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

Federation Council

Flood Study Report for Urana

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November 2017

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

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Cover photo: Urana Aquatic Centre Dam

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Revision	Date	Description	By	Review	Approved
1	15/10/2015	Progress Report – Urana Calibration and Verification Report	MR	A Hossain	A Hossain
2	23/06/2016	Progress Report – Urana Design Flood Estimation Report	MR, AH	A Hossain	A Hossain
3	29/08/2017	Draft Flood Study Report	MR, AH	A Hossain	A Hossain
4	22/09/2017	Draft Flood Study Report (public exhibition)	MR, AH	A Hossain	A Hossain
5	08/11/2017	Final Flood Study Report	AH	A Hossain	A Hossain

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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 (formerly Urana Shire 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 Urana.

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 Urana 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.

1. Introduction

Urana is located in Federation Council, approximately 100km northwest of Albury and 100km southwest of Wagga Wagga. It has a population of 384 people (2016 census) and is located on the banks of the ephemeral Urangeline Creek (also known as Urana Creek) (refer **Figure 1-1)**. The creek flows in a north-westerly direction along the western side of the township and discharges into Lake Urana, a natural storage area approximately 4km downstream of the town. Lake Urana stores approximately 164,000ML when filled to its Cocketgedong Creek outlet level of 113.39m AHD (Bewsher 2002). High lake levels can influence flooding at Urana by reducing the hydraulic head and backing water up Urangeline Creek as far as the Urana Aquatic Centre Dam, just upstream of the village (Yeo 2013). Urana is serviced by a small informal levee running from Stephen Street to Chapman Street. An underground stormwater system drains water from Osborne and Chapman Streets and discharges it downstream of the levee.

Flooding in Urana occurs primarily from Urangeline Creek and to a lesser extent breakout flows from Billabong Creek. The floodwaters from Billabong Creek join Urangeline Creek upstream of Urana and are typically slow moving and peak well after the dominant Urangeline Creek peak (Yeo 2013). The town has experienced several major floods including June 1889, July 1891, June 1931, January 1934, October 1934, July 1936, January 1974, October 2010, February 2011 and March 2012. The 2012 flood is likely to be the largest flood event at Urana since 1889, and may be the highest flood since observations were documented (Yeo 2013). The Aquatic Centre Dam levee was overtopped by up to 0.6m and some 29 houses and 12 commercial/public sector buildings experienced above floor flooding. Approximately 84 properties had inundation of yards (Yeo 2013). A cut was placed in the embankment of the Aquatic Centre Dam during the flood events of 2010 and 2012 to take pressure off the spillway (Yeo 2013).

1.1 Objectives

The primary objective is to define the nature and extent of flood behaviour in and adjacent to Urana town. 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 Urana. 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

Legend

- Urana levee
- Railway
- Watercourses
- Cadastre

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.

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

DRAWN MR	PROJECT # IA055600	FIGURE 1-1
CHECK AH	DATE 25/08/2017	

Section 10: provides details on references citied in this report

Section 11: provides a glossary of terms used in this report

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

Appendix D: details on hydraulic modelling

Appendix E: contains flood maps for the design flood events

2. Available Data

2.1 Site Inspection

A site inspection was carried out on 28 October 2014 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 Department of Primary Industries – Water (DPI Water), State Emergency Services (SES) and the Bureau of Meteorology, were contacted to collect information on flooding, topographic data and flood evacuation etc. A summary of the information relevant to Urana is presented in the following sections.

2.2.1 Available Reports

- **Lockhart Flood Study, Lockhart Shire Council, July 2014 (WMAwater 2014)**

The report investigates flood behaviour in Lockhart due to flooding in Brookong Creek and its tributaries for the full range of flood events. Brookong Creek has a catchment area of 150 km^2 in Lockhart and flood events of March 2012 and October 2010 surpassed all previous flood events in term of both magnitude and damage. A global hydrologic model using WBNM was set up for the catchment area of Brookong Creek at Lockhart and a TUFLOW hydraulic model using 5m grid was set up for the flood study area. In the absence of recorded stream flow data for Brookong Creek, both models were calibrated and validated in tandem against observed flood levels of March 2012 and October 2010 flood events. Rainfall recorded at Lockhart Bowling Club was used to define the spatial distribution and the rainfall recorded at the Reid Street gauge (privately owned) was used to define temporal pattern of rainfall for both flood events. Initial losses of 20mm and 50mm were adopted for 2012 and 2010 flood events respectively. A continuing rain loss rate of 2mm/hour was adopted for both flood events. The flood event of March 2012 was similar to the 1% AEP event (peak discharge 231 m^3/s at Green Street causeway) and the October 2010 event was similar to the 2% AEP event (peak discharge 185 m^3/s at Green Street causeway).

- **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)**

This report, produced by the SES is a valuable document to understand flood behaviour within the local government area of Federation Council. The report contains general information about the floods in the region, including rainfall data, information about flood behaviour (levels, timing, depth, velocity, extent, history, etc.) and its consequences (buildings, yards, road affected, evacuations, etc). The key findings from the report on the town of Urana are provided below:

- The 2012 flood was the highest on record since the 1889 flood at Urana, and could be the highest in recorded history.
- The Urana Aquatic Centre Dam and the Railway embankment immediately downstream significantly control flooding in the town downstream. It is reported that the embankment of the Dam was overtopped along most of its length to a maximum depth of up to 0.6m and an approximately 10m long section of the embankment on the eastern side of the spillway was breached. The embankment of the disused railway appeared to serve as a detention basin.
- A section of Federation Way south of Urangeline Creek bridge, east of Urana, was overtopped.
- During the 2012 flood, the peak travel time between Boree Creek / Lockhart and Urana is estimated to be approximately 33 hours.

- Floodwaters from Billabong Creek arrived at Urana approximately 3 days after the flood peaked at Rand.
- Flood depths in Urana are relatively shallow (up to 1.0m) and velocities in the town are generally slow.
- Surveyed flood heights for 34 locations for the 2012 event are tabulated in the report along with descriptions of flood behaviour and a number of photographs of the flood.

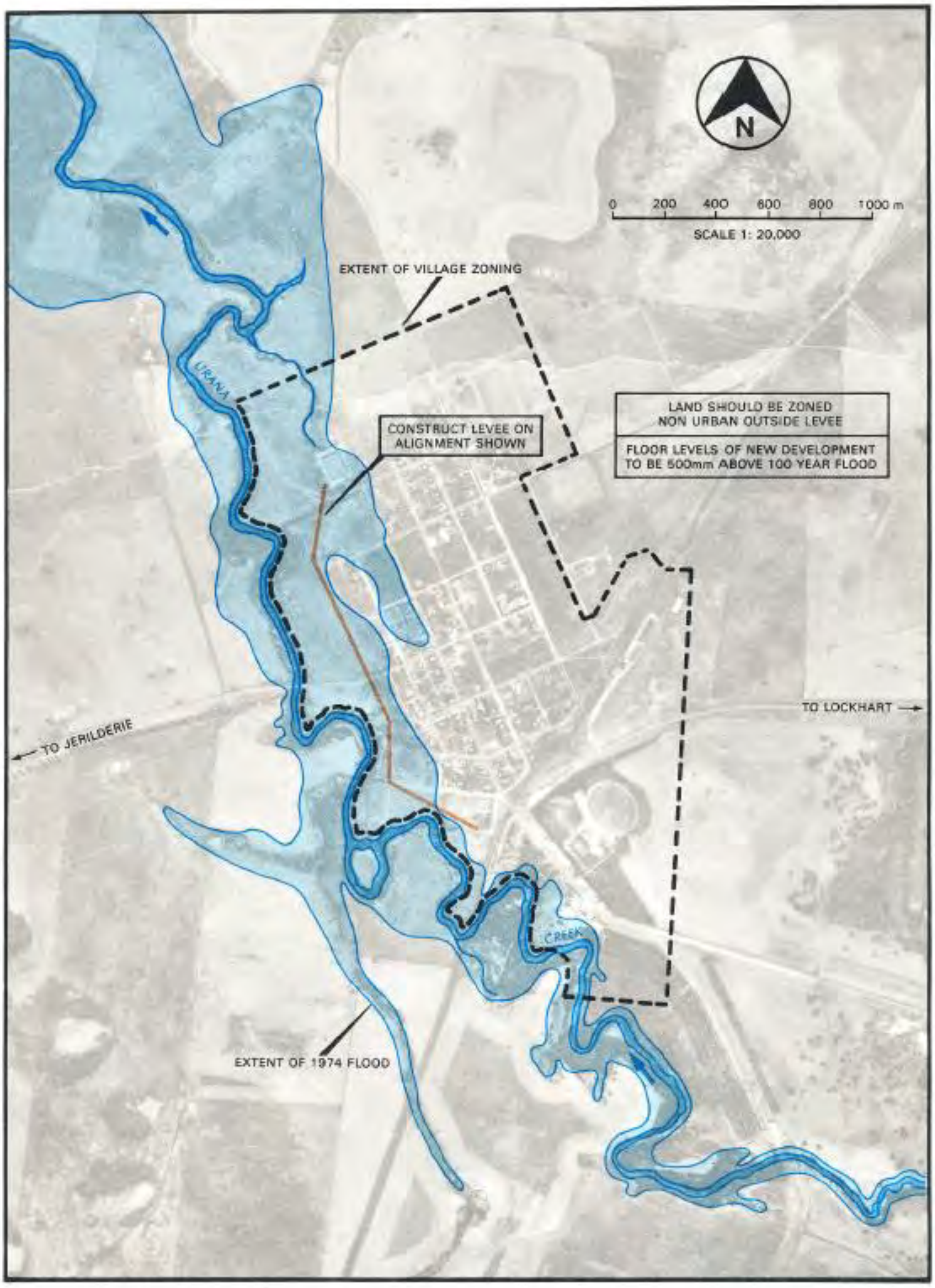
- **Billabong Creek Floodplain Management Plan (Bewsher 2002)**

Bewsher Consulting was engaged by the NSW Department of Land & Water Conservation in 1999 to undertake a floodplain management plan for Billabong Creek in two phases. The available data and the flood behaviour were reviewed in the first phase and a report entitled "Phase A – Data Review and Flood Behaviour, Main Report" was produced as the outcome of Phase A. The scope of the Phase A activities included community consultation; review of planning and environmental aspects; review of flood hydrology including review of rainfall records, streamflow records and flood extents; undertaking flood frequency analysis and formulation, calibration and verification of a hydraulic computer model using MIKE11. The MIKE11 model was calibrated against flood events of 1981 and 1970 and verified against flood events of 1974, 1983 and 1995. The MIKE11 model was subsequently used in the Phase 2 of the study to estimate flow distribution in the floodways for a range of floodplain management options. A floodway network was adopted in the Billabong Creek Floodplain Management Plan (DNR 2006) for which the adopted design flood was the flood event of 1983 (25 year average recurrence interval) in the vicinity of Urana. The flood event of 1974 (32 year average recurrence interval) was the design flood for the lower floodplain of Billabong Creek.

- **Murrumbidgee Valley Floodplain Management Study (SKP 1987)**

The study was one of a series of studies carried out on major inland river valleys of NSW. A principle objective of the study was the preparation of an atlas of maps showing land subject to flooding. Billabong Creek was included in the Lower Murrumbidgee Floodplain Atlas. The atlas includes five plans for the Billabong Creek floodplain between Walbundrie and Jerilderie, at a scale of 1:100,000. The extent of flood affected land was based on the extent of inundation experienced in the 1974 flood, determined through a number of interviews with landholders. The flood extent for the 1974 flood event and the floodplain management plan for Urana are shown in **Figure 2-1**. The floodplain management plan included alignment of a proposed levee to protect the town from flooding.

Figure 2-1 Physical Features and Floodplain Management Plan for Urana (*source: SKP 1987*)



2.2.2 Topographic Data

2.2.2.1 LiDAR Data

LiDAR data for Urana was provided by OEH which was originally captured by NSW Land and Property Information (LPI) between 10 July and 25 November 2013 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 grid data and is shown in **Figure 2-2**.

2.2.2.2 SRTM Data

The Shuttle Radar Topography 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 a 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 Urangeline Creek, which are located beyond the extent of the LiDAR data.

2.2.2.3 Aerial Photography

Aerial photography was obtained from Council. Urana is covered by the 'Urana' tile. It was captured in 2008. It has a 50cm resolution and was provided as a georeferenced raster. Aerial flood photography was also provided for the October 2010 flood over the region. This is provided as a false colour image over Urana showing limited out of bank flooding implying that the imagery was captured several days after the flood event peaked in Urana. The exact date of capture of the imagery is not known.

2.2.2.4 Stormwater Details

A CAD file for Urana was provided by Council (shown in **Appendix A**). This outlines the boundaries and features in Urana including roads, buildings, stormwater network and culverts. Some drainage details are given. The drawing was compiled in February 2009.

2.2.2.5 Additional Topographic Data

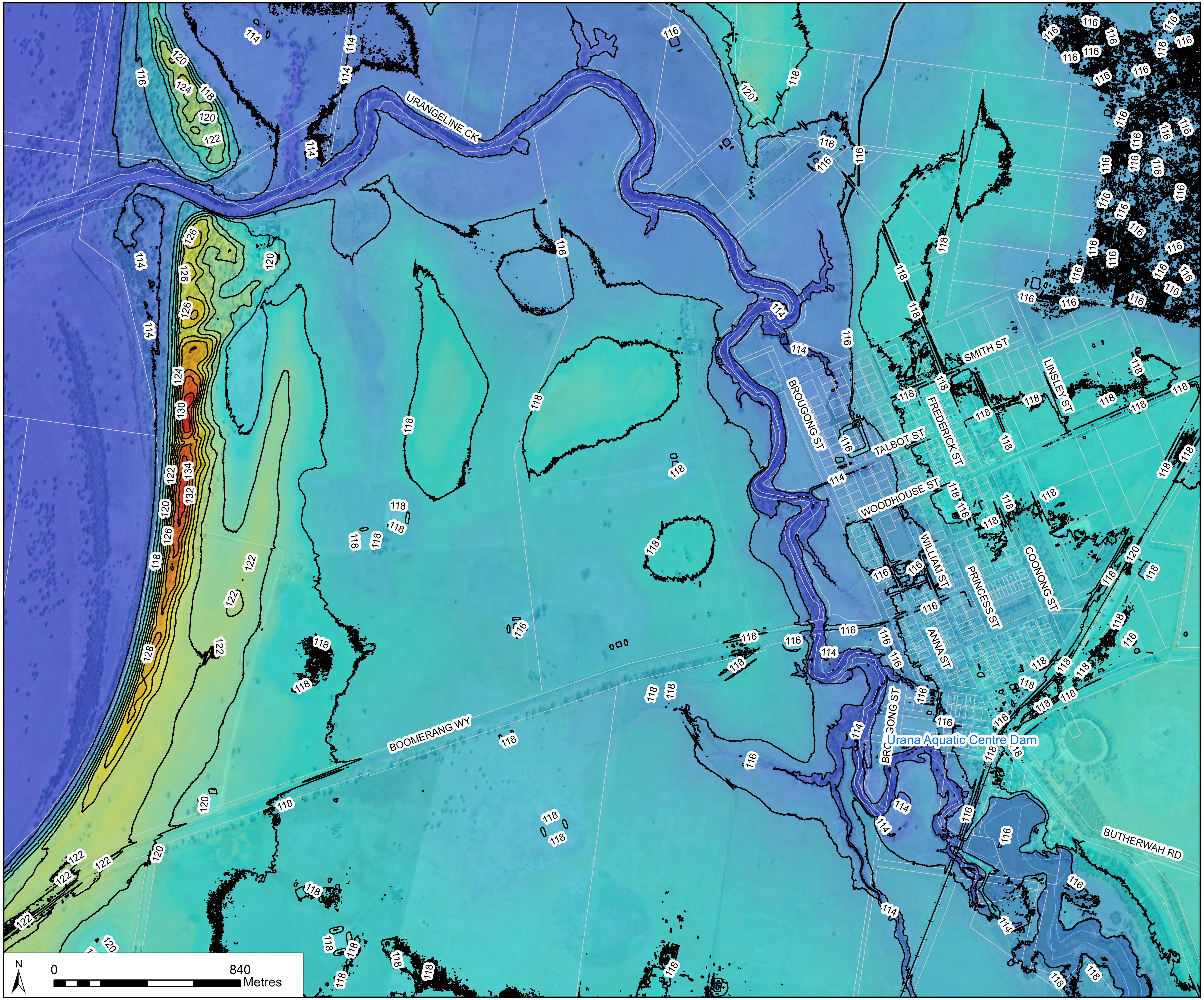
Additional topographic features, such as stream networks, road and rail networks, and cadastral boundaries were held in-house and utilised for this study.

2.2.3 Rainfall Data

Rainfall data used in this study was for a RORB model of Urangeline Creek to Lake Urana. The details of the rainfall data used are contained in the following sections.

2.2.3.1 Daily Rainfall

The Bureau of Meteorology (BoM) maintains a network of daily rainfall gauges and there are a number of them located in and adjacent to the Urangeline Creek catchment. Data for 8 sites was obtained from the Bureau's website. A summary of the rainfall stations used is tabulated in **Table 2-1** and their location is displayed in **Figure 2-3**. A private rain gauge, also located in the catchment (Illawong, 9547 Mahonga Rd), was recorded in the SES Flood Intelligence Report (Yeo 2013) and has data for the 2012 event. An average of three private rain gauges located in the Boree Creek catchment, also recorded in Yeo 2013, was used in the absence of rainfall data at the Boree Creek official gauge for the 2012 event.



Legend

- 2m contours
- Cadastre
- Railway
- Watercourses

Urana DEM

Elevation (m AHD)

High : 135

Low : 110

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.

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

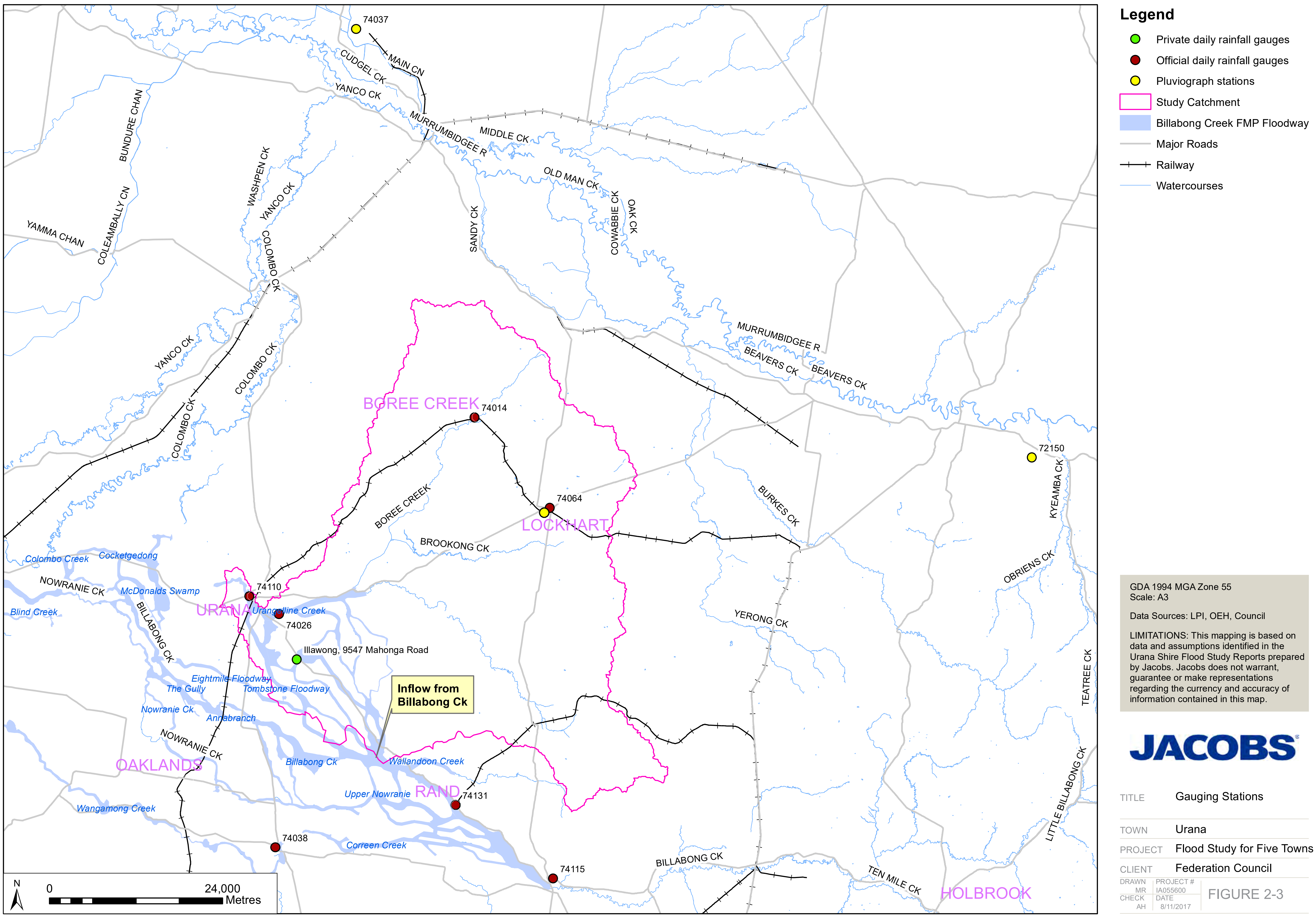
DRAWN MR	PROJECT # IA055600	FIGURE 2-2
CHECK AH	DATE 25/08/2017	

Table 2-1 Daily rainfall gauge data used for Urana

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
074026	Urana (Butherwah)	1/3/1870	31/01/2015	145.0	95.8
074038	Daysdale (Dennison St)	1/11/1914	31/03/2013	98.5	97.1
074064	Lockhart Bowling Club	1/12/1898	24/02/2015	116.3	97.1
074110	Urana Post Office	1/1/1871	24/02/2015	144.2	93.6
074115	Walbundrie (Crediton Street)	1/2/1882	31/01/2015	133.1	82.5
074131	Rand Post Office	1/06/1954	6/08/2011	57.2	99.0
074257	Pleasant Hills (Killarney)	1/01/1963	31/12/2011	49.0	69.7

2.2.3.2 Pluviograph

The BoM and DPI Water hold pluviograph data in catchments adjacent to Urangeline Creek. No sub-daily rainfall data exists within the Urangeline Creek catchment. Data for 3 pluviograph stations was obtained and are outlined in **Table 2-2**. These stations are also shown in **Figure 2-3**. Cumulative rainfall graphs are also provided for the 2010, 2011 and 2012 storm events in **Figure 2-4**, **Figure 2-5** and **Figure 2-6** respectively. It is to be noted that hourly pluviograph data from a private gauge located in Lockhart were provided by WMAwater for flood events of October 2010 and March 2012. The pluviograph data became available at the later stage of this study and considering the similarity of the data for the 2010 flood event to the data recorded at Yanco gauge, the data for the private gauge was used for the flood event of 2012.



Legend
Private daily rainfall gauges
Official daily rainfall gauges
Pluviograph stations
Study Catchment
Billabong Creek FMP Floodway
Major Roads
Railway
Watercourses
74037
MAIN CN
CUDGEL CK
YANCO CK
MURRUMBIDGEE R
MIDDLE CK
OLD MAN CK
BUNDURE CHAN
COLEAMBALLY CN
YAMMA CHAN
WASHPEN CK
COLOMBO CK
SANDY CK
COWABBIE CK
OAK CK
BEAVERS CK
BOREE CREEK
74014
74064
LOCKHART
BROOKONG CK
BURKES CK
72150
KYEAMBA CK
OBRIENS CK
YERONG CK
TEATREE CK
Colombo Creek
Cocketgedong
NOWRANIE CK
McDonalds Swamp
Blind Creek
BILLABONG CK
74110
URANA
Urangeline Creek
74026
Illawong, 9547 Mahonga Road
Eightmile Floodway
The Gully
Tombstone Floodway
Nowranie Ck
Annabranch
Inflow from Billabong Ck
OAKLANDS
Billabong Ck
Wallandoon Creek
Upper Nowranie
RAND
74131
Wangamong Creek
74038
Correen Creek
74115
BILLABONG CK
TEN MILE CK
HOLBROOK
LITTLE BILLABONG CK
N
0
24,000
Metres
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.
TITLE Gauging Stations
TOWN Urana
PROJECT Flood Study for Five Towns
CLIENT Federation Council
DRAWN MR
CHECK AH
PROJECT # IA055600
DATE 8/11/2017
FIGURE 2-3

Table 2-2 Pluviograph data used for Urana

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
401015	Bowna Creek at Yambla	DPI Water	Every 0.2mm	Oct 2010, Feb 2011, Mar 2012

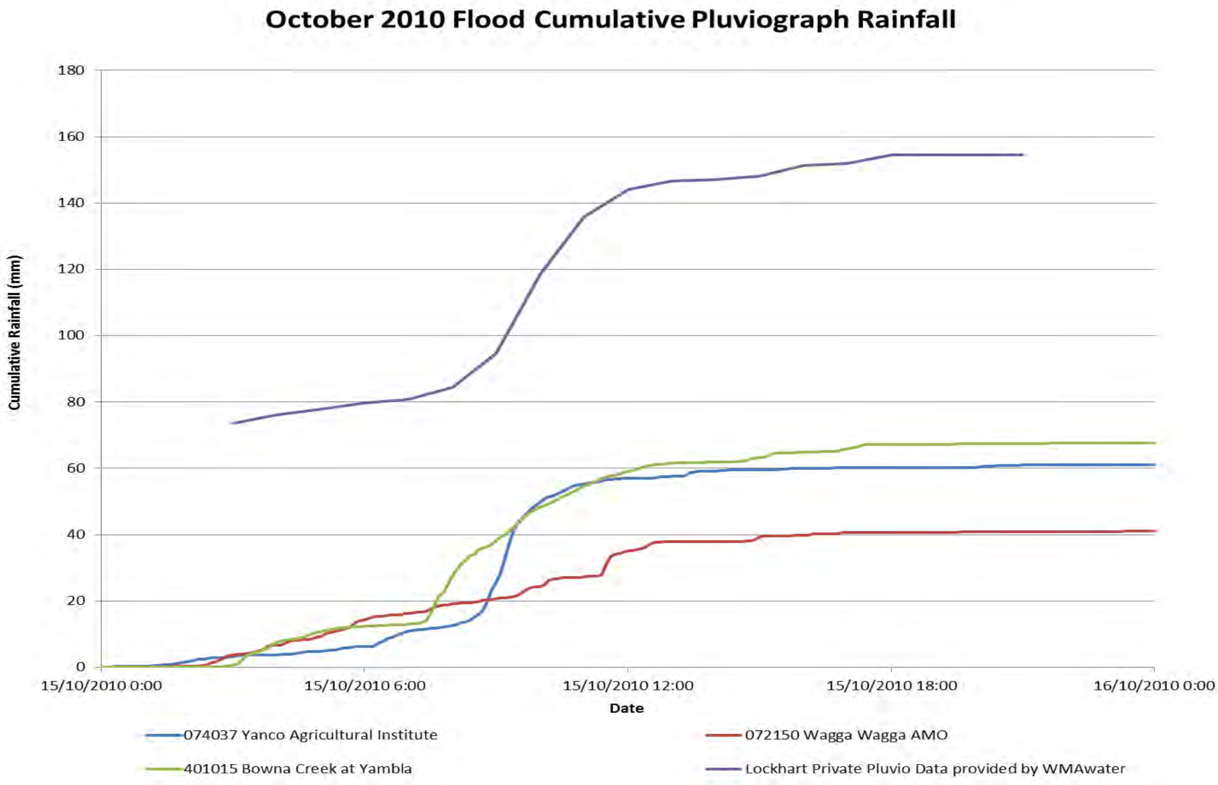


Figure 2-4 Cumulative pluviograph rainfall for the October 2010 event

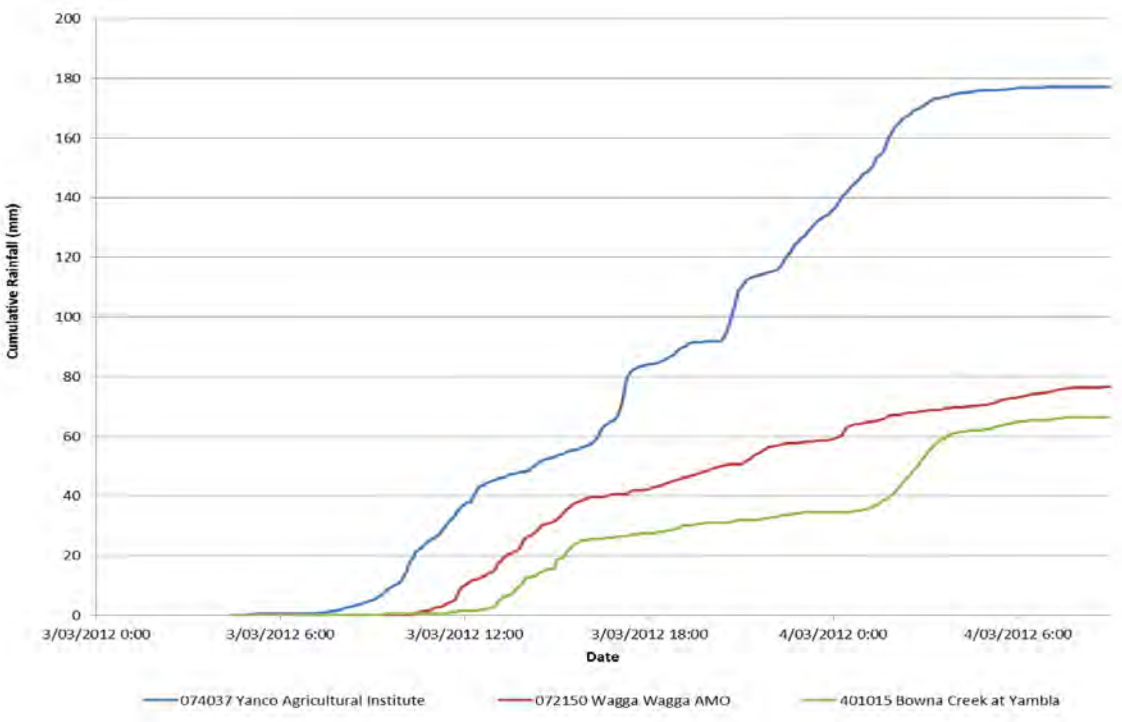


Figure 2-5 Cumulative pluviograph rainfall for the February 2011 event

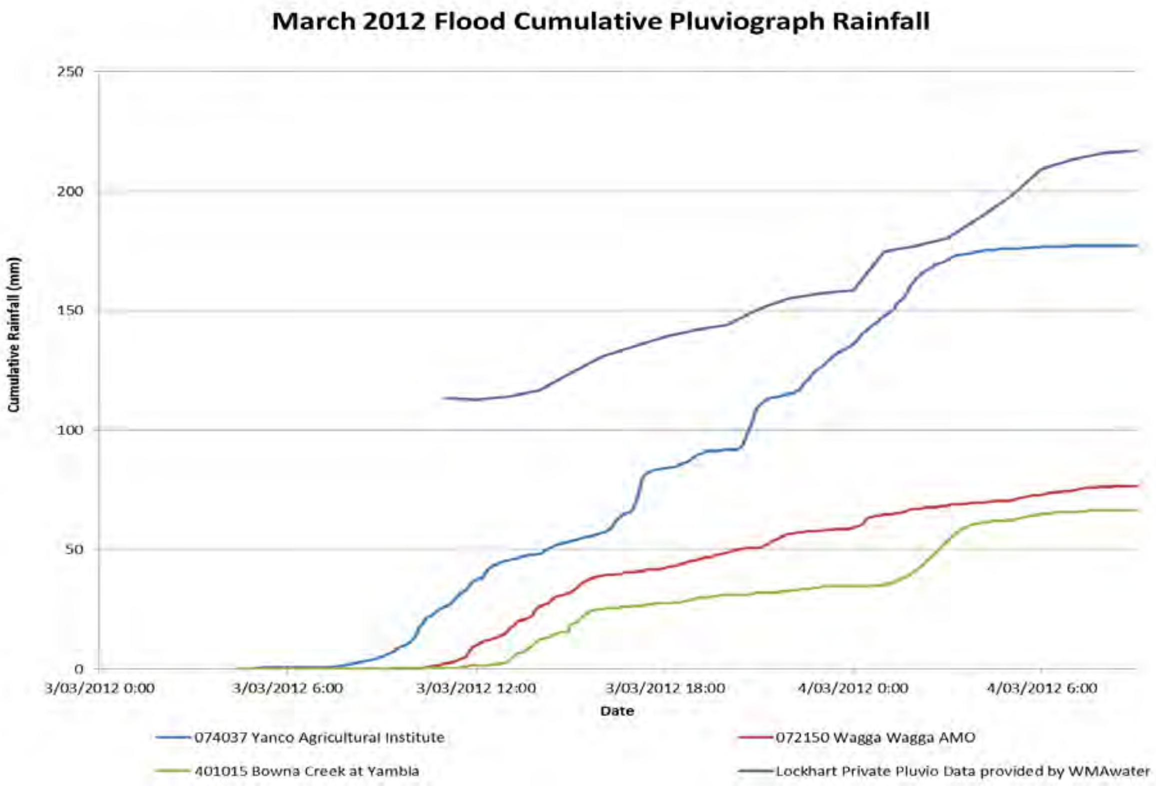


Figure 2-6 Cumulative pluviograph rainfall for the March 2012 event

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2.2.4 Streamflow Data

There are no stream gauges located on Urangeline Creek or its tributaries.

2.2.5 Flood Modelling Data

The MIKE11 modelling data from the Bewsher 2002 study was collected by Jacobs from NSW Office of Environment and Heritage for use in this study. The MIKE11 model was developed using version 2000 of MIKE11. A schematic of the MIKE11 model is presented in **Appendix D**. The model uses 1D flowpaths with link channels to represent a quasi-2D flood behaviour. MIKE11 cross sections are not geo-referenced within the model, however, a list of each cross section and its location is reported.

The MIKE11 model will be used to define distribution of discharges between Billabong Creek and its flood runners located in the vicinity of Rand, Urana and Oaklands for the full range of flood events up to and including the PMF. In order to use the MIKE11 model in this study, the model was updated to v2014 of MIKE11. The updated model was run for the flood event of 1974 and a comparison of peak flows at modelled cross sections indicated almost no change in modelled peak flows in Billabong Creek at Rand (Chainage 37,000m), Nowranie Creek near Oaklands (Chainage 43,910m) and Urangelaine Creek at Urana (Chainage 99,750m).

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

There were no residents in Urana that responded to the questionnaire. This is due to the fact that residents provided detailed information on flooding to the study undertaken by the NSW SES (Yeo 2013) and no major flooding occurred in Urana after the flood events of 2012.

2.4 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 and agreed with Council, 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, etc) for 5 culverts (Culvert No. 2 and No 4-7);
- Details for 4 bridge structures listed below. Details included deck and underside levels, length, width, railing height, location and width of piers and photographs.
  - Collingullie-Jerilderie Road / Cocketgedong Road over Urangeline Creek
  - Oaklands Railway Line bridge directly downstream of the Urana Dam spillway
  - Oaklands Railway Line bridge just south of the Urana Dam spillway
  - Oaklands Railway Line bridge crossing a small tributary of Urangeline Creek, south of Urana Dam
- Details of the Urana Aquatic Centre Dam (including spot heights along its embankments, details of the low-flow outlet and spillway, including photographs;
- Details of the Urana levee, extending approximately 480m from Stephen Street to Chapman Street (including spot heights along its length and photographs); and
- Details of the two underground stormwater networks on Osborne and Chapman Streets. Details included the location, size, top level and invert levels of pits, pipe sizes and their outlet (downstream of the Urana levee).

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 Urana is presented in **Appendix A**.

Another topographic survey was undertaken by Federation Council on 2 June 2017 to capture the existing spot levels along the north-western embankment of Urana Aquatic Centre Dam. The survey works was undertaken to confirm crest levels for the lowered section of the embankment which was lowered after the flood event of 2012.

3. Catchment Hydrology

3.1 Catchment Description

Urangeline Creek drains a catchment area of approximately 2,370km^2 to Lake Urana. Tributaries of Urangeline Creek include Boree Creek and Brookong Creek from the north (via Hallidays Cut and Lake Cullivel), and Washpool Creek and Sandhill Creek from the south. Urangeline Creek also receives floodwater from Billabong Creek when it breaks out along its northern bank, downstream of Mahonga Hill. These floodwaters flow into Washpool Creek, Sandhill Creek and the Tombstones floodway (among others). These water sources combine and flow into the Urana Aquatic Centre Dam, located just upstream of the Urana town. The creek then flows along the western edge of the town and discharges into Lake Urana, approximately 4km downstream. Lake Urana is a large natural storage, with a capacity of approximately 164,000ML when filled to its Cocketgedong Creek outlet level of 113.39m AHD (Bewsher 2002). When the lake reaches this level, water is discharged via Cocketgedong Creek which flows into Billabong Creek near its confluence with Colombo Creek. High lake levels can influence flooding at Urana by reducing the hydraulic head and backing water up Urangeline Creek as far as the Urana Aquatic Centre Dam, just upstream of the village (Yeo 2013).

The Urangeline Creek catchment is predominantly cleared rural land, with the majority of land being used for grazing, dryland cropping and horticulture. The catchment's highest elevation is approximately 380m AHD, however, it commonly rises from 250m to 300m AHD along a ridge on its eastern boundary and drains westward to Lake Urana, which has a bed level of approximately 110m AHD.

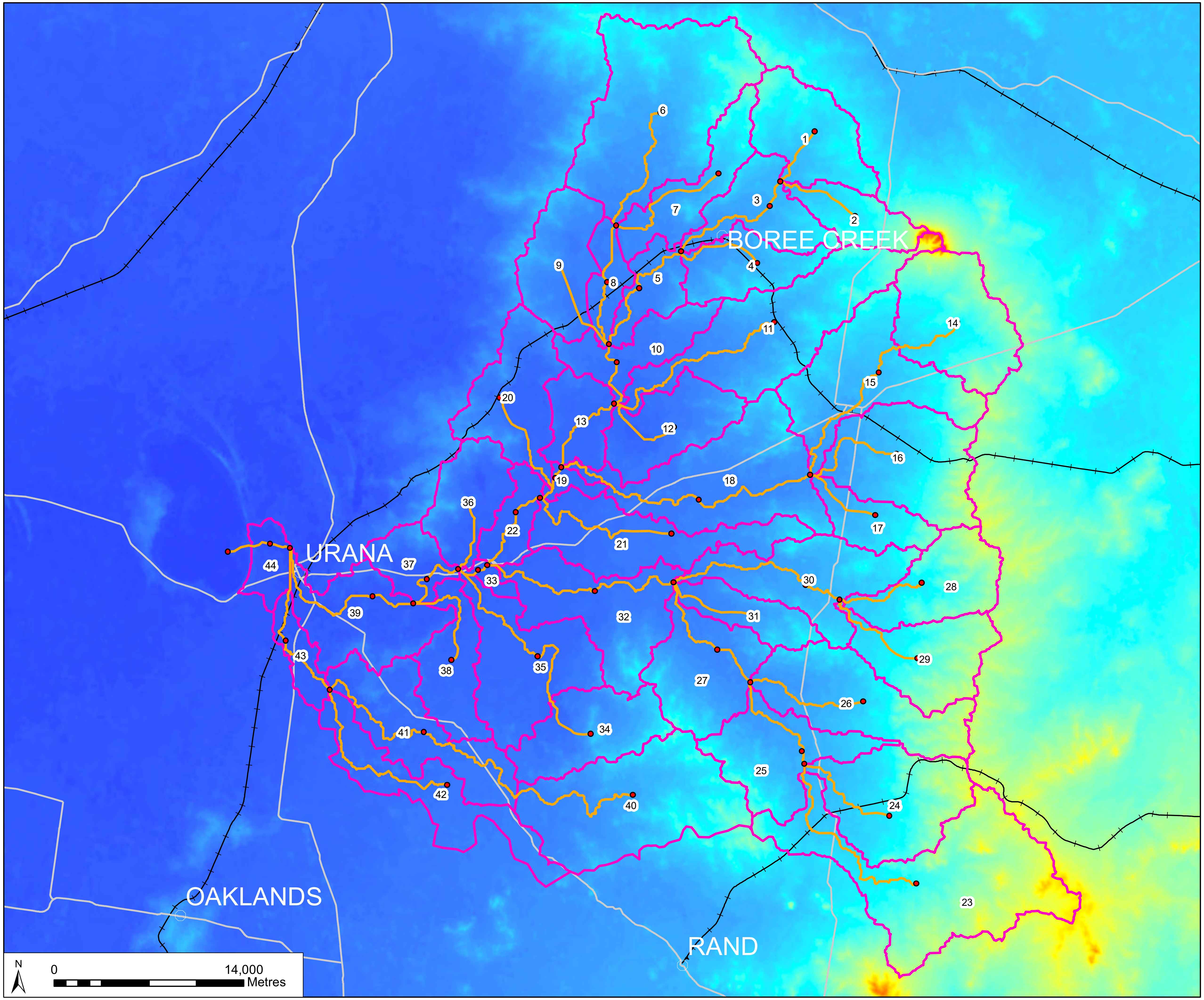
3.2 Catchment Modelling

3.2.1 Methodology

The Urangeline Creek catchment to Lake Urana was modelled using RORB (version 6.18), a runoff routing program (Laurenson et al 2010). RORB is one of the most widely used models of its type in Australia, and consequently there is substantial information available on the value of the model parameters for a wide range of catchments. The model has the capability to simulate both linear and non-linear catchment behaviour, and exhibits many desirable modelling features, such as areally distributed inputs, flexible reservoir-routing options and the ability to model flows at a number of points throughout the catchment.

3.2.2 RORB Model Configuration

The Urangeline Creek sub-catchments were delineated based on the 30m SRTM DEM, which covers the entire catchment to be modelled. A total of 44 sub-catchments were delineated to Lake Urana, covering an area of 2,370km^2. An outline of the RORB catchments is shown in **Figure 3-1**. Catchment routing channels followed overland flow paths and elevations were obtained from the SRTM DEM. The model was developed using MiRORB. A nominal impervious fraction of 5% was used across the catchment. Further details on the RORB model are provided in **Appendix C**.



Legend

- RORB nodes
- RORB links
- RORB subcatchments
- Railway
- Major Roads

SRTM DEM

Elevation (m AHD)

High : 380

Low : 90

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	RORB Model Setup
TOWN	Urana
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE 3-1
CHECK AH	DATE 25/09/2017	

4. Hydraulic Modelling

4.1 Model Selection

A TUFLOW combined one-dimensional (1D) and two-dimensional (2D) hydrodynamic model has been developed for Urana. 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.

4.2 TUFLOW Model Configuration

4.2.1 Extent and Structure

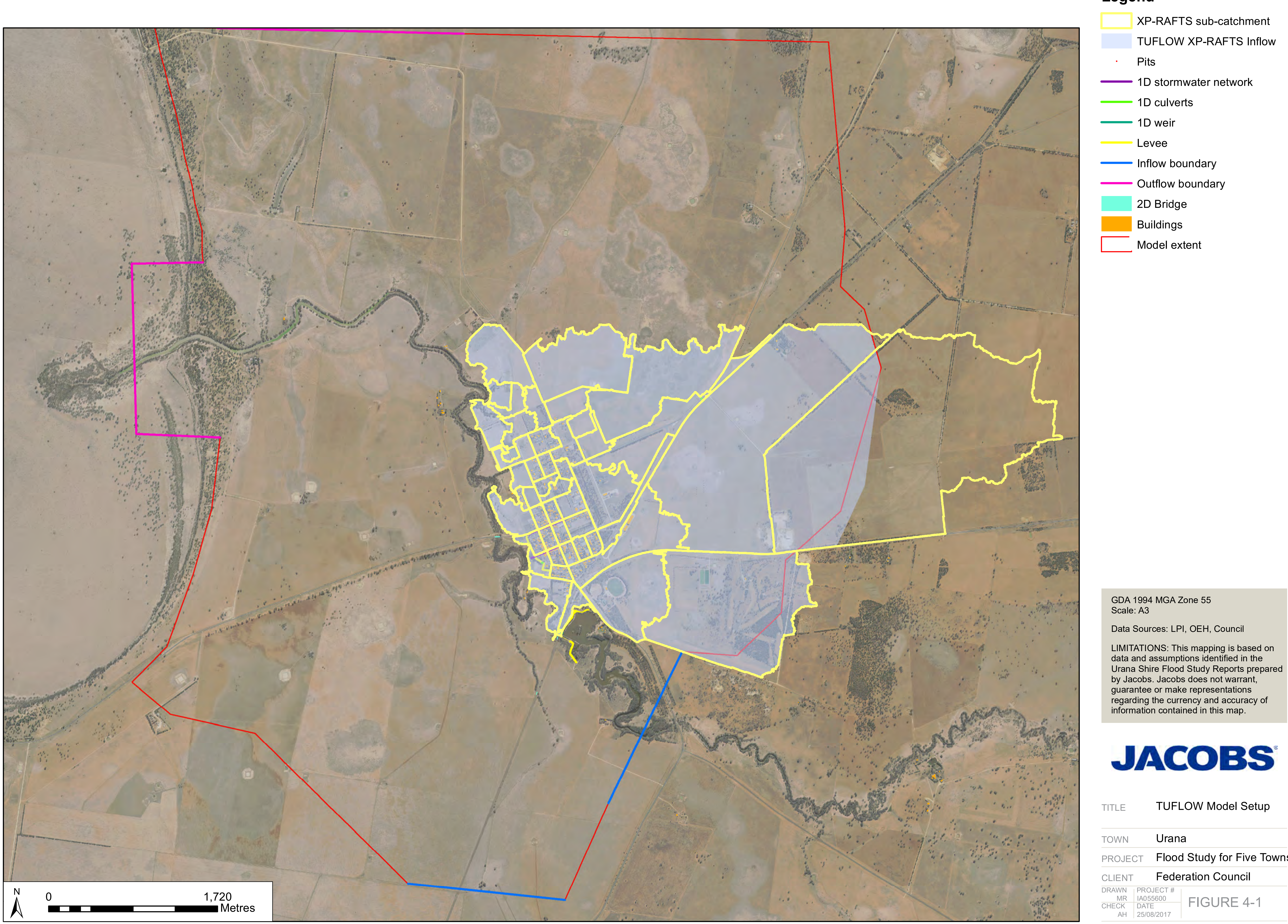
The Urana TUFLOW model is comprised of:

- A 2D domain of the catchment surface reflecting the catchment topography, with varying roughness as dictated by land use
- 1D representations of the culvert structures and the surveyed underground stormwater network, dynamically linked to the 2D domain
- 1D representation of the Urana Aquatic Centre Dam spillway and a 2D z-line was used to define the embankment of the Dam on the basis of the topographic survey data
- A 2D z-line was used to define the levee on the basis of the topographic survey data
- A 2D representation of the bridge structures including 3 railway bridges and 1 road bridge
- 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**.

4.2.2 Model Topography

The topography of the catchment is represented in the model using a 5m grid. The grid size was selected to optimise model run time and to achieve a level of precision required for adequate representation of the main channel of Urangeline Creek and flood behaviour within the study area. The basis of the topographic grid used in the TUFLOW model is the LiDAR data set for Urana (**Figure 2-2**).



Legend
XP-RAFTS sub-catchment
TUFLOW XP-RAFTS Inflow
Pits
1D stormwater network
1D culverts
1D weir
Levee
Inflow boundary
Outflow boundary
2D Bridge
Buildings
Model extent
N
0
1,720
Metres
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 Urana
PROJECT Flood Study for Five Towns
CLIENT Federation Council
DRAWN MR
CHECK AH
PROJECT # IA055600
DATE 25/08/2017
FIGURE 4-1

4.2.3 Bridges

There are three railway bridges that are included in the model – two in the vicinity of Urana Dam and one to the south of the dam. There is one road bridge modelled – Collingullie Jerilderie / Cocketgedong Road crossing Urangeline Creek. These bridges were modelled as 2D structures and the details of these bridges were obtained from the topographic survey undertaken for this study by TJ Hinchcliffe & Associates in 2015. The underside, deck and railing levels were included in the model along with a blockage and form loss factor for each layer.

4.2.4 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.

4.2.5 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.

4.2.6 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

4.3 Boundary Conditions

4.3.1 Model Inflows

The Urangeline Creek RORB model was used to generate flows for the 2010, 2011 and 2012 flood events. Details on the input data used to generate the inflow hydrographs are provided in **Section 5.2**. These flows, in combination with hourly flow data for Billabong Creek @ Walbundrie gauge were extracted from PINNEENA for the same flood events were used in the MIKE11 model developed for the Billabong Creek Floodplain Management Plan (Bewsher 2002). The model simulates the complex interconnecting floodways between Billabong Creek and Urangeline Creek. Simulated flows at MIKE11 cross section “URANGELINE 97507.5”, “TOMBSTONES 25100” and “U/S RAIL 1 4732.33” (refer **Appendix D1**) were used as the upstream inflows for the TUFLOW model. The modelled water level in Lake Urana was used as the downstream boundary. These hydrographs and stage curve are shown in **Figure 4-2** to **Figure 4-4** for the 2010, 2011 and 2012 flood events.

Figure 4-2 : MIKE11 modelled flows upstream of Urana and water level in Lake Urana for 2010 Flood

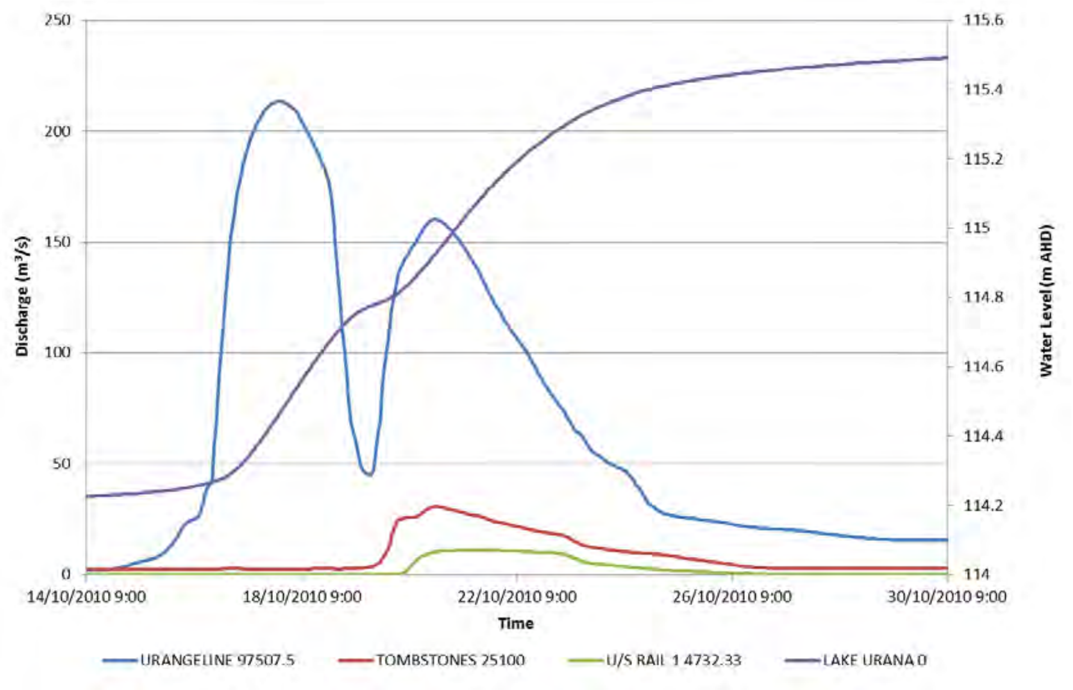


Figure 4-3 : MIKE11 modelled flows upstream of Urana and water level in Lake Urana for 2011 Flood

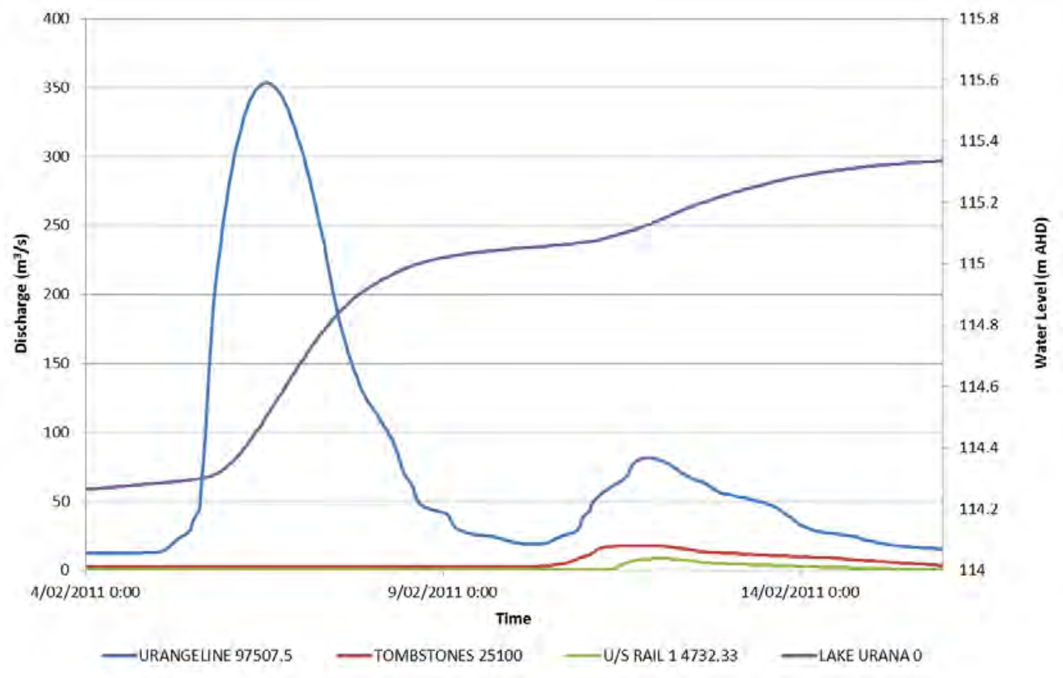
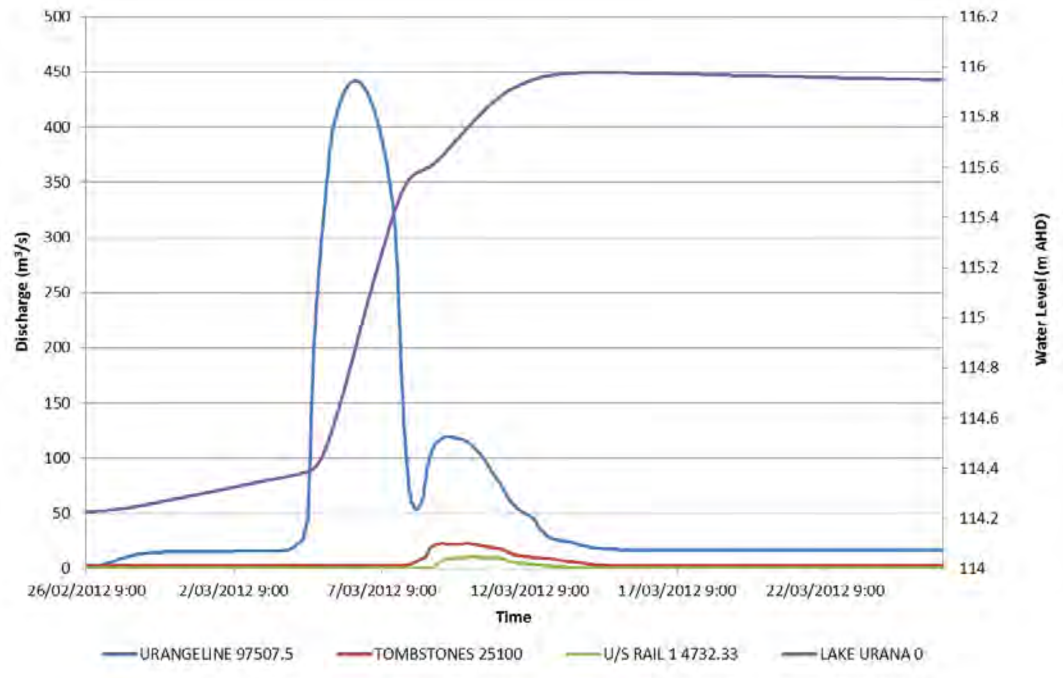


Figure 4-4 : MIKE11 modelled flows upstream of Urana and water level in Lake Urana for 2012 Flood



4.3.2 Tailwater Conditions

The TUFLOW model for Urana incorporated three downstream boundaries, including Lake Urana and two breakout locations to the north of the town. The lake boundary was a dynamic water level boundary (see **Figure 4-2** to **Figure 4-4** for the 2010, 2011 and 2012 stage curves) simulated by the MIKE11 model. The lake boundary was located approximately 4km downstream of the town. The water level in the lake can impact on the flow of Urangeline Creek past the town since the backwater can extend as far as Urana Dam. Water that inundates the floodplain just upstream of Lake Urana can also flow north. Two normal depth boundaries have been used at this location, approximately 5km downstream of the town.

4.3.3 Initial Conditions

Small inflows were assumed at the start of the model runs and an initial water level was set in the lake (including the effect of backwater).

5. Calibration and Verification

5.1 Selection of Calibration and Verification Events

Floods events that impacted Urana in the past occurred in 1889, 1891, 1931, 1934, 1936, 1974, 2010, 2011 and 2012. Due to availability of accurate flood level data, however, the most recent flood events of 2010, 2011 and 2012 was selected for calibration and verification of hydrologic and hydraulic models. Since there are no stream gauges on Urangeline 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 Urana RORB model was calibrated to the 2012 flood event through a simultaneous calibration process with the TUFLOW hydraulic model. A number of rainfall gauges located across the catchment were used to determine the spatial variability of the rainfall event. The available pluviograph data shown in **Table 2-2** was used to define the timing and the temporal distribution of the rainfall across the catchment. The adopted rainfall loss parameters were 25mm initial loss and 2.0mm/hr continuing loss. These were the parameters that were calibrated for the Boree Creek hydrologic model (Jacobs 2017a) and used in the Lockhart Flood Study (WMAwater 2014) for the 2012 flood event. Both of these areas are located in the upper Urangeline Creek catchment. The ‘m’ value was retained at the recommended 0.8 and the adopted ‘Kc’ value was 117.5 for the catchment draining to the inflow location of the MIKE-11 model. The calibrated Kc value used the ‘RORB Manual’ (Laurenson et al. 2010) recommended value and increased it by 20%. This was similar to the calibrated Kc parameter in the modelled adjacent catchment (Billabong Creek to Walbundrie – see Jacobs 2017b for details), where the Kc value was slightly higher than that recommended by the RORB Manual Equation.

5.2.2 2010 Event

The Urana RORB model was verified with the 2010 flood event through a simultaneous calibration process with the TUFLOW hydraulic model. A number of rainfall gauges located across the catchment were used to determine the spatial variability of the rainfall event. The available pluviograph data shown in **Table 2-2** was used to define the timing and the temporal distribution of the rainfall across the catchment. The adopted rainfall loss parameters were 50mm initial loss and 2.0mm/hr continuing loss. These were the parameters that were calibrated for the Boree Creek hydrologic model (Jacobs 2017a) and used in the Lockhart Flood Study (WMAwater 2014) for the 2012 flood event. Both of these areas are located in the upper Urangeline Creek catchment. The ‘m’ value was retained at the recommended 0.8 and the adopted ‘Kc’ value was 117.5 for the catchment draining to the inflow location of the MIKE11 model. The calibrated Kc value used the ‘RORB Manual’ (Laurenson et al. 2010) recommended value and increased it by 20%. This was similar to the calibrated Kc parameter in the modelled adjacent catchment (Billabong Creek to Walbundrie – see Jacobs 2017b for details), where the Kc value was slightly higher than that recommended by the RORB Manual Equation.

5.2.3 2011 Event

The Urana RORB model was verified with the 2011 flood event through a simultaneous calibration process with the TUFLOW hydraulic model. A number of rainfall gauges located across the catchment were used to determine the spatial variability of the rainfall event. The available pluviograph data shown in **Table 2-2** was used to define the timing and the temporal distribution of the rainfall across the catchment. The adopted rainfall loss parameters were 25mm initial loss and 2.0mm/hr continuing loss. Given the lack of available data to calibrate against, these values are considered reasonable (Engineers Australia 2001). The ‘m’ value was retained at the recommended 0.8 and the adopted ‘Kc’ value was 117.5, as for the calibration events.

5.3 Hydraulic Modelling

5.3.1 2012 Event

The flows simulated by the MIKE11 model for this flood event were used as the upstream boundary conditions for the Urana TUFLOW model, with the simulated MIKE11 water level in Lake Urana used for the downstream boundary condition. The majority of flow entering the model is from Urangeline Creek. The flows exceed bankfull capacity and spill onto the floodplain upstream of Urana Dam. Water enters the dam but also bypasses to the left of the dam, overtopping the Boree Creek-Oaklands Railway Line. The dam spillway is activated and water overtops the dam levee along its right embankment. This is consistent with descriptions of the dam overtopping (Yeo 2013). Water is then restricted by the railway embankment immediately downstream as it serves as a detention basin. The peak of the flood overtops the railway line to a depth of 0.1 to 0.2m. This is higher than the reported depth of 0.02-0.03m. The Council observed afflux of about 0.8m was modelled to be approximately 0.4m. Downstream of the railway, the floodwaters enter the Urana township. Water from Urangeline Creek flows around and overtops the Urana Levee. Floodwaters extend as far as Coonong Street. The flow in the town is generally shallow (up to 1m) and has low velocities (less than 0.5m/s), which is consistent with reports of the flooding (Yeo 2013).

The flood map for the 2012 event can be seen in **Figure 5-1**. The modelled peak water level profile along Urangeline Creek near Urana can be seen in **Figure 5-2**. The flood extent is in good agreement with the approximate extent found in Yeo 2013. The floodwater extends east almost to Federation Way at the railway embankment location and crosses over William Street near Osborne Street. This water extends to Coonong Street. Further downstream the flood extends to between William and Princess Street. The approximate flood extent is largely based on aerial flood photography taken on 5th March 2012 by Kylie Esler and supplemented by street level photos (Yeo 2013).

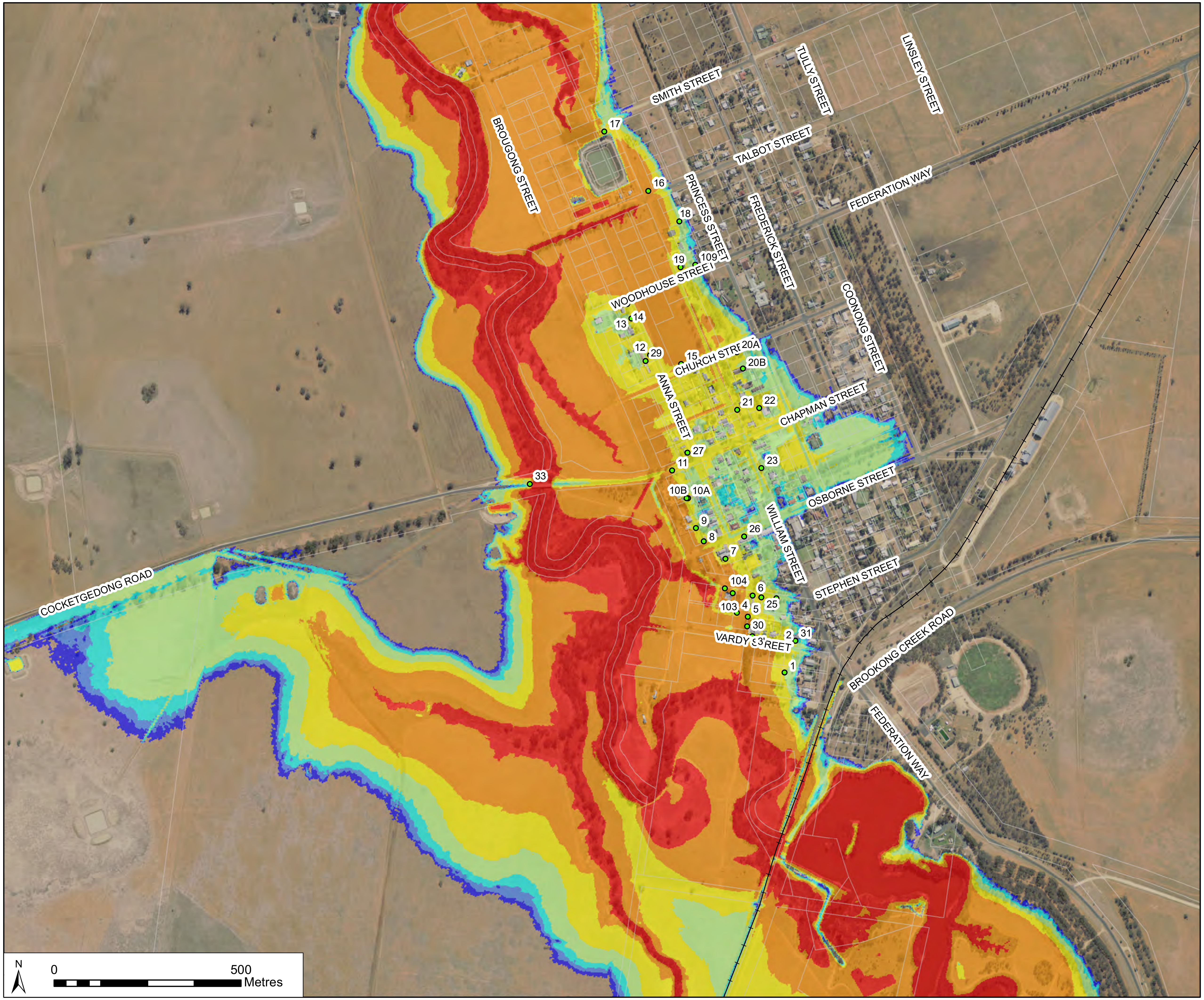
Following the 2012 flood event, Esler and Associates was engaged to survey a number of flood levels throughout Urana. A total of 34 flood levels are recorded in Yeo 2013. Federation Council provided 2012 flood levels at an additional three locations. A comparison of these flood levels with the modelled flood levels is provided in **Table 5-1**. The modelled flood levels (locations shown in **Figure 5-1**) are within 0.1m for those locations upstream of the Urana levee and along Urangeline Creek. The flood levels within the town are generally 0.1 to 0.4m higher. This is most likely due to the fact that there was an informal 'levee' constructed along Brougong Street and sand bags were placed along Vardy Street and Anna Street which would have restricted the flows into the town around the existing levee. Additional sandbagging may have also been implemented which would reduce flood levels around inhabited dwellings. Accurate details of these flood mitigation measures are not available and hence have not been modelled.

Table 5-1 Urana calibration results for the 2012 flood event

Location Reference	Recorded Flood Level (m AHD)	Modelled Flood Level (m AHD)	Difference (m)
1	117.10	117.12	0.02
2	117.04	117.11	0.07
3	117.07	117.10	0.03
4	117.01	117.08	0.07
5	117.02	117.08	0.06
6	117.03	117.07	0.04
7	116.87	117.07	0.19
8	116.76	117.05	0.28
9	116.78	117.03	0.26
10B	116.62	116.98	0.36
10A	116.60	116.97	0.37

Location Reference	Recorded Flood Level (m AHD)	Modelled Flood Level (m AHD)	Difference (m)
11	116.64	116.92	0.28
12	116.36	116.80	0.44
13	116.46	116.78	0.32
14	116.56	116.77	0.20
15	116.47	116.81	0.34
16	116.39	116.75	0.36
17	116.36	116.58	0.22
18	116.45	116.75	0.30
19	116.42	116.77	0.35
20A	116.60	116.81	0.22
20B	116.60	116.82	0.21
21	116.69	116.86	0.16
22	116.77	116.87	0.10
23	116.76	116.89	0.14
24	117.00	117.07	0.08
25	116.94	117.07	0.13
26	116.72	117.00	0.28
27	116.59	116.91	0.31
29	116.47	116.81	0.34
30	117.06	117.08	0.02
31	117.28	117.11	-0.17
32D	118.42	Outside modelled extent	
33	116.92	116.86	-0.05
103	117.17	117.07	-0.10
104	117.19	117.07	-0.13
109	116.69	116.77	0.08

The modelled 2012 flood is in good agreement with the flood marks, flood photography and descriptions of flooding, and where marked differences in flood levels, this can be explained by the temporary flood mitigation works that were undertaken during the flood but not included in the modelling.



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	Urana
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE 5-1
CHECK AH	DATE 25/08/2017	

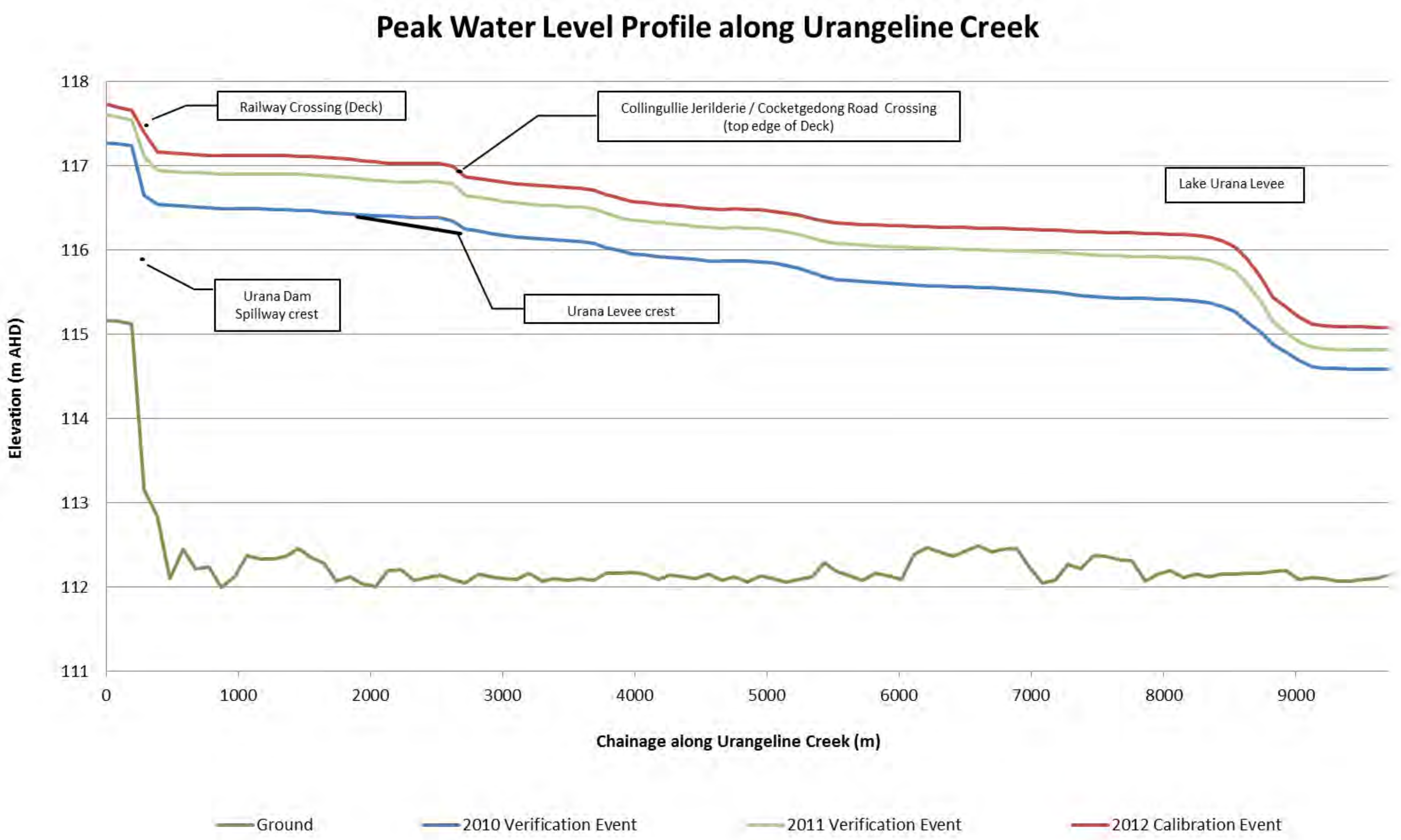
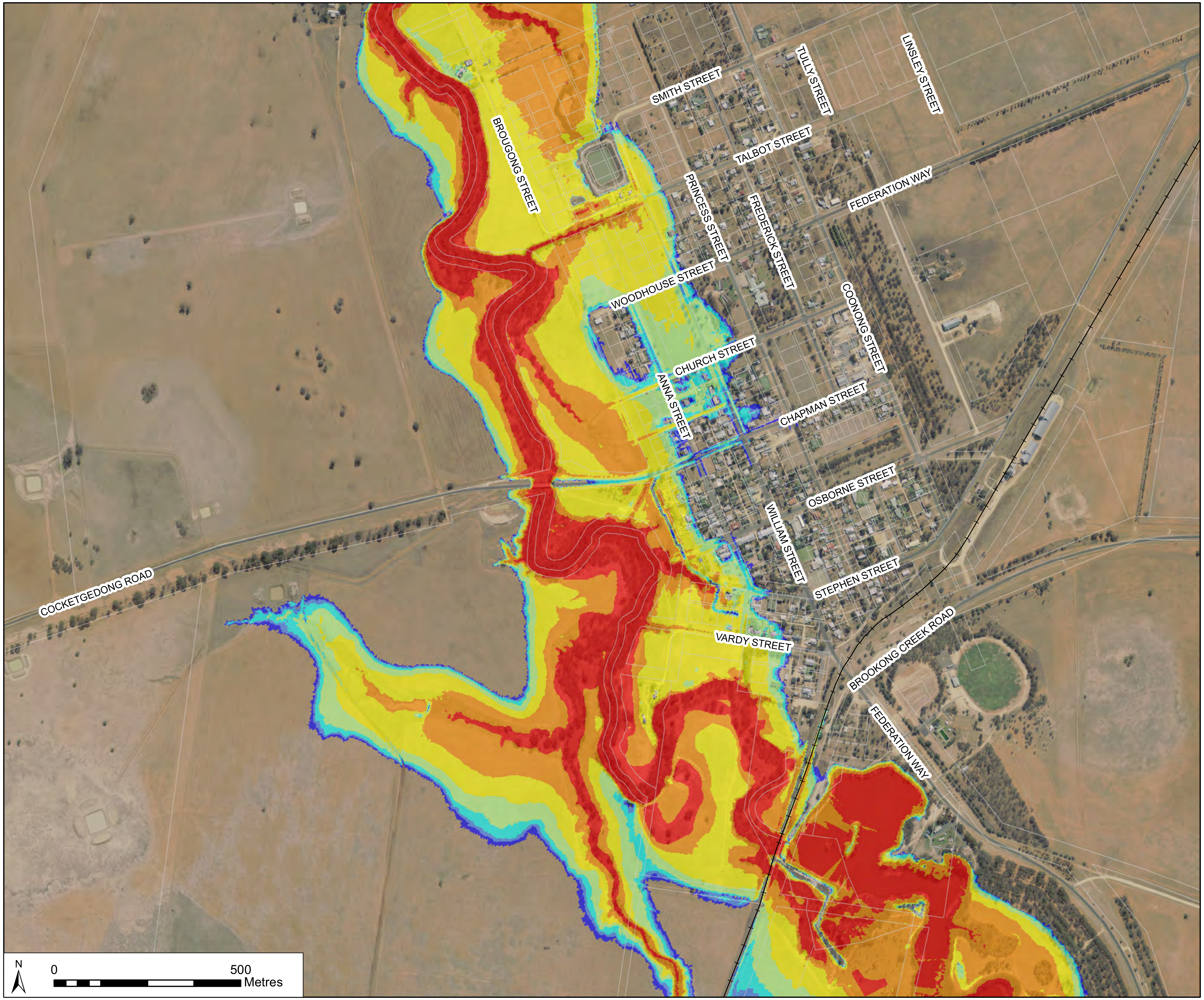


Figure 5-2 Peak Water Level Profiles along Urangeline Creek at Urana for calibration events

5.3.2 2010 Event

The flows simulated by the MIKE11 model for this flood event were used as the upstream boundary conditions for the Urana TUFLOW model, with the simulated MIKE11 water level in Lake Urana used for the downstream boundary condition. The majority of flow entering the model is from Urangeline Creek. The flows exceed bankfull capacity and spill onto the floodplain upstream of Urana Dam. Water enters the dam but also bypasses to the left of the dam but does not overtop the Boree Creek-Oaklands Railway Line. The dam spillway is activated and a small amount of water overtops the dam levee along its right embankment. While there was no overtopping recorded during this flood event, the dam levee was cut on the western side to ease pressure on the dam spillway (Yeo 2013). Water is then conveyed through the railway bridges towards Urana. A small amount of flow is conveyed around and over the Urana levee bank and into the town. This only extends to Anna Street where the levee is present, and just past William Street where the levee stops. The modelled flood behaviour is consistent with all available data for the flood event. The modelled peak water level profile along Urangeline Creek near Urana can be seen in **Figure 5-2**. The flood map for the 2010 event can be seen in **Figure 5-3**.



Legend

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

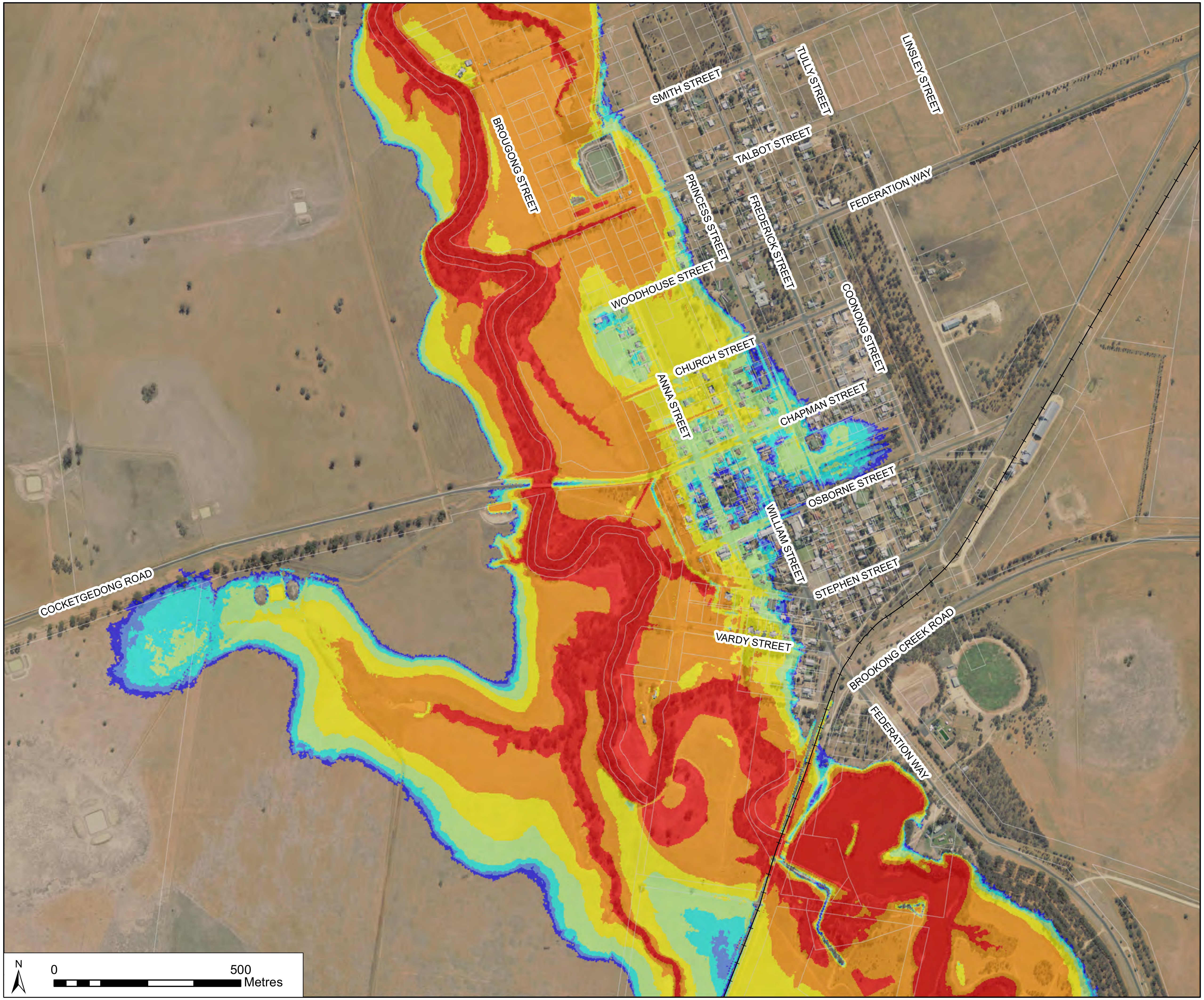
TITLE	2010 Verification Event Flood Depth Map
TOWN	Urana
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council
DRAWN MR	PROJECT # IA055600
CHECK AH	DATE 25/08/2017

FIGURE 5-3

5.3.3 2011 Event

The flows simulated by the MIKE11 model for this flood event were used as the upstream boundary conditions for the Urana TUFLOW model, with the simulated MIKE11 water level in Lake Urana used for the downstream boundary condition. The majority of flow entering the model is from Urangeline Creek. The flows exceed bankfull capacity and spill onto the floodplain upstream of Urana Dam. Water enters the dam but also bypasses to the left of the dam and causes some minor overtopping (< 0.1m) of the Boree Creek-Oaklands Railway Line. The dam spillway is activated and water overtops the eastern embankment (up to 0.15m deep). Although the water level in the dam was recorded to peak just 0.01m below the crest of the dam, the secondary spillway (cut in 2010) was still in operation (Yeo 2013) which accounts for the water modelled to overtop the dam levee. This additional spillway was not included in the modelling due to lack of data. Water is then conveyed through the railway bridges towards Urana. Water is conveyed around and over the Urana levee and inundates the town.

The flood extends to beyond Princess Street where the low point is located between Osborne and Chapman Streets. The extent of flooding is greater than the 2010 event. Three houses were recorded to be inundated along Stephen and Osborne Streets (Yeo 2013), and this is likely given the modelled flood depths of approximately 0.6m at the lower end of these streets where dwellings are located. Floodwater was reported to have reached the gutter in William Street adjacent to Urana Central School (Yeo 2013), however the modelled extent reaches the next street behind the school (Princess Street). This difference could be attributed to the fact that an emergency levee was constructed along Vardy and Anna Streets, with houses in Anna Street sandbagged also. This levee (not included in the modelling due to a lack of data) would restrict the flow that would enter the town around the existing levee. The modelled peak water level profile along Urangeline Creek near Urana can be seen in **Figure 5-2**. The flood map for the 2010 event can be seen in **Figure 5-4**. The modelled flood behaviour is reasonably consistent with all available data for the flood event.



Legend

- Railway
- Cadastre

2011 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	2011 Verification Event Flood Depth Map
TOWN	Urana
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE 5-4
CHECK AH	DATE 25/08/2017	

5.4 Sensitivity Analysis (2012 Flood Event)

A sensitivity analysis was conducted using the 2012 flood event, since it is the largest event experienced in over 100 years. The following hydraulic model parameters were changed: inflows, Manning's n roughness, blockage of structures and the downstream boundaries. 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 Hydrologic Parameter

The primary hydrologic parameter (Kc in the RORB model) was varied by +/-20%. Increasing the Kc value by 20% results in a reduction in the flow generated by the hydrologic model. The resulting inflows into the hydraulic model were reduced by approximately 14%. This resulted in a reduction in flood levels of 0.13 to 0.18m. The distribution of flows remains similar. Decreasing the Kc value by 20% results in an increase in flows simulated by the hydrologic model. The resulting inflows into the hydraulic model were increased by approximately 11%. The flood level was increased by approximately 0.11m and this was similar across all the calibration locations.

5.4.2 Initial Loss

The initial rainfall loss value used in the RORB hydrologic model was adjusted by +/-20%. Decreasing the initial loss resulted in an increase of only 5% of the inflows into the hydraulic model. With this increase, the flood levels at the calibration locations only increased by a maximum of 0.04m. Increasing the initial loss had a similar impact, where the flows were decreased by approximately 5% resulted in a decrease in flood levels of up to 0.05m.

5.4.3 Manning's n

The Manning's n roughness values adopted (**Table 4-1**) were adjusted by +/-20%. Increasing the Manning's roughness values resulted in flows being generally less along Urangeline Creek, although the flow tends to spread into alternate flow paths. The flood levels increase by approximately 0.15m. Decreasing the Manning's n value resulted in more flows being conveyed in the main channel, although the differences in flow in the upstream and mid reaches are minimal. The flood levels, however, are reduced by up to 0.19m.

5.4.4 Blockage of Structures

The blockage of structures was not considered in the sensitivity analysis for Urana. This is due to the fact that overland flows have not been considered in the 2012 flood event modelling, hence the stormwater network and culvert system is unlikely to influence the mainstream flood behaviour. The only structure along Urangeline Creek that affects flows is the Collingullie-Jerilderie Road / Cocketgedong Road over Urangeline Creek. This bridge, however, is a large structure that is unlikely to be affected by blockage.

5.4.5 Downstream Boundary

A normal water depth was used at the breakout boundaries and the water level in Lake Urana simulated in the MIKE11 model was used as the downstream boundary. In both cases a sensitivity analysis was conducted by changing the tailwater level by +/-0.5m. Raising the tailwater boundary had the greatest impact to the distribution of outflows from the model. Approximately 14m^3/s of flow was diverted from the lake outflow to the breakout flow to the north. Other flows remained similar. The flood level increased by a maximum of 0.03m. Decreasing the tailwater level increased the flows into Lake Urana by approximately 6m^3/s. The decrease in flood level was less than 0.01m.

5.4.6 Breach of Urana Aquatic Centre Dam Embankment

A 10m breach in the embankment was assumed on the north-eastern side of the spillway. The breach formation time was assumed to be 12 hours. A review of modelling results indicated no significant change in peak water levels both upstream and downstream of the dam. It is to be noted that the crest of the embankment was defined in the TUFLOW model based on the surveyed data and the geometry of the embankment elsewhere was defined using the LiDAR data including the section of the embankment which was lowered after the flood event of 2012. The topographic survey undertaken by Federation Council confirms that the lowered section of the embankment was captured by the LiDAR survey. This means that the existing lowered section of the embankment was included in the TUFLOW model and hence model results were insensitive to any assumed breach of the embankment.

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.

Two hydrologic models developed as part of this study (a RORB for the catchment area of Urangeline Creek and an XP-RATFS hydrologic model developed for the local sub-catchments areas of the township) and two hydraulic models (an existing MIKE11 model for Billabong Creek and a TUFLOW model for Urana developed as part of this study) were utilised in the estimation of design flood for Urana. Initially, the calibrated and verified RORB model for Urangeline Creek was run to estimate inflow hydrographs for the required design flood events which were then utilised in the MIKE11 model for Billabong Creek. Inflow hydrographs simulated by the MIKE11 model were then extracted and in combination with inflow hydrographs simulated by the XP-RAFTS model were subsequently utilised as inflow boundaries for the TUFLOW model.

6.1 Input Data for Hydrologic Modelling

An XP-RAFTS hydrology model was developed for a total catchment area of 13.8 km^2 for the township and its surrounding areas to simulate rainfall runoff generated from the catchments. Details on the XP-RAFTS model are provided in **Appendix C**.

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 RORB 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	RORB model	XP-RAFTS model
Zone	2	2
1 hour 2 year ARI mm/hr	19.29	18.9
12 hour 2 year ARI mm/hr	3.45	3.39
72 hour 2 year ARI mm/hr	0.89	0.88
1 hour 50 year ARI mm/hr	43.19	43.14
12 hour 50 year ARI mm/hr	6.79	6.79
72 hour 50 year ARI mm/hr	1.61	1.60
Skewness G	0.15	0.14

Data Description	RORB model	XP-RAFTS model
Geographical factor 2 year ARI F2	4.33	4.33
Geographical factor 50 year ARI F50	15.26	15.23

Areal reduction factors (ARF) built within RORB model for ARR 1987 were applied to the estimated design rainfall depths for events up to, and including, the 0.5% AEP event. However, in the case of the XP-RAFTS model an ARF of 1 was adopted considering smaller sub-catchment areas.

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). Estimates of the PMP for longer duration storms were prepared using the *Guidelines to the Estimation of Probable Maximum Precipitation: Generalised Southeast Australia Method* (BoM, 2006).

6.1.3 Model Parameter Values

The adopted value of k_c and m were 117.5 and 0.8 respectively on the basis of calibration results. In the XP-RAFTS model for the township, 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 RORB and XP-RAFTS model for Zone 2. The temporal pattern for the PMP event was sourced from BoM (2003 and 2006).

6.1.5 Design Rainfall Losses

An initial loss of 15mm was adopted for 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.

6.2 Design Discharges

The RORB model for Urangeline Creek catchment was run for a range of storm durations for the selected design flood events to estimate design inflow hydrographs. The 18 hour storm duration produced peak discharge for all but the PMF event. The 36 hour storm produced peak discharge for the PMF event. The estimated design discharges for the modelled events are shown in **Table 6-2**.

- **Table 6-2 Comparison of Peak Discharges (m^3/s) for Urangeline Creek**

Event	RORB Model - Urangeline Creek This Study (catchment area 1,980 km^2)	Culcairn (WMAwater 2013) (catchment area 1,847 km^2)
20% AEP	128	248
10% AEP	171	315
5% AEP	229	424
2% AEP	323	553
1% AEP	412	687
0.5% AEP	510	812
0.2% AEP	654	-
PMP	7075	7306

A comparison of design discharges estimated in this study and design discharges adopted for Culcairn in the Culcairn, Henty, Holbrook Flood Studies (WMAwater 2013) is shown in **Table 6-2**, which shows that design discharges estimated in this study for 20% AEP to 0.5% AEP events are almost within 50% to 60% of the peak discharges adopted for Culcairn (WMAwater 2013). However, in the case of the PMF event, the peak flow estimated in this study is almost the same magnitude of the peak flow adopted for Culcairn.

The difference in peak flows between the two studies results from catchment slope and catchment shape. Urangeline Creek has a relatively flatter catchment slope and major flooding in Urangeline Creek results from rainfall runoff generated from its two main tributaries, Boree Creek and Brookong Creek. The combined catchment area of Boree Creek and Brookong Creek is almost similar to the remaining catchment area of Urangeline Creek at Urana.

6.3 Hydraulic Model Parameters for Design Events

6.3.1 MIKE11 Inflows

Critical inflow hydrographs simulated by the RORB model for the design events Urangeline Creek were used as input in the MIKE11 model Billabong Creek. Concurrent flooding in Billabong Creek corresponding to the design flood events for Urangeline Creek was estimated based on the guideline outlined in Book VI of the Australian Rainfall and Runoff. The adopted concurrent flood events in Billabong Creek corresponding to the design flood events for the catchment area of Urangeline Creek are shown in **Table 6-3**. Inflow hydrographs for Urangeline Creek are shown in **Figure 6-1** and the inflow hydrographs for Billabong Creek @ Walbundrie are shown in **Figure 6-2**.

Table 6-3 Adopted Concurrent Flooding in Urangeline and Billabong Creek Catchments

Design flood event in Urangeline Creek	Concurrent design flood event in Billabong Creek @ Walbundrie
20% AEP	50% AEP
10% AEP	50% AEP
5% AEP	20% AEP
2% AEP	10% AEP
1% AEP	10% AEP
0.5% AEP	10% AEP
0.2% AEP	10% AEP
PMP	1% AEP

The MIKE11 model simulated the complex interconnecting floodways between Billabong Creek and Urangeline Creek. Simulated flows at MIKE11 cross sections "URANGELINE 97507.5", "TOMBSTONES 25100" and "U/S RAIL 1 4732.33" were used as the upstream inflows for the TUFLOW model. Modelled hydrographs for the design events for the cross sections are shown in **Appendix D**.

6.3.2 Local Catchment Inflows

Discharge hydrographs simulated by the XP-RAFTS model for the design events were included in the TUFLOW model. Design storm events producing peak discharges from the sub-catchments were included in the TUFLOW model in combination with discharge hydrographs generated by the MIKE11 model. The critical storm duration for all design events for the sub-catchments varied between 15 minutes (for the probable maximum precipitation event) and 36 hours (for 20% AEP event).

Figure 6-1 Inflow hydrographs – Urangeline Creek

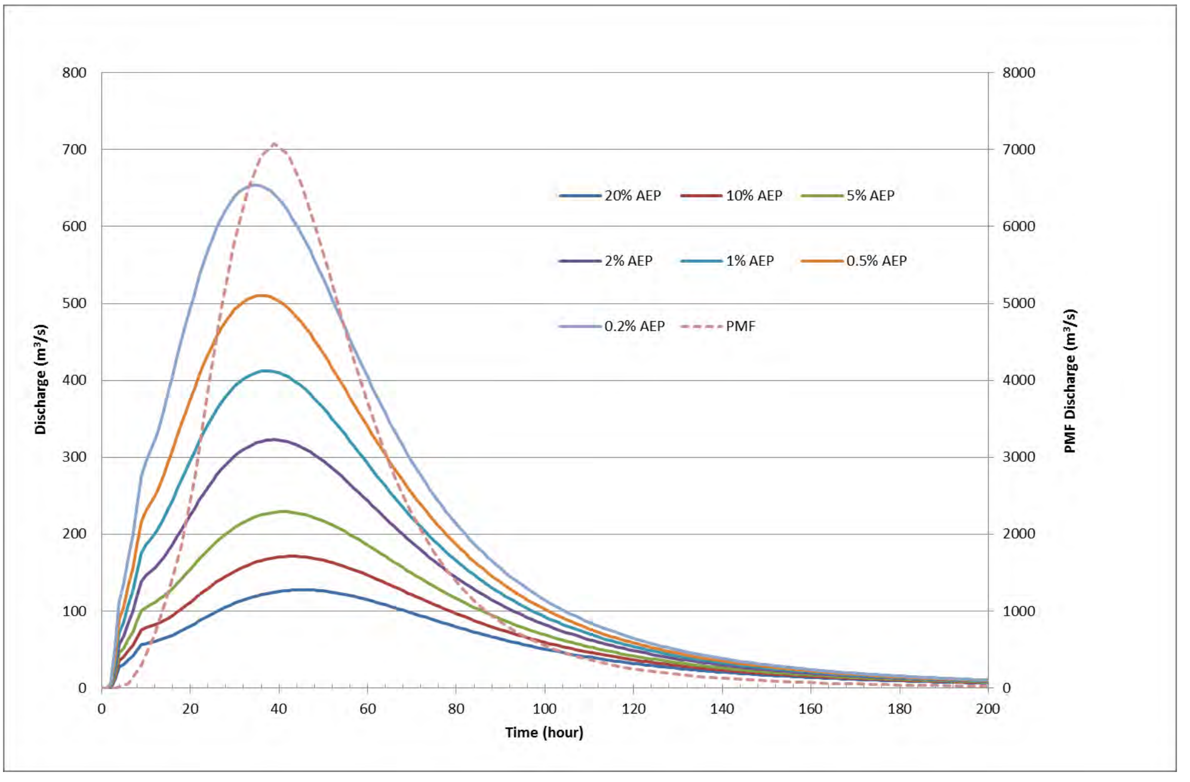
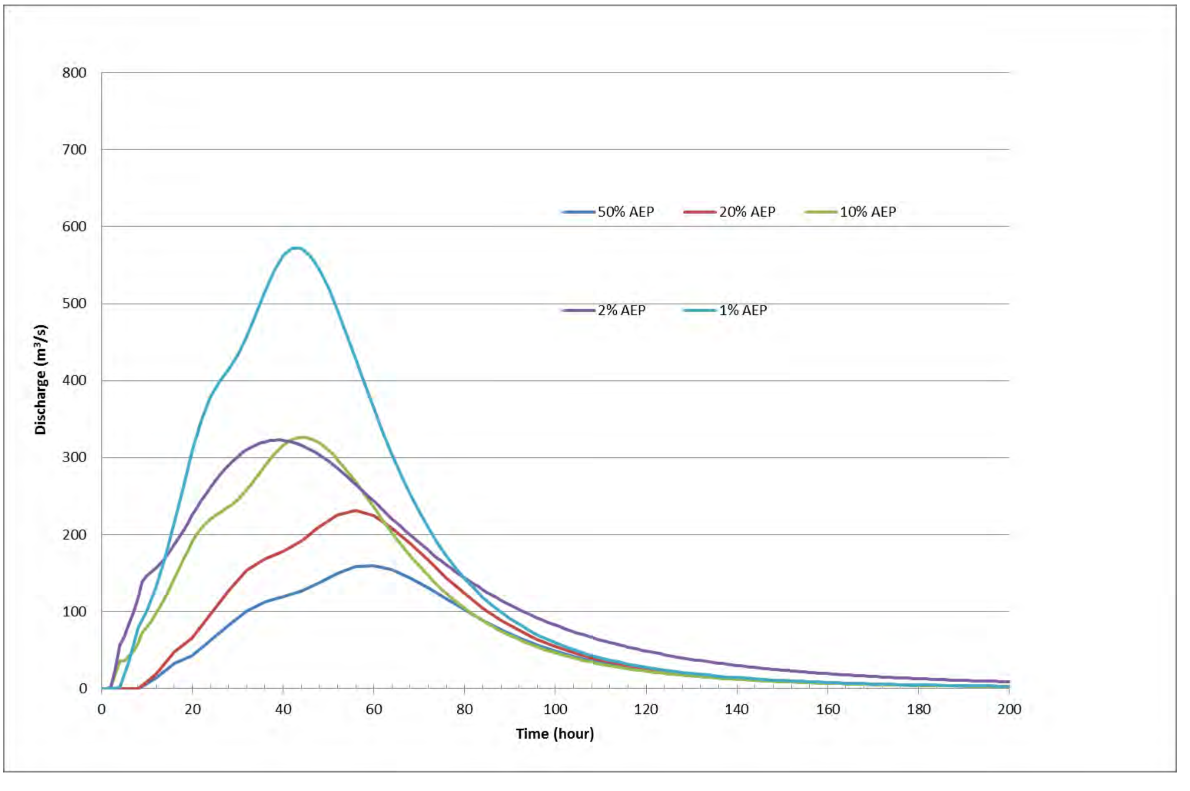


Figure 6-2 Inflow hydrographs – Billabong Creek @ Walbundrie



6.3.3 Tailwater Conditions

The TUFLOW model for Urana incorporates three downstream boundaries, including Lake Urana and two breakout locations to the north of the town. The dynamic lake boundary was represented by MIKE11 simulated water levels (refer **Appendix D**) in the Lake for the design events. Similar to the calibration and verification events, two normal depth boundaries defined at the two breakouts location have been used.

6.3.4 Initial Conditions

Small baseflows were assumed in the model and Urana Aquatic Centre Dam was assumed to be at full supply level and the initial water level in Lake Urana was selected based on MIKE11 model results.

6.4 Simulated Design Events

The storm durations assessed for all design events were selected based on runs in undertaken using MIKE11 the XP-RAFTS hydrologic model to capture the critical storm durations throughout the study area resulting from both mainstream and overland flooding.

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**) which include both mainstream and overland flooding within the study area:

- Almost the entire length of Brougong Street excluding the section between Woodhouse Street and Church Street is flooded in the 20% AEP event and properties are subjected to yard flooding. One property located at the northern end of Brougong Street is surrounded by floodwater in the 20% AEP event. Properties located on the western side of Vardy Street are also subjected to yard flooding in the 20% AEP event.
- Sections of the levee are overtopped and extensive flooding occurs on the area located on the western side of William Street and the northern side Woodhouse Street in the 5% AEP event.
- Properties bounded by Church Street to south, Woodhouse Street to the north, Anna Street to the East and Brougong Street to the west are surrounded by floodwaters in the 2% AEP event.
- Almost the entire levee is overtopped in the 1% AEP event and additional properties along William Street, Church Street, Anna Street, Chapman Street and Osborne Street are subject to flooding.
- Properties located on both sides of Princess Street are subjected to flooding in the 0.5% AEP event.
- All areas of the Township located on the western side of Princess Street are subject to more than 1m depth of flooding in the PMF event and the Township is cut off from the adjoining areas.

A flood depth map for the 1% AEP event resulting from the local catchments (ie. XP-RAFTS sub-catchments) around the township of Urana is shown in **Figure E-15** in **Appendix E.** A range of storm durations between 25 minutes and 6 hour for the 1% AEP event was assessed using the TUFLOW model. A steady inflow (25 m^3/s) and a constant level (112.65 mAHD) were assumed in Lake Urana to ensure that flooding in the township is not influenced by Urangeline Creek or Lake Urana. A comparison of **Figure E-5** and **Figure E-15** confirms that the Urangeline Creek is the major source of flooding for the township.

7.2 Flood Surface Profiles

The peak flood surface profiles are plotted in **Figure 7-1** for Urangeline Creek located within the study area. **Figure 7-1** shows that the flood profiles for 20% AEP to 0.2% AEP events are generally uniform between the Railway Bridge and Lake Urana Levee. The difference between the 20% AEP profile and the 0.2% AEP profile is approximately 1.3m and the Railway Bridge and Cocketgedong Road Bridge are slightly overtopped in the 0.5% AEP event. The peak water level profile for the PMF event is located approximately 2m above the profile for the 0.2% AEP event. It is to be noted that the higher water level in Lake Urana for the PMF event occurs several hours after the peak flow crosses Urana. Urana levee is overtopped in the 5% AEP event. The peak water level profile for the 0.5% AEP event is similar to the modelled profile for the flood event of 2012 and the peak water level profile for the 5% AEP event is similar to the modelled profile for the flood event of 2010. **Table 7-1** shows the peak water levels at modelled waterway crossings.

Figure 7-1 Peak Water Level Profiles – Urangeline Creek

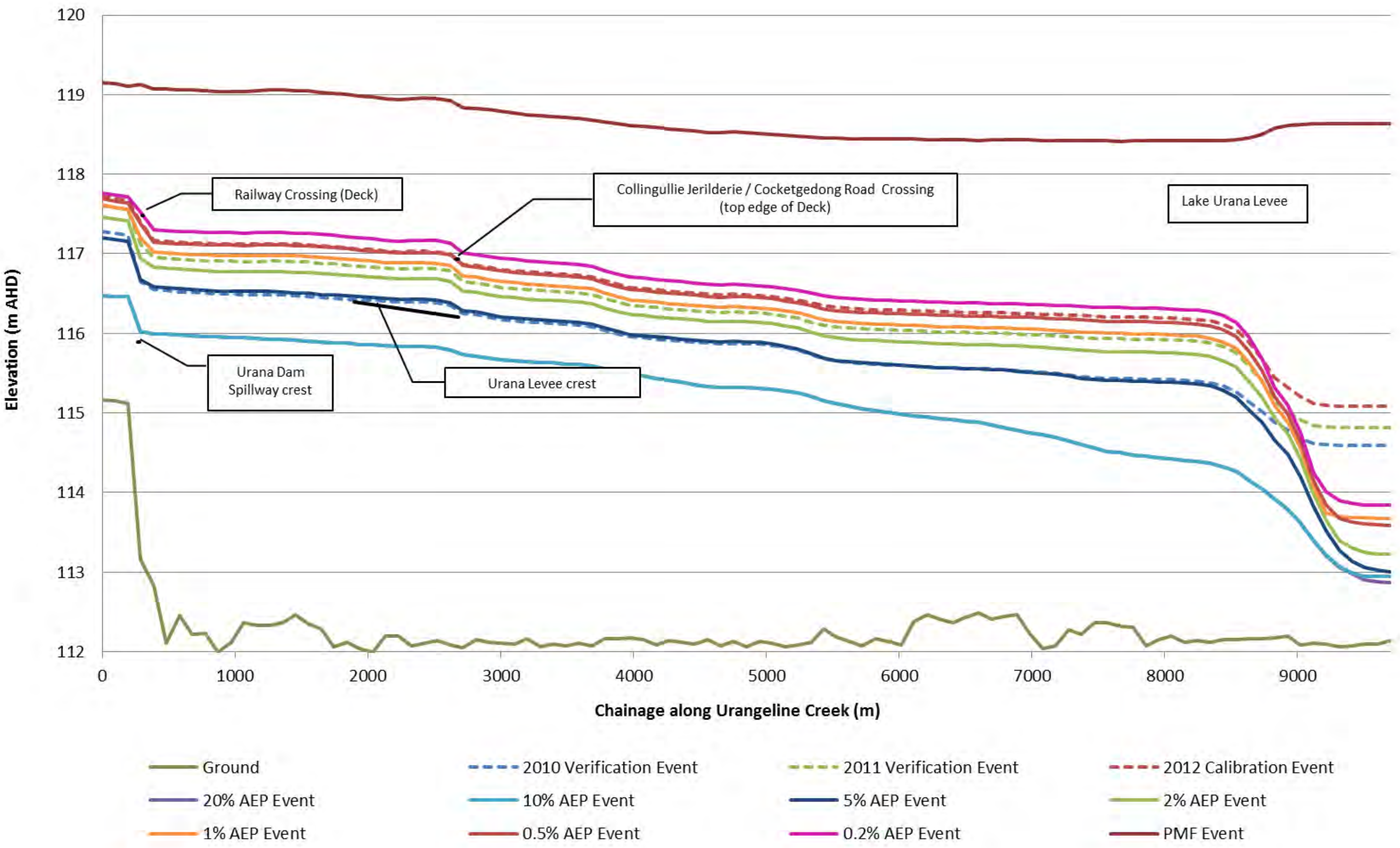


Table 7-1 Modelled Peak Water Levels at Waterway crossings

Waterway Crossing	Soffit Level (mAHD)	Deck Level (mAHD)	Peak Water Levels (mAHD)				
			20% AEP	5% AEP	1% AEP	0.5% AEP	PMF
Railway 1	116.98	117.48	116.03	116.68	117.21	117.38	119.19
Railway 2	116.94	117.44	116.07	116.88	117.44	117.55	119.13
Railway 3	116.98	117.63	116.65	116.52	117.48	117.58	119.20
Cocketgedong Rd	116.45	117.1	115.75	116.32	116.82	116.96	118.91

7.3 Summary of Peak Flows

Peak 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 7-2**. 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.

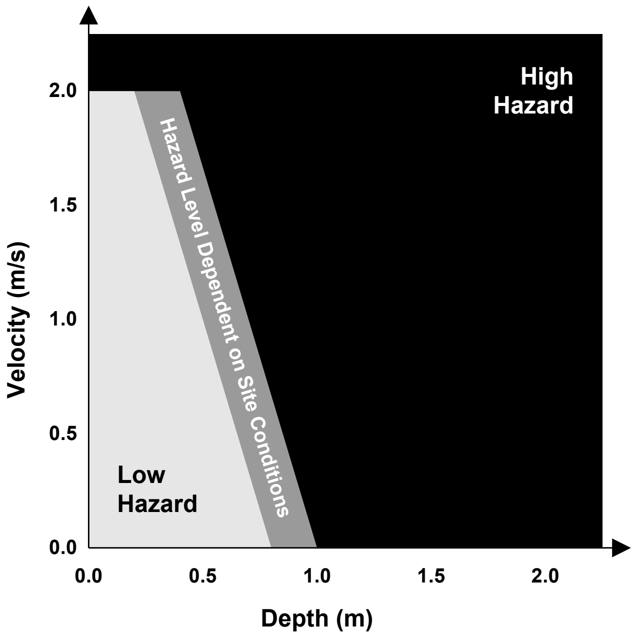


Figure 7-2 Hydraulic Hazard Category Diagram (reproduced from Figure L2 in *NSW Floodplain Development Manual*)

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**. The figures show than the flood hazard is low in the majority of the developed areas in Urana and high hazard areas are located at the north western corner of the town.

A flood hazard map for the 1% AEP event due to rainfall runoff from catchment areas around the township is shown in **Figure E-16** in **Appendix E**. A comparison of **Figure E-10** and **Figure E-16** confirms that high flood hazards within the township results from mainstream flooding.

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 on the basis of 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.

Floodways estimated based on the above criteria and the floodway defined in the Billabong Creek FMP are shown in **Appendix E** (**Figure E-12**). It is to be noted that the floodway defined in the Billabong Creek FMP in the vicinity of Urana was based on the flood event of 1983 the floodway was delineated using coarse topographic data. The area flooded in the 5% AEP event is considerably more extensive than floodways identified using the other three criteria. Also the high hazard area in the 1% AEP event is more extensive than the other two criteria. An encroachment analysis was undertaken using the floodway defined by the four criteria using an iterative approach. Increase in 1% AEP flood levels was assessed after each iteration and a final encroachment analysis was undertaken to ensure no increase in flood levels in excess of 0.1m. It is to be noted that the encroachment analysis was undertaken for the existing catchment and floodplain conditions. 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 Urana 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 Urana.

7.7 Flood Intelligence

Currently there is no flood gauge and hence no flood intelligence card for Urangeline Creek at Urana and it is recommended that two staff gauges: (one at the Federation Way Bridge upstream of the town and one at the Cocketgedong Road Bridge immediately west of the town) be installed at Urana (Yeo, 2013). Modelled flood levels at Cocketgedong Road Bridge are presented in **Table 7-1**.

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.

Almost the entire township is impacted by flooding in the PMF event (refer to **Figure E-8**) with flood depths being greater than 1m deep. Properties located within the area bounded by Tully Street to the east, Princess Street to the west, Smith Street to the north and Woodhouse Street to the south are subject to up to 0.3m flooding in the PMF event. Hence, residents from other areas within the town need to be evacuated prior to an extreme flood event.

Access to Urana from the south by Federation Way and from the west by Cocketgedong Road is cutoff in the 1% AEP event and properties located within the area bounded by Smith Street to the north, Woodhouse Street to the south, William Street to the east and Brougong Street to the west are subject to more than 1m depth of flooding in the 1% AEP event.

8. Conclusions

In accordance with NSW Government Policy, Federation Council is committed to preparing a Floodplain Risk Management Plan for the local government area including the town of Urana. This report documents the up-to date progress on preparing the first two stages of the process of preparing the Plan – that is, the preparation of a flood study report.

A community consultation process was undertaken to collect information on flooding from the community however there were no responses to the questionnaire from residents in Urana.

The available LiDAR survey for Urana 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 5 culverts, 4 bridges and the Urana stormwater network for which adequate information was not available to this study. The ground survey also collected crest levels along Urana levee and details about Urana Dam including the embankments, spillway and low flow outlet.

Recent flood events of 2010, 2011 and 2012 were selected for calibration and verification of hydrologic and hydraulic models. The flood event of 2012 is likely to be the largest flood on record. SES undertook a detailed flood investigation on the impact of the recent flood events at Urana.

A hydrologic model using RORB was set up for Urangeline Creek to Lake Urana, covering an area of 2,370km^2. Since no stream gauges are located on Urangeline Creek, the RORB model and the TUFLOW hydraulic models were calibrated in tandem against recorded flood marks for the 2012 event. A verification of the model was performed on the 2010 and 2011 flood events where the modelled flood was compared against the documented flood behaviour.

An existing hydraulic model for Billabong Creek (Walbundrie to Jerilderie) developed as part of the Billabong Creek Floodplain Management Study (Bewsher 2002) was available to this study. The hydraulic model developed using MIKE11 modelling system was upgraded from v2000 to v2014 for use in this study. Observed flows for Billabong Creek @ Walbundrie gauge were routed through the MIKE11 model in conjunction with flows estimated from the RORB model to estimate flows in Urangeline Creek upstream of Urana.

A TUFLOW hydraulic model for Urana was developed utilising a 5m grid based on a 1m LiDAR DEM. The model included the surveyed culverts, bridges, stormwater network, levee and dam. Buildings were modelled as obstructions to the flow. Modelled inflows for the calibration and verification events upstream of Urana were used to model flood behaviour for the flood events of 2010, 2011 and 2012. The flood levels modelled were within 0.1m of the recorded levels upstream of the informal Urana levee and along Urangeline Creek. The flood levels within the town were generally 0.1 to 0.4m higher, which can be attributed to the construction of informal and temporary ‘levees’ which were not modelled. These results confirm that both the hydrologic and hydraulic models were successfully calibrated and verified. The TUFLOW model can be used to simulate design events with confidence.

A sensitivity analysis was undertaken to assess sensitivity in flood behaviour for the 2012 event by changing the hydrologic parameters, initial rainfall loss, Manning’s roughness and tailwater boundary conditions.

The calibrated and validated RORB, MIKE11 and TUFLOW models and an XP-RAFTS hydrology model for the local catchment in Urana 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. There is a reasonable consistency between peak discharges estimated in this study and peak discharges estimated in Culcairn, Henty, Holbrook Flood Studies (WMAwater 2013).

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. A comparison of model results for the design events shows that the flood event of 2012 was similar to the 0.5% AEP event. The informal Urana levee is overtopped in the 5% AEP event. Almost the entire township is subject to flooding in the PMF and township would be cut-off from the neighbouring towns.

Flood behaviour within the township resulting from the rainfall runoff generated from the local catchment areas draining through the town was assessed for the 1% AEP event and it is concluded that the flood behaviour within the town is dominated by mainstream flooding.

The flood intelligence and flood emergency response for Urana 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 Urana Creek.

9. Acknowledgements

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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:

- Residents of Urana
- Federation Council
- Office of Environment and Heritage
- SES
- DPI Water

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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: Urana Town drawing with stormwater features (Council)
- A4: Survey of crest levels along the embankment of Urana Aquatic Centre Dam

Urana Flood Study Survey – Report

For Urana Shire Council and Jacobs

By TJ Hinchcliffe & Associates: Chris Ryan

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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.

Numbered Structures

Urana

1: Bridge

This brige is the main westerly exit from Urana along the Collingullie-Jerilderie Road over Urana Creek.

Table 1 shows the pertinent physical information about the bridge.

Bridge 1

	Start Centreline		End Centreline	
	Easting	Northing	Easting	Northing
Coordinates	432794.42	6090090.44	432852.20	6090092.90
Levels	Start	Middle	End	
Deck	116.68	116.69	116.70	
Underside	116.44	116.45	116.46	
Length	57.8			
Width	8.9			
Height Rails/Barriers	1.24	Above Deck		
Edge	0.24	Above Deck		

Table 1: Bridge 1 West of Urana.

The following images (1-4) show Bridge 1 from the upstream side looking downstream.

Image 1: Structure 1 Downstream.

Image 2: Structure 1 Downstream.

Image 3: Structure 1 Downstream.

Image 4: Structure 1 Downstream.

The downstream facing images show that the waterway has very little water, at time of survey the creek was not flowing and had been reduced to various standing pools.

Image 5 shows Bridge 1 from the downstream side facing upstream.

Image 5: Structure 1 Upstream.

Image 5 shows many small gum saplings growing in the riverbed in the direct path of future flows.

2: Culvert

This culvert takes flow from outside the Urana levee and allows it to flow into the adjoining creek.

Table 2 shows the pertinent physical information about the culvert.

Culvert 2

	Inlet		Outlet	
	Easting	Northing	Easting	Northing
Coordinates	433072.9	6090026.23	433069.22	6090018.93
Length	8.1			
Dimensions (Diameter)	0.6			
Number of Cells	1			
	Cell 1			
	Upstream	Downstream		
Invert Levels (AHD m)	114.06	114.04		
Blockage %	10	10		

Table 1: Culvert 1, between Urana's levee bank and Urana Creek.

Image 6 shows Culvert 2 Outlet with concrete rubble and prickly pear to slow the outlet.

Image 6: Culvert 2 Outlet

Image 7 shows culvert 2 inlet with standing water below the invert level.

Image 7: Culvert 2 Outlet.

3: Stormwater outflow

Structure 5 appears to be the outlet of Urana Stormwater network from Osborne Street.

Table 3 shows the pertinent physical information about the structure.

Culvert 3				
	This is an outlet that seems to discharge the stormwater system from Osborne Street		Outlet	
			Easting	Northing
Coordinates			433169.01	6089878.45
Length				
Dimensions (Diameter)	0.38			
Number of Cells	1			
	Cell 1			
	Upstream	Downstream		
Invert Levels (AHD m)		113.05		
Blockage %	10	10		

Table 3: Culvert 3 details.

Image 8 & 9 show structure 3 facing upstream.

Image 8: Structure 3 facing upstream.

Image 9: Structure 3 facing upstream.

4: Culvert

Structure 4 is a Culvert that allows flow under the Federation Way. It's flow should be combined with that of structure 5.

Table 4 shows the pertinent physical information about the structure.

Culvert 4

	Inlet		Outlet	
	Easting	Northing	Easting	Northing
Coordinates	433631.57	6089612.81	433622.59	6089601.25
Length	14.60			
Dimensions (HxW)	0.45x0.90			
Number of Cells	1			
	Cell 1			
	Upstream	Downstream		
Invert Levels (AHD m)	117.17	116.92		
Blockage %	30	50		

Table 4: Culvert 4 details.

Image 10 shows the structure 4 facing downstream.

Image 10: Structure 4 facing downstream.

5: Culvert

Structure 5 is a Culvert that allows flow under the Federation Way. It's flow should be combined with that of structure 4.

Table 5 shows the pertinent physical information about the structure.

Culvert 5

	Inlet		Outlet	
	Easting	Northing	Easting	Northing
Coordinates	433644.99	6089597.78	433637.05	6089584.53
Length	15.40			
Dimensions (HxW)	0.475x0.90			
Number of Cells	2			
	Cell 1		Cell 2	
	Upstream	Downstream	Upstream	Downstream
Invert Levels (AHD m)	117.18	117.08	117.21	117.08
Blockage %	20	0	0	0

Table 5: Structure 5 details.

Image 11 shows structure 5 facing downstream.

Image 11: Structure 5 facing downstream.

Image 12 shows the structure 5 facing upstream.

Image 12: Structure 5 facing upstream.

6: Culvert

Structure 6 is a Culvert at a low point in the road north-east of Urana it is paired with the rail culvert 7.

Table 6 shows the pertinent physical information about the structure.

Culvert 6

	Inlet		Outlet	
	Easting	Northing	Easting	Northing
Coordinates	434904.45	6091493.25	434895.80	6091502.30
Length	12.50			
Dimensions (Diameter)	0.375			
Number of Cells	2			
	Cell 1		Cell 2	
	Upstream	Downstream	Upstream	Downstream
Invert Levels (AHD m)	116.19	116.19	116.19	116.19
Blockage %	0	0	20	20

Table 6: Structure 6 details.

Image 13 shows the structure 6 facing downstream.

Image 13: Structure 6 facing downstream.

Image 14 shows the structure 6 facing upstream.

Image 14: Structure 6 facing upstream.

7: Culvert

Structure 7 is a Culvert at a low point in the rail north-east of Urana it is paired with the road culvert 6.

Table 7 shows the pertinent physical information about the structure.

Culvert 7

	Inlet		Outlet			
	Easting	Northing	Easting	Northing		
Coordinates	434918.37	6091477.71	434914.08	6091482.47		
Length	6.40					
Dimensions (Diameter)	0.600					
Number of Cells	3					
	Cell 1		Cell 2		Cell 3	
	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Invert Levels (AHD m)	116.14	116.15	116.17	116.15	116.17	116.14
Blockage %	5	5	5	5	5	5

Table 7: Structure 7 details.

Image 15 shows the structure 7 facing upstream.

Image 15: Structure 7 facing upstream.

8: Bridge

Structure 8 is a bridge directly downstream from the Urana Dam Spillway. It is the largest flow inhibitor on the outflow from the Urana Dam Spillway when combined with the rail embankment and the Bridge 9 to the south.

Table 8 shows the pertinent physical information about the structure.

Bridge 8

	Start Centreline		End Centreline	
	Easting	Northing	Easting	Northing
Coordinates	433446.79	6089098.99	433467.01	6089160.93
Levels	Start	Middle	End	
Deck	117.43	117.44	117.45	
Underside	116.97	116.98	116.99	
Length	65.16			
Width	2.65			
Height Rails/Barriers	0.00			

Table 8: Structure 8 details.

Images 16-18 shows the structure 8 facing downstream.

Image 16: Structure 8 facing downstream.

Image 17: Structure 8 facing downstream.

Image 18: Structure 8 facing downstream.

Images 19-21 shows the structure 8 facing upstream.

Image 19: Structure 8 facing upstream.

Image 20: Structure 8 facing upstream.

Image 21: Structure 8 facing upstream.

9: Bridge

Structure 9 is a rail bridge slightly separated from the outflow of the spillway of Urana Dam. It is just south of Bridge 8.

Table 9 shows the pertinent physical information about the structure.

Bridge 9

	Start Centreline		End Centreline	
	Easting	Northing	Easting	Northing
Coordinates	433428.52	6089043.42	433438.03	6089072.72
Levels	Start	Middle	End	
Deck	117.49	117.50	117.48	
Underside	116.94	116.95	116.93	
Length	30.70			
Width	2.75			
Height Rails/Barriers	0.00			

Table 9: Bridge 9 details.

Images 22-24 show structure 9 facing downstream.


Image 22: Structure 9 facing downstream.


Image 23: Structure 9 facing downstream.

Image 24: Structure 9 facing downstream.

Images 25-27 show structure 9 facing upstream.

Image 25: Structure 9 facing upstream.


Image 26: Structure 9 facing upstream.


Image 27: Structure 9 facing upstream.

10: Bridge

Structure 10 crosses a small feeder stream south of Urana Creek. This bridge is old and very dilapidated. There was a survey control mark on the bridge, it was painted yellow and black and is of unknown origin.

Table 10 shows the pertinent physical information about the structure.

Bridge 10

	Start Centreline		End Centreline	
	Easting	Northing	Easting	Northing
Coordinates	433217.33	6088486.76	433227.55	6088511.10
Levels	Start	Middle	End	
Deck	117.44	117.43	117.43	
Underside	116.99	116.98	116.98	
Length	26.40			
Width	2.80			
Height Rails/Barriers	0.00			

Table 10: Structure 10 details.

Images 28 & 29 show structure 10 facing downstream.

Image 28: Structure 10 facing downstream.

Image 29: Structure 10 facing downstream.

Image 30 shows structure 10 facing upstream.

Image 30: Structure 10 facing upstream.

Morundah

11: Bridge

Structure 11 is a small bridge over Colombo creek 1.5km north of Morundah

Table 11 shows the pertinent physical information about the structure.

Bridge 11

	Start Centreline		End Centreline	
	Easting	Northing	Easting	Northing
Coordinates	434454.73	6135627.49	434475.66	6135630.51
Levels	Start	Middle	End	
Deck	129.83	129.89	129.84	
Underside	129.07	129.13	129.08	
Length	21.15			
Width	4.30			
Height Rails/Barriers	0.00			

Table 11: Structure 11 details.

Image 31 shows structure 11 facing downstream.

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.

Image 91: Urana Dam Spillway.

Image 92: Urana Dam Spillway.

Image 93 shows the overflow access way above the Urana Dam Spillway.

Image 93: Urana Dam Spillway overflow access.

Image 94 shows the Urana Dam outflow. It is a 1.2m round concrete pipe.

Image 94: Urana Dam Spillway outlet.

Image 95-96 show the downstream side of the spillway.

Image 95: Urana Dam Spillway.

Image 96: Urana Dam Spillway.

Urana Levee

Urana Levee is about 480m long. It runs along the south western edge of Urana and separates it from Urana creek. At its northern end a round concrete pipe forms an outlet from the Chapman street storm water system to outside the levee. There are two areas where the Levee is breached at the end of Osborne Street, although these are only a few meters wide. Structure 3 appears to be an outlet of the Urana Storm-water system at Osborne Street. Another round concrete pipe runs from inside the levee to outside the levee at the extension of Stephen Street.

Images 97-99 show the general state of the Urana Levee Bank.

Image 97: Urana Levee Bank.

Image 98: Urana Levee Bank.

Image 99: Urana Levee Bank so areas are in a state of disrepair.

Images 100 and 101 show the washouts in the levee at the end of Osborne street.

Image 100: Urana Levee Bank washout at Osborne Street.

Image 101: Urana Levee Bank washout at Osborne Street.

Images 102 and 103 show the round concrete pipe under the levee bank at the continuation of Stephen Street.

Image 102: Outlet of 375mm RCP at the continuation of Stephen Street.

Image 103: Inlet of 375mm RCP at the continuation of Stephen Street.

Urana Storm-Water Network

Urana is a very flat town and the storm water network has been created over a period of time. It contains many non-standard pits, pipes and culverts. There are two substantial parts of the network identified in this report.

The section along Chapman Street from Princess Street in the East to the outside of the Levee Bank in the West consists of a variety of entry structures that drain into a 600mm round concrete pipe. Along the last 270 meters of this network the grade averages -0.33%. The pit at the South West intersection of Chapman and Princess Streets was inaccessible and could not be lifted.

The following images 104 – 109 show the network of pits that run along Chapman Street.

Image 104: North-East Intersection of Chapman and William Street facing West.

Image 105: South-East Intersection of Chapman and William Street facing North.

Image 106: South-West Intersection of Chapman and William Street facing East.

Image 107: North-West Intersection of Chapman and William Street facing East. This culvert seems to be on strip footings with earth as its base.

Image 108: South-East Intersection of Chapman and Anna Street facing East.

Image 109: Outflow of Chapman Street Storm-water system.

The storm-water system of Urana has a significant component that runs along Osborne Street. There are varying pipe sizes running along the southern side of the street. At the south east corner of Anna and Osborne Streets there is a large pit that has a pipe running out of it to the west. This pit was inaccessible (the photograph was taken by extending an arm through a small opening).

The following images, 110-116 show the storm-water system running along Osborne Street from William Street in the East to the outflow passed the levee bank in the West.

Image 110: Grated storm-water pits at the South-East corner of the Intersection of William and Osborne Streets facing East.

Image 111: Kerb inlet pit at the South-West corner of the Intersection of William and Osborne Streets facing South.

Image 112: North-East corner of the Intersection of Anna and Osborne Streets facing South.

Image 113: South-East corner of the Intersection of Anna and Osborne Streets facing North.

Image 114: Large pit at the South-East corner of the Intersection of Anna and Osborne Streets.

Image 115: West of the Intersection of Anna and Osborne Streets on the south side of Osborne Street.

Image 116: structure 3 outlet west of Osborne Street outside the levee bank.

The storm-water system is old, as shown in the photographs. The outflow at the structure 3 is a 375mm round concrete pipe, this pipe may flow from the the large pit found at the intersection of Anna and Osborne, however further inspection would be required.

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
- Levee surveyed
- Stormwater network surveyed
- Dam surveyed
- Railway
- Watercourses

GDA 1994 MGA Zone 55
Scale: A3

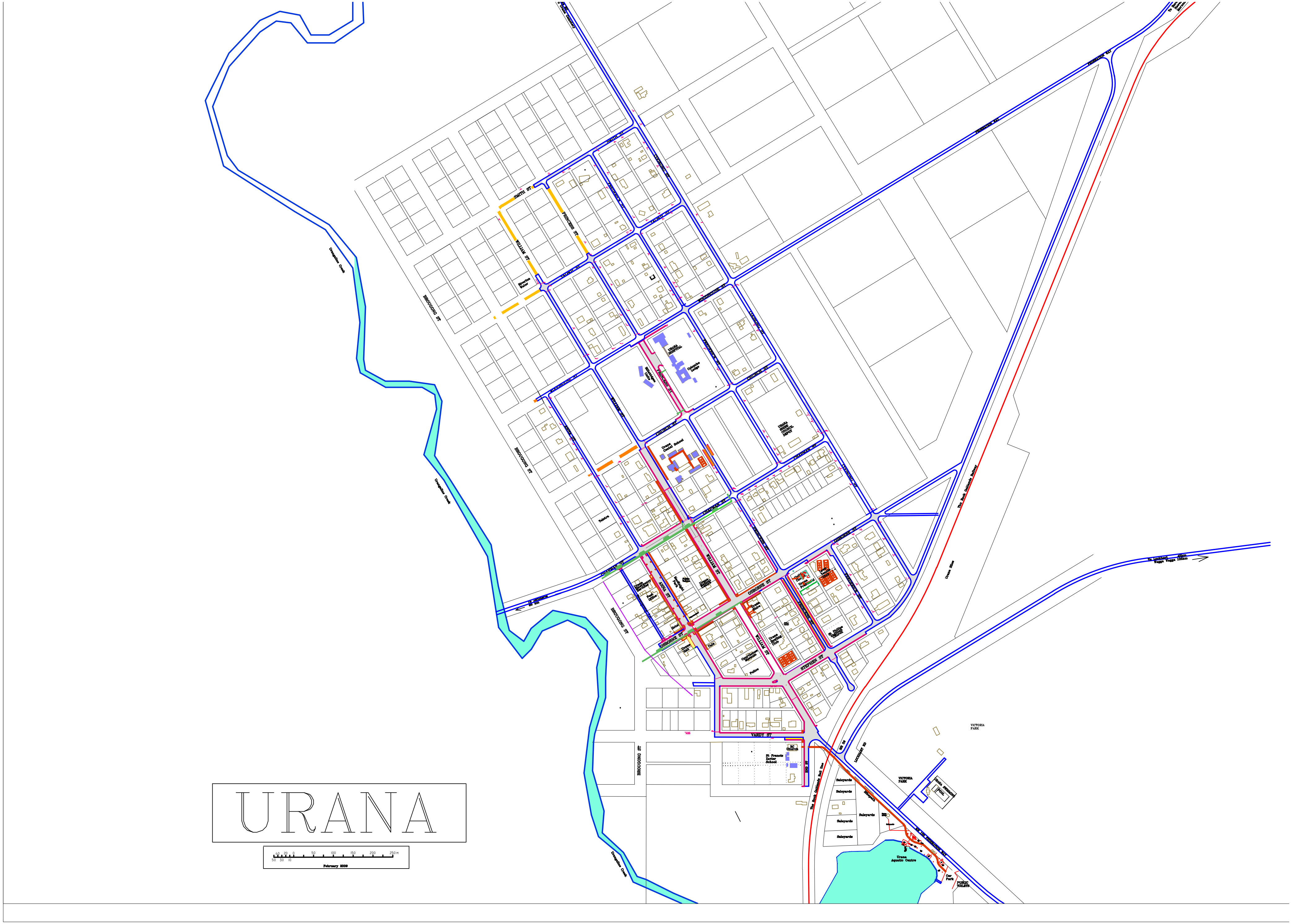
Data Sources: LPI, OEH, Council

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	Urana
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council
DRAWN MR / CHECK AH	PROJECT # IA055600 / DATE 25/08/2017

APPENDIX A-2


URANA
SMITH ST
WILLIAM ST
PRINCESS ST
BROUGONG ST
CHAPMAN ST
OSBORNE ST
ANNA ST
STEPHEN ST
VARDY ST
VICTORIA PARK
Urana Aquatic Centre
Saleyards
February 2009

- A4: Survey of crest levels along the embankment of Urana Aquatic Centre Dam


117.477
102
TB*
117.583
200
TB*
115.928
985
dam wall
115.917
984
dam wall
17-29
DP756447/155
DP756447/344
DP756447/203
DP756447/89A
DP867110/2
117.809
201
TB*
117.870
202
TB*
4637
DP43188/1
DP756447/190
DP1024271/7006
DP437201/1
117.676
203
TB*
4637
DP756447/367
118.090
204
TB*
116.173
205
TB*
DP756447/260
DP756447/366
116.273
206
TB*
DP756447/191
116.306
207
TB*

Appendix B. Questionnaire

Urana Shire Flood Study Questionnaire (February 2015)

Urana

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 Urana. 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 Urana. 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 27 March 2015**.

Alternatively, you could drop off your response to the questionnaire at Council's Reception Desk, 30-32 William Street, Urana by 27 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

Question No.	Question and Answer
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) ……………………
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

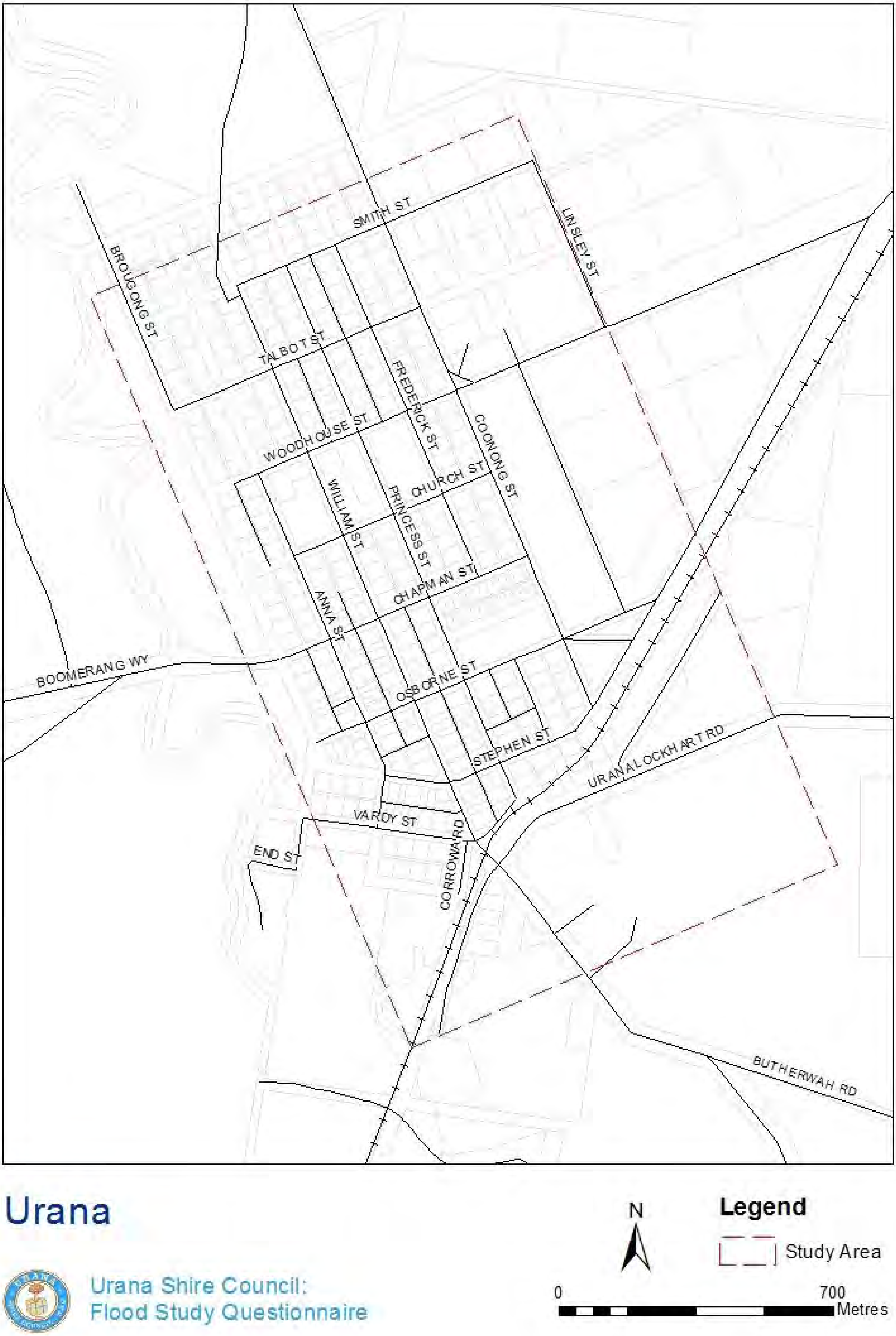
Question No.	Question and Answer
	D Other damages, please list……………………………… E What was the approximate cost of the repairs, if any?………………….
11.	**Was vehicle access to/from your property disrupted due to floodwaters during the worst flooding/storm event?** A Not affected B Minor disruption (roads flooded but still driveable) 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 ……………………………………………………………...

Question No.	Question and Answer
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 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

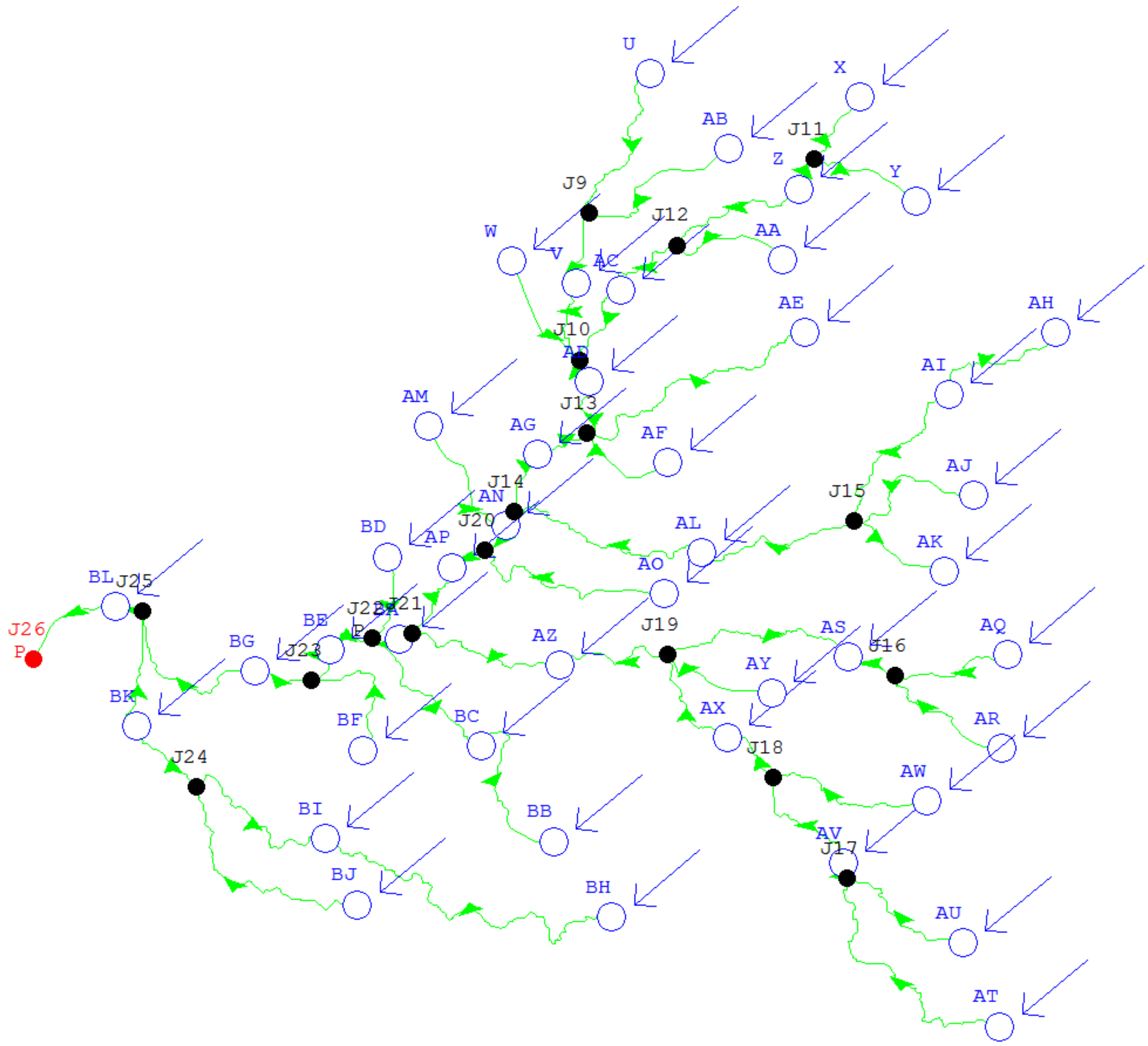
Map – Study Area for Urana



Appendix C. Hydrologic Modelling

- C1: RORB model configuration for Urangeline Creek
- C2: RORB model sub-catchment data for Urangeline Creek
- C3: XP-RAFTS model sub-catchments
- C4: XP-RAFTS model sub-catchment data for Urana

- C1: RORB Model Configuration for Urangeline Creek



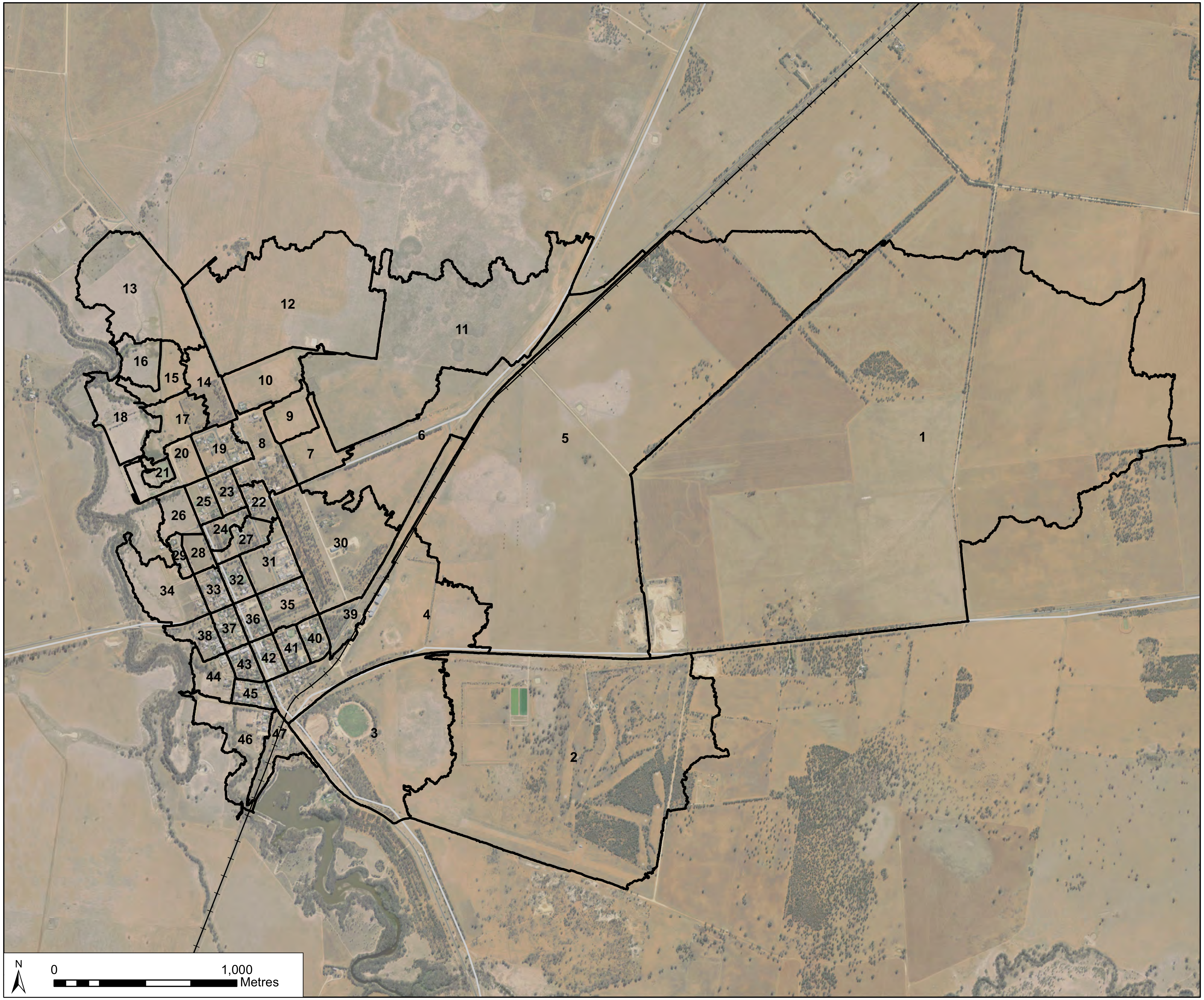
- C2: RORB Model sub-catchment data for Urangeline Creek

Node Number	Sub-catchment Name[1]	Area (km^2)	Impervious fraction
1	X	53.8	0.05
2	Y	29.0	0.05
3	Z	41.6	0.05
4	AA	36.9	0.05
5	AC	25.0	0.05
6	U	132.0	0.05
7	AB	42.6	0.05
8	V	19.3	0.05
9	W	48.5	0.05
10	AD	35.6	0.05
11	AE	100.3	0.05
12	AF	46.8	0.05
13	AG	28.8	0.05
14	AH	70.3	0.05
15	AI	81.8	0.05
16	AJ	75.5	0.05
17	AK	27.3	0.05
18	AL	96.2	0.05
19	AN	6.3	0.05
20	AM	57.5	0.05

21	AO	67.3	0.05
22	AP	20.6	0.05
23	AT	137.9	0.05
24	AU	71.8	0.05
25	AV	57.2	0.05
26	AW	73.9	0.05
27	AX	59.0	0.05
28	AQ	49.6	0.05
29	AR	52.5	0.05
30	AS	66.3	0.05
31	AY	27.3	0.05
32	AZ	71.3	0.05
33	BA	5.2	0.05
34	BB	53.1	0.05
35	BC	71.3	0.05
36	BD	40.3	0.05
37	BE	24.2	0.05
38	BF	39.7	0.05
39	BG	59.1	0.05
40	BH	108.9	0.05
41	BI	63.8	0.05
42	BJ	57.2	0.05

43	BK	16.8	0.05
44	BL	16.5	0.05

1 Subcatchments ‘A’ to ‘T’ drain to Lake Urana on its western side and do not contribute to flow in Urangeline Creek, hence they have been omitted.



Legend
XP-RAFTS Sub-catchments
Railway
Major Roads

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.

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TITLE	XP-RAFTS Sub-catchments
TOWN	Urana
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE C-3
CHECK AH	DATE 25/08/2017	

- C4: XP-RAFTS Model sub-catchment data for Urana

Sub-catchment[1]	Area (km^2)	Impervious fraction (%)	Slope (%)	Roughness
1	432.6	5	0.533	0.040
2	156.2	5	0.294	0.045
3	53.2	5	0.125	0.040
4	41.5	10	0.092	0.040
5	255.4	5	0.333	0.040
6	39.6	5	0.208	0.040
7	7.5	5	0.214	0.040
8	9.9	20	0.167	0.035
9	5.6	5	0.444	0.040
10	10.5	5	0.364	0.040
11	78.7	5	0.175	0.040
12	57.7	5	0.230	0.040
13	28.1	5	0.750	0.040
14	7.0	5	0.263	0.040
15	5.7	5	0.875	0.040
16	5.5	5	0.320	0.040
17	7.8	5	0.857	0.040
18	10.9	5	0.477	0.040
19	6.0	30	0.400	0.030

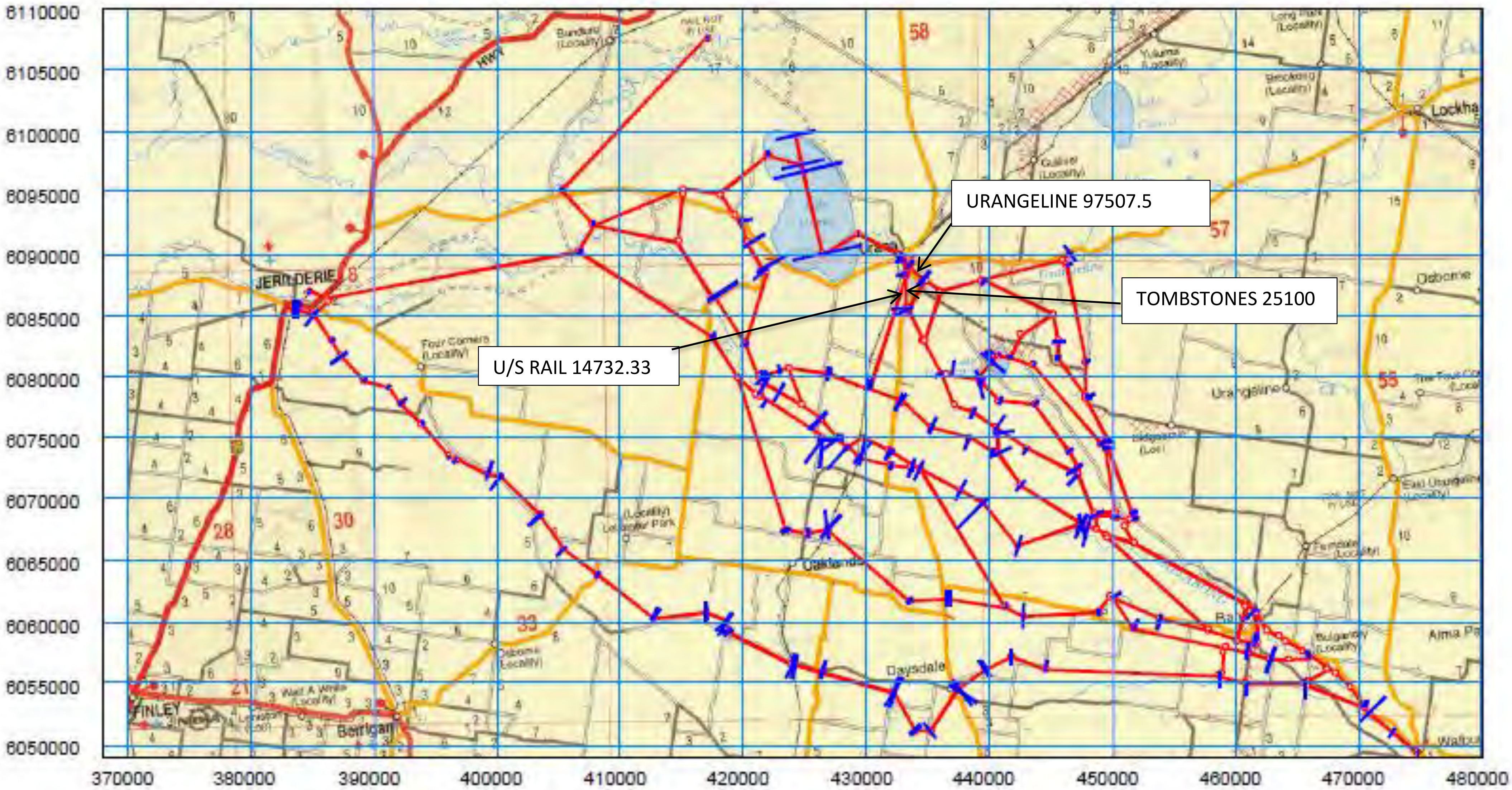
Sub-catchment[1]	Area (km^2)	Impervious fraction (%)	Slope (%)	Roughness
20	6.7	5	1.233	0.040
21	2.1	5	3.571	0.035
22	2.9	30	0.250	0.030
23	3.3	30	0.917	0.030
24	3.2	30	1.000	0.030
25	3.2	20	2.167	0.030
26	4.8	5	0.167	0.040
27	4.1	20	0.649	0.030
28	2.8	5	0.147	0.040
29	1.7	40	0.364	0.030
30	29.5	5	0.214	0.045
31	7.3	20	0.633	0.030
32	3.2	40	0.750	0.030
33	3.2	40	0.818	0.030
34	12.2	5	0.557	0.040
35	6.2	15	0.280	0.035
36	3.2	20	0.400	0.030
37	3.2	40	0.100	0.030
38	4.2	30	0.720	0.030
39	11.1	5	0.077	0.040
40	3.1	40	0.500	0.030

Sub-catchment[1]	Area (km^2)	Impervious fraction (%)	Slope (%)	Roughness
41	3.2	40	0.300	0.030
42	3.2	40	0.400	0.030
43	2.7	40	0.455	0.030
44	5.1	10	1.067	0.035
45	2.9	40	0.783	0.030
46	12.6	5	1.629	0.040
47	5.7	5	0.873	0.040

[1] refer to **Figure C-3**

Appendix D. Hydraulic Modelling

- D1: MIKE-11 model network diagram (Bewsher 2002)
- D2: Map showing reporting locations of flows and flood levels for TUFLOW model
- D3: Reporting tables for the 2010, 2011 and 2012 flood events
- D4: Reporting tables for the sensitivity runs – peak water levels
- D5: Reporting tables for the sensitivity runs – peak discharges
- D6: Modelled water level and discharge hydrographs for design events simulated by MIKE-11 model
- D7: Peak discharges for design events
- D8: Modelled peak water levels



LEGEND

Model Cross Section Location

Appendix D1: MIKE11 Model Schematic for Billabong Creek

Source: Bewsher 2002

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	Urana
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	APPENDIX D-2
CHECK AH	DATE 25/08/2017	

- D3: Modelled flows for the 2010, 2011 and 2012 calibration events

Flow line	2010 Flow (m^3/s)	2011 Flow (m^3/s)	2012 Flow (m^3/s)
F01	213	354	428
F02	3	3	3
F03	0	1	4
F04	1	27	51
F05	215	354	430
F06	216	355	431
F07	1	2	5
F08	216	354	431
F09	0	0	0
F10	0	0	0
F11	216	354	430
F12	0	0	0
F13	215	353	430
F14	215	352	427
F15	0	1	3
F16	0	0	0
F17	210	321	372
F18	0	25	52

- D4: Flood level differences (m) for the sensitivity runs (2012 event)

Mark	Base	+Kc	-Kc	+IL	-IL	+n	-n	+TWL	-TWL
1	117.12	-0.04	0.04	0.11	-0.15	-0.16	0.14	0.01	0.00
2	117.11	-0.04	0.04	0.11	-0.15	-0.16	0.14	0.01	0.00
3'	117.10	-0.04	0.04	0.11	-0.15	-0.16	0.14	0.01	0.00
4	117.08	-0.04	0.04	0.11	-0.16	-0.16	0.14	0.01	0.00
5	117.08	-0.04	0.04	0.11	-0.16	-0.16	0.14	0.01	0.00
6	117.07	-0.04	0.04	0.11	-0.16	-0.16	0.14	0.01	0.00
7	117.07	-0.04	0.04	0.11	-0.15	-0.16	0.14	0.01	0.00
8	117.05	-0.04	0.04	0.11	-0.15	-0.15	0.14	0.01	0.00
9	117.03	-0.04	0.04	0.11	-0.15	-0.15	0.14	0.01	0.00
10B	116.98	-0.04	0.04	0.11	-0.15	-0.16	0.14	0.01	0.00
10A	116.97	-0.04	0.04	0.10	-0.15	-0.16	0.14	0.01	0.00
11	116.92	-0.04	0.04	0.11	-0.16	-0.17	0.15	0.01	0.00
12	116.80	-0.05	0.04	0.11	-0.17	-0.19	0.16	0.02	-0.01
13	116.78	-0.05	0.04	0.11	-0.17	-0.18	0.16	0.02	-0.01
14	116.77	-0.04	0.04	0.11	-0.17	-0.18	0.16	0.02	-0.01
15	116.81	-0.05	0.04	0.11	-0.17	-0.18	0.16	0.02	-0.01
16	116.75	-0.04	0.04	0.11	-0.17	-0.17	0.15	0.02	-0.01
17	116.58	-0.04	0.03	0.10	-0.16	-0.17	0.15	0.03	-0.01
18	116.75	-0.04	0.04	0.11	-0.17	-0.17	0.15	0.02	-0.01
19	116.77	-0.05	0.04	0.11	-0.17	-0.18	0.16	0.02	-0.01

Mark	Base	+Kc	-Kc	+IL	-IL	+n	-n	+TWL	-TWL
20A	116.81	-0.05	0.04	0.12	-0.18	-0.19	0.16	0.02	-0.01
20B	116.82	-0.05	0.04	0.12	-0.18	-0.19	0.16	0.02	-0.01
21	116.86	-0.05	0.04	0.11	-0.17	-0.18	0.16	0.02	-0.01
22	116.87	-0.05	0.04	0.11	-0.17	-0.18	0.16	0.02	-0.01
23	116.89	-0.05	0.04	0.11	-0.18	-0.18	0.16	0.02	-0.01
24	117.07	-0.04	0.04	0.11	-0.16	-0.16	0.14	0.01	0.00
25	117.07	-0.04	0.04	0.11	-0.16	-0.16	0.14	0.01	0.00
26	117.00	-0.04	0.03	0.10	-0.13	-0.13	0.14	0.01	0.00
27	116.91	-0.04	0.04	0.11	-0.16	-0.17	0.15	0.02	0.00
29	116.81	-0.05	0.04	0.11	-0.17	-0.18	0.16	0.02	-0.01
30	117.08	-0.04	0.04	0.11	-0.15	-0.16	0.14	0.01	0.00
31	117.11	-0.04	0.04	0.11			0.14	0.01	0.00
33	116.86	-0.04	0.04	0.11	-0.14	-0.16	0.16	0.02	-0.01
103	117.17	-0.04	0.04	0.11	-0.15	-0.16	0.14	0.01	0.00
104	117.19	-0.04	0.04	0.11	-0.15	-0.16	0.14	0.01	0.00
109	116.69	-0.05	0.04	0.11	-0.17	-0.18	0.16	0.02	-0.01

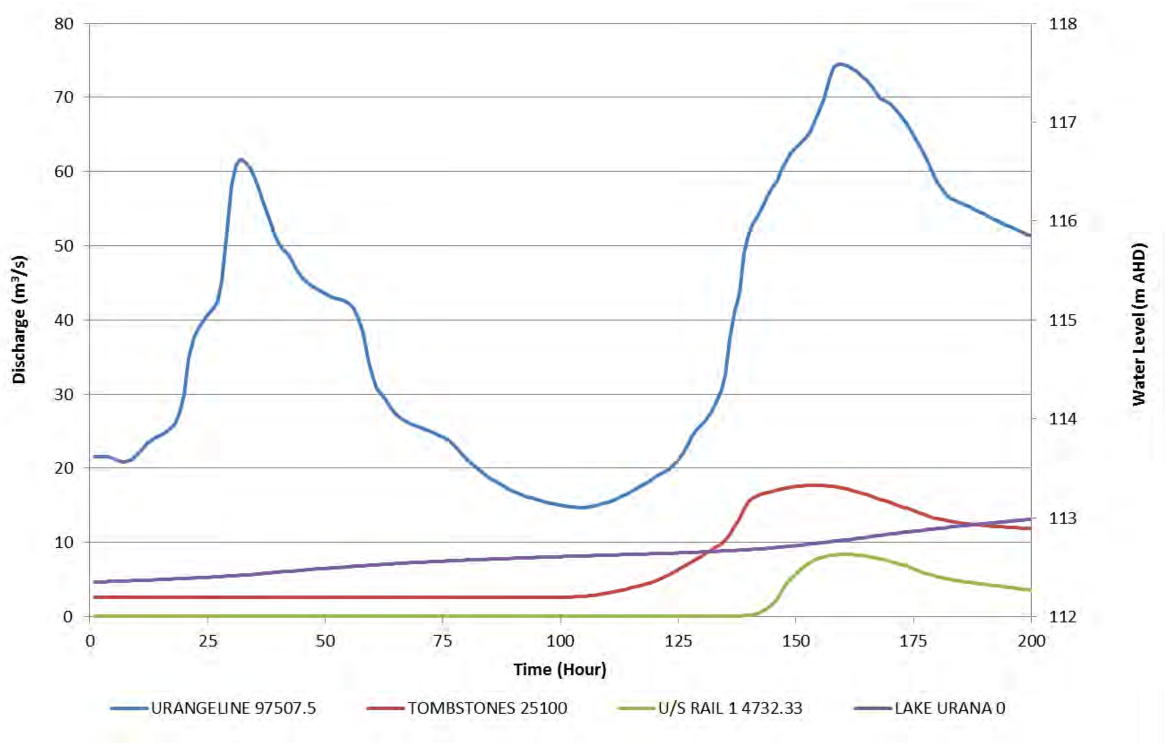
Base = Base case; Kc = Hydrologic Model Parameter (+/-20%); IL = Initial loss (+/-20%); n = Manning's n (+/-20%); TWL = Tailwater level (+/- 0.5m)

- D5: Flow differences (m^3/s) for the sensitivity runs (2012 event)

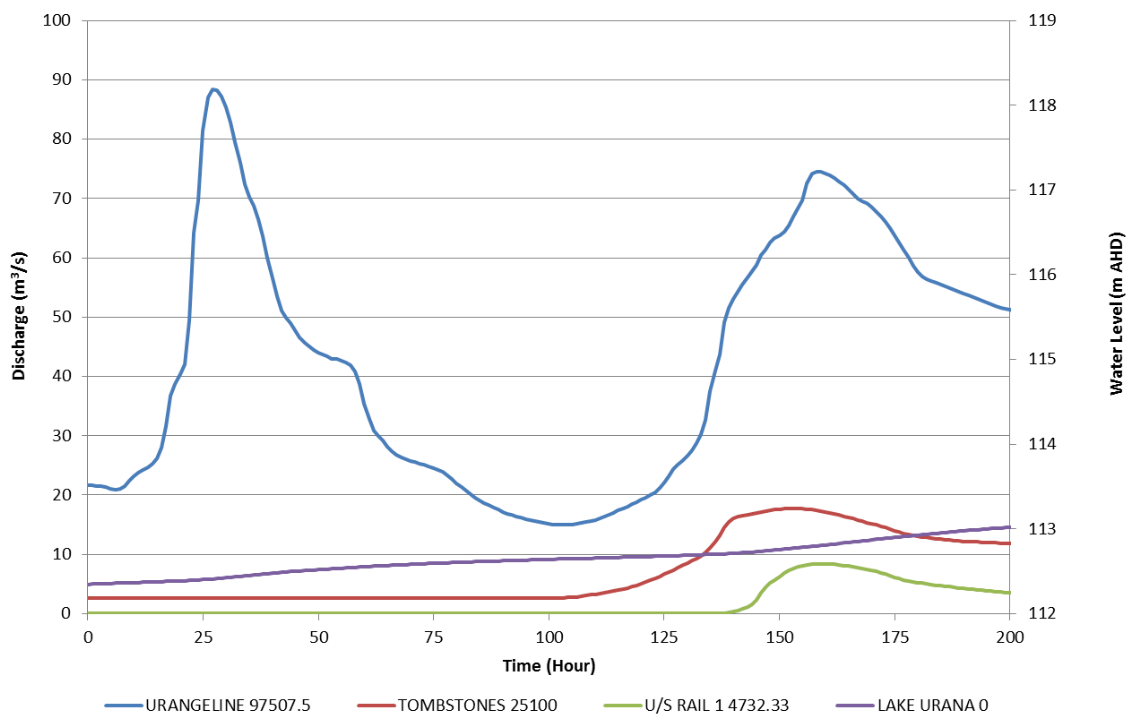
Flow line	Base	+Kc	-Kc	+IL	-IL	+n	-n	+TWL	-TWL
F01	442	-20	20	49	-62	0	0	0	0
F02	3	0	1	8	0	0	0	0	0
F03	5	-1	1	4	-3	-2	2	0	0
F04	55	-5	6	15	-19	-5	5	0	0
F05	444	-20	20	55	-63	0	1	0	0
F06	445	-20	20	55	-64	0	0	0	0
F07	3	0	0	1	-1	-1	1	0	0
F08	445	-20	19	54	-65	0	-2	0	0
F09	0	0	0	0	0	0	0	0	0
F10	0	0	0	0	0	0	1	0	0
F11	444	-20	19	54	-66	0	-2	0	0
F12	0	0	0	0	0	0	0	0	0
F13	444	-20	19	54	-67	0	-2	0	0
F14	440	-19	17	50	-66	3	-5	-2	1
F15	3	-1	1	4	-2	-2	4	1	0
F16	0	0	0	0	0	0	0	0	0
F17	378	-12	10	31	-50	17	-15	-14	6
F18	59	-7	3	15	-31	-13	9	13	-4

Base = Base case; Kc = Hydrologic Model Parameter (+/-20%); IL = Initial loss (+/-20%); n = Manning's n (+/-20%); TWL = Tailwater level (+/- 0.5m)

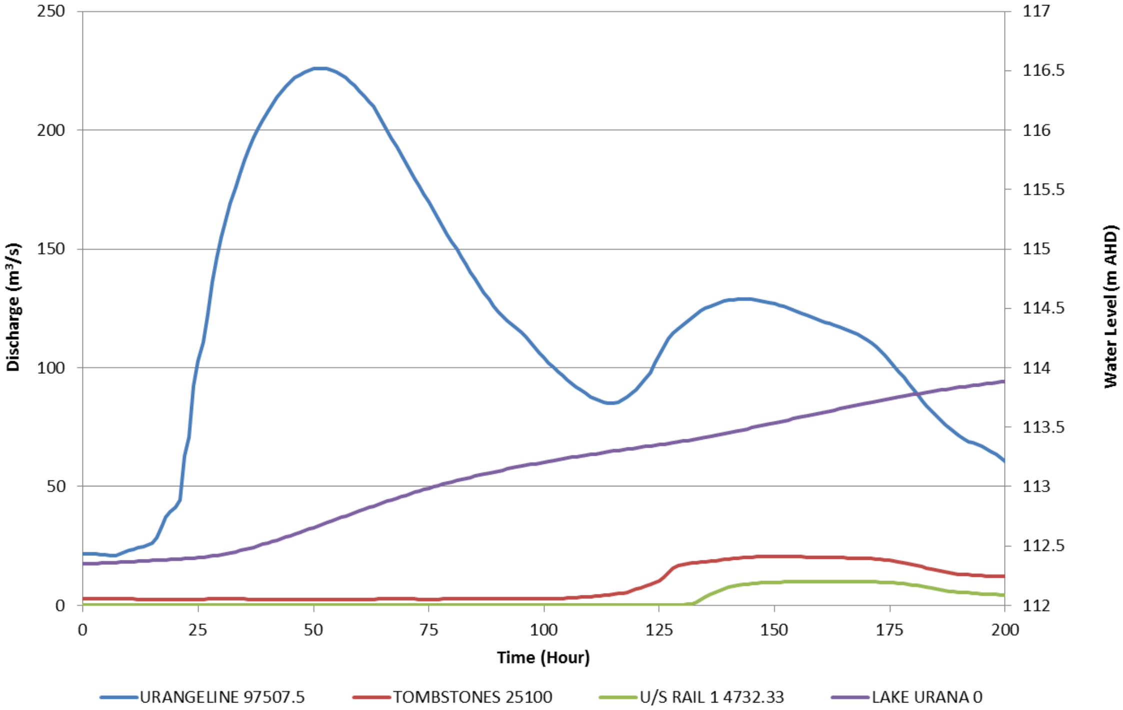
- D6 – Modelled water level and discharge hydrographs for design events simulated by MIKE-11 model for use in the TUFLOW model
    - Hydrographs for 20% AEP event



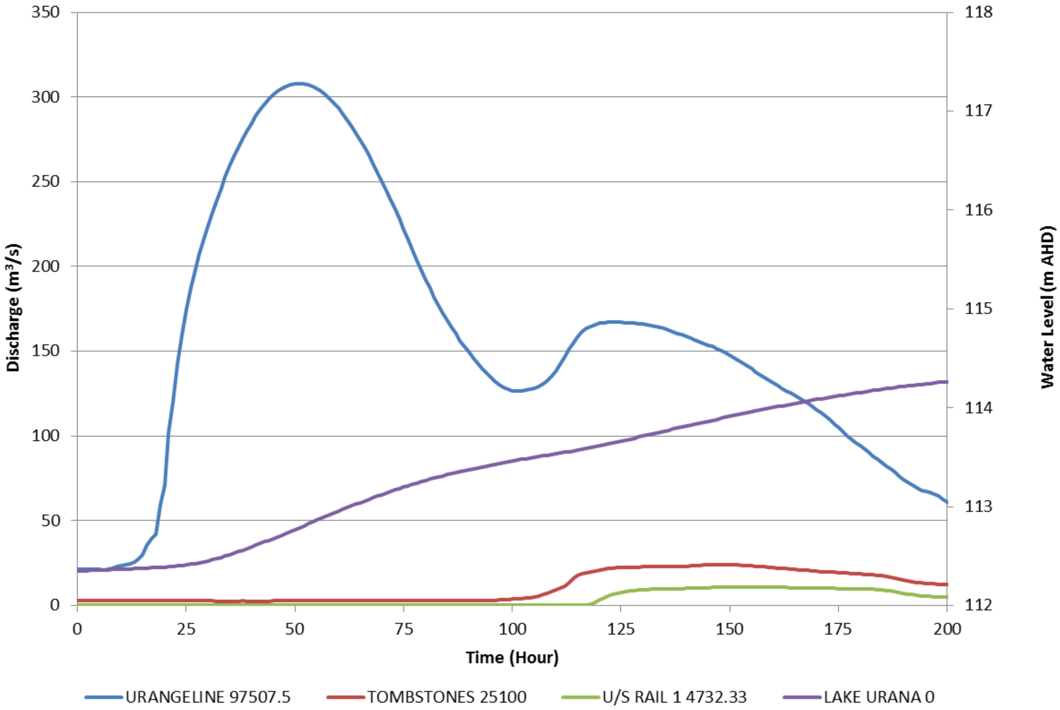
- Hydrographs for 10% AEP event



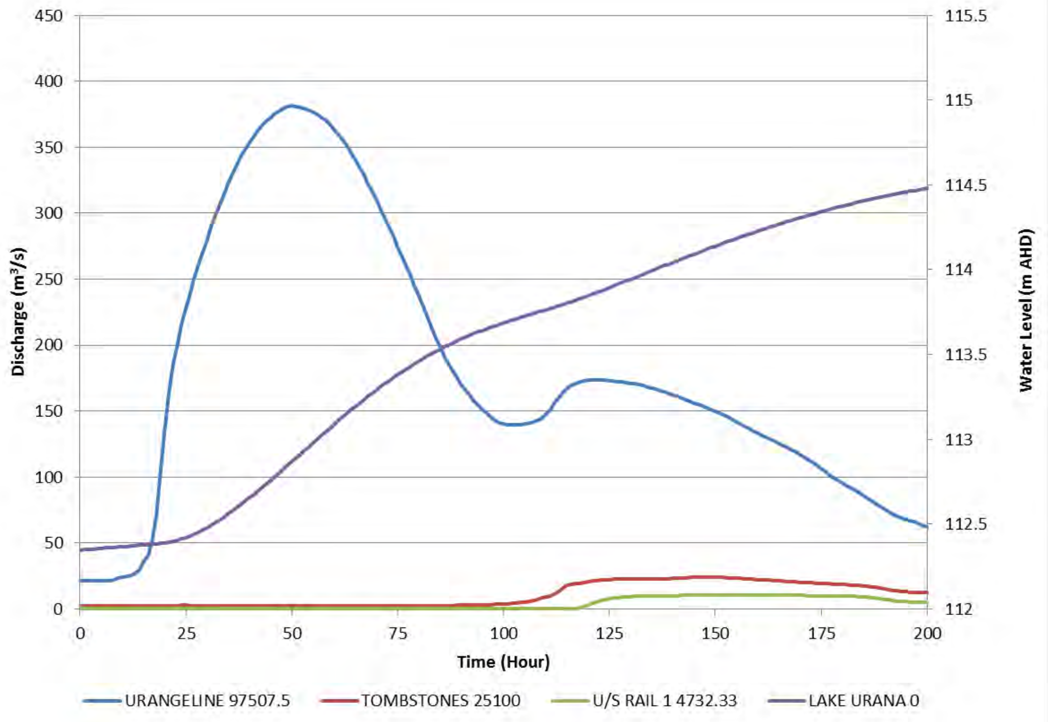
- Hydrographs for 5% AEP event



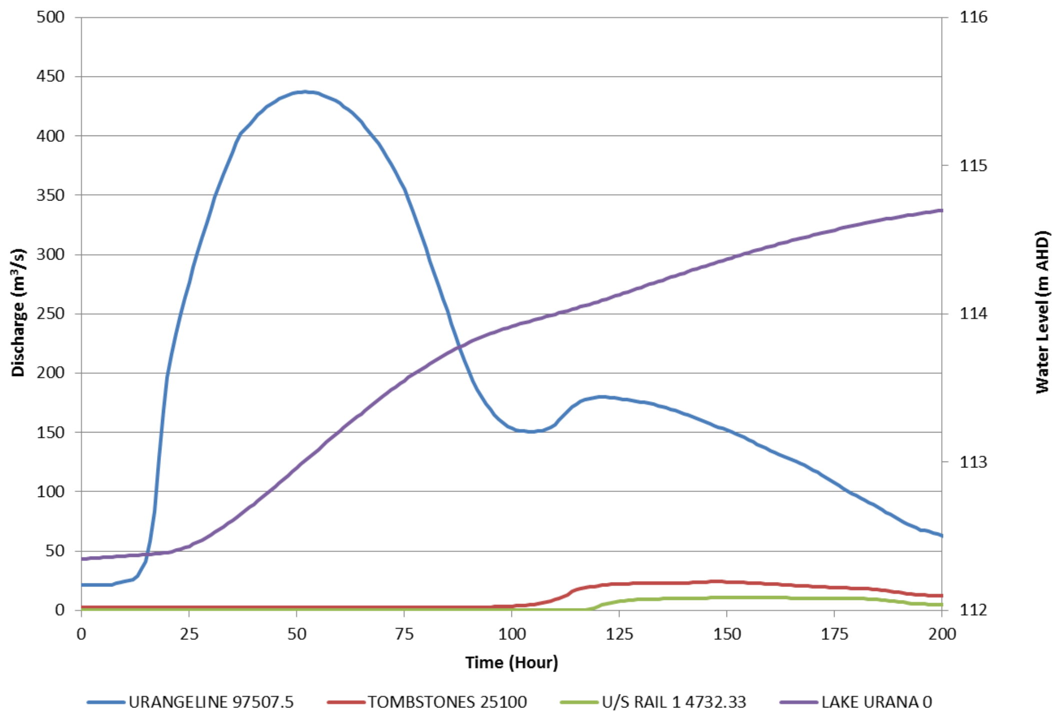
- Hydrographs for 2% AEP event



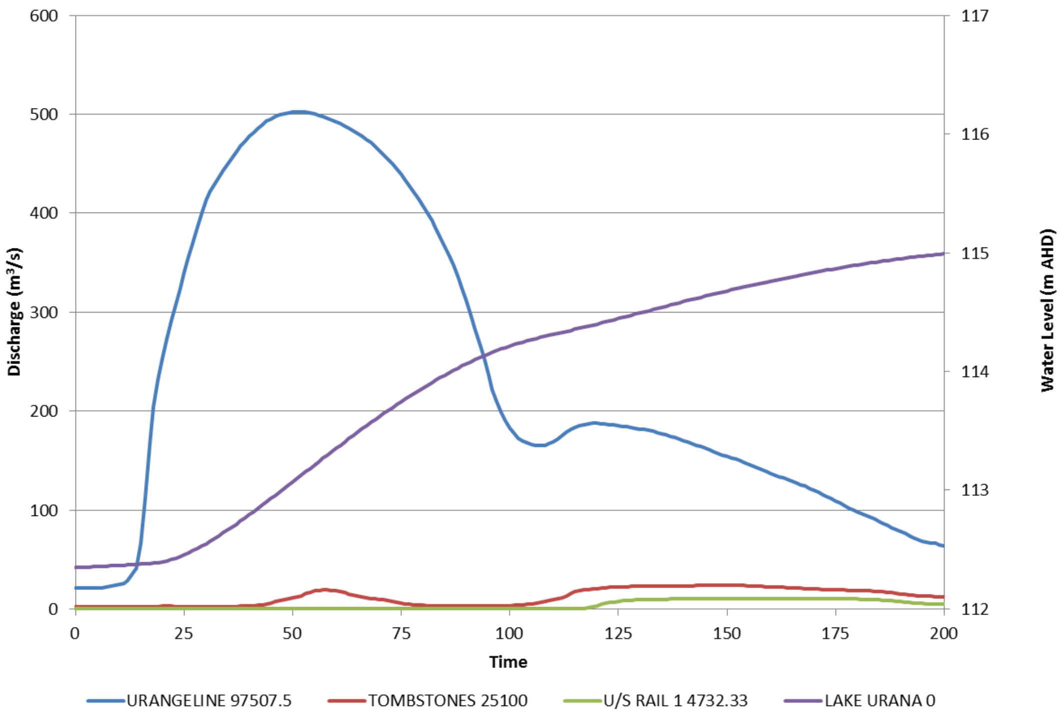
- Hydrographs for 1% AEP event



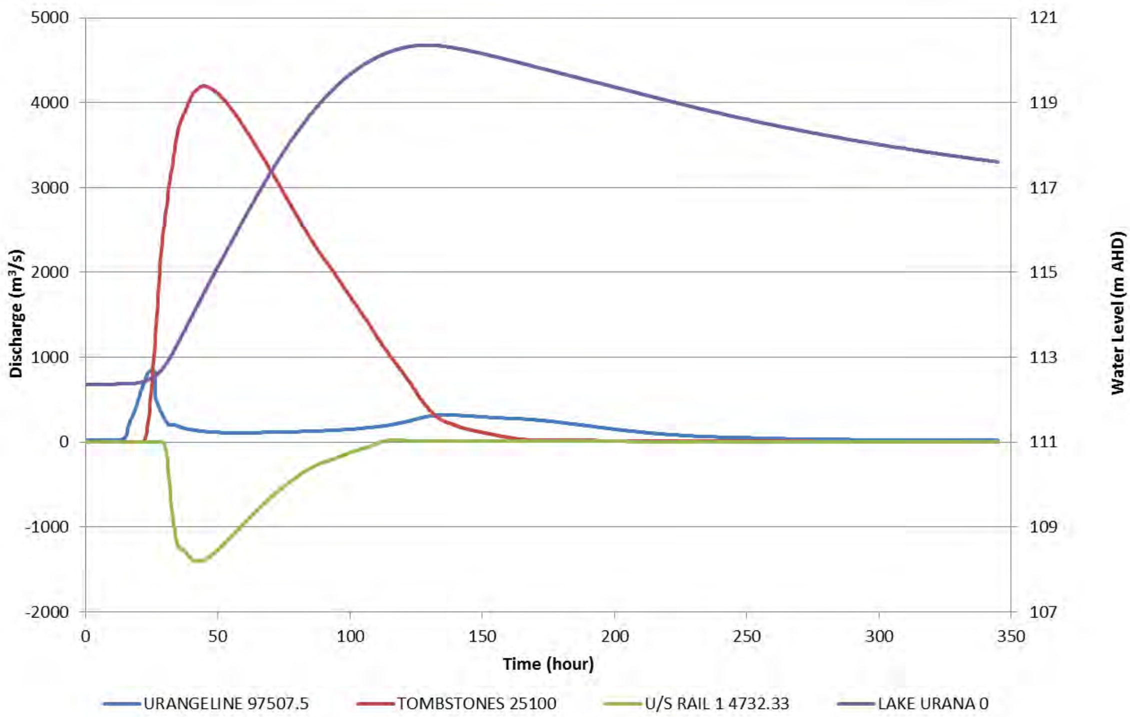
- Hydrographs for 0.5% AEP event



- Hydrographs for 0.2% AEP event



- Hydrographs for PMF event



- D7: Modelled peak flows for the design events

Flow line	20% AEP Event	10% AEP Event	5% AEP Event	2% AEP Event	1% AEP Event	0.5% AEP Event	0.2% AEP Event	PMF Event
F01	74	74	226	308	381	437	502	842
F02	26	26	3	3	4	3	19	2742
F03	241	227	192	272	234	381	282	93
F04	0	0	1	7	28	46	66	477
F05	100	100	227	309	382	438	515	1943
F06	100	100	228	310	383	440	516	1923
F07	0	0	1	2	2	3	4	226
F08	99	99	228	310	383	439	515	1695
F09	0	0	0	0	0	0	0	3
F10	0	0	0	0	0	0	1	1112
F11	99	99	228	310	383	439	515	1734
F12	0	0	0	0	0	0	0	341
F13	99	99	228	309	382	439	515	2204
F14	99	99	228	309	381	436	507	2023
F15	0	0	0	1	1	3	8	424
F16	0	0	0	0	0	0	0	385
F17	96	96	223	295	346	383	427	1022
F18	0	0	0	12	32	51	78	2712

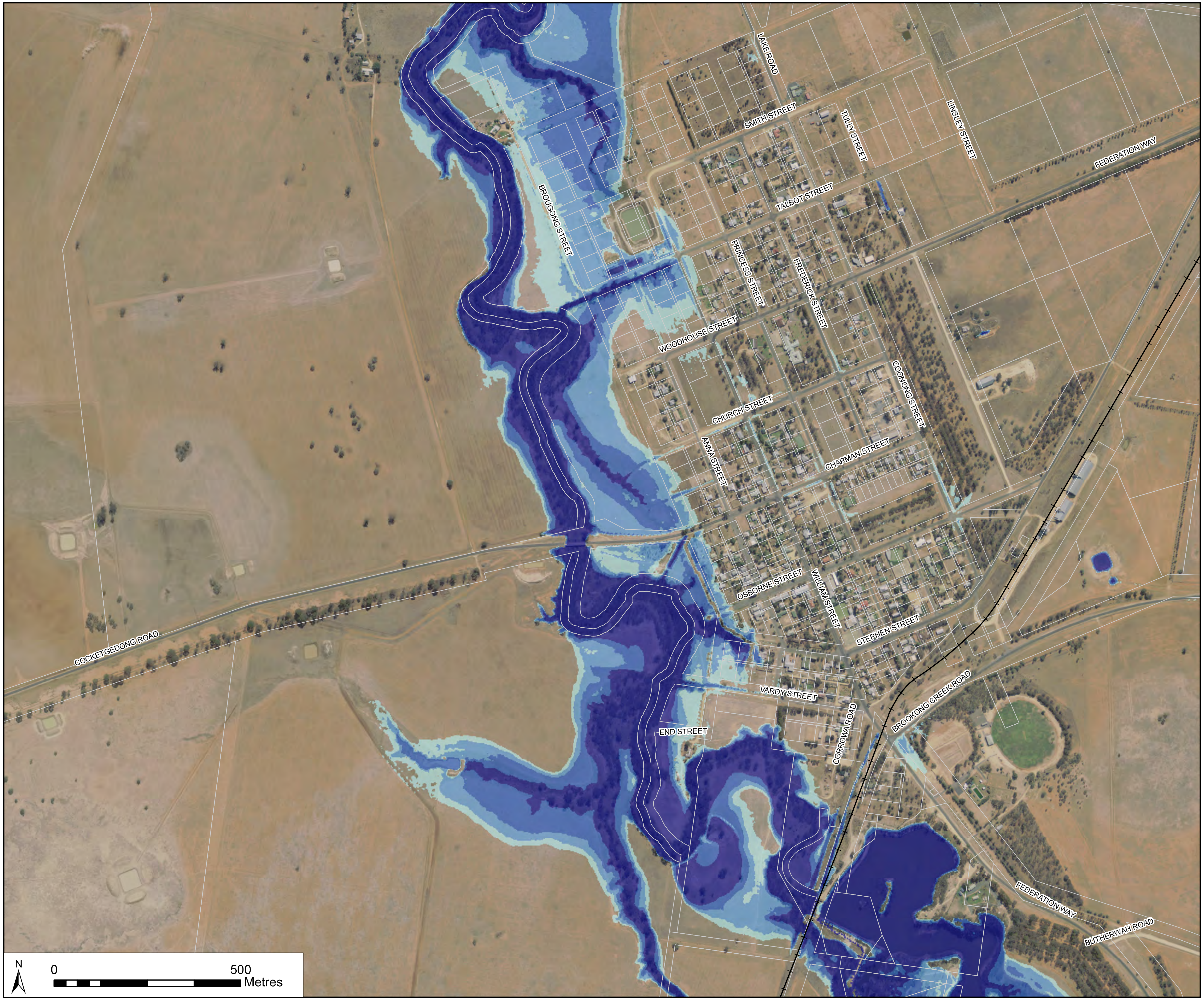
- D8: Modelled peak water levels for the design events

Location*	2010	2011	2012	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
1	116.61	116.90	117.08	116.61	116.61	116.61	116.78	116.97	117.10	117.26	119.03
2	116.48	116.89	117.08	116.27	116.27	116.52	116.77	116.97	117.10	117.25	119.02
3	116.47	116.88	117.07	116.07	116.07	116.51	116.76	116.96	117.09	117.24	119.01
4	116.43	116.86	117.04	116.39	116.39	116.47	116.73	116.93	117.06	117.21	118.98
5	116.44	116.86	117.05	116.05	116.05	116.48	116.74	116.93	117.06	117.22	118.98
6	116.42	116.85	117.04	116.19	116.19	116.46	116.73	116.93	117.05	117.21	118.97
7	116.42	116.85	117.03	116.39	116.39	116.46	116.72	116.92	117.05	117.20	118.97
8	116.40	116.83	117.02	116.09	116.09	116.44	116.71	116.91	117.03	117.19	118.96
9	116.38	116.82	117.00	116.36	116.36	116.42	116.69	116.89	117.02	117.17	118.94
10B	116.33	116.77	116.95	116.25	116.25	116.35	116.64	116.84	116.96	117.11	118.89
10A	116.34	116.76	116.94	116.23	116.23	116.37	116.64	116.83	116.96	117.11	118.88
11	116.28	116.70	116.89	115.84	115.84	116.32	116.58	116.77	116.90	117.06	118.86
12	116.12	116.57	116.76	116.00	116.00	116.16	116.44	116.64	116.78	116.94	118.78
13	116.12	116.55	116.75	116.00	116.00	116.16	116.43	116.62	116.76	116.92	118.75
14	116.12	116.54	116.73	115.78	115.78	116.15	116.42	116.61	116.75	116.91	118.74
15	116.13	116.58	116.78	115.78	115.79	116.17	116.45	116.65	116.79	116.96	118.79
16	116.11	116.53	116.72	115.61	115.61	116.15	116.41	116.60	116.73	116.89	118.67
17	116.10	116.37	116.55	116.07	116.08	116.13	116.29	116.43	116.55	116.71	118.53
18	116.26	116.53	116.72	116.26	116.26	116.27	116.41	116.60	116.73	116.89	118.70
19	116.11	116.54	116.73	116.11	116.11	116.15	116.41	116.61	116.74	116.90	118.73
20A	116.13	116.57	116.78	116.01	116.02	116.17	116.45	116.65	116.79	116.96	118.80
20B	116.49	116.58	116.78	116.49	116.49	116.49	116.49	116.65	116.79	116.96	118.80
21	116.16	116.62	116.82	116.12	116.16	116.21	116.49	116.70	116.84	117.00	118.83
22	116.16	116.63	116.83	116.16	116.17	116.22	116.50	116.71	116.85	117.01	118.83
23	116.42	116.65	116.86	116.42	116.42	116.42	116.52	116.73	116.87	117.04	118.86
24	116.63	116.85	117.04	116.63	116.63	116.63	116.73	116.93	117.05	117.21	118.97
25	116.42	116.85	117.04	116.36	116.36	116.46	116.73	116.93	117.05	117.21	118.97
26	116.60	116.82	116.97	116.60	116.60	116.60	116.71	116.88	116.99	117.13	118.90
27	116.28	116.68	116.87	116.27	116.27	116.31	116.56	116.75	116.88	117.04	118.85
29	116.34	116.58	116.77	116.34	116.34	116.34	116.45	116.65	116.79	116.95	118.78
30	116.44	116.86	117.05	116.02	116.02	116.48	116.74	116.94	117.06	117.22	118.98
31	116.85	116.90	117.08	116.85	116.85	116.85	116.85	116.97	117.10	117.25	119.02
32D	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
33	116.64	116.67	116.82	116.64	116.64	116.64	116.64	116.72	116.83	116.99	118.82
100	116.78	116.90	117.08	116.78	116.78	116.78	116.78	116.97	117.10	117.25	119.02
101	116.42	116.85	117.03	115.99	115.99	116.46	116.72	116.92	117.05	117.20	118.97
103	116.42	116.85	117.03	115.99	115.99	116.46	116.72	116.92	117.05	117.20	118.97
104	116.42	116.85	117.03	115.85	115.85	116.46	116.72	116.92	117.05	117.20	118.97
106	116.42	116.85	117.03	115.98	115.98	116.46	116.72	116.92	117.05	117.20	118.98
107	116.42	116.85	117.03	115.85	115.85	116.46	116.72	116.92	117.05	117.20	118.98
108	116.30	116.70	116.88	116.09	116.09	116.33	116.58	116.77	116.90	117.05	118.86
109	116.60	116.60	116.74	116.60	116.60	116.60	116.60	116.62	116.75	116.92	118.75

*refer to **Figure 5-1**

Appendix E. Flood Mapping for Design Events

- Figure E-1: 20% AEP flood depth map
- Figure E-2: 10% AEP flood depth map
- Figure E-3: 5% AEP flood depth map
- Figure E-4: 2% AEP flood depth map
- Figure E-5: 1% AEP flood depth map
- Figure E-6: 0.5% AEP flood depth map
- Figure E-7: 0.2% AEP flood depth map
- Figure E-8: PMF flood depth map
- Figure E-9: 5% AEP flood hazard map
- Figure E-10: 1% AEP flood hazard map
- Figure E-11: 0.5% AEP flood hazard map
- Figure E-12: 1% AEP floodways
- Figure E-13: 1% AEP hydraulic categories map
- Figure E-14: Flood planning area map
- Figure E-15: 1% AEP flood depth for major overland flooding (MOFF)
- Figure E-16: 1% AEP flood hazard for major overland flooding (MOFF)



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

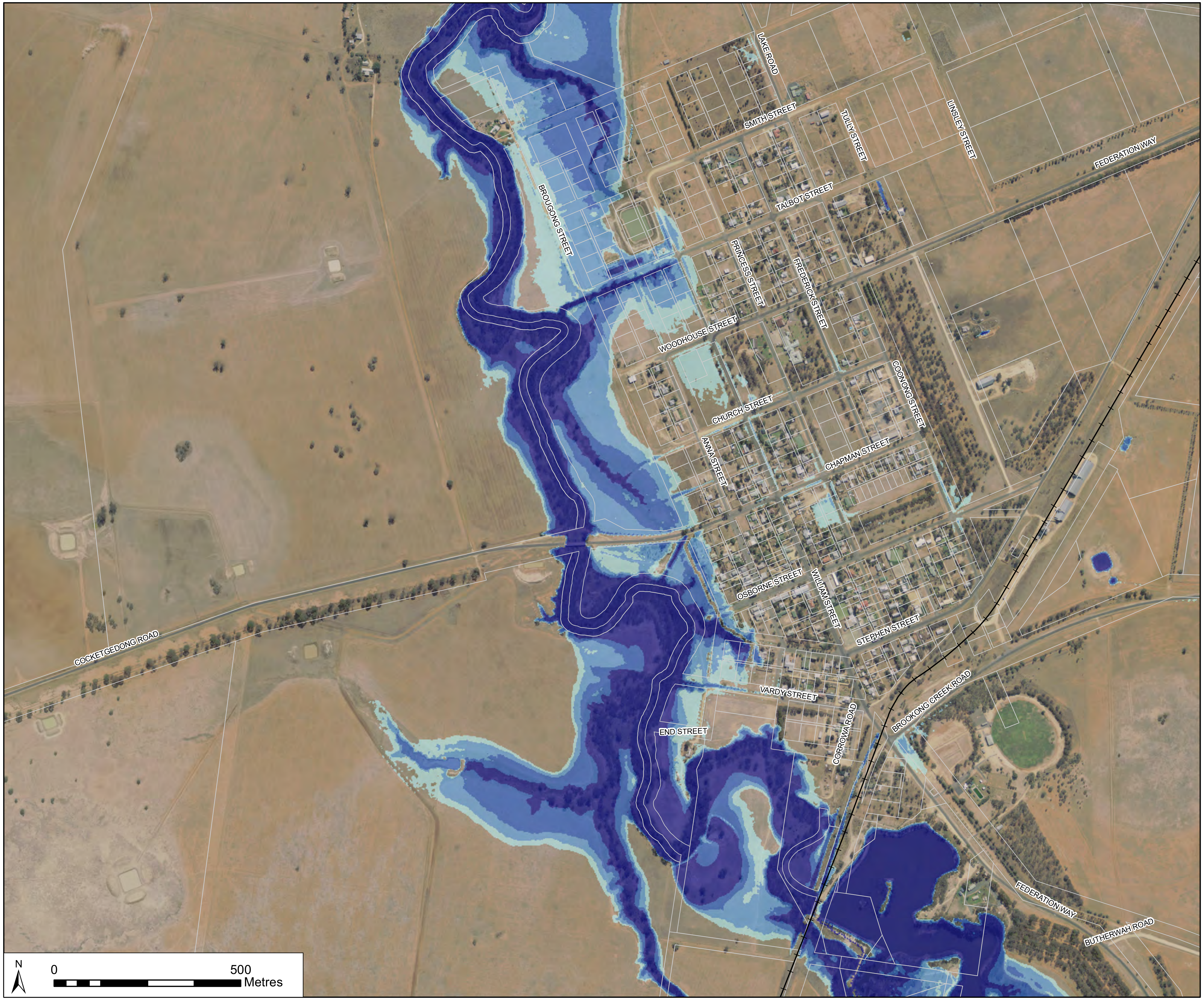
Data Sources: LPI, OEH, Council

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	Urana
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE E-1
CHECK AH	DATE 29/06/2017	



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

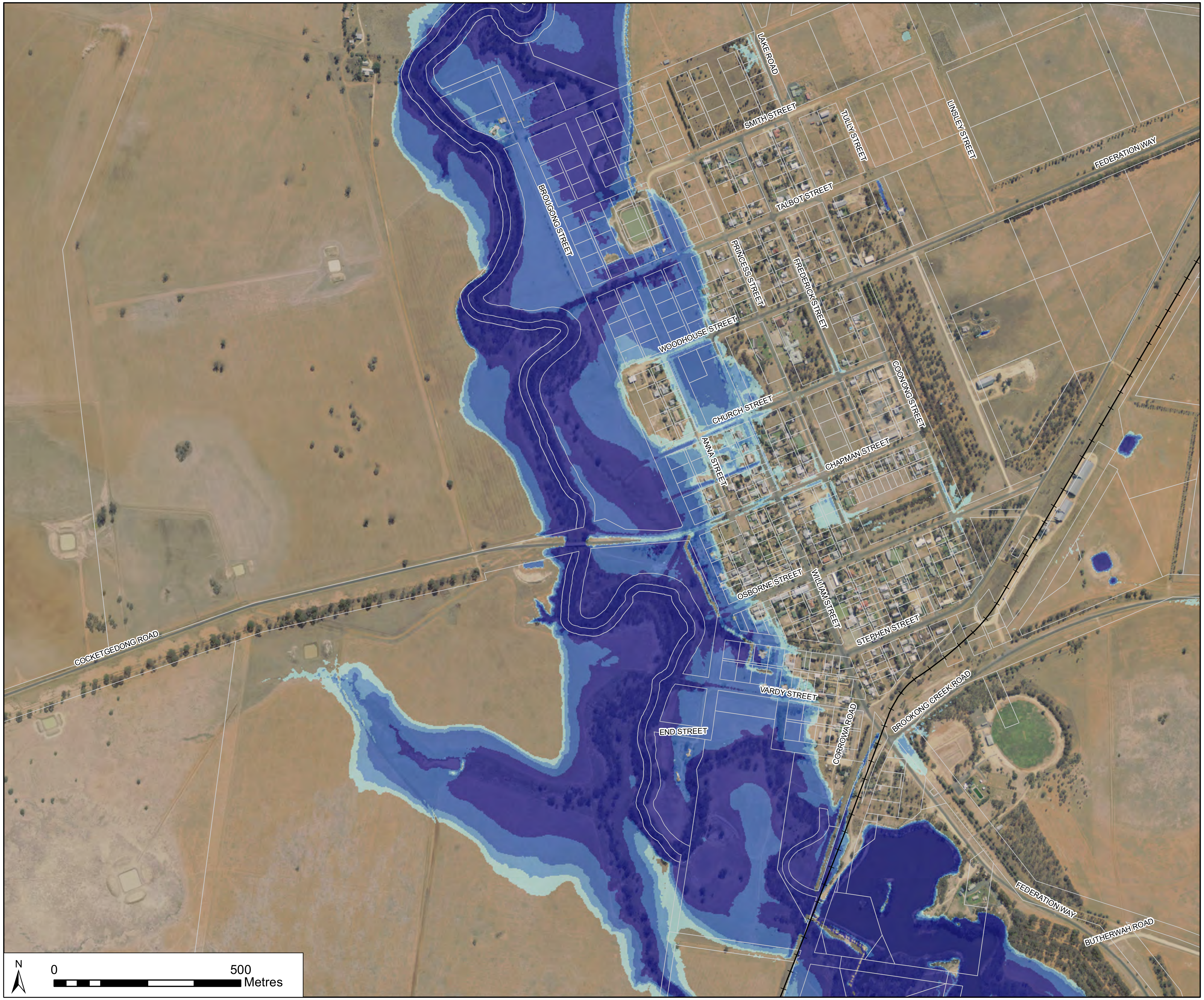
Data Sources: LPI, OEH, Council

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	Urana
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE E-2
CHECK AH	DATE 29/06/2017	



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

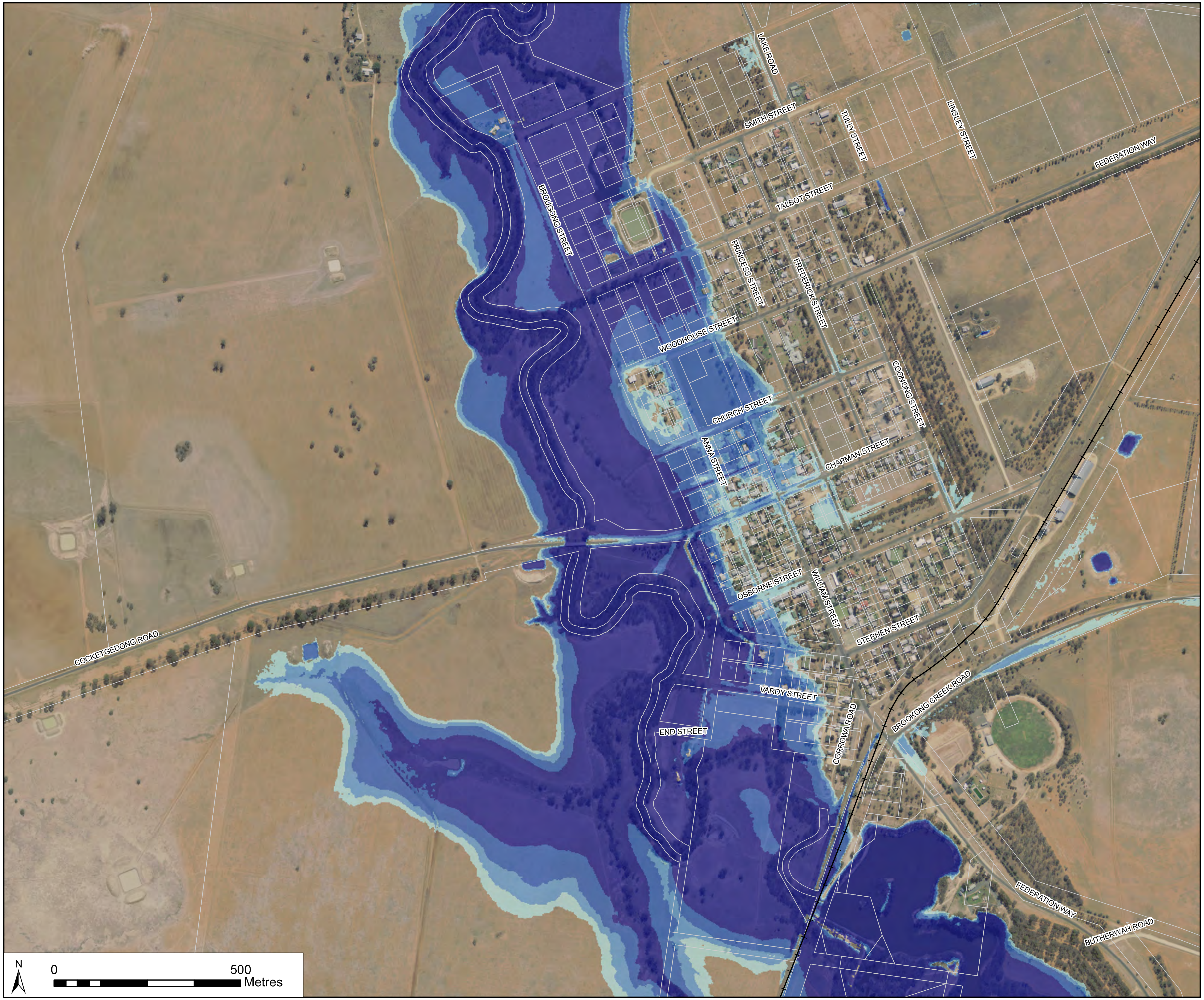
Data Sources: LPI, OEH, Council

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

DRAWN MR	PROJECT # IA055600	FIGURE E-3
CHECK AH	DATE 29/06/2017	



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

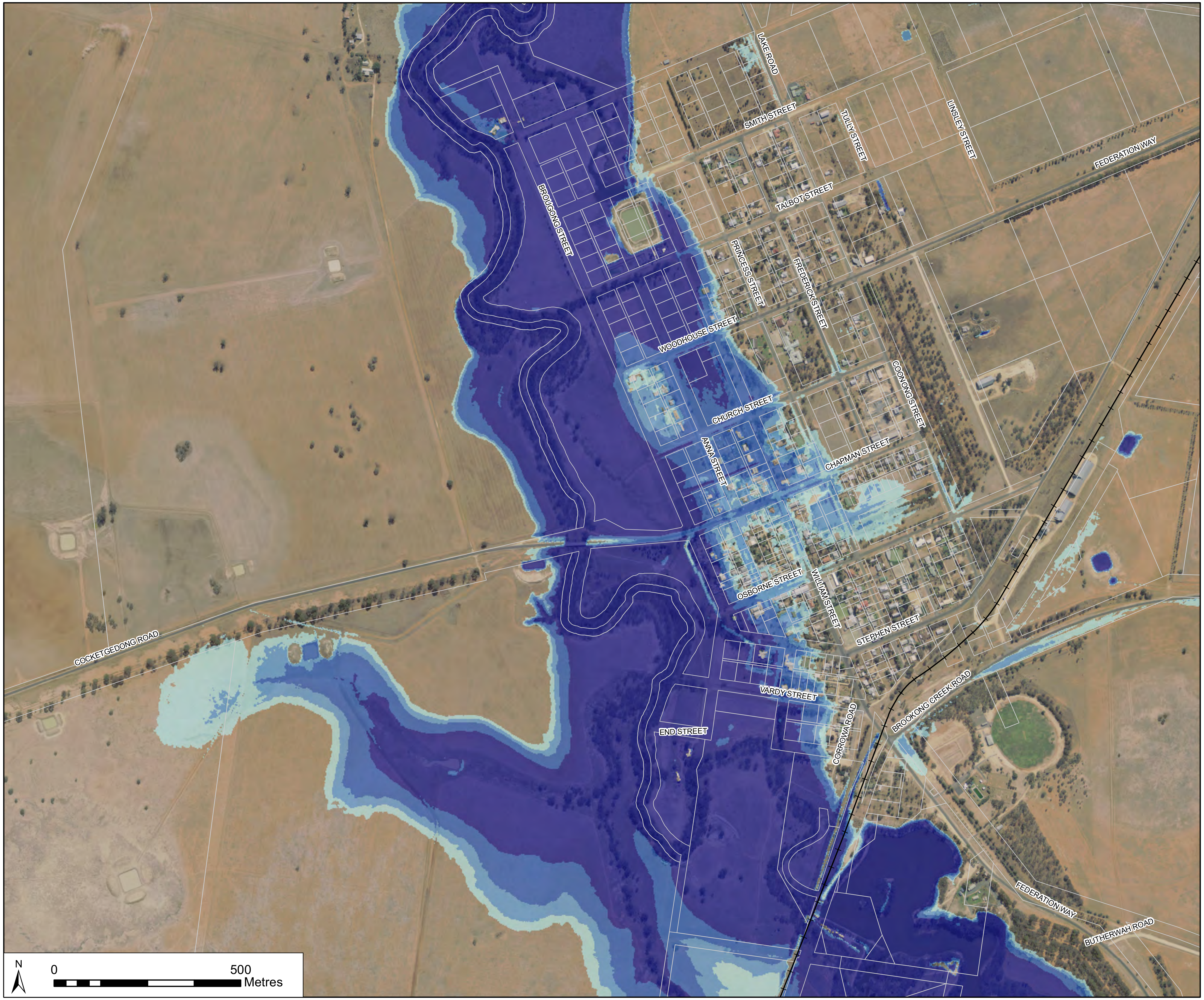
Data Sources: LPI, OEH, Council

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	Urana
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE E-4
CHECK AH	DATE 29/06/2017	



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

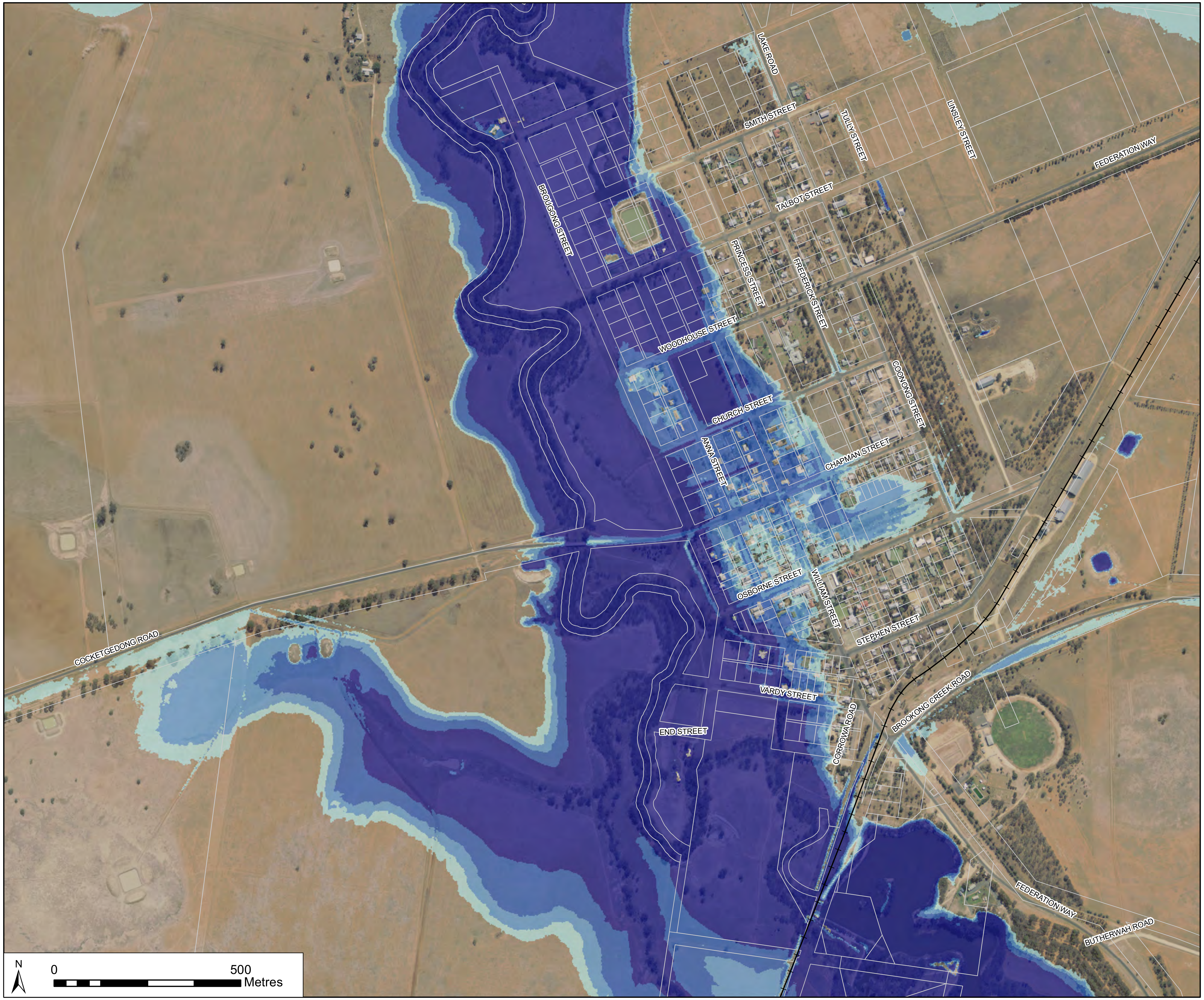
Data Sources: LPI, OEH, Council

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	Urana
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN	PROJECT #	
MR	IA055600	FIGURE E-5
CHECK	DATE	
AH	29/06/2017	



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

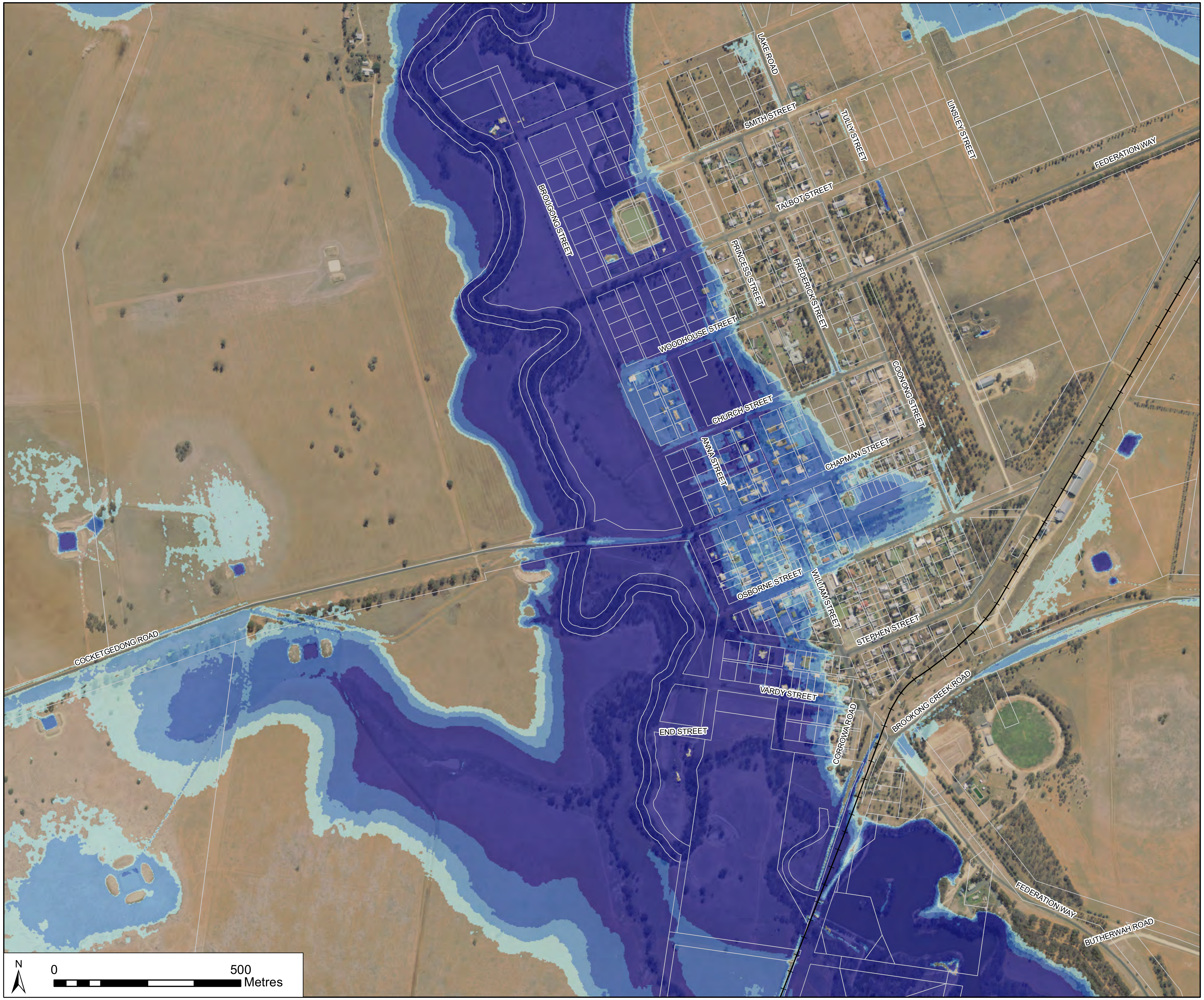
Data Sources: LPI, OEH, Council

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

DRAWN MR	PROJECT # IA055600	FIGURE E-6
CHECK AH	DATE 29/06/2017	



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

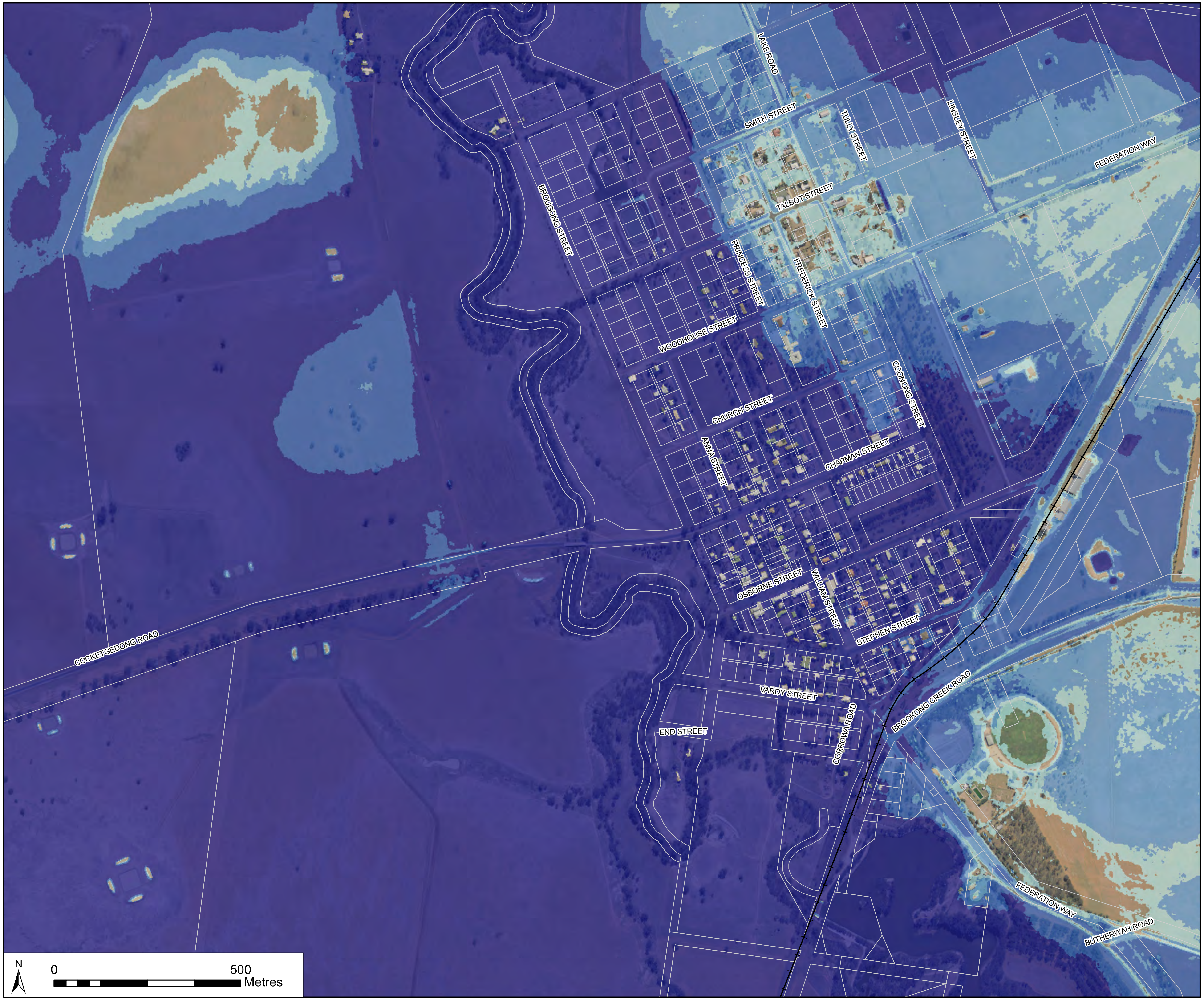
Data Sources: LPI, OEH, Council

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

DRAWN MR	PROJECT # IA055600	FIGURE E-7
CHECK AH	DATE 29/06/2017	



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

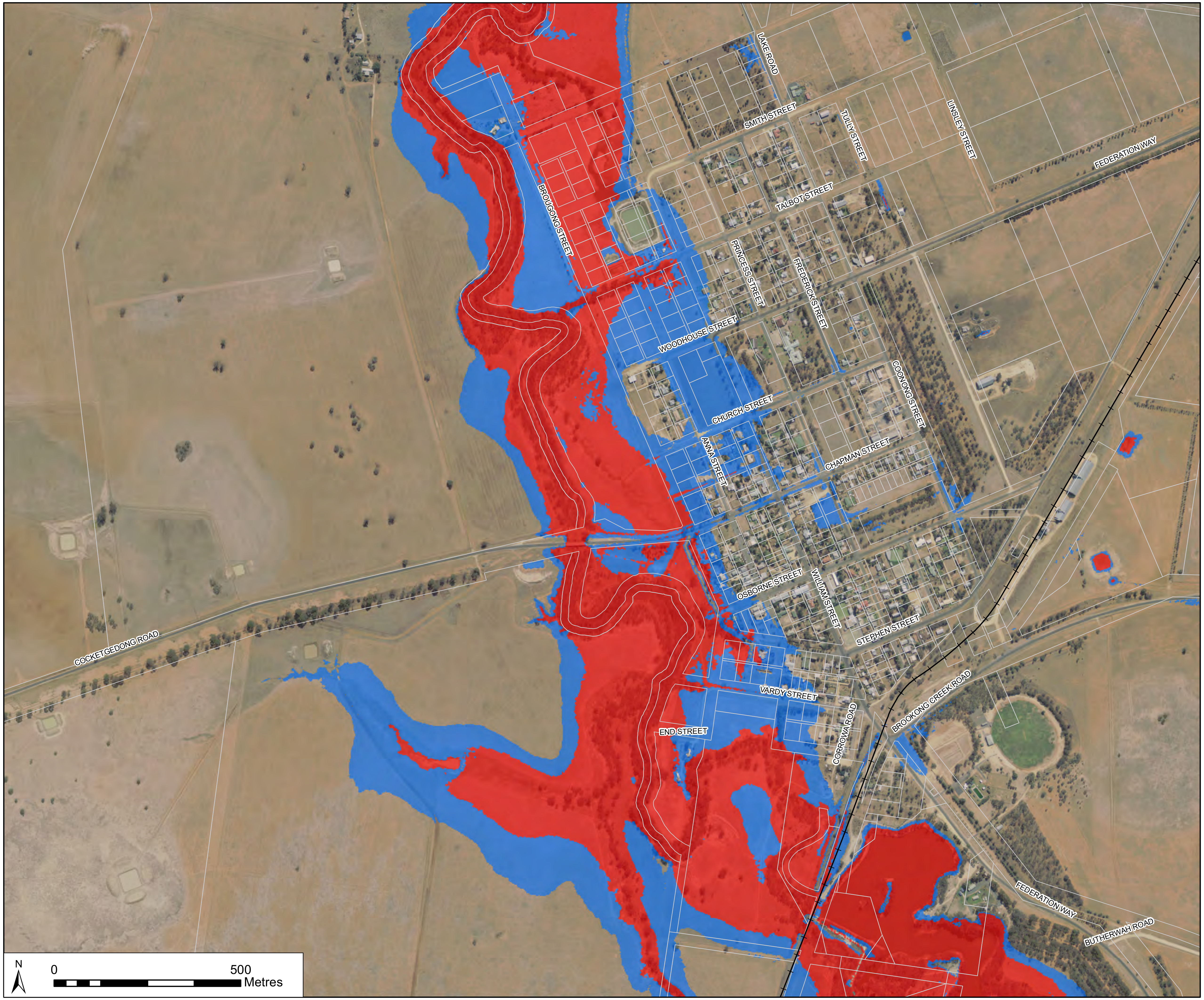
Data Sources: LPI, OEH, Council

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	Urana
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE E-8	
CHECK AH	DATE 29/06/2017		



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

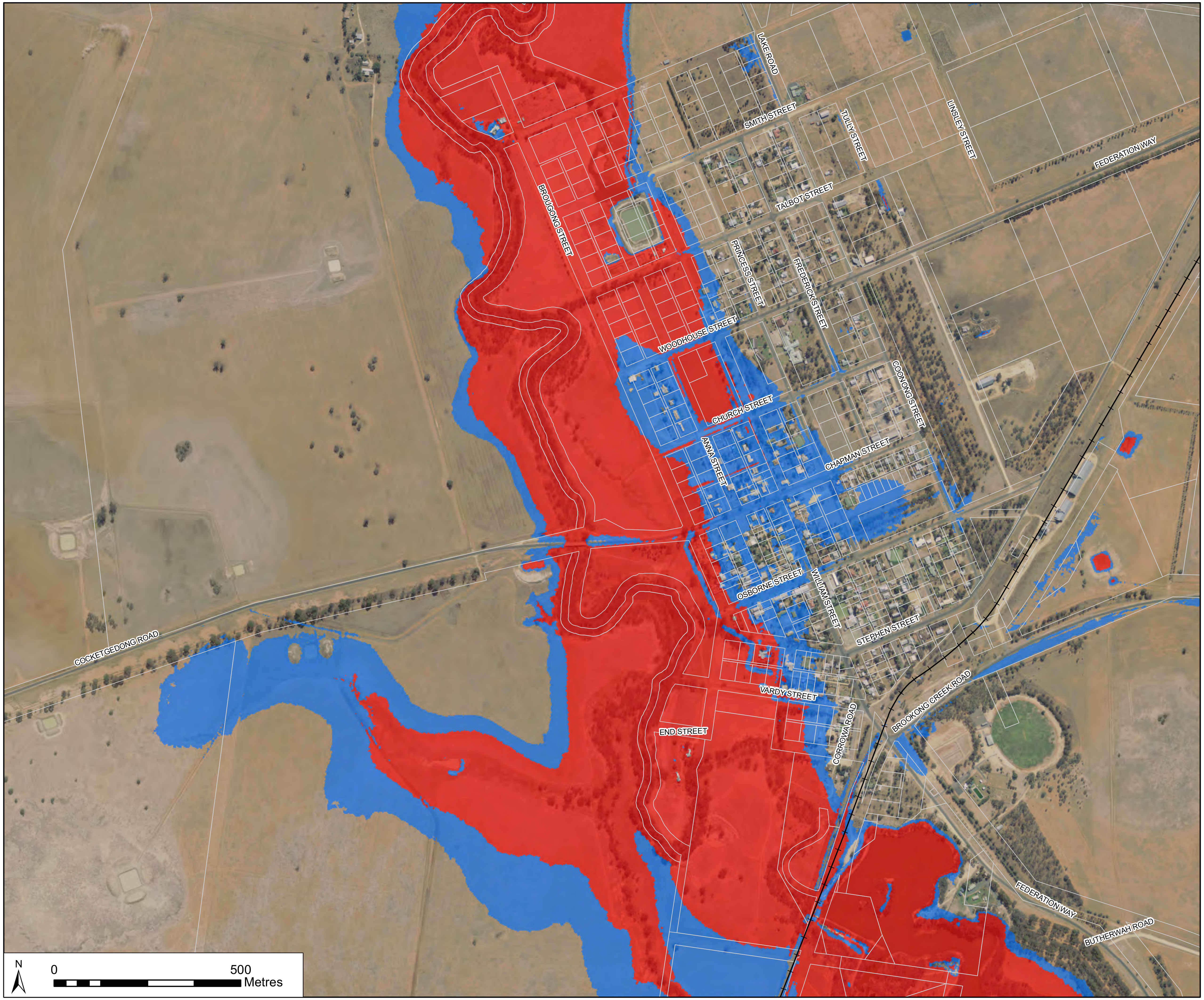
LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

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

DRAWN MR | PROJECT # IA055600
CHECK AH | DATE 29/06/2017

FIGURE E-9



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

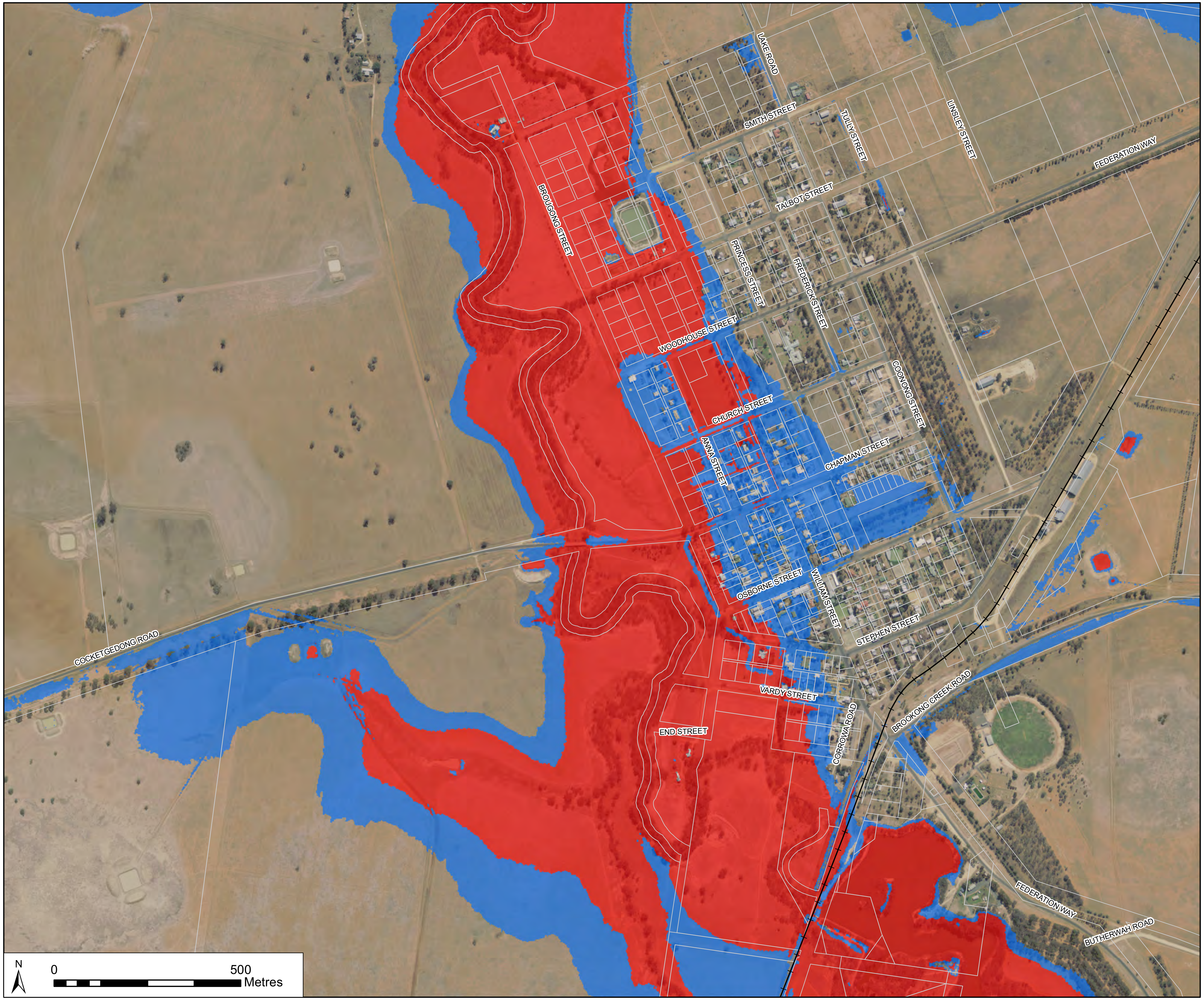
Data Sources: LPI, OEH, Council

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	Urana
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE E-10
CHECK AH	DATE 29/06/2017	



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

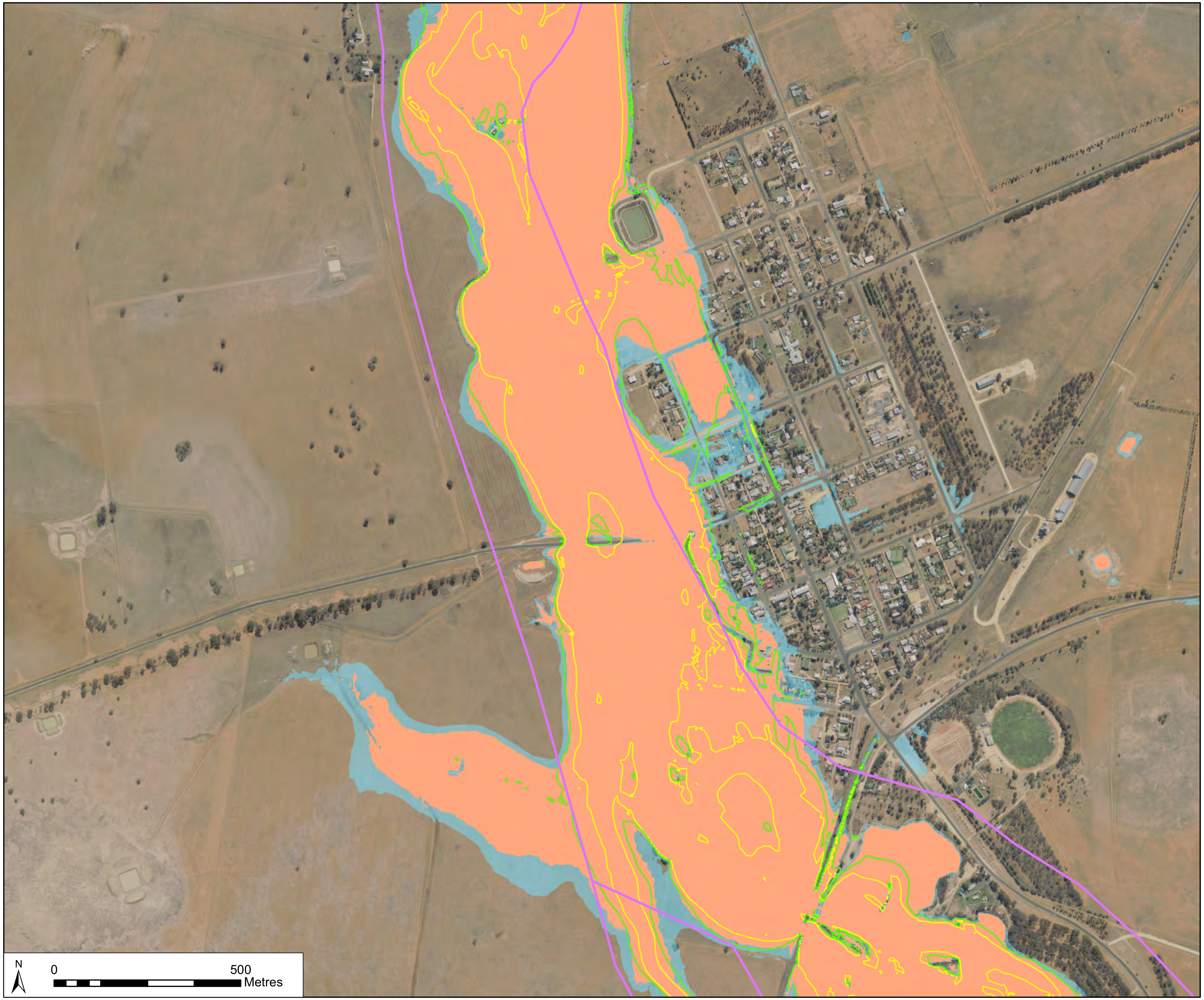
Data Sources: LPI, OEH, Council

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

DRAWN MR	PROJECT # IA055600	FIGURE E-11
CHECK AH	DATE 29/06/2017	



Legend

- Floodway (Billabong Ck FMP)
- VD > 0.25
- VD > 0.5
- 1% AEP High Hazard
- 5% AEP Flood Extent

GDA 1994 MGA Zone 55
Scale: A3

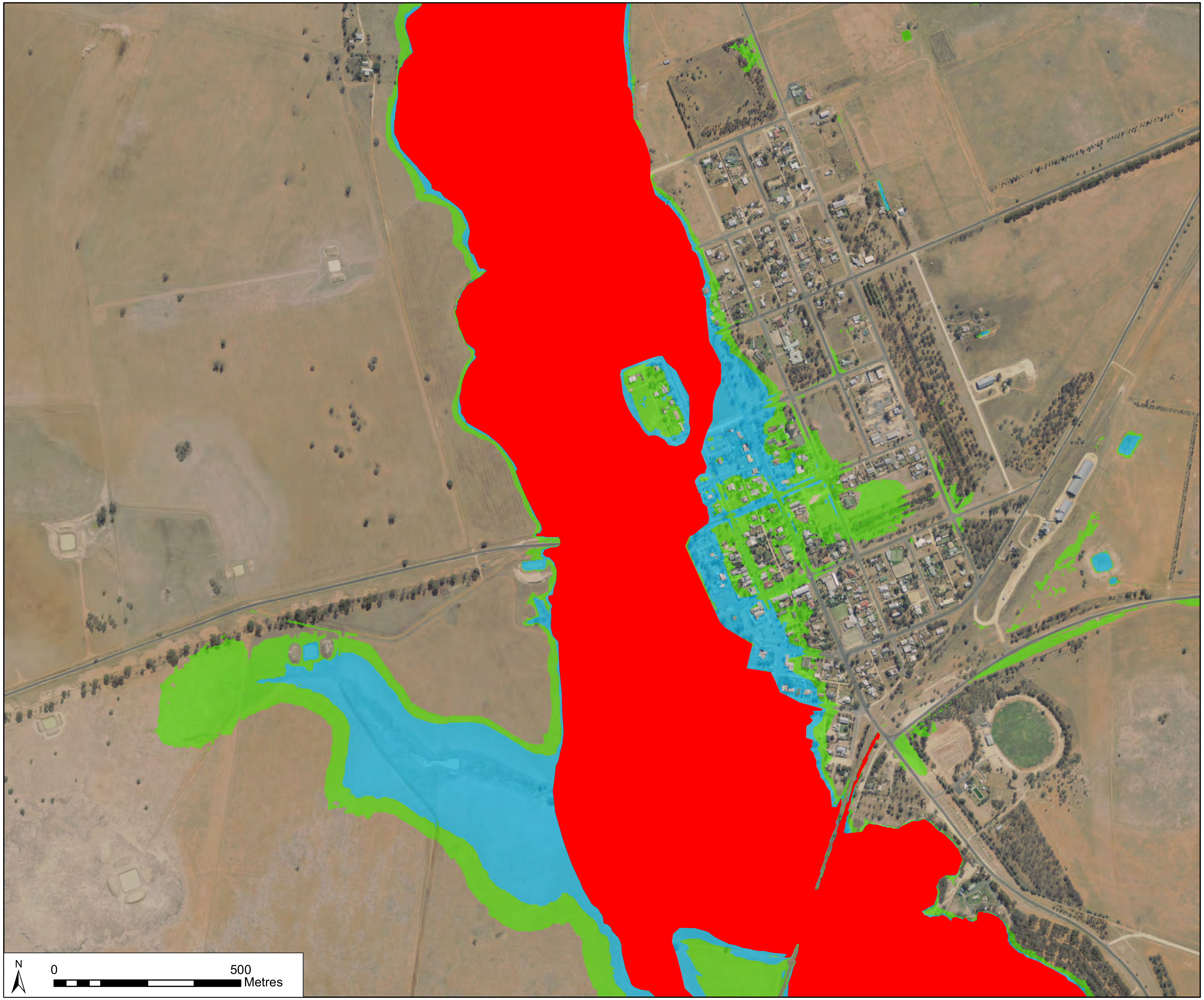
Data Sources: LPI, OEH, Council

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	Floodway delineation
TOWN	Urana
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE E-12
CHECK AH	DATE 29/06/2017	



Legend

- Floodway
- Flood Storage
- Flood Fringe

Depths below 150mm have been trimmed from this map

GDA 1994 MGA Zone 55
Scale: A3

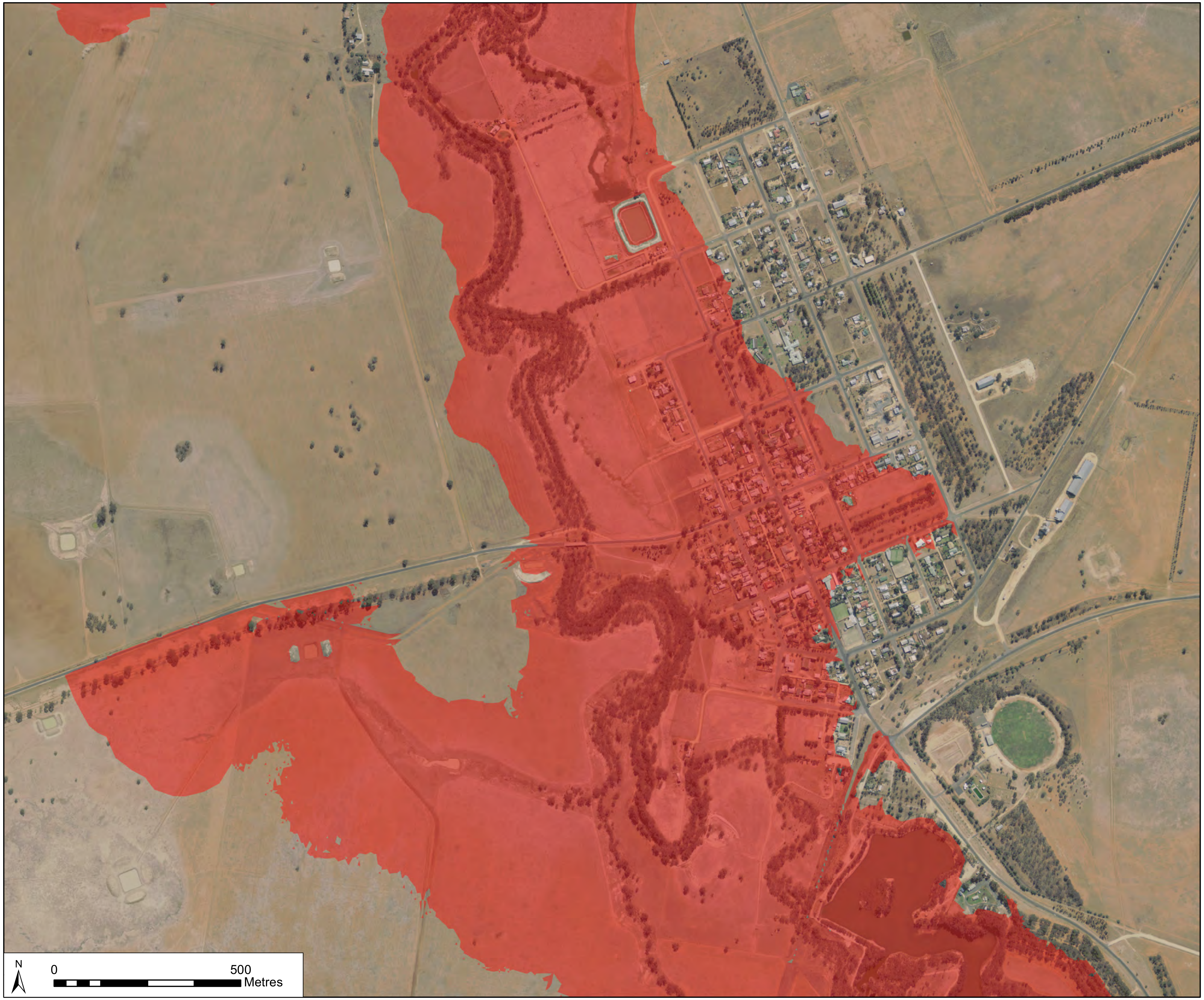
Data Sources: LPI, OEH, Council

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 Categories - 1% AEP
TOWN	Urana
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE E-13
CHECK AH	DATE 25/08/2017	



Legend

Flood Planning Area

GDA 1994 MGA Zone 55
Scale: A3

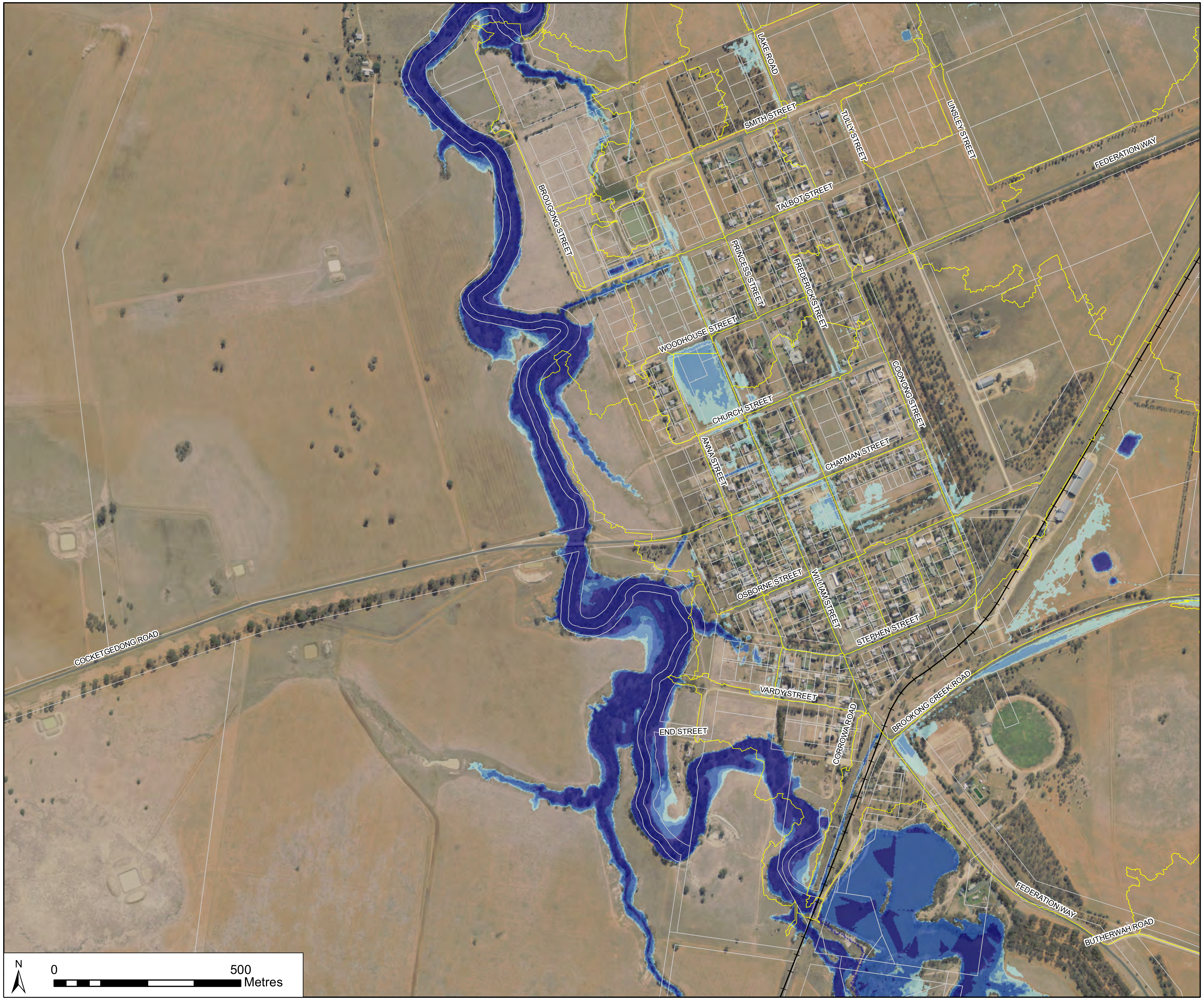
Data Sources: LPI, OEH, Council

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	Flood Planning Area
TOWN	Urana
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE E-14
CHECK AH	DATE 25/08/2017	



Legend

- Sub-Catchments
- 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

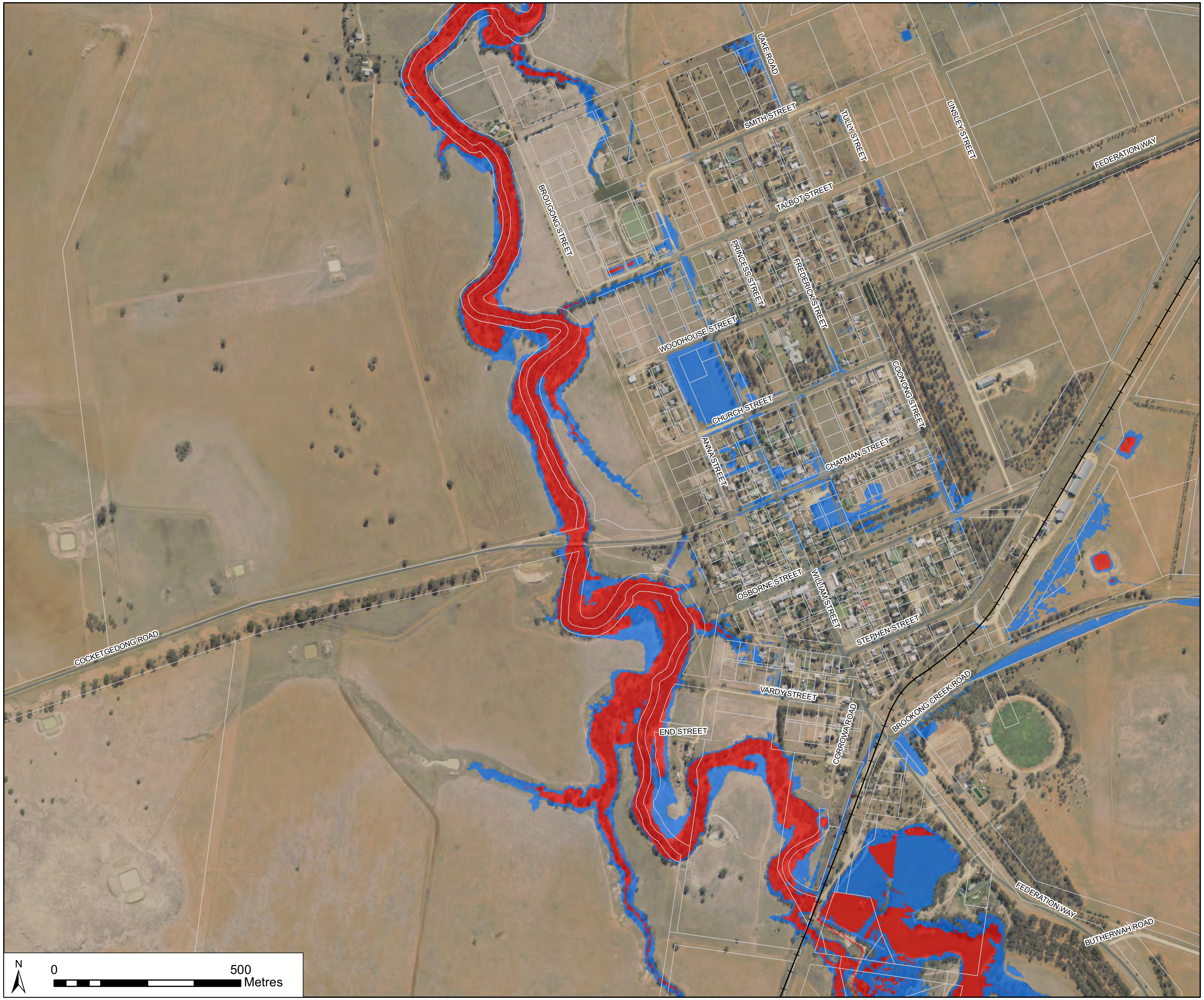
LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	1% AEP Event Flood Depth MOFF
TOWN	Urana
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR | PROJECT # IA055600
CHECK AH | DATE 25/08/2017

FIGURE E-15



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 MOFF
TOWN	Urana
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE E-16
CHECK AH	DATE 25/08/2017	