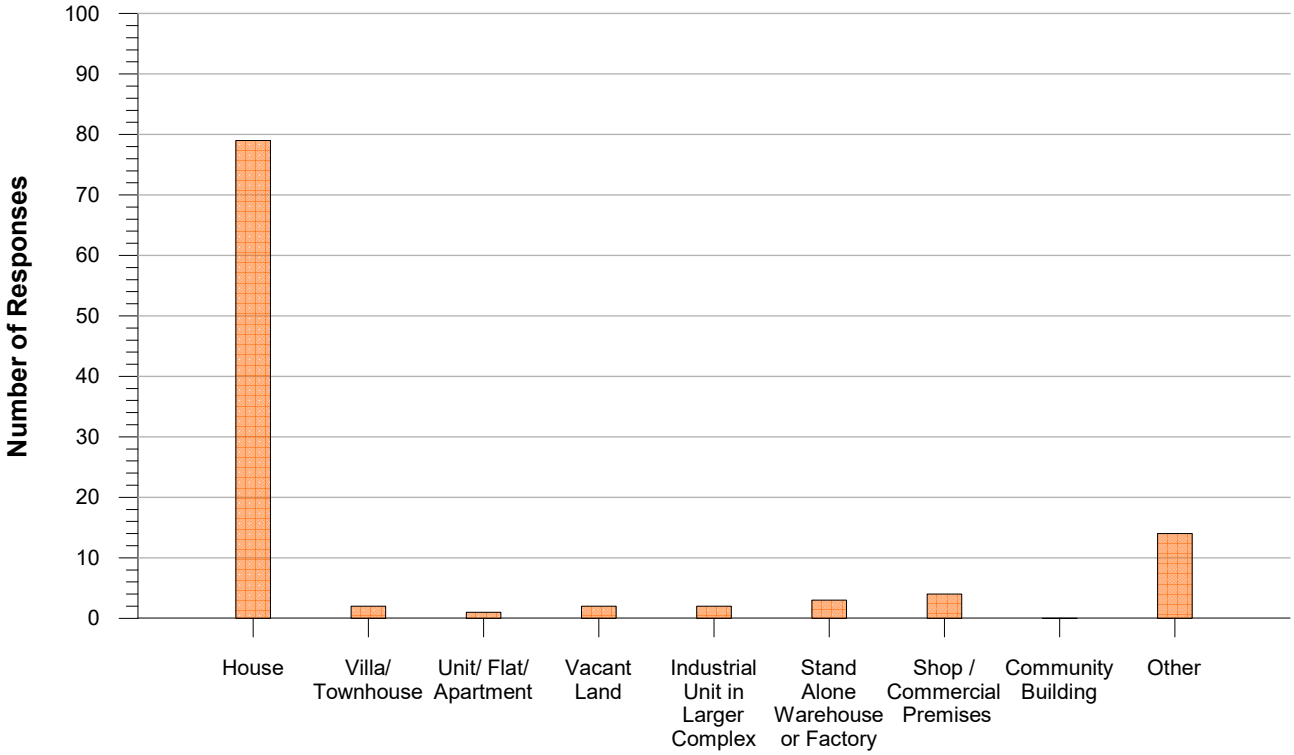
Q2. Residential Status



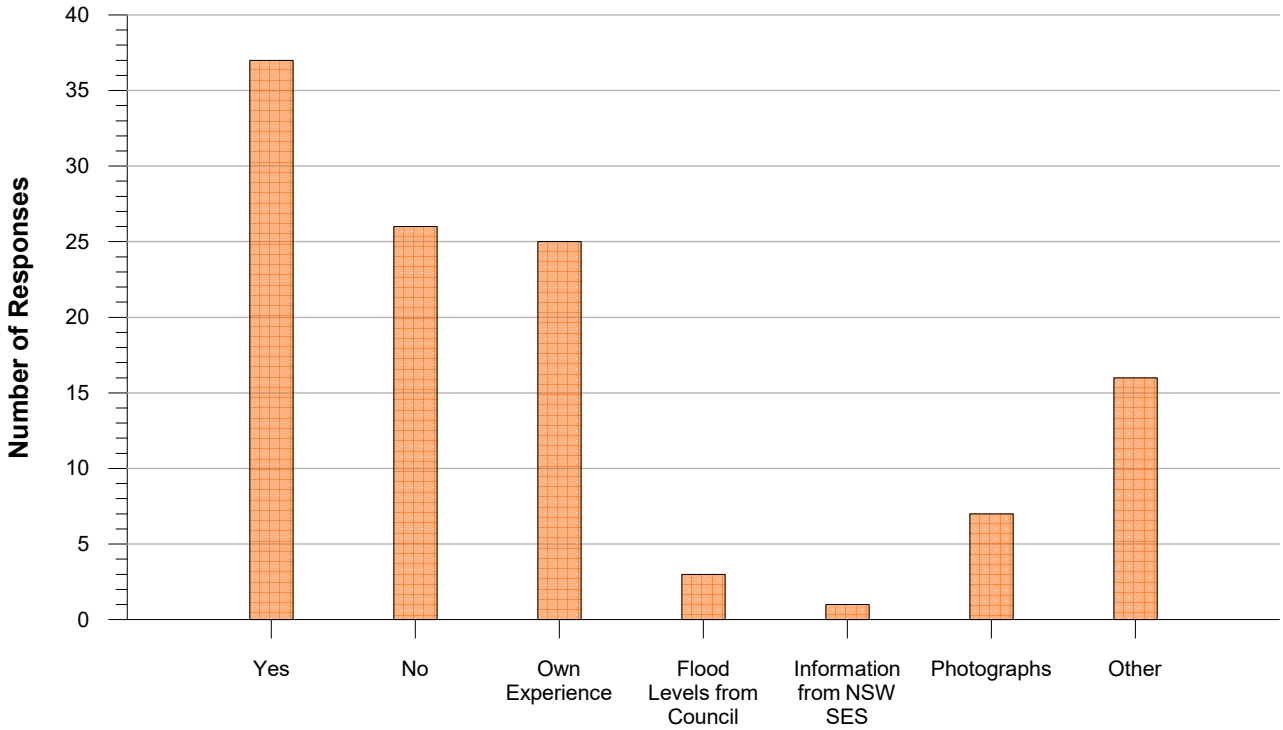
Q3. How long have you been at this address?



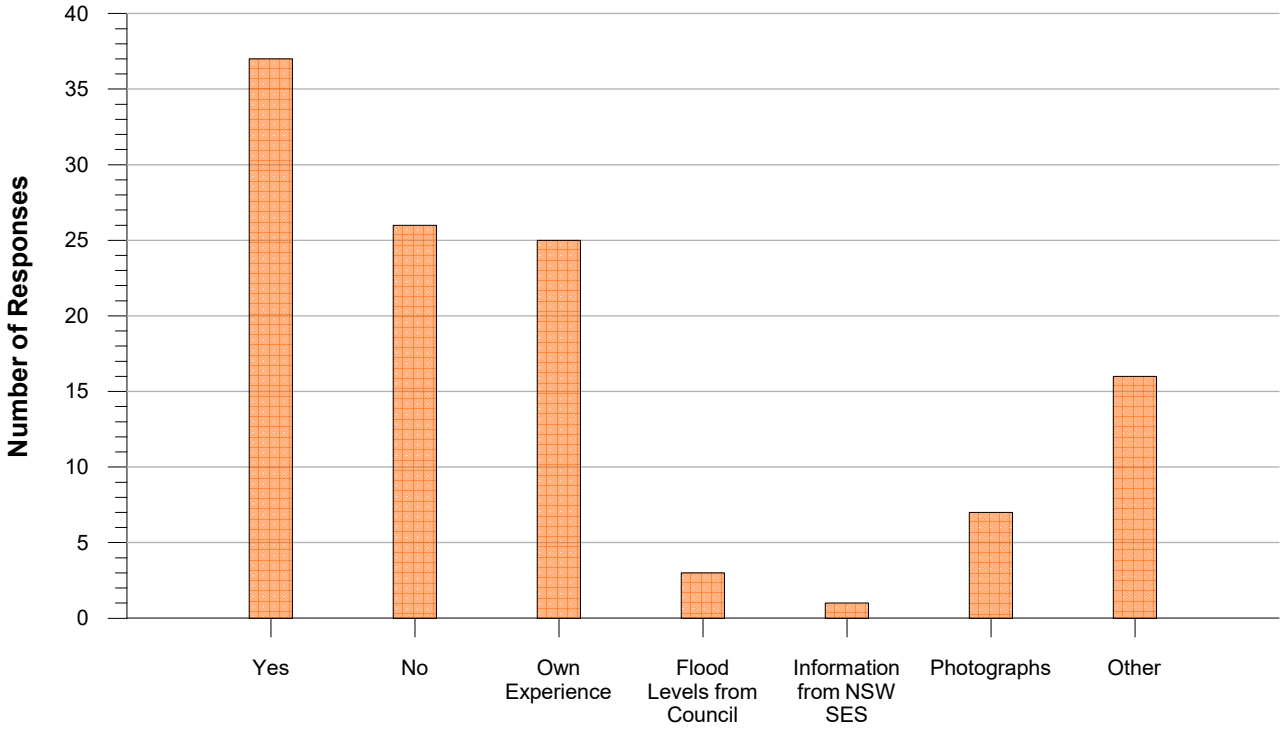
Q4. Type of Property



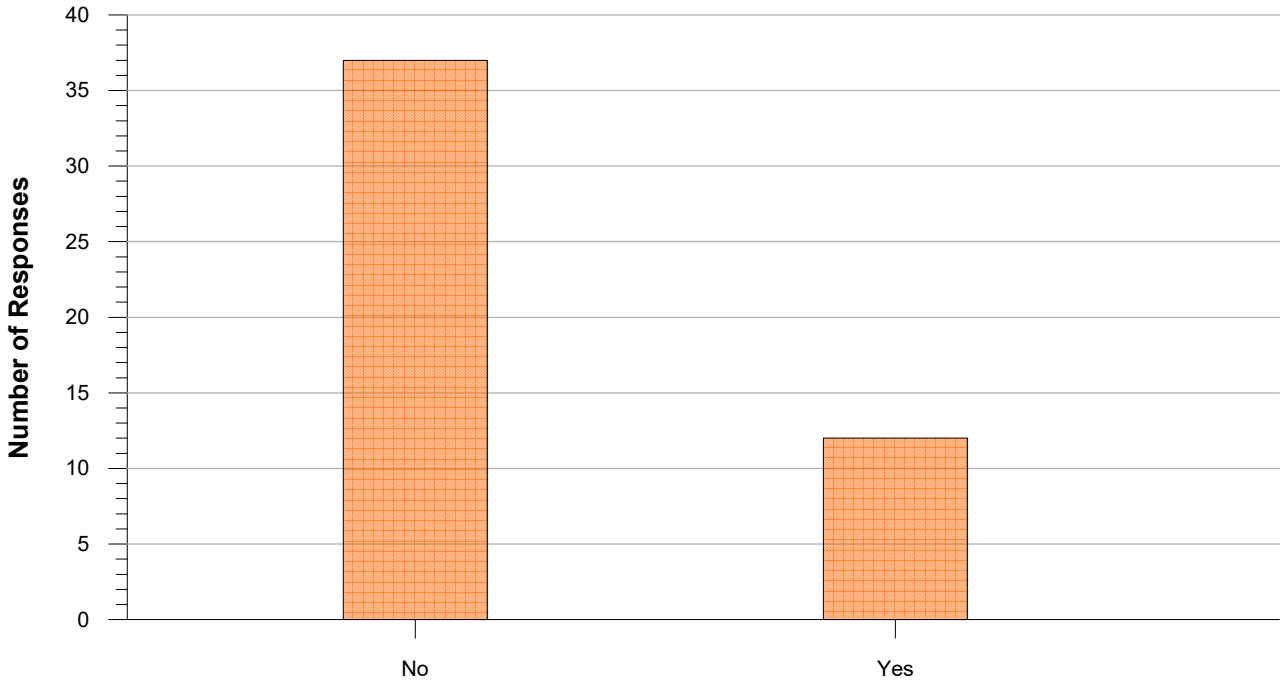
Q5. Do you have any information about flooding at your property?



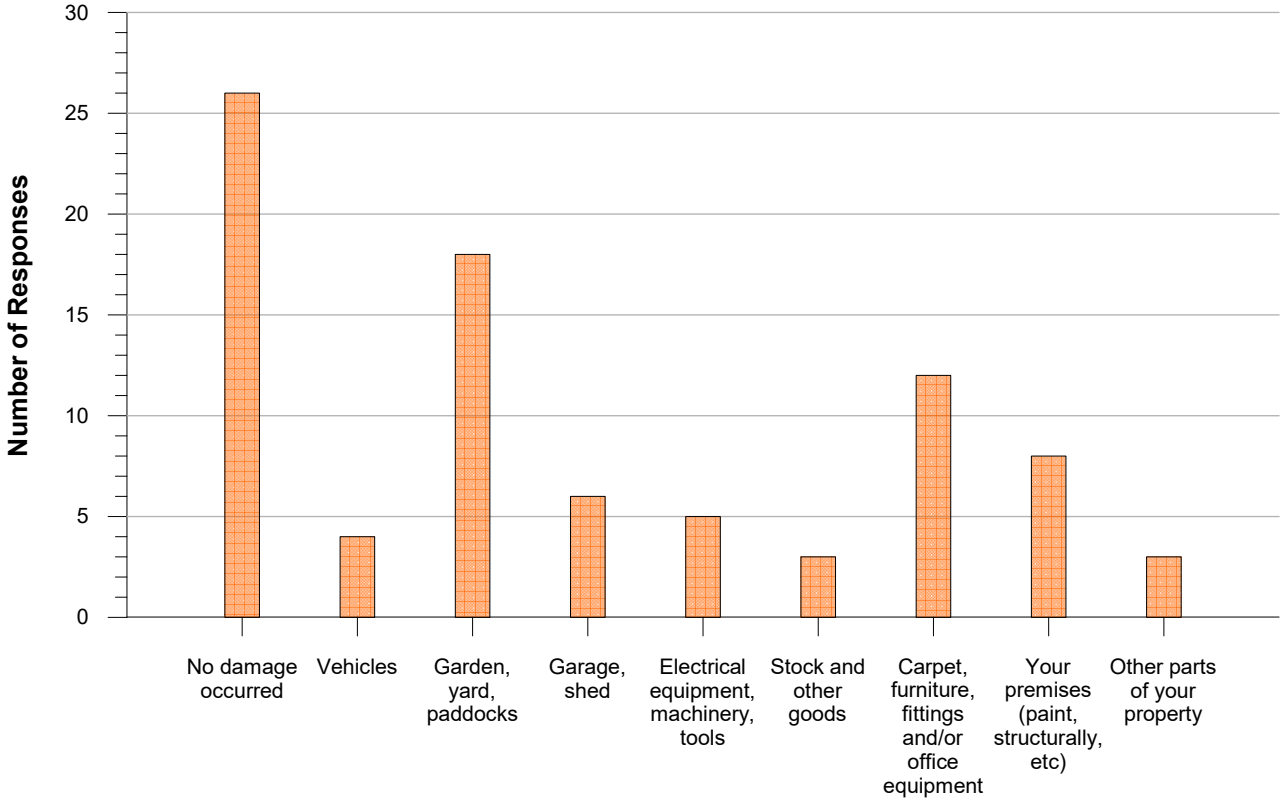
Q6. Have you experienced flooding?



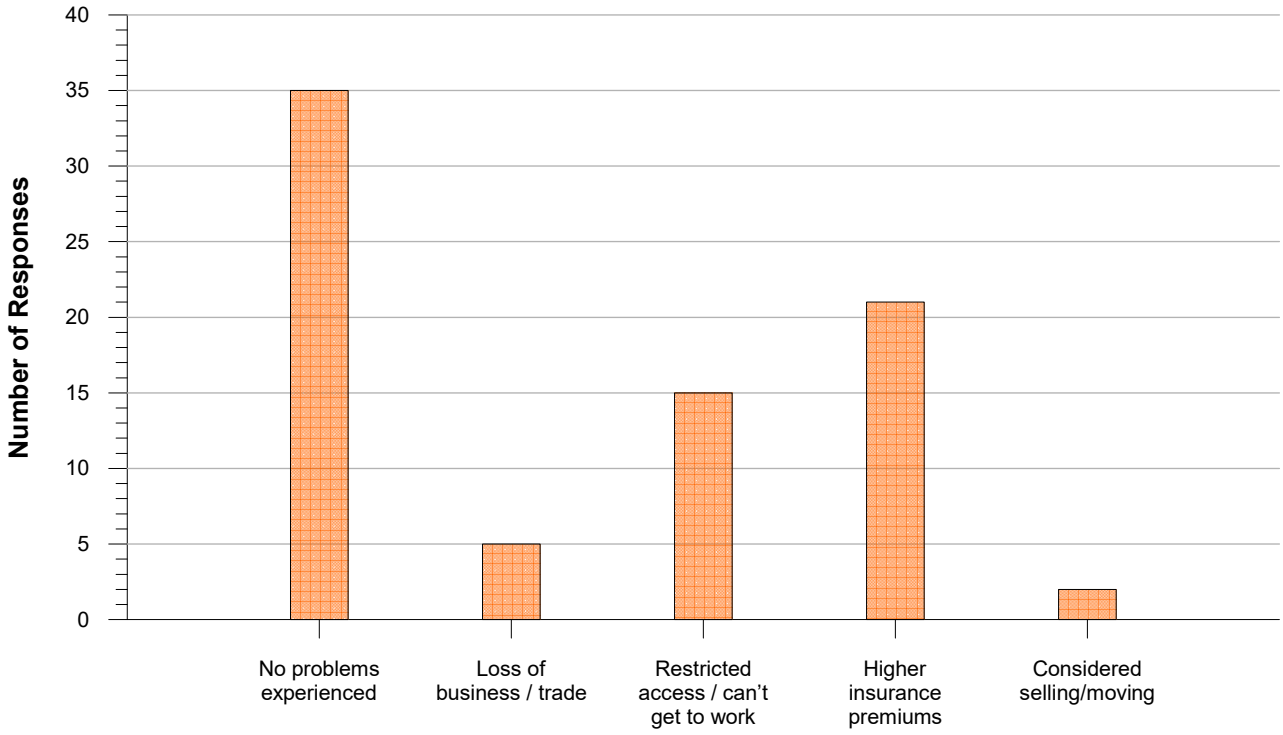
Q7. Was the main building of your property flooded above floor level?



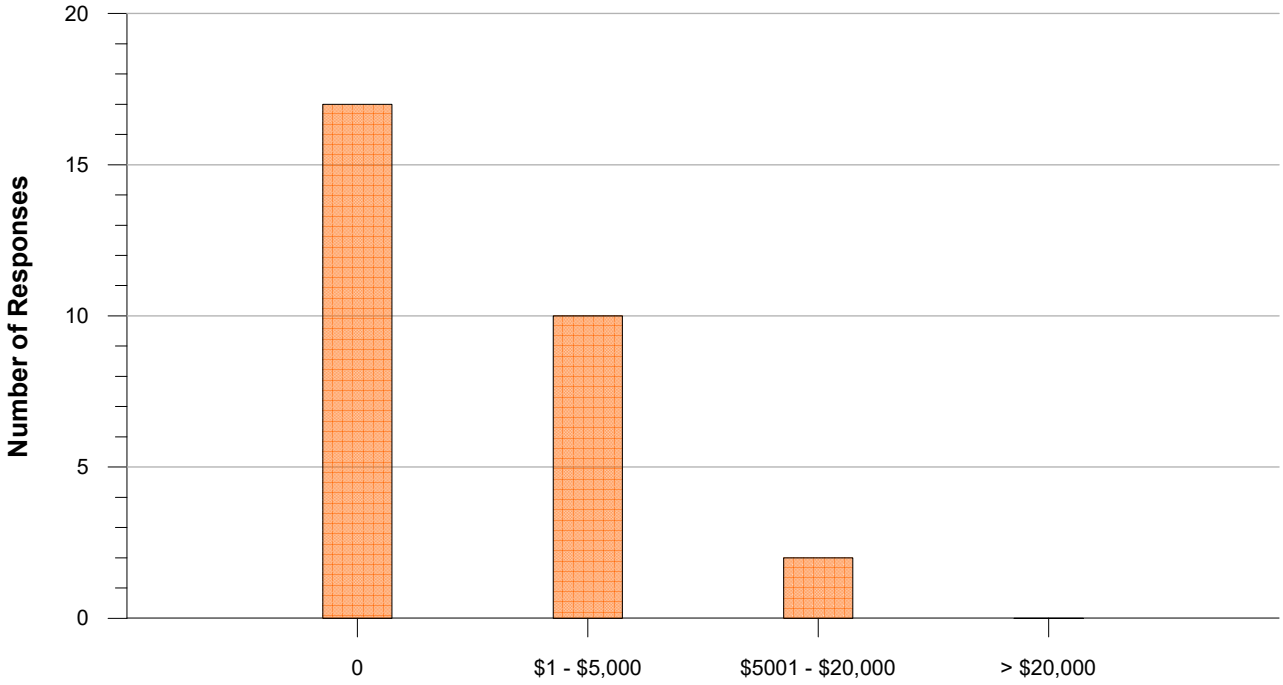
Q8. What was damaged by floodwaters?



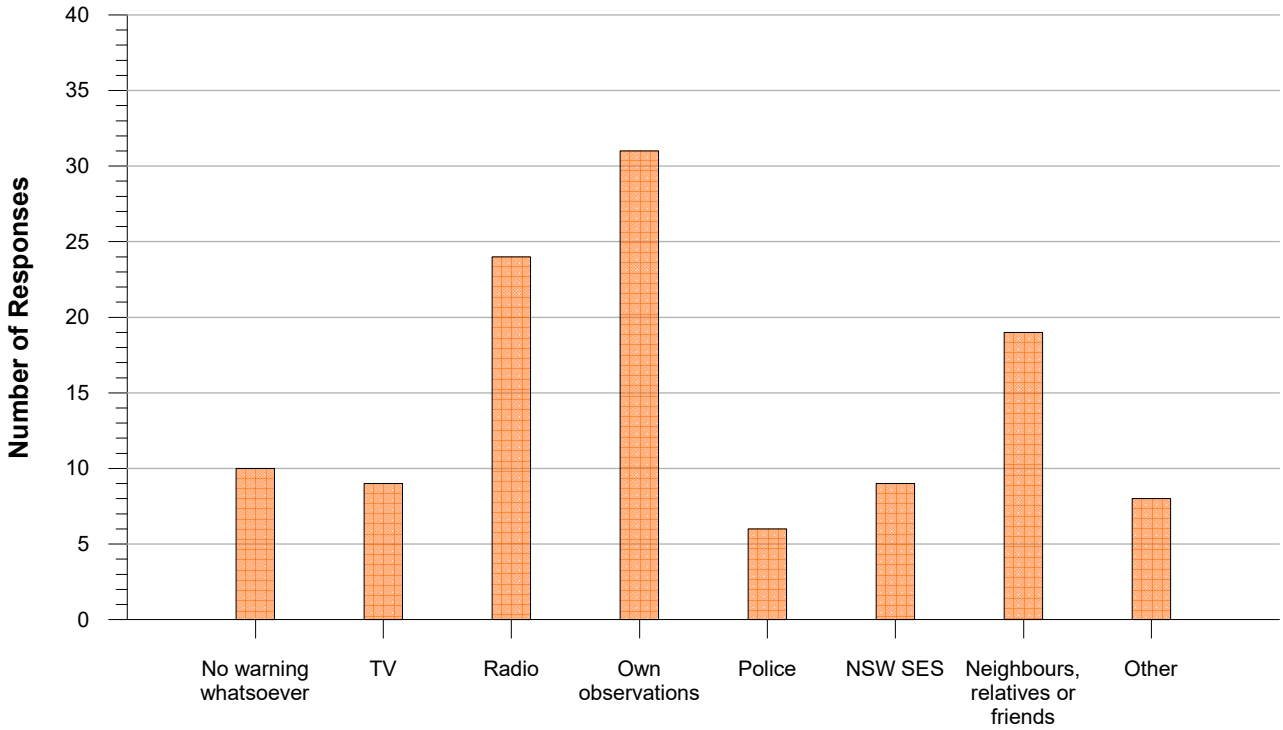
Q9. Did you experience any problems due to flooding?



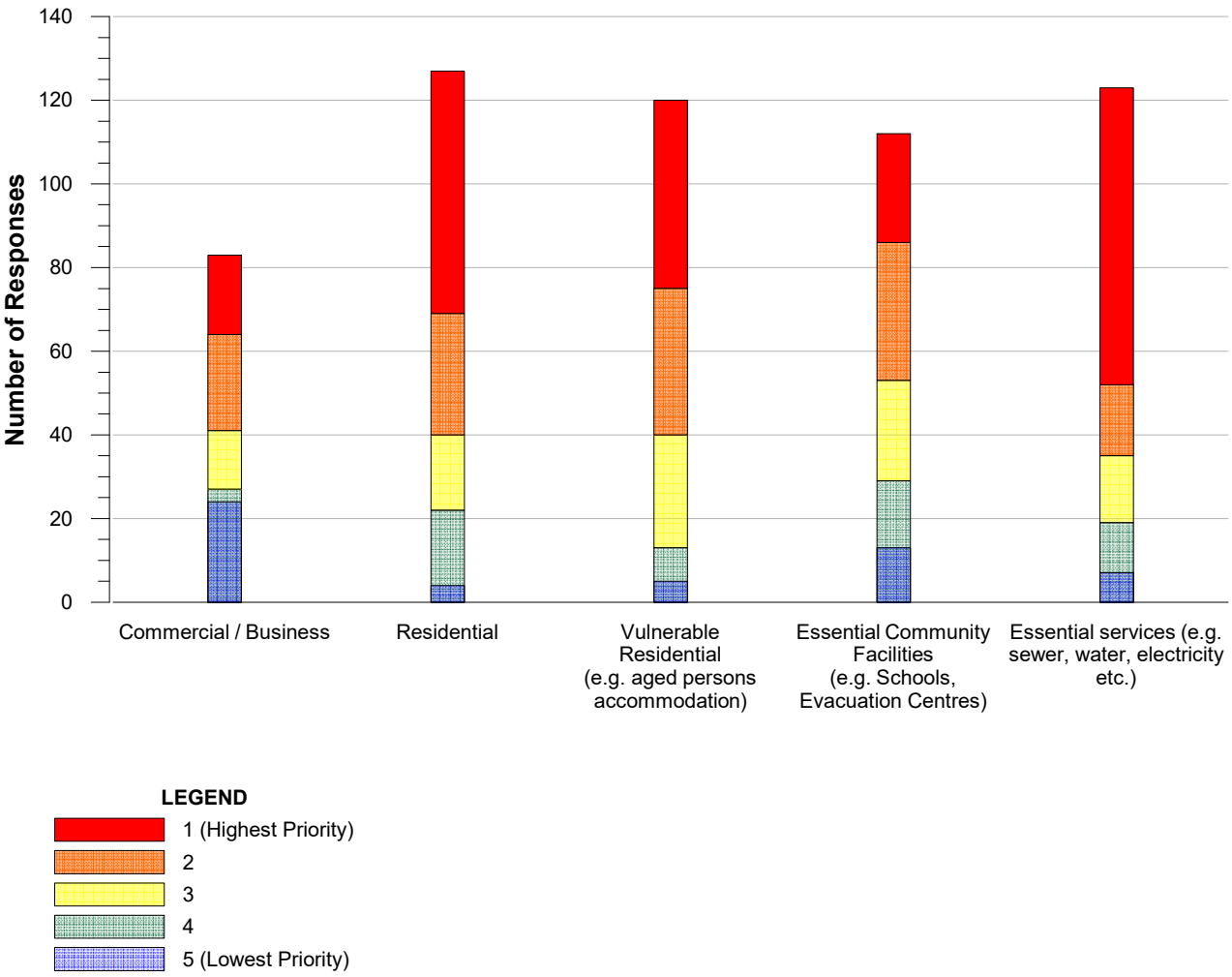
Q10. What was the cost of the damage?



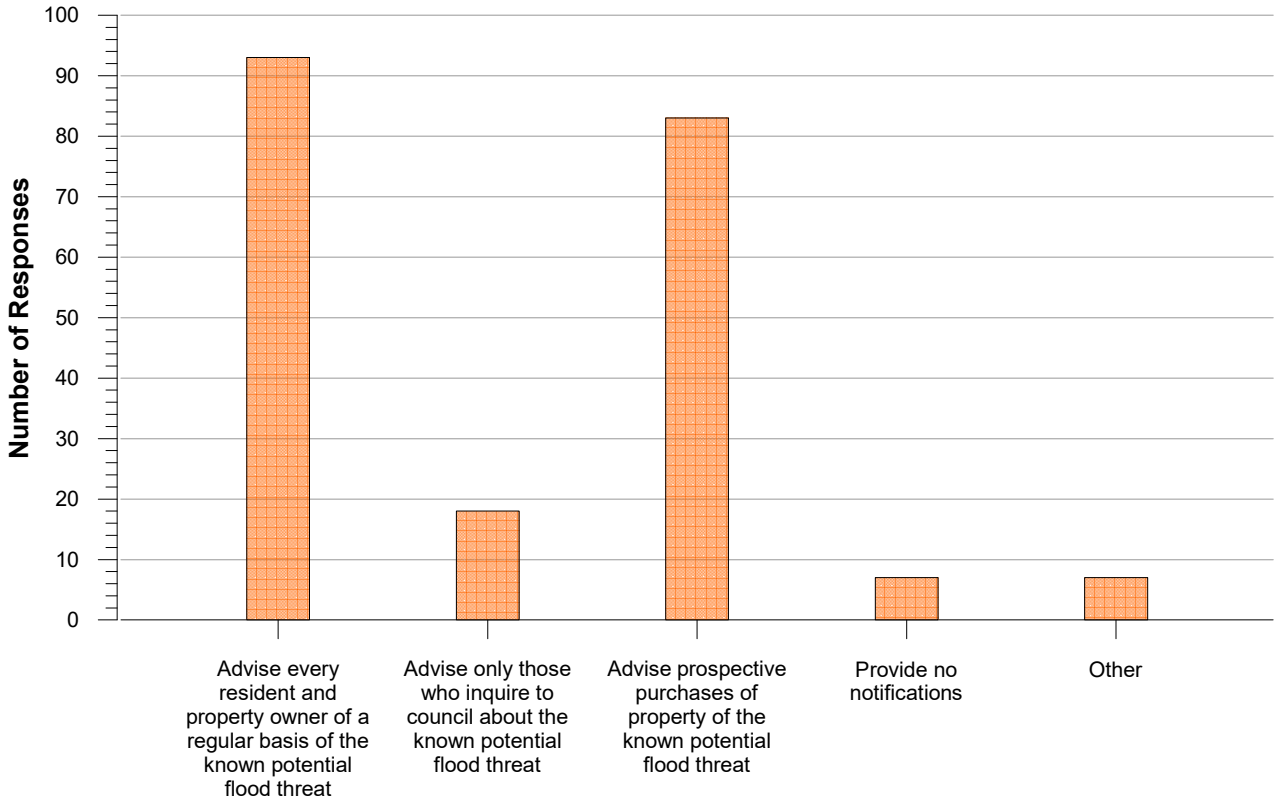
Q11. Where did the flood warning come from?



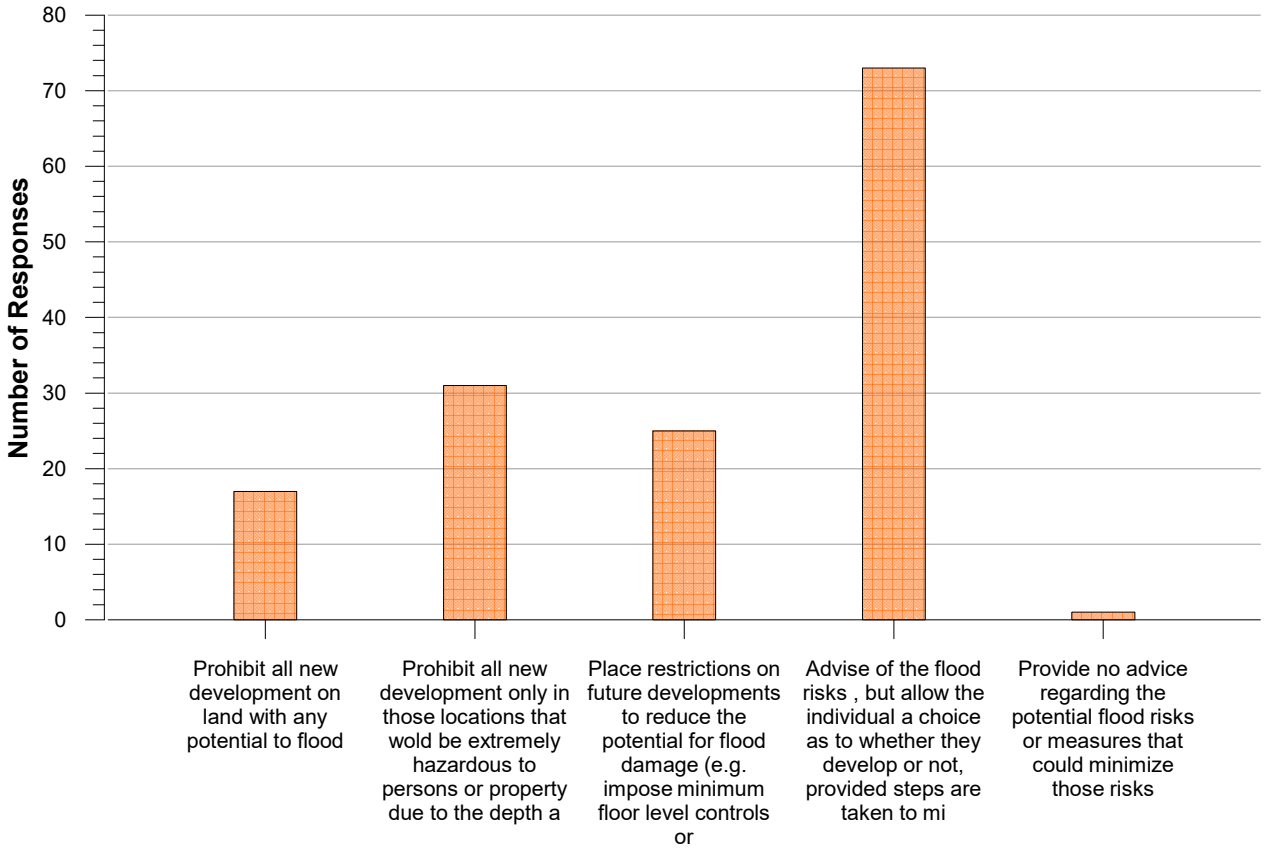
Q12. Ranking of development types by importance to protect from floods



Q13. What notifications should Council give about the potential flood affectation of properties?



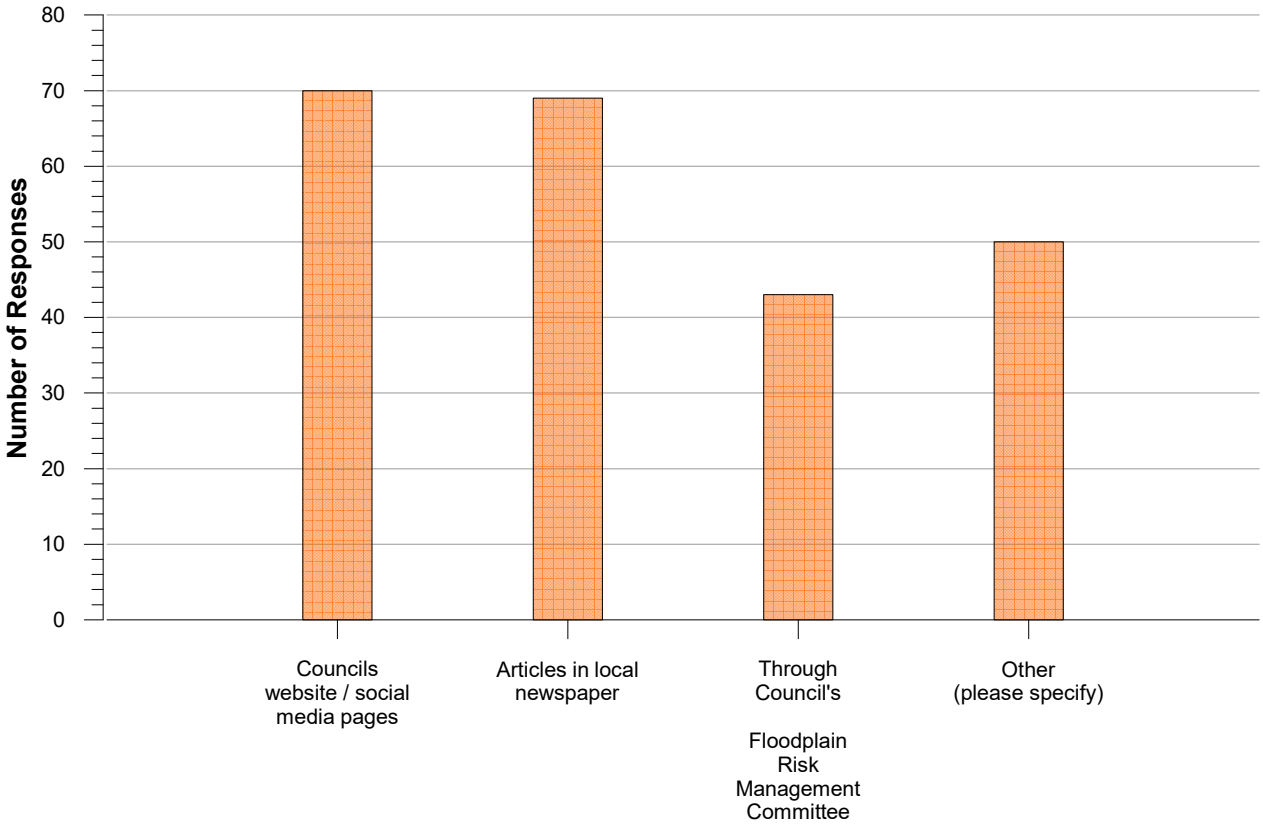
Q14. What level of control should Council place on new development to minimise flood-related risks?



Attachment No. 1

Q15. Possible Floodplain Management Measures

Q16. Best methods to get input and feedback from the local community



APPENDIX B

FLOOD DAMAGES

TABLE OF CONTENTS

Page No.

FIGURES
(BOUND IN VOLUME 2)

B8.1 Damage - Frequency Curves and Cumulative Flooded Properties versus Depth of Inundation Diagram – 1% AEP

B1. INTRODUCTION AND SCOPE

B1.1. Introduction

Damages from flooding belong to two categories:

- **Tangible Damages**
- **Intangible Damages**

Tangible damages are defined as those to which monetary values may be assigned, and may be subdivided into direct and indirect damages. Direct damages are those caused by physical contact of floodwater with damageable property. They include damages to commercial and industrial and residential building structures and contents, as well as damages to infrastructure services such as electricity and water supply. Indirect damages result from the interruption of community activities, including traffic flows, trade, industrial production, costs to relief agencies, evacuation of people and contents and clean up after the flood.

Generally, tangible damages are estimated in dollar values using survey procedures, interpretation of data from actual floods and research of government files.

The various factors included in the **intangible damage** category may be significant. However, these effects are difficult to quantify due to lack of data and the absence of an accepted method. Such factors may include:

- inconvenience
- isolation
- disruption of family and social activities
- anxiety, pain and suffering, trauma
- physical ill-health
- psychological ill-health.

B1.2. Scope of Investigation

In the following sections, tangible damages to residential, commercial / industrial and public properties have been estimated resulting from flooding in Narromine. Intangible damages have not been quantified. The threshold floods at which damages may commence to infrastructure and community assets have also been estimated, mainly from site inspection and interpretation of flood level data. However, there is no data available to allow a quantitative assessment of damages to be made to this category.

B1.3. Terminology

Definitions of the terms used in this Appendix are presented in **Chapter B8** which also summarises the value of Tangible Flood Damages.

B2. DESCRIPTION OF APPROACH

The damage caused by a flood to a particular property is a function of the depth of inundation above floor level and the value of the property and its contents. The warning time available for residents to take action to lift property above floor level also influences damages actually experienced. A spreadsheet model which has been developed by DPIE for estimating residential damages and an in-house spreadsheet model which has been developed for previous investigations of this nature for estimating commercial, industrial and public building damages were used to estimate damages on a property by property basis according to the type of development, the location of the property and the depth of inundation.

Using the results of the updated flood modelling, a peak flood elevation for each event was derived at each property. The property flood levels were input to the spreadsheet models which also contained property characteristics and depth-damage relationships. The depth of above-floor inundation was computed as the difference between the interpolated flood level and the floor elevation at each property. The elevations of building floors were assessed based on surveyed floor levels for those properties that are located along the southern bank of the Macquarie River and a nominal 0.3 m height of floor above a representative natural surface within the allotment (as estimated by visual inspection) to the natural surface elevation determined from LiDAR survey for the remainder of the properties in Narromine. The type of structure and potential for property damage were also assessed during the visual inspection.

The depth-damage curves for residential damages were determined using procedures described in *Guideline No. 4*. Damage curves for other categories of development (commercial and industrial, public buildings) were derived from previous floodplain management investigations.

Damages to the non-residential sector depend on the nature of the enterprise, the depth of inundation over the floor area and the time available for owners to take action to mitigate losses to contents. A spreadsheet model was used which was similar to the residential model in terms of estimation of depths of inundation, but used typical unit damage data which had been adopted in similar studies in NSW in recent years.

It should be understood that this approach is not intended to identify individual properties liable to flood damages and the value of damages in individual properties, even though it appears to be capable of doing so. The reason for this caveat lies in the various assumptions used in the procedure, the main ones being:

- the assumption that computed water levels and topographic data used to define flood extents are exact and without any error;
- the assumption that the water levels as computed by the hydraulic model are not subject to localised influences;
- the estimation of property floor levels by visual inspection rather than by formal field survey;
- the use of "average" stage-damage relationships, rather than a unique relationship for each property;
- the uncertainties associated with assessing appropriate factors to convert *potential damages* to *actual flood damages* experienced for each property after residents have taken action to mitigate damages to contents.

The consequence of these assumptions is that some individual properties may be inappropriately classified as flood liable, while others may be excluded. Nevertheless, when applied over a broad area these effects would tend to cancel, and the resulting estimates of overall damages, would be expected to be reasonably accurate.

For the above reasons, the information contained in the spreadsheets used to prepare the estimates of flood damages for the catchments should not be used to provide information on the depths of above-floor inundation of individual properties.

B3. SOURCES OF DATA

B3.1. General

To estimate A*verage Annual Flood Damages* for a specific area it is necessary to estimate the damages for several floods of different magnitudes, i.e. of different frequencies, and then to integrate the area beneath the damage – frequency curve computed over the whole range of frequencies up to the Extreme Flood. To do this it is necessary to have data on the damages sustained by all types of property over the likely range of inundation. There are several ways of doing this:

- The ideal way would be to conduct specific damage surveys in the aftermath of a range of floods, preferably immediately after each. An example approaching this ideal is the case of Nyngan where surveys were conducted in May 1990 following the disastrous flood of a month earlier (DWR, 1990). This approach would not be practicable at Narromine given the limited data that are available on historic flood damages.
- The second best way is for experienced loss adjusters to conduct a survey to estimate likely losses that would arise due to various depths of inundation. This approach is used from time to time, but it can add significantly to the cost of a floodplain management study (LMJ, 1985). It was not used for the present investigation.
- The third way is to use generalised data such as that published by CRES (Centre for Resource & Economic Studies, Canberra) and used in the Floodplain Management Study for Forbes (SKM, 1994). These kinds of data are considered to be suitable for generalised studies, such as broad regional studies. They are not considered to be suitable for use in specific areas, unless none of the other approaches can be satisfactorily applied.
- The fourth way is to adapt or transpose data from other flood liable areas. This was the approach used for the present study. As mentioned, the *Guideline No 4* procedure was adopted for the assessment of residential damages. The approach was based on data collected following major flooding in Katherine in 1998, with adjustments to account for changes in values due to inflation, and after taking into account the nature of development and flooding patterns in the study area. The data collected during site inspection in the flood liable areas assisted in providing the necessary adjustments. Commercial and industrial damages were assessed via reference to recent floodplain management investigations of a similar nature to the present study.

B3.2. Property Data

The properties were divided into three categories: residential, commercial / industrial, and public buildings.

For residential properties, the data used in the damages estimation included:

- the location/address of each property
- an assessment of the type of structure
- natural surface level
- floor level

For commercial / industrial and public properties, the required data included:

- the location of each property
- the nature of each enterprise
- an estimation of the floor area
- natural surface level
- floor level

The property descriptions were used to classify the commercial and public developments into categories (i.e. high, medium or low value properties) which relate to the magnitude of likely flood damages.

The total number of residential properties, commercial / industrial and public buildings is shown in **Table B3.1**.

TABLE B3.1
NUMBER OF PROPERTIES INCLUDED IN DAMAGES DATABASE

Development Type	Number of Properties
Residential(1)	1,683
Commercial / Industrial	176
Public	27
Total	**1,886**

1. Includes individual residential units

B3.3. Flood Levels Used in the Analysis

Damages were computed for the design flood levels determined from the hydraulic model that was developed as part of the present investigation. The design levels assume that the drainage system is operating at optimum capacity. They do not allow for any increase in levels resulting from wave action, debris build-ups in the channels which may cause a partial blockage of bridges and which may result in conversions of flow from the supercritical to the subcritical flow regime, as well as other local hydraulic effects. These factors are usually taken into account by adding a factor of safety (freeboard) to the “nominal” flood level when assessing the “level of protection” against flooding of a particular property. Freeboard could also include an allowance for the future effects of climate change.

A particular level of protection could not be ascribed to a development unless it were protected against the nominal flood level of a particular return period plus the freeboard allowance. For this reason, damages assessments were also carried out with the design flood levels increased by the freeboard allowance. Freeboard is related to the fetch length and velocity of flow, which is itself dependent on the bed slope and hydraulic roughness of the drainage system. Fetch length and flow velocities tend to increase with peak flow and therefore increasing the freeboard with increase in flood return period could be justified. For the present analysis, a 500 mm freeboard allowance was adopted for assessing damages for the 1% AEP and greater floods, reducing to 300 mm for the 2% AEP and 5% AEP floods. No freeboard was assumed for the 10% and 20% AEP floods given their inbank nature.

B4. RESIDENTIAL DAMAGES

B4.1. Damage Functions

The procedures identified in *Guideline No 4* allow for the preparation of a depth versus damage relationship which incorporates structural damage to the building, damage to internals and contents, external damages and clean-up costs. In addition, there is the facility for including allowance for accommodation costs and loss of rent. Separate curves are computed for three residential categories:

- Single storey slab on ground construction
- Single storey elevated floor
- Two storey residence

The level of flood awareness and available warning time are taken into account by factors which are used to reduce "potential" damages to contents to "actual" damages. "Potential" damages represent losses likely to be experienced if no action were taken by residents to mitigate impacts. A reduction in the potential damages to "actual" damages is usually made to allow for property evacuation and raising valuables above floor level, which would reduce the damages actually experienced. The ability of residents to take action to reduce flood losses is mainly limited to reductions in damages to contents, as damages to the structure and clean-up costs are not usually capable of significant mitigation.

The reduction in damages to contents is site specific, being dependent on a number of factors related to the time of rise of floodwaters, the recent flood history and flood awareness of residents and emergency planning by the various Government Agencies (BoM and NSW SES).

Water levels in the Macquarie River at Narromine generally rise over a period of several days. There is also a well-tested flood warning system operated by BoM and specific flood response procedures are incorporated in the *Narromine Shire Local Flood Plan 2014*. Consequently, there would be considerable time in advance of a flood event in which to warn residents and for them to take action to mitigate flood losses. Provided warning is available, house contents may be raised above flood level to about 0.9 m, which corresponds with the height of a typical table/bench height. The spreadsheet provides two factors, one for above and one for below the typical bench height. The reduction in damages is also dependent on the likely duration of inundation of contents, which in the case of Narromine extend for several days.

Table B4.1 over shows total flood damages estimated for the three classes of residential property using the procedures identified in *Guideline No. 4*, for typical depths of above-floor inundation of 0.3 m and 1.0 m (The maximum depth of above-floor inundation in Narromine is about 3.9 m at the 1% AEP level of flooding). A typical ground floor area of 240 m^2 was adopted for the assessment. The values in **Table B4.1** allow for damages to buildings and contents, as well as external damages and provision for alternative accommodation.

B4.2. Total Residential Damages

Table B4.2 over summarises residential damages for the range of floods in Narromine. The damage estimates were carried out for floods between the 20% AEP and the Extreme Flood, which were modelled hydraulically as part of the present study.

TABLE B4.1
DAMAGES TO RESIDENTIAL PROPERTIES

Type of Residential Construction	0.3 m Depth of Inundation Above Floor Level	1.0 m Depth of Inundation Above Floor Level
Single Storey Slab on Ground	$110,365	$149,814
Single Storey High Set	$73,305	$131,385
Double Storey	$51,313	$91,969

Note: These values allow for damages to buildings and contents, as well as external damages and provision for alternative accommodation.

While the threshold of above-floor flooding for residential type development in Narromine is a 2% AEP flood, when two dwellings, one of which is located on River Drive and the other on Warren Road would be inundated by a maximum of 150 mm, large-scale flood damages are not experienced in Narromine until the southern bank of the river is overtopped during a slightly larger flood event. For example, the total number of dwellings that would experience above-floor inundation at the 1% AEP level of flooding would be 449, increasing to 1, during a 0.5% AEP flood event. Almost all of the existing dwellings in Narromine would experience above-floor flooding in an extreme flood event.

The maximum depth of above-floor inundation in the worst affected dwelling would increase from about 1.3 m during a 1% AEP flood event, increasing to about 1.7 during a 0.5% AEP flood event and about 4 m in the Extreme Flood.

The total residential damages in Narromine would increase from about $43.3 Million at the 1% AEP level of flooding to about $315 Million at the upper limit of flooding based on nominal flood levels, increasing to about $88 Million and $336 Million for the 1% AEP and Extreme Floods, respectively when freeboard is taken into account.

TABLE B4.2
RESIDENTIAL FLOOD DAMAGES IN NARROMINE

Design Flood Event (% AEP)	Nominal Flood Levels			Nominal Flood Levels Plus Freeboard		
	Number of Properties		Damages ($ Million)	Number of Properties		Damages ($ Million)
	Flood Affected	Flood Above Floor Level	Flood Affected	Flood Affected	Flood Above Floor Level	
20	0	0	0	0	0	0
10	0	0	0	0	0	0
5	0	0	0	0	0	0
2	10	2	0.27	13	8	0.77
1	747	449	43.32	904	883	88.01
0.5	1310	1126	108.31	1339	1329	160.06
0.2	1512	1446	201.94	1541	1540	257.57
Extreme	1659	1655	314.53	1663	1661	335.65

B5. COMMERCIAL / INDUSTRIAL DAMAGES

B5.1. Direct Commercial / Industrial Damages

The method used to calculate damages requires each property to be categorised in terms of the following:

- damage category
- floor area
- floor elevation

The damage category assigned to each enterprise may vary between "low", "medium" or "high", depending on the nature of the enterprise and the likely effects of flooding. Damages also depend on the floor area.

It has recently been recognised following the 1998 flood in Katherine that previous investigations using stage-damage curves contained in proprietary software tends to seriously underestimate true damage costs. DPIE are currently researching appropriate damage functions which could be adopted in the estimation of commercial and industrial categories as they have already done with residential damages. However, these data were not available for the present study.

On the basis of previous investigations the following typical damage rates are considered appropriate for potential external and internal damages and clean-up costs for both commercial and industrial properties. They are indexed to a depth of inundation of 2 metres. At floor level and 1.2 m inundation, zero and 70% of these values respectively were assumed to occur:

Low value enterprise	$280/m^2	(e.g. Commercial: small shops, cafes, joinery, public halls. Industrial: auto workshop with concrete floor and minimal goods at floor level, Council or Government Depots, storage areas.)
Medium value enterprise	$420/m^2	(e.g. Commercial: food shops, hardware, banks, professional offices, retail enterprises, with furniture/fixtures at floor level which would suffer damage if inundated. Industrial: warehouses, equipment hire.)
High value enterprise	$650/m^2	(e.g. Commercial : electrical shops, clothing stores, bookshops, newsagents, restaurants, schools, showrooms and retailers with goods and furniture, or other high value items at ground or lower floor level. Industrial: service stations, vehicle showrooms, smash repairs.)

The factor for converting potential to actual damages depends on a range of variables such as the available warning time, flood awareness and the depth of inundation. Given sufficient warning time, a well prepared business will be able to temporarily lift property above floor level. However, unless property is actually moved to flood free areas, floods which result in a large depth of inundation, will cause considerable damage to stock and contents.

For the present study, the potential damages described above were converted to actual damages using a multiplier which ranged from between 0.5 and 0.8 depending on the depth of above-floor inundation.

B5.2. Indirect Commercial and Industrial Damages

Indirect commercial and industrial damages comprise costs of removal of goods and storage, loss of trading profit and loss of business confidence.

Disruption to trade takes the following forms:

- The loss through isolation at the time of the flood when water is in the business premises or separating clients and customers. The total loss of trade is influenced by the opportunity for trade to divert to an alternative source. There may be significant local loss but due to the trade transfer this may be considerably reduced at the regional or state level.
- In the case of major flooding, a downturn in business can occur within the flood affected region due to the cancellation of contracts and loss of business confidence. This is in addition to the actual loss of trading caused by closure of the business by flooding.

Loss of trading profit is a difficult value to assess and the magnitude of damages can vary depending on whether the assessment is made at the local, regional or national level. Differences between regional and national economic effects arise because of transfers between the sectors, such as taxes, and subsidies such as flood relief returned to the region.

Some investigations have lumped this loss with indirect damages and have adopted total damage as a percentage of the direct damage. In other cases, loss of profit has been related to the gross margin of the business, i.e. turnover less average wages. The former approach has been adopted in this present study. Indirect damages have been taken as 50% of direct actual damages. A clean-up cost of \$15/m^2 of floor area of each flooded property was also included.

B5.3. Total Commercial and Industrial Damages

Table B5.1 over summarises estimated commercial and industrial damages in Narromine.

The threshold of above-floor flooding in commercial and industrial type development in Narromine is a flood which is slightly larger than 2% AEP, when flood water would surcharge the southern bank of the Macquarie River and enter the town.

A total of 72 commercial/industrial type development would experience above-floor inundation at the 1% AEP level of flooding, increasing to 138 at the 0.5% AEP level of flooding. Almost all of the commercial and industrial type properties in Narromine would experience above-floor inundation during an extreme flood event.

The maximum depth of above-floor inundation in the worst affected property would increase from about 1 m during a 1% AEP flood event, increasing to about 1.3 m during a 0.5% AEP flood event and about 4 m in the Extreme Flood.

The total commercial/industrial damages in Narromine would increase from about \$3.3 Million at the 1% AEP level of flooding to about \$78 Million at the upper limit of flooding based on nominal flood levels, increasing to about \$9.4 Million and \$93 Million for the 1% AEP and Extreme Floods respectively when freeboard is taken into account.

TABLE B5.1
COMMERCIAL AND INDUSTRIAL FLOOD DAMAGES IN NARROMINE

Design Flood Event (% AEP)	Nominal Flood Levels			Nominal Flood Levels Plus Freeboard		
	Number of Properties		Damages ($ Million)	Number of Properties		Damages ($ Million)
	Flood Affected	Flood Above Floor Level	Flood Affected	Flood Affected	Flood Above Floor Level	
20	0	0	0	0	0	0
10	0	0	0	0	0	0
5	0	0	0	0	0	0
2	0	0	0	0	0	0
1	111	72	3.30	122	120	9.36
0.5	153	138	11.93	157	154	24.19
0.2	168	159	30.10	172	172	51.85
Extreme	176	175	78.46	176	176	92.65

B6. DAMAGES TO PUBLIC BUILDINGS

B6.1. Direct Damages – Public Buildings

Included under this heading are government buildings, churches, swimming pools and parks. Damages were estimated individually on an area basis according to the perceived value of the property. Potential internal damages were indexed to a depth of above-floor inundation of 2 m as shown below. At floor level and 1.2 m depth of inundation, zero and 70% of these values respectively were assumed to occur.

Low value	\$280/m^2	
Medium value	\$420/m^2	(e.g. council buildings, NSW SES HQ, fire station)
High value	\$650/m^2	(e.g. schools)

These values were obtained from the Nyngan Study (DWR, 1990), as well as commercial data presented in the Forbes Water Studies report (WS, 1992) and adjusted for inflation. External and structural damages were taken as 4 and 10% of internal damages respectively.

B6.2. Indirect Damages – Public Buildings

A value of \$15/m^2 was adopted for the clean-up of each property. This value is based on results presented in the Nyngan Study and adjusted for inflation. Total "welfare and disaster" relief costs were assessed as 50% of the actual direct costs.

B6.3. Total Damages – Public Buildings

Table B6.1 over summarises estimated damages to public buildings in Narromine.

Similar to the findings for commercial/industrial type development, the threshold of above-floor flooding for public buildings in Narromine is equivalent to a flood which is slightly larger than 2% AEP. The number of public buildings in Narromine that are above-floor inundated increases from 7 at the 1% AEP level of flooding to 17 during a 0.5% AEP flood event. All of the public buildings in Narromine would experience above-floor flooding during an extreme flood event.

The maximum depth of above-floor inundation in the worst affected property would increase from about 1 m during a 1% AEP flood event, increasing to about 1.3 m during a 0.5% AEP flood event and about 3.6 m in the Extreme Flood.

The total public building damages in Narromine would increase from about \$3.1 Million at the 1% AEP level of flooding to about \$24 Million at the upper limit of flooding based on nominal flood levels, increasing to about \$6.1 Million and \$27 Million for the 1% AEP and Extreme Floods respectively when freeboard is taken into account..

TABLE B6.1
PUBLIC FLOOD DAMAGES IN NARROMINE

Design Flood Event (% AEP)	Nominal Flood Levels			Nominal Flood Levels Plus Freeboard		
	Number of Properties		Damages ($ Million)	Number of Properties		Damages ($ Million)
	Flood Affected	Flood Above Floor Level	Flood Affected	Flood Affected	Flood Above Floor Level	
20	0	0	0	0	0	0
10	0	0	0	0	0	0
5	0	0	0	0	0	0
2	0	0	0	0	0	0
1	10	7	3.07	13	13	6.10
0.5	24	17	5.71	25	25	11.25
0.2	26	26	12.25	26	26	16.80
Extreme	27	27	23.77	27	27	27.47

B7. DAMAGES TO INFRASTUCTURE AND COMMUNITY ASSETS

No data are available on damages experienced to infrastructure and community assets during historic flood events. However, a qualitative matrix of the effects of flooding on critical assets in Narromine is presented in **Table 2.7** of the Main Report.

B8. SUMMARY OF TANGIBLE DAMAGES

B8.1. Tangible Damages

Floods have been computed for a range of flood frequencies from 20% AEP up to the Extreme Flood. From **Table B8.1** over the page, the threshold for flood damages is the 2% AEP flood event. **Figures B8.1** and **B8.2** show the damage-frequency curves and cumulative distribution of above-floor depths of inundation at the 1% AEP flood level for residential, commercial and industrial and public buildings in Narromine for the "nominal flood level" and the "nominal flood level plus freeboard" cases.

B8.2. Definition of Terms

Average Annual Damages (also termed "expected damages") are determined by integrating the area under the damage-frequency curve. They represent the time stream of annual damages, which would be expected to occur on a year by year basis over a long duration.

Using an appropriate discount rate, average annual damages may be expressed as an equivalent "*Present Worth Value"* of damages and used in the economic analysis of potential flood management measures.

A flood management scheme which has a design 1% AEP level of protection, by definition, will eliminate damages up to this level of flooding. If the scheme has no mitigating effect on larger floods then these damages represent the benefits of the scheme expressed on an average annual basis and converted to the *Present Worth Value* via the discount rate.

Using the procedures outlined in *Guideline No. 4*, as well as current NSW Treasury guidelines, economic analyses were carried out assuming a 50 year economic life for projects and discount rates of 7% pa. (best estimate) and 11% and 4% pa. (sensitivity analyses).

B8.3. Average Annual Damages

The average annual damages for all flood events up to the Extreme Flood are shown below in **Table B8.2** over the page. Note that values have been quoted to two decimal places to highlight the relatively small recurring damages.

B8.4. Present Worth of Damages at Narromine

The *Present Worth Value* of damages likely to be experienced for all flood events up to the 1% AEP and Extreme Flood, for a 50 year economic life and discount rates of 4, 7 and 11 per cent are shown in **Table B8.3** over the page.

For a discount rate of 7% pa and economic life of 50 years, the *Present Worth Value* of damages for all flood events up to the Extreme Flood is about $22.5 Million for the nominal flood level case, increasing to about $35.8 Million when freeboard is taken into account. Therefore one or more schemes costing up to this amount could be economically justified if they eliminated damages in Narromine for all flood events up to this level. While schemes costing more than this value would have a benefit/cost ratio less than 1, they may still be justified according to a multi-objective approach which considers other criteria in addition to economic feasibility. Flood management measures are considered on a multi-objective basis in **Chapter 4** of the Main Report.

TABLE B8.1
TOTAL FLOOD DAMAGES IN NARROMINE
$ MILLION

Design Flood Event (% AEP)	Nominal Flood Levels				Nominal Flood Levels Plus Freeboard			
	Residential	Commercial/ Industrial	Public	Total	Residential	Commercial/ Industrial	Public	Total
20	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
2	0.27	0	0	0.27	0.77	0	0	0.77
1	43.32	3.30	3.07	49.69	88.01	9.36	6.10	103.47
0.5	108.31	11.93	5.71	125.95	160.06	24.19	11.25	195.50
0.2	201.94	30.10	12.25	244.29	257.57	51.85	16.80	326.22
Extreme	314.53	78.46	23.77	416.76	335.65	92.65	27.47	455.77

TABLE B8.2
AVERAGE ANNUAL DAMAGES IN NARROMINE
$ MILLION

Design Flood Event (% AEP)	Nominal Flood Levels				Nominal Flood Levels Plus Freeboard			
	Residential	Commercial/Industrial	Public	Total	Residential	Commercial/Industrial	Public	Total
20	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
2	0.004	0	0	0.004	0.012	0	0	0.012
1	0.22	0.02	0.02	0.25	0.46	0.05	0.03	0.53
0.5	0.60	0.06	0.04	0.69	1.08	0.13	0.07	1.28
0.2	1.36	0.16	0.08	1.60	2.10	0.32	0.14	2.56
Extreme	1.39	0.16	0.08	1.63	2.13	0.32	0.15	2.60

TABLE B8.3
PRESENT WORTH VALUE OF DAMAGES IN NARROMINE
$ MILLION

Discount Rate (%)	Nominal Flood Levels		Nominal Flood Levels Plus Freeboard	
	All Floods up to 1% AEP	All Floods up to Extreme Flood	All Floods up to 1% AEP	All Floods up to Extreme Flood
4	5.4	35.1	11.4	55.8
7	3.5	22.5	7.3	35.8
11	2.3	14.7	4.8	23.4

B9. REFERENCES

DECC (Department of Environment and Climate Change, NSW) (2007) ***"Floodplain Management Guideline No 4. Residential Flood Damages"***.

DWR (Department of Water Resources, NSW) (1990) ***"Nyngan April 1990 Flood Investigation"***.

LMJ (Lyall, Macoun and Joy, Willing and Partners Pty Ltd) (1985) ***"Camden Floodplain Management Study"***.

SKM (Sinclair Knight Merz) (1994) ***"Forbes Floodplain Management Report and Draft Floodplain Management Plan, Volume 1"***.

WS (Water Studies) (1986) ***"The Sydney Floods of August 1986"***, Volume I Residential Flood Damage Survey, Report prepared for CRCE Water Studies Pty Ltd for the NSW PWD.

WS (Water Studies) (1992) ***"Forbes Flood Damage Survey, August 1990 Flood"***.

APPENDIX C

IMPACT OF ASSESSED RIVER BANK LEVEE OPTIONS ON FLOOD BEHAVIOUR

(REFER FIGURES BOUND IN VOLUME 2 OF THIS REPORT)

APPENDIX D

SUGGESTED WORDING FOR INCLUSION IN NARROMINE SHIRE COUNCIL DEVELOPMENT CONTROL PLAN

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FIGURES
(BOUND IN VOLUME 2)

D1.1 Introduction

This section of the Plan sets out specific controls to guide development of flood liable land in the Narromine Shire LGA. The approach to managing future development that is subject to flooding supports the findings of a series of location specific floodplain risk management studies and plans that have been prepared as part of the NSW Government's program to mitigate the impact of major floods and reduce the associated hazards in the floodplain.

D1.2 Objectives in Relation to Flood Risk Management

a) To minimise the potential impact of development and other activity upon the aesthetic, recreational and ecological value of the waterway corridors.

b) Increase public awareness of the hazard and extent of land affected by all potential floods, including floods greater than the 1% Annual Exceedance Probability (AEP) flood and to ensure essential services and land uses are planned in recognition of all potential floods.

c) Inform the community of Council's controls and policy for the use and development of flood prone land.

d) Reduce the risk to human life and damage to property caused by flooding through controlling development on land affected by potential floods.

e) Provide detailed controls for the assessment of applications lodged in accordance with the *Environmental Planning and Assessment Act 1979* on land affected by potential floods.

f) Provide different guidelines, for the use and development of land subject to all potential floods in the floodplain, which reflect the probability of the flood occurring and the potential hazard within different areas.

g) Apply a "merit-based approach" to all development decisions which takes account of social, economic and ecological considerations.

h) To control development and other activity within each of the individual floodplains within the LGA having regard to the characteristics and level of information available for each of the floodplains, in particular the availability of floodplain risk management studies and plans prepared in accordance with the *Floodplain Development Manual*, issued by the NSW Government.

i) Deal equitably and consistently with applications for development on land affected by potential floods, in accordance with the principles contained in the *Floodplain Development Manual*.

D1.3 Procedure for Determining What Controls Apply to Proposed Development

The procedure Council will apply for determining the specific controls applying to proposed development in flood liable areas is set out below. Upon enquiry by a prospective applicant, Council will make an initial assessment of the flood affectation and flood levels at the site using the following procedure:

- Assess whether the development is located on flood liable land from the **Flood Planning Map**.
- Determine which set of prescriptive flood related planning controls apply to the development from the **Flood Planning Map** (i.e. Main Stream Flooding or Major Overland Flow).

- Identify the category of the development from **Schedule1: Land Use Categories.**
- Determine the appropriate flood level at the site from the results of the location specific flood or floodplain risk management study.
- Determine which part of the floodplain the development is located in from the **Flood Planning Constraint Category Map**.
- Confirm that the development conforms with the relevant performance criteria, as well as the prescriptive controls set out in either **Schedule 2A** for Main Stream Flooding affected areas and **Schedule 2B** for Major Overland Flow affected areas.

With the benefit of this initial information from Council, the applicant will:

- Prepare the documentation to support the Development Application according to the requirements of **Section D1.12**.

A survey plan showing natural surface levels over the site will be required as part of the Development Application documentation. Provision of this plan by the applicant at the initial enquiry stage will assist Council in providing flood related information.

D1.4 Land Use Categories

The policy recognises seven different types of land use for which a graded set of flood related controls apply. They are included in **Schedule 1: Land Use Categories**.

D1.5 Flood Planning Constraint Categories

For those floodplains where Council has adopted a flood or floodplain risk management study, the identified flood liable land has been divided into the following four *Flood Planning Constraint Categories* (**FPCCs**):

- **Flood Planning Constraint Category 1 (FPCC 1)**, which comprises areas where factors such as the depth and velocity of flow, time of rise, and evacuation problems mean that the land is unsuitable for most types of development. The majority of new development types are excluded from this zone due to its potential impact on flood behaviour and the hazardous nature of flooding.
- **Flood Planning Constraint Category 2 (FPCC 2)**, which comprises areas which lie within the extent of the *Flood Planning Area* where the existing flood risk warrants careful consideration and the application of significant flood related controls on future development.
- **Flood Planning Constraint Category 3 (FPCC 3)**, which comprises areas which lie within the extent of the *Flood Planning Area* but outside areas designated FPCC1 and FPCC2. Areas designated FPCC3 are more suitable for new development and expansion of existing development provided it is carried out in accordance with the controls set out in this document.
- **Flood Planning Constraint Category 4 (FPCC 4)**, which comprises the area which lies between the extent of the *Flood Planning Area* and the Probable Maximum Flood (**PMF**)/Extreme Flood. Flood related controls in areas designated FPCC4 are typically limited to flood evacuation and emergency response, although additional controls apply to essential community facilities and utilities that are critical for response and recovery, as well as community hospitals, residential care facilities and group homes.

D1.6 Development Controls

The development controls have been graded relative to the severity and frequency of potential floods, having regard to the FPCCs determined by the relevant Floodplain Risk Management Study and Plan or, if no such study or plan exists, Council's interim considerations.

The objectives of the development controls are:

a) To require developments with high sensitivity to flood risk to be designed so that they are subject to minimal risk.

b) To allow development with a lower sensitivity to the flood hazard to be located within the floodplain, provided the risk of harm and damage to property is minimised.

c) To minimise the intensification of the high flood risk areas, and if possible, allow for their conversion to natural waterway corridors.

d) To ensure design and siting controls required to address the flood hazard do not result in unreasonable social, economic or environmental impacts.

e) To minimise the risk to life by ensuring the provision of reliable access from areas affected by flooding.

f) To minimise the damage to property arising from flooding.

g) To ensure the proposed development does not expose existing development to increased risks associated with flooding.

The performance criteria which are to be applied when assessing a proposed development are:

a) The proposed development should not result in any significant increase in risk to human life, or in a significant increase in economic or social costs as a result of flooding.

b) The proposal should only be permitted where effective warning time and reliable access is available to an area free of risk from flooding, consistent with any relevant Flood Plan or flood evacuation strategy.

c) Development should not significantly increase the potential for damage or risk other properties either individually or in combination with the cumulative impact of development that is likely to occur in the same floodplain.

d) Procedures would be in place, if necessary, (such as warning systems, signage or evacuation drills) so that people are aware of the need to evacuate are capable of identifying the appropriate evacuation route.

e) Development should not result in significant impacts upon the amenity of an area by way of unacceptable overshadowing of adjoining properties, privacy impacts (e.g. by unsympathetic house–raising) or by being incompatible with the streetscape or character of the locality.

The prescriptive controls which apply to development that is proposed on land affected by Main Stream Flooding and Major Overland Flow are set out in **Schedules 2A** and **2B**, respectively.

D1.7 Proposals to Modify Flood Planning Constraint Categories

In certain situations it may be feasible to modify existing flood behaviour through engineering works which in turn would enable the extent of the FPCCs to be modified at a particular location. Proposals to modify an FPCC at a particular location would need to be supported by a detailed flooding investigation, further details of which are set out in **Section D1.12** below. Proposals would also need to demonstrate consistency with the flood related objectives and performance criteria of both the *Narromine Local Environmental Plan* and the *Narromine Shire Development Control Plan*.

D1.8 Development Requiring a Higher Level of Protection

Developments including nursing homes, aged care facilities and the like are usually recommended to be built at levels higher than the residential FPL, noting the limited mobility of occupants. However, in the case of Narromine, flood warning times are such that adequate notification of the need to evacuate in times of extreme flooding is available.

The *Narromine Shire Development Control Plan* therefore nominates the 1% AEP flood level plus 0.5 m as the FPL for Flood Vulnerable Residential Development (which includes nursing homes, aged care facilities and the like). The applicant is to ensure that valuable equipment necessary for the operation of the facility is located at or above the nominated FPL, either permanently or via relocation to a temporary storage area suitable for this purpose. Additionally, these types of developments are to contain flood compatible building materials up to the PMF/Extreme Flood level to ensure that damage suffered by these important buildings is lessened in a more severe flood and inhabitants can move back into their residences faster after flood waters have subsided.

D1.9 Additions to Existing Dwellings and Ancillary Developments

For all new developments, it is recognised that the residential FPL is the minimum benchmark for floor levels. Additions are separately categorised in **Annexures 2A** and **2B** for instances where building up to the residential FPL is impractical or unreasonable. Appendix I 6.3.2 of the *Floodplain Development Manual 2005* states that additions can be built below the FPL *'where, in the opinion of Council, the floor level requirement is impractical or unreasonable'*.

A range of criteria has been applied to this section to clarify instances where Council is of the opinion that building up to the residential FPL would be impractical or unreasonable for various types of developments, as outlined below:

Dwelling Additions

- The addition is not to exceed 50% of the floor area of the existing dwelling (habitable floor area), and
- The addition is to be designed to withstand the force of floodwaters including debris and buoyancy forces. A detailed report from a practising structural engineer certifying that the addition can achieve this is required. NOTE: For calculation of debris forces, assume a solid object of mass 250 kg travelling at a velocity of 2.0 metres/second, and
- The addition is proposed to be built from flood compatible materials (as included in **Annexures 3A** and **3B**) up to the 1% plus 0.5 m level, and

- The addition is proposed in a precinct which allows such additions to be captured by this clause, as shown in **Annexures 2A** and **2B** and on **Figure D1.2**.

If an addition to a dwelling meets all of the above criteria, it may be built at the same floor level as the existing building. Council reserves the right to review each application submitted and potentially applying to this section on individual merits and in some cases, building up to the residential FPL may be warranted. Applications submitted under this subsection (Dwelling Additions) may only be approved once for each individual allotment or building, to ensure cumulative impacts are minimised/controlled.

Outbuildings

- The outbuilding is proposed in a precinct which allows such development to be captured by this clause, as shown in **Annexures 2A** and **2B** and on **Figure D1.2**, and
- The outbuilding is proposed to be built from flood compatible building materials (as specified in **Annexures 3A** and **3B**) up to the 1% plus 0.5 m level, and
- The outbuilding is to be designed to withstand the force of floodwaters including debris and buoyancy forces. A detailed report from a practising structural engineer certifying that the addition can achieve this is required. NOTE: For calculation of debris forces, assume a solid object of mass 250 kg travelling at a velocity of 2.0 metres/second, and
- A location for the storage of goods during a flood event is to be provided inside the outbuilding with a minimum floor area of 10% of the gross floor area of the outbuilding proposed. This area is to be built to at least the residential FPL, being the 1% plus 0.5 m level.

D1.10 Special Requirements for Skypark Development

Skypark is a special use development, unique in its concept of providing lots for residential dwellings with a hangar for aircraft storage in the backyard. Skypark is located off the Warren Road zoned *R1 Residential*, under *Narromine LEP 2011*. Further flood modelling has been carried out over the Skypark site to determine flood levels for new residential development in this area. In this area the Macquarie River surcharges its left bank and floodwaters flow in generally a westerly direction across the Warren Road and into the aerodrome.

Development Controls

i. Hangars at Skypark are able to be built at natural ground surface levels. This is in recognition that the Skypark covenant does not allow a hangar to be built without a dwelling also being built on the site. The dwelling needs to be built to the 1% AEP flood level plus 0.5 m freeboard and as such, adequate storage for any important items in the hangar, is available in the dwelling.

ii. For the lots which run in an east-westerly direction (being 20-25 inclusive, 59-61 incl, 51, 26-30 incl, 45-46, 58, 31-44 incl, 85), not more than 50% of the width of the lot frontage to the street is to be impeded by impenetrable walls or fences. This is to allow floodwaters to escape to the west in the design 1% AEP flood. Any fences proposed must ensure that 50% of the lot width is open. Any dwellings built on these lots are not to be more than 50% of the width of the lot frontage. Any hangars built on these lots must be able to be opened at both the eastern and western ends to a width of 50% of their allotment width. This can be done with roller or hangar doors or personal access doors

D1.11 Special Requirements for Fencing

The objectives are:

a) To ensure that fencing does not result in the undesirable obstruction of the free flow of floodwater.

b) To ensure that fencing does not become unsafe during floods so as to threaten the integrity of structures or the safety of people.

c) Fencing is to be constructed in a manner which does not significantly increase flood damage or risk on surrounding land.

The performance criterion which is to be applied when assessing proposed fencing are:

a) Fencing is to be constructed in a manner that does not affect the flow of floodwater so as to detrimentally increase flood affection on surrounding land.

b) Fencing shall be certified by an engineer specialising in hydraulic engineering, that the proposed fencing is adequately constructed so as to withstand the force of floodwater, or collapse in a controlled manner to prevent the undesirable impediment of floodwater.

The prescriptive controls which apply to any proposed fencing on land designated FPCC 1, FPCC 2 and FPCC 3 are:

a) An applicant will need to demonstrate that the fence (new or replacement fence) would create no impediment to the flow of floodwater. Appropriate fences must satisfy the following:

- an open collapsible hinged fence structure or pool type fence, or louvre fencing;
- must not be constructed of non-permeable materials; or
- must allow floodwaters to equalised on both sides and minimise entrapment of flood debris.

D1.12 Explanatory Notes on Lodging Applications

Follow these major steps to lodge the application:

a) Check the proposal is permissible in the zoning of the land by reference to any applicable environmental planning instruments.

b) Consider any other relevant planning controls of Council (e.g. controls in any other relevant part of the DCP).

c) Check whether your property is located either partially or wholly within the Flood Planning Area or Outer Floodplain, as defined on the **Flood Planning Map**.

d) Determine which set of prescriptive flood related planning controls apply to the development from the **Flood Planning Map**.

e) Determine which Flood Planning Constraint Category (FPCC) applies to the developable portion of your property by reference to the **Flood Planning Constraint Category Map**. Enquire with Council regarding existing flood risk mapping or whether a site–specific assessment may be warranted. A property may be located in more than one FPCC and the assessment must consider the controls that apply in each. The flow diagram below summarises this consideration process.

f) Determine the land use category relevant to the development proposal, by firstly confirming how it is defined by the relevant environmental planning instrument and secondly by ascertaining the land use category from **Schedule 1: Land Use Categories**.

g) Assess and document how the proposal will achieve the performance criteria for proposed development and associated fencing set out in **Sections D1.6** and **D1.8**.

h) Check if the proposal will satisfy the prescriptive controls for different land use categories in different FPCCs, as specified in either **Schedule 2A** or **Schedule 2B**.

i) If the proposal does not comply with the prescriptive controls, determine whether the performance criteria are nonetheless achieved.

j) Illustrations provided in this plan to demonstrate the intent of development controls are diagrammatic only. Proposals must satisfy all relevant controls contained in this plan and associated legislation.

k) The assistance of Council staff or an experienced engineer or planner may be required at various steps in the process to ensure that the flood risk management related requirements of this Plan are fully and satisfactorily addressed.

Note that compliance with all the requirements of this plan does not guarantee that an application will be approved.

Information required with an application to address this plan is as follows:

a) Applications must include information which addresses all relevant controls listed above, and the following matters as applicable.

b) Applications for alterations and additions (see either **Schedule 2A** or **Schedule 2B**) to an existing dwelling on flood liable land shall be accompanied by documentation from a registered surveyor confirming existing floor levels.

c) Development applications affected by this plan shall be accompanied by a survey plan showing:

   i. The position of the existing building/s or proposed building/s;

   ii. The existing ground levels to Australian Height Datum around the perimeter of the building and contours of the site; and

   iii. The existing or proposed floor levels to Australian Height Datum.

d) Applications for earthworks, filling of land and subdivision shall be accompanied by a survey plan (with a contour interval of 0.25 m) showing relative levels to Australian Height Datum.

e) For large scale developments, or developments where an existing catchment based flood study is not available, a flood study using a fully dynamic one or two dimensional computer model may be required. For smaller developments the existing flood study may be used if available and suitable (e.g. it contains sufficient local detail), or otherwise a flood study prepared in a manner consistent with the latest edition of *Australian Rainfall and Runoff* and the *Floodplain Development Manual*, will be required. From this study, the following information shall be submitted in plan form:

   i. water surface contours;

   ii. velocity vectors;

   iii. velocity and depth product contours;

iv. delineation of flood risk precincts relevant to individual floodplains; and

v. show both existing and proposed flood profiles for the full range of events for total development including all structures and works (such as revegetation/ enhancements).

This information is required for the pre–developed and post–developed scenarios.

f) Where the controls for a particular development proposal require an assessment of structural soundness during potential floods, the following impacts must be addressed:

i. hydrostatic pressure;

ii. hydrodynamic pressure;

iii. impact of debris; and

iv. buoyancy forces.

Foundations need to be included in the structural analysis.

D1.13 Glossary of Terms

Note: For expanded list of definitions, refer to Glossary contained within the NSW Government Floodplain Development Manual, 2005.

TERM	DEFINITION
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, for a flood magnitude having five per cent AEP, there is a five per cent probability that there would be floods of greater magnitude each year.
Australian Height Datum (AHD)	A common national surface level datum corresponding approximately to mean sea level.
Floodplain	Area of land which is subject to inundation by floods up to and including the Probable Maximum Flood or Extreme Flood event, that is, flood prone land.
Flood Planning Area	The area of land that is shown to be in the Flood Planning Area on the *Flood Planning Map*.
Flood Planning Map	The *Flood Planning Map* shows the extent of land on which flood related development controls apply in a given area, noting that other areas may exist which are not mapped but where flood related development controls apply.
Flood Planning Constraint Category 1 (FPCC 1)	Comprises areas where factors such as the depth and velocity of flow, time of rise, and evacuation problems mean that the land is unsuitable for most types of development. The majority of new development types are excluded from this zone due to its potential impact on flood behaviour and the hazardous nature of flooding
Flood Planning Constraint Category 2 (FPCC 2)	Comprises areas which lie below the *Flood Planning Level* where the existing flood risk warrants careful consideration and the application of significant flood related controls on future development.
Flood Planning Constraint Category 3 (FPCC 3)	Comprises areas which lie below the *Flood Planning Level* but outside areas designated FPCC1 and FPCC2. Areas designated FPCC3 are more suitable for new development and expansion of existing development provided it is carried out in accordance with the controls set out in this document.
Flood Planning Constraint Category 4 (FPCC 4)	Comprises the area which lies above the *Flood Planning Level* but within the extent of the Probable Maximum Flood or Extreme Flood. Flood related controls in areas designated FPCC4 are typically limited to flood evacuation and emergency response, although additional controls apply to essential community facilities and utilities that are critical for response and recovery, as well as community hospitals, residential care facilities and group homes.
Flood Planning Level (FPL)	Flood levels selected for planning purposes, as determined by the relevant adopted floodplain risk management study and plan, or as part of a site specific study In the absence of an adopted floodplain risk management study and plan for a particular location, the FPL is defined as the peak 1% AEP flood level plus the addition of a 0.5 m freeboard.

TERM	DEFINITION
Flood Prone/Flood Liable Land	Land susceptible to flooding by the Probable Maximum Flood or Extreme Flood. Flood Prone land is synonymous with Flood Liable land.
Floodway	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
Flood Storage Area	Those parts of the floodplain that may be important for the temporary storage of floodwaters during the passage of a flood. Loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation.
Freeboard	Provides reasonable certainty that the risk exposure selected in deciding a particular flood chosen as the basis for the *Flood Planning Level* is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the *Flood Planning Level*.
Habitable Room	In a residential situation: a living or working area, such as a lounge room, dining room, kitchen, bedroom or workroom. In an industrial or commercial situation: an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
Local Drainage	Land on an overland flow path where the depth of inundation during the 1% AEP storm event is less than 0.1 m.
Main Stream Flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
Major Overland Flow	Where the depth of overland flow during the 1% AEP storm event is greater than 0.1 m.
Probable Maximum Flood (PMF) or Extreme Flood	The largest flood that could conceivably occur at a particular location. Generally, it is not physically or economically possible to provide complete protection against this event. The Probable Maximum Flood or Extreme Flood defines the extent of flood prone land, that is, the floodplain.

SCHEDULE 1
LAND USE CATEGORIES

Essential Community Facilities and Critical Utilities and land uses	Flood Vulnerable Residential	Subdivision and Filling	Residential	Commercial/ Industrial	Recreation or Non-Urban	Additions to Dwellings and Ancillary Developments
Place of Assembly or Public building that may provide an important contribution to the notification and evacuation of the community during flood events; Hospitals; Telecommunication facilities; Public Utility Installation that may cause pollution of waterways during flooding, or if affected during flood events would significantly affect the ability of the community to return to normal activities after the flood events. Hazardous industry; Hazardous storage establishments.	Group home; Housing for aged or disabled persons; and Units for aged persons; Child care centre, Institutions, Educational establishments.	Subdivision of land involving the creation of new allotments for residential purposes; Earthworks or filling operations covering 100 m^2 or more than 0.3 m deep.	Dwelling; Residential flat building; Home industry; Boarding house; Professional consulting rooms; Public utility undertakings (other than critical utilities); Utility installation (other than critical utilities); Caravan Park (vans do not have to be built up, only permanent structures with footings and/or tie-downs).	Bulk Store; Bus depot; Bus station; Car repair stations; Club; Commercial premises; General store; Health care professional; Hotel; Intensive livestock keeping; Junkyard; Liquid fuel depot; Motel; Motor showroom; Place of Assembly (other than essential community facilities; Place of public worship; Public building (other than essential community facilities); Recreation facility; Refreshment room; Road transport terminal; Rural industry; Service station; Shop; Tourist facilities; Warehouse, car repair station, church, light industry, industry, plant nursery, roadside stall, sawmill.	Agriculture; Extractive industry; Forestry; Mine; Plantation forest; Retail nursery; Recreation area; Roadside stall; Stock and saleyard, hangar.	Dwelling Additions* Outbuildings* Change of Use* Private Swimming Pools* *For specific criteria on these, refer **Section D1.9**.

SCHEDULE 2A
PRESCRIPTIVE FLOOD RELATED DEVELOPMENT CONTROLS – MAIN STREAM FLOODING

Planning considerations	Flood Planning Constraint Category 1 (FPCC 1)							Flood Planning Constraint Category 2 (FPCC 2)							Flood Planning Constraint Category 3 (FPCC 3)							Flood Planning Constraint Category 4 (FPCC 4)						
	Essential Community Facilities and Critical Utilities and land uses	Flood Vulnerable Residential	Subdivision and Filling	Residential	Commercial / Industrial	Recreational and Non-Urban	Additions to Dwellings and Ancillary Developments	Essential Community Facilities and Critical Utilities and land uses	Flood Vulnerable Residential	Subdivision and Filling	Residential	Commercial / Industrial	Recreational and Non-Urban	Additions to Dwellings and Ancillary Developments	Essential Community Facilities and Critical Utilities and land uses	Flood Vulnerable Residential	Subdivision and Filling	Residential	Commercial / Industrial	Recreational and Non-Urban	Additions to Dwellings and Ancillary Developments	Essential Community Facilities and Critical Utilities and land uses	Flood Vulnerable Residential	Subdivision and Filling	Residential	Commercial / Industrial	Recreational and Non-Urban	Additions to Dwellings and Ancillary Developments
Minimum Habitable Floor Level						A1	A2 A3				A2	A4	A1	A2 A3	A2	A2		A2	A4	A1	A2 A3	A2	A2					
Building Components						B1	B1				B1	B1	B1	B1	B2	B2		B1	B1	B1	B1	B2	B2					
Structural Soundness						C2	C1				C1	C1	C1	C1	C2	C2		C1	C1	C1	C1	C2	C2					
Flood Affectation						D1	D1			D1	D1	D1	D1	D2	D1	D1	D1	D1	D1	D1	D2							
Emergency Response						E4	E2 or E3			E4 E5	E3 E4	E3 E4	E4	E2 or E3	E2 E4	E2 E4	E4 E5	E2 E4	E2 E4	E4	E2 or E3	E2 or E3	E2 E4					
Management and Design						F2 F3	F2 F3			F1	F2	F2 F3 F4	F2 F3	F2 F3	F2 F3 F4	F2 F3 F4	F1	F2	F2 F3 F4	F2	F2 F3	F2 F3	F2 F3 F4					
Stormwater							G2			G1 G2	G1 G2	G1 G2		G2	G1 G2	G1 G2	G1 G2	G1 G2	G1 G2		G2	G1	G1					
Parking and Driveway Access						H2 H4 H6 H7	H6 H7 H8			H1 H3 H5 H6 H7	H1 H3 H5 H6 H7	H1 H3 H5 H6 H7	H2 H4 H6 H7	H6 H7 H8	H1 H3 H5 H6 H7	H1 H3 H5 H6 H7	H1 H3 H5 H6 H7	H1 H3 H5 H6 H7	H1 H3 H5 H6 H7	H2 H4 H6 H7	H6 H7 H8	H3	H3					

	Not Relevant		Unsuitable Land Use

SCHEDULE 2B
PRESCRIPTIVE FLOOD RELATED DEVELOPMENT CONTROLS – MAJOR OVERLAND FLOW

Flood Planning Constraint Category 1 (FPCC 1)

Planning considerations	Essential Community Facilities and Critical Utilities and land uses	Flood Vulnerable Residential	Subdivision and Filling	Residential	Commercial / Industrial	Recreational and Non-Urban	Additions to Dwellings and Ancillary Developments
Minimum Habitable Floor Level						A1	A2 A4
Building Components						B1	B1
Structural Soundness						C1	C1
Flood Affectation						D1	D1
Emergency Response						E1	E1
Management and Design						F2	F2
Stormwater							
Parking and Driveway Access						H2 H4 H6 H7	H6 H7 H8

Flood Planning Constraint Category 2 (FPCC 2)

Planning considerations	Essential Community Facilities and Critical Utilities and land uses	Flood Vulnerable Residential	Subdivision and Filling	Residential	Commercial / Industrial	Recreational and Non-Urban	Additions to Dwellings and Ancillary Developments
Minimum Habitable Floor Level				A2	A4	A1	A2 A3
Building Components				B1	B1	B1	B1
Structural Soundness				C1	C1	C1	C1
Flood Affectation			D1	D1	D1	D1	D2
Emergency Response			E5				
Management and Design			F1 F3	F2	F2 F4	F2	F2
Stormwater			G1	G1	G1		
Parking and Driveway Access			H1 H3 H5 H6 H7	H1 H3 H5 H6 H7	H1 H3 H5 H6 H7	H2 H4 H6 H7	H6 H7 H8

Flood Planning Constraint Category 3 (FPCC 3)

Planning considerations	Essential Community Facilities and Critical Utilities and land uses	Flood Vulnerable Residential	Subdivision and Filling	Residential	Commercial / Industrial	Recreational and Non-Urban	Additions to Dwellings and Ancillary Developments
Minimum Habitable Floor Level	A2	A2		A2	A4	A1	A2 A3
Building Components	B2	B2		B1	B1	B1	B1
Structural Soundness	C2	C2		C1	C1	C1	C1
Flood Affectation							
Emergency Response	E2 orE 3	E2 E4	E5				
Management and Design	F2 F3	F2 F3 F4	F1 F3		F4		
Stormwater	G1	G1	G1	G1	G1		
Parking and Driveway Access	H1 H3 H5 H6	H1 H3 H5 H6	H1 H3 H5 H6	H1 H3 H5 H6	H1 H3 H5 H6	H2 H4 H6	H6 H8

Flood Planning Constraint Category 4 (FPCC 4)

Planning considerations	Essential Community Facilities and Critical Utilities and land uses	Flood Vulnerable Residential	Subdivision and Filling	Residential	Commercial / Industrial	Recreational and Non-Urban	Additions to Dwellings and Ancillary Developments
Minimum Habitable Floor Level	A2	A2					
Building Components	B2	B2					
Structural Soundness	C2	C2					
Flood Affectation							
Emergency Response	E2 or E3	E2 E4					
Management and Design	F2 F3	F2 F3 F4					
Stormwater	G1	G1					
Parking and Driveway Access	H3	H3					

Legend	
(green)	Not Relevant
(purple)	Unsuitable Land Use

Prescriptive controls for associated planning considerations under each FPCC

Minimum Habitable Floor Level

A1 Habitable floor levels to be set no lower than the 2% AEP flood level plus freeboard(1) unless justified by site specific assessment.

A2 Habitable floor levels to be set no lower than the 1% AEP flood level plus freeboard(1).

A3 Habitable floor levels to be as close to the Minimum Habitable Floor Level as practical and no lower than the existing floor level when undertaking concessional development.

A4 Habitable floor levels to be as close to the 1% AEP flood level plus freeboard(1) as practical, but no lower than the 2% AEP flood level plus freeboard(1). In situations where the habitable floor level is set below the 1% AEP flood level plus freeboard(1), a mezzanine area equal to 20% of the total habitable floor area or 20 m^2 (whichever is the largest) is to be provided, the elevation of which is to be set no lower than the 1% AEP flood level plus freeboard(1).

Building Components & Method

B1 All structures to have flood compatible building components below the 1% AEP flood level plus freeboard(1) (refer **Schedules 3A** and **3B**).

B2 All structures to have flood compatible building components below the 1% AEP flood plus freeboard(1) or the PMF/Extreme Flood level, whichever is the highest (refer **Schedules 3A** and **3B**).

Structural Soundness

C1 Engineers report to certify that any structure can withstand the forces of floodwater, debris and buoyancy up to and including a 1% AEP flood plus freeboard(1).

C2 Applicant to demonstrate that any structure can withstand the forces of floodwater, debris and buoyancy up to and including a 1% AEP flood plus freeboard(1) or a PMF/Extreme, whichever is the greatest.

Flood Affectation

D1 Engineers report required to certify that the development will not increase flood affectation elsewhere.

D2 The impact of the development on flooding elsewhere to be considered.

Note: When assessing flood affectation the following must be considered:
1. Loss of storage in the floodplain (Only for development being assessed under Schedule 2A).
2. Changes in flood levels and flow velocities caused by alteration of conveyance of flood waters.
3. Impacts of urbanisation on peak flood flows and volumes.

Emergency Response

E1 Reliable egress for pedestrians and vehicles required during a 1% AEP flood.

E2 Reliable egress for pedestrians and vehicles required during a PMF/Extreme Flood.

E3 Reliable egress for pedestrians or vehicles is required from the building, commencing at a minimum level equal to the lowest habitable floor level to an area of refuge above the PMF/Extreme Flood level, or a minimum of 20 m^2 of the dwelling to be above the PMF/Extreme Flood level.

E4 The development is to be consistent with any relevant flood evacuation strategy or similar plan.

E5 Applicant to demonstrate that there is rising road egress/access from all allotments internal to the subdivision to land which lies above the PMF/Extreme Flood.

Management and Design

F1 Applicant to demonstrate that potential development as a consequence of a subdivision or development proposal can be undertaken in accord with this Plan.

F2 Flood Safe Plan (home or business or farm houses) to address safety and property damage issues (including goods storage and stock management) considering the full range of flood risk.

F3 Site Emergency Response Flood Plan required considering the full range of flood risk

F4 No external storage of materials below the Minimum Habitable Floor Level which may cause pollution or be potentially hazardous during any flood.

Stormwater

G1 Engineers report required to certify that the development will not affect stormwater drainage.

G2 The impact of the development on local overland flooding to be considered.

Parking and Driveway Access

H1 The minimum surface level of open car parking spaces or carports shall be as high as practical, but no lower than the 2% AEP flood or the level of the crest of the road at the location where the site has access. In the case of garages, minimum surface level shall be as high as practical but no lower than the 2% AEP flood.

H2 The minimum surface level of open car parking spaces, carports or garages shall be as high as practical

H3 Garages capable of accommodating more than three motor vehicles on land zoned for urban purposes, or enclosed car parking, must be protected from inundation by floods up to the 1% AEP flood plus freeboard(1).

H4 The driveway providing access between the road and parking space shall be as high as practical and generally rising in the egress direction.

H5 The level of the driveway providing access between the road and parking space shall be no lower than 0.3 m below the 1% AEP flood or such that the depth of inundation during a 1% AEP flood is not greater than either the depth at the road or the depth at the car parking space. A lesser standard may be accepted for single detached dwelling houses where it can be demonstrated that risk to human life would not be compromised.

H6 Enclosed car parking and car parking areas accommodating more than three vehicles (other than on Rural zoned land), with a floor level below the 2% AEP flood or more than 0.8 m below the 1% AEP flood level, shall have adequate warning systems, signage and exits.

H7 Restraints or vehicle barriers to be provided to prevent floating vehicles leaving the site during a 1% AEP flood.

H8 Driveway and parking space levels to be no lower than the design ground/floor levels. Where this is not practical, a lower level may be considered. In these circumstances, the level is to be as high as practical, and, when undertaking concessional development, no lower than existing levels.

H9 Flood related parking and access requirements to be advised by Council if necessary. Contact Council for advice as early as possible.

Unless stated otherwise in an adopted location specific Floodplain Risk Management Study and Plan, freeboard is equal to 0.5 m for development being assessed under Schedule 2A and 0.3 m for development being assessed under Schedule 2B.

SCHEDULE 3A
GENERAL BUILDING MATTERS

Electrical and Mechanical Equipment

For dwellings constructed on land to which this policy applies, the electrical and mechanical materials, equipment and installation should conform to the following requirements.

Main Power Supply

Subject to the approval of the relevant authority the incoming main commercial power service equipment, including all metering equipment, shall be located above the relevant elevation referred to in control B1 or B2 of **Schedules 2A** and **2B**. Means shall be available to easily isolate the dwelling from the main power supply.

Wiring

All wiring, power outlets, switches, etc, should be, to the maximum extent possible, located above the relevant elevation referred to in control B1 or B2 of **Schedules 2A** and **2B**. All electrical wiring installed below this level should be suitable for continuous underwater immersion and should contain no fibrous components. Earth leakage circuit breakers (core balance relays) must be installed. Only submersible type splices should be used below the relevant elevation referred to in control B1 or B2 of **Schedules 2A** and **2B**. All conduits located below the relevant designated flood level should be so installed that they will be self-draining if subjected to flooding.

Equipment

All equipment installed below or partially below the relevant elevation referred to in control B1 or B2 of **Schedules 2A** and **2B** should be capable of disconnection by a single plug and socket assembly.

Reconnection

Should any electrical device and/or part of the wiring be flooded it should be thoroughly cleaned or replaced and checked by an approved electrical contractor before reconnection.

Heating and Air Conditioning Systems

Where viable, heating and air conditioning systems should be installed in areas and spaces of the house above the relevant elevation referred to in control B1 or B2 of **Schedules 2A** and **2B**. When this is not feasible, every precaution should be taken to minimise the damage caused by submersion according to the following guidelines:

i) Fuel

Heating systems using gas or oil as a fuel should have a manually operated valve located in the fuel supply line to enable fuel cut-off.

ii) Installation

The heating equipment and fuel storage tanks should be mounted on and securely anchored to a foundation pad of sufficient mass to overcome buoyancy and prevent movement that could damage the fuel supply line. All storage tanks should be vented to the relevant elevation referred to in control B1 or B2 of **Schedules 2A** and **2B**.

iii) Ducting

All ductwork located below the relevant elevation referred to in control B1 or B2 of **Schedules 2A** and **2B** should be provided with openings for drainage and cleaning. Self-draining may be achieved by constructing the ductwork on a suitable grade. Where ductwork must pass through a watertight wall or floor below the relevant flood level, a closure assembly operated from above the relevant elevation set out under B1 or B2 of **Schedules 2A** and **2B** should protect the ductwork.

Sewer

All sewer connections to properties in flood prone areas are to be fitted with reflux valves.

SCHEDULE 3B
FLOOD COMPATIBLE MATERIALS

Building Component	Flood Compatible Material	Building Component	Flood Compatible Material
Flooring and Sub Floor Structure	• Concrete slab-on-ground monolith construction. Note: clay filling is not permitted beneath slab-on-ground construction which could be inundated. • Pier and beam construction or • Suspended reinforced concrete slab	**Doors**	• Solid panel with waterproof adhesives • Flush door with marine ply filled with closed cell foam • Painted material construction • Aluminium or galvanised steel frame
Floor Covering	• Clay tiles • Concrete, precast or in situ • Concrete tiles • Epoxy formed-in-place • Mastic flooring, formed-in-place • Rubber sheets or tiles with chemical set adhesive • Silicone floors formed-in-place • Vinyl sheets or tiles with chemical-set adhesive • Ceramic tiles, fixed with mortar or chemical set adhesive • Asphalt tiles, fixed with water resistant adhesive • Removable rubber-backed carpet	**Wall and Ceiling Linings**	• Brick, face or glazed • Clay tile glazed in waterproof mortar • Concrete • Concrete block • Steel with waterproof applications • Stone natural solid or veneer, waterproof grout • Glass blocks • Glass • Plastic sheeting or wall with waterproof adhesive
Wall Structure	Solid brickwork, blockwork, reinforced, concrete or mass concrete	**Insulation**	• Foam or closed cell types
Windows	Aluminium frame with stainless steel or brass rollers	**Nails, Bolts, Hinges and Fittings**	• Galvanised • Removable pin hinges

NARROMINE SHIRE COUNCIL

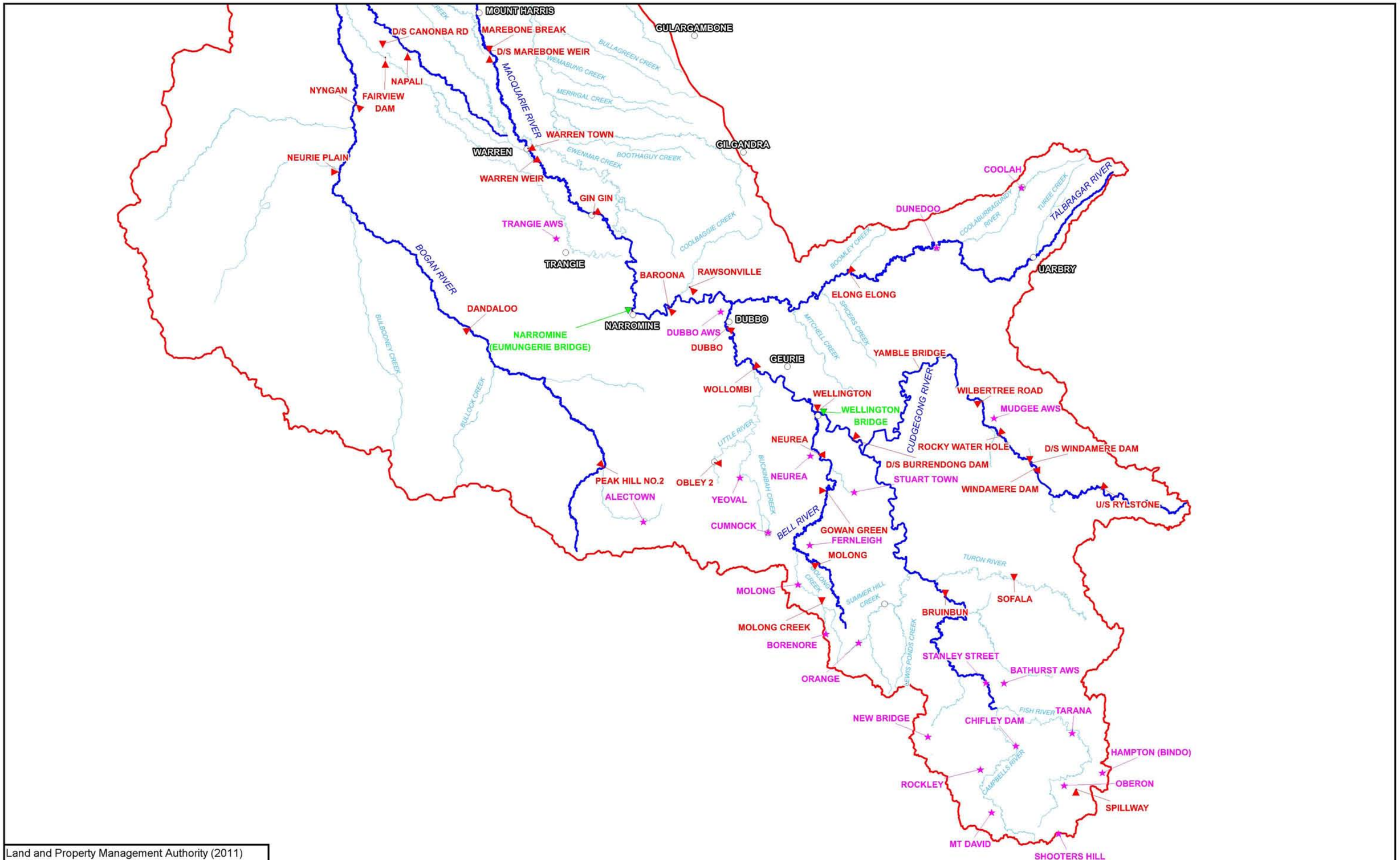
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

JULY 2021

VOLUME 2 – FIGURES

Job No: AT477 File: NTFRMSPU_V2_Figures_[Rev 1.6].docx	Date: July 2021 Rev No: 1.6	Principal: SAB Author: SAB

LIST OF FIGURES



Land and Property Management Authority (2011)
State of New South Wales through NSW SES (2011)

N

12.5 0 12.5 25 37.5 km

Scale: 1:1,250,000

Lyall & Associates

LEGEND

- Rain Gauge (Telemetered)
- Stream Gauge (Telemetered)
- Stream Gauge (Manual)
- Town Location

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 1.1

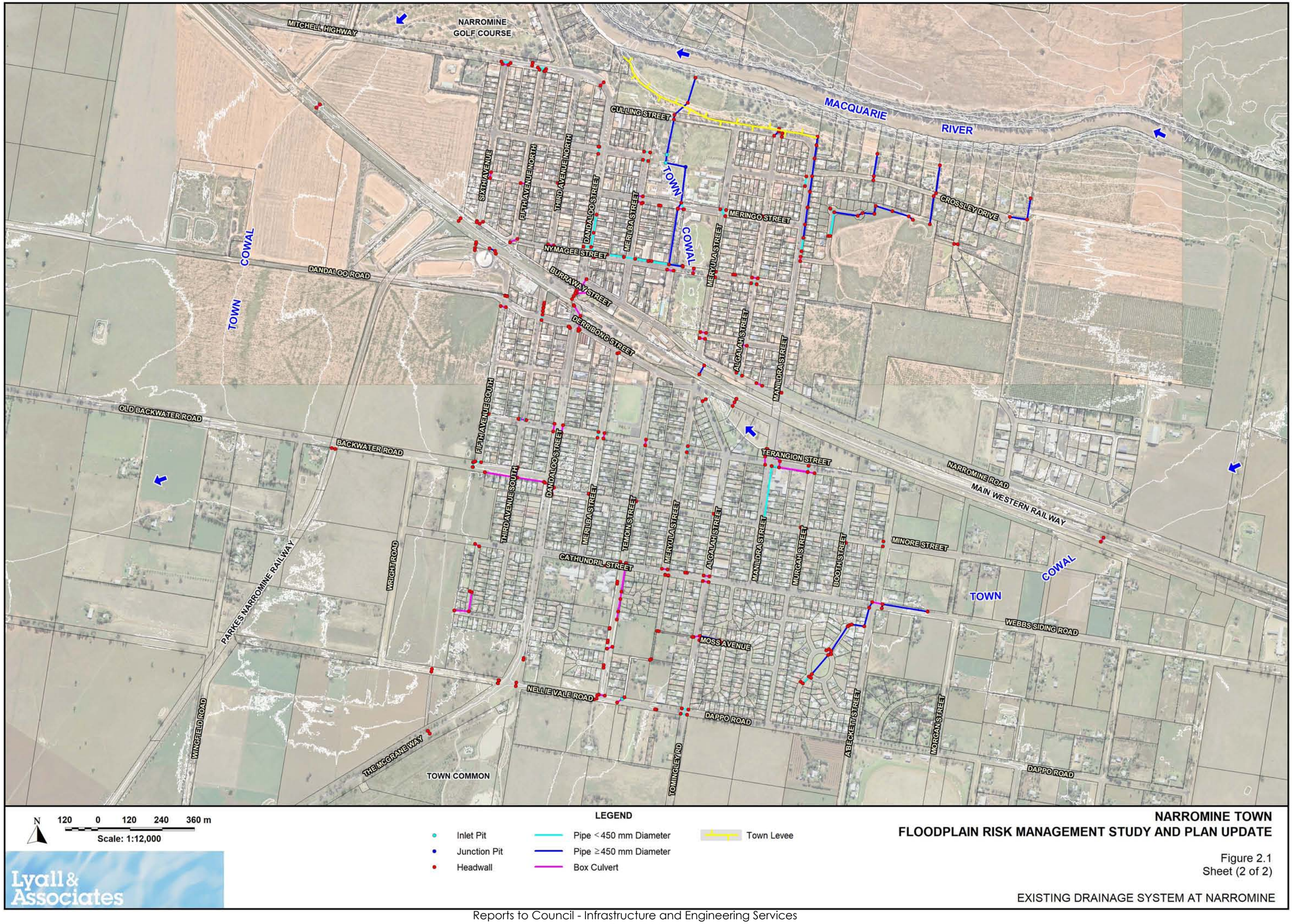
LOCATION AND VALLEY-WIDE CATCHMENT PLAN

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.1
Sheet (1 of 2)

EXISTING DRAINAGE SYSTEM AT NARROMINE

Lyall & Associates


MITCHELL HIGHWAY
NARROMINE GOLF COURSE
MACQUARIE RIVER
CULLING STREET
TOWN COWAL
SIXTH AVENUE
FIFTH AVENUE NORTH
THIRD AVENUE NORTH
DANDALOO STREET
MERLEA STREET
NYMAGEE STREET
MERINGO STREET
MERYULA STREET
CROSSLEY DRIVE
DANDALOO ROAD
TOWN COWAL
BURRAWAY STREET
DERRIBONG STREET
ALGALAH STREET
MANILDRA STREET
OLD BACKWATER ROAD
BACKWATER ROAD
FIFTH AVENUE SOUTH
THIRD AVENUE SOUTH
DANDALOO STREET
MERLEA STREET
TEMON STREET
MERYULA STREET
ALGALAH STREET
MANILDRA STREET
MURGAH STREET
BOOTH STREET
TERANGION STREET
NARROMINE ROAD
MAIN WESTERN RAILWAY
MINORE STREET
TOWN COWAL
WEBBS SIDING ROAD
PARKES NARROMINE RAILWAY
WRIGHT ROAD
CATHUNDRIL STREET
MOSS AVENUE
NELLIE VALE ROAD
DAPPO ROAD
WINGFIELD ROAD
THE McGRANE WAY
TOWN COMMON
TOMINGLEY RD
ABERCROMBIE STREET
MORGAN STREET
DAPPO ROAD
N
120 0 120 240 360 m
Scale: 1:12,000
LEGEND
Inlet Pit
Junction Pit
Headwall
Pipe <450 mm Diameter
Pipe ≥450 mm Diameter
Box Culvert
Town Levee
Lyall & Associates
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure 2.1
Sheet (2 of 2)
EXISTING DRAINAGE SYSTEM AT NARROMINE

NOTE:
Aerial photography taken on 7 December 2010. floodwater first reached its peak of 14.07m at the Narromine gauge at about 1000 hours on 7 December 2010.

WEIR GAUGE
BRIDGE GAUGE
TOWN GAUGE
237.18
237.54
238.38
238.84
238.4
238.64
239.55
239.71
239.48
239.78
239.71
240.86
MACQUARIE RIVER
NARROMINE AEROMODROME
SKY PARK
NARROMINE GOLF CLUB
MAIN WESTERN RAILWAY
NARROMINE SHOWGROUNDS
TOWN
COWAL
MITCHELL HWY
DANDALOO RD
OLD BACKWATER RD
BACKWATER RD
NARROMINE EUMUNGERIE RAIL RD
NUMBAIR RD
BURROWAY RD
NARROMINE NYNGAN RAIL RD
CULLING ST
MERINGO ST
NYMAGEE ST
TERAMOJON ST
NARROMINE RD
MINORE ST
MEBBS SIDING RD
DAPPO RD
DAPPO ROAD
JONES CIRCUIT
NELLIE VALE RD
THE MORRAWA WAY
WRIGHT RD
PARKES
HOLPARK RD
RIVER RD

N
250 0 250 500 750 m
Scale: 1:25,000

Lyall & Associates

LEGEND

- Alignment of LiDAR Survey Data Levels Along Southern Bank of Macquarie River
- Alignment of LiDAR Survey Data Levels Along Mitchell Highway
- Alignment of LiDAR Survey Data Levels Along Main Western Railway
- 238.27 Surveyed December 2010 Flood Mark (m AHD)
- Stream Gauge

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.2

AERIAL PHOTOGRAPH SHOWING HISTORIC FLOODING AT NARROMINE
DECEMBER 2010 FLOOD

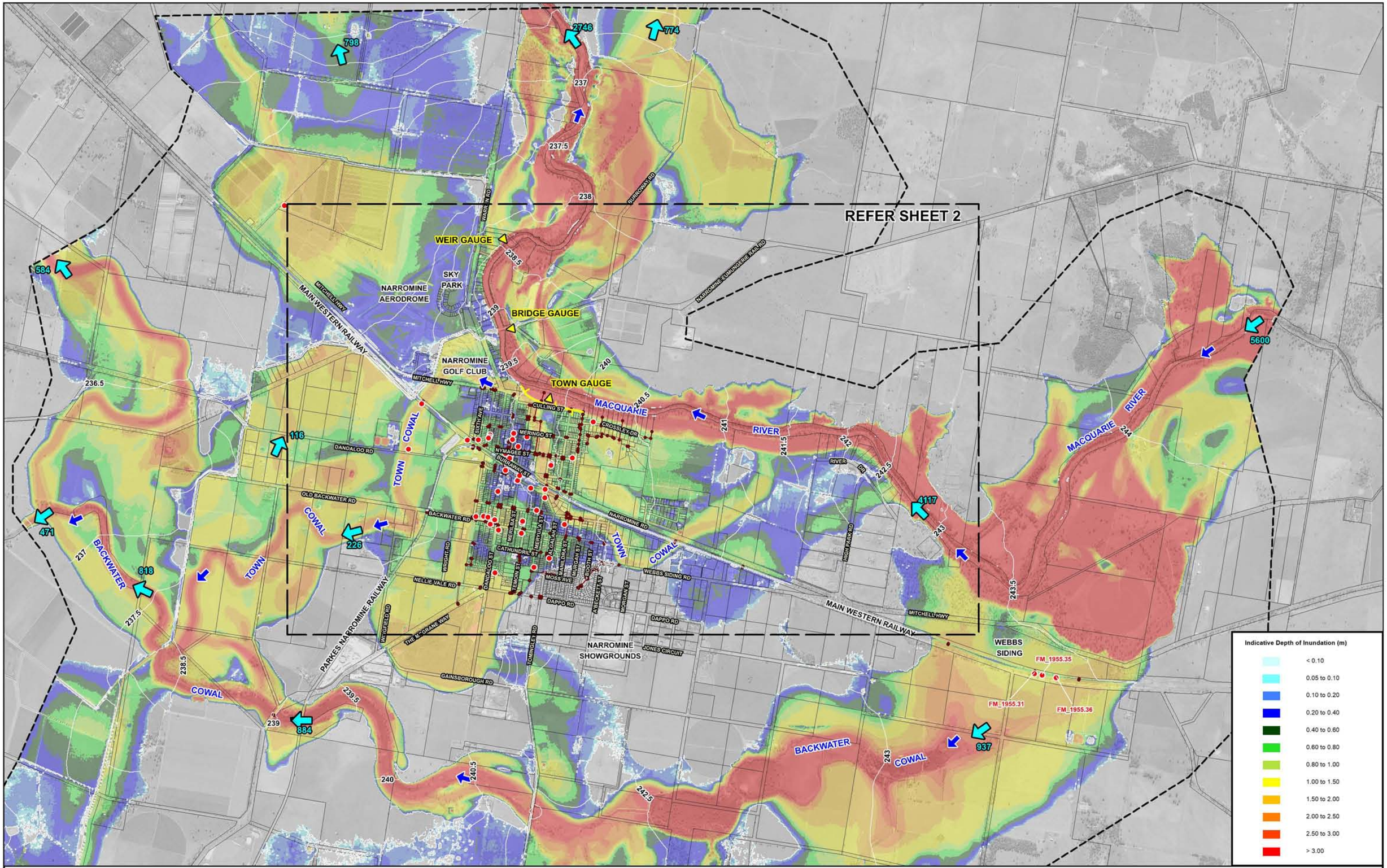
NOTE : TIME ZERO ON CALENDAR DAY AXIS = 0000 HOURS ON 28 JULY 1990
0000 HOURS ON 28 NOVEMBER 2010

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.3

STREAM GAUGE DATA
MACQUARIE RIVER AT BAROONA STREAM GAUGE (GS 421127)

Lyall & Associates



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

NOTE:
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Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

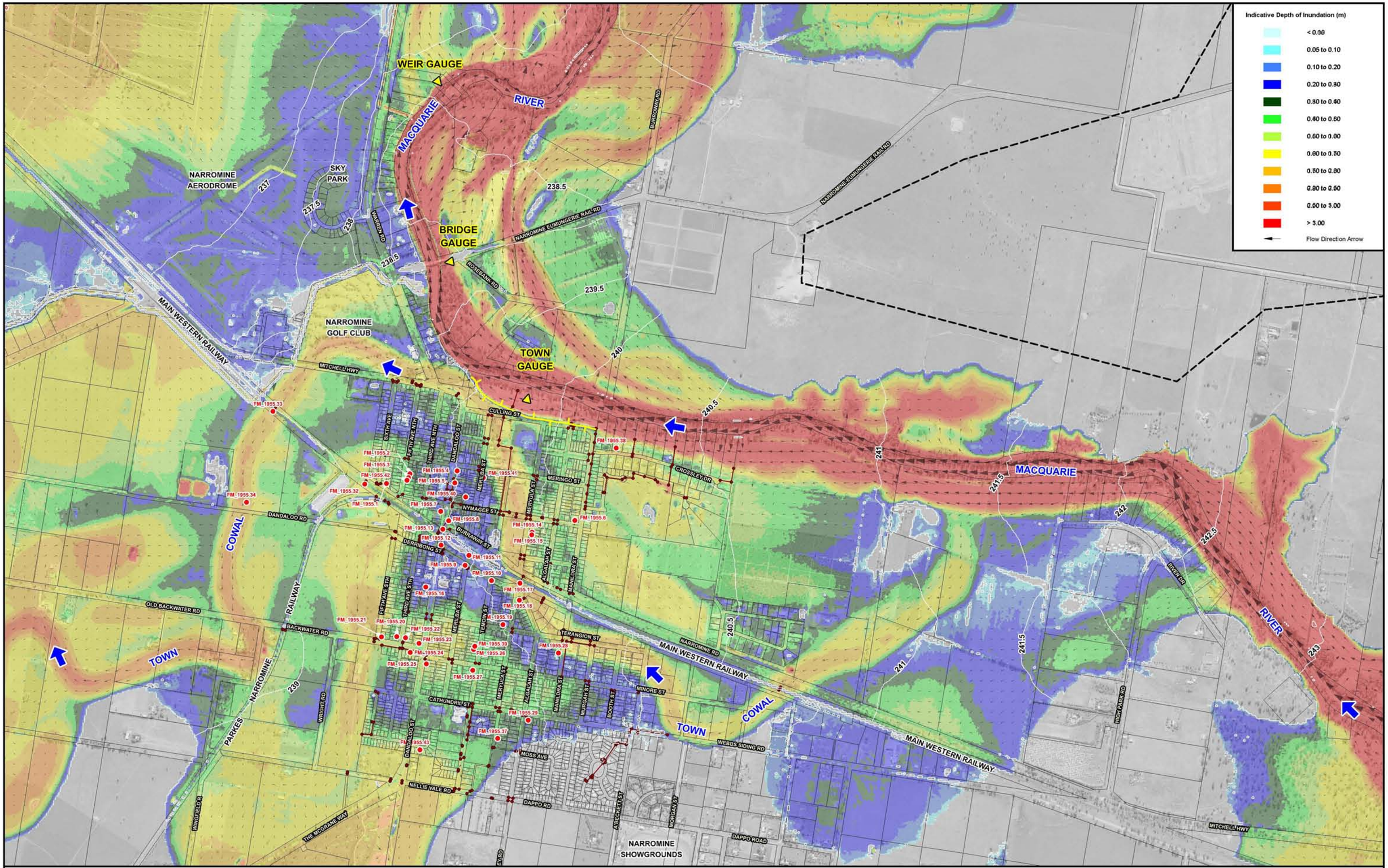
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- 5600 Peak Overland Flow(m³/s)
- Town Levee
- 238.5 Water Surface Elevation Contour (m AHD)
- FM_1955.15 Historical Flood Mark and Identifier (Source of Flood Marks: Bewsher, 1998)

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.4
(Sheet 1 of 2)

INDICATIVE EXTENT AND DEPTH OF MAIN STREAM FLOODING
FEBRUARY 1955 FLOOD



N

200 0 200 400 600 m

Scale: 1:20,000

Lyall & Associates

NOTE:
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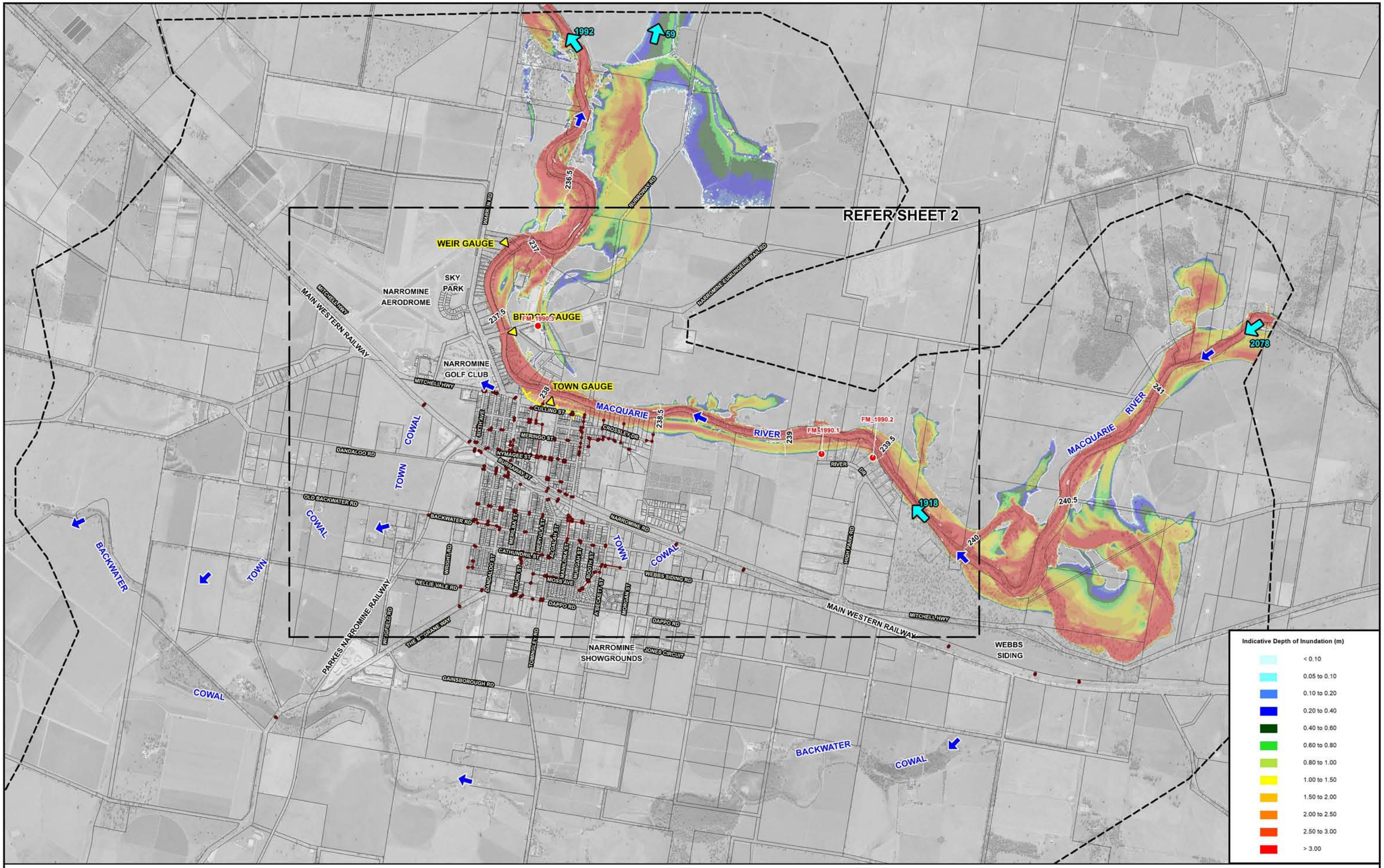
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Town Levee
- Water Surface Elevation Contour (m AHD) — 238.5
- Historical Flood Mark and Identifier (Source of Flood Marks: Bewsher, 1998) — FM_1955.15

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.4
(Sheet 2 of 2)

INDICATIVE EXTENT AND DEPTH OF MAIN STREAM FLOODING
FEBRUARY 1955 FLOOD



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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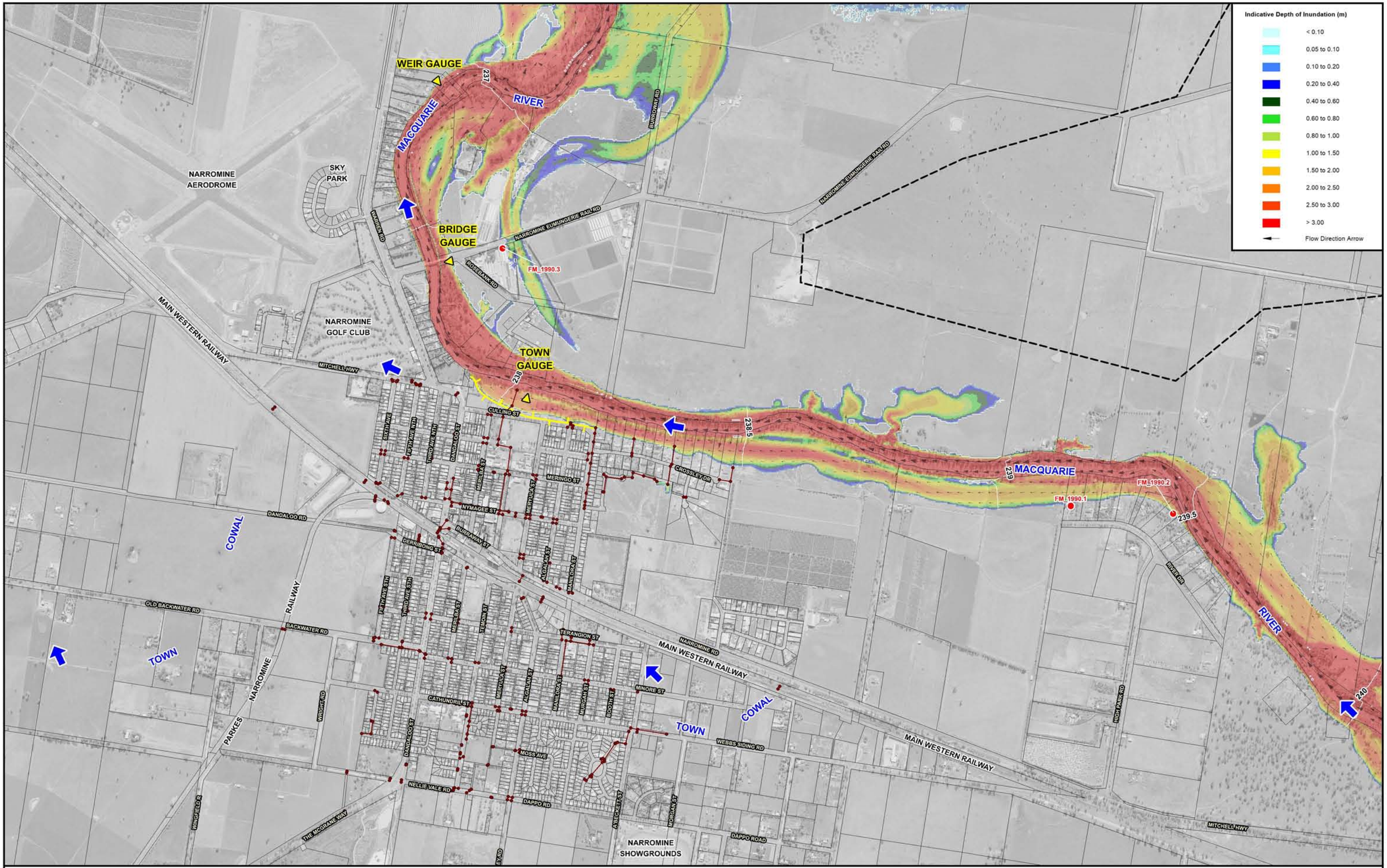
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- 5600 Peak Overland Flow(m^3/s)
- Town Levee
- 238.5 Water Surface Elevation Contour (m AHD)
- FM_1990.1 Historical Flood Mark and Identifier (Source of Flood Marks: Bewsher, 1998)

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.5
(Sheet 1 of 2)

INDICATIVE EXTENT AND DEPTH OF MAIN STREAM FLOODING
AUGUST 1990 FLOOD


Indicative Depth of Inundation (m)
< 0.10
0.05 to 0.10
0.10 to 0.20
0.20 to 0.40
0.40 to 0.60
0.60 to 0.80
0.80 to 1.00
1.00 to 1.50
1.50 to 2.00
2.00 to 2.50
2.50 to 3.00
> 3.00
Flow Direction Arrow
WEIR GAUGE
237
MACQUARIE RIVER
BURRAWAY RD
NARROMINE AERODROME
SKY PARK
NARROMINE-EUMUNGERIE RAIL RD
WARREN RD
BRIDGE GAUGE
ROSEBANK RD
FM_1990.3
MAIN WESTERN RAILWAY
NARROMINE GOLF CLUB
MITCHELL HWY
TOWN GAUGE
238
238.5
CULLING ST
SIXTH AVE
FIFTH AVE NTH
THIRD AVE NTH
DANDALOO ST
MERIDA ST
MERINGO ST
CROSSLEY DR
239
MACQUARIE
FM_1990.2
FM_1990.1
239.5
NYMAGEE ST
MERKULA ST
DANDALOO RD
COWAL
BURRAWAY ST
DERRIBONG ST
ALGALAH ST
MANILDRA ST
RIVER DR
RIVER
FIFTH AVE STH
THIRD AVE STH
OLD BACKWATER RD
RAILWAY
BACKWATER RD
TERANGION ST
NARROMINE RD
MAIN WESTERN RAILWAY
TOWN
NARROMINE
WRIGHT RD
CATHUNDRIL ST
MURGAN ST
BOORA ST
MINORE ST
COWAL
PARKES
DANDALOO ST
MOSS AVE
WEBBS SIDING RD
MAIN WESTERN RAILWAY
HIGH PARK RD
240
NELLIE VALE RD
DAPPO RD
WINGFIELD ST
THE MCGRANE WAY
ABERCRAIL ST
MORGAN ST
NARROMINE SHOWGROUNDS
DAPPO ROAD
MITCHELL HWY
N
200 0 200 400 600 m
Scale: 1:20,000
NOTE:
The ground surface model incorporated in TUFLOW is based on LiDAR survey which has been sampled on a 10 m grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.
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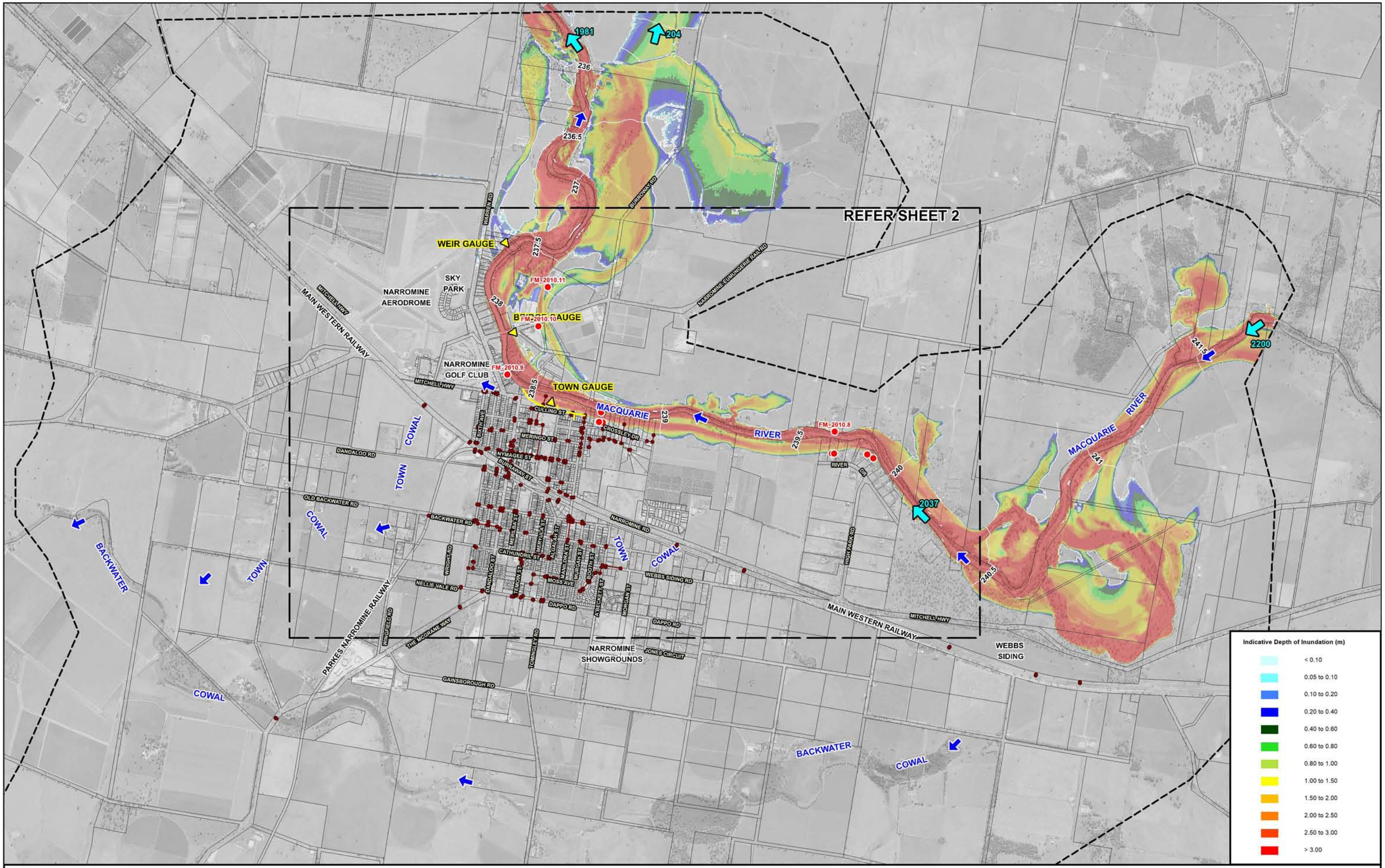
LEGEND
Two-Dimensional Model Boundary
Modelled Stormwater Drainage System
Stream Gauge
Town Levee
238.5
Water Surface Elevation Contour (m AHD)
FM_1990.1
Historical Flood Mark and Identifier (Source of Flood Marks: Bewsher, 1998)
Lyall & Associates
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure 2.5
(Sheet 2 of 2)
INDICATIVE EXTENT AND DEPTH OF MAIN STREAM FLOODING
AUGUST 1990 FLOOD



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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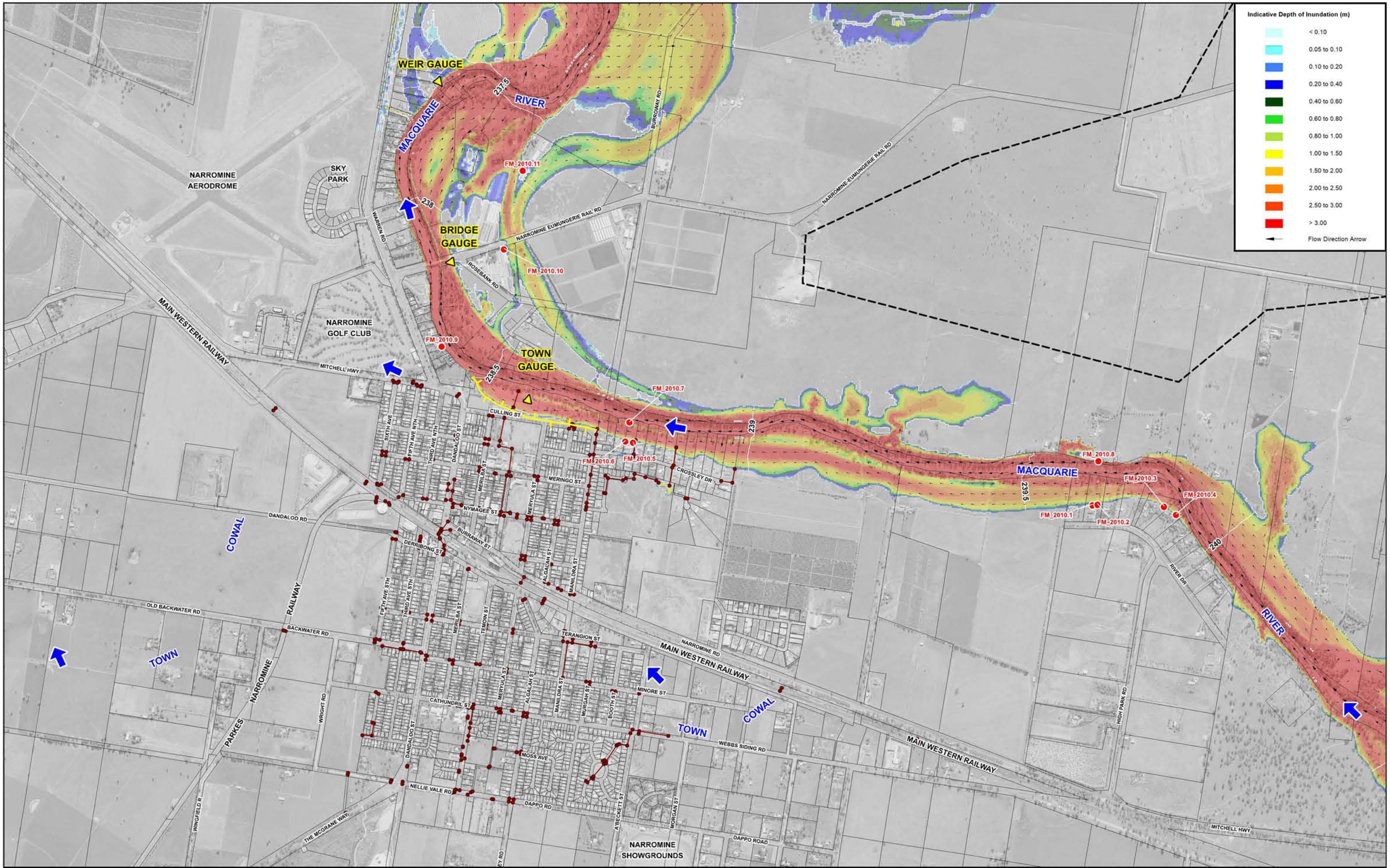
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- 5600 Peak Overland Flow(m^3/s)
- Town Levee
- 238.5 Water Surface Elevation Contour (m AHD)
- FM_2010.5 Historical Flood Mark and Identifier (Source of Flood Marks: NSW SES)

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.6
(Sheet 1 of 2)

INDICATIVE EXTENT AND DEPTH OF MAIN STREAM FLOODING
DECEMBER 2010 FLOOD


Indicative Depth of Inundation (m)
< 0.10
0.05 to 0.10
0.10 to 0.20
0.20 to 0.40
0.40 to 0.60
0.60 to 0.80
0.80 to 1.00
1.00 to 1.50
1.50 to 2.00
2.00 to 2.50
2.50 to 3.00
> 3.00
Flow Direction Arrow
WEIR GAUGE
BRIDGE GAUGE
TOWN GAUGE
MACQUARIE RIVER
237.5
238
238.5
239
239.5
240
FM_2010.1
FM_2010.2
FM_2010.3
FM_2010.4
FM_2010.5
FM_2010.6
FM_2010.7
FM_2010.8
FM_2010.9
FM_2010.10
FM_2010.11
NARROMINE AERODROME
SKY PARK
NARROMINE GOLF CLUB
NARROMINE SHOWGROUNDS
MAIN WESTERN RAILWAY
NARROMINE EUMUNGERIE RAIL RD
BURROWAY RD
ROSEBANK RD
MITCHELL HWY
DANDALOO RD
COWAL
CULLING ST
SIXTH AVE
FIFTH AVE NTH
THIRD AVE NTH
DANDALOO ST
MERILBA ST
MERINGO ST
CROSSLEY DR
NYMAGEE ST
MERYULA ST
BURRAWAY ST
DERRIBONG ST
ALGALAH ST
MANILDRA ST
FIFTH AVE STH
THIRD AVE STH
OLD BACKWATER RD
BACKWATER RD
RAILWAY
TERANGION ST
NARROMINE RD
MURGAH ST
BOOTH ST
MINORE ST
CATHUNDRIL ST
TOWN
NARROMINE
WRIGHT RD
PARKES
WINGFIELD R
THE McGRANE WAY
MOSS AVE
NELLIE VALE RD
DAPPO RD
ABBECKETT ST
MORGAN ST
WEBBS SIDING RD
DAPPO ROAD
HIGH PARK RD
RIVER DR
N
200 0 200 400 600 m
Scale: 1:20,000
Lyall & Associates
NOTE:
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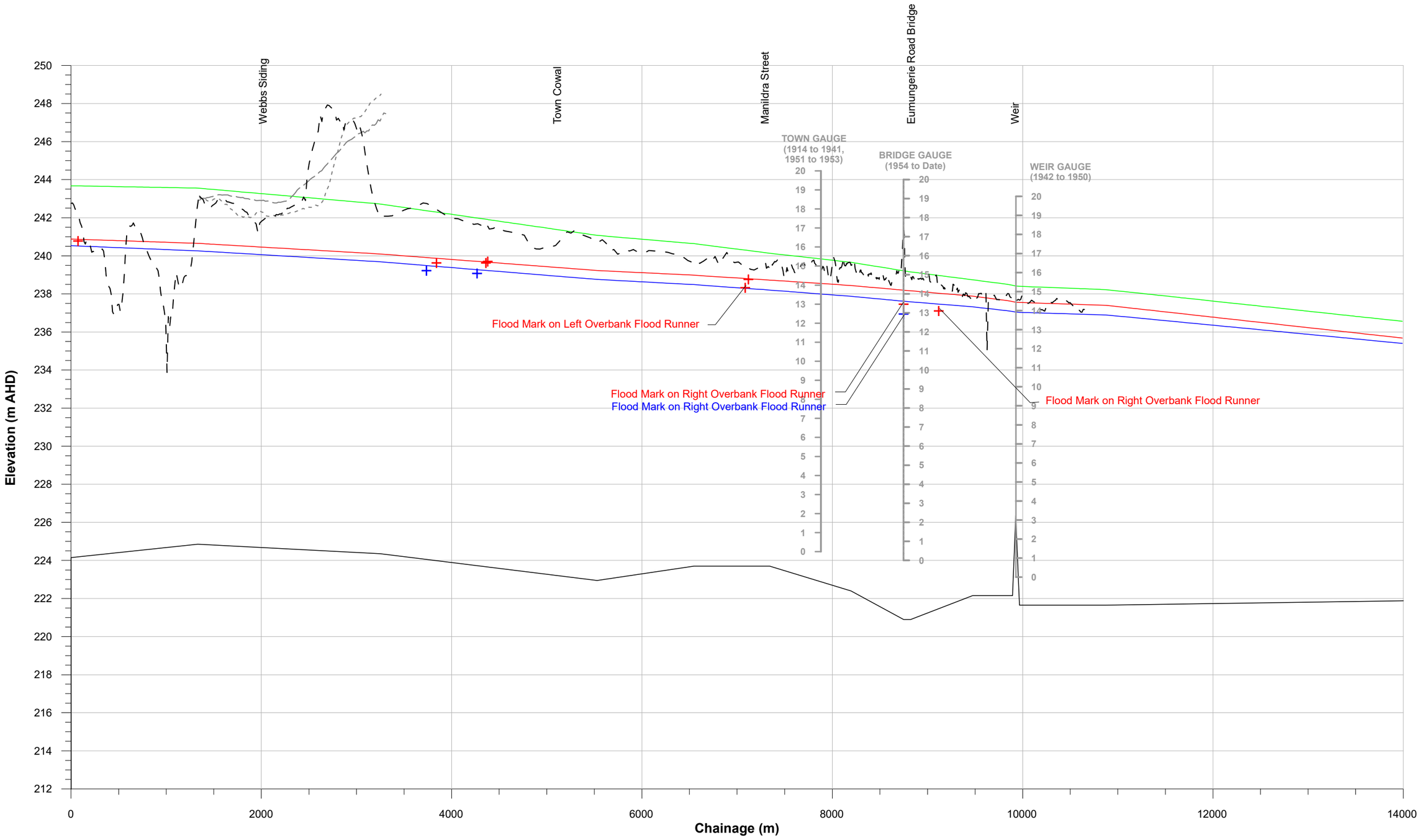
LEGEND
Two-Dimensional Model Boundary
Modelled Stormwater Drainage System
Stream Gauge
Town Levee
238.5
Water Surface Elevation Contour (m AHD)
FM_2010.5
Historical Flood Mark and Identifier (Source of Flood Marks: NSW SES)
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure 2.6
(Sheet 2 of 2)
INDICATIVE EXTENT AND DEPTH OF MAIN STREAM FLOODING
DECEMBER 2010 FLOOD



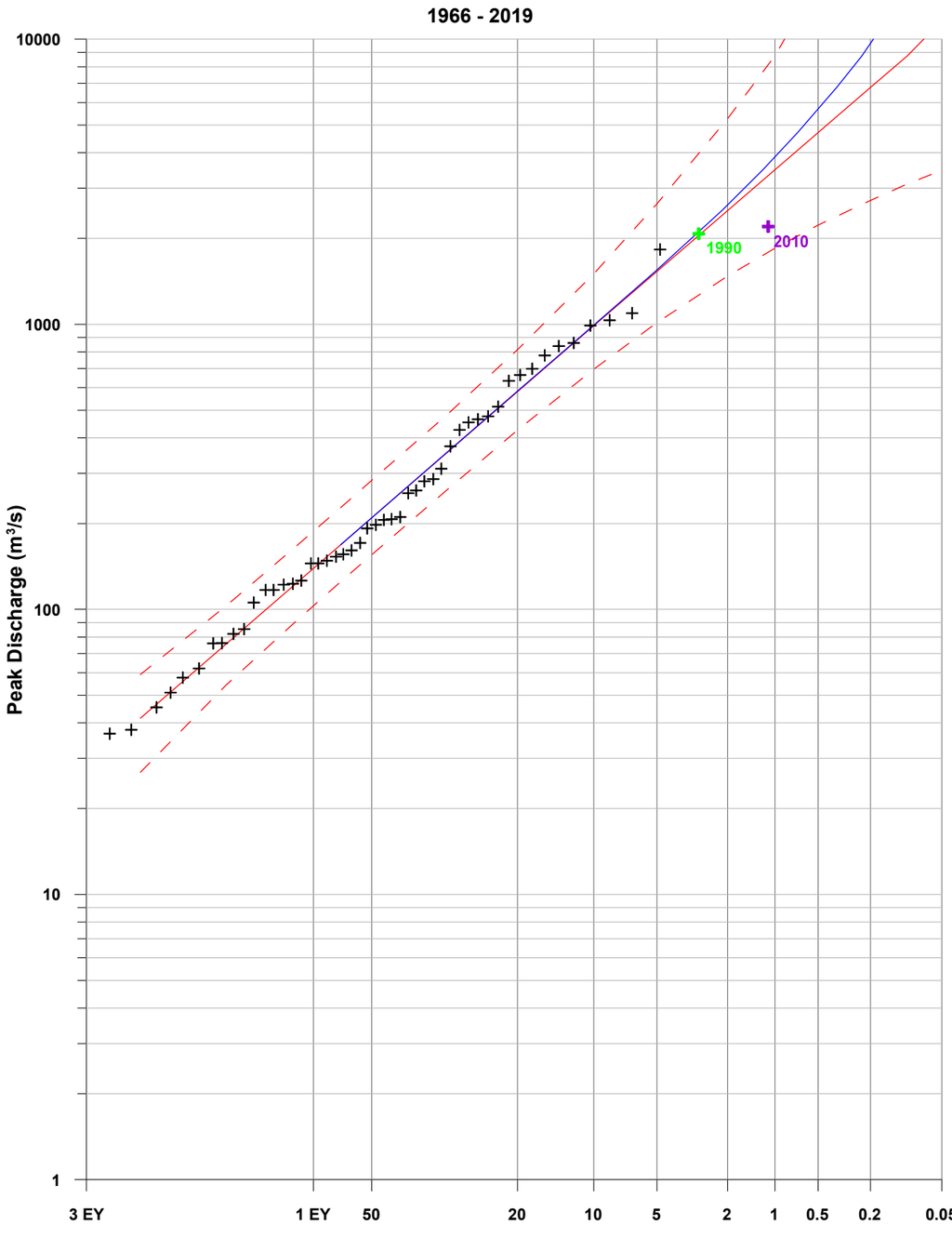
LEGEND

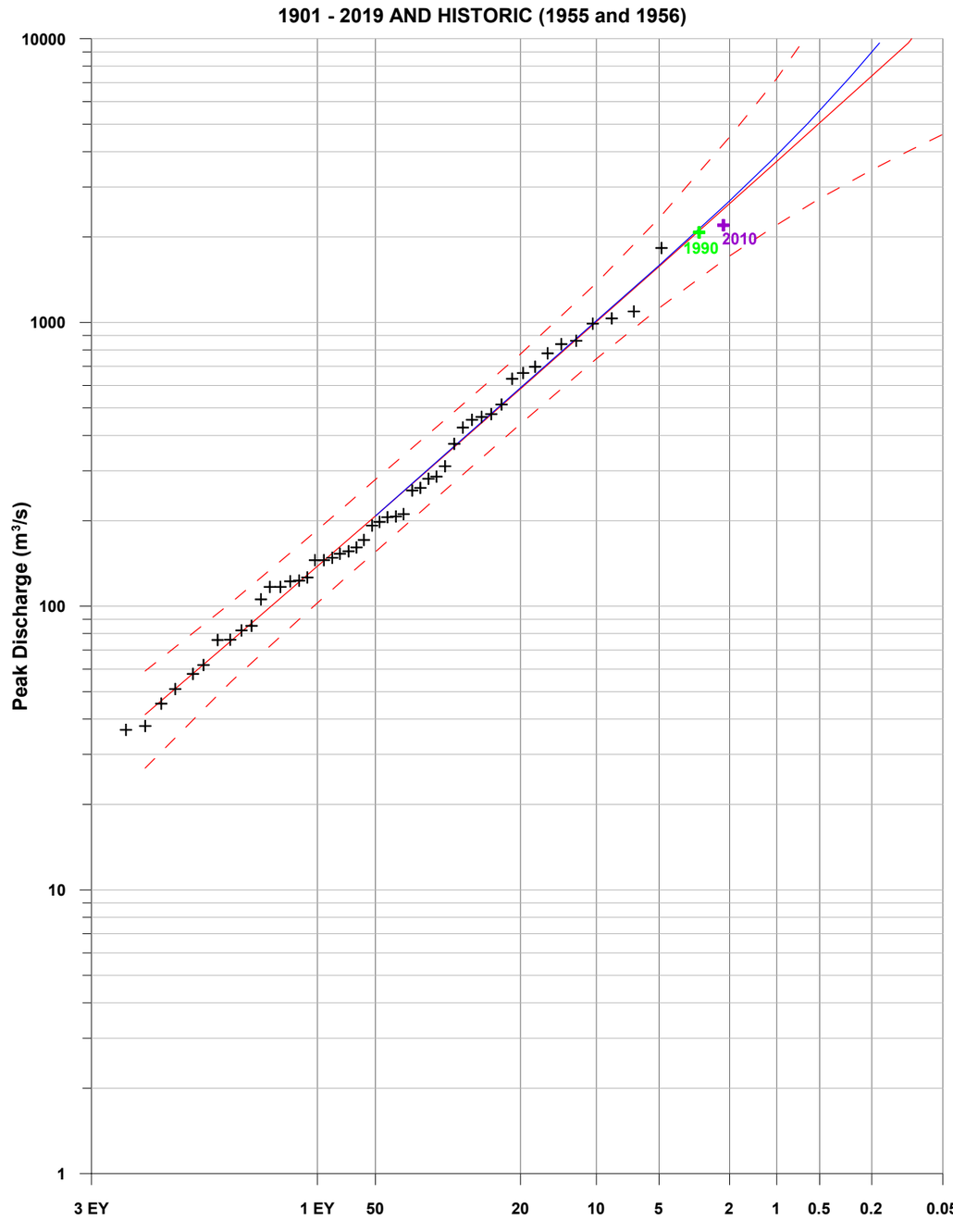
- February 1955 Flood (TUFLOW Model)
- December 2010 Flood (TUFLOW Model)
- August 1990 Flood (TUFLOW Model)
- December 2010 Flood Mark (Source: SES)
- August 1990 Flood Mark (Source: Bewsher, 1998)
- Channel Invert
- LiDAR Survey Data Levels along Southern Bank of Macquarie River
- LiDAR Survey Data Levels along Mitchell Highway
- LiDAR Survey Data Levels along Main Western Railway

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.7

HISTORIC WATER SURFACE PROFILES
MACQUARIE RIVER





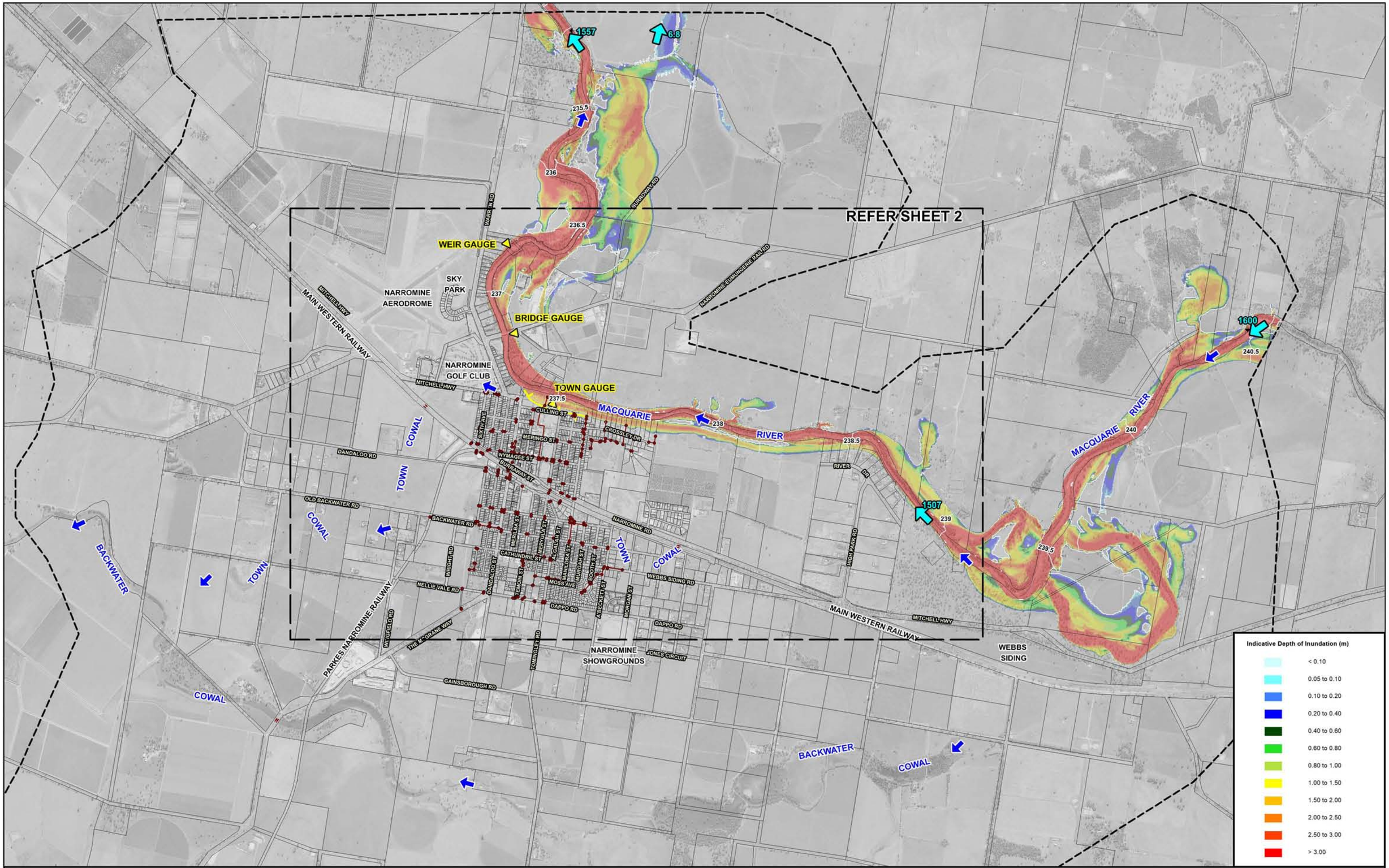
LEGEND

- Expected Probability Adjustment
- Log-Pearson III 5% Confidence Limits
- Log-Pearson III Fit
- \+ Recorded Annual Maximum Discharge

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.8

UPDATED FLOOD FREQUENCY ANALYSIS
MACQUARIE RIVER AT BAROONA STREAM GAUGE (GS 421127)



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

NOTE:
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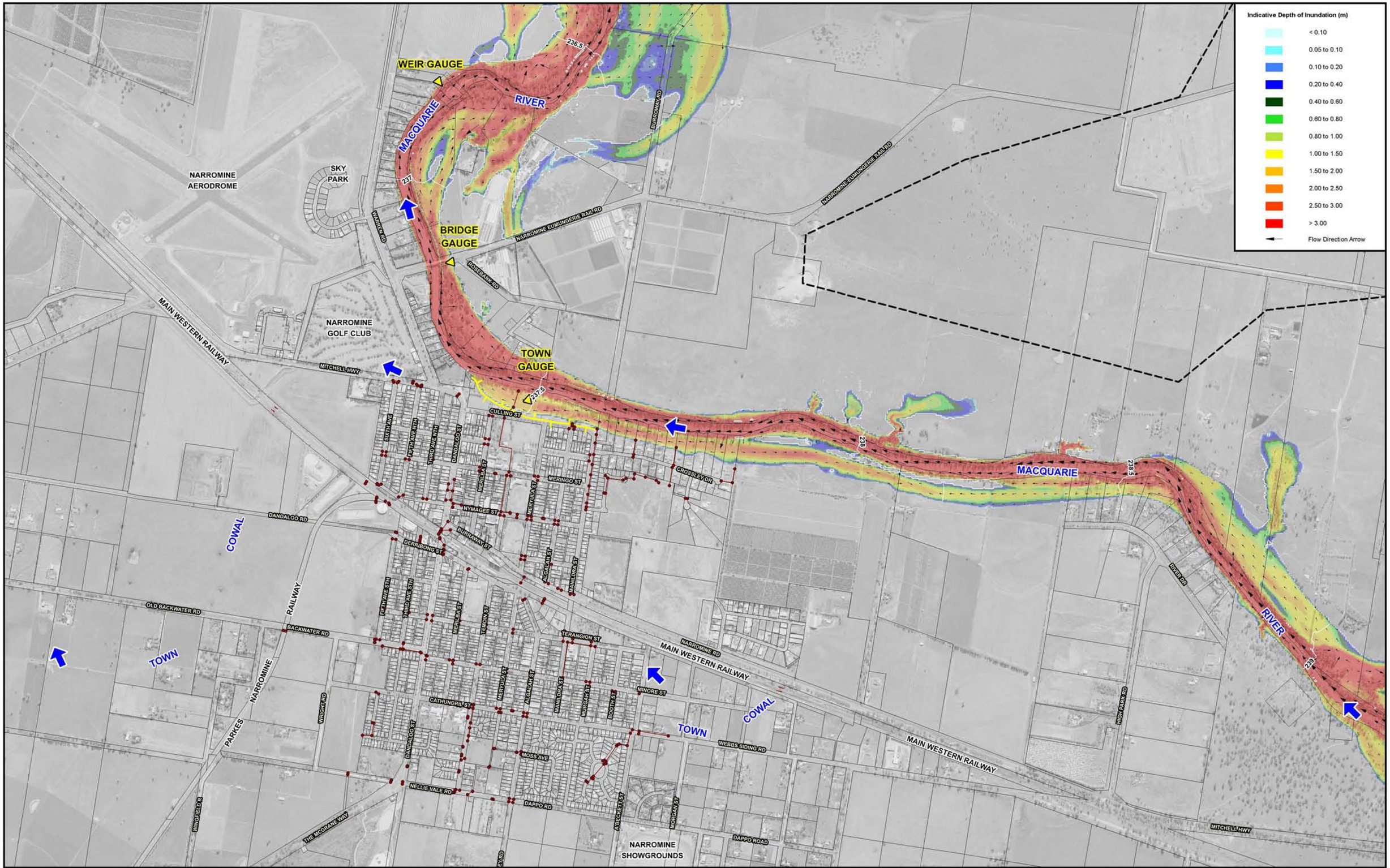
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- 5600 Peak Overland Flow(m^3/s)
- Town Levee
- 238.5 Water Surface Elevation Contour (m AHD)

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.9
(Sheet 1 of 2)

INDICATIVE EXTENT AND DEPTH OF MAIN STREAM FLOODING
5% AEP



N

200 0 200 400 600 m

Scale: 1:20,000

Lyall & Associates

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LEGEND

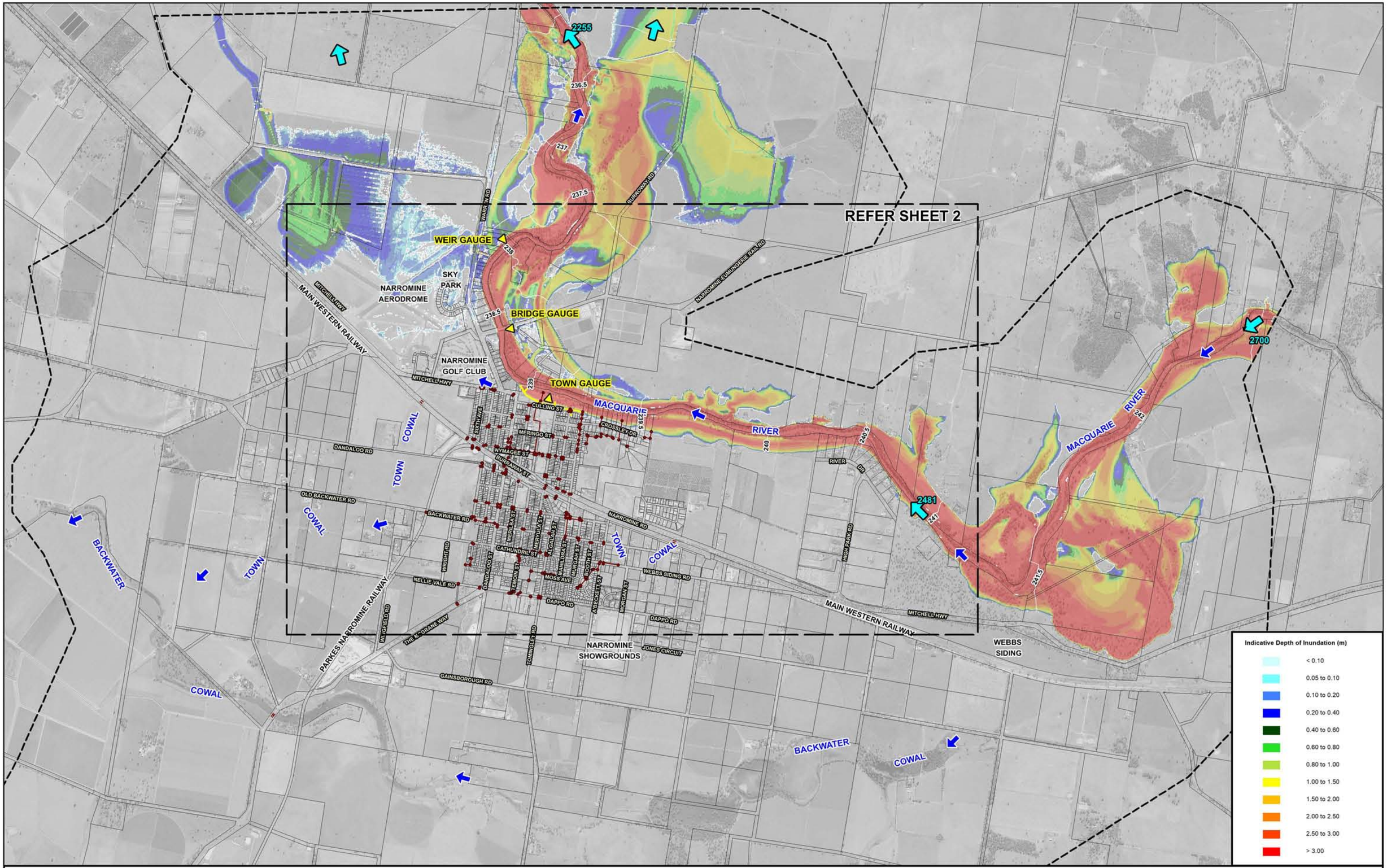
- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Town Levee
- 238.5 Water Surface Elevation Contour (m AHD)

NARROMINE TOWN

FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.9
(Sheet 2 of 2)

INDICATIVE EXTENT AND DEPTH OF MAIN STREAM FLOODING
5% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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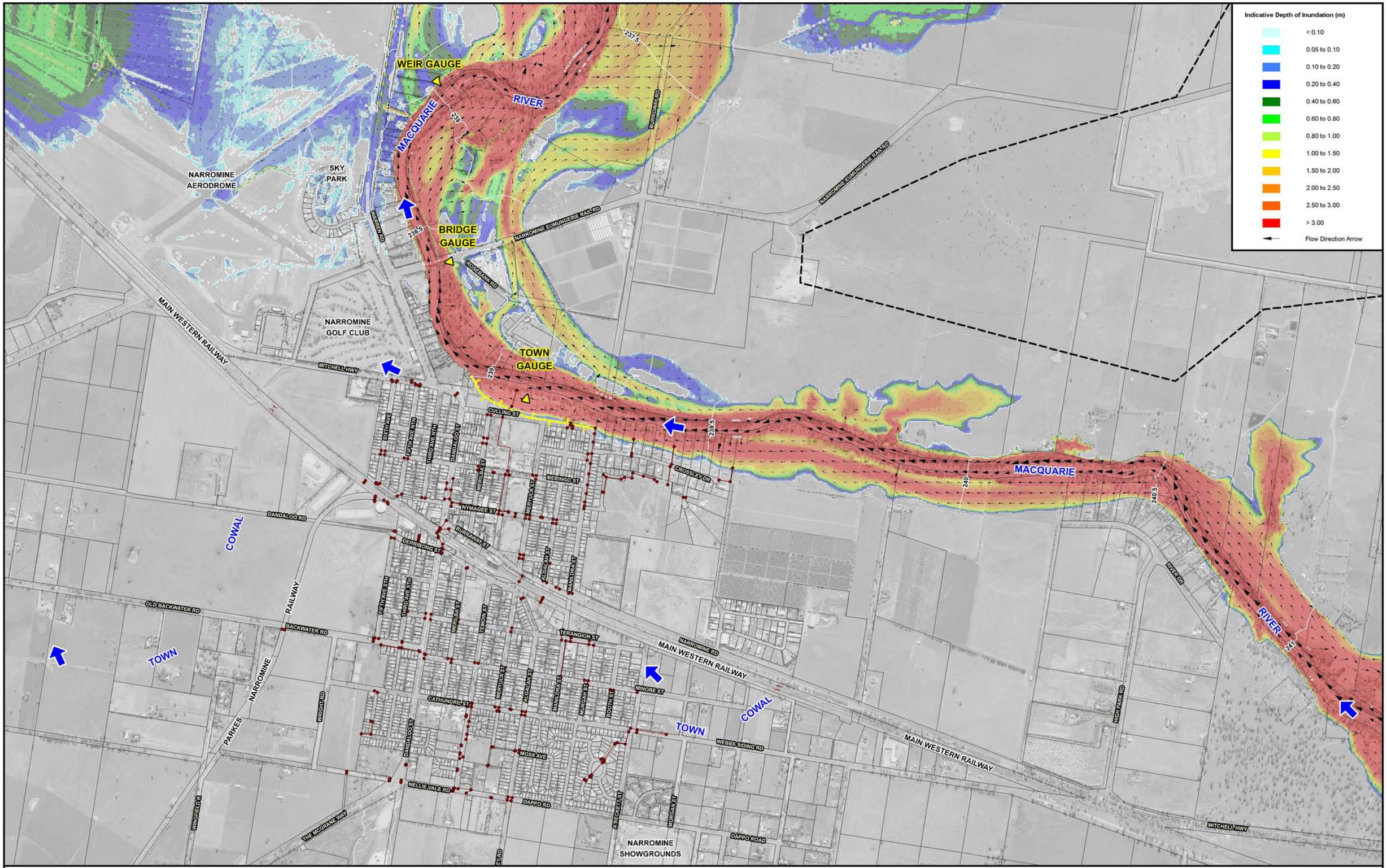
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- 5600 Peak Overland Flow(m^3/s)
- Town Levee
- 238.5 Water Surface Elevation Contour (m AHD)

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.10
(Sheet 1 of 2)

INDICATIVE EXTENT AND DEPTH OF MAIN STREAM FLOODING
2% AEP



N

200 0 200 400 600 m

Scale: 1:20,000

Lyall & Associates

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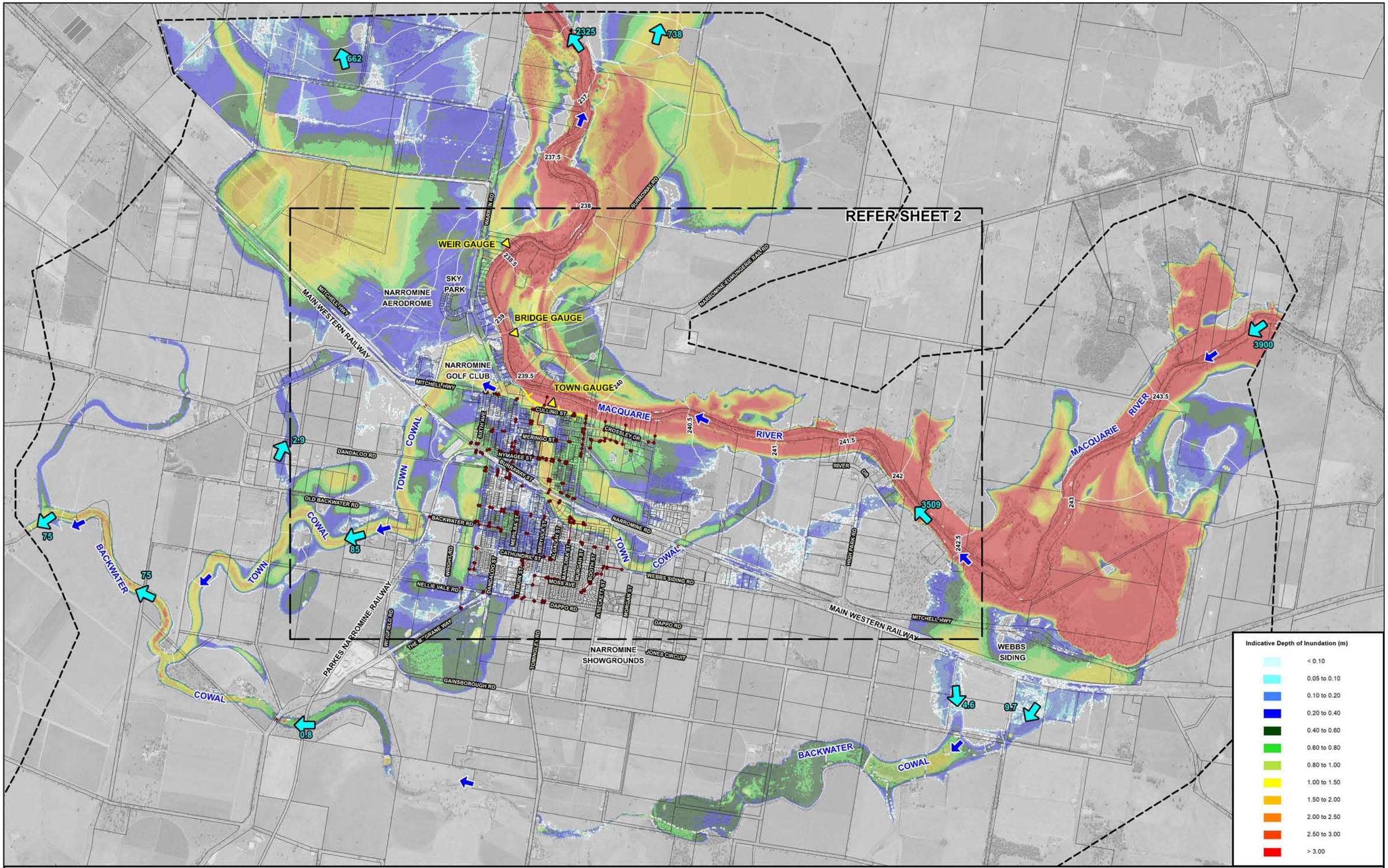
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Town Levee
- 238.5 Water Surface Elevation Contour (m AHD)

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.10
(Sheet 2 of 2)

INDICATIVE EXTENT AND DEPTH OF MAIN STREAM FLOODING
2% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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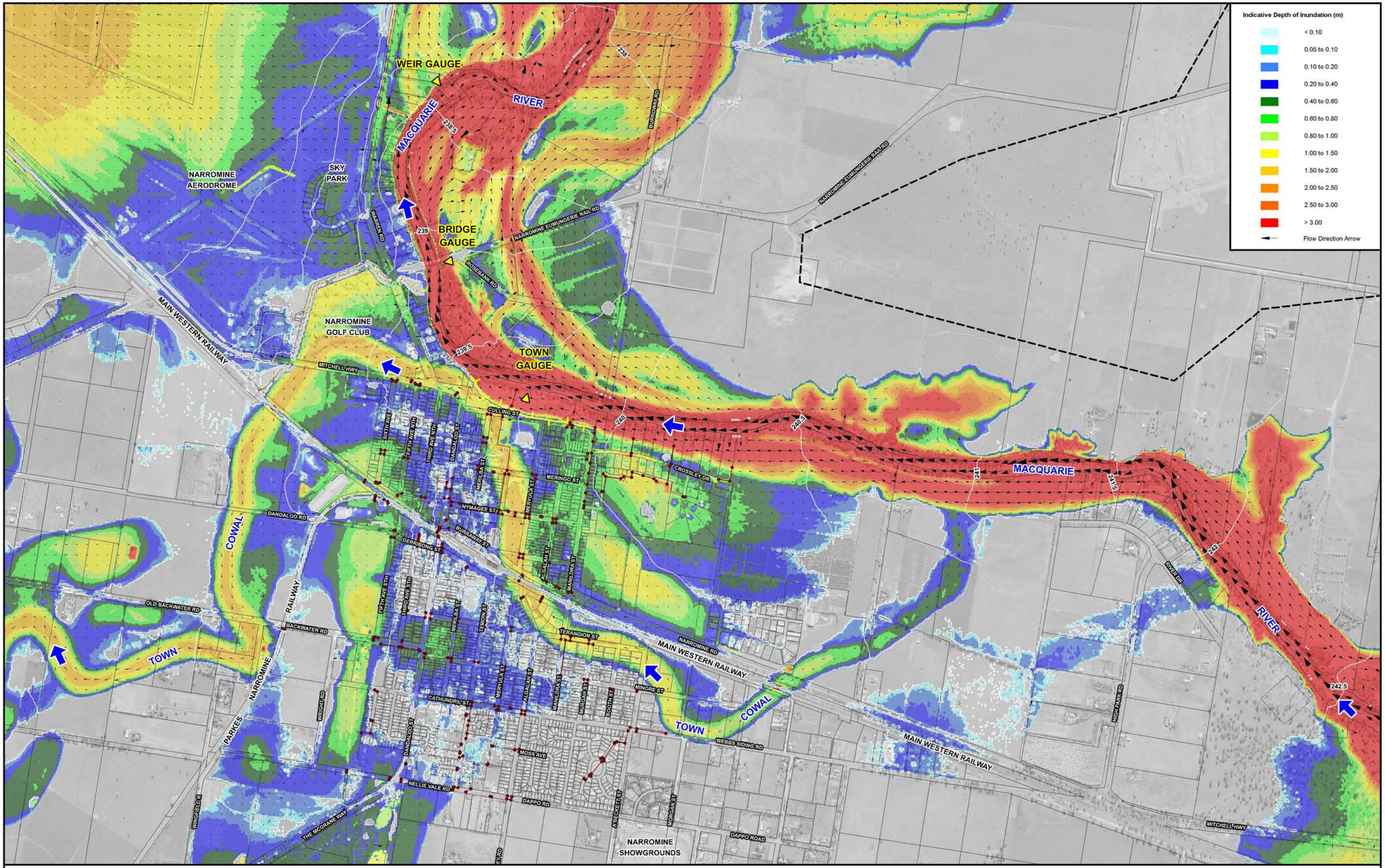
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- 5600 Peak Overland Flow(m³/s)
- Town Levee
- 238.5 Water Surface Elevation Contour (m AHD)

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.11
(Sheet 1 of 2)

INDICATIVE EXTENT AND DEPTH OF MAIN STREAM FLOODING
1% AEP



N

200 0 200 400 600 m

Scale: 1:20,000

Lyall & Associates

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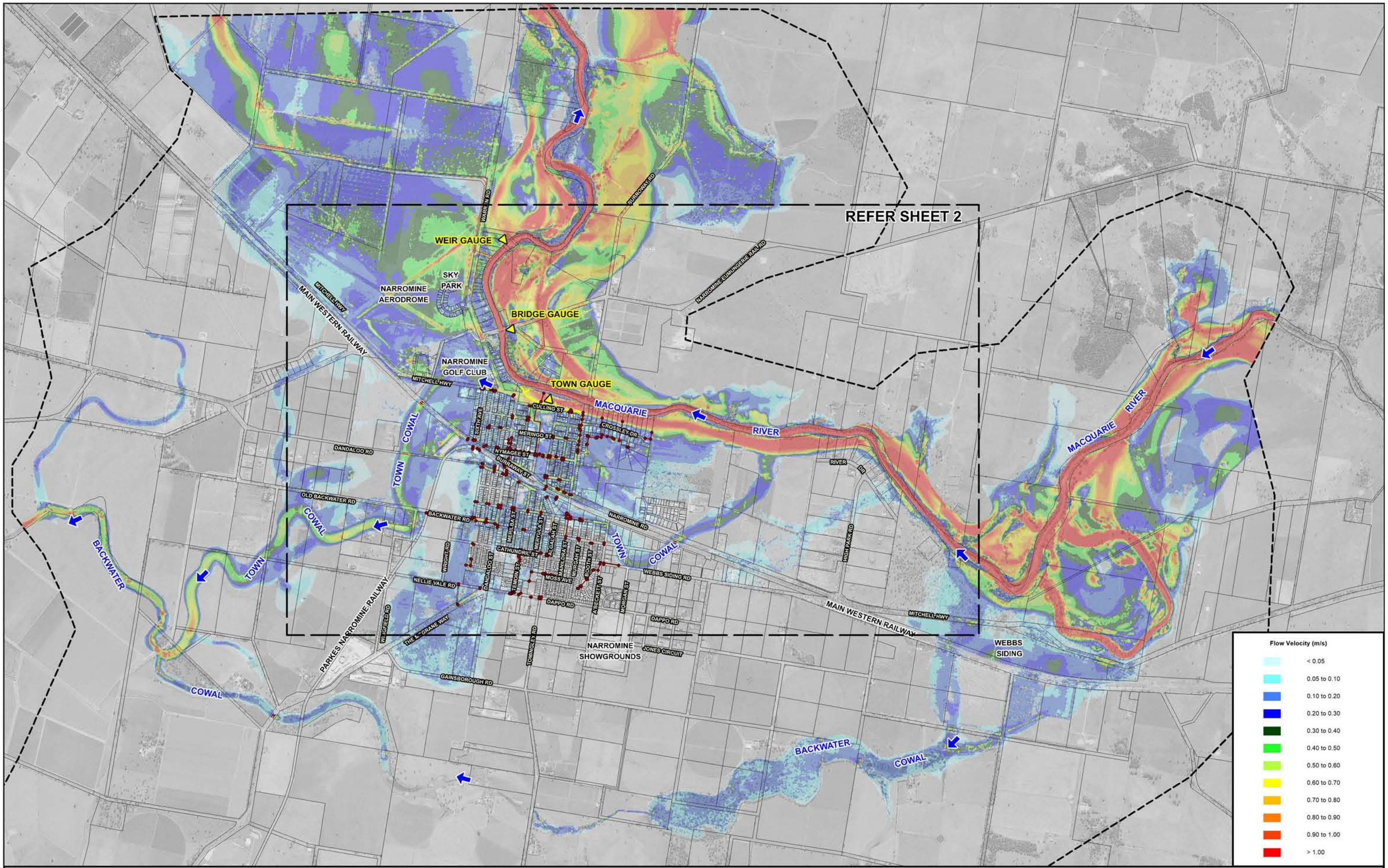
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Town Levee
- Water Surface Elevation Contour (m AHD) — 238.5

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.11
(Sheet 2 of 2)

INDICATIVE EXTENT AND DEPTH OF MAIN STREAM FLOODING
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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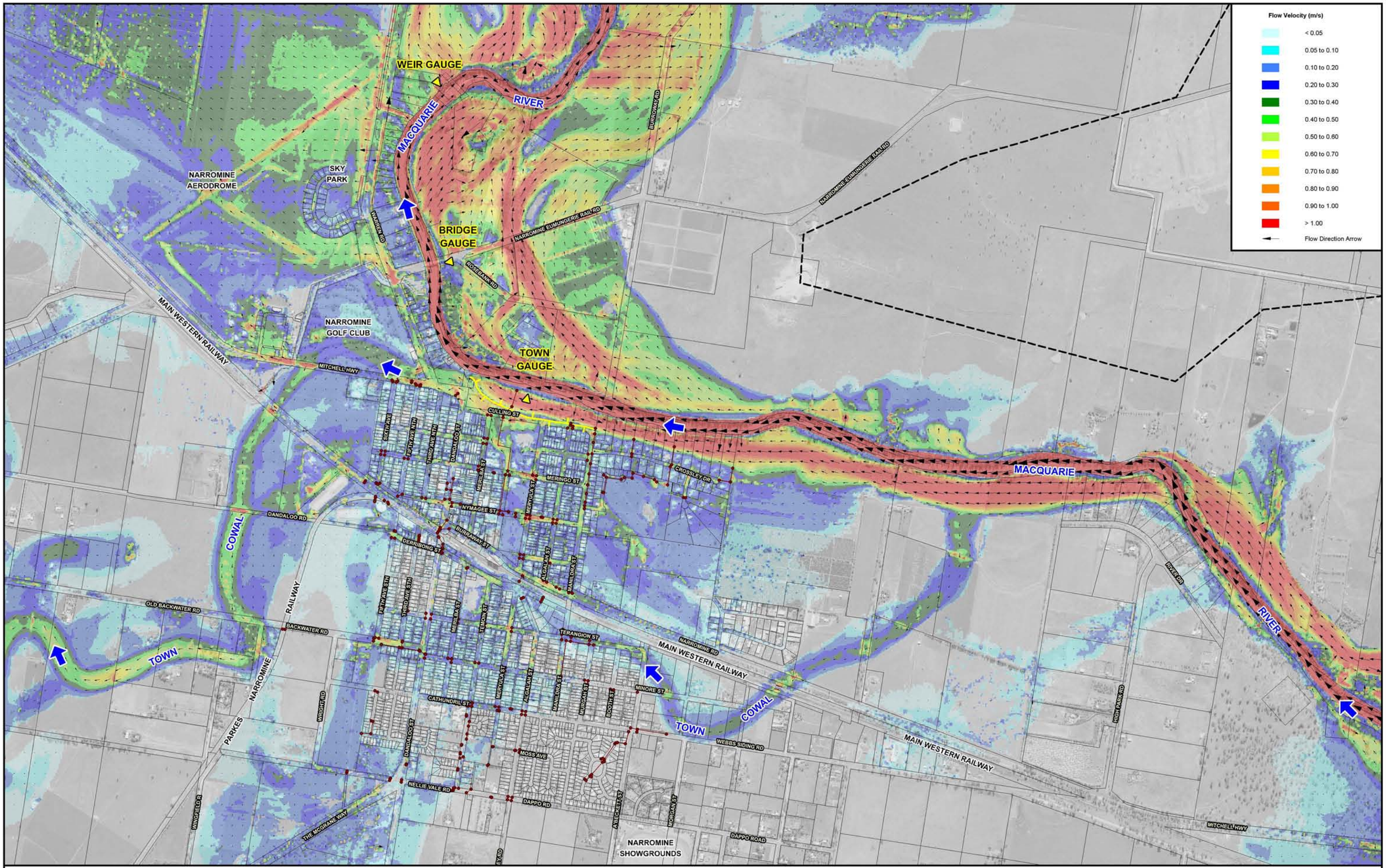
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Town Levee

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.12
(Sheet 1 of 2)

MAXIMUM MAIN STREAM FLOODING FLOW VELOCITIES
1% AEP



NOTE:
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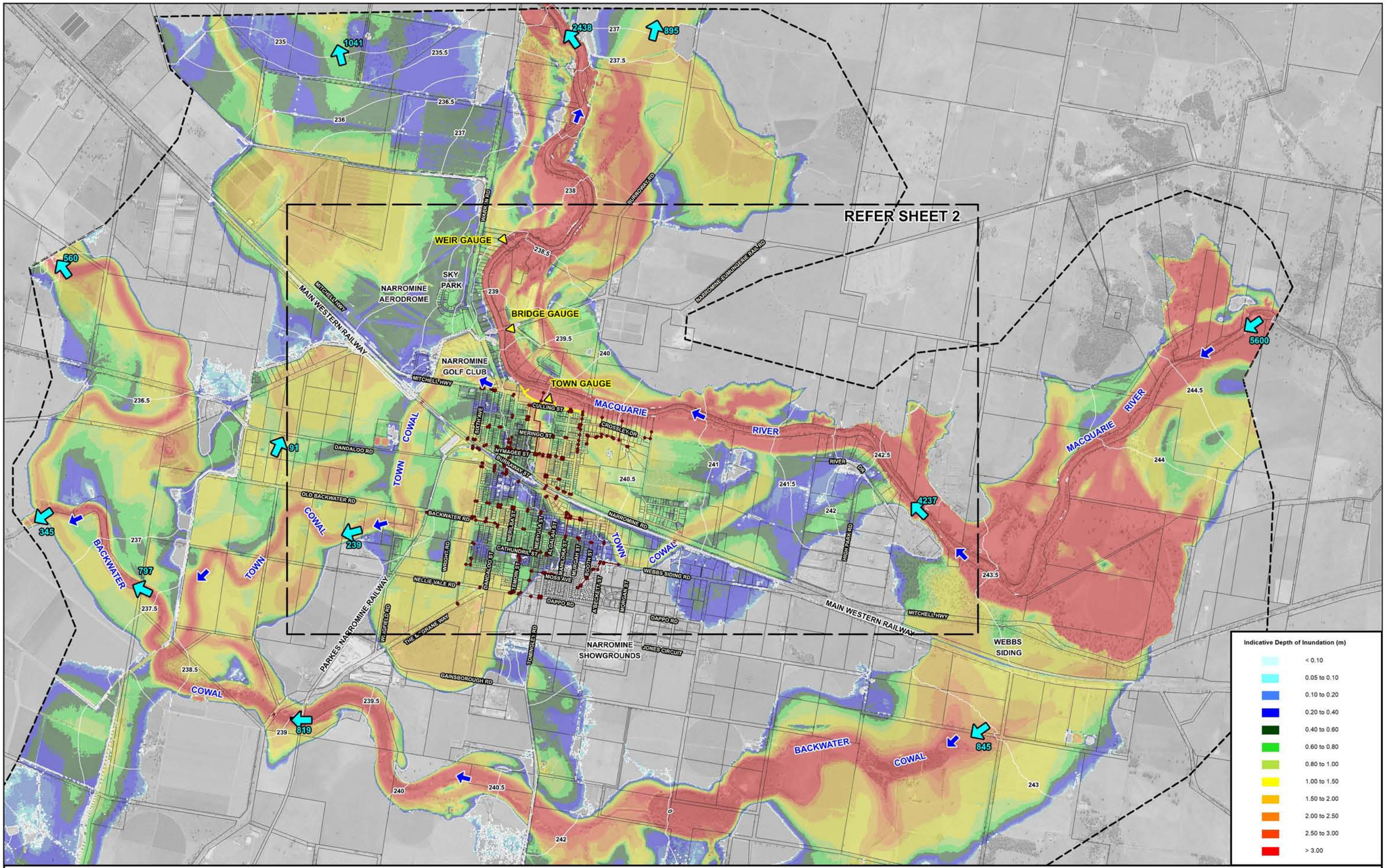
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.12
(Sheet 2 of 2)

MAXIMUM MAIN STREAM FLOODING FLOW VELOCITIES
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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LEGEND

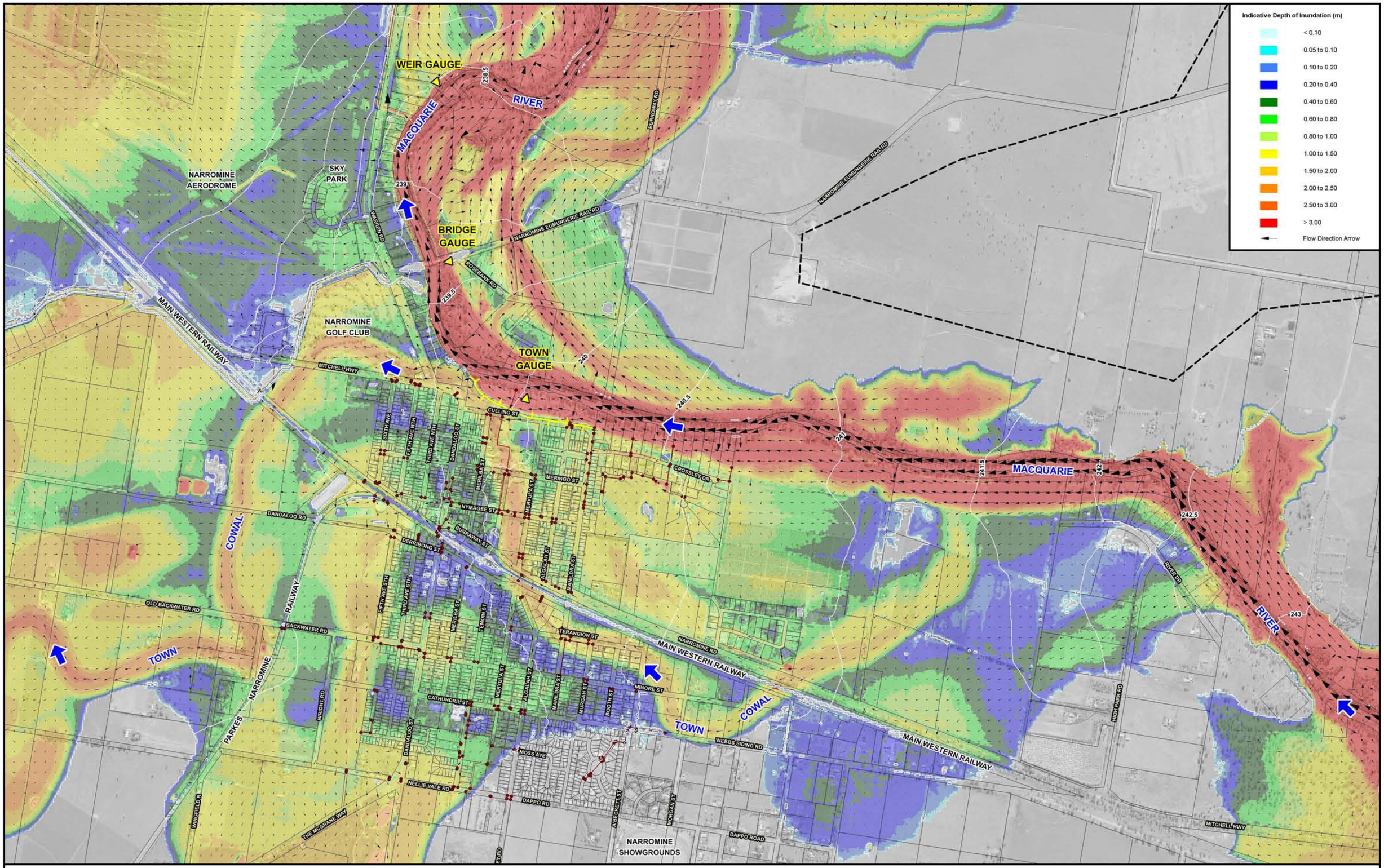
- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- 5600 Peak Overland Flow(m^3/s)
- Town Levee
- 238.5 Water Surface Elevation Contour (m AHD)

NARROMINE TOWN

FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.13
(Sheet 1 of 2)

INDICATIVE EXTENT AND DEPTH OF MAIN STREAM FLOODING
0.5% AEP


Indicative Depth of Inundation (m)
< 0.10
0.05 to 0.10
0.10 to 0.20
0.20 to 0.40
0.40 to 0.60
0.60 to 0.80
0.80 to 1.00
1.00 to 1.50
1.50 to 2.00
2.00 to 2.50
2.50 to 3.00
> 3.00
Flow Direction Arrow
WEIR GAUGE
BRIDGE GAUGE
TOWN GAUGE
MACQUARIE RIVER
NARROMINE AERODROME
SKY PARK
NARROMINE GOLF CLUB
NARROMINE SHOWGROUNDS
MAIN WESTERN RAILWAY
NARROMINE ELUMUNGERIE RAIL RD
BURRAWAY RD
ROSEBANK RD
MITCHELL HWY
CULLING ST
CROSSLEY DR
MERINGO ST
NYMAGEE ST
DERRIBONG ST
BURRAWAY ST
DANDALOO RD
COWAL
OLD BACKWATER RD
BACKWATER RD
NARROMINE
PARKES
WINGFIELD R
THE MCGRANE WAY
TERANGION ST
MINORE ST
CATHUNDRIL ST
NELLIE VALE RD
DAPPO RD
DAPPO ROAD
WEBBS SIDING RD
MOSS AVE
RIVER DR
HIGH PARK RD
WARREN RD
WRIGHT RD
BYRD
ABBECKETT ST
MORGAN ST
SIXTH AVE
FIFTH AVE NTH
THIRD AVE NTH
DANDALOO ST
MERILBA ST
MERKULA ST
ALGALAH ST
MANILDRA ST
MURGAH ST
BOOTH ST
TEMON ST
238.5
239
239.5
240
240.5
241
241.5
242
242.5
243
TOWN
N
200 0 200 400 600 m
Scale: 1:20,000
Lyall & Associates
NOTE:
The ground surface model incorporated in TUFLOW is based on LiDAR survey which has been sampled on a 10 m grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.
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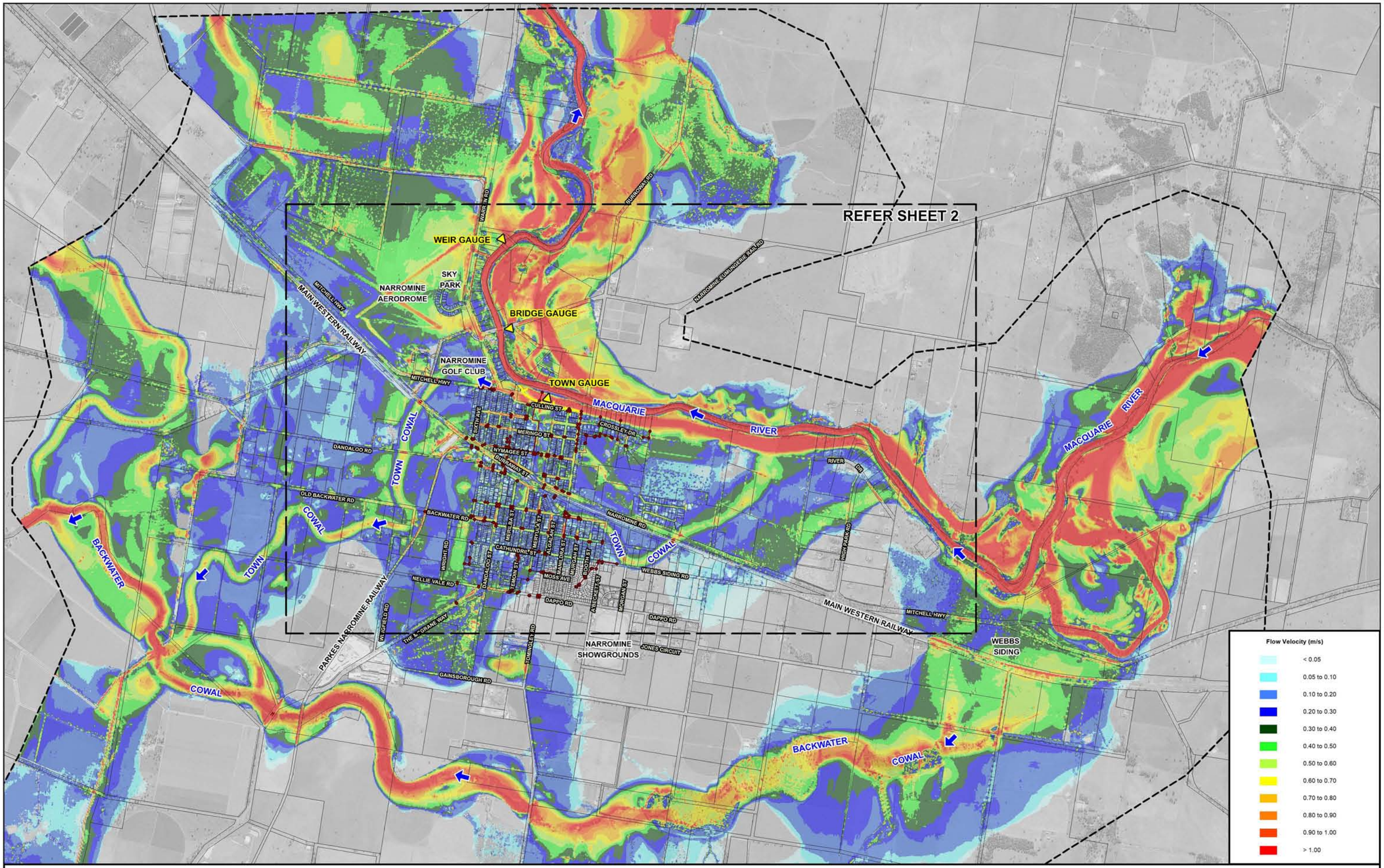
LEGEND
Two-Dimensional Model Boundary
Modelled Stormwater Drainage System
Stream Gauge
Town Levee
238.5
Water Surface Elevation Contour (m AHD)
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure 2.13
(Sheet 2 of 2)
INDICATIVE EXTENT AND DEPTH OF MAIN STREAM FLOODING
0.5% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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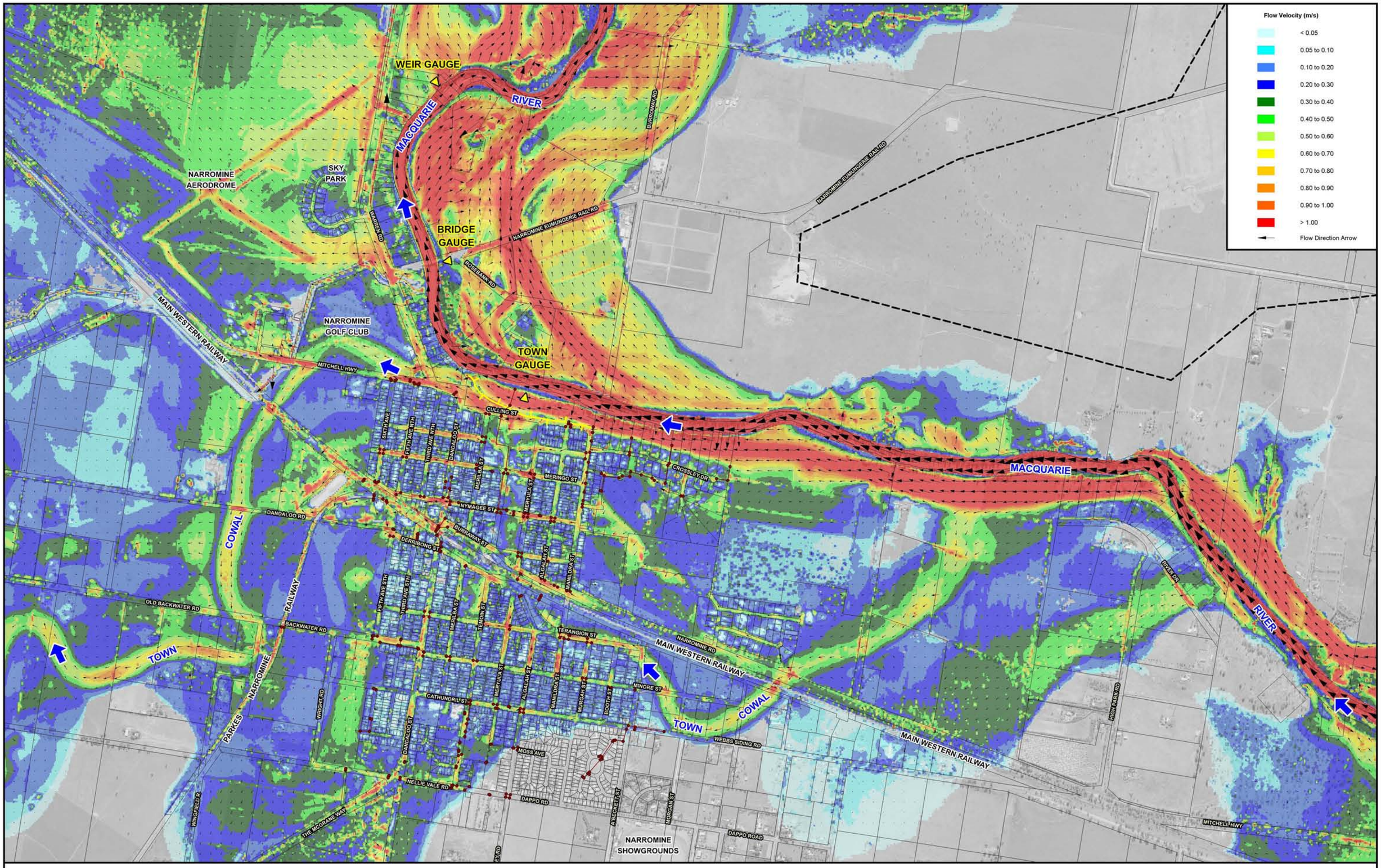
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Town Levee

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.14
(Sheet 1 of 2)

MAXIMUM MAIN STREAM FLOODING FLOW VELOCITIES
0.5% AEP



N

200 0 200 400 600 m

Scale: 1:20,000

Lyall & Associates

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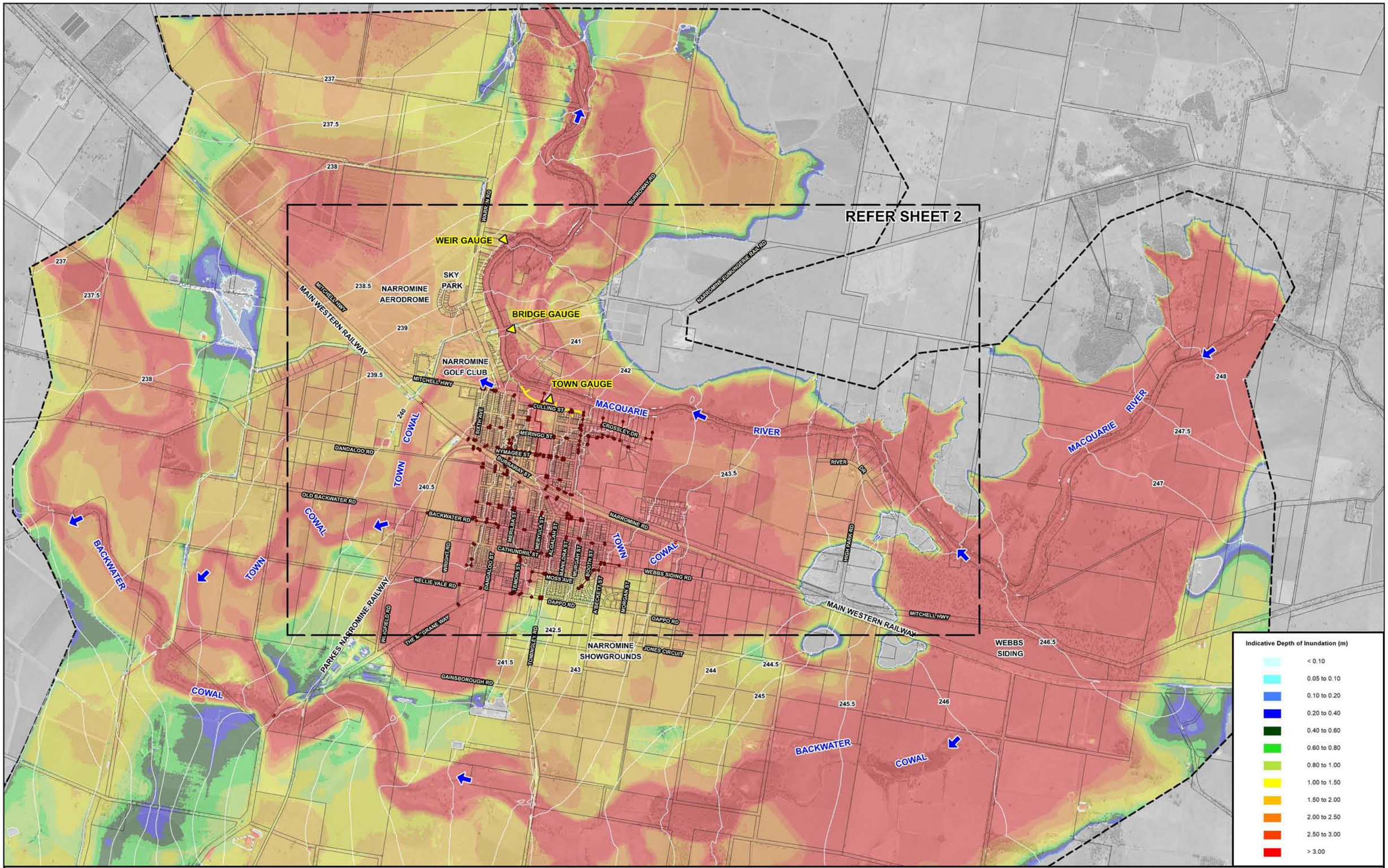
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Town Levee

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.14
(Sheet 2 of 2)

MAXIMUM MAIN STREAM FLOODING FLOW VELOCITIES
0.5% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

NOTE:

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LEGEND

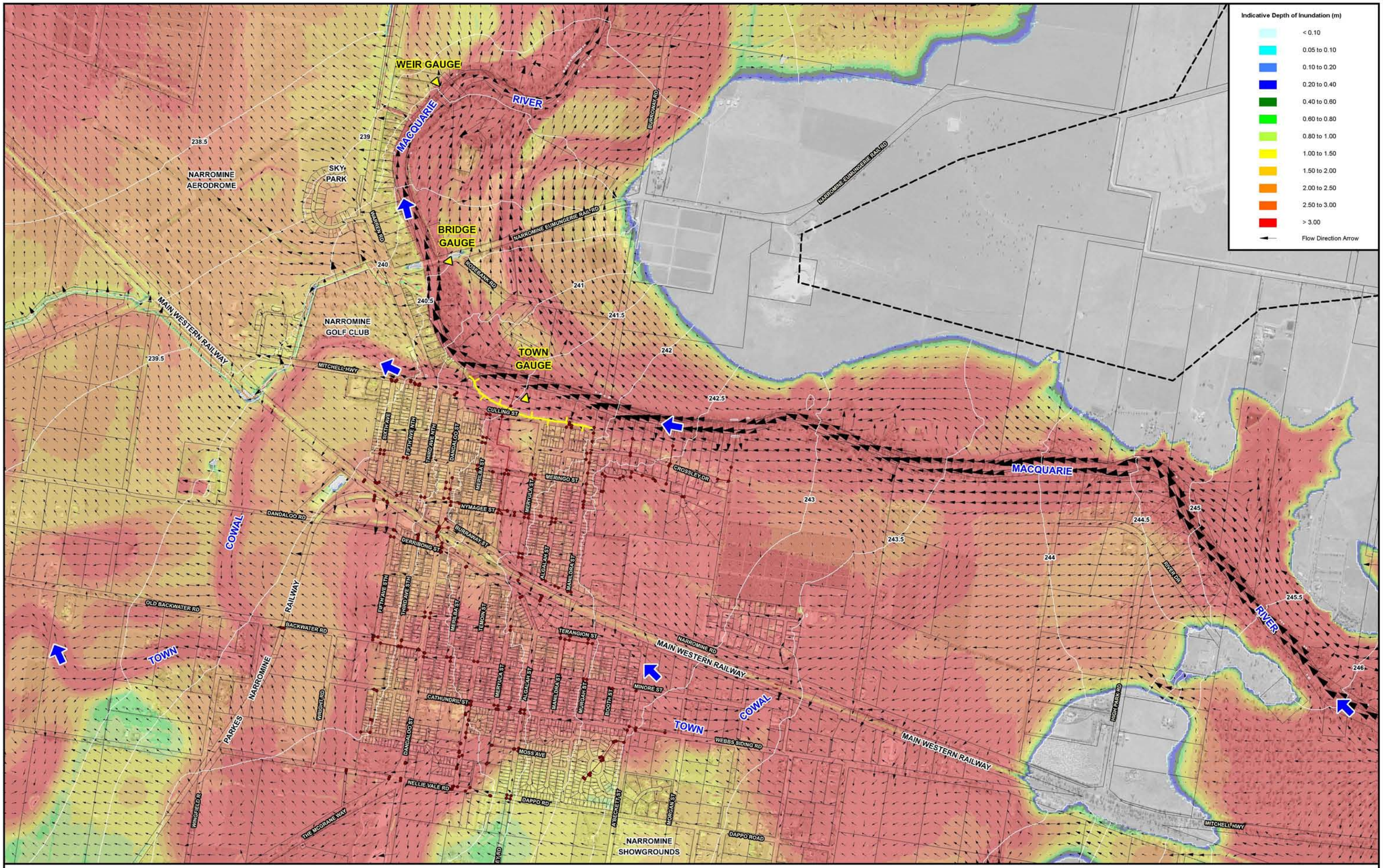
- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Town Levee
- 238.5 Water Surface Elevation Contour (m AHD)

NARROMINE TOWN

FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.15
(Sheet 1 of 2)

INDICATIVE EXTENT AND DEPTH OF MAIN STREAM FLOODING
EXTREME FLOOD


Indicative Depth of Inundation (m)
< 0.10
0.05 to 0.10
0.10 to 0.20
0.20 to 0.40
0.40 to 0.60
0.60 to 0.80
0.80 to 1.00
1.00 to 1.50
1.50 to 2.00
2.00 to 2.50
2.50 to 3.00
> 3.00
Flow Direction Arrow
WEIR GAUGE
MACQUARIE RIVER
BRIDGE GAUGE
TOWN GAUGE
NARROMINE AERODROME
SKY PARK
NARROMINE GOLF CLUB
NARROMINE SHOWGROUNDS
MAIN WESTERN RAILWAY
NARROMINE ELUMUNGERIE RAIL RD
BURRAWAY RD
MARREN RD
ROSEBANK RD
MITCHELL HWY
CULLING ST
SIXTH AVE
FIFTH AVE NTH
THIRD AVE NTH
DANDALOO ST
MERRIBA ST
MERINGO ST
MERVULA ST
CROSSLEY DR
NYMAGEE ST
DANDALOO RD
COWAL
DERRIBONG ST
ALGALAMA ST
MANILDRA ST
FIFTH AVE STH
THIRD AVE STH
TEMORA ST
OLD BACKWATER RD
BACKWATER RD
RAILWAY
TERANGION ST
NARROMINE RD
MINORE ST
TOWN
CATHUNDRIL ST
MURGAH ST
BOOTH ST
WEBBS SIDING RD
PARKES
WRIGHT RD
MOSS AVE
NELLIE VALE RD
DAPPO RD
DAPPO ROAD
ARBECHEE ST
MORGAN ST
WINGFIELD R.
THE MCGRANE WAY
EVERD
MACQUARIE RIVER
RIVER RD
HIGH PARK RD
238.5
239
239.5
240
240.5
241
241.5
242
242.5
243
243.5
244
244.5
245
245.5
246
N
200 0 200 400 600 m
Scale: 1:20,000
Lyall & Associates
NOTE:
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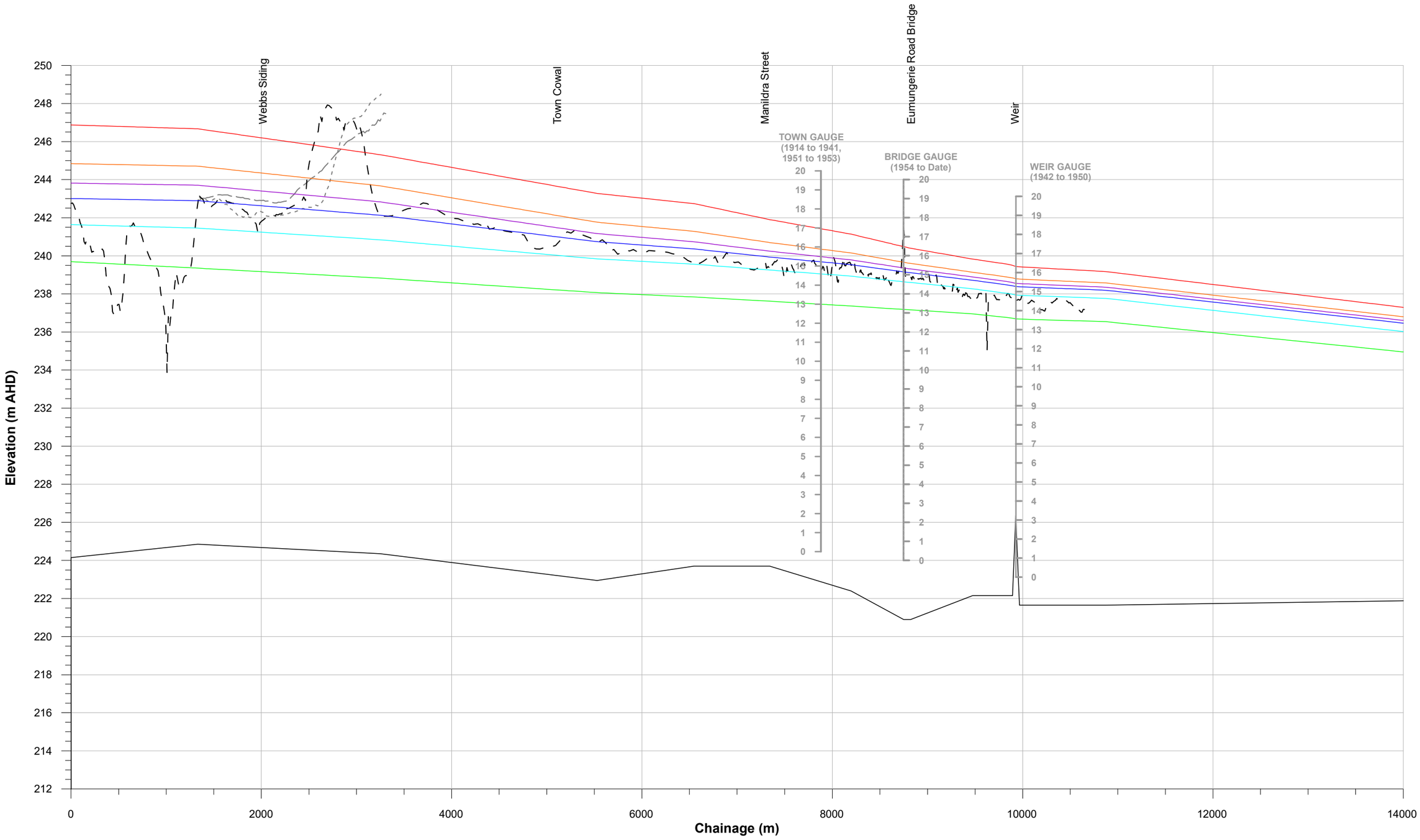
LEGEND
Two-Dimensional Model Boundary
Modelled Stormwater Drainage System
Stream Gauge
Town Levee
238.5
Water Surface Elevation Contour (m AHD)
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure 2.15
(Sheet 2 of 2)
INDICATIVE EXTENT AND DEPTH OF MAIN STREAM FLOODING
EXTREME FLOOD



LEGEND

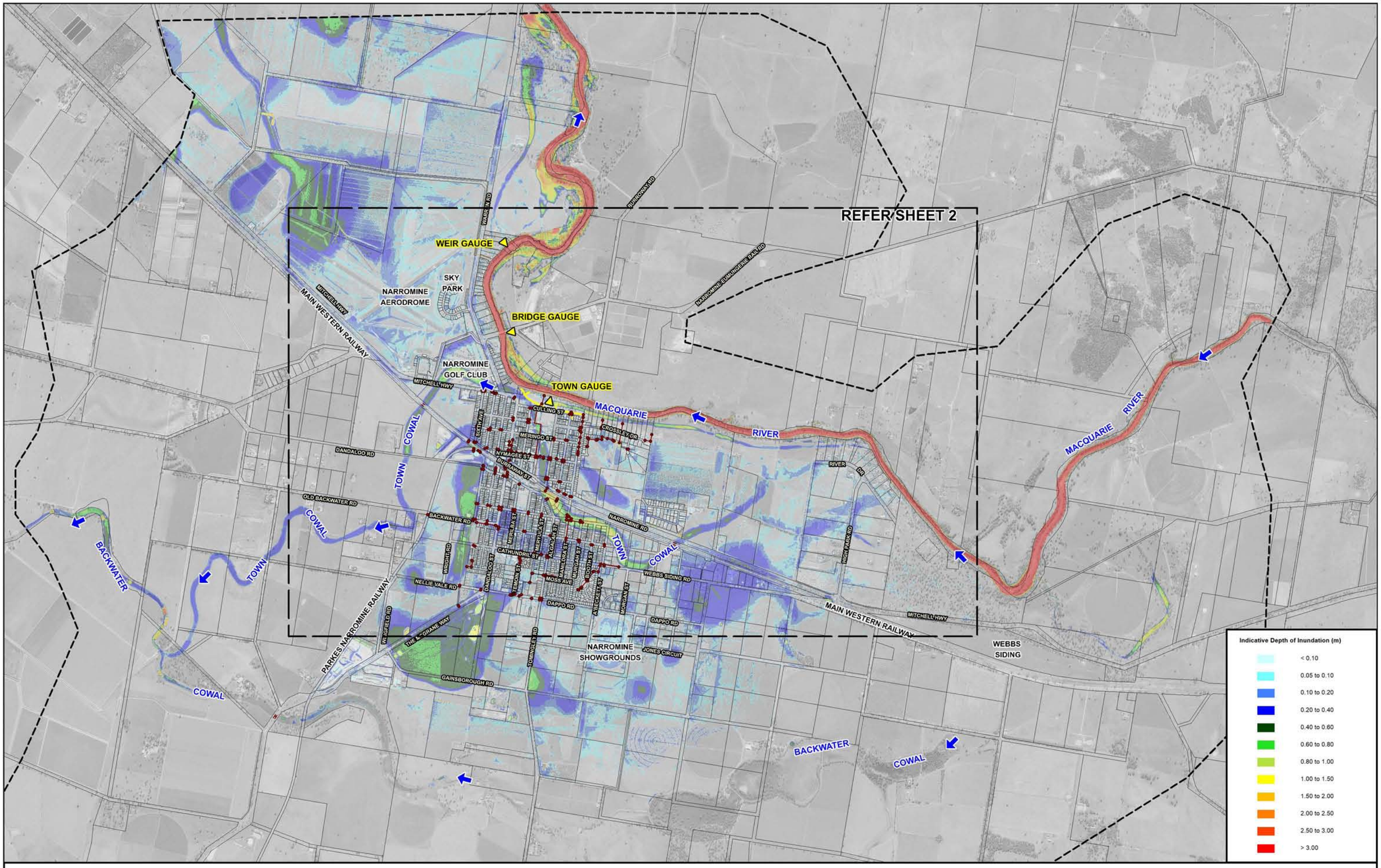
- Extreme Flood
- 0.2% AEP
- 0.5% AEP
- 1% AEP
- 2% AEP
- 5% AEP
- Channel Invert
- LiDAR Survey Data Levels along Southern Bank of Macquarie River
- LiDAR Survey Data Levels along Mitchell Highway
- LiDAR Survey Data Levels along Main Western Railway

Lyall & Associates

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.16

DESIGN WATER SURFACE PROFILES
MACQUARIE RIVER



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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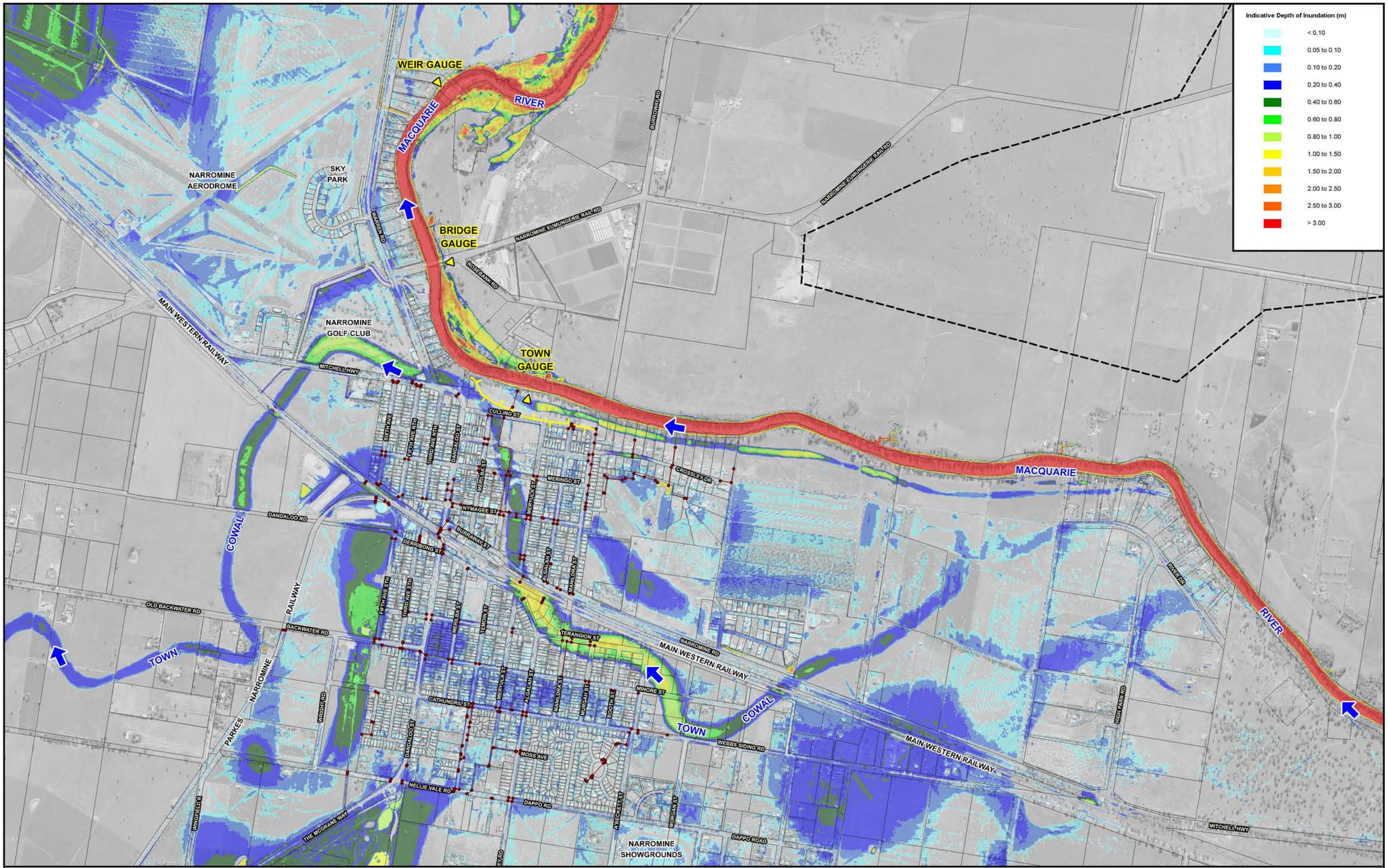
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Town Levee

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.17
(Sheet 1 of 2)

INDICATIVE EXTENT AND DEPTH OF MAJOR OVERLAND FLOW
1% AEP


Indicative Depth of Inundation (m)
< 0.10
0.05 to 0.10
0.10 to 0.20
0.20 to 0.40
0.40 to 0.60
0.60 to 0.80
0.80 to 1.00
1.00 to 1.50
1.50 to 2.00
2.00 to 2.50
2.50 to 3.00
> 3.00
WEIR GAUGE
BRIDGE GAUGE
TOWN GAUGE
MACQUARIE RIVER
NARROMINE AERODROME
SKY PARK
NARROMINE GOLF CLUB
NARROMINE SHOWGROUNDS
MAIN WESTERN RAILWAY
NARROMINE EUMUNGERIE RAIL RD
BURRAWAY RD
WARREN RD
ROSEBANK RD
MITCHELL HWY
CULLING ST
SIXTH AVE
FIFTH AVE NTH
THIRD AVE NTH
DANDALOO ST
MERRILA ST
MERVILLA ST
MERINGO ST
CROSSLEY DR
NYMAGEE ST
ALGALAH ST
MANILDRA ST
DANDALOO RD
COWAL
DERRIBONG ST
BURRAWAY ST
FIFTH AVE STH
THIRD AVE STH
TEMORA ST
TERANGION ST
NARROMINE RD
MINORE ST
CATHUNDRIL ST
HURGAH ST
BOOTH ST
WRIGHT RD
PARKES
WEBBS SIDING RD
MOSS AVE
NELLIE VALE RD
DAPPO RD
ABERCKET ST
MORGAN ST
DAPPO ROAD
WINGFIELD R
THE McGRANE WAY
BYRD
OLD BACKWATER RD
BACKWATER RD
RAILWAY
NARROMINE
TOWN
RIVER DR
HIGH PARK RD
N
200 0 200 400 600 m
Scale: 1:20,000
Lyall & Associates
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LEGEND
Two-Dimensional Model Boundary
Modelled Stormwater Drainage System
Stream Gauge
Town Levee
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure 2.17
(Sheet 2 of 2)
INDICATIVE EXTENT AND DEPTH OF MAJOR OVERLAND FLOW
1% AEP

EXTENT OF INUNDATION
- 5% AEP
- 2% AEP
- 1% AEP
- 0.5% AEP
- Extreme

COMMUNITY ASSET
- Sewer System
- Airport
- Electricity Substation
- Water Supply
- Major Road Crossing and Identifier

EMERGENCY SERVICES
- RFS Station
- Police Station
- F&R NSW Station
- Ambulance Facility
- SES Station
- Evacuation Centre

VULNERABLE DEVELOPMENT
- Educational Facility
- Chid Care Facility
- Caravan Park
- Aged Care Facility
- Hospital

WEIR GAUGE
BRIDGE GAUGE
TOWN GAUGE
MACQUARIE RIVER
NARROMINE AERODROME
SKY PARK
NARROMINE GOLF CLUB
NARROMINE EUMUNGERIE RAIL RD
BURROWAY RD
WARREN RD
ROSEBANK RD
MAIN WESTERN RAILWAY
MITCHELL HWY
DANDALOO RD
OLD BACKWATER RD
BACKWATER RD
NARROMINE RD
COWAL
TOWN
CULLING ST
MERINGO ST
NYMAGEE ST
DERRIBONG ST
CATHUNDRIL ST
MINORE ST
WEBBS SIDING RD
NELLIE VALE RD
DAPPO RD
DAPPO ROAD
MOSS AVE
CROSSLEY DR
RIVER DR
HIGH PARK RD
NARROMINE SHOWGROUNDS
SS1 SS2 SS3 SS4 SS5 SS6 SS7 SS8 SS9
WS1 WS2 WS3
MC1 MC2 MC3 MC4
EC1 EC2
EF1 EF2 EF3 EF4
AC1 AC2 AC3
HC1 HC2
CC1 CC2 CC3
CP1 CP2

N
200 0 200 400 600 m
Scale: 1:20,000

Lyall & Associates

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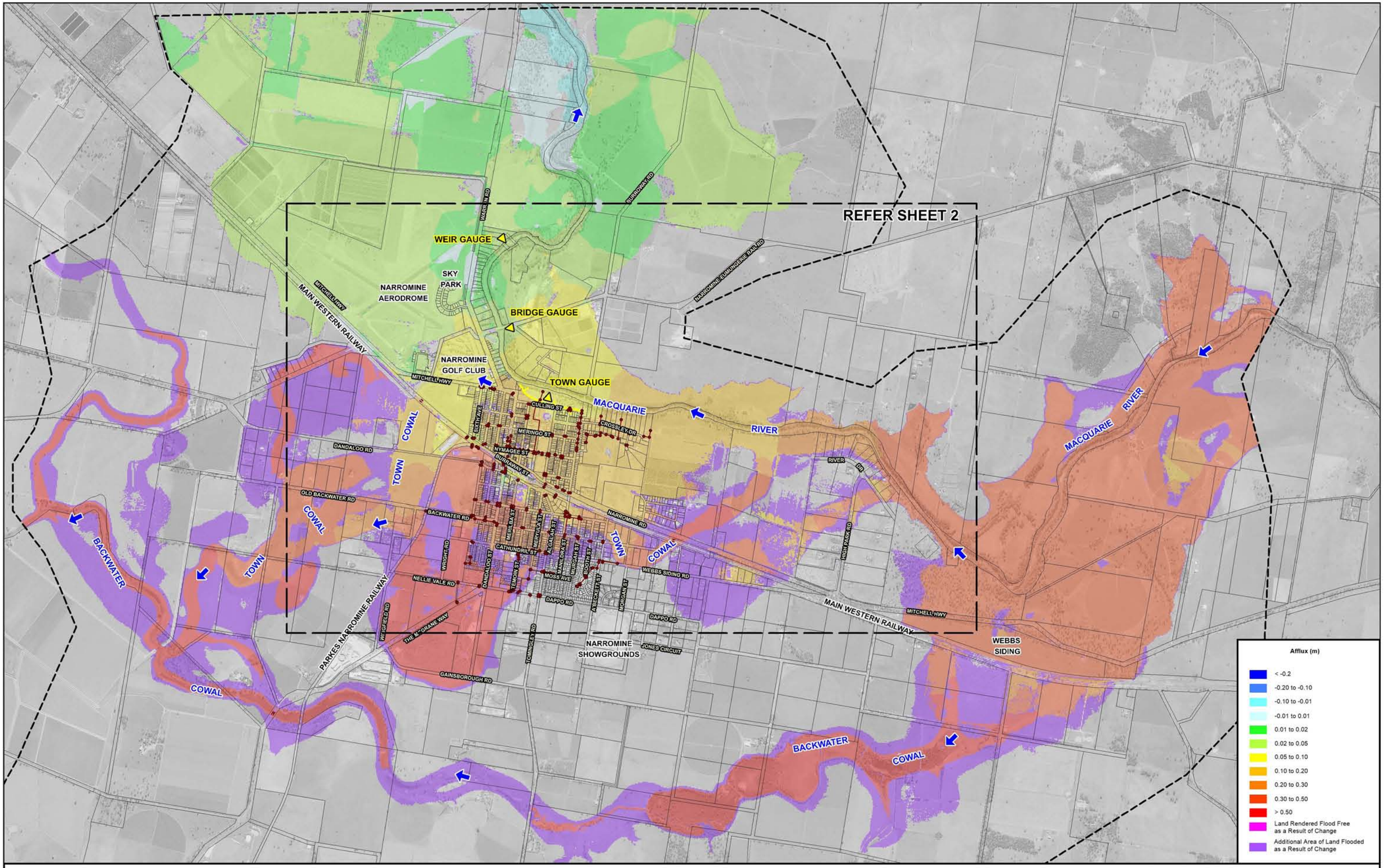
LEGEND
- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Town Levee

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure 2.18

INDICATIVE EXTENT OF MAIN STREAM FLOODING AND LOCATION OF VULNERABLE DEVELOPMENT AND CRITICAL INFRASTRUCTURE



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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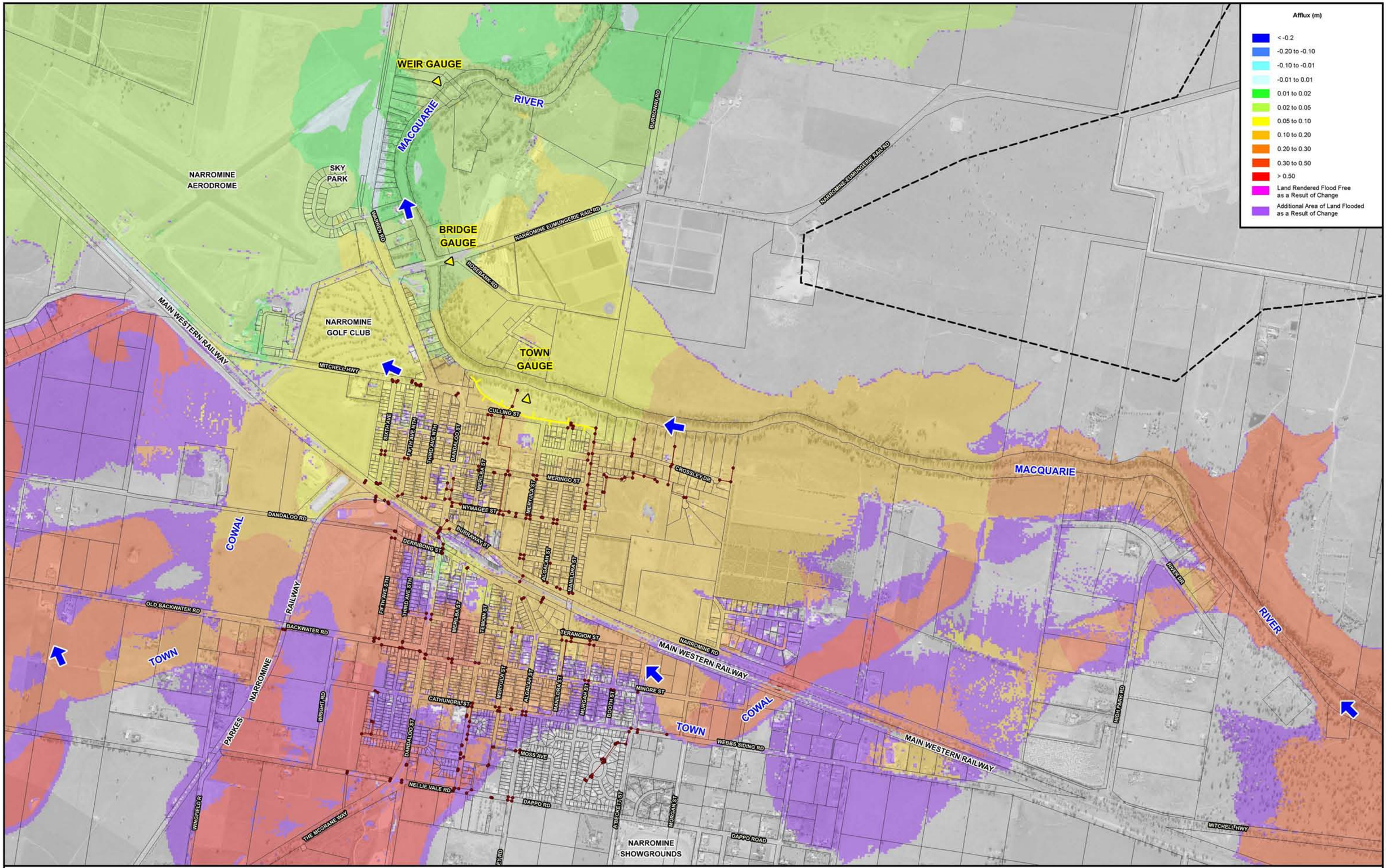
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Town Levee

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.19
(Sheet 1 of 2)

SENSITIVITY OF MAIN STREAM FLOODING TO 20% INCREASE IN HYDRAULIC ROUGHNESS VALUES
1% AEP


Afflux (m)
< -0.2
-0.20 to -0.10
-0.10 to -0.01
-0.01 to 0.01
0.01 to 0.02
0.02 to 0.05
0.05 to 0.10
0.10 to 0.20
0.20 to 0.30
0.30 to 0.50
> 0.50
Land Rendered Flood Free as a Result of Change
Additional Area of Land Flooded as a Result of Change
WEIR GAUGE
MACQUARIE RIVER
BURROWAY RD
NARROMINE AERODROME
SKY PARK
WARREN RD
BRIDGE GAUGE
NARROMINE ELUMUNGERIE RAIL RD
ROSEDALE RD
MAIN WESTERN RAILWAY
NARROMINE GOLF CLUB
MITCHELL HWY
TOWN GAUGE
CULLING ST
SIXTH AVE
FIFTH AVE NTH
THIRD AVE NTH
DANDALOO ST
MERRIBA ST
MERYULA ST
MERINGO ST
CROSSLEY DR
NYMAGEE ST
DANDALOO RD
COWAL
BURRAWAY ST
DERRIBONG ST
ALGALAH ST
DAMILORA ST
FIFTH AVE STH
THIRD AVE STH
TEMORA ST
OLD BACKWATER RD
RAILWAY
BACKWATER RD
TERANGION ST
NARROMINE RD
TOWN
NARROMINE
PARKES
WRIGHT RD
CATHUNDRIL ST
MINORE ST
MANILDRA ST
MURGAH ST
BOOTH ST
WEBBS SIDING RD
MOSS AVE
NELLIE VALE RD
DAPPO RD
WINGFIELD DR
THE MCGRANE WAY
EYRD
ARBECHE ST
MORGAN ST
NARROMINE SHOWGROUNDS
DAPPO ROAD
RIVER DR
HIGH PARK RD
MITCHELL HWY
N
200 0 200 400 600 m
Scale: 1:20,000
Lyall & Associates
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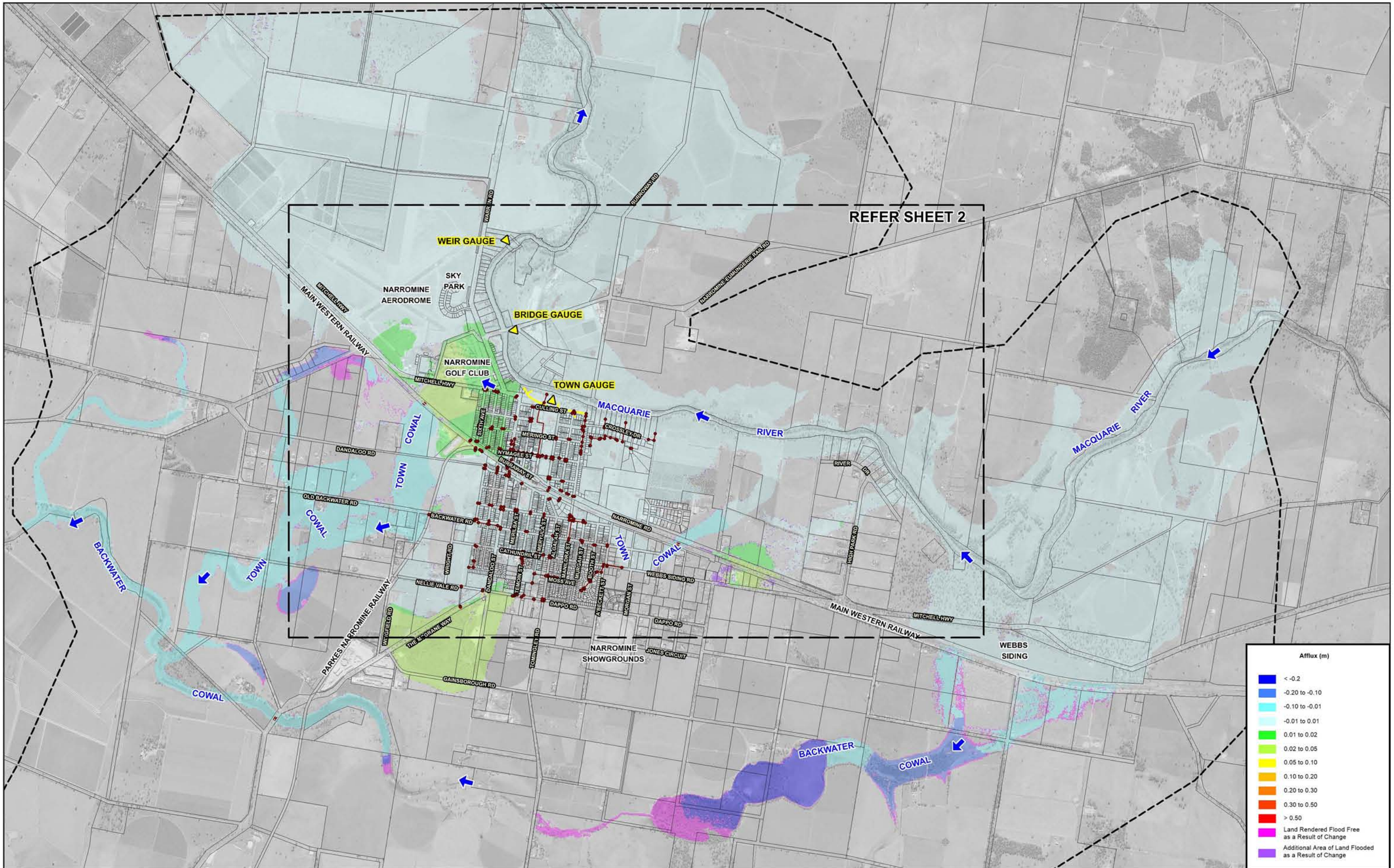
LEGEND
Two-Dimensional Model Boundary
Modelled Stormwater Drainage System
Stream Gauge
Town Levee
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure 2.19
(Sheet 2 of 2)
SENSITIVITY OF MAIN STREAM FLOODING TO 20% INCREASE IN HYDRAULIC ROUGHNESS VALUES
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

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LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Town Levee

Lyall & Associates

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.20
(Sheet 1 of 2)

SENSITIVITY OF MAIN STREAM FLOODING TO PARTIAL BLOCKAGE OF HYDRAULIC STRUCTURES
1% AEP

NOTE:
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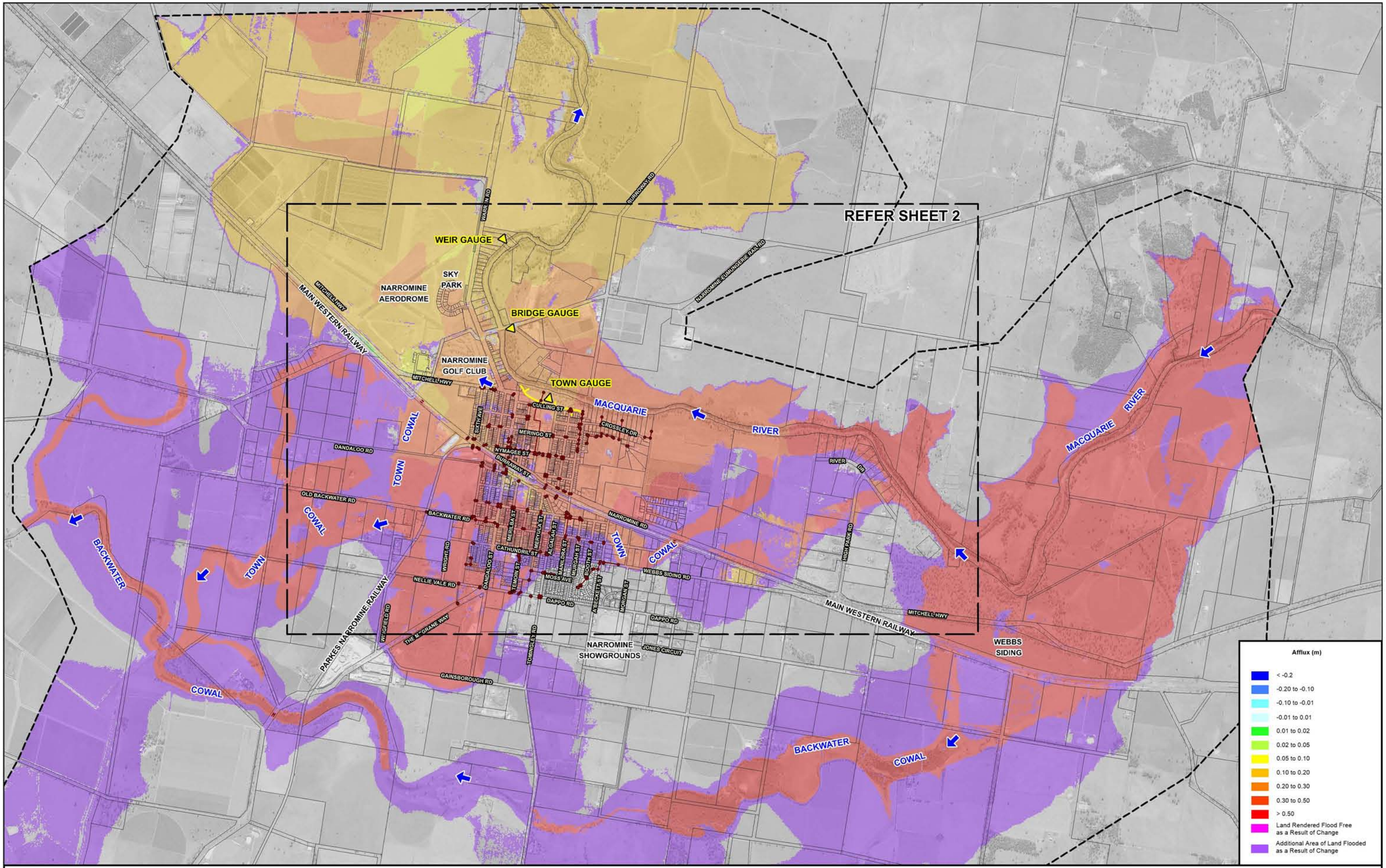
LEGEND
- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Town Levee

Lyall & Associates

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.20
(Sheet 2 of 2)

SENSITIVITY OF MAIN STREAM FLOODING TO PARTIAL BLOCKAGE OF HYDRAULIC STRUCTURES
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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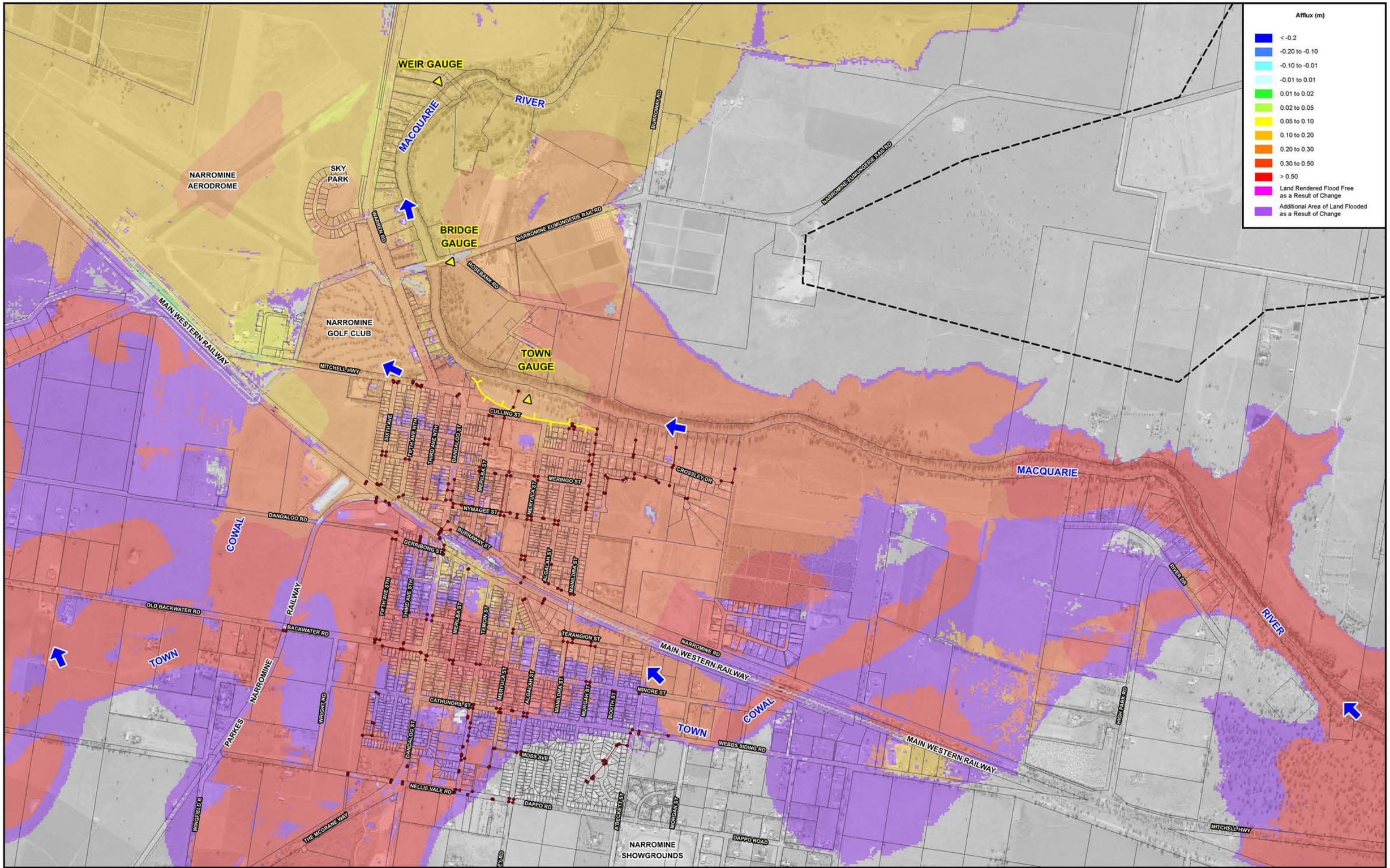
LEGEND

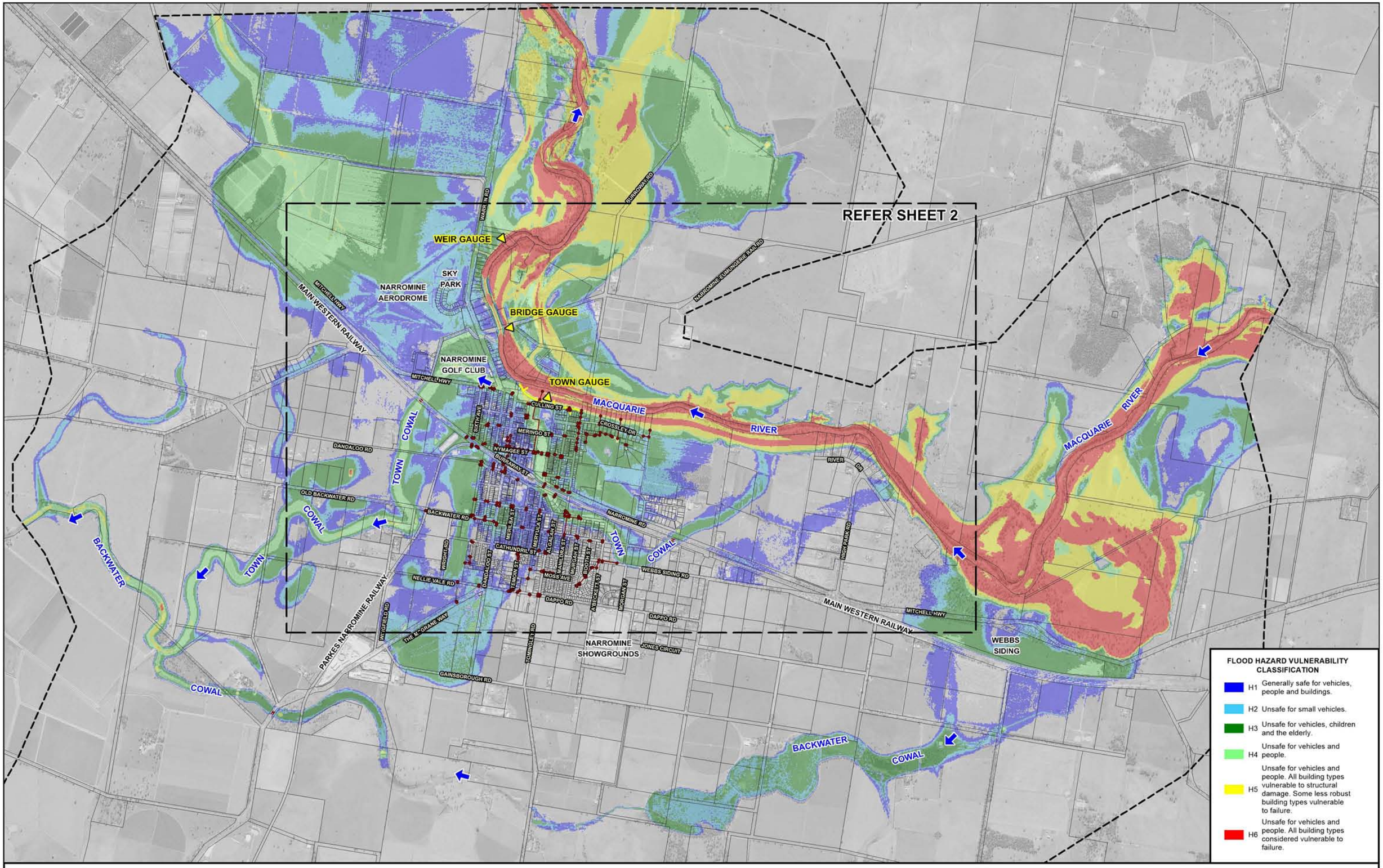
- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Town Levee

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.21
(Sheet 1 of 2)

POTENTIAL IMPACT OF CLIMATE CHANGE ON MAIN STREAM FLOODING
1% AEP


Afflux (m)
< -0.2
-0.20 to -0.10
-0.10 to -0.01
-0.01 to 0.01
0.01 to 0.02
0.02 to 0.05
0.05 to 0.10
0.10 to 0.20
0.20 to 0.30
0.30 to 0.50
> 0.50
Land Rendered Flood Free as a Result of Change
Additional Area of Land Flooded as a Result of Change
WEIR GAUGE
RIVER
MACQUARIE
BURRAWAY RD
NARROMINE AERODROME
SKY PARK
WARREN RD
BRIDGE GAUGE
NARROMINE EUMUNGERIE RAIL RD
ROSEBANK RD
MAIN WESTERN RAILWAY
NARROMINE GOLF CLUB
MITCHELL HWY
TOWN GAUGE
CULLING ST
SIXTH AVE
FIFTH AVE NTH
THIRD AVE NTH
DANDALOO ST
MERILDA ST
MERINGO ST
CROSSLEY DR
NYMAGEE ST
MERKULA ST
DANDALOO RD
COWAL
BURRAWAY ST
DERRIBONG ST
ALGALAH ST
MANILDRA ST
OLD BACKWATER RD
RAILWAY
BACKWATER RD
TOWN
NARROMINE
PARKES
WRIGHT RD
FIFTH AVE STH
THIRD AVE STH
MERILDA ST
TEMORA ST
TERANGION ST
NARROMINE RD
MERVILLA ST
CATHUNDRIL ST
MURGAH ST
BOOTH ST
MINORE ST
WEBBS SIDING RD
MOSS AVE
NELLIE VALE RD
DAPPO RD
WINGFIELD R
THE McGRANE WAY
ABBECKET ST
MORGAN ST
NARROMINE SHOWGROUNDS
DAPPO ROAD
RIVER DR
HIGH PARK RD
MITCHELL HWY
N
200 0 200 400 600 m
Scale: 1:20,000
Lyall & Associates
NOTE:
The ground surface model incorporated in TUFLOW is based on LiDAR survey which has been sampled on a 10 m grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.
Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.
LEGEND
Two-Dimensional Model Boundary
Modelled Stormwater Drainage System
Stream Gauge
Town Levee
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure 2.21
(Sheet 2 of 2)
POTENTIAL IMPACT OF CLIMATE CHANGE ON MAIN STREAM FLOODING
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

NOTE:
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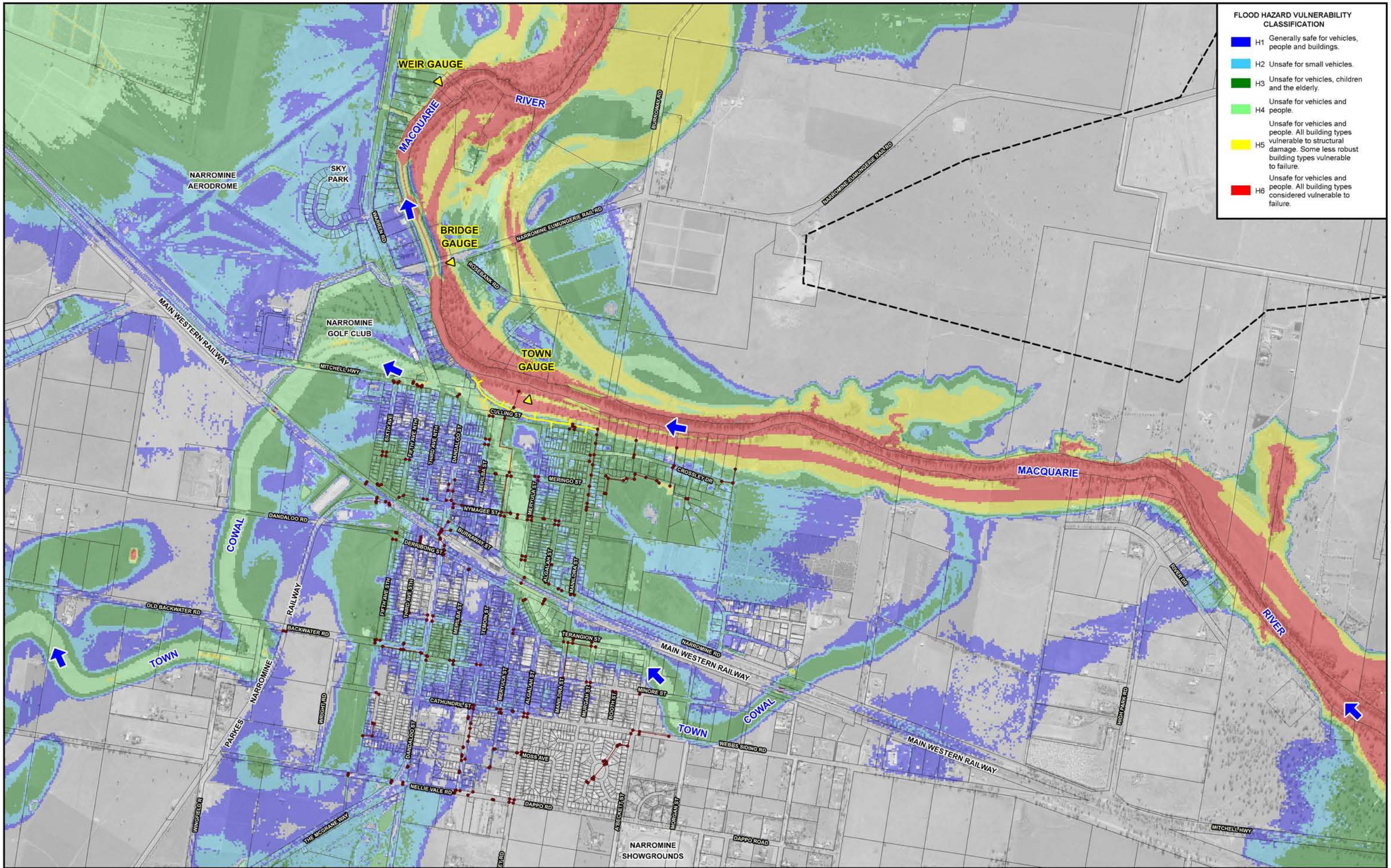
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Town Levee

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.22
(Sheet 1 of 2)

FLOOD HAZARD VULNERABILITY CLASSIFICATION - MAIN STREAM FLOODING
1% AEP


FLOOD HAZARD VULNERABILITY CLASSIFICATION
H1 Generally safe for vehicles, people and buildings.
H2 Unsafe for small vehicles.
H3 Unsafe for vehicles, children and the elderly.
H4 Unsafe for vehicles and people.
H5 Unsafe for vehicles and people. All building types vulnerable to structural damage. Some less robust building types vulnerable to failure.
H6 Unsafe for vehicles and people. All building types considered vulnerable to failure.
WEIR GAUGE
MACQUARIE RIVER
BRIDGE GAUGE
TOWN GAUGE
NARROMINE AERODROME
SKY PARK
NARROMINE GOLF CLUB
NARROMINE SHOWGROUNDS
MAIN WESTERN RAILWAY
NARROMINE EUMUNGERIE RAIL RD
NARROMINE-EUMUNGERIE RAIL RD
BURRAWAY RD
WARREN RD
ROSEBANK RD
MITCHELL HWY
CULLING ST
SIXTH AVE
FIFTH AVE NTH
THIRD AVE NTH
DANDALOO ST
MERILDA ST
MERYULA ST
MERINGO ST
CROSSLEY DR
NYMAGEE ST
DANDALOO RD
COWAL
DERRIBONG ST
BURRAWAY ST
ALGALAH ST
MANILDRA ST
FIFTH AVE STH
THIRD AVE STH
TEMON ST
TERANGION ST
NARROMINE RD
MINORE ST
CATHUNDRIL ST
HURGAH ST
BOOTH ST
WEBBS SIDING RD
MOSS AVE
NELLIE VALE RD
DAPPO RD
ARBECKETT ST
MORGAN ST
DAPPO ROAD
OLD BACKWATER RD
BACKWATER RD
RAILWAY
NARROMINE
PARKES
WRIGHT RD
WINGFIELD R
THE MCGRANE WAY
BYRD
TOWN
RIVER RD
HIGH PARK RD
MACQUARIE
RIVER
MITCHELL HWY
N
200 0 200 400 600 m
Scale: 1:20,000
NOTE:
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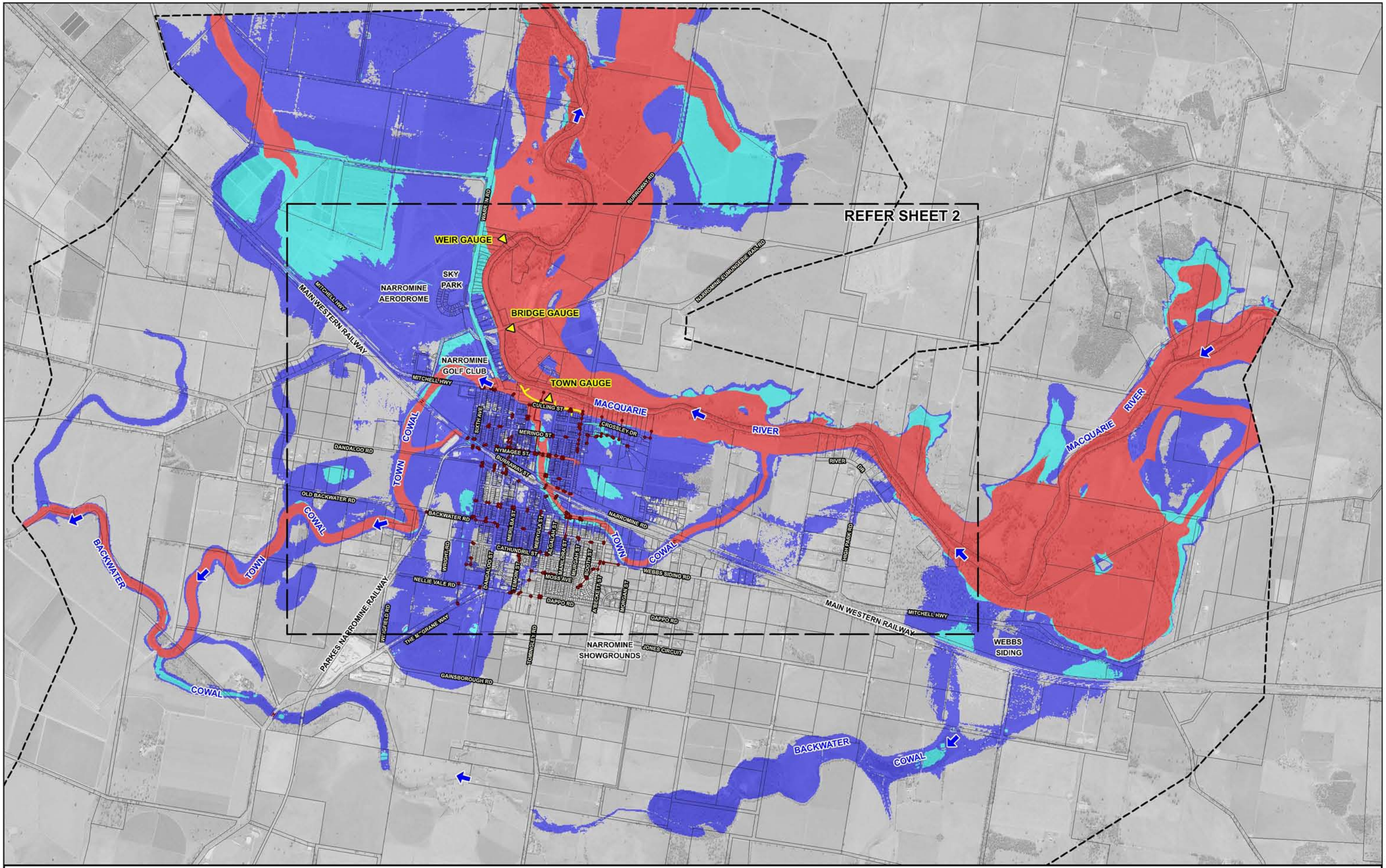
LEGEND
Two-Dimensional Model Boundary
Modelled Stormwater Drainage System
Stream Gauge
Town Levee
Lyall & Associates
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure 2.22
(Sheet 2 of 2)
FLOOD HAZARD VULNERABILITY CLASSIFICATION - MAIN STREAM FLOODING
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

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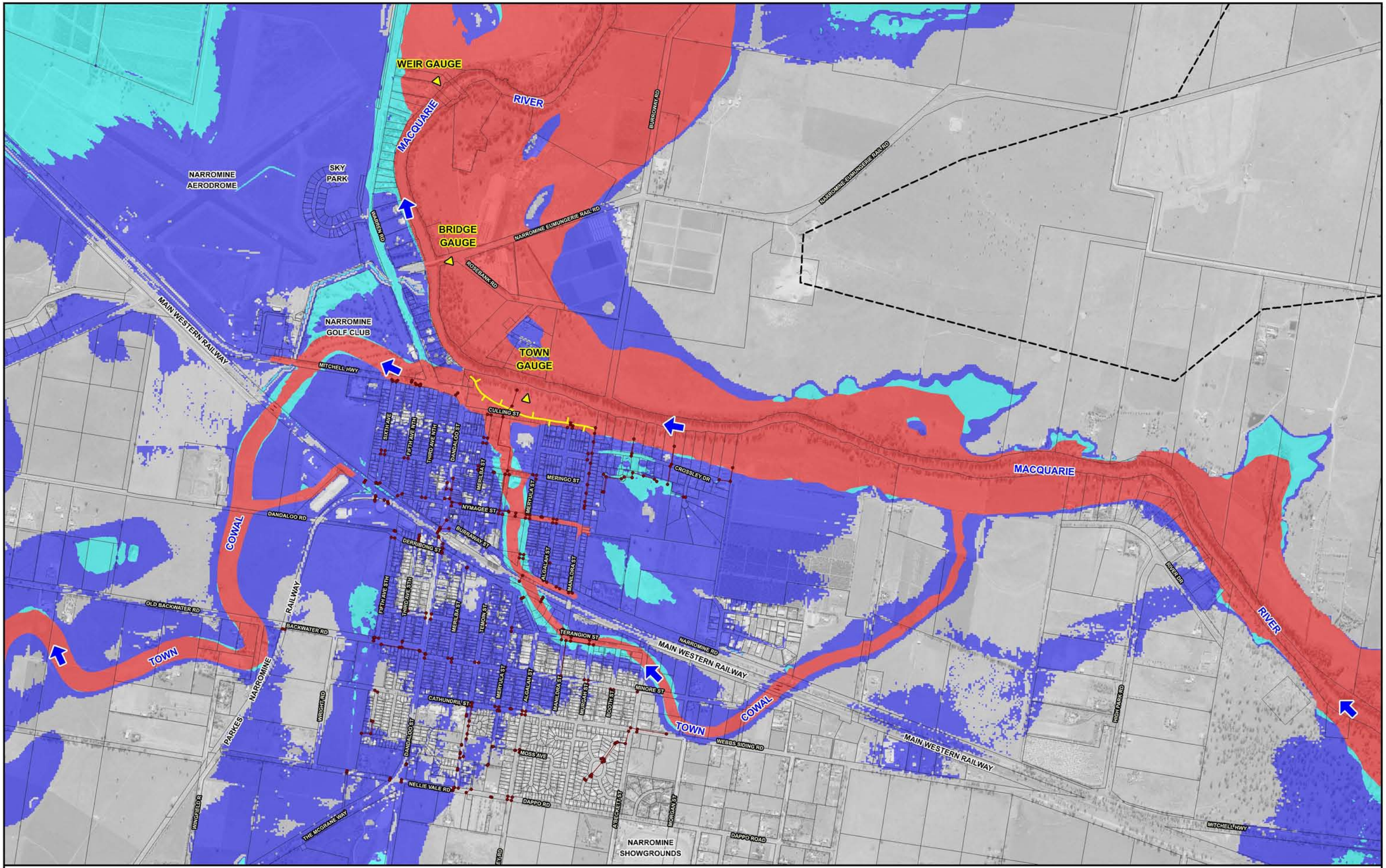
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Town Levee
- Floodway
- Flood Storage
- Flood Fringe

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.23
(Sheet 1 of 2)

HYDRAULIC CATEGORISATION OF FLOODPLAIN - MAIN STREAM FLOODING
1% AEP


WEIR GAUGE
MACQUARIE RIVER
BURROWAY RD
NARROMINE AERODROME
SKY PARK
WARREN RD
BRIDGE GAUGE
NARROMINE EUMUNGERIE RAIL RD
NARROMINE-EUMUNGERIE RAIL RD
ROSEBANK RD
MAIN WESTERN RAILWAY
NARROMINE GOLF CLUB
MITCHELL HWY
TOWN GAUGE
CULLING ST
SIXTH AVE
FIFTH AVE NTH
THIRD AVE NTH
DANDALOO ST
MERILBA ST
MERINGO ST
CROSSLEY DR
MACQUARIE
NYMAGEE ST
MERVULA ST
DANDALOO RD
COWAL
DERRIBONG ST
BURRAWAY ST
ALGALAH ST
MANILDRA ST
RIVER DR
RIVER
FIFTH AVE STH
THIRD AVE STH
TEMORA ST
OLD BACKWATER RD
RAILWAY
BACKWATER RD
TERANGION ST
NARROMINE RD
MAIN WESTERN RAILWAY
TOWN
NARROMINE
WRIGHT RD
CATHUNDRIL ST
MURGAH ST
BOOTH ST
MINORE ST
COWAL
PARKES
DANDALOO ST
MOSS AVE
WEBBS SIDING RD
MAIN WESTERN RAILWAY
HIGHPARK RD
NELLIE VALE RD
DAPPO RD
WINGFIELD RD
THE McGRANE WAY
ARRECKEM ST
MORGAN ST
NARROMINE SHOWGROUNDS
DAPPO ROAD
MITCHELL HWY
N
200 0 200 400 600 m
Scale: 1:20,000
NOTE:
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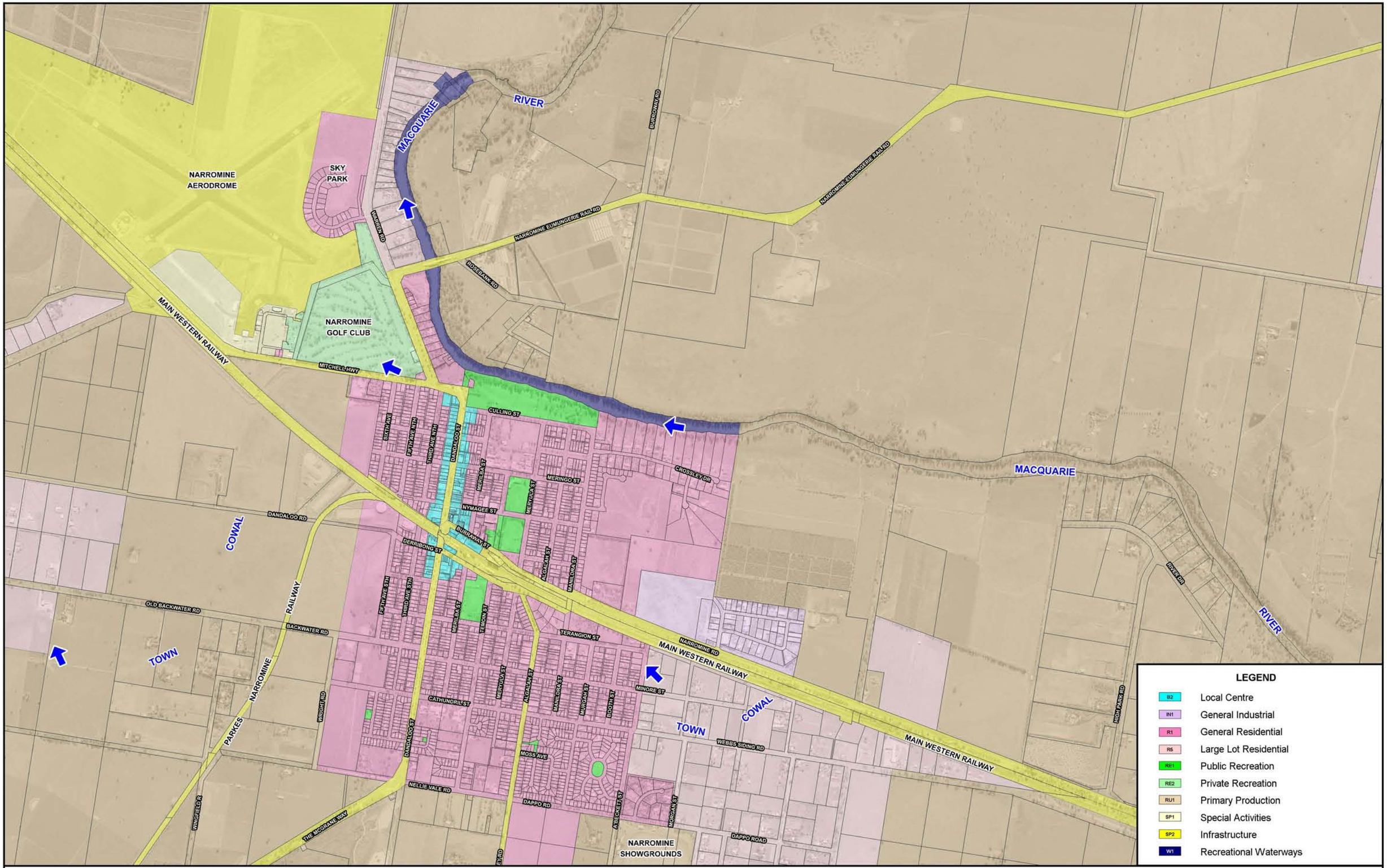
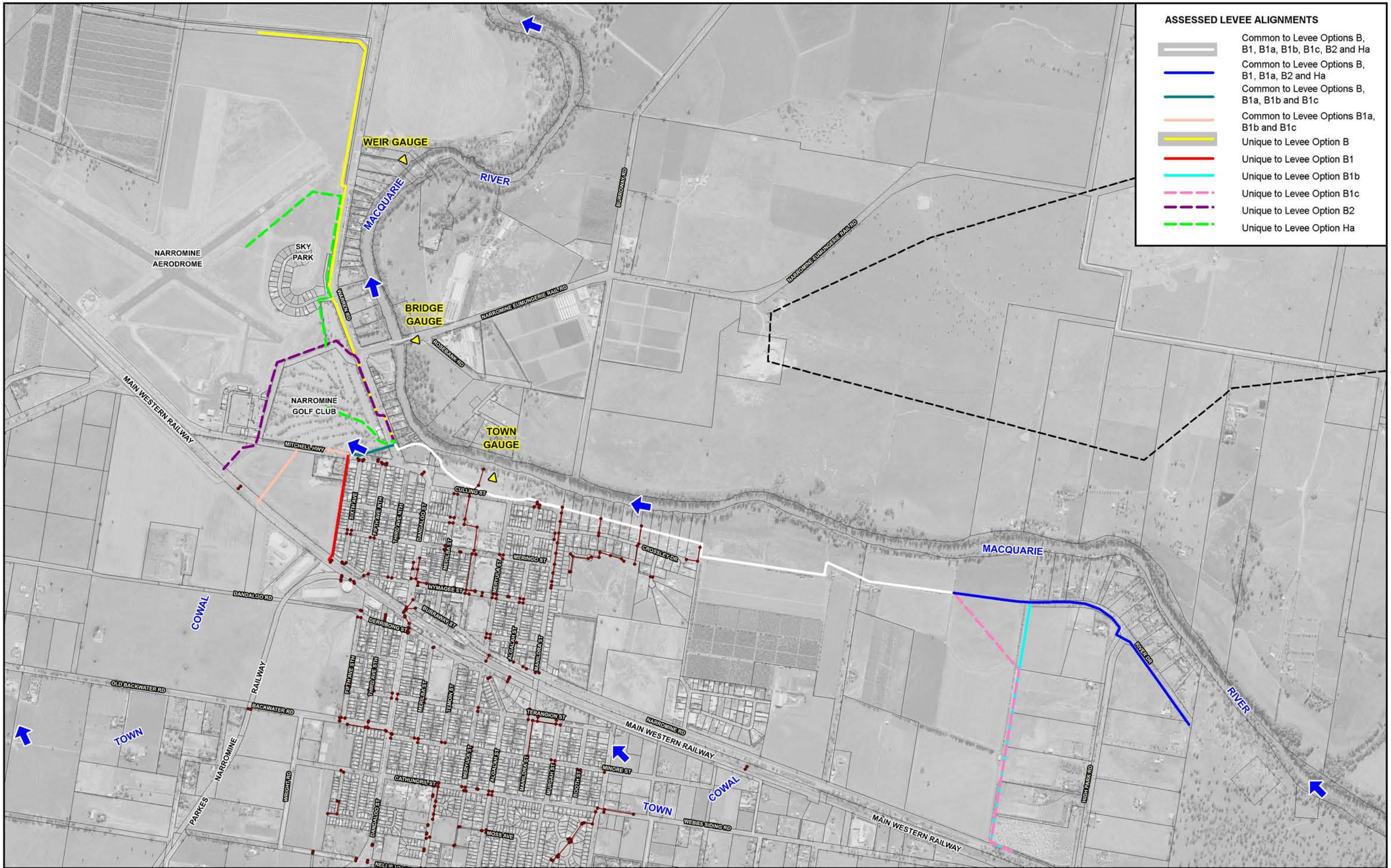
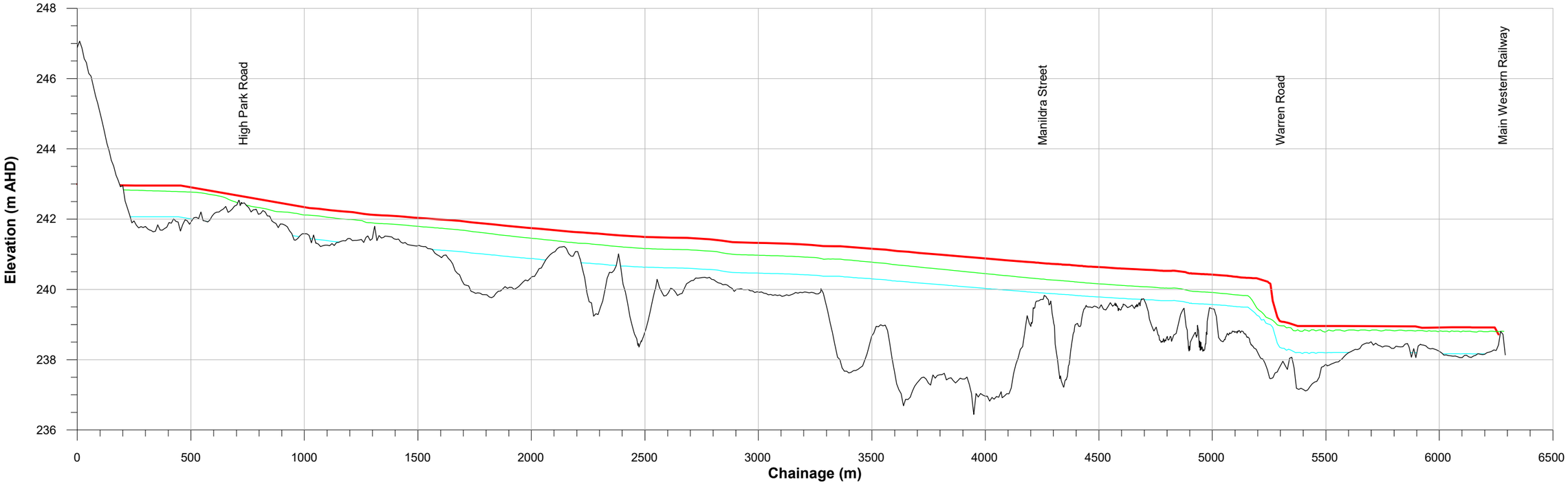
LEGEND
Two-Dimensional Model Boundary
Modelled Stormwater Drainage System
Stream Gauge
Town Levee
Floodway
Flood Storage
Flood Fringe
Lyall & Associates
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure 2.23
(Sheet 2 of 2)
HYDRAULIC CATEGORISATION OF FLOODPLAIN - MAIN STREAM FLOODING
1% AEP

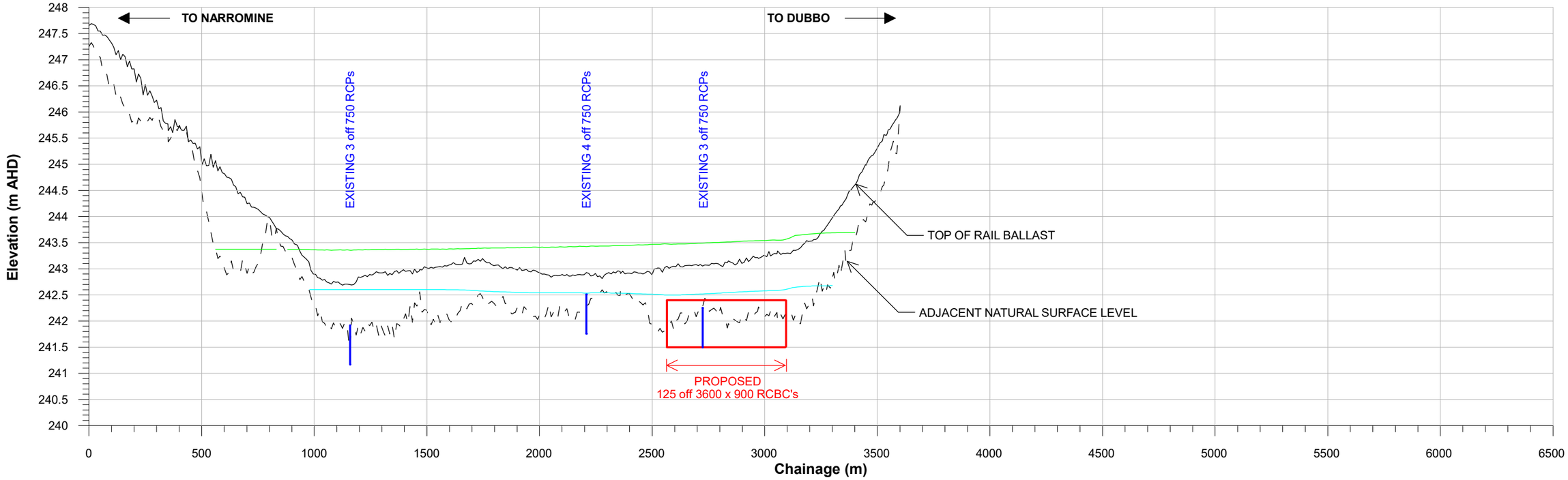

NARROMINE AERODROME
SKY PARK
MACQUARIE RIVER
BURRAWAY RD
NARROMINE EUMUNGERIE RAIL RD
NARROMINE EUMUNGERIE RAILRD
WARREN RD
ROSEBANK RD
MAIN WESTERN RAILWAY
NARROMINE GOLF CLUB
MITCHELL HWY
CULLING ST
SIXTH AVE
FIFTH AVE NTH
THIRD AVE NTH
DANDALOO ST
MERRIDA ST
MERIMULA ST
MERINGO ST
CROSSLEY DR
NYMAGEE ST
BURRAWAY ST
DERRIBONG ST
ALGALAH ST
MANILDRA ST
DANDALOO RD
COWAL
MACQUARIE
RIVER DR
RIVER
OLD BACKWATER RD
BACKWATER RD
TOWN
NARROMINE
RAILWAY
FIFTH AVE STH
THIRD AVE STH
TEMORA ST
TERANGION ST
NARROMINE RD
MAIN WESTERN RAILWAY
MINORE ST
COWAL
TOWN
WEBBS SIDING RD
MAIN WESTERN RAILWAY
HIGH PARK RD
WRIGHT RD
CATHUNDRIL ST
MURGAH ST
BOOTH ST
PARKES
DANDALOO ST
MOSS AVE
NELLIE VALE RD
DAPPO RD
ASBECKER ST
MORGAN ST
DAPPO ROAD
WINGFIELD R
THE MOGRANE WAY
NARROMINE SHOWGROUNDS
LEGEND
B2 Local Centre
IN1 General Industrial
R1 General Residential
R5 Large Lot Residential
RE1 Public Recreation
RE2 Private Recreation
RU1 Primary Production
SP1 Special Activities
SP2 Infrastructure
W1 Recreational Waterways
N
200 0 200 400 600 m
Scale: 1:20,000
Lyall & Associates
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure 2.24
NARROMINE LEP 2011 ZONING


ASSESSED LEVEE ALIGNMENTS
Common to Levee Options B, B1, B1a, B1b, B1c, B2 and Ha
Common to Levee Options B, B1, B1a, B2 and Ha
Common to Levee Options B, B1a, B1b and B1c
Common to Levee Options B1a, B1b and B1c
Unique to Levee Option B
Unique to Levee Option B1
Unique to Levee Option B1b
Unique to Levee Option B1c
Unique to Levee Option B2
Unique to Levee Option Ha
WEIR GAUGE
BRIDGE GAUGE
TOWN GAUGE
MACQUARIE RIVER
NARROMINE AERODROME
SKY PARK
NARROMINE GOLF CLUB
MAIN WESTERN RAILWAY
NARROMINE EUMUNGERIE RAILRD
DUBBOMAY RD
WARREN RD
ROSEBANK RD
MITCHELL HWY
CULLING ST
CROSSLEY DR
MERINGO ST
NYMAGEE ST
DANDALOO RD
BURRAWAY ST
DERRIBONG ST
OLD BACKWATER RD
BACKWATER RD
TERANGION ST
NARROMINE RD
MINORE ST
CATHUNDRIL ST
WEBBS SIDING RD
MOSS AVE
HIGH PARK RD
RIVER RD
COWAL
TOWN
NARROMINE
PARKES
WRIGHT RD
RAILWAY
FIRST AVE STH
SECOND AVE STH
THIRD AVE STH
FOURTH AVE STH
FIFTH AVE STH
DANDALOO ST
MERYULA ST
TERADIN ST
AGERAM ST
MANILDRA ST
MURGAH ST
BOOTH ST
N
200 0 200 400 600 m
Scale: 1:20,000
LEGEND
Two-Dimensional Model Boundary
Modelled Stormwater Drainage System
Stream Gauge
Lyall & Associates
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure 3.1
ASSESSED RIVER BANK LEVEE ALIGNMENTS AND RAIL UPGRADE WORKS

LEVEE OPTION B1a



EXISTING RAIL EMBANKMENT AT WEBBS SIDING



LEGEND

- Crest Level
- 0.5% AEP Peak Flood Level
- 1% AEP Peak Flood Level
- Existing Natural Surface Level

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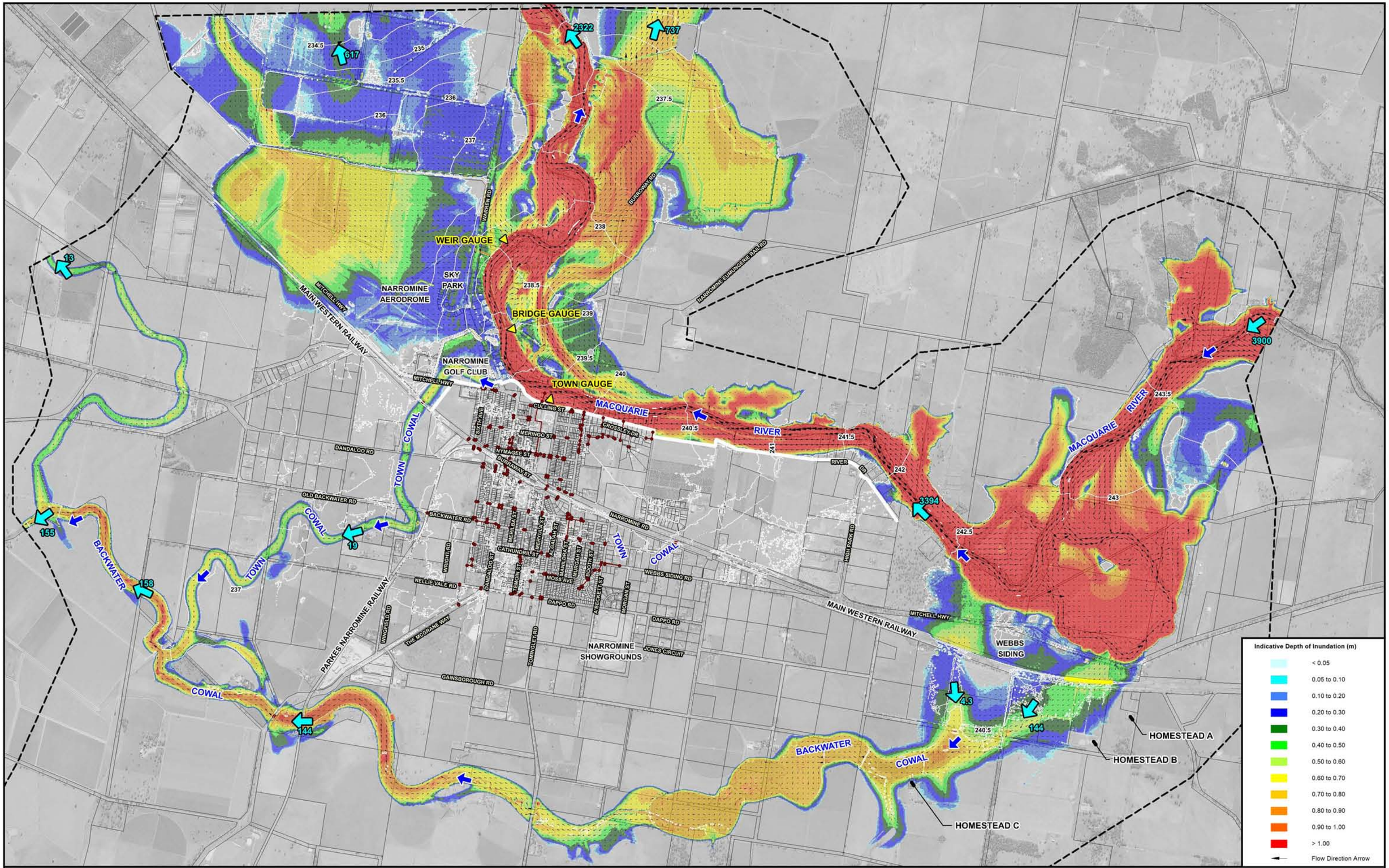
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 3.2

LONG SECTIONS OF PREFERRED FLOOD MITIGATION SCHEME



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

NOTE:
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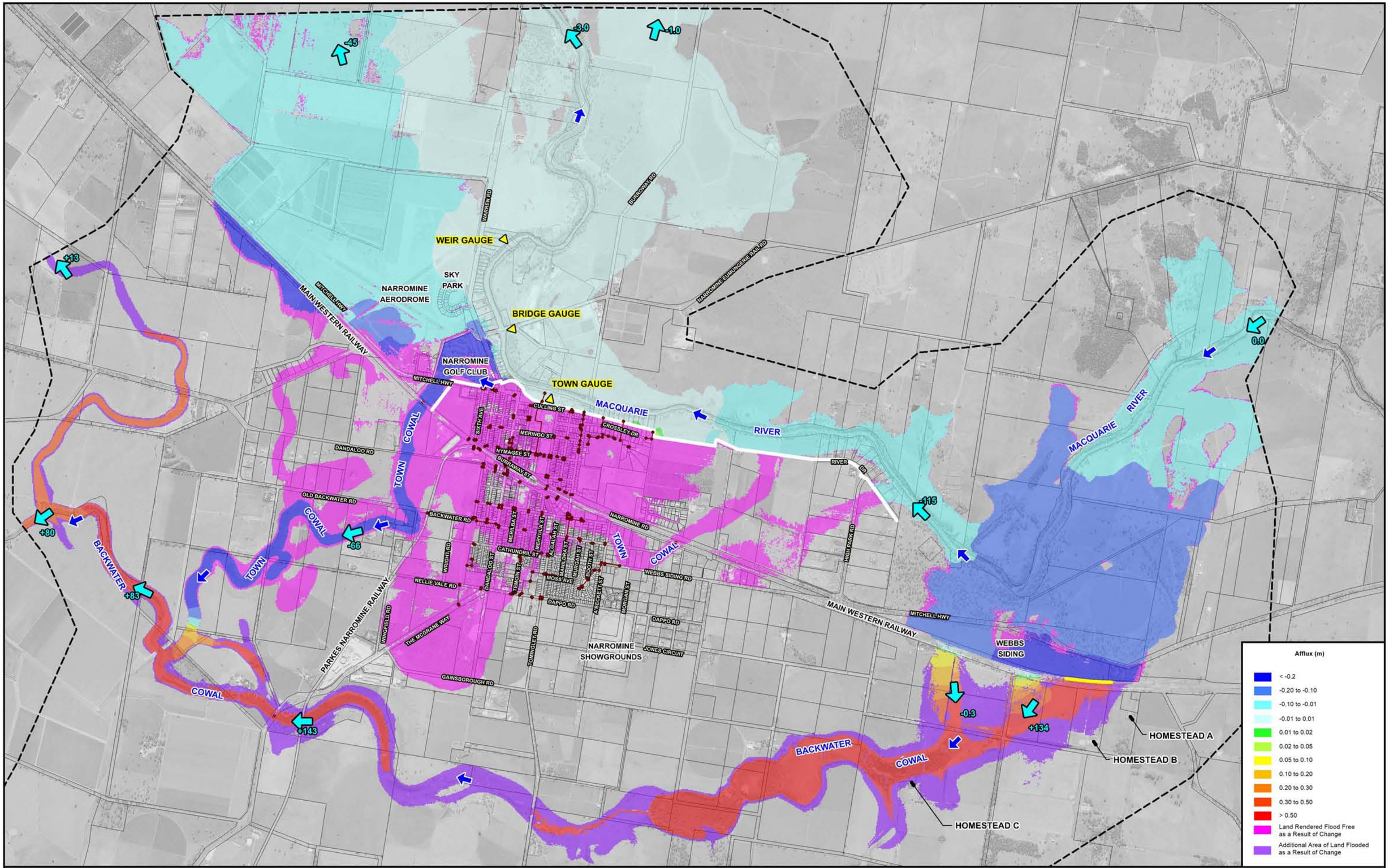
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- 5600 Peak Overland Flow(m^3/s)
- 238.5 Water Surface Elevation Contour (m AHD)
- Proposed Levee Alignment
- Proposed Railway Culvert Upgrade

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 3.3

INDICATIVE EXTENT AND DEPTH OF MAIN STREAM FLOODING
POST-PREFERRED FLOOD MITIGATION SCHEME CONDITIONS - 1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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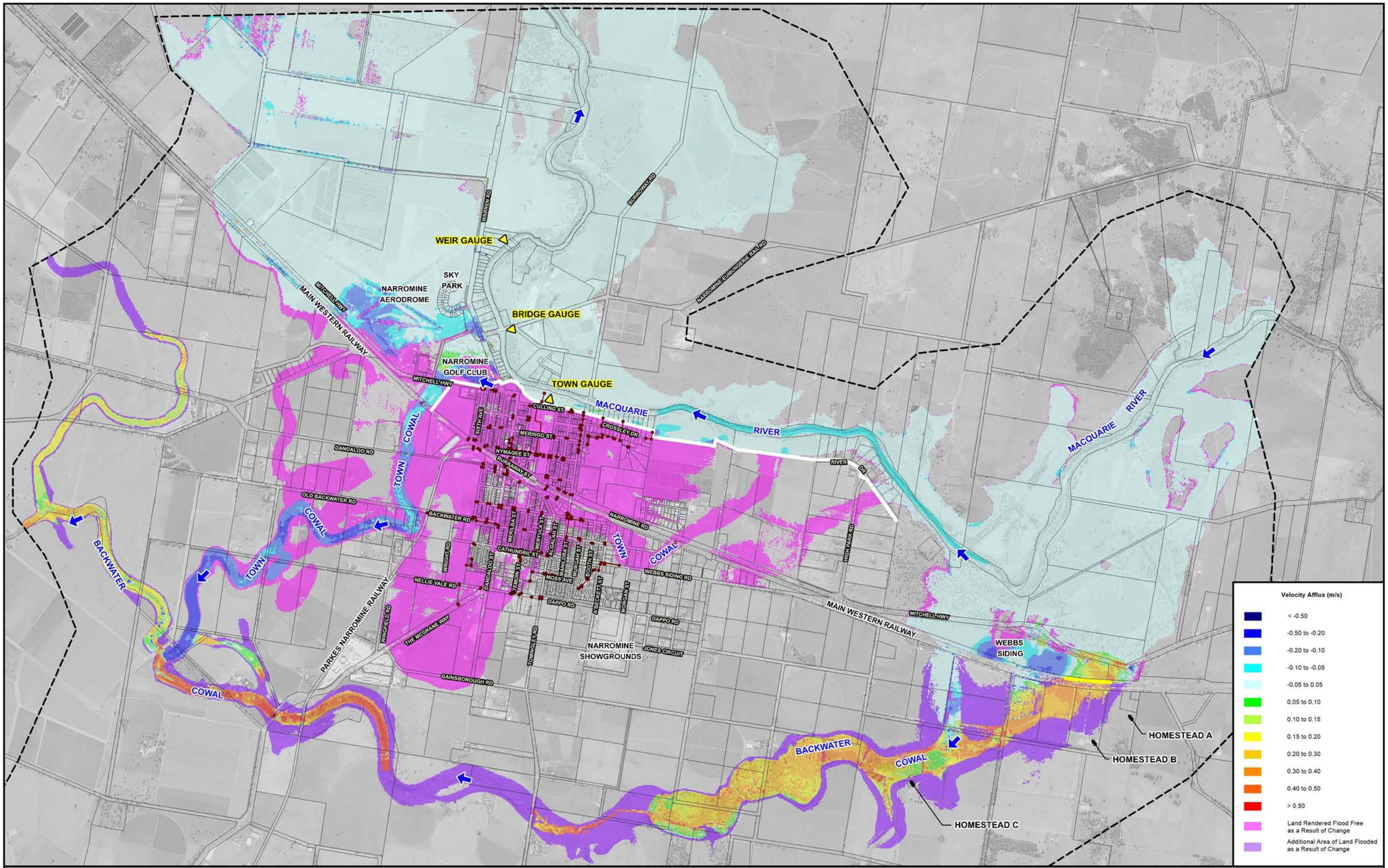
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- +13 Change in Peak Overland Flow (m³/s) (A positive value represents an increase, and conversely a negative value represents a decrease in peak flow when compared to baseline conditions.)
- Proposed Levee Alignment
- Proposed Railway Culvert Upgrade

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure 3.4

IMPACT OF PREFERRED FLOOD MITIGATION SCHEME ON MAIN STREAM FLOODING
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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LEGEND

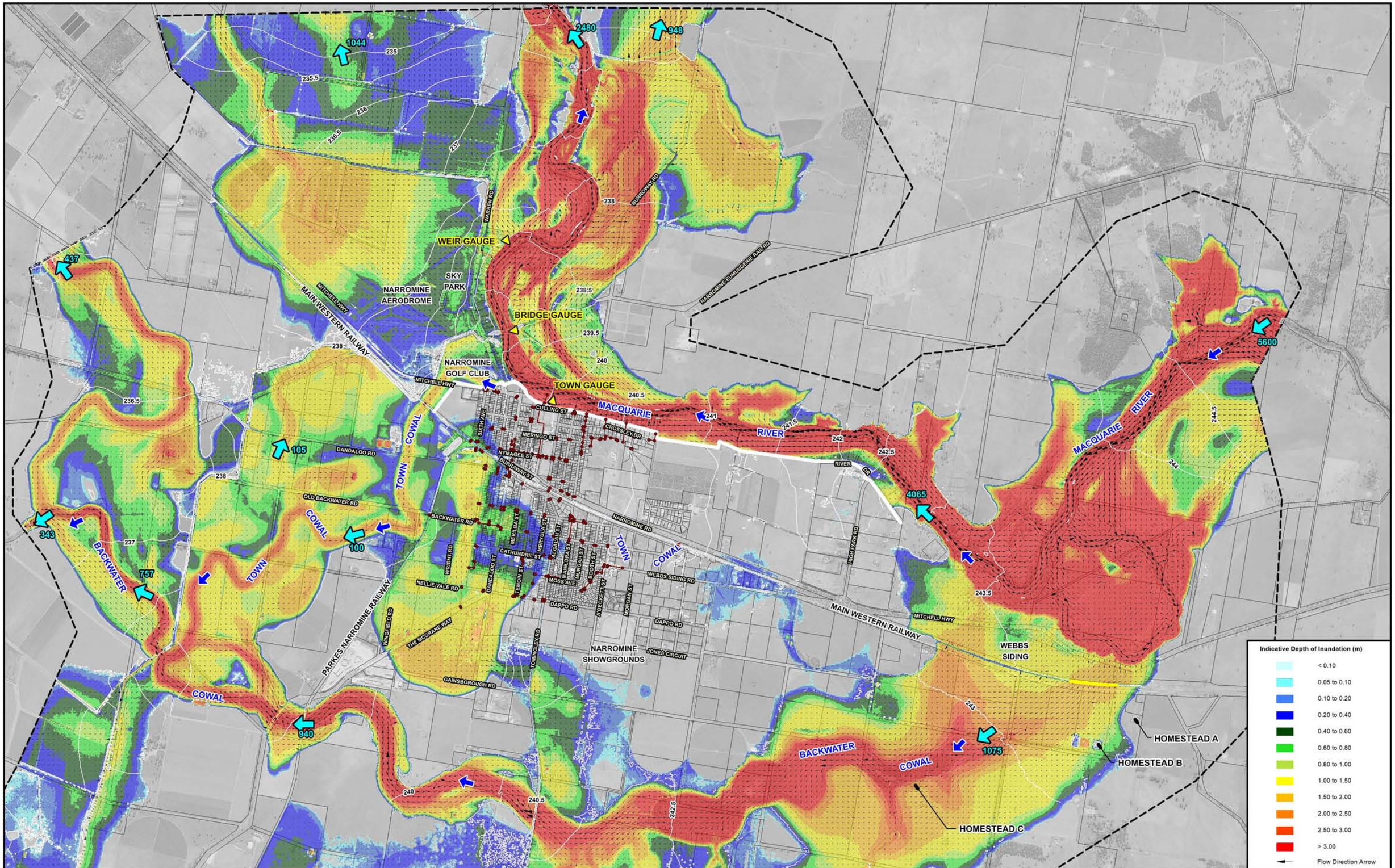
- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment
- Proposed Railway Culvert Upgrade

NARROMINE TOWN

FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 3.5

IMPACT OF PREFERRED FLOOD MITIGATION SCHEME ON MAXIMUM MAIN STREAM FLOODING FLOW VELOCITIES
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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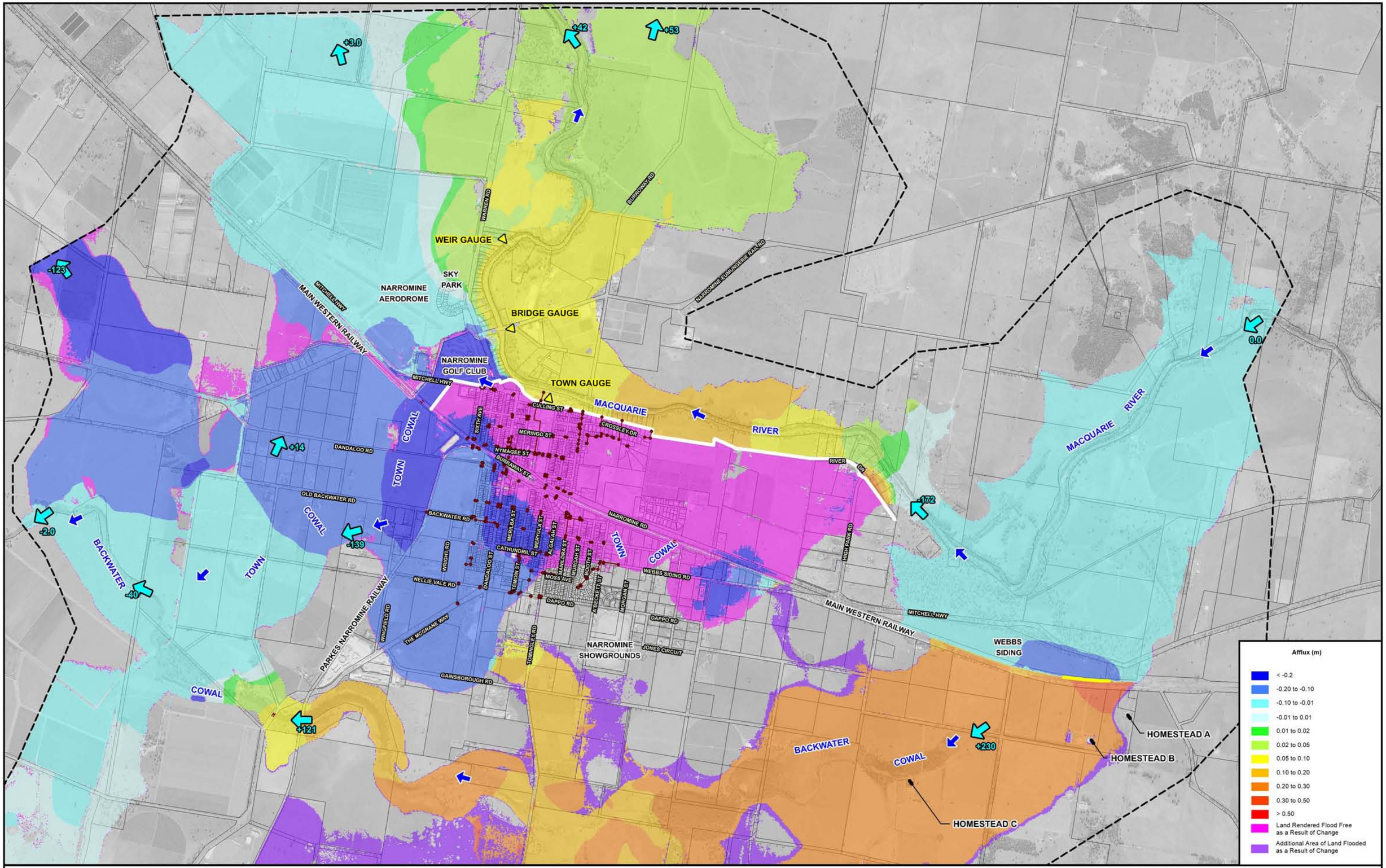
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- 5600 Peak Overland Flow(m^3/s)
- 238.5 Water Surface Elevation Contour (m AHD)
- Proposed Levee Alignment
- Proposed Railway Culvert Upgrade

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 3.6

INDICATIVE EXTENT AND DEPTH OF MAIN STREAM FLOODING
POST-PREFERRED FLOOD MITIGATION SCHEME CONDITIONS - 0.5% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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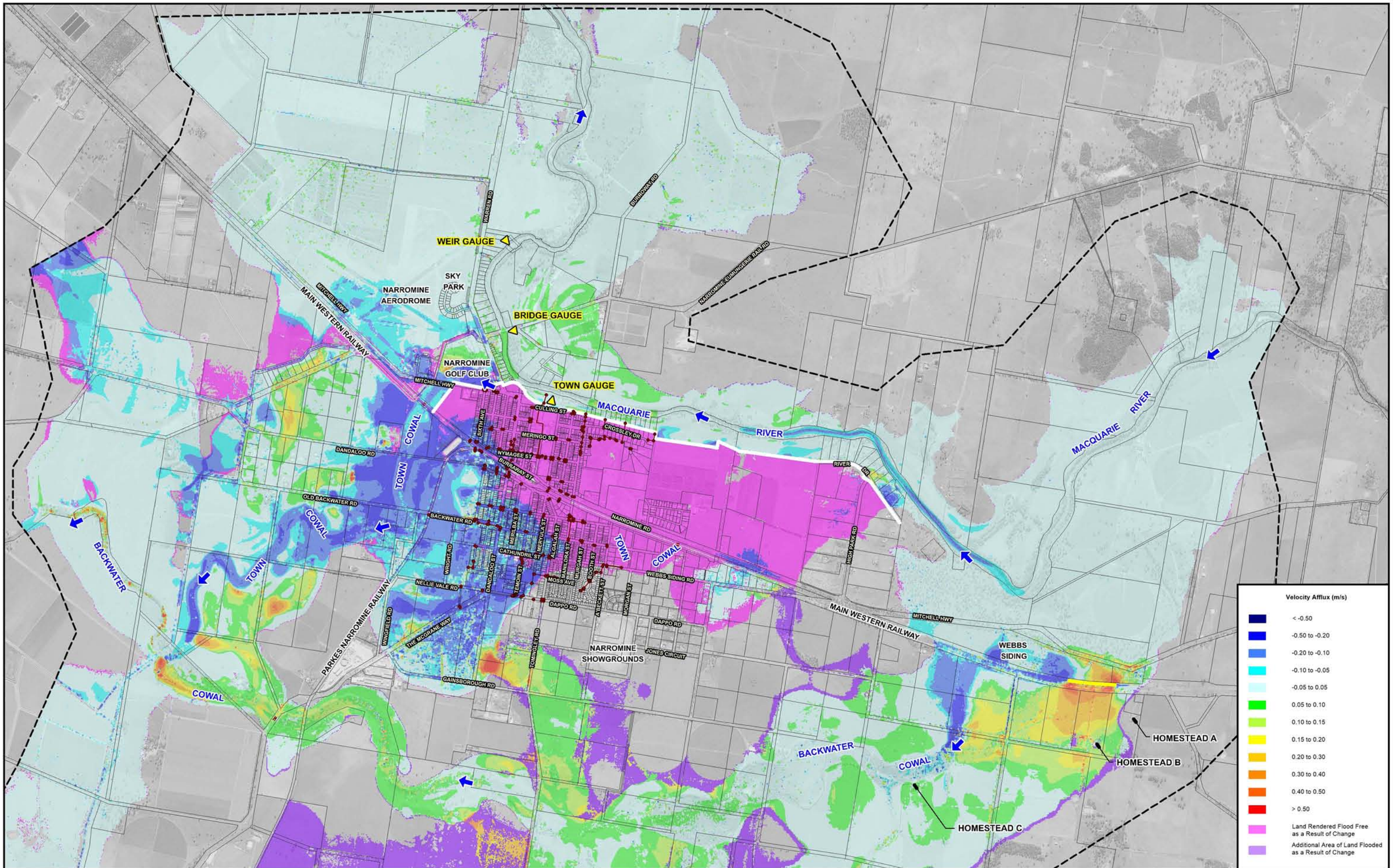
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- +13 Change in Peak Overland Flow (m³/s) (A positive value represents an increase, and conversely a negative value represents a decrease in peak flow when compared to baseline conditions.)
- Proposed Levee Alignment
- Proposed Railway Culvert Upgrade

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure 3.7

IMPACT OF PREFERRED FLOOD MITIGATION SCHEME ON MAIN STREAM FLOODING
0.5% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

NOTE:

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LEGEND

Two-Dimensional Model Boundary

Modelled Stormwater Drainage System

Stream Gauge

Proposed Levee Alignment

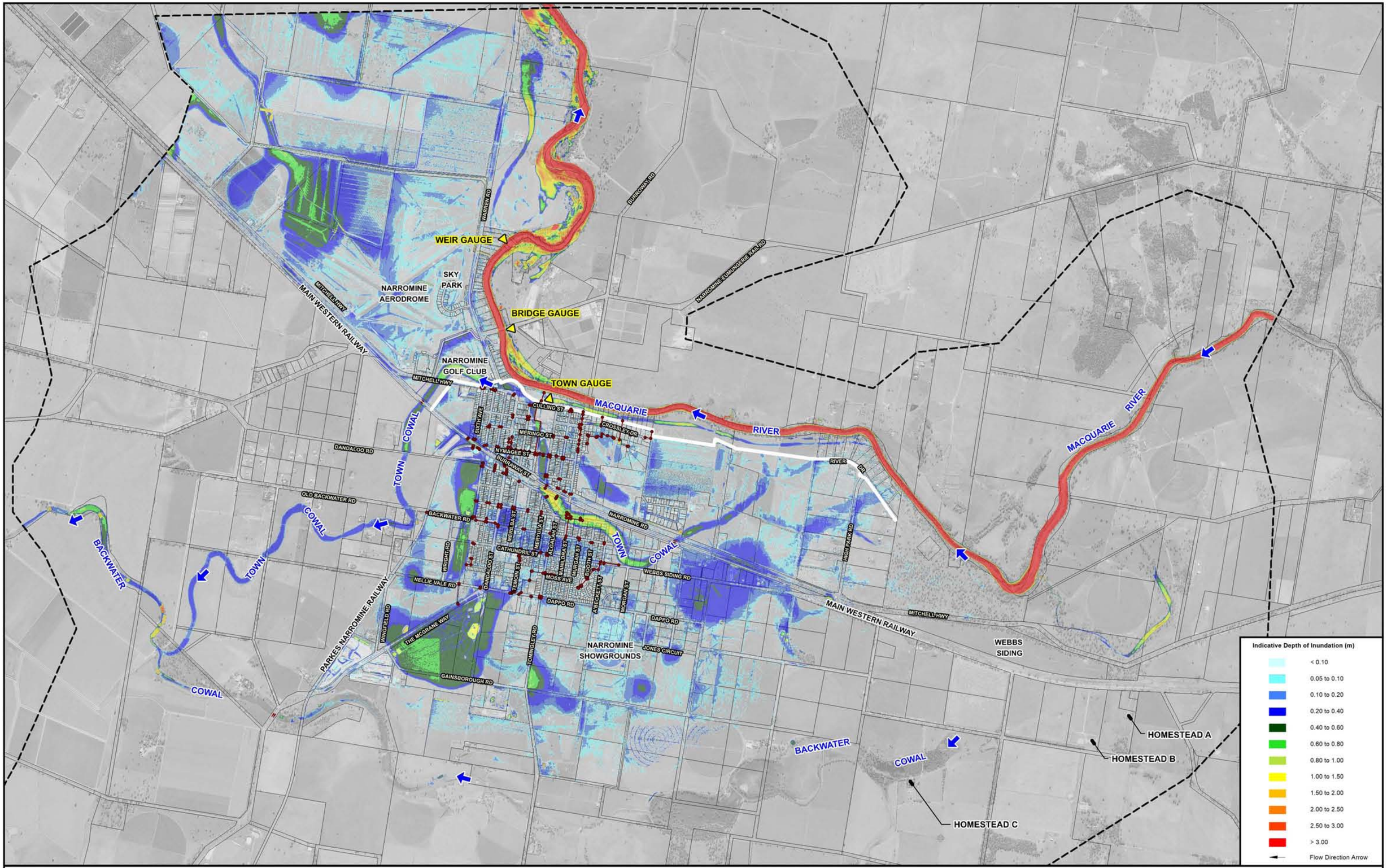
Proposed Railway Culvert Upgrade

NARROMINE TOWN

FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 3.8

IMPACT OF PREFERRED FLOOD MITIGATION SCHEME ON MAXIMUM MAIN STREAM FLOODING FLOW VELOCITIES
0.5% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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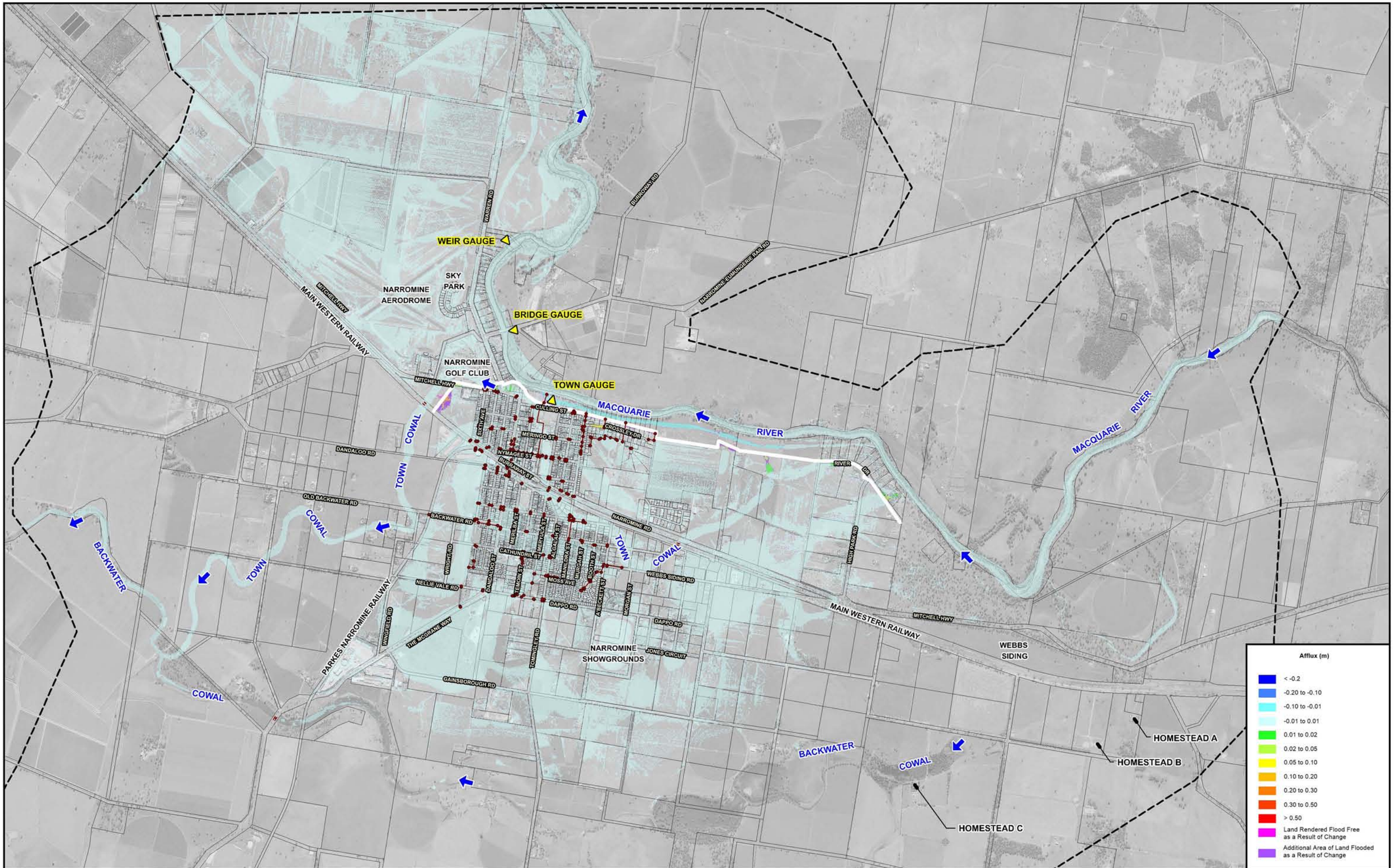
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- 238.5 Water Surface Elevation Contour (m AHD)
- Proposed Levee Alignment

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure 3.9

LOCAL CATCHMENT FLOODING – FLOOD GATES FULLY OPEN
POST-PREFERRED FLOOD MITIGATION SCHEME CONDITIONS - 1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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LEGEND

Two-Dimensional Model Boundary

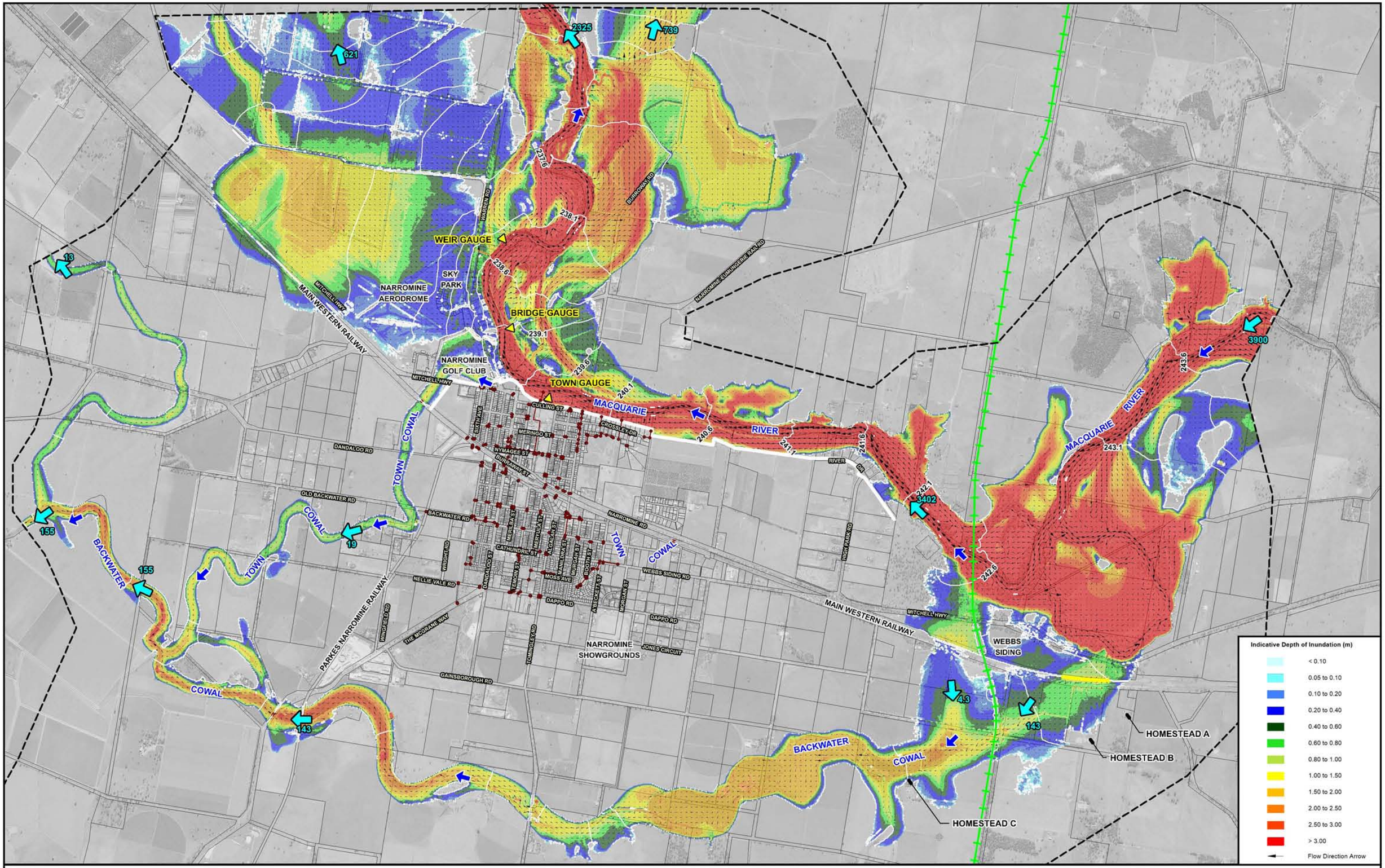
Modelled Stormwater Drainage System

Stream Gauge

Proposed Levee Alignment

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure 3.10

IMPACT OF ELEVATED RIVER LEVELS ON LOCAL CATCHMENT FLOODING – POST-PREFERRED FLOOD MITIGATION SCHEME CONDITIONS
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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LEGEND

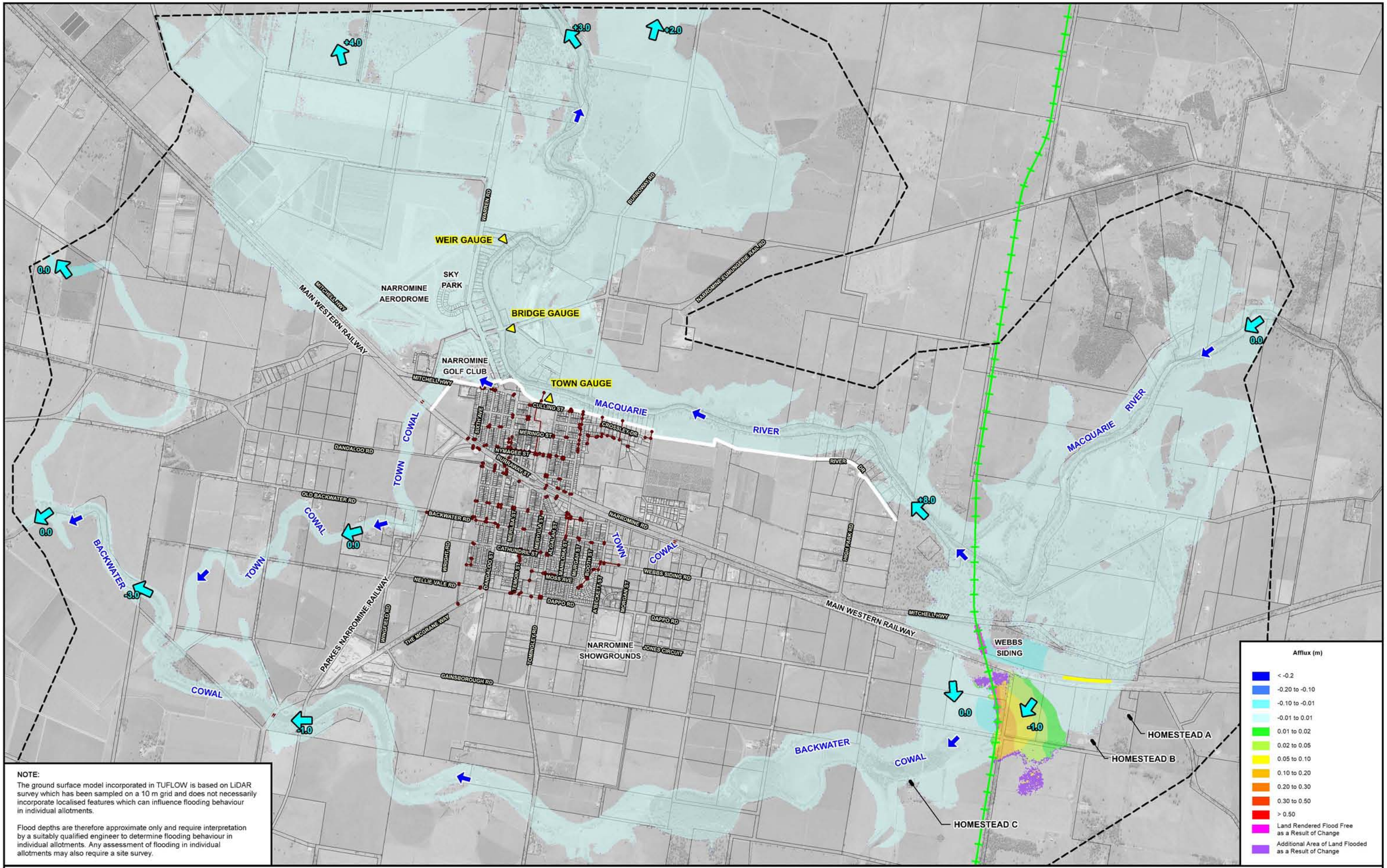
- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment
- 5600 Peak Overland Flow(m^3/s)
- 238.5 Water Surface Elevation Contour (m AHD)
- Proposed Inland Rail Alignment
- Proposed Railway Culvert Upgrade

NARROMINE TOWN

FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 3.11

INDICATIVE EXTENT AND DEPTH OF MAIN STREAM FLOODING POST-PREFERRED FLOOD MITIGATION SCHEME AND INLAND RAIL PROJECT CONDITIONS - 1% AEP



NOTE:

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Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

N

400 0 400 800 1200 m

Scale: 1:40,000

+13 (A positive value represents an increase, and conversely a negative value represents a decrease in peak flow when compared to baseline conditions.)

LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment
- Proposed Railway Culvert Upgrade
- Proposed Inland Rail Alignment

Lyall & Associates

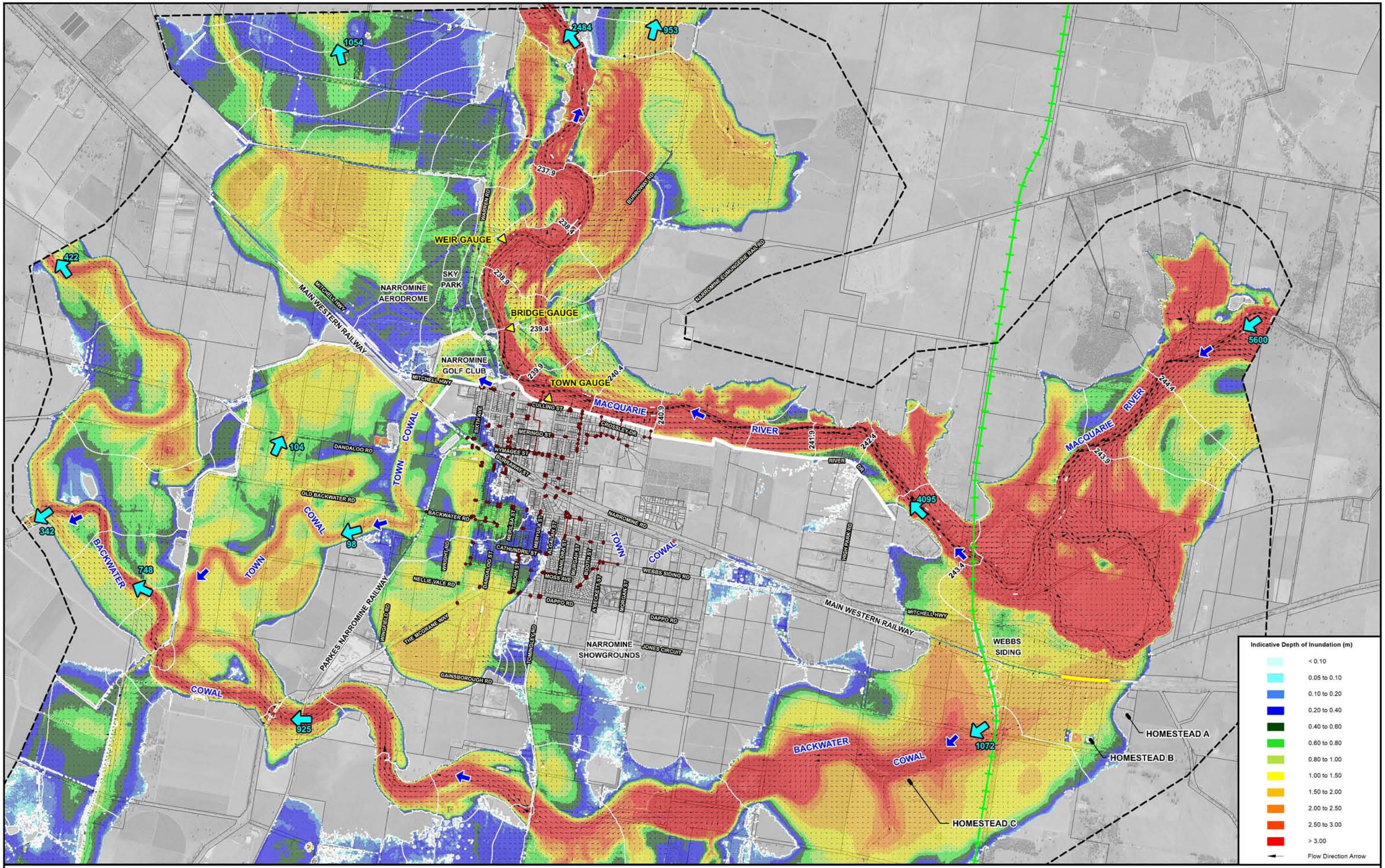
NARROMINE TOWN

FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 3.12

IMPACT OF INLAND RAIL PROJECT ON FLOOD BEHAVIOUR UNDER POST-PREFERRED FLOOD MITIGATION SCHEME CONDITIONS

1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

NOTE:

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LEGEND

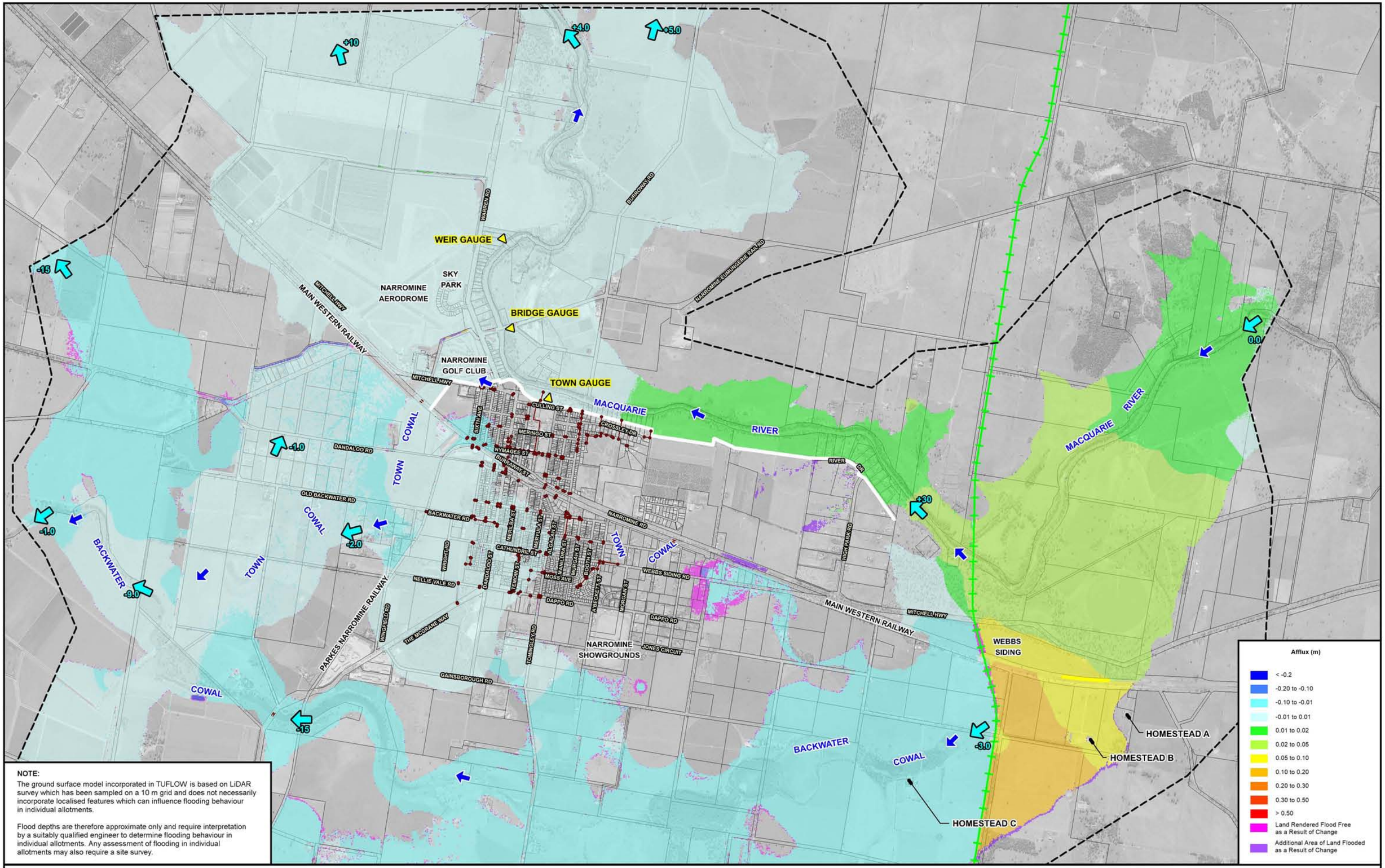
- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment
- 5600 Peak Overland Flow(m^3/s)
- 238.5 Water Surface Elevation Contour (m AHD)
- Proposed Inland Rail Alignment
- Proposed Railway Culvert Upgrade

NARROMINE TOWN

FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 3.13

INDICATIVE EXTENT AND DEPTH OF MAIN STREAM FLOODING POST-PREFERRED FLOOD MITIGATION SCHEME AND INLAND RAIL PROJECT CONDITIONS - 0.5% AEP



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N

400 0 400 800 1200 m

Scale: 1:40,000

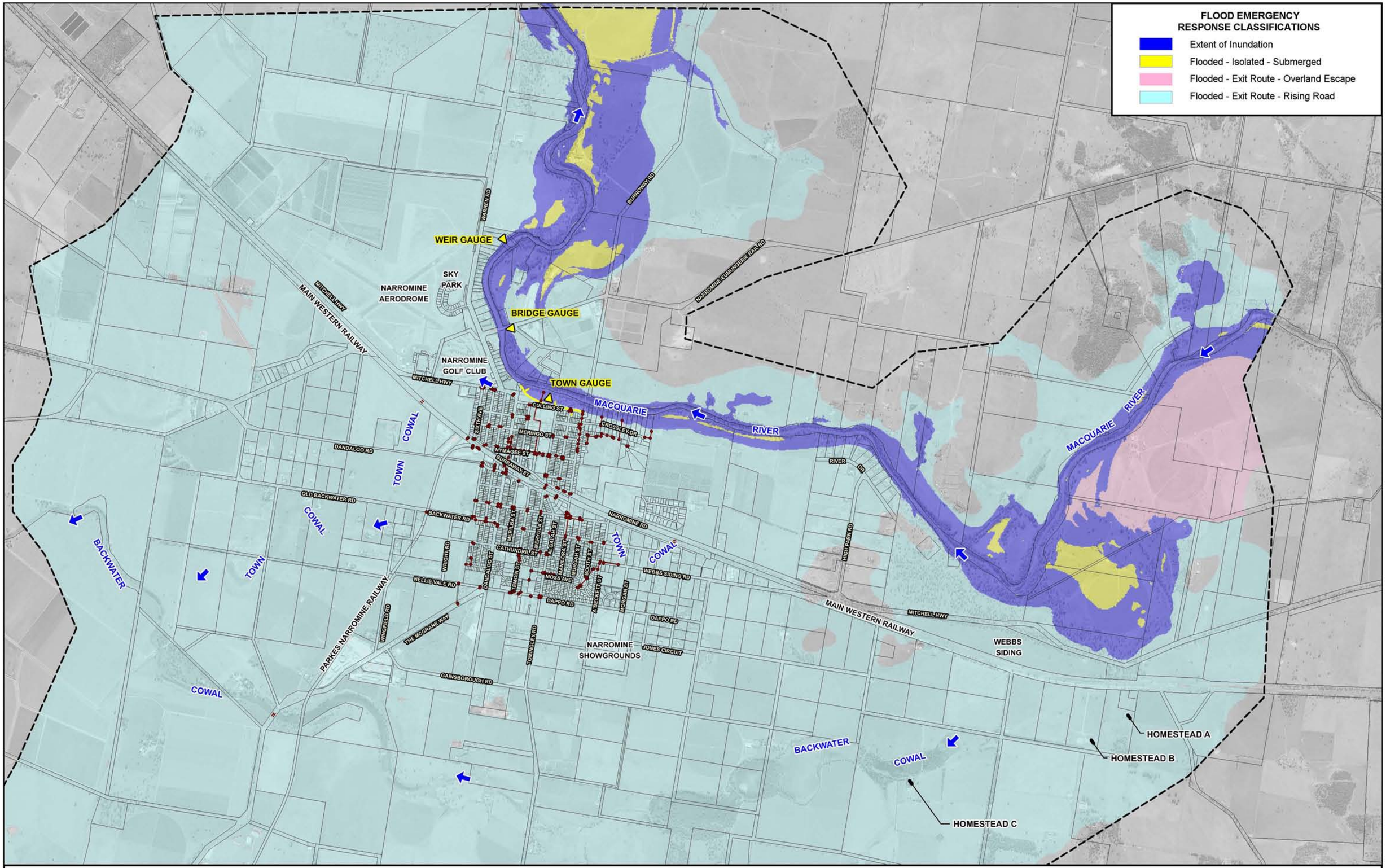
+13 (A positive value represents an increase, and conversely a negative value represents a decrease in peak flow when compared to baseline conditions.)

LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment
- Proposed Railway Culvert Upgrade
- Proposed Inland Rail Alignment

Lyall & Associates

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure 3.14
IMPACT OF INLAND RAIL PROJECT ON FLOOD BEHAVIOUR UNDER POST-PREFERRED FLOOD MITIGATION SCHEME CONDITIONS
0.5% AEP


FLOOD EMERGENCY RESPONSE CLASSIFICATIONS
Extent of Inundation
Flooded - Isolated - Submerged
Flooded - Exit Route - Overland Escape
Flooded - Exit Route - Rising Road
WEIR GAUGE
BRIDGE GAUGE
TOWN GAUGE
NARROMINE AERODROME
SKY PARK
NARROMINE GOLF CLUB
NARROMINE SHOWGROUNDS
WEBBS SIDING
MACQUARIE RIVER
COWAL
BACKWATER
TOWN
MAIN WESTERN RAILWAY
MITCHELL HWY
WARREN RD
BURROWAY RD
NARROMINE RD
DANDALOO RD
OLD BACKWATER RD
BACKWATER RD
WEBBS SIDING RD
DAPPO RD
GAINSBOROUGH RD
NELLIE VALE RD
CULLING ST
MERINGO ST
NYMAGEE ST
CROSSLEY DR
HIGH PARK RD
HOMESTEAD A
HOMESTEAD B
HOMESTEAD C
N
400 0 400 800 1200 m
Scale: 1:40,000
NOTE:
The ground surface model incorporated in TUFLOW is based on LiDAR survey which has been sampled on a 10 m grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.
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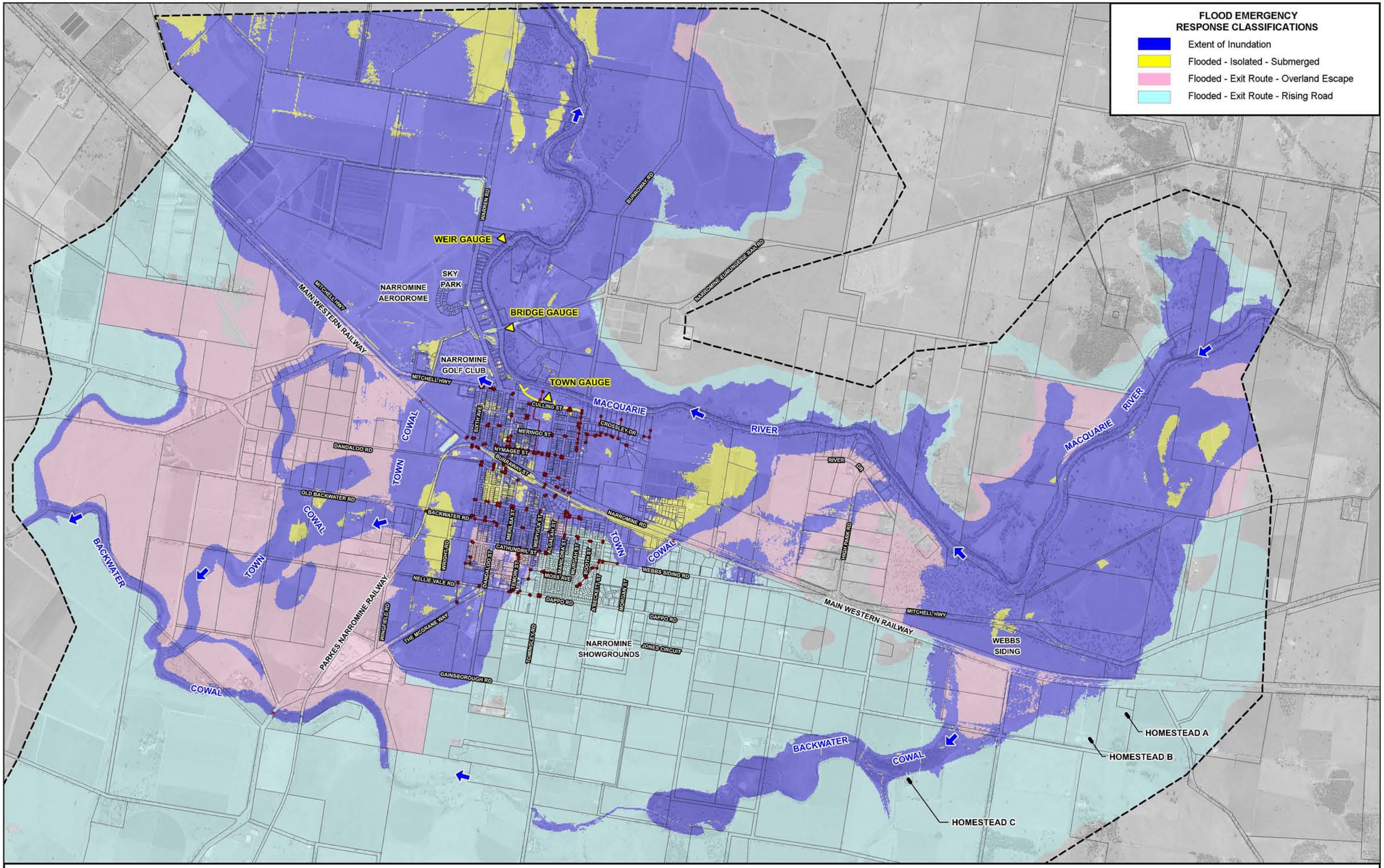
LEGEND
Two-Dimensional Model Boundary
Modelled Stormwater Drainage System
Stream Gauge
Town Levee
Lyall & Associates
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure 3.15
FLOOD EMERGENCY RESPONSE PLANNING CLASSIFICATION
5% AEP


FLOOD EMERGENCY RESPONSE CLASSIFICATIONS
Extent of Inundation
Flooded - Isolated - Submerged
Flooded - Exit Route - Overland Escape
Flooded - Exit Route - Rising Road
WEIR GAUGE
BRIDGE GAUGE
TOWN GAUGE
NARROMINE AERODROME
SKY PARK
NARROMINE GOLF CLUB
NARROMINE SHOWGROUNDS
WEBBS SIDING
HOMESTEAD A
HOMESTEAD B
HOMESTEAD C
MACQUARIE RIVER
COWAL
BACKWATER
TOWN
MAIN WESTERN RAILWAY
MITCHELL HWY
WARREN RD
BURROWAY RD
NARROMINE-SUMMERDERIE RAIL RD
CULLING ST
MERINGO ST
NYMAGEE ST
BURRAWAY ST
CROSSLEY DR
RIVER DR
SIXTH AVE
DANDALOO RD
OLD BACKWATER RD
BACKWATER RD
NARROMINE RD
WRIGHT RD
MERILBA ST
MERVULA ST
ALGALAH ST
MANILDRA ST
MURGAH ST
BOOTH ST
CATHUNDRIL ST
DANDALOO ST
TENANDRA ST
MOSS AVE
ABLECHETT ST
MORGAN ST
DAPPO RD
NELLIE VALE RD
WINGFIELD RD
THE MCGRANE WAY
PARKES NARROMINE RAILWAY
TOMINGLEY RD
JONES CIRCUIT
GAINSBOROUGH RD
WEBBS SIDING RD
HIGH PARK RD
N
400 0 400 800 1200 m
Scale: 1:40,000
NOTE:
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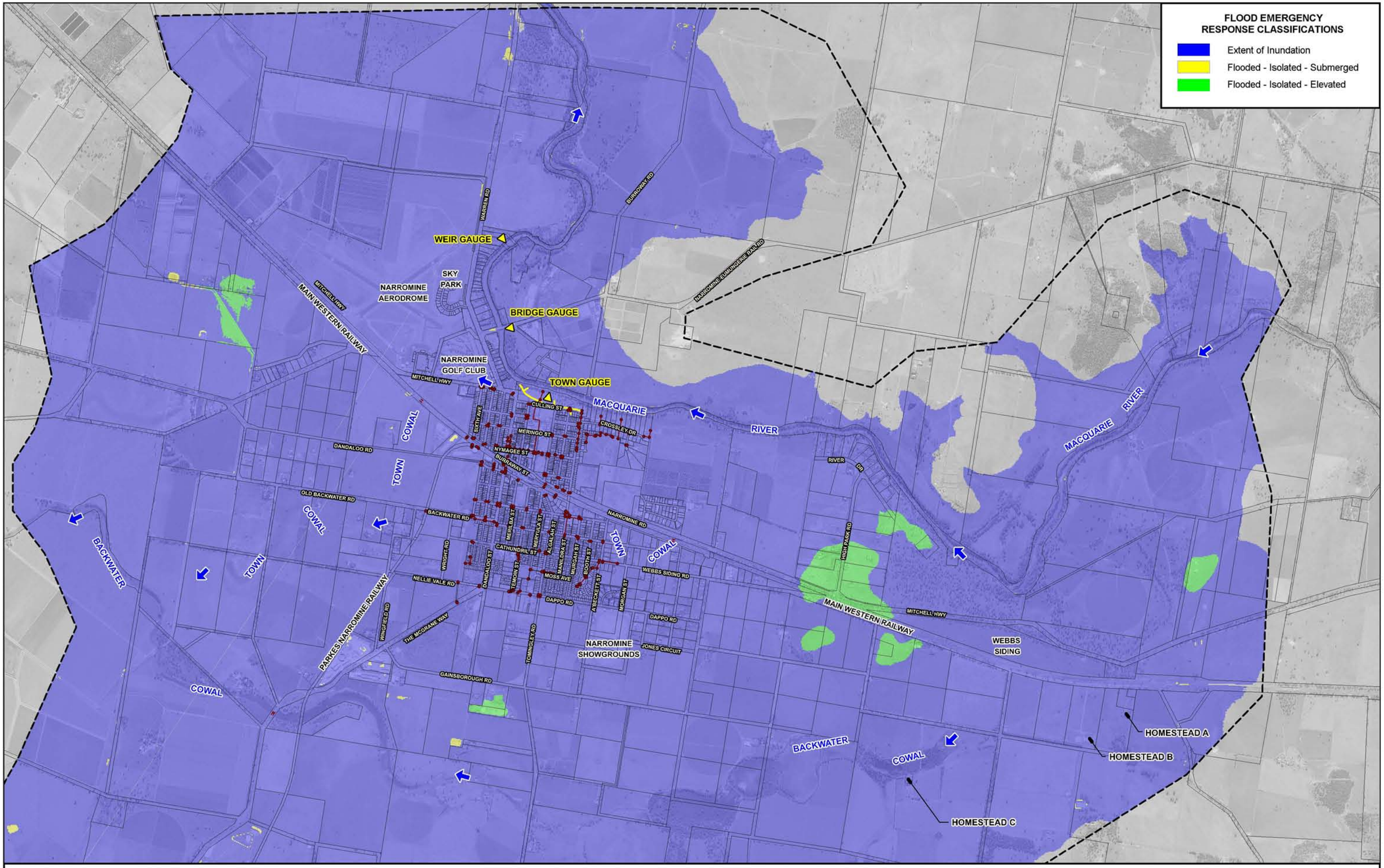
LEGEND
Two-Dimensional Model Boundary
Modelled Stormwater Drainage System
Stream Gauge
Town Levee
Lyall & Associates
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure 3.16
FLOOD EMERGENCY RESPONSE PLANNING CLASSIFICATION
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Town Levee

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

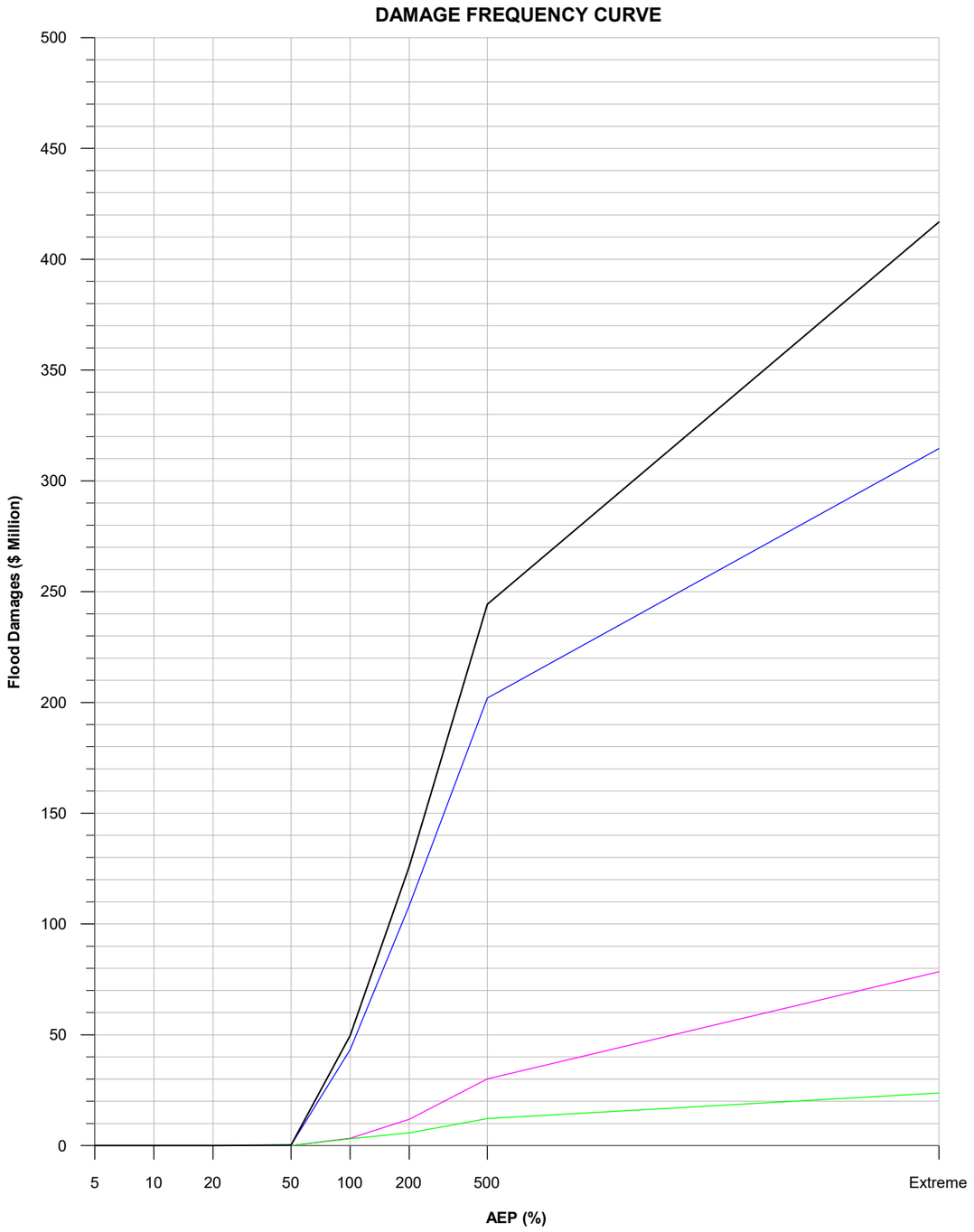
Figure 3.17

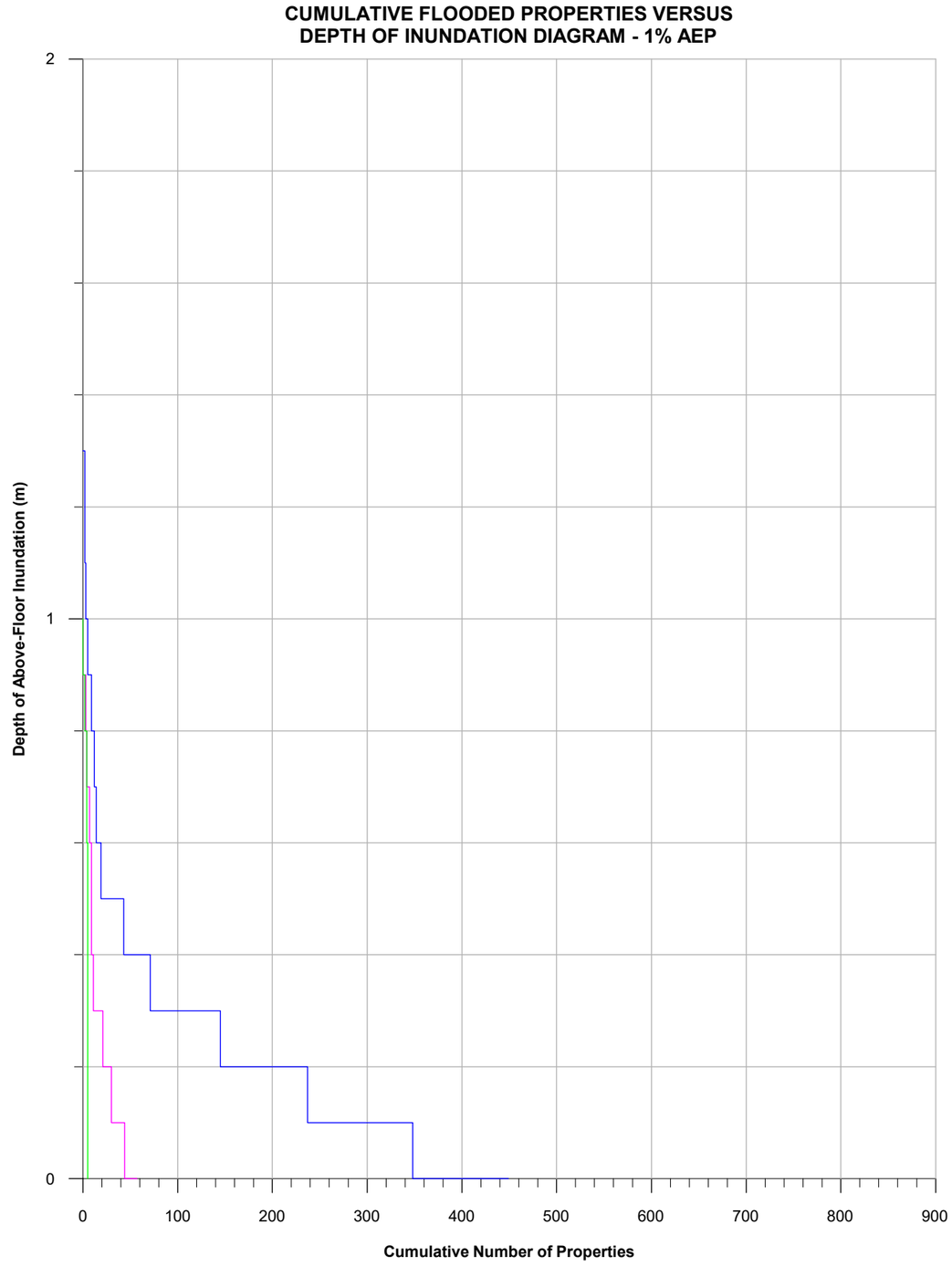
FLOOD EMERGENCY RESPONSE PLANNING CLASSIFICATION
EXTREME FLOOD

APPENDIX B

FLOOD DAMAGES

LIST OF FIGURES (APPENDIX B)





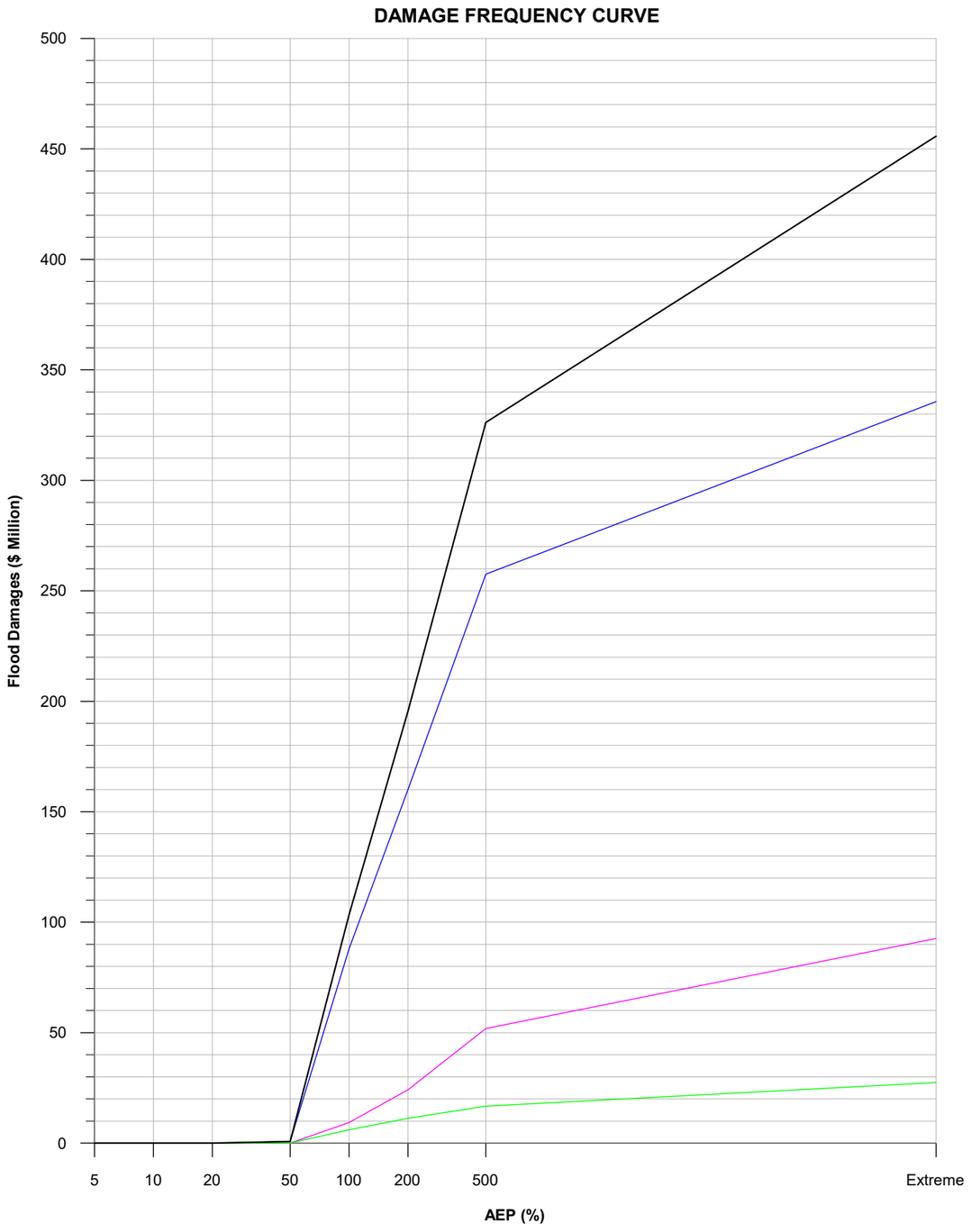
LEGEND
- Total
- Residential
- Commercial
- Public

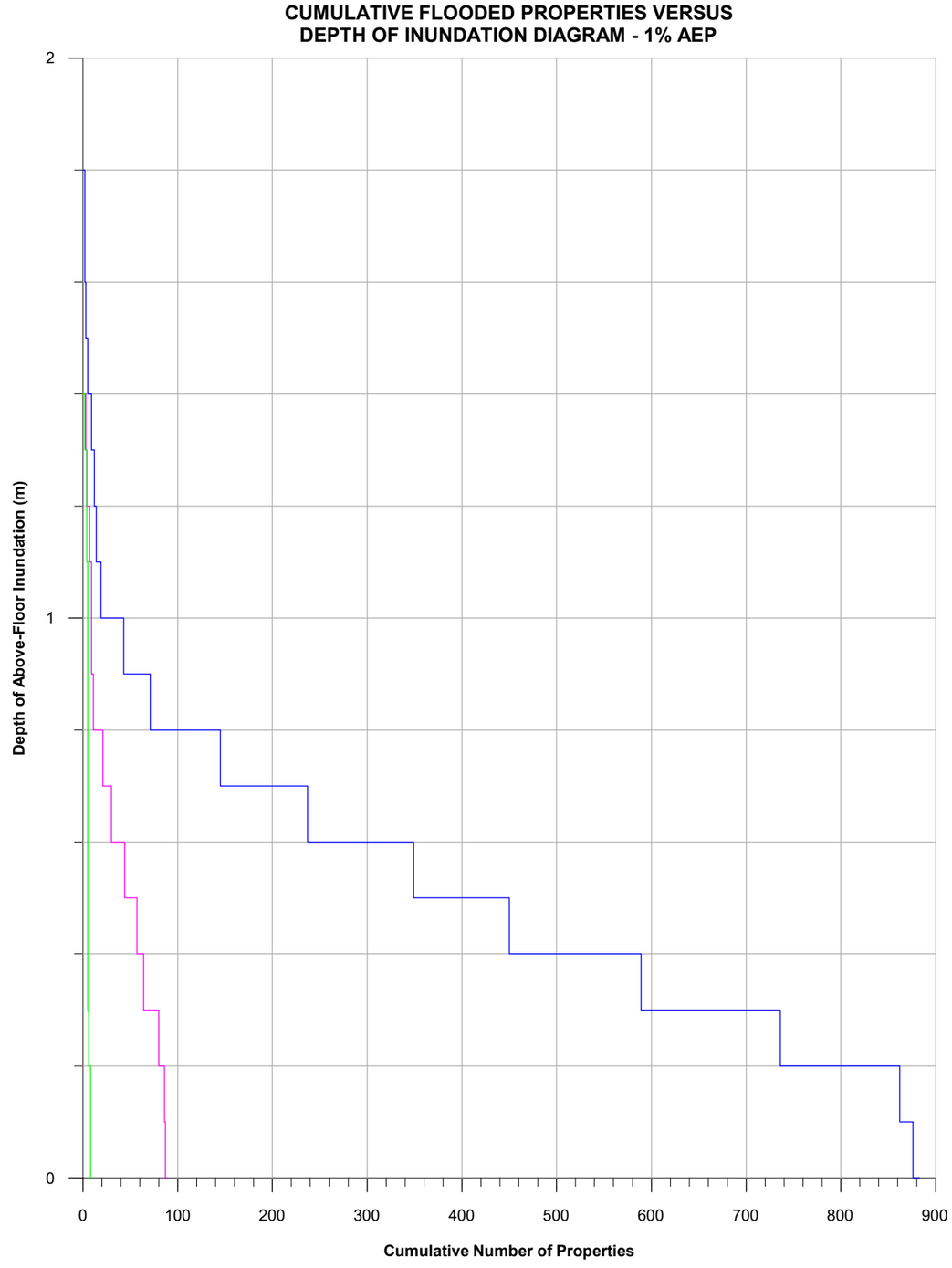
Lyall & Associates

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure B8.1

DAMAGE - FREQUENCY CURVES AND
CUMULATIVE FLOODED PROPERTIES VERSUS DEPTH OF INUNDATION DIAGRAM
1% AEP NOMINAL FLOOD LEVELS





LEGEND
- Total
- Residential
- Commercial
- Public

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NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

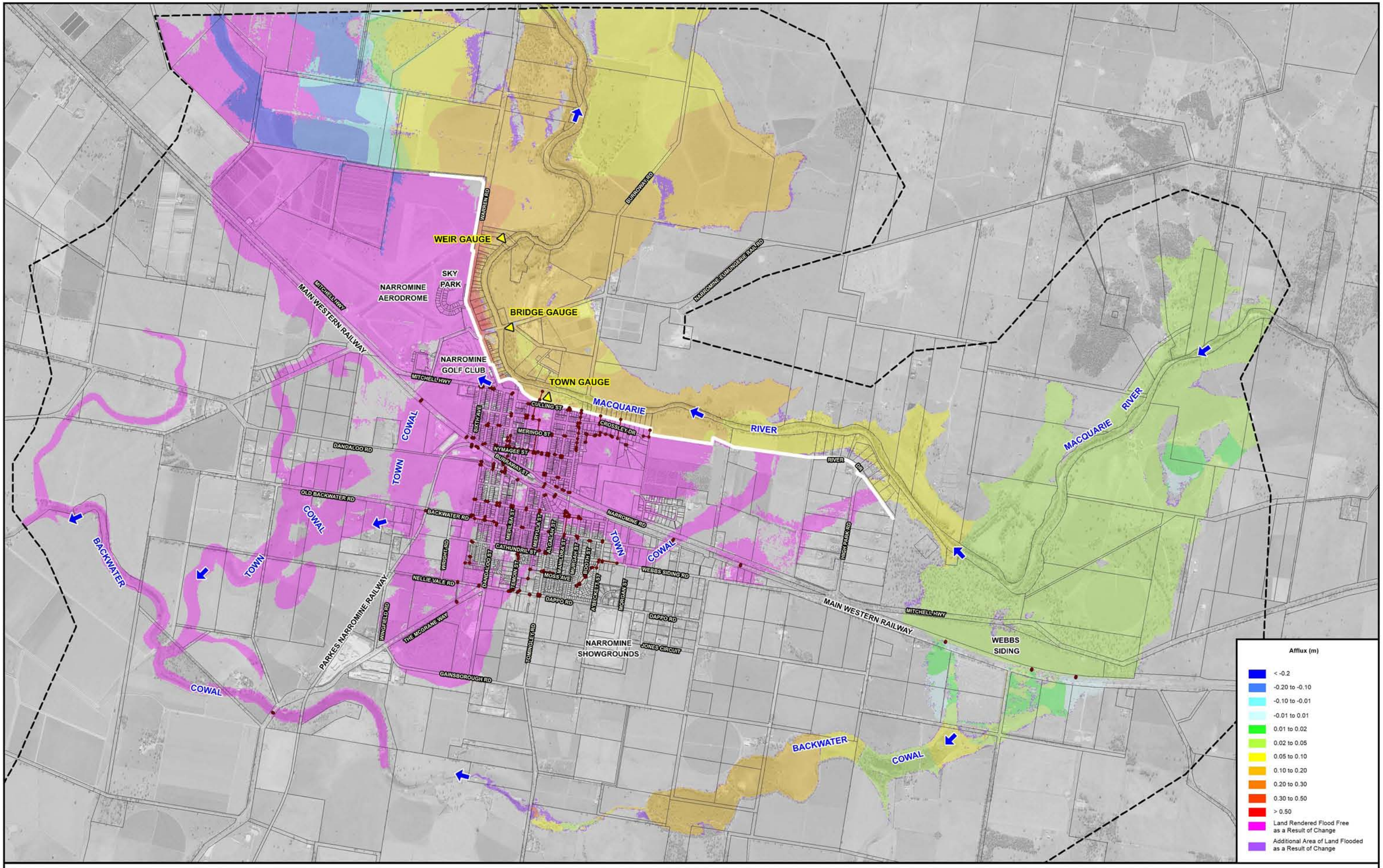
Figure B8.2

DAMAGE - FREQUENCY CURVES AND
CUMULATIVE FLOODED PROPERTIES VERSUS DEPTH OF INUNDATION DIAGRAM
1% AEP NOMINAL FLOOD LEVELS WITH FREEBOARD

APPENDIX C

IMPACT OF ASSESSED RIVER BANK LEVEE OPTIONS ON FLOOD BEHAVIOUR

LIST OF FIGURES (APPENDIX C)



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

NOTE:
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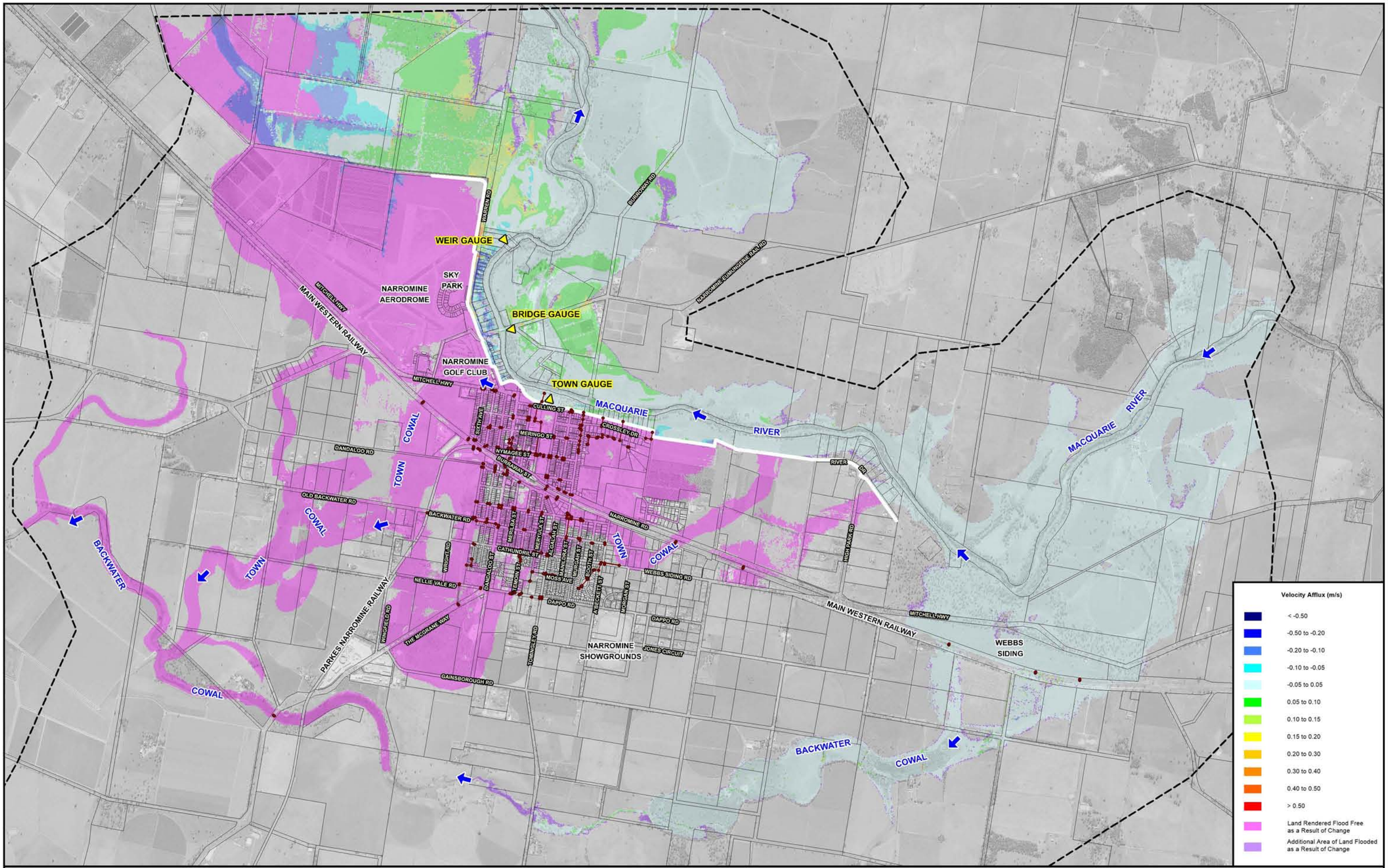
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure C1.1

IMPACT OF LEVEE OPTION B ON MAIN STREAM FLOODING
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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LEGEND

Two-Dimensional Model Boundary

Modelled Stormwater Drainage System

Stream Gauge

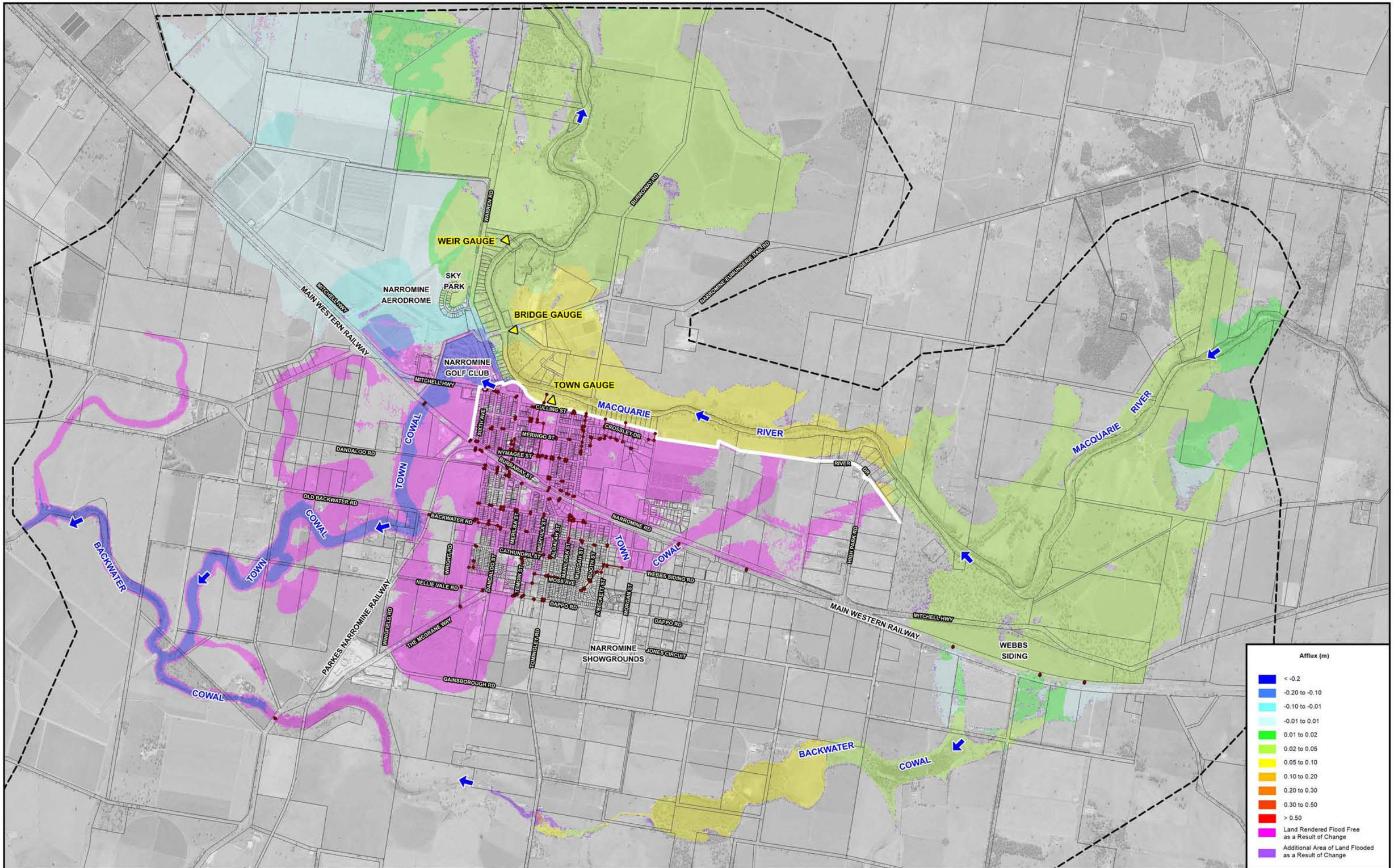
Proposed Levee Alignment

NARROMINE TOWN

FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure C1.2

IMPACT OF LEVEE OPTION B ON MAXIMUM MAIN STREAM FLOODING FLOW VELOCITIES
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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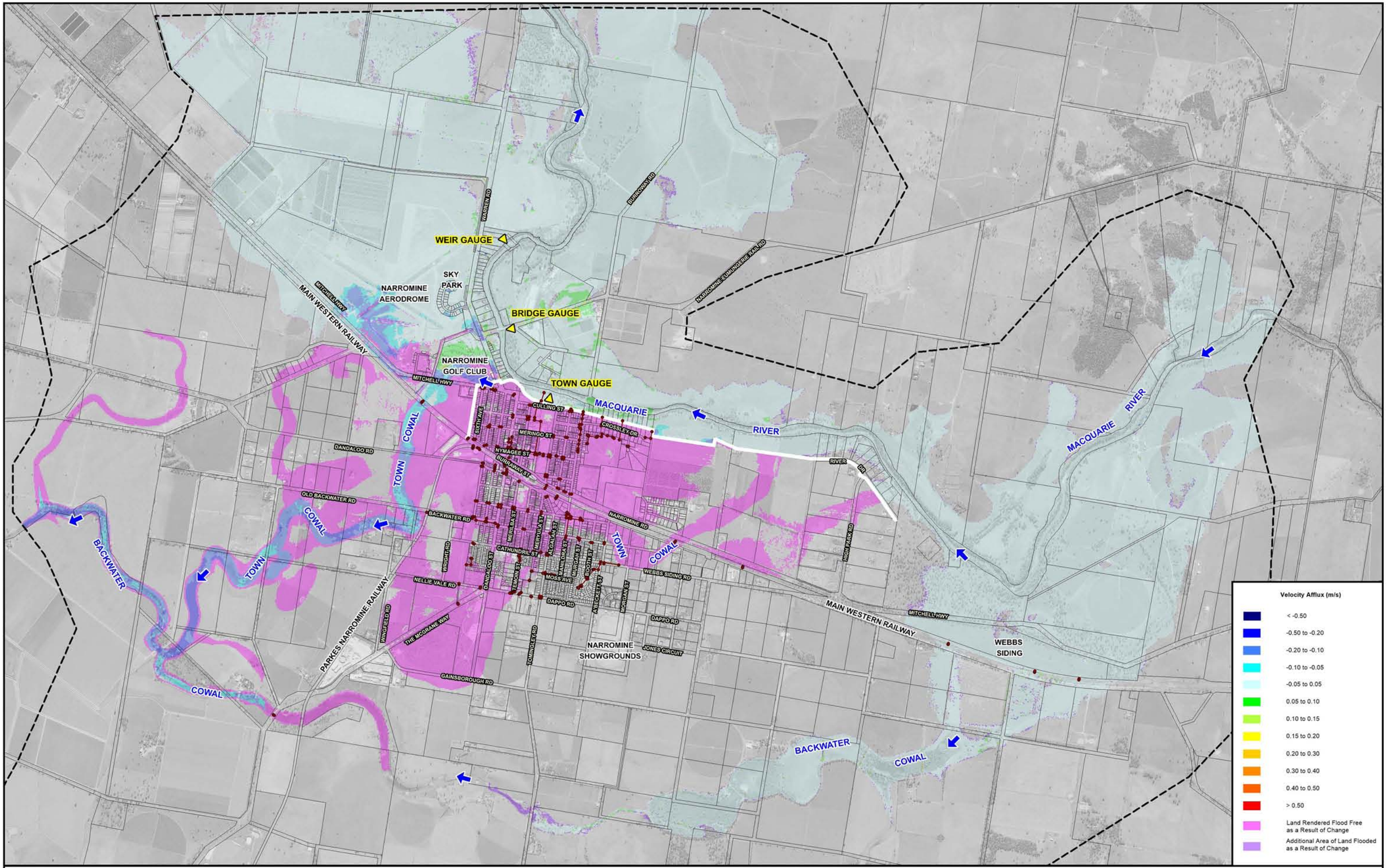
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure C1.3

IMPACT OF LEVEE OPTION B1 ON MAIN STREAM FLOODING
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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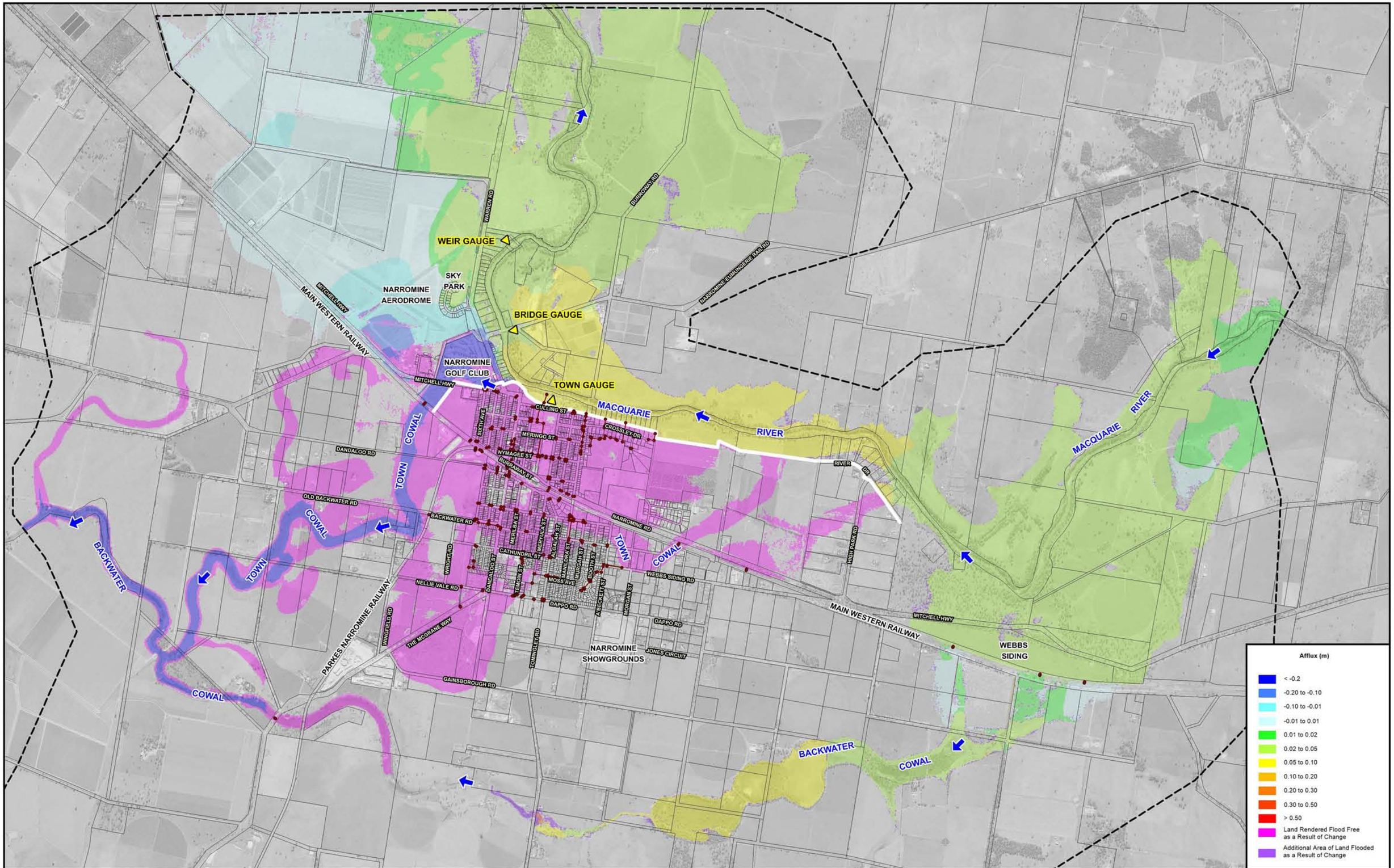
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure C1.4

IMPACT OF LEVEE OPTION B1 ON MAXIMUM MAIN STREAM FLOODING FLOW VELOCITIES
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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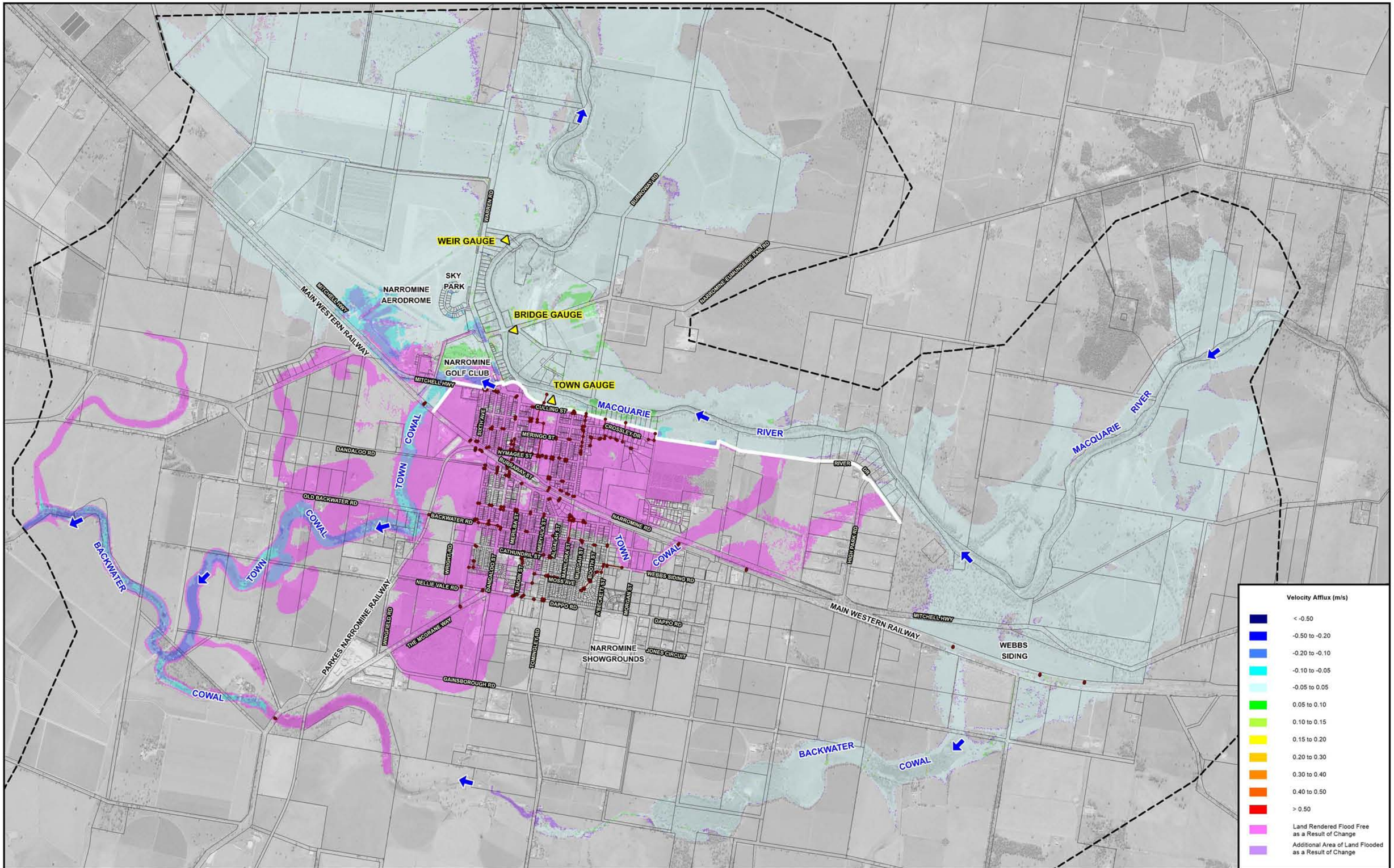
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure C1.5

IMPACT OF LEVEE OPTION B1A ON MAIN STREAM FLOODING
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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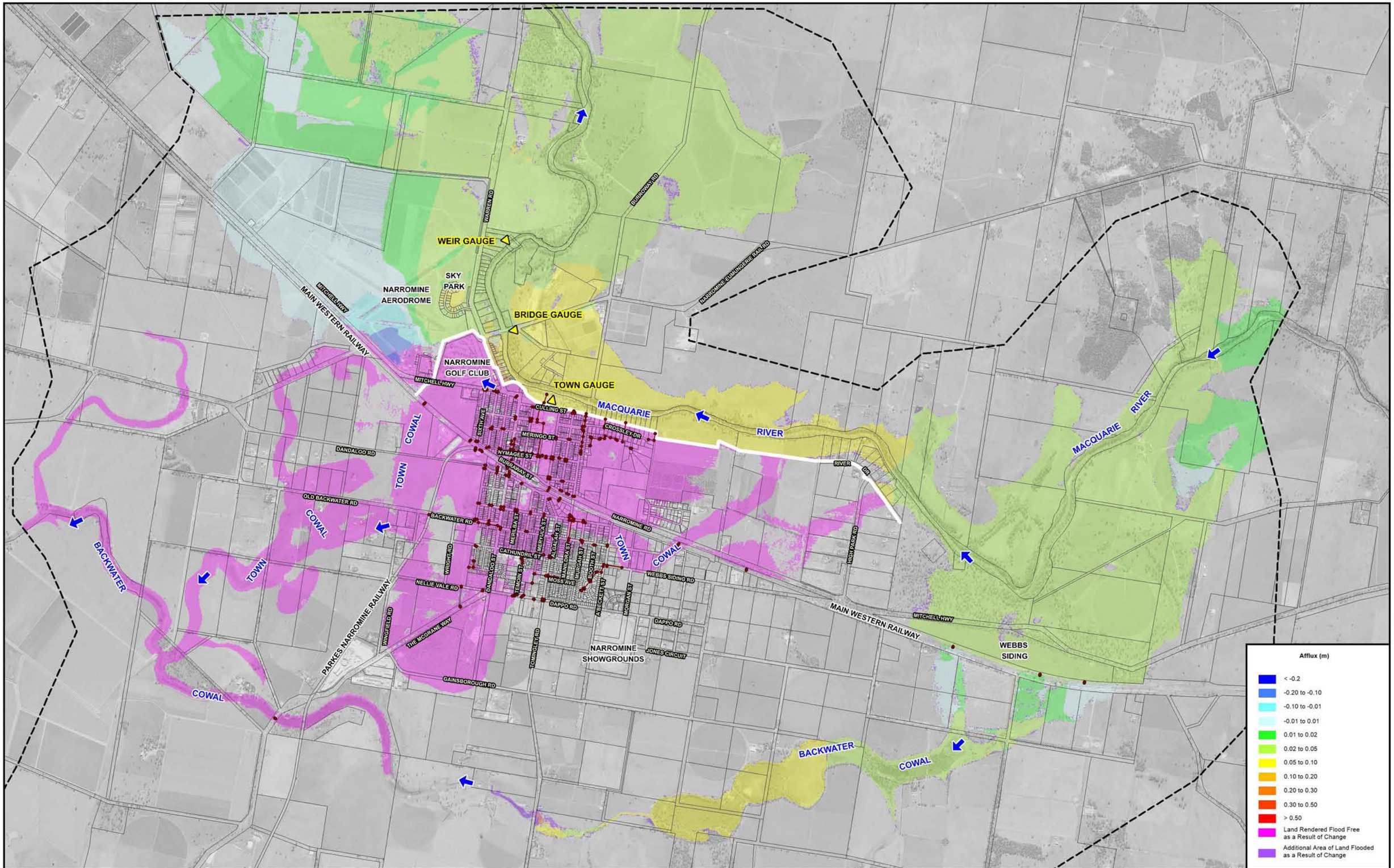
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure C1.6

IMPACT OF LEVEE OPTION B1A ON MAXIMUM MAIN STREAM FLOODING FLOW VELOCITIES
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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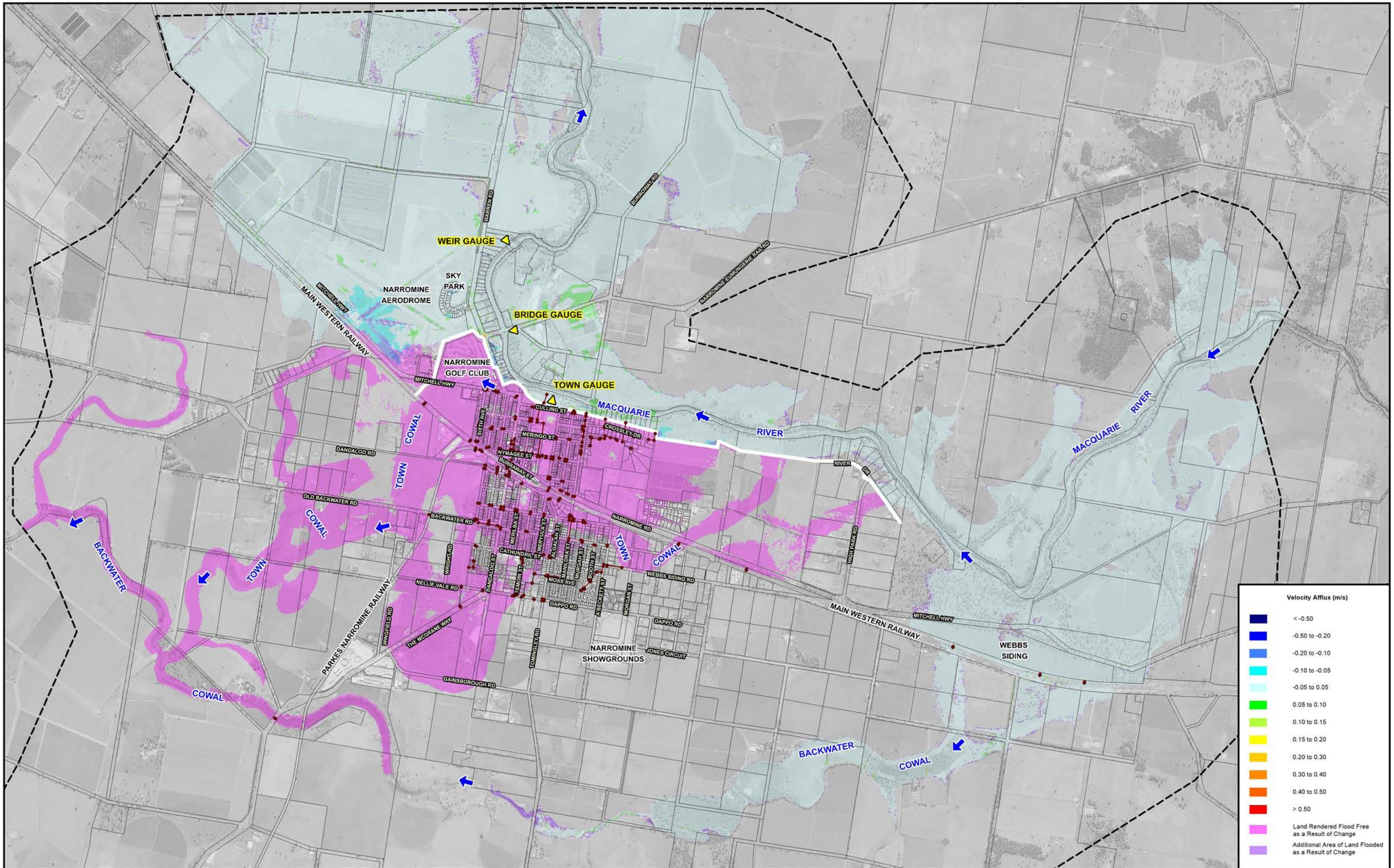
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure C1.7

IMPACT OF LEVEE OPTION B2 ON MAIN STREAM FLOODING
1% AEP



Velocity Afflux (m/s)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to 0.05
- 0.05 to 0.10
- 0.10 to 0.15
- 0.15 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- > 0.50
- Land Rendered Flood Free as a Result of Change
- Additional Area of Land Flooded as a Result of Change

N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

NOTE:
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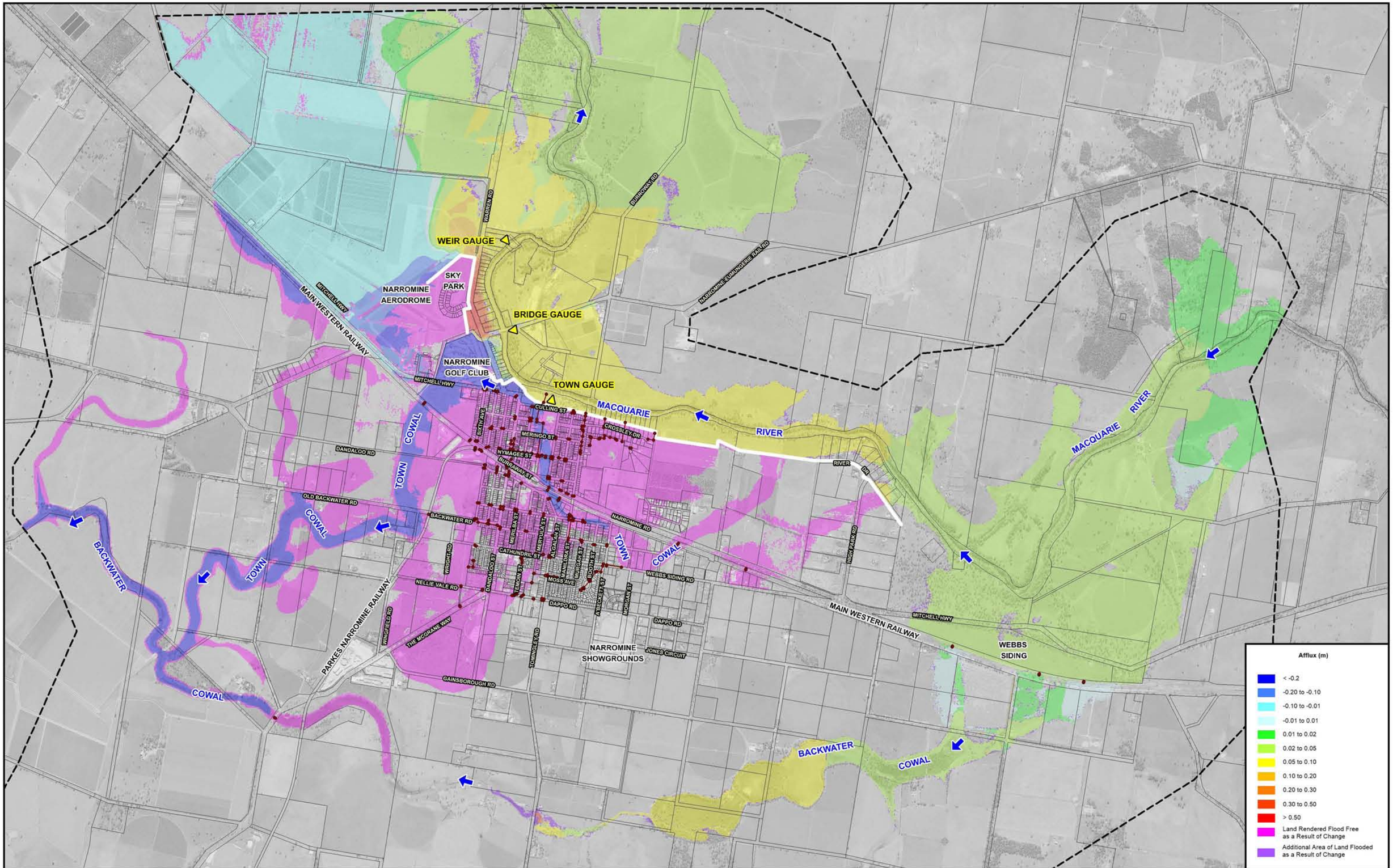
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure C1.8

IMPACT OF LEVEE OPTION B2 ON MAXIMUM MAIN STREAM FLOODING FLOW VELOCITIES
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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LEGEND

Two-Dimensional Model Boundary

Modelled Stormwater Drainage System

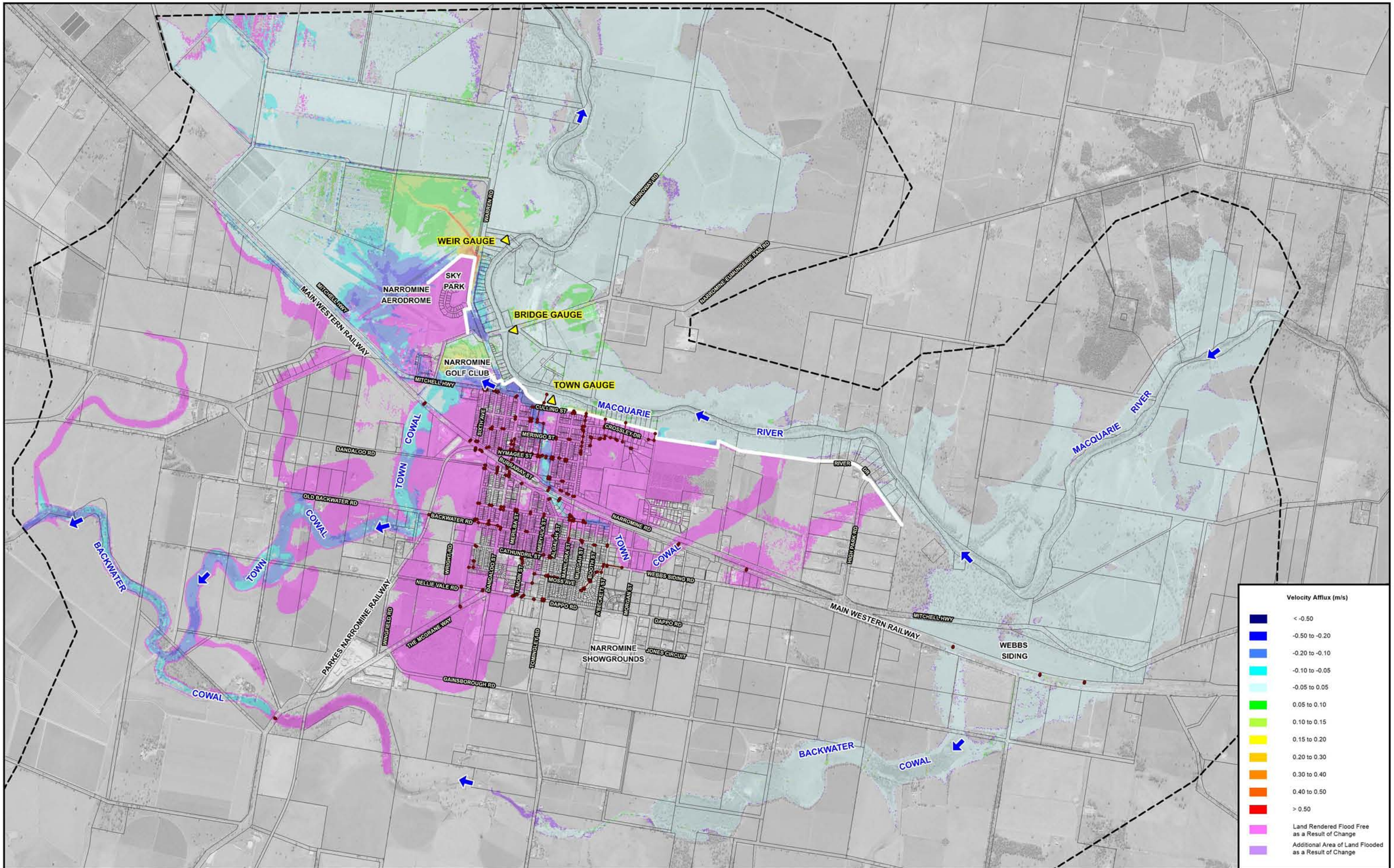
Stream Gauge

Proposed Levee Alignment

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure C1.9

IMPACT OF LEVEE OPTION Ha ON MAIN STREAM FLOODING
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

NOTE:
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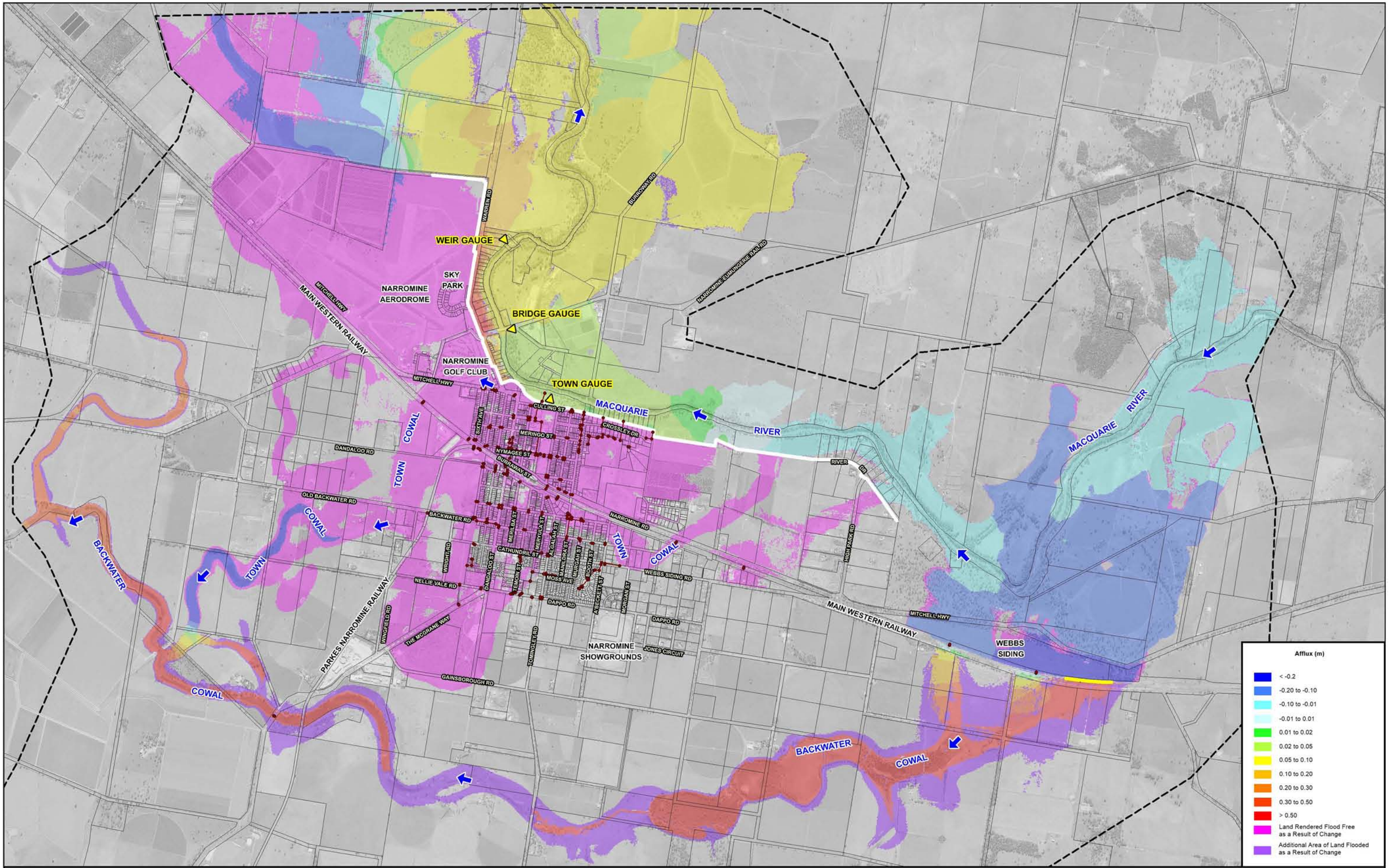
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure C1.10

IMPACT OF LEVEE OPTION Ha ON MAXIMUM MAIN STREAM FLOODING FLOW VELOCITIES
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

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LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment
- Proposed Railway Culvert Upgrade

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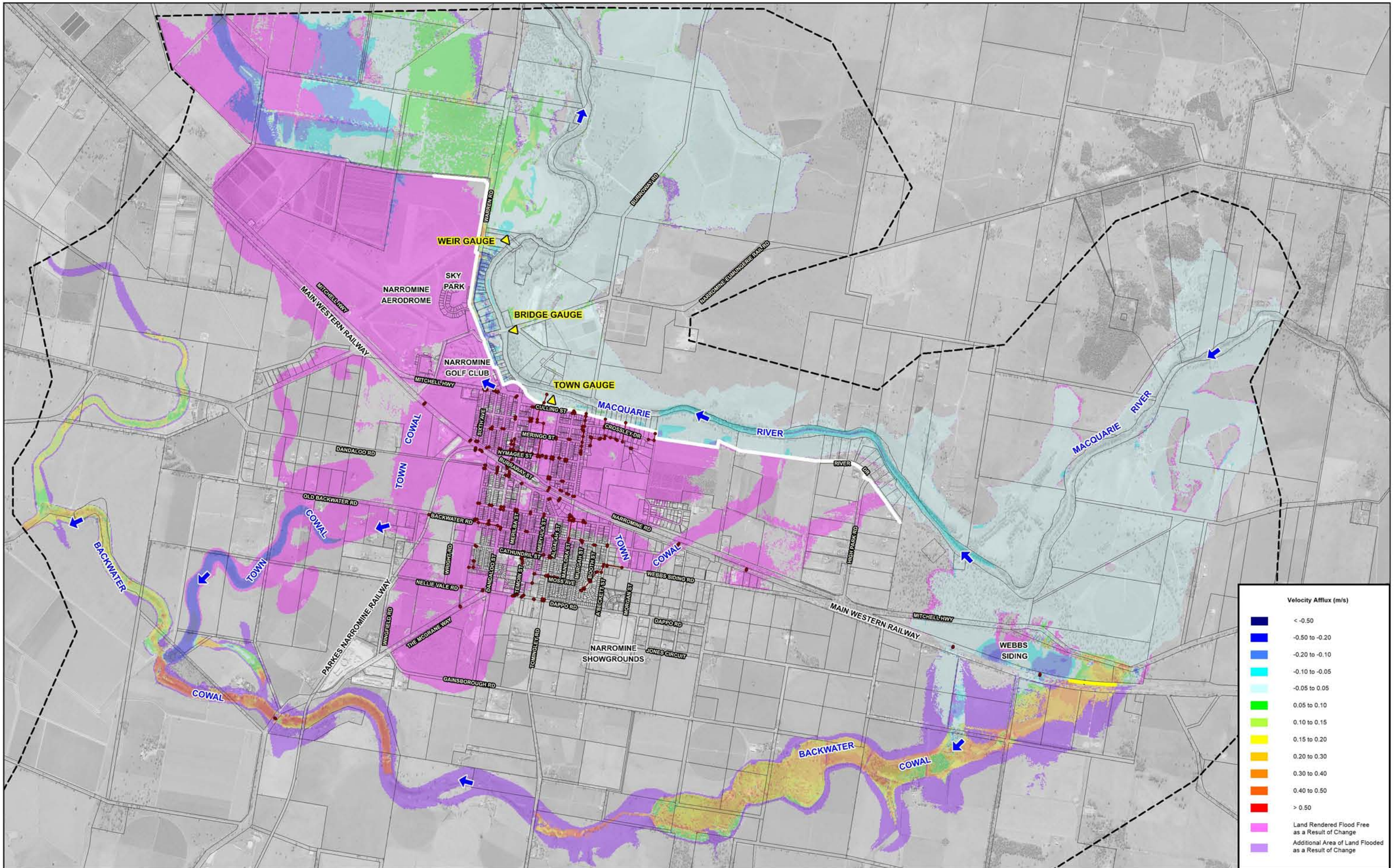
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure C1.11

IMPACT OF LEVEE OPTION B WITH RAILWAY CULVERT UPGRADE ON MAIN STREAM FLOODING
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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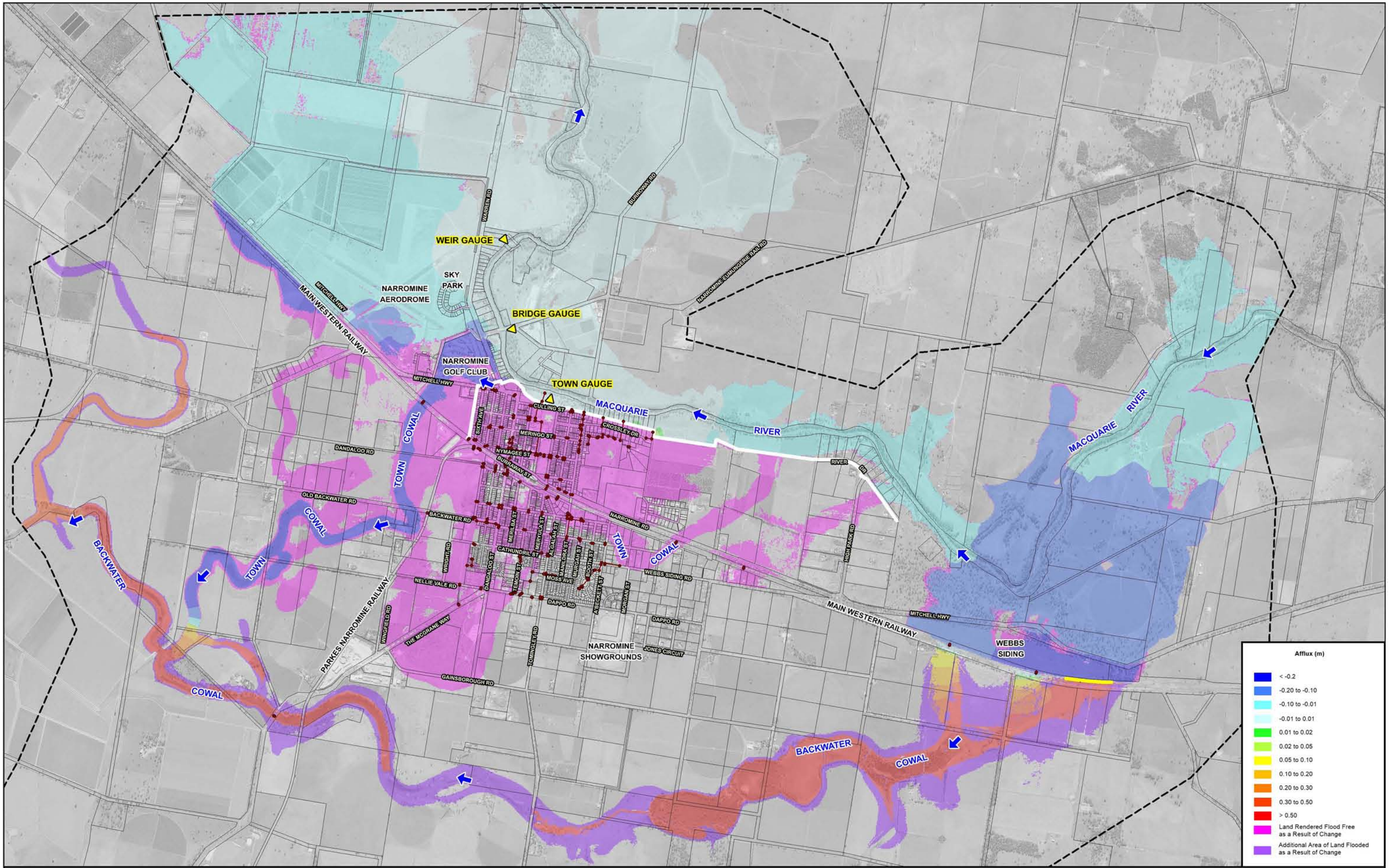
LEGEND

Two-Dimensional Model Boundary
Modelled Stormwater Drainage System
Stream Gauge
Proposed Levee Alignment
Proposed Railway Culvert Upgrade

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure C1.12

IMPACT OF LEVEE OPTION B WITH RAILWAY CULVERT UPGRADE ON MAXIMUM MAIN STREAM FLOODING FLOW VELOCITIES
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

NOTE:
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LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment
- Proposed Railway Culvert Upgrade

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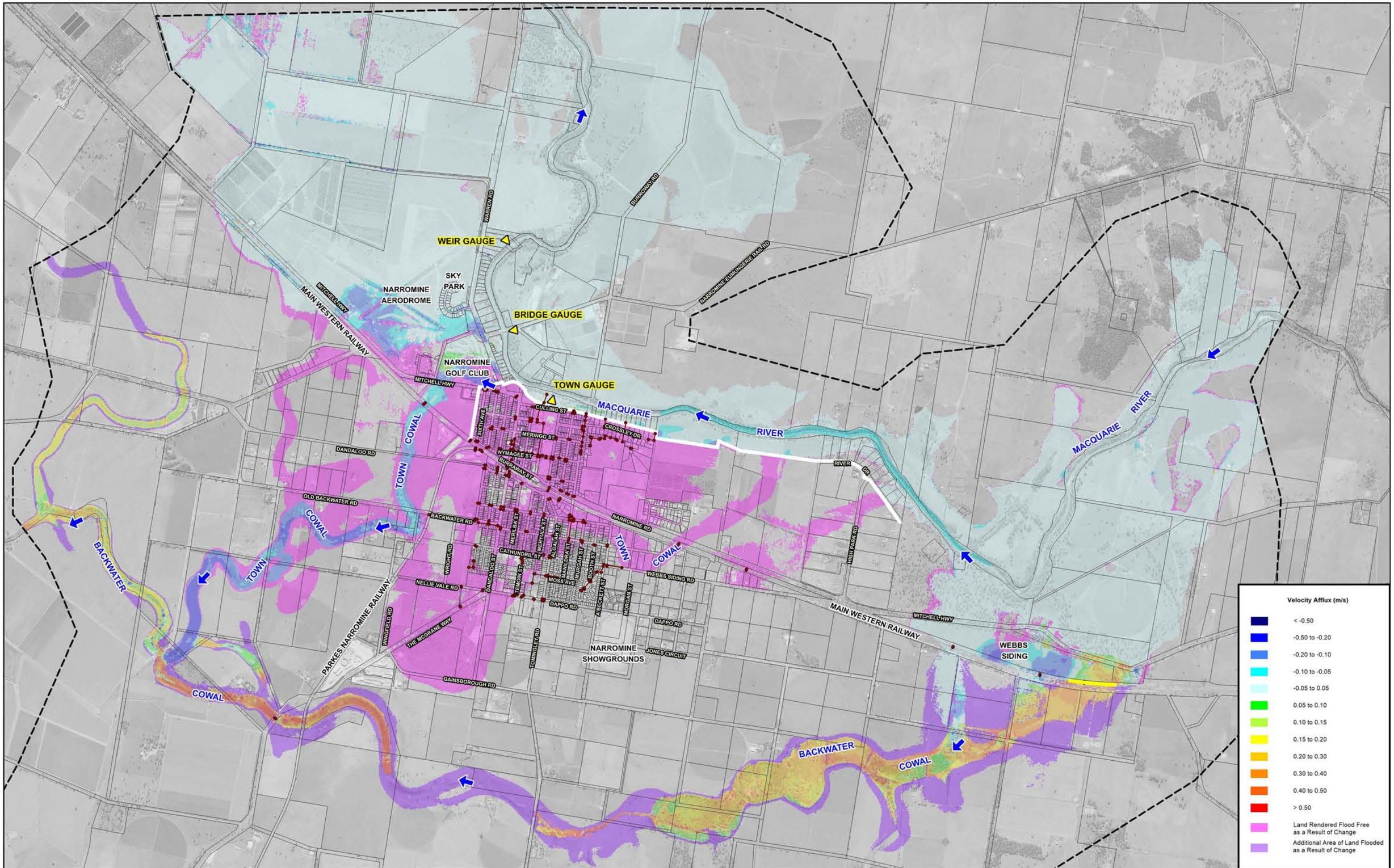
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure C1.13

IMPACT OF LEVEE OPTION B1 WITH RAILWAY CULVERT UPGRADE ON MAIN STREAM FLOODING
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

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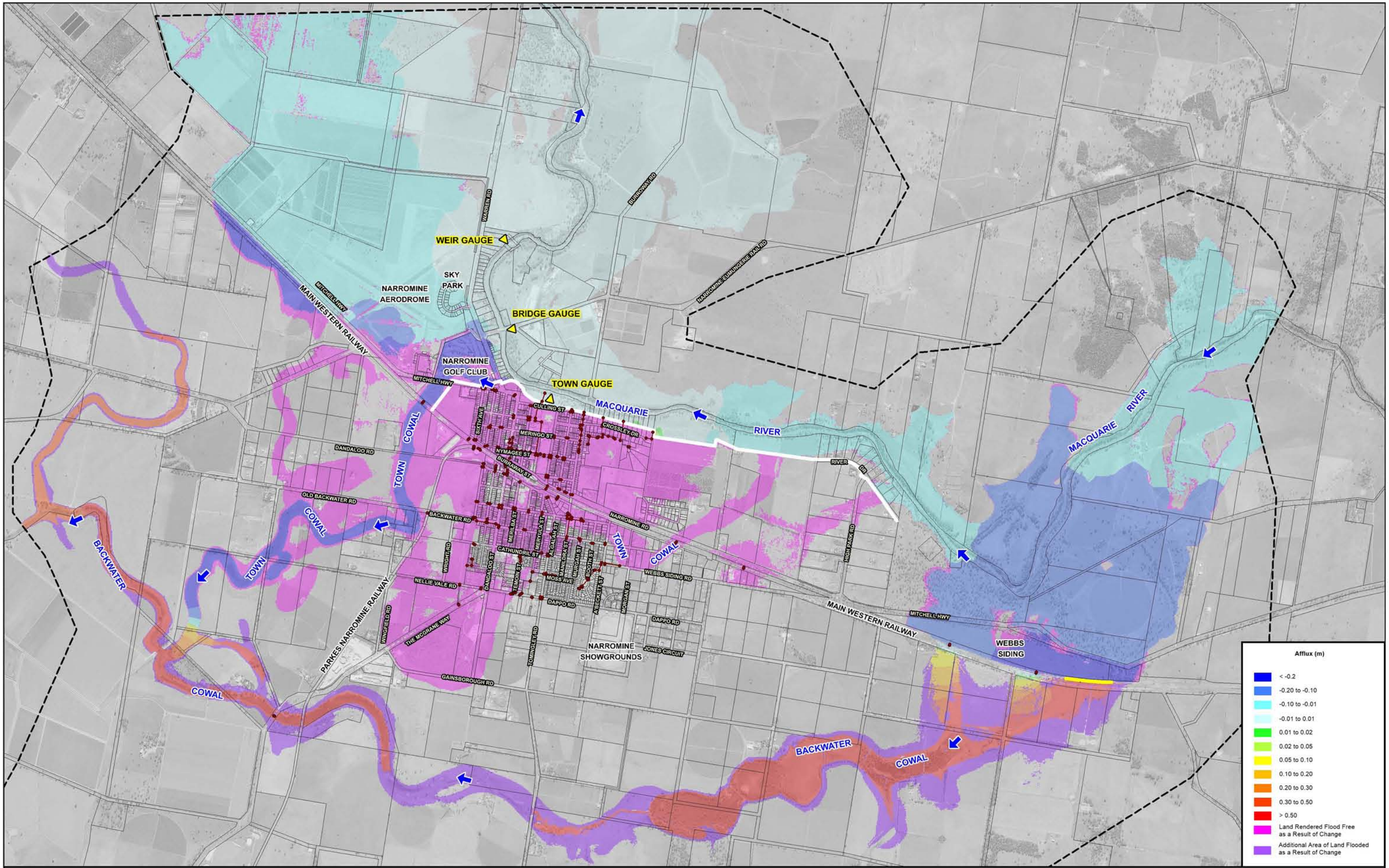
LEGEND

Two-Dimensional Model Boundary
Modelled Stormwater Drainage System
Stream Gauge
Proposed Levee Alignment
Proposed Railway Culvert Upgrade

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure C1.14

IMPACT OF LEVEE OPTION B1 WITH RAILWAY CULVERT UPGRADE ON MAXIMUM MAIN STREAM FLOODING FLOW VELOCITIES
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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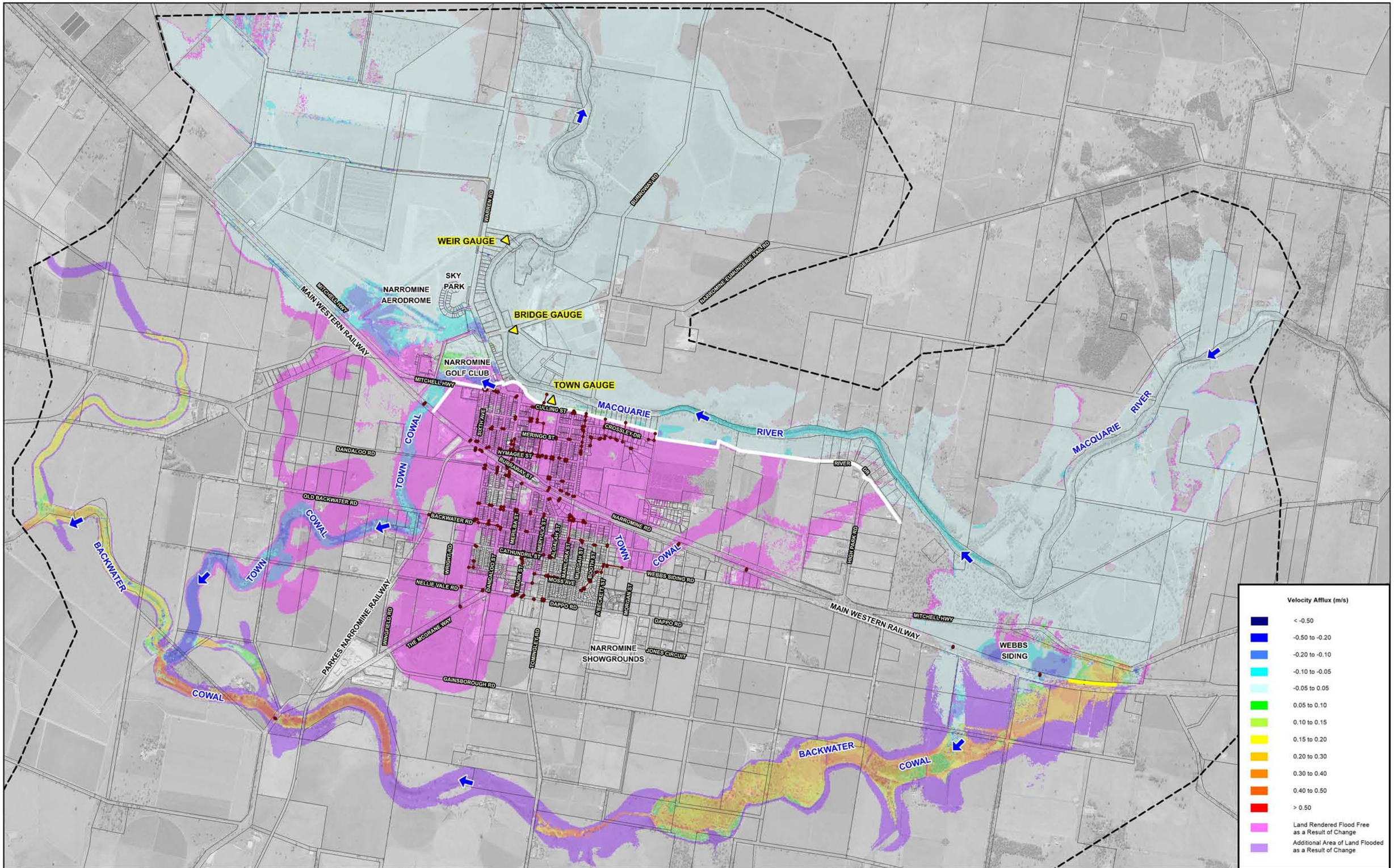
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment
- Proposed Railway Culvert Upgrade

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure C1.15

IMPACT OF LEVEE OPTION B1A WITH RAILWAY CULVERT UPGRADE ON MAIN STREAM FLOODING
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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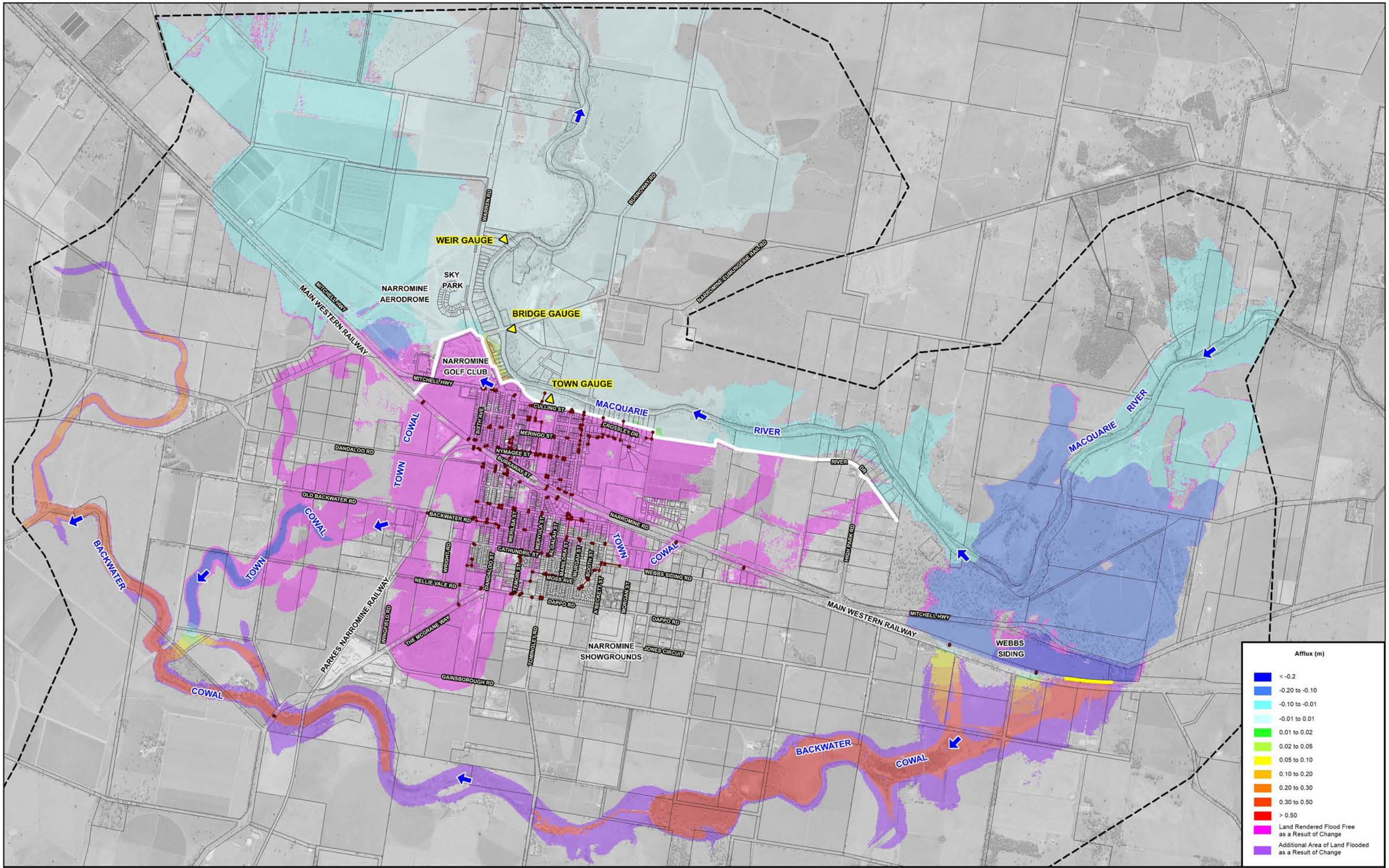
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment
- Proposed Railway Culvert Upgrade

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure C1.16

IMPACT OF LEVEE OPTION B1A WITH RAILWAY CULVERT UPGRADE ON MAXIMUM MAIN STREAM FLOODING FLOW VELOCITIES
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

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LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment
- Proposed Railway Culvert Upgrade

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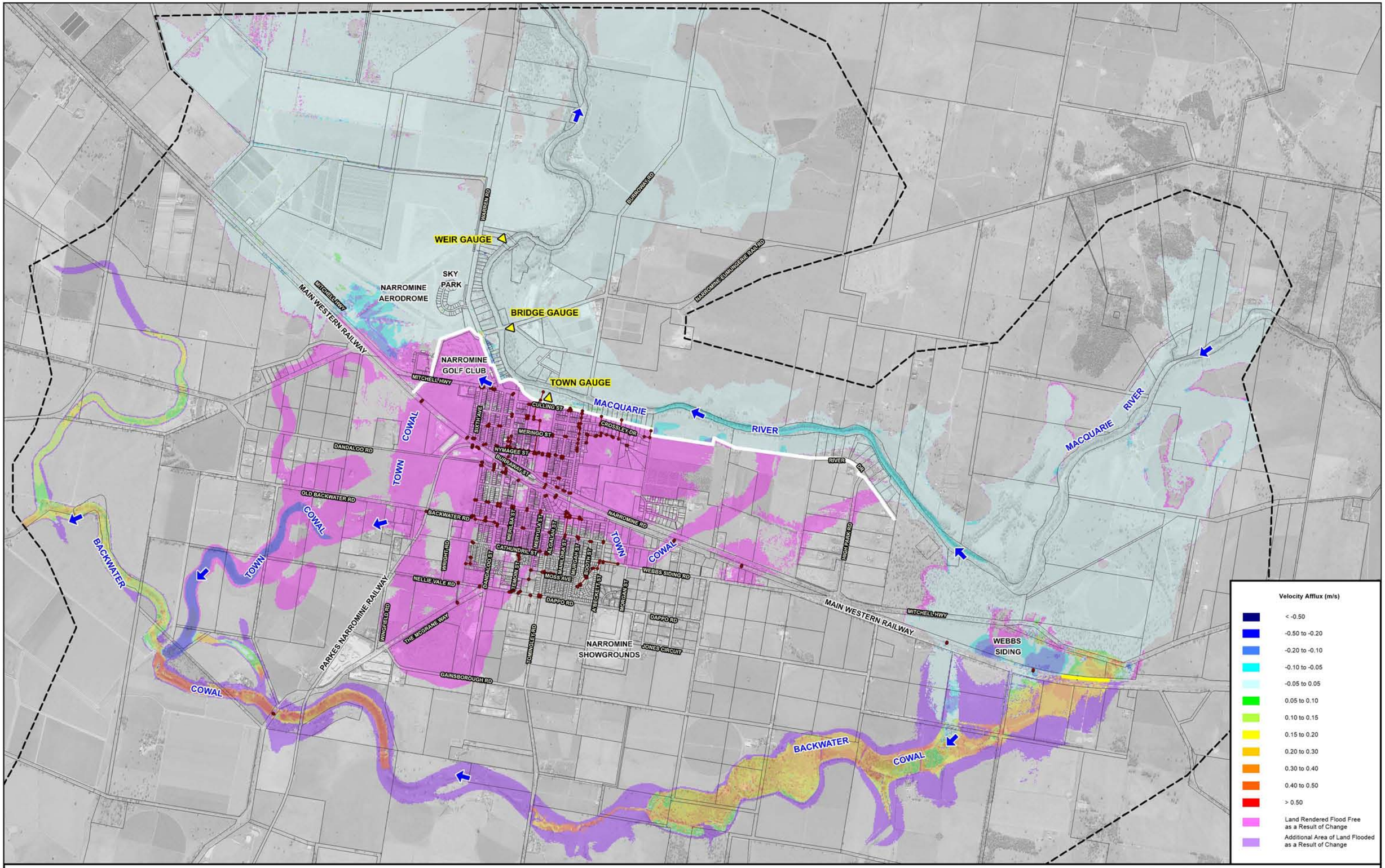
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure C1.17

IMPACT OF LEVEE OPTION B2 WITH RAILWAY CULVERT UPGRADE ON MAIN STREAM FLOODING
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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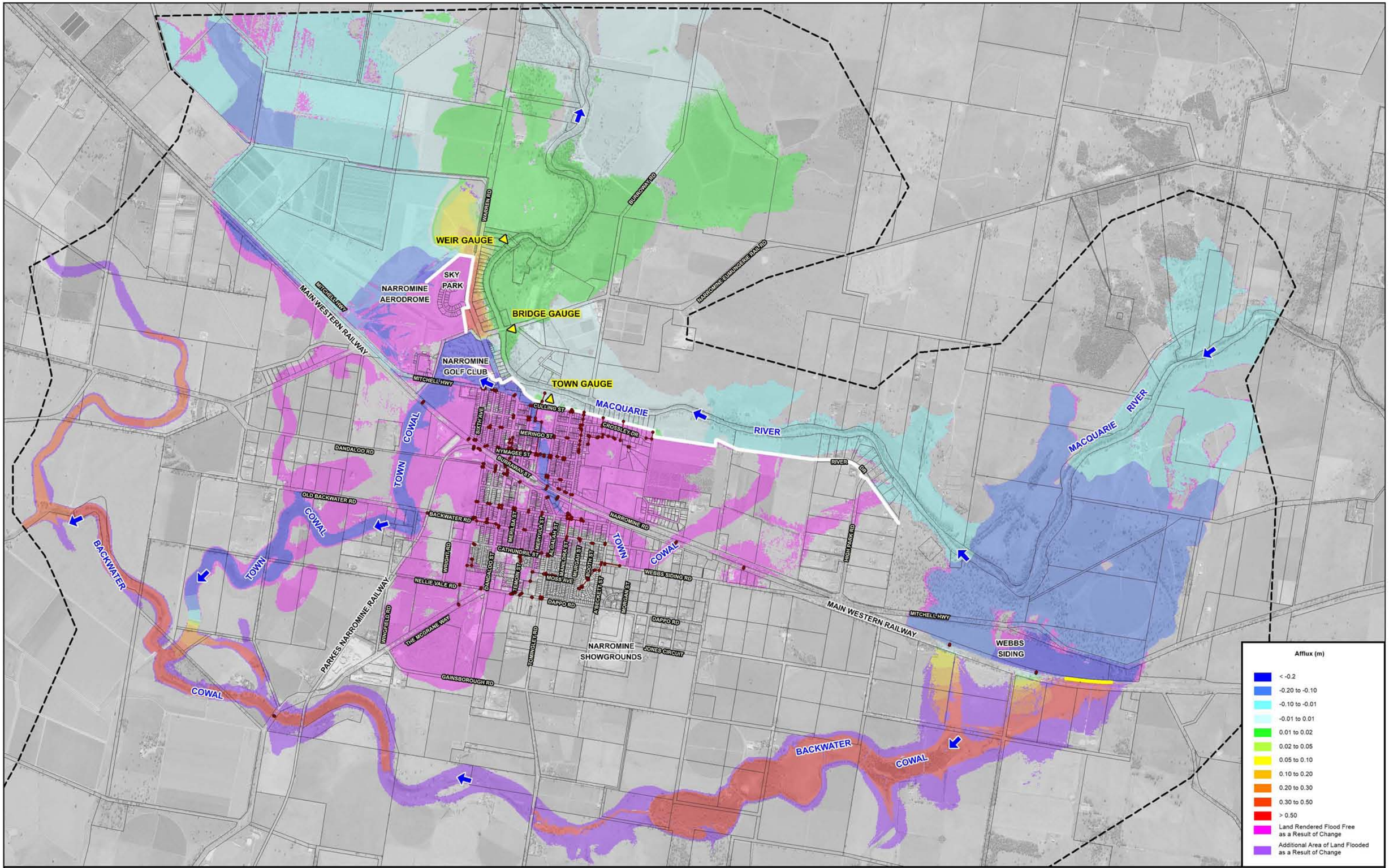
LEGEND

Two-Dimensional Model Boundary
Modelled Stormwater Drainage System
Stream Gauge
Proposed Levee Alignment
Proposed Railway Culvert Upgrade

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure C1.18

IMPACT OF LEVEE OPTION B2 WITH RAILWAY CULVERT UPGRADE ON MAXIMUM MAIN STREAM FLOODING FLOW VELOCITIES
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

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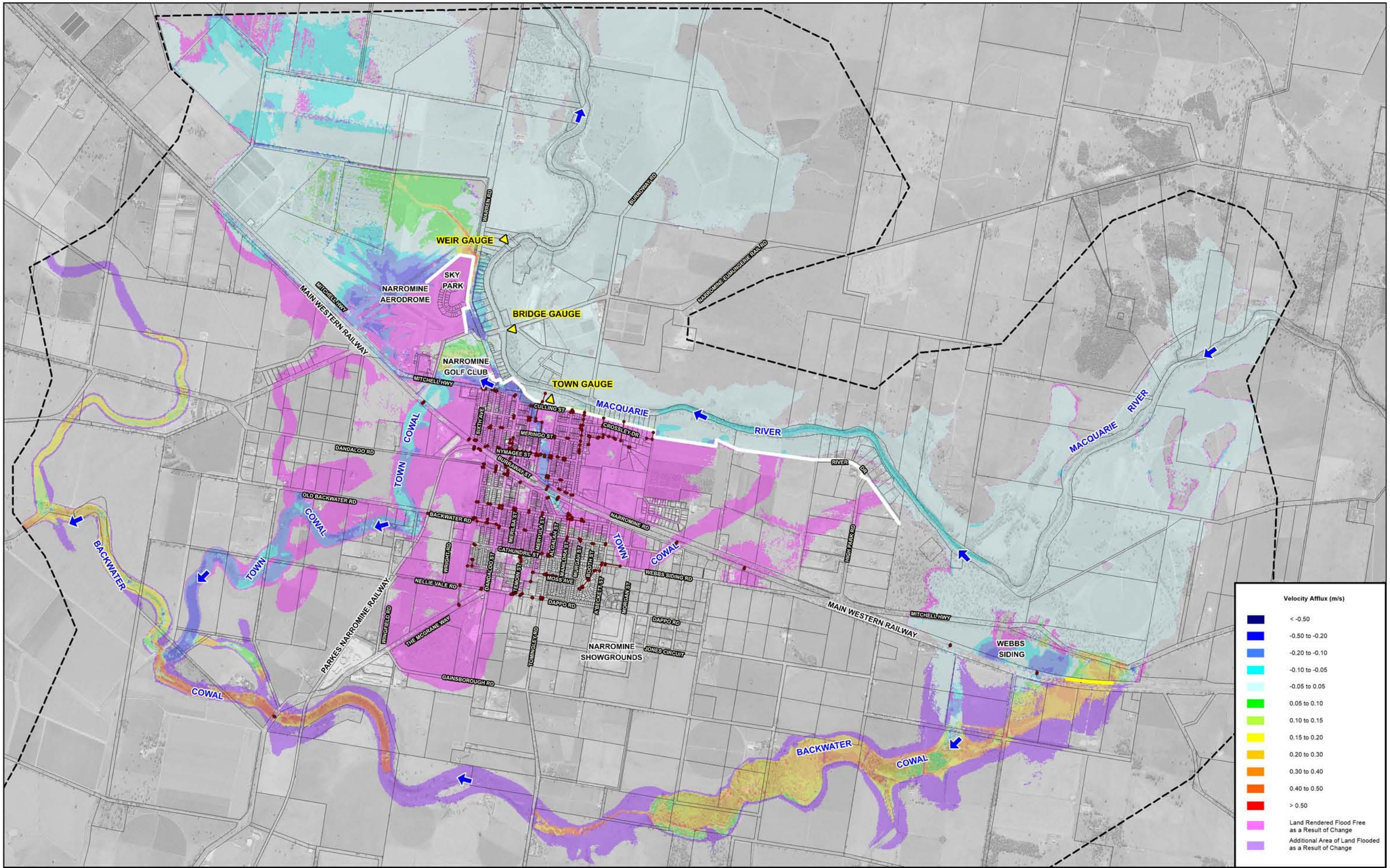
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment
- Proposed Railway Culvert Upgrade

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure C1.19

IMPACT OF LEVEE OPTION Ha WITH RAILWAY CULVERT UPGRADE ON MAIN STREAM FLOODING
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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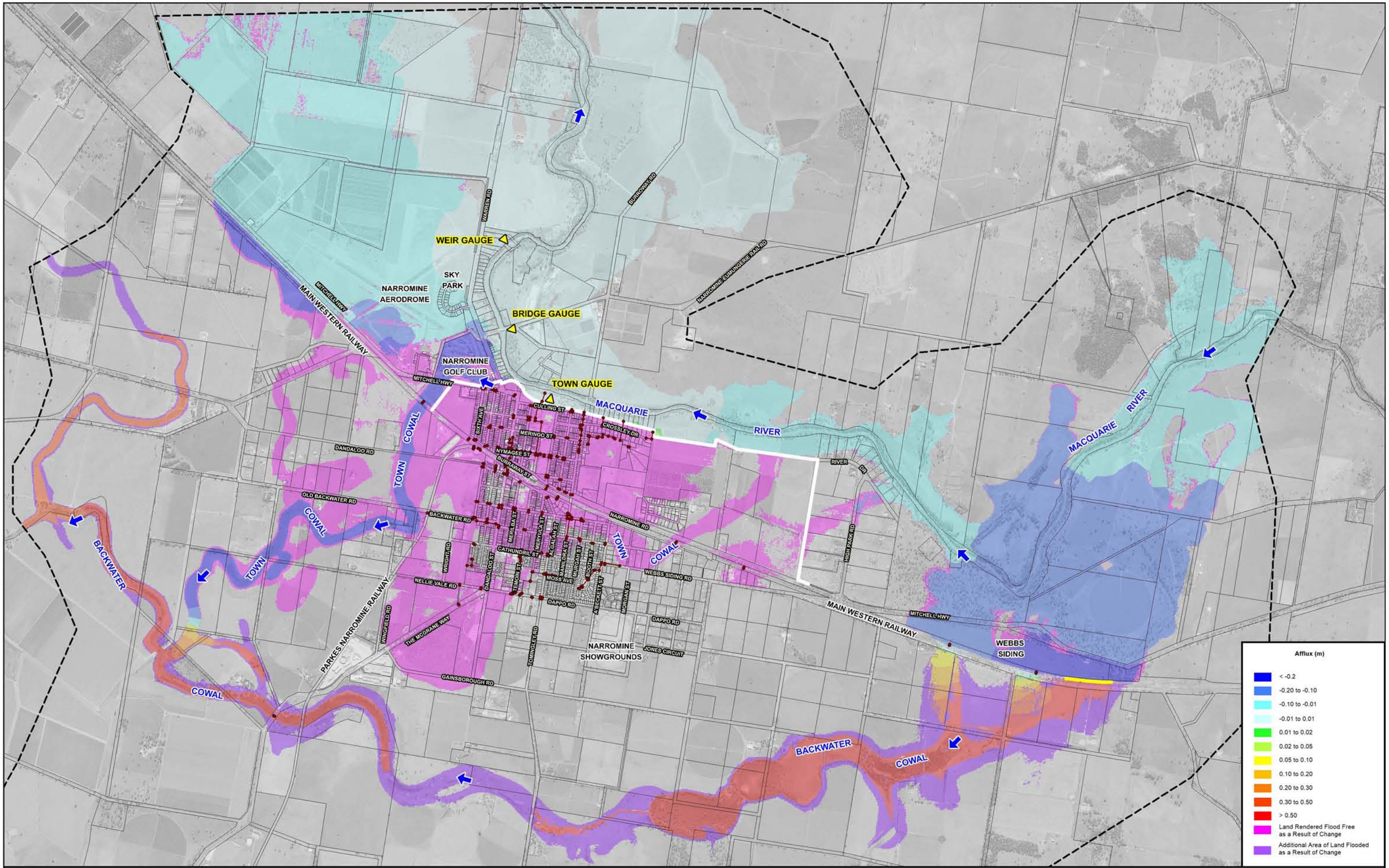
LEGEND

Two-Dimensional Model Boundary
Modelled Stormwater Drainage System
Stream Gauge
Proposed Levee Alignment
Proposed Railway Culvert Upgrade

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure C1.20

IMPACT OF LEVEE OPTION Ha WITH RAILWAY CULVERT UPGRADE ON MAXIMUM MAIN STREAM FLOODING FLOW VELOCITIES
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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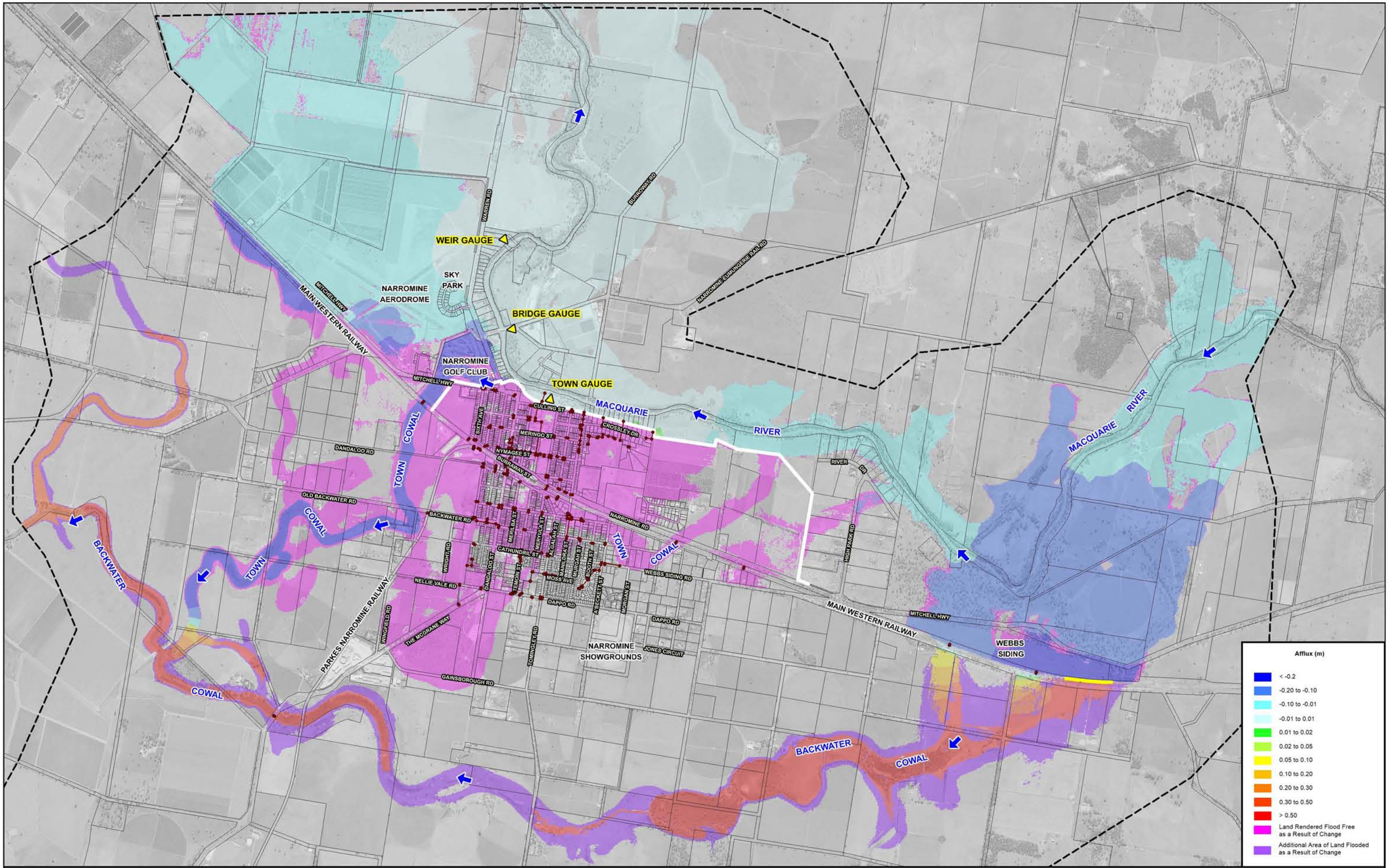
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment
- Proposed Railway Culvert Upgrade

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure C1.21

IMPACT OF LEVEE OPTION B1B WITH RAILWAY CULVERT UPGRADE ON MAIN STREAM FLOODING
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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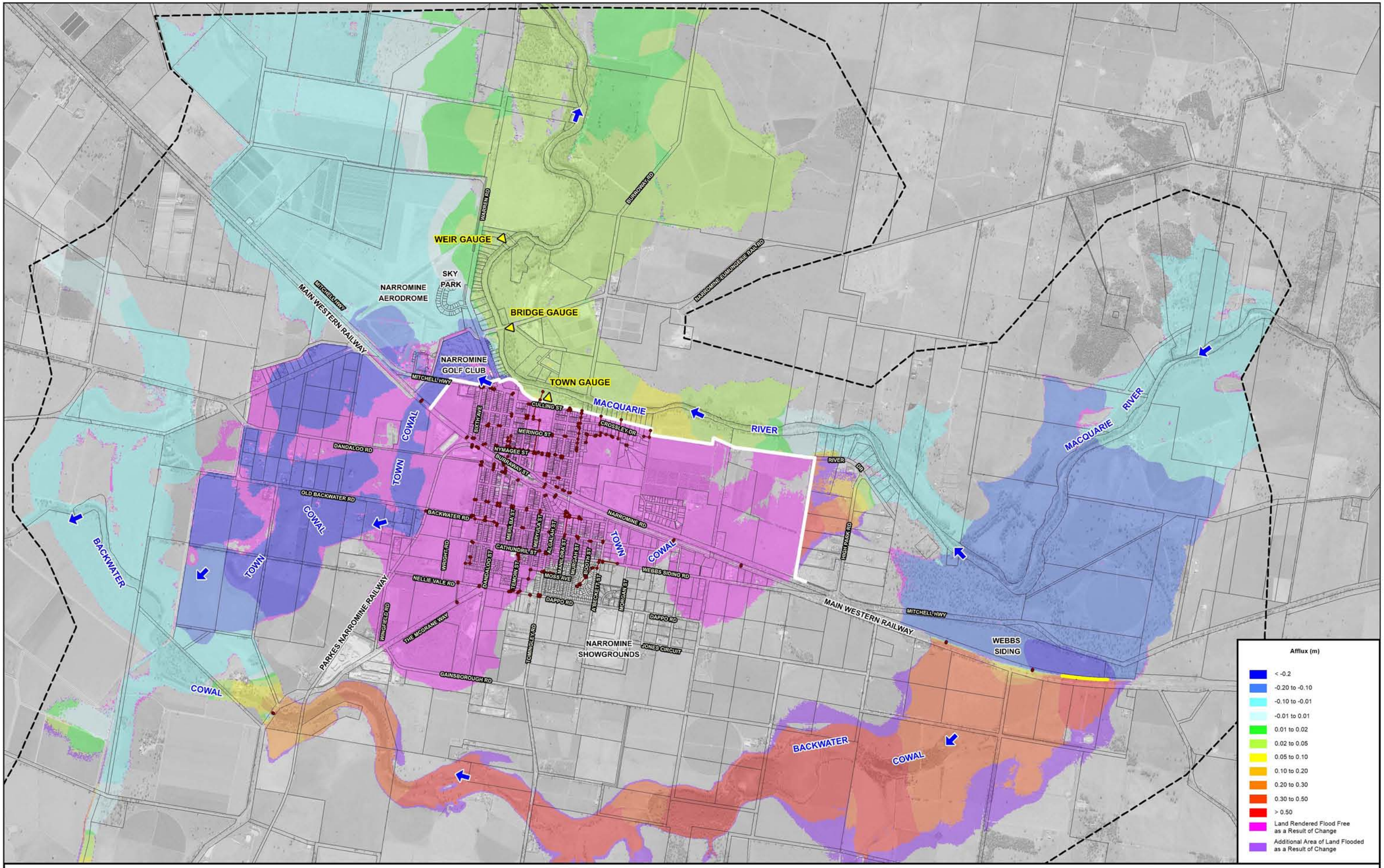
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment
- Proposed Railway Culvert Upgrade

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure C1.22

IMPACT OF LEVEE OPTION B1C WITH RAILWAY CULVERT UPGRADE ON MAIN STREAM FLOODING
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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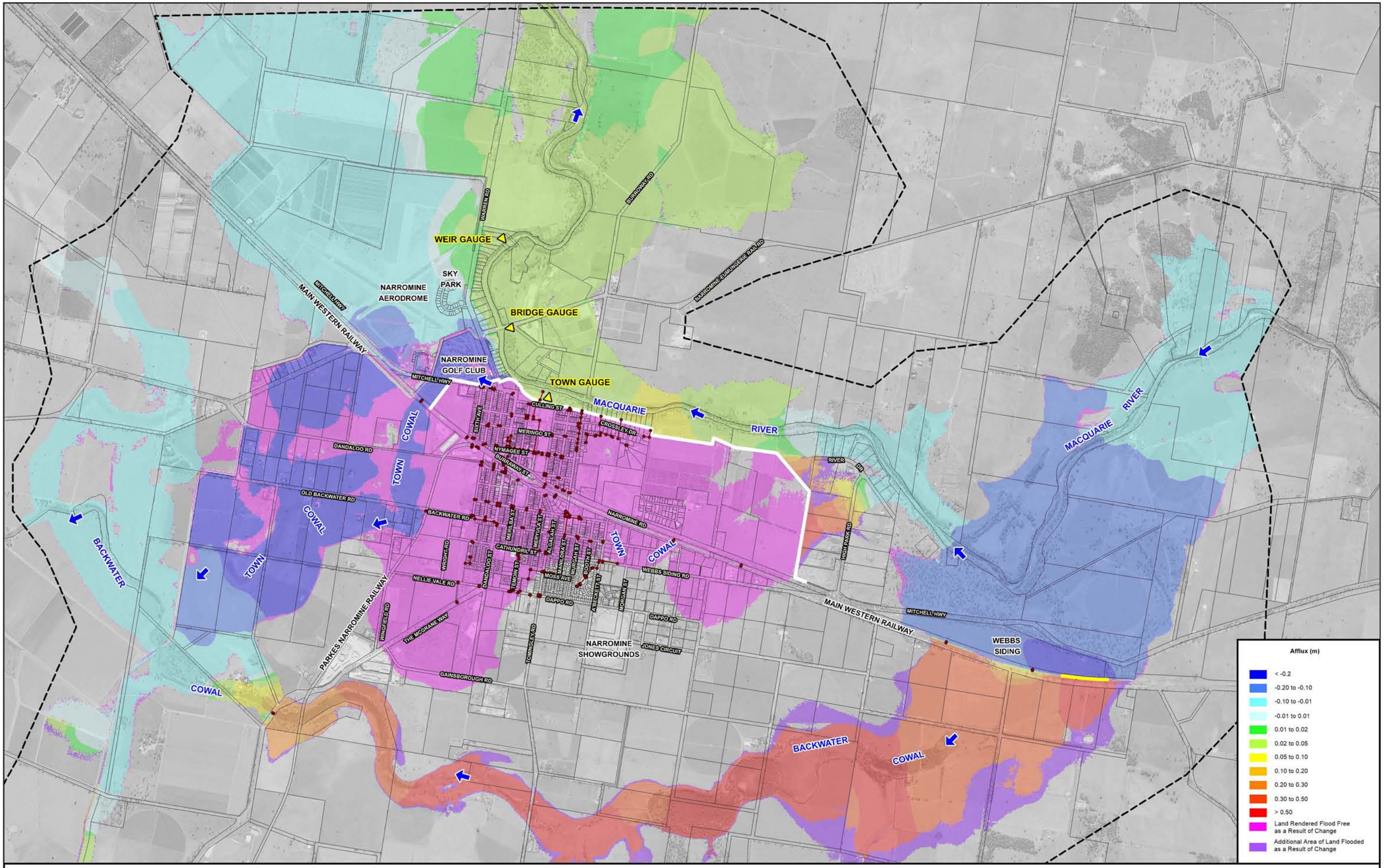
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment
- Proposed Railway Culvert Upgrade

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure C1.23

IMPACT OF LEVEE OPTION B1B WITH RAILWAY CULVERT UPGRADE ON MAIN STREAM FLOODING
MINOR INCREASE IN PEAK 1% AEP FLOW



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment
- Proposed Railway Culvert Upgrade

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

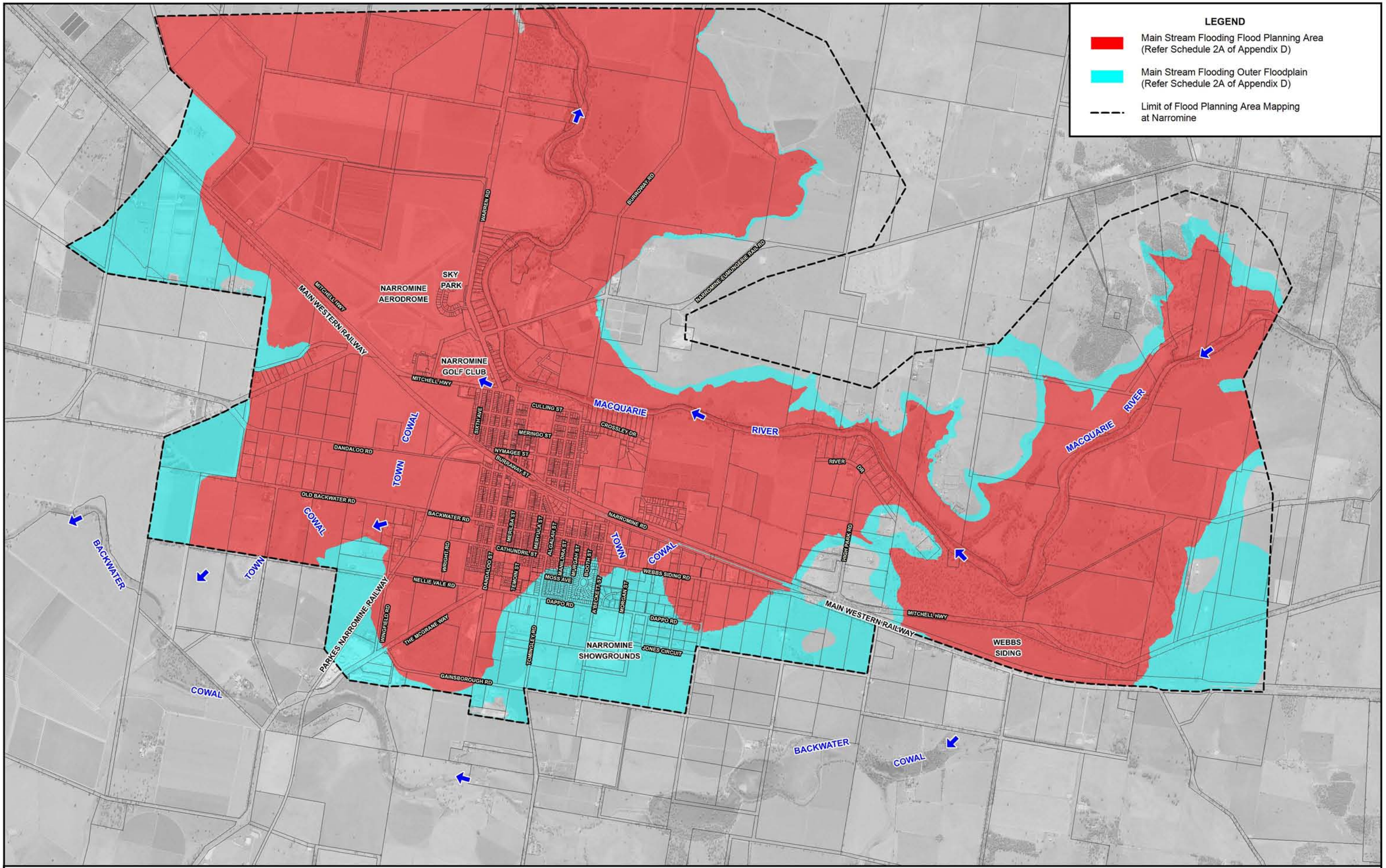
Figure C1.24

IMPACT OF LEVEE OPTION B1C WITH RAILWAY CULVERT UPGRADE ON MAIN STREAM FLOODING
MINOR INCREASE IN PEAK 1% AEP FLOW

APPENDIX D

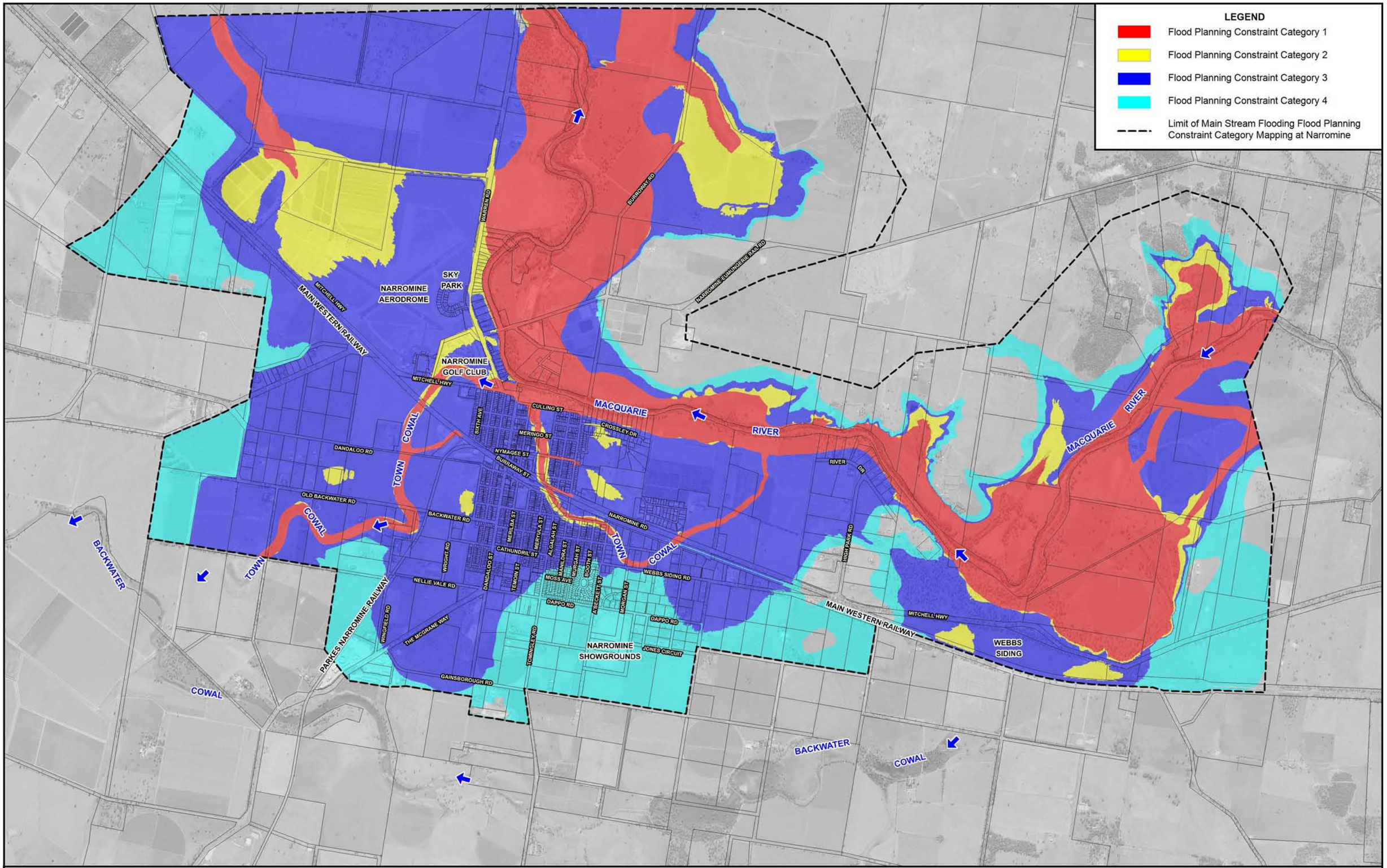
SUGGESTED WORDING FOR INCLUSION IN NARROMINE SHIRE DEVELOPMENT CONTROL PLAN

LIST OF FIGURES (APPENDIX D)



NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure D1.1

EXTRACT OF FLOOD PLANNING MAP AT NARROMINE



Back to Report

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure D1.2

EXTRACT OF FLOOD PLANNING CONSTRAINT CATEGORY MAP AT NARROMINE