



Draft: Regional Flood Mapping: Concongella Creek – Stage 1

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Draft: Regional Flood Mapping: Concongella Creek – Stage 1

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<p>Synopsis: This report documents the data collation for the Regional Riverine Flood Mapping: Concongella Creek Catchment Pilot Study</p>		

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Glossary

Annual Exceedance Probability (AEP)	The likelihood of occurrence of a flood of a given size or greater occurring in any one year. AEP is expressed as a percentage (%). For example, if a peak flood discharge of 1,000 ML/D has an AEP of 1% there is a 1% chance of a flood with a peak of 1,000 ML/D or greater occurring in a given year. AEP is reciprocal of ARI (see below) The convention of AEP has been adopted for this study.
Ararat Rural City Council (ARCC)	Ararat Rural City Council
Average Annual Damages (AAD)	The average annual damage is the average cost in dollars per year that would occur in a particular area from flooding over a very long period of time.
Australian Height Datum (AHD)	The national height datum that approximately corresponds to mean sea level. Elevation is in meters.
Average Recurrence Interval (ARI)	An estimate of the average period in years between floods of a given magnitude or greater. For example the 50 year ARI flood will occur on average once every 50 years.
Catchment	The area of land draining to a particular location and may include the catchments of tributary streams as well as the main stream.
DEPI	Department of Environment and Primary Industries
Design Flood Event	A hypothetical flood representing a given probability.
Design Rainfall	The hypothetical rainfall event representing a given probability.
Digital Elevation Model (DEM)	Three dimensional computer representation of terrain
Flood Frequency Analysis (FFA)	A statistical method to estimate the frequency and discharge of large floods
Flood Model	A computer model developed to represent the flood behaviour within the study area, including both the hydrologic and hydraulic models.
Floodway Overlay (FO)	Overlays with the planning scheme that identify waterways, major floodpaths, drainage depressions and high hazard areas which have the greatest risk and frequency of being affected by flooding in rural areas. In urban areas these are known as Urban Floodway Zone (UFZ).
Floodplain	Area of land subject to inundation by floods up to and including the probable maximum flood (PMF) event.
Fraction Imperviousness (FI)	The fraction of the catchment that is impervious, that is, land which does not allow infiltration of water
Hydraulic Model	A computer model developed to extent, depth and velocity of surface water based on the Shallow Wave equations. The TUFLOW modelling package was adopted for this study.

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Hydrologic Model	A computer model that converts rainfall into runoff. The RORB modelling package was adopted for this study.
Hydrograph	A graph showing discharge versus time at a particular location.
Hyetograph	A graph showing rainfall versus time at a particular location.
Pluviograph	A rain gauge measuring the depth of rainfall over a small period of time (much less than a day). Often use to produce a graph of rainfall over time.
Land Subject to Inundation Overlay	Overlays with the planning scheme that, identify land in a flood storage or flood fringe area affected by the 1% AEP flood event or any area determined by the floodplain management authority
LSIO	
LiDAR	Light Detection and Ranging – Ground survey taken from an aeroplane typically using a laser. Using the laser pulse properties the ranging and reflectivity is used to determine properties of the laser strike, soil type/tree/building/road/etc. It is usual to filter non-ground strikes (trees/buildings/etc) from the LiDAR before it is used to generate a DEM.
ML	Mega-Litres (1,000,000 L)
Manning's n	Hydraulic roughness due to ground conditions, typically averaged over an area of relative homogeneity, e.g. it's harder for water to flow through an area of heavy brush and trees than maintained grass.
NGSC	Northern Grampians Shire Council
Probable Maximum Flood (PMF)	The flood resulting from the Probable Maximum Precipitation and, where applicable, snow melt with wet antecedent conditions.
Probable Maximum Precipitation (PMP)	The probable greatest depth of precipitation meteorologically possible for a given duration, for a given size storm area, with no allowance made for long-term climatic trends.
PSM	Permanent Survey Mark
Rating Curve	The relationship defining discharge for a given stage (water level) at a particular recording location.
Runoff	The amount of rainfall from a catchment that is converted to flowing water.
Stage	Refers to the water level, often to a local datum, at a particularly location typically streamgauages.
TUFLOW	A 1D / 2D finite difference numerical model that simulates hydrodynamic behaviour in rivers, floodplain and urban drainage environments. This is the hydraulic modelling package adopted for this study.
VFD	Victorian Flood Database

1 Introduction

The existing flood mapping for Victoria has been derived from a number of sources over many years. The accuracy and reliability of these flood maps varies considerably depending on its source. To address these issues and provide Victoria with a set of robust flood mapping products the Department of Environment and Primary Industries have initiated the Regional Riverine Flood Mapping Project. The aim of this project is to develop methodologies to undertake robust regional riverine flood mapping.

The Regional Riverine Flood Mapping Project has a number of pilot studies on catchments throughout Victoria, including Concongella Creek. The Department of Primary Industries (DEPI) has engaged BMT WBM Pty Ltd (BMT WBM) to undertake the pilot study for the Concongella Creek Catchment (the Study). This investigation has been prompted by recent and ongoing advancements in the state of the art of techniques and procedures in generating flood mapping products.

1.1 Study Background

Reliable flood mapping enhances the quality of flood related decision making. The long term objective of the regional scale riverine flood mapping program is to expand the coverage of good quality flood risk mapping of regional floodplains for use in:

- Land use planning;
- Flood emergency response;
- Community education; and
- Flood risk insurance.

1.2 Catchment Description

The Concongella Creek Catchment has an approximate area of 340 km² and is located in Central West Victoria (refer to Figure 1-1). The catchment includes a number of waterways, namely, Concongella Creek, Salt Creek and Allnavale Creek along with their tributaries. Concongella Creek is a tributary of the Wimmera River. The Wimmera River influences the downstream reaches of the catchment. The majority of the catchment is used for agricultural purposes, predominately grazing. The main townships within the catchment are Great Western along with the outskirts of Stawell (refer to Figure 1-2).

The catchment originates in the mountainous regions of the Ararat Hills and is located between the Upper Wimmera catchment to the east and the Mount William catchment to the west. From the Ararat Hills, Concongella Creek and its tributaries generally flow in a northerly direction towards Glenorchy. The upper part of the catchment is steep with numerous well defined flowpaths. However, as the watercourse near the confluence of the Wimmera River, the topography flattens to form a wide floodplain.

The town of Great Western is located in the south of the study catchment, approximately 16 kilometres northwest of Ararat, and approximately 13 kilometres southeast of Stawell, and is part of

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the Northern Grampians Shire Council. The town is situated along the southern bank of Concongella Creek immediately downstream of the confluence of Allanvale Creek.

1.3 Study Area

Details of the study area are shown in in Figure 1-2 including Concongella Creeks catchment area and key hydrologic features. The study area extends from the upper reaches of the Concongella Creek catchment to the Wimmera River at the Glenorchy gauging station. The study area will be modelled in detail using a hydraulic model to simulate the flood behaviour within the study area using inputs from various hydrologic models of the Concongella Creek Catchment.

1.4 Historical Flooding

The Concongella Creek has a history of flooding and during the flood events in Victoria in 2010 and 2011 the Concongella Creek catchment was most significantly impacted during the January 2011 flood event. The Concongella Creek catchment has been subjected to extensive flooding events throughout history.

As documented in the *Wimmera Region Flood Report – January 2011*, (Water Technology, 2011), the January 2011 flood event was the largest recorded flood event within the Concongella Creek catchment. This event lead to the highest recorded flood heights at both the Concongella Creek and Glenorchy stream gauges. The township of Great Western recorded 185 millimetres of rain in a three day period between the 10th and 14th of January 2011. This rainfall event resulted in significant flooding and widespread damage within the catchment.

1.5 Key Objectives

The key aims of the pilot study are to expand the coverage of good quality flood risk mapping for regional floodplains for:

- land use planning;
- flood emergency response;
- community education; and
- flood risk insurance.

To delivery robust defendable flood risk mapping products will require the following aspects to be addressed:

- Topographic data analysis:
 - Use and assessment of various topographic data sets (various accuracies and resolutions);
 - Verification of topographic data accuracy; and
 - Treatment of key landscape features (levees, embankments, waterway channels etc).

Hydrologic analysis:

- Design hydrograph estimation with particular focus on determining the Annual Exceedance Probability (AEP) within a catchment;

Introduction

- Approaches to estimating the PMF;
- Verification/comparison against other techniques including flood frequency analysis and regional techniques; and
- Treatment of concurrent flooding across catchments in a basin.

Hydraulic analysis:

- Approaches to calibration and verification against observed flood extents and levels, in particular at key river height gauge locations;
- Approaches to modelling structures;
- Treatment of changing critical storm durations across a catchment; and
- Limitations on approaches due to model run times.

Mapping:

- Range of mapping outputs/products (flood extents, depths, velocities, hazard, time to peak, time to drain, duration etc) for a range of design events.
- Discussion on uncertainties in mapping outputs.

General:

- Discussion on the data requirements, strengths and limitations of the methodology proposed.

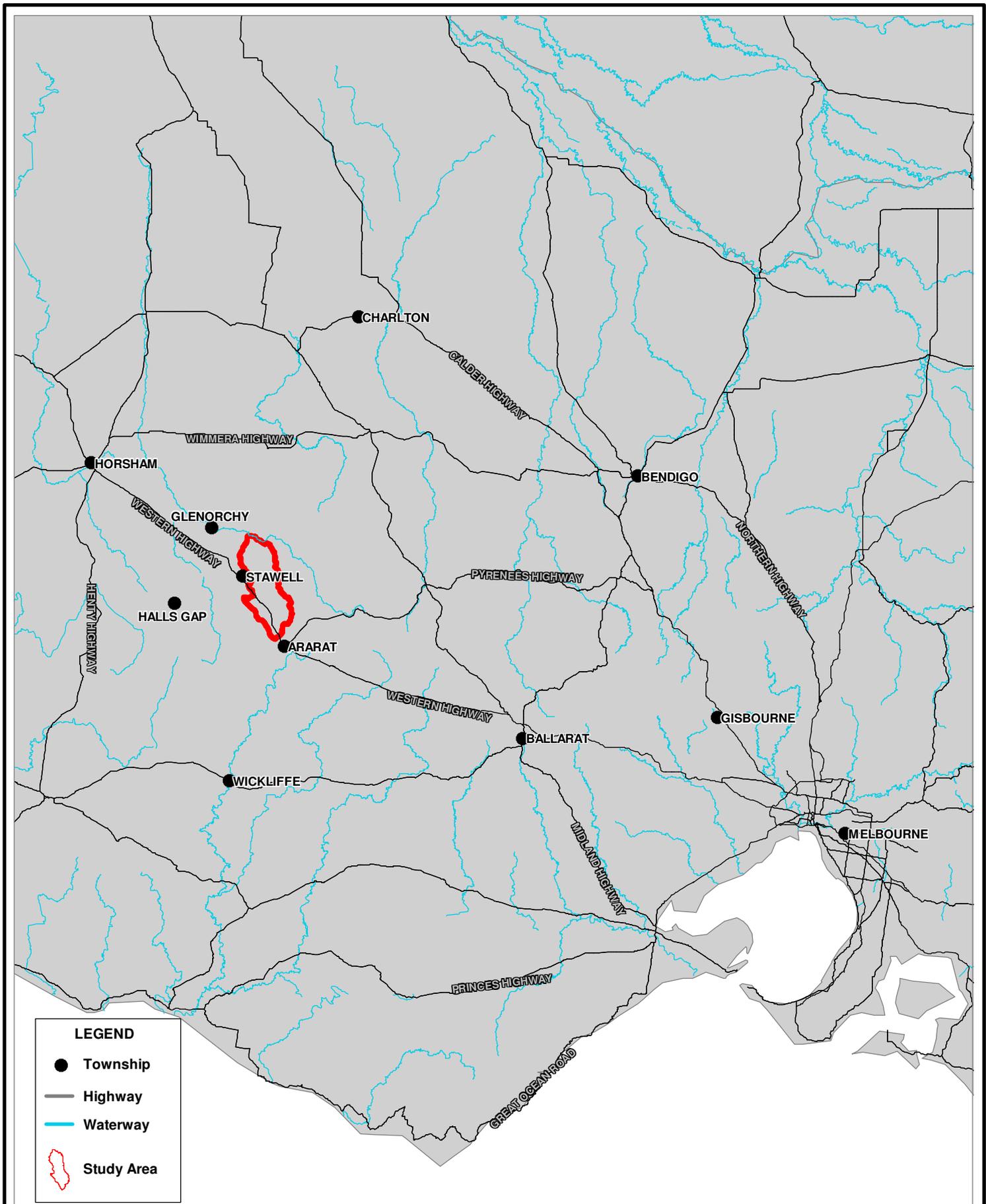
1.6 Study Approach

To enhance the study outcomes and in particular to provide insights into the different broad scale flood modelling and mapping methodologies a staged approach was undertaken. This staged approach allowed the comparison of a number of flood modelling and mapping methodology from a basic approach relying on numerous assumptions through to a comprehensive method that provides a high degree of certainty.

The Study was undertaken in the following stages:

- Stage 1A – Basic modelling: Peak flow estimates coupled with a hydraulic model.
- Stage 1B – Calibrated hydrological model coupled with a calibrated hydraulic model.
- Stage 2 – Monte Carlo simulation coupled with a calibrated hydraulic model.

The report documents Stage 1A and Stage 1B.



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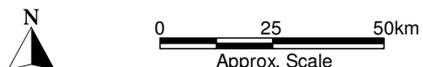
- Township
- Highway
- Waterway
- Study Area

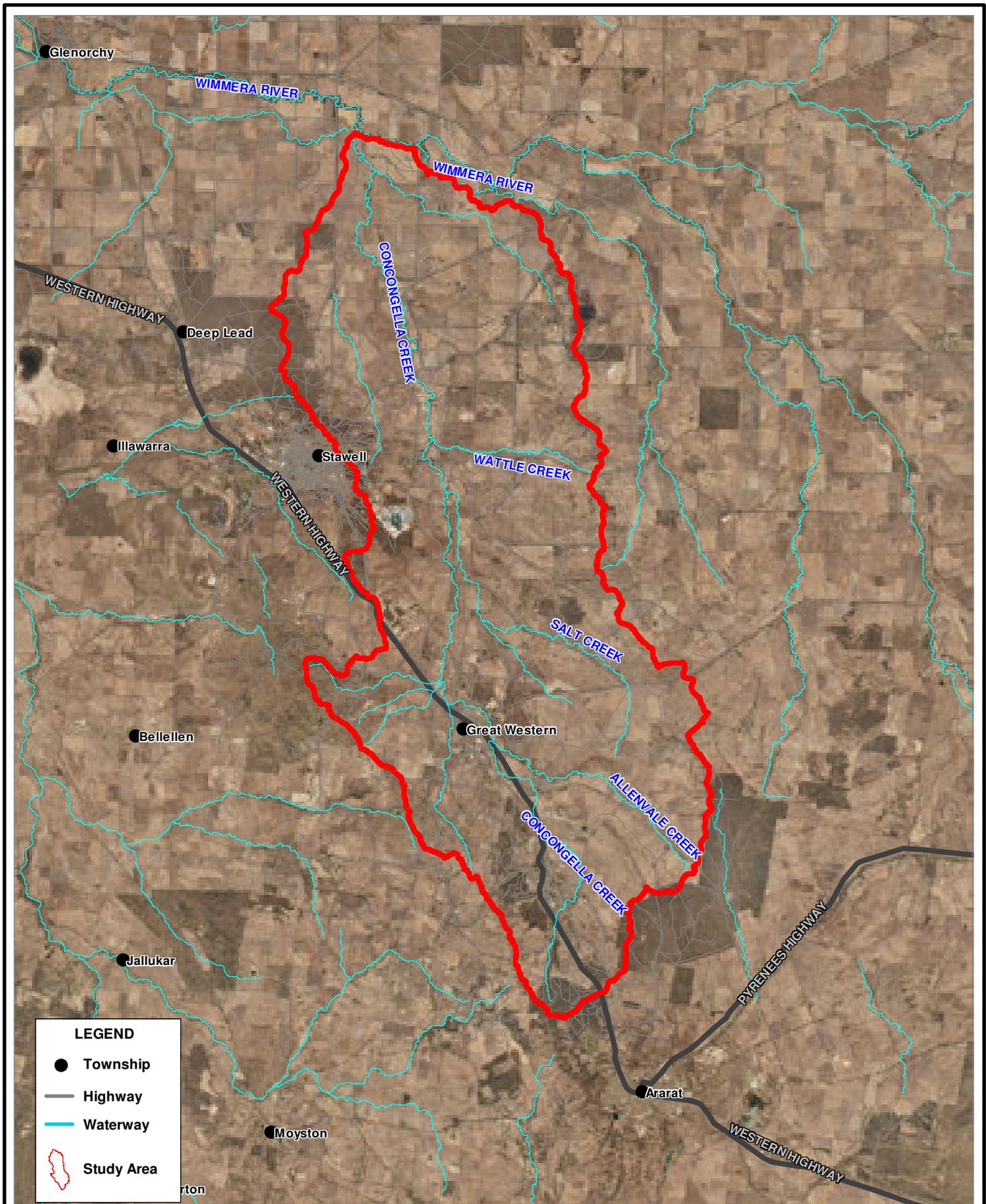
Title:
Regional Flood Mapping: Concongella Creek Pilot Study Catchment Locality

Figure:
1-1

Rev:
A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.





LEGEND

- Township
- Highway
- Waterway
- Study Area

Title:
Regional Flood Mapping: Concongella Creek Pilot Study Study Catchment

Figure: 1-2	Rev: A
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0 2.5 5km
 Approx. Scale



2 Data Collation

This section documents the data that was collected and collated by BMT WBM for the Study. BMT WBM has obtained data from a number of agencies, including:

- Bureau of Meteorology (BoM);
- Department of Environment and Primary Industries (DEPI)¹;
- Thiess Services;
- VicRoads; and
- Wimmera Catchment Management Authority (WCMA).

2.1 Previous Reports

Several previous flood reports and documents have been made available that detail and document the flooding history of the Concongella Creek catchment. These reports and documents include:

- Flood Data Transfer Project – Shire of Northern Grampians (DNRE, 2000);
- Glenorchy Flood Study Report Final (Water Technology, 2006);
- Glenorchy Floodplain Management Plan Study Report Final (Water Technology, 2006);
- Glenorchy Flood Emergency Response Plan (NGSC, 2006);
- Glenorchy-Horsham Flood Scoping Study: Executive Summary (Water Technology, 2003);
- Glenorchy-Horsham Flood Scoping Study: Full Report (Water Technology, 2003);
- January 2011 Great Western Flood Summary (WCMA, undated);
- January 2011 Flood Impact Assessment Summary (NGSC, 2011);
- Wimmera Region Flood Report – January 2011 (Water Technology, 2011);
- VicRoads Western Highway duplication - Flood Investigation-Phase A (Bonacci, 2011);
- Western Highway Project Section 2 – (Beaufort to Ararat) Environment Effects Statement (GHD, 2011);
- Western Highway Project Section 3 – (Ararat to Stawell) Environment Effects Statement (GHD, 2011);
- Report for Western Highway Duplication EES & PSA – Section 3 – Surface Water – Existing Conditions Report – DRAFT (GHD, 2011);
- Western Highway Duplication (section 2 and 3) EES & PSA – Study Scopes and Methodologies (GHD, 2011);
- Western Highway Project – Section 3: Ararat to Stawell – Surface Water Impact Assessment Report (GHD, 2012); and

¹ Including previously received information from the Department of Sustainability and Environment (DSE) which was the predecessor of the Department of Environment and Primary Industries

Data Collation

- Western Highway Project – Section 3 – Chapter 12 Surface Water (VicRoads, undated)

The flood data transfer project provides some background information into the available flood data of the Concongella Creek system. The Glenorchy and Wimmera River studies provide detailed information about the lower reaches of the catchment.

2.2 Topographic Data

Topographic data, including airborne ground survey (LiDAR), were used to generate the Digital Elevation Model (DEM) which forms the basis of both the hydrologic and hydraulic modelling components of the study. A number of datasets were provided, and these are listed below.

Wimmera Catchment Management Authority:

- Contour Data Sets
 - 0.5m Wimmera Trench contours
 - 1m contours
- LiDAR Data Sets
 - Warracknabeal & Jeparit - Airborne Laser Survey (2005)
 - All returns, all ground and thinned data sets provided
 - Index of Stream Conditions (ISC) Rivers (2010)
 - 1m ASCII gridded LiDAR
 - Wimmera CMA Stage 2 Floodplains LiDAR (2011) – coverage of Great Western and surrounds
 - 1m LiDAR (all returns, all ground and thinned data set provided)

Department of Environment and Primary Industries:

- Permanent Survey Marks (PSM) within the catchment obtained from DEPI (13/02/12) with a vertical accuracy of 1 mm.

The provided LiDAR datasets have been checked to ensure they are suitable for use in the Study. The following sections detail the data verification process that has been undertaken to ensure the accuracy and suitability of the provided topographic information.

The LiDAR (with the exception of ISC Rivers) has been supplied as three individual data sets: all returns, all ground and thinned.

The 'all returns' data set includes every return strike and includes strikes from building roofs, vegetation, parked cars, etc. Whilst this information is not used for the modelling it can be used to check the all ground data and ensure that the filtering process to remove all non-ground strikes is suitable for the catchment. This checking ensures that floodplains controls (levees, embankments, etc) have not been inadvertently removed as part of the filtering process.

The 'all ground' data set includes all strikes that have been determined to have hit the ground level. The 'thinned' data set is a version of the 'all ground' whereby points where similar elevations in close proximity are removed.

Whilst the WCMA LiDAR covers the entire catchment the other two data sets cover specific portions of the catchment. The Warracknabeal & Jeparit LiDAR covers the township of Great Western as well as the immediate surrounds. The ISC Rivers LiDAR covers the main channel of Concongella Creek and the Wimmera River however does not cover the other tributaries within the catchment. The ISC Rivers LiDAR typically extends a few hundred metres from the centreline of the creek.

2.2.1 Vertical Accuracy

The vertical accuracy of a LiDAR dataset can be demonstrated through the comparison of the LiDAR elevations to the elevation of known points within the study catchment. BMT WBM obtained details of all Permanent Survey Marks (PSMs) within the study catchment by the Department of Sustainability and Environment (DSE).

Digital Elevation Models (DEMs) of the three LiDAR datasets were constructed. The elevation information contained within these DEMs and the elevations of the PSMs were cross checked to validate the vertical accuracy.

The results from the analysis of the vertical accuracy for each DEM are detailed in Table 2-1.

Table 2-1 Statistical Summary of LiDAR - Vertical Accuracy

Statistical Measure	Great Western LiDAR	ISC LiDAR	WCMA LiDAR
Number of PSMs	10	50	198
Mean	0.00	-0.02	-0.03
Median	-0.03	0.01	-0.04
25th Percentile	-0.08	-0.12	-0.23
75th Percentile	0.15	0.11	0.22

As discussed above the WCMA LiDAR covers the whole DEM and has the largest number of PSM's to validate against whilst the other two have substantially less. As can be seen in Table 2-1 all three LiDAR datasets were found to compare very favourably with the PSM's with little divergence from the mean. The distribution of differences between the WCMA LiDAR and the PSM's are displayed visually in Figure 2-1 below.

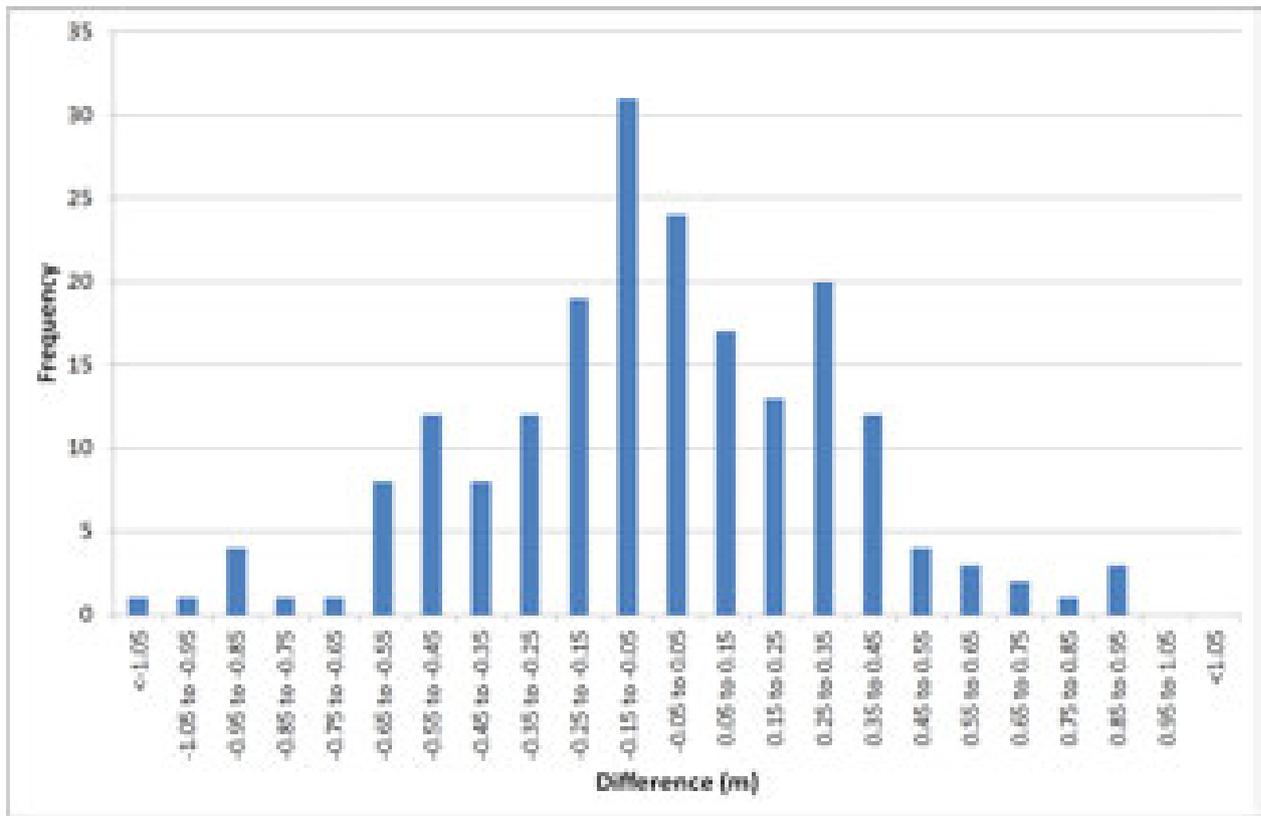


Figure 2-1 Wimmera CMA catchment LiDAR - Vertical Accuracy

2.2.1.1 Horizontal Accuracy

Whilst the true horizontal accuracy of LiDAR based elevation products can only be determined from system and sensor calibration studies undertaken at the time of the LiDAR capture. BMT WBM verified the horizontal accuracy through an analysis of distinct features which are identifiable in the elevation data with other data sources. This method is outlined in ICSM 2010 as an accepted alternative method for checking horizontal accuracy.

The horizontal accuracy of the LiDAR from Wimmera CMA was checked through the comparison of the alignments of identifiable features (roads, farm dams, ovals, etc) within the terrain with aerial photography, cadastre and DSE permanent survey marks (PSM) throughout the catchment.

The DEMs generated from the LiDAR was inspected at several locations throughout the catchment to ensure accuracy throughout the entire model. Visual inspection of the DEMs compared to the properties boundaries indicated some discrepancies along certain roads. Where this occurred the aerial photography was inspected which was found to align within the margin of visual inspection. Additionally, GPS tracks taken by BMT WBM staff during the site inspections recorded along the roads were used to verify the road alignment. Similarly the aerial photography at a number of waterways and farm dams were inspected which were found to validate the horizontal accuracy.

2.2.2 Summary

Review of the LiDAR data indicates that all three LiDAR datasets accurately represent the catchment when compared to the available Permanent Survey Marks (PSMs) aerial photography, road alignments and GPS tracks. The provided LiDAR was deemed suitable for use in this study.

All three data sets were used to construct the DEM used as the basis for TUFLOW hydraulic model as described in Section 3.2.1.

2.3 Aerial Photography

Aerial Photography of the catchment is an important tool for verifying catchment characteristics such as land use, building footprints and other structures. During the hydrologic modelling stage it can be used, along with the planning scheme overlays, to estimate the fraction imperviousness of the catchment. Similarly, when developing the hydraulic model it can be used to aid the assignment of surface roughness's to the catchment and any blockages caused by buildings. In addition, aerial photography during a flood event can be used to verify the model results by comparing extents and breakaway flows.

Wimmera Catchment Management Authority:

- Two geo-referenced tiles covering the entire catchment (photography flown in 2010);
- 146 geo-referenced tiles covering the entire catchment and surrounds (photography flown in 2004/5);
- One geo-referenced tile covering Concongella and Allanvale Creek with a buffer of roughly 1.5 km from the channel (photography flown in 2009);
- Four geo-referenced tiles covering the Wimmera River and part of the Concongella catchment during the January 2011 flood event (dated 14th & 15th January 2011); and
- 424 non-tile non-geo-referenced photographs covering the entire catchment and surrounds(photography flown in 1940);

2.4 Planning Scheme Information

The planning scheme layers are used in conjunction with the aerial photography and on-ground photography to define the current land use of the catchment. The planning scheme layers are used in both the hydrologic and hydraulic model to define factors such as fraction impervious and Manning's 'n' value (ground roughness).

Planning scheme information has been obtained from the State Government of Victoria website (<http://services.land.vic.gov.au> accessed 13/11/2013).

2.5 Infrastructure

Culvert and bridge information is typically only used during the hydraulic modelling component of the flood investigation. It is important to incorporate any assets in the hydraulic model using as accurate information as possible. Locating the asset in the wrong location may disconnect it from the main flow channel. Whilst applying incorrect attributes (width/height/inverts/weirs/drops/etc) may result in incorrect flows passing through the structure. This may result in either elevated or depressed flooding upstream and over the road and elevated or depressed water levels downstream depending on which attributes are incorrect.

Whilst the aim of this Study is not to undertake detailed modelling of the Catchment, rather develop a robust method for regional flood mapping technique.

VicRoads were able to supply information on a number of culvert and bridge structures throughout the catchment. VicTrack was contacted however were unable to supply digital copies of their asset information.

2.6 Stream Gauge Data

Stream gauge data can be used for all stages of the investigation. Historic data can be used to calibrate or verify the hydrologic model. It can be used in a similar manner to verify hydraulic models where gauges have instantaneous flow or gauge height. In addition, gauging tables can be used in flood warning as trigger heights to initiate mobilisation of resources, evacuation and other flood intelligence (which roads are blocked, etc).

Department of Environment and Primary Industries:

- Instantaneous Flow (ML/Day), Station Height (m) and Mean Daily Flow where available (ML/d)
 - 415201 Wimmera River @ Glenorchy Weir Tail Gauge (25/05/1964 to 27/08/2013)
 - 415206 Wimmera River @ Glynwylln (30/05/1956 to 27/08/2013)
 - 415237 Concongella Creek @ Stawell (17/12/1976 to 17/07/2013)
 - 415263 Salt Creek East Branch @ Great Western (12/07/1995 to 01/09/2010)
 - 415264 Salt Creek West Branch @ Great Western (12/07/1995 to 01/09/2010)
- Rating Curves
 - 415201 Wimmera River @ Glenorchy Weir Tail Gauge – including manual readings
 - 415206 Wimmera River @ Glynwylln
 - 415237 Concongella Creek @ Stawell – including manual readings
 - 415263 Salt Creek East Branch @ Great Western
 - 415264 Salt Creek West Branch @ Great Western

The flows and heights for the above gauges can be compared to hydrologic and hydraulic outputs respectively within the streams at those locations.

2.7 Rainfall Data

Rainfall data is required for the calibration of the hydrologic model. The following rainfall data has been sourced.

Department of Environment and Primary Industries:

- 415237 Concongella Creek @ Stawell (17/1/1993 to 17/07/2013)
- 415264 Salt Creek West Branch @ Great Western (12/07/1995 to 01/09/2010)

Bureau of Meteorology:

Daily Rainfall

- 79010 Drung Drung (November 1905 to October 2012)

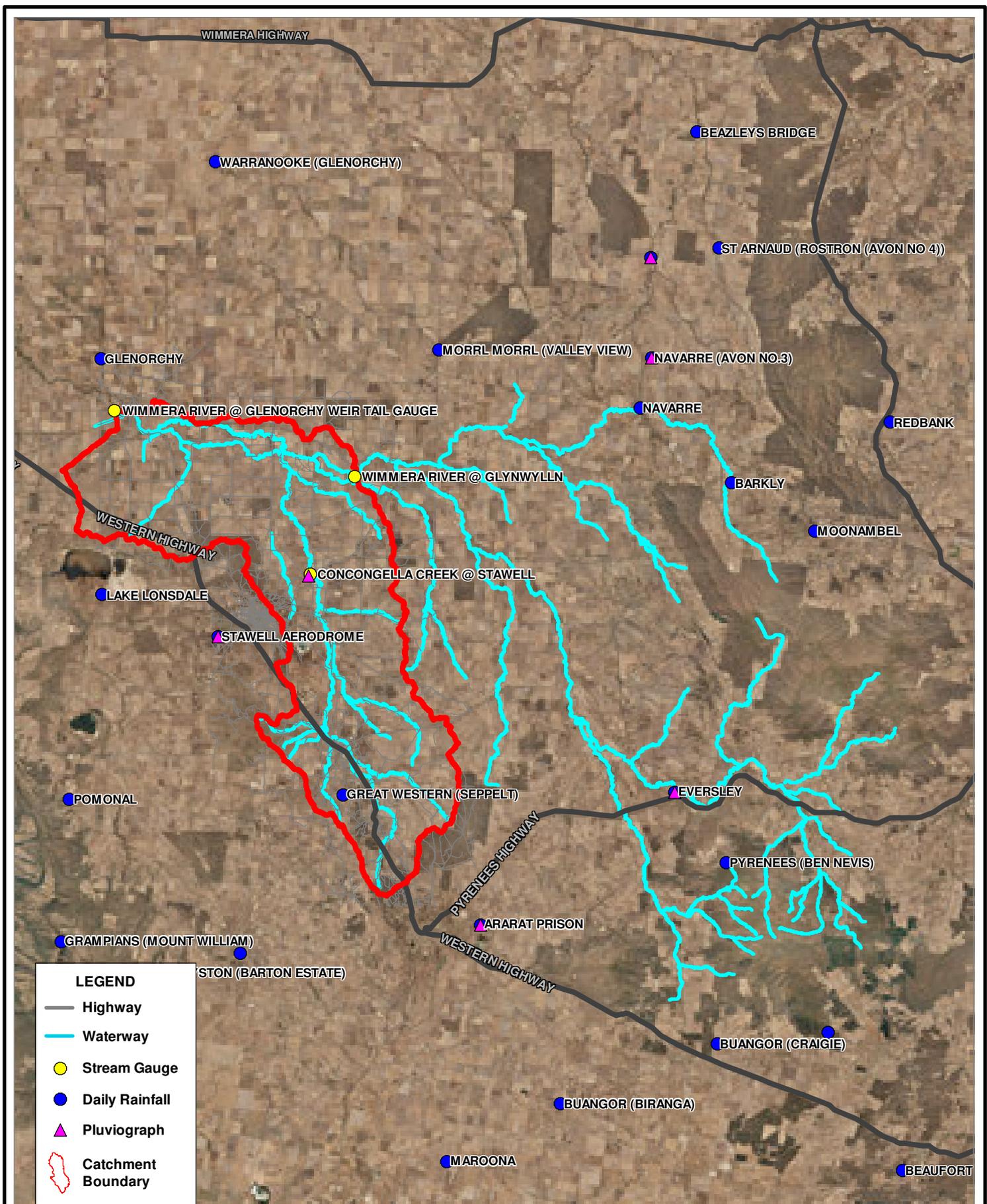
- 79014 Eversley (February 1888 to September 2012)
- 79015 Glenorchy (January 1913 to December 2011)
- 79016 Warranooke (Glenorchy) (January 1878 to September 2012)
- 79019 Great Western (Seppelt) (August 1891 to September 2012)
- 79032 Morri Morri (Valley View) (November 1902 to September 2012)
- 79034 Moyston (June 1886 to January 2012)
- 79035 Murtoa (January 1883 to June 2012)
- 79046 Wartook Reservoir (February 1890 to September 2012)
- 79050 Moyston (Barton Estate) (January 1906 to September 2012)
- 79073 Pomonal (January 1955 to May 2012)
- 79074 Halls Gap (May 1958 to September 2012)
- 79077 Dadswell Bridge (November 1968 to September 2012)
- 790982 Horsham (June 1958 to September 2012)
- 79103 Grampians (Mount William) (December 2005 to October 2012)
- 79015 Stawell Aerodrome (February 1996 to October 2012)
- 89019 Mirranatwa (Bowacka) (February 1901 to September 2012)
- 89034 Willaura (Main Street) (July 1902 to October 2012)
- 89080 Maroona (September 2001 to June 2012)
- 89085 Ararat Prison (May 1969 to October 2012)
- 89109 Buangor (Cragie) (May 1996 to September 2012)

30 minute Rainfall Totals

- 79028 Longerenong (May 1997 to August 2012)
- 79015 Stawell Aerodrome (February 1996 to March 2012)
- 79013 Grampians (Mount William) (December 2005 to March 2012)

Pluviographs

- 79046 Wartook Reservoir (May 1974 to September 2012)
- 89019 Mirranatwa (Bowacka) (May 1974 to August 2011)
- 89085 Ararat Prison (November 1981 to June 2011)

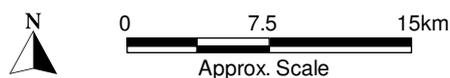


Title:
Regional Flood Mapping: Concongella Creek Pilot Study
Hydrologically Significant Features

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2.8 Other Flood Data

It is understood that there has been a number of sizable rainfall events in the Concongella Creek catchment. These include extensive flooding along Concongella Creek and its tributaries. Significant flooding occurred across the catchment in the January 2011 flood event, where rainfall depths recorded between the 11th and 15th of 166mm (Stawell Airport), 185mm (Great Western) and 191mm (Concongella Creek gauge) were recorded within the catchment.

Wimmera Catchment Management Authority:

- January 2011 flood event
 - Survey marks
 - Ground level photography
 - Gauge reading
 - Flood Extent Line Scan 2011
- December 2010 flood event
 - Gauge reading
- September 2010 flood event
 - Survey marks
 - Gauge reading
- August 2010 flood event
 - Gauge reading
- Other data
 - Extensive flood photography during both the January 2011 and historical flood events throughout the catchment and surrounds;
 - Flight tracks (taken during aerial flyovers of the January 2011 flood event, used to help located the flood photography taken from the aircraft);
 - A number of flood marks for floods between 1909 and 1985.

3 Stage 1A

In this stage a basic flood model was constructed. The modelling framework that was used was a direct rainfall or rain-on-grid approach to a 2D hydraulic model. The runoff in the hydraulic model was then calibrated to peak flow estimates throughout the catchment.

Peak flow estimates were generated at a number of locations throughout the catchment through flood frequency analysis at the stream gauge and using Regional Flood Frequency Estimates at key points throughout the catchment. In addition, a regional estimate of the Probable Maximum Flood (PMF) would be derived from Hydrological Recipes: Estimation Techniques in Australian Hydrology (Grayson et al, 1996).

In parallel a 2D only hydraulic TUFLOW GPU model of the catchment was developed. The timing and shape of hydrographs were determined from application of initial boundaries to the hydraulic model. Once these were determined the hydraulic model was compared to the peak flow estimates. Design flood events based on design rainfall were also determined.

This stage addressed the following Key Objectives under the heading of Hydrologic Analysis and Hydraulic analysis:

- Hydrologic Analysis
 - Design hydrograph estimation with particular focus on determining the Annual Exceedance Probability (AEP) within a catchment;
 - Approaches to estimating the PMF;
 - Verification/comparison against other techniques including flood frequency analysis and regional techniques; and
 - Treatment of concurrent flooding across catchments in a basin.
- Hydraulic Analysis
 - Limitations on approaches due to model run times.

3.1 Stage 1 A Hydrology

At this stage (Stage 1) peak Annual Exceedance Probability (AEP) flows were estimated using two techniques and the Probable Maximum Flood (PMF) flow estimated using another technique. The peak flows were calculated for the annual exceedance events listed in Table 3-1 as well as the PMF. The techniques used were:

- ARR Regional Flood Frequency Estimation (RFFE) Model Test version 2012;
- Flood Frequency Analysis (FFA); and
- Probable Maximum Flood estimation technique outlined in Hydrological Recipes (Grayson et al., 1996).

Table 3-1 Modelled AEP Events

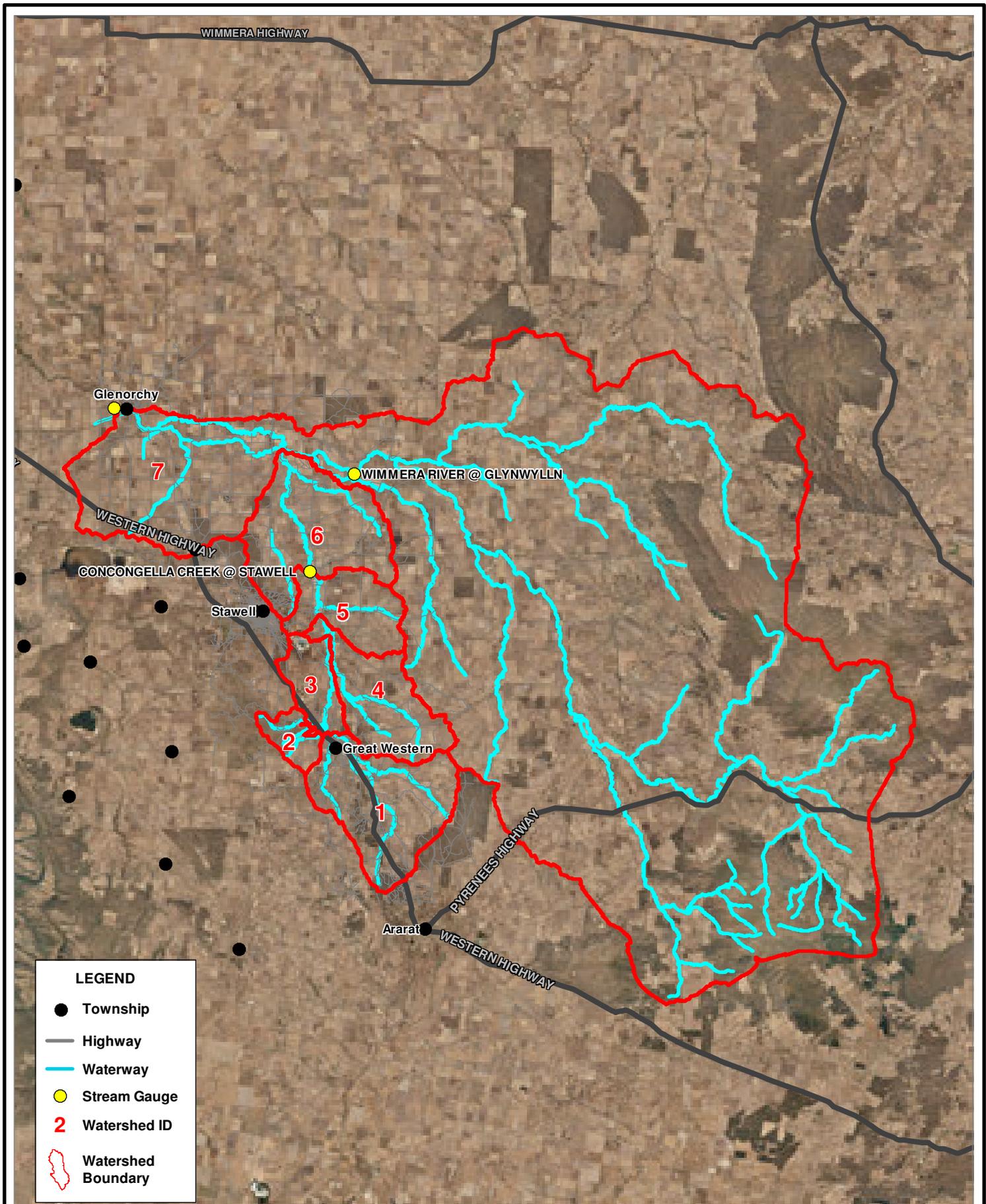
50%	20%	10%	5%	2%	1%
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3.1.1 Regional Flood Frequency Estimation

Regional Flood Frequency Estimates (RFFE) were completed at the locations shown in Figure 3-1 and the events listed in Table 3-1. This has been completed using the methodology developed as part of Project 5 of the ARR revision, which was released in Dec 2012 as a test version. This method uses catchment area and design rainfall intensity as predictor variables and calculates flood quantiles for a number of AEP events together with uncertainty bounds. The model coefficients are estimated from a set of nearby gauged catchments (region-of-influence approach) using Bayesian generalised least squares (GLS) regression. The model coefficients have been estimated at over 600 gauged catchment locations in Australia including Victoria. A leave-one-out validation technique has shown that the method provides accurate flood quantile estimates over a wide range of circumstances (Rahman et al, 2012).

The results from the ARR RFFE Model 2012 (test version) for the reporting locations are presented in Table 3-3 together with key catchment characteristics. The sub-catchments for each location are shown in Figure 3-2. It should be noted that ARR RFFE Model 2012 (test version) is based on ARR 1987 IFD data. It is not expected that the updated RFFE model and IFD data will be available before completion of the Study.

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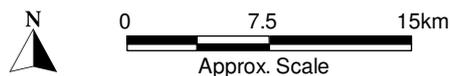


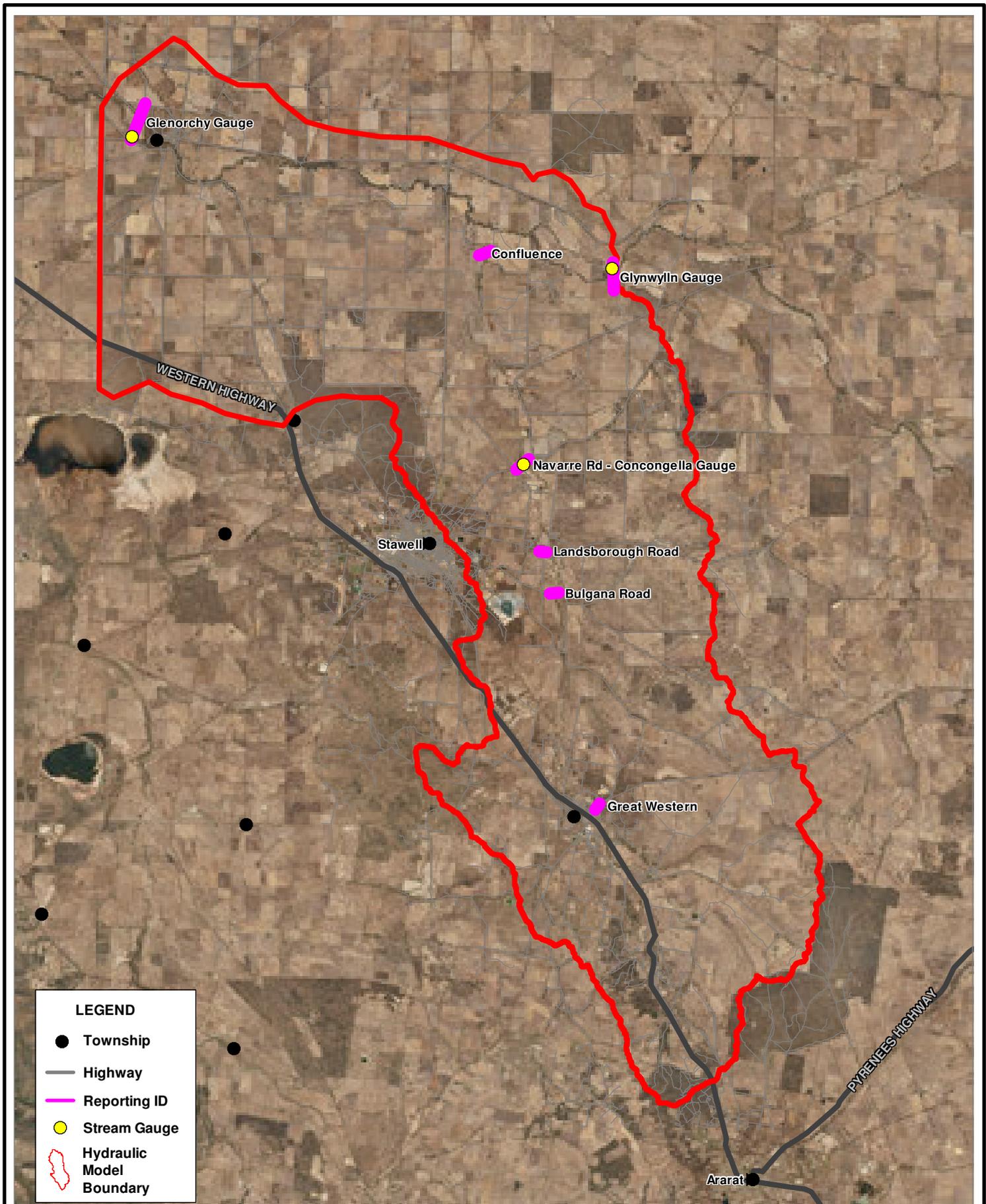
Title:
**Regional Flood Mapping: Concongella Creek Pilot Study
 Hydrological Water Sheds**

Figure:
3-1

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LEGEND

- Township
- Highway
- Reporting ID
- Stream Gauge
- Hydraulic Model Boundary

Title:
**Regional Flood Mapping: Concongella Creek Pilot Study
 Hydraulic Model Reporting Location**

Figure:
3-2

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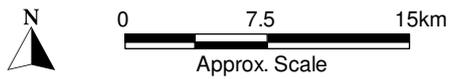


Table 3-2 RFFE Parameters

Watershed ID	Description	Catchment Area (km ²)	2 Year ARI 12 Hour rainfall intensity (mm/h)
1	Downstream end of Great Western	89	3.45
2	Upstream of Railway	3.4*	3.40
3	Bulgana Road	131	3.40
4	Landsborough Road	195	3.40
5	Navarre Road (Concongella Gauge)	241	3.38
6	Concongella Creek - Wimmera River Junction	337	3.35
7	Glenorchy	1968	3.38

* The ARR RFFE technique is recommended for catchments greater than 25km².

Table 3-3 Unadjusted RFFE Peak Flow Estimates – Discharge m³/s

Description	Estimated 20% AEP Discharge (m ³ /s)	Estimated 10% AEP Discharge (m ³ /s)	Estimated 5% AEP Discharge (m ³ /s)	Estimated 2% AEP Discharge (m ³ /s)	Estimated 1% AEP Discharge (m ³ /s)
Downstream end of Great Western	9	22	33	45	74
Upstream of Railway	3	6	10	13	22
Bulgana Road	11	27	41	56	77
Landsborough Road	14	36	55	75	102
Navarre Road (Concongella Gauge)	16	41	62	85	140
Concongella Creek - Wimmera River Junction	20	51	77	104	172
Glenorchy	71	180	273	371	610

3.1.2 Flood Frequency Analysis

Flood Frequency Analysis (FFA) was completed at the gauging stations within the catchment, namely Concongella on the Concongella Creek and Glenorchy on the Wimmera River. The FFA was completed using the methods outlined in the draft version of ARR Book IV Peak Flow Estimation. The FFA was completed using the Flike Software package (Kuczera, 1999). This package provides a Bayesian framework for comprehensive at-site flood frequency estimation that allows the inclusion of ungauged historical events and prior information as well as an error model to account for rating curve extrapolation error. It also allows the incorporation of regional estimates of parameters (output of ARR RFFE Model) to be used as prior information to enhance accuracy of the at-site flood quantile estimates. This is particularly useful when the at-site record length is relatively short.

The fitting of flood frequency distributions using Flike was undertaken with the following steps:

- Gauged streamflow data for Concongella Creek and Glenorchy were collected from the Victorian State Government’s Water Monitoring web site (<http://data.water.vic.gov.au/monitoring.htm>);
- Standard data checks were undertaken on the stream flow data including checking error codes, cataloguing data gaps and undertaking visual inspections;
- Annual maxima series were extracted and peaks checked for independence; and
- Extreme value distributions were fitted using Flike, this involves:
 - Censoring low flows: low flows were systematically removed using a multiple Grubbs Beck test from the data to ensure that the distributions are ‘aware’ of the full length of record as opposed to block censoring the data; and
 - ARR RFFE Parameters: Distribution parameter estimates from the RFFE model were applied to Flike as prior information.

The results of the at-site FFA are presented in Table 3-4 together with the results from the RFFE. The ARR RFFE method tended to predict lower flows than the FFA, with greater differences at Navarre Road than at Glenorchy. This is further discussed below.

Table 3-4 At-site FFA Peak Flow Estimates m³/s

AEP	Navarre Road (Concongella Gauge) m ³ /s			Glenorchy Gauge m ³ /s		
	At-site FFA	ARR RFFE	Difference (%)	At-site FFA	ARR RFFE	Difference (%)
50%	19	16	-16%	64	71	-11%
20%	58	41	-29%	157	180	-15%
10%	95	62	-35%	234	273	-17%
5%	136	85	-38%	314	371	-18%
2%	197	116	-41%	421	506	-20%
1%	246	140	-43%	503	610	-21%

At this stage of the study (Stage 1A) the flood history of Concongella Creek and the Wimmera River at Glenorchy has not yet been incorporated. A review of the rating curve at the Concongella gauge will be undertaken during Stage 1B. Once this information has been incorporated the FFA will be revised.

3.1.3 Probable Maximum Flood

The probable maximum flood was calculated at the reporting locations using the method outlined in Hydrological Recipes (Grayson et al., 1996). The results are presented in Table 3-5 below.

Table 3-5 Probable Maximum Flood Estimate*

Watershed ID	Description	Area (km ²)	Flow (m ³ /s)	Volume (ML)	Time to Peak (Hours)
1	Downstream end of Great Western	89	2,050	41,226	4.4
2	Upstream of Railway	3.4	274	1,659	1.3
3	Bulgana Road	131	2,601	60,306	5.0
4	Landsborough Road	195	3,323	89,199	5.8
5	Navarre Road (Concongella Gauge)	241	3,787	109,868	6.3
6	Concongella Creek - Wimmera River Junction	337	4,655	152,811	7.1
7	Glenorchy	1968	13,805	867,538	13.5

* The estimated AEP for the PMF at all locations is 1×10^{-6} %

3.1.4 Comparison of Peak Flow Estimates and Discussion

Peak flow estimates at the gauging locations (Concongella Creek at Concongella and Wimmera River at Glenorchy) were calculated using two methods, RFFE and at-site FFA. A comparison of the results is presented in Table 3-4. Comparison of the results from the two techniques at the Concongella Creek gauge indicates that the regional method produces lower flood quantiles across all AEP events. While the peak discharges at the Concongella Creek gauge were not in close agreement, the at-site FFA estimates were within the uncertainty bounds of the RFFE estimates and vice versa. The results for the Glenorchy gauge are similar between the two techniques for all AEP events. It is of note that flood quantiles calculated by these two techniques are not expected to be identical.

The reason for the underestimation by the RFFE method for Concongella might be due to the fact this is an unusual catchment, being relatively steep. The steepness of the catchment means that the response time is relatively quick leading to higher observed peak flows, which the regional model does not replicate well.

3.1.4.1 Adjustment of Discharge at a Given Location

When there is a streamflow gauge with a reasonable record length, preference should be given to the results of the FFA analysis. However, it is good practice to compare flood quantiles from each technique with particular attention to the comparison between flood quantiles up to the length of the stream gauge record. If flood quantiles from the FFA are diverging from the RFFE flood quantiles for AEP events less than the stream gauge record length then the FFA results are to be preferred. For example in Table 3-4 above the FFA flood quantiles are greater than the RFFE quantiles for all AEP events including those less than the 2% AEP event, which is approximately equal to the record length of the Concongella gauge of 37 years. In this case the FFA quantiles are preferred.

Given that the FFA quantiles are preferred the peak flow estimates at the other locations should be adjusted. It is recommended that the RFFE flood quantiles at other locations are scaled by the ratio of the FFA flood quantile to the RFFE flood quantile for a given AEP, i.e:

$$Q_{X\% \text{ Adjusted Location}} = Q_{X\% \text{ RFFE Location}} \frac{Q_{X\% \text{ FFA Gauge}}}{Q_{X\% \text{ RFFE Gauge}}}$$

where $Q_{X\% \text{ Adjusted Location}}$ is the adjusted discharge at a given location for the X% AEP event, $Q_{X\% \text{ RFFE Location}}$ is the discharge calculated by the RFFE method at a given location for the X% AEP event, $Q_{X\% \text{ FFA Gauge}}$ is the discharge calculated by the FFA at the gauge for the X% AEP event and $Q_{X\% \text{ RFFE Gauge}}$ is the discharge calculated by the RFFE at the gauge for the X% AEP event.

Using this technique the 1% AEP flows calculated for various locations are listed in Table 3-6. Note that the peak flows at Glenorchy have not been presented as the at-site FFA results were used in preference to the RFFE method.

Table 3-6 Adjusted RFFE Peak Flow Estimates m³/s

Watershed ID	Description	Discharge with AEP Event in m ³ /s					
		50%	20%	10%	5%	2%	1%
1	Downstream end of Great Western	10	31	51	72	105	131
2	Upstream of Railway	2	6	10	14	20	24
3	Bulgana Road	13	39	63	90	130	163
4	Landsborough Road	17	51	84	119	173	216
5	Navarre Road (Concongella Gauge)	19	58	96	136	197	246
6	Concongella Creek - Wimmera River Junction	24	72	117	167	242	302

3.1.5 Hydrology Summary

Three methods for calculating peak flow in the catchment were undertaken, these were:

- ARR Regional Flood Frequency Estimation (RFFE) Model Test version 2012 (see results in Table 3-3);
- Flood Frequency Analysis (FFA) (see the results in Table 3-4); and
- Adjusted RFFE method (ARFFE) (see the results in Table 3-6).

Of these the RFFE methods is able to produce peak flow estimates at any location throughout the catchment whereas the FFA method is only able to produce peak flow estimates at gauge locations. However, the RFFE method is, in general, not considered as accurate as the FFA method where there is a reliable gauged record. In order to produce reliable estimates for peak flows throughout the catchment it is necessary to reconcile these two methods and this was done

using the ARFFE method. The ARFFE method results were adopted as the peak flow estimates throughout the catchment.

In addition the PMF was estimated using the method outlined in Hydrological Recipes. The results are shown in Table 3-5.

The analysis outlined in this section has addressed the following key objectives:

- Verification/comparison against other techniques including flood frequency analysis and regional techniques.
- The peak flow estimates for the catchment have been determined using FFA and regional techniques and the adopted peak flow estimates have been reconciled against each other.
- Treatment of concurrent flooding across catchments in a basin.
- As peak flow estimates have been determined for a given AEP event at a number of locations throughout the catchment the issue of concurrent flooding have been addressed.
- Approaches to estimating the PMF.

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3.2 Stage 1A Hydraulic Modelling

For the Stage 1A hydraulic modelling component a 2D only TUFLOW GPU hydraulic model of the Concongella Creek catchment was built. This model was based on a digital elevation model (DEM) of the catchment and was designed to represent only the key floodplain features. At this stage significant floodplain structures such as bridges and floodplain crossings have not be incorporated into the model beyond their representation in the DEM. However, where significant ponding was noted behind a road or rail embankment an opening within the embankment was created to allow the ponded water to flow.

3.2.1 Topography and Structures

The topography used within the hydraulic model was based on a DEM using the data sets as described in the Section 2.2. The various data sources were:

- Wimmera CMA Stage 2 Floodplains LiDAR (2011) – coverage of Great Western and surrounds
- Index of Stream Conditions (ISC) Rivers (2010)
- Warracknabeal & Jeparit - Airborne Laser Survey (2005)

The order of preference used in the topographical data used was based on the age, accuracy and reliability of the provided data. Therefore, the 2011 WCMA LiDAR was used as highest preference, however, it only covered the township of Great Western and its surrounds. The LiDAR captured during the ISC project covered the main waterways of Concongella Creek and the Wimmera River with the 2005 ALS used to infill the remaining areas of the catchment not covered by the other two data sets.

Where large structures such as road culverts were not filtered in the DEM, the DEM was hydrologically reinforced with a nominal opening in the road or railway. This was necessary to reduce the water ponding behind road and rail embankments and the like.

From the initial model results it was found that there could be significant differences in flows depending on the resolution of the hydraulic model. To ensure conveyance along the main waterway was maintained for coarser model resolution models the terrain along the centreline of Concongella Creek and the Wimmera River was reinforced. To achieve this, a single grid cell was manipulated to ensure that the waterway was unimpeded and able to flow at coarser model resolutions.

It should be noted that the TUFLOW GPU hydraulic model relies on the topography being defined at the centre point of the grid rather than the 9 locations for each grid cell (cell corners, mid points on cell sides and cell centre) used in TUFLOW 'classic'.

3.2.2 Surface Roughness

For the Stage 1A model a coarse roughness layer was created. The roughness layer was based on a DEPI supplied tree coverage GIS dataset of Victoria. This coverage map breaks down the level of tree cover into three categories. Each category was assigned a Manning's 'n' roughness factor. Where there is no tree cover a global roughness parameter was set which corresponded to general grazing/agricultural land. The parameters used are presented in Table 3-7 below.

Table 3-7 2D Domain Manning’s ‘n’ Coefficients

Land use	Manning's 'n'
Unmaintained grass/crops	0.04
Scattered Tree Cover	0.04
Medium Tree Cover	0.05
Dense Tree Cover	0.06

3.2.3 Boundaries

As part of Stage 1A a direct rainfall model has been constructed with an upstream boundary at Glynwylln on the Wimmera River and a downstream boundary at Glenorchy on the Wimmera River. Hyetographs were generated for each storm event and were applied to TUFLOW on every grid cell based on the IFD parameters described below. To account for the hydrological loss processes an initial loss (IL) and continuing losses (CL) model was used within TUFLOW.

The external hydrologic boundary condition for the Upper Wimmera River at Glynwylln was taken from the outputs of the Upper Wimmera Flood Investigation (BMT WBM, 2014). This was applied as a Flow-Time (QT) boundary. The downstream boundary was schematised to ensure breakout flows from the catchment are accurately modelled through the use of a Head-Flow (HQ) relationship.

3.2.3.1 IFD Parameters

In order to define the design rainfall for ARI events, Intensity Frequency Duration (IFD) parameters for the Concongella Creek catchment were generated by the Bureau of Meteorology (<http://www.bom.gov.au/hydro/has/cdirswebx/cdirswebx.shtml> accessed 27/11/2013) using a method based on the maps from Volume 2 of Australia Rainfall and Runoff (AR&R) - A Guide to Flood Estimation. These parameters are presented in Table 3-8 below. From these parameters the IFD table was generated for standard storm durations. To generate the storm hyetographs the standard temporal patterns outlined in ARR 87 were used.

Table 3-8 IFD Parameters

IFD Parameter		Adopted Value
Rainfall Intensity (mm/hr)	2 Year ARI, 1 Hour Duration	18.92
	2 Year ARI, 12 Hour Duration	3.34
	2 Year ARI, 72 Hour Duration	0.91
	50 Year ARI, 1 Hour Duration	40.72
	50 Year ARI, 12 Hour Duration	6.70
	50 Year ARI, 72 Hour Duration	1.81
Skew Coefficient		0.32
Geographical Factor F2		4.36
Geographical Factor F50		14.83
Zone		2

3.2.4 Modelling and Calibration

The hydraulic model was initially run with standard design event hyetographs and standard loss parameters. This model was then calibrated to the peak flow estimates from the combined RFFE and at-site FFA. Prior to this, the hydraulic model was run to determine the critical event for the catchment and it was also demonstrated that the catchment was a conveyance dominated system.

3.2.4.1 Critical Event Selection

The results of the initial runs were analysed and it was determined that the 18 hour event produced the critical flood height and flows along Concongella Creek. This event was used for all further works investigated in Stage 1A.

3.2.4.2 Preliminary Direct Rainfall Results

As described above, the preliminary hydraulic model runs using the design rainfalls were undertaken for all durations using typical IL and CL for a rural catchment. These results are referred to as the Preliminary Direct Rainfall (PRD) results.

The results of the Preliminary Direct Rainfall models were compared to the FFA and adjusted RFFE in Table 3-12. Overall the Preliminary Direct Rainfall models overestimated the flows along Concongella Creek by an average of 15% when compared to the 1% AEP RFFE.

3.2.4.3 Direct Rainfall Calibrated to Regional Method

The Direct Rainfall Calibrated to Regional Method (DRCRM) involved calibrating the peak flows within the hydraulic model to the peak flows from the RFFE method discussed in Section 3.1.1. This was achieved by adjusting the initial and continuous losses within the hydraulic model. The calibration was undertaken using Shuffled Complex Evolution as implemented in the hydromad package (<http://hydromad.catchment.org/>) (Andrews et al, 2011). The model was calibrated simultaneously to peak flows at the reporting locations with the Concongella Creek stream gauge having a weighting factor of 2 using a Root Mean Squared Error (RMSE) objective. Extra weighting was applied to the gauge as this location was considered to have the best information.

To allow numerous model runs to be completed the effect of grid size on modelled results was investigated and a discussion on this is presented in Section 3.4. During the 1% AEP event a model grid size of 15m was found to produce similar results to a model with a 5m grid and the coarser grid was used for the calibration. Once the calibration model parameters were determined these were applied to the 5m grid model. All tabulated results are from the 15m model except where explicitly noted.

Table 3-9 Direct Rainfall Calibrated to Regional Method Design Losses

AEP	IL (mm)	CL (mm/hr)
20% AEP	20	2.0
10% AEP	20	2.5
5% AEP	20	3.0
2% AEP	20	4.0
1% AEP	20	5.0

Table 3-12 shows a comparison between the peak flows generated within the hydraulic model for the PDR, DRCRM and ARM calibration methods.

3.2.4.4 Direct Rainfall Calibrated to the Adjusted Regional Method

As described above, a similar methodology was undertaken to calibrate the TUFLOW model to the Adjusted Regional Method (ARM). This resulted in subtly different design losses for the more frequent events, however a significant decrease in losses was noted for the larger, less frequent events.

Table 3-10 Direct Rainfall Calibrated to Adjusted Regional Method Design Losses

AEP	IL (mm)	CL (mm/hr)
20% AEP	15	2.0
10% AEP	15	2.5
5% AEP	15	3.0
2% AEP	15	3.5
1% AEP	15	4.0

It is of note that the results presented above illustrate increasing CL with increasing ARI. Typically, continuing loss values in uncalibrated catchments remain the same or decrease with increasing ARI. Interestingly the adopted continuing losses are approximately proportional to 65% of the IFD intensity for the 18 hour event irrespective of the AEP as shown in Table 3-11.

Table 3-11 Direct Rainfall Calibrated to Adjusted Regional Method IFD comparison

AEP	20%	10%	5%	2%	1%
IFD Intensity (mm/hr)	3.26	3.77	4.46	5.42	6.20
Continuing Loss (mm/hr)	2.0	2.5	3.0	3.5	4.0
Ratio of CL / Intensity	0.61	0.66	0.67	0.65	0.65

Table 3-12 shows a comparison between the peak flows generated within the hydraulic model for the PDR, DRCRM and ARM calibration methods.

3.2.5 Comparison of Peak Flow Estimates

As can be seen in Table 3-12, with the exception of Great Western and the Concongella Creek - Wimmera River Junction, the flows generated by the hydraulic model along Concongella Creek are

broadly similar to those predicted by the RFFE and the FFA. The ARM results have an average difference from the adjusted RFFE hydrology values of -8% with a smaller variance (std dev = 0.08 or 8% and range of 6% to -24%) than the Preliminary Direct Rainfall (PDR) method illustrated in Table 3-12. Note that the results for the Concongella Creek – Wimmera River confluence were not included in the analysis due to the attenuation of the flood wave (see Section 3.4.2.3).

On the other hand, the PDR method using typical losses produced results, across all modelled AEP events, on average 18% greater than the adjusted RFFE (see Table 3-12). However, there was considerable variance (std dev = 0.13 or 13%) in the percentage difference between the two approaches. While the 1% AEP results are reasonable, in the more frequent storm events the difference between the Preliminary Direct Rainfall and RFFE values varied from 53% to 0%. The considerable variance in the results is particularly concerning reducing confidence in any resulting mapping. Again the Concongella Creek – Wimmera River confluence were not included in this analysis, due to the influence of Wimmera River flows.

Table 3-12 TUFLOW Peak Flow Estimate Comparison (m³/s)

AEP		20%	10%	5%	2%	1%
Downstream end of Great Western	PDR	38	51	76	114	145
	DRCRM	20	30	48	69	78
	ARM	29	39	60	88	106
Bulgana Road	PDR	51	66	95	149	197
	DRCRM	22	36	62	86	108
	ARM	37	51	77	123	154
Landsborough Road	PDR	58	96	136	197	246
	DRCRM	28	51	93	128	154
	ARM	54	77	116	174	212
Navarre Road (Concongella Gauge)	PDR	83	106	151	226	291
	DRCRM	29	52	97	140	174
	ARM	56	81	128	197	246
Concongella Creek - Wimmera River Junction	PDR	72	117	167	242	302
	DRCRM	30	54	90	139	182
	ARM	56	77	126	210	264

A full discussion of these results is presented in Section 3.4.

3.2.6 Hydraulic Summary

Three hydraulic modelling methods and the results of these methods are shown in Table 3-12. The three methods undertaken were:

- Preliminary Direct Rainfall (PDR);
- Direct Rainfall Calibrated to Regional Method (DRCRM); and

- Direct Rainfall Calibrated to Adjusted Regional Method (ARM).

The PDR results were based on direct rainfall results using typical loss values. In the DRCRM method the hydraulic model was 'calibrated' to the RFFE peak flow estimates by adjusting the loss parameters. The ARM method was identical to the DRCRM method except the hydraulic model was calibrated to the ARFFE peak flows.

It is of note that the ARFFE flows from the hydrology and the hydraulic (ARM) results are different. This is an expected result as the hydraulic model accounts for the attenuation of discharges whereas hydrology models do not. For this reason the preferred peak flow estimates throughout the catchment are the ARM peak flows listed in Table 3-12.

In addition to the key objectives addressed in the hydrology section the analysis presented in this section has addressed the following key objective:

- Limitations on approaches due to model run times.

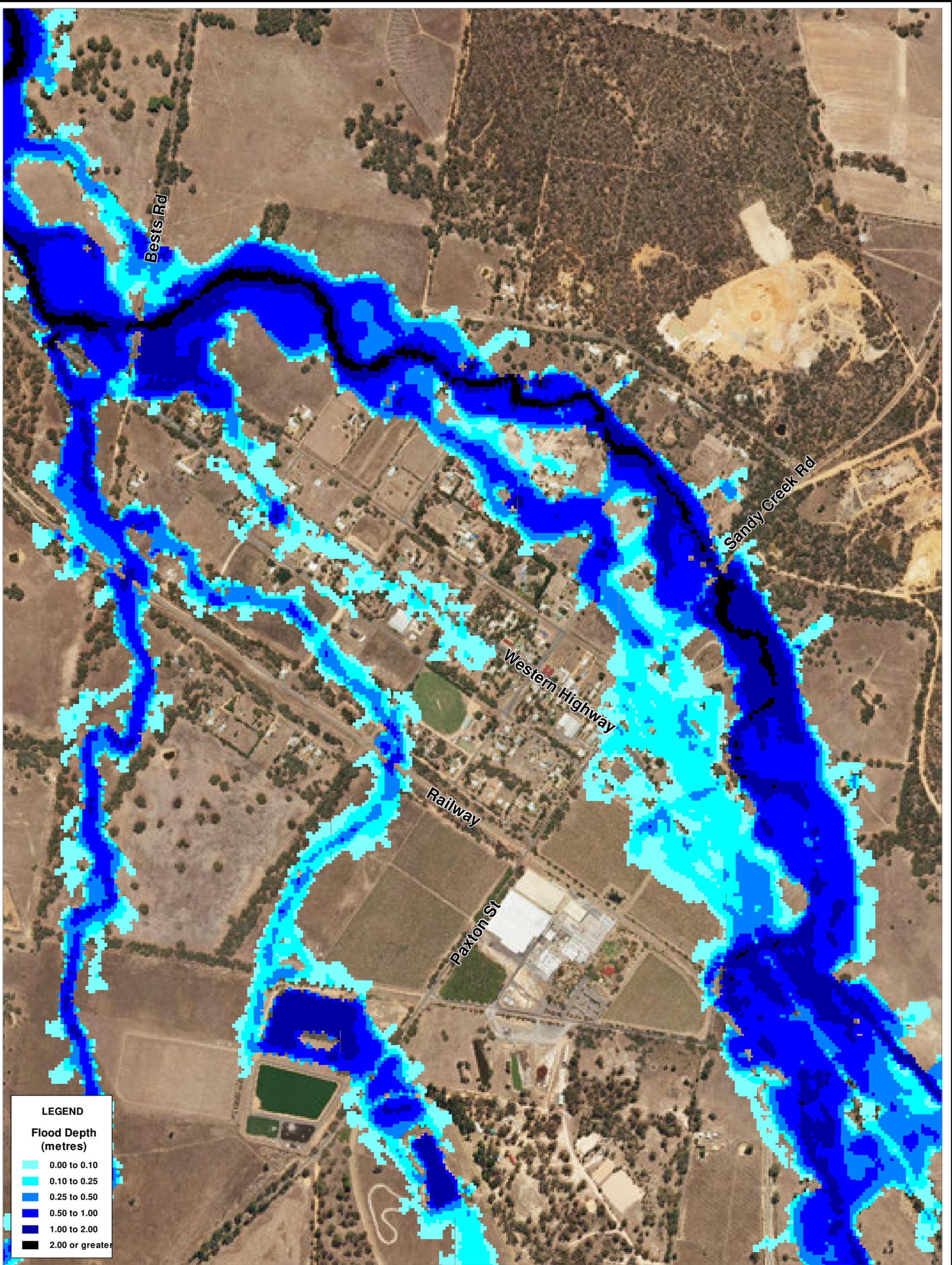
A number of grid sizes and hence model run times have been investigated as part of the investigation. The limitations and the ways of managing these limitations have been outlined in Section 3.4.

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3.3 Stage 1A Flood Mapping

As the Stage 1A hydraulic modelling was undertaken using a direct rainfall technique it was necessary to filter the results. This was done by creating a mapping extent polygon. To do this flood depths less than 0.1m were removed from the flood extent. Smaller tributaries were then trimmed from the flood extent manually. The resulting extent was then buffered to add the flood fringe. The 1% AEP flood depth maps showing the three methodologies in the area around Great Western are present in Figure 3-3 to Figure 3-5.

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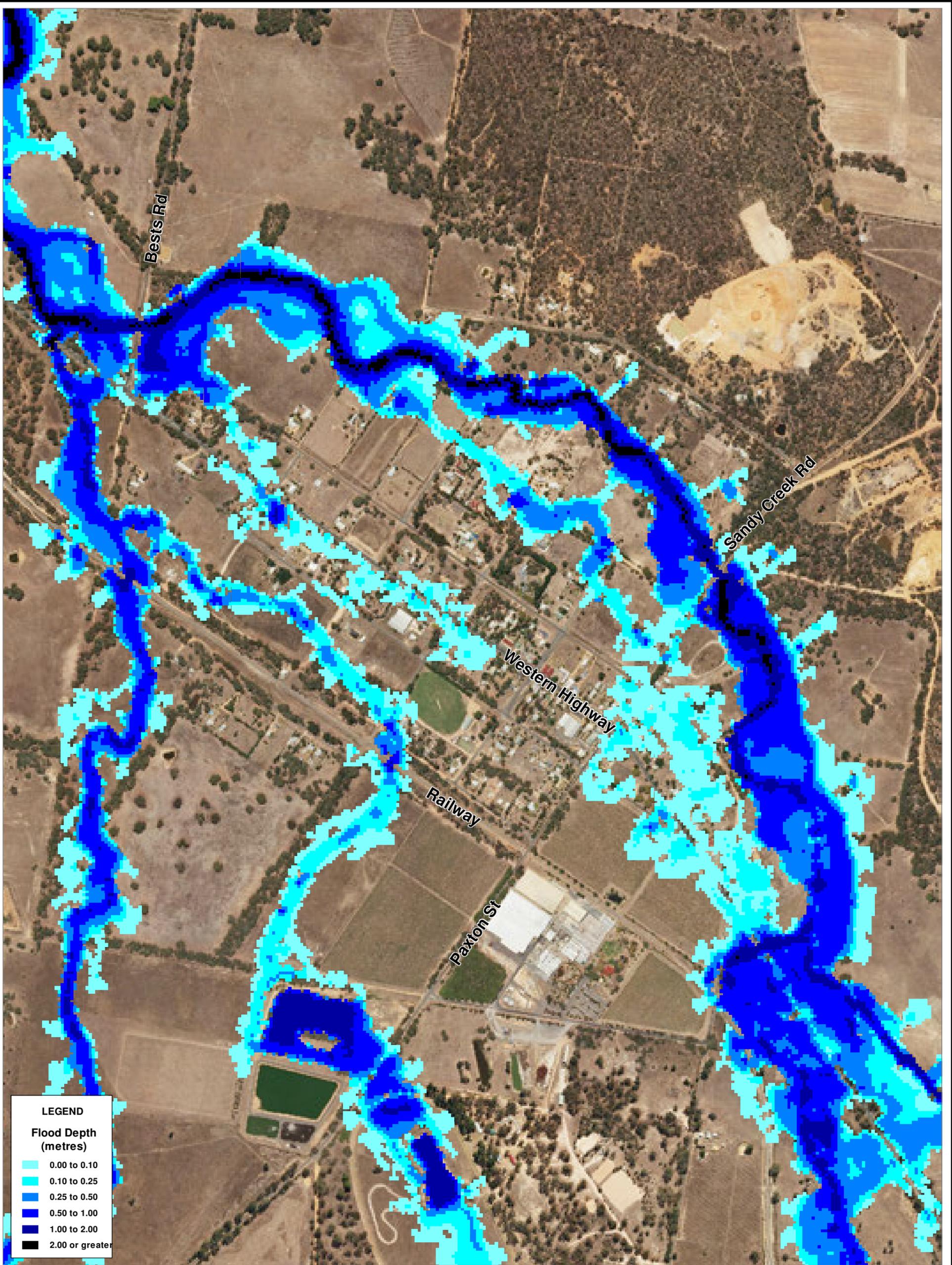
Title:
Regional Flood Mapping: Concongella Creek Pilot Study - Great Western
1% AEP Flood Depths - Preliminary Direct Rainfall

Figure:
3-3

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LEGEND

Flood Depth (metres)

Lightest Blue	0.00 to 0.10
Light Blue	0.10 to 0.25
Medium Blue	0.25 to 0.50
Dark Blue	0.50 to 1.00
Very Dark Blue	1.00 to 2.00
Black	2.00 or greater

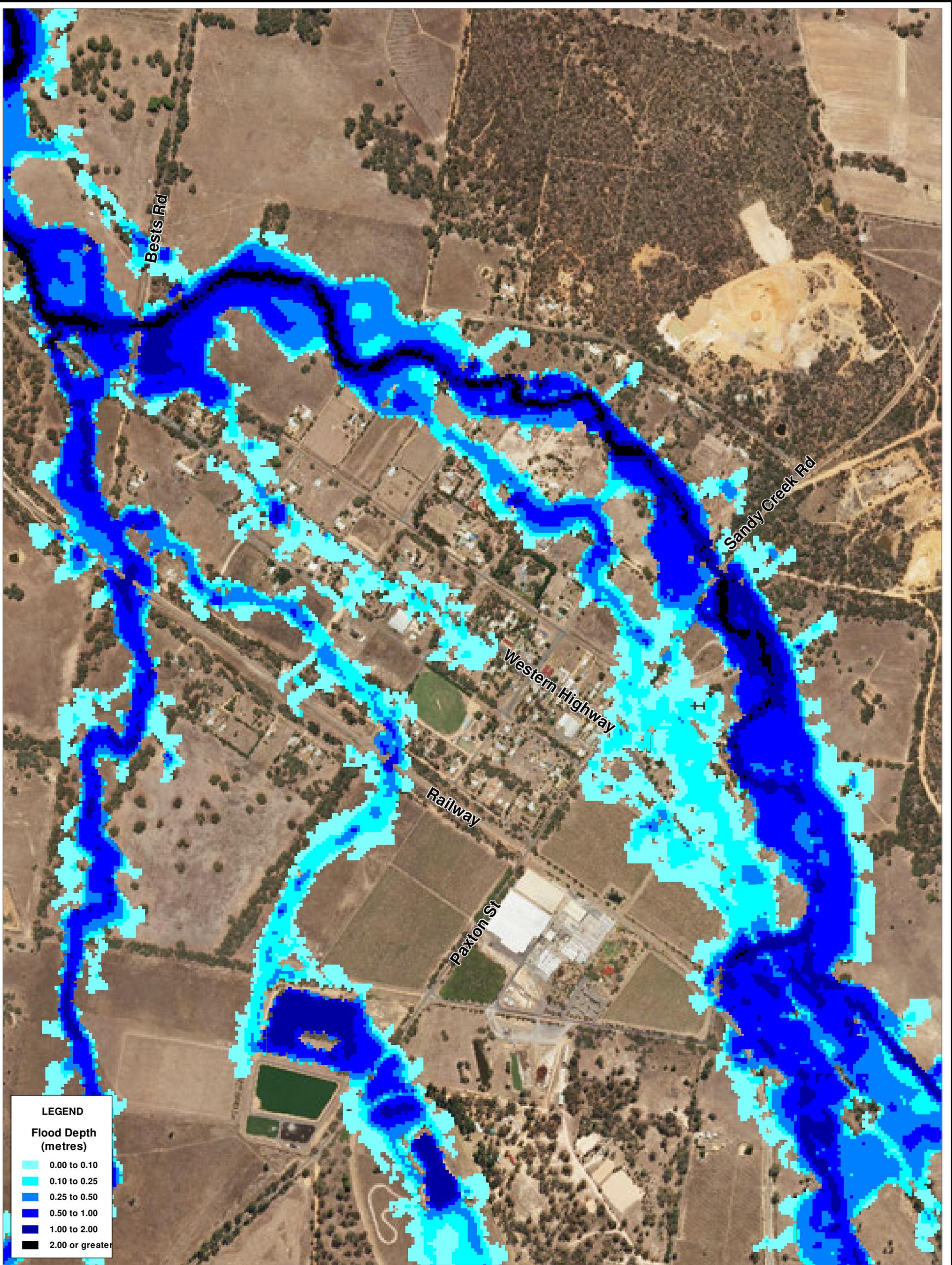
Title: **Regional Flood Mapping: Concongella Creek Pilot Study - Great Western
1% AEP Flood Depths - Direct Rainfall Calibrated to Regional Method**

Figure: **3-4**

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Title: **Regional Flood Mapping: Concongella Creek Pilot Study - Great Western
1% AEP Flood Depths - Adjusted Direct Rainfall Calibrated to Regional Method**

Figure:
3-5

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3.4 Discussion, Recommendations and Conclusions

The direct rainfall methodologies presented above have provided reasonable results for the flood mapping of the Concongella Creek catchment. The first of these methods, the Preliminary Direct Rainfall method, in general produced higher peak flows of around 20% when run with typical design losses. The second method, Calibrated Direct Rainfall to Adjusted Regional method, resulted in an underestimate of around 10% (excluding Glenochy).

While the presented methodologies result in reasonable flood maps there are a number of significant discussion points. These have been organised under the following headings:

- Hydrology Modelling; and
- Hydraulic Modelling

3.4.1 Hydrology Modelling

3.4.1.1 Regional Flood Frequency Estimate

Peak flows for a number of AEP events were determined at locations throughout the catchment using the draft RFFE method. The draft RFFE method has been developed to replace the Probabilistic Rational Method developed in ARR 87. The draft RFFE has been demonstrated to provide improved performance when compared to the Probabilistic Rational Method (Haddad et al, 2011).

The RFFE method has been used to estimate flood discharges at ungauged locations throughout the Concongella Catchment. This technique has been applied to partially address two of the study objectives:

- Verification/comparison of peak flow estimates against other techniques including flood frequency analysis and regional techniques; and
- Design hydrograph estimation with particular focus on determining the Annual Exceedance Probability (AEP) within a catchment.

The RFFE method produces peak flows for a given AEP events at any location throughout a catchment, although it is only recommended for catchments greater than 25km². This allows the determination of peaks flows at multiple locations throughout a catchment for a given AEP event and comparison with other techniques. These comparisons were presented in Table 3-4 and Table 3-12. Note that the RFFE flows (or regional method) may require adjustment as discussed in Section 3.4.1.2.

To ensure a consistent probability of occurrence in the design flood mapping throughout the catchment the hydraulic model was calibrated to the peak flows a various locations.

It is of note that the draft RFFE method is currently being revised as part of ARR Revision project (Project 5). While it is unlikely that the revised method will produce the identical results to the existing method, the revised method can be used in the same manner as the existing RFFE method.

Recommendations

The RFFE software is currently being updated by ARR Project 5. The revised RFFE technique and software should be used for future studies.

3.4.1.2 Scaling of RFFE Results to At-site FFA Results

Given there were two methods for estimating peak flows in the Concongella Creek catchment, the at-site FFA and the RFFE methods, a decision is required on which produces the preferred results. The results from the two sets of peak flow estimates at the gauge on Concongella Creek were different, as expected. As outlined above, the at-site FFA results were considered more reliable as they were based on a reasonable length of record of 36 years.

To resolve the inconsistency between the at-site FFA and RFFE results, scaling factors to convert between the two were determined. These were then applied to the RFFE estimates at other locations.

This scaling or factoring approach is widely used in hydrology and is considered the most appropriate technique to adjust the RFFE estimates to account for local conditions. This can be considered tuning of the RFFE results.

Recommendations

In instances where more than one method is undertaken to determine peak flows, the various methods should be compared and a decision should be made on which is more reliable. The final flood estimates throughout a catchment should be adjusted to ensure consistency with the more reliable of the flood estimation methods. Typically, the methods will be a regional method and an at-site FFA. Where there is a reasonable gauge record length and good quality data, the more reliable technique will tend to be the at-site FFA. If this is the case the regional flood estimates at the gauge should be adjusted to match the at-site FFA estimates and appropriate scaling factors applied to other locations throughout the catchment.

3.4.2 Hydraulic Modelling

In undertaking the Stage 1A calibration of the hydraulic model, a number of assumptions and limitations on the approach were necessary. These assumptions and limitations were considered appropriate given the aim of the Study was to produce flood maps of the entire catchment. If a more detailed assessment of the hydraulic character of a given location was required, for instance for bridge design, a more detailed model would be required.

As the direct rainfall approach was undertaken it was necessary to incorporate a loss model in the hydraulic model. As discussed above an Initial Loss (IL) and Continuing Loss (CL) model was used. This is further discussed below.

One of the aims of the Study was to investigate *the limitation on the approach due to model runtime*. This is considered to be a significant issue when undertaking 2D hydraulic models given model runtimes of days or even weeks. Such long model runtimes can effectively prohibit computationally expensive techniques such as automatic parameter optimisation and Monte Carlo Simulations as well as limiting the size of the catchment modelled and its resolution. For this reason a hydraulic modelling strategy with varying grid resolutions was investigated. The

investigation of this strategy exposed a number of issues concerning grid size. These are also discussed below.

3.4.2.1 Loss Modelling

Conventional approaches typically look to adjust initial and continuing losses (or runoff proportion) within hydrological models developed for flood estimation. This approach has been translated to the hydraulic modelling presented here. It is important to note that the loss model used here does not replicate the physical process of rainfall loss and it is a simplification of the actual runoff process. The loss models account for a variety of processes including interception, depression storage, losses to the soil store, and recharge to groundwater table. A loss model is therefore required to account for a large variety of physical processes which are dependent on, typically, heterogeneous variables such as soil properties. As there is no physical basis for hydrological losses, there is no reason that the application of typical design losses developed for hydrological models will implicitly work for the direct rainfall approach.

Using typical loss values in the Preliminary Direct Rainfall method produced reasonable results, although there was considerable variance in these results which reduces the confidence in the final flood mapping. The results indicate that translating hydrological loss values into a direct rainfall model will not necessarily produce correct results. Note that Hall (2014) found that using regional parameter estimates for runoff-coefficient resulted in a poor model calibration using the direct rainfall technique in a catchment in South West Western Australia.

As noted above Calibrated Direct Rainfall loss values (Table 3-11) did not follow a typical design loss convention; that loss values decrease with event rarity. A possible explanation is that the lower losses in the more frequent events compensate for the additional storage on the coarser grid (see Section 3.4.2.2 for a description of the effect of grid size on model storage). The results indicate that loss values increase with event rarity. This demonstrates that the use of typical loss conventions may not be suitable in the direct rainfall techniques.

Recommendations

The results presented here indicate that typical design losses are a reasonable starting point for direct rainfall modelling, however, there is no reason these will produce acceptable results. This is an area that requires further investigation. It is recommended that in direct rainfall models the loss values are used as calibration parameters. Further, it is recommended that typical design losses from hydrological models are not simply used for direct rainfall modelling.

3.4.2.2 Grid Size

During the initial model schematisation a number of model grid sizes were trialled. It was found the modelled peak flows could be sensitive to grid size varying by up to 50% in the 20% AEP event. However the larger events were far less sensitive with variance in peak flow values typically within a few percent. This is illustrated in Figure 3-6 and Figure 3-7 for the 20% and 1% AEP respectively.

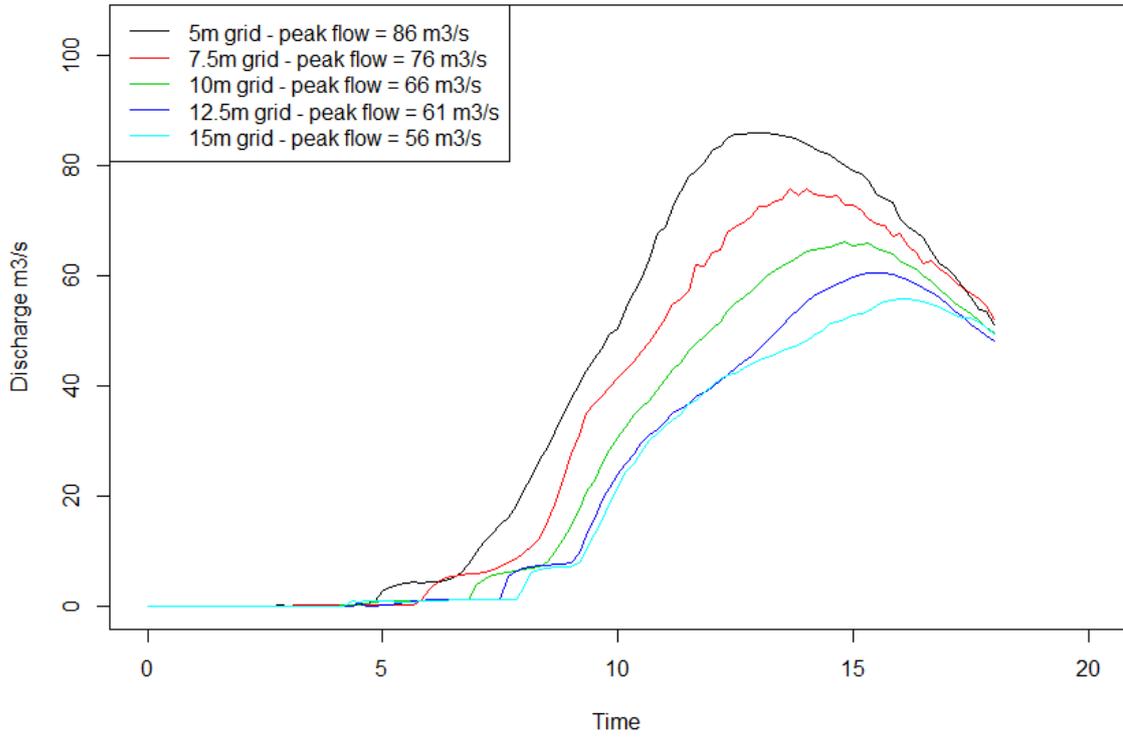


Figure 3-6 Hydrographs for various grid sizes at Navarre Road – 20% AEP

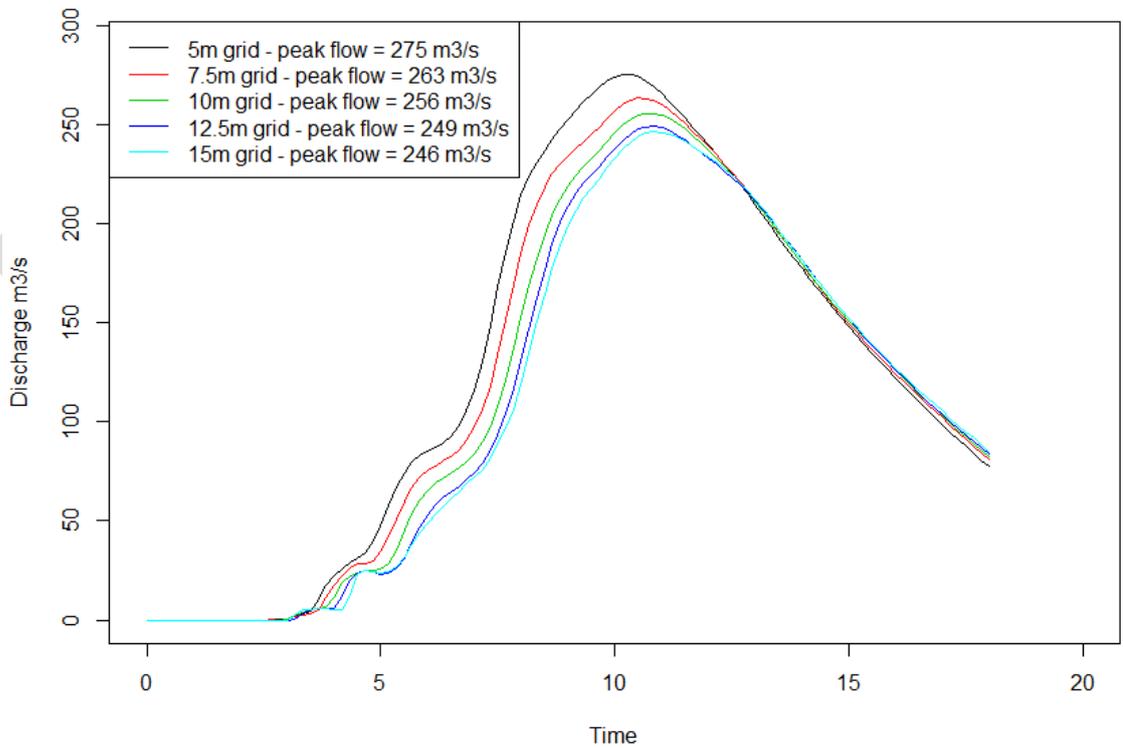


Figure 3-7 Hydrographs for various grid sizes at Navarre Road – 1% AEP

3.4.2.3 Attenuation

Due to the specific nature of the catchment attenuation of flows were noted in the hydraulic modelling results. This was most notable along the Wimmera River but also some was attenuation was observed along Concongella Creek. This is demonstrated in Figure 3-8 and Figure 3-9 for the 1% AEP.

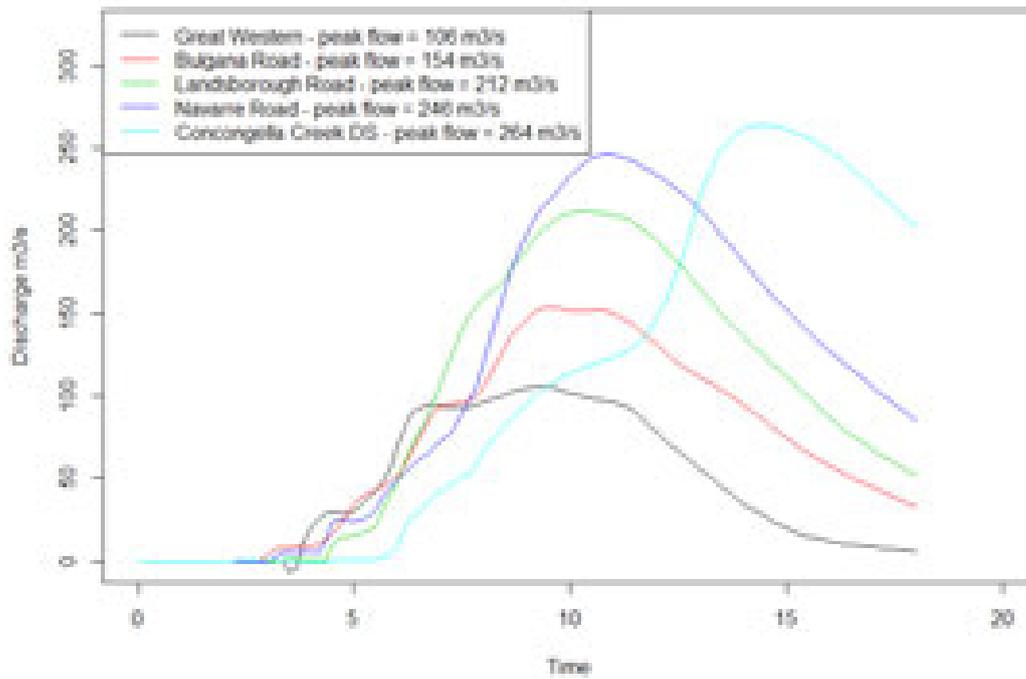


Figure 3-8 Concongella Creek Flow Locations (15m grid) – 1% AEP

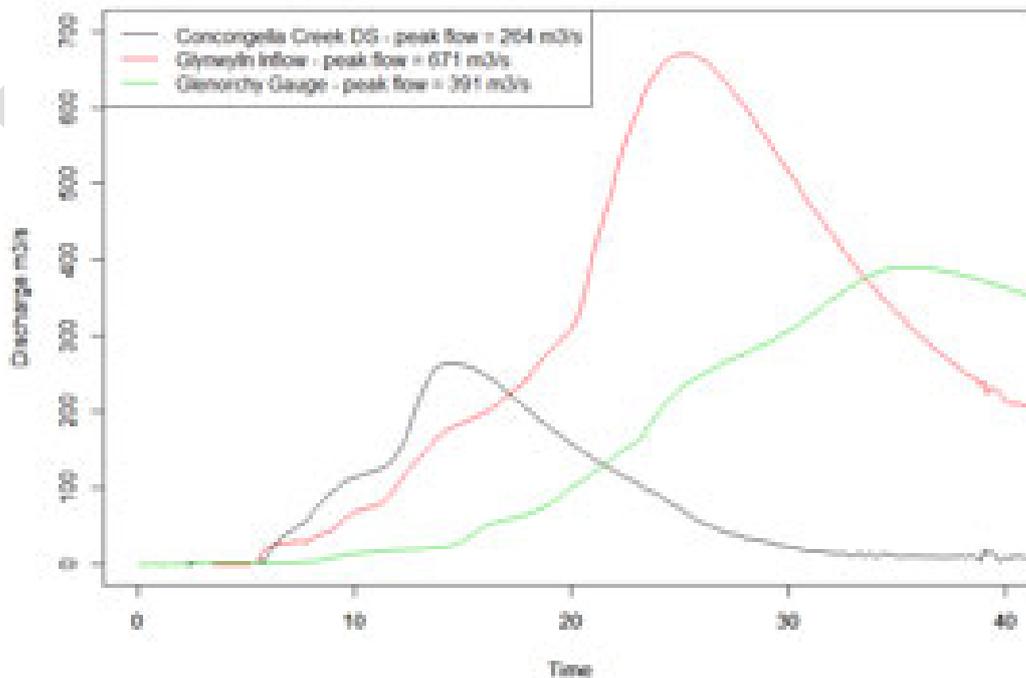


Figure 3-9 Wimmera River Flow Locations (15m grid) – 1% AEP

3.4.3 Conclusions

This Section presents two methodologies for undertaking catchment scale flood mapping: the Preliminary Direct Rainfall and the Calibrated Direct Rainfall methods. Both methods were able to achieve acceptable flood mapping results at the catchment scale, however, there are limitations with both methods. The Calibrated (both to the adjusted and unadjusted RFFE) Direct Rainfall method is an extremely promising method that can deliver the majority of the study objectives, it does however, require further research and guidance to be a reliable practical methodology. This is the preferred method as it provides a higher level of certainty and achieves more of the studies objectives than the Preliminary Direct Rainfall method.

The Preliminary Direct Rainfall method produced peak discharges at reporting locations that were approximately 20% greater than the peak discharges produced by at-site FFA and the RFFE methods. Although these results were broadly similar to the peak flow estimates produced by other techniques, it is not recommended that the direct rainfall method be applied without calibration to an alternative method. However, this method may still have application in rapid broad scale assessment, for instance, in real time emergency management.

The Calibrated Direct Rainfall method was able to reproduce the peak flow estimates obtained through other techniques. There are, however, a number of considerations when using this technique. This technique is not suitable for systems where the peak flood levels are produced by the largest volume events; in these systems it will be necessary to investigate a variety of storms. Furthermore, this technique is not guaranteed to produce peak flood levels throughout the catchment for a given AEP event if only one storm duration is used. The impact of different storm durations at key locations throughout the catchment needs to be investigated as part of catchment specific studies.

Given that there are numerous techniques available to determine peak flows throughout a catchment, a decision is required on which is considered to be the most reliable. Once this has been determined adjustments need to be made to ensure consistency of peak flow estimates throughout the catchment. In the catchment investigated here the at-site FFA was preferred, with the RFFE estimates at ungauged sites adjusted through a scaling factor.

Analysis of the results of the Calibrated Direct Rainfall method revealed a number of further considerations with the direct rainfall technique. Of particular note was the impact of grid size on the final results. The analysis above demonstrates that stream conveyance was important to the peak flows determined along the main stream. When using a coarser grid attention needs to be given to maintaining the conveyance along the main stream and this can be achieved through hydrological reinforcement. A further issue is the impact of grid size on floodplain storage. The results presented here indicate that coarser grid sizes lead to increased storage on the floodplain and decreased runoff. This is an important result and requires further investigation.

When calibrating a hydraulic model to peak flows throughout a catchment based on regional methods, flood wave attenuation needs to be considered. In certain circumstances it is expected that flood waves will attenuate through the catchment and this will be reflected in the hydraulic modelling results, whereas the hydrologic results will not explicitly represent this affect. This effect should be taken into account when reviewing model results.

4 Stage 1B

In this stage the flood model was calibrated to known events. This involved developing a hydrologic model and calibrated to this known flood events. The results of the hydrology model were then applied to the 2D hydraulic model of the study area. The hydraulic model used in this stage included significant floodplain features and hydraulic constrictions. Design events were then modelled including the PMF. A joint calibration approach was undertaken whereby the hydrology and hydraulic models were iteratively adjusted to ensure consistent results between the hydrology and hydraulics.

This stage addressed the following Key Objectives under the heading under the headings of Hydrologic Analysis and Hydraulic Analysis.:

- Hydrologic analysis:
 - Design hydrograph estimation with particular focus on determining the Annual Exceedance Probability (AEP) within a catchment.
 - Verification/comparison against other techniques including flood frequency analysis and regional techniques.
 - Treatment of concurrent flooding across catchments in a basin.
- Hydraulic analysis:
 - Approaches to calibration and verification against observed flood extents and levels, in particular at key river height gauge locations.
 - Treatment of changing critical storm durations across a catchment.
 - Limitations on approaches due to model run times.

4.1 Stage 1B Hydrology

At this stage (Stage 1B) rainfall-runoff modelling or hydrologic modelling, of the Concongella Creek Catchment was undertaken with the URBS hydrologic modelling package. The outputs from the URBS model provide inputs for the TUFLOW hydraulic model. A joint calibration process with the TUFLOW hydraulic model was then undertaken. This stage builds upon the work undertaken in Stage 1A and documented in Section 3 above. This chapter presents the following:

- Hydrological modelling
 - URBS model development;
 - Calibration and Validation of the URBS model; and
 - Design event modelling
- Hydraulic modelling

4.1.1 URBS Model Development

Rainfall runoff modelling is a method utilised to estimate the amount of runoff produced by a catchment for a given rainfall event, taking into account the hydrologic characteristics of that catchment.

The URBS model incorporates an area of approximately 505 km². To ensure accurate representation of the hydrological response of the overall catchment, the model was divided into 41 individual sub-catchments. These boundaries were initially determined using the software package CatchmentSIM, based on the Wimmera CMA LiDAR elevation dataset. The catchment breakup was then refined to ensure that consistency in sub-catchment size and shape was achieved. The URBS model layout is shown in

Conceptual reaches (approximate overland flow paths) were defined and the recorded hydrograph at Concongella Creek was included for calibration purposes.

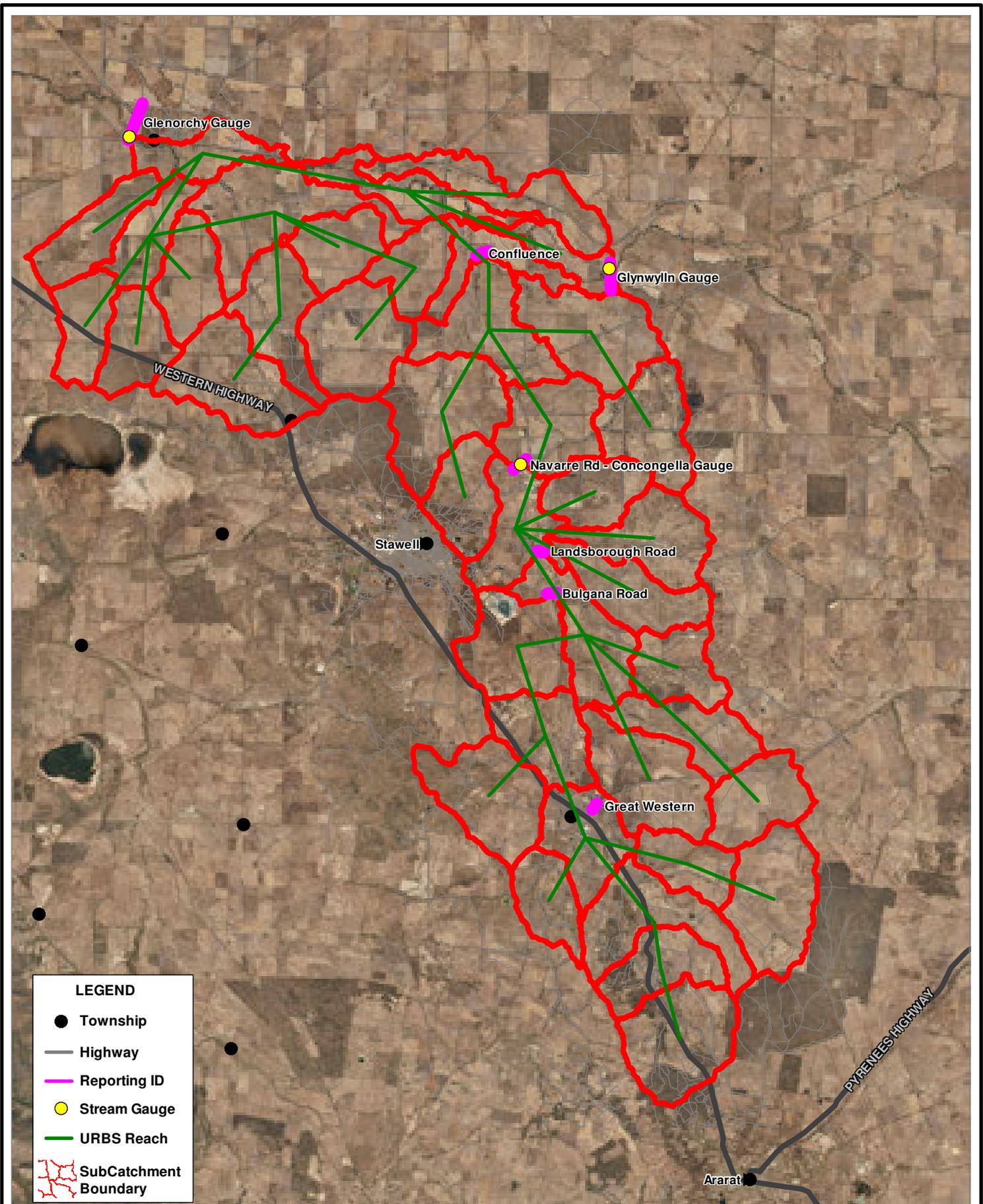
Formal storages identified in the catchment (farm dams, etc), were determined not to be large enough to significantly affect the runoff from the catchment during large storm events. Consequently, there were no other storages included in the hydrologic model.

4.1.1.1 Fraction Impervious

Whilst the Concongella Creek catchment is predominately a rural catchment, fraction impervious values were adopted for this study for other land-use types such as areas of state park and rural townships. The adopted values are shown in Table 4-1, and are consistent with previous studies undertaken for the Wimmera Catchment Management Authority (WCMA). These values are based on standard industry values recommended by Melbourne Water (Melbourne Water Flood Mapping Guidelines and Technical Specifications 2010) for fraction impervious and from inspection of aerial photography.

Table 4-1 Fraction Impervious Values

Land Use Type	Fraction Impervious
Farm Zone	0.05
Low Density Residential	0.2
Public Conservation	0
Public Park & Recreation	0.1
Service and Utilities	0.5
Railway	0.7
Rural Conservation	0.05
Major Roads	0.7
Secondary Roads	0.6
Rural Living	0.2
Township	0.55

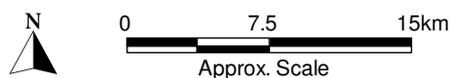


Title:
Regional Flood Mapping: Concongella Creek Pilot Study
URBS Hydrology Model Schematisation

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4.1.1.2 URBS Model Calibration

To establish that the hydrologic modelling is suitably representing runoff behaviour of the catchment, and in turn providing reasonable inputs for the hydraulic modelling process, model calibration and validation to flood events was undertaken; the model was calibrated to 11 events at the Concongella Creek gauge. The calibration process is described in detail below. The calibration results were assessed using the Nash-Sutcliffe Efficiency (NSE) coefficient.

4.1.1.3 Calibration and Validation Process

The hydrologic modelling calibration process involves the following steps:

- (1) Collect, collate and verify relevant data including streamflow hydrographs, rainfall pluviographs and daily rainfall totals.
- (2) Choose the historical storm events to be used in the calibration and validation process based on the available data and the nature of the event.
- (3) Create the storm event inputs to be used in the calibration and validation process.
- (4) Apply the calibration storm event to the URBS model and optimise the model parameters to achieve model calibration.
- (5) Undertake further iterative calibration as part of a joint calibration process with the hydraulics model, if required.

The following sections detail these processes and outline the assumptions used in the hydrologic calibration process.

4.1.2 Collect, Collate and Verify Data

There are a number of pluviograph stations and daily rainfall stations located in and around the study catchment, as shown in Figure 2-2. Only a single stream gauge was available. Initially all events with a peak flow of greater than 46 m³/s at the Concongella gauge were investigated.

For each event identified, the pluviograph and daily rainfall data was filtered to remove the stations that were inactive during a specific event. The data recorded at each station was then checked to ensure that there were no errors in the recorded data, and then compared to surrounding stations to check for consistency in the rainfall patterns. The temporal pattern from the hyetographs was used to disaggregate the daily rainfalls.

As only the Concongella Creek gauge was available for the calibration process. Events where gauge data was unavailable or suspect were removed from the event selection list.

Once the filtering of events was complete a total of 11 events were deemed to have met the criterion outlined above and to be of sufficient quality for the calibration process.

4.1.3 Calibration Parameters

The URBS parameters that are available for calibration are; *alpha*, *m*, and the loss parameters initial loss (*IL*) and continuing loss (*CL*). The URBS program provides the facility to manually adjust the calibration parameters until an acceptable fit is found. An automated process was developed to

calibrate the model by evaluating a model's performance against observed data and calculating the Nash-Sutcliffe Efficiency (NSE) coefficient.

The NSE is a measure of how much of the residuals (the difference between the calculated and observed) variance is explained by the model. A value of 1 indicates a perfect fit to the model data whereas a value of 0 indicates simply modelling the average value would perform equally well. A value of less than 0 indicates poor model performance. NSE is defined as:

$$NSE = 1 - \frac{var(Res)}{var(hyd)} \quad \text{Equation 1}$$

where $var(Res)$ is the variance of the model residuals or the difference between the observed and calculated flows, and $var(hyd)$ is the variance of the observed hydrograph.

The observed peak discharge, approximate AEP of the event, NSE and best fit parameters determined for each event are presented below in Table 4-2 below.

Table 4-2 Concongella Creek Hydrology Calibration Values

Approx. Date of Event	Peak Discharge (m ³ /s)	Approx. AEP	NSE	alpha	m	IL	CL
20/01/1979	58	20%	0.948	0.0115	0.75	80.2	6.18
05/10/1979	101	10%	0.941	0.0128	0.78	7.0	8.81
20/08/1980	52	>20%	0.894	0.0276	0.68	0.6	1.96
20/08/1984	50	>20%	0.792	0.0238	0.84	4.9	1.76
22/10/1986	57	20%	0.924	0.0226	0.98	13.8	0.75
31/03/1988	160	3%	0.887	0.0095	0.69	50.9	6.23
02/09/1988	120	7%	0.969	0.0153	0.78	23.3	0.15
30/08/1992	67	20%	0.924	0.0212	0.90	14.2	1.12
29/09/1992	47	>20%	0.929	0.0206	0.74	10.5	1.47
04/09/2010	50	>20%	0.973	0.0290	0.92	8.0	1.17
14/01/2011	305	<1%	0.972	0.0134	0.82	29.1	0.34

In general, all events achieve a good or very good fit when individually calibrated to the observed records. However, there is significant divergence in the α and to a less extent the m parameters with the size of the event. The resulting α and m parameters were plotted and a distinct pattern emerged as shown in Figure 4-2 below. Generally, events around the 20% AEP and more frequent had an averaged α of 0.0223, whereas less frequent events were found to have an average α of 0.0128 with a standard deviation of 0.0024.

For the design event modelling an α of 0.0128 was adopted as larger events are the primary interest from a flood perspective. Similarly, an average m of 0.77 based on the larger events was adopted for the design event model.

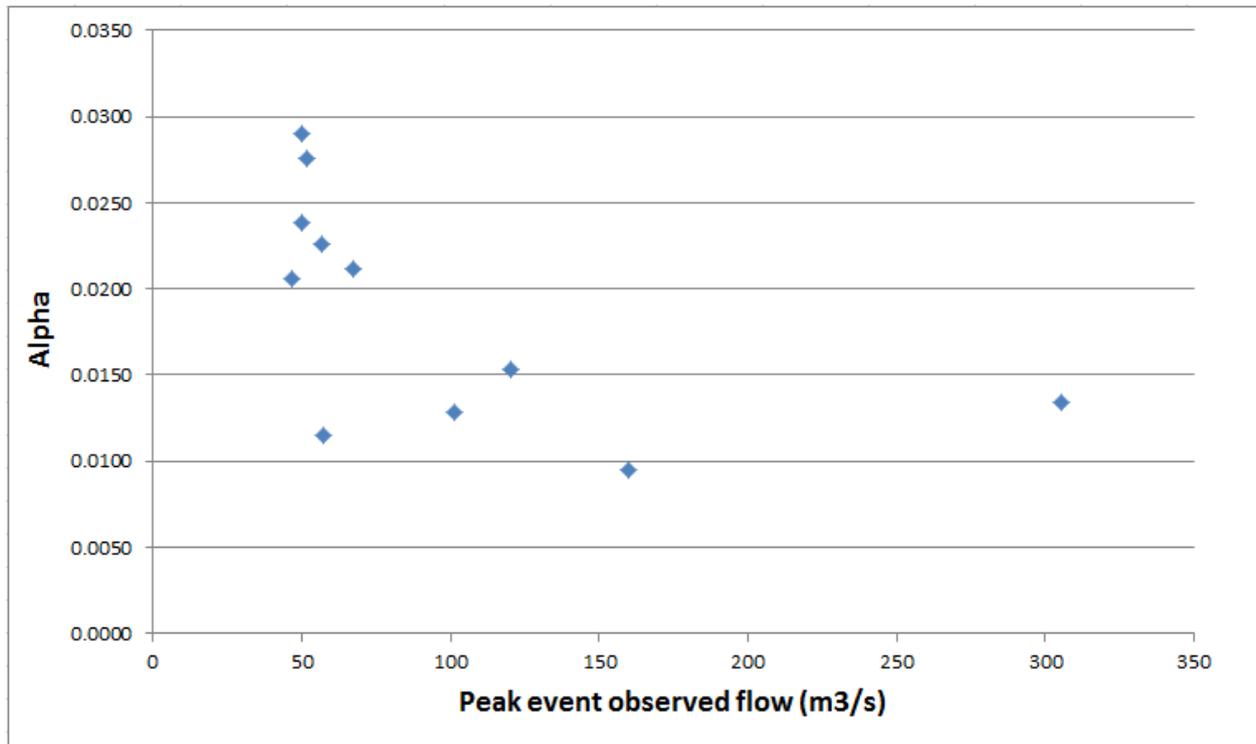


Figure 4-2URBS alpha versus Peak Flow

4.1.3.1 Design Event Calibration

As discussed above, the URBS parameters were taken from the average of the historic calibration events. For the design event modelling an *alpha* of 0.0128 was adopted with an *m* of 0.77. The initial and continuing loss parameters were determined by joint calibration with the hydraulic model. This is discussed below in Section 4.2. Table 4-3 presents the design event peak flows from the hydrologic model and the Adjusted RFFE peak flows for the given AEP events. In general, the peak flows at each location are higher in the URBS model results than those produced by the Adjusted RFFE method. This was an intentional result as the initial hydraulic model runs indicated that there was significant attenuation of the flood wave along Concongella Creek. To account for this, peak design flows in the hydrologic model were increased above the Adjusted RFFE peak flow for a given AEP event. This is further discussed in Section 4.2.2.1 and 4.3.1.2.

Table 4-3 Hydrology Model Design Flow Comparison (m³/s)

AEP		20%	10%	5%	2%	1%
Downstream end of Great Western	URBS	85.2	116	141.3	164	220.1
	Adjusted RFFE	31	51	72	105	131
	% Dif	175%	127%	96%	56%	68%
Bulgana Road	URBS	78.7	107.8	133.1	151.2	201.5
	Adjusted RFFE	39	63	90	130	163
	% Dif	102%	71%	48%	16%	24%
Landsborough Road	URBS	110.1	150.1	185.6	215.5	282.7
	Adjusted RFFE	51	84	119	173	216
	% Dif	116%	79%	56%	25%	31%
Navarre Road (Concongella Gauge)	URBS	101.1	139.7	171.9	209.8	279.5
	Adjusted RFFE	58	96	136	197	246
	% Dif	74%	46%	26%	6%	14%
Concongella Creek - Wimmera River Junction	URBS	90.7	125.9	154.7	201	271.7
	Adjusted RFFE	72	117	167	242	302
	% Dif	26%	8%	-7%	-17%	-10%

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4.2 Stage 1B Hydraulic Modelling

For the Stage 1B hydraulic modelling a modified version of the 2D only TUFLOW GPU hydraulic model of the Concongella Creek catchment from Stage 1A was used.

4.2.1 Hydraulic Model Review and Changes from Stage 1A

For Stage 1B a review of the hydraulic model used in Stage 1A was undertaken. Primarily the review considered the suitability of the materials layer distribution as well as the structures.

As discussed above in Section 3.2.2 the materials distribution was based on a DEPI supplied tree coverage GIS dataset of Victoria that categorised vegetation based on density. This was reviewed in detail along the main flow paths using aerial photography. The review determined that the tree density layer provided a reasonable delineation for the Manning's layer and as such the materials distribution was not altered. However, the Manning's n parameters assigned to these layers were changed as part of the calibration process. Whilst this was appropriate for a predominately rural environment, in urban areas the planning scheme may provide a better basis for the delineation of the Manning's layer.

The representation of the structures in the Stage 1A model was reviewed and this review demonstrated that the openings of the bridges were broadly matched. However, no hydraulic losses were applied to account for piers and the like. Whilst this would not be appropriate for a detailed hydraulic study it is not appropriate for a regional method model.

Further, by not altering the materials or structure configurations it allows easier comparison to the results presented in Stage 1A.

However, modifications to the hydraulic model used in Stage 1A were required to facilitate the application of hydrologic boundaries from the URBS hydrologic model. These inflows were applied as distributed flows along the centreline of the waterways. The centrelines were determined using the software package CatchmentSIM, based on the WCMA LiDAR elevation dataset.

4.2.2 Joint Calibration

For Stage 1B a joint calibration process was undertaken whereby the outputs from the hydraulic model were used to refine the hydrologic model until an acceptable outcome was achieved.

4.2.2.1 January 2011 Calibration

Due to the nature of the hydraulic model there are limited 'levers' which can be pulled to facilitate calibration. As discussed above grid size was found to have an effect on the peak flows within the hydraulic model. For expedience and to aid backward comparison the 15m grid resolution was retained for the calibration.

The other 'lever' that can be readily adjusted in the hydraulic model is the Manning's n applied to the materials layers. This was the method undertaken for the calibration of the hydraulic model.

For the calibration of the hydraulic model the January 2011 event, the largest event on record, was selected.

Following an initial run of the January 2011 event, it was observed that approximately 10% of the inflow volume was not reaching the gauging station. This is due to the double counting of

depression storages in the hydrologic and hydraulic models as discussed in Section 3.4.2. When the hydraulic model resolution was decreased to 5m this loss decreased to 5% of the volume. To account for these losses the URBS hydrology model was rerun with 6mm less initial loss which resulted in volume difference at the gauge of less than 0.5%. All other URBS parameters were as presented in Table 4-2.

Similar to the process used to calibrate the URBS models above, an automated process was created that varied the Manning's n parameters within a certain bounds whilst optimising for the NSE coefficient. In this way the general shape of the hydrographs were matched not merely the peak flow rate.

The best fit hydraulic and hydrologic calibration results are presented along with the observed record in Figure 4-3. An NSE of 0.85 was achieved for the hydraulic calibration to the January 2011 event.

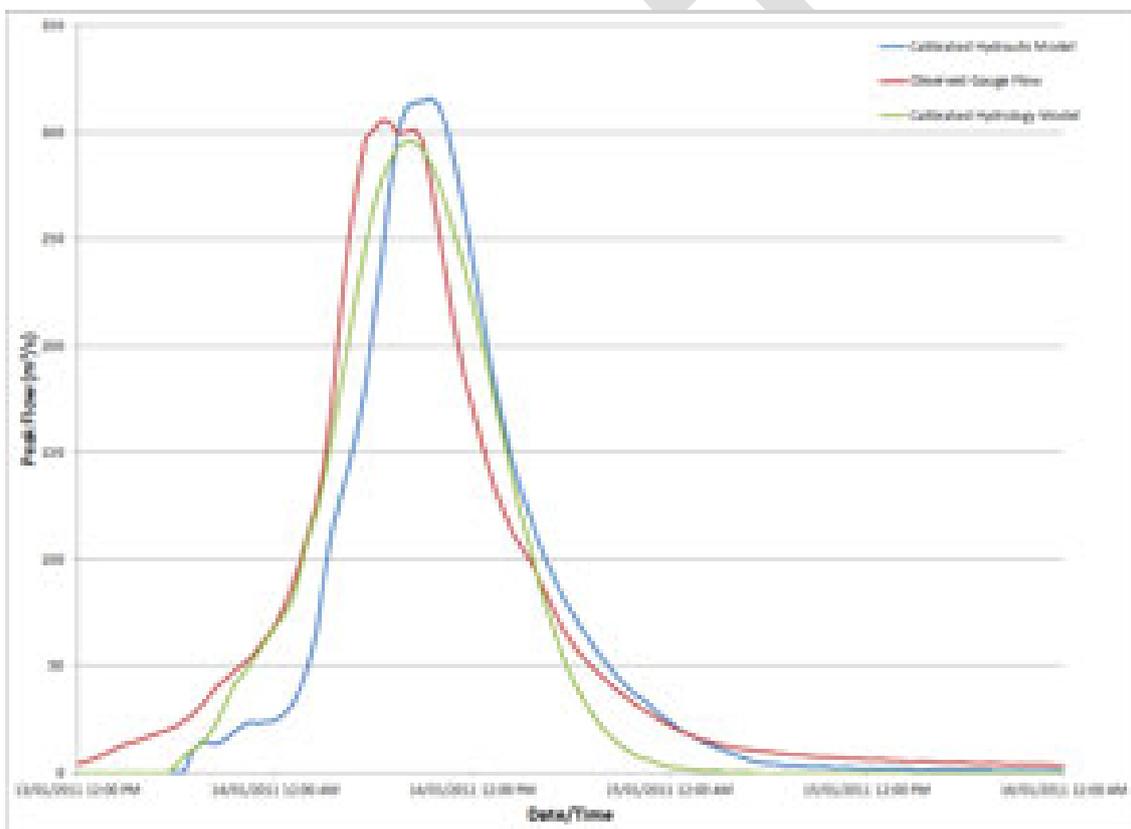


Figure 4-3 January 2011 Calibration

The parameters determined from the calibration process are presented in Table 4-4 below.

Table 4-4 Calibrated 2D Domain Manning's 'n' Coefficients

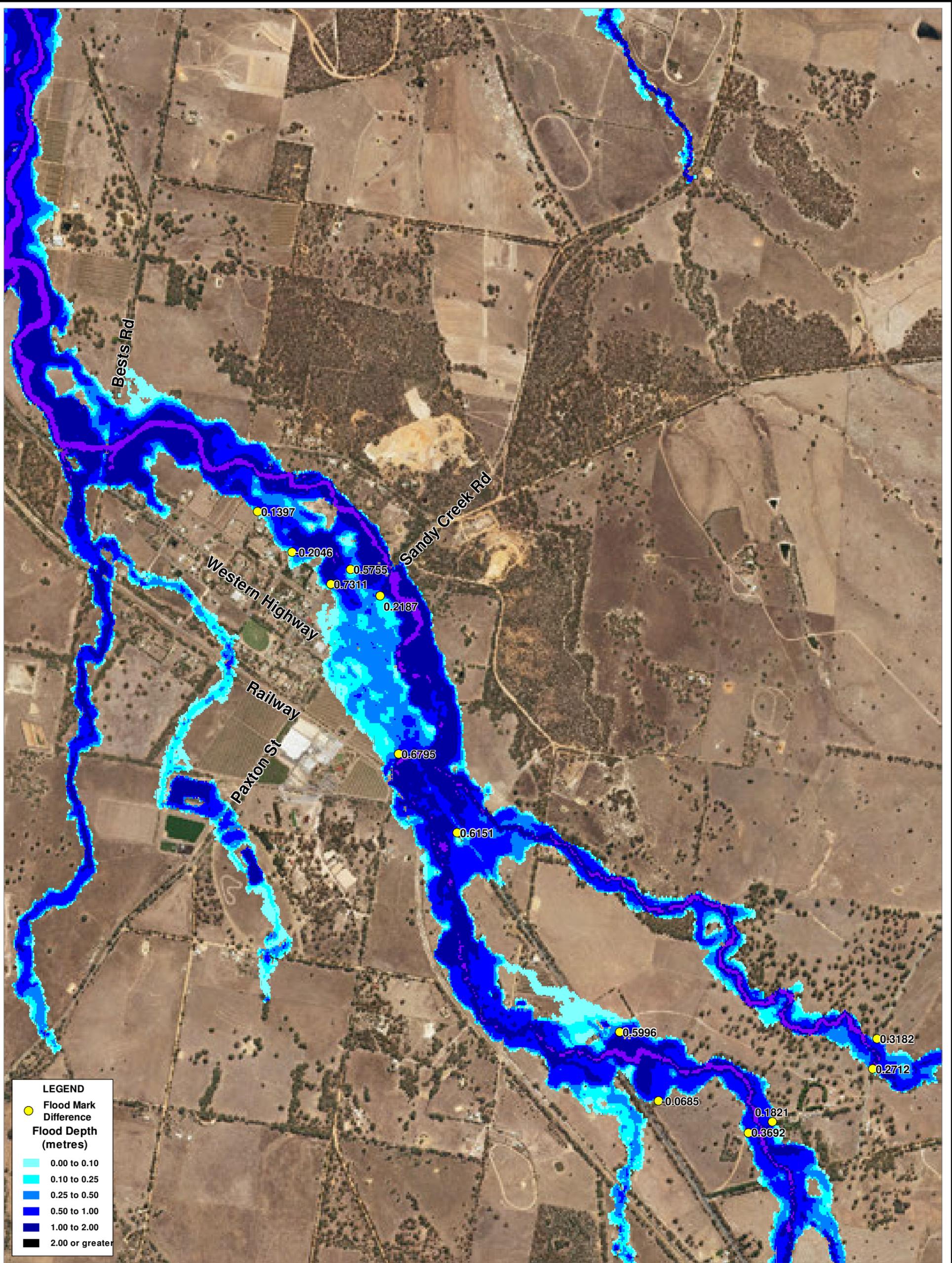
Land use	Manning's 'n'
Unmaintained grass/crops	0.055
Scattered Tree Cover	0.075
Medium Tree Cover	0.090
Dense Tree Cover	0.110

The Manning's n parameters presented in Table 4-4 are at the upper end of typical accepted values. These high Manning's values may be a consequence of the January 2011 event occurring at a time when there was dense vegetation within the catchment.

Flood Marks

A number of flood marks from the January 2011 flood event were captured by the WCMA. These flood marks as shown in Figure 4-4 together with the calibrated January 2011 flood extents. The values next to the flood marks are the difference between the modelled flood level and the flood mark level. In general, the hydraulic model has produced high flood levels compared with the flood marks. It should be noted that at this stage the hydraulic model has been calibrated to discharge not flood levels.

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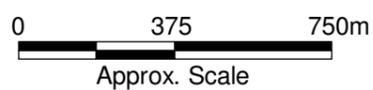


Title: **Regional Flood Mapping: Concongella Creek Pilot Study - Great Western**
 January 2011 - Calibrated TUFLOW with URBS Hydrology

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4.2.2.2 Design Event

With a suitably calibrated hydraulic model the URBS design events were calibrated to the peak flow estimates generated from the Adjusted RFFE as described in Section 3.4.1.2. This was undertaken as a joint calibration whereby the IL and CL were modified in the URBS model before being run through the hydraulic model. The peak flows at the various locations were then compared to those predicted by the Adjusted RFFE hydrology. The IL and CL losses were then refined and this process was iterated until an acceptable fit was achieved.

The URBS hydrology parameters are presented in Table 4-5 below. To account for the double counting of depression storage in the smaller events the initial loss was decreased.

Table 4-5 Concongella Creek Hydrology Design Event Calibration Values

AEP	alpha	M	IL	CL
20%	0.0128	0.77	20	3.0
10%			20	
5%			25	
2%			30	
1%			30	

The resulting peak flow comparison is presented in Table 4-6 below. In general, there is good agreement between the two methods presented in Table 4-6 for the less frequent events. Both methods also produce similar results at Bulgana Road, Landsborough Road and Navarre Road. However, the results at the Downstream end of Great Western and Concongella Creek - Wimmera River Junction are not as good particularly for the more frequent events.

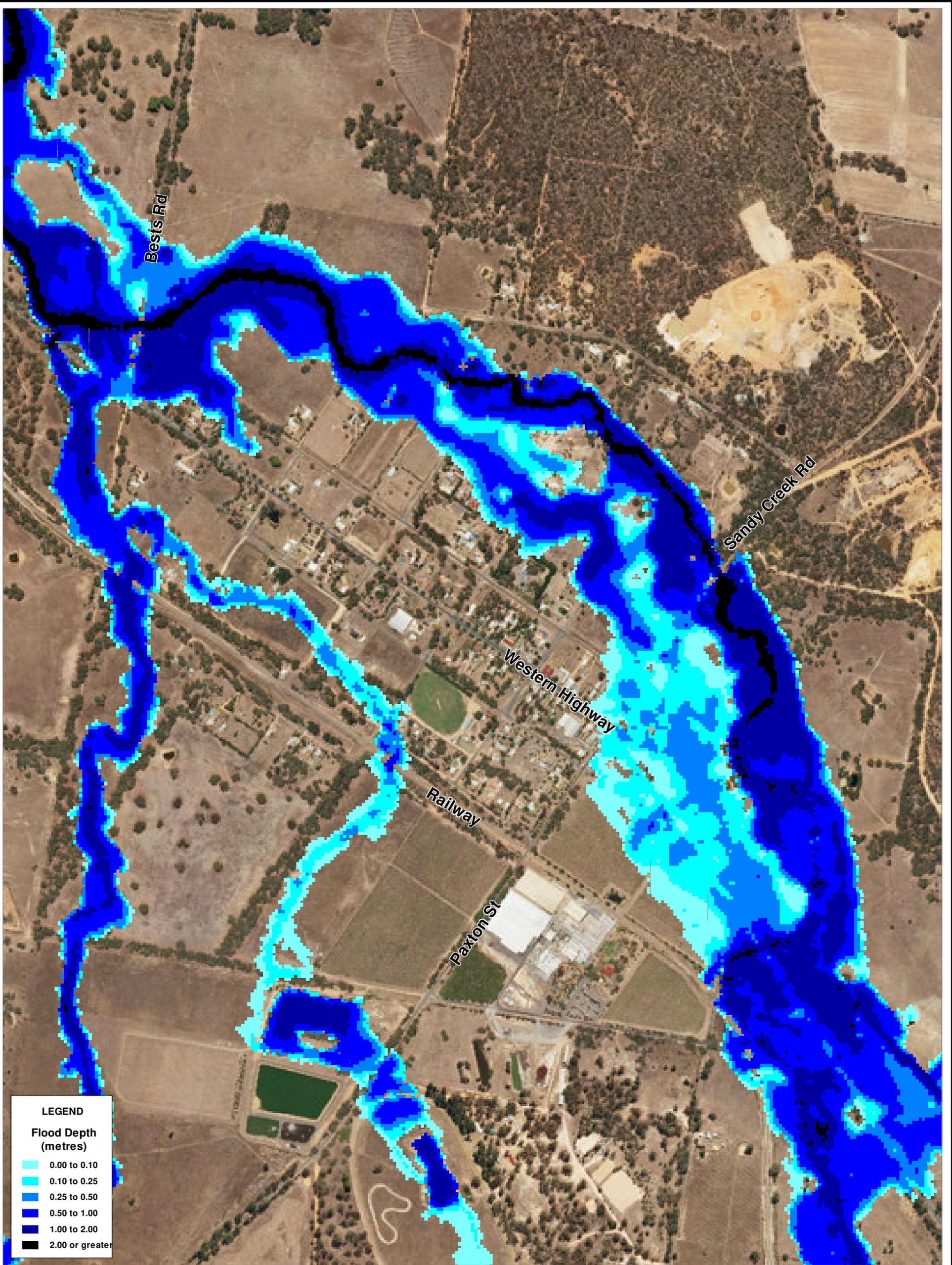
The poor results at Great Western are likely to be due to the lumped parameter selection whereas the poor results at Concongella Creek – Wimmera River confluence are due to attenuation which the regional method does account for.

Table 4-6 Hydraulic Model Design Flow Comparison (m³/s)

AEP		20%	10%	5%	2%	1%
Downstream end of Great Western	TUFLOW	53	79	105	104	128
	Adjusted RFFE	31	51	72	105	131
	% Dif	72%	56%	46%	-1%	-2%
Bulgana Road	TUFLOW	42	71	97	131	199
	Adjusted RFFE	39	63	90	130	163
	% Dif	7%	12%	8%	1%	22%
Landsborough Road	TUFLOW	48	83	117	169	241
	Adjusted RFFE	51	84	119	173	216
	% Dif	-6%	-1%	-2%	-2%	12%
Navarre Road (Concongella Gauge)	TUFLOW	46	81	113	170	258
	Adjusted RFFE	58	96	136	197	246
	% Dif	-21%	-16%	-17%	-14%	5%
Concongella Creek - Wimmera River Junction	TUFLOW	43	65	94	147	237
	Adjusted RFFE	72	117	167	242	302
	% Dif	-40%	-45%	-44%	-39%	-22%

4.2.2.3 Results and Mapping

As the Stage 1B hydraulic modelling was undertaken using centreline applied hydrology boundaries a filtering of the results was not required. The 1% AEP flood depth map in the area of Great Western is present in Figure 4-5.



LEGEND

Flood Depth (metres)

	0.00 to 0.10
	0.10 to 0.25
	0.25 to 0.50
	0.50 to 1.00
	1.00 to 2.00
	2.00 or greater

<p>Title:</p> <p>Regional Flood Mapping: Concongella Creek Pilot Study - Great Western</p> <p>1% AEP Flood Depths - Calibrated TUFLOW with URBS Hydrology</p>		<p>Figure:</p> <p>4-5</p>	<p>Rev:</p> <p>A</p>
<p>BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.</p>	<p>N</p> <p>0 200 400m</p> <p>Approx. Scale</p>	<p>BMT WBM</p> <p>www.bmtwbm.com.au</p>	
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4.3 Discussion, Recommendations and Conclusions

The traditional flood modelling approach has been applied in this stage to flood model the entire catchment. The traditional approach involves using a hydrologic model to characterise a catchments response to rainfall and the results from this model are then used this as input into a hydraulic model. In this case, the models have also been calibrated to known flood events.

Typically, when the traditional approach is calibrated the area that is being calibrated is relatively focused and only a small part of the overall catchment. However, this was not the case in this stage of the Study where the hydrologic model and hydraulic flood model were calibrated to different points in the catchment.

This method has produced reasonable results across the catchment for the 1% and 2% AEP events; however, for more frequent events the results have are not as good. In these more frequent events, the hydraulic model results in the upper catchment overestimate flow peaks while lower in the catchment they underestimate peak flows.

While the presented methodology results in reasonable flood maps there are a number of significant discussion points. These have been organised under the following headings:

- Hydrology Modelling; and
- Hydraulic Modelling

4.3.1 Hydrology Modelling

An URBS hydrologic model was built for this stage of the Study. The URBS model is a non-linear runoff-routing mode, that in this instance, has been applied semi-distributed model with lumped parameters. Given the relatively small catchment size this approach was considered to be appropriate, however the results suggest the model was more sensitive to this schematisation than anticipated.

4.3.1.1 Hydrology Model Schematisation

As discussed above, the hydrologic model was schematised as a lumped, runoff outing model which is generally considered appropriate for a small catchment such as Concongella Creek. However, the results presented in Table 4-5 and Table 4-6 indicate that, for this particular catchment, this may not be an appropriate assumption. It should be noted that hydrologic model such as URBS provide facilities to address this and allow parameters to be distributed on a sub-catchment basis.

In particular, the routing parameters α and m have been calibrated to produce the correct peak flow at the Concongella Creek gauge. While catchment's response to the gauge has been calibrated, it has not been calibrated to other locations in the catchment. This topic is discussed in URBS user manual which states:

It is worth noting that when calibration is achieved for a gauged location within the catchment, calibration of the summation of upstream flows is achieved, but to say any individual contribution is calibrated is fraught with danger.

Therefore, it should not simply be expected that a single set of model parameters determined for one location will produce the correct response at other locations. This can be particularly important in heterogeneous catchments.

It was also noted that more frequent events did not perform as well as less frequent events in terms of the percentage difference between hydrologic model results and Adjusted RFFE results. This could be due to the use of a single storage component as opposed to a split storage (split between channel and catchment storage).

The results presented above are particularly relevant to *Key Objective: Treatment of concurrent flooding across catchments in a basin*. These results highlight challenge of producing consistent AEP flooding across a catchment, even a relatively small catchment such as Concongella Creek.

Recommendations

Given the need to produce consistent AEP flood information across a catchment the use of a more sophisticated modelling approach should be investigated. This approach would involve the use of distributed parameters that are calibrated to flows at multiple locations throughout the catchment. Alternatively, the use of a Monte Carlo simulation approach would also address some of these issues and this will be completed as part of the next Stage of the Study.

4.3.1.2 Double Counting of Storage Loss

Given the use of both a hydrologic model and a hydraulic model there was the potential for the double counting of storage loss. In the hydrologic model an initial loss / continuing loss Loss model was used. In the hydraulic model storage loss is explicitly accounted for in the terrain representation in the hydraulic model (based on the DEM and the models grid size). For these reason there is the potential for the double counting of storage loss in both the hydrologic and hydraulic models.

This effect was noted during the model calibration stage as discussed in Section 4.2.2.1. To account for this effect it was necessary to reduce the initial loss in the hydrology model.

4.3.2 Hydraulic Modelling

With the exception of minor adjustments for structures and the Manning's values, the hydraulic model used in this stage (Stage 1B) was identical to the hydraulic model used in Stage 1A. The Manning's values were used as calibration parameters for the hydraulic model.

4.3.2.1 Manning's value

The calibrated Manning's values are considered to be near the upper bounds of acceptable limits. This is understood to be partly due to the time of year of the calibration event, January. In January and particularly January 2011 it is expected that the vegetation would have been mature and providing more resistance to flow and hence requiring higher Manning's values.

While the Manning's values are considered to be at the upper bounds of acceptable these values produce reasonable discharges compared with the Adjust RFFE method as shown in Table 4-6 for the majority of locations. However, while the flows are considered reasonable, the model flood levels in and around Great Western are higher than the surveyed flood marks. These flood level

can be significantly reduced by using typical Manning's values; however, the discharges at reporting locations are then significantly different to the Adjusted RFFE method.

Recommendations

There are a number of factors involved in the determination of the Manning's values including the calibration of the hydrologic model. That is, the overall flood model had a number of calibration parameters namely, the loss parameters (initial loss and continuing loss), the URBS routing parameters (*alpha* and *m*) and the Manning's values. As these parameters were individually calibrated it did not allow for feedback between the parameters and meant that parameters determined later in the process (Manning's *n*) were constrained by the parameters determined earlier in the process. To address this, a modelling framework that allows a full joint calibration would be recommended. It is of note that this will be partly addressed using a Monte Carlo Simulation such Stage 2.

4.3.3 Flood Mapping

Comparisons of the four flood modelling methodologies undertaken are presented in Figure 4-6. As discussed previously, there are greater flood depths in the vicinity of Great Western in the TUFLOW-URBS model results when compared to the three direct rainfall models. Though the overall flood extents are similar, due to the relatively well confined nature of the catchment in this area, the flood depths show noticeable differences.

There are a number of reasons for this, such as;

- Higher Manning's *n* values were used in the TUFLOW-URBS model as determined by the calibration process; and
- The concentration of hydrographs into the waterways.

Of these two reasons the concentration of flow is thought to be the primary cause. Whilst the various models may have similar total volumes applied, the direct rainfall models have a significant volume of water in off-line storages (as well as grid depressions) that do not connect to the main waterway or at least slow the ingress of water to the waterway leading to a decrease the flood peaks in Concongella Creek. Whereas in the TUFLOW-URBS model all the flows are applied directly to the waterways and therefore the ineffective flows areas within the catchment are not represented.

4.3.4 Conclusions

The application of a traditional flood modelling approach to catchment wide flooding mapping has been analysed in this stage of the Study. This this approach has resulted in reasonable flows throughout the catchment for design events and a good calibration to flow at the Concongella gauge. However, the calibration to flood marks in the vicinity of Great Western were generally high.

The analysis above has demonstrated that the flood model (hydrologic and hydraulic) should be calibrated to multiple locations throughout the catchment to ensure that the correct catchment response is modelled. This is necessary as the catchment response will vary throughout the catchment and there is no reason that a single set of hydrologic parameters should be suitable for

all locations throughout a catchment. This would require adjustments to the traditional modelling approach as discussed above including the use of semi-distributed parameters in the hydrologic model. It should also be noted that this would be a more time-consuming hydrologic model setup and calibration.

4.3.4.1 Comparison of modelling methodologies

A number of flood modelling methodologies have been undertaken as part of this stage (Stage 1) of the Study. Of these methodologies it is worthwhile to compare the Calibrate Direct Rainfall methods with the Traditional Flood Modelling method discussed in this section.

Both these methods produce reasonable results across the catchment when the peak flows are compared to the Adjusted RFFE peak flow results. However, it should be noted that only the Traditional Flood Modelling method was calibrated to historic events.

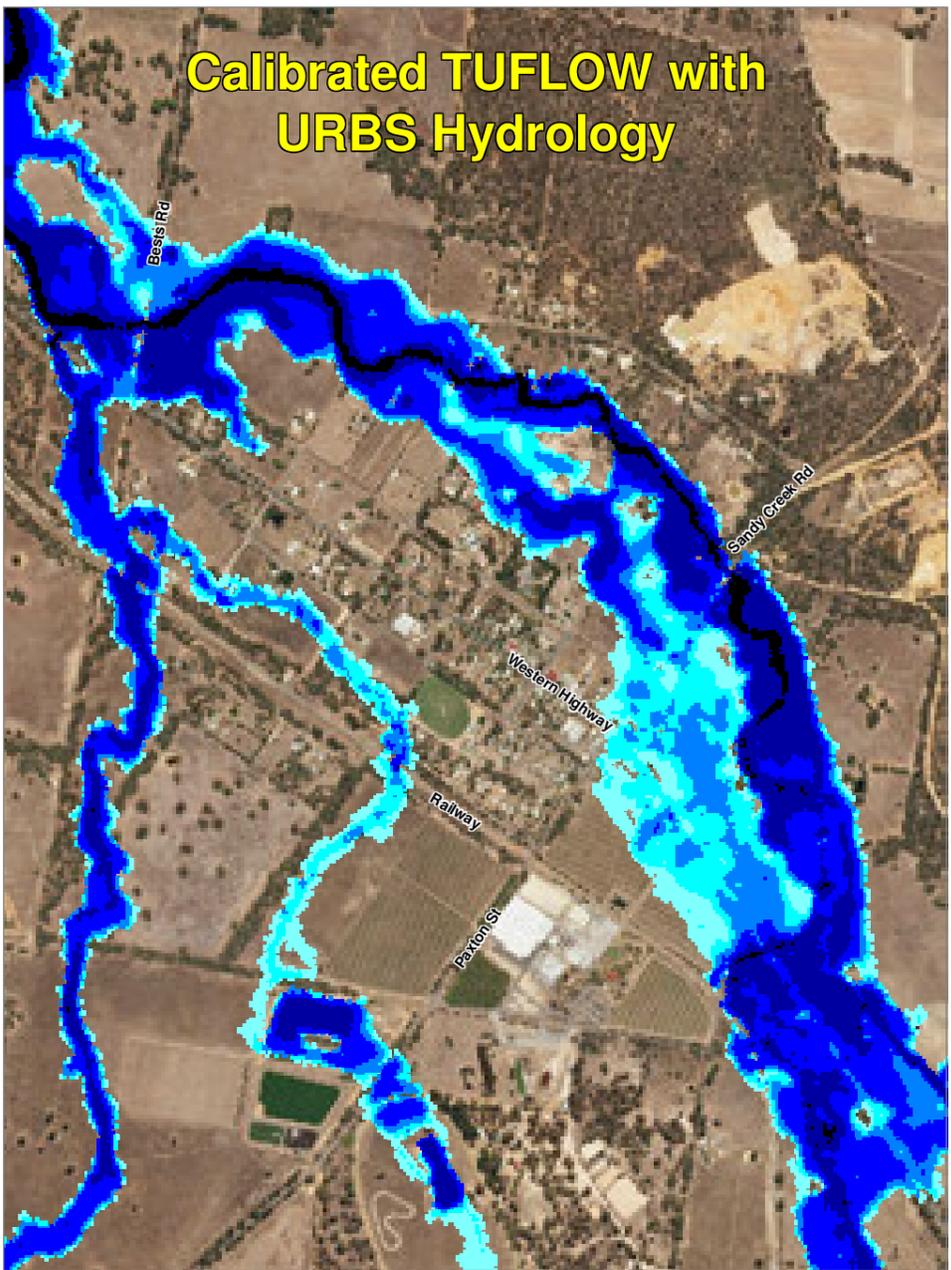
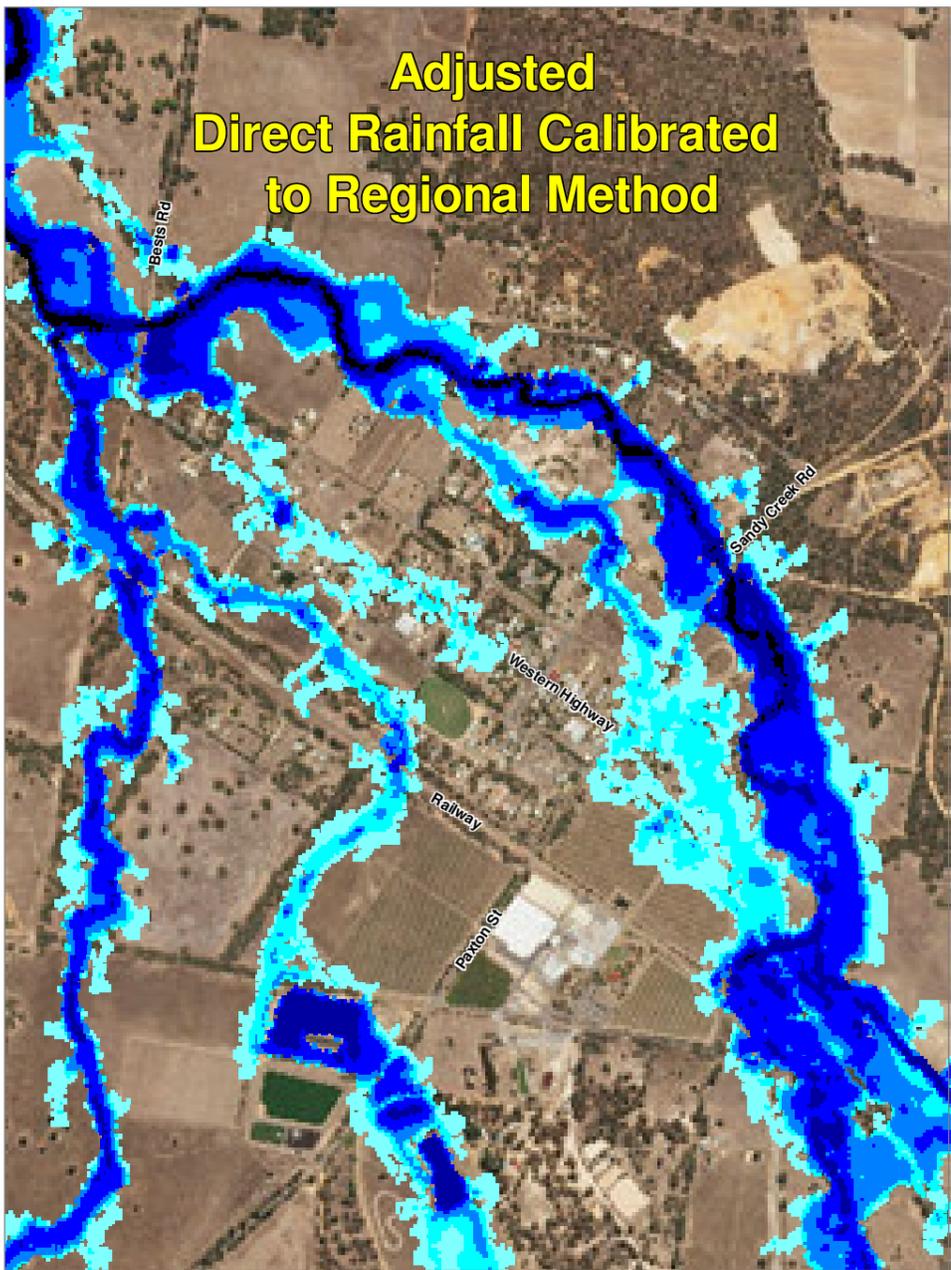
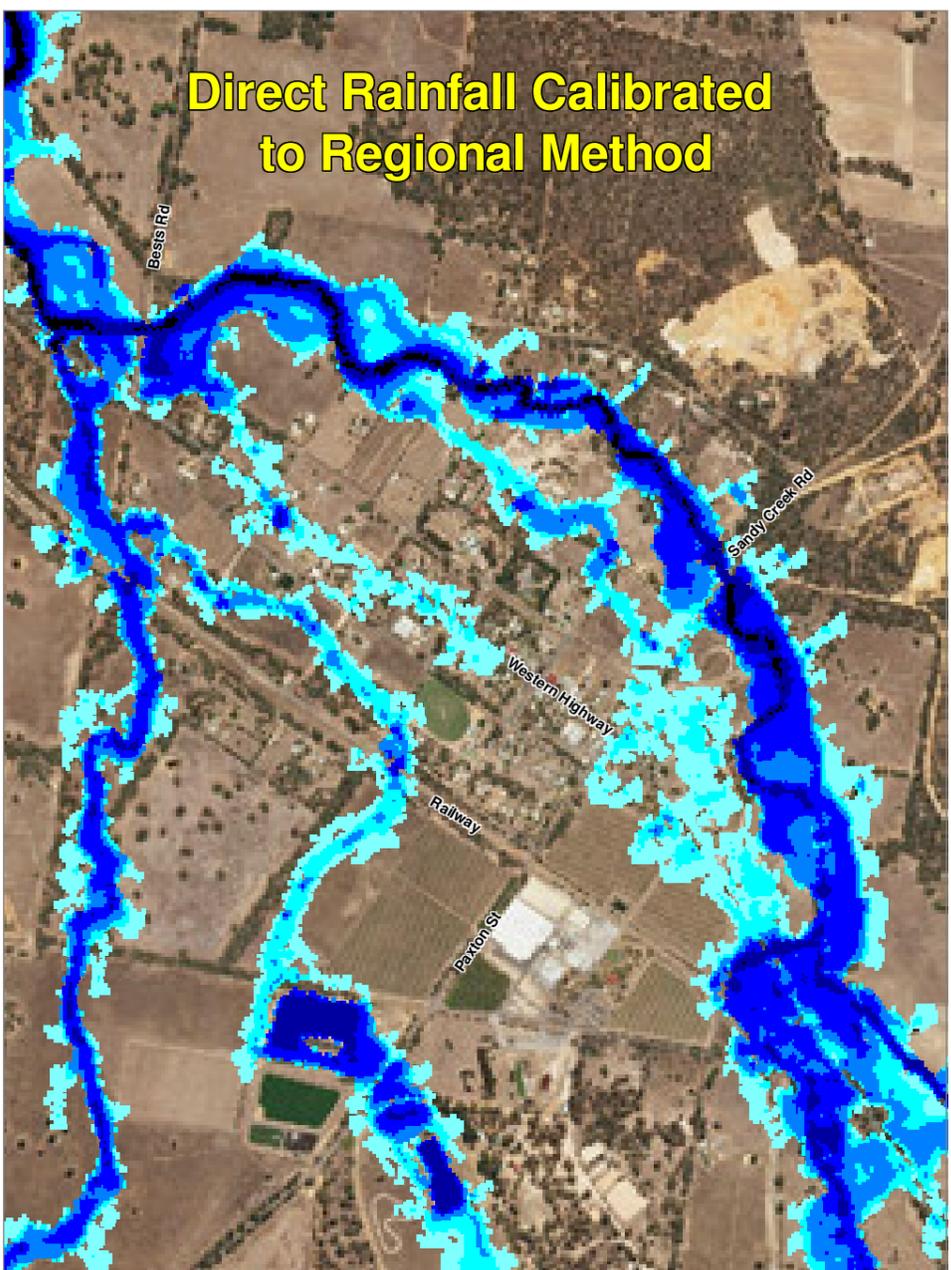
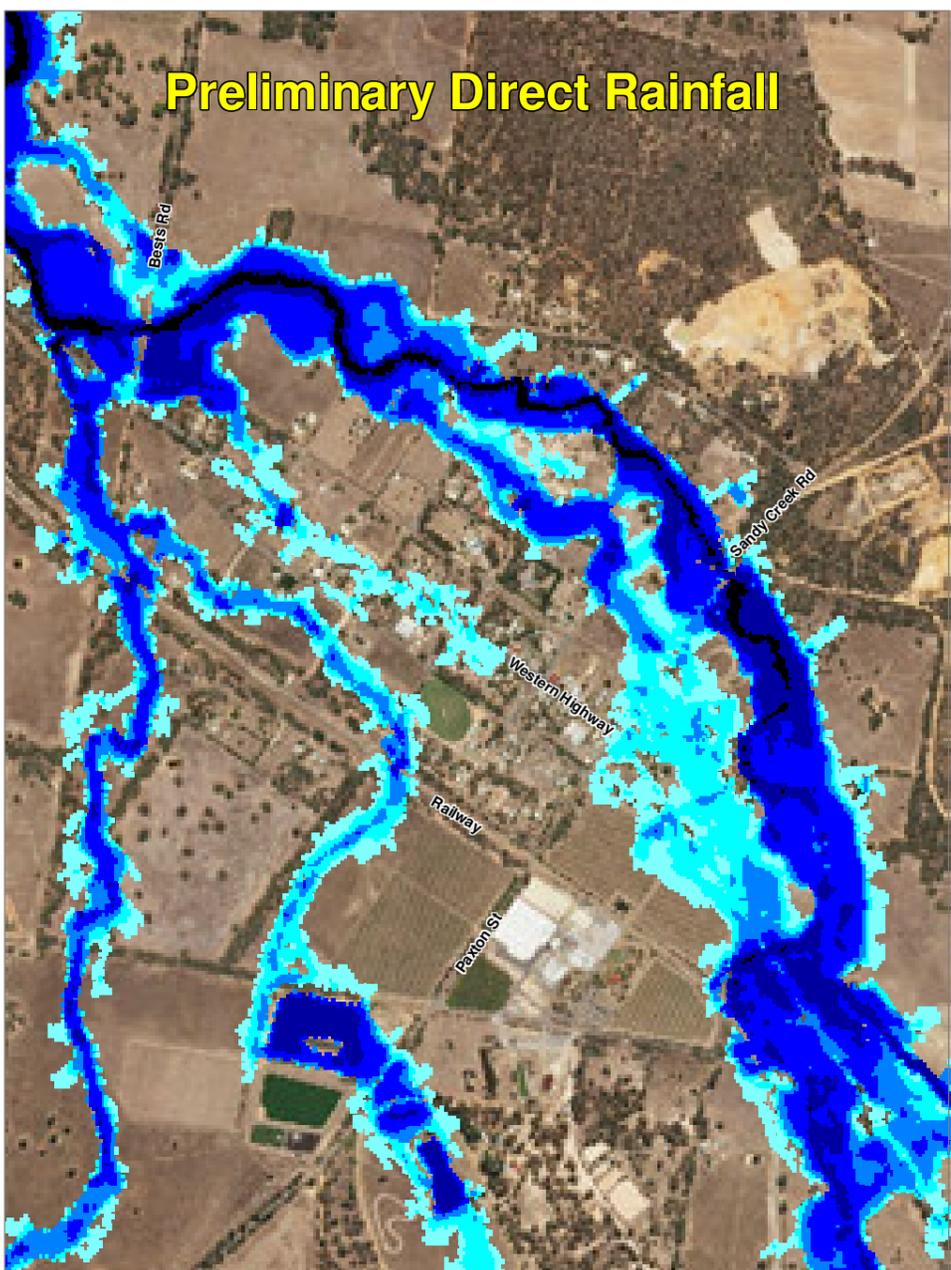
While both methods produced reasonable results the Traditional Method Produced results that were high in the vicinity of Great Western compared to the flood marks and Direct Rainfall Methods. It is understood that the two main reasons for this are:

- The concentration of flow into the waterway in the Traditional Approach (as discussed above); and
- The use of lumped (in the traditional method) versus distributed routing methods (in the direct rainfall method).

Both these methods produce reasonable results across the catchment when the peak flows are compared to the Adjusted RFFE peak flow results. However, it should be noted that only the Traditional Flood Modelling method was calibrated to historic events.

4.3.4.2 Recommendations

Given the aims of the Study are to produce catchment flood information for a variety of purposes and not site specific flood information, the resulting method needs to be applicable of wide area at a reasonable cost. The analysis undertaken here has demonstrated that the hydrologic modelling in the traditional approach may not achieve the aims of producing reliable flow information at various locations without undertaking a sophisticated hydrologic modelling approach. Such an approach is likely to be time-consuming and hence expensive. Conversely, the direct rainfall approaches outlined in Stage 1A have the potential to produce cost effect flood information suitable for the purposes of the study. However, this is an emerging field and there are a number of potential issues that need further work. Furthermore, it is considered essential that this method is calibrated at the very minimum to peak flow estimates. For these reasons the direct rainfall approach is recommended as the more appropriate method for the objectives of the Study.



Title: **Regional Flood Mapping: Concongella Creek Pilot Study - Great Western
1% AEP Flood Depths - Model Technique Comparison**

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