INDEX OF REPORTS OF THE BLAYNEY SHIRE EXTRAORDINARY COUNCIL MEETING HELD ON MONDAY 18 MAY 2015

INFRASTRUCTURE SERVICES REPORTS

Blayney Flood Study

BLAYNEY SHIRE COUNCIL

Flood Study Report

DRAFT

30 January 2015

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Flood Study Report

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Blayney Flood Study

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Document history and status

Revision	Date	Description	By	Review	Approved
0	13-10-2014	Draft Flood Study Report	L Chong	A Hossain	A Hossain
1	30-1-2015	Draft Flood Study Report updated for public exhibition	LC	A Hossain	A Hossain

Contents

Forward

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

Blayney Shire Council proposes to develop a Floodplain Risk Management Plan for the Town of Blayney to address the existing, future and continuing flood problems, in accordance with the NSW Floodplain Development Manual (2005).

This report represents the first and the second stages of the management process and has been prepared for Council by Jacobs (Sinclair Knight Merz merged with Jacobs in December 2013). It documents the nature and flooding extents within the Study Area for Blayney and is an essential resource for the subsequent stages of the floodplain management process.

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 the Town of Blayney located in New South Wales in accordance with the scope of services set out in the contract between Jacobs and Blayney Shire 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

1.1 Background

The Town of Blayney is located in the Central West region of New South Wales approximately 240km west of Sydney in the Blayney Shire Council area. Blayney Township (population 3,355 at the 2011 census) is the urban centre of Blayney Shire Council (hereafter Council) and provides the administrative, commercial, retail and industrial centre for the Shire. Blayney is strategically located on the junction of the Mid-Western Highway and the road between Orange and Goulburn. It is also located on the intersection of the Main Western Railway and the Blayney – Demondrille Railway, which provides a link between the Western and Southern lines and direct rail access into Melbourne.

The town is located in the upper reaches of the catchment, so flooding occurs with little or no warning, other than the contributory rain. Severe weather events in September and December 2010 and March 2012 resulted in the Belubula River and its tributaries all experiencing high flows which caused damage to the infrastructure including roads and bridges. Roads were closed in the town due to elevated water levels and SES attended houses in the area.

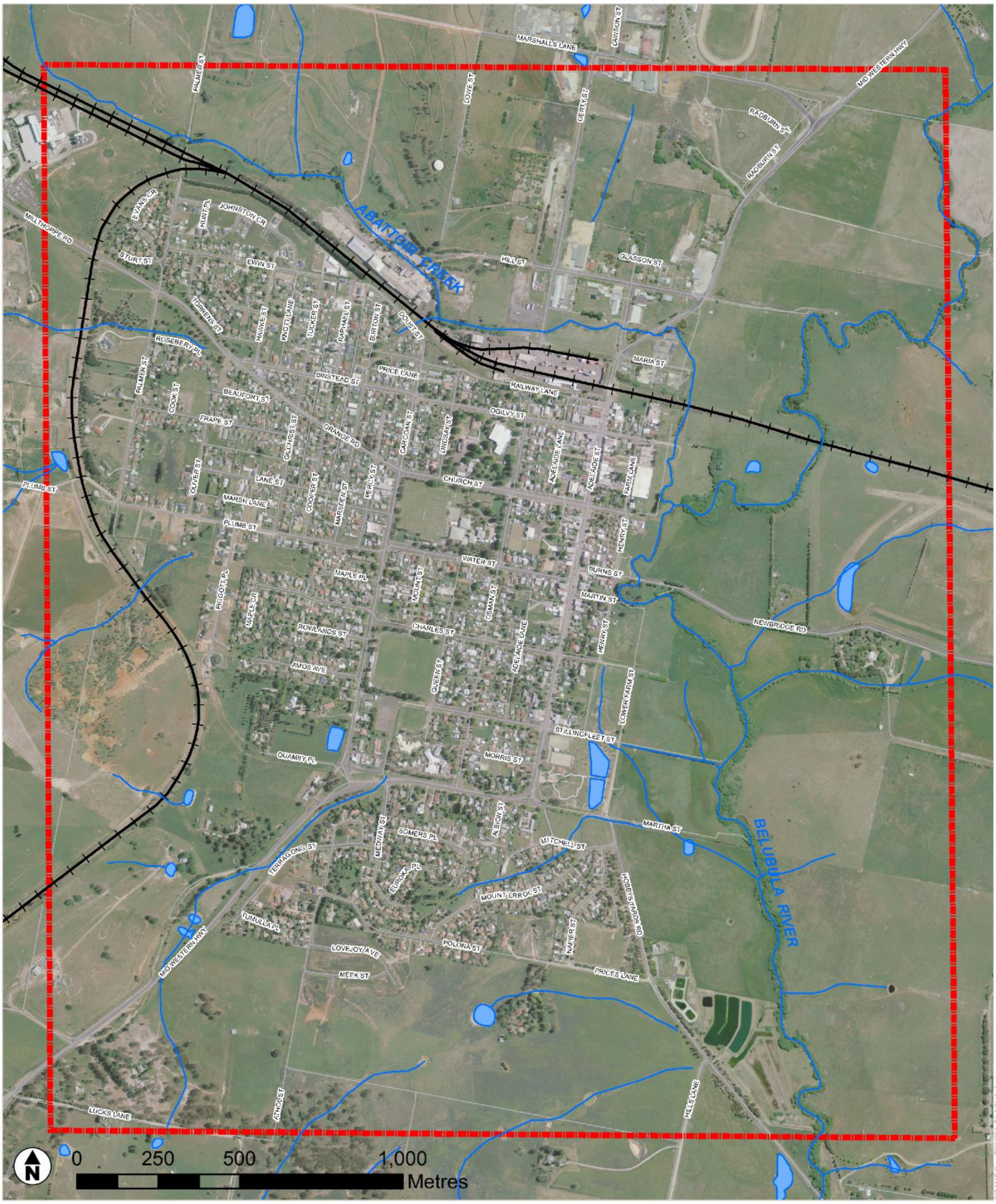
Council proposes to develop a Floodplain Risk Management Plan for the Town of Blayney to address the existing, future and continuing flood risk. Council wishes to develop formal floodplain risk management strategies to provide an appropriate level of protection for the community. Further, Council wishes to develop formal emergency management strategies to effectively manage the continuing flood risk for Blayney. Hence, Council proposes to develop a Floodplain Risk Management Plan in phases, in accordance with the NSW Government's (2005) Floodplain Development Manual. Initial investigations (including data collection and review of all relevant data) and a Flood Study, are components of the first phase (Phase 1). A Floodplain Risk Management Study (the Study) and Plan (the Plan) will be developed in the second phase (Phase 2), with the Plan being implemented in the third phase (Phase 3).

Sinclair Knight Merz (operating as Jacobs since December 2013) was engaged by Council in May 2013 to develop a Floodplain Risk Management Plan for the Town of Blayney encompassing all activities in Phases 1 and 2. This report details outcomes from Phase 1 (Flood Study) of the project.

1.2 Study Area

The town of Blayney sits in the Belubula River valley, part of the larger Lachlan River basin, and is surrounded by rolling hills that range from 890m to 930m above sea level and falling to the river corridor at approximately 850m to 860m. The town generally drains from west to east, with the major watercourse being the Belubula River running north to south along the eastern edge of the urban area (catchment size approximately 120km^2 upstream of the town). Remaining watercourses are either drainage channels or intermittent watercourses that generally run from the higher elevations to the north and west towards the Belubula River in the east. The only other named watercourse is Abattoir Creek (sometimes referred to as Farm Creek and with an approximate catchment of 20km^2), which arises in the rural lands and undulating hills to the north west and drains along the northern edge of town, north of the Main Western Railway, before joining the Belubula River. As a result of this pattern of watercourses and the catchment topography there are potential drainage/flooding issues present in Blayney.

The study area for Blayney is presented in **Figure 1-1**, which shows that the urban area is generally a typical grid pattern running in a north-south and east-west direction. Blayney is the key centre in the Blayney Shire with a variety of land uses including business, industrial, community and residential land uses and open space and recreation.



Legend

- Railway
- Road
- Study Area

SCALE	1:11,625 A3
SHEET	1 of 1 GDA 1994 MGA Zone 55
TITLE	Study Area
PROJECT	Blayney Flood Study and FRMS&P
CLIENT	Blaney Shire Council
DRAWN RDM	PROJECT # EN04201
MAP #	FIGURE 1-1
REV	1
VER	1
CHECK RDM	DATE 9/10/2014

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Data Sources: LPI, Council

1.3 Nature of Flooding

The major watercourse adjacent to the town of Blayney is the Belubula River which runs along the eastern edge of the urban area. The remainder of the watercourses are either drainage channels or intermittent watercourses that generally run from the higher elevations to the north and west towards the Belubula River in the east. The only other named watercourse is Abattoir Creek located north of the Main Western Railway. As a result of this pattern of watercourses and the catchment topography there are potential drainage/flooding issues present in Blayney.

During the severe weather events of September and December 2010, and March 2012 the Belubula River and its tributaries all experienced high flows causing damage to infrastructure including roads and bridges. Roads closed in the Town of Blayney due to elevated water levels included Hobbys Yards Road (MR390), Farm Lane, Henry Street and Newbridge Road. State Emergency Services attended houses in the Farm Lane and Henry Street area.

The Abattoir Creek catchment rises to the north-west of Blayney, through the undulating hills of rural lands, before entering the more built up area alongside the Main Western Railway in the vicinity of the old abattoir located at the western end of Hills Street. At the western end of the Intermodal Terminal at Blayney Railway station it joins with an unnamed water course from the urban area to the south of the Newcrest dewatering facility, prior to travelling east toward St Joseph's Central School, located north of the railway line at the intersection of Adelaide and Hill Streets. The school has been affected by overland flows along Abattoir Creek, in recent years, and most notably on 1 June 1990.

The unnamed water course that meets Abattoir Creek rises to the west of the Blayney-Demondrille Railway through rural lands before entering the piped stormwater system, before day lighting at the intersection of Burton and Smith Streets and passing under the Main Western Railway at the western end of the Intermodal Terminal.

Residents have previously complained about ongoing development in the catchment, generating larger overland flows between Burton and Doust Streets exceeding the capacity of the drainage path.

The area to the south-west of Blayney on the western side of the Blayney- Demondrille Railway is generally directed to a single culvert under the railway, despite three culverts existing, and toward the piped system in the vicinity of the intersection Plumb Street and Piggot Place. On 21 December 2007, residents were affected by overland flows causing over floor flooding to dwellings at the lower end of Piggott Place.

To the south of Blayney, there are two drainage paths that carry flows into the urbanised environment. A catchment drains alongside the Mid-Western Highway through open flow paths, before crossing the highway in the vicinity of the Blayney Ambulance Station and passing along a concrete lined open channel to Stillingfleet Street into the piped network. The recently developed Highlands Estate to the south of Polona Street delivers stormwater to a natural watercourse running behind properties to the west of Mount Errol Street before crossing Hobbys Yards Road. Residents complained about surcharging of the stormwater pit at Polona Street to Council.

1.4 Objectives

The objective of this Flood Study is to define the riverine flood behaviour of the Belubula River and Abattoir Creek as well as the overland flood behaviour in Blayney and their possible combined effects of the town area of Blayney. The study produces information on flood levels, velocities and flows for a full range of riverine and overland flood events under existing catchment conditions. These results will enable Council to progress to the next phases in the floodplain risk management process, by identifying the possible management options within the Floodplain Risk Management Study and development of a draft Risk Management Plan (the Plan) for Council's consideration.

The overall development of the Plan is being undertaken in two major phases:

Phase 1

Initial Investigations (Stage 1)

- Undertake a comprehensive site inspection;
- Review of all relevant documents, data and reports and anecdotal evidences on ground;
- Undertake a comprehensive consultation with the local community, Council and relevant agencies;
- Collate and assess all data and information required to satisfy the objective of this study including the current status of the material;
- Identify any "gaps" in the available data including surveys required to complete the study and update all information as required, with the approval of the Council.

Flood Study (Stage 2)

- Establish appropriate hydrologic model/s of both the Belubula River and the sub-catchments for overland flooding assessment to be used in the estimation of design floods for riverine and overland flooding and /or modelling of flood storages;
- Establish appropriate hydraulic model/s for the Belubula River, Farm Creek and overland flowpaths within the study area, to be used in the estimation of design flood levels and modelling of any preferred/ recommended flood mitigation measures;
- Identification of flood velocities and flood levels for 0.5%, 1%, 5% and 20% annual exceedance probability (AEP) events and the Probable Maximum Flood (PMF);
- Mapping of flood extents and peak velocities for all investigated design events and preparing provisional hydraulic and hazard categorisation mapping for the 1% AEP event, and preparing a provisional Flood Planning Area map (based on the 1% AEP flood levels with a 0.5m freeboard).

Phase 2 Floodplain Risk Management Study and Plan (Stages 3 & 4)

- An assessment of potential flood management and mitigation measures in order to achieve improvements necessary to meet the required service levels. Such measures may include flood modification (eg. levees, bypass floodways, retarding basins, channel modifications etc.), property modifications (eg. development control, rezoning, voluntary purchase of high hazard properties, house floor raising, flood proofing etc) and response modification (eg. flood education, flood preparedness, flood warning, local flood plans etc.);
- Estimates of the flood damages in the design floods and annual average damages and their net present worth;
- An economic assessment of the floodplain management measures based on life cycle costs and benefits; and
- Completed application for financial assistance for all recommended mitigation and/or management objectives.

1.5 Structure of the Report

This report describes the outcomes from Phase 1 as defined in **Section 1.4**. The outcomes of the Floodplain Risk Management Study and the Plan (Phase 2) will be produced in separate documents. 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 hydrologic assessment undertaken for this study

Section 4: details formulation of a hydraulic model to serve the overall objective of this study

Section 5: provides details on the estimation of design floods

Section 6: provides outcomes from the flood modelling including flood mapping

Section 7: provides conclusions and recommendations on the study

Section 8: acknowledges contribution received from others in undertaking this study

Section 9: provides details on references citied in this report

Section 10: provides the glossary of terms

Appendix A: contains the Newsletter and Questionnaire sent to residents

Appendix B: details on topographic survey

Appendix C: details on hydrologic modelling

Appendix D: provides flood depths and flood extent maps for all design events for the existing conditions

Appendix E: contains peak flow velocity maps

Appendix F: summarises peak flows at selected locations for the design flood events

Appendix G: contains flood hazard maps

Appendix H: contains sensitivity analysis flood impact maps for the 1% AEP events

2. Initial Investigations

2.1 Site Inspection

A site inspection was carried out on 6 June 2013 to gain an overall appreciation of the study area including flood behaviour. Experience gained from the site reconnaissance has been 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 organisations including NSW Office of Water, State Emergency Services (SES), NSW Office of Environment and Heritage (OEH), State Water Corporation and the Bureau of Meteorology were contacted to collect information on flooding, GIS layers, hydrologic and hydrologic investigations undertaken for various projects and flood evacuation etc. Reports and data available to this study are discussed below.

2.2.1 Available Reports

- **Flooding Advice for Proposed Upgrade of Belubula River Crossing at Blayney (August 2012)** prepared by Cardno for Blayney Shire Council - A flood frequency analysis was undertaken on the available recorded streamflow data for two gauging stations on the Belubula River near Blayney for the period 1992 to 2002. Considering the relatively short length of records and the quality of the recorded streamflow data, design discharges in the Belubula River at the proposed crossing was estimated using the Probabilistic Rational Method for Eastern NSW as defined in AR&R 1998. The 20 and 100 year ARI peak discharges in the Belubula River at the proposed crossing in Blayney were estimated at 123 m^3/s and 235 m^3/s respectively. The adopted design discharge for the 2000 year ARI event was 500 m^3/s. In order to undertake the flood impact assessment a local 2D TUFLOW model (grid size 2m x 2m) was assembled of a reach of the Belubula River from downstream of the crossing to a section just downstream of the Railway Line. Constant discharges were used in the 2D TUFLOW model to define flood behaviour at the proposed crossing both under the existing and the proposed conditions. A number of flood maps are referenced in the flood advice prepared by Cardno. However, these maps were not available to this study. Estimated peak flood levels and velocities estimated in the flood study with the proposed crossing are shown in **Table 2-1**.

- **Table 2-1 Estimated Peak Flood Levels and Velocities at the Proposed Crossing**

Location	20 year ARI		100 year ARI		2000 year ARI	
	Flood Level (mAHD)	Velocity (m/s)	Flood Level (mAHD)	Velocity (m/s)	Flood Level (mAHD)	Velocity (m/s)
Upstream	862.21	2.56	862.52	2.61	863.05	2.93
Downstream	862.12	1.72	862.42	2.36	862.84	2.91

- **Draft Blayney Settlement Strategy (October 2010)** prepared by Blayney Shire Council – Blayney is the key town in the Blayney Shire and a mature settlement with a wide range of land uses including business, industrial, community and residential land uses and open space and recreation. The Draft Settlement Strategy recommends several significant changes to the existing land use patterns for Blayney. The strategy identifies that part of the existing urban area of Blayney is located on flood prone land primarily along the Belubula River floodplain and associated drainage channels through the town and has the potential to constrain development, particularly to the east of Blayney.

- **Blayney Shire Local Flood Plan (November 2009 Edition) –** The plan prepared by the SES covers preparedness measures, the conduct of response operations and the coordination of immediate recovery measures from all levels of flooding within the Blayney Shire Council area and includes the town of Blayney. The plan identifies specific roles and responsibilities of emergency service organisations and supporting services.

  A defining characteristic of flooding within Blayney is the rapid rise and fall of floodwaters. The plan identifies that the three major floods on record at Blayney occurred in in October 1934, January 1972 and January 1980. The 1934 flood was the most severe, but those of 1972 and 1980 were of similar heights (4mm and 13mm lower than the 1934 event). The height of the 1972 flood is marked on a concrete wall on Henry Street, Blayney (858.7m AHD). In August 1990, the flood level rose to within 50mm of the 1972 flood mark. Another major flood occurred in June 1952 which may have exceeded the 1934 flood, but no records are available for this event.

  The plan identifies that land within the town of Blayney is largely flood free except for the area along Abattoir Creek and land in the vicinity of the Belubula River (Church, Henry and Burns Streets). Flooding along Abattoir Creek occurs largely due to backwater effects from the Belubula River. The plan identifies that a total of about seven (7) buildings were affected in a major flood and most of these buildings were located in the vicinity of Henry Street between Church and Burns Streets.

  The plan identifies that localised flooding on 21 December 2007 occurred due to a heavy local rainfall of 55mm in a 5-hour period which resulted in over floor flooding of a residential property in Adelaide Street, flooding of lower levels of a business property in Osman Street (near Water Street) and Plumb Street was closed.

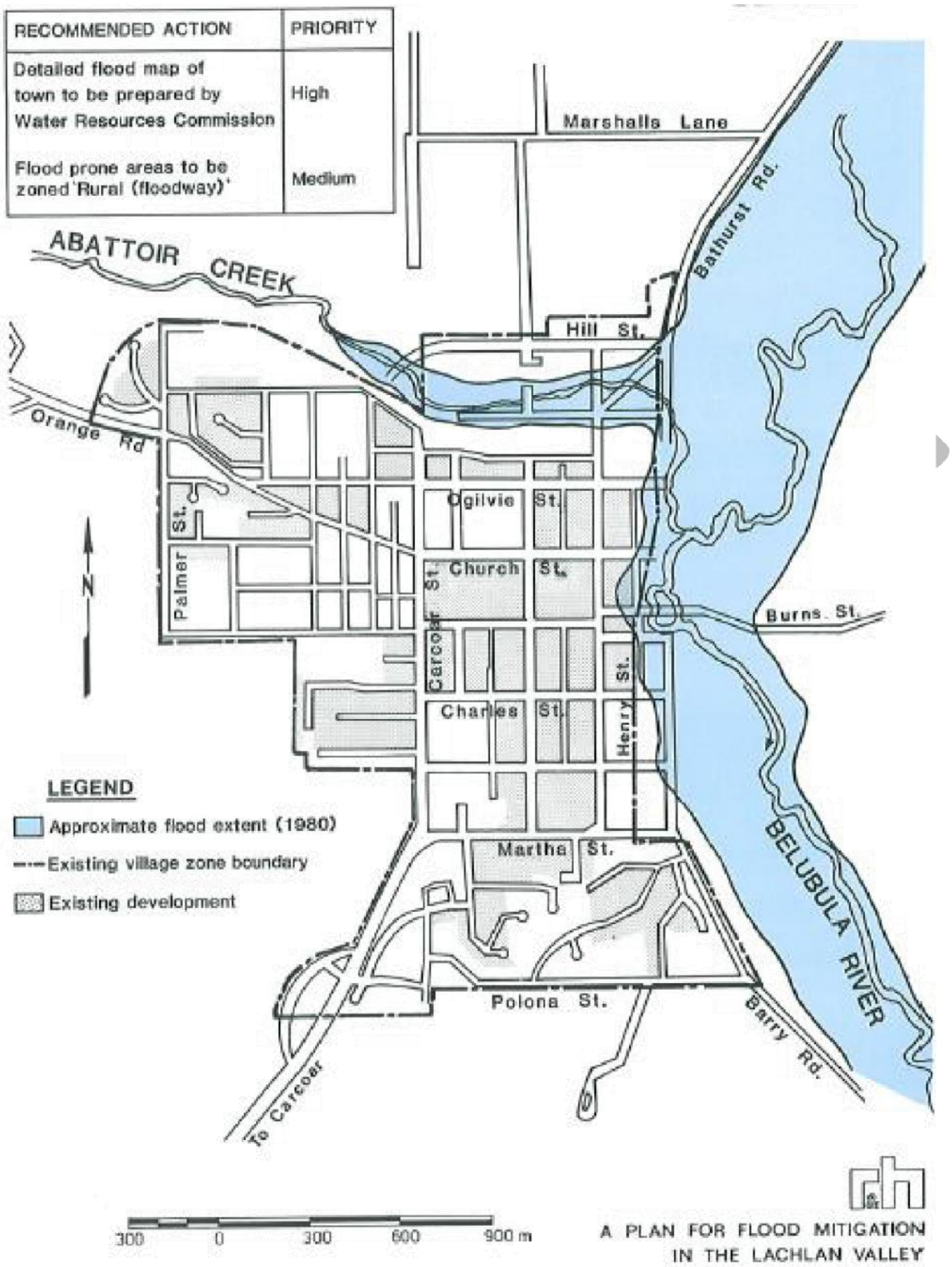
- **Blayney Concentrate Dewatering Facility Flood Impact Assessment Report (July 2000)** - The report was prepared by Gilbert and Associates for Cadia Holdings Pty Ltd to address impact of the Blayney Concentrate Dewatering Facility on the flood behaviour in Abattoir Creek. The dewatering facility is located adjacent to Abattoir Creek which drains a catchment 19.5 km^2 near the dewatering facility. A hydrologic model was developed using RORB for the catchment area of Abattoir Creek to estimate the 100 year average recurrence interval (ARI) event at the dewatering facility. In the absence of recorded streamflow data the RORB model was not calibrated. RORB model parameter values (kc, m and rainfall losses) adopted in the estimation of the 100 year ARI design discharges are not defined in the report. The report considered peak design discharges both in the main channel and a tributary catchment located near the dewatering facility, the report does not identify critical storm durations for the main channel and the tributary catchment. The estimated 100 year ARI peak discharge in Abattoir Creek was 67.2 m^3/s. A hydraulic model was developed using HEC-RAS to assess flood impacts due to construction of the dewatering facility which involved some filling within the site for the dewatering facility. The 100 year ARI discharge at the confluence of Belubula River and Abattoir Creek (total catchment area 140 km^2) was estimated at 224 m^3/s applying the Probabilistic Rational Method of AR&R 1998 for eastern NSW.

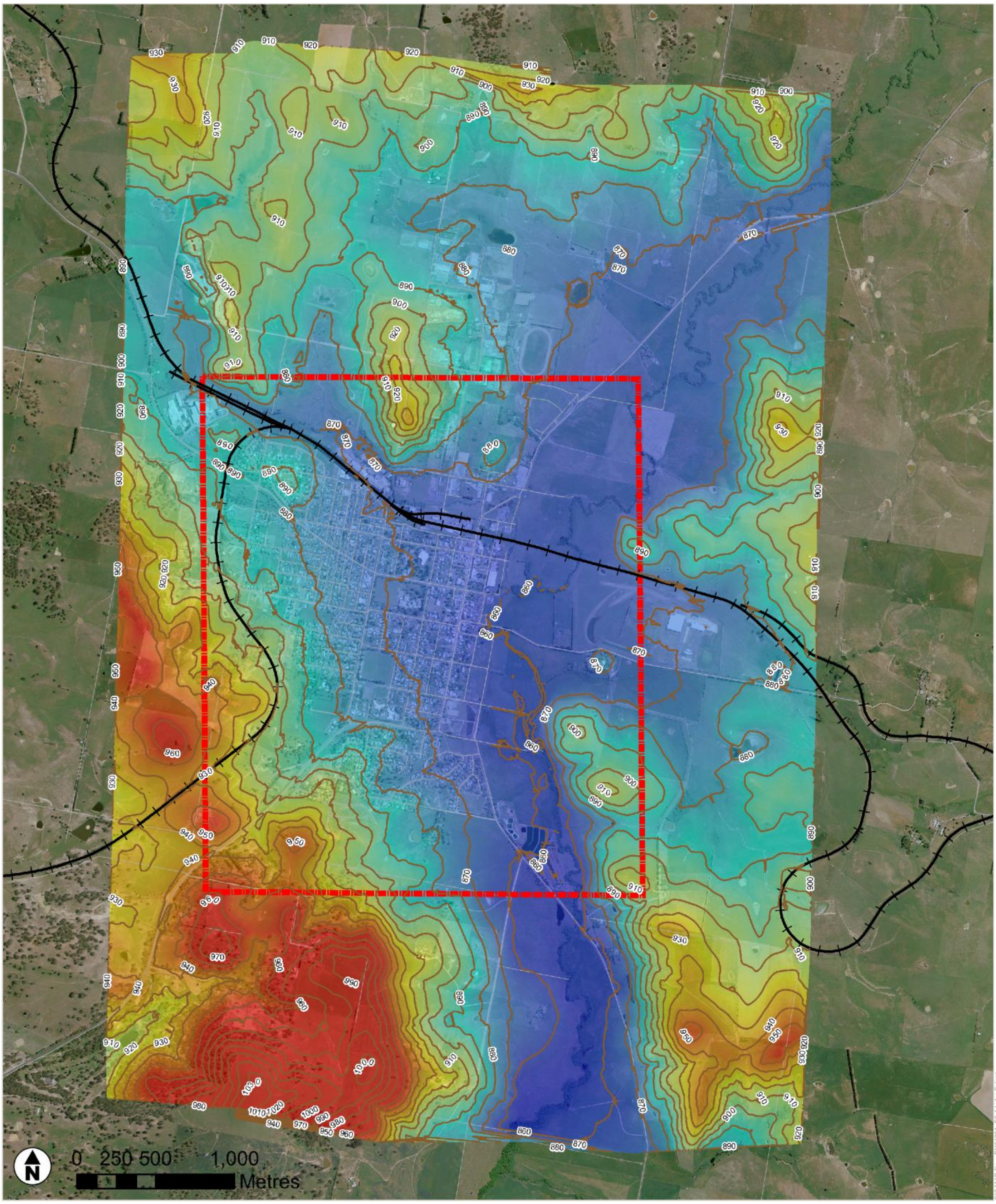
- **New South Wales Inland Rivers Flood Plain Management Studies, Lachlan Valley (1983)** – The report was prepared by Rankine & Hill to recommend a program of works and other measures for floodplain management in the Lachlan Valley. The report identifies flood events of October 1934, January 1972 and January 1980 as the three major floods on record at Blayney. The approximate flood extent during major flood events in Blayney is included in the report and is shown in **1**. The report identifies that a total of seven buildings including houses and commercial premises are affected by floodwaters in a major flood. Most of these buildings are located in the vicinity of Henry Street between Church and Burns Streets.

2.2.2 Topographic Data and Imagery

LiDAR data for Blayney was captured by Land and Property Information (LPI) on 5 February 2009. The captured LiDAR data was processed by LPI and 1m, 2m, 5m and 10m digital elevation models (DEM) were provided to Jacobs in ASCII format which covered the entire study area. The extent of the LiDAR data is shown in **Figure 2-2**. The horizontal spatial accuracy of the data is 0.8m and the vertical spatial accuracy is 0.3m and LPI identified that the accuracy specifications (95% confidence interval) meet ICSM guidelines for digital elevation data. In addition to the LiDAR data, LPI provided a 50cm imagery (in .ecw format) for Blayney and its surrounding areas captured in 2007 areas and a 10cm imagery for the township of Blayney captured in 2009.

- **Figure 2-1 Approximate Flood Extent During Major Flood Events (Source: Rankine & Hill (1983))**





Legend

Ground Elevation (m AHD)
High : 1038
Low : 853

10m contour (m AHD)
Railway
Study Area

SCALE	A3
SHEET	1 of 1 — GDA 1994 MGA Zone 55
TITLE	Extent of LiDAR Data
PROJECT	Blayney Flood Study and FRMS&P
CLIENT	Blaney Shire Council
DRAWN	LC
PROJECT #	EN04201
MAP #	FIGURE 2-2
REV	1
VER	1
CHECK	AH
DATE	20/01/2015

Data Sources: LPI, Council.

Council provided drawings for the following bridges:

- Engineers working drawings as constructed, Bridge over Belubula River (floodplain bridge), Newbridge Road Blayney dated 13 July 1978, Blayney Shire Council;
- Bridge over Belubula River (2.4km South of Blayney, also known as Hobbys Yards Road Bridge), approved on 30 March 1982, Department of Main Roads, NSW;
- Bridge over Belubula River 35.0km South-West of Bathurst (Mid-Western Highway), construction drawings prepared by GHD on 22 March 2006 for Roads and Traffic Authority of NSW; and
- Bridge over Belubula River (main channel) at Blayney, Newbridge Road, Construction drawings prepared by Cardno on 15 August 2013 for Blayney Shire Council.

2.2.3 Stormwater Network

Council provided the stormwater network for Blayney in MapInfo format. The stormwater network included approximate pipe alignment and sizes of some stormwater pipes. The stormwater network is shown in **Figure 2-3**.

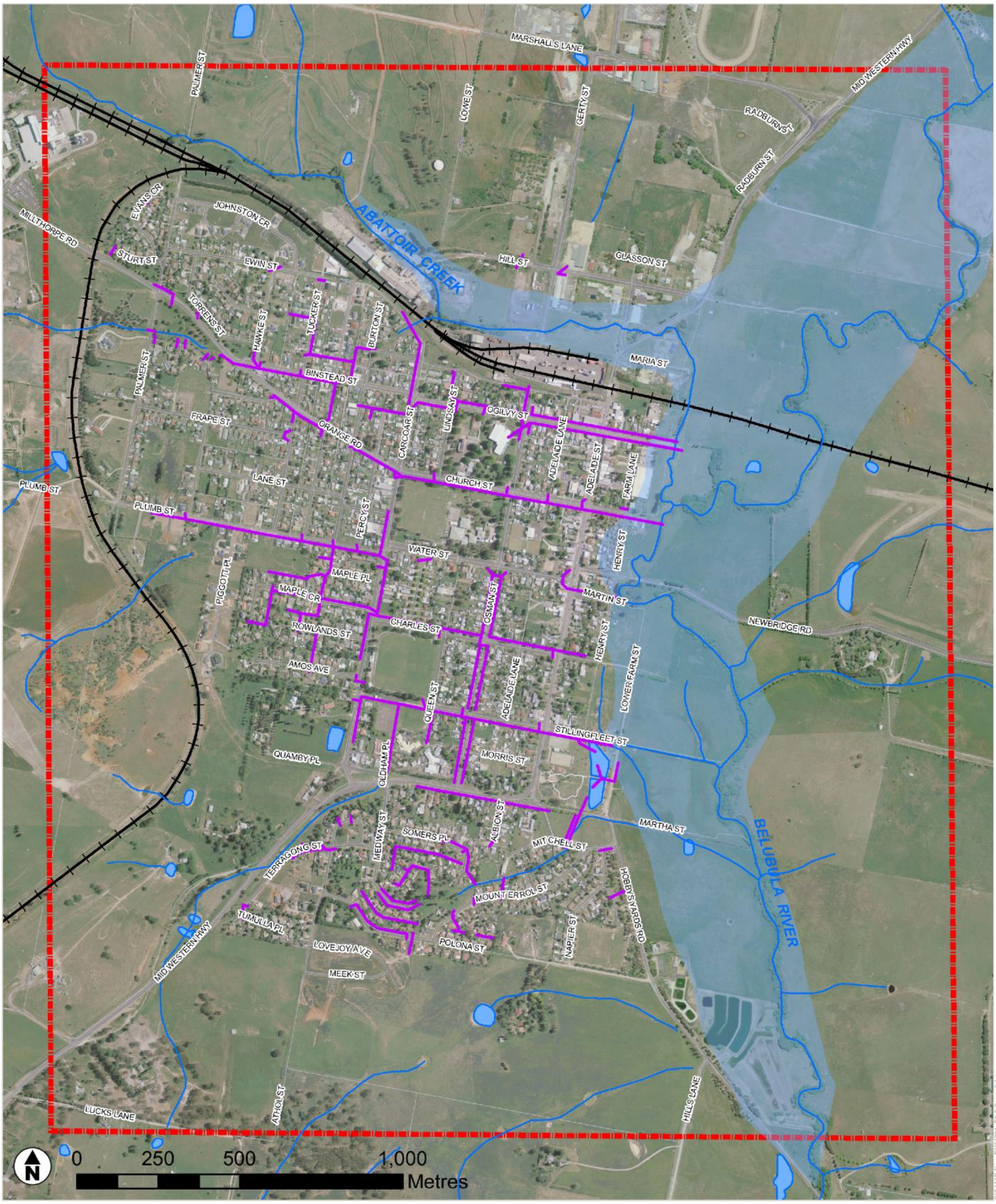
2.2.4 Rainfall Data

A search of the Bureau of Meteorology's website located rainfall stations in close proximity to Blayney. Daily rain gauges around Blayney are shown in **Figure 2-4**, which shows that there are six rain gauges that are located within the catchment area of the Belubula River. Of the six rain gauges, only one rain gauge (No. 63294) is currently open. The rain gauge No. 63294 was opened on April 1990 and is located approximately 1.5 km north-west of rain gauge No. 63010 with the longest length of records (June 1885 to July 1992). Ten (10) highest 1-day (9 am to 9 am) rainfall events recorded at the two rain gauges are shown in **Table 2-2**, which shows that the highest daily rainfall depth (119.4 mm) recorded in Blayney occurred on 25 March 1926.

Table 2-2 Ten Highest Recorded Daily Rainfall in Blayney

Date	1 Day Peak Rainfall (mm)	Rain Gauge
25/03/1926	119.4	63010
2/04/1959	106.2	63010
25/07/1922	104.6	63010
31/01/1978	94.8	63010
7/08/1967	94.7	63010
21/03/1900	92.5	63010
20/01/1887	88.9	63010
22/06/1925	88.4	63010
12/02/1997	86.4	63294
4/11/1907	83.8	63010

No pluviograpghs are located within the catchment area of the Belubula River in the vicinity of Blayney. The closest pluviograph stations (No. 63253 and 63254) to Blayney were located in Orange, approximately 30km north-east of Blayney. The pluviograph station No. 63253 was operational for the period August 1955 to July 1973 and the pluviograph station no. 63254 was operational for the period May 1984 to May 2011.



Legend

- Railway
- Road
- Study Area
- Council's Stormwater Network
- Floodplain Region Defined by Council

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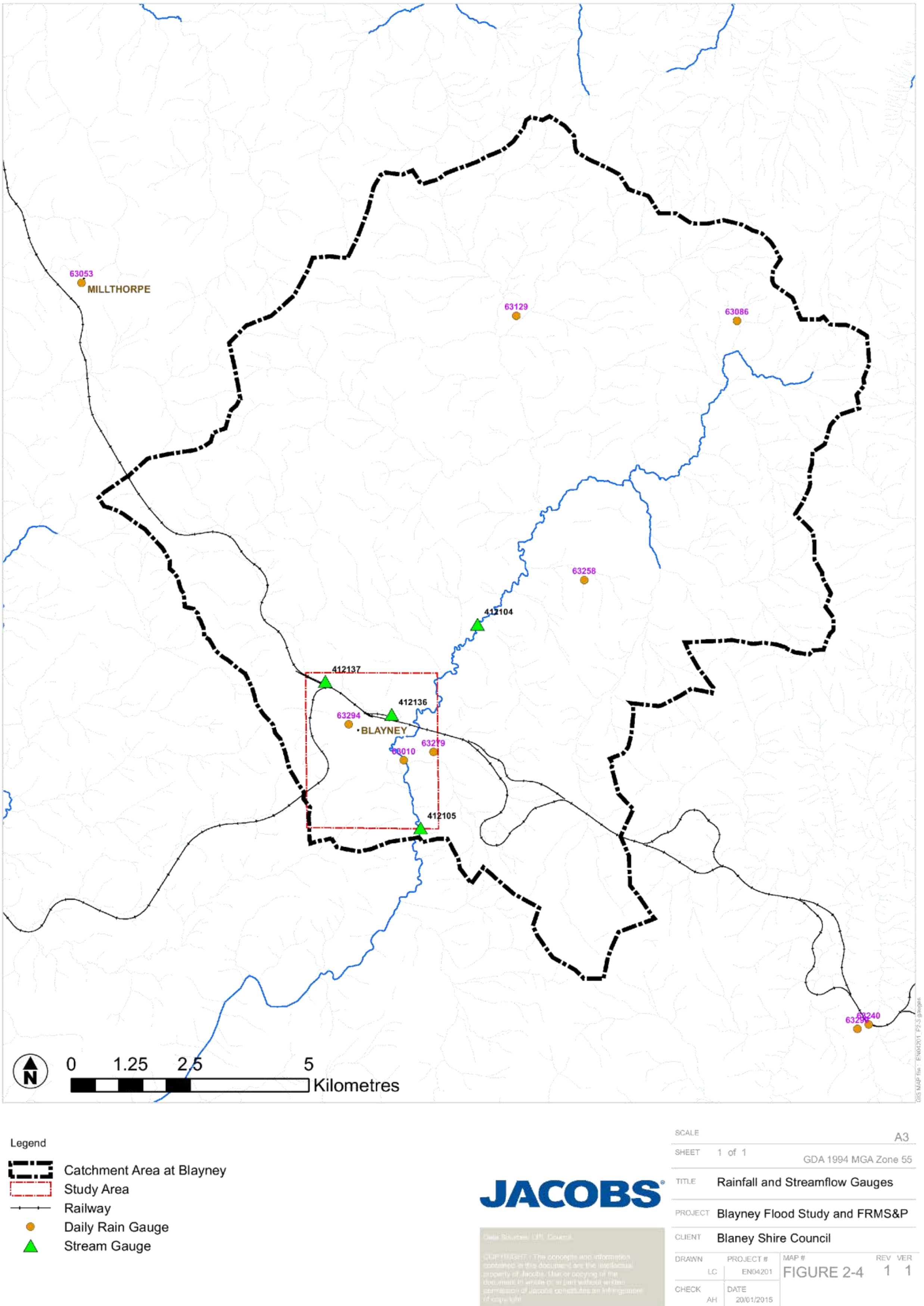
Data Sources: LPI, Council.

SCALE	1:11,625		A3
SHEET	1 of 1		GDA 1994 MGA Zone 55
TITLE	Stormwater Network and Floodplain		
PROJECT	Blayney Flood Study and FRMS&P		
CLIENT	Blaney Shire Council		
DRAWN RDM	PROJECT # EN04201	MAP # FIGURE 2-3	REV 1 VER 1
CHECK RDM	DATE 20/01/2015		


63053
MILLTHORPE
63129
63086
63258
412104
412137
412136
63294
BLAYNEY
412105
63240
0
1.25
2.5
5
Kilometres
N
Legend
Catchment Area at Blayney
Study Area
Railway
Daily Rain Gauge
Stream Gauge
JACOBS
SCALE
A3
SHEET
1 of 1
GDA 1994 MGA Zone 55
TITLE
Rainfall and Streamflow Gauges
PROJECT
Blayney Flood Study and FRMS&P
CLIENT
Blaney Shire Council
DRAWN
LC
PROJECT #
EN04201
MAP #
FIGURE 2-4
REV
1
VER
1
CHECK
AH
DATE
20/01/2015

2.2.5 Streamflow Data

Streamflow gauging stations of relevance to this study are shown in **Figure 2-4** and details on the stations provided by NSW Office of Water are presented in **Table 2-3**. It is to be noted that discharges were measured at the gauging sites at different times and hence there are inconsistencies in measured highest discharges between upstream and downstream gauging stations.

Table 2-3 Details on Streamflow Gauging Stations

Gauge No.	Description	Catchment Area (km^2)	Date Commenced and Ceased	Comment/ Data Type
412137	Abattoir Creek @ Palmer Street	16.7	21/06/1989 – 05/02/1998	Highest measured discharge 23 Ml/d
412136	Abattoir Creek @St. Joseph's College	19.8	21/06/1989 – 05/02/1998	Highest measured discharge 102 Ml/d
412104	Belubula River @ U/S Blayney	108	23/11/1976 – 24/9/1997	Highest measured discharge 115 Ml/d
412105	Belubula River @ D/S Blayney	154	23/11/1976 – 05/08/2002	Highest measured discharge 1710 Ml/d

NSW Office of Water also provided the available daily water levels and discharges for the two gauging stations in the Belubula River near Blayney for the period 1992 to 2002. Peak discharges at the two gauging stations were 7.5 m^3/s (642 Ml/d) at GS 412104 and 25.2 m^3/s (2179 Ml/d) at GS 412105 and both gauges were not referenced to AHD. On the basis of the limited length of records available for the stations, the available streamflow data was considered to have limited value to this study.

2.2.6 Information on Flooding

Council provided a number of photographs (shown in **Figure 2-5**) captured on 19 August 2010 which shows the nature and the extent of flooding in the Belubula River near the intersection of Henry Street and Newbridge Road. It is to be noted that a rainfall of 19.2 mm was recorded at rain gauge No. 63294 on 19 August 2010 and 68mm rain was recorded at the gauge during the period 9 to 17 August 2010.

In addition to the flood photographs for the flood event of 19 August 2010, Council also provided a GIS layer showing the extent of the floodplain (refer to **Figure 2-3**) along the Belubula River and Abattoir Creek which were sourced from Rankine & Hill (1983). The source and the accuracy of the GIS layer were unknown.

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 (included in **Appendix A**) to residents and landowners within the study area in Blayney. The newsletter introduced the floodplain management process to the residents of the areas, 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.

- **Figure 2-5 August 2010 Flood Photographs**

Photo 1 – Flooding on Henry Street (looking towards south)

Photo 2 – Flooding at corner of Henry Street and Newbridge Road (looking towards north)

Photo 3 – Bridge over the Belubula River (main channel) along Newbridge Road (looking east)

Photo 4 - Bridge over the Belubula River floodplain along Newbridge Road (looking east)

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 during flooding
- 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 the Consultant
- Residents intention for further development on their lands
- Ranking of development types for protection against flooding
- Ranking of potential flood mitigation measures

Any comments on any other issues associated with this study

2.3.2 Summary of Responses to Flood Questionnaire

In total 220 questionnaires were sent to residents of Blayney with reply paid envelopes and sixteen (16) responses were received from the community to the questionnaire and all respondents were residents of the study area. One response was received from Blayney Hospital. A summary of responses is provided in the following paragraphs.

Residency status (Question 1)

All respondents were residents of Blayney.

Length of Residency in Blayney and Business Activity (Questions 2-4)

Respondents lived in Blayney between 3 months to 45 years with an average residency of 17 years. Two (2) respondents managed a business located within the study area.

Experiences of Flooding (Questions 5-12)

Five (5) respondents experienced flooding during the flood events of 1973, 2007, 2011, 2012 and 2013. Three (3) respondents experienced flooding in their houses, two (2) respondents experienced flooding at their workplace and one (1) respondent experienced flooding elsewhere and the depth of flooding varied between 0.3m to 1.2m. Two respondents reported that the duration of flooding was less than 2 hours and one respondent identified the duration of flooding being less than six hours and another respondent identified the duration of flooding more than one day.

Three respondents identified minor flood damage to garden, lawn and backyard whilst one respondent identified minor damage to external wall of the house. One respondent identified minor damage to property fence.

Two (2) respondents identified that vehicular access to their properties were cut off and one business identified loss of income due to road closure by flood waters.

Flood Affection to properties due to works (Questions 13 - 14)

Three (3) respondents identified that flood impact on their properties was aggravated due road works and new developments along Newbridge Road, south of Polona Street and Smith Street.

Intention of Respondents for further development (Question 15)

Nine (9) respondents were not expecting to undertake any further developments on their lands and three (3) respondents were expecting to undertake minor extensions to their properties.

Priority for protecting different types of developments from flooding (Question 16)

Respondents were asked to rank different types of development for protection against flooding. Nine (9) respondents gave the emergency facilities (Hospital, Police Station, etc.) the greatest priority for protection against flooding, whilst five (5) respondents assigned the highest priority for protection of residential properties against flooding.

Priority for flood mitigation measures (Question 17)

Eight (8) respondents identified flood protection of house/business as the greatest priority. Three (3) respondents identified flood warning as their greatest priority and three (3) respondents assigned their highest priorities to providing an emergency flood free access to properties.

Willingness to provide additional information (Question 18)

Willows in the Belubula River were a major concern to a respondent.

Contact details for respondents (Question 19)

Fourteen (14) respondents provided their contact details.

2.4 Additional Topographic Survey

The available topographic data was reviewed and gaps in the data were identified and a technical brief was prepared to collect the additional topographic data in two stages. In consultation with Council, Geolyse Pty Ltd was engaged to collect the required additional topographic data for this project. The following items were surveyed by Geolyse with assistance from Council staff:

- Details for five (5) bridges;
- Details (eg. size, shape, invert level, top of road level etc.) for 44 culverts;
- Details for 75 stormwater pits and associated stormwater pipes;
- Four (4) streamflow gauges located in the vicinity of the study area were connected to AHD; and
- Four flood marks were connected to AHD. The flood mark (for the flood event of 23 January 1972).on concrete wall at 76 Henry St was connected to AHD. The flood mark was set at RL 862.39 mAHD by Geolyse. A review of the LiDAR data indicated that ground levels in the vicinity of the flood mark were above RL 862 mAHD. However, Blayney Shire Local Flood Plan (November 2009 Edition) defines the height of the 1972 flood at this location at 858.7m AHD which is approximately 3.3m below the surrounding ground levels which is considered unrealistic.

Details of the survey are presented in **Appendix B** and all surveyed data provided by Geolyse were provided to Council and OEH. Floor levels of selected properties will be surveyed at the floodplain risk management stage.

3. Catchment Hydrology

3.1 Catchment Description

Belubula River is a perennial river which is part of the Lachlan River catchment. Belubula River rises south of Vittoria, mid-way between Bathurst and Orange and generally flows south and west. It is joined by eight minor tributaries before flowing east of the township of Blayney and then through Lake Carcoar where its flow is regulated, before reaching its mouth at the Lachlan River east of Gooloogong. Carcoar Dam, constructed in 1970, is a 52m high concrete arch dam with a capacity of 35800 ML (www.statewater.com.au). Water stored in Carcoar Dam is used for irrigation, stock and domestic usage, town water supply and water conservation. The full supply level of the dam is at RL 847.2 mAHD which is located approximately 10m below the bed level of the Belubula River in Blayney. This means that the flood levels in Blayney are unlikely to be impacted by backwater flooding due to Carcoar Dam.

The majority of the catchment area of the Belubula River upstream of Blayney was cleared for agriculture. A part of Vittori Stare Forest is located along the upper northern catchment of the river. Abattoir Creek is a major tributary which joins the river near Blayney. The bed level of the Belubula River drops approximately 670m over its 165km course.

3.2 Catchment Modelling Methodology

A RORB hydrologic model was developed by Jacobs (formerly SKM) for State Water for the catchment area of Carcoar Dam as part of "Portfolio Risk Assessment for 24 Dams" in 2001. State Water was contacted to provide the updated hydrologic modelling data for use in this flood study. However, at the time undertaking this study, Jacobs did not receive any updated hydrologic model for Carcoar Dam catchment.

A 1:100 000 topographic map was used in the 2001 study to delineate sub-areas for the RORB model and the catchment area of Carcoar Dam was sub-divided into 17 sub-areas. On the basis of the available recorded pluviograph and streamflow data provided by the former NSW Department of Land and Water Conservation, the RORB model was calibrated against recorded streamflow data for the Belubula River downstream of Carcoar Dam (GS 412077) for flood events of November 1973, August 1974 and September 1974. The calibrated RORB model was utilised in the estimation of design inflows into Lake Carcoar for a range of storm events between 2% AEP and the PMF.

Considering the facts that a calibrated and a validated RORB model was available for the catchment area of Carcoar Dam, no further recorded data was available to enhance model calibration, and the need for a more refined representation of sub-catchments within the study area (ie. catchment area located between GS 412104 and GS 412105), design inflow hydrographs produced by the RORB model at GS 412104 were adopted and another hydrologic model using XP-RAFTS was developed for the catchment area of the Belubula River between GS .412104 and GS 412105. Hence both the RORB and the XP-RAFTS hydrologic models were used in the estimation of design floods in this study.

3.2.1 Model Set Up

Model set up for the RORB and XP-RAFTS models are shown in **Appendix C**.

3.2.1.1 Catchment Areas

Sub- areas of the RORB model were delineated as part of 2001 study using 1:100,000 topographic map. Sub-catchments for the XP-RAFTS model were delineated using the LiDAR topographic data, where available, and outside the range of LiDAR data, the available 10m contours were used. These sub-catchments were then digitised using ArcMap, and the catchment areas obtained from the GIS.

3.2.1.2 Pervious and Impervious Fractions

In the case of the RORB model, all sub-areas were considered rural. However, in the case of the XP-RAFTS model, pervious and impervious fractions for each sub-catchment were estimated from the available aerial photography. For each sub-catchment, the major landuses were identified and the area of each landuse estimated. The following impervious fractions were used for different landuse types:

- Residential – impervious fraction = 40%;
- Industrial/commercial – impervious fraction = 90%; and
- Open space – impervious fraction = 5%.

Manning's roughness values were assigned based on the dominant land use within the sub-catchment. A roughness value of 0.025 was adopted for urban areas and a roughness value of 0.04 was adopted for rural areas.

3.2.1.3 Vectored Slopes

In the case of the XP-RAFTS model, vectored slopes were calculated for each sub-catchment by measuring the length of the flowpath from the highest point in the sub-catchment to the sub-catchment outlet. The height difference between these two points was divided by the flowpath length.

3.2.1.4 Channel Routing

The channel routing option was used in XP-RAFTS to estimate travel times between nodes. Wherever possible, the LiDAR data was used to define channel cross sections. Aerial photography of the area and a site reconnaissance were used to assign Manning's n values to model cross sections.

3.3 Input Data for Design Flood Estimation

3.3.1 Rainfall Depths

The rainfall design data for this study for events up to and including the 0.5% AEP was generated within the XP-RAFTS model applying the rainfall intensity, frequency and duration (IFD) relationship based on data presented in **Table 3-1**. It is to be noted that the rainfall design data adopted in this study are similar to the rainfall design data provided in Blayney Shire Council's Engineering Guidelines.

- **Table 3-1: Data Used to Estimate Rainfall IFD**

Data Description	Parameter
Zone	2
1 hour 2 year ARI mm/hr	24.18
12 hour 2 year ARI mm/hr	4.48
72 hour 2 year ARI mm/hr	1.13
1 hour 50 year ARI mm/hr	46.86
12 hour 50 year ARI mm/hr	7.45
72 hour 50 year ARI mm/hr	1.96
Skewness G	0.25
Geographical factor 2 year ARI F2	4.32
Geographical factor 50 year ARI F50	15.61

Areal reduction factors based on Australian Rainfall and Runoff (Engineers Australia, April 2013) were applied to the estimated design rainfall depths for events up to, and including, the 0.5% AEP event.

Estimates of the Probable Maximum Precipitation (PMP) for the study catchment up to 6 hours duration were prepared using the procedures given in *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method* (BOM, 2003).

3.3.2 Model Parameter Values

In the case of the RORB model, adopted values of k_c and m for the catchment area of Carcoar Dam were 13.85 and 0.8 respectively. In the case of the XP-RAFTS model for Blayney, the adopted value of Bx was 1.0.

3.3.3 Temporal Patterns

Temporal patterns for all events storm durations up to, and including, the 0.5% AEP event were sourced from the XP-RAFTS model for Zone 2. The temporal pattern for the PMP event was sourced from BoM (2003).

3.3.4 Design Rainfall Losses

An initial loss of 0mm and a continuing loss of 0mm/hr were adopted for impervious areas for all design events considered in this study. Design rainfall losses for the pervious areas were generally based on recommendations made by Walsh *et. al.* (1991). Considering watering of lawns and gardens in the Blayney urban area, a revised initial rainfall loss of 10mm was adopted for the pervious areas within the township.

In the case of the PMP event, an initial loss of 0mm and a continuing loss of 1mm/hr were adopted for pervious areas.

3.4 Validation of Design Discharges

Both the RORB and the XP-RAFTS model were run for a range of storm durations for the selected design flood events to estimate design inflow hydrographs. Whilst the RORB model was used to generate inflow hydrographs in the Belubula River upstream of Blayney gauge, the XP-RAFTS model was used to simulate hydrographs for the downstream sub-catchments. Results from the RORB and the XP-RAFTS model were reviewed to identify storm durations which produced peak discharges for each sub-catchment.

A comparison of design discharges estimated in this study and adopted in the previous studies is shown in **Table 3-2**, which shows that design discharges estimated in this study are generally higher than that adopted in the previous studies. It is to be noted that the RORB model for Abattoir Creek developed by Gilbert & Associates (2000) was not calibrated and the report does not provide details on the adopted rainfall losses or RORB model parameter values k_c and m. The design discharges adopted by Cardno (2013) are based on the Probabilistic Rational Method for Eastern NSW and hence considered to be a generalised estimate. Although design discharges estimated in this study are larger than the other available estimates, considering the lack of observed streamflow data for the study area and the paucity of observed streamflow data for Western NSW, parameter values adopted in the hydrologic models were not refined further.

It is explained in Section 3.2 that design inflow hydrographs produced by the RORB model at GS 412104 were adopted in this study. It is to be noted that 10 sub areas were defined in the RORB model upstream of GS 412104. Moreover, **Table 3-2** shows that the adopted discharges for the 5% and 1% AEP events at GS 412104 are similar to the corresponding discharges estimated using the Probabilistic Rational Method for a 30% larger catchment area. Hence, the estimated design inflow hydrographs extracted from the RORB model at GS 412104 are considered reasonable estimates.

- **Table 3-2 Comparison of Design Discharges (m^3/s)**

Location	Catchment Area (km^2)	Estimated Design Discharges (m^3/s) and Critical Storm Duration					Other Estimates on Design Discharges	
		20% AEP	5% AEP	1% AEP	0.5% AEP	PMF	5% AEP	1% AEP
GS 412104	108	48 (9 hr)	123 (6 hr)	246 (3 hr)	286 (2 hr)	4,420 (2 hr)		
Sub-catchment C16	20	32 (30 hr)	52 (30 hr)	91 (2 hr)	114 (2 hr)	1,051 (2 hr)		67[a]
Juction of Abattoir Ck and Belubula River	142	58 (9 hr)	157 (6 hr)	320 (3 hr)	424 (3 hr)	5,601 (3 hr)	123[b]	235[b]
GS 412105	156	73 (30 hr)	164 (6 hr)	337 (3 hr)	463 (3 hr)	6,076 (3 hr)		

[a] Estimated by Gilbert & Associates (2000) using a RORB model

[b] Estimated by Cardono (2013) using the Probabilistic Rational Method for Eastern NSW

4. Hydraulic Modelling

4.1 Model Selection

A TUFLOW combined one-dimensional (1D) and two-dimensional (2D) hydrodynamic model has been developed for this study. 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.
- Capability in representing the stormwater drainage network, including pit inlet capacities and interflows between the network and floodplain including system surcharges.
- 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-AA-w64, in double-precision mode.

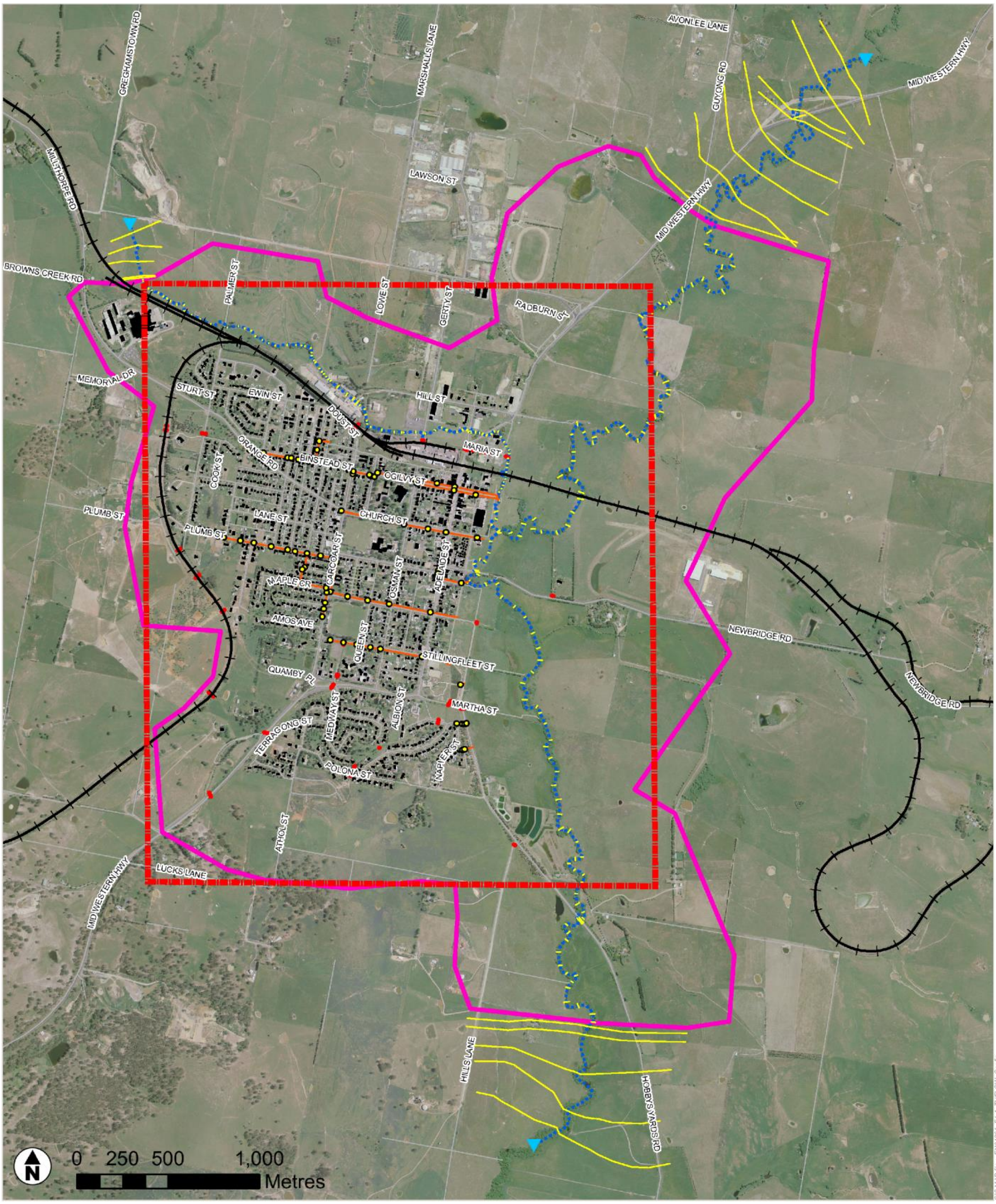
4.2 TUFLOW Model Configuration

4.2.1 Extent and Structure

The TUFLOW model is comprised of:

- A 2D domain of the catchment surface reflecting the catchment topography, with varying roughness as dictated by land use.
- A 1D network of the mainstream channels, including Belubula River and Abattoir Creek.
- An additional 1D network of pits and pipes representing the stormwater network, which is connected to the mainstream network at the pipe outlet points. The pits have a defined inflow capacity as dictated by their type and size.
- Additional hydraulic structures including culverts (1D) and road and rail bridges (1D and 2D).
- 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 on **Figure 4-1**.



Legend

Upstream/Downstream Boundary	2D Bridge
1D Stormwater pit	2D Model Domain
1D Stormwater pipe	2D buildings
1D Cross Section	Railway
1D Channel	Study Area
1D Culvert or Bridge	

JACOBS

Data Sources: LPI, Council

SCALE	A3
SHEET	1 of 1 GDA 1994 MGA Zone 55
TITLE	TUFLOW model Configuration
PROJECT	Blayney Flood Study and FRMS&P
CLIENT	Blaney Shire Council
DRAWN LC	PROJECT # EN04201 · MAP # FIGURE 4-1 · REV 1 · VER 1
CHECK AH	DATE 10/10/2014

4.2.2 Model Topography

The topography of the catchment is represented in the model using a 3m grid. The grid size was selected to optimise model run time and to achieve a level of precision required for adequate representation of flood behaviour within the study area. The basis of the topographic grid used in the TUFLOW model is the LiDAR data set in addition to ground survey at key locations. The model topography is shown in **Figure 2-2**.

4.2.3 Stormwater Network

A selected number of main branches in the overall network were represented in the TUFLOW model. Typically, the selected branches were aligned with the main overland flow paths in the study area. The modelled stormwater network is indicated on **Figure 4-1**.

4.2.4 Stormwater Pits

The stormwater pits provide a dynamic linkage between the underground drainage network and the 2D TUFLOW model domain, representing the floodplain. Water is able to flow between the drainage network and floodplain, depending on the hydraulic conditions.

The location of the stormwater pits and associated attributes were exported directly from the topographic survey undertaken by Geolyse Pty Ltd. Pit inflow relationships were defined in terms of flow depths versus pit inflow.

TUFLOW automatically calculates hydraulic energy losses in the pits based on the alignment of pipes connected to each pit and the flows in each pipe. The calculations are based on the Engelhund manhole loss approach (*TUFLOW User Manual*, BMT WBM, 2010).

4.2.5 Stormwater Conduits

The surveyed stormwater conduits are represented as circular pipes or rectangular culverts with dimensions as indicated by the pit and pipe survey. Other characteristics such as invert levels and lengths are represented.

4.2.6 Building Polygons

This study considers buildings as solid objects in 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.

4.2.7 Property Fencelines

Fencelines have typically not been explicitly 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 unvalidated assumptions about depths at which fences overflow or fail.

Hence, the potential obstruction to flow caused by fences was represented in the model by increasing the cell roughness (Manning's n values) for certain land uses, as described in **Section 4.2.8**. The limitation of this approach is that the flood levels may be slightly overestimated and flow velocities slightly underestimated for flooding within properties depending on the actual locations of obstructions and the interaction of flood flows with these obstructions. However, this approach does preserve the likely typical flooding behaviour, in which floodwaters use the road corridor as the preferential flow path.

4.2.8 Surface Roughness

All parts of the study area within the TUFLOW model were assigned hydraulic roughness values according to the LEP zoning and ground cover, refer to **Table 4-1**. These are based on engineering experience and typical values used in previous flood studies undertaken in the Sydney Region and Western NSW by Jacobs and other consultants. The relatively high Manning's n values for the residential land use accounts for expected obstructions such as minor structures (sheds, etc.) and fences.

Table 4-1 TUFLOW Model Grid Hydraulic Roughness Values

Land Use Type	Manning's n	Comment
Existing roads and proposed pavement	0.015	
Rail	0.05	
Urban (including fences)	0.2	Accounts for landscaping and fences
Sparse Vegetation	0.05	
Medium Vegetation	0.1	
Dense Vegetation	0.12	
Creeks	0.05	
Industrial	0.03	Assumed mainly paved
Short grass	0.035	
Wetlands	0.12	
Vegetated Drain	0.05	
Concrete Channel	0.02	

4.3 Boundary Conditions and Initial Conditions

4.3.1 Model Inflows

Runoff generated in the sub-catchments from the XP-RAFTS hydrologic model was input to the TUFLOW model via one of three methods:

- At the pits located at the outlet of each sub-catchment. Sealed pits are not assigned a flow. The amount of surface flow entering the pit is dictated by the pit inflow relationship. Flows in excess of the pit inlet capacity remain in the 2D model domain as point inflows, subsequently forming overland flow.
- At the outlet to the overland flow sub-catchment if there are no pits in that sub-catchment as a 2D inflow. Flows are initially input at the lowest point of the sub-catchment and then distributed to wet areas in the catchment as the storm progresses.
- At the outlet to the mainstream sub-catchment if the sub-catchment directly drains to Abattoir Creek or the Belubula River.

Pit surcharge flows are caused when flows in the drainage network exceed network capacity and spill out of the pits and into the 2D domain. Pit surcharges would similarly form overland flow in the model. Depending on the hydraulic conditions in the pipe system, overland flows can re-enter the pipe system via the stormwater pits.

5. Estimation of Design Floods

5.1 Hydraulic Model Parameters for Design Events

5.1.1 Blockages

Only a selected number of pits and pipes in the overall stormwater network were represented in the TUFLOW model, namely those on the main pipe lines with the minor feeder branches omitted. Approximately 40% of the total number of pits and pipes located within the study area were modelled. As such, only a part of the total pit inlet capacity in the system was represented. A zero blockage factor was therefore applied to stormwater pits and culverts in the study area.

5.1.2 Tailwater Conditions

The downstream model boundary was located some distance (approximately 1.5km) downstream of the study area boundary, to eliminate the potential influence of the boundary conditions on flood conditions in the study area. A normal depth condition has been assumed at the boundary.

5.1.3 Initial Conditions

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

5.2 Simulated Design Events

The storm events modelled include the 20%, 5%, 2%, 1% and 0.5% AEP and PMF events. The storm durations assessed were selected based on runs in the XP-RAFTS hydrologic model to capture the critical storm durations throughout the study area. The event durations assessed are summarised below.

Table 5-1 Storm Event Durations Modelled

Event AEP	Durations modelled
20%	25 minute; 3, 9, 30 and 36 hour
5%	25 minute; 1, 6, 30 and 36 hour
1%	25 minute; 1, 2 and 6 hour
0.5%	25 minute; 1, 2 and 3 hour
PMF	15 and 30 minute; 1 and 2 hour

6. Results Mapping and Analysis

6.1 Foreword on the Flood Mapping

The maximum envelope of flood behaviour parameters (depth, level, velocity, velocity x depth, flood hazard) was derived for each event AEP, considering the maximum values over each combination of storm event duration.

6.2 Flood Depth and Flood Level Mapping

Flood depths and flood level contours are mapped in **Appendix D** for the 20%, 5%, 2%, 1% and 0.5% AEP events and the PMF event. A review of the map indicates widespread shallow flooding in the central area of Blayney bounded by Adelaide Street, Water Street, Carcoar Street and Mid Western Highway in the 20% AEP event. Shallow flooding occurs for in the 20% AEP event along Henry Street, Martin Street, Mitchell Street, Mount Errol Street, Hobbys Yards Road, Polona Street, Napier Street, Plumb Street, Orange Road, Ogilvy Street and a number of other street within the township of Blayney implying that the township can be inaccessible by car from Orange, Bathurst and Carcoar in a 20% AEP flood event

In the case of the 5% AEP event, more extensive flooding occurs along the Belubula River than the 20% AEP event. Extents of flooding along Abattoir Creek and unnamed water courses running through the township are generally similar to the 20% AEP event.

The flood extent for the 1% AEP event is similar to that for the 5% AEP event with increased depth of flooding in the 1% AEP event. In the case of the 1% AEP event a number of properties in central Blayney and northern Blayney are subject to flood depths of 0.2m to 0.5m. A number of the properties are subject to flooding up to 1m depth in the 0.5% AEP event.

During the PMF event, a number of streets in the central and northern parts of Blayney are subject to flooding up to 1m in depth and more than 2m depth of flooding occurs along Mid Western Highway, Farm Lane and Henry Street. Bathurst is completely inaccessible by road and Orange may only be accessible by trucks and large vehicles during the PMF event. The SES requires information regarding the flood behaviour of the PMF event for planning flood evacuation routes and evacuation centre locations.

6.3 Flood Surface Profiles

The peak flood surface profiles are plotted in **Figure 6-1** and **Figure** 6-2 for Belubula River and Abattoir Creek, respectively, for the sections of each waterway located within the study area. **Figure 6-1** shows that the Railway and Newbridge Road are two major hydraulic controls along the Belubula River. In particular, the afflux at the Railway is very prominent in the 5%, 1% and 0.5% AEP flood events. The afflux at Newbridge Road is less pronounced than the Railway. The sewage treatment lagoons also encroach on the floodplain of the Belubula River up to and including the 0.5% AEP event. The Railway is also the major hydraulic control along Abattoir Creek as shown in **Figure 6-2**.

Modelled peak flood levels at the major waterway crossings along Abattoir Creek and the Belubula River within the study area are provided in Table 6-1. Table 6-1 shows that Mid Western Highway is overtopped in 1% AEP event due to flooding in Abattoir Creek and deck levels of other major waterway crossings are located above 0.5% AEP peak water levels.

Figure 6-1 Peak Water Level Profiles – Belubula River

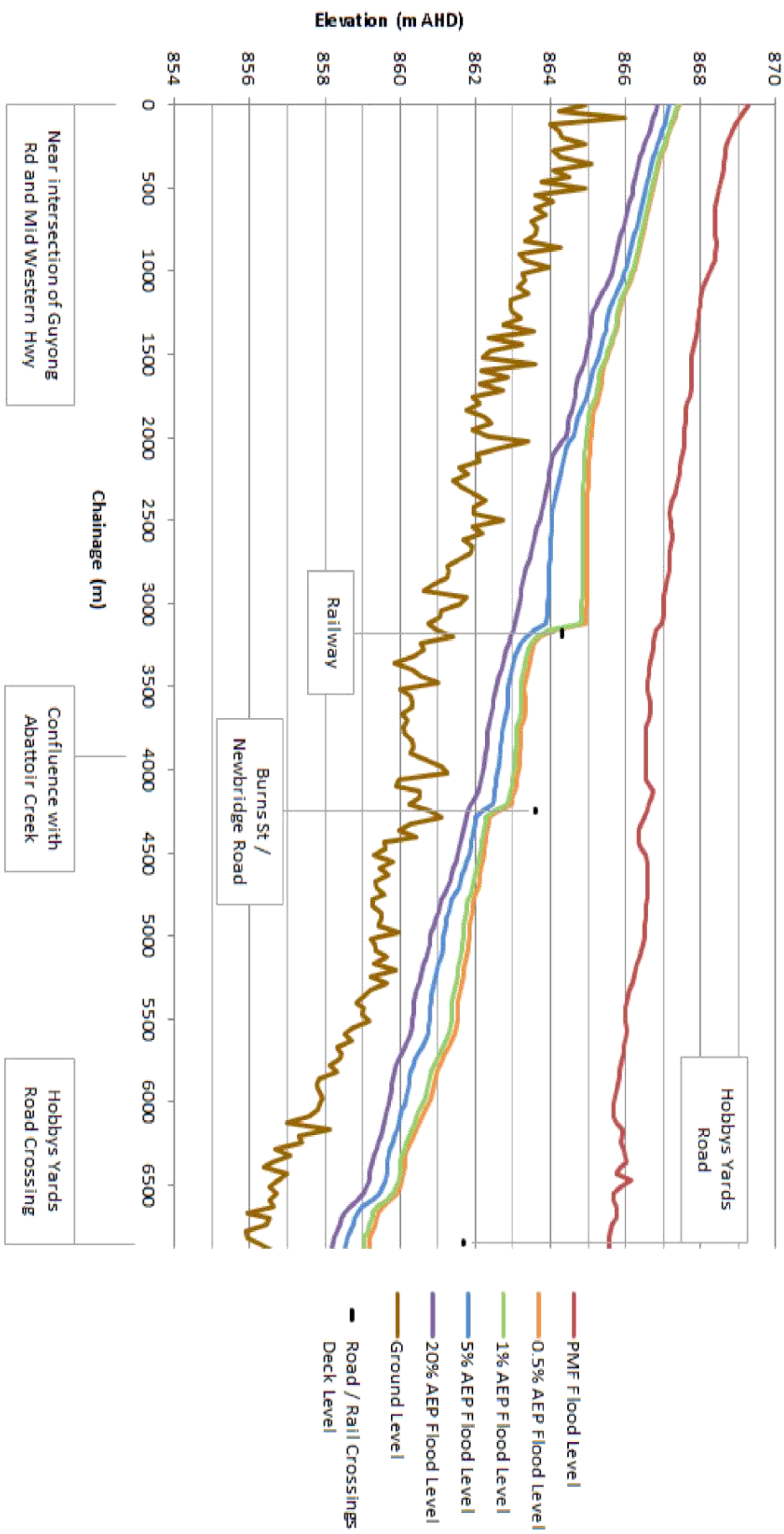


Figure 6-2 Peak Water Level Profiles – Abattoir Creek

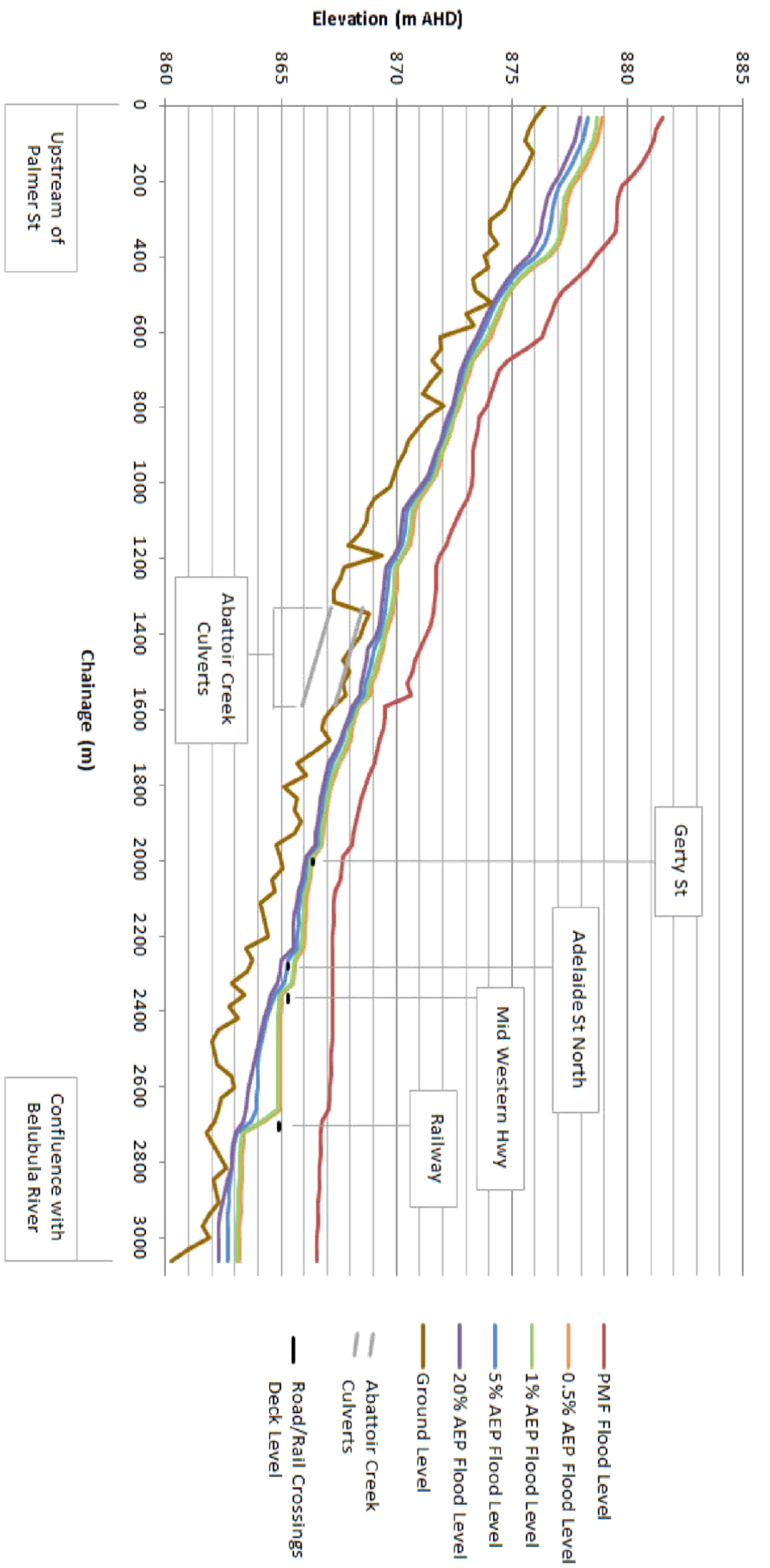


Table 6-1 Modelled Peak Water Levels at Major Waterway Crossings

Waterway Crossing	Deck Level (mAHD)	Soffit Level (mAHD)	Peak Water Levels (mAHD)					
			Location	20% AEP	5% AEP	1% AEP	0.5% AEP	PMF
Abattoir Creek at Mid Western Highway	865.28	864.47	U/S	864.83	865.16	865.46	865.55	867.22
			D/S	864.46	864.59	864.90	865.00	867.23
Abattoir Creek at Railway	864.9	863.8	U/S	863.39	863.73	864.19	864.26	866.80
			D/S	863.01	863.11	863.29	863.37	866.75
Belubula River at Railway	864.3	863.13	U/S	863.01	863.55	863.98	864.06	866.82
			D/S	862.96	863.36	863.65	863.73	866.77
Belubula River at Burns Street	863	861.56	U/S	861.89	862.47	862.86	862.98	866.62
			D/S	861.76	862.01	862.28	862.37	866.51
Belubula River Floodplain at Newbridge Road	863.57	862.5	U/S	862.11	862.56	863.02	863.15	866.75
			D/S	861.58	861.90	862.19	862.25	866.41
Belubula River at Hobbys Yards Road	859.96	859.43	U/S	858.26	858.58	859.05	859.20	865.57
			D/S	858.21	858.55	859.03	859.18	865.56

6.4 Flow Velocities

The peak flow velocities for each of the modelled events are mapped in **Appendix E**. A number of streets in Blayney act as main overland flowpaths during significant flood events and hence velocities along a number of streets are higher than 1m/s in the 20% AEP event.

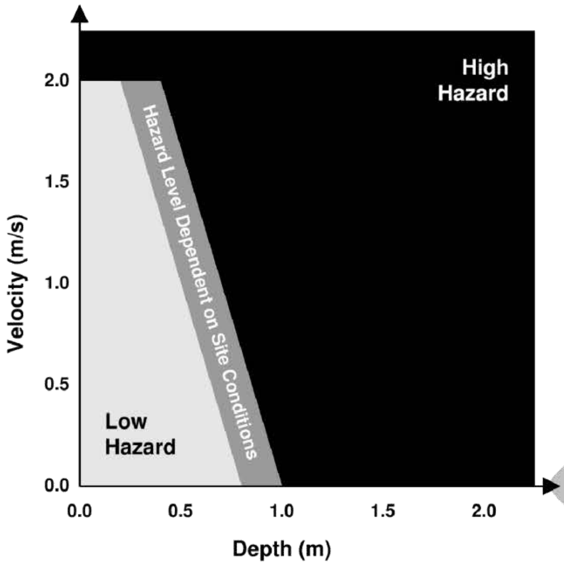
6.5 Summary of Peak Flows

Peak overland, piped and total flows are tabulated and mapped for selected locations in **Appendix F** for the modelled design flood events.

6.6 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% and 1% AEP event results, based on the hydraulic hazard category diagram presented in the *Floodplain Development Manual* (DECC, 2005), shown in **Figure 6-3**. The TUFLOW model calculates the hazard rating at each cell and computational time step, rather than calculating the rating based on the peak depth and peak velocity.

Figure 6-3 Hydraulic Hazard Category Diagram (reproduced from Figure L2 in *NSW Floodplain Development Manual*)



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

6.7 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. It was agreed that hydraulic categories mapping for Blayney is to be undertaken as part of the Floodplain Risk Management Study.

6.8 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. Other controls are considered, such as policies on fence construction, or rezoning at the floodplain risk management study stage. It was agreed that flood planning area mapping for Blayney is to be undertaken as part of the Floodplain Risk Management Study.

6.9 Sensitivity Analysis

A number of scenarios have been assessed for the 1% AEP flood event to test the sensitivity of the model results to changes in the adopted parameter values. The scenarios are described and the impacts summarised in **Table 6-2**.

6.10 Comparison of modelled flood levels

Modelled flood levels in this study are compared against recorded flood marks, floor levels and estimated flood levels in the previous studies which are discussed below:

- 76 Henry St, mark on concrete wall for 1972 flood: The modelled flood level in the 20% AEP event is 0.03m below the 1972 flood level (RL 862.39 mAHD) and the modelled 5% and 1% AEP flood levels are respectively 0.12m and 0.53m above the recorded 1972 flood level.
- 6 Smith Street (surveyed floor level 871.81mAHD): Ground levels within the property are located above RL 871 mAHD and the modelled 20% to 0.5% AEP events do not flood the property. Only in the PMF event is the property inundated to 871.94 mAHD. The owner of the property explained that the backyard of the property received rainfall runoff from the unnamed lane located behind Smith Street during the flood event of 2007. It is expected that the observed flooding in 2007 may have occurred due to local drainage issues.
- 7 Mt Erroll St (surveyed floor level 867.75 mAHD): The lowest ground level within the property is located above RL 866 mAHD and modelled flood levels at the property vary between 866.58 mAHD (20% AEP) to 867.20 mAHD (PMF) implying that property may have experienced below floor flooding in the past.
- 26 Hill Street (surveyed floor level 872.94 mAHD): Resident had no knowledge on the location of the flood mark. Modelled flood levels for the PMF are lower than ground levels within the property.
- 1% AEP modelled flood levels at Abattoir Creek culvert: The 1% AEP flood level estimated by Gilbert & Associates (2000) is similar to the 5% AEP flood level estimated in this study. Gilbert & Associate underestimated 1% AEP flood level up to 0.29m.
- Flood levels adopted by Cardno (2013) for the proposed upgrade of Belubula River Crossing for 5% and 1% AEP events are respectively 0.22m and 0.3m lower than that adopted in this study. This is due to the fact that the design discharges adopted in this study are higher than that adopted by Cardno.

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Table 6-2 Sensitivity Analysis Description and Results

Scenario	Description	Change in Flood Level[1]
Hydraulic Roughness – increase	Increase Manning's n in TUFLOW 2D domain by 20%	• Typically negligible or minor change (up to 0.03m) in overland flow area and isolated new areas flooded • Typically between 0.02 – 0.05m increase in Abattoir Creek and Belubula River upstream of Railway • Up to 0.1m increase in Belubula River downstream of Railway
Hydraulic Roughness – decrease	Decrease Manning's n in TUFLOW 2D domain by 20%	• Typically negligible change in overland flow area, some localised increases up to 0.05m • Reductions of 0.02 – 0.08m in Abattoir Creek and Belubula River upstream of Railway • Reductions of up to 0.12 in Belubula River downstream of Railway
Tailwater Level – increase	Increase tailwater level by 0.5m	• No change in study area
Tailwater Level – decrease	Increase tailwater level by 0.5m	• No change in study area
Blockage	50% blockage of culverts and pits in TUFLOW	• Typically negligible or minor change (up to 0.03m) in overland flow area • Up to 0.02m increase in Belubula River upstream of the Railway • Up to 0.06m increase in Abattoir Creek at Adelaide Street • Up to 0.25m increase in watercourse along Martha Street, between Medway Street and lower Farm Street. Some redistribution of flows with new areas flooded and (pink areas) and reduced overland flows (green areas) around Morris Street, Queen Street and Adelaide Lane.

1 Comparison of sensitivity case to design case peak flood level in 1% AEP event

7. Conclusions and Recommendations

In accordance with NSW Government Policy, Blayney Shire Council is committed to preparing a Floodplain Risk Management Plan for the township of Blayney. This report documents 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. Information provided by the community identified isolated minor flooding issues for the study area. The Local Flood Plan identifies the nature of historic flood damages in Blayney.

The available LiDAR survey undertaken by LPI was supplemented with a ground survey to capture the required topographic data for this flood study. The ground survey captured data on the selected stormwater pits and pipe systems, details of culverts and bridges for which adequate information was not available to this study. In addition, four flood marks and gauge zero of four streamflow gauges located in the vicinity of Blayney were referenced to AHD.

A calibrated RORB hydrologic model for the Belubula River catchment was available which was utilised to estimate catchment runoff from 108 km^2 upper catchment area of the Belubula River for the full range of flood events between 20% AEP and PMF. A detailed hydrologic model was formulated for the downstream catchments of the Belubula River and its tributaries to estimate catchment runoff for 20%, 5%, 1%, 0.5% AEP and PMF events for a range of storm durations.

A detailed 1D and 2D integrated hydrodynamic model was set up for this study using TUFLOW to represent flood behaviour in the main channel, on the floodplain and in the selected stormwater systems for 20%, 5%, 1%, 0.5% AEP and PMF events. The TUFLOW model generated flood behaviour within the study area which was generally consistent with observations made during significant flood events.

Detailed flood mapping was undertaken to define peak flood depths, maximum flood extents and peak flow velocities for the full range of flood events. Provisional flood hazard mapping was undertaken for the 5% AEP and 1% AEP events. A provisional hydraulic category map was prepared for the 1% AEP event. In addition a preliminary flood planning area map was created showing the extent of the 1% AEP flood level with a 0.5m freeboard. The flood behaviour shown in the flood maps is generally consistent with the flood behaviour experienced by the community.

A sensitivity analysis was undertaken and flood impact maps produced for the 1% AEP event due to changes in the adopted Manning's n value, tailwater conditions and blockage of pits and culverts.

Detailed hydrologic and hydraulic modelling undertaken in this study provide a sound platform for the flood modelling tasks that will be undertaken during preparation of the Floodplain Risk Management Study and Plan for Blayney.

8. Acknowledgement

The study was carried out by Jacobs with funding provided from Blayney Shire Council and NSW Government.

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 Blayney;
- Blayney Shire Council;
- Office of Environment and Heritage;
- SES; and
- NSW Office of Water.

9. References

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10. 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.
Development	Is defined in Part 4 of the EP&A Act In fill development: 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.
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 "cumec". 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.
MIKE11	A computer program used for analysing behaviour of unsteady flow in open channels and floodplains.
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.
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.
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.
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. Questionnaire

Flood Study for the Town of Blayney

Blayney Shire Council has contracted the Consultant, Sinclair Knight Merz (SKM), to undertake a flood study for the Town of Blayney. The flood study area for the Town of Blayney is shown in the attached Map 1.

The study is aimed at addressing the flooding issues due to riverine (Belubula River and its tributaries) and overland flooding and their combined impacts on flooding within the Town of Blayney. The Consultant 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 the Town of Blayney.

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 send your response** to this questionnaire **by 31 August 2013 using the attached reply paid envelope**.

If you would prefer to provide a letter with your comments to the Consultant, this would also be welcomed. Contact details of the Consultant's Project Manager are provided below:

Akhter Hossain
P O Box 164
St Leonards, NSW 1590
email: ahossain@globalskm.com

Place a tick or write a number in the relevant box as per instruction or write answers.

Quest-ion No.	Question and Answer
1.	**Do you live (reside) or have lived in the study area shown on Map 1?** A Yes (Please provide your address and put an 'X' on the relevant map) .... B No (Go to Question 3)
2.	**Do you own or rent your residence in the study area shown on Map 1?** A Own B Rent C How long have you lived in the study area? (Please write number of years)………........ ***If you are not sure whether you are in the map or not, please provide address
3.	**Do you own or manage a business in the study area?** A Yes, For how many years? ………………. B No (go to Question 5)
4.	**What kind of business is yours?**

Quest-ion No.	Question and Answer
	A Home based business B Shop/commercial premises C Light industrial D Heavy industry E Others, please write type of business ………………………
5.	**Have you had any experience of flooding (due to both Belubula River/ Farm Creek and/or storm events as well) in and around where you live or work?** A Yes B No (Go to Question 15)
6.	**How deep was the floodwater (from both Belubula River/ Farm Creek 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? ……………………….......................
7.	**How long did the floodwaters stay up?** A Less than 2 hours B less than 6 hours C Approximately 1 day
8.	**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?………………….........
9.	**What damage resulted from this flood in your business?** (Please indicate either "none", "minor", "moderate" or "major".) A Damage to surroundings B Damage to building C Damage to stock D Other damages, please list………………….. E What was the cost of the repairs, if any?………………….
10.	**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
11.	**Did you or members of your family required assistance from SES during flood events?**

Quest-ion No.	Question and Answer
	A No B Yes, Please specify how many times (in total) members of your family required assistance? ....
12.	**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 Any permanent marks indicating maximum flood level for particular floods D Memory of flow directions, depth or velocities
13.	**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
14.	**Do you have any photographs of past floods that would be useful for the consultant to help him understand the area flooded or other flood effects 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
15.	**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) ____
16.	**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 ____
17.	**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 residents/business from flooding B Protecting land of residents/businesses from flooding