Flood Study for the Towns of Urana, Morundah, Boree Creek, Oaklands and Rand

Federation Council

Flood Study Report for Boree Creek

IA055600 | FINAL

November 2017

Flood Study for the Towns of Urana, Morundah, Boree Creek, Oaklands and Rand

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Cover photo: Drummond Street crossing Boree Creek

Document history and status

Revision	Date	Description	By	Review	Approved
1	14/08/2015	Model Calibration and Verification Report (Progress Report)	MR/AH	AH	AH
2	8/4/2016	Design Flood Estimation Report (Progress Report)	MR/AH	AH	AH
3	24/8/2017	Draft Flood Study Report	MR/AH	AH	AH
4	22/9/2017	Draft Flood Study Report (Public exhibition)	MR/AH	AH	AH
5	9/11/2017	Final Flood Study Report	AH	A Hossain	A Hossain

Contents

Foreword

The primary objective of the New South Wales Government's Flood Prone Land Policy is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods, utilising ecologically positive methods, wherever possible. Under the Policy, the management of flood prone land remains the responsibility of local government.

The policy provides for a floodplain management system comprising the following five sequential stages:

1.	**Data Collection**	Involves compilation of existing data and collection of additional data
2.	**Flood Study**	Determines the nature and extent of the flood problem
3.	**Floodplain Risk Management Study**	Evaluates management options in consideration of social, ecological and economic factors relating to flood risk with respect to both existing and future development
4.	**Floodplain Risk Management Plan**	Involves formal adoption by Council of a plan of management for the floodplain
5.	**Implementation of the Plan**	Implementation of flood, response and property modification measures (including mitigation works, planning controls, flood warnings, flood preparedness, environmental rehabilitation, ongoing data collection and monitoring by Council

Federation Council proposes to develop a Floodplain Risk Management Plan for the townships of Boree Creek, Morundah, Oaklands, Rand and Urana to address the existing, future and continuing flood problems, in accordance with the NSW Floodplain Development Manual (2005).

This report documents data collection and flood study for Boree Creek.

Important note about this report

The sole purpose of this report and the associated services performed by Jacobs is to undertake a flood study for five towns within Federation Council (formerly Urana Shire Council), located in New South Wales in accordance with the scope of services set out in the contract between Jacobs and Federation Council (the Client). That scope of services, as described in this report, was developed with the Client.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced from the Client, third parties, and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Jacobs for use of any part of this report in any other context.

All topographic data used in this study were sourced from a LiDAR survey and a ground survey which were undertaken by third parties. Undertaking independent checks on the accuracy of the topographic data was outside Jacobs's scope of work for this study.

This report has been prepared on behalf of, and for the exclusive use of, Jacobs's Client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the Client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

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1. Introduction

Boree Creek is located within Federation Council, approximately 39km northeast of Urana and 16km northwest of Lockhart. It has a declining population of 199 people (2016 census) and is located adjacent to Boree Creek. The creek drains a catchment area of approximately 141km^2 to the town, flowing in a south-westerly direction along the southern edge of the village. The creek then continues towards Lake Cullivel and is then joined by Brookong Creek before flowing into Urangeline Creek, which discharges into Lake Urana. An overview of the Boree Creek study area can be seen in **Figure 1-1**.

Flooding in the Boree Creek village occurs primarily from the Boree Creek watercourse and the village experienced several major floods including the recent flood events of 2012 and 2010. At least, 24 houses and 10 commercial/public section buildings were flooded above floor during March 2012 flood which was the largest flood in recent time (Yeo 2013). Federation Council proposes to develop Floodplain Risk Management Plans for the townships of Boree Creek, Morundah, Oaklands, Rand and Urana to address the existing, future and continuing flood problems. Council has engaged Jacobs Group (Australia) Pty Ltd to prepare flood studies for the five towns within Federation Council.

1.1 Objectives

The primary objective of the flood study for Boree Creek is to define the nature and extent of flood behaviour in and adjacent to Boree Creek village. The study will produce information on flood levels, velocities, flows, hydraulic categories and provisional hazard categories for 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2% annual exceedance probability (AEP) events and the probable maximum flood (PMF) event.

1.2 Structure of the Report

This report describes the up-to-date progress on the Flood Study for Boree Creek. This report has been divided into the following sections:

Section 1: introduces the study

Section 2: provides details on the initial investigations undertaken for the study including review of the available data and community consultation

Section 3: details catchment hydrology including the development of a hydrologic model for the catchment area of interest to this study

Section 4: details development of a hydraulic model for the study area

Section 5: provides details on calibration and verification of the hydrologic and the hydraulic models and sensitivity analysis

Section 6: details on the input data used in the estimation of design flood

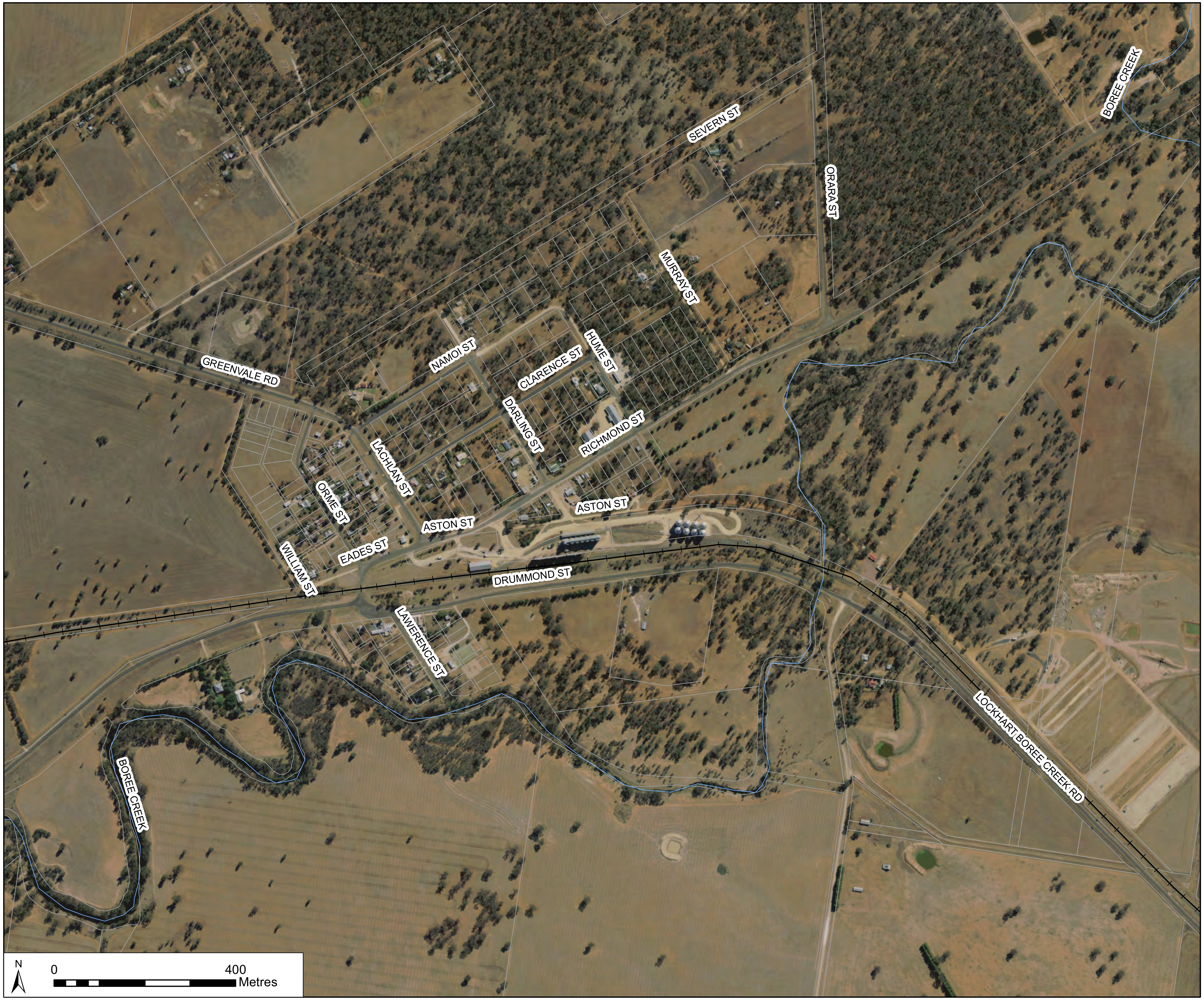
Section 7: discusses modelled flood behaviour for the design events

Section 8: provides conclusions on the study

Section 9: provides acknowledgements for this study

Section 10: provides details on references citied in this report

Section 11: provides the glossary of terms



Legend

- Cadastre
- Railway
- Watercourses

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	Study Area
TOWN	Boree Creek
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE 1-1
CHECK AH	DATE 20/09/2017	

Appendix A: provides further details on the available data

Appendix B: contains the Newsletter and Questionnaire sent to residents

Appendix C: details on hydrologic modelling and results

Appendix D: details on hydraulic modelling results

Appendix E: contains flood maps for the design flood events

2. Available Data

2.1 Site Inspection

A site inspection was carried out on 29 October 2015 to gain an overall appreciation of the study area, including flood behaviour. Information gained from the site reconnaissance was utilised to define the scope of the topographic survey for this study and to determine modelling parameters such as Manning's roughness coefficients for channels and floodplains located within the study area.

2.2 Data Collection and Review

Council and a number of government agencies including NSW Office of Environment and Heritage (OEH), NSW Office of Water, State Emergency Services (SES) and the Bureau of Meteorology, were contacted to collect information on flooding, topographic data and flood evacuation etc. However, very limited information was available from the agencies.

2.2.1 Available Reports

- **Flood Intelligence Collection and Review for 24 Towns and Villages in the Murray and Murrumbidgee Regions following the March 2012 Flood, Final Report, June 2013** (Yeo 2013) The flood intelligence and review study for 24 Town and villages including Boree Creek was funded by the NSW State Emergency Service (SES). Data collected included rainfall and information about flooding (levels, timing, depth, velocity, extent, history) and its consequences (buildings, yards, roads affected; people obliged to evacuate. The collected information was used in the first instance to prepare and update SES's flood intelligence systems, especially its Local Flood Plans and Flood Intelligence Cards. The report collected the available information on flooding for the flood events of March 2012, October 2010 and February 2011 at Boree Creek. The report compiled a history of flooding at Boree Creek based on a search of historical newspapers from the National Library of Australia's online database. Major flooding occurred at Boree Creek in 1890, 1931, 1934, two floods in 1936, 1939, 2010 and 2012. At least 24 houses and 10 commercial/public sector buildings flooded over floor due to 135mm of rain recorded at a private gauge on 4 March 2012. The flood event of 2010 was about 0.3m below the March 2012 flood peak at 'Emro' homestead. Flooding in February 2011 had few effects at Boree Creek as it was a smaller flood than October 2010. Known comparisons with the 1931, 1936 and 1939 floods, plus a long history of floods from 'Emro', suggest that the March 2012 flood was a record flood at Boree Creek.

- **Lockhart Flood Study, Final Report, July 2014** (WMAwater 2014). The Lockhart Flood Study was completed in 2014. The town of Lockhart is just 16km from Boree Creek and located in the adjacent catchment. The information contained in the report regarding regional flooding information, historic flooding, hydrologic and hydraulic model parameters, setup and calibration are all useful to understand the flood behaviour around Lockhart and its applicability to the Boree Creek catchment.

- **Urana Local Environmental Plan (LEP) 2011 -** The Objectives of Clause 6.5 Flood Planning are to

  - minimise the flood risk to life and property associated with the use of land;
  - allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change; and
  - avoid significant adverse impacts on flood behaviour and the environment.

This clause applies to land that is shown as "Flood Planning Area" on the Flood Planning Map, and other land at or below the flood planning level. However, the Flood Planning Map (Sheet FLD_002) does not show any flood planning area at Boree Creek.

- **Urana Development Control Plan (DCP) 2011 -** The DCP refers to "Flood Prone Land" identified in the LEP 2011. However, no flood prone land is identified for Boree Creek in the LEP 2011.

2.2.2 Topographic Data

2.2.2.1 LiDAR Data

LiDAR data for Boree Creek was provided by OEH which was originally captured by NSW Land and Property Information (LPI) on 11-13 February 2014 and also processed by LPI. OEH provided 1m square, 5m square and 10m square grid data for the ground surface. The full LiDAR point cloud was classified to Level 3 by LPI. The spatial horizontal accuracy of the LiDAR data was 0.8m @ 95% confidence interval (CI) and the vertical accuracy of the LiDAR data was 0.3m @ 95% CI with a minimum point density of one laser return per square metre. A Digital Elevation Model (DEM) was created using the 1m square grid data and is shown in **Figure 2-1**.

2.2.2.2 SRTM

The Shuttle Radar Topographic Mission (SRTM) data was collected during a 10 day NASA Space Shuttle mission in February 2000. It was processed to produce a 1 arc second digital surface model covering most of the earth's landmass. The 1 Second (30m) DEM is national elevation data product derived from the SRTM data. Seven (7) SRTM tiles covering the former Urana Shire area were provided by OEH. The SRTM data was utilised to delineate catchment boundaries for Boree Creek which are located beyond the extent of the LiDAR data.

2.2.2.3 Aerial Photography

Aerial photography was obtained from Council. Boree Creek is covered by the ‘Lockhart’ tile. It was captured in 2008. It has a 50cm resolution and was provided as a georeferenced raster.

2.2.2.4 Stormwater Details

Council provided two drawing files (shown in **Appendix A**) containing the following information on stormwater drainage:

- A plan of Boree Creek showing lot boundaries and drainage assets (no dimensions)
- Boree Creek Drainage, Drainage Construction, Underground Drainage Long Sections (Dwg. No. 1301-03 of 30 Sep 2013)

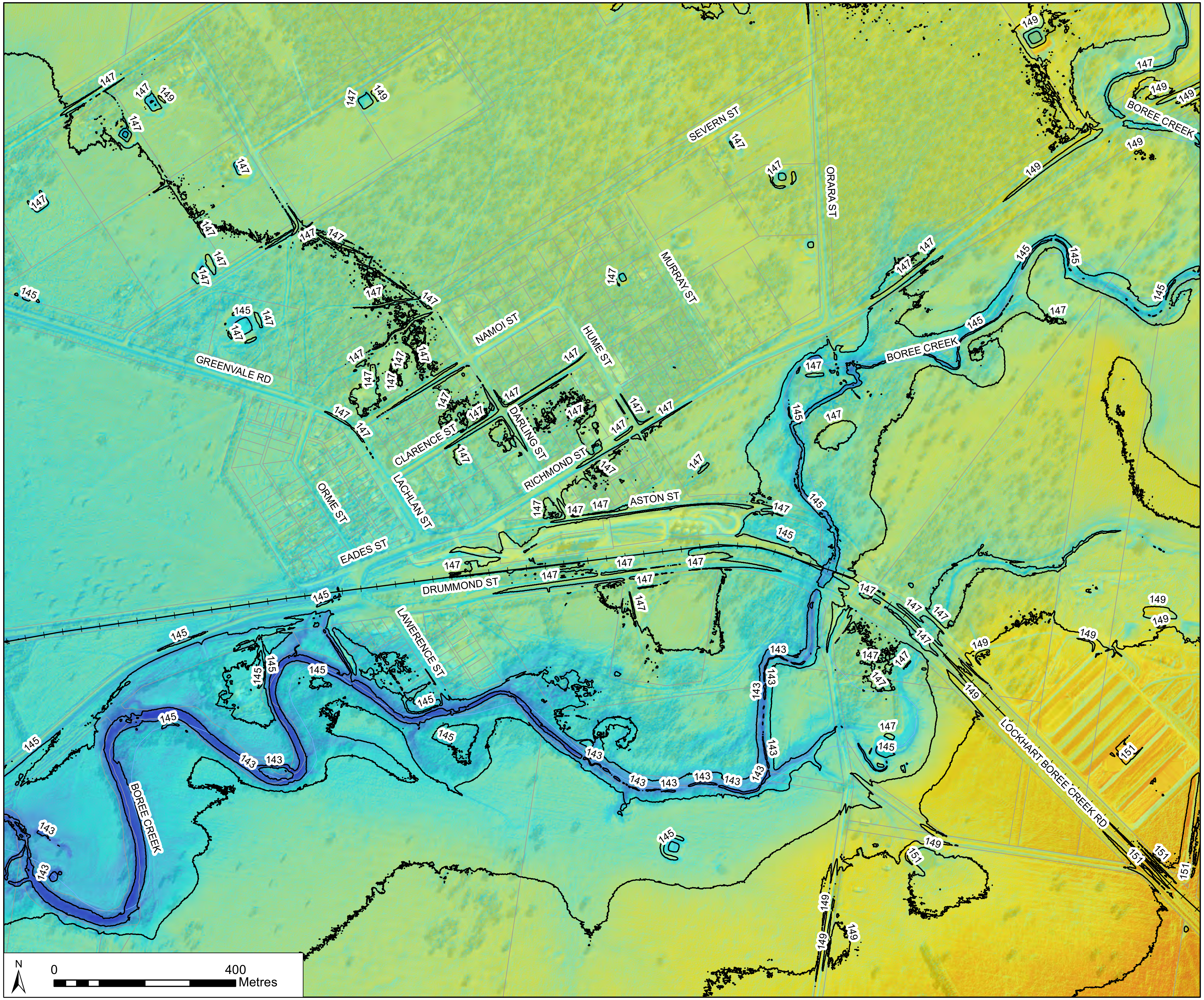
2.2.2.5 Additional topographic data

Additional topographic features, such as stream networks, road and rail networks, and cadastral boundaries were held in-house and utilised for this study.

2.2.3 Rainfall Data

2.2.3.1 Daily rainfall

The Bureau of Meteorology (BoM) maintains a network of daily rainfall gauges and there are two gauges located within the Boree Creek catchment. Only one of these gauges has data for recent years. A summary of this rainfall station is provided in **Table 2-1** and its location in the Boree Creek village is displayed in **Figure 2-2**. This gauge, however, does not have any data available for the 2012 event. For this event, the SES sourced three private rain gauges located in Boree Creek (Table 12.2 in Yeo 2013). These gauges are summarised in **Table 2-2**.



Legend

- 2m contours
- Railway
- Watercourses
- Cadastre

Boree Creek DEM

Elevation (m AHD)

High : 160

Low : 140

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	Digital Elevation Model
TOWN	Boree Creek
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN	PROJECT #	
MR	IA055600	FIGURE 2-1
CHECK	DATE	
AH	24/08/2017	

Table 2-1 BoM daily rainfall gauge data used for Boree Creek

Gauge number	Gauge name	Start Date	End Date	Length of record (years)	Completeness (%)
074014	Boree Creek (Richmond St)	1/09/1924	4/04/2014	89.7	98.1

Table 2-2 Private daily rainfall gauge data used for Boree Creek 2012 event *(source: Yeo 2013)*

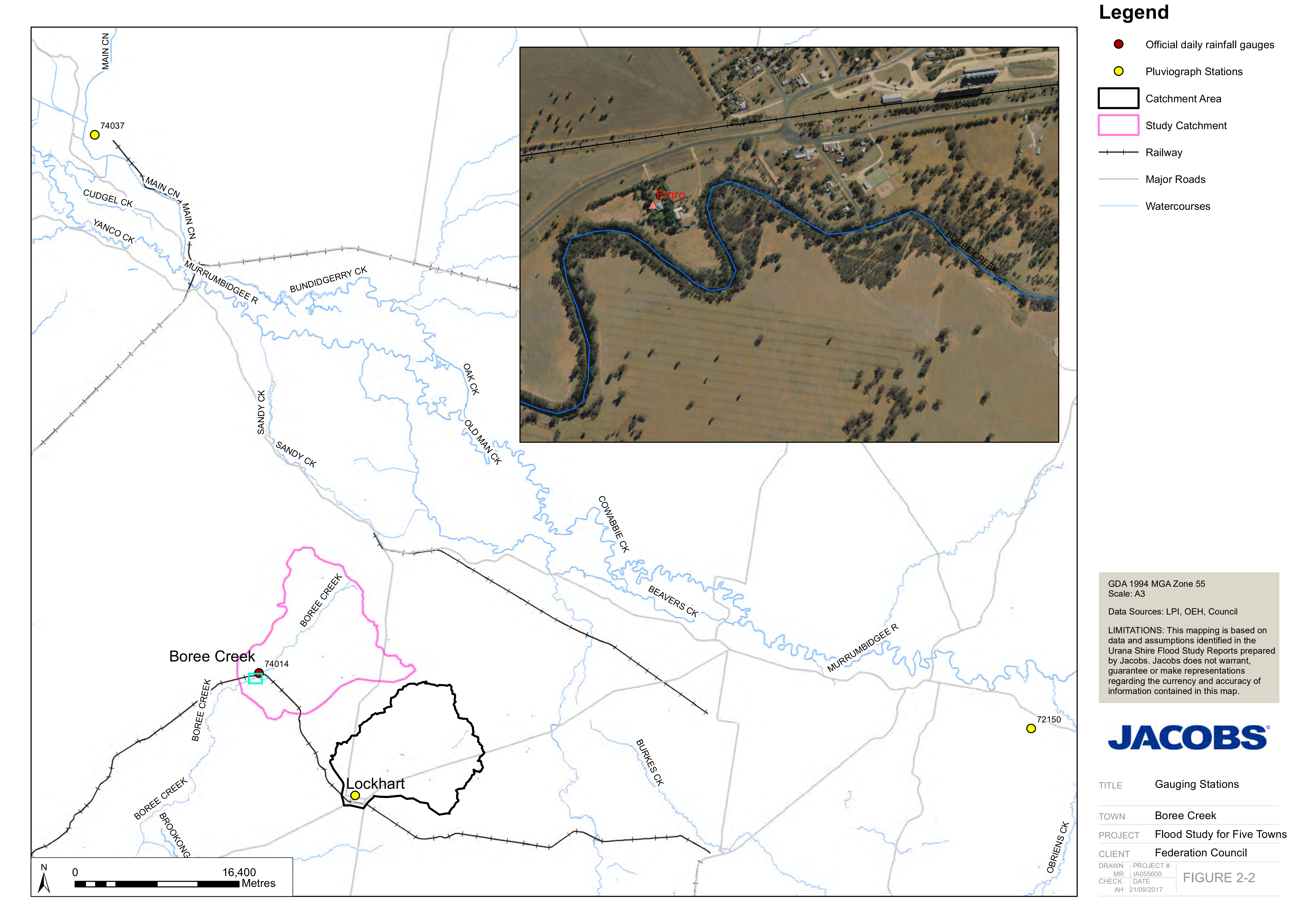
Gauge location	Status	Rain to 9am (mm)		
		3/3/12	4/3/12	5/3/12
'Oak Hill', Lockhart-Kywong Road	Private	0	159	
7-13 Darling St	Private		127	
17-19 Darling St	Private	0	135	0.5

2.2.3.2 Pluviograph

The Bureau of Meteorology (BoM) holds pluviograph (6 minute) rainfall data. The closest gauges to the Boree Creek catchment are located at Yanco (approximately 59km away from the village) and Wagga Wagga (approximately 76km away from the village). A private pluviograph is located at Lockhart (outside the catchment area of Boree Creek) and the hourly data (WMAwater 2013) became available after calibration and verification of hydrologic and hydraulic models. These stations are summarised in **Table 2-3** and location of the stations are on the map in **Figure 2-2**. Cumulative rainfall graphs are also provided for the 2010 and 2012 storm events in **Figure 2-3** and **Figure 2-4** respectively which show similarity of the data for the private pluviograph for both 2010 and 2012 events to the data recorded at the Yanco gauge.

Table 2-3 Available Pluviograph data

Gauge number	Gauge name	Source	Resolution	Storm events with data available
074037	Yanco Agricultural Institute	BoM	6 minute	Oct 2010, Feb 2011, Mar 2012
072150	Wagga Wagga AMO	BoM	6 minute	Oct 2010, Feb 2011, Mar 2012
N/A	Lockhart	Private	hourly	Feb 2011, Mar 2012



Legend
Official daily rainfall gauges
Pluviograph Stations
Catchment Area
Study Catchment
Railway
Major Roads
Watercourses
MAIN CN
74037
CUDGEL CK
YANCO CK
MURRUMBIDGEE R
BUNDIDGERRY CK
OAK CK
SANDY CK
OLD MAN CK
COWABBIE CK
BEAVERS CK
BOREE CREEK
Boree Creek
74014
Lockhart
BURKES CK
72150
OBRIENS CK
BROOKONG
Emro
0
16,400
Metres
N
GDA 1994 MGA Zone 55
Scale: A3
Data Sources: LPI, OEH, Council
LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
JACOBS
TITLE Gauging Stations
TOWN Boree Creek
PROJECT Flood Study for Five Towns
CLIENT Federation Council
DRAWN MR
CHECK AH
PROJECT # IA055600
DATE 21/09/2017
FIGURE 2-2

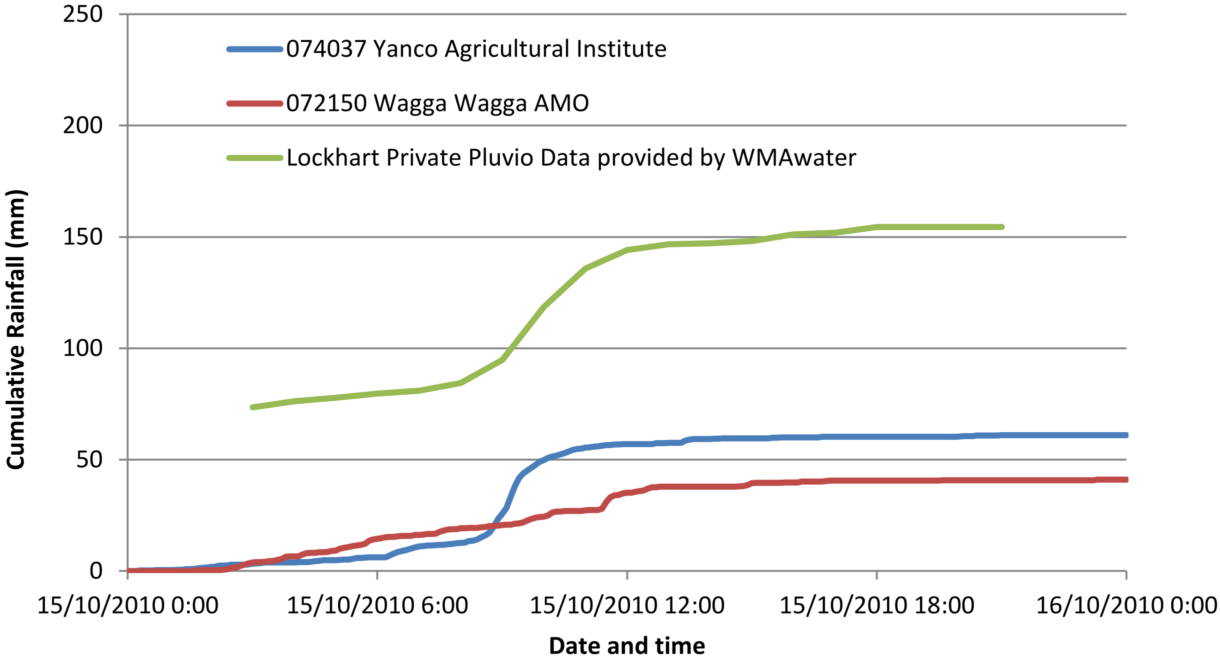


Figure 2-3 Cumulative pluviograph rainfall for the October 2010 event

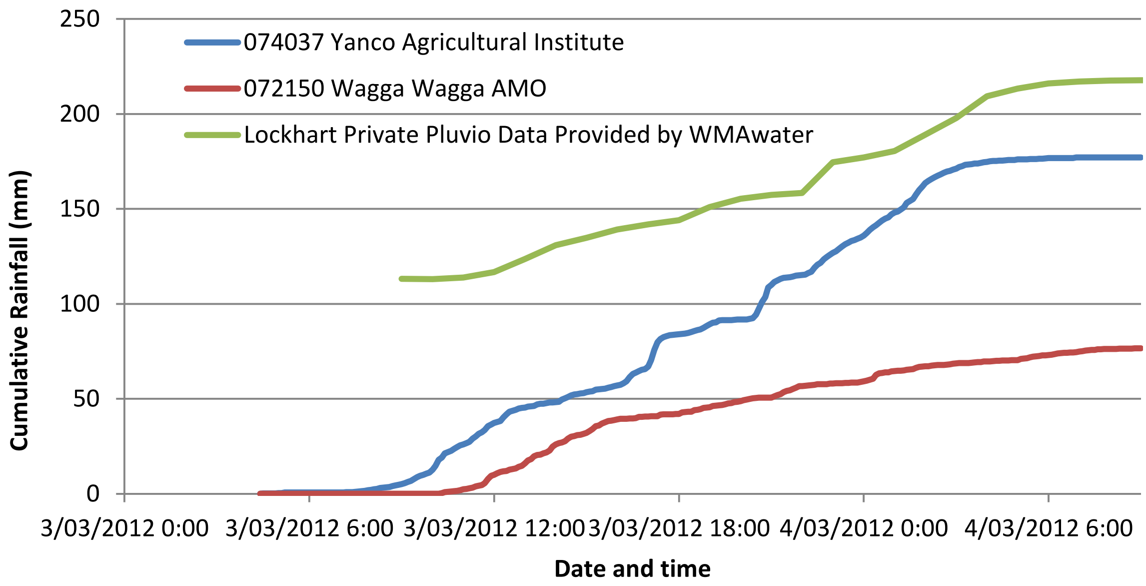


Figure 2-4 Cumulative pluviograph rainfall for the March 2012 event

2.2.4 Streamflow Data

No streamflow gauging stations are located on Boree Creek.

2.3 Community Consultation

2.3.1 Flood Questionnaire

A community consultation process was initiated to obtain flood information for past events. This involved sending a newsletter and a questionnaire (refer to **Appendix B**) to residents and landowners within the study area. The newsletter introduced the floodplain management process to the residents of the village, described the purpose of the questionnaire and provided the residents with contacts for their responses. The questionnaire was prepared in consultation with Council to help identify flooding issues for the study area and to provide reliable flood information to assist in the validation of the hydrologic and hydraulic computer models.

The flood information that was requested included:

- General information, such as:
  - Residents from the Study Area
  - Ownership of the residence
  - How long residents lived at the property
- Specific flood information, such as:
  - Experience on flooding in residence and/or at work
  - Location and depth of flood water in the worst flood experienced
  - Duration of flooding
  - Flood damages to residence and business
  - Disruption to vehicular access to residence during flooding
  - Assistance required by residents from SES
  - Flooding to residence made worse by works on other properties or by construction of roads or other structures
  - Identify information (eg. flood photographs, newspaper clippings, flood marks etc) that can be provided to Consultant
  - Residents intention for further development on their lands
  - Ranking of development types for protection against flooding
  - Ranking of potential flood mitigation measures
  - Any comments on any other issues associated with this study.

2.3.2 Summary of Responses to Flood Questionnaire

In total, seven (7) responses were received from the community to the questionnaire. A summary of responses is provided in the following paragraphs.

Residency status (Question 1-2)

All respondents were residents of the study area.

Length of Residency in Boree Creek and Business Activity (Questions 3-5)

Respondents lived in the Study Area between 4 to 53 years with an average residency of 28 years. Three (3) respondents managed business located within the study area.

Experiences of Flooding (Questions 6-12)

All respondents experienced flooding in their properties and five (5) respondents identified the flood event of 2012 as the major flood event and the duration of flooding was longer than 6 hours.

Flooding cut off access to five properties and two respondents estimated flood damages to their properties were approximately $150,000. Residents of one property required assistance from the SES during the flood.

Flood Evidence (Questions 13, 15)

Five (5) respondents indicated they could provide more information regarding flooding behaviour including information on flood extent or depth at particular locations, newspaper clippings, marks indicating maximum flood levels, recollections of flow directions, depths or velocities and photographs of past floods.

Flood Affects to properties due to works (Questions 14)

Two (2) respondents identified that the railway aggravated flooding within the town area.

Intention of Respondents for further development (Question 16)

Five (5) respondents were not expecting to undertake any further developments to their properties and respondents were unsure about any further development to their properties.

Priority for protecting different types of developments from flooding (Question 17)

Respondents were asked to rank different types of development for protection against flooding. Five (5) respondents gave the highest priority for protection of residences against flooding and three respondents gave the highest priority for protecting emergency facilities.

Priority for flood mitigation measures (Question 18)

Protecting residential buildings from flooding were given the highest priority by five (5) respondents and three (3) respondents gave the highest priority to providing flood warning.

Further comments / willingness to provide further information (Question 19)

Three (3) respondents indicated their availability to be contacted.

Wanting to be kept informed (Question 20)

Six (6) respondents indicated that they would like to be kept informed of the study's progress.

Contact details for respondents (Question 21)

Six (6) respondents provided their contact details.

2.4 Additional Topographic Survey

A topographic survey was undertaken as part of this study to collect additional data to satisfy the scope of the study. The scope of the topographic survey was identified by Jacobs, with Council engaging T J Hinchcliffe & Associates to undertake the ground survey. T J Hinchcliffe & Associates provided the following results from the ground survey to Jacobs:

- Details (eg. size, shape, invert level, top of road level etc) for 9 culverts (Culvert No. 22 to Culvert No. 31);
- Zero mark of two flood depth indicators at Culvert No. 28 and Culvert No. 31 were connected to AHD; and
- Flood marks at “Emro” property for 2010 and 2012 were connected to AHD. The flood level for the 2010 event is 145.52 mAHD and the flood level for the 2012 event is 145.85 mAHD.

Details on the topographic survey are presented in the Urana Flood Study Survey Report prepared by T J Hinchcliffe & Associates. The relevant topographic survey information collected by T J Hinchcliffe & Associates for Boree Creek is presented in **Appendix A.**

3. Catchment Hydrology

3.1 Catchment Description

The catchment draining to the Boree Creek village is approximately 141km^2. The catchment is predominantly cleared rural land, with a large proportion of the land being used for dryland cropping, horticulture and grazing. The catchment's highest elevation is approximately 380m AHD. Boree Creek rises in the northeast of the catchment at an elevation of approximately 180m AHD and drops to approximately 145m AHD when it reaches the village. The creek covers a length of approximately 13.5km upstream of the village.

3.2 Catchment Modelling

3.2.1 Methodology

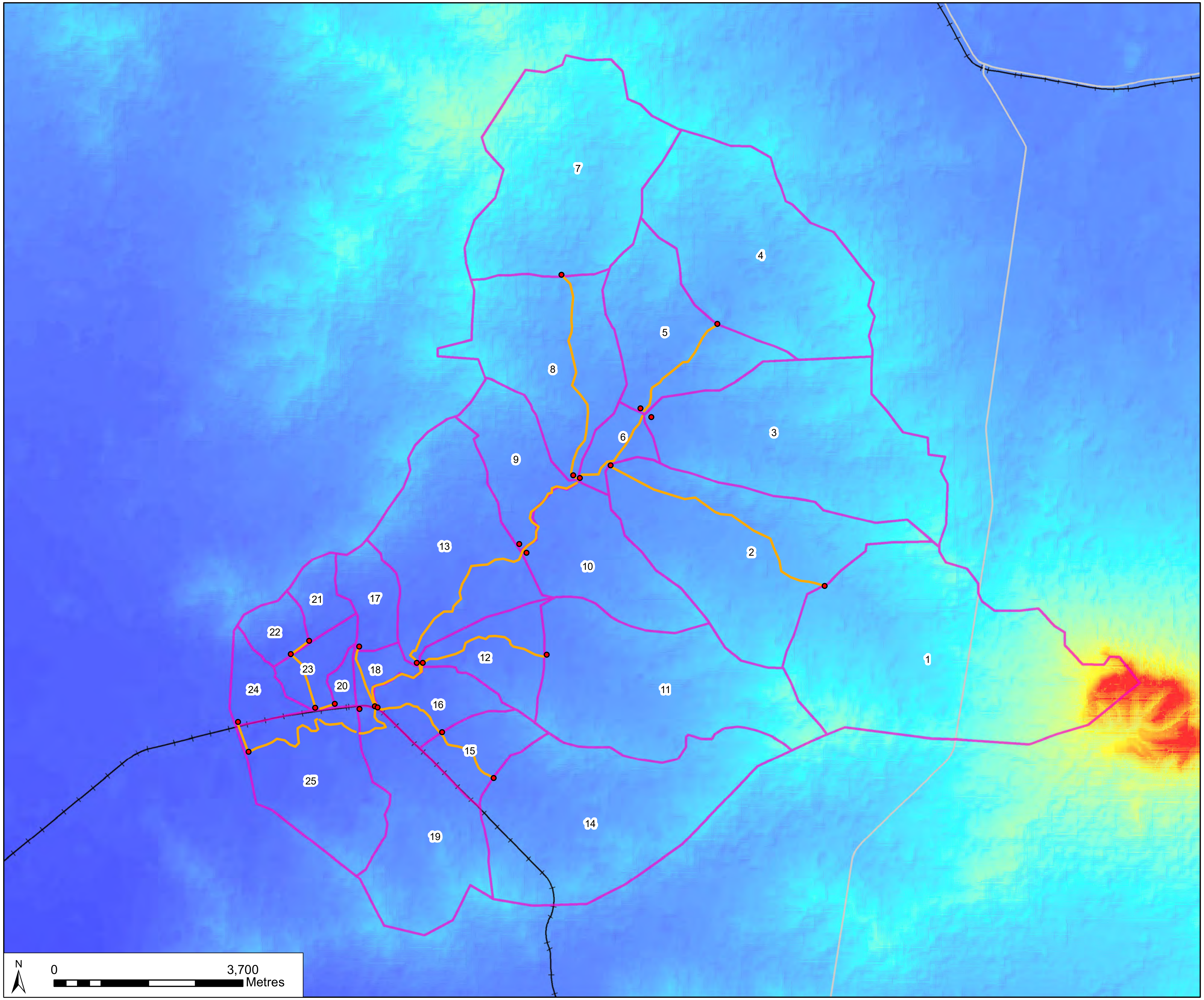
The Boree Creek catchment was modelled using XP-RAFTS which has been widely used in Australia to estimate runoff from both rural and urban areas. XP-RAFTS has the ability to simulate sub-catchments of varying sizes and the routing of flows between them, and it was considered the most suitable modelling platform. Both total and local sub-catchment flows are able to be obtained from the model for inclusion in the hydraulic model.

The model can be calibrated by varying the initial and continuing losses applied to the rainfall.

3.2.2 XP-RAFTS Model Configuration

The Boree Creek sub-catchments were delineated using a combination of the 1m DEM and the 30m SRTM DEM, which covers the entire catchment. A total of 25 sub-catchments were delineated covering the Boree Creek catchment to the limit of the hydraulic model downstream of the village (totalling 154km^2). An outline of the XP-RAFTS catchments is shown in **Figure 3-1**. The length of the flow path was measured from the highest point in the sub-catchment to the sub-catchment outlet. The vectored slope of the flow path was calculated using the SRTM DEM and a typical cross section was cut from the DEM to represent the channel routing option in XP-RAFTS.

A Manning's n roughness value of 0.04 was used for channel routing. Manning's n roughness values of the catchment varied from 0.04 for cleared agricultural land to 0.08 for areas where vegetation is present. These were based on the available aerial photography over the catchment from 2008. A nominal impervious fraction of 5% was used across the catchment. Further details on the XP-RAFTS model are provided in **Appendix C**.



Legend

- RAFTS Nodes
- RAFTS Channels
- RAFTS Subcatchments
- Major Roads
- Railway

SRTM DEM

Elevation (m AHD)

High : 400

Low : 130

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	XP-RAFTS Model Setup
TOWN	Boree Creek
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE 3-1
CHECK AH	DATE 24/08/2017	

4. Hydraulic Modelling

4.1 Model Selection

A TUFLOW combined one-dimensional (1D) and two-dimensional (2D) hydrodynamic model has been developed for Boree Creek. TUFLOW is an industry-standard flood modelling platform, which was selected for this assessment as it has:

- Capability in representing complex flow patterns on the floodplain, including flows through street networks and around buildings and on flat terrain where flow patterns may not be concentrated or well defined
- Capability in accurately modelling flow behaviour in 1D channel, bridge and culvert structures and interflows with adjacent 2D floodplain areas
- Easy interfacing with GIS and capability to present the flood behaviour in easy-to-understand visual outputs

The model was developed and run in TUFLOW version 2013-12-AD-w64, in double-precision mode.

4.1.1 TUFLOW Model Configuration

4.1.2 Extent and Structure

The Boree Creek TUFLOW model is comprised of:

- A 2D domain of the catchment surface reflecting the catchment topography, with varying roughness as dictated by land use
- A 1D network of the hydraulic structures including culverts and bridges
- Obstructions to flow are represented as 2D objects, including existing buildings.

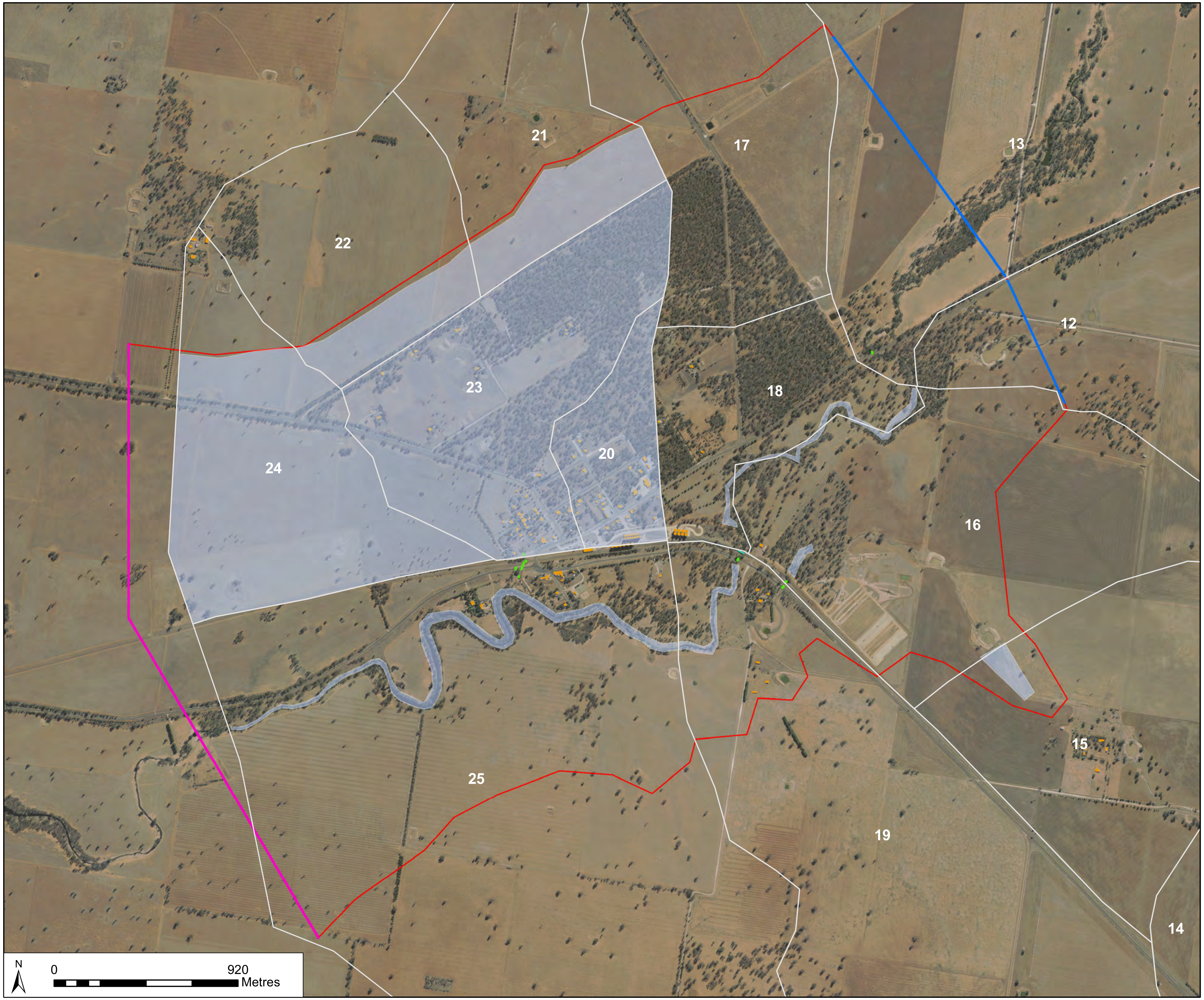
Refer to the following report sections for details on these features. The locations of various features in the TUFLOW model are shown in **Figure 4-1**.

4.1.3 Model Topography

The topography of the catchment is represented in the model using a 4m grid. The grid size was selected to optimise model run time and to achieve a level of precision required for adequate representation of both mainstream and overland flood behaviour within the study area. The basis of the topographic grid used in the TUFLOW model is the LiDAR data set for Boree Creek.

4.1.4 Culverts

A number of culverts are included in the TUFLOW model. Culvert locations and details were obtained from the topographic survey undertaken for this study by TJ Hinchcliffe & Associates in 2015. Details such as culvert dimensions, length and upstream and downstream invert levels are included in the model. One culvert, which was partially buried at the time of the survey, has a blockage factor applied. The small underground stormwater network in Boree Creek (along Eades Street) has not been included in the model, rather, only cross-drainage structures pertinent to flooding have been included.



XP-RAFTS Sub-Catchment
XP-RAFTS Inflow
1D culverts
Inflow boundary
Outflow boundary
Buildings
2D Bridge
Model Extent

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	TUFLOW Model Setup
TOWN	Boree Creek
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council
DRAWN MR	PROJECT # IA055600
CHECK AH	DATE 21/08/2017

FIGURE 4-1

4.1.5 Building Polygons

This study considers buildings as solid objects on the floodplain. This means that buildings form impermeable boundaries within the model and while water can flow around buildings, it cannot flow across their footprint. The building polygons were superimposed on the model grid to make model computational cells under the footprints inactive. This will reduce the availability of temporary floodplain storage, however, this will be negligible in comparison to the overall flood volume and is considered a conservative approach.

4.1.6 Property Fencelines

Fencelines have not been represented in the model and floodwaters are allowed to flow across them freely. Although fences may obstruct overland flood flows in some parts of the catchment, experience indicates that representing fences in the hydraulic model requires making invalidated assumptions about depths at which fences overflow or fail. The dominant type of rural fencing consists of wooden posts and barbed wire, which allows floodwaters to pass through. It has been assumed that these fences do not cause any significant obstruction to the flow.

4.1.7 Surface Roughness

All parts of the study area within the TUFLOW model were assigned hydraulic roughness values according to areas defined based on aerial photography. These are based on engineering experience and typical values used in previous flood studies undertaken in Western NSW by Jacobs and other consultants. These are provided in **Table 4-1** below.

Table 4-1 TUFLOW model grid hydraulic roughness values

Land Use Type	Manning's n
Low density residential areas	0.08
Open rural areas	0.045
Dense vegetation	0.12
Roads and paved areas	0.02
Railway	0.05
Creeks	0.045

4.2 Boundary Conditions

4.2.1 Model Inflows

Runoff generated from the sub-catchments from the XP-RAFTS hydrologic model was applied to the TUFLOW model via one of two methods (refer to **Figure 4-1**):

- Total catchment flows draining to the upstream end of the TUFLOW model were applied at the boundary. Flows from Boree Creek and a small tributary adjacent to it were applied to the 2D cells, initially at the lowest point along the boundary and then distributed to wet areas in the catchment as the storm progresses.

- Local catchment flows which include runoff generated from areas within the TUFLOW model extent were applied directly to the main creek (in the case of upstream areas) or applied over the sub-catchment where areas of overland flow are of concern (around the Boree Creek village).

4.2.2 Tailwater Conditions

The downstream model boundary was located some distance (approximately 1.8km) downstream of the Boree Creek village, to eliminate the potential influence of the boundary conditions on flood behaviour in the study area. A normal depth condition has been assumed at the boundary.

4.2.3 Initial Conditions

Small inflows were used at start of the model runs.

5. Calibration and Verification

5.1 Selection of Calibration and Verification Events

There have been a number of events that have impacted the Boree Creek village, including 1890, 1931, 1934, 1936, 1939, 2010 and 2012. Due to the availability of rainfall data (both spatial and temporal) and accurate flood level data, the 2010 and 2012 flood events will be used for calibration. Since there are no stream gauges on Boree Creek to calibrate the hydrologic model to, simultaneous calibration of the hydrologic and hydraulic models was undertaken.

5.2 Hydrologic Modelling

5.2.1 2012 Event

The XP-RAFTS hydrologic model was calibrated to the 2012 event through a simultaneous calibration process with the TUFLOW hydraulic model. The only available rain gauges within the catchment were private rain gauges with an unknown accuracy. The average of three gauge recordings was taken (**Table 2-2)** as the rainfall depth across the catchment. This was temporally distributed using the Yanco Agricultural Institute Pluviograph (074037) since it had the closest match to the recorded rainfall depth within the catchment. The initial and continuing losses were varied and the resultant flows were used as inflows to the TUFLOW model. The modelled flood levels were compared at the 27 surveyed flood marks. The adopted rainfall loss parameters were 25mm initial loss and 2.0mm/hr continuing loss. These are the same losses that were used in the calibration of the hydrologic model for the 2012 event for the Lockhart Flood Study (WMAwater 2014) and provided reasonable calibration to the recorded flood levels. The XP-RAFTS model simulated a peak flow of 270 m^3/s at the XP-RAFTS model outlet for Boree Creek (catchment area 155 km^2) and the flow hydrograph is presented in **Appendix C**.

5.2.2 2010 Event

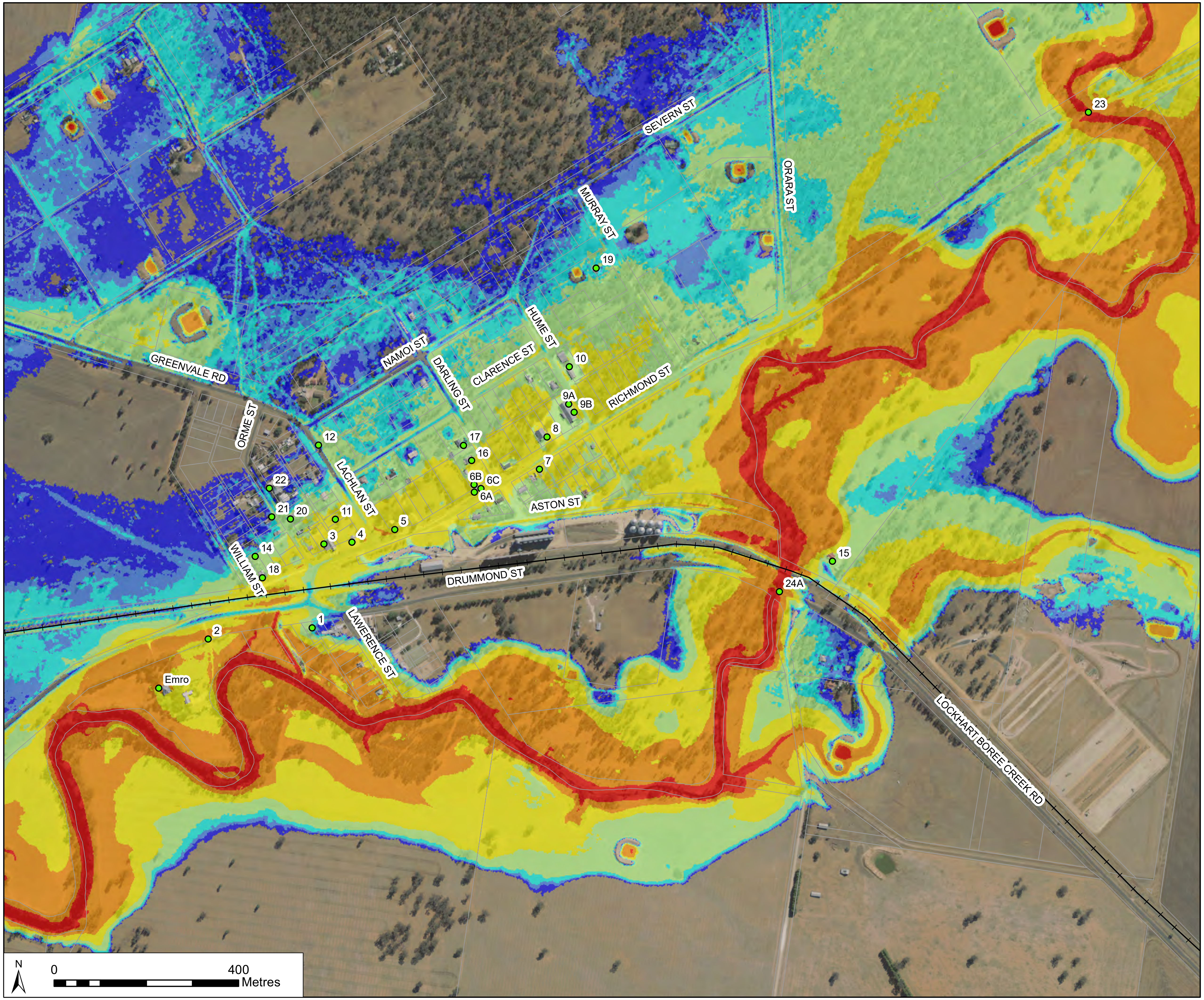
The XP-RAFTS hydrologic model was also calibrated to the 2010 event through a simultaneous calibration process with the TUFLOW hydraulic model. The only available rain gauge within the catchment was the BoM gauge 'Boree Creek (Richmond Street)' (074014). This rainfall depth was temporally distributed using the 'Wagga Wagga AMO' Pluviograph (072150). The Wagga Wagga pluviograph had a more representative distribution of rainfall that provided more accurate flows in the hydraulic model. The initial and continuing losses were varied and the resultant flows were used as inflows to the TUFLOW model. The modelled flood levels were compared at the single surveyed flood mark at the 'Emro' property. The adopted rainfall loss parameters were 50mm initial loss and 2.0mm/hr continuing loss. These are again the same losses that were used in the Lockhart Flood Study (WMAwater 2014) for the calibration of the hydrologic model for the 2010 event and provided the most accurate replication of the flood level at 'Emro'. The difference in initial loss values between the 2010 and 2012 flood events is possibly due to the lack of spatiotemporal resolution of rainfall data across the catchment and the difference in antecedent moisture conditions before the storm burst for both events.

The XP-RAFTS model simulated a peak flow of 160 m^3/s at the XP-RAFTS model outlet for Boree Creek (catchment area 155 km^2) and the flow hydrograph is presented in **Appendix C**.

5.3 Hydraulic Modelling

5.3.1 2012 Event

For the 2012 event, there are 26 flood levels that were surveyed as part of the SES flood intelligence review (Yeo 2013) and one at the 'Emro' property that was surveyed for this study. Calibration was undertaken by adjusting parameters simultaneously in the hydrologic and hydraulic models. The flood depth map is presented in **Figure 5-1**. The difference in recorded flood levels at the locations shown in the map is presented in **Table 5-1**. The flood levels were within -0.28 and +0.25 m of the recorded levels, with a mean absolute difference of 0.14m. There was one location where a recorded flood level on Orme Street was modelled to be flood free. The water encroaches on the resident's yard, but does not reach the house where the flood mark was recorded.



Legend

- Recorded flood level locations
- Railway
- Cadastre

2012 flood depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- > 2

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	2012 Calibration Event Flood Depth Map
TOWN	Boree Creek
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE 5-1
CHECK AH	DATE 21/08/2017	

This flood level, however, was only given 'medium' confidence in the Flood Intelligence Review (Yeo 2013). In general, the flood behaviour described in Yeo (2013) and by the community via the community consultation process was recreated. Further details on the TUFLOW model calibration are provided in **Appendix D**.

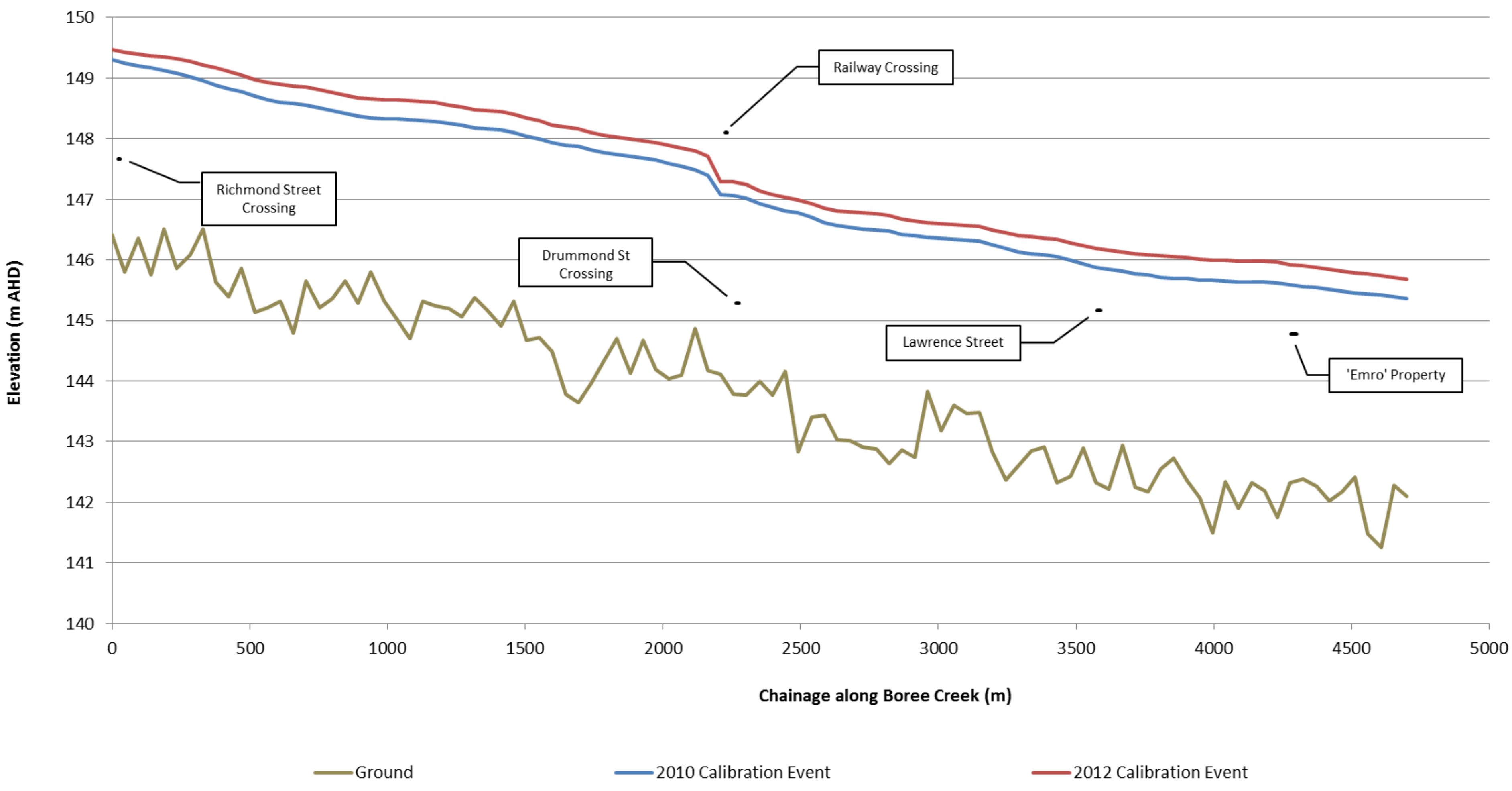
Table 5-1 Boree Creek calibration results for the 2012 flood event

Location Reference	Recorded Flood Level	Modelled Flood Level	Difference
1	146.23	146.10	-0.13
2	145.89	145.97	0.08
3	146.71	146.51	-0.20
4	146.83	146.65	-0.18
5	147.1	146.82	-0.28
6A	147.36	147.17	-0.19
6B	147.3	147.23	-0.07
6C	147.29	147.28	-0.01
7	147.29	147.54	0.25
8	147.73	147.62	-0.11
9A	147.9	147.76	-0.14
9B	147.87	147.77	-0.10
10	147.83	147.75	-0.08
11	146.81	146.67	-0.14
12	147.01	146.92	-0.09
14	146.33	146.33	0.00
15	148.01	147.79	-0.22
16	147.44	147.35	-0.09
17	147.36	147.34	-0.02

Location Reference	Recorded Flood Level	Modelled Flood Level	Difference
18	146.41	146.23	-0.18
19	147.72	147.90	0.18
20	146.6	146.48	-0.12
21	146.66	146.46	-0.20
22	147.02	N/A	
23	149.37	149.40	0.03
24A	147.49	147.23	-0.26
Emro	145.85	145.81	-0.04

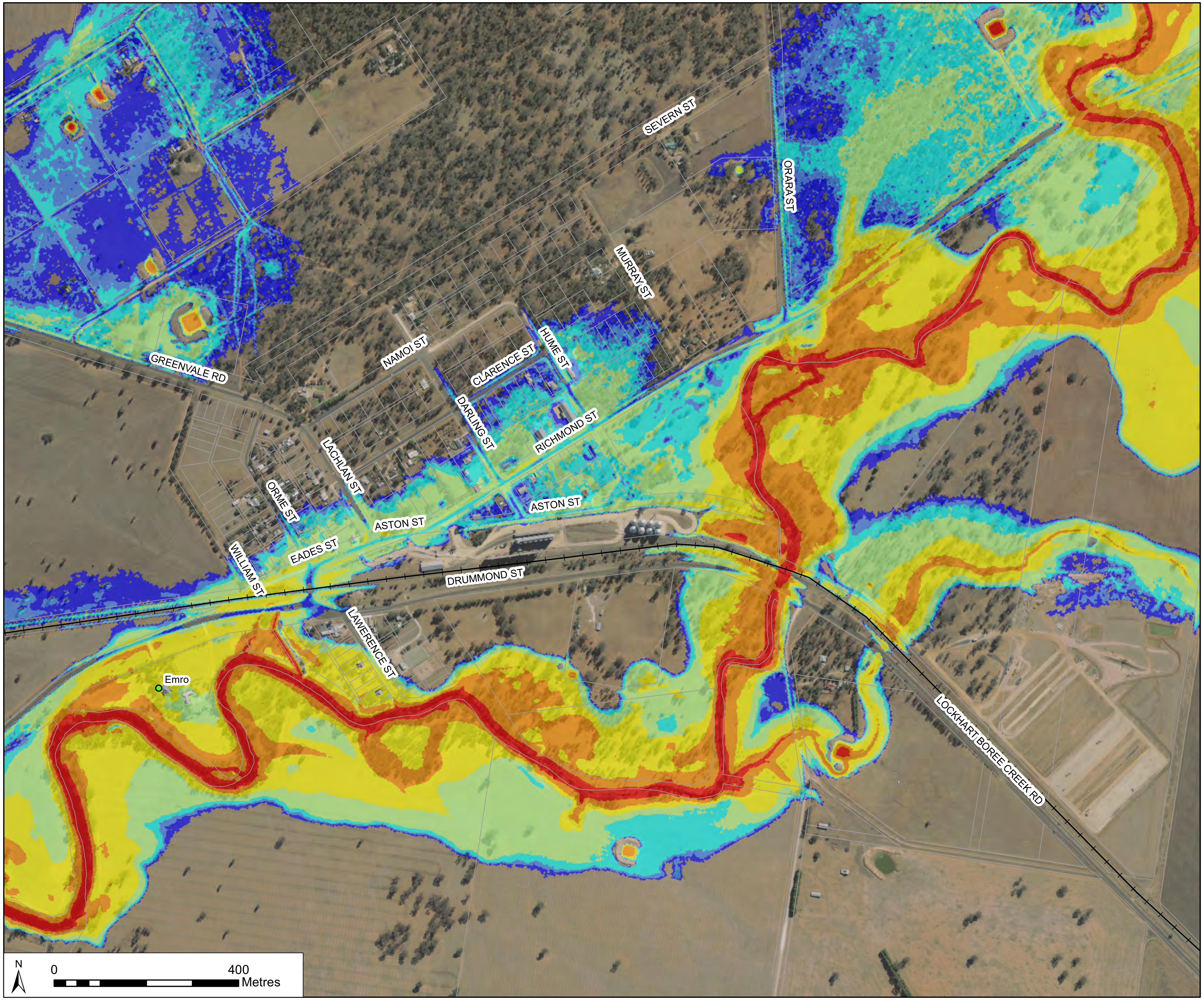
The estimated flood extent created based on oblique aerial photography, street level photography and resident sketches as recorded in the flood intelligence review (Fig 12.3, Yeo 2013) closely follows the modelled flood extent within the town, along the flood free 'island' to the south of the town and through to Boree Creek itself. Shallow depths of inundation (generally <0.2m) are modelled to occur north of Namoi Street which are not included in the estimated flood extent, but the school and houses are flood free in this area, as observed during the flood. A flood profile is plotted in **Figure 5-2** along Boree Creek. The 2012 storm was successfully calibrated in the XP-RAFTS and TUFLOW models.

Figure 5-2 Boree Creek Peak Water Level Profiles for the Calibration Events



5.3.2 2010 Event

For the 2010 event, there is only one recorded flood level located at the ‘Emro’ property that was surveyed for this study. Calibration was undertaken by adjusting parameters in the hydrologic and hydraulic models. The flood depth map is presented in **Figure 5-3**. The difference in recorded flood level at this location (shown on the map) is -0.04m. In general, the flood behaviour described in Yeo (2013) and by the community via the community consultation process was recreated. Floodwaters are conveyed by Richmond Street, with shallow inundation (up to 0.3m modelled, 0.1m reported) along Murray Street and Orme Street, and the depth of flooding at the lower end of Lawrence Street is modelled to be up to 0.8m, which is likely to cause above-floor flooding to the property located there, as reported (Yeo 2013). The peak water level profile for the 2010 event is shown in **Figure 5-2**. The 2010 storm was successfully calibrated in the XP-RAFTS and TUFLOW models. Further details on the TUFLOW model calibration are provided in **Appendix D**.



Legend

Recorded flood level locations

Railway

Cadastre

2010 flood depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- > 2

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	2010 Calibration Event Flood Depth Map
TOWN	Boree Creek
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE 5-3
CHECK AH	DATE 21/08/2017	

5.4 Sensitivity Analysis (2012 Flood Event)

A sensitivity analysis was conducted using the 2012 flood event. The following hydrologic and hydraulic model parameters were changed: initial loss, Manning's roughness, blockage of culverts and the downstream boundary. Each of these is addressed in the sections below and further details on the results from the sensitivity analysis are provided in **Appendix D**.

5.4.1 Initial loss

The adopted initial rainfall loss for the 2012 event was 25mm. This was adjusted by +/- 20%, i.e. becoming 30mm and 20mm. Increasing or decreasing the initial loss resulted in a negligible change in peak water level in the village (at the recorded flood mark locations), being less than ±0.001m. The change in flow is also insignificant.

5.4.2 Manning's n

The Manning's roughness values adopted (**Table 4-1**) were adjusted by +/- 20%. Increasing the Manning's n roughness resulted in flood levels up to 0.11m higher in the village and the flow diverted through the town increases by approximately 14%. Decreasing the Manning's n roughness resulted in a decrease in flood levels of up to 0.32m within the village and up to 1m in locations along Boree Creek. This also diverted approximately 25% more flow through the railway culverts and along the creek rather than through the town.

5.4.3 Blockage of Structures

The 2012 event was run assuming no blockage of culverts (except for one partially buried culvert). This sensitivity analysis investigated the impact of a 50% blockage and 100% blockage factor applied to the culverts in Boree Creek. This was applied to the 1D elements (as shown in **Figure 4-1**) and the railway culverts (2D structure), being so large, were assumed to not be blocked. The flood level in the village increased by 0.04m and 0.07m under the 50% and 100% blockage scenarios, respectively. The flow and flow distributions remained largely the same.

5.4.4 Downstream Boundary

A normal water depth was assumed at the downstream boundary. A sensitivity analysis was conducted by changing the tailwater levels by +/- 0.5m. This did not change the modelled flood levels within the village or the distribution or magnitude of flows through the village, indicating that the outflow boundary is located far enough downstream to not impact the modelled flood levels within the village.

6. Estimation of Design Flood

The scope of the study included flood modelling for 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2% AEP events and the PMF event. Details on the input data used in hydrologic and hydraulic modelling for the design events are discussed in this section.

6.1 Input Data for Hydrologic Modelling

6.1.1 Land Use

Hydrologic modelling was undertaken for the existing land use.

6.1.2 Rainfall Depths

The rainfall design data for this study for events up to and including the 0.2% AEP was generated within the XP-RAFTS (v 2013) model applying the rainfall intensity, frequency and duration (IFD) relationship based on data presented in **Table 6-1**.

- **Table 6-1: Data used to estimate rainfall IFD**

Data Description	Parameter
Zone	2
1 hour 2 year ARI mm/hr	19.73
12 hour 2 year ARI mm/hr	3.47
72 hour 2 year ARI mm/hr	0.89
1 hour 50 year ARI mm/hr	43.6
12 hour 50 year ARI mm/hr	6.81
72 hour 50 year ARI mm/hr	1.62
Skewness G	0.16
Geographical factor 2 year ARI F2	4.33
Geographical factor 50 year ARI F50	15.28

Areal reduction factors (ARF) built within XP-RAFTS (2013) were applied to the estimated design rainfall depths for events up to, and including, the 0.5% AEP event. XP-RAFTS uses ARF values of 0.79, 0.81, 0.82 and 0.84 for 2 hour, 3 hour, 4 hour and 6 design storm durations respectively. In the case of 36 storm durations the ARF values adopted by XP-RAFTS varied between 0.92 and 0.93 and in the case of the 72 hour storm the ARF varied between 0.95 to 0.96.

Estimates of the Probable Maximum Precipitation (PMP) for the study catchment up to 3 hours duration were prepared using the procedures given in *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method* (BOM, 2003).

6.1.3 Model Parameter Values

The XP-RAFTS model for the study catchment the adopted value of Bx was 1.0.

6.1.4 Temporal Patterns

Temporal patterns for all events storm durations up to, and including, the 0.2% AEP event were sourced from the XP-RAFTS model for Zone 2. The temporal pattern for the PMP event was sourced from BoM (2003).

6.1.5 Design Rainfall Losses

An initial loss of 15mm was adopted for both events up to and including the 10% AEP event, and an initial loss of 10mm was adopted for events between 5% and 0.2% AEP. An initial loss of 0mm was adopted for the PMP event. A continuing loss of 2.5mm/hr was adopted for all design events up to and including the 0.2% AEP event and a continuing loss of 1mm/hr was adopted for the PMP event. Initial rainfall losses adopted in this study are based on the same losses adopted in the Lockhart Flood Study Report (WMAwater 2014).

6.1.6 Design Discharges

The XP-RAFTS model was run for a range of storm durations for the selected design flood events to estimate design inflow hydrographs. Results from the XP-RAFTS model were reviewed to identify storm durations which produced peak discharges for each sub-catchment and at the catchment outlet. The estimated design discharges for the modelled events and storm duration which produced the peak discharge are shown in **Table 6-2**. Modelled peak discharges at the XP-RAFTS outlet for the full range of storm durations between 1 hour and 72 hour storm for the 20% AEP up to and including the 0.2% AEP events are presented in **Appendix C**.

- **Table 6-2 Peak discharges (m^3/s) for Boree Creek and adopted peak discharges in the Lockhart Flood Study Report (WMAwater 2014)**

Event	Boree Creek (Catchment area 155 km^2)	Lockhart Flood Study (Catchment area 150 km^2)
20% AEP	71 (72 hr)	67
10% AEP	96 (72 hr)	95
5% AEP	155 (36 hr)	134
2% AEP	212 (6 hr)	185
1% AEP	272 (6 hr)	231
0.5% AEP	346 (6 hr)	281
0.2% AEP	474 (6 hr)	-
PMF	4178 (2 hr)	2876

A comparison of design discharges estimated in this study and design discharges adopted in the Lockhart Flood Study Report (WMAwater 2014) is shown in **Table 6-2**, which shows that design discharges estimated in this study for 20% AEP to 2% AEP events agree closely with discharges adopted in the Lockhart Flood Study Report. However, in the case of design events rarer than the 2% AEP events, peak discharges estimated in this study are consistently higher than that adopted in the Lockhart Flood Study Report.

Modelled XP-RAFTS peak flows at the catchment outlet for the 2012 and 2010 events are similar to the 1% AEP and 5% AEP events respectively for Boree Creek. This is consistent with the Lockhart Flood Study Report (WMAwater 2014).

6.2 Hydraulic Model Parameters for Design Events

6.2.1 Blockages

Only a selected number of pits and pipes in the overall stormwater network were represented in the TUFLOW model, namely those larger structures providing cross-drainage during flood events. A zero blockage factor was applied to all the culvert structures except one, which had a blockage factor applied as it was partially buried at the time of survey.

6.2.2 Tailwater Conditions

The downstream model boundary was located some distance (approximately 1.8km) downstream of the Boree Creek village, to eliminate the potential influence of the boundary conditions on flood behaviour in the study area. A normal depth condition has been assumed at the boundary.

6.2.3 Initial Conditions

The model was assumed to be dry at the start of the model runs.

6.3 Simulated Design Events

The storm durations assessed for all design events were selected based on runs in the XP-RAFTS hydrologic model to capture the critical storm durations throughout the study area. The event durations assessed are summarised below in **Table 6-3**.

- **Table 6-3: Storm event durations modelled**

Event AEP	Durations modelled
20%	72 hour
10%	72 hour
5%	36 hour
2%	2 hour, 6 hour
1%	2 hour, 6 hour
0.5%	2 hour, 6 hour
0.2%	2 hour, 6 hour
PMF	2 hour

7. Flood Behaviour for Design Flood Events

7.1 Flood Depth Mapping

The maximum envelope of flood depth mapped for all design events are included in **Appendix E**. The following observations are made from the flood depth maps (refer **Figure E-1** to **Figure E-8**):

- Overbank flooding occurs in the 20% AEP event and sections of Boree Creek Road located east of the intersection of Orara Street are subject to flooding. The railway culvert constricts the floodplain and the 'Emro' property is surrounded by floodwater.
- The railway culvert is a major hydraulic control in the 5% AEP event and causes extensive shallow flooding within the village and all access roads are subject to shallow flooding.
- Extensive flooding occurs in the village in the 1% AEP event and the majority of the roads within the village are flooded.
- The entire village is subject to more than 1m depth of flooding and the railway is overtopped during the PMF event.

7.2 Flood Surface Profiles

The peak flood surface profiles are plotted in **Figure 7-1** for Boree Creek located within the study area. **Figure 7-1** shows that the flood profiles for all modelled events are generally uniform. The railway crossing is a major hydraulic control for all but the PMF event. Differences in flood depth between the 20% AEP the 0.02% AEP event vary between 0.6m at the upper reach of the creek and 1.3m elsewhere.

The peak flood surface profiles along Richmond/ Eades Street between Boree Creek and the railway crossing are plotted in **Figure 7-2** which shows that apart from an approximately 300m section of Richmond Street between Boree Creek and Orara Street, the entire street is subject to flooding during all flood events. The maximum depth of flooding on Richmond Street for the PMF event is up to 3m.

Table 7-1 shows the peak water levels at the major crossings of Boree Creek for a range of flood events.

Figure 7-1 Peak Water Level Profiles – Boree Creek

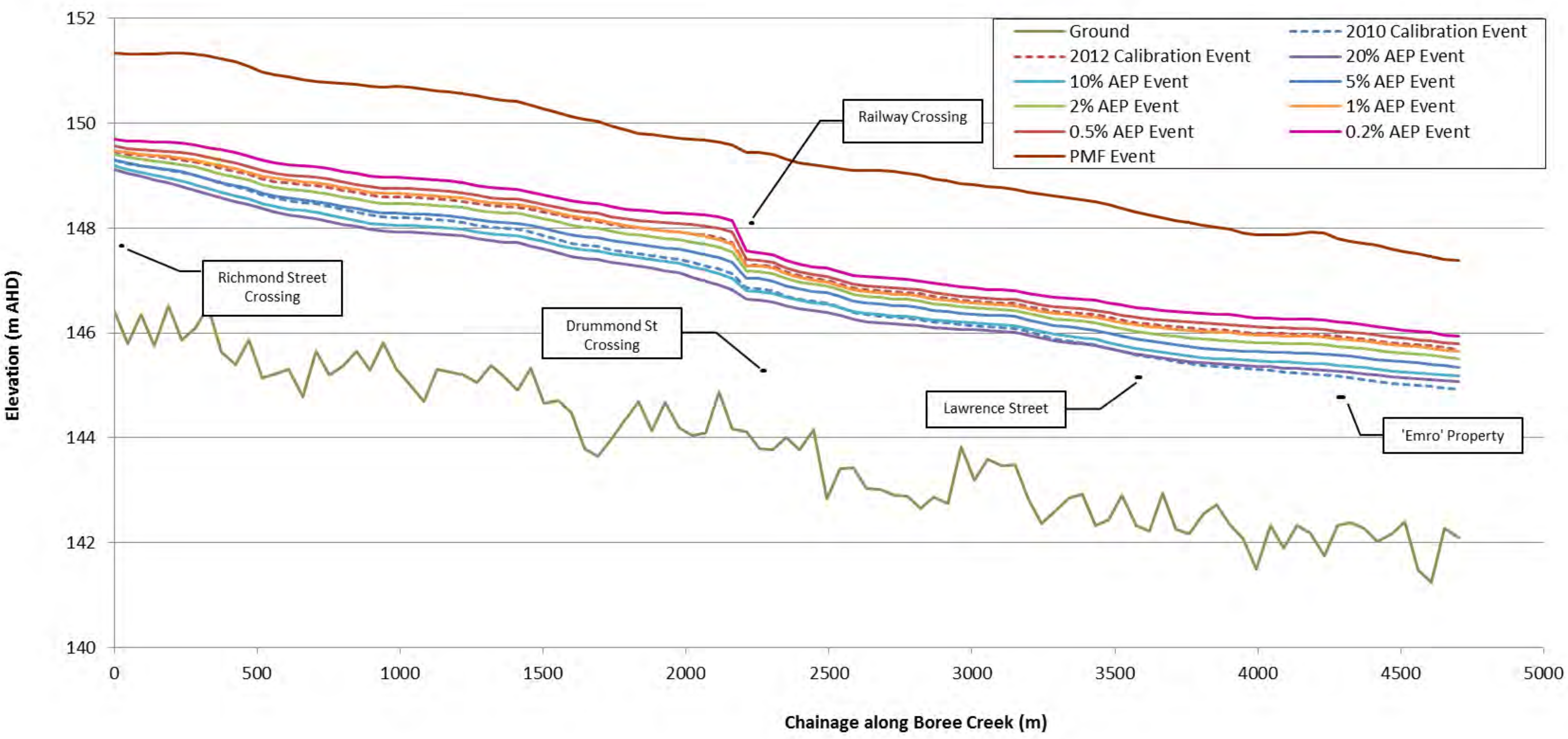


Figure 7-2 Peak Water Level Profiles – Richmond- Eades Street

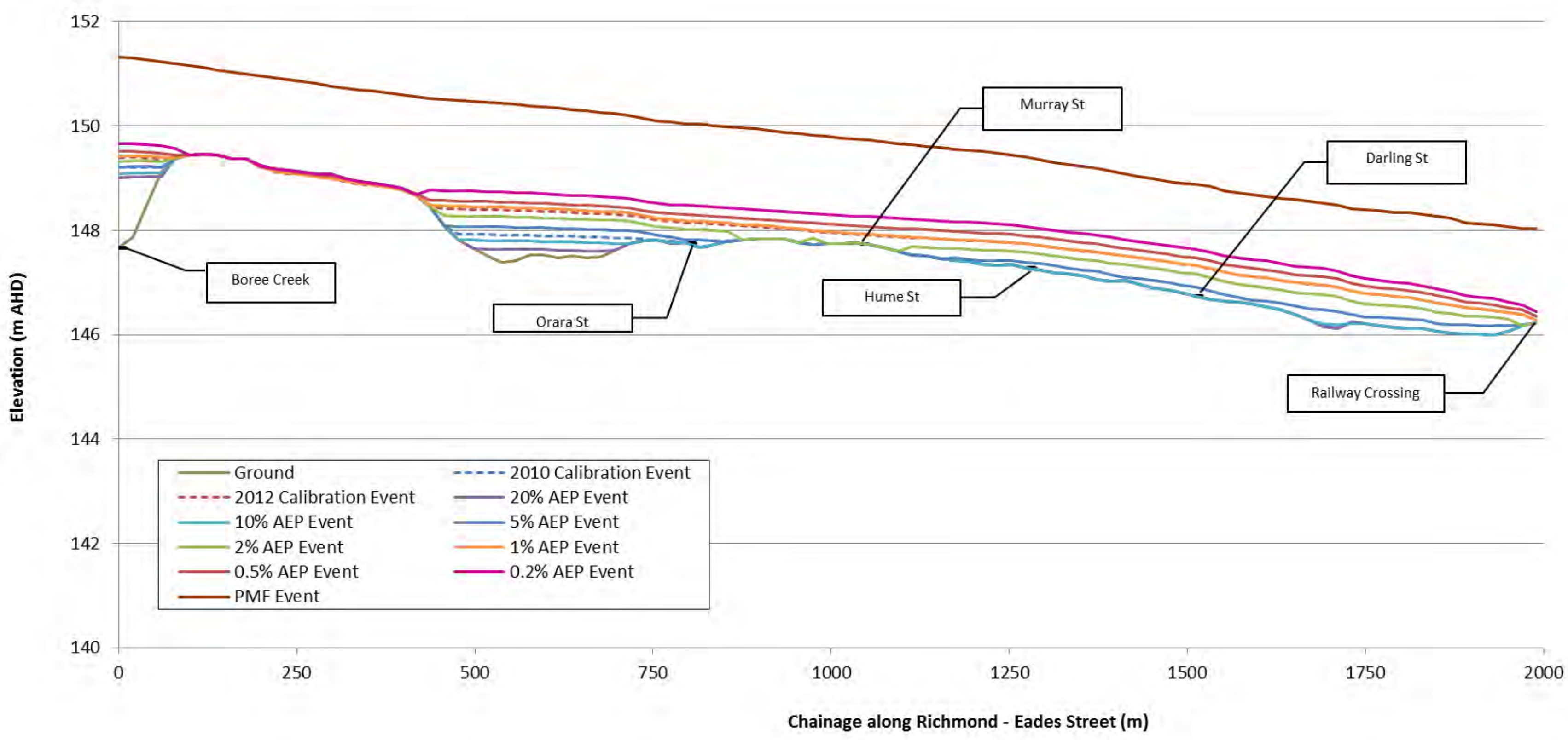


Table 7-1 Modelled Peak Water Levels at Major Waterway Crossings

Waterway Crossing[1]	Soffit Level (m AHD)	Deck Level[2] (m AHD)	Peak Water Levels (mAHD)				
			20% AEP	5% AEP	1% AEP	0.5% AEP	PMF
Richmond St	147.31	147.68	149.02	149.21	149.42	149.51	151.31
Railway Culvert (6 cells) [3]	147.56	148.27	146.67	147.10	147.38	147.58	149.54
Railway Culvert (3 pipes) [3]	147.04	148.56	147.63	147.81	147.92	148.11	149.54
Drummond Rd[3]	145.00	145.30	146.62	147.01	147.23	147.33	149.44
Urana Boree Creek Road[4]	143.85	145.95	145.41	145.96	146.20	146.28	148.02

[1] Crossings of Boree Creek, listed from upstream to downstream

[2] Deck level obtained from survey or estimated from LiDAR

[3] These two crossings are shown in Hotspot Map 1 (**Appendix E**)

[4] Taken at the culvert carrying overland flows from the Boree Creek village into Boree Creek, just to the west of the Drummond St and Eades St intersection. This area is shown in Hotspot Map 2 (**Appendix E**).

7.3 Summary of Peak Flows

Peak overland flows are tabulated for selected locations as detailed in **Appendix D** for the modelled design flood events.

7.4 Provisional Flood Hazard Mapping

The TUFLOW modelling results were used to delineate the preliminary flood hazard areas for the study area from interpretation of the 5%, 1% and 0.5% AEP event results, based on the hydraulic hazard category diagram presented in the *Floodplain Development Manual* (NSW Government 2005), shown in **Figure 7-3**. The TUFLOW model calculates the hazard rating at each cell and computational time step, rather than calculating the rating based on the peak depth and peak velocity, since these may occur at different times.

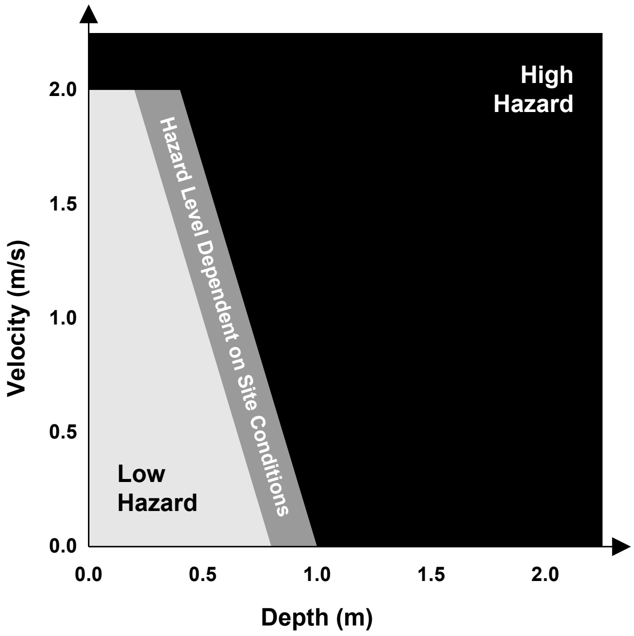


Figure 7-3 Hydraulic Hazard Category Diagram (reproduced from Figure L2 in *NSW Floodplain Development Manual*)

Hazard categories delineated in this study are based on depths and velocities of floodwaters and do not consider evacuation, isolation, flood damages and social impacts of flooding, hence, these categories are considered provisional. The provisional flood hazard mapping is presented in **Figure E-9** to **E-11** in **Appendix E**.

7.5 Hydraulic Categories Mapping

The three flood hydraulic categories identified in the *Floodplain Development Manual* (NSW Government 2005) are:

- Floodway, where the main body of flow occurs and blockage could cause redirection of flows. Generally characterised by relatively high flow rates; depths and velocities;
- Flood storage, characterised by deep areas of floodwater and low flow velocities. Floodplain filling of these areas can cause adverse impacts to flood levels in adjacent areas; and
- Flood fringe, areas of the floodplain characterised by shallow flows at low velocity.

There is no firm guidance on hydraulic parameter values for defining these hydraulic categories, and appropriate parameter values may differ from catchment to catchment. In this study, the floodway was delineated first and then the remaining floodplain was classified into flood storage or flood fringe on the basis of flood depth. If the flood depth is greater than 0.5m then the floodplain is classified as flood storage area otherwise the floodplain is classified as flood fringe.

Initially, potential floodway outlines for the 1% AEP event were identified (refer to **Figure E-12** in **Appendix E)** based on the relevant technical papers and professional judgement based on the following considerations:

- VxD > 0.25 m^2/s and V > 0.25 m/s; or V >1.0 m/s (Howells et al 2004);
- VxD > 0.50 m^2/s and V > 0.5 m/s; or V >1.0 m/s (Thomas and Golaszewski, 2012);
- High hazard areas in the 1% AEP event; and

- Area flooded in the 5% AEP event.

Floodway outlines derived based on the above considerations were reviewed and a preliminary floodway outline was selected for an encroachment analysis. An iterative approach was then undertaken to modify the preliminary floodway outline. Increase in flood levels between the baseline case (ie. without encroachment) and with encroachment for each iteration was assessed. The final floodway outline was adopted once the maximum increase in flood levels was limited to 0.1m. It is to be noted that the encroachment analysis was undertaken for the existing catchment and floodplain conditions. In particular, if the railway culvert is upgraded in the future, the extent of the floodway needs to be reassessed. The flood hydraulic categories are mapped and presented in **Appendix E** (**Figure E-13**).

7.6 Provisional Flood Planning Area

The provisional flood planning area is defined by the extent of the area below the flood planning level (usually the 1% AEP flood plus 0.5m freeboard) and delineates the area and properties where flood planning controls are proposed, for example minimum floor levels to ensure that there is sufficient freeboard of building habitable floor levels above the 1% AEP flood. The provisional flood planning area map for Boree Creek is included in **Appendix E** (**Figure E-14**). The flood planning level and the flood planning area will be adopted by Federation Council in the floodplain risk management plan for Boree Creek.

7.7 Flood Intelligence

Currently there is no flood intelligence card for Boree Creek (Yeo, 2013) and there are flood depth indicators at Culvert No. 28 and Culvert No. 31. The zero mark on the depth indicators were connected to AHD as part of this study and details on flood depth indicators are provided in Table 7-2.

▪ Table 7-2: Details on flood depth indicators

Location	Easting (m)	Northing (m)	Zero Mark (m AHD)
East of Culvert No. 28	465055	6114628	145.37
West of Culvert No. 28	465044	6114642	145.31
East of Culvert No. 31	465725	6115668	147.60
West of Culvert No. 31	465714	6115671	147.57

It is to be noted that four flood depth indicators connected to AHD as part of this study are not easily accessible during flooding.

7.8 Flood Emergency Response

Flood emergency response is an important outcome of the Floodplain Risk Management Process. The New South Wales State Emergency Service (SES) will use the information contained in the report to update the Federation Council Local Flood Plan.

The entire township is impacted by flooding in the PMF event with flood depths being greater than 1m deep and hence the town is a low flood island in the PMF event. The 2 hour storm is critical for the PMF event. Due to the relatively smaller catchment area of Boree Creek at the town, there would be limited opportunity to evacuate residents to a flood evacuation centre.

The two ovals in the town are high flood islands in the 1% AEP event however access to the ovals via Drummond Street is cut off in both directions. Strontian Road could be used to evacuate residents of the town towards Narrandera up to the 0.2% AEP event and residents located at the corner of Lockhart Boree Creek Road and Commera Wilson Lane could evacuate to high ground located south-east up to the 0.5% AEP event.

7.9 Hot Spots

Two railway culverts located east of the town are considered major hydraulic controls. The flood behaviour in the 1% AEP event in the vicinity of the two railway culverts is shown **Figure E-15** in **Appendix E**

The six cell (each cell 3.36m high and 3.4m wide) reinforced concrete box culvert under the railway constricts the main channel of Boree Creek (refer to **Figure E-15** in **Appendix E**) and a part of the flood flow breaks out the creek and moves along Richmond Street through the town as shown in **Figure E-16** in **Appendix E**. The breakout in combination with rainfall runoff generated from the local catchment areas within the town causes widespread flooding in the town. The breakout has major influence on flooding in the town during large flood events. The three 1.2m diameter reinforced concrete pipe culvert located under the railway is another major hydraulic control for the unnamed tributary of Boree Creek which drains a catchment area of approximately 17 km^2. The culvert is considered to have adequate capacity to pass the 20% AEP event.

Augmentation of capacity of the two railway culverts would be key consideration to reduce the existing flood risk for Boree Creek.

8. Conclusions

In accordance with NSW Government Policy, Federation Council is committed to preparing a Floodplain Risk Management Plan for the township of Boree Creek. This report documents the preparation of the first two stages of the process of preparing the Plan – that is, the preparation of a flood study report (this report).

A community consultation process was undertaken to collect information on flooding from the community and seven responses were received on the questionnaire. All respondents experienced flooding in their properties and five (5) respondents identified the flood event of 2012 as the major flood event and the duration of flooding was longer than 6 hours.

The available LiDAR survey for Boree Creek undertaken by LPI was supplemented with a ground survey to capture the required topographic data for this flood study. The ground survey captured details of culverts/bridges for which adequate information was not available to this study. The ground survey connected two flood marks within “Emro” property to AHD. Zero levels of four flood depth indicators were also referenced to AHD.

Recent flood events of 2010 and 2012 were selected for calibration of the hydrologic and hydraulic models due to the availability of observed data from the flood intelligence study commissioned by the SES (Yeo 2013). The flood event of 2012 is the highest flood in recent time in Boree Creek and the 2010 flood event was smaller than 2012 flood event.

A hydrologic model using XP-RAFTS was set up for Boree Creek covering a catchment area of 154km^2 using the available topographic data. No streamflow gauging stations are located on Boree Creek and hence the XP-RAFTS model and the TUFLOW hydraulic model were calibrated in tandem against recorded flood marks for both 2012 and 2010 flood events.

A TUFLOW hydraulic model for Boree Creek was developed utilising a 4m grid based on a 1m LiDAR DEM. The model included the surveyed culverts and buildings were modelled as obstructions to the flow. The model was used to define both mainstream and overland flooding within the study area. The modelled flood levels are within ±0.3m of the recorded flood levels for the 2012 event and 0.04m below the recorded flood level for the 2010 event. These results confirm that both the XP-RAFTS and the TUFLOW models have been calibrated and are suitable to simulate design events with confidence.

A sensitivity analysis was undertaken to assess changes in flood behaviour due to changes in the adopted initial rainfall loss, Manning’s n values, blockages and tailwater levels for the flood event of 2012.

The calibrated and validated XP-RAFTS and TUFLOW models were utilised to define flood behaviour for the design flood events of 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP events and the PMF. Rainfall losses and other input utilised in the estimation of design flood events are similar to that adopted in the Flood Study Report for Lockhart. There is a reasonable agreement between peak discharges for the design events for Boree Creek and Lockhart.

Outcomes from the flood modelling for the design events have been utilised to prepare flood extent maps, provisional hazard maps, flood hydraulic categories (ie. floodway, flood storage and flood fringe areas) and a flood planning area map. Modelling results were interrogated to identify major hydraulic controls in Boree Creek. Two railway culverts are major hydraulic controls in Boree Creek and the limited capacities of the culverts divert floodwaters through the developed areas of Boree Creek.

The flood intelligence and flood emergency response for Boree Creek are to be updated by NSW SES using information presented in this study and outcomes from the study are considered appropriate for undertaking a floodplain risk management study leading to the development of a floodplain risk management plan for Boree Creek.

9. Acknowledgements

This study was undertaken by Jacobs on behalf of Federation Council. Federation 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 Office of Environment and Heritage.

A number of organisations and individuals have contributed both time and valuable information to this study. The assistance of the following in providing data and/or guidance to the study is gratefully acknowledged:

- Urana Floodplain Risk Management Committee
- Residents of the study area
- Federation Council
- Office of Environment and Heritage
- State Emergency Service

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11. Glossary

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. In this study AEP has been used consistently to define the probability of occurrence of flooding. It is to be noted that design rainfalls used in the estimation of design floods up to and including 200 year ARI (ie. 0.5% AEP) events was derived from 1987 Australian Rainfall and Runoff. Hence the flowing relationship between AEP and ARI applies to this study. 20% AEP = 5 year ARI; 5% AEP = 20 year ARI; 1% AEP = 100 year ARI; 0.5% AEP = 200 year ARI
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long-term average number of years between the occurrences of a flood as big as or larger than the selected event. For example, floods with a discharge as great as or greater than the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
Catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
Digital Elevation Model (DEM)	A specialised three dimensional dataset that represents the surface topography using points of known elevations.
Development	Is defined in Part 4 of the EP&A Act <u>In fill development</u>: refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. New development: refers to development of a completely different nature to that associated with the former land use. Eg. The urban subdivision of an area previously used for rural purposes. New developments involve re-zoning and typically require major extensions of exiting urban services, such as roads, water supply, sewerage and electric power. Redevelopment: refers to rebuilding in an area. Eg. As urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either re-zoning or major extensions to urban services.

Effective Warning Time	The time available after receiving advise of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
Flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
Flood liable land	Is synonymous with flood prone land (i.e.) land susceptibility to flooding by the PMF event. Note that the term flooding liable land covers the whole floodplain, not just that part below the FPL (see flood planning area)
Floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is flood prone land.
Floodplain risk management options	The measures that might be feasible for the management of particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
Floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually include both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defines objectives.
Flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at state, division and local levels. Local flood plans are prepared under the leadership of the SES.
Flood planning levels (FPLs)	Are the combination of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the "designated flood" or the “flood standard” used in earlier studies.
Flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings and structures subject to flooding, to reduce or eliminate flood damages.
Flood readiness	Readiness is an ability to react within the effective warning time.
Flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below.

	Existing flood risk: the risk a community is exposed to as a result of its location on the floodplain. Future flood risk: the risk a community may be exposed to as a result of new development on the floodplain. Continuing flood risk: the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
Flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas
Floodway areas	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.
Freeboard	Provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL 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.
GDA	Geocentric Datum of Australia is a coordinate system for Australia which is used to keep track of locations.
Hazard	A source of potential harm or situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community.
Local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
m AHD	Metres Australian Height Datum (AHD)
m/s	Metres per second. Unit used to describe the velocity of floodwaters.
m^3/s	Cubic metres per second or "cumecs". A unit of measurement of creek or river flows or discharges. It is the rate of flow of water measured in terms of volume per unit time.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
MGA	MGA is a metric grid system (i.e. east and north) and the unit of measure is

	the metre. It is a Cartesian coordinate system based on the Universal Transverse Mercator projection and the Geocentric Datum of Australia (GDA) 1994.
MIKE11	A computer program used for analysing behaviour of unsteady flow in open channels and floodplains.
MiRORB	A tool which uses the geographical information system MapInfo™ to generate input data for use with RORB.
Modification measures	Measures that modify either the flood, the property or the response to flooding.
Overland flowpath	The path that floodwaters can follow as they are conveyed towards the main flow channel or if they leave the confines of the main flow channel. Overland flowpaths can occur through private property or along roads.
PINNEENA	PINNEENA is a surface water and groundwater monitoring database released by the NSW Government on DVD/CD.
Probable Maximum Flood (PMF)	The largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation couplet with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
RORB	RORB is a general runoff and streamflow routing computer program used to calculate flood hydrographs from rainfall and other channel inputs.
Runoff	The amount of rainfall which actually ends up as a streamflow, also known as rainfall excess.
Stage	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
TUFLOW	TUFLOW is a computer program which is used to simulate free-surface flow for flood and tidal wave propagation. It provides coupled 1D and 2D hydraulic solutions using a powerful and robust computation. The engine has seamless interfacing with GIS and is widely used across Australia.
Watershed Bounded Network Model (WBNM)	WBNM converts rainfall to runoff for both natural and urban catchments. WBNM is similar to RORB.
XP-RAFTS	XP-RAFTS is a computer program which is used to convert rainfall into runoff. XP-RAFTS is used for hydrologic analysis of stormwater drainage and conveyance systems. XP-RAFTS simulates both urban and rural

catchments ranging in size between a single house allotment up to thousands of square kilometre river systems.

Appendix A. Available Data

- A1: Extracts from the ‘Urana Flood Study Survey – Report’ by TJ Hinchcliffe & Associates
- A2: Map showing the locations of the surveyed features
- A3: Boree Creek overview (Council)

Urana Flood Study Survey – Report

For Urana Shire Council and Jacobs

By TJ Hinchcliffe & Associates: Chris Ryan

Table of Contents

Introduction

This report has been written to outline and describe the survey informaiton collected and prepared by TJ Hinchcliffe & Asssociates to aid in the Urana Flood Study being performed by Jacobs in the Urana Shire Council Local Governemnt Area.

The data contained within this report has been prepared to be used in conjunction with Lidar data in computer models that calculate water flow through a system.

Each structure identified by a number is listed and described in sequence. Following the structure reports are a series of sections describing the; Urana Dam, Urana Levee, Urana Stormwater System, Rand Levee.

Boree Creek

22: Culvert

Structure 22 is a reasonably blocked culvert under Eades Street in Boree Creek.

Table 22 shows the pertinent physical information about the structure.

Culvert 22

	Inlet		Outlet	
	Easting	Northing	Easting	Northing
Coordinates	463979.00	6114663.35	463980.97	6114657.74
Length	5.95			
Dimensions (Diameter)	0.375			
Number of Cells	2			
	Cell 1		Cell 2	
	Upstream	Downstream	Upstream	Downstream
Invert Levels (AHD m)	144.91	144.87	144.92	144.89
Blockage %	30	60	30	60

Table 22: Structure 22 details.

Image 53 shows the structure 22 inlet.

Image 53: Structure 22 inlet.

Image 54 shows the structure 22 outlet.

Image 54: Structure 22 outlet.

23: Culvert

Structure 23 is a culvert under the rail line west of the Boree Creek rail crossing.

Table 23 shows the pertinent physical information about the structure.

Culvert 23

	Inlet		Outlet			
	Easting	Northing	Easting	Northing		
Coordinates	463989.12	6114628.46	463989.71	6114624.27		
Length	4.20					
Dimensions (HxW)	0.62x0.90					
Number of Cells	3					
	Cell 1		Cell 2		Cell 3	
	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Invert Levels (AHD m)	144.85	144.82	144.84	144.81	144.82	144.80
Blockage %	0	0	0	0	0	0

Table 23: Structure 23 details.

Image 55 shows the structure 23 inlet.

Image 55: Structure 23 inlet.

Image 56 shows the structure 23 outlet.

Image 56: Structure 23 outlet.

24: Culvert

Structure 24 is a culvert under Urana-Boree Creek Road 105m west of the rail crossing.

Table 24 shows the pertinent physical information about the structure.

Culvert 24

	Inlet		Outlet	
	Easting	Northing	Easting	Northing
Coordinates	463940.41	6114594.03	463936.92	6114585.18
Length	9.50			
Dimensions (HxW)	1.23x1.87			
Number of Cells	1			
	Cell 1			
	Upstream	Downstream		
Invert Levels (AHD m)	144.25	144.14		
Blockage %	0	0		

Table 24: Structure 24 details.

Image 57 shows the structure 24 inlet.

Image 57: Structure 24 inlet.

Image 58 shows the structure 24 outlet.

Image 58: Structure 24 outlet.

25: Culvert

Structure 25 has an outflet that is a Round Concrete Pipe protruding from a large embankment south of the Urana- Boree Creek road 80m west of the rail crossing. The inlet for the structure is a grated storm water pit 1.7m deep located southwest of the outlet of structure 23. This pit also has an inbound pipe from the north. The author assumes this conveys stormwater from Boree Creek's underground stormwater system, however no investigation of this was undertaken.

Table 25 shows the pertinent physical information about the structure.

Culvert 25

	Inlet		Outlet	
	Easting	Northing	Easting	Northing
Coordinates	463980.43	6114618.58	463966.30	6114585.66
Length	35.80			
Dimensions (Diameter)	0.600			
Number of Cells	1			
	Cell 1			
	Upstream	Downstream		
Invert Levels (AHD m)	143.25	143.14		
Blockage %	N/A	10		

Table 25: Structure 25 details.

Image 59 shows the structure 25 inlet.

Image 59: Structure 25 inlet.

Image 60 shows the structure 25 outlet.

Image 60: Structure 25 outlet.

26: Culvert

Structure 26 is a culvert under an embankment South of the Urana-Boree Creek Road.

Table 26 shows the pertinent physical information about the structure.

Culvert 26

	Inlet		Outlet	
	Easting	Northing	Easting	Northing
Coordinates	463955.95	6114550.09	463956.28	6114545.55
Length	4.55			
Dimensions (Diameter)	0.600			
Number of Cells	1			
	Cell 1			
	Upstream	Downstream		
Invert Levels (AHD m)	142.95	142.93		
Blockage %	0	0		

Table 26: Structure 26 details.

Image 61 shows the structure 26 inlet.

Image 61: Structure 26 inlet.

Image 62 shows the structure 26 outlet.

Image 62: Structure 26 outlet.

27: Culvert

Structure 27 is a very large rail culvert. By some definitions it may be termed a bridge. It Accomodates the flow from a large catchment under the rail line into Boree Creek.

Table 27 shows the pertinent physical information about the structure.

Culvert 27

	Inlet		Outlet			
	Easting	Northing	Easting	Northing		
Coordinates	465067.71	6114674.89	465065.79	6114671.00		
Length	4.33					
Dimensions (HxW)	3.36x3.4					
Number of Cells	6					
	Cell 1		Cell 2		Cell 3	
	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Invert Levels (AHD m)	144.17	144.13	144.18	144.14	144.19	144.13
Blockage %	0	0	0	0	0	0
	Cell 4		Cell 5		Cell 6	
	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Invert Levels (AHD m)	144.19	144.14	144.21	144.16	144.19	144.17
Blockage %	0	0	0	0	0	0

Table 27: Structure 27 details.

Image 63 shows the structure 27 inlet.

Image 63: Structure 27 inlet.

Image 64 shows the structure 27 outlet.

Image 64: Structure 27 outlet.

28: Culvert

Structure 28 is a road culvert under the Boree Creek-Lockhart Road. It is just downstream from structure 27.

Table 28 shows the pertinent physical information about the structure.

Culvert 28								
	Inlet		Outlet					
	Easting	Northing	Easting	Northing				
Coordinates	465051.34	6114638.70	465045.98	6114631.08				
Length	9.30							
Dimensions (HxW)	1.25x1.85							
Number of Cells	4							
	Cell 1		Cell 2		Cell 3		Cell 4	
	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Invert Levels (AHD m)	143.75	143.59	143.74	143.60	143.75	143.60	143.77	143.59
Blockage %	0	0	0	0	0	0	0	0

Table 28: Structure 28 details.

Image 65 shows the structure 28 inlet.

Image 65: Structure 28 inlet.

Image 66 shows the structure 28 outlet.

Image 66: Structure 28 outlet.

29: Culvert

Structure 29 is a rail culvert south east of Structure 27 and north east of culvert 30. It is on the Boree Creek – Lockhart rail line.

Table 29 shows the pertinent physical information about the structure.

Culvert 29

	Inlet		Outlet			
	Easting	Northing	Easting	Northing		
Coordinates	465292.37	6114526.18	465286.03	6114519.78		
Length	9.00					
Dimensions (Diameter)	1.200					
Number of Cells	3					
	Cell 1		Cell 2		Cell 3	
	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Invert Levels (AHD m)	145.84	145.81	145.85	145.85	145.87	145.83
Blockage %	0	0	0	0	0	0

Table 29: Structure 29 details.

Image 67 shows the structure 29 inlet.

Image 67: Structure 29 inlet.

Image 68 shows the structure 29 outlet.

Image 68: Structure 29 outlet.

30: Culvert

Structure 30 is a road culvert that is downstream from the rail culvert 29.

Table 30 shows the pertinent physical information about the structure.

Culvert 30

	Inlet		Outlet					
	Easting	Northing	Easting	Northing				
Coordinates	465278.09	6114501.70	465271.84	6114493.89				
Length	10.00							
Dimensions (HxW)	1.23x1.85							
Number of Cells	4							
	Cell 1		Cell 2		Cell 3		Cell 4	
	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Invert Levels (AHD m)	145.79	145.69	145.73	145.68	145.79	145.68	145.8	145.7
Blockage %	0	0	0	0	0	0	0	0

Table 30: Structure 30 details.

Image 67 shows the structure 30 inlet.

Image 67: Structure 30 inlet.

Image 68 shows the structure 30 outlet.

Image 68: Structure 30 outlet.

31: Culvert

Structure 31 is a culvert on the Boree Creek-Kywong Road. At the time of survey there were various recent survey control pegs in the near vicinity that appeared to be for impending engineering works.

Table 31 shows the pertinent physical information about the structure.

Culvert 31

	Inlet		Outlet			
	Easting	Northing	Easting	Northing		
Coordinates	465718.07	6115673.05	465721.54	6115665.94		
Length	7.90					
Dimensions (HxW)	0.902.42					
Number of Cells	3					
	Cell 1		Cell 2		Cell 3	
	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Invert Levels (AHD m)	146.38	146.41	146.38	146.41	146.36	146.40
Blockage %	0	0	0	0	0	0

Table 31: Structure 31 details.

Image 69 shows the structure 31 inlet.

Image 69: Structure 31 facing downstream.

Image 70 shows the structure 31 outlet.

Image 70: Structure 31 outlet.

Structure 31, North East of Boree Creek, has a Flood Depth Indicator to its East and one to its West.

Table 39 shows the pertinent details about the Flood Depth Indicator.

Flood Depth Indicator 0m mark		
East of Structure 31		
	Easting	Northing
Coordinates	465725.22	6115668.00
AHD height	147.60	

Table 39: Flood Depth Indicator East of Structure 31.

Image 86 shows the flood depth indicator to the East of Structure 31.

Image 86: Flood Depth Indicator East of Structure 31.

Table 40 shows the pertinent details about the Flood Depth Indicator to the west of Structure 31.

Flood Depth Indicator 0m mark		
West of Structure 31		
	Easting	Northing
Coordinates	465713.98	6115670.78
AHD height	147.57	

Table 40: Flood Depth Indicator West of Structure 31.

Image 87 shows the flood depth indicator to the west of Structure 31.

Image 87: Flood Depth Indicator west of Structure 31.

Structure 28 has a Flood Depth Indicator to its East and one to its West.

Table 41 shows the pertinent details about the Flood Depth Indicator to the East.

Flood Depth Indicator 0m mark		
East of Structure 28		
	Easting	Northing
Coordinates	465054.77	6114628.30
AHD height	145.37	

Table 41: Flood Depth Indicator east of Structure 28.

Image 88 shows the flood depth indicator to the east of Structure 28.

Image 88: Flood Depth Indicator east of Structure 28.

Table 42 shows the pertinent details about the Flood Depth Indicator.

Flood Depth Indicator 0m mark		
West of Structure 28		
	Easting	Northing
Coordinates	465043.60	6114642.46
AHD height	145.31	

Table 42: Flood Depth Indicator west of Structure 28.

Image 89 shows the flood depth indicator to the west of Structure 28.

Image 89: Flood Depth Indicator west of Structure 28.

The Property 'Emro' lies just South West of Boree Creek. This two storey timber framed 'Queenslander' style property has two marks on a support pier on the the Northern side of the house. These marks were placed by Richard and Gail Alexander to mark the High Water Mark of the floods in 2010 and 2012.

Table 43 shows the pertinent details about the Flood Marks.

Flood Mark at "Emro" from 2010		
	Easting	Northing
Coordinates	463713.82	6114419.29
AHD height	145.52	
Flood Mark at "Emro" from 2012		
	Easting	Northing
Coordinates	463713.82	6114419.29
AHD height	145.85	

Table 43: Emro Flood Marks.

Image 90 shows the flood marks at Emro.

Image 90: Flood Marks at Emro.

Urana

Urana Dam

Urana Dam is one of the largest structures in this report. It is south-west of Urana and Dams the Urana Creek the outflow is via a 1.2m round concrete pipe that is situated in the base of a 42m spillway. A large man-made earthen wall spans the western and south-western edges of the dam. The wall appears to be in a good condition. Survey marks located on and around the spillway indicate that some form of monitoring has taken place recently. Crest levels along the downstream edge of the dam have been included in the associated dxf.

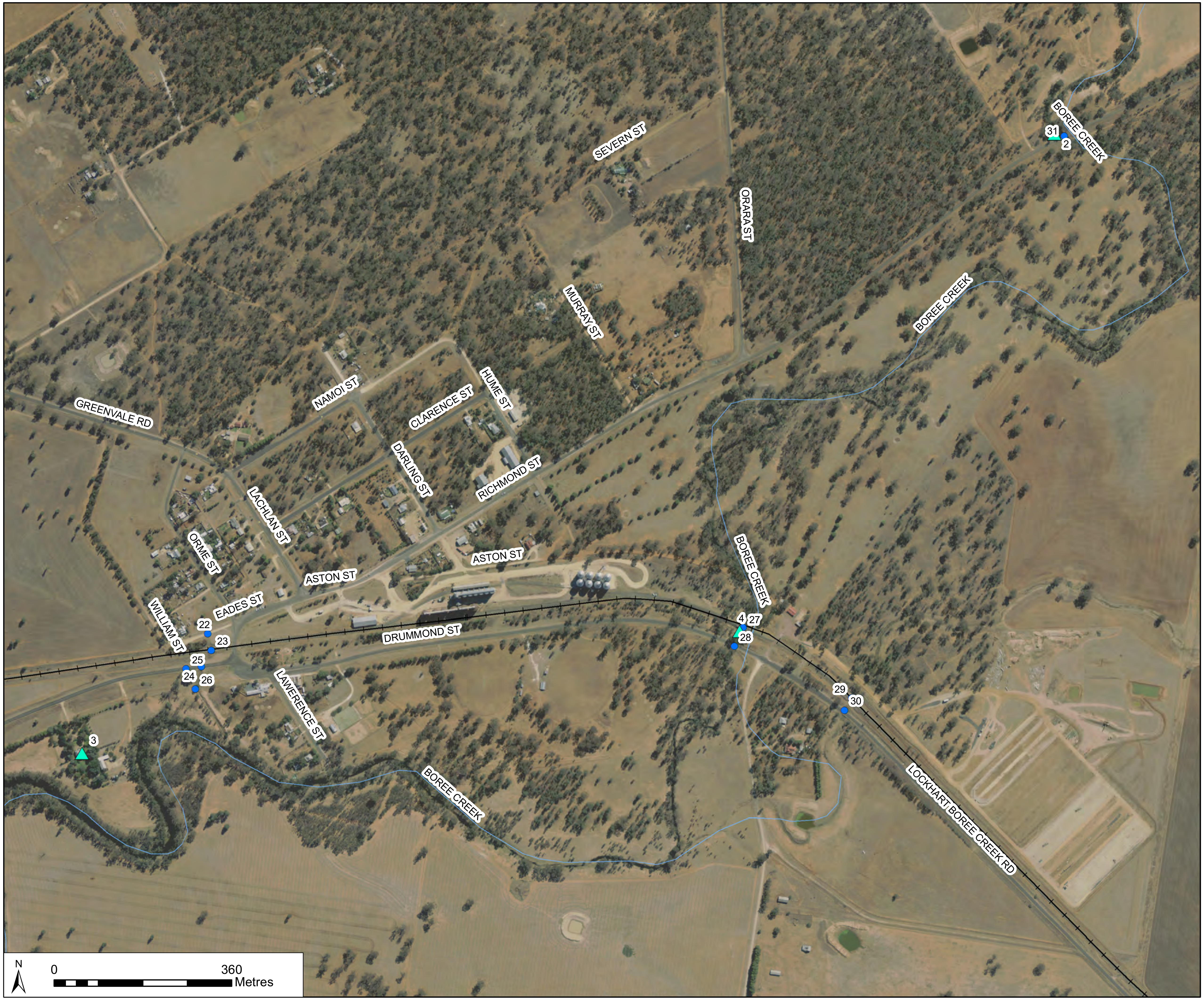
Images 91-92 show the upstream side of the spillway including the gate.

Lidar Test Points

Lidar test points were observed at various points around the survey area. While 10 points were required in the survey brief additional points have been included. The additional points are redundancies in case the initial points were obstructed at time of Lidar observation.

Lidar Test Points

Surface	Easting	Northing	AHD
Urana			
Bitumen	432875.94	6090092.28	116.73
Bitumen	433325.78	6089951.76	116.60
Bitumen	433452.70	6090004.57	116.82
Bitumen	433366.80	6089767.71	116.12
Oaklands			
Bitumen	425129.30	6066389.74	137.63
Bitumen	424337.79	6064799.09	147.25
Bitumen	424347.65	6064798.39	147.28
Bitumen	425332.06	6067753.44	127.55
Rand			
Bitumen	461715.76	6061111.65	157.06
Bitumen	461563.40	6061683.34	155.05
Morundah			
Bitumen	436328.52	6134113.76	128.39
Bitumen	435878.19	6135720.34	129.75
Boree Creek			
Bitumen	464520	6114905.52	146.97
Bitumen	464020.51	6114603.81	146.07
Bitumen	464036.17	6114602.82	146.05
Bitumen	465086.23	6114577.02	147.46



Legend

- Culverts/Bridges surveyed
- Flood Marks/Staff Gauges surveyed
- Railway
- Watercourses

GDA 1994 MGA Zone 55
Scale: A3

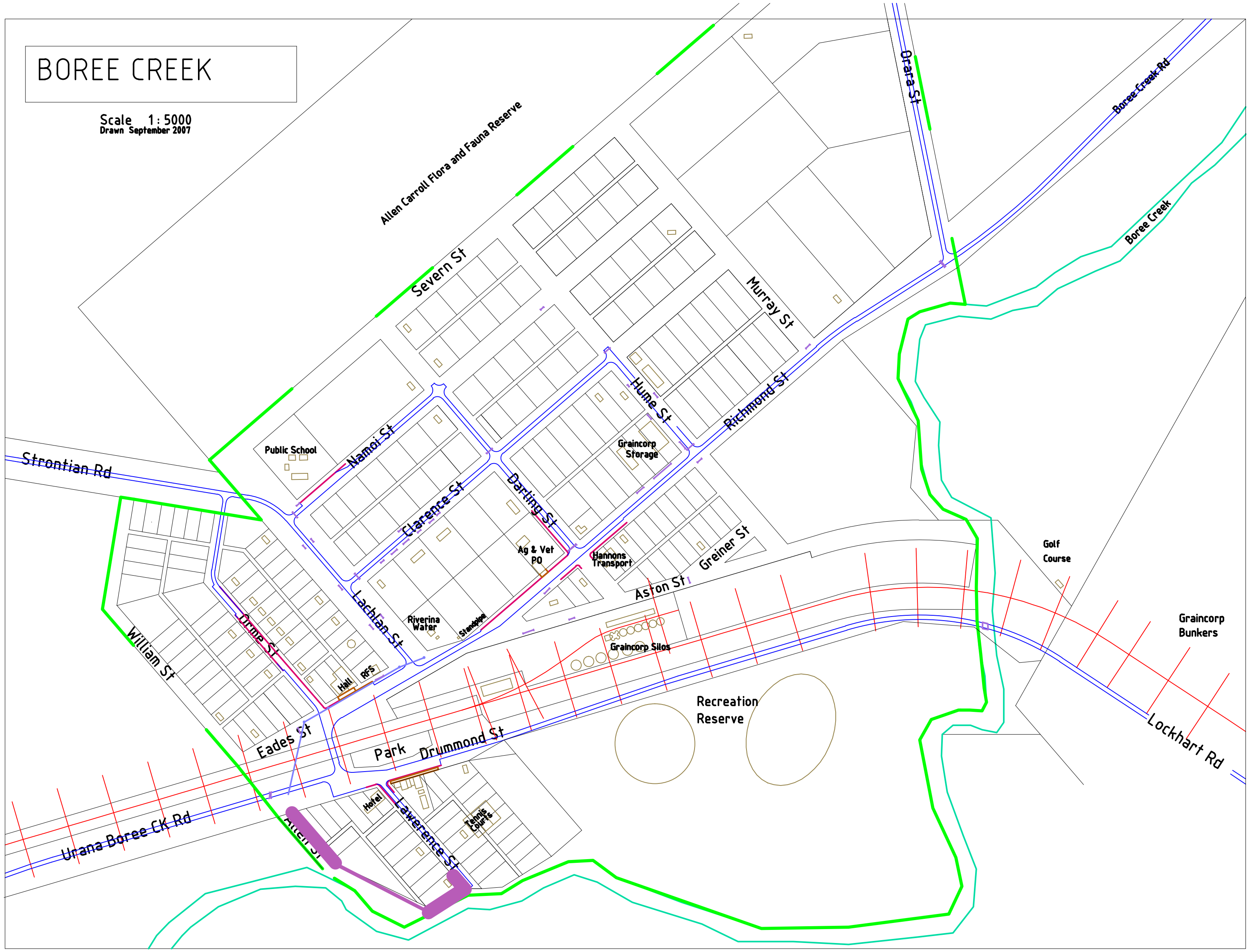
Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	Topographic Survey
TOWN	Boree Creek
PROJECT	Urana Shire Flood Study
CLIENT	Urana Shire Council

DRAWN MR	PROJECT # IA055600	APPENDIX A-2
CHECK AH	DATE 8/04/2016	


BOREE CREEK
Scale 1 : 5000
Drawn September 2007
Allen Carroll Flora and Fauna Reserve
Severn St
Orara St
Boree Creek Rd
Boree Creek
Murray St
Public School
Namoi St
Strontian Rd
Clarence St
Darling St
Hume St
Graincorp Storage
Richmond St
Ag & Vet PO
Hannons Transport
Greiner St
Aston St
Golf Course
Graincorp Bunkers
Lachlan St
Orme St
William St
Riverina Water
Standpipe
Graincorp Silos
Hall
RFS
Recreation Reserve
Eades St
Park
Drummond St
Lockhart Rd
Urana Boree CK Rd
Allen St
Hotel
Lawrence St
Tennis Courts

Appendix B. Newsletter and Questionnaire

Urana Shire Flood Study

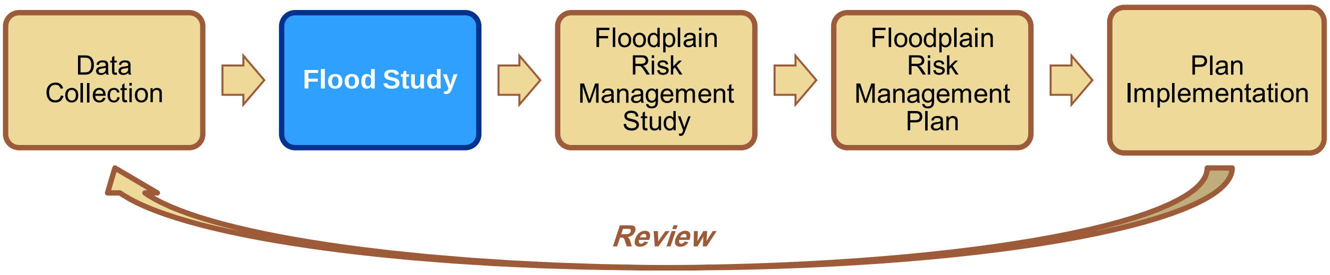
Community Bulletin February 2015

This Community Bulletin has been issued to inform Urana Shire residents of the Flood Study which recently commenced. It is the first in a series of Bulletins aimed at informing residents of the status of the project and how they can be involved in the process. Urana Shire Council has engaged consultants, Jacobs Group Australia, to undertake the Flood Study.

The purpose of the study is to develop an understanding of existing flooding behaviour in five towns in the Shire – Morundah, Urana, Boree Creek, Oaklands and Rand, from both riverine and overland flooding. This will assist Council to develop measures to manage the impact of flooding and guide strategic planning for future development of the area.

An integral part of the study process is community consultation and involvement. This element of the process aims to inform the community of the study and invite residents to provide information on their views and experiences with flooding in the area. The management of flood prone land is primarily the responsibility of Councils and follows a number of stages as shown below.

The Stages of Floodplain Risk Management



The Flood Study

The purpose of the flood study is to identify the existing flooding behaviour within towns located in Urana Shire Council (Morundah, Urana, Boree Creek, Oaklands and Rand). Riverine flooding from Colombo Creek, Boree Creek, Urangeline Creek and Billabong Creek will be assessed along with overland flooding. The Flood Study will:

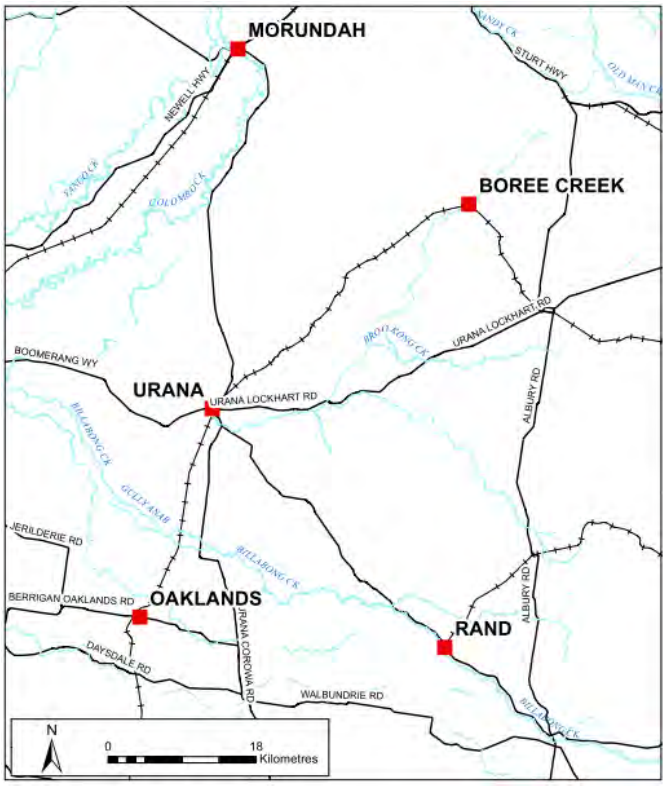
1) Define riverine and overland flood behaviour and their combined impact on flooding
2) Produce information on flood levels, velocities and discharges for a range of design events
3) Develop a Flood Study report including maps for: flood inundation; flood hazard; and flood planning areas.

The Flood Study will then provide input into the Floodplain Risk Management Study and Plan, which identifies the impact of flooding and proposes mitigation measures.

For more information contact Urana Shire Council on (02) 6930 9100
or visit www.urana.nsw.gov.au

Urana Shire Flood Study
Community Bulletin February 2015

Study Areas



The Flood Problem

In the recent severe weather events of January and February 2011 and March 2012, levees were overtopped at Urana and Rand, and the levee at Morundah was damaged in the last flood event. These events have also caused damage to residences, buildings and infrastructure, with widespread evacuations taking place.

How can you get involved?

Engagement of the community in the floodplain risk management process is very important to Council. We will be providing a number of opportunities for the community to have input during the course of this study.

Community Bulletins
- Background to the study and context
- Bulletins to update community on the project progress

Flood Data
- An opportunity to tell us about flooding in your area (via the attached questionnaire)

Community Forums
- Opportunity to find out more about flood studies for your area and provide some feedback

Council Website
- Contact details for queries relating to the study and how you can be involved.

Some of the most important information for the study is collected from residents and local business operators. We would be very interested to receive records of flooding in your area including photographs, observations of flood depths or some comments on your experience. You can help us with this information by completing the questionnaire for your area and returning the completed **questionnaire** by 27 **March 2015**. The questionnaires can be found in Council's web site www.urana.nsw.gov.au/. Urana Shire Council appreciates your cooperation and will keep you informed with ongoing community bulletins.

For more information contact Urana Shire Council on (02) 6930 9100
or visit www.urana.nsw.gov.au

Urana Shire Flood Study Questionnaire (February 2015)

Boree Creek

Urana Shire Council has contracted the Consultant, Jacobs, to undertake a flood study for five towns in the Shire: Morundah, Urana, Boree Creek, Oaklands and Rand. Council is seeking the community's input in providing historical data for the flood study in order to understand the behaviour of floods within Boree Creek. The flood study area is shown in the map on Page 6.

The study is aimed at addressing the flooding impacts due to both riverine and overland flooding. Jacobs would like to receive feedback from the community on a number of issues and topics already highlighted by the Council with regard to flooding in Boree Creek. This questionnaire provides an opportunity for your input into the flood study.

Please print the questionnaire and if you cannot answer any question in the questionnaire, or do not wish to answer a question, then leave it unanswered and proceed to the next question. **Your input to this important study will be greatly appreciated.** If you need additional space, please add sheets. **Please scan all pages of the questionnaire (including additional pages) filled in by you and send the scanned document** (preferably in PDF) **by email** to Akhter.Hossain@jacobs.com **by 13 March 2015**.

If you would prefer to send your response to the questionnaire by mail, this would also be welcomed. Contact details of the Jacobs' Project Manager are provided below:

Akhter Hossain
P O Box 164
St Leonards, NSW 1590
Email: Akhter.Hossain@jacobs.com

Place a tick or write the answer in the relevant box as per instructions.

Question No.	Question and Answer
1.	**Do you live (reside), or have lived, in the study area shown on the Map (p6)?** A Yes (Please provide your address and put an 'X' on the relevant map) .... B No (Go to Question 4) ***If you are not sure whether you are in the map or not, please provide address
2.	**Do you own or rent your residence in the study area shown on the Map?** A Own B Rent
3.	**How long have you lived in the study area?** (Please write number of years)

Question No.	Question and Answer
	……………………
4.	**Do you own or manage a business in the study area?** A Yes, For how many years? ………………………… B No (go to Question 6)
5.	**What kind of business is yours?** A Home based business B Shop/commercial premises C Light industrial D Heavy industry E Others, please write type of business ………………………………………………………
6.	**Have you had any experience of flooding (due to riverine and/or storm events as well) in and around where you live or work?** A Yes B No (Go to Question 16)
7.	**How deep was the floodwater (from riverine and/or storm water as well) in the worst flood/storm event that you experienced?** Please estimate the depth …………………………… What was the year of this flood?……………………… Where was this flood? A At your house? B At work? C Elsewhere? Please provide the street address for this flood? ……………………………………………………
8.	**How long did the floodwaters stay up?** A Less than 2 hours B Less than 6 hours C Greater than 6 hours, how long?
9.	**What damage resulted from this flood in your residence?** (Please indicate either "none", "minor", "moderate" or "major". A Damage to garden, lawns or backyard B Damage to external house walls C Damage to internal parts of house (floor, doors, walls etc) D Damage to possessions (fridge, television etc) E Damage to car F Damage to garage G Other damage, please list………………………………………. H What was the cost of the repairs, if any?…………………........
10.	**What damage resulted from this flood in your business?** (Please indicate either "none", "minor", "moderate" or "major".) A Damage to surroundings B Damage to building C Damage to stock D Other damages, please list……………………………… E What was the approximate cost of the repairs, if any?………………….
11.	**Was vehicle access to/from your property disrupted due to floodwaters during the worst flooding/storm event?** A Not affected B Minor disruption (roads flooded but still driveable)

Question No.	Question and Answer
	C Access cut off
12.	**Did you or members of your family require assistance from SES during flood events?** A No B Yes, Please specify how many times (in total) assistance was required?
13.	**What information can you provide on past floods/storm events that created flooding?** (You can tick more than one item). Please write any descriptions at the end of the questionnaire A No information B Information on extent or depth of floodwater at particular locations, newspaper clippings or other images on the past floods C Marks indicating maximum flood level for particular floods D Recollections of flow directions, depth or velocities
14.	**Do you consider that flooding of your property has been made worse by works on other properties, or by the construction of roads or other structures?** A Yes (please provide further details and attach extra pages if necessary. Please provide a sketch if possible). B Unsure C No
15.	**Do you have any photographs of past floods that would be useful for the study to help understand the flood behaviour and are you willing to provide copies?** If possible please attach the photographs (with dates and location) which will be copied and returned. A Yes (either attach or the consultant will contact you to arrange for a copy to be made and returned) B No
16.	**Do you expect to undertake any further development on your land in the future?** A No B Minor extensions C New building D Unsure E Other (please specify) …………………………………………………………..
17.	**Please rank the following development types according to what you consider should be assigned greatest priority in protecting from flooding** (1 = greatest priority to 7 = least priority). **Please identify specific items if necessary**. A Commercial ……………………………………………………………………………… B Heritage items, please specify ……………………………………………………………… C Residential …………………………………………………………………………… D Community facilities (schools, halls, etc.) ………………………………………………. E Critical utilities (power substations, telephone exchanges, etc.) ………………………… F Emergency facilities (Hospital, Police Station, etc.) ………………………………………… G Recreation areas and facilities …………………………………………………………....
18.	**Please rank the following by placing numbers from 1 to 6 (1 = greatest priority to 6 = least priority) next to A, B, C, D, E and F.** A Protecting residential buildings from flooding B Protecting commercial buildings from flooding C Maintaining an emergency flood free access

Question No.	Question and Answer
	D Providing flood signage for public safety E Support from SES F Providing flood warning
19.	**Do you wish to comment on any other issues associated with this study? Please add comments at the end of the questionnaire or please indicate your willingness to answer questions over the phone?** ____________________________________ ____________________________________ ____________________________________ ____________________________________ ____________________________________
20.	**Do you wish to remain on the mailing list for further details, newsletters etc?** A Yes (please provide contact details, see next question) B No
21.	If you would like, please provide details of where you live and how we can contact you if we need to follow up on some details or seek additional comment. **Name:** ____________________________ **Address:** ____________________________ ____________________________ **Telephone:** ____________________________ **Fax:** ____________________________ **Email**: ____________________________
Additional comment	**Space for additional comments** ____________________________________ ____________________________________ ____________________________________ ____________________________________ ____________________________________ ____________________________________ ____________________________________ ____________________________________ ____________________________________ ____________________________________ ____________________________________

Question No.	Question and Answer

Thank you for your assistance

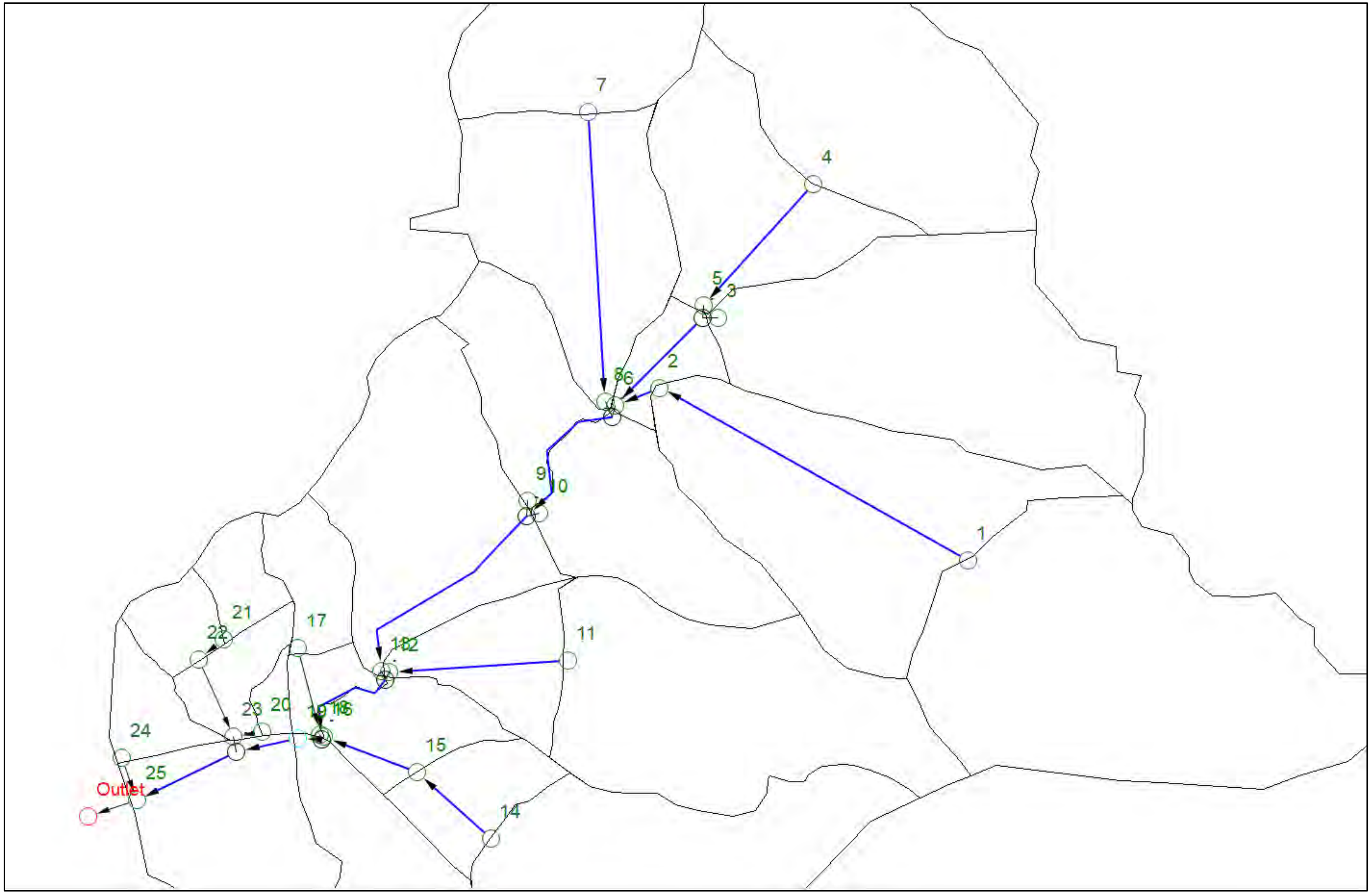
Map – Study Area for Boree Creek

Appendix C. Hydrologic Modelling

- C1: Figure showing XP-RAFTS model configuration for Boree Creek
- C2: Table showing XP-RAFTS model data for Boree Creek
- C3: XP-RAFTS hydrograph at the outlet for 2010 event
- C4: XP-RAFTS hydrograph at the outlet for 2012 event
- C5: Table showing modelled peak discharges at catchment outlet for the selected storm durations

JACOBS

- C1: XP-RAFTS Model Configuration for Boree Creek

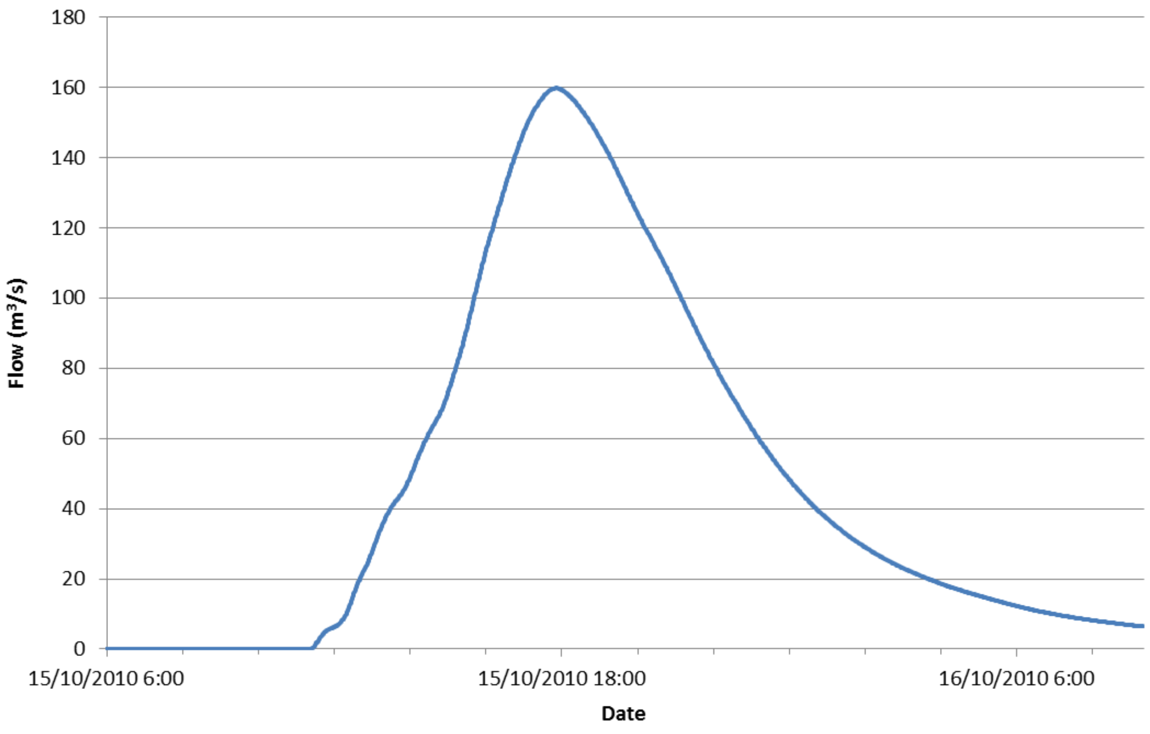


- C2: XP-RAFTS Model Data for Boree Creek:

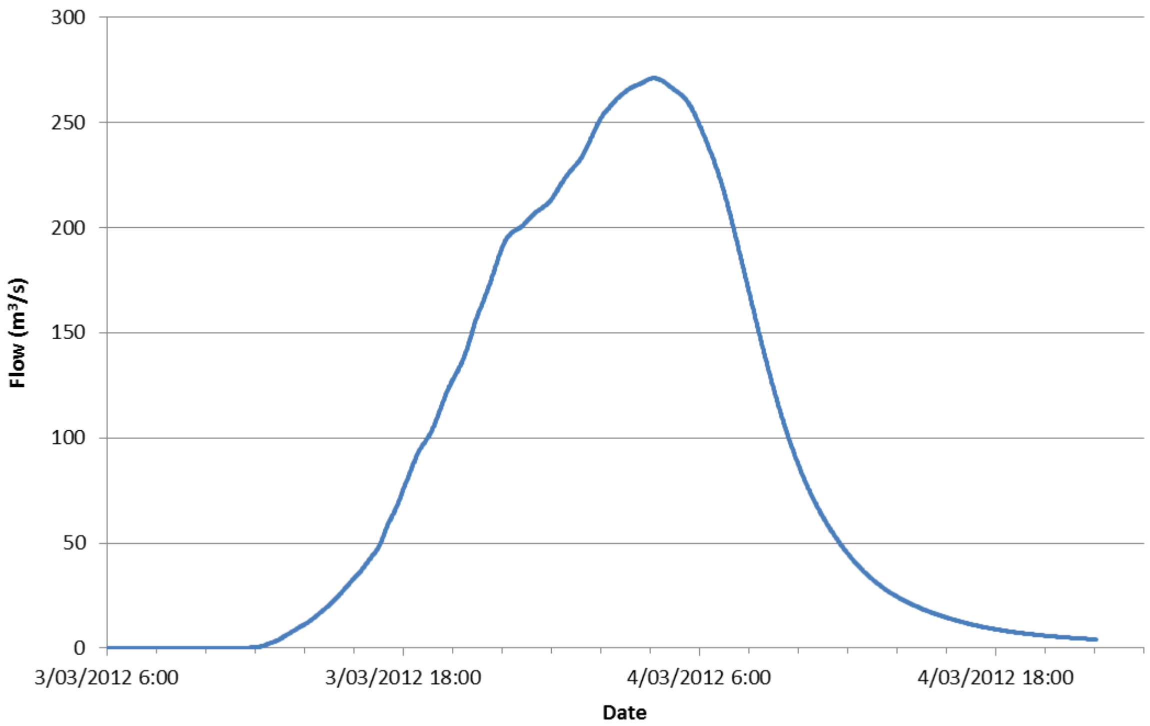
Node number	Area (ha)	Impervious fraction (%)	Slope (%)	Manning's n Roughness
1	1771.5	5	2.53	0.045
2	1179.3	5	2.73	0.04
3	1279.6	5	0.68	0.04
4	1240.8	5	0.69	0.04
5	627.0	5	0.72	0.04
6	138.2	5	0.28	0.04
7	1237.1	5	0.60	0.04
8	812.0	5	0.82	0.04
9	353.6	5	0.86	0.04
10	547.7	5	0.73	0.04
11	1130.5	5	0.85	0.04
12	305.0	5	0.62	0.04
13	876.9	5	0.57	0.04
14	1268.4	5	0.85	0.04
15	230.2	5	1.05	0.04
16	239.7	5	0.59	0.04
17	188.1	5	1.23	0.05
18	89.3	5	0.43	0.08
19	710.5	5	0.71	0.04
20	42.6	5	0.19	0.06

Node number	Area (ha)	Impervious fraction (%)	Slope (%)	Manning's n Roughness
21	125.1	5	0.77	0.04
22	124.2	5	1.48	0.04
23	153.1	5	0.17	0.07
24	148.7	5	1.11	0.04
25	615.6	5	0.47	0.04

- C3: XP-RAFTS Hydrograph at the outlet for 2010 event



- C4: XP-RAFTS Hydrograph at the outlet for 2012 event

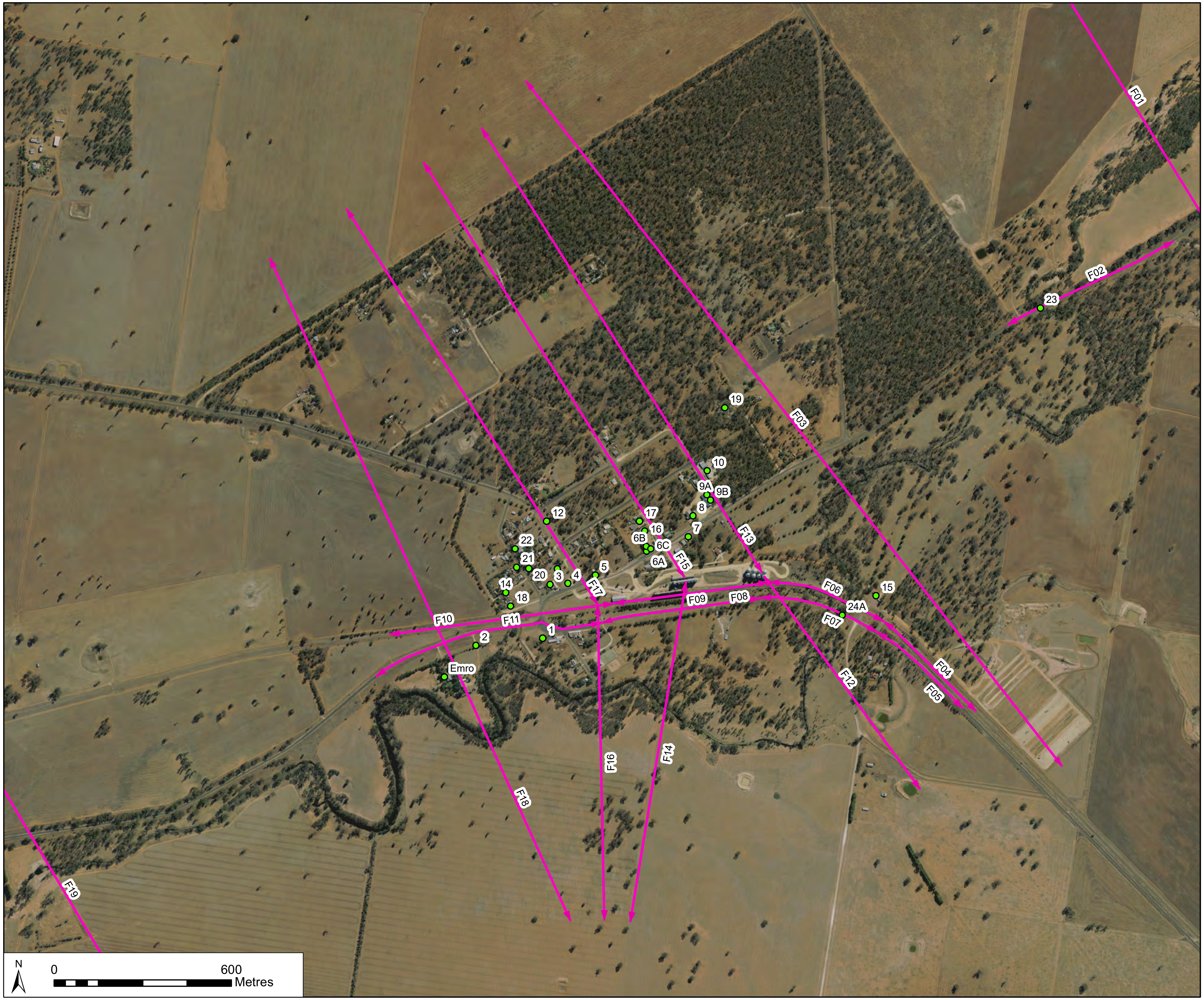


- C5: Modelled Peak Discharges at Catchment Outlet for the Selected Storm Durations

AEP	1 hour	1.5 hour	2 hour	3 hour	6 hour	12 hour	18 hour	24 hour	36 hour	48 hour	72 hour
20% AEP	1	2	6	17	47	40	52	56	59	60	71
10% AEP	2	6	12	36	76	63	76	85	91	89	96
5% AEP	5	20	36	120	150	136	137	153	155	149	142
2% AEP	13	35	98	195	212	175	181	200	190	182	154
1% AEP	20	55	133	256	273	230	225	249	238	229	202
0.5% AEP	31	103	205	333	346	292	279	307	296	288	253
0.2% AEP	37	157	259	455	474	392	374	402	389	374	345

Appendix D. Hydraulic Modelling Results

- D1: Map showing reporting locations of flows and flood levels
- D2: Reporting tables for the 2010 and 2012 flood events
- D3: Reporting tables for the sensitivity runs
- D4: Reporting tables for the design events
- D5: Water level hydrographs for 5% AEP, 1% AEP and PMF events



Legend

- Flood Level Locations
- Flow Lines

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	TUFLOW Model Reporting Locations
TOWN	Boree Creek
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	APPENDIX D-1
CHECK AH	DATE 8/04/2016	

- D2: Modelled flows for the 2010 and 2012 calibration events

Flow line	2010 Flow (m^3/s)	2012 Flow (m^3/s)
F01	128	209
F02	100	143
F03	114	235
F04	10	10
F05	10	10
F06	94	166
F07	94	171
F08	0	0
F09	0	0
F10	0	57
F11	1	56
F12	100	179
F13	0	61
F14	84	188
F15	2	63
F16	78	189
F17	3	64
F18	68	255
F19	36	262

- D3: Flood level differences for the sensitivity runs (2012 event)

Base = Base case

IL = Initial loss (+/- 20%)

n = Manning's n (+/- 20%)

B = Blockage factor (50%, 100%)

TWL = Tailwater level (+/- 0.5m)

Mark	Base	+ IL	- IL	+ n	- n	B50	B100	+ TWL	- TWL
1	146.06	0.00	0.00	+0.10	-0.11	0.00	+0.01	0.00	0.00
2	145.93	0.00	0.00	+0.10	-0.11	0.00	0.00	0.00	0.00
3	146.48	0.00	0.00	+0.07	-0.08	+0.01	+0.02	0.00	0.00
4	146.61	0.00	0.00	+0.07	-0.09	+0.01	+0.02	0.00	0.00
5	146.78	0.00	0.00	+0.07	-0.10	+0.01	+0.02	0.00	0.00
6A	147.13	0.00	0.00	+0.06	-0.11	+0.01	+0.02	0.00	0.00
6B	147.19	0.00	0.00	+0.05	-0.09	+0.01	+0.02	0.00	0.00
6C	147.24	0.00	0.00	+0.06	-0.09	+0.01	+0.02	0.00	0.00
7	147.50	0.00	0.00	+0.06	-0.09	+0.01	+0.02	0.00	0.00
8	147.58	0.00	0.00	+0.07	-0.09	+0.01	+0.02	0.00	0.00
9A	147.72	0.00	0.00	+0.06	-0.09	+0.01	+0.02	0.00	0.00
9B	147.73	0.00	0.00	+0.06	-0.09	+0.01	+0.02	0.00	0.00
10	147.72	0.00	0.00	+0.07	-0.09	+0.01	+0.01	0.00	0.00
11	146.63	0.00	0.00	+0.07	-0.10	+0.01	+0.02	0.00	0.00
12	146.88	0.00	0.00	+0.06	-0.08	+0.01	+0.02	0.00	0.00

14	146.30	0.00	0.00	+0.04	-0.05	+0.01	+0.02	0.00	0.00
15	147.73	0.00	0.00	+0.08	-0.08	+0.04	+0.07	0.00	0.00
16	147.32	0.00	0.00	+0.04	-0.08	+0.01	+0.01	0.00	0.00
17	147.30	0.00	0.00	+0.04	-0.08	+0.01	+0.01	0.00	0.00
18	146.21	0.00	0.00	+0.04	-0.04	+0.01	+0.02	0.00	0.00
19	147.86	0.00	0.00	+0.09	-0.06	0.00	+0.01	0.00	0.00
20	146.45	0.00	0.00	+0.07	-0.07	+0.01	+0.02	0.00	0.00
21	146.43	0.00	0.00	+0.07	-0.07	+0.01	+0.02	0.00	0.00
22	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
23	149.38	0.00	0.00	+0.07	-0.08	0.00	0.00	0.00	0.00
24A	147.20	0.00	0.00	+0.11	-0.15	+0.01	+0.02	0.00	0.00
Emro	145.77	0.00	0.00	+0.09	-0.10	0.00	0.00	0.00	0.00

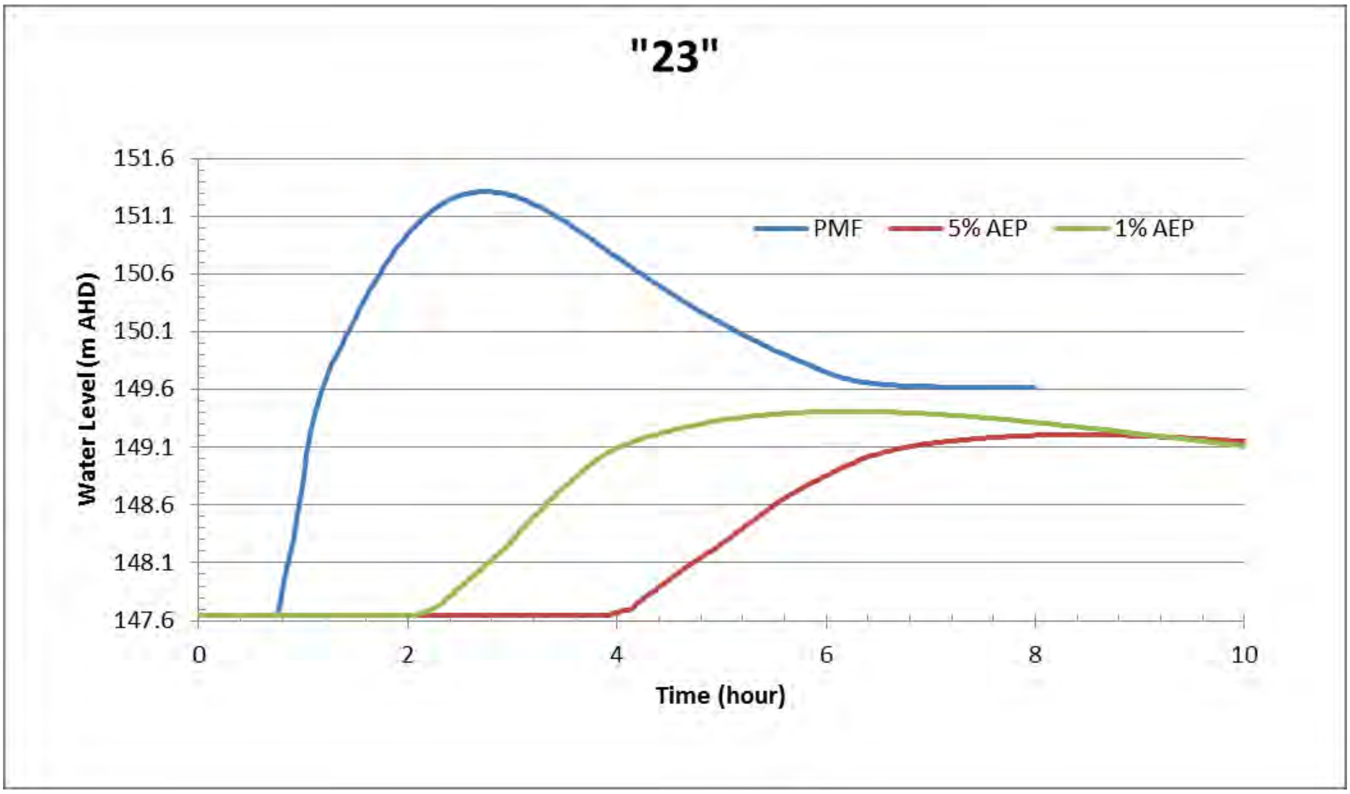
- D3: Flow differences for the sensitivity runs (2012 event)

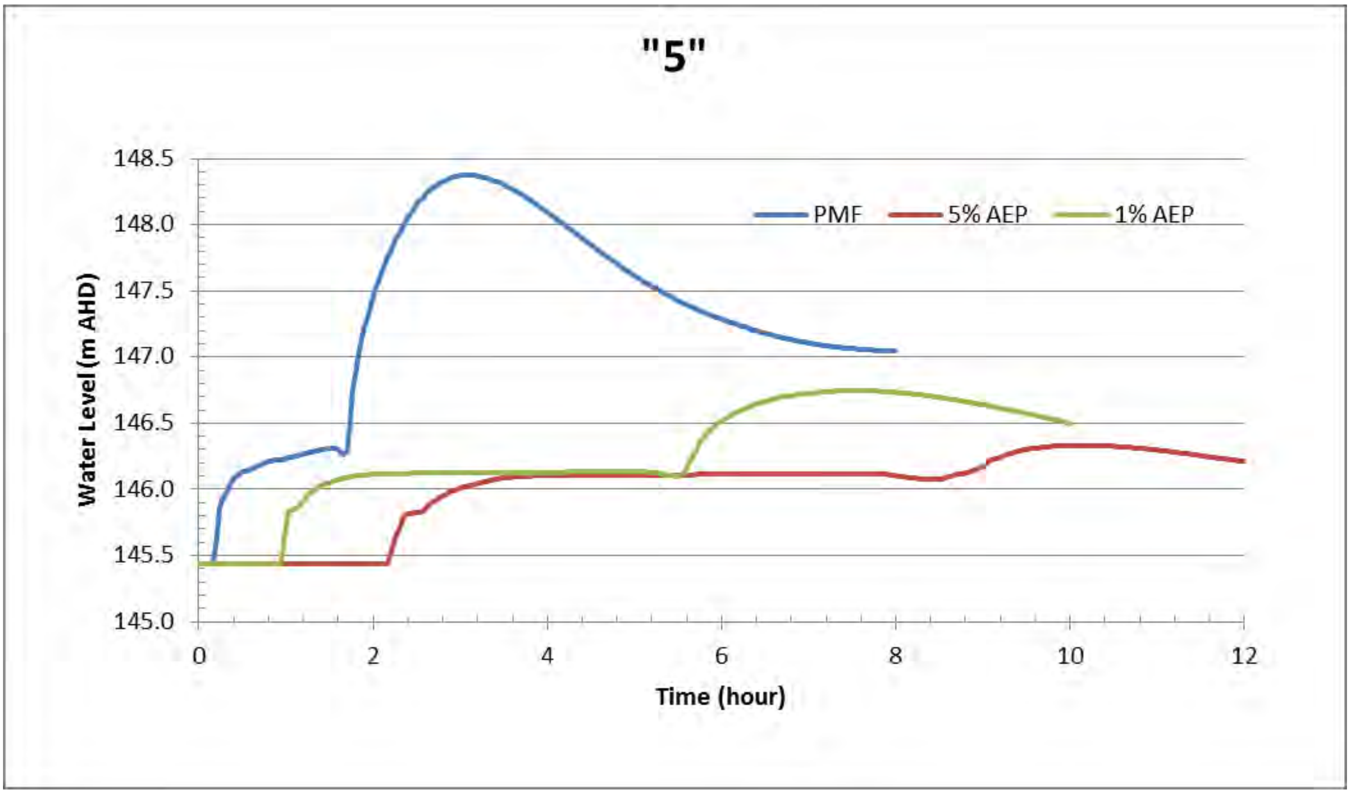
Line	Base	+ IL	- IL	+ n	- n	B50	B100	+ TWL	- TWL
F01	197.3	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0
F02	135.8	0.0	0.0	-8.5	+9.8	+1.3	+2.5	0.0	0.0
F03	216.6	-0.1	+0.1	-0.2	+1.1	+0.3	+0.3	0.0	0.0
F04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F06	156.0	-0.1	0.0	-8.7	+12.9	+2.9	+6.2	0.0	0.0
F07	160.3	-0.1	0.0	-9.2	+13.3	+0.8	1.8	0.0	0.0
F08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F09	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F10	53.0	-0.1	0.0	+6.3	-7.2	+2.0	+4.3	0.0	0.0
F11	49.0	-0.1	0.0	+4.9	-6.4	+2.9	+6.3	0.0	0.0
F12	166.8	-0.1	0.0	-8.3	+10.2	-0.9	-2.7	0.0	0.0
F13	57.1	-0.1	0.0	+8.1	-8.4	+1.5	+3.4	0.0	0.0
F14	174.0	-0.1	+0.1	-8.6	+10.6	-1.0	-2.5	0.0	0.0
F15	58.3	-0.1	+0.1	+8.0	-8.4	+1.5	+3.3	0.0	0.0
F16	174.7	-0.2	+0.1	-8.7	+10.6	-1.1	-2.5	0.0	0.0
F17	59.4	-0.1	+0.1	+8.0	-8.4	+1.4	+3.3	0.0	0.0
F18	236.8	-0.3	+0.2	-1.0	+2.9	+0.2	+0.5	0.0	0.0
F19	243.3	-0.4	+0.3	-2.5	+3.1	-0.1	+0.2	0.0	0.0

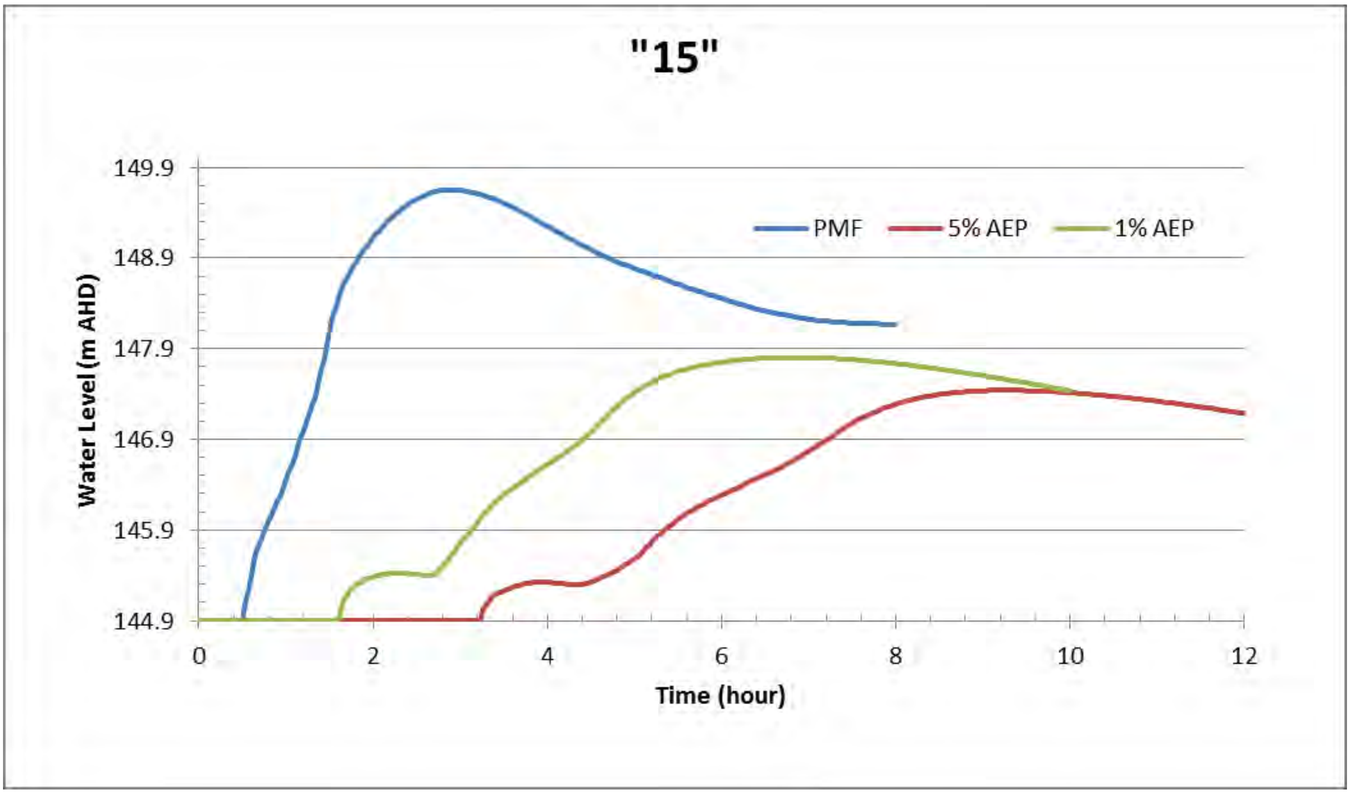
- D4: Modelled flows for the design events

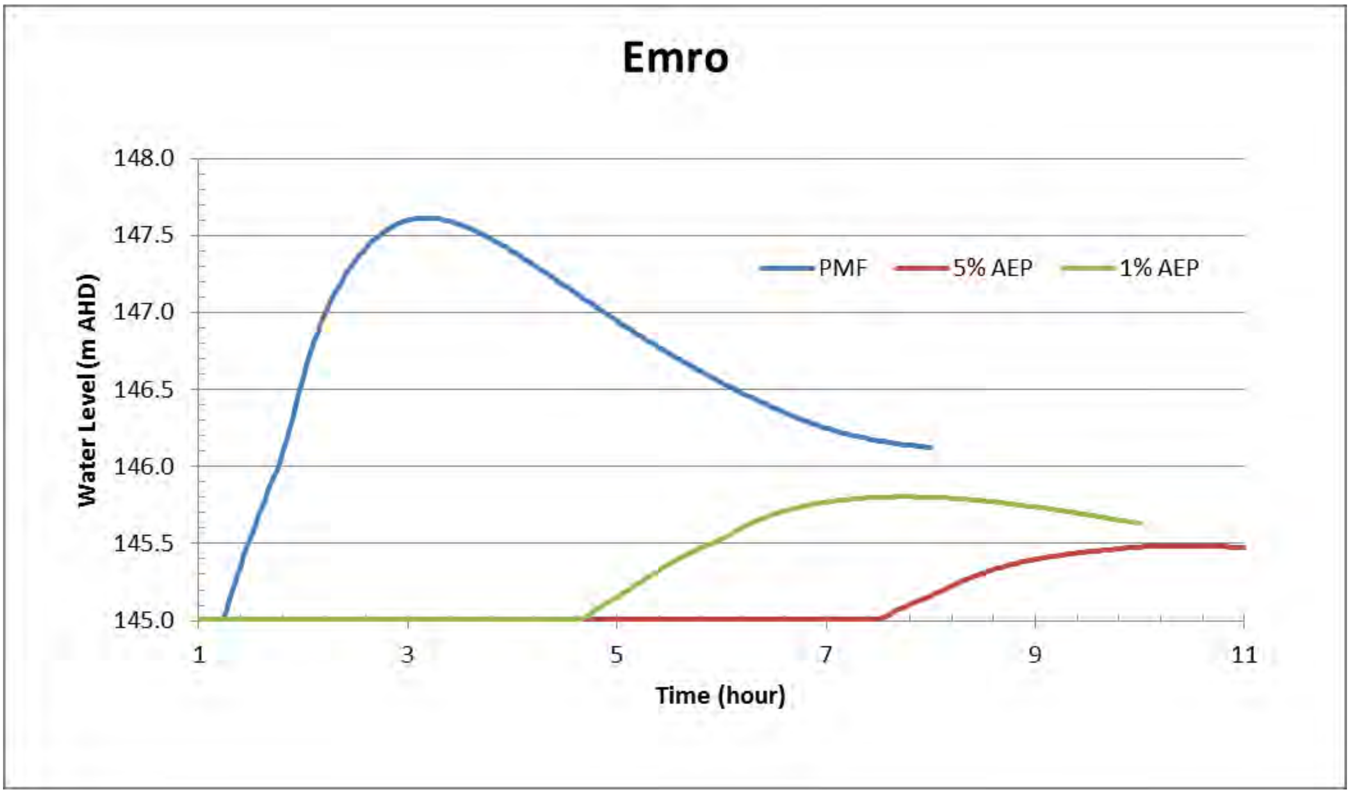
Flow line	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
F01	67	85	128	175	221	279	380	3232
F02	56	69	100	126	148	170	204	775
F03	71	90	134	183	234	300	410	3524
F04	9	10	10	11	11	11	15	565
F05	9	10	10	11	11	11	15	539
F06	65	82	116	142	164	188	230	1072
F07	64	82	118	145	169	194	236	1011
F08	0	0	0	0	0	0	6	262
F09	0	0	0	0	0	0	4	238
F10	0	0	7	28	54	86	121	152
F11	1	0	4	32	56	84	108	106
F12	72	91	126	152	176	201	250	1705
F13	0	0	9	31	59	100	162	1871
F14	72	92	128	155	180	206	262	1989
F15	1	2	9	32	59	100	158	1676
F16	72	92	128	154	179	206	262	2022
F17	2	2	9	32	59	100	159	1648
F18	73	93	137	188	239	304	424	3680
F19	74	94	138	188	238	302	420	3699

- D5: Water Level Hydrographs for 5% AEP (36 hour), 1% AEP (6 hour) and PMF (2 hour) events (location of points are shown in **Appendix D1**)

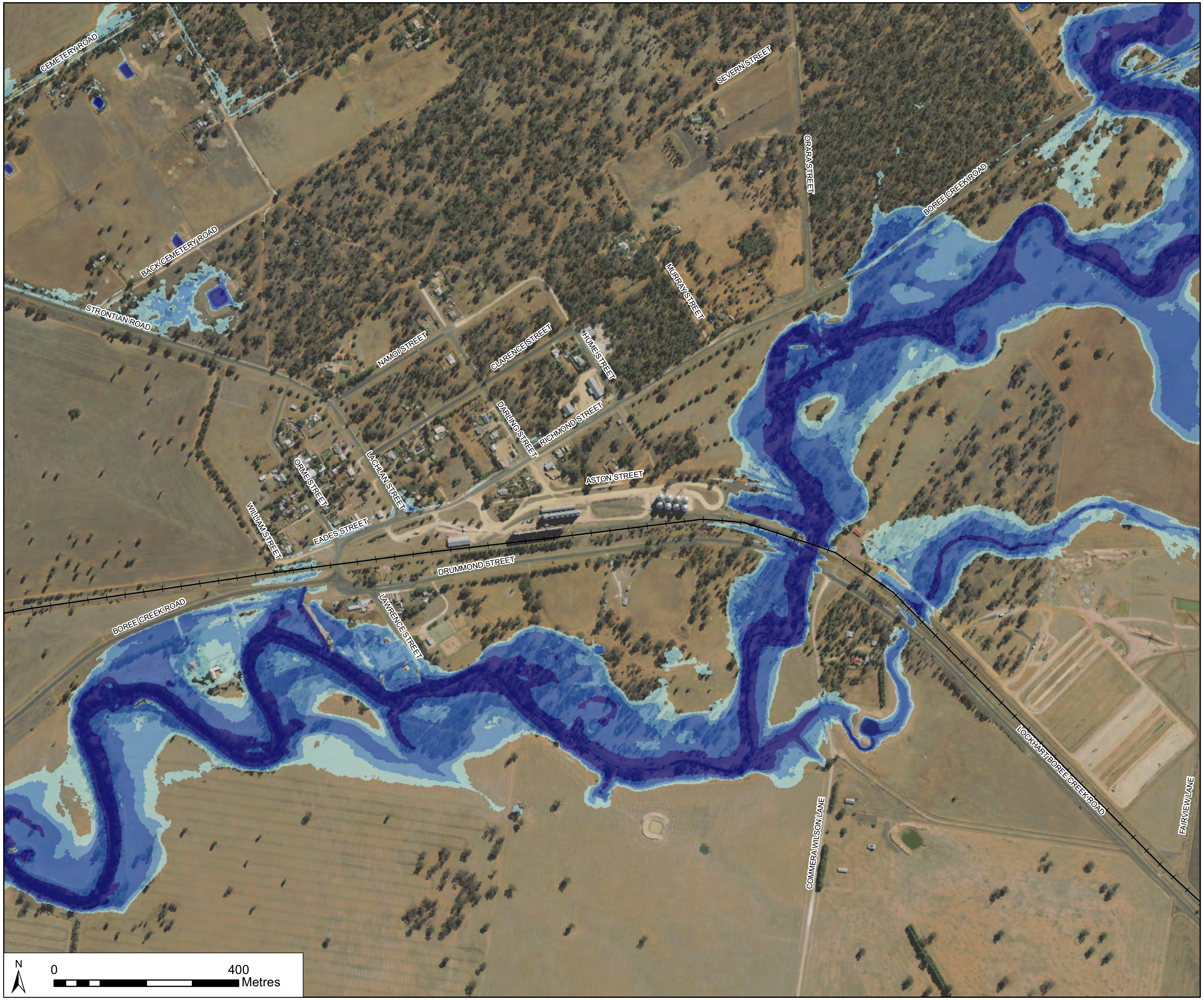





"15"
Water Level (m AHD)
149.9
148.9
147.9
146.9
145.9
144.9
0
2
4
6
8
10
12
Time (hour)
PMF
5% AEP
1% AEP


Emro
Water Level (m AHD)
148.0
147.5
147.0
146.5
146.0
145.5
145.0
1
3
5
7
9
11
Time (hour)
PMF
5% AEP
1% AEP

Appendix E. Design Flood Event Maps



Legend

Railway

Cadastre

flood depth (m)

- 0.15 - 0.3
- 0.3 - 0.5
- 0.5 - 1.0
- > 1.0

Depths below 150mm have been trimmed from this map

GDA 1994 MGA Zone 55
Scale: A3

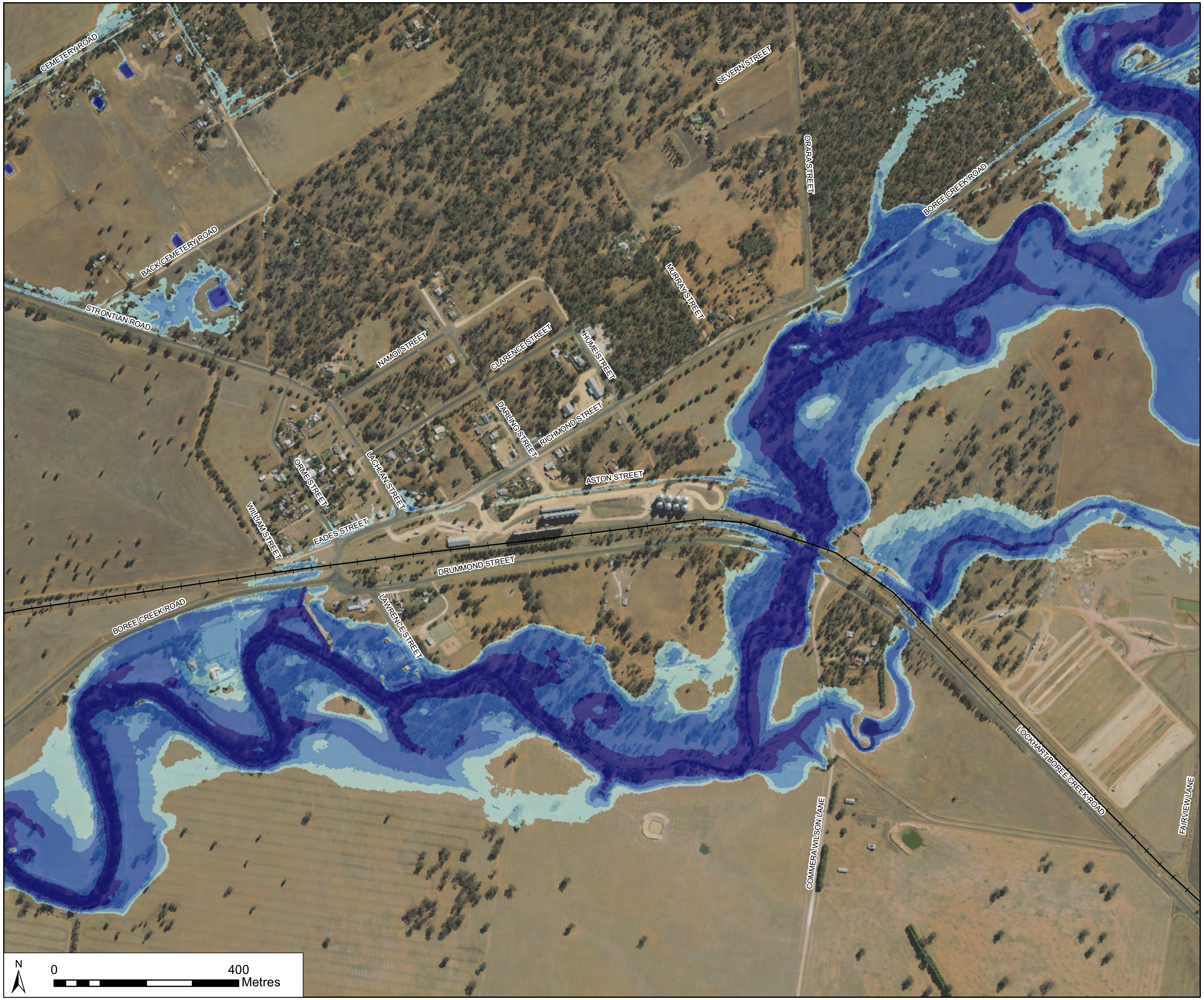
Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	20% AEP Event Flood Depth Map
TOWN	Boree Creek
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN AG	PROJECT # IA055600	FIGURE E-1
CHECK AH	DATE 30/06/2017	



Legend

Railway

Cadastre

flood depth (m)

- 0.15 - 0.3
- 0.3 - 0.5
- 0.5 - 1.0
- > 1.0

Depths below 150mm have been trimmed from this map

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

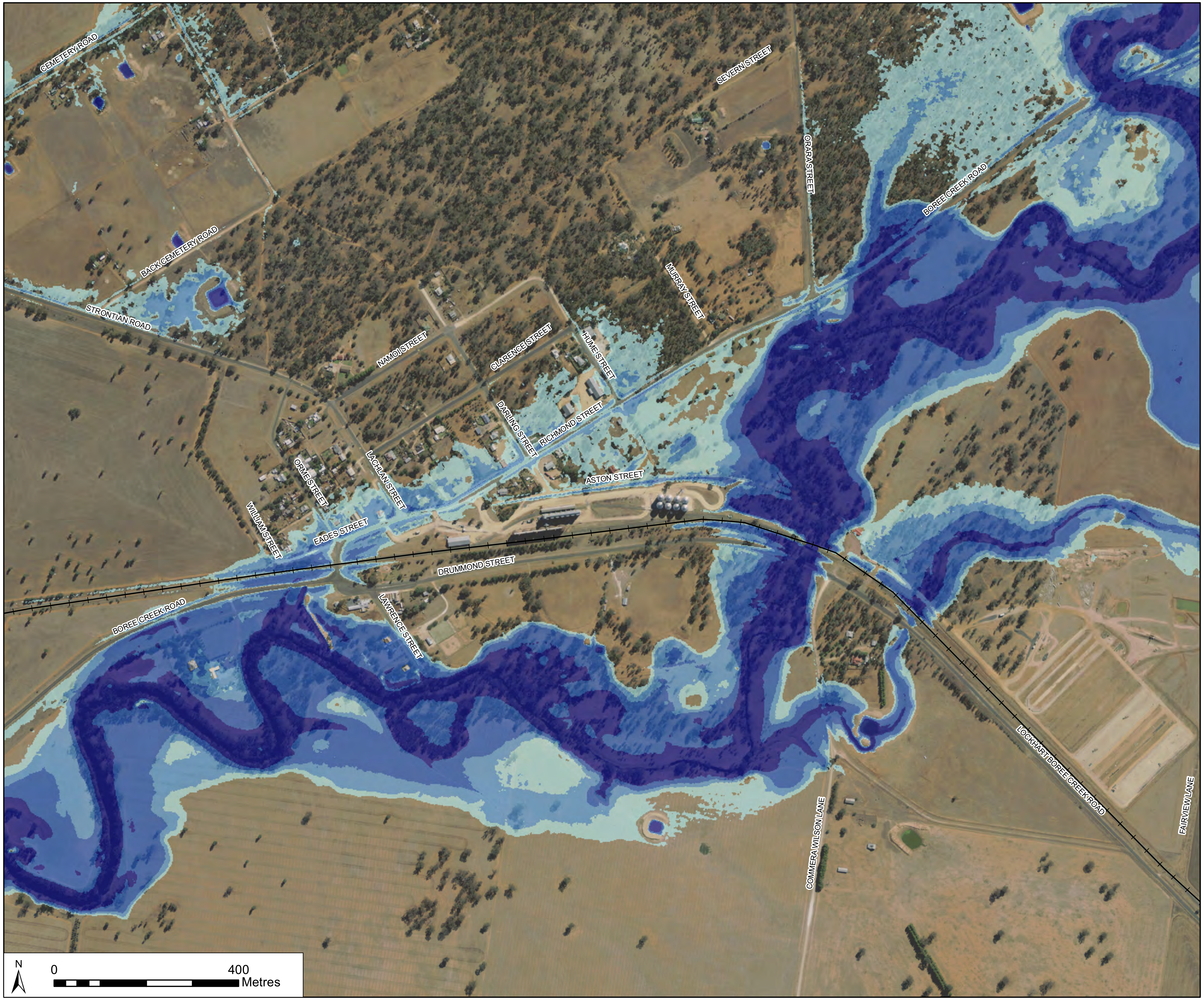
LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	10% AEP Event Flood Depth Map
TOWN	Boree Creek
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN AG | PROJECT # IA055600
CHECK AH | DATE 30/06/2017

FIGURE E-2



Legend

Railway

Cadastre

flood depth (m)

- 0.15 - 0.3
- 0.3 - 0.5
- 0.5 - 1.0
- > 1.0

Depths below 150mm have been trimmed from this map

GDA 1994 MGA Zone 55
Scale: A3

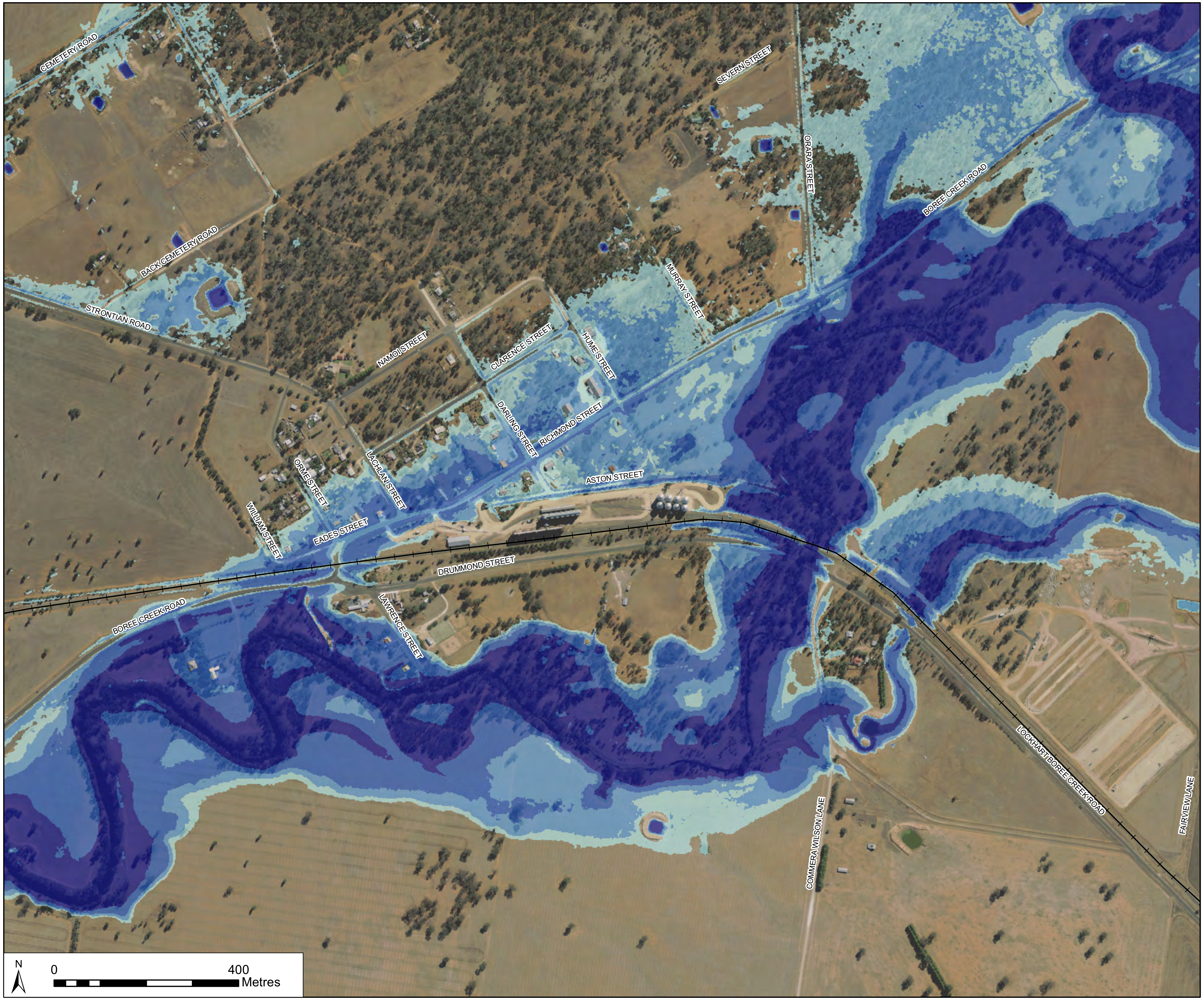
Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	5% AEP Event Flood Depth Map
TOWN	Boree Creek
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN AG	PROJECT # IA055600	FIGURE E-3
CHECK AH	DATE 30/06/2017	



Legend

Railway

Cadastre

flood depth (m)

- 0.15 - 0.3
- 0.3 - 0.5
- 0.5 - 1.0
- > 1.0

Depths below 150mm have been trimmed from this map

GDA 1994 MGA Zone 55
Scale: A3

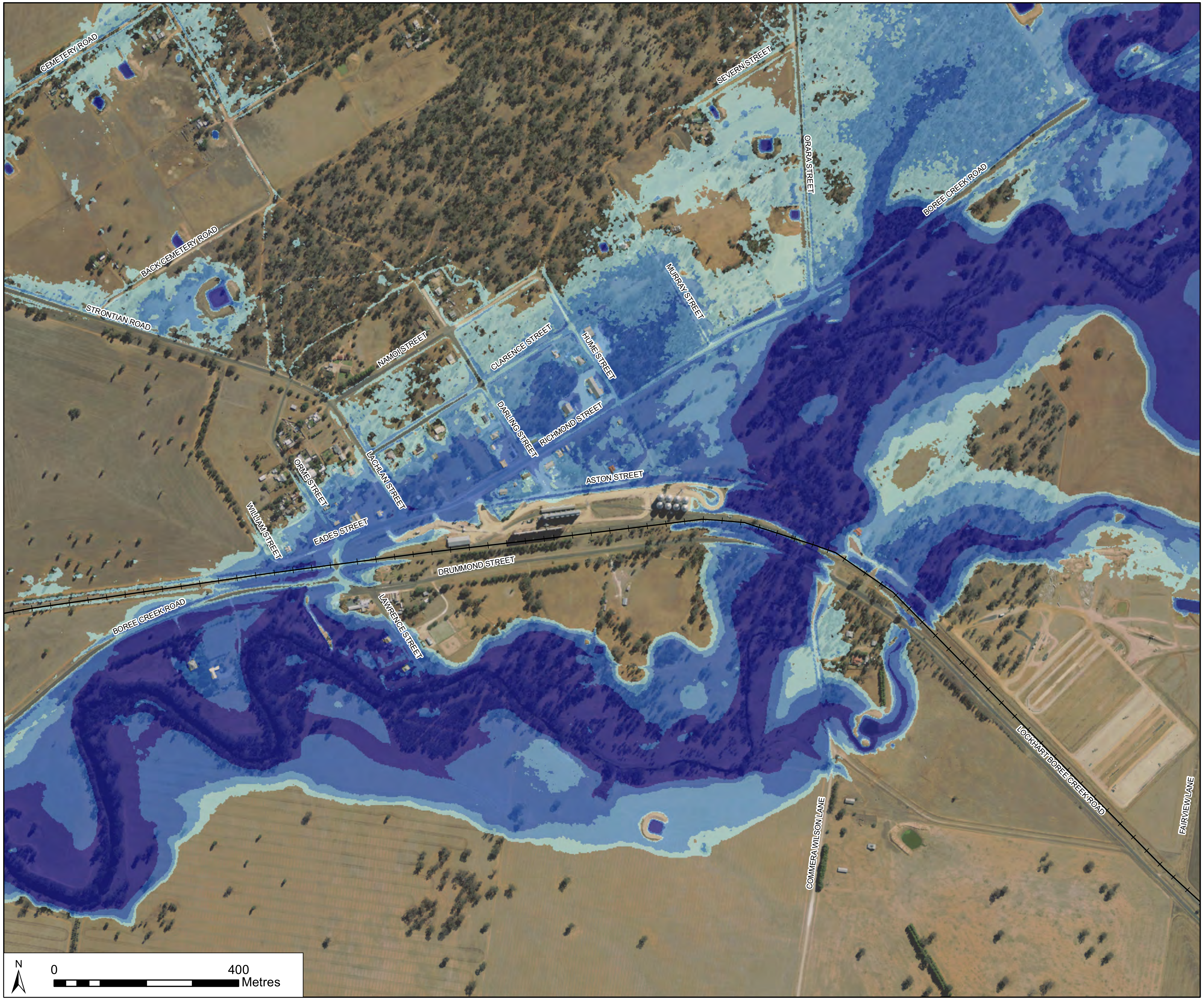
Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	2% AEP Event Flood Depth Map
TOWN	Boree Creek
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN AG	PROJECT # IA055600	FIGURE E-4
CHECK AH	DATE 30/06/2017	



Legend

Railway

Cadastre

flood depth (m)

0.15 - 0.3

0.3 - 0.5

0.5 - 1.0

> 1.0

Depths below 150mm have been trimmed from this map

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

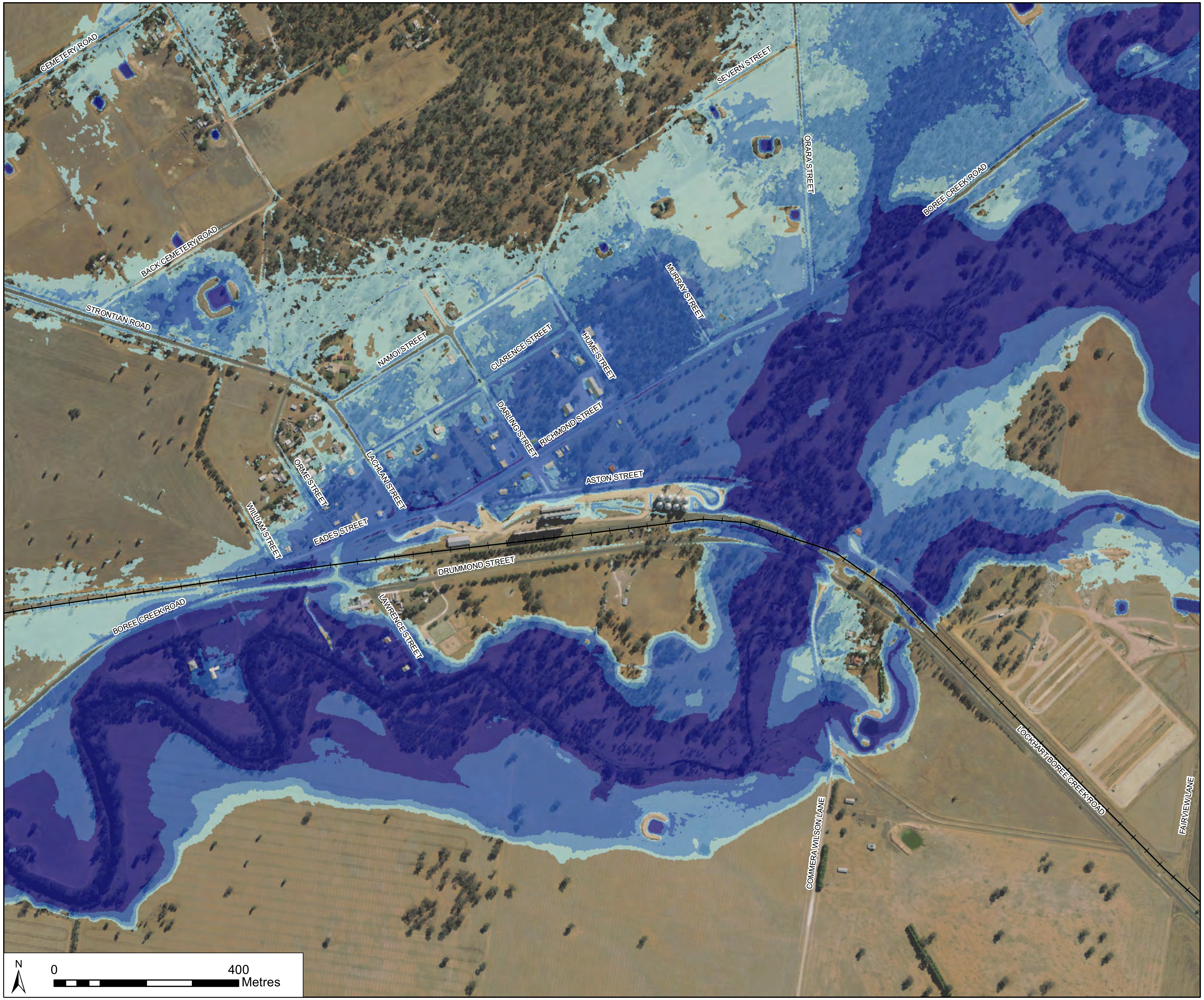
LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	1% AEP Event Flood Depth Map
TOWN	Boree Creek
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN AG | PROJECT # IA055600
CHECK AH | DATE 30/06/2017

FIGURE E-5



Legend

Railway

Cadastre

flood depth (m)

0.15 - 0.3

0.3 - 0.5

0.5 - 1.0

> 1.0

Depths below 150mm have been trimmed from this map

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

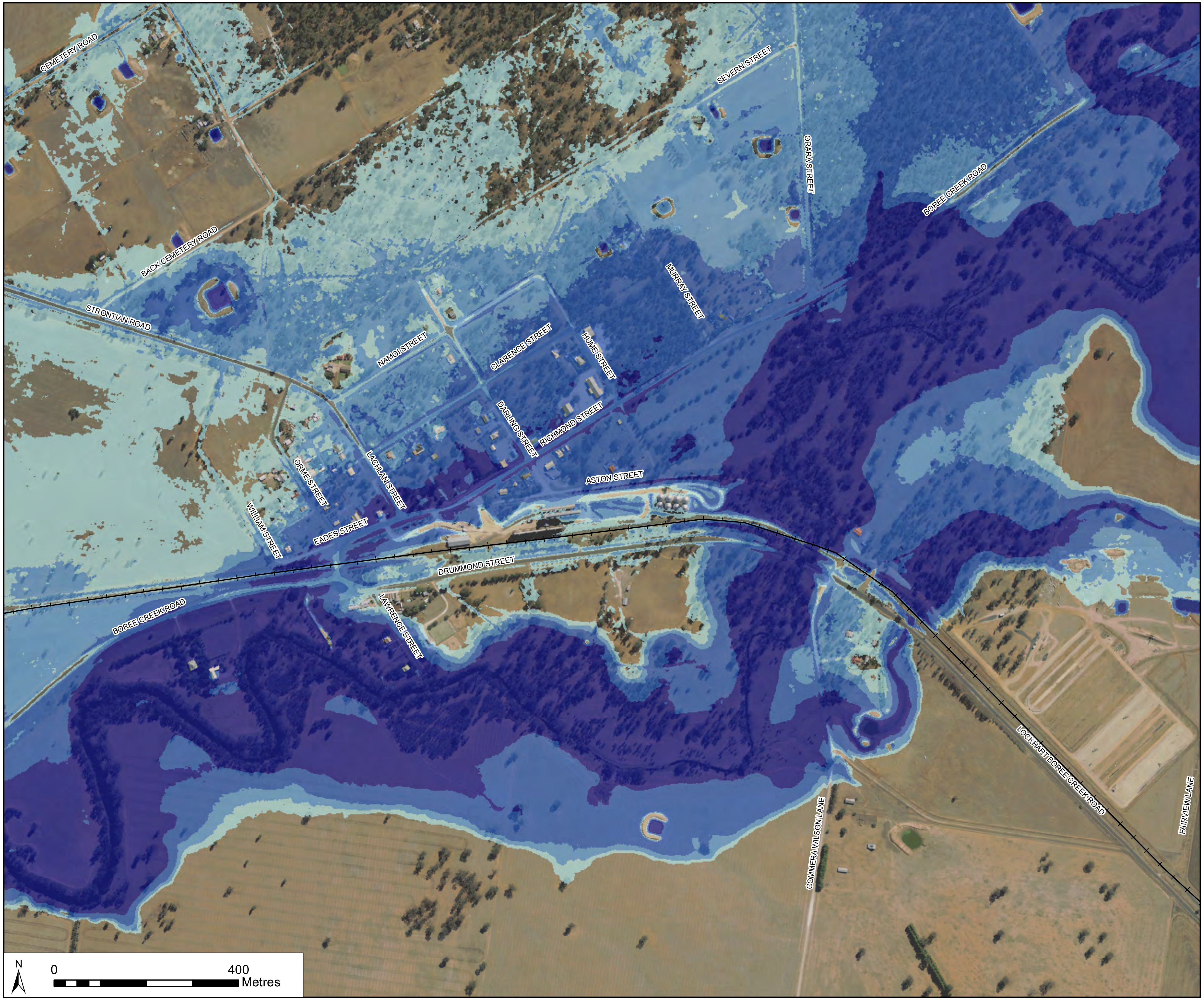
LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	0.5% AEP Event Flood Depth Map
TOWN	Boree Creek
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN AG | PROJECT # IA055600
CHECK AH | DATE 30/06/2017

FIGURE E-6



Legend

Railway

Cadastre

flood depth (m)

- 0.15 - 0.3
- 0.3 - 0.5
- 0.5 - 1.0
- > 1.0

Depths below 150mm have been trimmed from this map

GDA 1994 MGA Zone 55
Scale: A3

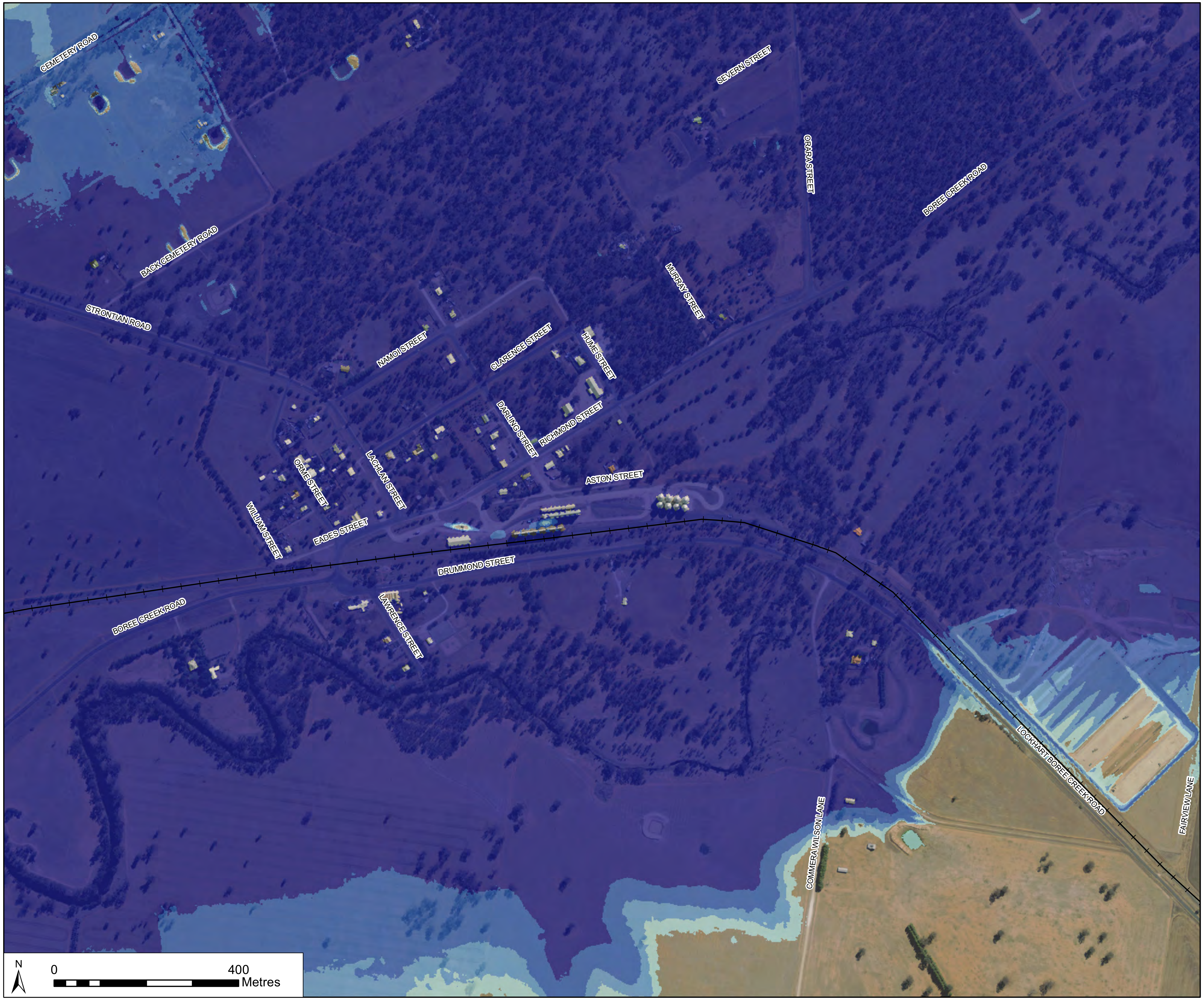
Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	0.2% AEP Event Flood Depth Map
TOWN	Boree Creek
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN AG	PROJECT # IA055600	FIGURE E-7
CHECK AH	DATE 30/06/2017	



Legend

Railway

Cadastre

flood depth (m)

0.15 - 0.3

0.3 - 0.5

0.5 - 1.0

> 1.0

Depths below 150mm have been trimmed from this map

GDA 1994 MGA Zone 55
Scale: A3

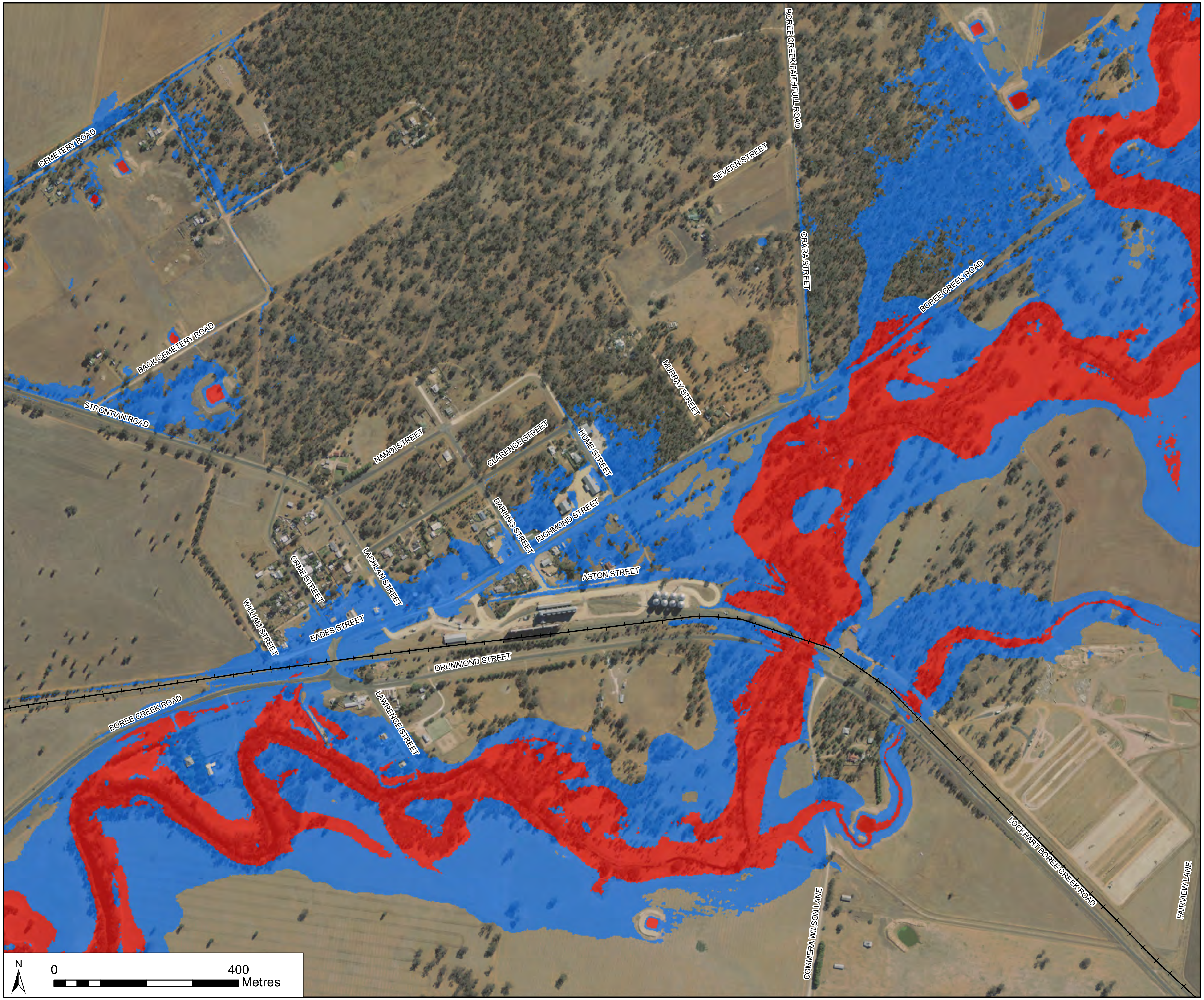
Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	PMF Event Flood Depth Map
TOWN	Boree Creek
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN AG	PROJECT # IA055600	FIGURE E-8
CHECK AH	DATE 30/06/2017	



Legend

Railway

Cadastre

Provisional hydraulic hazard

Low Hazard

High Hazard

Depths below 150mm have been trimmed from this map

GDA 1994 MGA Zone 55
Scale: A3

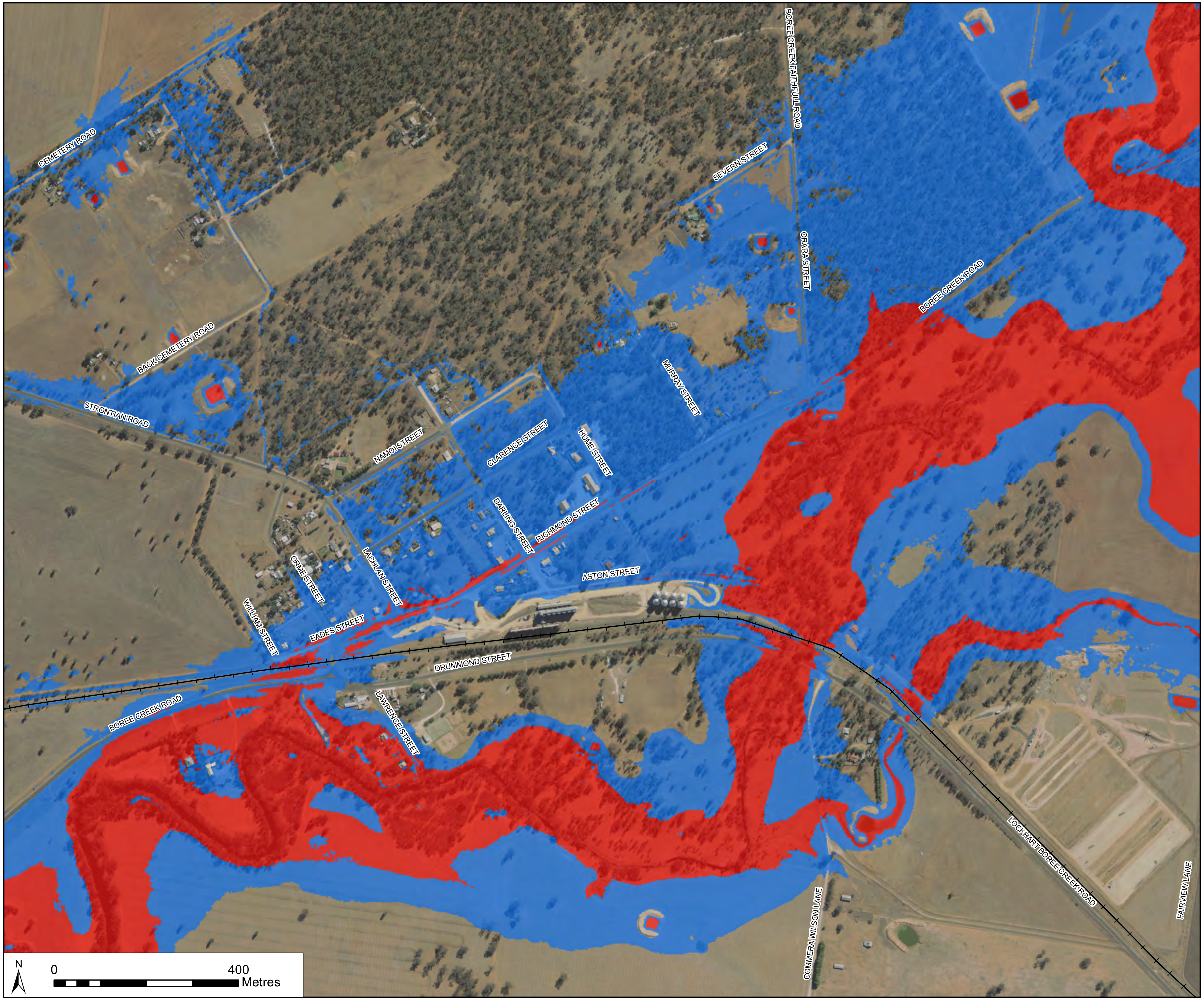
Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	5% AEP Event Provisional Hazard Map
TOWN	Boree Creek
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN AG	PROJECT # IA055600	FIGURE E-9
CHECK AH	DATE 10/15/2015	



Legend

Railway

Cadastre

Provisional hydraulic hazard

Low Hazard

High Hazard

Depths below 150mm have been trimmed from this map

GDA 1994 MGA Zone 55
Scale: A3

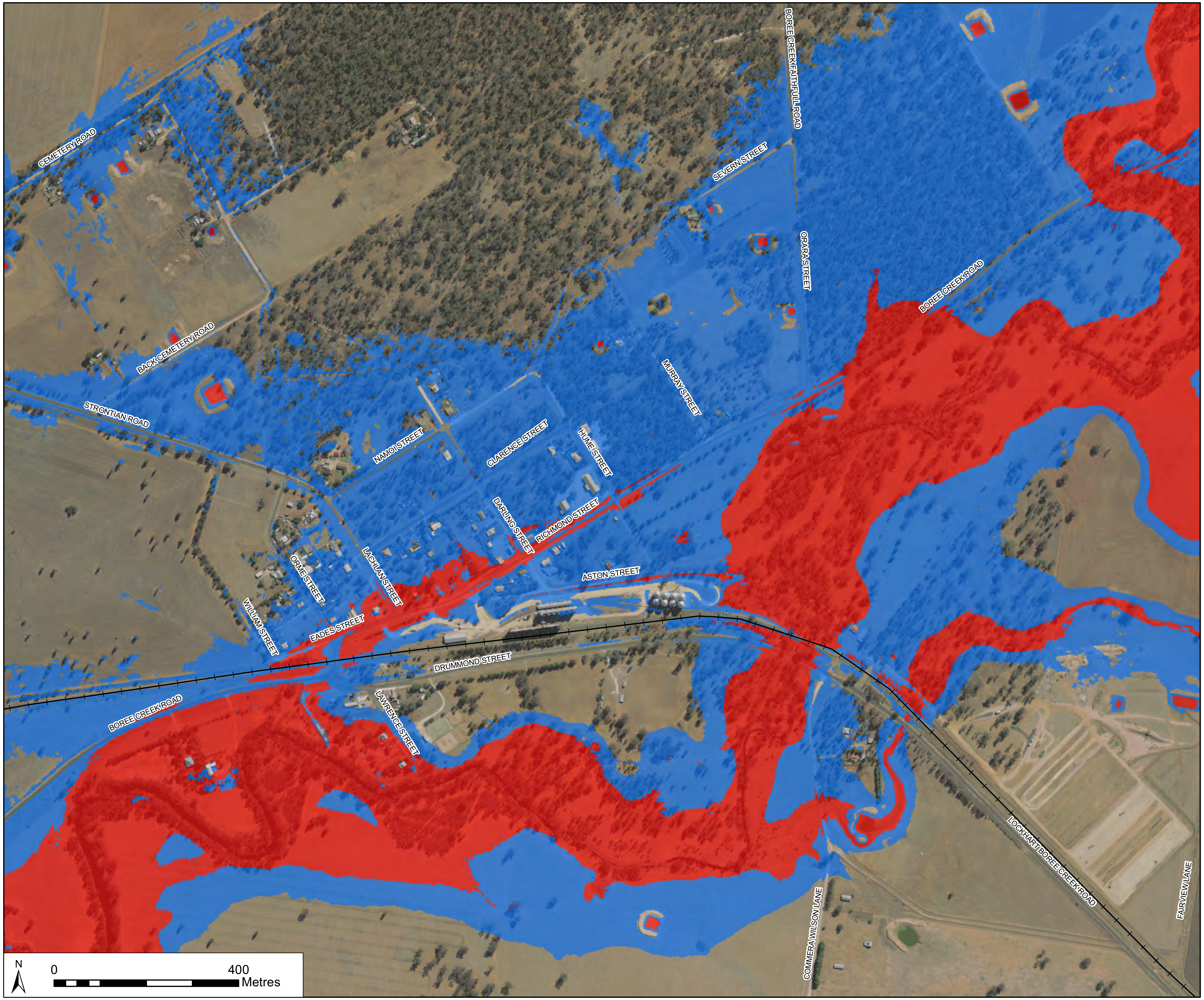
Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	1% AEP Event Provisional Hazard Map
TOWN	Boree Creek
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN AG	PROJECT # IA055600	FIGURE E-10
CHECK AH	DATE 10/15/2015	



Legend

Railway

Cadastre

Provisional hydraulic hazard

Low Hazard

High Hazard

Depths below 150mm have been trimmed from this map

GDA 1994 MGA Zone 55
Scale: A3

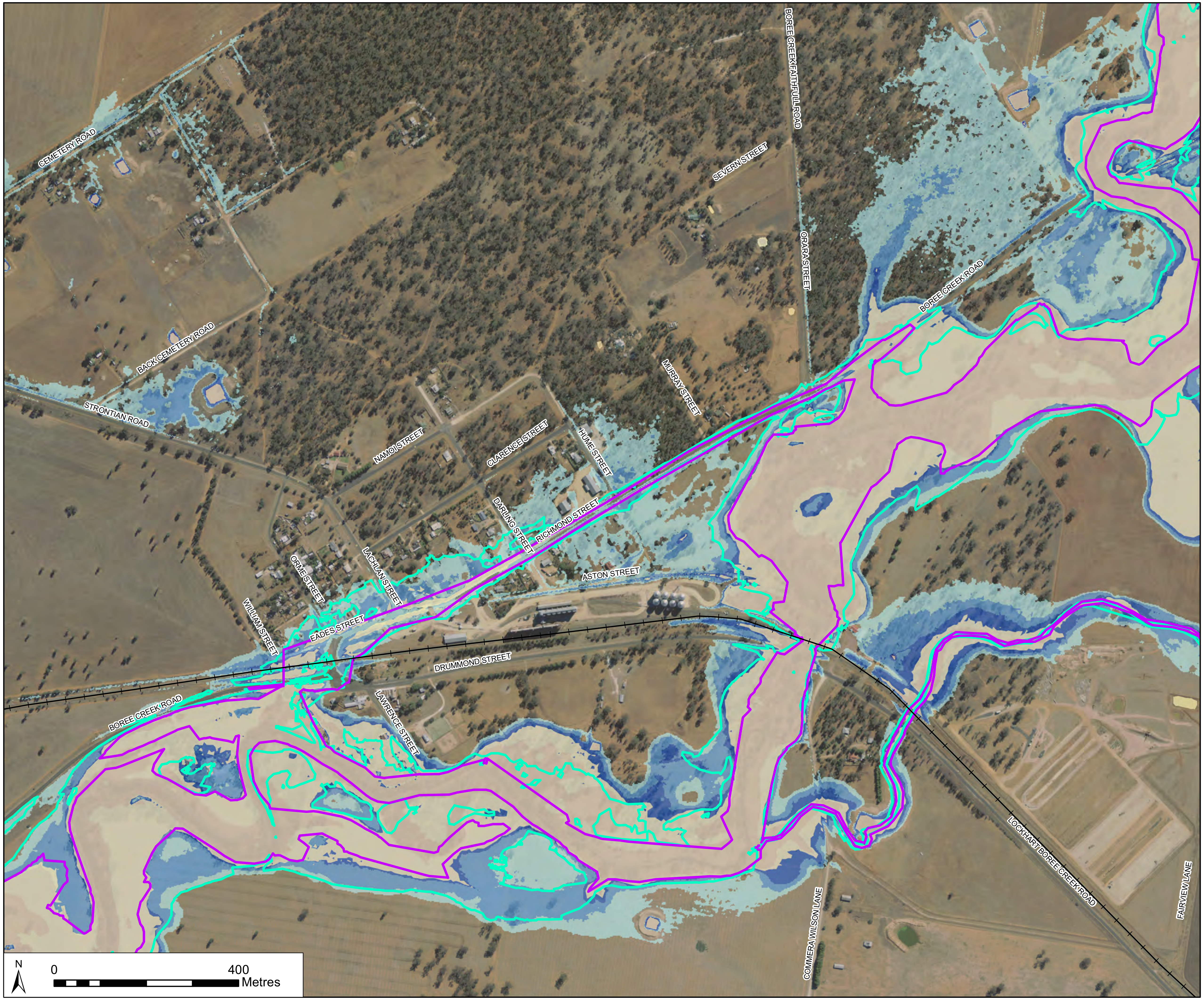
Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	0.5% AEP Event Provisional Hazard Map
TOWN	Boree Creek
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN AG	PROJECT # IA055600	FIGURE E-11
CHECK AH	DATE 10/15/2015	



Legend

- Railway
- VD > 0.5
- VD > 0.25
- 1% AEP High Hazard

5% AEP Flood depth (m)

- 0.15 - 0.3
- 0.3 - 0.5
- 0.5 - 1.0
- > 1.0

Depths below 150mm have been trimmed from this map

GDA 1994 MGA Zone 55
Scale: A3

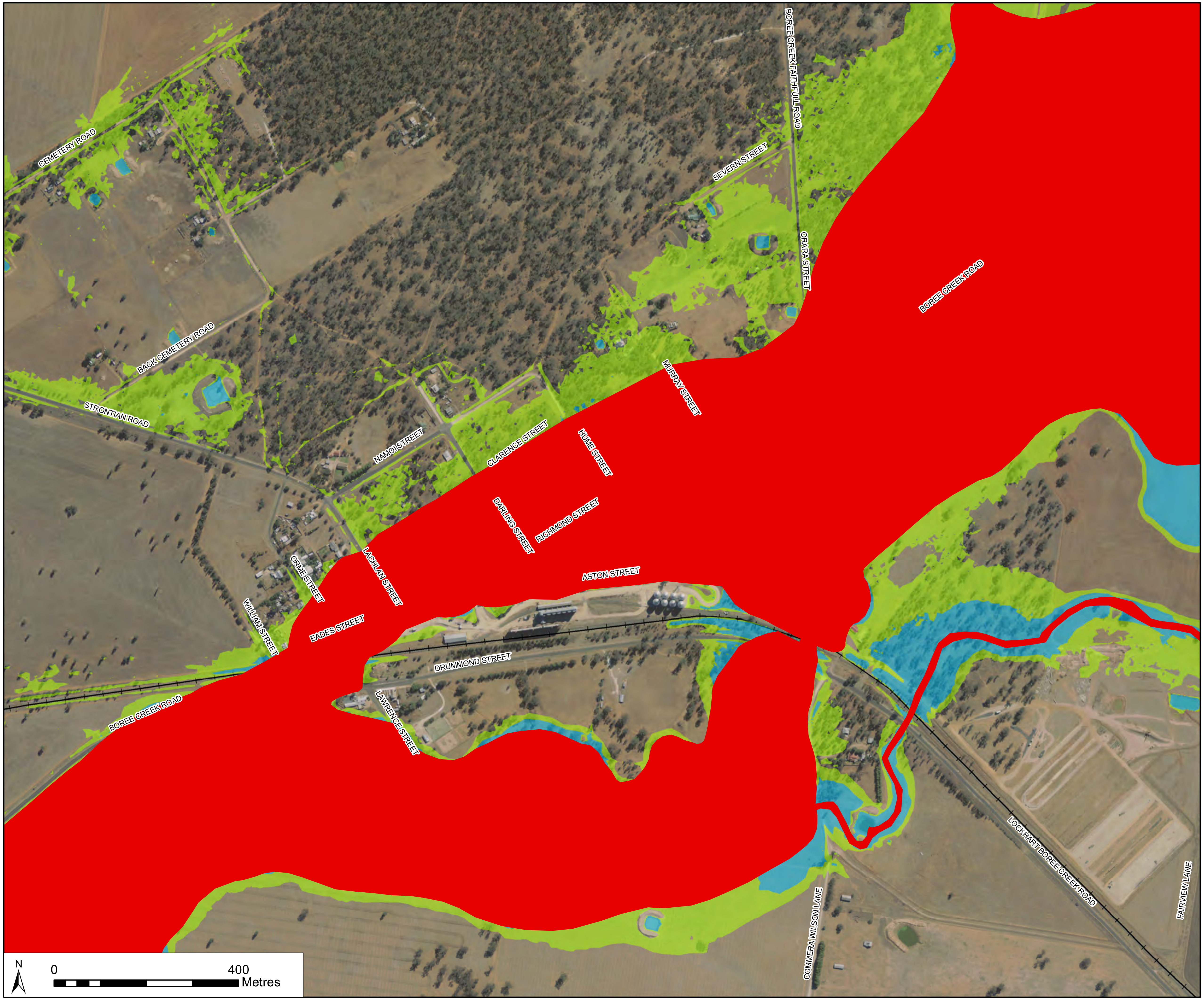
Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	Floodway Delineation
TOWN	Boree Creek
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN AG	PROJECT # IA055600	FIGURE E-12
CHECK AH	DATE 10/15/2015	



Legend

- Floodway
- Flood Storage
- Flood Fringe
- Railway

Depths below 150mm have been trimmed from this map

GDA 1994 MGA Zone 55
Scale: A3

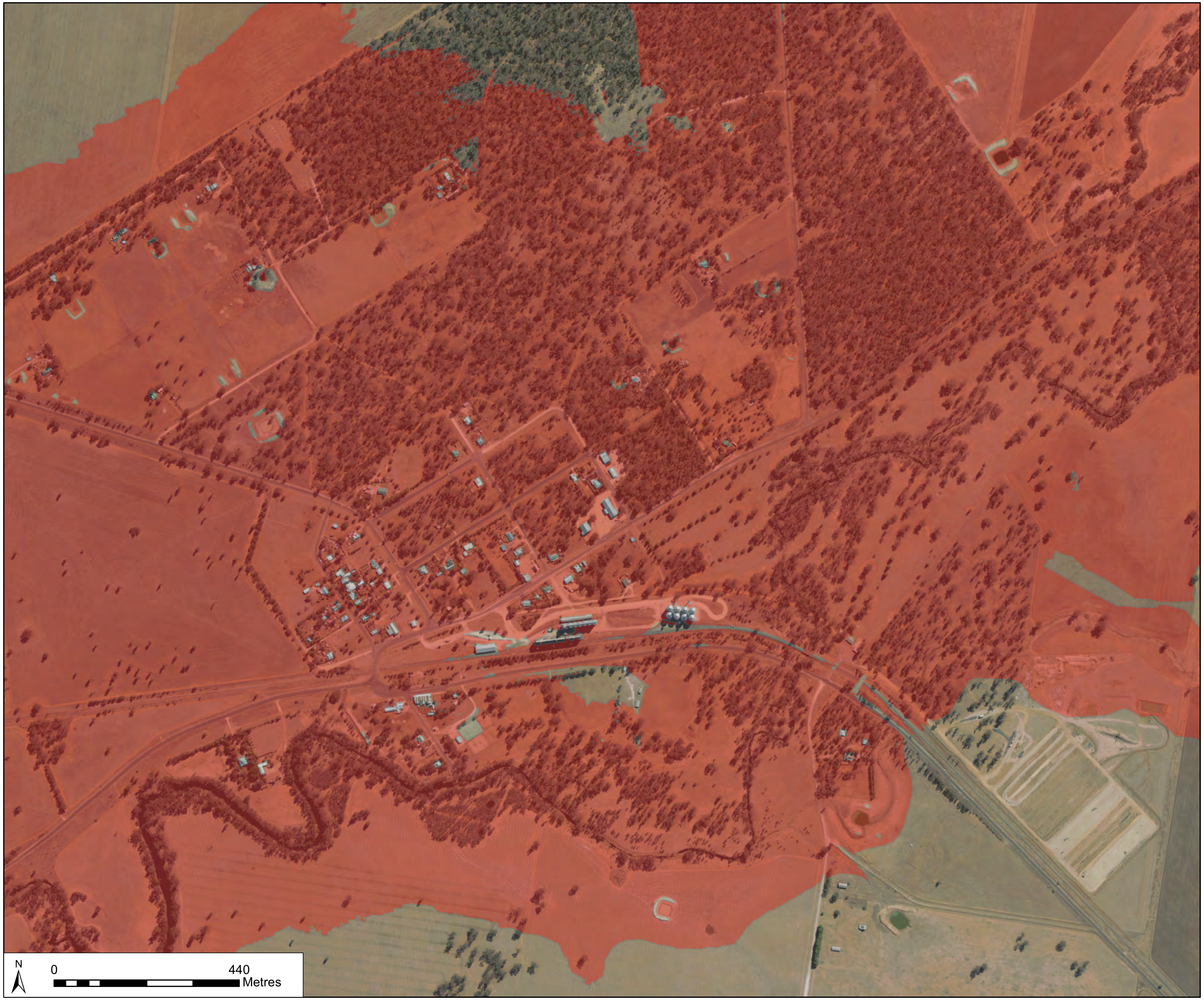
Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	Provisional Hydraulic Hazard Categories
TOWN	Boree Creek
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN AG	PROJECT # IA055600	FIGURE E-13
CHECK AH	DATE 10/15/2015	



Legend

Flood Planning Area

Depths below 150mm have been trimmed from this map

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

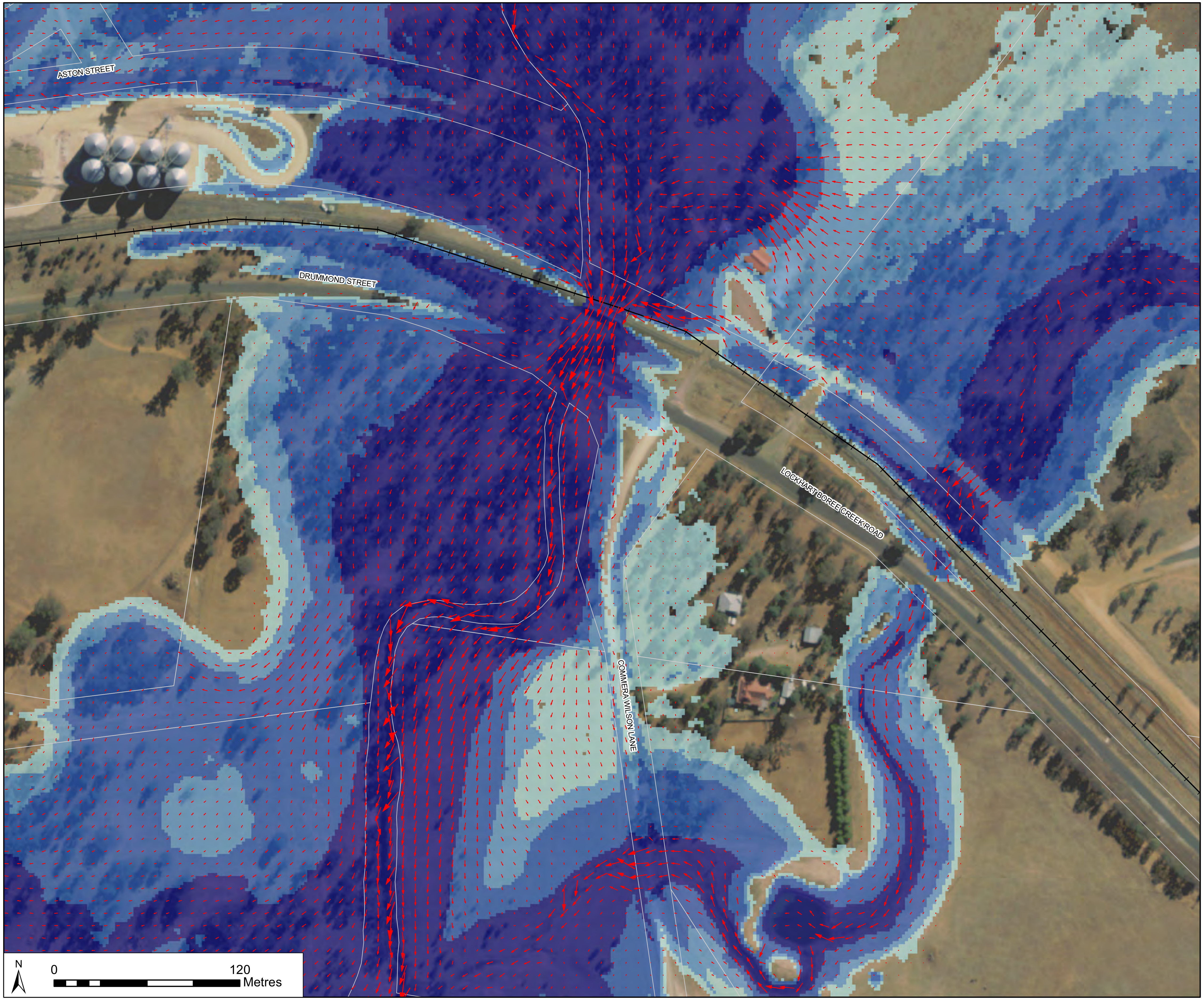
LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	Provisional Flood Planning Area
TOWN	Boree Creek
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR | PROJECT # IA055600
CHECK AH | DATE 21/08/2017

FIGURE E-14



Legend

Velocity (m/s)

Railway

Cadastre

flood depth (m)

0.15 - 0.3

0.3 - 0.5

0.5 - 1.0

> 1.0

Depths below 150mm have been trimmed from this map

GDA 1994 MGA Zone 55
Scale: A3

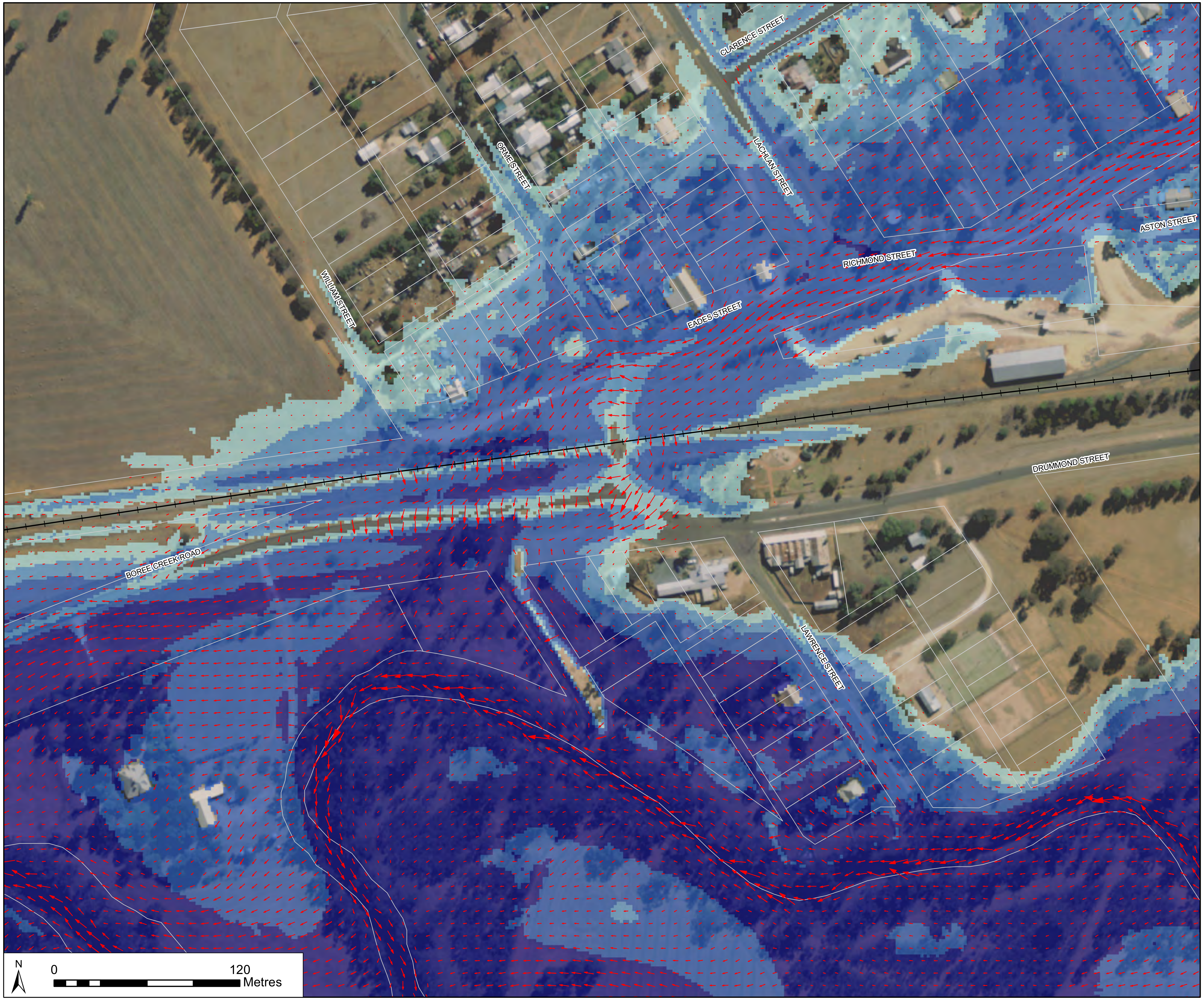
Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	1% AEP Event Hot Spot Map 1
TOWN	Boree Creek
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN AG	PROJECT # IA055600	FIGURE E-15
CHECK AH	DATE 12/14/2015	



Legend

- Velocity (m/s)
- Railway
- Cadastre

flood depth (m)

- 0.15 - 0.3
- 0.3 - 0.5
- 0.5 - 1.0
- > 1.0

Depths below 150mm have been trimmed from this map

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	1% AEP Event Hot Spot Map 2
TOWN	Boree Creek
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN AG | PROJECT # IA055600 | CHECK AH | DATE 12/14/2015

FIGURE E-16