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Leeton Shire Council

Leeton Shire Flood Study

Volume 1 - Report

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M9500_002

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EXECUTIVE SUMMARY

The Leeton Shire Flood Study has assessed the behaviour of flood waters within the Leeton Shire LGA for the 2012 historical event as well as design flood events.

In the absence of recorded historical data such as surveyed flood marks and stream flow data, the TUFLOW hydraulic model has been validated using anecdotal flood information provided by residents for the March 2012 event.

The purpose of the study was to allow LSC to:

- Better manage future development within the Shire.
- Understand and manage flood risks.
- Assess stormwater drainage systems.
- Apply for funding for a Floodplain Risk Management Study and Plan.

The approach for the flood study included applying the rain on grid method (direct rainfall applied to hydraulic model) for the hydrological (rainfall runoff) analysis and utilising available topographical data to achieve the study objectives. Three separate but interrelated hydraulic models were developed:

- *Regional Model* for the entire catchment (including Mirrool Creek) using 30 m hydrologically enforced SRTM data. The model provided catchment inflows to the Local Model.
- *Local Model* for the Leeton Shire local government area (LGA) using photogrammetry data. The model included direct rainfall over the model extent as well as inflows at the upstream model boundaries from the Regional Model. The model also provided catchment inflows to the Urban Model.
- *Urban Model* for Leeton and Yanco incorporating the subsurface drainage network (i.e. stormwater pipes and pits). The model included direct rainfall over the model extent as well as inflows from the Local Model at the upstream model boundaries.

Five flooding hot spot areas were identified around the Leeton and Yanco townships which were:

- Corbie Hill Road to Fivebough Road
- Petersham Road
- Leeton Township (CBD)
- Wattle Hill

- Yanco.

Flood depth results are summarised as follows:

- Flood depths through properties between Corbie Hill Road and Fivebough Road are typically up to 0.6 m outside of the open drains in a 1 % AEP event.
- Flood depths through properties along Petersham Road are typically less than 0.3 m in the 1 % AEP event.
- Flood depths through properties in Yanco west of Main Avenue are typically less than 0.3 m in the 1 % AEP.
- Flood depths greater than 1 m are predicted in the 1 % AEP event behind the railway, Binya Street and the pond in Yanco.
- Flood depths of typically less than 0.5 m are predicted in the 1 % AEP event east of Main Avenue.
- Flood depths of greater than 0.5 m in the 1% AEP are predicted east of Davis Road adjacent the open drain that conveys water from the MI main irrigation canal sub drain.

Flood evacuation via major roads during the 1 % AEP was predicted to be possible.

Hydraulic results have indicated that the majority of flooded areas in Leeton and Yanco are considered to be of low hazard category. The open drains surrounding Leeton and Yanco along with a few pockets of deep water where flood depths of greater than 1 m were predicted. These areas are considered to be of high hazard due to the excessive depths.

It was determined that the drainage channels were floodways with the remaining areas of inundation being flood storage areas. The floodways are also considered to be high hazard due to the greater flood depths, whilst the flood storage areas were generally considered to be low hazard apart from areas of significant ponding and greater flood depths.

Whilst the flood hazard across the Leeton Shire is predicted to be generally low, it is considered that flood mitigation and drainage improvement measures will significantly reduce the vulnerability of many homes to flood damage. As such, it is recommended that a Flood Risk Management Study and Plan be developed as part of Stages 2 and 3 of the floodplain risk management process.

It is recommended that LSC adopts the flood results from this study for development control and emergency management purposes and it is also advised that flood management provisions are incorporated into the Local Environmental Plan. Leeton Shire Council may wish to update this flood study should more detailed information become available such as topographic data and information from other studies in the region that could benefit the Leeton Shire Flood Study.

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ABBREVIATIONS

LSC	Leeton Shire Council
LGA	Local Government Area
AEP	Annual Exceedance Probability
MI	Murrumbidgee Irrigation
DEM	Digital Elevation Model
AR&R	Australian Rainfall & Runoff
BOM	Bureau of Meteorology
ARF	Areal Reduction Factors
GCC	Griffith City Council
PMP	Probable Maximum Precipitation
PMF	Probable Maximum Flood
GSDM	Generalised Short-Duration Method
LEP	Local Environmental Plan

1. INTRODUCTION

Engeny Water Management (Engeny) was engaged by Leeton Shire Council (LSC) to undertake the Leeton Shire Flood Study. The study has been undertaken in response to the 2012 flood which is considered to be the largest known event to impact the Leeton Shire. The Leeton Shire Flood Study was undertaken with oversight provided by the Floodplain Risk Management Committee.

The flood study objectives, study area, flood history and scope are outlined in the following sections.

1.1 Study Purpose and Objectives

The purpose of the study was to allow LSC to:

- Better manage future development within the Shire.
- Understand and manage flood risks.
- Assess stormwater drainage systems.
- Identify and assess flood risk hot spots in order to assist in scoping work for the next stage of the floodplain risk management process.
- Apply for funding for a Floodplain Risk Management Study and Plan.

The main objective of the flood study was to develop a flood model that could be used to define flood behaviour on a local and regional scale for the historical 2012 event as well as a range of design flood events. The flood behaviour has been defined in terms of the nature, flood extent and flood risks in the catchment.

1.2 Study Area and Flood History

Leeton is located approximately 126 km west of Wagga Wagga in New South Wales (NSW). The main townships with the LSC boundary consist of Leeton, Yanco, Murrami, Whitton and Wamoon. The catchment draining through the LSC boundary is approximately 850 km² in size and drains in a typically westerly direction from the Colinroobie Ranges located to the east of Leeton. Much of the catchment drainage has been modified by agricultural activities.

The catchment contains two Ramsar, namely Fivebough Swamp and Tuckerbill Swamp. A majority of the catchment to the east of Leeton drains towards Fivebough Swamp. Fivebough Swamp is 2 km north-east of Leeton, and Tuckerbil Swamp, less than 10 km from Fivebough, is approximately 12 km north-west of Leeton. Fivebough Swamp is a permanent, but fluctuating, fresh-brackish, shallow wetland and Tuckerbil Swamp is a seasonal, shallow, brackish-saline wetland. A drainage channel diverts flow around Fivebough Swamp however some flow enters the swamp. Fivebough Swamp is therefore considered to provide some flood mitigation benefit.

The Study Area Locality Plan is presented in **Figure 1.1**.

Leeton experienced local flooding during the March 2012 storm event where 170 mm of rain was recorded within 24 hours. Based on a comparison of the recorded rainfall against design rainfall data for the 24 hour period, the event is considered to be greater than a 1 % Annual Exceedance Probability (AEP) flood. Rainfall records also show that depths of around 100 mm fell across the catchment in the week preceding the March 2012 flood event. This storm event resulted in flash flooding throughout Leeton and other towns as well as neighbouring agricultural land. It is understood that the event resulted in inundation to homes within Landsdowne Estate as well as homes in Winlee Place (for locations refer to Figure B1 of Volume 2). The exact number of homes inundated by floodwater is unknown. The impacts are considered to have been caused by localised flooding which was not influenced by flooding from the Murrumbidgee River. The Murrumbidgee River is considered to have peaked at least 24 hours after the Leeton storm ocurred.

The event caused financial impacts to the agricultural industry surrounding Leeton which suffered losses of livestock, crops and property access.

1.3 Floodplain Risk Management Process and Study Scope

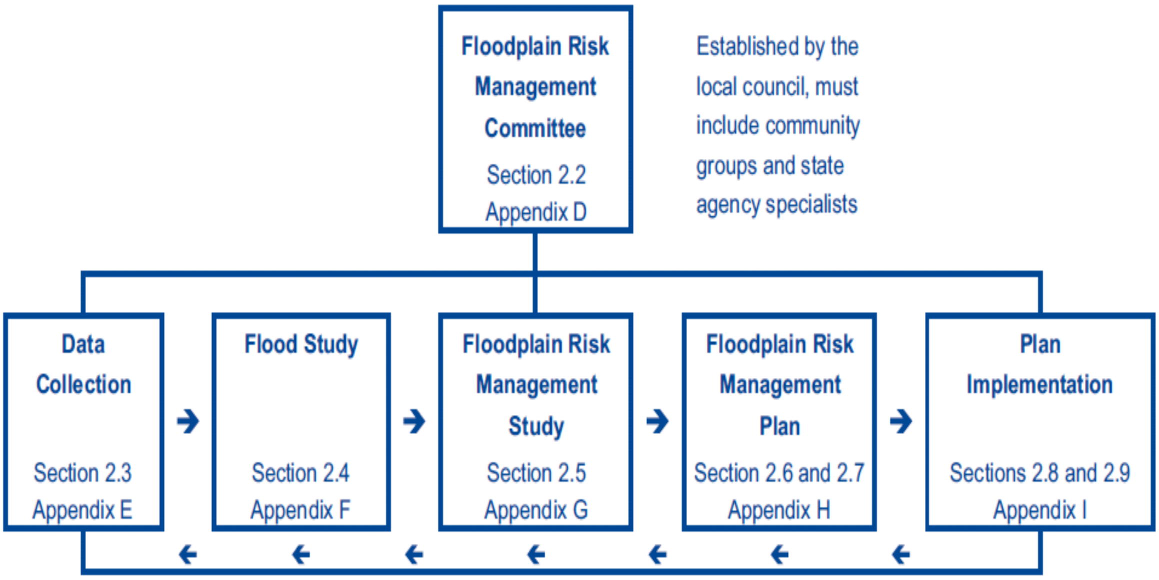
The Leeton Shire Flood Study has been jointly funded by LSC and the New South Wales Government Office of Environment and Heritage through the 2013/2014 floodplain management grants. This study has been undertaken in accordance with the Floodplain Development Manual (DIPNR, 2005). The Floodplain Risk Management Process and Scope of Works for this study are outlined in the following sections.

1.3.1 Floodplain Risk Management Process

The Leeton Shire Flood Study is Stage 1 of the Floodplain Risk Management Process which comprises of the following components:

- Stage 1 Flood Study
- Stage 2 Floodplain Risk Management Study
- Stage 3 Floodplain Risk Management Plan.

The Process as outlined in the Floodplain Development Manual is illustrated in the diagram below.



1.3.2 Flood Study Scope of Works

The scope of the Leeton Shire Flood Study has consisted of the following:

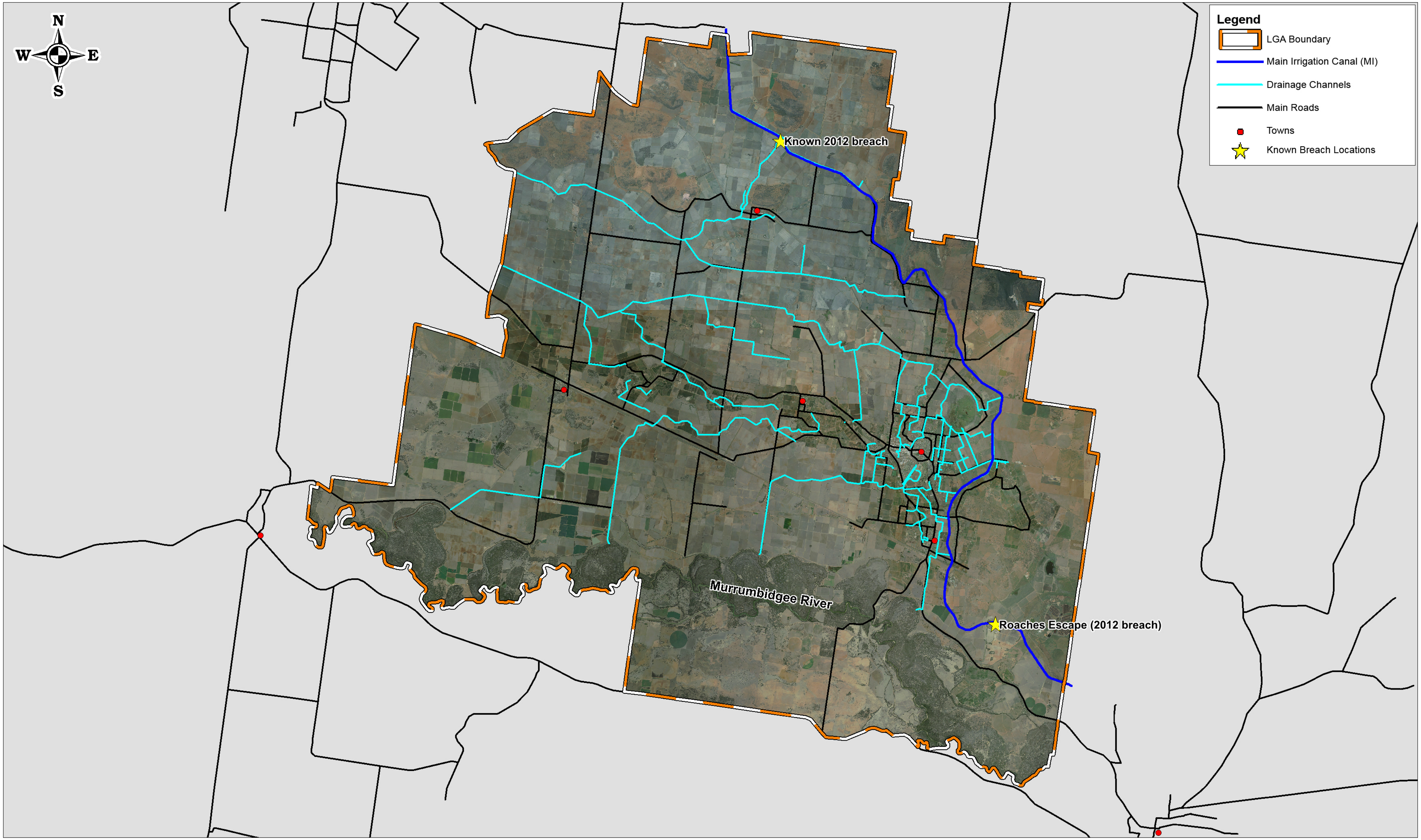
- Data collection and review.
- Site inspection.
- Hydrological analysis including preparation of rainfall data.
- Hydraulic model development for:
  - Regional Model for the catchment using 30 m hydrologically enforced SRTM data
  - Local Model for the Leeton Shire LGA using photogrammetry data.
  - Urban Model for Leeton and Yanco incorporating the subsurface drainage network (i.e. stormwater pipes and pits).
- Community Consultation including media releases, presentations and workshops.
- Hydraulic Model Validation.
- Hydraulic Assessment of the 50, 20, 10, 5, 2, 1 and 0.2 % AEP events as well as the Probable Maximum Flood event.
- Preparation of Flood Study Report including mapping.

1.4 Acknowledgement

Leeton Shire Council and Engeny would like to acknowledge the following for their contribution to this study:

- Floodplain Risk Management Committee.
- Office of Environment and Heritage – NSW Government.
- Murrumbidgee Irrigation.
- State Emergency Service.
- Leeton residents.

Leeton Shire Council has prepared this document with financial assistance from the NSW Government through its Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or Office of Environment and Heritage.



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Scale in Kilometres (1:200,000 @ A3)

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Leeton Flood Study

Figure 1.1

Study Area

Job Number: M9500_002
Revision: A
Drawn: JNA
Date: 01 Oct 2014

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2. INPUT DATA AND AVAILABLE INFORMATION

2.1 Catchment and Drainage Data

The following data was provided by LSC and Murrumbidgee Irrigation (MI) for use in the study:

- 2007 photogrammetry data as a 2 m digital elevation model (DEM) covering the LSC Local Government Area provided by MI.
- 2014 LiDAR land survey data covering approximately 480 km² of the Shire including Murrami, Leeton and Yanco provided by NSW Government Land & Property Information.
- Model breaklines representing features such as drainage channels, levee banks, roads and the irrigation canal were provided by MI.
- Various MapInfo GIS layers (such as cadastral boundaries, roads, development zoning, drainage channels, supply channels, stormwater pipes and pits, pump locations, etc.)Aerial photography (2008).

Topography data covering the entire catchment was also sourced from GeoScience Australia. The Shuttle Radar Topography Mission derived 1 second (30 m resolution) hydrologically enforced DEM (DEM-H) was obtained. This dataset was used to provide topographic information for the Leeton Shire catchment where LiDAR and photogrammetry data was not available.

2.2 Rainfall Data

There is a network of rainfall gauges across the region, which is operated by the Bureau of Meteorology (BOM). The majority of gauges are daily read gauges. Data from two pluviometric (pluvio) stations was sourced from BOM to generate historical temporal patterns for the March 2012 flood event that occurred within the catchment. The two pluvio stations used were Yanco Agricultural Institute (074037) and Griffith Airport AWS (075041).

Design rainfall estimates for the Leeton catchment were derived based upon the procedures outlined in Australian Rainfall and Runoff (AR&R) (IEAust, 1987) and sourced from BOM using the online IFD application. Storm durations ranging from 2 hours to 48 hours for each event were simulated in each of the hydraulic models to establish flow estimates for a complete range of design flood events in order to determine the critical storm duration. For design event rainfall it is also necessary to consider areal reduction factors (ARF), which scale down point rainfall intensities to a level appropriate to the scale of the area of interest.

The rainfall inputs for the historical validation events are discussed in further detail in **Section 3.2**.

2.3 Previous Investigations

A flood study has been undertaken on behalf of Griffith City Council (GCC) for the Griffith Main Drain J and Mirrool Creek catchment (WBM July 2014). The study was in draft phase at the completion of the Leeton Shire Flood Study and therefore no outputs from the study were available for inclusion into this flood study.

There have been no detailed flood studies/investigations undertaken for the Leeton catchment; however LSC has previously prepared Flood Planning Maps which were incorporated into the Leeton Local Environmental Plan 2014 and identified flood planning areas for the Murrumbidgee River. These Maps are provided in **Figure H – Volume 2**.

2.4 Site Inspections

A number of site inspections were undertaken to develop an understanding of the catchment in terms of catchment roughness (Manning's n), hydraulic controls (i.e. bridges, culverts, earth embankments, etc.) and to obtain measurements (where possible) of hydraulic structures. Some photos obtained during the site inspection are presented in the photos below.

Photo 2.1 Typical Drainage Channel in Leeton (Landsdowne Estate)

Photo 2.2 Drain Entrance to Fivebough Swamp (Fivebough Rd)

Photo 2.3 Typical Vegetation and Ground Slopes

2.5 Community and Stakeholders Engagement

It was identified at project inception that the community and key stakeholders had a vital role in the development and adoption of the Leeton Shire Flood Study. Engagement with the community and stakeholders in the early stages of the project and during the review of the 2012 flood modelling results provided an opportunity for these parties to actively contribute to the outcomes of the flood study.

2.5.1 Objectives of the Community and Stakeholder Engagement

The objectives of the community and stakeholder engagement were to:

- Raise community and stakeholder awareness of the flood study being undertaken by LSC.
- Obtain information from residents and stakeholders on the 2012 flood behaviour (i.e. flood depths and extents).
- Educate the community and stakeholders on the benefits of flood modelling as well as the limitations.
- Obtain feedback from the community and stakeholders on the general accuracy of the March 2012 flood modelling results for model validation purposes.

2.5.2 Community and Stakeholder Engagement Strategy

A strategy for Community and stakeholder engagement was developed and executed to ensure the objectives of the project were achieved. The following community and stakeholder engagement strategy was adopted:

- Presentation to Councillors and the Floodplain Risk Management Committee, detailing the purpose and objectives of the flood study and the steps required to achieve the desired outcomes.
- Letter to all rate payers notifying them of the project and consultation period.
- Hard copy and online questionnaire disseminated via post with study information letters. The main purpose of the questionnaire was to identify residents that had information that could be used for model validation.
- Collation and review of the questionnaire results to determine which residents had flood information (i.e. flood marks) from the 2012 flood.
- Phone hotline for residents' queries.
- One on one meetings with available residents who had over floor flooding and could provide estimated flood depths.

- Community information sessions at Leeton, Yanco and Murrami to provide residents with information on the purpose of the study and obtain additional information on the 2012 event.

- Second community workshop which included personal invitations being sent to questionnaire respondents.

- Strategic advertisements in local paper inviting residents to the second community workshop.

- Presentation of results to Councillors and the Floodplain Risk Management Committee. This included seeking feedback on the overall 2012 flood mapping results from both parties.

- Presentation of 2012 flood mapping results for comment at the second community workshop. The workshop included gathering comments from the community on the accuracy of the flood modelling results and informing the community of the relative magnitude of the March 2012 event compared to the range of design flood estimates from the Study.

2.5.3 Community and Stakeholder Engagement Outcomes.

An overwhelming response to the questionnaire resulted in 456 survey responses being received over the course of the project. The survey highlighted that 21 homes were reported to have experienced over floor flooding. Of these 21 homes, 6 were able to provide an approximate flood depth which was used for model validation as discussed in **Section 3.4**.

The second community and stakeholder workshops sought feedback on the mapping results of the 2012 historical event. The overall response to the mapping was that it was generally accurate throughout the majority of the catchment and model results in the Leeton and Yanco townships were acceptable.

3. FLOOD INVESTIGATION

3.1 Overall Approach

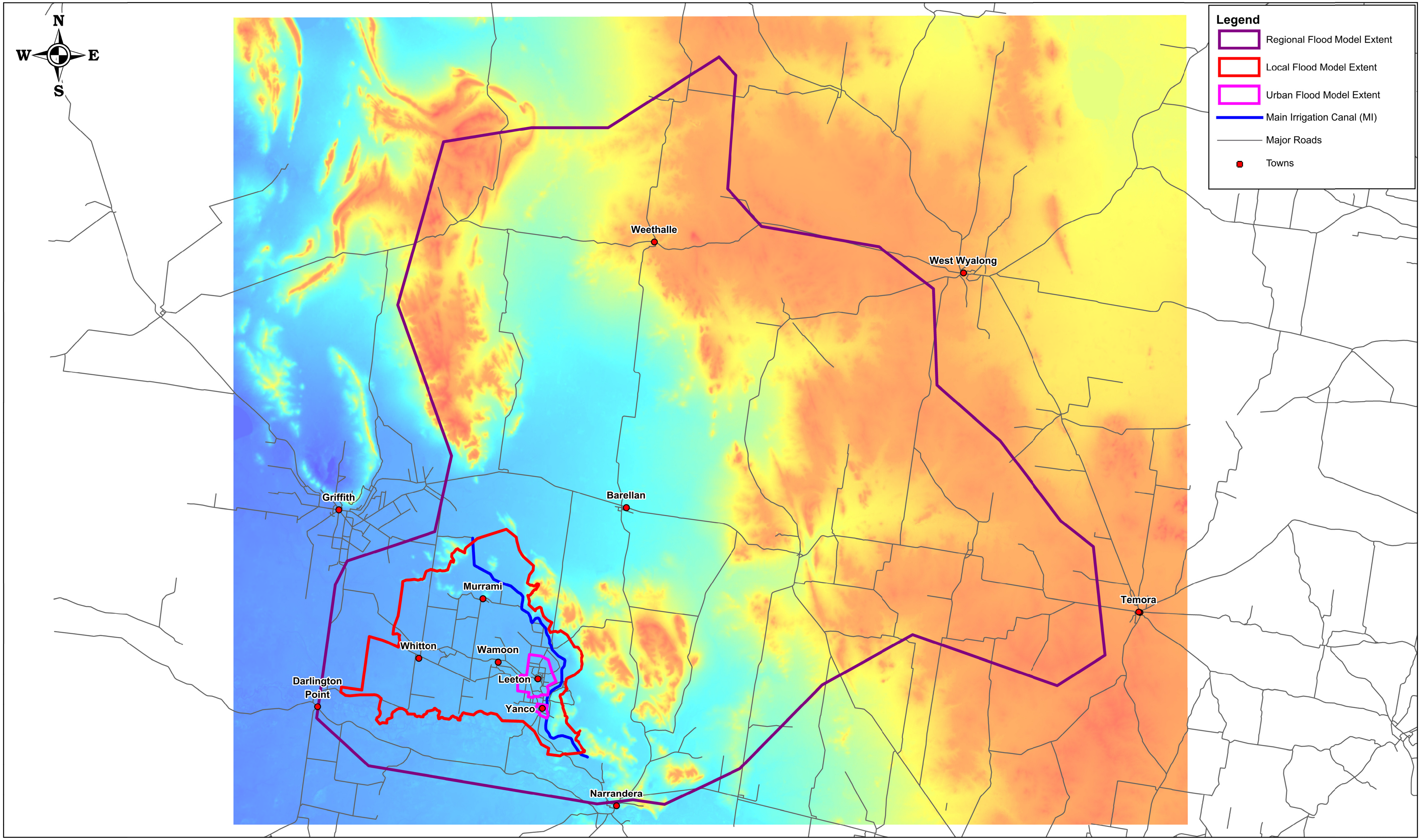
The hydraulic modelling package chosen for use in this study is the TUFLOW finite difference hydrodynamic flood simulation software. TUFLOW simulates depth-averaged, two and one-dimensional free-surface flows and uses a combination of 2D and 1D modelling schemes to model complex flooding behaviour.

The approach for the flood study included applying the rain on grid method (direct rainfall applied to hydraulic model) for the hydrological (rainfall runoff) analysis and utilising available topographical data to achieve the study objectives.

As such, the following three separate but inter-related hydraulic models have been developed:

- **Regional Model** for the entire catchment (including Mirrool Creek) using 30 m hydrologically enforced SRTM data. The model provided catchment inflows to the Local Model.
- **Local Model** for the Leeton Shire local government area (LGA) using photogrammetry data. The model included direct rainfall over the model extent as well as inflows at the upstream model boundaries from the Regional Model. The model also provided catchment inflows to the Urban Model. This model formed the basis for assessing flood behaviour at Murrami, Wamoon and Whitton.
- **Urban Models** for Leeton and Yanco using available LidAR data which covered the Leeton and Yanco townships. The models incorporated the subsurface drainage network (i.e. stormwater pipes and pits). The models included direct rainfall over the model extent as well as inflows from the Local Model at the upstream model boundaries.

The three hydraulic model extents are illustrated in **Figure 3.1**.



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Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Leeton Flood Study

Figure 3.1

Hydraulic Modelling Approach

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Revision: A
Drawn: JNA
Date: 01 Oct 2014

3.2 Hydrological Analysis

In recent years the advancement in computer technology has enabled the use of direct rainfall approach as a viable hydrological method. With the direct rainfall method the rainfall totals are applied directly to the individual cells of the 2D hydraulic model. The utilisation of the recently developed TUFLOW GPU solver enables catchments as large as the Leeton catchment to be simulated relatively quickly.

Rainfall estimates were undertaken for the 50, 20, 10, 5, 2, 1 and 0.2 % AEP events as well as the Probable Maximum Precipitation (PMP).

3.2.1 2012 Rainfall Analysis

Daily rainfall totals for the 3 March 2012 rainfall event were sourced from sixteen (16) BOM stations throughout the catchment. As mentioned earlier, two automatic (pluvio) stations were used to generate temporal patterns for the rainfall event.

The pluvio data provided 1 minute rainfall data that fell at the station. This was then converted to 15 minute totals to generate temporal patterns to apply within the TUFLOW model. Temporal patterns were spatially distributed within the study area in order to account for spatial variance of rainfall within the catchment during the historical rainfall events.

The rainfall stations and temporal patterns adopted for the 2012 flood event are presented in **Figure 3.2**.

3.2.2 Design Event Rainfall Analysis

Design rainfall estimates for the Leeton catchment were derived based upon the procedures outlined in Australian Rainfall and Runoff (IEAust, 1987) and sourced from BOM using the online IFD application (BOM, 2014). Storm durations ranging from 2 hours to 48 hours for each design event were simulated in the regional hydraulic model to establish flow estimates for a complete range of design flood events in order to determine the critical storm duration. The critical storm duration was determined to be the 6 and 24 hour storm due to the flood storage (i.e. volume) characteristics of the study area. As such, both durations were simulated for all design events. The 2, 3 and 6 hour storms were determined to be critical for the PMF event.

The design rainfall intensities derived according to AR&R are applicable strictly to a point location. For larger catchments, it is not realistic to assume that the same rainfall intensity can be maintained over the entire area and an ARF is typically applied.

In order to assess the spatial variance in point source rainfall intensity, IFD data was sourced from Leeton, Murrami and Whitton Townships. The variance between the three IFD datasets was typically less than 1 %. The three Townships are spread fairly evenly over the entire catchment, as such the ARF estimation was undertaken on the largest contributing area. This was deemed to be the Leeton catchment (approximately 380 km²). Therefore a catchment area of 380 km² has been used to determine appropriate ARFs.

The adopted methodology for determining ARFs is that proposed in the Review of ARFs Final Report (AR&R Revision Project 2, 2013).

Under the revised AR&R guidelines appropriate ARFs are calculated separately for both long duration events (18 hours or greater) and short duration events (18 hours or less). These calculations incorporate the catchment area, storm duration, event Annual Exceedance Probability (AEP) and a set of published parameters which vary according to the geographical location of the study area. The Leeton catchment is situated within the NSW GSAM zone. The calculated ARFs for the design events are presented in **Table 3.1** and **Table 3.2.**

Temporal patterns adopted within the study are based on the standard patterns in AR&R (2001). The study area is located within Zone 2 as it is west of the Great Dividing Range. The design event temporal patterns for Zone 2 have therefore been adopted within this study.

The PMP is used in deriving the Probable Maximum Flood (PMF) event. The AEP of the PMP/PMF event ranges between 10^4 to 10^7 years and is beyond the credible limit of extrapolation. Rainfall depths adopted for the PMF event were estimated using the techniques outlined in "The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method" (BOM, 2003). Given the PMF event often has a critical duration much shorter than design events (i.e. typically less than 6 hours), adopting the GSDM (appropriate method for short durations) was considered a reasonable representation of the PMF event. GSDM has only one temporal pattern which was adopted within the study.

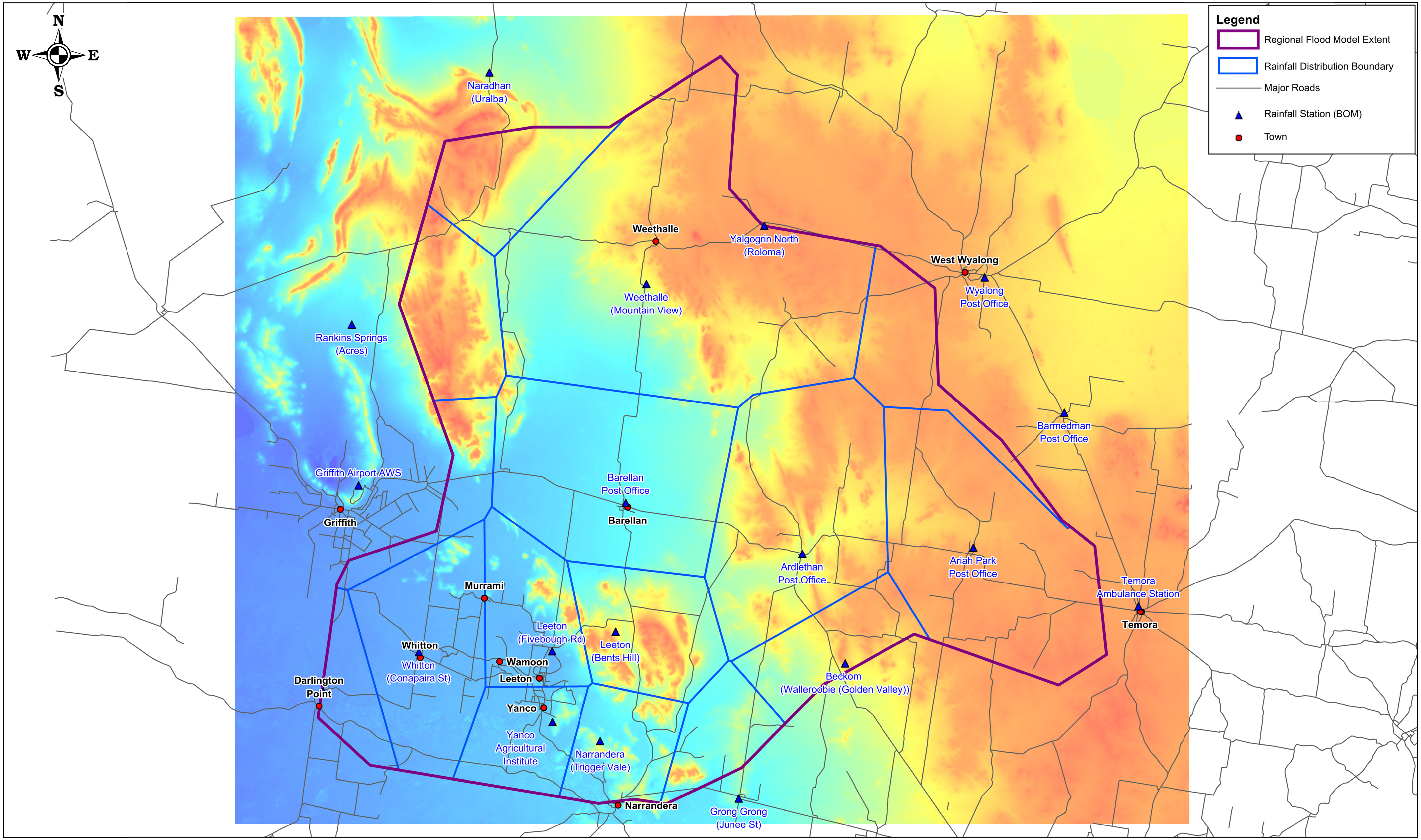
The 0.2 % AEP rainfall intensities were estimated using the techniques within AR&R to interpolate between the 1 % AEP and the PMP rainfall estimates.

Table 3.1 Areal Reduction Factors (Short Duration)

AEP	2 hour	3 hour	6 hour	9 hour	12 hour
50 %	0.730	0.758	0.806	0.834	0.854
20 %	0.730	0.758	0.806	0.834	0.854
10 %	0.730	0.758	0.806	0.834	0.854
5 %	0.730	0.758	0.806	0.834	0.854
2 %	0.730	0.758	0.806	0.834	0.854
1 %	0.730	0.758	0.806	0.834	0.854
0.2 %	0.730	0.758	0.806	0.834	0.854

Table 3.2 Areal Reduction Factors (Long Duration)

AEP	18 hour	24 hour	36 hour	48 hour
50 %	0.879	0.900	0.924	0.937
20 %	0.876	0.896	0.920	0.933
10 %	0.873	0.893	0.917	0.930
5 %	0.871	0.891	0.914	0.927
2 %	0.867	0.887	0.910	0.923
1 %	0.865	0.885	0.907	0.920
0.2 %	0.859	0.878	0.900	0.913



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Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Leeton Flood Study

Figure 3.2

Rainfall Stations

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Date: 01 Oct 2014

3.3 Hydraulic Model Development

3.3.1 Model Topography and Grid Cell Size

The following three topographic datasets were available for the study:

- SRTM Hydrologically enforced DEM (30 m resolution) covering the entire catchment.
- Photogrammetry data (2 m resolution) covering the Leeton Shire LGA.
- LiDAR data (1 m resolution) covering urban areas of Leeton and Yanco.

The SRTM dataset (30 m resolution) covers the entire contributing catchment of the Leeton Shire LGA boundary and was adopted for regional flood model (30 m grid cell size). The photogrammetry dataset (2 m resolution) only covers the LSC LGA boundary and was therefore adopted for the local flood model (10 m grid cell size). LiDAR data (1 m resolution) was only available for the urban areas of Leeton and Yanco and was therefore adopted for the local urban flood models of Yanco (5 m grid cell size) and Leeton (7 m grid cell size). A 7 m grid size was adopted for the Leeton model due to excessive run times for 5 m grid (i.e. more than double the CPU hours in comparison to the 5 m grid).

The hydraulic model extent for the Urban Models was defined taking into account the Leeton Local Environmental Plan (LEP). The model extents were defined in collaboration with LSC.

The model extents are presented in **Figure 3.1**.

3.3.2 Boundary Conditions

Boundary conditions within the model consisted of:

- Direct rainfall over the hydraulic model extent (rainfall depth over time).
- Model outflow boundary (normal depth).
- Model inflow boundaries to local flood model (obtained from the regional flood model).
- Model inflow boundaries to the urban flood models (obtained from the local flood model).

The downstream model boundary for the Urban Models were extended a sufficient distance beyond the area of interest to manage influence from boundary conditions.

3.3.3 Land Use and Hydraulic Roughness

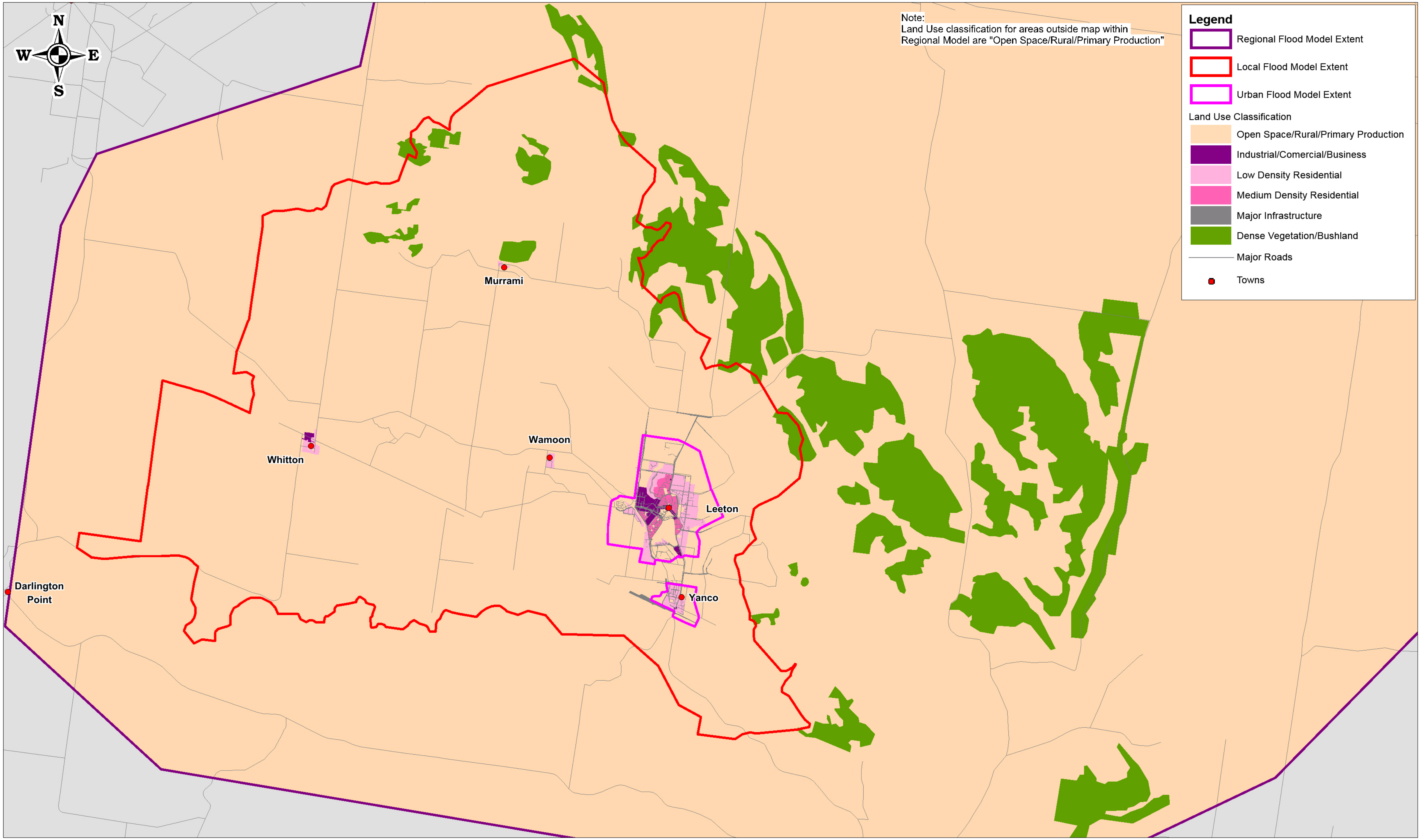
The land use and hydraulic roughness values adopted within the TUFLOW models is presented in **Table 3.3**. **Figure 3.3** presents the land use and hydraulic roughness boundaries throughout the study area.

Table 3.3 Land Use and Hydraulic Roughness

Land Use	Manning's 'n' Value	Impervious Fraction (%)
Open Space / Rural / Primary Production	0.06	0
Industry / Business / Commercial	0.3	90
Low Dense Residential / Village	0.1	40
General & Medium Density Residential	0.2	60
Major Infrastructure	0.025	90

Model roughness values applied within the urban flood models was slightly different to the local flood model. To allow the initial amounts of rainfall to runoff from impervious surfaces, such as roofs, within the development areas (i.e. business, residential, etc.) the first 20 mm of runoff depth had a Manning's value of 0.015 applied with the values within **Table 3.3** adopted above 20 mm runoff depth. Whilst the adoption of a 20 mm depth is considered to improve modelling performance, it is not considered to have any implications on the peak flood level results.

In the absence of building structure details (i.e. slab on ground or raised on stumps, floor level, etc.), buildings within the hydraulic model have been accounted for by applying a higher roughness to the relevant land use type.



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Leeton Flood Study

Figure 3.3

Land Use Classification

Job Number: M9500_002
Revision: A
Drawn: JNA
Date: 01 Oct 2014

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3.3.4 Infiltration Method

Soil data for the region was obtained from the Australian Soil Resource Information System and showed that two distinctly different soil types exist across the catchment. The area is characterised by a distribution of both well-drained sandy soils and less well-draining clay soils. The distribution of these soils across the catchment has been presented in **Figure 3.4**. Some adjustments to the soil distribution within the Mirrool Creek catchment were made based upon the initial findings of the Mirrool Creek Flood Study.

The continuous infiltration functionality of TUFLOW was incorporated into each hydraulic model. This approach assigns parameters based on soil types, utilising the Green-Ampt methods to determine initial and continuing rainfall losses. This approach represents the continuous infiltration of runoff as it travels through the catchment which is a prominent feature of the mountain ranges to the north and east of Leeton as well as the Mirrool Creek and Binya Creek catchment to the northeast of Murrami.

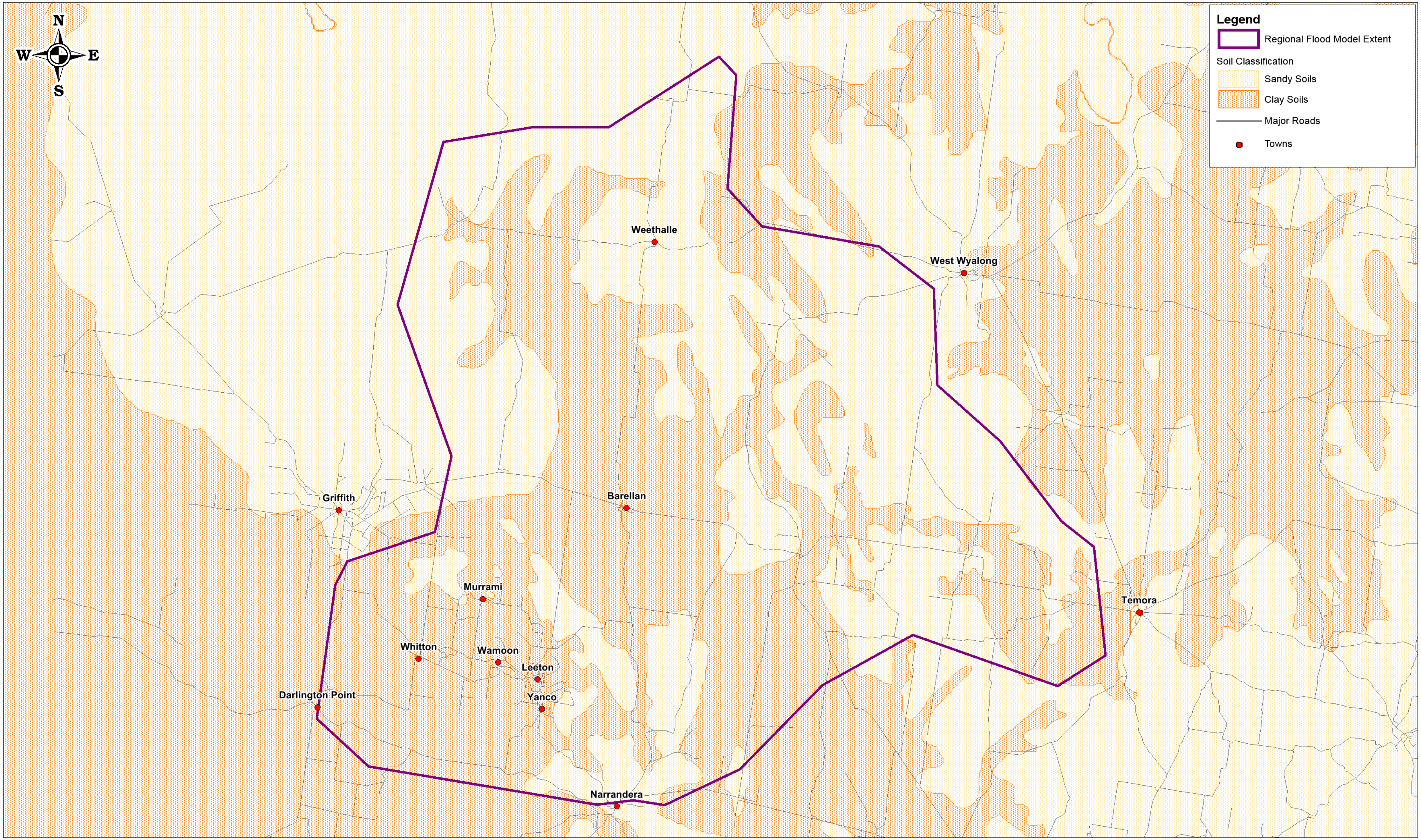
The Green-Ampt method defines soil infiltration properties using the following parameters:

- Suction (mm)
- Hydraulic Conductivity (mm/hr)
- Porosity (fraction).

An initial moisture fraction is also defined to represent the antecedent conditions at the onset of the modelled event. The suction, porosity and initial moisture fraction determine the initial loss of the soil, with the hydraulic conductivity representing the continuing loss.

Published parameters exist for standard soil types and were used as the basis for defining initial values for the two soil types within the catchment. For the clay soils a suction of 239 mm, hydraulic conductivity of 0.6 mm/h and a porosity of 0.321 was selected, which is the standard parameters of sandy clay. For the sandy soils a suction of 110.1 mm, hydraulic conductivity of 10.9 mm/h and a porosity of 0.412 was selected, which is the standard parameters of sandy loam. For the initial moisture fraction, values of 0.3 and 0.4 were adopted for the clays and sands respectively. This represents a saturated soil condition and was based on analysis of the rainfall preceding the storm event. Rainfall depths of around 100 mm fell across the catchment in the week preceding the March 2012 flood event.

This approach is consistent with the Mirrool Creek Flood Study Draft Report (July, 2014).



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Leeton Flood Study

Figure 3.4

Regional Soil Classification

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Drawn: JNA
Date: 01 Oct 2014

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3.3.5 Drainage Infrastructure (Topographic Controls)

Major topographic controls influencing catchment behaviour have been incorporated into the Local and Urban TUFLOW Models. These include:

- The main irrigation canal and other significant canals
- Water supply reaches
- Road centrelines
- Drainage channels
- Hydraulic structures (i.e. culverts, pits and pipes)
- Detention basins (as represented in LiDAR data).

The above topographic controls were input into the Local and Urban TUFLOW models to represent physical obstructions of the roads and irrigation canals as well as digitising drainage channels to ensure they were representation throughout the LSC LGA boundary.

The majority of the drainage channels in the vicinity of Leeton and Yanco townships are approximately 5 m wide, as such a 50% cell width reduction factor was applied to the drainage channels within the local flood model as the model cell size was 10m. Where the drainage channels became larger (i.e. approximately 10-15 m) no cell width reduction factors were applied. For 2D only models, Z shapes were also used to define the channel invert levels.

As the local flood model was undertaken utilising TUFLOW's GPU solver, no 1D elements (i.e. culverts, pits and pipes) were able to be incorporated into the model. To represent the transfer of water through major hydraulic controls (i.e. main irrigation canal and roads), an artificial channel was incorporated at the stormwater infrastructure location and a cell width reduction factor applied accordingly based upon the dimensions of the structure.

The urban flood models for Leeton and Yanco were simulated using the classic TUFLOW linked 1D/2D flood modelling approach. As such, stormwater infrastructure (i.e. culverts, pits and pipes) were included as 1D elements within the TUFLOW models.

Invert levels of pits and pipes within Leeton and Yanco were not available at the inception of the project. As such, LSC engaged Engeny to estimate stormwater inverts for pits and pipes based upon the surface levels, pipe diameters and a nominal cover over the pipe (i.e. 300 mm). Given the timeframes of the project this was deemed an acceptable approach for the study compared to undertaking detailed survey which would have been a long and expensive task. The stormwater network modelling approach included lumping of pits and it was assumed unlimited inlet capacity to ensure that pipes were flowing full.

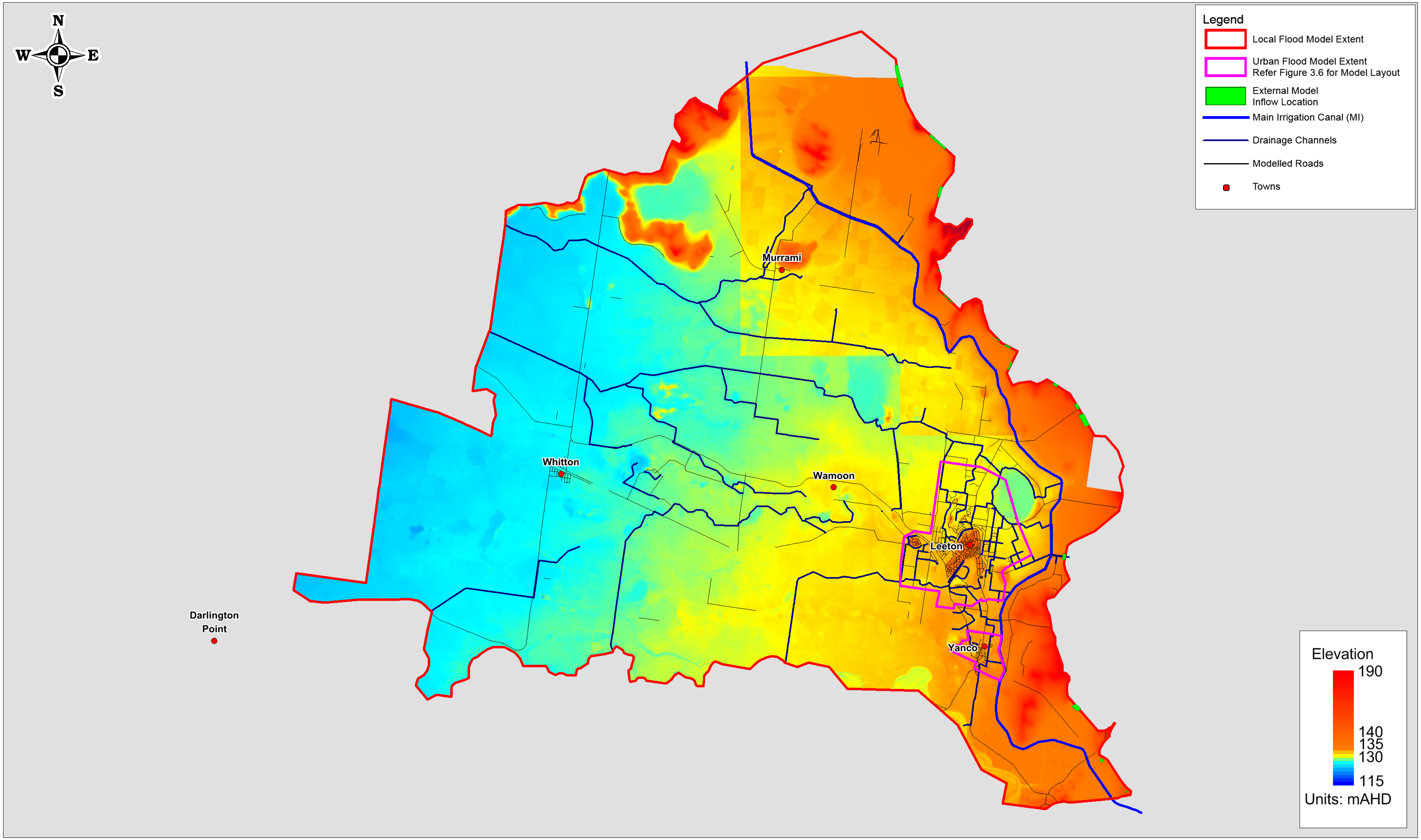
Whilst the subsurface drainage system has been incorporated into the Urban Models, the focus of the study is on overland flow. However, the drainage analysis provides a high level assessment of the existing drainage systems and provides a basis for more detailed drainage modelling and analysis.

Cross drainage culvert information was supplied by LSC that was obtained by undertaking visual inspection and measurements to determine dimensions and the current state of the culverts (i.e. blockage due to siltation and/or vegetation).

Bridges were incorporated into the Leeton urban flood model as layered flow constrictions. Bridge parameters (i.e. piers and deck thickness) were estimated based upon visual inspection and measurements obtained by LSC.

Pumps located within detention basins/storages around Leeton and Yanco were incorporated within the Urban Models to allow the detention basins to drain as they are located at lower levels than the drainage channels. Pump capacities were provided by LSC as approximately 15 L/s for all basins except Golf Club Drive which has a capacity of 35 L/s. Detention basins are located at Golf Club Drive, Parry Lane, Landsdowne Road, Teramo St, Bella Vista Drive, Dethridge Avenue, Kindred Place, Winlee Place, Ellendon Place in Leeton and Hebden Street in Yanco.

Hydraulic model layouts for the local and urban flood models are presented in **Figure 3.5** and **Figure 3.6** respectively.



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Leeton Flood Study

Figure 3.5

Local Hydraulic Model Layout

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Revision: A
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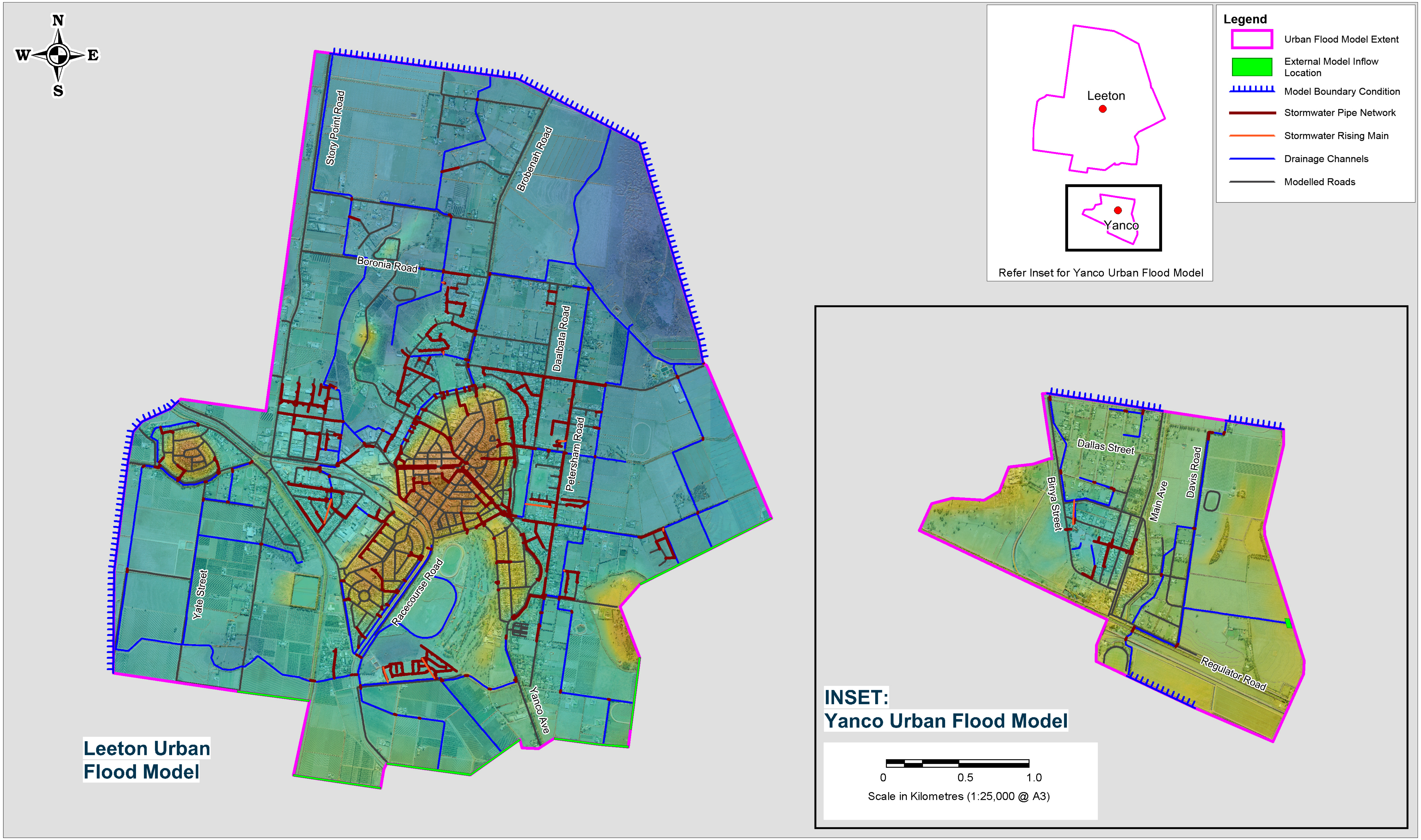

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Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
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Leeton Flood Study

Figure 3.6

Urban Hydraulic Model Layout

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Revision: A
Drawn: JNA
Date: 01 Oct 2014

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3.4 2012 Flood Analysis and Hydraulic Model Validation

The 2012 flood event is considered to be the most significant flood experienced by Leeton Shire residents and therefore has been used for validation of the TUFLOW hydraulic model. The 2012 event has been analysed using the Regional, Local and Urban hydraulic models. Anecdotal flood information for the 2012 event was obtained from residents within the Leeton Shire that were able to provide information. The flood information was gathered through community engagement activities as outlined in **Section 4**.

Whilst survey of 2012 flood marks was not available, some residents that responded to community engagement activities were able to provide indicative flood depths within their properties. This information has been used as a comparison to the hydraulic model results for the replicated 2012 event. Photographic evidence was also provided by some residents however this was of limited benefit as flooding was generally extensive and flood depths could not be determined from photographs.

The hydraulic model results and anecdotal flood information are presented in **Table 3.4**, whilst Leeton, Yanco, Murrami, Whitton and Wamoon flood maps for the 2012 event are presented as **Figures A1** to **A12** in Volume 2 of this report.

Table 3.4 Validation Results

Location	Reported Flood Depth (m)	Modelled Flood Depth (m)	Difference (m)
24 Binya Street, Yanco	0.70	0.66	-0.04
36 Hanwood Street, Yanco	0.35	0.39	0.04
132 Almond Road, Leeton	0.50	0.53	0.03
237 Petersham Road, Leeton	0.2	0.19	-0.01
343 Petersham Road, Leeton	0.15	0.12	-0.03
42-50 Wamoon Avenue, Leeton	0.2	0.23	0.03

Based on the validations results, it is considered that the hydraulic model has adequately represented the 2012 flood event. It is noted that there are likely to be some inaccuracies in modelled results for some areas within the Leeton Shire, however the results generally provide an acceptable representation of the 2012 flood based on the available study input data and anecdotal information.

In addition to the approximate flood depths provided by residents, the public consultation sessions were also used to provide an opportunity for residents to comment on the perceived accuracy of the flood maps presented for the 2012 event. This has provided a secondary means by which the hydraulic model has been validated. Whilst there was limited number of attendees at the public consultation sessions (approximately 12), the majority provided comments that the mapping generally reflected actual observations of the event.

Overall, it is considered that the hydraulic model developed for the Leeton Shire Flood Study is acceptable for adoption.

3.5 Design Flood Analysis

A range of design flood events have been modelled, the results of which are presented and discussed below for the 1 % AEP flood. Hydraulic modelling was undertaken for the 50, 20, 10, 5, 2, 1 and 0.2 % AEP and PMF events.

Flood results from the Urban Models provide the most accurate representation of flood behaviour for all models developed; however flood mapping for the Local Model has also been presented in Volume 2 of the report to provide an illustration of flood inundation and flood hazard across the Leeton Shire. The limitations associated with the Local Model should be considered with any use of the Regional and Local Model outputs.

3.5.1 Flood Behaviour

Flooding around the Leeton and Yanco townships has been discussed for five (5) areas of particular interest. The “hot spot” areas were defined based on hydraulic modelling results, anecdotal information and local experience of flood behaviour provided by LSC, SES and residents. The hot spot areas include:

- Corbie Hill Road to Fivebough Road
- Petersham Road
- Leeton Township (CBD)
- Wattle Hill
- Yanco.

Flooding between Corbie Hill Road and Fivebough Road is primarily caused by runoff generated from the Colinroobie Ranges and Corbie Hill situated to the east of the Murrumbidgee Irrigation (MI) main irrigation canal. The irrigation canal acts as a levee during flood events and has the ability to detain a significant volume of runoff behind the channel embankment. Flood waters pass through the irrigation canal via sub drains located at Corbie Hill Road and approximately 1.5 km north of Corbie Hill Road. The sub drains are essentially pipes underneath the channel where the capacity is largely determined by the upstream hydraulic head. Open drains convey flood water from the irrigation canal generally in a northerly direction towards and around Fivebough swamp. The flat gradients of the open drains result in limited conveyance capacity and widespread flooding across the area.

Flooding along Petersham Road is primarily caused by runoff generated from the main urban area of the Leeton Township to the west. Relatively informal open drains convey flood water from the township along Petersham Road towards and around Fivebough swamp.

Flooding within the Leeton CBD area is caused by direct rainfall runoff within the relatively small subcatchments. Flows are conveyed via underground stormwater pipes and kerb and channel prior to discharging into open drains that convey water in a generally north direction towards and around Fivebough swamp. Nuisance flooding may be experienced within the CBD due to minor drainage deficiencies; however results indicated that no major flood risks are evident in the area.

Wattle Hill has similar flooding characteristics as the Leeton CBD. However, the open drains located in Wattle Hill convey water in a southerly direction before travelling west away from Leeton. Nuisance flooding may be experienced in Wattle Hill; however results indicated that no major flood risks are evident in the area.

Flooding in Yanco occurs from two different sources (east and west of Main Avenue). The catchment west of Main Avenue drains towards the pond located to the west of town (adjacent to Binya Street). Flows within the pond are then pumped into an open drain and conveyed in a northerly direction towards Leeton. Runoff generated from developed areas east of Main Avenue and west of Davis Road is conveyed via open drains in a northerly direction towards Leeton. The MI main irrigation canal acts as a levee during flood events in this area that detains runoff generated from the Merungle Hill catchment to the east. Flood water is conveyed through the irrigation canal via a sub drain located approximately 600m north of Regulator Road. The open drain located at the outlet of the sub drain conveys floodwater from Merungle Hill south through Regulator Road and ultimately into the Murrumbidgee River.

3.5.2 Peak Flood Conditions

Flood depths through properties between Corbie Hill Road and Fivebough Road are typically up to 0.6 m outside of the open drains in a 1 % AEP event. Flows are generally contained within the open drains in the 50 % AEP with flood depths predicted to be typically less than 0.3 m in areas outside of the open drains. Due to the flat gradients in this area flood velocities are typically less than 0.2 m/s in both the 50 and 1 % AEP events.

Flood depths through properties along Petersham Road are typically less than 0.3 m in the 1 % AEP event. The open drains along Petersham Road north of Grevillia Street are predicted to have capacities of less than a 50 % AEP.

Flood depths through properties in Yanco west of Main Avenue are typically less than 0.3 m in the 1 % AEP. Flood depths greater than 1 m are predicted in the 1 % AEP event behind the railway, Binya Street and the pond in Yanco.

Flood depths of typically less than 0.5 m are predicted in the 1 % AEP event east of Main Avenue. Flood depths of greater than 0.5 m in the 1% AEP are predicted east of Davis Road adjacent the open drain that conveys water from the MI main irrigation canal sub drain.

Flood evacuation via major roads during the 1 % AEP is predicted to be possible.

3.5.3 Flood Hazard

The Floodplain Development Manual defines flood hazard as follows:

- High Hazard – possible danger to personal safety; evacuation by trucks is difficult; able-bodied adults would have difficulty wading to safety; potential for significant structural damage to buildings.

- Low Hazard – should it be necessary, trucks could evacuate people and their possessions; able-bodied adults would have little difficulty in wading to safety.

The provision of a flood hazard classification is often determined based on the predicted flood depth and velocity results. High flood depths will cause a hazardous situation whilst a low depth may only cause an inconvenience. High flood velocities are dangerous and have potential to cause structural damage whilst low velocities are generally considered to have no major threat. Figures L1 and L2 in the Floodplain Development Manual were used to determine the hazard categories within the Leeton and Yanco townships. These figures are reproduced in **Figure 3.7**.

Hydraulic results have indicated that the majority of flooded areas in Leeton and Yanco are considered to be of low hazard category. The open drains surrounding Leeton and Yanco along with a few pockets of deep water where flood depths of greater than 1 m were predicted. These areas are considered to be of high hazard due to the excessive depths. Flood hazard mapping for the 1% AEP design event is presented in Volume 2 of this report.

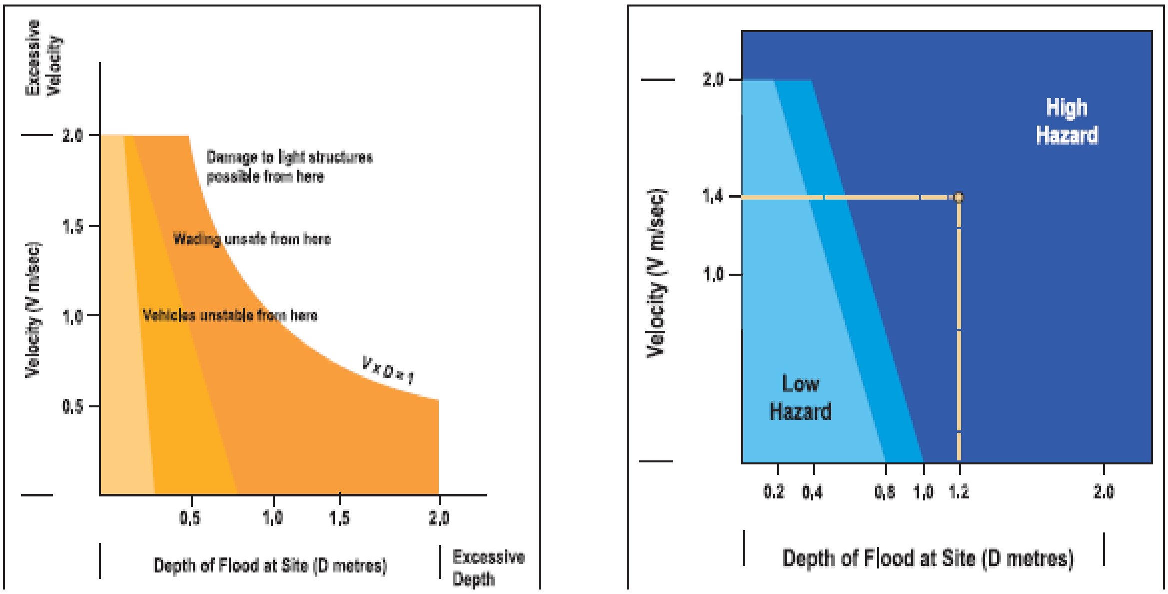


Figure 3.7 Provisional Flood Hazard Categorisation

3.5.4 Provisional Hydraulic Categorisation

The Floodplain Development Manual recognises three categories of flood prone land, these being:

- Floodways
- Flood storage
- Flood fringe.

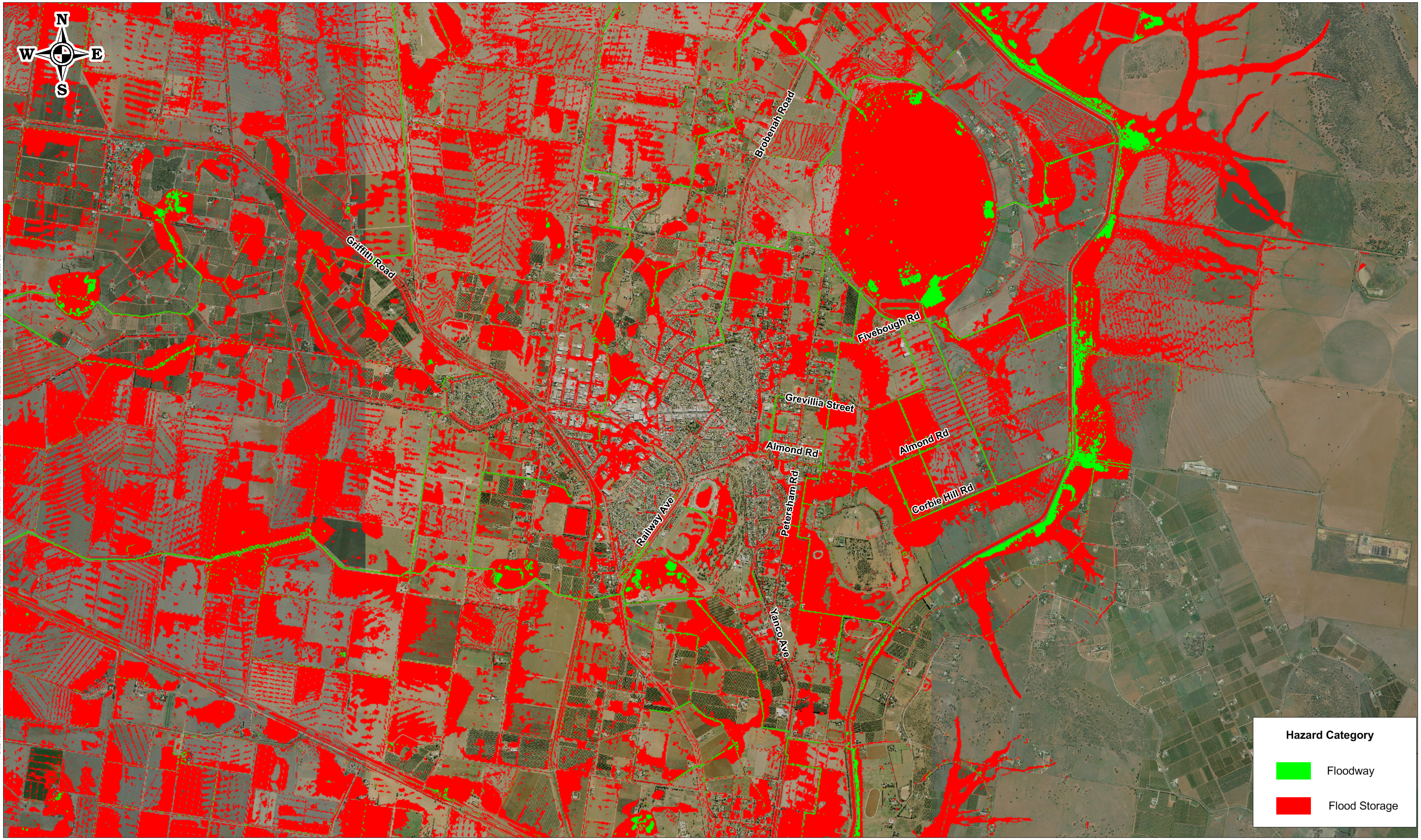
Floodways are defined as those areas where a significant volume of water flows during floods and are often aligned with obvious natural channels. They are generally flow conveyance areas as such have deeper flow and or higher velocities. Flood storage areas are generally defined as those parts of a flood plain that are important for the temporary storage of floodwaters during the passage of a flood. Flood fringe is the remaining area of land affected by flooding, after floodway and flood storage areas have been defined.

Given that the nature of flooding in the study area is not related to riverine flooding and the behaviour is generally related to overland flow, the following criteria has been developed in order to define the hydraulic categories within the Leeton and Yanco Township areas:

- Floodways: Depth greater than 0.5 m and velocity greater than 0.15 m/s
- Flood storage: all other areas not defined as floodway.

It was determined that the drainage channels were floodways with the remaining areas of inundation being flood storage areas. The floodways are also considered to be high hazard due to the greater flood depths, whilst the flood storage areas were generally considered to be low hazard apart from areas of significant ponding and greater flood depths.

Hydraulic categorisations maps for Leeton and Yanco are presented as **Figure 3.8** and **Figure 3.9** and are based on results from the Urban Hydraulic Model for each township.



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Grid: Map Grid of Australia, Zone 55

Leeton Flood Study

Figure 3.8

1% AEP Flood Hazard Categorisation
Leeton Extent (Local Model)

Job Number: M9500_002
Revision: A
Drawn: MJH
Date: 12 JUN 2015

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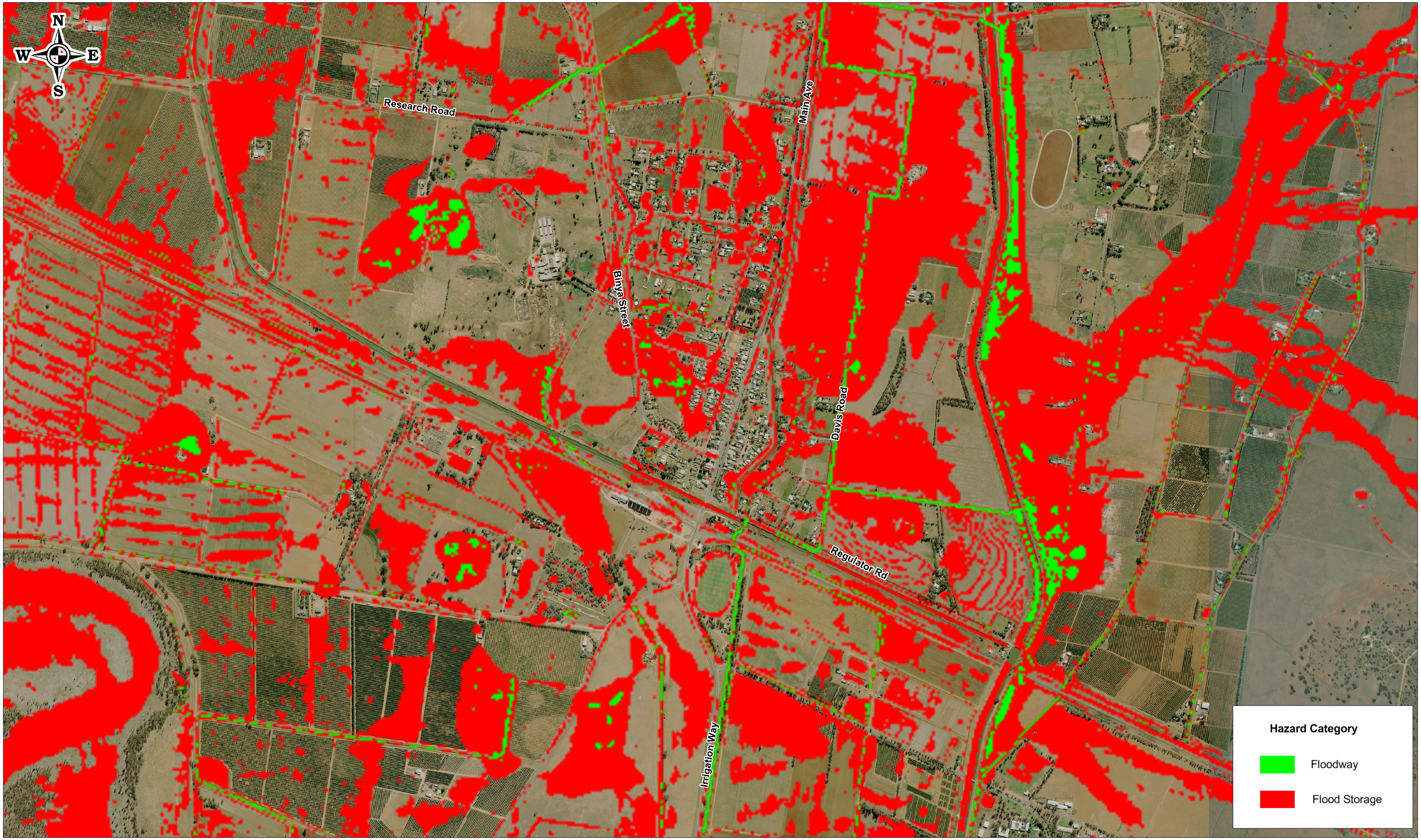

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Leeton Flood Study

Figure 3.9

1% AEP Flood Hazard Categorisation Yanco Extent (Local Model)

Job Number: M9500_002
Revision: A
Drawn: MJH
Date: 12 June 2015

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4. CONCLUSION AND RECOMMENDATION

4.1 Conclusion

The Leeton Shire Flood Study has assessed the behaviour of flood waters within the Leeton Shire LGA for the 2012 historical event as well as design flood events. In order for this to be undertaken, three separate but interrelated hydraulic models were developed. The Urban Model (1D/2D hydraulic model) provides the most accurate representation of flood behaviour in the Leeton and Yanco study areas

The outcomes from this study achieve the purpose of allowing LSC to better manage future development within the Shire, understand and manage flood risks, assess stormwater drainage systems, and apply for funding for a Floodplain Risk Management Study and Plan.

In the absence of recorded historical data such as surveyed flood marks and stream flow data, the TUFLOW hydraulic model has been validated using anecdotal flood information provided by residents for the March 2012 event. A comparison of modelled and reported flood levels at six properties showed that the hydraulic model generally produced flood levels within 50 mm of the levels reported by residents. In the absence of more reliable information, the model results were considered to adequately represent flood behaviour within the study area. Based on a comparison of the recorded rainfall data against IFD data for the 24 hour period, the March 2012 event is considered to be greater than a 1 % AEP flood.

Whilst the extent of inundation is generally widespread throughout the Shire, hydraulic results for the 1 % AEP flood have indicated that the majority of flooded areas in Leeton and Yanco are considered to be of low hazard category due to relatively shallow flood depths and low velocities. Flood evacuation in the 1 % AEP event is predicted to be possible for the majority of major access roads.

Community and stakeholder engagement proved to add significant value to the study, not only to obtain information for hydraulic model validation but also to increase an awareness of flood risks. An overwhelming response was received from the questionnaire (online and mailed) and information letters issued to residents, however there was a limited audience at public consultation meetings which were held in towns throughout the Leeton Shire LGA. Unfortunately, there was also a limited number of residents that were believed to experience house inundation that could be contacted during the consultation period to provide information or that were able to provide information suitable for model validation. The questionnaire identified that approximately 21 homes were inundated in the 2012 flood with the majority being in the Landsdowne Estate area. Homes north of the pond in Yanco were also reported to experience house inundation.

It is noted that at the time that this report was prepared, there was outstanding information from Griffith Shire Council's Mirrool Creek Flood Study that has also assessed breakout of flows from Mirrool Creek in the northern part of the Shire. Whilst the Leeton Shire Flood Study has considered the influence of flows that breakout from Mirrool Creek in the

Regional and Local Models, a comparison should be undertaken with the flows determined in the Mirrool Creek Flood Study. A revision of this flood study could be undertaken should this or any other updated information (i.e. LiDAR for minor towns) become available.

4.2 Recommendation

Whilst the flood hazard across the Leeton Shire is predicted to be generally low, it is considered that flood mitigation and drainage improvement measures will significantly reduce the vulnerability of many homes to flood damage. As such, it is recommended that a Floodplain Risk Management Study and Plan be developed as part of Stages 2 and 3 of the floodplain risk management process. Flood mitigation measures would be determined as part of the Floodplain Risk Management Plan and assessed using the TUFLOW hydraulic model developed as part of this study. Mitigation measures may include drainage channel modifications, stormwater pipe and culvert upgrades, detention basin improvements, house raising, review of pumping capacities and management of flood gates.

As part of the next stage in updating the Leeton Shire Flood Study and developing a Floodplain Risk Management Study and Plan, it is recommended that the following additional works be undertaken:

- Review and assess the Mirrool Creek flows from the Griffith Flood Study within the Local Model to ensure consistency between the two flood studies.
- Sensitivity analyses to confirm assumptions made during the development of the hydraulic models.
- Review of the provisional hydraulic categorisation of the floodplain within the Study Area.
- Undertake a more detailed hot spot analysis to develop a greater understanding of the constraints and opportunities in managing flood risk for all towns within the Leeton Shire.
- Evaluate the source of flooding and timing in terms of flood warning and evacuation.
- Assess hydraulic controls across the Study Area and the role they play in either worsening or mitigating the flood risk.
- Further investigation of the 2012 flood event to assist in developing floodplain risk management measures.
- Consider the influence of flooding from the Murrumbidgee River in the development of a Floodplain Risk Management Plan.
- Undertake difference mapping for the range of design events to assess the magnitude of the flood range across the Study Area.

It is recommended that LSC adopts the flood results from this study for development control and emergency management purposes and it is also advised that flood management provisions are incorporated into the Local Environmental Plan. Leeton Shire Council may wish to update this flood study should more detailed information become available such as topographic data and information from other studies in the region that could benefit the Leeton Shire Flood Study.

5. QUALIFICATIONS

a. In preparing this document, including all relevant calculation and modelling, Engeny Management Pty Ltd (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

b. Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

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g. This report does not provide legal advice.

6. REFERENCES

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