Upper Oxley Creek Flood Study

Flood Study Report

Logan City Council
1809-01-I2, 27 September 2023

Report Title	Upper Oxley Creek Flood Study Flood Study Report
Client	Logan City Council Logan QLD 4740
Report Number	1809-01-I2

Revision Number	Report Date	Report Author	Reviewer
2	27 September 2023	JF	AN/RC

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1 Introduction

1.1 BACKGROUND

Logan City Council (LCC) engaged WRM Water and Environment Pty Ltd (WRM) to develop and calibrate hydrologic and hydraulic models of the Upper Oxley Creek catchment. These models will be used by LCC as tools to estimate design discharges, flood levels, depths, velocities and flood hazard along Upper Oxley Creek and its tributaries within the LCC Local Government Area (LGA).

LCC engaged WRM to undertake the following:

- Set up and calibrate an URBS hydrologic and TUFLOW hydraulic model against available data for the January 2013, May 2015, March 2017 and February 2022 flood events; and
- Use the calibrated models to produce design discharge hydrographs, flood levels, depths, velocities and flood hazard maps for the 50% (1 in 2), 20% (1 in 5), 10% (1 in 10), 5% (1 in 20), 2% (1 in 50), 1% (1 in 100), 0.5% (1 in 200), 0.2% (1 in 500) and 0.05% (1 in 2,000) annual exceedance probability (AEP) design events as well as the Probable Maximum Precipitation Flood (PMPF) event for the current climate (2023) rainfall estimates.
- Apply the Future Climate (2090) estimates of rainfall to produce the design discharge hydrographs, flood levels, depths, velocities and flood hazard maps for the 20% (1 in 5), 10% (1 in 10), 5% (1 in 20), 2% (1 in 50), 1% (1 in 100), 0.5% (1 in 200) and 0.2% (1 in 500) annual exceedance probability (AEP) design events; and
- Undertake design event hydrologic and hydraulic modelling in accordance with the 2019 Australian Rainfall and Runoff guideline (ARR 2019) (Ball et al, 2019).

This report describes the configuration and calibration of the Upper Oxley Creek hydrologic and hydraulic models, and the use of the calibrated models to produce estimates of design discharges as well as peak flood levels, depths, velocities and flood hazard.

1.2 UPPER OXLEY CREEK CATCHMENT DESCRIPTION

Within the LCC LGA, the Upper Oxley Creek catchment drains in a northeasterly direction from its headwaters at the Flinders Peak Conservation Park to Johnson Road. The catchment area of Upper Oxley Creek to Johnson Road is approximately 11,456 ha and includes the suburbs of Lyons, New Beith, Greenbank, Forestdale and Boronia Heights. Oxley Creek discharges to the Brisbane River approximately 18 km downstream of Johnson Road.

Blunder Creek, a tributary of Oxley Creek, flows in a northeasterly direction parallel to and to the west of Oxley Creek through the suburb of Greenbank. Blunder Creek has a catchment area of approximately 1,416 ha to Johnson Road. Blunder Creek discharges to Oxley Creek approximately 9 km downstream of Johnson Road. A minor tributary of the Oxley Creek, referred to as the “Eastern Tributary” flows in a northerly direction through the residential areas of Forestdale and has a catchment area of approximately 104 ha to Johnson Road.

The Oxley Creek and Blunder Creek catchments downstream of Johnson Road are within the Brisbane City Council (BCC) LGA.

The topography of the upper catchment is characterised by hill terrain and valleys. The middle and lower sections of the catchment are characterised by wide and flat floodplains along the creek. catchment elevations vary from approximately 310 mAHD in the Flinders Peak Conservation Park to less than 20 mAHD at Johnson Road.

Land use in the upper (southwestern) half of the catchment is primarily forest/ conservation and rural uses. The middle part of the catchment (around New Beith and Greenbank) consists primarily of rural residential lots. The Greenbank Military Range, which is mainly forest, occupies most of the catchment between Goodna Road and Johnson Road. There are also existing rural residential lots at the northeastern part of the catchment within the suburbs of Forestdale and Boronia Heights. Several new residential developments are currently being constructed in Greenbank.

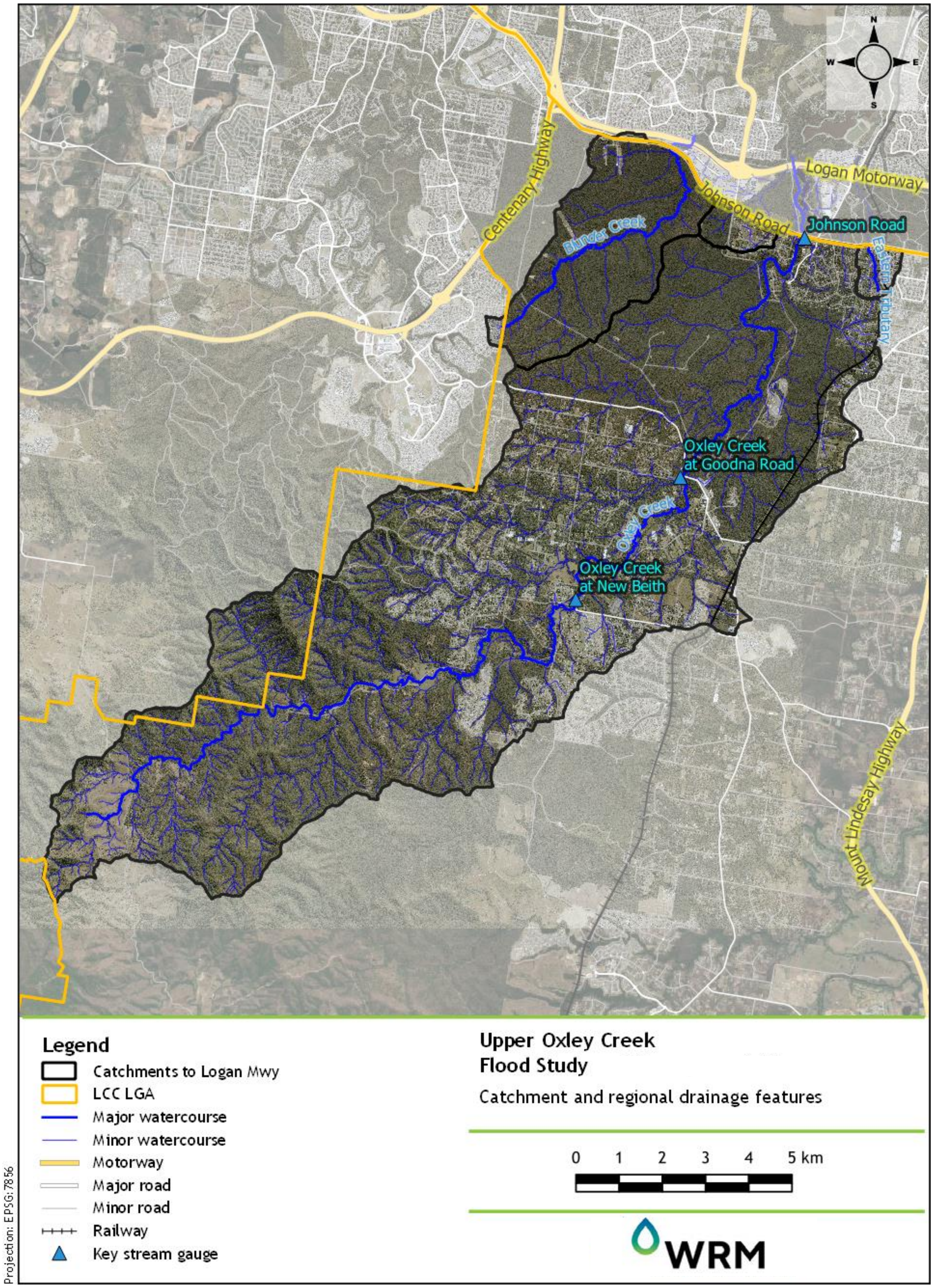


Figure 1.1 - Upper Oxley Creek catchment and regional drainage features

2 Study methodology

2.1 HYDROLOGIC MODEL DEVELOPMENT

An URBS rainfall runoff routing model (URBS Software, 2021) was developed for the catchment of Upper Oxley Creek to the Logan Motorway. The URBS hydrologic model was calibrated against the January 2013, May 2015, March 2017, and February 2022 flood events. The aim of the calibration was to match predicted peak discharges with rated peak discharges at the following stream gauges (if data is available) (see Figure 1.1 for locations):

- Oxley Creek at New Beith AL (GS 540097/GS 14033A);
- Oxley Creek at Oxley Creek AL (GS 540646); and
- Oxley Creek at Johnson Road (GS 040788).

2.2 HYDRAULIC MODEL DEVELOPMENT

A TUFLOW two-dimensional (2D) hydrodynamic model (BMT, 2019) was developed for Upper Oxley Creek and its tributaries upstream of the Logan Motorway. The hydraulic model includes embedded one-dimensional (1D) elements such as culverts, trunk stormwater pipes and stormwater inlet pits. The hydraulic model covers the entire Oxley Creek catchment upstream of the Logan Motorway.

The following two TUFLOW models were developed for this study:

- 'Fast Model' - This model was configured with a grid cell size of 9 m. The purpose of this model is to allow the selection of critical ARR 2019 design storms, which will then be simulated using the 'Detailed Model'.
- 'Detailed Model' - This model was configured with a grid cell size of 3 m. The purpose of this model is to run the critical design storms selected using the 'Fast Model' to obtain the design outputs.

The grid cell size of 9 m (a multiple of 3 m) for the fast model was selected to ensure compatibility of the 2D/1D connections with different model grid cell sizes. That is, it ensures that the same 2D/1D connections can be used for both the fast and detailed models.

Both the 'Fast Model' and the 'Detailed Model' were calibrated to match recorded water levels for the January 2013, May 2015, March 2017, and February 2022 flood events at the New Beith AL, Oxley Creek AL and Johnson Road stream gauging stations (where data is available).

2.3 MODEL CALIBRATION

Predicted inflow hydrographs from the hydrologic model were used as input to the hydraulic model. The resulting water level hydrographs from the hydraulic model were compared with recorded water level hydrographs at the recorded stream gauges for each of the historical events. Rating curves for stream gauges were combined with the results of the TUFLOW model to allow calibration of the hydrologic model.

For the January 2013 and May 2015 flood events, the predicted peak water levels from the hydraulic model were also compared against surveyed peak flood levels across the Upper Oxley Creek floodplain.

The calibration approach allowed the suitability of the discharges estimated by the hydrologic model to be confirmed, as well as testing the performance of the hydraulic model. The hydrologic and hydraulic model calibration is presented in Sections 5 and 7 of this report.

2.4 DESIGN DISCHARGE ESTIMATION

The calibrated hydrologic model was used to estimate design discharges in the Upper Oxley Creek and Blunder Creek catchments for the 50% (1 in 50), 20% (1 in 5), 10% (1 in 10), 5% (1 in 20), 2% (1 in 50), 1% (1 in 100), 0.5% (1 in 200), 0.2% (1 in 500) and 0.05% (1 in 2,000) AEP design events and the PMPF event. The calibrated hydraulic model was used to estimate design flood levels, depths and velocities along Upper Oxley Creek and its tributaries for the ten specified events.

Design event hydrology was undertaken in accordance with ARR 2019 (Ball et al, 2019) guidelines. A summary of the proposed design event hydrologic and hydraulic modelling methodology and inputs is provided in Section 9 of this report.

The hydrologic model design event discharges were reconciled against FFA estimates at the Oxley Creek at New Beith AL (GS 540097/GS 14033A) gauge.

2.5 ESTIMATION OF DESIGN FLOOD LEVELS, DEPTHS, VELOCITIES AND FLOOD HAZARD

The calibrated hydraulic model was used to estimate design flood levels, depths and velocities along Upper Oxley Creek, Blunder Creek, and their tributaries for the ten specified events ranging from the 50% AEP to the PMPF event. The hydraulic model was configured to produce maximum water surface levels, depths, velocities, depth-velocity products, and flood hazard outputs for each design event simulation.

The 'ensemble' method of design event modelling described in the AR&R 2019 requires simulating an 'ensemble' of 10 design storms for each duration for each event. This equates to a large number of hydraulic model simulations which cannot be completed within a reasonable timeframe using the 'detailed model'.

The coarser 'fast model' is designed to run significantly faster than the 'detailed model'. The 'fast model' was used to simulate all 10 design storm ensembles for each duration in each event. An 'asc_to_asc' utility (a TUFLOW post-processing tool) was then used to extract the mean depths, water levels, velocities and flood hazards for each cell in the model for each design event and storm duration. The 'asc_to_asc' utility also identifies which design storms would produce the mean results for each event. These design storms were then selected as the 'representative design storms'.

The finer 'detailed model' was used to simulate the 'critical design storms' selected using the 'Fast Model'. The 'asc_to_asc' utility was then be used to process the design flood surface grids for the critical design storms and produce 'max-max' flood surface grids (water surface levels, depth, velocities, depth-velocity products and flood hazard) for each event. These 'max-max' flood surface grids obtained from the 'fast model' were adopted as the final design outputs for this study.

3 Available data

3.1 PREVIOUS STUDIES

3.1.1 Oxley Creek Flood Study (Aurecon, 2013)

Aurecon Pty Ltd (Aurecon) developed an XP-RAFTS hydrologic and a TUFLOW hydraulic model of the Oxley Creek catchment as part of the Oxley Creek Flood Study undertaken for LCC in 2013 (Aurecon, 2013) to inform Council's flood hazard overlay and Planning Scheme 2015. The study area extended from the Oxley Creek headwater near Flinders Peak in Beaudesert Shire to the creek's confluence with the Brisbane River at Graceville.

The Aurecon (2013) hydrologic model was calibrated to the May 1996 and April 1990 historic events and validated against the May 2009 flood event. The hydraulic model was calibrated to the May 1996 event and validated against the May 2009 event. The Aurecon (2013) models were used to estimate peak design discharges for a range of events up to and including the PMF event and climate change scenarios.

3.1.2 Oxley Creek Flood Study (Aurecon, 2014)

Aurecon also undertook the Oxley Creek Flood Study for Brisbane City Council (BCC) in 2014 (Aurecon, 2014). This study was undertaken using the Aurecon (2013) hydrologic and hydraulic models which were adapted for use in the BCC LGA.

3.1.3 New Beith Road Hydraulic Assessment (WRM, 2018)

LCC engaged WRM to undertake concept design and hydraulic modelling for the upgrade of New Beith Road, including two upgraded waterway crossings. WRM used the Aurecon (2013) XP-RAFTS and TUFLOW models (supplied by LCC) to develop concept designs for two upgraded culverts crossings that resulted in no worsening of flooding outside of the LCC controlled waterway corridor area, or LCC held land parcels.

Data from this study was incorporated in the current flood study.

3.2 AERIAL PHOTOGRAPH

Aerial photographs of the Upper Oxley Creek catchment were provided by LCC for the year 2020 and the year 2022. Aerial photographs for the catchment were also obtained from Google Map, Queensland Globe and/or Near map.

3.3 TOPOGRAPHIC DATA

Figure 3.1 show the extents of available topographic data for this study. This data was used to generate a digital elevation model (DEM) for modelling and mapping purposes.

LCC provided LiDAR survey data flown in 2017, which covers the majority of the Upper Oxley Creek catchment upstream of Johnson Road within the LCC LGA. This data is referred to in this report as the LCC 2017 LiDAR data. LCC also provided LiDAR survey data flown in 2021, which is referred to in this report as the 2021 LiDAR data.

The LCC 2017 and 2021 LiDAR data cover areas that are within the LCC LGA. For areas outside of the LCC LGA (within the Oxley Creek catchment) that are not covered by the LCC 2017 and 2021 LiDAR data, the following additional topographical data were obtained from the Queensland Government's ELVIS spatial information services:

- LiDAR data flown in 2014 which cover the Ipswich City Council (ICC) LGA area within the catchment. This data is referred to in this report as the ICC 2014 LiDAR data;

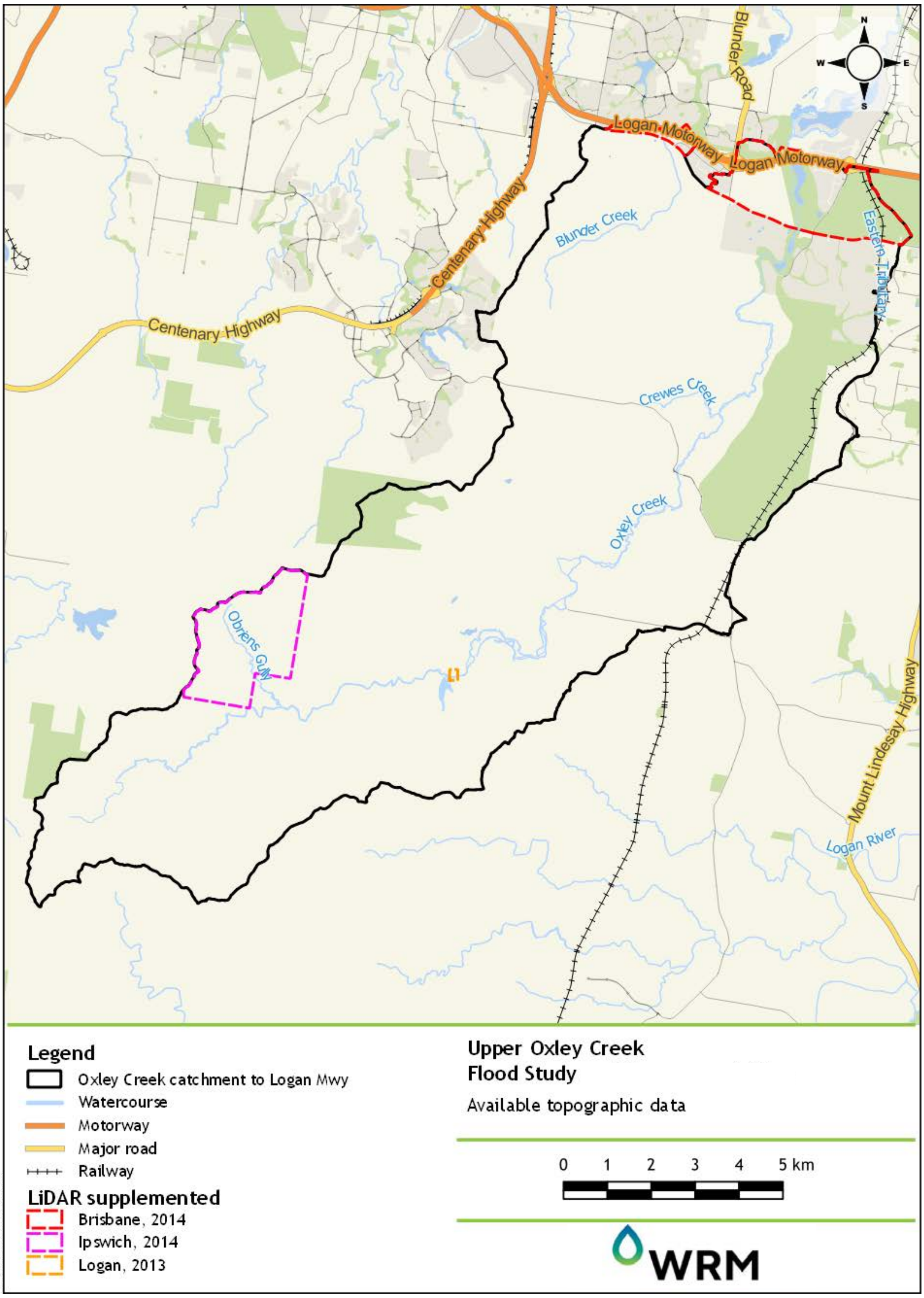


Figure 3.1 - Available topographic datasets

- LiDAR data flown in 2014 which cover BCC LGA area downstream of Johnson Road. This data is referred to in this report as the BCC 2014 LiDAR
- LiDAR data flown in 2013 covering a small area in the vicinity of the Spring Mountain Drive Bridge and the adjacent culverts (in the LCC LGA). This data is referred to in this report as the LCC 2013 LiDAR and was used in the hydraulic model for the January 2013, May 2015 and March 2017 hydraulic model calibration runs.

Bathymetric survey data for the Oxley Creek channel is not available for this study.

3.4 COUNCIL'S GIS DATABASE OF HYDRAULIC STRUCTURES

LCC supplied WRM with a GIS database of hydraulic structures in ESRI shape file format. The data contains detailed mapping of hydraulic structures including culverts, trunk stormwater pipes, stormwater inlet pits and manholes located throughout the Upper Oxley Creek catchment. The data also contains key details for the majority of these hydraulic structures including dimensions and invert levels.

This data was also used to configure the culverts, trunk stormwater pipes, inlet pits and manholes in the hydraulic model. This data was also used to refine the hydrologic model subcatchment delineation, particularly in the more urbanised areas of the catchment.

Historic data was provided for four structures along New Beith road prior to the road upgrade and used to configure the calibration model.

3.5 AS-CONSTRUCTED DRAWINGS

As-constructed drawings were provided by LCC for two culverts at the Covella Estate (Greenbank) and two culverts at the Spring Mountain Acreage Estate (New Beith). This data was used to configure these culverts in the TUFLOW model.

3.6 HYDRAULIC STRUCTURE SURVEY (2022)

LCC undertook site survey on a total of 89 culverts throughout the Upper Oxley Creek and Blunder Creek catchments. The survey was undertaken to obtain dimensions, invert levels, road deck levels, guard rail configurations and photos of these structures. The results of this survey supplemented the information in Council's hydraulic structures database which were either missing or incomplete.

LCC also undertook site survey and obtained photographs of 9 bridges throughout the Upper Oxley Creek catchment. This was done to confirm the road deck levels, deck thicknesses, pier configurations and guard rail heights of these bridges.

The survey results were supplied to WRM in a spreadsheet with accompanying photos. The data was used to configure the hydraulic structures in the Upper Oxley Creek TUFLOW model for the current study, and to inform the delineation of the catchments for the URBS model.

3.7 WRM SITE VISIT

WRM inspected a total of 37 culvert crossings and 8 bridges located throughout the Upper Oxley Creek catchment to determine the configuration of culverts (size and number of barrels) and bridges (deck thicknesses, pier configurations and guard rail heights) at these locations. The information obtained from the site visit was verified against other available data, and then used to configure the hydraulic structures in the Upper Oxley Creek TUFLOW model.

3.8 ARTC STRUCTURES

An existing rail track operated by Australian Rail Track Corporation (ARTC) runs from north to south along the eastern section of the Upper Oxley Creek catchment (between Forestdale and Greenbank). ARTC provided details for a total of 11 hydraulic structures within this section of the rail track. This data was used to configure these structures in the TUFLOW model.

3.9 RAINFALL DATA

Historical rainfall data from Commonwealth Bureau of Meteorology (BoM) stations was provided by LCC and/or obtained from BoM's Climate Data Online database for the January 2013, May 2015, March 2017 and February 2022 events.

Table 3.1 shows the available pluviograph (sub-daily) and daily rainfall data from rainfall stations within and in the vicinity of the Upper Oxley Creek catchment for the January 2013, May 2015, March 2017 and February 2022 events. Figure 3.2 shows the locations of these pluviograph and daily rainfall stations.

Table 3.2 shows the total rainfall depths recorded at each rainfall station during each of the four historical events. Figure 3.3, Figure 3.4, Figure 3.5, and Figure 3.6 show the recorded cumulative rainfall depths at the available pluviograph stations for the January 2013, May 2015, March 2017 and February 2022 events, respectively.

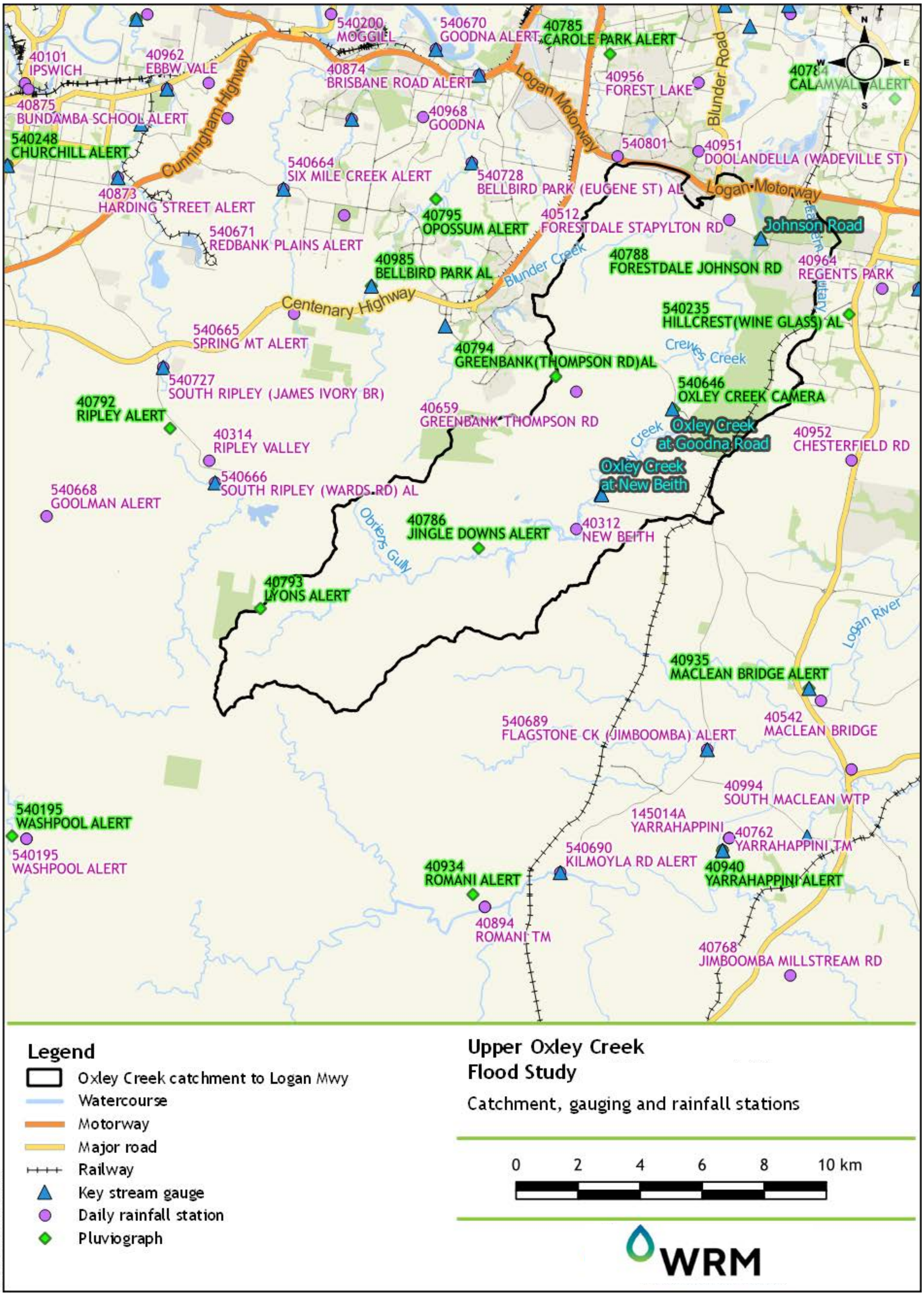


Figure 3.2 - Available rainfall and stream gauging stations

Table 3.1 - Rainfall data availability

<table>
<tr><th>Station no.</th><th>Station name</th><th>January 2013</th><th>May 2015</th><th>March 2017</th><th>February 2022</th></tr>
<tr><td colspan="6"><u>Pluviograph stations</u></td></tr>
<tr><td>40786</td><td>Jingle Downs Alert</td><td>X</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>40788</td><td>Forestdale (Johnson Rd) AL</td><td>X</td><td>X</td><td>✓</td><td>✓</td></tr>
<tr><td>40793</td><td>Lyons Alert</td><td>✓</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>40794</td><td>Greenbank Thompson Rd Alert</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>40935</td><td>Maclean Bridge AL</td><td rowspan="4" colspan="3">Not used [a]</td><td>✓</td></tr>
<tr><td>40985</td><td>Bellbird Park AL</td><td>✓</td></tr>
<tr><td>540065</td><td>Peak Crossing AL</td><td>✓</td></tr>
<tr><td>540195</td><td>Washpool AL</td><td>✓</td></tr>
<tr><td>540235</td><td>Hill Crest (Wine Glass) Alert</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>540646</td><td>Oxley Creek Alert (Goodna Road)</td><td>X</td><td>X</td><td>✓</td><td>✓</td></tr>
<tr><td>540666</td><td>South Ripley (Wards Rd) AL</td><td rowspan="3" colspan="3">Not used [a]</td><td>✓</td></tr>
<tr><td>540689</td><td>Flagstone Ck AL</td><td>✓</td></tr>
<tr><td>540690</td><td>Kilmoyla Rd AL</td><td>✓</td></tr>
<tr><td>540801</td><td>Rachele Close, Forest Lake</td><td>X</td><td>X</td><td>X</td><td>✓</td></tr>
<tr><td colspan="6"><u>Daily Rainfall Stations</u></td></tr>
<tr><td>40312</td><td>New Beith</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>40659</td><td>Greenbank Thompson Rd</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>40788</td><td>Forestdale (Johnson Rd) AL</td><td>✓</td><td>X</td><td>✓</td><td>✓y</td></tr>
<tr><td>40793</td><td>Lyons Alert</td><td>✓</td><td>✓</td><td>X</td><td>X</td></tr>
<tr><td>40951</td><td>Doolandella (Wadeville St)</td><td>✓</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>40964</td><td>Regents Park</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
</table>

[a] - Data may be available for the January 2013, May 2015 and March 2017 events, but were not used and were not required because adequate calibration results for these events were achieved without using additional data from these seven gauges.

There were seven pluviograph stations for which data may be available for the January 2013, May 2015 and March 2017 flood events. However, data from these stations were not used for these three events because they are located outside of the Upper Oxley Creek catchment and were not required as there was not a significant variation in rainfalls for these events around the outer extent of the catchment. Further, the hydrologic and hydraulic model calibration results for the January 2013, May 2015 and March 2017 events were found to be adequate without using additional data from these seven gauges.

Table 3.2 - Recorded event rainfall totals

Station no.	Station name	Recorded event rainfall total (mm)			
		January 2013	May 2015	March 2017	February 2022
Pluviograph stations					
40786	Jingle Downs Alert	- [na]	173.99	245.97	513 [dP]
40788	Forestdale (Johnson Rd) AL	- [na]	- [na]	300.71	734
40793	Lyons Alert	397.4	- [na]	- [f]	- [f]
40794	Greenbank Thompson Rd Alert	348.02	192.01	285.98	702
40935	Maclean Bridge AL	- [not used]			583
40985	Bellbird Park AL				578
540065	Peak Crossing AL				446
540195	Washpool AL				501
540235	Hill Crest (Wine Glass) Alert	257.01	236.97	270.98	732
540646	Oxley Creek Alert (Goodna Road)	- [na]	- [na]	306.06	659
540666	South Ripley (Wards Rd) AL	- [not used]			518
540689	Flagstone Ck AL				560
540690	Kilmoyla Rd AL				574
540801	Rachele Close, Forest Lake	- [na]	- [na]	- [na]	658
Daily Rainfall Stations					
40312	New Beith	326	177.6	283.4	631.4
40659	Greenbank Thompson Rd	310.2	188.2	274.4	559 [e]
40788	Forestdale (Johnson Rd) AL	296	- [na]	- [p]	- [p]
40793	Lyons Alert	- [p]	139.4	- [f]	- [f]
40951	Doolandella (Wadeville St)	280	- [na]	- [na]	- [na]
40964	Regents Park	300	206.4	242.8	691.8

[na] - no available data

[e] - excluded from analysis

[f] - station failed during the event

[d] - applied as daily data

[p] - pluviography data available

[not used] - Data may be available for the January 2013, May 2015 and March 2017 events, but were not used and were not required because adequate calibration results for these events were achieved without using additional data from these seven gauges.

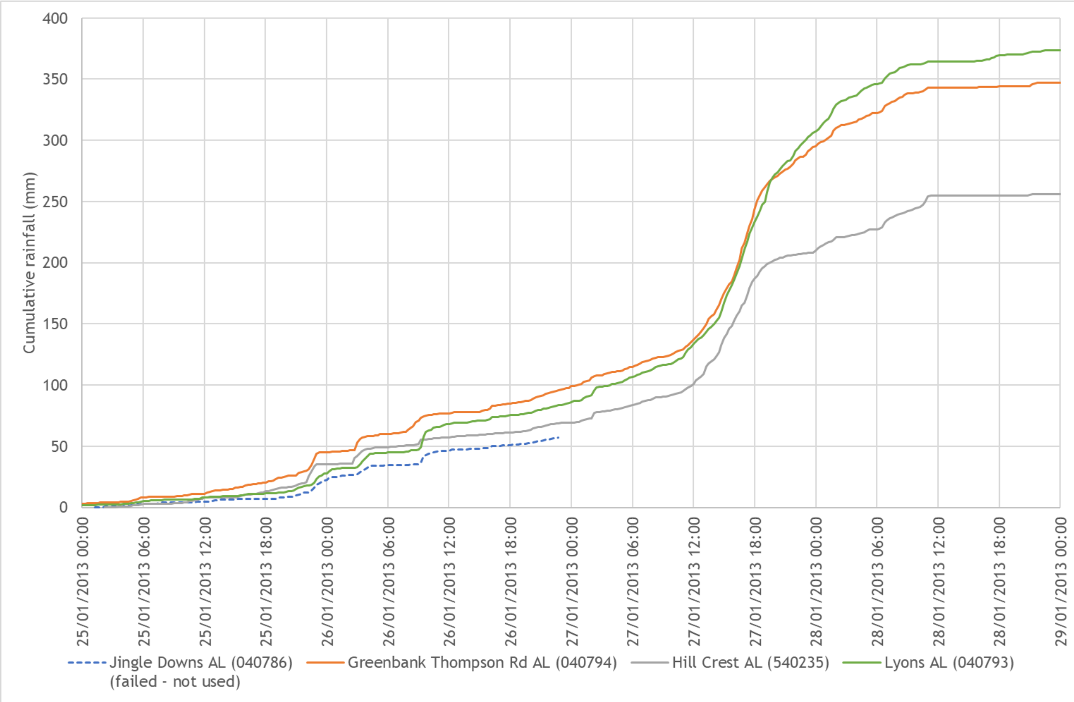


Figure 3.3 - Recorded cumulative rainfalls at available pluviography stations for the January 2013 event

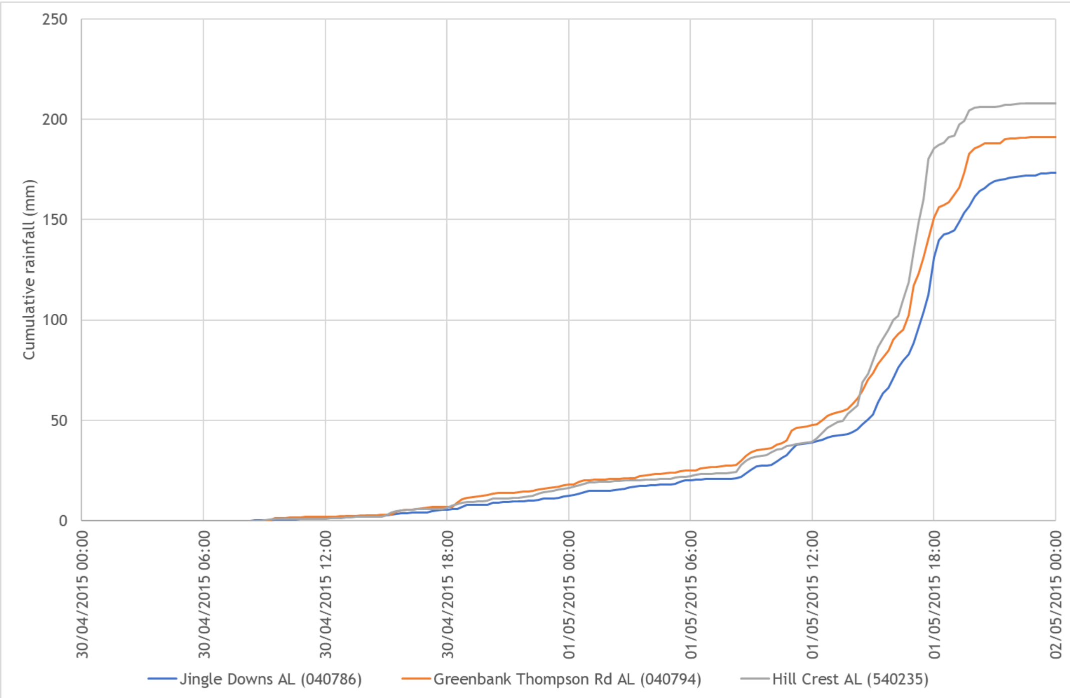


Figure 3.4 - Recorded cumulative rainfalls at available pluviography stations for the May 2015 event

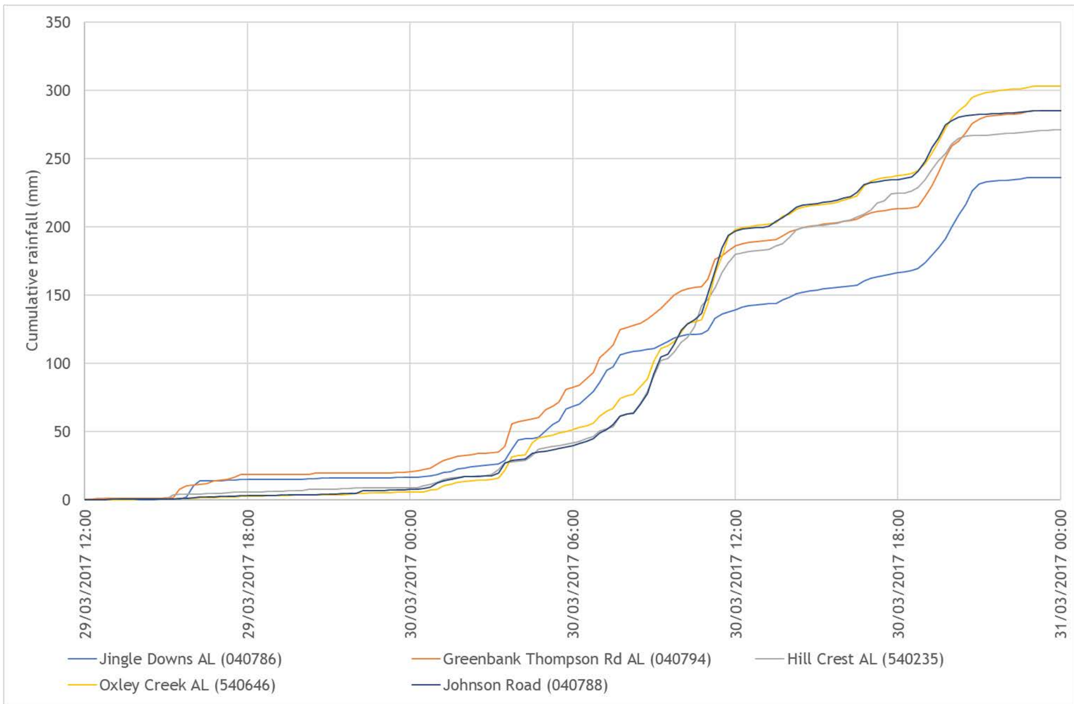


Figure 3.5 - Recorded cumulative rainfalls at available pluviography stations for the March 2017 event

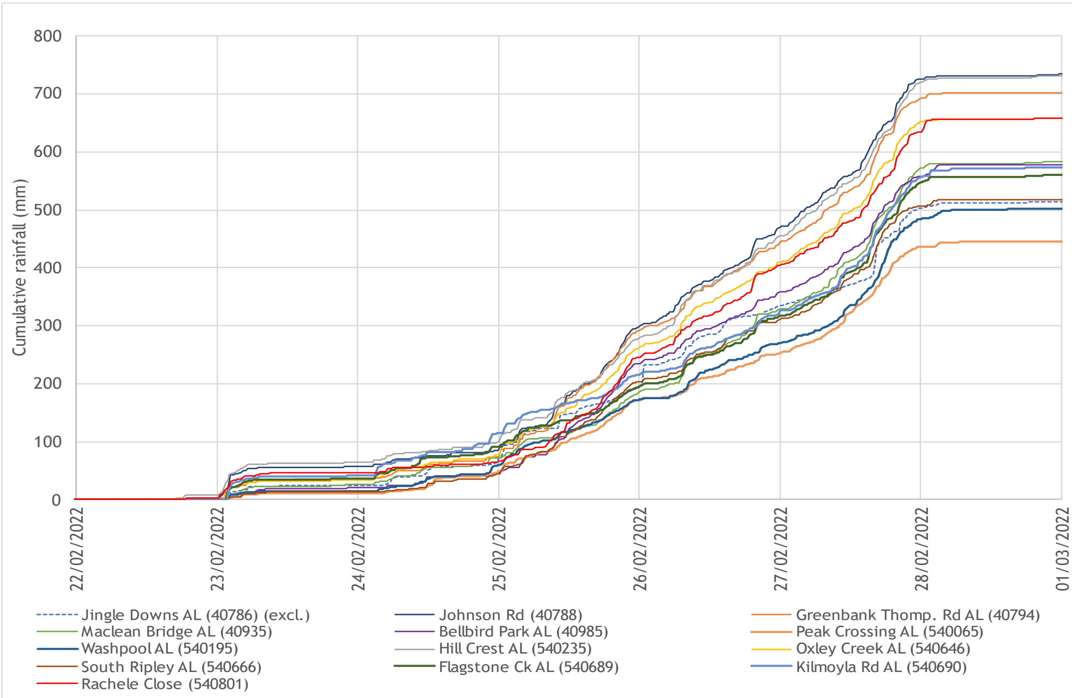


Figure 3.6 - Recorded cumulative rainfalls at available pluviography stations for the February 2022 event

3.10 STREAMFLOW DATA

BoM operates the New Beith AL (GS 540097) flood warning gauge. LCC operates the Oxley Creek AL (GS 540646) flood warning gauge located at Goodna Road. The New Beith gauge is also operated by the Department of Regional Development, Manufacturing and Water (RDMW) (RDMW GS 14033A). BCC operates a flood warning gauge at Forestdale (Johnson Road) (GS 040788). The locations of these gauges are shown in Figure 1.1 and Figure 3.2. Note that these three stream gauging stations are also pluviograph (sub-daily rainfall) stations.

Table 3.3 shows the availability of stream flow data at these key gauging stations for each calibration event. Figure 3.7, Figure 3.8, Figure 3.9 and Figure 3.10 show the recorded water level hydrographs at these key gauging stations for the January 2013, May 2015, April 2017 and February 2022 calibration events, respectively.

Table 3.3 - Stream gauge data availability for the Upper Oxley Creek catchment

Station no.	Station name	Stream name	Streamflow data availability			
			January 2013	May 2015	March 2017	February 2022
14033A	New Beith AL	Oxley Creek	✓	✓	✓	✓
540646	Oxley Creek AL	Oxley Creek	X	X	✓	✓
040788	Forestdale (Johnson Rd) AL	Oxley Creek	X	X	X	✓

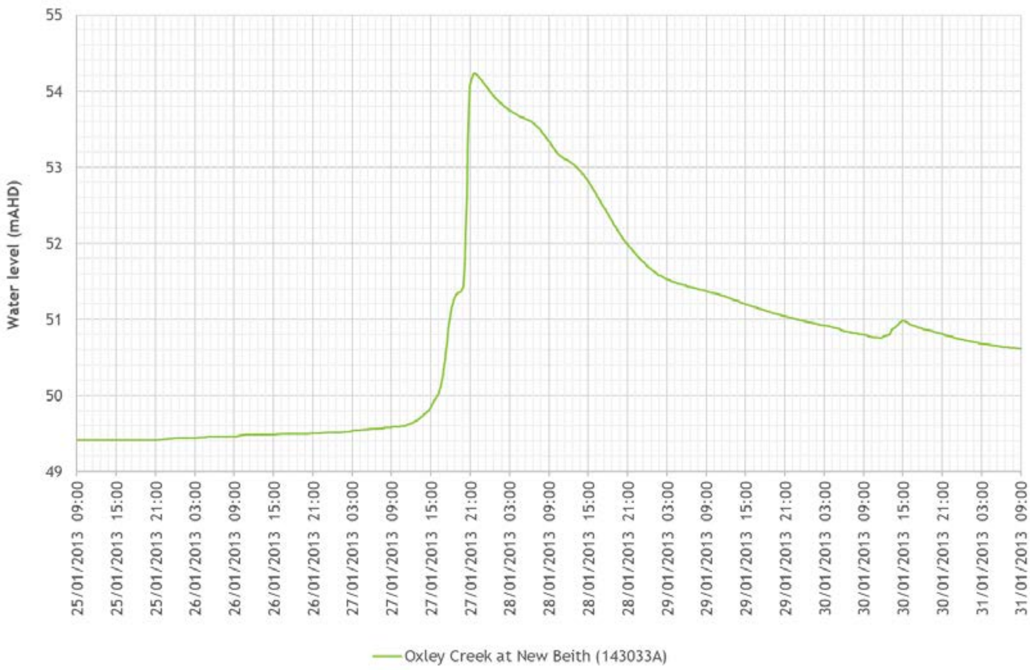


Figure 3.7 - Recorded water levels at New Beith AL for the January 2013 event

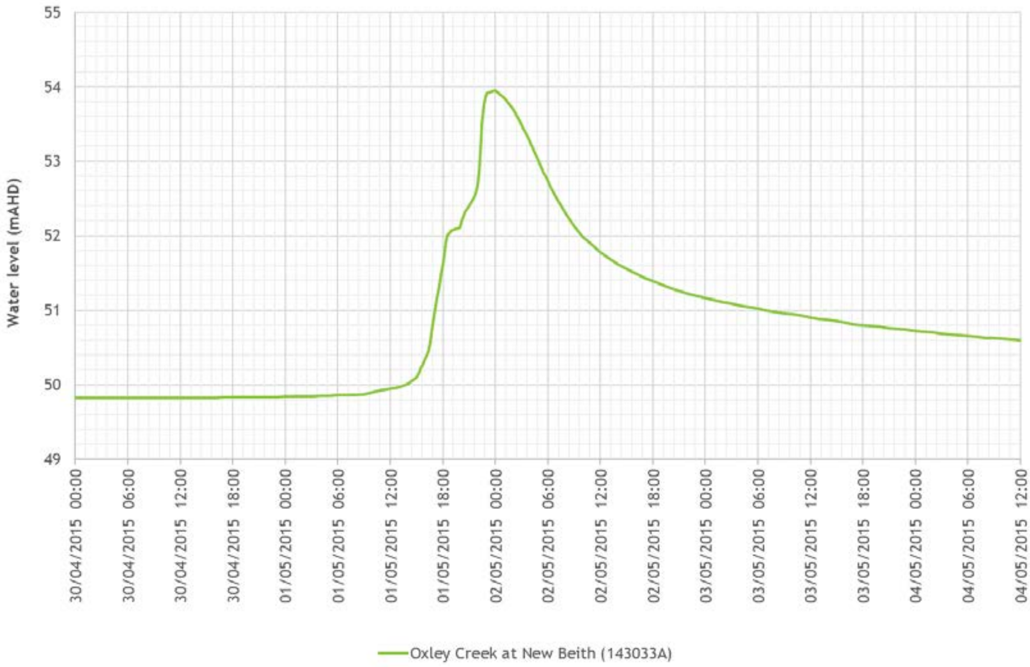


Figure 3.8 - Recorded water levels at New Beith AL for the May 2015 event

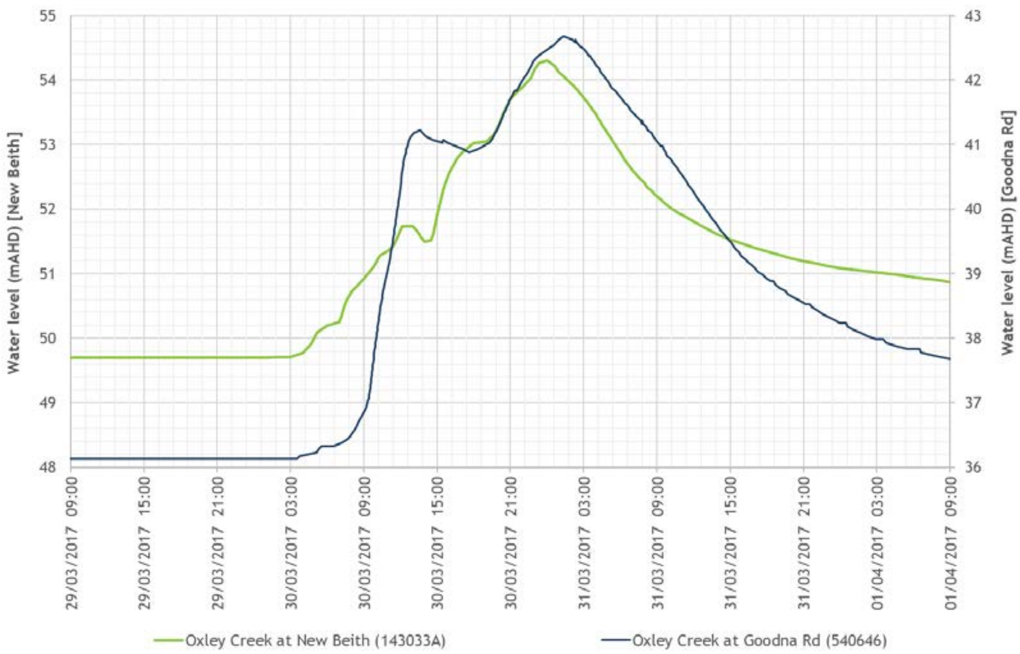


Figure 3.9 - Recorded water levels at New Beith AL and Oxley Creek AL for the March 2017 event

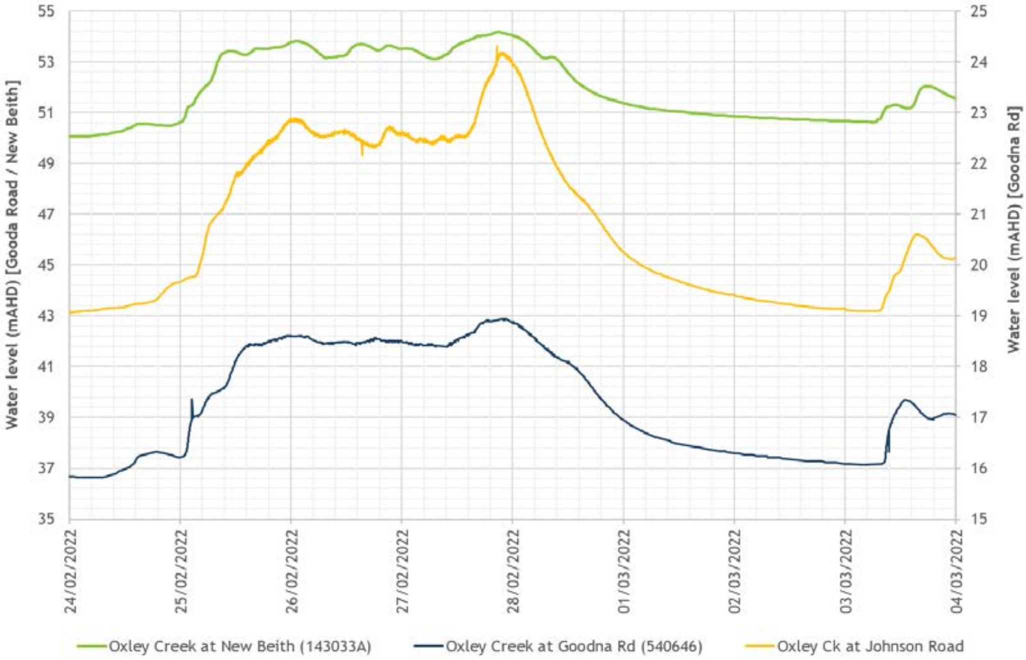


Figure 3.10 - Recorded water levels at New Beith AL, Oxley Creek AL and Johnson Road AL for the February 2022 event

3.11 RATING CURVES

3.11.1 Overview

The Oxley Creek at New Beith AL stream gauge is operated by RDMW and has a rating curve that is regularly updated based on gauges flows and changes in the waterway cross section at the gauge location. The rating curve for this gauge was reviewed as part of this study.

The Oxley Creek AL (Goodna Road) and Forestdale (Johnson Road) gauges are flood warning gauges and are unrated.

3.11.2 New Beith AL stream gauge

Figure 3.11 shows the available and adopted rating curves for New Beith. A total of 145 gaugings have been undertaken at this gauge over the period of record (December 1976 to present). The current RDMW rating curve for New Beith (rating Table 16) is based on gauged data up to 24.6 m^3/s at 3.38 metre gauge height (mGH), which is equivalent to 52.23 mAHD. The rating curve has been extrapolated above this point by BoM and RDMW. The highest gauging at this gauge was undertaken in May 1990, and the last gauging was undertaken in March 2017.

The rating curve generated from the calibrated Upper Oxley Creek hydraulic model developed as part of this study matches well with RDMW's latest rating (Table 16) for discharges less than 30 m^3/s. The hydraulic model is unlikely to be as accurate as the RDMW rating curve for flood events confined within the Oxley Creek channel banks. However, the rating curve produced by the hydraulic model for floods larger than the highest gauged flow (involving significant floodplain flow) are likely to be more accurate than the extrapolated RDMW rating curve at higher discharges.

New Beith Road immediately east of the New Beith AL gauge has recently been upgraded in 2020. The upgrade works included a new road embankment which has raised the New Beith Road crest level by up to four metres compared to pre-upgrade conditions. The upgrade works also included multiple banks of large box culverts beneath the new road embankment. These recent upgrade works potentially changed the hydraulic characteristics of Oxley Creek at the New Beith AL gauge location. However, no gaugings have been undertaken at the New Beith AL gauge since the completion of the road upgrade.

The following rating curves were adopted for the New Beith AL stream gauge:

- For the January 2013, May 2015 and April 2017 calibration events, the conversion of recorded water levels to rated flows was undertaken using the RDMW Table 16 up to the highest gauged flow (24.6 m^3/s at 3.38 mGH). Above this flow, the rating curve transitions to the hydraulic model rating curve that uses the LCC 2017 LiDAR data as the base model topography (i.e., excludes the recent New Beith Road upgrade works).
- For the February 2022 calibration event, the conversion of recorded water levels to rated flows was undertaken using the RDMW Table 16 up to the highest gauged flow (24.6 m^3/s at 3.38 mGH). Above this flow, the rating curve transitions to the hydraulic model rating curve that uses the LCC 2021 LiDAR data as the base model topography (i.e., includes the recent New Beith Road upgrade works).

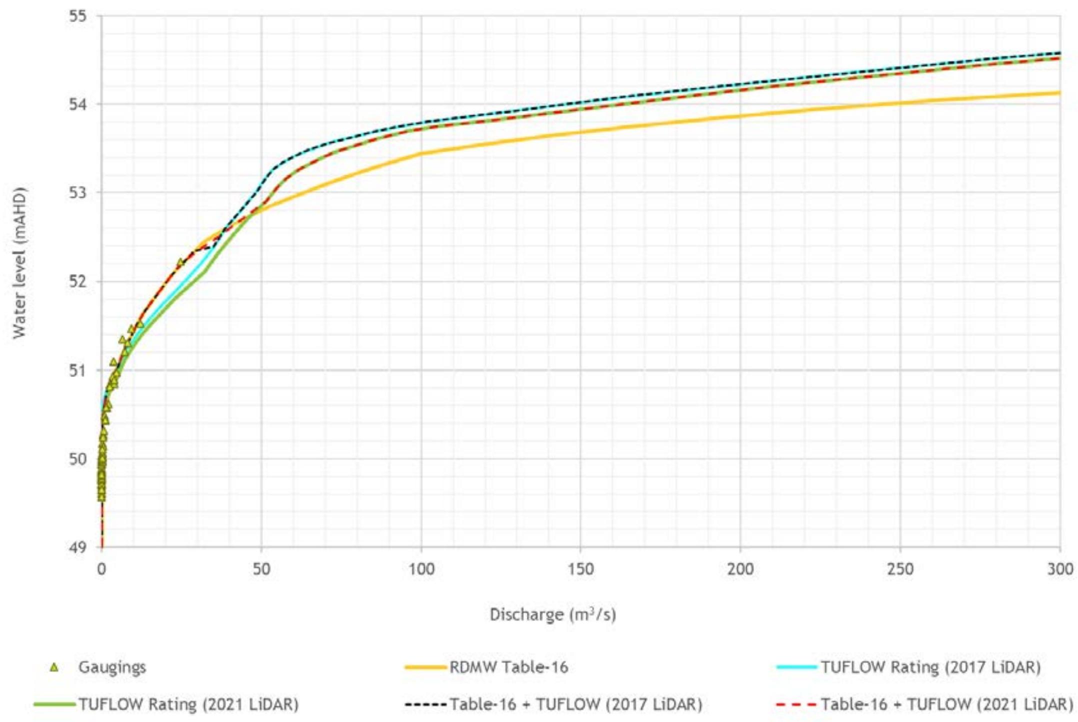


Figure 3.11 - Available and adopted rating curves, Oxley Creek at New Beith AL (GS 540097)

3.11.3 Oxley Creek AL (Goodna Road) stream gauge

Figure 3.12 shows the adopted rating curves for Oxley Creek at Oxley Creek AL (Goodna Road). Neither a BoM nor a RDMW rating curve is available for this gauging site. The rating curve for the gauge has been developed from the hydraulic model results and has been adopted for the conversion of recorded water levels to rated flows for the calibration events. Note that:

- For the January 2013, May 2015 and April 2017 calibration events, the hydraulic model rating curve was adopted based on the hydraulic model that uses the LCC 2017 LiDAR data as the base model topography.
- For the February 2022 calibration event, the hydraulic model rating curve was adopted based on the hydraulic model that uses the LCC 2021 LiDAR data as the base model topography.

3.11.4 Forestdale (Johnson Road) AL stream gauge

Figure 3.13 shows the adopted rating curves for Oxley Creek at Forestdale (Johnson Road) AL. Neither a BoM nor a RDMW rating curve is available for this gauging site. The rating curve for the gauge has been developed from the hydraulic model results and has been adopted for the conversion of recorded water levels to rated flows for the calibration events. Note that:

- For the January 2013, May 2015 and April 2017 calibration events, the hydraulic model rating curve was adopted based on the hydraulic model that uses the LCC 2017 LiDAR data as the base model topography.
- For the February 2022 calibration event, the hydraulic model rating curve was adopted based on the hydraulic model that uses the LCC 2021 LiDAR data as the base model topography.

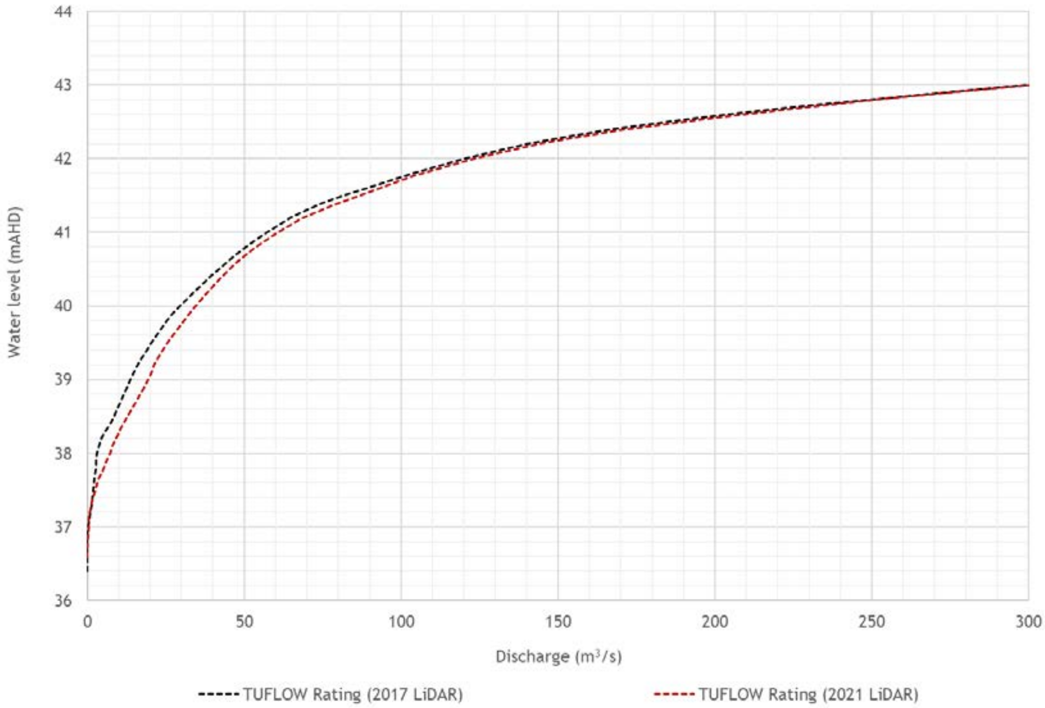


Figure 3.12 - Adopted rating curves, Oxley Creek AL (Goodna Road) stream gauge (GS 540646)

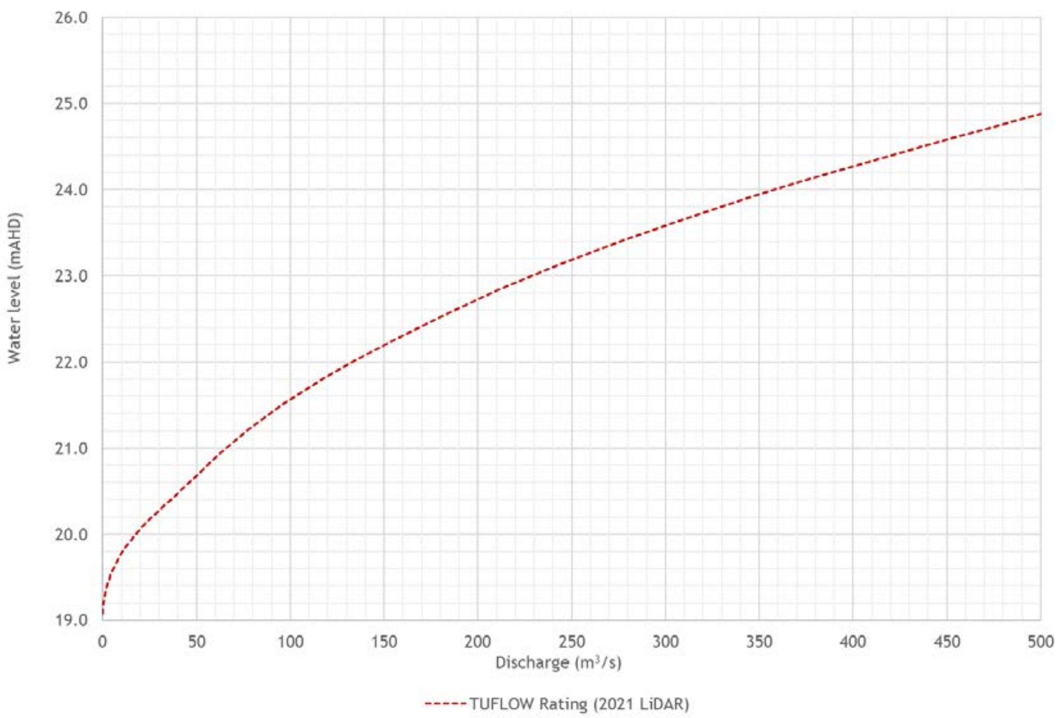


Figure 3.13 - Adopted rating curves, Oxley Creek at Forestdale (Johnson Road) AL stream gauge (GS 040788)

3.12 SURVEYED PEAK FLOOD LEVELS

3.12.1 January 2013 event

A total of 17 surveyed flood debris marks were available throughout the Upper Oxley Creek floodplain for the January 2013 flood event. The surveyed flood levels at these locations are given in Table 3.4. The locations of these debris marks are shown in Figure 3.14.

Table 3.4 - Surveyed flood levels (debris marks) throughout the Upper Oxley Creek floodplain, January 2013 event

ID	Surveyed peak flood level (mAHD)	Comment
0	55.55	Permanent survey marker
1	54.51	Road height
2	55.00	Estimated level
3	53.51	Water level
4	71.90	Estimated level
5	43.62	Debris line
6	43.64	Debris line
7	43.65	Debris line
8	44.38	Property height
9	44.37	Property height
10	44.39	Property height
11	44.42	Property height
12	44.44	Property height
13	43.46	Water level
14	43.47	Water level
15	42.81	Debris line on path
16	42.72	Debris line on rail bridge
17	42.52	Debris line on fence

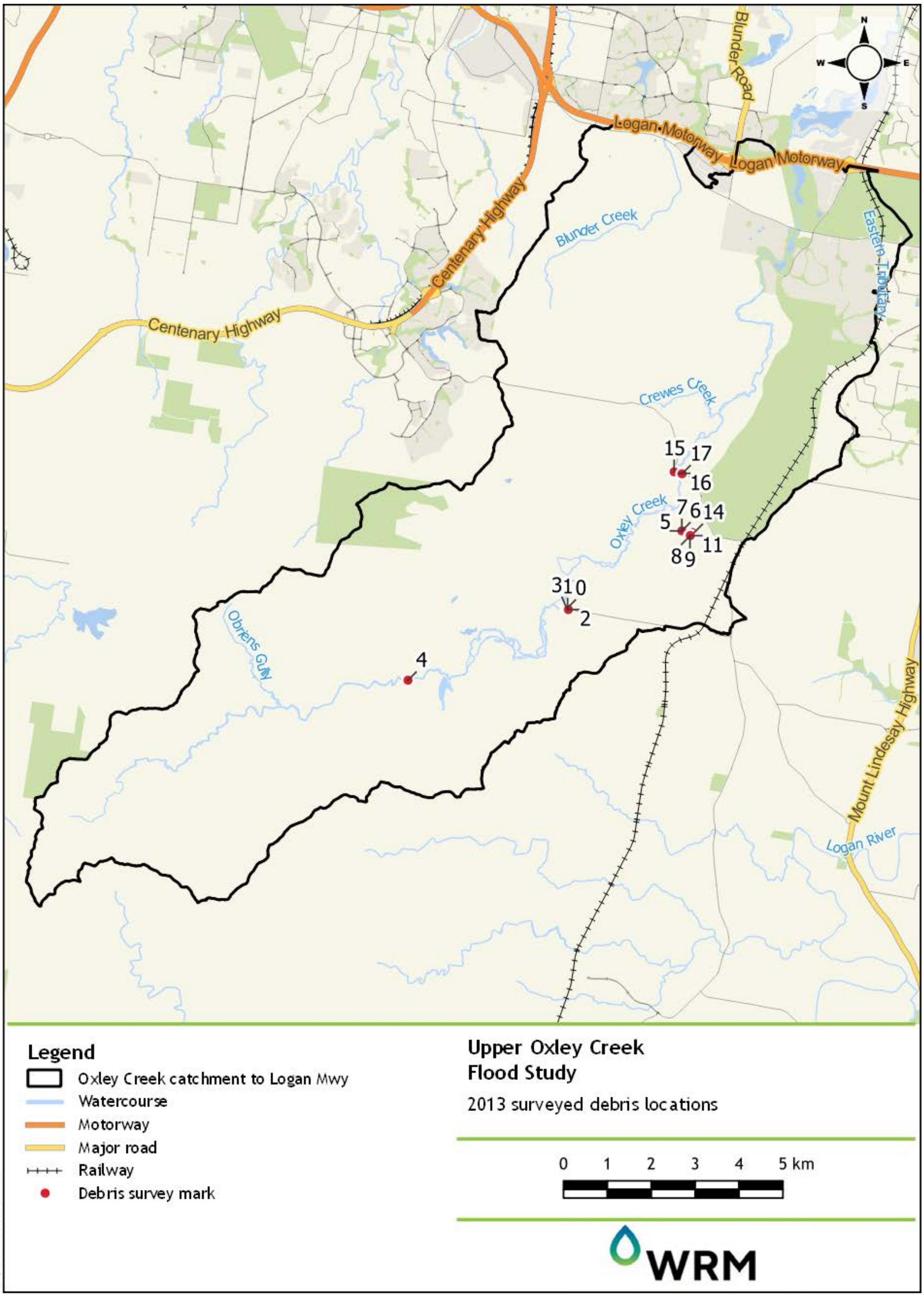


Figure 3.14 - Locations of surveyed peak flood levels (debris marks) throughout the Upper Oxley Creek floodplain, January 2013 event

3.12.2 May 2015 event

A total of 4 surveyed flood debris marks were available throughout the Upper Oxley Creek floodplain for the May 2015 flood event. The surveyed flood levels at these locations are given in Table 3.5. The locations of these debris marks are shown in Figure 3.15.

Table 3.5 - Surveyed flood levels (debris marks) throughout the Oxley Creek floodplain, May 2015 event

ID	Surveyed peak flood level (mAHD)	Comment
0	55.46	Permanent survey marker
1	55.23	Debris line on road marker
2	49.72	Debris line on sign post
3	44.00	Debris line on sign post
4	42.13	Debris line

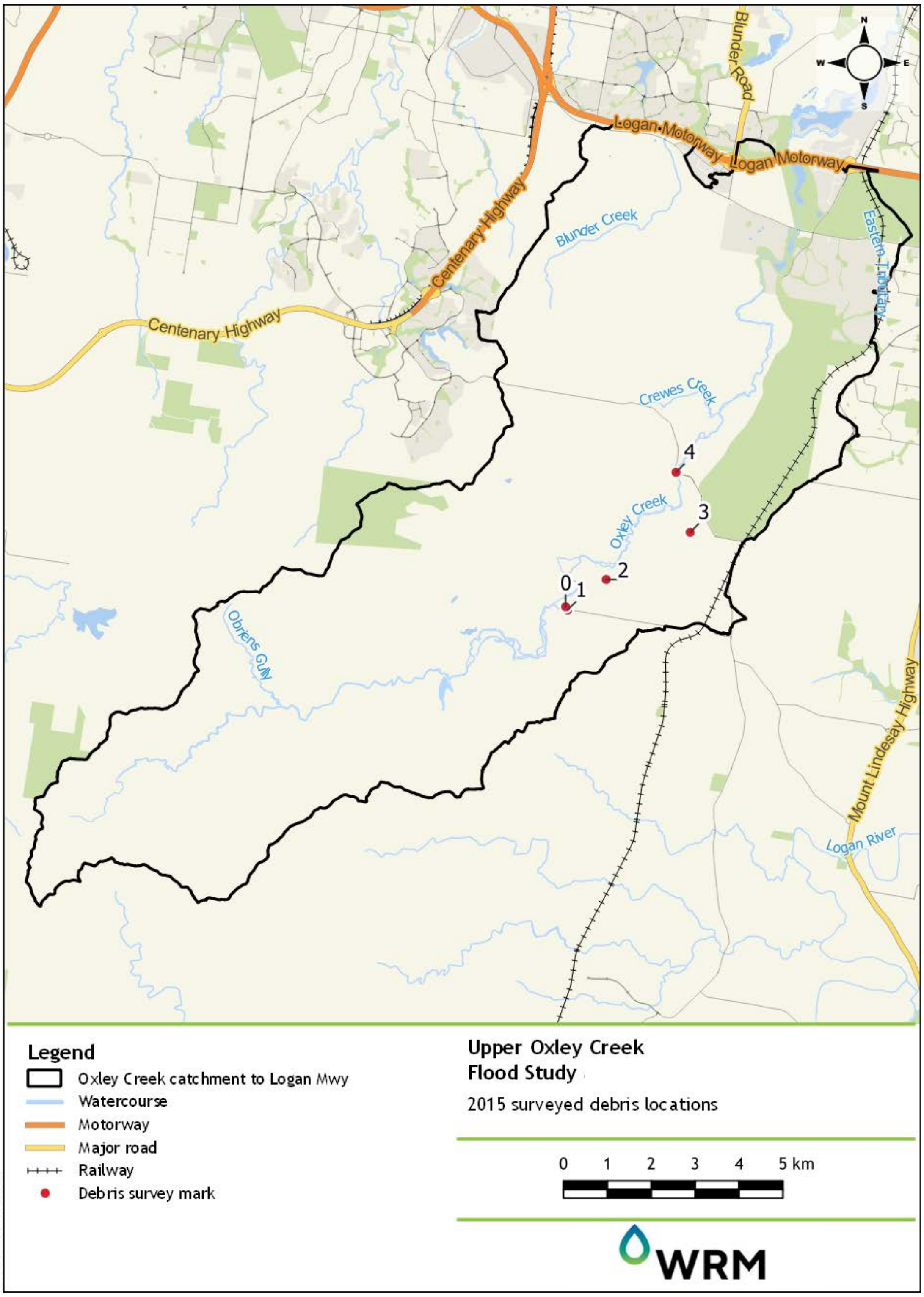


Figure 3.15 - Locations of surveyed peak flood levels (debris marks) throughout the Upper Oxley Creek floodplain, May 2015 event

4 Hydrologic model development

4.1 OVERVIEW

An URBS (Caroll, 2021) hydrologic model was developed for the Upper Oxley Creek catchment to the Logan Motorway. The URBS hydrologic model was calibrated against the January 2013, May 2015, March 2017 and February 2022 flood events. The URBS model was developed for the following scenarios:

- Existing catchment conditions - the adopted model parameters were based on existing development within the catchment. This model was used for model calibration to historical events.
- Ultimate catchment conditions - the adopted model parameters were based on ultimate development of the catchment in accordance with the current Council planning schemes. This model is used for design event modelling.

Details of the URBS model calibration methodology and results are described in Section 5 of this report. The methodology for the use of the calibrated URBS model to estimate design discharges is described in Section 9 of this report.

Figure 4.1 shows the URBS model subcatchments. Figures A.1 to A.4 in Appendix A shows the subcatchment IDs. Table A.1 in Appendix A outlines the subcatchment parameters.

4.2 URBS MODEL CONFIGURATION

4.2.1 Spatial configuration

Figure 4.1 shows the configuration and extent of the Upper Oxley Creek URBS hydrologic model. More detailed figures are provided in Appendix A.

The URBS model covers an area of 14,150 ha (142 km^2) and includes the entire Upper Oxley Creek catchment to the Logan Motorway. The model also includes the catchments of Blunder Creek to the Logan Motorway and the Eastern Tributary to just downstream of Johnson Road.

The URBS model consists of 660 subcatchments, ranging in area from 2.9 ha to 35.8 ha, with an average subcatchment area of 21.4 ha. Subcatchment delineation was initially undertaken automatically using the CatchmentSim software, and then the resulting CatchmentSim output was manually refined. Subcatchments were delineated to be approximately 30 ha or less where appropriate, particularly along the headwaters and outer perimeter of the catchment. Overall, the URBS model subcatchments were delineated sufficiently to provide hydraulic model inflows along all of LCC's defined waterway corridor. The URBS model subcatchment areas are provided in Table A.1 in Appendix A.

4.2.2 Global parameters

The URBS model uses channel lag parameter (α), catchment lag parameter (β), channel routing exponent (N), catchment non-linearity parameter (m) as global catchment and routing parameters. These parameters were adjusted during the model calibration process to achieve the best possible fit between the predicted and rated discharge hydrographs. The following parameters were adopted:

- Alpha (α) = 0.055;
- Beta (β) = 1.0;
- N = 0.8; and
- M = 0.715.

The URBS model was configured to adopt the Laurenson's (1964) subcatchment routing method, in which the URBS model subdivides each subcatchment into 10 equal subareas. As such, the adopted parameter values of 0.715 for "M" and 1.0 for "β" are required by the URBS manual for the Laurenson's method to work.

4.2.3 Subcatchment parameters

The Upper Oxley Creek URBS model uses area, catchment slope, PERN (n) and fraction impervious as catchment variables. Subcatchment areas and slopes were derived using the available topographic data. Subcatchment fraction impervious and PERN (n) were weighted by area based on the distribution of land-use types in each subcatchment. For existing catchment conditions, the distribution of land-use types within the catchment were determined based on the available aerial photographs. For ultimate catchment conditions, the distribution of land-use types within the catchment were determined based on the zoning in current Council planning schemes.

The adopted fraction impervious and roughness (PERN) for each land-use type are shown in Table A.1 in Appendix A. The adopted (weighted) subcatchment parameters (total area, fraction impervious, catchment slope and PERN) for each subcatchment are given in Table A.2 for existing catchment conditions and in Table A.3 for ultimate catchment conditions.

4.2.4 Losses

The URBS model uses a uniform initial (IL) and continuing loss (CL) for the entire Upper Oxley Creek catchment. Initial and continuing losses were configured based on an adopted percentage imperviousness of the model subcatchments. The URBS model applies zero losses to the impervious part of a subcatchment, and the specified IL and CL to the pervious part of the catchment. The specified uniform IL and CL values for each event were determined based on the model calibration process (described in Section 5).

4.2.5 Routing Parameters

Channel routing in the URBS model was based on the Muskingum method. The URBS model routing was configured by specifying the reach lengths (L), channel slope (Sc) and reach length factors (a calibration parameter).

A reach length factor of 0.85 was adopted within the steeper upper catchments just upstream of New Beith. A reach length factor of 1.0 was adopted within the more urbanised areas of New Beith and Greenbank up to Goodna Road. A reach length factor of 0.8 was adopted between Goodna Road and the model outlet. The adopted reach length factors were determined during the model calibration process.

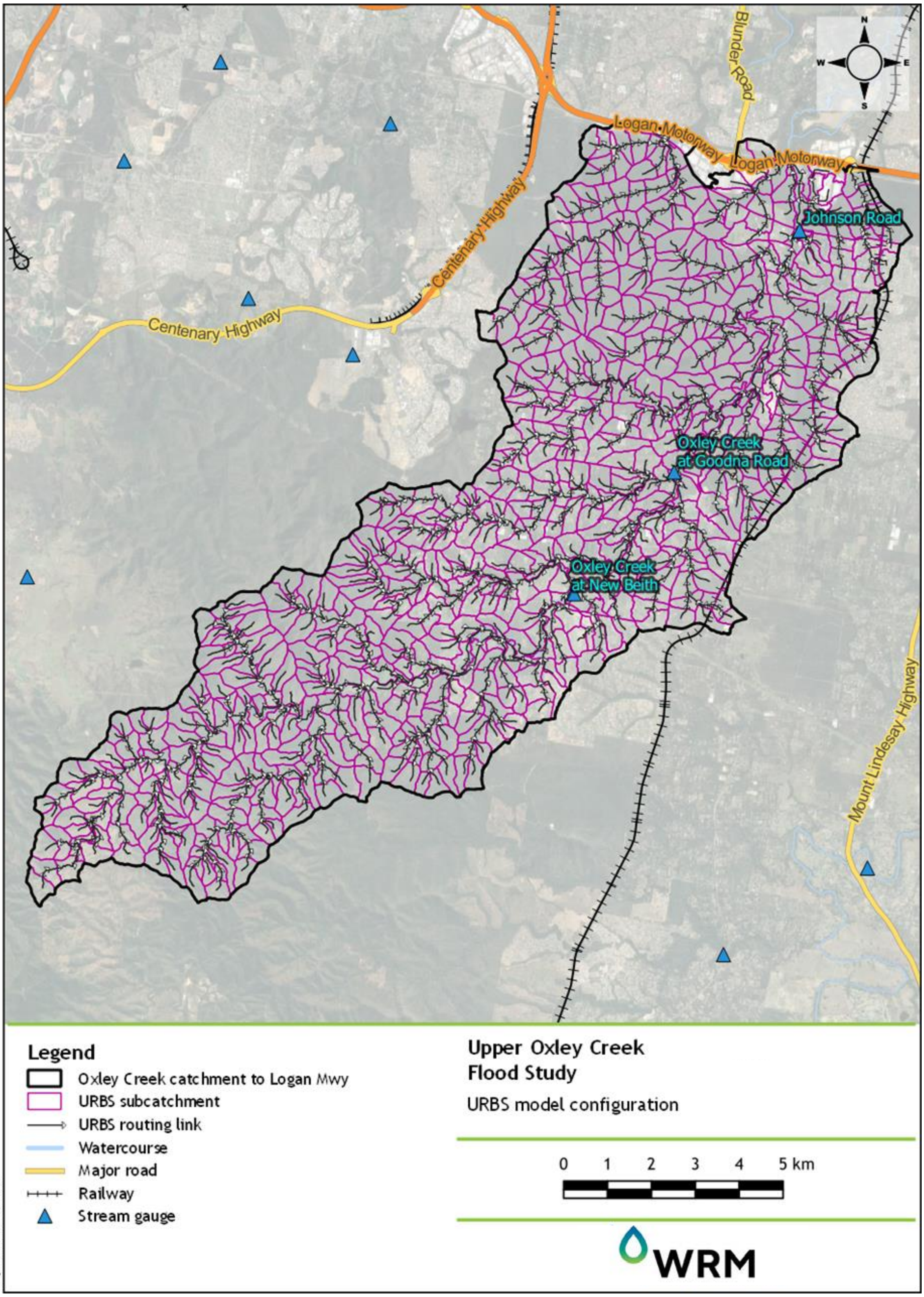


Figure 4.1 - URBS model subcatchments (overview)

5 Hydrologic model calibration

5.1 METHODOLOGY

The Upper Oxley Creek URBS hydrologic model was calibrated against recorded discharge hydrographs at the following three stream gauges (if data is available):

- New Beith AL (GS 143033A);
- Oxley Creek AL (GS 540646); and
- Forestdale (Johnson Road) AL (GS 040788).

At these three gauges, the calibration attempted to match the predicted and recorded flood peaks, volumes and shapes of the flood hydrograph.

5.2 CALIBRATION EVENTS

The hydrologic model was calibrated against the January 2013, May 2015, March 2017 and February 2022 events. The analysis period of each event was as follows:

- January 2013: 25/01/2013 0900 hours to 29/01/2013 2100 hours (4 days);
- May 2015: 29/04/2015 0900 hours to 04/05/2015 0900 hours (5 days);
- March 2017: 29/03/2017 0900 hours to 03/04/2017 0900 hours (5 days); and
- February 2022: 22/02/2022 0900 hours to 02/03/2022 0900 hours (8 days).

The selected calibration events represent the four largest events recorded over the last 29 years within the Upper Oxley Creek catchment. Table 5.1 shows the rated peak discharges for each event at each of the key gauging stations used for model calibration. The peak discharges reported in Table 5.1 are based on the adopted rating curves described in Section 3.8.

Table 5.1 - Rated peak discharges during the calibration events

Gauging station name	Gauging station no.	Rated peak discharge (m^3/s) [a]			
		Jan 2013	May 2015	Mar 2017	Feb 2022
New Beith AL	143033A	188	133	219	204
Oxley Creek AL	540646	n/a	n/a	223	272
Forestdale (Johnson Road) AL	040788	n/a	n/a	n/a	394

[a] - Recorded peak water levels converted to peak discharges using rating curves

5.3 ADOPTED CATCHMENT AND ROUTING PARAMETERS

The adopted subcatchment and routing parameters are described in Section 4 and Appendix A. The adopted parameters were selected to achieve the best possible fit between the predicted and rated discharge hydrographs. The URBS model uses the same parameter values channel lag parameter (α), catchment lag parameter (β), channel routing exponent (N), catchment non-linearity parameter (m) for all calibration events.

5.4 ASSIGNMENT OF TOTAL RAINFALLS AND TEMPORAL PATTERNS

Total rainfalls and temporal patterns were assigned to the model subcatchments based on the proximity of each subcatchment to the nearest pluviograph or daily rainfall station following a inverse distance weighting approach. Where recorded daily data was used, the temporal pattern from the nearest pluviograph station was applied to the daily rainfall data.

Some adjustment of pluviograph assignment was required to improve the Upper Oxley Creek calibration for the February 2022 event. The following is of note:

- For the January 2013, May 2015 and March 2017 events, there was sufficient coverage of pluviograph data within the Upper Oxley Creek catchment, resulting in good model calibration results for these events (refer to Section 5.6). Therefore, pluviograph data from stations outside of the Upper Oxley Catchment (if available) were not used for these three calibration events.
- For the February 2022 event:
    - The recorded rainfall temporal pattern at the Jingle Downs Alert (GS 040786) pluviograph station was found to be inconsistent with recorded temporal patterns from surrounding stations (refer to Figure 3.6). Therefore, the temporal pattern data from this gauge was ignored and only the total event rainfall data from this station was used. In addition, the Lyons Alert (GS 40793) pluviograph station failed during this event.
    - Due to the above, the upper (southern) half of the Upper Oxley Creek catchment is not covered by any pluviograph data from within the catchment, as pluviograph data from the Jingle Downs Alert and Lyons Alert was either not available or could not be used. Therefore, pluviograph data from additional rainfall stations outside of the Upper Oxley Creek catchment was included for the assignment of rainfalls for this event, particularly for subcatchments in the upper (southern) half of the catchment.

5.5 INITIAL AND CONTINUING LOSSES

Initial (IL) and continuing (CL) losses were configured based on an adopted relationship with the faction imperviousness of the model subcatchments as outlined in Section 4.2.4.

Table 5.2 outlines the initial (IL) and continuing (CL) losses adopted for the four calibration events for subcatchments with zero fraction imperviousness. Table A.1 and Table A.2 in Appendix A shows the percentage imperviousness adopted for each subcatchment for existing and ultimate catchment conditions, respectively.

It is of note that the adopted ILs for the January 2013 and March 2017 events are significantly higher than those adopted for the May 2015 and February 2022 events, which is likely due to drier antecedent conditions for the January 2013 and March 2017 events.

The adopted ILs for the January 2013 and March 2017 are generally consistent with the adopted ILs in the Logan and Albert Rivers Flood Study (WRM, 2022) for the same calibration events. The adopted IL for the May 2015 event is also generally consistent with the adopted IL in the Slacks and Scrubby Creeks Flood Study (WRM, 2022) for the same event. Therefore, despite the wide range of adopted ILs between calibration events for the Upper Oxley Creek catchment, they are considered to be within reasonable bounds.

Table 5.2 - Adopted initial (IL) and continuing (CL) losses for subcatchments with zero fraction impervious

Event	IL (mm)	CL (mm/hr)
January 2013	170	3.1
May 2015	90	3.1
March 2017	130	3.1
February 2022	45	3.1

5.6 CALIBRATION RESULTS

The hydrologic model results for the calibration events were compared against the results of the hydraulic model calibration. The models were adjusted to ensure consistency between hydrology and hydraulic results.

5.6.1 January 2013 event

Table 5.3 shows a comparison of rated peak discharges and modelled peak discharges at key gauging stations for the January 2013 event. Figure 5.1 compares rated and modelled discharge hydrographs at the New Beith Alert gauging station for the January 2013 event. This is the only stream gauging station with available data to calibrate the model for this event.

Table 5.3 - Rated and modelled peak discharges at key gauging stations, January 2013 flood event

Gauging station name	Gauging station no.	Peak discharge (m^3/s)		Difference (%)
		Rated [a]	Modelled (URBS)	
New Beith AL	143033A	187.6	203.0	8.2%

[a] - Recorded peak water levels converted to peak discharges using rating curves.

The following is of note with regard to the January 2013 calibration:

- The January 2013 flood is considered a moderate flood event in the Upper Oxley Creek catchment (approximately between a 1 in 10 and 1 in 20 AEP event).
- The calibration at New Beith is acceptable, with the predicted hydrograph accurately reproducing the recorded hydrograph shape, flood volume and timing of the peak water level, but slightly overestimates the peak discharge.
- The hydraulic model calibration results (refer to Section 7) show that once the URBS model discharges are routed through the TUFLOW model, some attenuation occurs and the resulting peak discharge in the TUFLOW model matches the rated peak discharge. As a result, a good calibration of the TUFLOW hydraulic model was achieved (refer to Section 7) using these URBS model discharges.

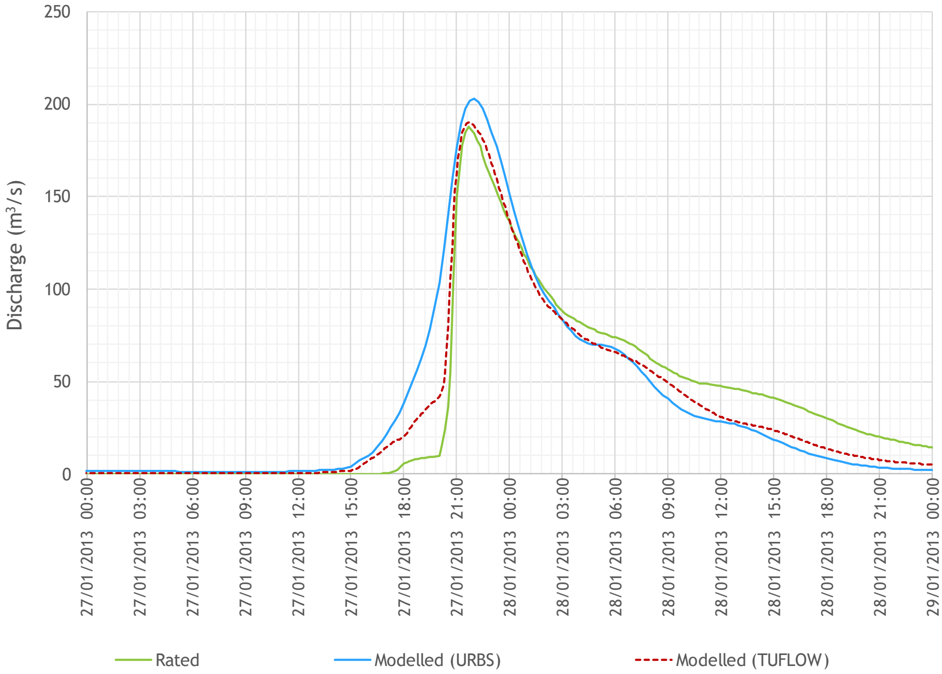


Figure 5.1 - Modelled and rated flows at the New Beith Alert gauge (143033A), January 2013

5.6.2 May 2015 event

Table 5.4 shows a comparison of rated peak discharges and modelled peak discharges at the New Beith Alert gauging station for the May 2015 event. Figure 5.2 compares the rated and modelled discharge hydrographs at the New Beith Alert gauging station for the May 2015 event. This is the only stream gauging station with available data to calibrate the model for this event.

Table 5.4 - Rated and modelled peak discharges at key gauging stations, May 2015 flood event

Gauging station name	Gauging station no.	Peak discharge (m^3/s)		Difference (%)
		Rated [a]	Modelled (URBS)	
New Beith AL	143033A	132.8	148.7	11.9%

[a] - Recorded peak water levels converted to peak discharges using rating curves.

The following is of note with regard to the May 2015 calibration:

- The May 2015 flood is considered a moderate flood event in the Upper Oxley Creek catchment (approximately between a 1 in 5 and 1 in 10 AEP event).
- The calibration at New Beith is generally acceptable, with the predicted hydrograph accurately reproducing the hydrograph shape. However, the URBS model overestimates the peak discharge by approximately 12%. The timing of the predicted peak in the URBS model is also slightly early compared to the recorded hydrograph.
- The hydraulic model calibration results (refer to Section 7) show that once the URBS model discharges are routed through the TUFLOW model, significant attenuation occurs and the resulting peak discharge in the TUFLOW model match more closely to the rated peak discharge. As a result, a good calibration of the TUFLOW hydraulic model was achieved (refer to Section 7) using these URBS model discharges.

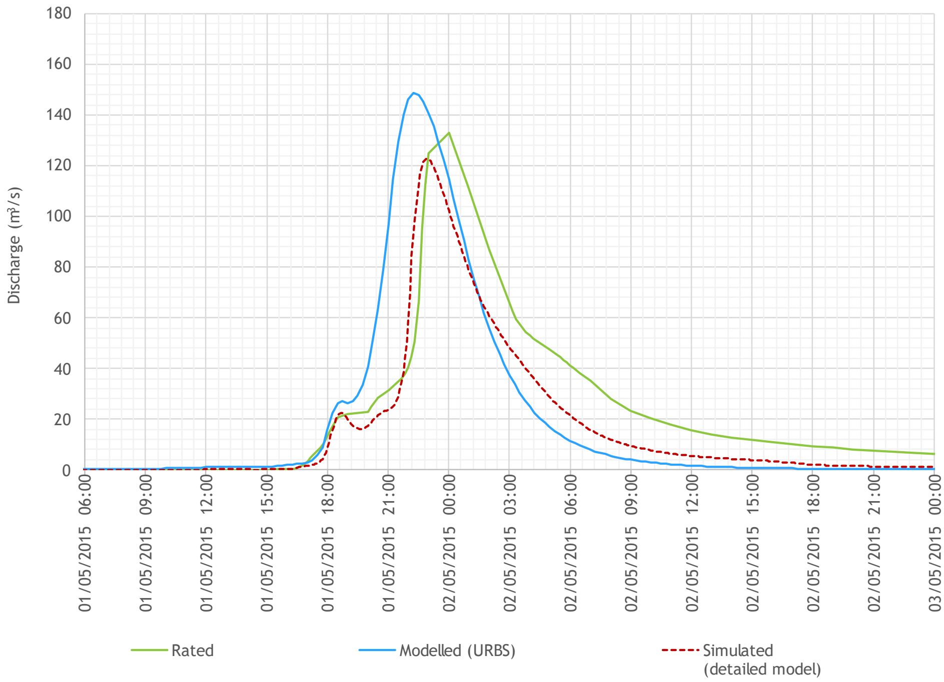


Figure 5.2 - Modelled and rated flows at the New Beith Alert gauge (GS 143033A), May 2015

5.6.3 March 2017 event

Table 5.5 shows a comparison of rated peak discharges and modelled peak discharges at the available gauging stations for the March 2017 event. Figure 5.3 and Figure 5.4 compare the rated and modelled discharge hydrographs at the New Beith Alert and the Oxley Creek Alert (Goodna Road) at gauging stations, respectively, for the March 2017 event.

Table 5.5 - Rated and modelled peak discharges at key gauging stations, March 2017 flood event

Gauging station name	Gauging station no.	Peak discharge (m^3/s)		Difference (%)
		Rated [a]	Modelled (URBS)	
New Beith AL	143033A	219.2	218.4	-0.4%
Oxley Creek AL (Goodna Road)	540646	222.6	225.7	1.4%

[a] - Recorded peak water levels converted to peak discharges using rating curves.

The following is of note with regard to the March 2017 calibration:

- The March 2017 flood is considered a moderate flood event in the Upper Oxley Creek catchment (approximately between a 1 in 20 and 1 in 50 AEP event).
- The calibration is good, with the modelled hydrographs accurately reproducing the recorded hydrograph shape, peak discharge, flood volume and flood timing at New Beith and Goodna Road.

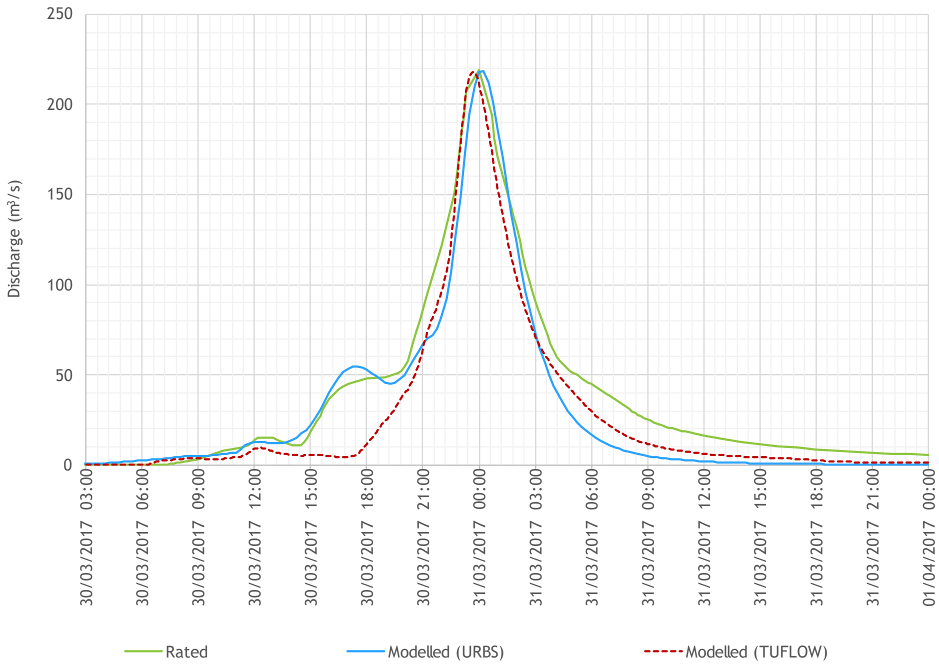


Figure 5.3 - Modelled and rated flows at the New Beith Alert gauge (GS 143033A), March 2017

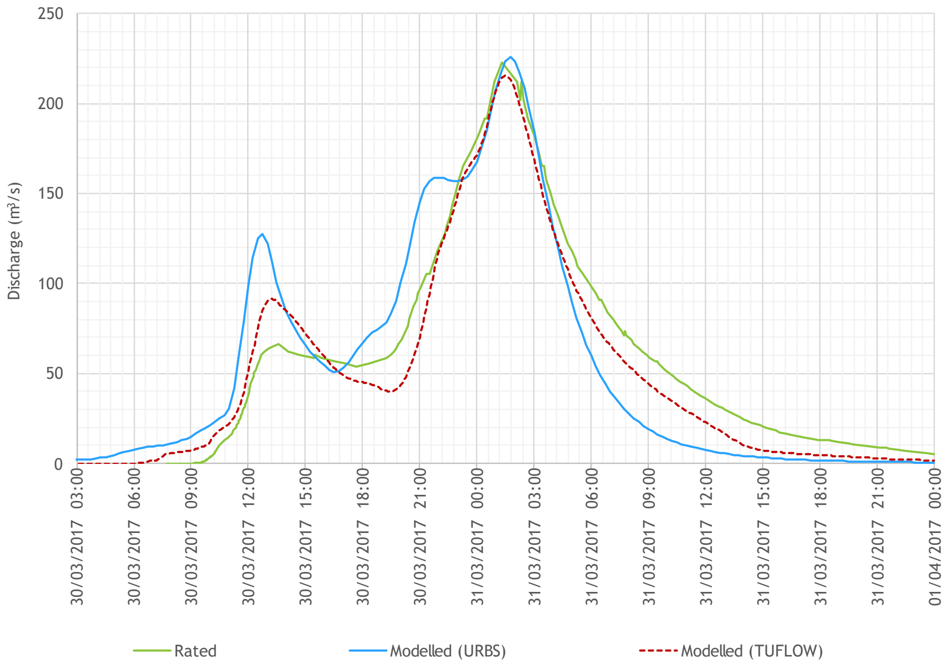


Figure 5.4 - Modelled and rated flows at the Oxley Creek Alert gauge (GS 540646), March 2017

5.6.4 February 2022 event

Table 5.6 shows a comparison of rated peak discharges and modelled peak discharges at the available gauging stations for the February 2022 event. Figure 5.5, Figure 5.6, and Figure 5.7 compare the rated and modelled discharge hydrographs at New Beith Alert, Oxley Creek Alert (Goodna Road) and Forestdale (Johnson Road) Alert gauging stations, respectively, for the February 2022 event.

Table 5.6 - Rated and modelled peak discharges at key gauging stations, February 2022 flood event

Gauging station name	Gauging station no.	Peak discharge (m^3/s)		Difference (%)
		Rated [a]	Modelled (URBS)	
New Beith AL	143033A	203.9	207.4	1.7%
Oxley Creek AL (Goodna Road)	540646	272.0	290.9	7.0%
Forestdale (Johnson Road) AL	40788	394.0	378.8	-4.1%

[a] - Recorded peak water levels converted to peak discharges using rating curves.

The following is of note with regard to the February 2022 calibration:

- The February 2022 flood is considered a moderate flood event in the Upper Oxley Creek catchment (approximately between a 1 in 20 and 1 in 50 AEP event). This event occurred over a period of about five days and consisted of multiple smaller peaks followed by a significantly larger peak on the fifth day of the event.

- The calibration at New Beith and Goodna Road is considered acceptable, with the modelled hydrograph accurately reproducing the recorded hydrograph shape, peak discharge and flood timing.
- The calibration at Johnson Road is considered acceptable, with the predicted hydrograph adequately reproducing the recorded hydrograph shape. The model was able to match the timing of the earlier flood peaks. However, the last and largest flood peak in the model occurred about 3 hours later than the recorded peak.
- The model generally underestimates flood volume for this event, particularly midway through the flood event. The reason for this is likely due to inadequate rainfall data coverage within the upper reaches of the catchment where no pluviograph data is available within the catchment (refer to Section 5.4). Pluviograph data from stations well outside of the catchment were used which may not be representative of rainfalls that occurred in the upper reaches of the catchment during this event.

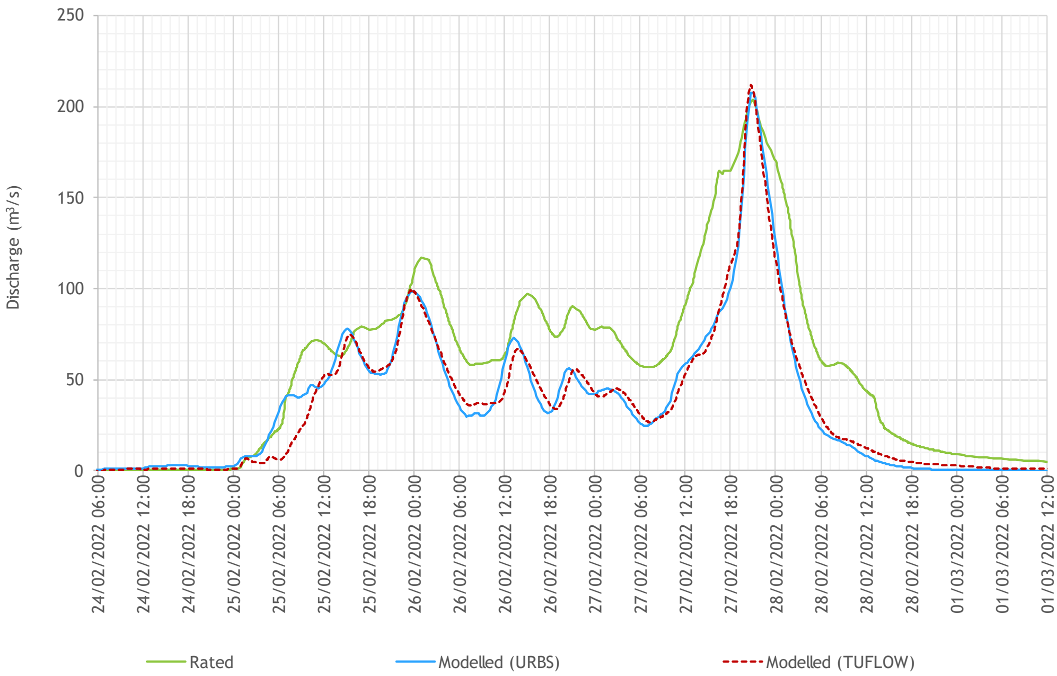


Figure 5.5 - Modelled and rated flows at the New Beith Alert gauge (GS 143033A), February 2022

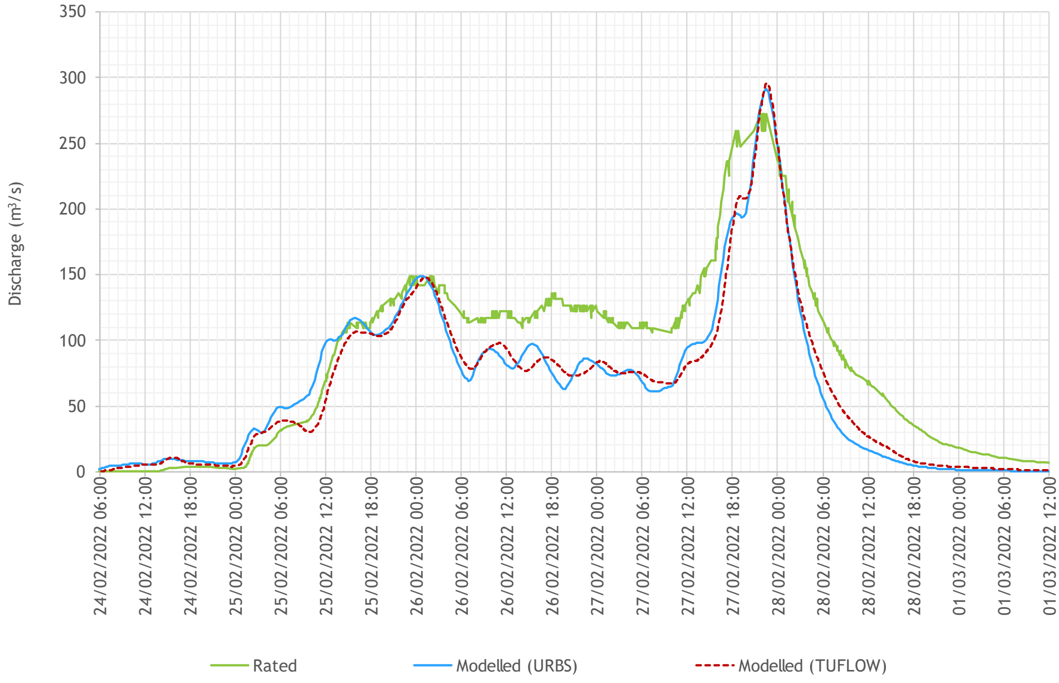


Figure 5.6 - Modelled and rated flows at the Oxley Creek Alert (Goodna Road) gauge (GS 540646), February 2022

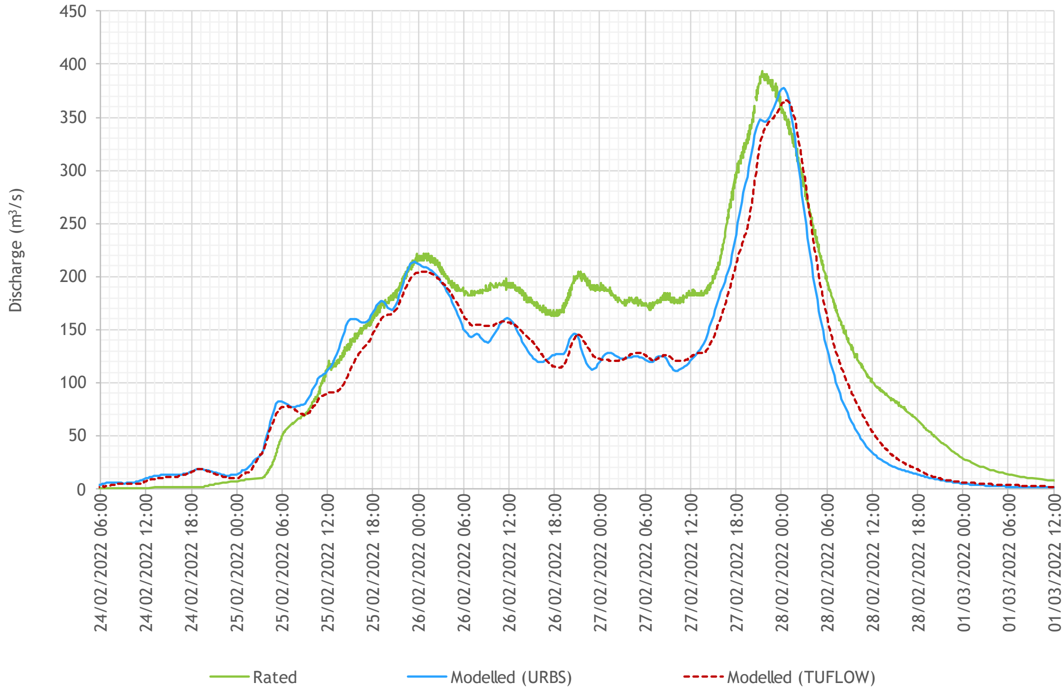


Figure 5.7 - Modelled and rated flows at the Forestdale (Johnson Road) Alert gauge (GS 040788), February 2022

6 Hydraulic model development

6.1 OVERVIEW

A TUFLOW two-dimensional hydrodynamic model (BMT, 2019) was used to estimate flood behaviour (depths, levels and velocities) throughout the Upper Oxley Creek catchment.

TUFLOW represents hydraulic conditions on a fixed grid by solving the full two-dimensional depth averaged momentum and continuity equations for free surface flow. The model automatically identifies breakout points and flow directions within the study area. All hydraulic modelling has been undertaken using the TUFLOW Build 2020-10-AB with the HPC-GPU solver.

The TUFLOW modelling package is suited to simulation of dynamic hydraulic behaviour of complex overland flow in rural areas and was considered the most appropriate tool to determine the flood characteristics of Upper Oxley Creek and its tributaries.

The discharges estimated using the calibrated URBS hydrologic model were adopted as inflows to the TUFLOW hydraulic model. Local inflow hydrographs for each individual subcatchment were applied within the model boundary. At four locations within the model, total inflow hydrographs were applied where there is more than one subcatchment upstream of an inflow location.

6.2 MODEL EXTENT

Figure 6.1 shows the extent of the TUFLOW hydraulic model for Upper Oxley Creek. The TUFLOW model extent is similar to the URBS model extent, which includes the entire Upper Oxley Creek catchment to the Logan Motorway. I LCC LGA only extends to Johnson Road, but the TUFLOW model extends further downstream to the Logan Motorway to minimise the influence of tailwater conditions on the hydraulic model results at the downstream (northern) areas of the LCC LGA (i.e., in the vicinity of Johnson Road). A tailwater sensitivity assessment is described in Section 10.8.

6.3 GRID CELL SIZE

The following two models were developed:

- **'Fast Model'** - This model was configured with a grid cell size of 9 m. The purpose of this model is to allow the selection of critical ARR 2019 design storms, which will then be simulated using the 'Detailed Model'.
- **'Detailed Model'** - This model was configured with a grid cell size of 3 m. The purpose of this model is to simulate the critical design storms selected using the 'Fast Model' to obtain the design outputs.

A grid cell size of 3 m is also considered to be most suitable for generating the design outputs for this study. However, the 'Fast Model' (with a 9 m grid) was required for this study to more efficiently implement the 'ensemble' method of design event modelling described in ARR 2019. Sub-grid sampling was adopted with a sampling distance of one metre.

Calibration of hydraulic model parameters was undertaken for both the Fast and Detailed hydraulic models. This is to ensure that both models can adequately reproduce historical events and to ensure consistency between the two models.

6.4 TOPOGRAPHY

Figure 6.1 shows the topography of the TUFLOW hydraulic model. More detailed figures are provided in Appendix B. The base model topography was configured using the available topographic data described in Section 3.2. The base hydraulic model topography was configured as follows:

- For the 2013, 2015, and 2017 calibration events, the base model topography was configured using the 2017 LiDAR data. For areas within the model not covered by the 2017 LiDAR data, the 2014 LiDAR data was used. The Spring Mountain Drive bridge area was identified as a key change and represented using the 2013 LiDAR.
- For the 2022 calibration event and the design events, the base model topography was configured using the 2021 LiDAR data. For areas within the model not covered by the 2021 LiDAR data, the 2014 LiDAR data was used.

Bathymetric survey data for the section of Oxley Creek located within the LCC LGA is not available for this study. Hence the channel topography was configured based on the available LiDAR data.

A review of the LCC 2017 LiDAR data identified an issue where road embankments at a few culvert crossings had been removed. For these areas, The LCC 2017 LiDAR data was manually adjusted by reinstating the missing road sections using TUFLOW z-shapes.

A review of the LCC 2021 LiDAR data identified an issue where three bridges within the catchment had not been removed from the data. For these areas, the LCC 2021 LiDAR data was manually adjusted by using z-shapes to remove the bridge structure and/or splicing the LCC 2017 LiDAR to the area in the immediate vicinity of the bridge.

All topographic datasets used within the model were converted from their existing projection to the GDA 2020 datum. This reflects the tectonic motion of Australia and has no impact on the production of modelled results.

6.5 INFLOW BOUNDARIES

The TUFLOW model inflow boundaries are based on the URBS model subcatchments. Local inflow hydrographs generated from the URBS model for existing catchment conditions were adopted as inflows at the 2D boundaries. At four locations within the model, total inflow hydrographs comprising two subcatchments were applied.

A total of 714 local model inflow boundaries and 4 total model inflow boundaries were applied within the 2D model domain, including split and factored inflow boundaries to improve the catchment representation. Using 2D surface-area “SA” polygons, flows are initially applied to the lowest point within each SA polygon, and then gradually applied over a larger area within the SA polygon as the discharge increases. Inflows were generally applied at the catchment centroid. Where required to represent the waterway corridor, revised locations and associated routing were accounted for in the hydrologic model, or SA polygons were split through a subcatchment and factored by area.

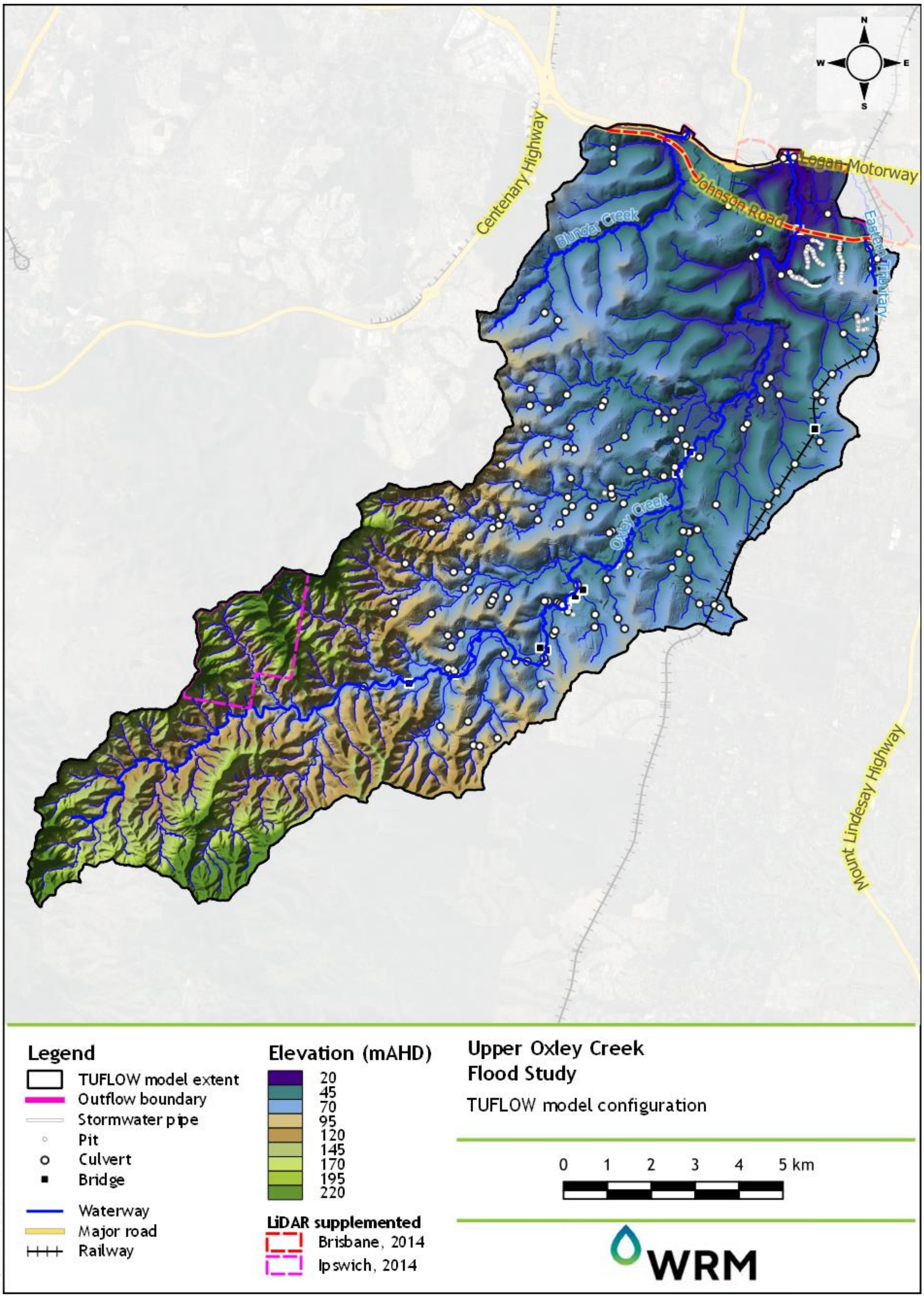


Figure 6.1 - TUFLOW model extent and configuration

6.6 OUTFLOW BOUNDARIES

The TUFLOW model has three outflow locations configured as normal depth boundaries at the following locations (refer to Figure 6.1):

- In Blunder Creek approximately 150 m downstream of the Logan Motorway based on a slope of 0.3%;
- in Oxley Creek approximately 200 m downstream of the Logan Motorway based on a slope of 0.2%; and
- in the Eastern Tributary approximately 400 m downstream of Johnson Road based on a slope of 1%.

The location of the three outflow boundaries were selected based on the available topographic data and to minimise the influence of tailwater conditions on the hydraulic model results at the downstream (northern) areas of the LCC LGA (i.e., in the vicinity of Johnson Road).

6.7 HYDRAULIC ROUGHNESS

6.7.1 Overview

Hydraulic roughness in the TUFLOW model is represented by Manning's 'n' roughness coefficients. Manning's 'n' values for the various surface types were initially selected based on typical published values (such as those in Chow, 1959) and adjusted as necessary to achieve the best possible calibration result against recorded data. Material mapping within the hydraulic model extent was determined using aerial photography.

For most of the TUFLOW model extent, a single Manning's 'n' approach was adopted. For some sections of the main Oxley Creek channel through the middle reaches of the catchment, a depth-varying Manning's 'n' approach was adopted.

Based on the aerial photography, there were no significant differences in the distribution of landuses within the Upper Oxley Creek catchment between the 2013, 2015 and 2017 calibration events. Therefore, the mapping of material (hydraulic roughness coefficients) is the same for these three calibration events. For the 2022 calibration event, the mapping of material (hydraulic roughness coefficients) was adjusted to include recently completed residential developments within the catchment. For design event modelling, the material mapping of future developed areas was further adjusted.

Table 6.1 shows the adopted hydraulic roughness (Manning's n) values for each material type in the hydraulic model. Figures B1 to B4 in Appendix B show the adopted material mapping throughout the catchment.

Table 6.1 - Adopted hydraulic roughness coefficients

Land-use type	Mannings ‘n’
Grassed open space	0.050
Rough waterway channel	0.045
Smooth waterway channel	0.035
Dense Bushland	0.095
Medium Bushland	0.070
Rural Residential	0.055
Low Density Residential	0.100
Medium Density Residential	0.200
Industrial	0.300
Road	0.020
Water Body (inc. Riparian Vegetation)	0.020
Vegetated Waterway Corridor (sensitivity)	0.150
Oxley Creek US New Beith	Depth varying (see Table 6.2 and Table 6.3)
Oxley Creek DS New Beith	Depth varying (see Table 6.2 and Table 6.3)
Oxley Creek Greenbank	Depth varying (see Table 6.2 and Table 6.3)

6.7.2 Depth-varying Manning’s ‘n’

For the relatively wide sections of the Oxley Creek channel in the middle reaches of the catchment (around the urbanised areas of New Beith and Greenbank), Manning’s ‘n’ values were varied with depth. This approach reflects the variation in vegetation density at various depths within the river channels. Figure 6.2 illustrates the three adopted ‘depth regions’ within the creek channel. The following is of note:

- At the lowest depth region (region ‘n1’), hydraulic roughness would be relatively low due to minimal vegetation at the bottom surface of the channel.
- At depth region ‘n2’, the presence of vegetation such as shrubs and tree trunks would significantly increase the hydraulic roughness of the channel in this depth region (compared to the bottom of the channel).
- At depth region ‘n3’, water would generally flow above the thickest shrubs and shorter trees, but taller tree trunks may still be present at these depths. Therefore, the hydraulic roughness for this depth region would be lower than in region ‘n2’.

Slightly different Manning’s ‘n’ values were adopted for the depth varying Mannings ‘n’ regions between the fast model (9 m grid) and the detailed model (3 m grid), so that both the fast detailed models would produce similar results when applied equal inflows. Table 6.2 and Table 6.2 and Table 6.3 show the depth-varying hydraulic roughness coefficients adopted for the “fast model” and the “detailed model”, respectively.

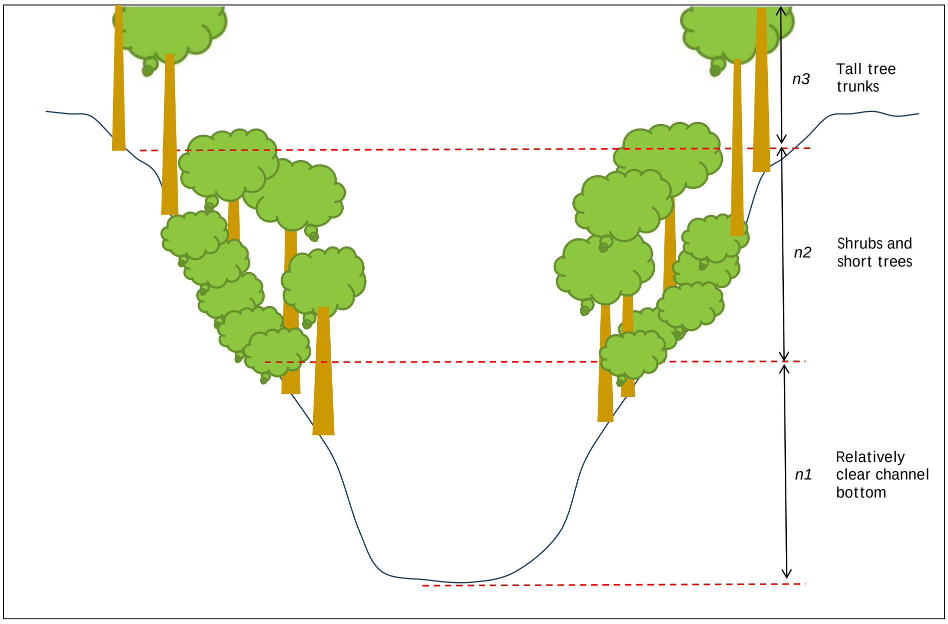


Figure 6.2 - Illustration of depth-varying Manning's 'n' for the Oxley Creek Channel

Table 6.2 - Adopted depth-varying hydraulic roughness coefficients for the Oxley Creek Channel in the 9 m grid 'fast model'

Depth band	Oxley Creek u/s New Beith		Oxley Creek d/s New Beith		Oxley Creek Greenbank	
	Depth (m)	Manning's 'n'	Depth (m)	Manning's 'n'	Depth (m)	Manning's 'n'
n1	≤ 2.5	0.045	≤ 2.5	0.045	≤ 2.5	0.045
n2	2.5 to 3.3	0.100	2.5 to 3.6	0.100	2.5 to 4.6	0.100
n3	> 3.3	0.045	> 3.6	0.045	> 4.6	0.045

Table 6.3 - Adopted depth-varying hydraulic roughness coefficients for the Oxley Creek Channel in the 3 m grid 'fast model'

Depth band	Oxley Creek u/s New Beith		Oxley Creek d/s New Beith		Oxley Creek Greenbank	
	Depth (m)	Manning's 'n'	Depth (m)	Manning's 'n'	Depth (m)	Manning's 'n'
n1	≤ 2.5	0.045	≤ 2.5	0.045	≤ 2.5	0.045
n2	2.5 to 3.3	0.080	2.5 to 3.6	0.080	2.5 to 4.6	0.080
n3	> 3.3	0.045	> 3.6	0.045	> 4.6	0.045

6.8 HYDRAULIC STRUCTURES

6.8.1 Overview

The model includes hydraulic structures as both 1D elements and 2D layered flow constrictions. Structures have been included based on survey or from the existing LCC database. Stormwater pits and pipe networks have been included within the model in Forestdale. This urban area is potentially affected by floodwater surcharging via the stormwater network.

The total number of modelled structures were different for each event, which reflect the level of development within the catchment during each event. For example, more structures were included for the February 2022 calibration event to account for recently completed developments and road upgrade works.

A summary of all hydraulic structures included in the hydraulic model is as follows:

- Up to 271 stormwater culverts and trunk stormwater pipes, made up of up to:
  - 63 sets of box culverts;
  - 115 pipe culverts; and
  - 93 trunk stormwater pipes.
- 131 stormwater inlet pits, made up of:
  - 61 field inlet pits; and
  - 70 stormwater manholes.
- 11 bridge structures.

For the February 2022 event (and for design event modelling), the recently constructed New Beith Road culverts (which consist of large banks of box culverts) were modelled as bridges (using layered flow constrictions) to improve model stability.

The locations of these structures are shown in Figure 6.1 and Figures B.5 to B.8 in Appendix B. Details of the culvert structures are shown in Table B1 in Appendix B. Details of the culvert structures are shown in Table B1 in Appendix B. Details of the stormwater network are shown in Table B.2 to B.4 in Appendix B.

6.8.2 Culverts

Details of the culvert structures are shown in Table B.1 in Appendix B, including the source used to configure each structure. It is of note that some culverts were configured based on multiple sources of information. The structure locations are shown in Figures B.5 to B.8 in Appendix B. The following is of note:

- Stormwater pipe and box culvert details were generally obtained from the LCC hydraulic structures survey, where available, or from data obtained during the WRM site visit. Where survey data is not available, details of stormwater pipe and box culverts were obtained from the LCC hydraulic structures database.
- 3 culverts in the new development in Greenbank (Tivoli Avenue and Australis Circuit) and 2 culverts in the new development area in New Beith (near Split Log Crescent) were included in the model based on As-Constructed drawings provided by LCC.
- Data from the LCC hydraulic structures survey and the LCC hydraulic structures database were verified against measurements taken during the site visit by WRM.
- Some stormwater pipe and box culvert invert levels were missing from the LCC hydraulic structures database. For these structures, invert levels were obtained from the LCC 2017 LiDAR data.

Culverts in the TUFLOW model were modelled as 1D structures embedded within the 2D model domain. For calibration event modelling, no blockage was applied to any culverts in the model.

For design event modelling, structure blockage was determined based on recommendations in the ARR 2019 guidelines and is further described in Section 10.5.

6.8.3 Trunk stormwater network

Details of the trunk stormwater structures are shown in Table B.2 in Appendix B. The structure locations are shown in Figures B.5 to B.8 in Appendix B.

Trunk stormwater pipes were generally configured based on information in the LCC hydraulic structures database. Where pipe invert levels are not available in the LCC hydraulic structures database, invert levels were interpolated based on the known invert levels of upstream and downstream connecting pipes.

6.8.4 Stormwater inlet pits

Details of the stormwater inlet pits are shown in Table B.3 in Appendix B. The structure locations are shown in Figures B.5 to B.8 in Appendix B.

Stormwater inlet pits were modelled as 1D structures embedded within the 2D model domain. Stormwater inlet pits in the model were configured as follows:

- Stormwater inlet pits were generally configured based on information provided in the LCC hydraulic structures database.
- The model only includes stormwater inlet pits located adjacent to the modelled trunk stormwater drainage pipes. The model also does not include the majority of small pipes connecting the inlet pits to the main trunk drainage pipes. Instead, the “pit search distance” TUFLOW feature was adopted to automatically connect the stormwater pits to the trunk stormwater pipe network.
- Side entry inlet pits were classified as either “S” (small), “M” (medium) or “L” (large) lintel inlet pits. The stage-discharge relationships for these lintel inlet pits were obtained from standard BCC pit curves.
- Grated field inlet pits were classified based on their grate dimensions if details are available in the LCC hydraulic structures database. The stage-discharge relationships for these inlet pits were derived using the weir and orifice flow equations.
- Pit invert levels were obtained from the LCC hydraulic structures database (if available) If invert information is not available from the supplied data, pit surface levels were assumed as 0.05 m below the LiDAR surface to ensure that overland flows are captured in the inlet pits.

6.8.5 Stormwater manholes

Details of the stormwater manholes are shown in Table B.4 in Appendix B. The structure locations are shown in Figures B.5 to B.8 in Appendix B.

Manholes were manually created within the 1D model domain using TUFLOW “1D_mh” objects. Details of manually created culverts were obtained from the LCC hydraulics structures database. Where details are not available from the supplied data, manhole dimensions were assumed based on the total widths of all connecting pipes.

6.8.6 Bridges

Bridges in the TUFLOW model were configured based on the LCC and WRM site visit observations and photos supplied by LCC. Information on the two bridges across the Logan Motorway was obtained from the Aurecon (2014) report. Table 6.4 outlines the bridge details. The structure locations are shown in Figures B5 to B8 in Appendix B.

Historical aerial imagery indicates that the bridge at Spring Mountain Drive (ID 107) was constructed in August 2017. The bridge was included for the 2022 calibration event and for design event modelling.

Bridges in the TUFLOW model were modelled as "layered flow constrictions". Using this approach, bridges are modelled as partial blockages to incoming flows.

Table 6.4 - Bridge modelling detail

Structure ID	Easting	Northing	Width (m)	Soffit (mAHD)	Block (%)	Deck (m)	Guard (m)	Name
5	500015.6	6941006	9	25.02	2.9	0.8	0.65	Adermann Bridge
22	500375.1	6936470	3	47	6.67	0.8		Rail
32	497244.9	6935474	11	41.11	0	1.4	1.2	Edwards Bridge
80	494723.2	6932397	7	54.68	1.67	0.85	0.8	
98	494118.3	6931489	7	57.86	0	0.8	1.2	Wilson Bridge
99	494257	6931437	7	57.69	0	0.8	1.2	McTaggart Bridge
107*	492155	6930875	12	70.34	1	1.25	1	Spring Mt Drive
111	491133.2	6930681	4.5	70.59	1.72	0.75		
121	497531.7	6935950	5	39.42	0	1.3	0.75	
520	499782.4	6942642	9	25.87	5	0.53	1	Logan Motorway
520	499782.4	6942642	9	25.87	5	0.53	1	Logan Motorway

* constructed between August and October 2017

6.8.7 Structure blockage

Bridge structure blockages were determined as percentages based on the configuration of bridge piers, deck and guard rails of each bridge. For the bridge opening, the pier width over the bridge span was assumed as a blockage. The percentage blockage due to the bridge piers range between 0% and 7% depending on the bridge pier configuration. Bridge decks were considered as full blockages (100% blockage). Solid road barriers were also considered as full blockages (100% blockage). Guard rails immediately above the bridge were considered as full blockages (100% blockage).

For the calibration events, guard rails adjacent to the bridge were assumed as partially blocked (25.5%) and represented as per the TMR standard specifications. Culverts were assumed to be free of any blockage.

For design event modelling, all guard rails were assumed to be fully blocked (100% blockage). Culvert blockages for the design events were determined based on recommendations in the ARR 2019 guidelines. The adopted blockage factors for culverts and bridges were determined individually depending on the size and configuration of each structure and the debris assessment for the catchment and are further described in Section 10.3.

7 Hydraulic model calibration

7.1 METHODOLOGY

Inflow hydrographs for the January 2013, May 2015, March 2017 and February 2022 events were generated from the calibrated URBS hydrologic model and used as input to the TUFLOW hydraulic model. The TUFLOW model predicted water level hydrographs were then compared with recorded water level hydrographs from the available stream gauges for all four events. The hydraulic model results for the January 2013 and May 2015 events were also compared with surveyed debris marks throughout the Upper Oxley Creek catchment.

The above approach allows the suitability of the discharges estimated by the hydrologic model to be confirmed, as well as testing the performance of the hydraulic model. Calibration was undertaken for both the fast (9 m grid) and detailed (3 m grid) TUFLOW models.

7.2 JANUARY 2013

7.2.1 Overview

For this event, the TUFLOW model predicted water level hydrograph was compared with recorded water level hydrograph at New Beith as well as surveyed debris marks throughout the Upper Oxley Creek catchment. No data is available at the Oxley Creek AL (Goodna Road) and Forestdale (Johnson Road) AL stream gauges for this event.

7.2.2 January 2013 calibration results

Table 7.1 compares recorded and modelled peak water level at New Beith. Figure 7.5 compares the recorded and modelled water level hydrograph at New Beith. Figure 7.2 show the differences between the modelled peak flood levels and surveyed debris marks at the debris locations within the model extent.

The January 2013 calibration results indicate the following:

- The modelled water level hydrographs (for both the fast and detailed models) generally match well with the shape of the recorded hydrograph at New Beith.
- The timing of the peak water level at New Beith match well with the recorded hydrograph. The modelled peak water level at New Beith (for both the fast and detailed models) also match well with the recorded peak water level.
- A comparison of modelled peak flood levels against surveyed debris marks for this event indicates the following (refer to Figure 7.2):
    - In the upper reach of Oxley Creek (at mark #4 near the Tully Road crossing), the modelled peak water level matches well (within 0.03 m) with the surveyed level.
    - In the vicinity of the Oxley Creek crossing at Pub Lane and Spring Mountain Drive (marks #2 and #3), the modelled peak water level is about 0.39 m higher than the surveyed level at mark #2. The surveyed level at mark #3 is not reliable as it is 1.5 m below the surveyed level at Mark #2 despite being nearby.
    - In the vicinity of New Beith Road (marks #5 to #14), the modelled peak water levels are approximately 0.54 m to 0.73 m higher than the surveyed levels. These debris marks were labelled as “water level” and hence the type of debris is uncertain. It is possible that these debris were mobile and may have moved as the flood receded.
    - In the vicinity of the Oxley Creek crossing at Goodna Road, the modelled peak water levels match well with surveyed levels at marks #15 and #16 (within 0.03 m) and are about 0.11 m lower than the surveyed level at mark #17.

Table 7.1 - Recorded and modelled peak water levels, January 2013 event

Gauging station name	Gauging station no.	Recorded peak water level (mAHD)	Fast (9 m grid) model		Detailed (3 m grid) model	
			Modelled peak water level (mAHD)	Difference (m)	Modelled peak water level (mAHD)	Difference (m)
New Beith AL	143033A	54.23	54.23	0.00	54.21	-0.02

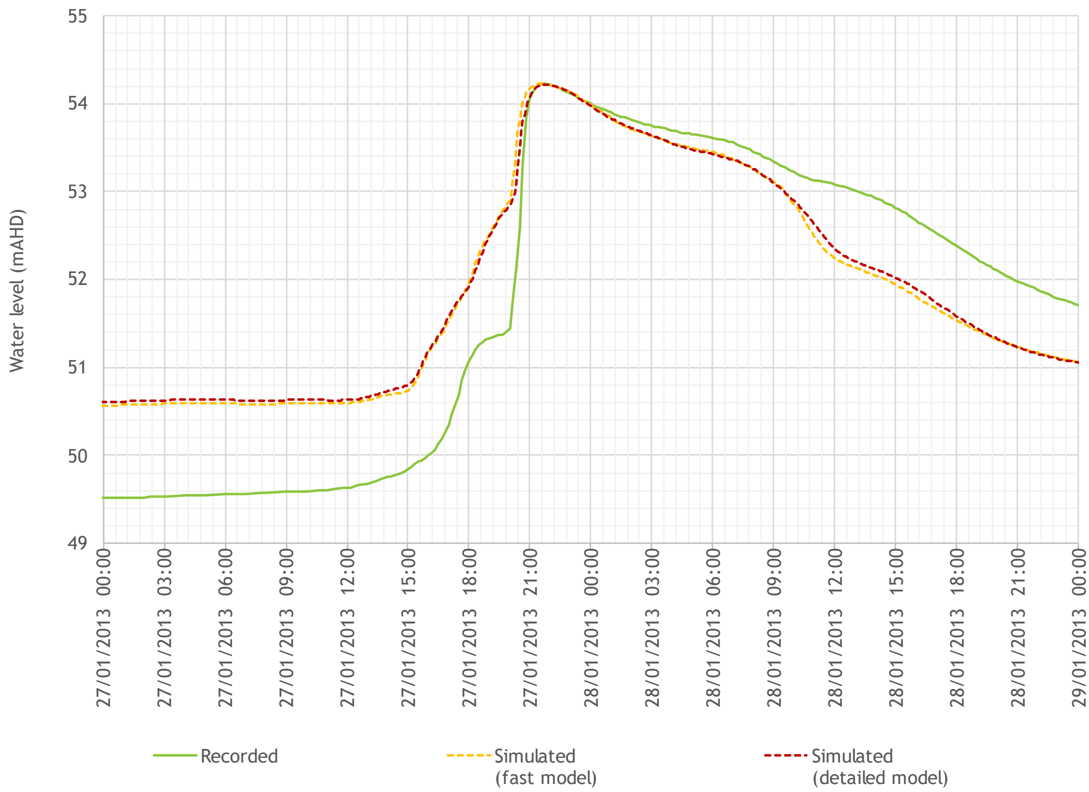
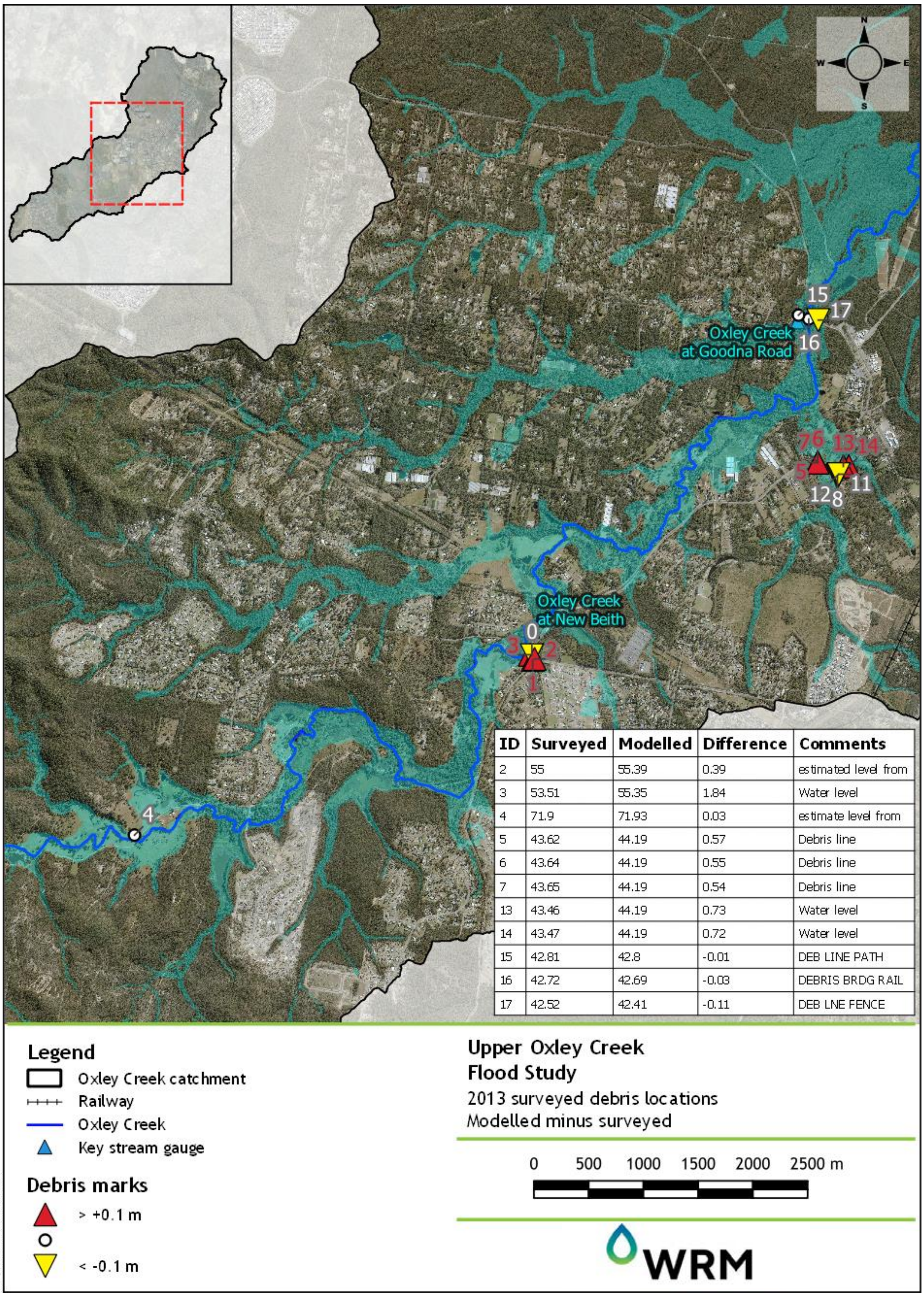


Figure 7.1 - Modelled and recorded water level hydrographs in Oxley Creek at New Beith (RDMW GS 14033A), January 2013 flood event



ID	Surveyed	Modelled	Difference	Comments
2	55	55.39	0.39	estimated level from
3	53.51	55.35	1.84	Water level
4	71.9	71.93	0.03	estimate level from
5	43.62	44.19	0.57	Debris line
6	43.64	44.19	0.55	Debris line
7	43.65	44.19	0.54	Debris line
13	43.46	44.19	0.73	Water level
14	43.47	44.19	0.72	Water level
15	42.81	42.8	-0.01	DEB LINE PATH
16	42.72	42.69	-0.03	DEBRIS BRDG RAIL
17	42.52	42.41	-0.11	DEB LNE FENCE

Figure 7.2 - Differences between modelled peak water levels and surveyed debris marks, January 2013 flood event

7.3 MAY 2015

7.3.1 Overview

For this event, the TUFLOW model predicted water level hydrograph was compared with recorded water level hydrograph at New Beith as well as surveyed debris marks throughout the Upper Oxley Creek catchment. No data is available at the Oxley Creek AL (Goodna Road) and Forestdale (Johnson Road) AL stream gauges for this event.

7.3.2 May 2015 calibration results

Table 7.1 compares recorded and modelled peak water level at New Beith. Figure 7.5 compares the recorded and modelled water level hydrograph at New Beith. Figure 7.2 show the differences between the modelled peak flood levels and surveyed debris marks at the debris locations within the model extent.

The May 2015 calibration results indicate the following:

- The modelled water level hydrographs (for both the fast and detailed models) generally match well with the shape of the recorded hydrograph at New Beith.
- The modelled flood peak occurs approximately one hour earlier than the recorded flood peak, but the modelled peak water levels (for both the fast and detailed models) match well with the recorded peak water level.
- A comparison of modelled peak flood levels against surveyed debris marks for this event (refer to Figure 7.4) indicates that:
  - The modelled peak water levels are approximately 0.23 m lower than the surveyed levels at Pub Lane (mark #1), and approximately 0.26 m and 0.27 m lower than the surveyed levels along New Beith Road (marks #2 and #3). This is considered a reasonably good match.
  - At the Oxley Creek at Goodna Road gauge (mark #4), the modelled peak water levels are approximately 0.02 m lower than the surveyed levels. This is considered an excellent match.
  - Debris marks #1 to #4 were classified as debris on posts and road markers and therefore, the surveyed levels at these locations are likely to be reasonably accurate.

Table 7.2 - Recorded and modelled peak water levels, May 2015 event

Gauging station name	Gauging station no.	Recorded peak water level (mAHD)	Fast (9 m grid) model		Detailed (3 m grid) model	
			Modelled peak water level (mAHD)	Difference (m)	Modelled peak water level (mAHD)	Difference (m)
New Beith AL	143033A	53.95	53.95	0.00	53.89	-0.06

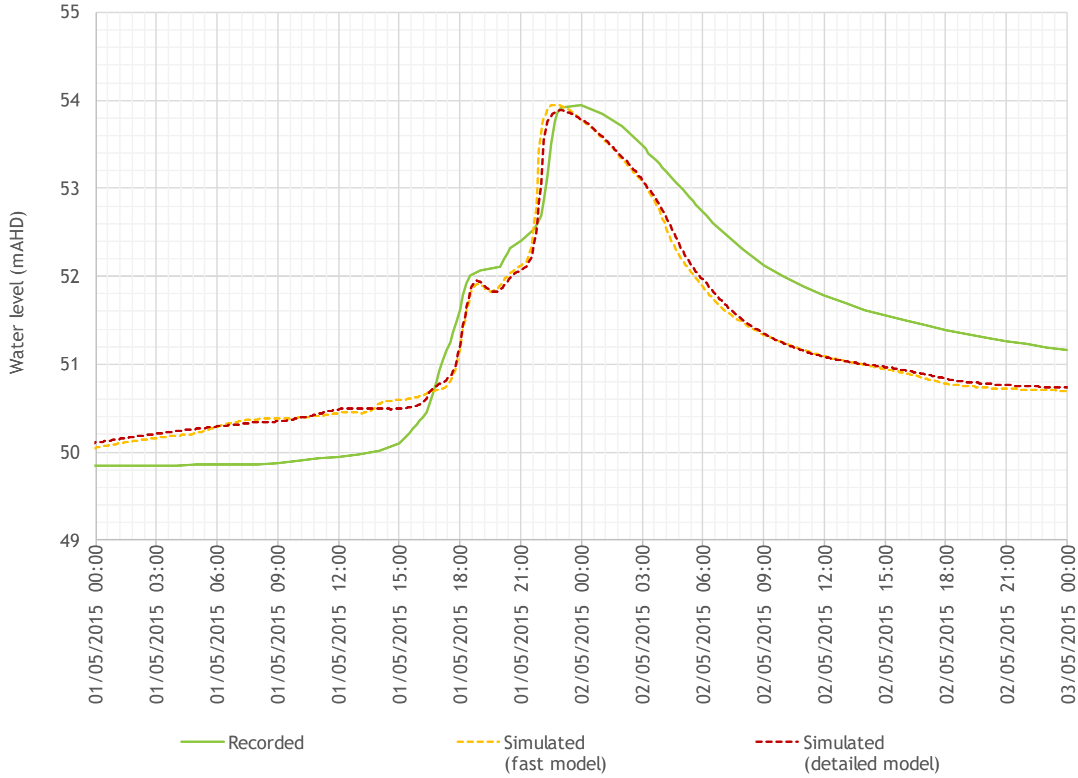
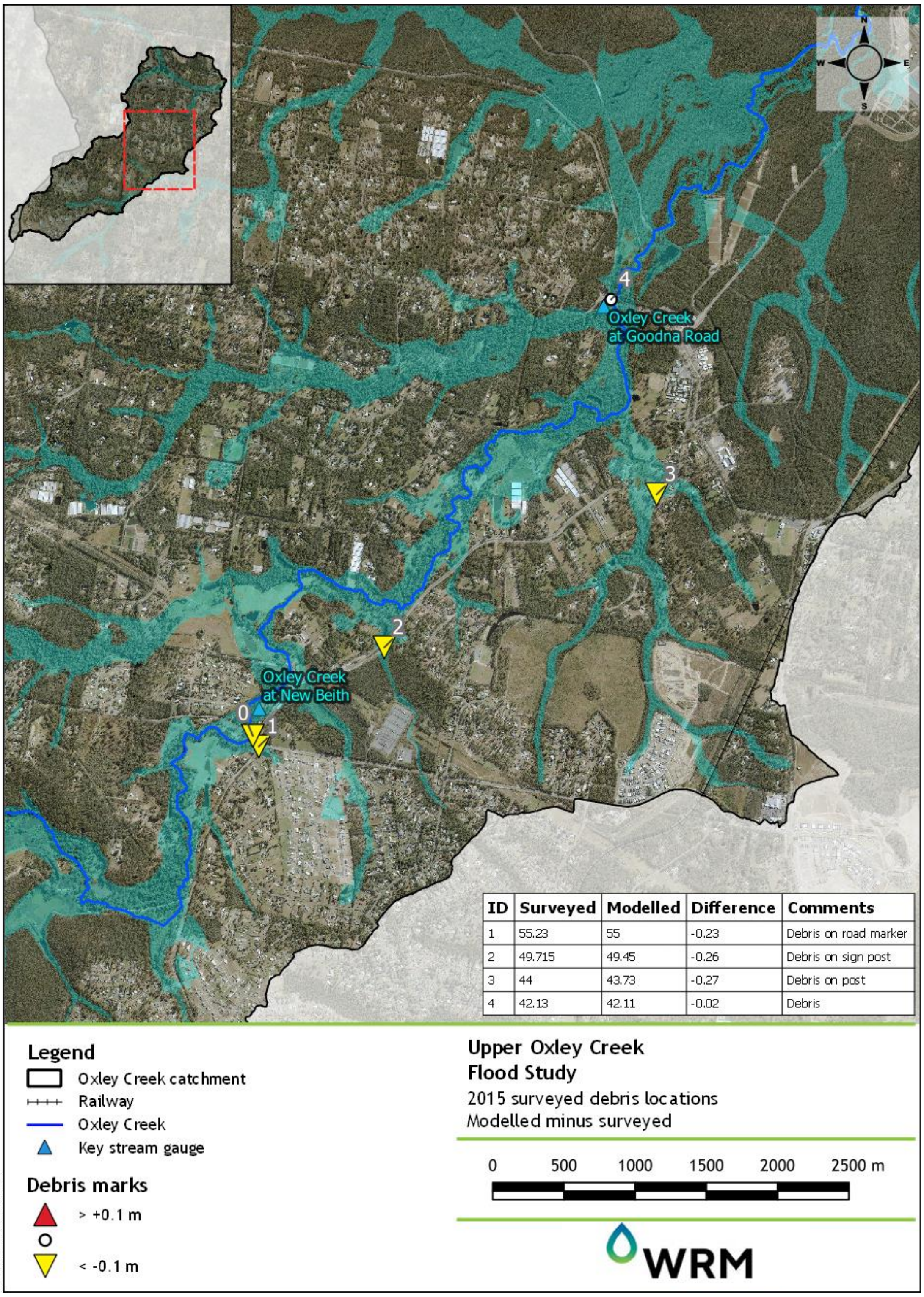


Figure 7.3 - Modelled and recorded water level hydrographs in Oxley Creek at New Beith (RDMW GS 14033A), May 2015 flood event



ID	Surveyed	Modelled	Difference	Comments
1	55.23	55	-0.23	Debris on road marker
2	49.715	49.45	-0.26	Debris on sign post
3	44	43.73	-0.27	Debris on post
4	42.13	42.11	-0.02	Debris

Figure 7.4 - Differences between modelled peak water levels and surveyed debris marks, May 2015 flood event

7.4 MARCH 2017

7.4.1 Overview

For this event, the TUFLOW model predicted water level hydrographs were compared with recorded water level hydrographs at New Beith and Goodna Road. No data is available at the Forestdale (Johnson Road) AL stream gauge for this event. Surveyed debris marks were not available for this event.

7.4.2 March 2017 calibration results

The March 2017 calibration results indicate the following:

- At New Beith, the modelled water level hydrograph (for both the fast and detailed models) generally matches well with the shape of the recorded hydrograph. The timing of the peak water level at New Beith match well with the recorded hydrograph. The modelled peak water level at New Beith (for both the fast and detailed models) also match well with the recorded peak water level.
- At Goodna Road:
  - The modelled water level hydrographs (for both the fast and detailed models) generally match well with the shape of the recorded hydrograph.
  - The modelled peak water level and the timing of the peak water level match well with the recorded hydrograph. However, the model overestimates the peak water level of the earlier (smaller) flood peak, which is due to the URBS model overestimating discharges for this earlier flood peak.

Table 7.3 - Recorded and modelled peak water levels, March 2017 event

Gauging station name	Gauging station no.	Recorded peak water level (mAHD)	Fast (9 m grid) model		Detailed (3 m grid) model	
			Modelled peak water level (mAHD)	Difference (m)	Modelled peak water level (mAHD)	Difference (m)
New Beith AL	143033A	54.31	54.33	0.02	54.32	0.01
Oxley Creek AL (Goodna Road)	540646	42.68	42.63	-0.05	42.67	-0.01

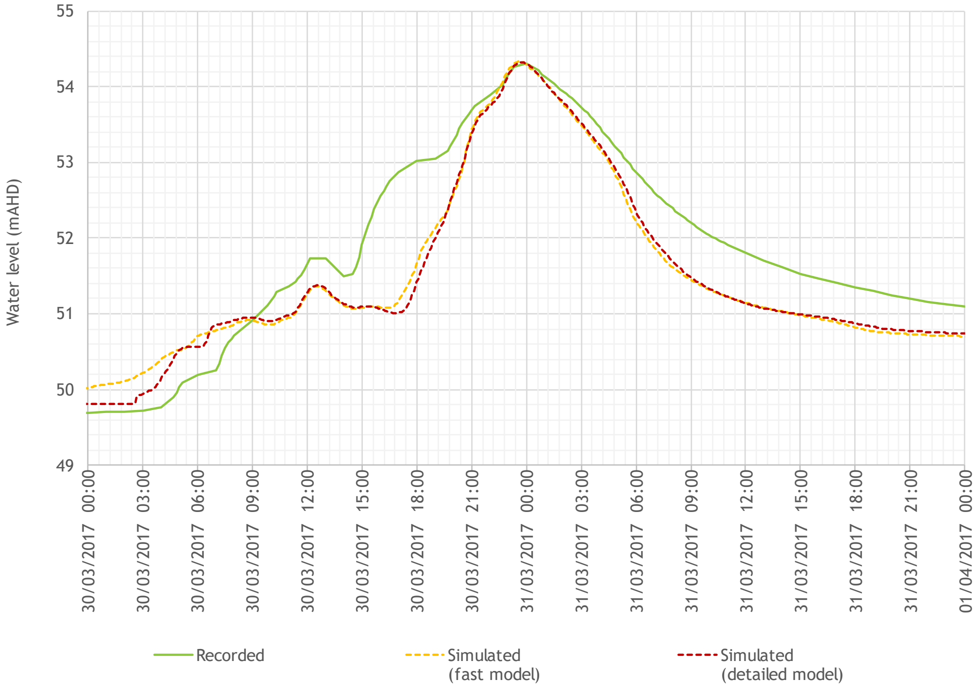


Figure 7.5 - Modelled and recorded water level hydrographs in Oxley Creek at New Beith (RDMW GS 14033A), March 2017 flood event

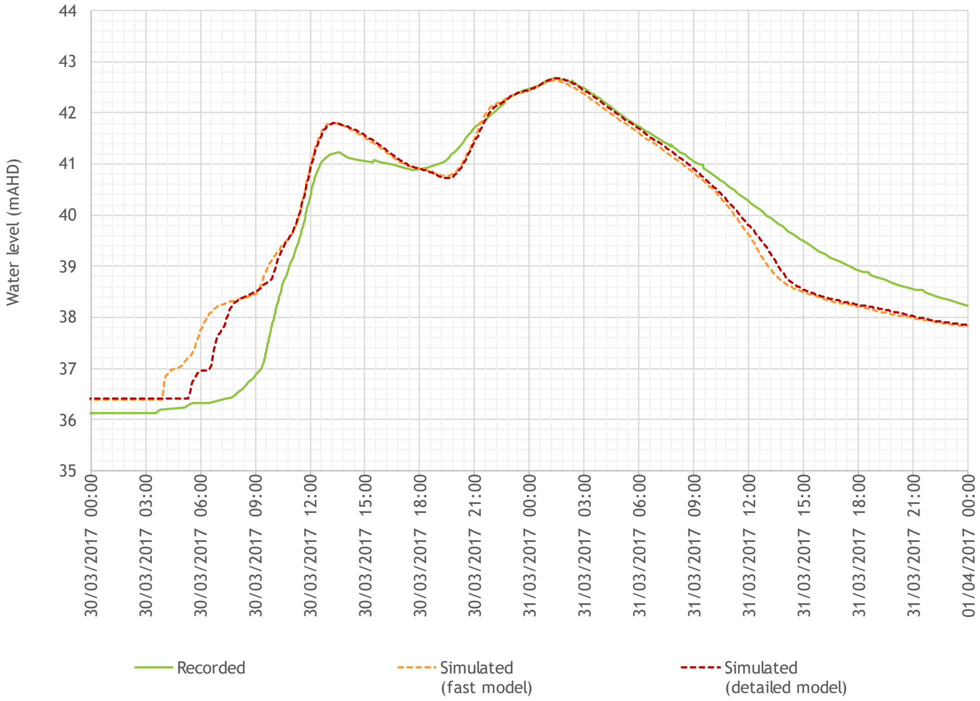


Figure 7.6 - Modelled and recorded water level hydrographs in Oxley Creek at Oxley Creek AL (Goodna Road) (GS 540646), March 2017 flood event

7.5 FEBRUARY 2022

7.5.1 Overview

For this event, the TUFLOW model predicted water level hydrographs were compared with recorded water level hydrographs at New Beith, Goodna Road and Johnson Road. Surveyed debris marks were not available for this event.

7.5.2 February 2022 calibration results

The February 2022 calibration results indicate the following:

- At New Beith and Goodna Road, the modelled water level hydrographs (for both the fast and detailed models) generally replicate the recorded hydrograph shape reasonably well. The modelled peak water level and the timing of the multiple peaks match well with the recorded hydrograph at these gauges.
- At Johnson Road:
  - The modelled water level hydrographs (for both the fast and detailed models) generally match well with the shape of the recorded hydrograph. The model was able to replicate the water level of the first peak, and the model slightly underestimates the peak water level of the later (larger) peak.
  - The modelled timing of the earlier flood peaks generally matches the recorded hydrograph. However, the modelled time of peak water level for the final and largest peak occurs approximately 3 hours later than the recorded hydrograph.
  - It is possible that significant scouring occurred along the Oxley Creek channel between Goodna Road and Johnson Road during the later stage of the February 2022 flood event, which may have changed the hydraulic characteristics of the channel downstream of Goodna Road. This may have resulted in Oxley Creek flows downstream of Goodna Road being routed faster during the later stage of the flood. The TUFLOW model was not able to replicate this change in hydraulic behaviour.
- The model generally underestimates flood volume for this event, particularly midway through the flood event. The reason for this is likely due to the URBS model underestimating discharges and flood volume midway through the flood (refer to Section 5.4 and Section 5.6.4).

Table 7.4 - Recorded and modelled peak water levels, February 2022 event

Gauging station name	Gauging station no.	Recorded peak water level (mAHD)	Fast (9 m grid) model		Detailed (3 m grid) model	
			Modelled peak water level (mAHD)	Difference (m)	Modelled peak water level (mAHD)	Difference (m)
New Beith AL	143033A	54.18	54.25	0.07	54.23	0.05
Oxley Creek AL (Goodna Road)	540646	42.88	42.91	0.03	42.99	0.11
Forestdale AL (Johnson Road)	40788	24.19	24.14	-0.05	24.19	0.00

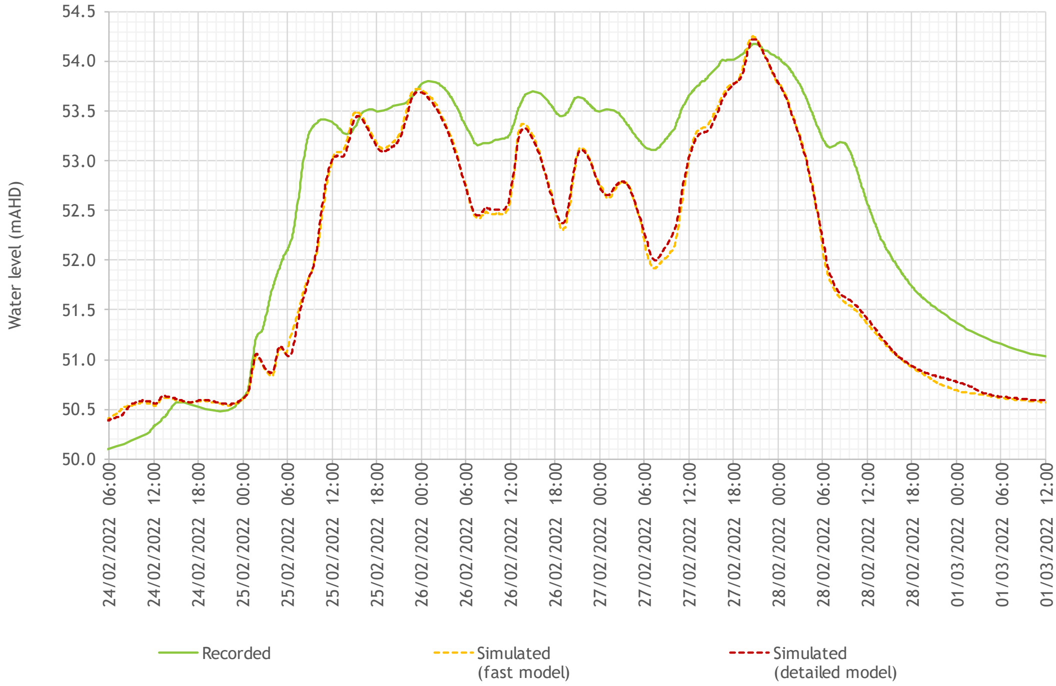


Figure 7.7 - Modelled and recorded water level hydrographs in Oxley Creek at New Beith (RDMW GS 14033A), February 2022 flood event

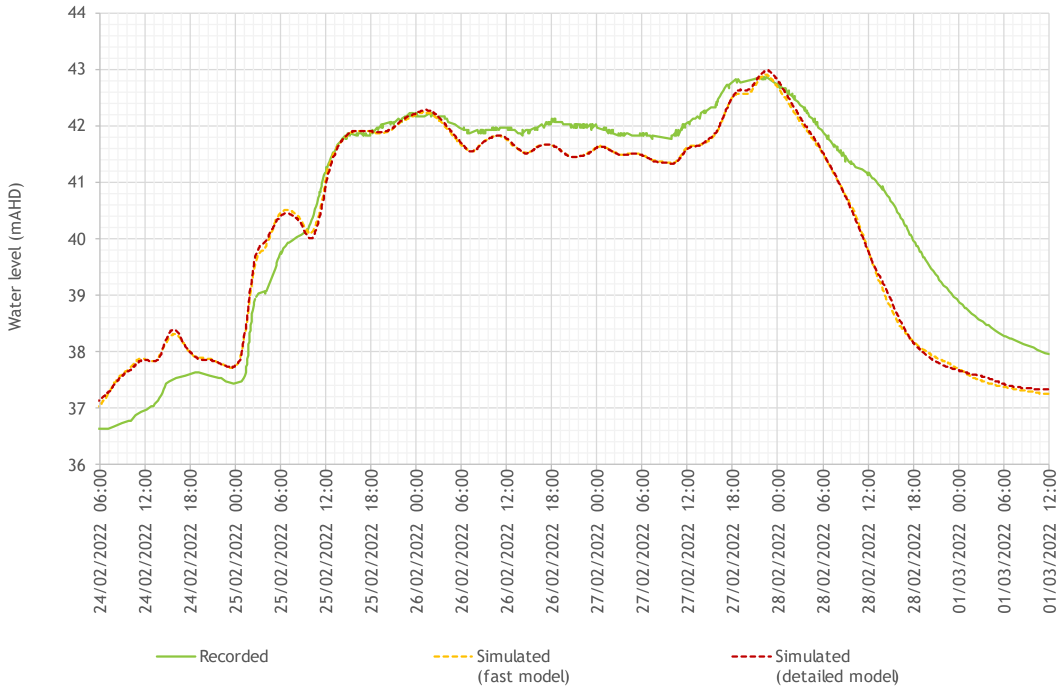


Figure 7.8 - Modelled and recorded water level hydrographs in Oxley Creek at Oxley Creek AL (Goodna Road) (GS 40788), February 2022 flood event

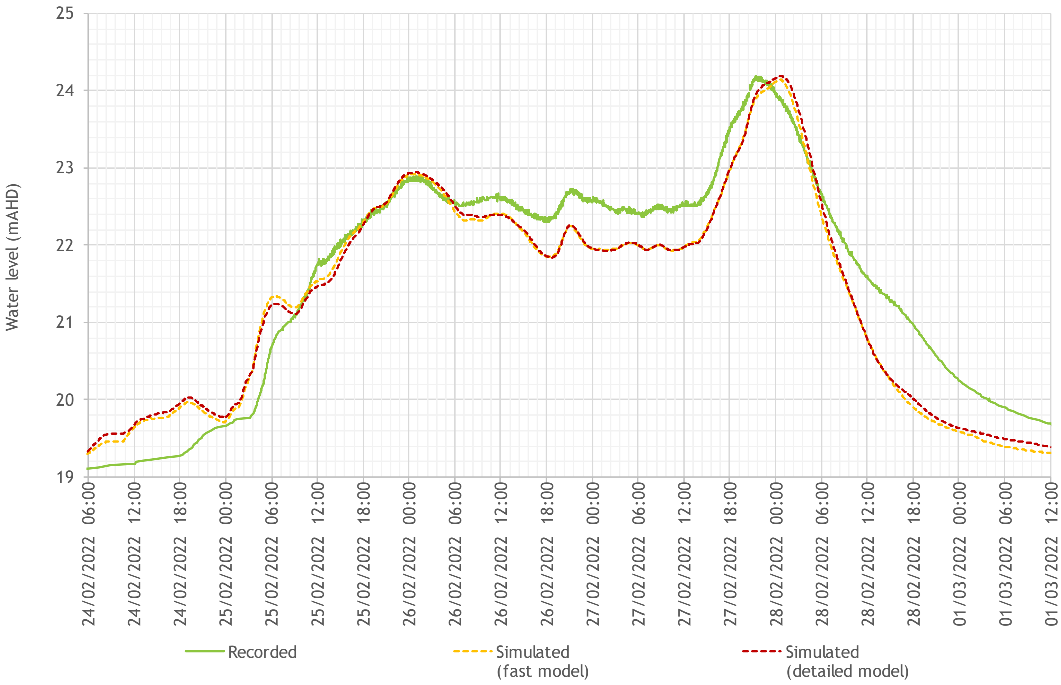


Figure 7.9 - Modelled and recorded water level hydrographs in Oxley Creek at Forestdale (Johnson Road) AL (GS 540646), February 2022 flood event

8 Flood frequency analysis

8.1 METHODOLOGY

Design flood discharges were estimated by flood frequency analysis (FFA) using all available height data and the adopted rating curves (refer to Section 3.11). The FFA was undertaken using the RMC-BestFit software (version 1.0) and in accordance with guidelines in Book 3, Chapter 2 of ARR 2019 (Ball et al, 2019).

The FFA was undertaken on recorded stream flow data at the New Beith AL (GS 540097) stream gauge, which is located in the middle of the Upper Oxley Creek catchment and has over 40 years of historical record. The Oxley Creek AL (GS 540646) and Johnson Road (GS 040788) gauges are unrated, with less than 10 years of historical record at both gauges. Therefore, the Oxley Creek AL and Johnson Road gauges are not suitable for undertaking an FFA.

Annual maximum series (AMS) and peak over threshold (POT) series analyses were undertaken based on fitting Generalised Extreme Value (GEV) distributions to the data series. The Log-Pearson Type III (LPIII) distribution was also considered, but was found to produce a poor fit between the expected flood quantiles and the recorded data compared to the GEV distribution.

The discharge estimates obtained by FFA were confirmed against the rainfall probabilities and associated flood magnitudes of the four calibration events.

8.2 AVAILABLE DATA

8.2.1 Annual maximum series (AMS) data

The peak annual gauge heights and discharges recorded at the gauge were obtained from the RDMW website. Discharges were estimated using the combined RDMW and TUFLOW rating curves adopted for the New Beith AL gauge (refer to Section 3.11).

For years prior to 2020, peak flood heights were converted to peak discharges using the combined 2017 rating curve. From 2020 onwards, peak flood heights were converted to peak discharges using the combined 2021 rating curve. The change in the adopted rating curve from 2020 onwards is due to the New Beith Road upgrade which affects the hydraulic characteristics of the Oxley Creek channel and floodplain in the vicinity of the New Beith AL gauge.

Peak series data at the New Beith gauge is available from 1976 to 2022. This data was used to generate an annual maximum series (AMS) based on water years (i.e., October to September). However, years 1987 and 1955 were excluded from the assessment because data for these years are mostly missing, including for the months that are expected to be wet. In total, 44 years of recorded data at the New Beith gauge were used to generate the AMS data.

8.2.2 Peak over threshold (POT) data

A POT series was derived using continuous water level data at the New Beith AL gauge. Guidelines and recommendations in ARR 2019 (Ball et al, 2019) were used to derive the POT series.

For the POT series analysis, the number of data points (m) was made equal to the number of data years (n) as recommended in ARR 2019. A key aspect of the POT series analysis is the selection of the m data points from statistically independent flood events. The period between statistically independent flood peaks (the interdependency period) were initially estimated based on a study conducted by Beard (1974) and referred to in ARR 2019, which recommends separating flood peaks by *five days plus the natural logarithm of the square miles of drainage area*. The Beard (1974) method results in interdependency periods of approximately 8 days at the New Beith gauge. The resulting peak flow series was then filtered further by removing the lowest ranked flows until the number of data points (m) equalled the number of data years (n).

8.2.3 Other historic data

No historical flood data (pre-dating the period of record) was available at the New Beith AL gauge for this study.

8.3 ANALYSIS AND RESULTS

The RMC-BestFit software was used to estimate peak flood discharges for various AEP events at the selected gauge. The following is of note with regards to the adopted FFA methodology:

- The GEV distribution was adopted with the Bayesian inference method for both the POT series and annual series FFA.
- For the POT series, low flows smaller than 11.5 m^3/s were censored, resulting in 1 event point being censored as a low flow outlier. A data series of 43 points remained for the POT series FFA.
- For the annual series, low flows smaller than 0.4 m^3/s were censored, resulting in 12 years of data being censored as low flow outliers. A data series of 32 points remained for the annual series FFA. The low flow threshold was adopted based on the lowest recorded annual peak discharge of 0.4 m^3/s which occurred during the water year ending 1978, noting that this water year has a full year of record.

Table 8.1 shows the flood frequency distributions at the gauge, including the 5% and 95% confidence limits obtained for the results. Figure 8.1 and Figure 8.2 show plots of the flood frequency distribution results at the gauge for the annual series and the POT series, respectively. The following is of note:

- Based on the expected flood quantiles, fitted POT series values are higher than the annual series values for all events from 50% to 1% AEP.
- The flood frequency distributions at the New Beith AL gauge are based on 44 years of historical record. As such, the discharge estimates for events up to and including 5% (1 in 20) AEP are expected to be reasonably accurate. However, there is a high degree of uncertainty attached to the 1% (1 in 100) AEP, and to a lesser extent the 2% (1 in 50) AEP discharge estimates at the New Beith AL gauge.
- In accordance with recommendations in ARR 2019, the FFA peak discharges in Oxley Creek at New Beith AL were adopted based on the the POT series values for events up to and including 10% AEP, and the annual series values for events larger than 10% AEP.

Table 8.1 - Flood frequency analysis results, New Beith AL gauge (GS 540097)

AEP	Annual series peak discharge (m^3/s)			POT series peak discharge (m^3/s)		
(%)	5% confidence limit	Expected quantile	95% confidence limit	5% confidence limit	Expected quantile	95% confidence limit
50	20	35	57	36	45 [a]	60
20	75	96	146	76	93 [a]	134
10	115	143	243	110	138 [a]	230
5	152	194 [a]	405	146	195	393
2	192	272 [a]	770	195	296	791
1	216	338 [a]	1,237	234	400	1,351

[a] - adopted as the FFA design discharge in Oxley Creek at New Beith AL

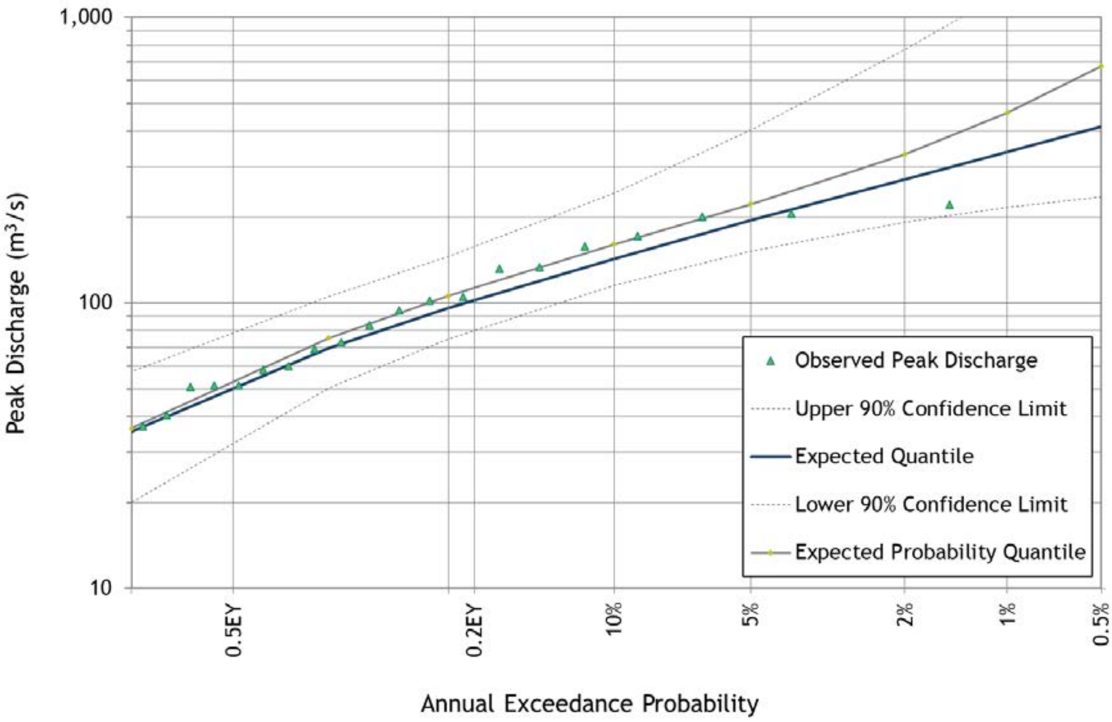


Figure 8.1 - Plot of AMS flood frequency distribution at the New Beith AL gauge (GS 540097)

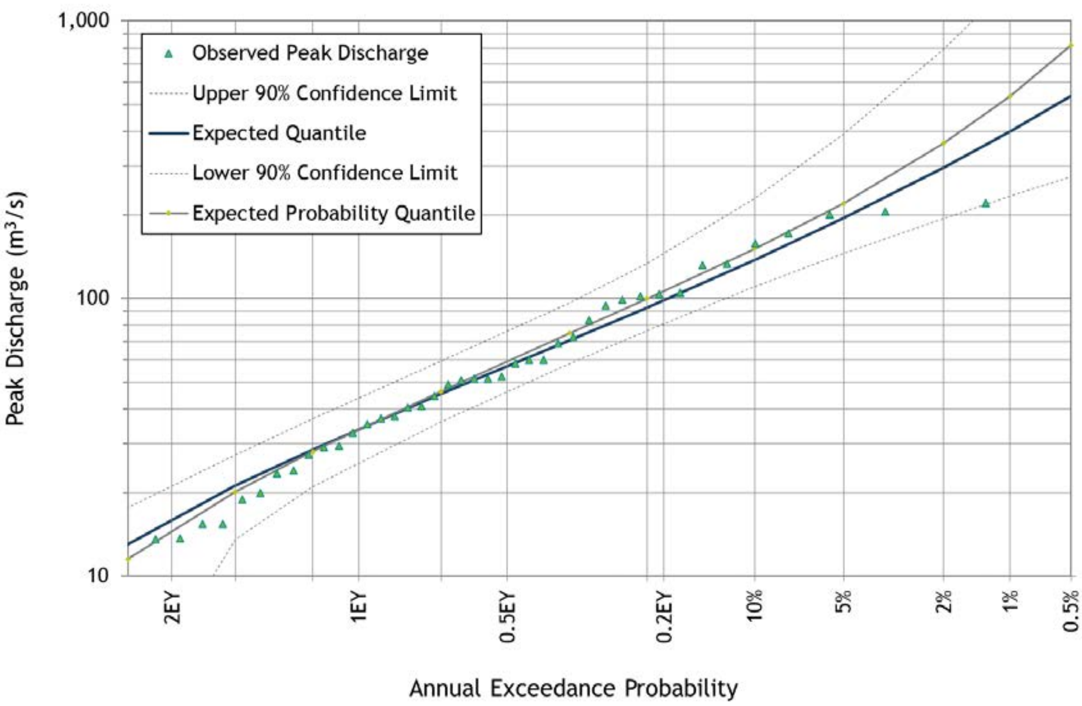


Figure 8.2 - Plot of POT series flood frequency distribution at the New Beith AL gauge (GS 540097)

8.4 COMPARISON WITH MAGNITUDES AND SEVERITIES OF PAST FLOOD EVENTS

Table 8.2 provides a summary of rated peak discharges at New Beith AL for the January 2013, May 2015, April 2017 and February 2022 flood events (the four calibration events). Table 8.2 also shows the recorded rainfall severities within the catchment upstream of New Beith AL, based on the 6-hour to 24-hour durations which are expected to be critical in the Oxley Creek channel at New Beith.

Table 8.2 shows that within the last 10 years, there were four major flood events in the Upper Oxley Creek catchment, which produced peak discharges at New Beith AL ranging from 133 m^3/s to 204 m^3/s. The corresponding rainfall severities in the upper catchment for these four events range from 15.2% AEP to 2.3% AEP for the 6-hour to 24-hour durations which are expected to be critical at New Beith. In comparison, the adopted FFA peak discharges (shown in Table 8.1) were estimated to be 138 m^3/s, 181 m^3/s and 255 m^3/s for the 10%, 5% and 2% AEP events, respectively.

On the basis of the above, the estimated FFA peak discharges are generally consistent with the magnitudes and corresponding severities of past flood events. This gives confidence that the FFA peak discharge estimates (shown in Table 8.1) are reasonable.

Table 8.2 - Summary of rated peak discharges at New Beith AL for four historical events and the corresponding rainfall severities in the upstream catchment

Historical flood event	Rated peak discharge at New Beith AL (m^3/s)	Rainfall severity (AEP) (6 to 24-hour durations)
January 2013	188	3.7% to 2.0%
May 2015	133	11.8% to 4.3%
April 2017	219	15.2% to 3.3%
February 2022	204	8.8% to 2.3%

8.5 COMPARISON WITH PREVIOUS (AURECON, 2014) STUDY

Table 8.3 compares FFA peak discharges from the current study against TUFLOW peak discharges from the previous (Aurecon, 2014) study at New Beith. An FFA was undertaken as part of the Aurecon (2014) study. However, peak discharges from the FFA and the Aurecon (2014) hydrologic model at the New Beith AL gauge were not reported in Aurecon (2014). Hence the TUFLOW peak discharges at New Beith AL reported in Aurecon (2014) were used instead for comparison.

Table 8.3 shows that the FFA peak discharges from the current study are smaller (by 4% to 42%) than the Aurecon (2014) peak discharge estimates. The differences are more significant for the more frequent flood events. The reason for this is described as follows:

- The Aurecon (2014) FFA was undertaken using a synthetic annual maximum series, derived using 101 years of continuous rainfall data at the Brisbane CBD. This involved computing the maximum 30 minute, 1, 2, 3, 6, 9, 12, 24, 48 and 72-hour rainfall burst for each year, and then running these storm bursts through an XP-RAFTS hydrologic model to obtain peak discharges at key locations within the catchment. Zero initial and continuing losses were used for all years modelled. An FFA was then undertaken on the XP-RAFTS peak discharges.
- This approach implies that even short duration rainfall bursts (shorter than 3 hours) would occur evenly over the entire Oxley Creek catchment, which is considered unrealistic. Combined with zero rainfall losses, the resulting XP-RAFTS peak discharges would have been overly conservative. Undertaking an FFA on this synthetic data would have resulted in

the overestimation of peak discharges in the Oxley Creek catchment, especially for the more frequent flood events.

Table 8.3 - Comparison of FFA peak discharges from the current study against TUFLOW peak discharges from the previous (Aurecon, 2014) study at New Beith AL gauge

Event AEP (%)	FFA peak discharge (current study) (m^3/s)	TUFLOW peak discharge [a] (Aurecon, 2014) (m^3/s)	Difference (current - previous)
63	- [b]	102	- [b]
50	45	- [b]	- [b]
20	93	161	-42%
10	143	200	-29%
5	194	244	-20%
2	272	305	-11%
1	338	351	-4%

[a] - Peak discharge reported for Oxley Creek at Spring Mountain Drive, just upstream of the New Beith AL gauge.

[b] - Not estimated for this study, hence peak discharges between the two studies could not be compared.

In contrast, the FFA undertaken for the current study was based on actual recorded water level data at the New Beith AL gauge, converted to discharges using with a rating curve derived from a well-calibrated TUFLOW hydraulic model. The resulting FFA peak discharges are also shown to be consistent with the magnitudes and severities of past flood events (refer to Section 8.4). On this basis, the FFA peak discharge estimates from the current study are considered to be more accurate and reliable compared to the Aurecon (2014) estimates.

9 Design event hydrologic modelling

9.1 OVERVIEW

This section describes the methodology adopted to estimate design discharges throughout the Upper Oxley Creek catchment. A summary of the adopted design hydrology methodology for this study is given in Table 9.1.

The calibrated URBS model was used to estimate design flood discharges throughout the Oxley Creek catchment in accordance with the ARR 2019 guidelines. The URBS model design event discharges were reconciled against Flood Frequency Analysis (FFA) estimates at the New Beith Alert stream gauge (RDMW GS 143033A).

Design flood discharge hydrographs were estimated for the full range of storm durations for the 50% (1 in 2), 20% (1 in 5), 10% (1 in 10), 5% (1 in 20), 2% (1 in 50), 1% (1 in 100), 0.5% (1 in 200), 0.2% (1 in 500), 0.05% (1 in 2,000) AEP events and the PMPF event.

Climate change scenarios were simulated for the 1% (1 in 100) AEP event based on representative concentration pathways 4.5 (RCP 4.5), RCP 6 and RCP 8.5, and for the 20% (1 in 5), 10% (1 in 10), 5% (1 in 20), 2% (1 in 50), 0.5% (1 in 200) and 0.2% (1 in 500) AEP events based on RCP 4.5 for the 2090 future climate scenario.

Subcatchment parameters (fraction impervious and PERN N) for the URBS model for design events were derived based ultimate catchment conditions (based on land uses defined in the LCC, BCC and ICC planning schemes).

Table 9.1 - Summary of proposed methodology for design event hydrology

Design flood parameter	AEP (1 in X)	Source/method	Comment
Rainfall depth	≤ 100	ARR 2019	Industry standard.
	> 100 to 2,000	ARR 2019	Industry standard.
	PMPF	BoM GSDM	Adopted for durations ≤ 12 hours.
		BoM GTSMR	Adopted for durations > 12 hours.
Areal Reduction Factor (ARF)	≤ 2000	ARR 2019	ARF were derived based on a single focal point at the outlet of the Upper Oxley Creek catchment at Johnson Road, determined in consultation with LCC.
	PMFDF	BoM GSDM and GTSMR	Industry standard.
Temporal pattern	≤ 2000	ARR 2019	'Point' temporal patterns for durations ≤ 9 hours. 'Areal' temporal patterns for the Upper Oxley Creek catchment for durations ≥ 12 hours. The ARR 2019 'rare bin' temporal patterns were adopted for the 1 in 200, 500 and 2,000 AEP events
	PMPF	BoM GSDM	Adopted for durations ≤ 12 hours.
		BoM GTSMR	Adopted for durations > 12 hours.
Spatial distribution	≤ 2,000	Catchment centroid	Intensity-Frequency-Duration (IFD) data obtained at three locations within the Oxley Creek catchment to Johnson Road to account for the variations in design rainfall throughout the catchment.
	PMPF	BoM GSDM and GTSMR	Adopt PMP spatial distribution for events greater than 1 in 2,000 AEP as recommended by ARR 2019.
Rainfall losses	≤ 100	ARR 2019	Adopted rainfall losses were determined by reconciliation with Flood Frequency Analysis (FFA) results, and then adjusted on a subcatchment basis according to subcatchment imperviousness.
	> 100 to PMPF	Adopt minimum losses	Adopt 0.0 mm initial loss and calibration event continuing losses for this range of event magnitudes.

9.2 DESIGN RAINFALL DEPTH ESTIMATION

9.2.1 50% (1 in 2) to 0.05% (1 in 2,000) AEP design events

Design rainfalls for different storm durations for all AEPs up to and including the 0.05% (1 in 2,000) AEP event were estimated using the 2016 IFDs from BoM (BoM, 2016) as per the procedure outlined in ARR 2019 (Ball et al, 2019). Rainfall intensity-frequency-duration (IFD) data was obtained and applied in the model for three representative locations within the Upper Oxley Creek Catchment, to account for the variation in design rainfalls between the upper, middle and lower reaches of the catchment.

The adopted 50% to 0.05% AEP design rainfall depths (non-areally reduced) are shown in Table 9.2, Table 9.3 and Table 9.4 for the upstream, middle and lower reaches of the catchment, respectively.

Table 9.2 - Design rainfall depths (non-areally reduced) - upstream (obtained from Lat: -27.762, Long: 152.872)

Duration (hrs)	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.05% AEP	PMP
0.5	27.4	37.9	45	52	61.1	68.1	77	89.8	111	244
0.75	31.6	43.8	52.2	60.4	71.4	79.9	90.4	106	131	307
1	34.6	47.9	57.2	66.5	78.8	88.5	100	117	145	361
1.5	38.9	53.9	64.5	75.2	89.7	101	114	134	166	416
2	42.1	58.4	70	81.8	97.9	111	125	146	181	466
3	47.4	65.6	78.8	92.2	111	126	142	166	205	521
4.5	53.6	74.4	89.4	105	126	144	162	189	233	601
6	59	81.9	98.5	116	140	159	179	208	256	659
9	68.2	94.9	114	134	163	186	209	242	298	729
12	75.9	106	128	151	183	209	235	272	335	783
18	88.9	125	152	179	217	249	280	326	402	866
24	99.4	141	172	203	247	283	320	373	462	930
30	108	155	189	224	273	313	358	420	526	1036
36	116	166	203	242	296	340	391	461	581	1132
48	128	185	228	272	334	384	445	527	668	1324
72	144	211	261	314	388	448	516	613	782	1657

Table 9.3 - Design rainfall depths (non-areally reduced) - middle (obtained from Lat: -27.714, Long: 152.936)

Duration (hrs)	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.05% AEP	PMP
0.5	27.6	38.6	45.9	53.1	62.5	69.7	79	92.1	114	244
0.75	31.9	44.6	53.3	61.9	73.2	82	93	109	135	307
1	34.8	48.8	58.5	68.1	80.9	91	103	121	150	361
1.5	39.2	54.9	66	77.1	92.2	104	118	138	171	416
2	42.5	59.5	71.6	83.9	101	114	129	151	187	466
3	47.8	66.9	80.6	94.5	114	129	146	171	212	521
4.5	54.2	75.8	91.3	107	130	148	167	194	240	601
6	59.7	83.4	101	118	143	163	184	214	264	659
9	69.1	96.6	116	137	166	190	213	248	305	729
12	77.1	108	130	153	186	213	239	278	343	783
18	90.3	127	154	182	221	253	285	332	410	866
24	101	144	174	206	251	287	325	379	470	930
30	110	157	191	226	276	317	363	427	535	1036
36	118	169	206	245	299	344	396	469	591	1132
48	130	188	231	275	338	389	450	535	680	1324
72	146	214	265	317	392	454	524	622	795	1657

Table 9.4 - Design rainfall depths (non-areally reduced) - lower (obtained from Lat: -27.655, Long: 153.000)

Duration (hrs)	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.05% AEP	PMP
0.5	28.7	39.7	47.1	54.3	63.8	70.9	80.2	93.6	116	244
0.75	33.2	46.2	55	63.7	75.2	84.1	95.2	111	138	307
1	36.5	50.8	60.7	70.5	83.7	93.9	106	124	154	361
1.5	41.2	57.5	69	80.6	96.2	109	123	144	178	416
2	44.8	62.7	75.3	88.2	106	120	135	158	196	466
3	50.6	70.8	85.3	100	121	137	155	180	223	521
4.5	57.4	80.5	97.1	114	138	157	177	206	255	601
6	63.2	88.7	107	126	153	174	196	228	281	659
9	73	103	124	146	178	203	228	265	325	729
12	81.3	115	139	164	199	228	255	297	365	783
18	94.8	135	163	193	235	269	303	353	435	866
24	106	151	184	218	266	305	344	401	497	930
30	115	165	201	239	292	336	384	452	566	1036
36	123	177	217	257	316	363	418	494	624	1132
48	135	196	241	288	354	408	473	562	714	1324
72	151	222	275	330	409	473	546	649	830	1657

9.2.2 PMPF event

PMP rainfall depths for durations up to 6 hours were estimated using the methodology given in *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method - GSDM* (BoM, 2003).

PMP rainfall depths for durations 24 hours and longer were estimated using the standard methodology given in the *Generalised Tropical Storm Method - Revised Edition - GTSMR* (BoM, 2005), based on the catchment area of Upper Oxley Creek upstream of Johnson Road. The adopted PMP design rainfall depths are shown in Table 9.2, Table 9.3 and Table 9.4.

PMP rainfall depths for durations of between 6 and 24 hours were interpolated between the GSDM and GTSMR estimates.

9.3 AREAL REDUCTION FACTORS

For the purpose of reconciliating URBS model predicted design discharges with the FFA, areal reduction factors (ARFs) were determined based on the Upper Oxley Creek catchment to the New Beith AL gauge.

For design event discharge estimation, ARFs were determined based on the Upper Oxley Creek catchment to Johnson Road. ARFs were calculated in accordance with the ARR 2019 guidelines and vary according to storm duration and AEP. Table 9.5 shows the adopted ARFs for the 1% AEP event only.

Table 9.5 - Adopted areal reduction factors for the 1% AEP event for varying durations

Duration (hours)	New Beith [a] ($51 km^2$)	Johnson Road ($118 km^2$)
0.5	0.776	0.708
1	0.816	0.759
2	0.836	0.786
3	0.846	0.799
6	0.903	0.871
9	0.930	0.905
12	0.936	0.913
18	0.944	0.927
24	0.952	0.941
30	0.956	0.946
36	0.959	0.950
48	0.964	0.957
72	0.970	0.966

[a] - used in FFA reconciliation

9.4 TEMPORAL PATTERNS

9.4.1 50% (1 in 2) to 1% (1 in 100) AEP design events

Temporal patterns were obtained from the ARR 2019 data hub for the 'East Coast North' region, which is appropriate for the entire Upper Oxley Creek catchment. For durations up to and including 9 hours, 'point' temporal patterns were adopted. 'Areal' temporal patterns for the Upper Oxley Creek catchment to Johnson Road were adopted for durations equal to or longer than 12 hours.

The ARR 2019 temporal pattern methodology involves the use of an 'ensemble' of 10 temporal patterns, which produces 10 design storms for each duration for each AEP. The temporal pattern which results in a peak flood discharge closest to the average of the 10 design storms for each storm duration is selected as the representative temporal pattern for that storm duration.

For design event hydraulic modelling, the URBS design discharge hydrographs for all 10 temporal patterns for each storm duration in each event were simulated using the 'fast model', but only one representative design storm for each duration was selected for simulation using the 'detailed model'. This process is discussed in more detail in Section 10.

An ensemble analysis to select critical design storms was not undertaken using the URBS model. Ensemble analysis on the URBS model results was done only to determine the peak discharges at key locations (for reporting purposes) and for the reconciliation process with FFA. The selection of representative design storms was undertaken spatially at all locations in the TUFLOW model domain using the "fast model" results. These selected representative design storms were then simulated using the detailed model. This selection process is described in Section 10.

9.4.2 0.5% (1 in 200) to 0.05% (1 in 2,000) AEP design events

Initial findings during the *Logan and Albert Rivers Flood Study* (WRM, 2022) indicated that the GSDM and GTSMR temporal patterns for the 0.5% event resulted in a discontinuity in the hydraulic model results between the 1% and 0.5% AEP events (i.e., 0.5% AEP peak flood levels were lower than the 1% AEP peak flood levels in some areas). It was found that the difference in temporal patterns (ARR vs. GSDM and GTSMR) was causing this discontinuity of results.

To ensure continuity between the 1% AEP and 0.5% AEP hydraulic model results, the representative design temporal patterns (ARR rare bin areal temporal patterns) selected for the 1% AEP event were also adopted for the 0.5%, 0.2% and 0.05% AEP events. Note that Table 8.3.3 (Book 8 - Chapter 3) of ARR 2019 allows for the use of areal temporal patterns for extreme events if required when dealing with inconsistencies and smoothing of results.

By adopting the ARR rare bin areal temporal patterns for the 0.5%, 0.2% and 0.05% AEP events, continuity is achieved between the 1% and 0.5% AEP events (i.e., 0.5% AEP peak flood levels are higher than the 1% AEP peak flood levels at all areas. Therefore, the ARR rare bin areal temporal patterns produce higher peak discharges and water levels compared to the GSDM and GTSMR temporal pattern for the 0.5%, 0.2% and 0.05% AEP events.

9.4.3 PMPF event

The temporal patterns for durations up to and including 12 hours were obtained from the GSDM guideline (BoM, 2003). Temporal patterns for durations longer than 12 hours were obtained from the GTSMR guideline (BoM, 2005).

9.5 SPATIAL DISTRIBUTION

9.5.1 50% (1 in 2) to 0.05% (1 in 2,000) AEP design events

The design rainfalls for events up to and including 0.05% (1 in 2,000) AEP were estimated at 3 representative IFD points throughout the modelled catchments as shown in Figure 9.1, to account for spatial variation in design rainfalls throughout a catchment. The adopted design rainfall depths at each of these locations are shown in Table 9.2, Table 9.3 and Table 9.4. The following is of note:

- Design rainfall depths in the upper reaches of the Upper Oxley Creek catchment are lower (but generally within 5%) than those at the catchment centroid;
- Design rainfall depths at the lower reaches of the Upper Oxley Creek catchment are higher (but generally within 5%) than those at the catchment centroid; and
- Design rainfall depths are highest in the lower reaches of the Upper Oxley Creek catchment.

9.5.2 PMPF event

Spatial distribution of rainfall for storm durations up to 6 hours is accounted for in the GSDM guideline (BoM, 2005). Spatial distribution of rainfall for storm durations longer than 6 hours is accounted for in the GTSMR guideline (BoM, 2005).

9.6 RAINFALL LOSSES

9.6.1 50% (1 in 2) to 1% (1 in 100) AEP design events

The initial loss (IL) / continuing loss (CL) method of accounting for rainfall losses was adopted for this study. ILs were varied between events and were determined by reconciliation of the URBS design peak discharges and the FFA peak discharge estimates at the New Beith gauge. A uniform CL of 3.1 mm/hr was adopted for the 50% to 1% AEP design events, based on the adopted CL for the four calibration events. Table 9.6 shows the adopted ILs and CLs for all design events up to the PMPF.

9.6.2 0.5% (1 in 200) to 0.05% (1 in 2,000) AEP design events

A 0.0 mm initial loss was adopted for 0.5% (1 in 200) to 0.05% (1 in 2,000) AEP design events. A uniform CL of 3.1 mm/hr was adopted as per the 50% to 1% AEP events.

9.6.3 PMPF event

A 0.0 mm initial loss was adopted for the PMPF event. A uniform CL of 3.1 mm/hr was adopted as per the 50% to 1% AEP events.

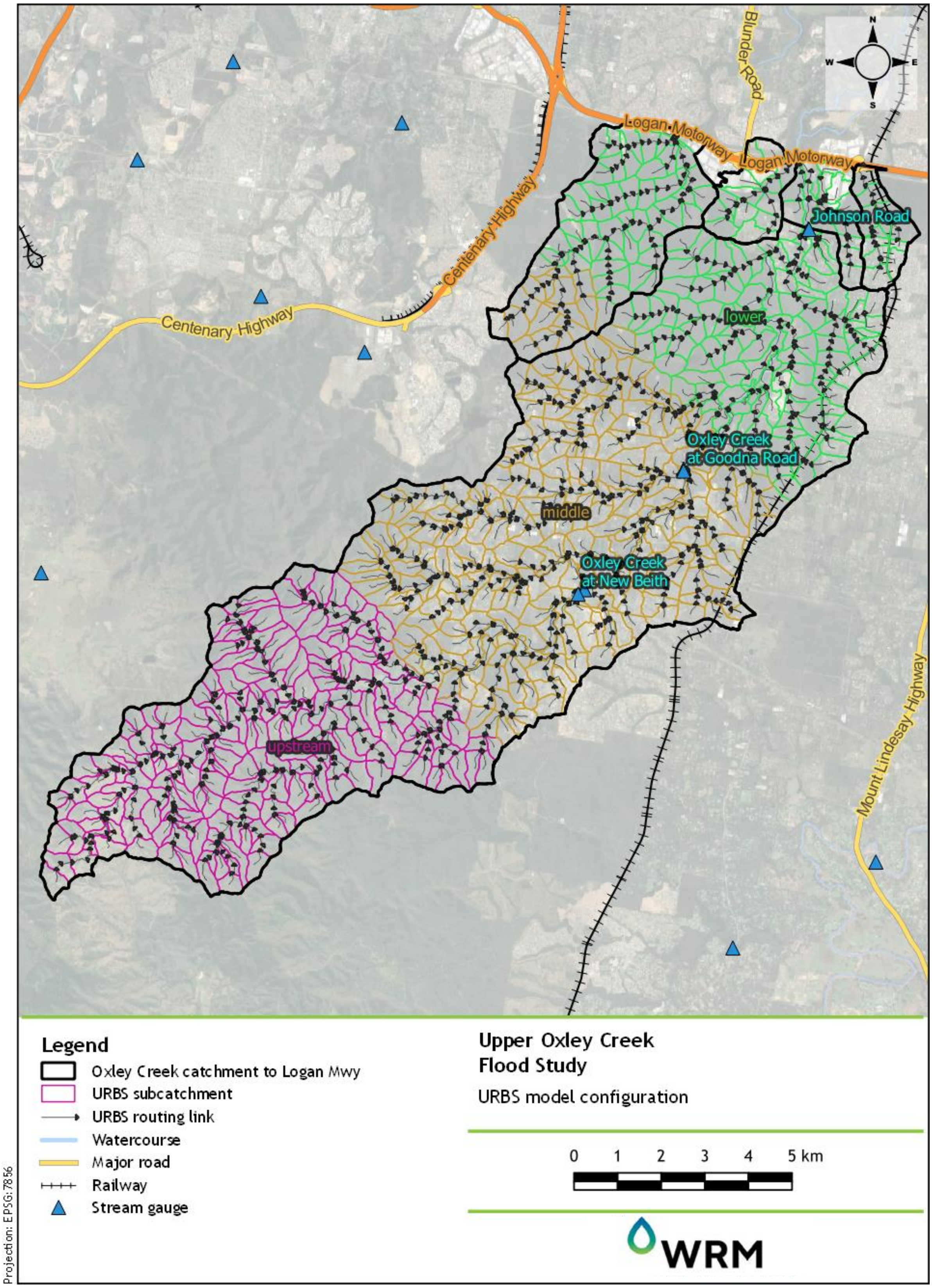


Figure 9.1 - URBS IFD catchment assignment

Table 9.6 - Adopted initial and continuing losses for design event simulations

AEP (%)	Adopted IL (mm)	Adopted CL (mm/hr)
50	60	3.1
20	55	3.1
10	50	3.1
5	50	3.1
2	50	3.1
1	45	3.1
0.2	0	3.1
0.5	0	3.1
0.05	0	3.1
PMPF	0	3.1

9.7 RECONCILIATION WITH FLOOD FREQUENCY ANALYSIS RESULTS

Table 9.7 compares the URBS model estimated peak design discharges at the New Beith AL gauge against the peak discharge estimates obtained from the FFA (described in Section 8) for the 50% to 1% AEP events.

Figure 9.2 and Figure 9.3 show the URBS model predicted design peak discharges plotted against the flood frequency distribution curves for the annual (AMS) series and POT series, respectively for the 50% to 1% AEP events. Table 9.7 summarises the adopted ILs and CLs for each event and the differences between the URBS and FFA design peak discharges at the New Beith AL gauge. The following is of note:

- For the purpose of reconciling URBS design discharge estimates with the FFA, ARFs were adopted based on the catchment area to the New Beith AL gauge.
- For events up to and including 10% AEP, ILs were selected to produce the best match between URBS model peak discharges and the POT series FFA peak discharges. For events rarer than the 10% AEP, ILs were selected to produce the best match between URBS model peak discharges and the annual series FFA peak discharges. This approach is consistent with guidelines in Book 3 - Chapter 2.2.2.3 of ARR, which recommend adopting the POT series approach for more frequent events up to the 10% AEP, and the using the annual series approach for events rarer than 10% AEP.
- The URBS model predicted design peak discharges match well with those predicted by the FFA for all events up to the 1% AEP event, using the adopted ILs and CLs. The URBS discharge estimates are well within the flood frequency confidence limits.
- The adopted ILs decrease with increasing event magnitude. This is considered reasonable because for larger events, the main storm burst is often preceded by a smaller and less severe storm. This creates wetter antecedent conditions for rarer events compared to the more frequent events.

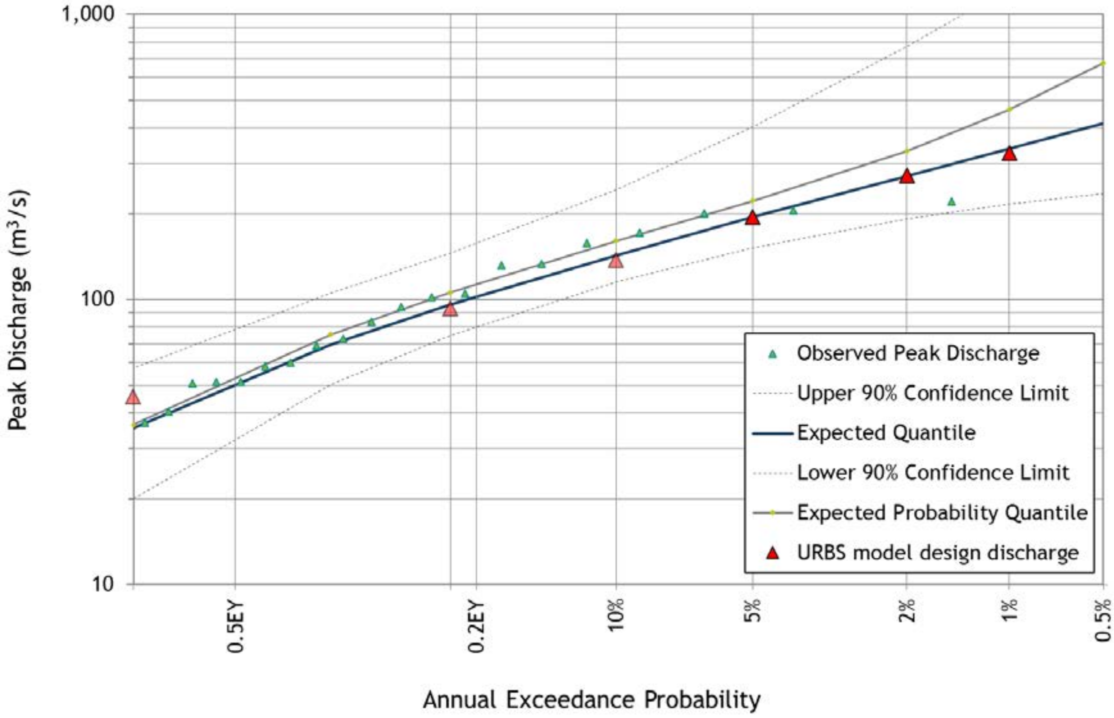


Figure 9.2 - Comparison of URBS design discharges and AMS flood frequency distribution

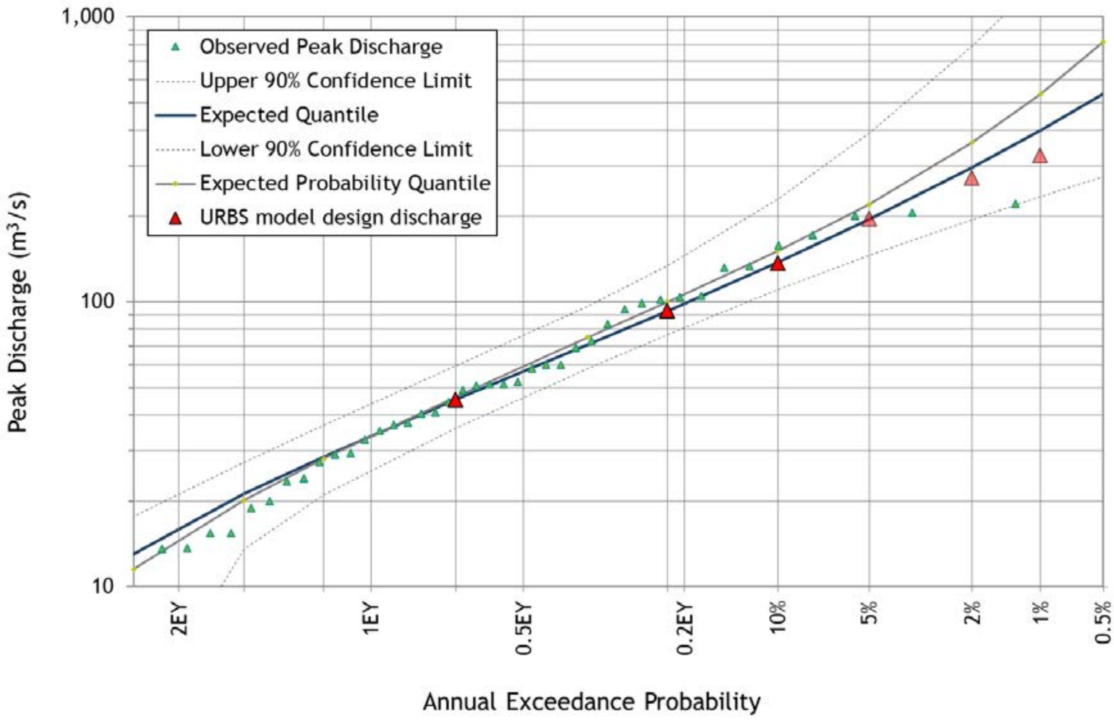


Figure 9.3 - Comparison of URBS design discharges and POT frequency distribution

Table 9.7 - Adopted loss values (50% to 1% AEP events) and comparison of FFA and URBS design discharge estimates at New Beith gauge

AEP (%)	Design discharge estimates (m^3/s) URBS	FFA (AMS)	FFA (POT)	Difference (%)	Adopted IL (mm)	Adopted CL (mm/hr)
50	46	35	45	+0.6% [1]	60	3.1
20	93	96	93	+0.4% [1]	55	3.1
10	137	143	138	-1.0% [1]	50	3.1
5	195	194	195	+0.3% [2]	50	3.1
2	272	272	296	+0.1% [2]	50	3.1
1	326	338	400	-3.7% [2]	45	3.1

[1] For these events, URBS peak discharges were compared against the POT series FFA peak discharges.

[2] For these events, URBS peak discharges were compared against the annual series (AMS) FFA peak discharges.

9.8 FUTURE CLIMATE SCENARIO (2090)

To obtain future climate scenario design discharges, design rainfalls in the URBS hydrologic model were increased in accordance with the guidelines in Book 1 Chapter 6 of ARR 2019 (Ball et al, 2019). The following design rainfall change factors were adopted for the different RCPs:

- RCP 4.5: rainfalls were increased by a factor of 1.095 (9.5% increase);
- RCP 6: rainfalls were increased by a factor of 1.115 (11.5% increase); and
- RCP 8.5: rainfalls were increased by a factor of 1.197 (19.7% increase).

The adopted multiplication factor is based on a planning horizon of year 2090 and a projected warming of 1.862, 2.227, and 3.679 degrees Celsius, respectively.

Design rainfall losses and all other hydrologic model parameters are the same for both the current climate and future climate scenarios.

9.9 DESIGN DISCHARGES - CURRENT CLIMATE (2023)

9.9.1 50% (1 in 2) AEP to 1% (1 in 100) AEP design events

Table 9.8 and Table 9.9 show the URBS model predicted design peak discharges and critical durations for the 50% (1 in 2), 20% (1 in 5), 10% (1 in 10), 5% (1 in 20), 2% (1 in 50) and 1% (1 in 100) AEP events. The following is of note:

- The peak design discharges estimated by the URBS model are as follows:
  - Peak discharges at the New Beith gauge range from 28 m^3/s for the 50% AEP event to 310 m^3/s for the 1% AEP event;
  - Peak discharges at the Goodna Road gauge range from 44 m^3/s for the 50% AEP event to 395 m^3/s for the 1% AEP event;
  - Peak discharges at the Johnson Road gauge range from 58 m^3/s for the 50% AEP event to 504 m^3/s for the 1% AEP event; and
  - Peak discharges at Blunder Creek at Johnson Road range from 14 m^3/s for the 50% AEP event to 108 m^3/s for the 1% AEP event.
- The URBS model critical durations for key locations throughout the catchment are as follows:
  - New Beith: 24 hours for the 50% AEP event, 18 hours for the 20% to 5% AEP events, 6 hours for the 2% to 1% AEP events;

- Goodna Road: 24 hours for the 50% to 20% AEP event, 18 hours for all other AEPs;
- Johnson Road: 24 hours for the 50% to 5% AEP event, 18 hours for the 2% to 1% AEP events; and
- Blunder Creek: 24 hours for the 50% AEP event, 18 hours for the 20% to 10% AEP events, 6 hours for the 5% to 1% AEP events.

Table 9.8 - Upper Oxley Creek URBS predicted design discharges at key locations, 50% (1 in 2) AEP to 1% (1 in 100) AEP events

Location	Peak URBS design discharge (m^3/s)					
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
New Beith	28	110	155	194	261	310
Goodna Road	44	130	192	250	330	395
Johnson Road	58	153	236	311	417	504
Blunder Creek	14	38	51	65	91	108

Table 9.9 - Upper Oxley Creek URBS predicted critical storm durations at key locations, 50% (1 in 2) AEP to 1% (1 in 100) AEP events

Location	Peak URBS critical storm duration (hours)					
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
New Beith	24	18	18	18	6	6
Goodna Road	24	24	18	18	18	18
Johnson Road	24	24	24	24	18	18
Blunder Creek	24	18	18	6	6	6

9.9.2 0.5% (1 in 200) AEP to 0.05% (1 in 2,000) AEP design events

Table 9.10 and Table 9.11 show the URBS model predicted peak discharges and critical durations for the 0.5% (1 in 200), 0.2% (1 in 500) and 0.05% (1 in 2000) AEP events. The following is of note:

- The peak design discharges estimated by the URBS model are as follows:
  - Peak discharges at the New Beith gauge range from 355 m^3/s for the 0.5% AEP event to 528 m^3/s for the 0.05% AEP event;
  - Peak discharges at the Goodna Road gauge range from 457 m^3/s for the 0.5% AEP event to 701 m^3/s for the 0.05% AEP event;
  - Peak discharges at the Johnson Road gauge range from 585 m^3/s for the 0.5% AEP event to 914 m^3/s for the 0.05% AEP event; and
  - Peak discharges at Blunder Creek at Johnson Road range from 124 m^3/s for the 0.5% AEP event to 184 m^3/s for the 0.05% AEP event.
- The URBS model critical durations for key locations throughout the catchment are as follows:
  - New Beith: 6 hours for all AEPs;
  - Goodna Road: 18 hours for all AEPs;

- Johnson Road: 18 hours for the 0.5% to 0.2% AEP event, 24 hours for the 0.05% AEP event; and
- Blunder Creek: 6 hours for all AEPs

9.9.3 PMPDF event

Table 9.10 and Table 9.11 show the URBS model predicted peak discharges and critical durations for the PMPDF event. The following is of note:

- The PMPDF peak design discharge at the New Beith Gauge is 2,297 m^3/s and the critical duration is 2 hours;
- The PMPDF peak design discharge at the Goodna Road Gauge is 2,619 m^3/s and the critical duration is 4.5 hours;
- The PMPDF peak design discharge at the Johnson Road gauge is 3,074 m^3/s and the critical duration is 6 hours; and
- The PMPDF peak design discharge at Blunder Creek at Johnson Road is 760 m^3/s and the critical duration is 2 hours.

Table 9.10 - Upper Oxley Creek URBS predicted design discharges at key locations, 0.5% (1 in 200) AEP to 0.05% (1 in 200) AEP and the PMPDF event

Location	Peak URBS design discharge (m^3/s)			
	0.5% AEP	0.2% AEP	0.05% AEP	PMPDF
Oxley Creek at New Beith AL	355	421	528	2,297
Oxley Creek at Goodna Road	457	549	701	2,619
Oxley Creek at Johnson Road	585	705	914	3,074
Blunder Creek at Johnsons Road	124	147	184	760

Table 9.11 - Upper Oxley Creek URBS predicted critical storm durations at key locations, 0.5% (1 in 200) AEP to 0.05% (1 in 200) AEP and the PMPDF event

Location	Peak URBS critical storm duration (hours)			
	0.5% AEP	0.2% AEP	0.05% AEP	PMPDF
Oxley Creek at New Beith AL	6	6	6	2
Oxley Creek at Goodna Road	18	18	18	4.5
Oxley Creek at Johnson Road	18	18	24	6
Blunder Creek at Johnsons Road	6	6	6	2

9.10 DESIGN DISCHARGES - FUTURE CLIMATE (2090)

9.10.1 20% (1 in 5) AEP to 1% (1 in 100) AEP design events

Table 9.12 and Table 9.13 show the URBS model predicted peak discharges and critical durations for the future climate 20% (1 in 5), 10% (1 in 10), 5% (1 in 20), 2% (1 in 50) and 1% (1 in 100) AEP events. The following is of note:

- The peak design discharges estimated by the URBS model are as follows:
  - Peak discharges at the New Beith gauge range from 129 m^3/s for the 20% AEP event to 347 m^3/s for the 1% AEP event (RCP4.5);
  - Peak discharges at the Goodna Road gauge range from 153 m^3/s for the 20% AEP event to 443 m^3/s for the 1% AEP event (RCP4.5);
  - Peak discharges at the Johnson Road gauge range from 185 m^3/s for the 20% AEP event to 567 m^3/s for the 1% AEP event (RCP4.5); and
  - Peak discharges at Blunder Creek at Johnson Road range from 44 m^3/s for the 20% AEP event to 121 m^3/s for the 1% AEP event (RCP4.5).
- The URBS model critical durations are unchanged from the current climate scenario.

Table 9.12 - Upper Oxley Creek URBS predicted future climate design discharges at key locations, 20% (1 in 5) AEP to 1% (1 in 100) AEP events

Location	Peak URBS design discharge (m^3/s)						
	20% AEP (RCP4.5)	10% AEP (RCP4.5)	5% AEP (RCP4.5)	2% AEP (RCP4.5)	1% AEP (RCP4.5)	1% AEP (RCP6)	1% AEP (RCP8.5)
Oxley Creek at New Beith AL	129	176	219	293	347	355	388
Oxley Creek at Goodna Road	153	222	285	372	443	454	496
Oxley Creek at Johnson Road	185	274	356	472	567	580	635
Blunder Creek at Johnsons Road	44	58	75	102	121	124	135

Table 9.13 - Upper Oxley Creek URBS predicted future climate critical storm durations at key locations, 20% (1 in 5) AEP to 1% (1 in 100) AEP events

Location	Peak URBS critical storm duration (hours)						
	20% AEP (RCP4.5)	10% AEP (RCP4.5)	5% AEP (RCP4.5)	2% AEP (RCP4.5)	1% AEP (RCP4.5)	1% AEP (RCP6)	1% AEP (RCP8.5)
Oxley Creek at New Beith AL	18	18	18	6	6	6	6
Oxley Creek at Goodna Road	24	18	18	18	18	18	18
Oxley Creek at Johnson Road	24	24	24	18	18	18	18
Blunder Creek at Johnsons Road	18	18	6	6	6	6	6

9.10.2 0.5% (1 in 200) AEP to 0.5% (1 in 500) AEP design events

Table 9.14 shows the URBS model predicted future climate peak discharges and critical durations for the 0.5% (1 in 200) and 0.2% (1 in 500) AEP events.

Table 9.14 - Upper Oxley Creek URBS predicted future climate design discharges and critical durations at key locations, 0.5% (1 in 200) AEP and 0.2% (1 in 500) AEP events

Location	Critical duration (hours)		Design discharge (m^3/s)	
	0.5% AEP	0.2% AEP	0.5% AEP	0.2% AEP
Oxley Creek at New Beith AL	6	6	397	469
Oxley Creek at Goodna Road	18	18	512	613
Oxley Creek at Johnson Road	18	18	656	788
Blunder Creek at Johnsons Road	6	6	138	164

10 Design event hydraulic modelling

10.1 OVERVIEW

The calibrated TUFLOW model was used to estimate flood levels, depths, velocities and flood hazard in Upper Oxley Creek and its tributaries for the 50% (1 in 2), 20% (1 in 5), 10% (1 in 10), 5% (1 in 20), 2% (1 in 50), 1% (1 in 100), 0.5% (1 in 200), 0.2% (1 in 500) and 0.05% (1 in 2,000) AEP design events as well as the PMPF event, for a range of storm durations up to 72 hours. Future climate flood events were also simulated.

Sensitivity testing was undertaken for the 1% (1 in 100) AEP event to assess the impact of changes to hydraulic roughness, changes to hydraulic structure blockages and changes to downstream outflow boundary conditions on the model results. For the 5% (1 in 20) and 1% (1 in 100) AEP events, the impact of proposed revegetation within the waterway corridor was also assessed.

This section presents the methodology adopted to produce the desired outputs from the hydraulic model throughout the Upper Oxley Creek catchment.

10.2 DESIGN MODELLING APPROACH

Design event hydraulic modelling was undertaken in accordance with ARR 2019 for the ten specified design events ranging from 50% AEP to the PMPF event. The following two hydraulic models were developed for this study:

- **'Fast Model'** - This model was configured with a grid cell size of 9 m. The purpose of this model is to allow the selection of critical ARR 2019 design storms, which was then simulated using a finer 'detailed model'.
- **'Detailed Model'** - This model was configured with a grid cell size of 3 m. The purpose of this model is simulate the critical design storms selected using the 'Fast Model' to obtain the design outputs.

The 'Fast Model' was run for all 10 ensemble temporal patterns for each storm duration for each event, using inflow hydrographs extracted from the Ultimate Catchment Conditions URBS model.

The TUFLOW asc_to_asc utility was used to extract the mean water levels for each cell in the model for each design event and storm duration. A max-max selection of the mean grids for each storm duration was used to ensure the representative temporal pattern and critical duration results are identified and mapped for each design event.

The TUFLOW asc_to_asc utility ranks the 10 peak water level grids produced by each temporal pattern for each duration and selects the 5th ranked grid as the mean storm for that duration. Note that this would result in a 'mean' water surface level that is either higher or lower than the true mean value.

The TUFLOW asc_to_asc utility only returns a mean value when all 10 of the input gids for a given storm duration have a numeric value at a cell. If a model cell is wet by 9 of the 10 ensemble temporal patterns, but not wet by the tenth, the TUFLOW asc_to_asc utility returns a NULL value. This means that the mean result grids will not capture a true extent of flooding, as there will be cells along the fringe of the flood extents that are not wet by all 10 of the ensemble temporal patterns for each duration. However, asc_to_asc utility was only used for the purpose of selecting the 'representative design storms' and not to generate the final water surface grids. Therefore, this limitation in the TUFLOW asc_to_asc utility is acceptable.

The mean water surface grids produced by the 'Fast Model' for each duration were analysed spatially over the entire model extent to determine one 'representative design storm' for each duration.

The calibrated 'Detailed Model' (with a 3 m grid cell size) was run only for the 'representative design storms' selected using the 'Fast Model' for all events. The TUFLOW asc_to_asc utility was then used to create a max-max water surface grid from the critical design storm results, to create the final water surface grid.

10.3 HYDRAULIC MODEL CONFIGURATION

10.3.1 Topography

The model topography adopted for the 2022 calibration event was adopted in the TUFLOW model for design events. Where possible, the latest and higher resolution 2021 LiDAR was used to replace the 2017 LiDAR.

The local road topography at the new development areas in Greenbank (Tivoli Avenue and Australis Circuit) and New Beith (near Split Log Crescent) was modified using TUFLOW z-shapes based on the As-Constructed drawings provided by LCC.

10.3.2 Hydraulic structures

The configuration of culverts and bridges in the design event TUFLOW model is identical to the February 2022 calibration event TUFLOW model.

10.3.3 Design event blockage

Blockage of hydraulic structures (culverts and bridges) for design events was determined based on guidelines in Book 6 - Chapter 6 of ARR 2019 (Ball et al, 2019). Table 10.1 shows the adopted design blockage factors, which were determined based on the following methodology:

- The adopted blockage factors for culverts and bridges were determined individually depending on the size and configuration of each structure.
- The debris potential classification for structures located within the main Oxley Creek channel was determined as "High", based on an "L10" value of 3 m reflecting the predominantly forested areas upstream of Greenbank. The "L10" value describes the average length of the longest 10% of the debris that could potentially contribute to streams within the study area.
    - The "debris availability" classification was determined as "High", based on the natural forested areas in the upstream reaches.
    - The "debris mobility" classification was determined as "High", based on steep upstream source areas with fast catchment response times and high annual rainfall, the modelled streams are considered to frequently overtop their banks, and the main debris areas being close to the streams.
    - The "debris transportability" was determined as "Medium", based on the study area containing a mixture of streams with flat and steep bed slopes, deep and wide streams relative to the potential debris dimension, and streams that generally meander through the floodplain.
- The debris potential classification for the remaining structures within the model (outside of the main Oxley Creek channel) was determined as "Medium", based on an "L10" value of 1.5 m within the predominantly more urbanised areas in Greenbank, New Beith and Forestdale.
    - The "debris availability" classification was determined as "Medium", based on the modelled streams having moderate to flat slopes with stable bed and banks, and floodplains consisting of well-maintained rural lands and paddocks with some state forest areas as well as urbanised areas.

- The “debris mobility” classification was determined as “Medium”, based on moderately steep source areas and infrequently overtopping tributaries.
- The “debris transportability” was determined as “Medium”, based on the study area containing a mixture of streams with flat and steep bed slopes, deep and wide streams relative to the potential debris dimension, and streams that generally meander through the floodplain.

Culvert structures were assigned with a ‘Blockage Category’ from A to H. The Blockage Category for each structure was determined based on its dimensions, its location within the model and its debris potential, as summarised below:

- Blockage Category A/D for control dimension inlet clear width (W) < L10;
- Blockage Category B/E for L10 ≤ W ≤ 3*L10;
- Blockage Category C/F for L10 > 3*L10; and
- Blockage Category G/H for sensitivity testing to determine the impact of blockage on the 1% AEP simulations.

For bridges:

- The default blockage factor below the bridge deck was determined based on the pier configuration (pier number, width and spacing).
- All bridge spans within the model are wider than the maximum adopted L10 value of 3 m. Therefore, no additional debris blockage was applied below the bridge deck.
- A blockage factor of 100% was adopted for the bridge deck, guard rails and handrails.

Table 10.1 - Design event culvert Blockage Categories and the adopted blockage factors

Event	Oxley Creek tributaries (‘Medium’ debris potential)			Main Oxley Creek channel (‘High’ debris potential)			Sensitivity	
	A	B	C	D	E	F	G	H
50% AEP	50% [1]	0%	0%	50%	10%	0%	0%	100%
20% AEP	50% [1]	0%	0%	50%	10%	0%	0%	100%
10% AEP	50% [1]	0%	0%	50%	10%	0%	0%	100%
5% AEP	50%	10%	0%	100%	20%	10%	0%	100%
2% AEP	50%	10%	0%	100%	20%	10%	0%	100%
1% AEP	50%	10%	0%	100%	20%	10%	0%	100%
0.5% AEP	50%	10%	0%	100%	20%	10%	0%	100%
0.2% AEP	50% [2]	20%	10%	100%	20%	10%	0%	100%
0.05% AEP	50% [2]	20%	10%	100%	20%	10%	0%	100%
PMF	50% [2]	20%	10%	100%	20%	10%	0%	100%

[1] increased from 25% to 50% to ensure consistency in the hydraulic model results between the frequent (up to 10% AEP) and intermediate (5% to 0.5% AEP) design events
[2] reduced from 100% to 50% to ensure consistency in the hydraulic model results between the intermediate (5% to 0.5% AEP) and extreme (rarer than 0.5% AEP) design events

For Category A culverts, the default ARR guidelines recommend an AEP adjusted debris potential of 25% for events up to up to 10% AEP, a much higher blockage of 50% for the 5% to 0.5% AEP events, and full blockage (100%) for extreme events (rarer than 0.5% AEP). Based on preliminary results of design event hydraulic modelling, it was found that adopting these default ARR blockage values resulted in inconsistencies in flood levels between the frequent and intermediate design events, and between the intermediate and rare design events. For example, there were several cases where the 10% AEP design flood levels were found to be higher than the 5% AEP design flood levels downstream of some Category A culverts due to significant step-up in blockage from 25% to 50% between the 10 % and 5% AEP events, which in turn resulted in lower culvert outflows for the 5% AEP event compared to the 10% AEP event. Similarly, backwater-affected areas would remain dry in extreme events with backflow through culverts being inhibited as a result of the full culvert blockage.

Over 60% of the culverts in the TUFLOW model were assigned with Blockage Category A, hence the issue described above potentially affects many areas within the model. To resolve this, the blockage factor for Category A structures was increased from 25% (the ARR default) to 50% for the frequent events (up to 10% AEP) and reduced from 100% (the ARR default) to 50% for the extreme events (rarer than 0.5% AEP), resulting in an equal blockage factor across all events for Category A culverts.

Similarly, 8 out of 45 structures that were initially assigned as Category B were instead assigned as Category F to avoid inconsistencies in flood levels between the intermediate and extreme events.

This approach described above is a departure from the default ARR 2019 recommendations, but it was considered necessary to ensure consistency in the model results between the frequent and intermediate design events and between the intermediate and extreme events.

10.3.4 Hydraulic roughness

The distribution of hydraulic roughness parameters (Manning's 'n') in the design event hydraulic model are generally identical to the February 2022 calibration event model, except for some undeveloped areas that are zoned for future development or are currently being developed. For these future development areas, the hydraulic roughness of the overbank areas was modified to reflect the proposed land use. However, the waterway channels in these areas were assumed to remain close to existing conditions.

10.3.5 Inflow boundaries

The locations of 2D (SA) inflow boundaries in the hydraulic model were unchanged from the calibration event TUFLOW model. Inflow hydrographs generated from the URBS model for ultimate catchment conditions were applied at the model inflow boundaries.

The 'fast model' was run for all 10 design storms for each storm duration in each event. The 'detailed model' was run for the 'critical design storms' selected using the 'fast model' as described in Section 10.2.

10.4 SELECTION OF REPRESENTATIVE DESIGN STORMS

10.4.1 Current climate representative design storms

This section describes the adopted process for selecting representative design storms for each duration in each event based on the 'fast model' results.

As described in Section 10.2, the mean water surface grids for produced by the 9 m grid 'Fast Model' and the corresponding source grids were analysed for each duration to determine one dominant design storm per duration. These design storms selected using the above process would be considered as the 'representative design storms'. The procedure for determining the 'representative design storms' for each duration in each event is outlined below:

- Using the 'fast model', a mean water surface grid was produced for each duration and AEP. A Max-Max water surface grid was then produced for each event based on the maximum of the mean water surface grids from all durations in each event from the 'fast model' results.
- Figure 10.1 shows the Max-Max water surface source grid for the 1% AEP event and indicates the critical storm durations based on the 'fast model' results.
- Figure 10.2 shows the distribution of mean design storms throughout the hydraulic model extent for the 1% AEP event 18-hour duration from the 'fast model':

- For areas in which the 18-hour storm is expected to be critical (the lower reaches of Oxley Creek around Johnson Road gauge), design storm #10 is the mean design storm.
- Design storm #10 was therefore selected as the representative design storm for the 1% AEP event 18-hour duration and was then included in the design event simulations using the 'detailed model'.

Table 10.2 shows the 'representative design storms' selected using the procedure outlined above. Only these representative design storms were simulated using the 3 m grid 'detailed model'. The representative design storms selected for the 1% AEP event were also simulated for the 0.5% to 0.05% AEP events, with the reasoning for this provided in Section 9.4.2.

To minimise the detailed hydraulic model simulation time, not all storm durations were simulated using the 'detailed model':

- For the 50% and 20% AEP events, the 'fast model' results indicate that storm durations of 48-hours and longer are not critical anywhere in the model. Therefore, only representative design storms up to and including 36-hours were simulated using the 'detailed model' for these events.
- For the 10% to 1% AEP events, the 'fast model' results indicate that storm durations of 48-hours and longer are not critical anywhere in the model. Therefore, only representative design storms up to and including 36-hours were simulated using the 'detailed model' for the 10% to 1% AEP events as well as the 0.5% to 0.05% AEP events.
- For all events except for the 20% AEP event, the 'fast model' results indicate that the 0.5-hour design storm is not critical anywhere in the model. Therefore, the 0.5-hour design storm was not simulated using the 'detailed model' for these events.

Table 10.2 - Representative design storms selected for the 'detailed model'

Storm duration (hours)	Design event representative temporal patterns								
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.05% AEP
0.5	-	5	-	-	-	-	-	-	-
0.75	8	7	5	6	9	6	6	6	6
1	4	4	6	3	10	2	2	2	2
1.5	5	8	9	9	5	2	2	2	2
2	4	4	3	8	10	8	8	8	8
3	1	9	3	9	4	6	6	6	6
4.5	9	6	4	4	7	5	5	5	5
6	6	3	4	10	3	5	5	5	5
9	9	6	6	2	3	4	4	4	4
12	10	1	1	1	1	1	1	1	1
18	10	10	1	6	10	10	10	10	10
24	5	9	5	5	5	2	2	2	2
30	2	6	6	3	6	6	6	6	6
36	2	2	-	-	-	-	-	-	-

10.4.2 Future climate representative design storms

The adopted 'representative design storms' for the future climate scenarios are the same as the current climate scenario (shown in Table 10.2). Only these representative design storms were simulated using the 3 m grid 'detailed model' for the Future Climate (2090) scenarios. This approach assumes that the selected representative design storms for the current climate scenarios would still be the appropriate for future climate scenarios.

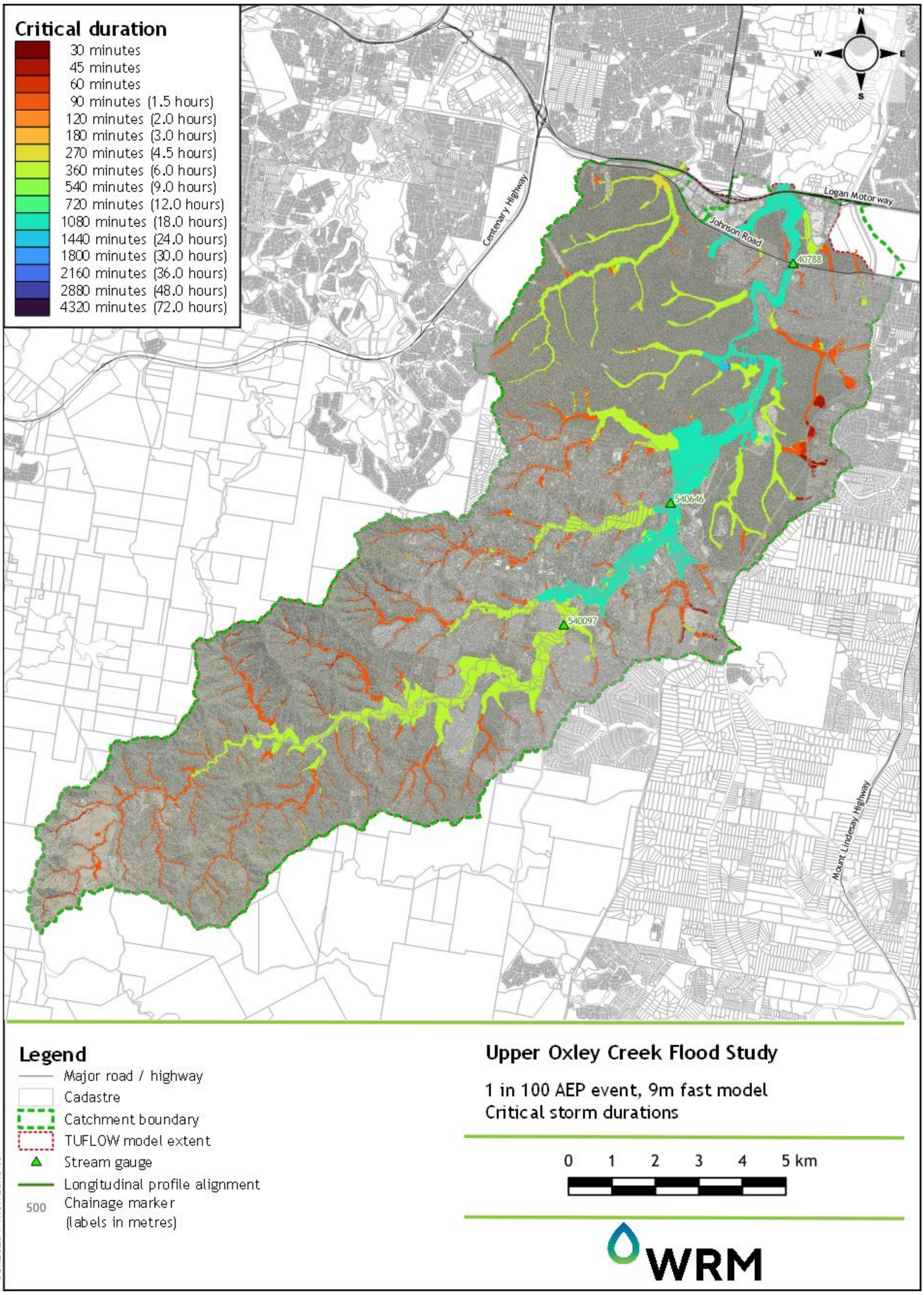


Figure 10.1 - Expected critical storm durations for the 1% AEP event based on the 9 m grid 'Fast Model' results

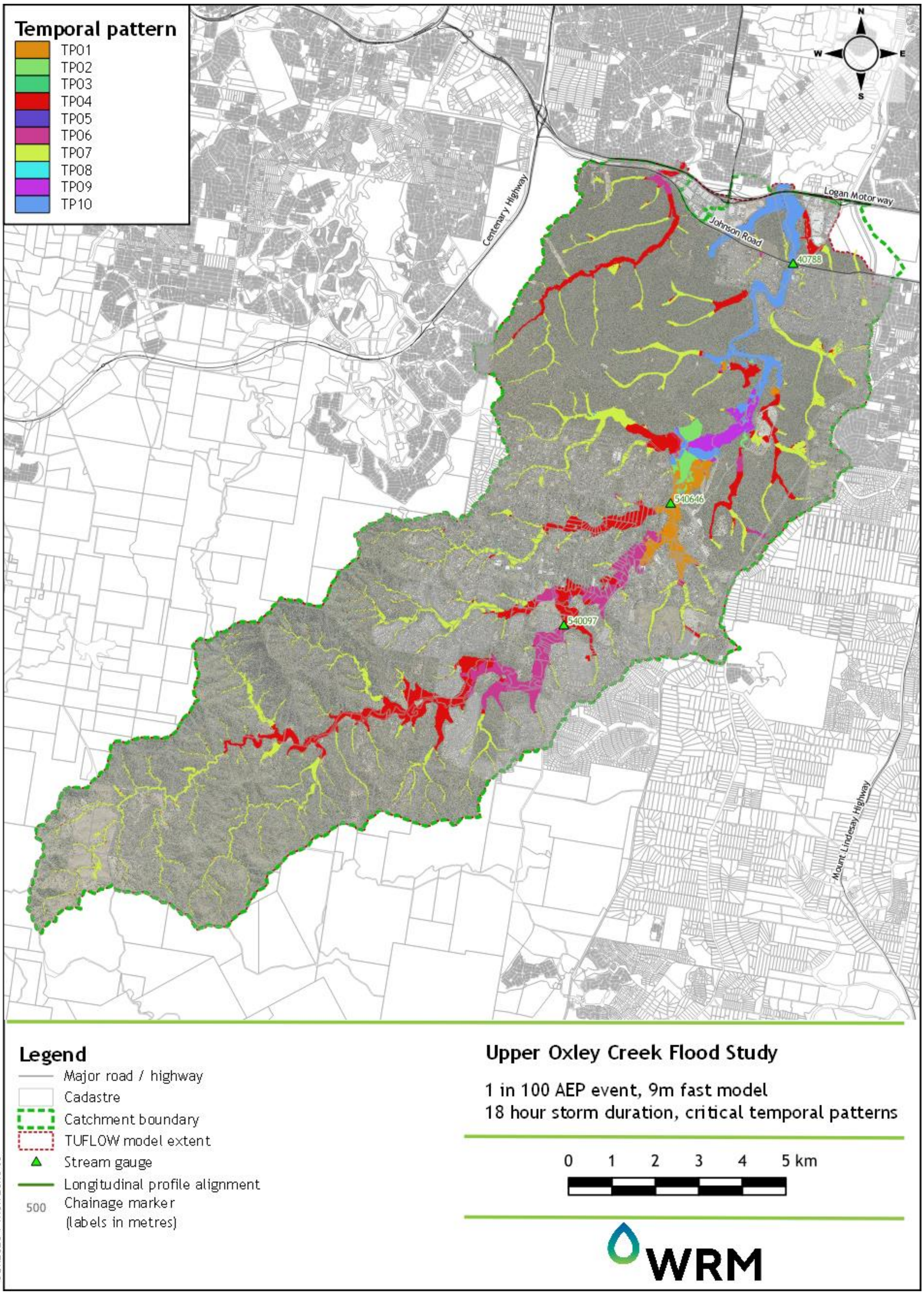


Figure 10.2 - Distribution of mean design temporal patterns for the 1% AEP 18-hour storm duration, for the 9 m grid 'Fast Model'

10.5 SUMMARY OF MODEL OUTPUTS

10.5.1 Overview

The following peak water surface grids (in Binary Float format) are provided as part of this study for all design storms for the 9 m grid 'fast model' and for the representative design storms for the 3 m grid 'detailed model':

- Peak water surface levels;
- Peak flood depth;
- Peak velocity;
- Critical storm duration;
- Flood hazard classifications for the following four flood hazard criteria:
  - Peak velocity x depth (dV) product;
  - Flood hazard mapping based on the Australian Guidelines (CSIRO, 2000);
  - Flood hazard category as outlined by the Australian Emergency Management Institute in 2014 (AEMI, 2014); and
  - Hazard categories for the Queensland Reconstruction Authority (QRA, 2012).

Longitudinal profile plots of water surface levels are also provided in this section.

10.5.2 Max-Max grids

A 'max-max' water surface grid (in binary Float format) was developed for each design event and for each output type described above by interrogating the results for the representative design storms from the 'detailed model', to obtain Max-Max results for every location impacted by flooding from the Upper Oxley Creek and its tributaries within the LCC LGA.

Additional post-processing was undertaken on the Max-Max result grids for the 'detailed model'. The Max-Max grids were remapped onto a finer resolution (1.5 m grid size) DEM. This was undertaken to minimise partially wet cells (an artefact of sub-grid sampling) that potentially shows areas along the flood fringe as being flooded when it should be flood free upon interrogating the underlying topography. This remapping process produces a more realistic flood extent compared to the raw hydraulic model outputs.

For events up to and including 1% AEP, the 'Max-Max' water surface grids do not represent the absolute maximum of all simulated durations. Rather, the 'Max-Max' grids represent the maximum of the selected mean grids from all simulated durations. Generating a maximum of all simulated durations would result in a water surface grid that captures the maximum value from all 10 design storms for each duration, which is not consistent with the intent of the ensemble approach of ARR 2019.

10.5.3 Flood mapping of Current Climate and Future Climate design flood events

Appendix D of the report contains flood maps in A3 size and pdf format. Mapping is provided for the current climate scenario for:

- Design peak flood levels;
- Design peak flood depths;
- Design peak flood velocities;
- Critical storm duration maps;
- Flood hazard classifications for the following four flood hazard criteria:
  - Peak velocity x depth (dV) product;
  - Flood hazard mapping based on the Australian Guidelines (CSIRO, 2000);

- Flood hazard category as outlined by the Australian Emergency Management Institute in 2014 (AEMI, 2014); and
- Hazard categories for the Queensland Reconstruction Authority (QRA, 2012).

Flood level impact mapping is further provided for sensitivity analyses results (described in Section 10.8):

- Impact of globally increasing the hydraulic roughness on the 1% AEP design flood levels;
- Impact of globally decreasing the hydraulic roughness on the 1% AEP design flood levels;
- Impact of removing culvert and guard rail blockages on 1% AEP design flood levels;
- Impact of steeper tailwater flood slopes on the 1% AEP design flood levels;
- Impact of shallower tailwater flood slopes on the 1% AEP design flood levels; and
- Impact of revegetation within the waterway corridor on the 1% AEP and 5% AEP design flood levels.

Mapping is provided for the future climate scenario for:

- Design peak flood levels;
- Design peak flood depths; and
- Impact of future climate on peak flood levels.

10.6 SUMMARY OF CURRENT CLIMATE DESIGN FLOOD LEVELS

10.6.1 Overview

Table 10.3 summarises the estimated design flood levels at key locations throughout the Upper Oxley Creek catchment for the 50% (1 in 2) AEP to PMPF design flood events based on the 'detailed' TUFLOW model results. Table 10.4 shows the corresponding critical storm durations.

Figure 10.3 shows the predicted max-max water surfaces for the 10% (1 in 10) AEP event. Figure 10.4 shows the predicted max-max water surfaces for the 1% (1 in 100) AEP event.

Figure 10.5 and Figure 10.6 are longitudinal section plots showing the TUFLOW model topography and design peak water surface levels along the main Oxley Creek channel (refer to Figure 10.3 and Figure 10.4 for chainages).

10.6.2 50% (1 in 2) to 1% (1 in 100) AEP design events

The design flood levels for the 50% (1 in 2) to 1% (1 in 100) AEP events are summarised as follows:

- All levels and extents reported are based on the max-max water surface for each design event (i.e., the maximum water level from all representative design storms simulated using the 'detailed model').
- Flood mapping in this section of the report is provided only for water surface levels for the 10% (1 in 10) and 1% (1 in 100) AEP events. Flood mapping for all other events and for all other output types are provided in Appendix D.
- Design flood levels at Oxley Creek at Tully Road range from 71.38 mAHD for the 50% AEP to 71.94 mAHD for the 1% AEP event. The January 2013 recorded peak flood level at Tully Road is approximately 71.9 mAHD (based on surveyed debris mark #4).
- Design flood levels at the New Beith AL gauge range from 51.76 mAHD for the 50% AEP to 54.56 mAHD for the 1% AEP event. The recorded flood levels for the January 2013, May 2015, March 2017 and February 2022 events are 54.23 mAHD, 53.95 mAHD, 54.31 mAHD, and 54.18 mAHD, respectively.

- Design flood levels at Goodna Road range from 39.99 mAHD for the 50% AEP to 43.38 mAHD for the 1% AEP event.
  - The January 2013 recorded peak flood level at Goodna Road is between 42.81 mAHD to 42.72 mAHD (based on surveyed debris marks #15 and #16).
  - The May 2015 recorded peak flood level at Goodna Road is 42.13 mAHD (based on surveyed debris marks #4).
  - The recorded flood levels for the March 2017 and February 2022 events are 42.68 mAHD and 42.88 mAHD, respectively.
- Design flood levels at Johnson Road range from 20.79 mAHD for the 50% AEP to 24.79 mAHD for the 1% AEP event. The recorded peak flood level for the February 2022 event is 24.19 mAHD.
- Design flood levels in Blunder Creek at Johnson Road range from 28.86 mAHD for the 50% AEP to 31.19 mAHD for the 1% AEP event.

To illustrate the variation in peak water levels from the ensemble of 10 temporal patterns for each storm duration for the 1% AEP, Figure C.1 to Figure C.4 in Appendix C provide box and whisker plots (box plots) showing the distribution of 1% AEP peak water levels in Oxley Creek at New Beith, Goodna Road and Johnson Road and in Blunder Creek at Johnson Road.

10.6.3 0.5% (1 in 200) to 0.05% (1 in 2,000) AEP design events

The design flood levels for the 0.5% (1 in 200) to 0.05% (1 in 2,000) AEP events are summarised as follows:

- Oxley Creek 0.5% AEP peak flood levels are typically between 0.2 m and 0.4 m higher than 1% AEP flood levels.
- Oxley Creek 0.2% AEP peak flood levels are typically between 0.3 m and 1.1 m higher than 1% AEP flood levels.
- Oxley Creek 0.05% AEP peak flood levels are typically between 0.5 m and 1.9 m higher than 1% AEP flood levels.

10.6.4 PMPF design event

Oxley Creek PMPF flood level are typically between 3.0 m and 4.9 m higher than 1% AEP flood levels.

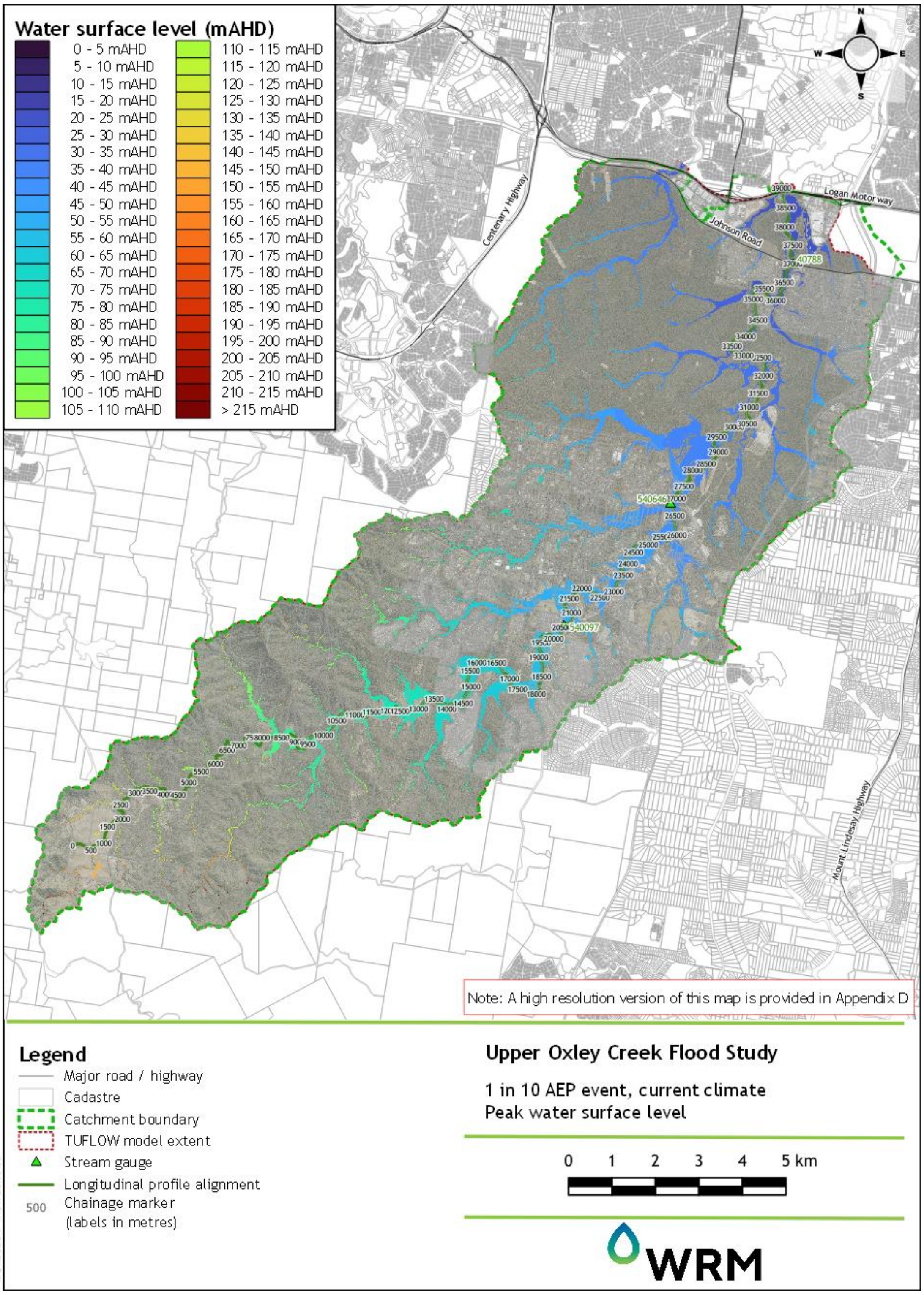


Figure 10.3 - TUFLOW model predicted 10% (1 in 10) AEP peak water surface levels, maximum of all simulated durations, current climate

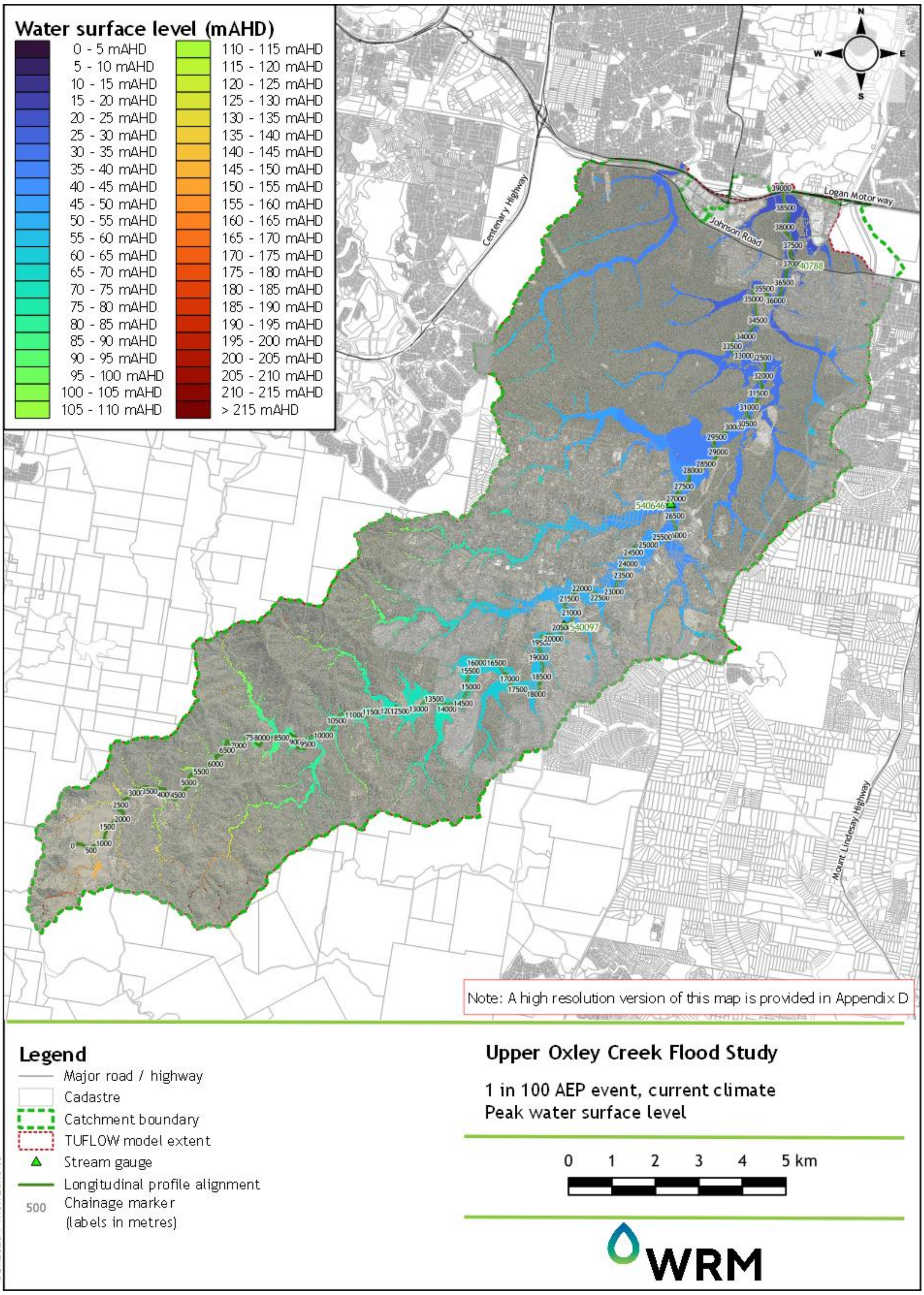


Figure 10.4 - TUFLOW model predicted 1% (1 in 100) AEP peak water surface levels, maximum of all simulated durations, current climate

Table 10.3 - Predicted Oxley Creek Current Climate design peak flood levels at key locations

Location	Design peak water level (mAHD)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.05 % AEP	PMPF
Oxley Ck at Tully Road	71.38	71.60	71.67	71.81	71.86	71.94	72.12	72.24	72.43	75.34
Oxley Creek at New Beith AL	51.76	53.63	53.95	54.17	54.37	54.56	54.70	54.88	55.15	57.57
Oxley Creek at Goodna Road	39.99	41.83	42.49	42.77	43.17	43.38	43.55	43.75	44.06	46.45
Oxley Creek at Johnson Road	20.79	21.88	22.72	23.30	24.23	24.79	25.24	25.84	26.68	29.65
Blunder Ck at Johnson Road	28.86	29.56	29.88	30.52	30.87	31.19	31.38	31.61	31.81	35.55

Table 10.4 - Predicted Oxley Creek Current Climate critical storm durations at key locations

Location	Critical duration (hours)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.05% AEP	PMPF
Oxley Ck at Tully Road	24	18	18	6	4.5	4.5	2	1.5	1.5	2
Oxley Creek at New Beith AL	24	18	18	18	6	6	6	6	6	3
Oxley Creek at Goodna Road	24	24	18	18	18	18	18	18	18	4.5
Oxley Creek at Johnson Road	24	24	18	24	18	18	18	18	18	6
Blunder Ck at Johnson Road	24	18	18	6	6	6	3	2	2	2

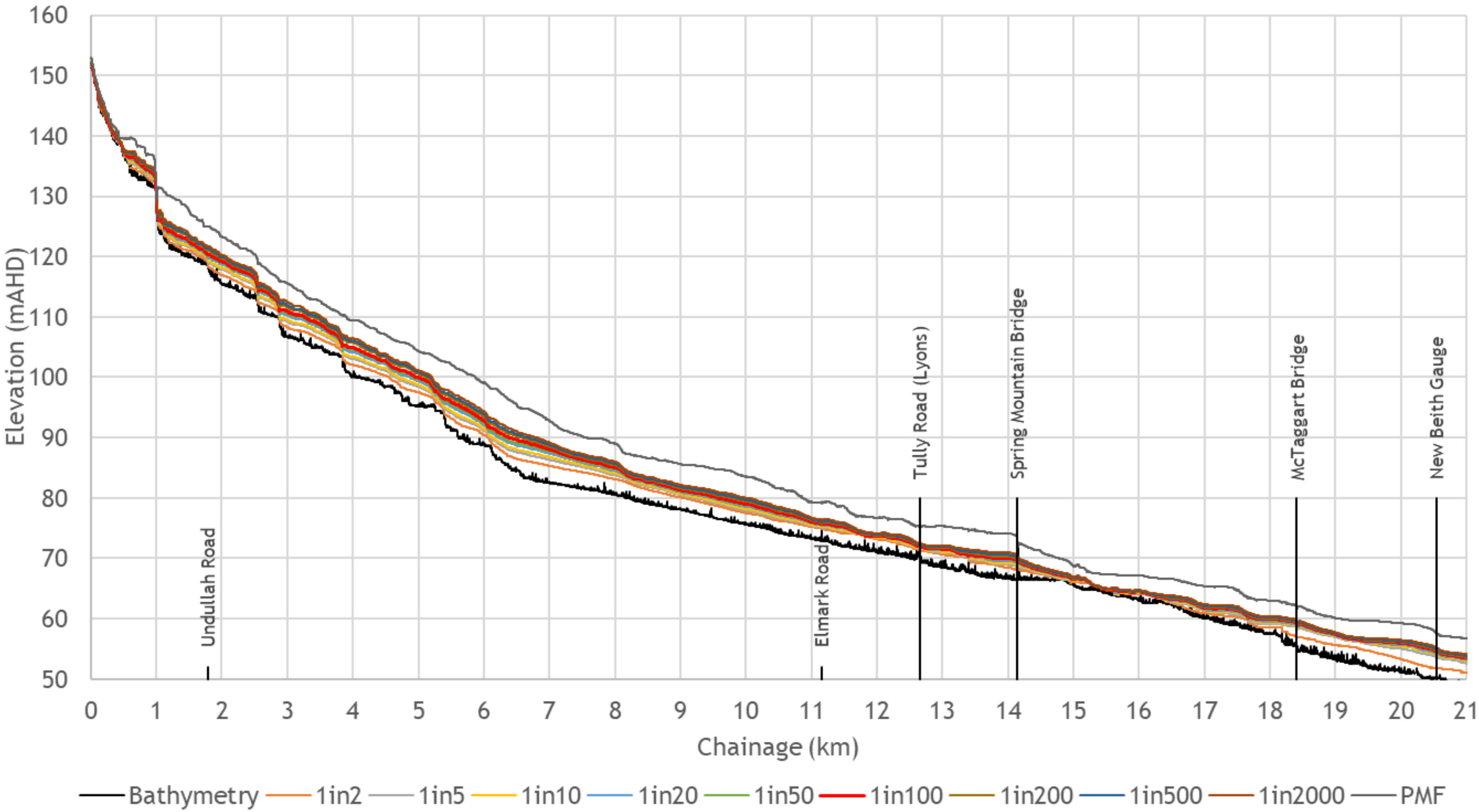


Figure 10.5 - Longitudinal section of TUFLOW model topography and design peak water surface levels along Oxley Creek (upstream of New Beith AL gauge)

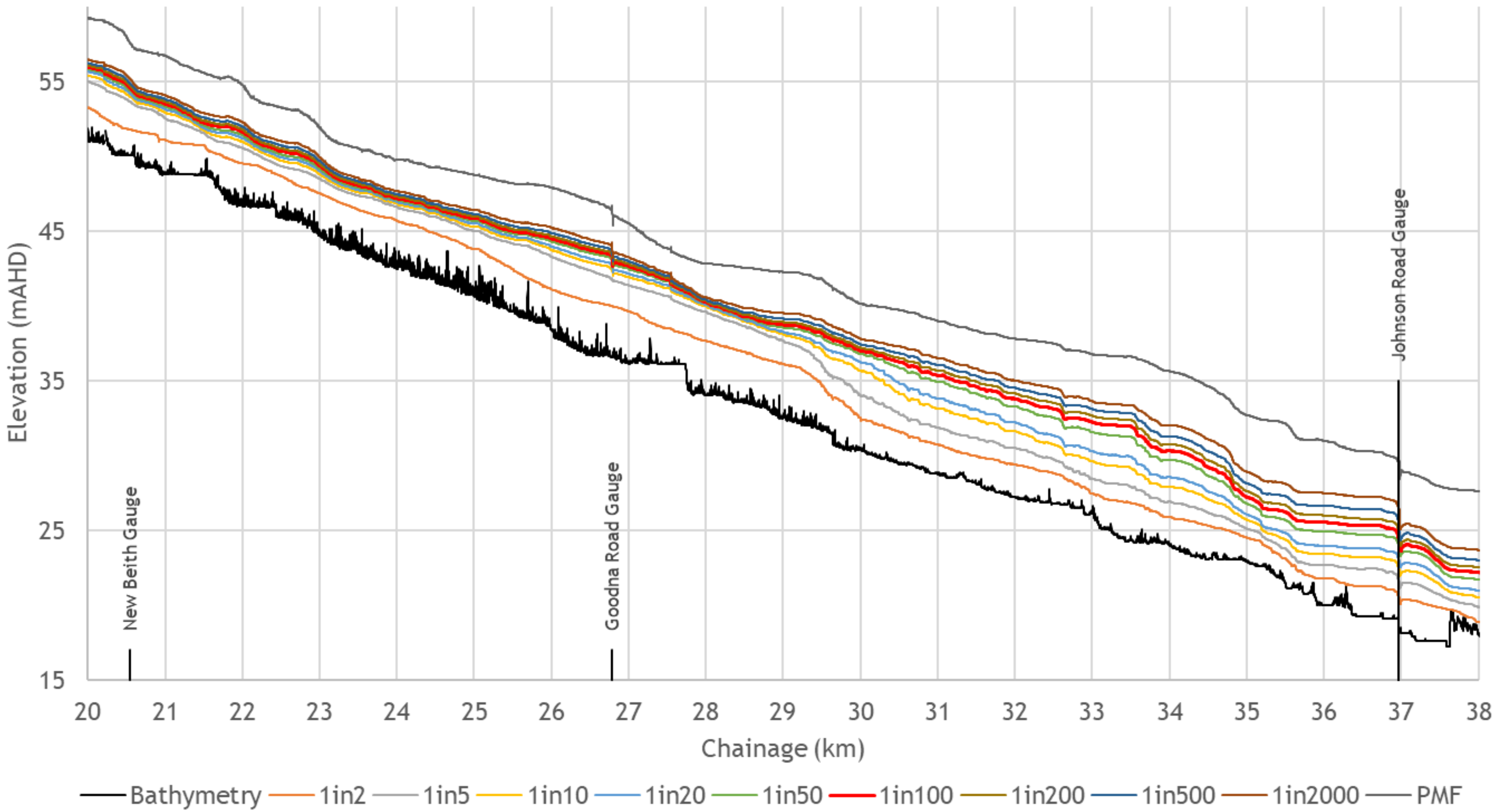


Figure 10.6 - Longitudinal section of TUFLOW model topography and design peak water surface levels along Oxley Creek (downstream of New Beith AL gauge)

10.7 SUMMARY OF FUTURE CLIMATE CHANGE DESIGN FLOOD LEVELS

10.7.1 Overview

Table 10.5 summarises the estimated design flood levels at key locations throughout the Upper Oxley Creek catchment for the 50% (1 in 2) AEP to PMPF design flood events based on the 'detailed' TUFLOW model results. Table 10.6 shows the corresponding critical storm durations.

Figure 10.7 shows the predicted max-max water surfaces for the 10% (1 in 10) AEP event (RCP4.5, year 2090). Figure 10.8 shows the predicted max-max water surfaces for the 1% (1 in 100) AEP event (RCP4.5, year 2090).

Figure 10.9 and Figure 10.10 are longitudinal section plots showing the TUFLOW model topography and design peak water surface levels along the main Oxley Creek channel (refer to Figure 10.7 and Figure 10.8 for chainages).

10.7.2 10% (1 in 10) to 1% (1 in 100) AEP design events

The design flood levels for the future climate 10% (1 in 10) to 1% (1 in 100) AEP events are summarised as follows:

- All levels and extents reported are based on the max-max water surface for each design event (i.e., the maximum water level from all representative design storms simulated using the 'detailed model').
- Flood mapping in this section of the report is provided only for water surface levels for the 10% (1 in 10) and 1% (1 in 100) AEP events (RCP4.5, event horizon 2090). Flood mapping for all other events and for all other output types are provided in Appendix D.
- Compared to the 1% AEP current climate peak flood levels, the 1% AEP future climate scenario design flood levels along the Oxley Creek main channel are increased as follows:
  - by up to 0.37 m in the RCP4.5 scenario;
  - by up to 0.45 m in the RCP6 scenario; and
  - by up to 0.75 m in the RCP8.5 scenario.
- Design flood levels at Oxley Creek at Tully Road range from 71.70 mAHD for the 10% AEP to 72.01 mAHD for the 1% AEP event. The January 2013 recorded peak flood level at Tully Road is between 71.9 mAHD (based on surveyed debris mark #4).
- Design flood levels at the New Beith AL gauge range from 54.05 mAHD for the 10% AEP to 54.68 mAHD for the 1% AEP event. The recorded flood levels for the January 2013, May 2015, March 2017 and February 2022 events are 54.23 mAHD, 53.95 mAHD, 54.31 mAHD, and 54.18 mAHD, respectively.
- Design flood levels at Goodna Road range from 42.70 mAHD for the 10% AEP to 43.51 mAHD for the 1% AEP event.
  - The January 2013 recorded peak flood level at Goodna Road is between 42.81 mAHD to 42.72 mAHD (based on surveyed debris marks #15 and #16).
  - The May 2015 recorded peak flood level at Goodna Road is 42.13 mAHD (based on surveyed debris marks #4).
  - The recorded flood levels for the March 2017 and February 2022 events are 42.68 mAHD and 42.88 mAHD, respectively.
- Design flood levels at Johnson Road range from 23.13 mAHD for the 10% AEP to 25.13 mAHD for the 1% AEP event. The recorded peak flood level for the February 2022 event is 24.19 mAHD.
- Design flood levels in Blunder Creek at Johnson Road range from 30.01 mAHD for the 10% AEP to 31.30 mAHD for the 1% AEP event.

10.7.3 0.5% (1 in 200) to 0.2% (1 in 500) AEP design events

The design flood levels for the future climate 0.5% (1 in 200) and 0.2% (1 in 500) AEP events are summarised as follows:

- Oxley Creek 0.5% AEP peak flood levels are typically between 0.1 m and 0.5 m higher than 1% AEP flood levels.
- Oxley Creek 0.2% AEP peak flood levels are typically between 0.3 m and 1.1 m higher than 1% AEP flood levels.

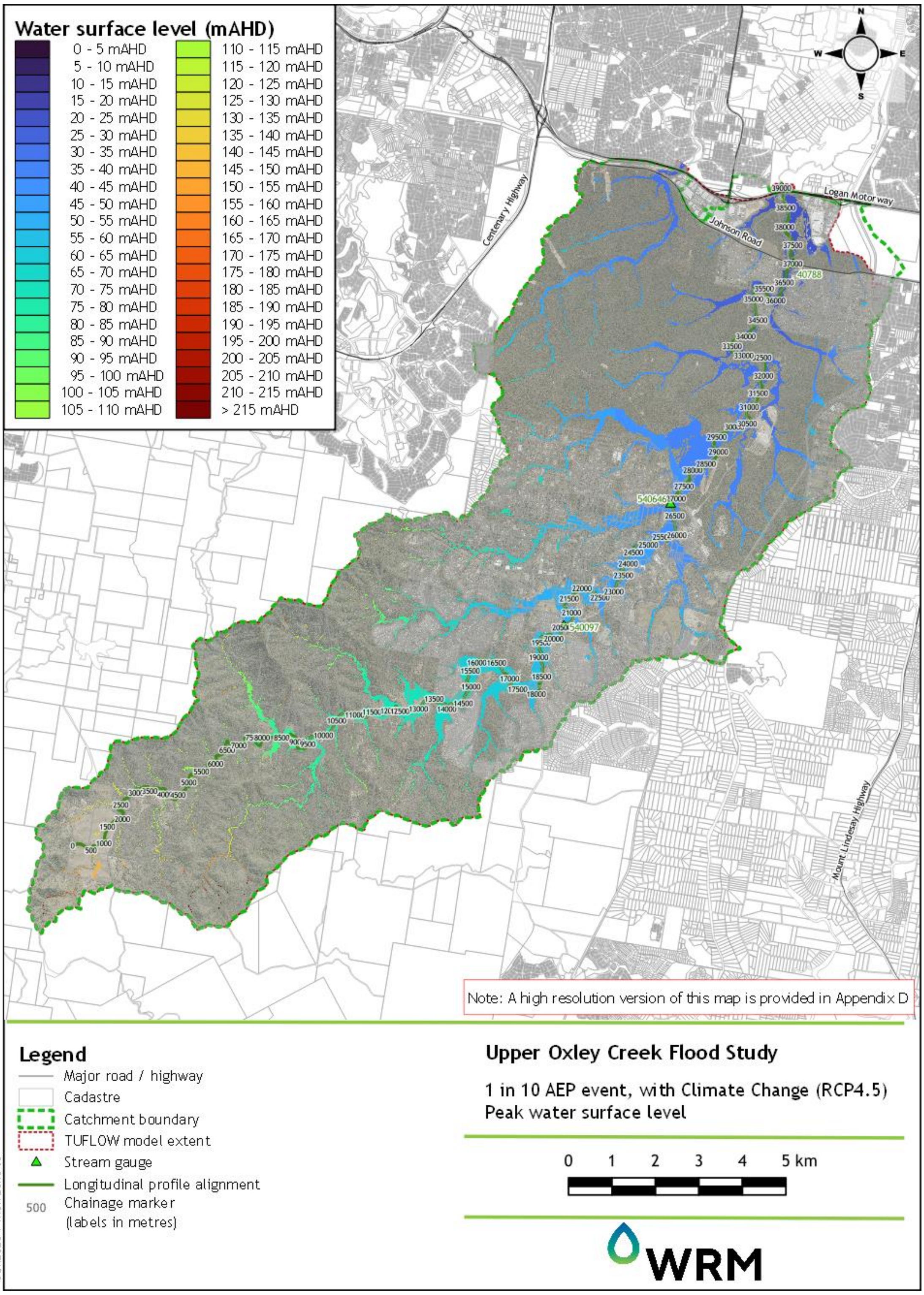


Figure 10.7 - TUFLOW model predicted 10% (1 in 10) AEP peak water surface levels, maximum of all simulated durations, future climate (RCP 4.5, year 2090)

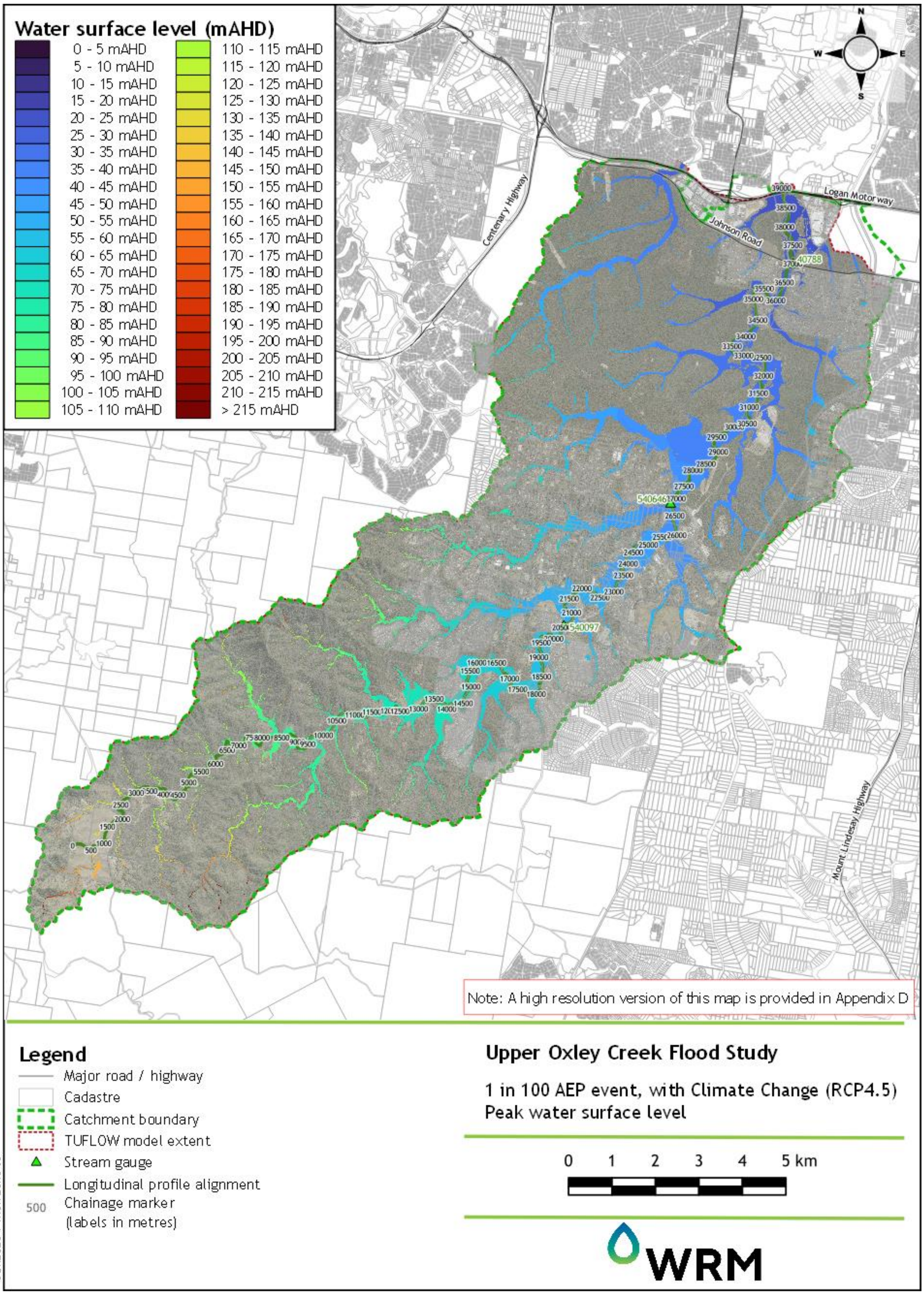


Figure 10.8 - TUFLOW model predicted 1% (1 in 100) AEP peak water surface levels, maximum of all simulated durations, future climate (RCP 4.5, year 2090)

Table 10.5 - Predicted Oxley Creek Future Climate (2090) design peak flood levels at key locations

Location	Design peak water level (mAHD)								
	20% AEP (RCP4.5)	10% AEP (RCP4.5)	5% AEP (RCP4.5)	2% AEP (RCP4.5)	1% AEP (RCP4.5)	1% AEP (RCP6)	1% AEP (RCP8.5)	0.5% AEP (RCP4.5)	0.2% AEP (RCP4.5)
Oxley Ck at Tully Road	71.63	71.70	71.85	71.92	72.01	72.02	72.08	72.20	72.33
Gauge New Beith	53.75	54.05	54.28	54.49	54.68	54.70	54.79	54.82	55.01
Gauge Goodna Road	42.15	42.70	42.97	43.32	43.51	43.54	43.64	43.67	43.89
Gauge Johnson Road	22.19	23.13	23.63	24.58	25.13	25.21	25.50	25.60	26.23
Blunder Ck at Johnson Road	29.69	30.01	30.75	31.14	31.30	31.32	31.39	31.49	31.71

Table 10.6 - Predicted Oxley Creek Future Climate (2090) critical storm durations at key locations

Location	Critical duration (hours)								
	20% AEP (RCP4.5)	10% AEP (RCP4.5)	5% AEP (RCP4.5)	2% AEP (RCP4.5)	1% AEP (RCP4.5)	1% AEP (RCP6)	1% AEP (RCP8.5)	0.5% AEP (RCP4.5)	0.2% AEP (RCP4.5)
Oxley Ck at Tully Road	18	6	6	4.5	4.5	4.5	4.5	2	1.5
Gauge New Beith	18	18	6	6	6	6	6	6	6
Gauge Goodna Road	24	18	18	18	18	18	18	18	18
Gauge Johnson Road	24	18	18	18	18	18	18	18	18
Blunder Ck at Johnson Road	18	6	6	6	6	6	6	2	2

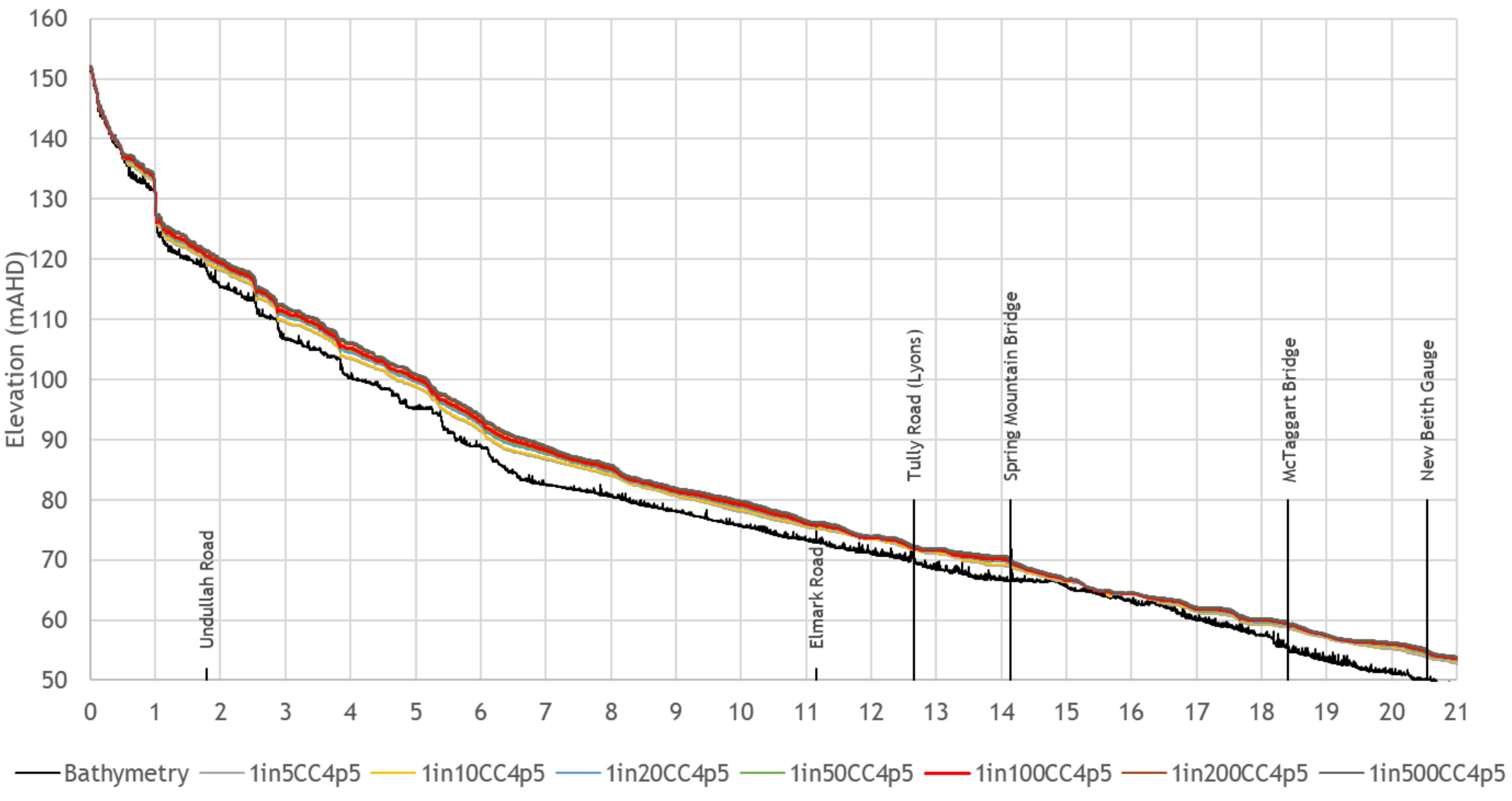


Figure 10.9 - Longitudinal section of TUFLOW model topography and design peak water surface levels along Oxley Creek, future climate (RCP 4.5, year 2090) (upstream of New Beith gauge)

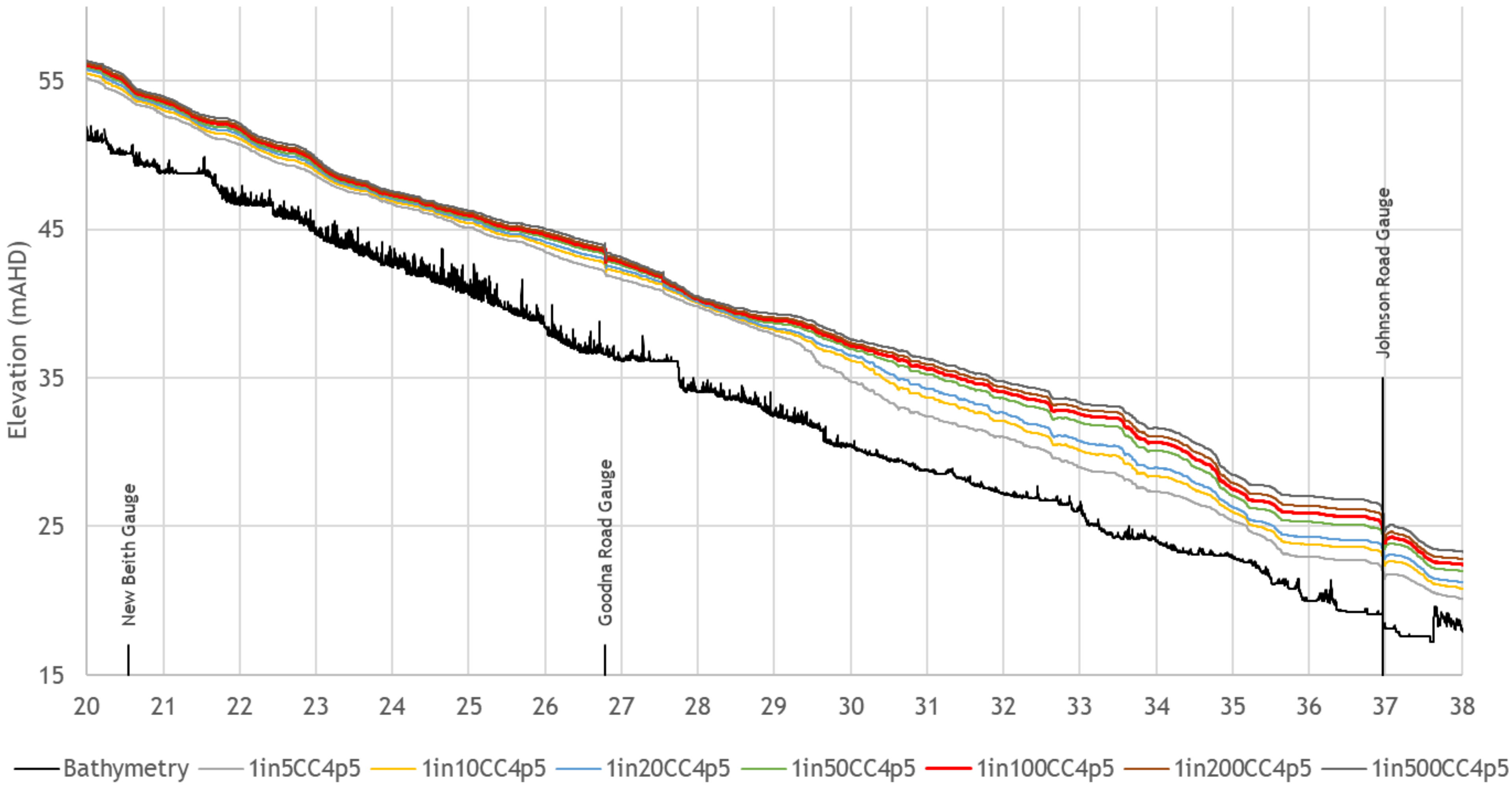


Figure 10.10 - Longitudinal section of TUFLOW model topography and design peak water surface levels along Oxley Creek, future climate (RCP 4.5 year, 2090) (downstream of New Beith gauge)

10.8 SENSITIVITY ANALYSIS

10.8.1 Overview

The following six sensitivity analyses were undertaken:

- Impact of globally increasing the hydraulic roughness on the 1% AEP design flood levels;
- Impact of globally decreasing the hydraulic roughness on the 1% AEP design flood levels;
- Impact of removing culvert and guard rail blockages on 1% AEP design flood levels;
- Impact of steeper outflow boundary flood slopes on the 1% AEP design flood levels;
- Impact of shallower outflow boundary flood slopes on the 1% AEP design flood levels; and
- Impact of revegetation within the waterway corridor on the 1% AEP and 5% AEP design flood levels.

Flood level afflux maps showing the predicted changes in peak flood levels for these sensitivity analyses scenarios are provided in Appendix D.

10.8.2 Impact of increased hydraulic roughness

The hydraulic roughness (Manning's n) values for all landuses (shown in Table 6.1) were increased by 20% (e.g., the Manning's n value for 'grassed open space' was increased from 0.05 to 0.06). Table 10.7 compares the hydraulic roughness (Manning's n) values adopted for the 'base case' and the 'increased roughness' case. The TUFLOW hydraulic model was then re-run for the 1% AEP event using the higher hydraulic roughness (Manning's n) values.

A flood level impact map showing the predicted impact of increased hydraulic roughness (Manning's 'n') values on the 1% (1 in 100) AEP peak flood levels is provided in Appendix D. The model results indicate that a 20% increase of hydraulic roughness (Manning's 'n') values results in increases in peak flood levels throughout most the Upper Oxley Creek catchment, with reductions in peak flood levels predicted in some areas. The predicted increases in peak flood levels for this scenario are summarised as follows:

- In the upstream tributaries of Oxley Creek in Undullah and Lyons, the predicted increases in peak flood levels are generally between 0.01 m to 0.1 m, with localised increases of up to 0.15 m in some areas. There are no significant changes to the predicted flood extent along these tributaries.
- Downstream of Undullah Road and in the vicinity of Tully Road between Lyons and Greenbank, the predicted increases in peak flood levels are more pronounced and generally between 0.1 m and 0.15 m, with localised increases of up to 0.25 m.
- Along Tully Road between Lyons and Greenbank, peak flood level increases are generally less than 0.1 m.
- Along Tully Road between Greenbank and New Beith and upstream of Pub Lane in New Beith, peak flood level increases are generally less than 0.1 m, with localised increases of up to 0.15 m.
- Impacts on peak flood levels in the upper reaches in Greenbank are generally less than 0.1 m.
- Impacts on peak flood levels in the urbanised areas of Forestdale are generally less than 0.1 m.
- Impacts on peak flood levels in Blunder Creek are generally less than 0.1 m, with localised increases of up to 0.15 m.
- In the main channel of Oxley Creek, the predicted increases in peak flood levels are generally between 0.1 m and 0.15 m.

- At New Beith gauge, Goodna Road gauge, and Johnson Road gauge, the predicted increase in peak flood level is 0.09 m.
- Immediately downstream of the Edwards Bridge at the Goodna Road gauge, the predicted increases in peak flood levels exceed 0.1 m.
- In the urban reaches in Spring Mountain, New Beith, Greenbank, and Forestdale, predicted increases in peak flood levels are generally between 0.01 m to 0.1 m. There are no noticeable changes in flood extent in these areas.
- There are some minor reductions in peak flood levels predicted in some areas, particularly in areas immediately upstream of major culvert crossings. Peak flood levels in these areas are predominantly controlled by the hydraulic capacity of the adjacent structure, with the hydraulic roughness having little to no influence. However, the higher hydraulic roughness value has the effect of attenuating flows in the channels upstream of these culvert/bridge crossings, resulting in lower peak flood levels at these crossings.

10.8.3 Impact of decreased hydraulic roughness

The hydraulic roughness (Manning's n) values for all landuses (shown in Table 6.1) were decreased by 20% (e.g., the Manning's n value for 'grassed open space' was decreased from 0.05 to 0.04). Table 10.7 compares the hydraulic roughness (Manning's n) values adopted for the 'base case' and the 'decreased roughness' case. The TUFLOW hydraulic model was then re-run for the 1% AEP event using the lower hydraulic roughness (Manning's n) values.

A flood level impact map showing the predicted impact of decreased hydraulic roughness (Manning's 'n') values on the 1% (1 in 100) AEP peak flood levels is provided in Appendix D. The model results indicate that a 20% decrease of hydraulic roughness (Manning's 'n') values results in decreases in peak flood levels of up to 0.15 m throughout most the Upper Oxley Creek catchment, with increases in peak flood levels predicted in some areas. The predicted increases in peak flood levels for this scenario are summarised as follows:

- In the vicinity of Tully Road in Lyons and Greenbank, increases in peak flood levels of up to 0.03 m are predicted.
- Increases in peak flood levels of up to 0.05 m are predicted upstream of several culvert crossings.

Table 10.7 - Comparison between adopted hydraulic roughness (Manning's 'n') values for the base case and for the sensitivity analyses

Land-use type	Mannings 'n' roughness coefficient		
	Design value (base case)	Sensitivity analysis (increased roughness)	Sensitivity analysis (decreased roughness)
Grassed open space	0.050	0.06	0.040
Rough Channel	0.045	0.054	0.036
Smooth Channel	0.035	0.042	0.028
Dense Bushland	0.095	0.114	0.076
Medium Bushland	0.07	0.084	0.056
Rural Residential	0.055	0.066	0.044
Low Density Residential	0.100	0.120	0.080
Medium Density Residential	0.200	0.240	0.160
Industrial	0.300	0.360	0.240
Road	0.020	0.024	0.016
Water Body (inc. Riparian Vegetation)	0.020	0.024	0.016
Oxley Creek US NewBeith	Depth varying (see Table 6.2 and Table 6.3)		
Oxley Creek DS NewBeith			
Oxley Creek Greenbank			

10.8.4 Impact of removing culvert blockage

A flood level impact map showing the predicted impact of removing the design blockage from culverts and bridges (from typically 50% to zero) on peak flood levels is provided in Appendix D.

The model results indicate that the removal of culvert blockages results in reductions in peak flood levels in areas immediately upstream of major culvert crossings, while increases in peak flood levels are predicted downstream of these crossings. The predicted impacts on peak flood levels for this scenario are summarised as follows:

- Reductions in flood levels are less pronounced where roads overtop.
- Reductions in peak flood levels are generally between 0.01 m and 0.1 m. Larger reductions include (but are not limited to):
  - The area upstream of Dawson Close in New Beith, with predicted reductions of 0.53 m;
  - At the new development at Crystal Brook Road / Loch Ness Court in New Beith, with a predicted reduction of 0.35 m;
  - The area upstream of Orchid Drive in Greenbank, with predicted reductions of up to 0.9 m;
  - The area between Pardalote Court and Kingfisher Road in Greenbank, with a predicted reduction of 0.73 m;
  - The area upstream of Platypus Drive in Greenbank, with a predicted reduction of 0.57 m;

- The area upstream of the Logan Motorway culverts, with predicted reductions exceeding 1.5 m as a result of the Blockage Category 'D' culverts being fully blocked in the design blockage scenario; and
- In Sienko Park, a reduction of 0.57 m is predicted.

- Downstream of culverts and bridge crossings, there are generally minor increases in peak flood levels. The predicted flood level increases are generally not significant (within 0.05 m). The predicted flood level increases are noticeably more significant in the following areas:
  - Downstream of Spring Mountain Drive, increases of up to 0.2 m are predicted;
  - Downstream of Thornbill Drive in Greenbank, increases of up to 0.15 m are predicted;
  - Between Orchid Drive and Tivoli Avenue and downstream of Australis Circuit adjacent to the new development in Greenbank, increases of up 0.15 m are predicted;
  - Downstream of Hobury Road in Greenbank, increases of 0.05 m to 0.1 m are predicted; and
  - Downstream of Sienko Park, increases of 0.05 m to 0.1 m are predicted.

10.8.5 Impact of steeper outflow boundary flood slopes

The adopted flood slopes at the three normal depth outflow boundaries (refer to Figure 6.1) were increased and the TUFLOW hydraulic model re-run for the 1% AEP event using the increased tailwater slope values.

A flood level impact map showing the predicted impact of increasing the outflow boundary flood slopes on the 1% (1 in 100) AEP peak flood levels is provided in Appendix D. The results indicate that increasing the outflow boundary flood slopes results in negligible changes in peak flood levels (less than 0.01 m impact) within the LCC LGA

- In Blunder Creek approximately 150 m downstream of the Logan Motorway, the outflow boundary flood slope was increased from 0.3% to 1.0%;
- In Oxley Creek approximately 200 m downstream of the Logan Motorway, the outflow boundary flood slope was increased from 0.2% to 1.0%; and
- In the Eastern Tributary approximately 400 m downstream of Johnson Road, the outflow boundary flood slope was increased from 1% to 3.0%.

10.8.6 Impact of shallower tailwater flood slopes

The adopted tailwater flood slopes at the three normal depth outflow boundaries (refer to Figure 6.1) were lowered and the TUFLOW hydraulic model re-run for the 1% AEP event using the lowered slope tailwater values.

A flood level impact map showing the predicted impact of decreased outflow boundary flood slopes on the 1% (1 in 100) AEP peak flood levels is provided in Appendix D. Decreasing the tailwater slopes generally results in negligible change in peak flood levels (less than 0.01 m impact) within the LCC LGA.

- In Blunder Creek approximately 150 m downstream of the Logan Motorway, the outflow boundary flood slope was lowered from 0.3% to 0.05%;
- in Oxley Creek approximately 200 m downstream of the Logan Motorway, the outflow boundary flood slope was lowered from 0.2% to 0.05%; and
- in the Eastern Tributary approximately 400 m downstream of Johnson Road, the outflow boundary flood slope was lowered from 1% to 0.5%.

10.8.7 Impact of waterway restoration (revegetation)

Increasing Manning's 'n' hydraulic roughness in the LCC waterway corridors to 0.15 (to simulate dense revegetation) generally results in increases in peak flood levels in most areas of the model. Flood level impact maps showing the predicted impacts of increased hydraulic roughness within the waterway corridor on the 5% (1 in 20) AEP and 1% (1 in 100) AEP and on the peak flood levels are provided in Appendix D.

- In the Oxley Creek main channel upstream of New Beith gauge, the predicted increases in peak flood levels are generally between 0.4 m and 0.6 m for the 1% AEP event (0.35 m average increase), and between 0.2 m and 0.4 m for the 5% AEP event (0.23 m average increase), with localised peaks of up to 1.2 m and 0.8 m, respectively. At New Beith gauge, the predicted increase in peak flood level is 0.2 m and 0.15 m in the 1% AEP and 5% AEP events, respectively.
- In the Oxley Creek main channel between New Beith gauge and Goodna Road gauge, the predicted increases in peak flood levels are generally less than 0.4 m for the 1% AEP event (0.22 m average increase), and less than 0.15 m for the 5% AEP event.
- In the Oxley Creek main channel between Goodna Road gauge and Johnson Road gauge, there are predicted increases in peak flood levels exceeding 1 m for both the 1% AEP event and the 5% AEP event in the forested military areas, with increases in flood extent over the meandering channel's overbank areas (average increase of 0.6 m). In the main channel at Forestdale, predicted increases in peak flood levels are generally between 0.4 m and 0.6 m for both events. At Johnson Road gauge, the predicted increase in peak flood level is 0.45 m and 0.6 m in the 1% AEP and 5% AEP events, respectively.
- The predicted impacts on peak flood levels in the minor tributaries and in the urbanised areas are generally approximately 0.2 m.
- Impacts on peak flood levels in Blunder Creek are generally between 0.2 m and 0.4 m.

11 Summary and conclusions

11.1 OVERVIEW

An URBS hydrologic model and a TUFLOW hydraulic model were developed for the Upper Oxley Creek catchment. The models were calibrated against the January 2013, May 2015, March 2017 and February 2022 flood events.

The calibrated URBS and TUFLOW models were used to estimate design discharges, flood levels, depths, velocities and flood hazard in the Upper Oxley Creek catchment for the 50% (1 in 2), 20% (1 in 5), 10% (1 in 10), 5% (1 in 20), 2% (1 in 50), 1% (1 in 100), 0.5% (1 in 200), 0.2% (1 in 500) and 0.05% (1 in 2,000) AEP design events as well as the PMPF event. Future climate flood events were also simulated. Design event hydrologic and hydraulic modelling was undertaken in accordance with ARR 2019 (Ball et al, 2019).

Sensitivity testing was undertaken for the 1% (1 in 100) AEP event to assess the impact of changes to hydraulic roughness, changes to hydraulic structure blockages and changes to downstream outflow boundary conditions on the model results. For the 5% (1 in 20) and 1% (1 in 100) AEP events, the impact of proposed revegetation within the waterway corridor was also assessed.

11.2 HYDROLOGIC MODEL DEVELOPMENT

An URBS model was developed for 'existing catchment conditions' for model calibration purposes. An URBS model was developed for 'ultimate catchment conditions' for design event modelling.

The URBS model comprises the entire Upper Oxley Creek catchment to the Logan Motorway, the Blunder Creek catchment to the Logan Motorway, and the catchment of the 'Eastern Tributary' to the Logan Motorway. The model consists of 660 subcatchments, ranging in area from 2.9 ha to 35.8 ha, with an average subcatchment area of 21.4 ha. The URBS model was configured to adopt the Laurenson's (1964) subcatchment routing method.

Channel routing in the URBS model was based on the Muskingum method. The URBS model routing was configured by specifying the reach lengths (L), channel slope (Sc) and reach length factors.

11.3 HYDRAULIC MODEL DEVELOPMENT

The Upper Oxley Creek TUFLOW model extents from the upper headwaters of the catchment to the Logan Motorway. All hydraulic modelling has been undertaken using the TUFLOW Build 2020-10-AB with the HPC-GPU solver. The TUFLOW sub-grid sampling feature was utilised to maximise the available topographic information.

The following two models were developed:

- **'Fast Model'** - This model was configured with a grid cell size of 9 m. The purpose of this model is to allow the selection of critical ARR 2019 design storms to be run using a finer 'Detailed Model'.
- **'Detailed Model'** - This model was configured with a grid cell size of 3 m. The purpose of this model is to run the critical design storms selected using the 'Fast Model' to obtain the design outputs.

Both the fast and detailed models were calibrated against recorded data for the January 2013, May 2015, March 2017 and February 2022 events, using discharge hydrographs generated from the calibrated URBS hydrologic model as inputs.

The model inflow boundaries were configured using 2D surface-area (SA) polygons. The model has a total of 712 local inflow and 4 total inflow boundaries. No total inflows were applied within the model. The TUFLOW model inflow boundaries were configured using 2D surface-area (SA) polygons. Inflow hydrographs generated from the URBS model were adopted as inflows at the 2D SA inflow boundaries.

The TUFLOW model has three outflow boundaries located downstream of Johnson Road, including an outflow at Blunder Creek, an outflow within the main Oxley Creek channel, and an outflow at the Eastern Tributary. Outflow boundaries were defined as normal depth boundaries based on the flood slope.

Hydraulic roughness (Manning's 'n') values for the various waterway channel types were initially selected based on typical published values (such as those in Chow (1959)). Manning's 'n' values were then adjusted as necessary to achieve the best possible calibration result against recorded data. For bushland areas, forested areas and built-up areas (residential, industrial and roads), a single Manning's 'n' approach was adopted. For river channels and open floodplain areas, a depth-varying Manning's 'n' approach was adopted.

The hydraulic model includes a significant number of hydraulic structures including 164 culverts (106 RCPs and 58 RCBCs) and 11 bridges. Due to their size, the culverts at the New Beith road upgrade were configured as bridge structures with enforced slabs. Culverts in the TUFLOW model were modelled as 1D structures embedded within the 2D model domain. The 1D to 2D connections were modelled using 'SX polygons'. Bridges were represented in the hydraulic model using two-dimensional 'layered flow constrictions'. Structure blockage for design events was determined individually for each structure based on guidelines in Book 6 - Chapter 6 of AR&R 2019 (Ball et al, 2019).

11.4 MODEL CALIBRATION AND VALIDATION

The hydrologic and hydraulic models were calibrated against rated peak flows and recorded peak flood levels for the January 2013, May 2015, March 2017 and February 2022 flood events. For the January 2013 and May 2015 events, calibration was further undertaken against surveyed debris marks.

Hydraulic model calibration to the January 2013, May 2015 and March 2017 events was undertaken based on the model topography configured using the 2017 LiDAR data. Hydraulic model calibration to the February 2022 event as well as design event hydraulic modelling was undertaken with the base topography configured using the 2021 LiDAR data.

The hydrologic and hydraulic model calibration confirms that the calibrated URBS hydrologic model produces discharges that generally result in good reproduction of historical peak water levels for the January 2013, May 2015, March 2017 and February 2022 flood events.

The model calibration is considered acceptable and the calibrated URBS and TUFLOW models are suitable for adaptation for use in design event modelling.

11.5 DESIGN FLOOD DISCHARGES

The calibrated URBS model was used to estimate design flood discharges throughout the Upper Oxley Creek catchment in accordance with the AR&R 2019 guidelines. The URBS model design event discharges were reconciled against FFA estimates at the New Beith gauge.

Design flood discharge hydrographs were estimated for the full range of storm durations for the 50% (1 in 2), 20% (1 in 5), 10% (1 in 10), 5% (1 in 20), 2% (1 in 50), 1% (1 in 100), 0.5% (1 in 200), 0.2% (1 in 500), 0.05% (1 in 2,000) AEP events and the PMPF event.

Design flood discharges were also estimated for the future climate scenario based on RCP 4.5, RCP 6 and RCP 8.5 for the 2090 climate horizon. An increase in rainfall intensity of 9.5%, 11.5%, and 19.7%, respectively, is predicted for the future climate scenarios.

Subcatchment parameters (fraction impervious and PERN 'N') for the URBS model for design events were derived based ultimate catchment conditions (based on the landuses identified in the LCC, BCC and ICC planning schemes).

11.6 FLOOD FREQUENCY ANALYSIS

Design flood discharges were estimated by Flood Frequency Analysis (FFA) using the RMC-BestFit software (version 1.0) in accordance with guidelines in Book 3, Chapter 2 of AR&R 2019 (Ball et al, 2019). FFA was undertaken at the New Beith gauge based on annual maximum series (AMS) and peak over threshold (POT) methodology.

Initial losses for the URBS model were derived by reconciliation with the FFA at New Beith gauge. For events up to and including the 10% AEP, design rainfall losses were derived by reconciliation against POT series results. For events rarer than the 10% AEP, the annual series FFA results were adopted.

The design peak discharges estimated by the URBS model correspond well to the flood frequency discharge estimates for all events up to the 1% AEP event. The URBS discharge estimates match well with those predicted by the FFA and are well within the flood frequency confidence limits.

The FFA discharge estimates were found to be consistent with the recorded magnitude and severities of the January 2013, May 2015, April 2017 and February 2022 events. This gives confidence that the FFA peak discharge estimates are reasonable.

11.7 DESIGN FLOOD LEVELS, DEPTHS, VELOCITIES, FLOOD HAZARD AND CRITICAL STORM DURATIONS

The calibrated TUFLOW model was used to estimate flood levels, depths, velocities and flood hazard in the Oxley Creek catchment for the 50% (1 in 2), 20% (1 in 5), 10% (1 in 10), 5% (1 in 20), 2% (1 in 50), 1% (1 in 100), 0.5% (1 in 200), 0.2% (1 in 500), 0.05% (1 in 2,000) AEP events and the PMPF event, for a range of storm durations up to 72 hours in the 'Fast Model', and up to 36 hours in the 'Detailed Model'. Future climate flood events were also simulated.

The 'Fast Model' was used to select the representative ARR 2019 design storms, which was then simulated using a finer 'Detailed Model'. The 'Detailed Model' was run for the representative design storms selected using the 'Fast Model' to obtain the design outputs for both current climate and future climate scenarios.

The TUFLOW 'asc_to_asc' utility was used to extract the mean water levels for each design event and storm duration. The extracted levels were confirmed against the true mean water levels at key locations throughout the model, and the selected storm adjusted were required. A max-max selection of the selected mean grids for each storm duration was used to ensure the representative temporal pattern and critical duration results are identified and mapped for each design event.

High resolution flood maps (in A3 size and PDF format) are provided in Appendix D of this report. Longitudinal profiles of design peak water levels along the Oxley Creek channel are provided for both current and future climate conditions.

11.8 SENSITIVITY ANALYSES

The sensitivity analyses results indicate the following:

- Peak flood levels are generally not sensitive to increases in hydraulic roughness in the urbanised areas in New Beith, Greenbank and Forestdale. Peak flood levels are moderately sensitive to increases in hydraulic roughness within most of the Oxley Creek main channel. The flood extent remains generally unchanged.
- Peak flood levels are moderately sensitive to an increase in hydraulic roughness due to waterway corridor restoration in the urban reaches of New Beith, Greenbank and Forestdale.
- Peak flood levels are more sensitive to an increase in hydraulic roughness due to waterway corridor restoration in the Oxley Creek main channel, particularly in the forested areas between the Goodna Road and Johnson Road gauges.

- Peak flood levels are generally not sensitive to decreases in hydraulic roughness. Minor increases in peak flood levels are predicted upstream of some culvert crossings.
- Peak flood levels adjacent to culvert crossings are sensitive to variations in culvert blockages. The removal of blockages from these culverts may reduce peak flood levels upstream, while increasing peak flood levels downstream, particularly in the urbanised areas in Greenbank.
- Peak flood levels within the LCC LGA are not affected by a variation in outflow boundary flood slopes.

11.9 LIMITATIONS OF THIS STUDY

The Upper Oxley Creek Flood Study described in this report is a catchment wide investigation of flooding throughout the Upper Oxley Creek catchment. Although every effort has been taken to ensure that the model accurately represents flooding throughout the study area, it should be noted that there are limitations to the accuracy of the modelling, including the flood mapping especially at the edges of the flood extent. In particular, the results of the study should not be relied upon at an individual allotment scale in areas where flooding is due to exceedances of the trunk stormwater pipe network (i.e., outside of the extent of creek flooding).

This is due to the fact that not all stormwater network infrastructure has been included in the model. Stormwater pipes, tanks and pits not owned and maintained by LCC are generally not represented in the model. In addition, most minor LCC stormwater pipes and pits also have been excluded. It is also possible that there is trunk stormwater infrastructure represented inaccurately (e.g., assumed invert levels) due to lack of available survey or as-constructed data, or missing records in the LCC GIS database. Further, the extent of overland flow shown through private allotments should not be relied upon due to approximations with regards to model topography and roughness mapping at an allotment scale.

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Appendix A - URBS model parameters

Contents

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A1 URBS subcatchments maps

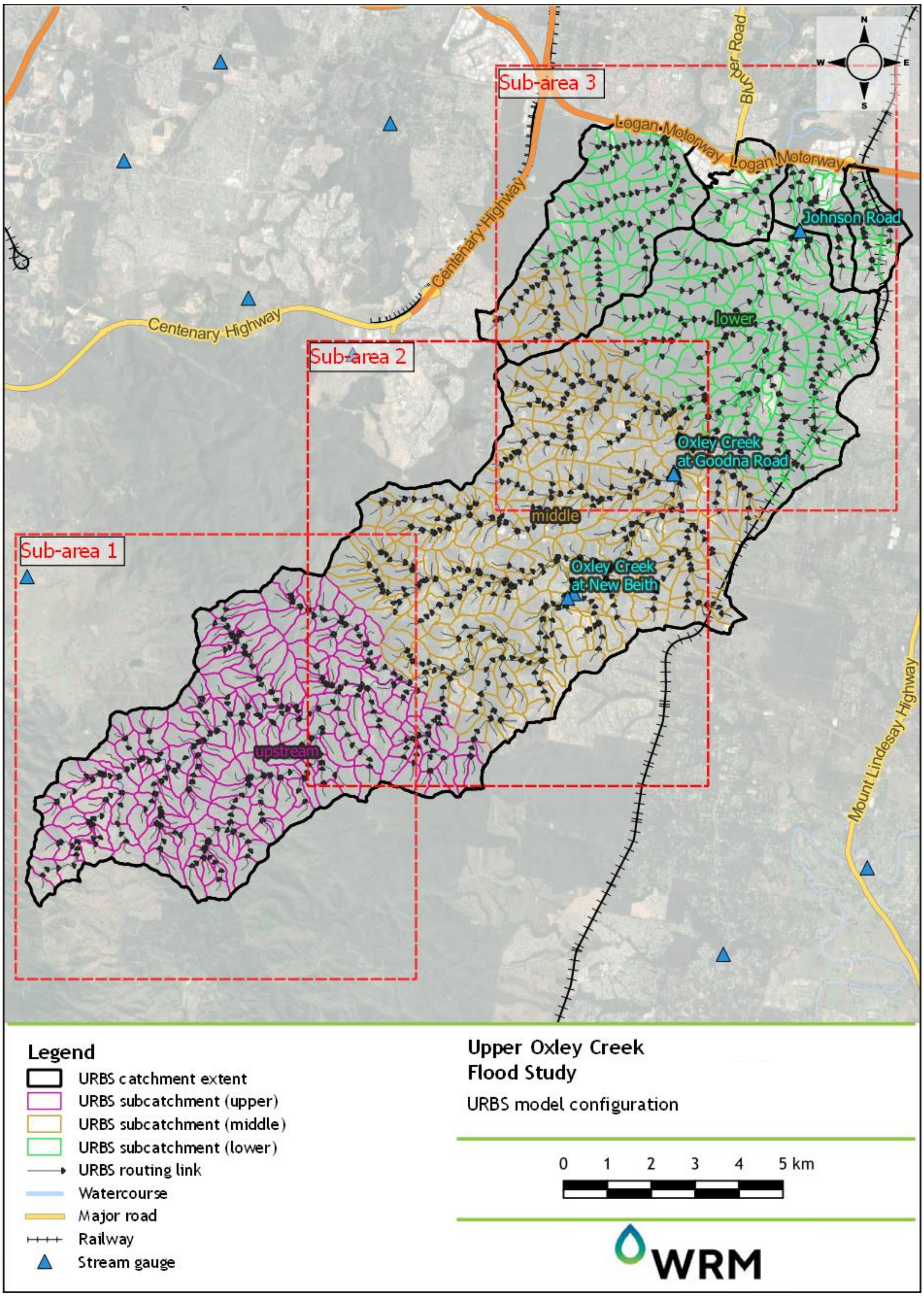

Figure A.1 - URBS model configuration, overview

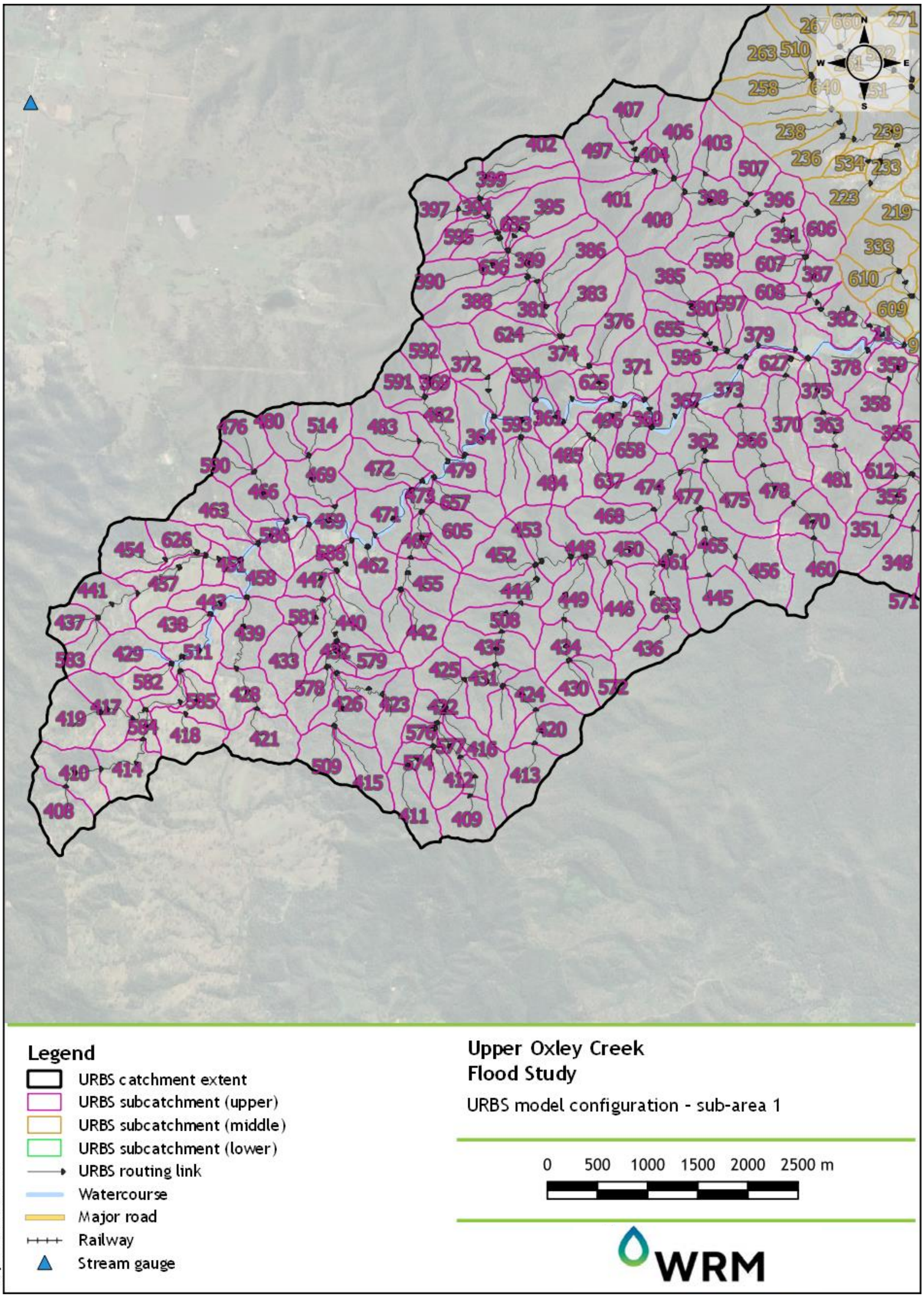

Figure A.2 - URBS model configuration, sub-area 1

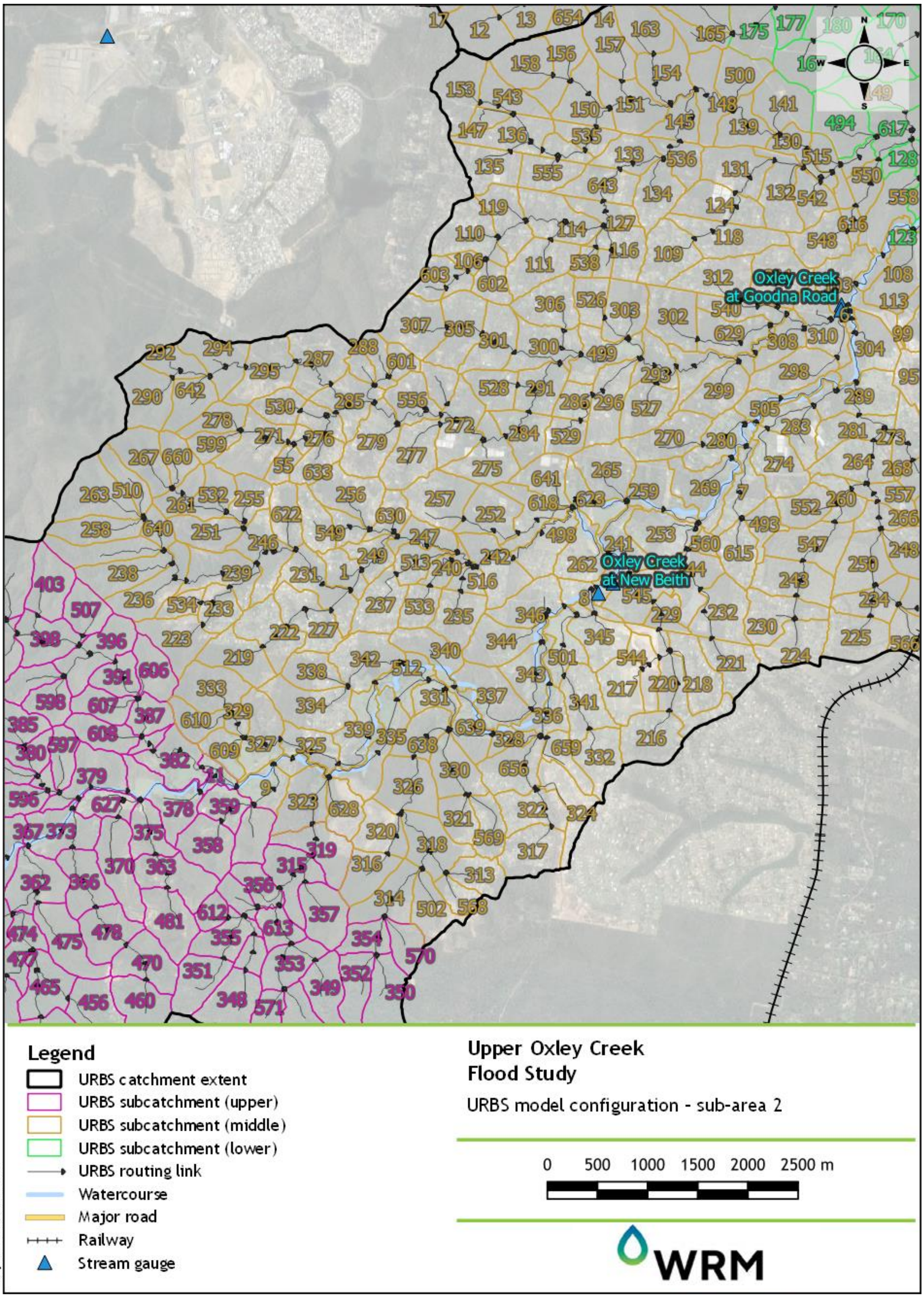

Figure A.3 - URBS model configuration, sub-area 2

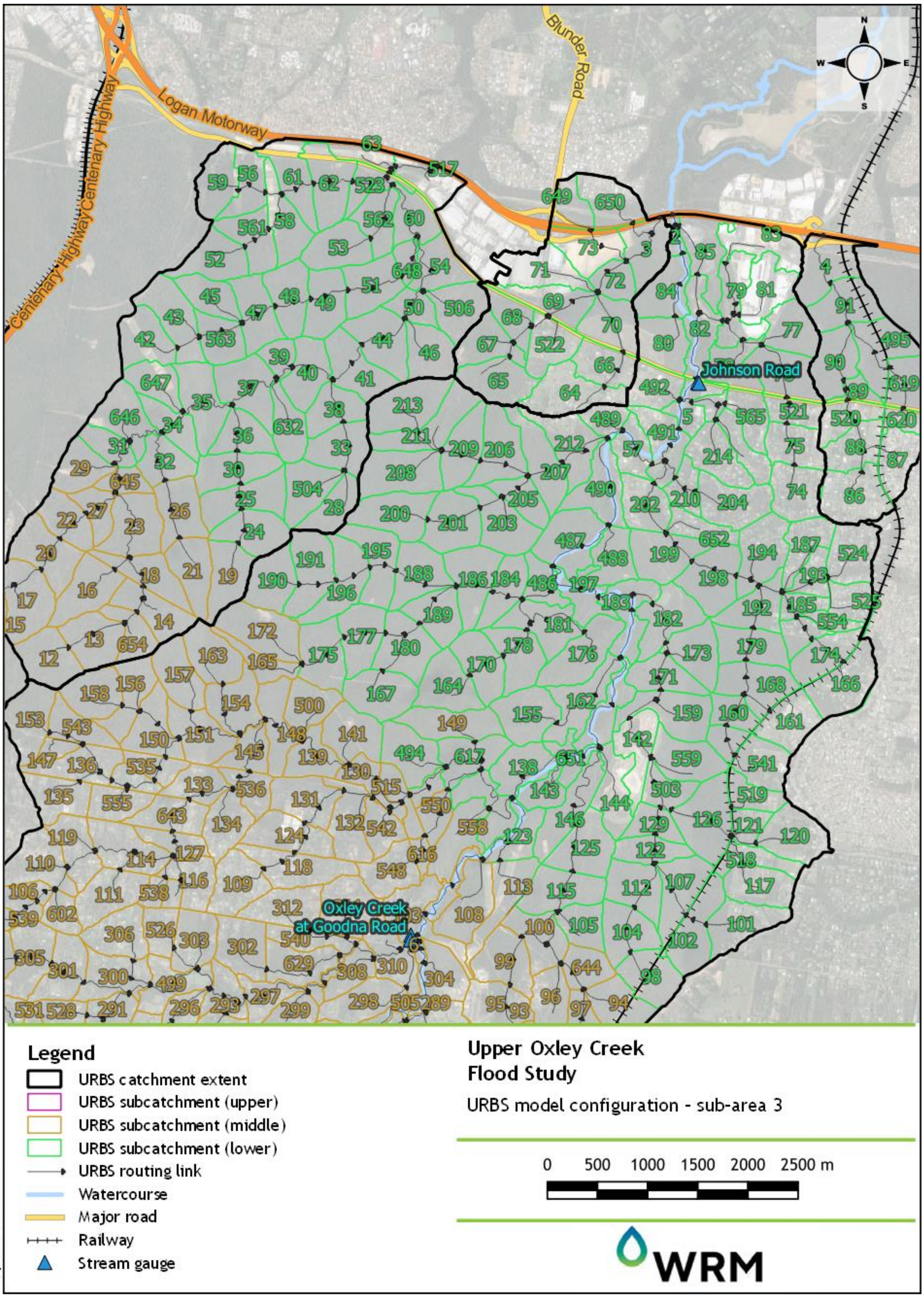

Figure A.4 - URBS model configuration, sub-area 3

A2 URBS adopted parameters

Table A.1 - Adopted percentage impervious and PERN (n) values for each landuse type

Land-use type (refer to Council planning scheme)	Fraction impervious (%)	PERN N
Centre	90	0.025
Community facilities	50	0.050
Emerging community	50	0.050
Environmental management and conservation	0	0.080
Low density residential	50	0.050
Low impact industry	90	0.025
Low-medium density residential	70	0.038
Medium density residential	85	0.028
Medium impact industry	90	0.025
Mixed use	90	0.025
Recreation and open space	0	0.080
Road	75	0.035
Rural residential	15	0.060
Rural	5	0.075
Watercourse	0	0.080
Priority Development Area	85	0.028
Special Purpose	0	0.080
Industry	90	0.025

A3 URBS parameters existing catchment conditions

Table A.2 - Adopted URBS subcatchment parameters for existing catchment conditions

ID	Area (ha)	Slope (%)	Imp. (%)	PERN N	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
1	14.2	6.0	13.6	0.066				38.9							53.7		7.4	
2	5.4	10.1	7.7	0.075				80.5									10.3	9.3
3	25.2	5.1	11.4	0.073				86.1	6.1								7.8	
4	30.6	6.4	12.2	0.073				83.8	0.4								15.8	
5	16.0	4.9	23.5	0.066		15.3		41.5		26.4			6.8				3.6	6.5
6	5.4	7.3	15.8	0.068				43.1							21.9	10.8	16.7	7.6
7	22.0	6.6	19.9	0.058											91.8		8.2	
8	11.2	7.7	21.1	0.060				13.9							67.1		14.7	4.3
9	16.4	7.1	4.9	0.075				67.7							21.8		2.1	8.4
10	6.6	8.7	19.4	0.064				29.4							36.4		18.6	15.6
11	8.0	8.6	2.6	0.078				87.7									3.5	8.9
12	26.8	4.6	0.0	0.080												100.0		
13	26.9	5.9	0.0	0.080												100.0		
14	24.9	5.7	0.0	0.080												100.0		
15	25.6	5.9	42.2	0.055						78.8			4.5			13.0	3.7	
16	28.1	4.4	0.0	0.080												100.0		
17	34.3	5.9	3.0	0.078						3.4						94.9	1.6	
18	23.9	5.9	0.0	0.080												100.0		
19	25.4	3.5	0.0	0.080												100.0		
20	30.5	5.4	0.2	0.080												99.8		
21	25.0	4.6	0.0	0.080												100.0		

					Percentage of the catchment (%)													
ID	Area (ha)	Slope (%)	Imp. (%)	PERN N	Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
22	21.0	6.0	0.0	0.080												100.0		
23	31.5	5.0	0.0	0.080												100.0		
24	25.3	5.7	0.0	0.080												100.0		
25	29.2	5.4	0.0	0.080												100.0		
26	26.2	6.1	0.0	0.080												100.0		
27	14.6	4.9	0.0	0.080												100.0		
28	18.8	3.7	0.0	0.080												100.0		
29	20.9	5.6	0.0	0.080												100.0		
30	25.3	6.5	0.0	0.080												100.0		
31	14.1	5.9	0.0	0.080												100.0		
32	20.0	6.0	0.0	0.080												100.0		
33	25.5	6.7	0.0	0.080												100.0		
34	17.7	6.7	0.0	0.080												100.0		
35	29.7	5.9	0.0	0.080												100.0		
36	19.9	6.7	0.0	0.080												100.0		
37	30.3	7.2	0.0	0.080												100.0		
38	21.3	7.1	0.0	0.080												100.0		
39	10.4	8.5	0.0	0.080												100.0		
40	24.2	6.1	0.0	0.080												100.0		
41	28.0	6.5	0.0	0.080												100.0		
42	25.4	4.4	0.0	0.080												100.0		
43	30.3	3.9	0.0	0.080												100.0		
44	29.9	6.9	0.0	0.080												100.0		
45	19.2	3.8	0.0	0.080												100.0		
46	23.8	6.6	0.0	0.080												100.0		

ID	Area (ha)	Slope (%)	Imp. (%)	PERN N	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
47	25.6	5.0	0.0	0.080												100.0		
48	25.1	5.6	0.0	0.080												100.0		
49	25.0	6.2	0.0	0.080												100.0		
50	13.1	7.2	0.0	0.080												100.0		
51	26.6	7.8	0.0	0.080												100.0		
52	25.0	4.5	0.0	0.080												100.0		
53	25.4	4.7	0.0	0.080												100.0		
54	23.3	7.4	6.2	0.076												91.7	8.3	
55	8.5	14.8	17.8	0.062		2.1		24.4							64.0		9.5	
56	19.9	6.5	3.4	0.078												95.5	4.5	
57	17.5	6.7	22.2	0.067				52.1		40.5							2.6	4.8
58	24.7	5.8	0.0	0.080												100.0		
59	23.5	6.5	1.1	0.079												98.6	1.4	
60	20.4	8.7	4.8	0.077												93.6	6.4	
61	26.5	6.9	21.9	0.067					11.4							73.0	15.6	
62	29.1	7.7	14.8	0.071					6.7							81.6	11.7	
63	12.2	6.9	76.9	0.033					45.7				6.6				47.7	
64	32.8	3.4	52.2	0.049						90.1							9.5	
65	26.5	5.0	6.0	0.076						8.7						89.0	2.3	
66	22.1	4.3	47.7	0.051						90.9			6.1				3.0	
67	22.3	5.1	0.0	0.080												100.0		
68	17.1	5.7	3.9	0.078												94.8	5.2	
69	24.1	5.8	36.8	0.058				54.8	23.6				1.0				20.7	
70	25.5	5.9	55.0	0.046				37.6	54.8								7.6	
71	28.3	2.4	84.8	0.028				4.0	85.4								10.6	

					Percentage of the catchment (%)													
ID	Area (ha)	Slope (%)	Imp. (%)	PERN N	Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
72	14.1	6.2	0.1	0.080				99.9										
73	25.4	6.4	83.2	0.029				3.0	69.6								27.4	
74	25.8	5.3	49.9	0.050						79.6			6.9				13.5	
75	22.2	6.9	43.8	0.054						72.4			17.5				10.1	
76	27.6	6.6	2.6	0.078				96.6									3.4	
77	23.0	6.4	9.5	0.074				88.4	5.0								6.6	
78	20.7	3.0	6.2	0.076				91.6									7.9	
79	26.7	3.0	33.8	0.059				62.5	37.5									
80	24.6	4.9	28.9	0.062				66.8	27.0								6.2	
81	25.8	2.3	85.9	0.028				3.0	87.8								9.3	
82	25.6	8.8	4.0	0.078				86.7									5.4	8.0
83	24.9	2.5	84.8	0.028				3.6	83.1								13.3	
84	25.0	5.8	0.0	0.080				96.5										3.5
85	27.1	4.8	7.8	0.075				90.1	2.8								7.1	
86	25.2	4.4	51.5	0.049						85.1			3.0				11.9	
87	24.1	4.6	46.1	0.052						58.1			12.7			6.5	22.7	
88	28.3	5.6	46.0	0.052						80.9			8.8			2.9	7.4	
89	7.6	5.8	9.2	0.074				87.7									12.3	
90	25.9	6.9	0.2	0.080				99.8										
91	26.5	6.6	4.9	0.077				93.5									6.5	
92	29.7	5.0	21.8	0.067									0.4		0.4	70.1	29.0	
93	23.9	3.5	1.3	0.079												98.0	1.8	
94	28.4	4.0	1.6	0.079												97.8	2.2	
95	29.4	4.2	6.2	0.075											7.5	85.7	6.8	
96	28.7	3.2	0.0	0.080												100.0		

ID	Area (ha)	Slope (%)	Imp. (%)	PERN N	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
97	15.0	3.3	0.0	0.080												100.0		
98	25.5	3.9	2.2	0.079												97.0	3.0	
99	28.2	3.8	0.0	0.080												100.0		
100	25.1	3.4	0.0	0.080												100.0		
101	27.2	4.5	42.9	0.054						70.0						19.4	10.5	
102	29.7	4.3	0.9	0.079												98.8	1.2	
103	27.8	7.6	16.8	0.066				23.3							33.6	23.2	15.6	4.3
104	25.7	3.8	0.0	0.080												100.0		
105	17.6	4.1	0.0	0.080												100.0		
106	5.4	8.1	16.0	0.062				19.6							73.7		6.6	
107	28.9	4.2	0.0	0.080												100.0		
108	29.8	3.8	0.0	0.080												100.0		
109	27.4	4.2	19.5	0.058											92.6		7.4	
110	29.9	8.9	16.9	0.061				10.2							84.1		5.7	
111	27.5	6.2	17.0	0.059											96.7		3.3	
112	25.8	4.0	0.0	0.080												100.0		
113	25.9	3.4	0.0	0.080												100.0		
114	29.4	6.6	15.8	0.060				4.4							93.1		2.5	
115	29.1	4.6	0.0	0.080												100.0		
116	20.4	4.6	19.9	0.058											91.9		8.1	
117	24.9	4.8	49.2	0.050						88.3			0.6			4.4	6.7	
118	30.1	4.0	15.3	0.062									14.3		81.6		4.1	
119	23.1	7.1	23.0	0.057											86.6		13.4	
120	28.9	5.4	53.2	0.048						87.2							12.8	
121	11.2	5.2	43.1	0.054						72.6						18.3	9.1	

ID	Area (ha)	Slope (%)	Imp. (%)	PERN N	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
122	17.0	4.7	0.0	0.080												100.0		
123	19.4	5.9	0.0	0.080												100.0		
124	27.3	4.4	19.0	0.058											93.4		6.6	
125	29.2	5.6	0.0	0.080												100.0		
126	35.8	4.0	0.0	0.080												100.0		
127	13.8	5.8	11.5	0.069				54.0							38.4		7.6	
128	24.2	3.4	0.0	0.080												100.0		
129	14.8	4.1	0.0	0.080												100.0		
130	15.1	3.6	5.9	0.076												92.2	7.8	
131	26.9	4.6	22.0	0.057											88.3		11.7	
132	26.8	4.9	23.2	0.057											86.1		13.7	
133	18.1	5.4	20.1	0.058											91.5		8.5	
134	23.2	4.7	18.9	0.058											93.5		6.5	
135	23.4	7.0	22.7	0.057											87.2		12.8	
136	24.4	6.3	23.7	0.056											85.5		14.5	
137	9.5	8.8	18.8	0.058											93.6		6.4	
138	24.1	5.6	0.0	0.080												100.0		
139	19.9	3.9	1.9	0.079												97.5	2.5	
140	7.2	2.1	0.0	0.080												100.0		
141	26.8	7.8	0.0	0.080												100.0		
142	24.5	4.2	0.0	0.080												100.0		
143	13.9	4.6	0.0	0.080												100.0		
144	25.0	4.0	0.0	0.080												100.0		
145	16.4	4.2	4.7	0.077												93.7	6.3	
146	28.4	3.7	0.0	0.080												100.0		

					Percentage of the catchment (%)													
ID	Area (ha)	Slope (%)	Imp. (%)	PERN N	Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio- rity	Rec	Rural	Rur. Res.	Spe- cial	Road	Water
147	6.8	6.5	23.0	0.057											86.7		13.3	
148	23.9	4.5	1.1	0.079												98.5	1.5	
149	27.1	6.1	0.0	0.080												100.0		
150	25.5	6.2	2.7	0.078												96.4	3.6	
151	27.1	5.7	1.9	0.079												97.5	2.5	
152	10.3	3.7	0.0	0.080												100.0		
153	28.4	6.9	8.5	0.073				3.0							21.3	68.7	7.1	
154	26.1	4.4	0.0	0.080												100.0		
155	28.0	4.2	0.0	0.080												100.0		
156	23.8	6.0	0.0	0.080												100.0		
157	24.9	5.6	0.0	0.080												100.0		
158	24.5	7.9	0.0	0.080												100.0		
159	31.2	5.1	0.0	0.080												100.0		
160	13.4	4.9	0.0	0.080												100.0		
161	24.7	5.2	50.0	0.050						86.0						4.7	9.3	
162	28.6	3.7	0.0	0.080												100.0		
163	25.4	6.2	0.0	0.080												100.0		
164	27.5	4.8	0.0	0.080												100.0		
165	14.1	4.6	0.0	0.080												100.0		
166	31.6	5.5	46.9	0.052						78.5			7.0			4.4	10.2	
167	28.6	5.9	0.0	0.080												100.0		
168	29.7	5.0	0.0	0.080												100.0		
169	20.7	5.3	0.0	0.080												100.0		
170	25.1	5.2	0.0	0.080												100.0		
171	21.1	4.6	0.0	0.080												100.0		

ID	Area (ha)	Slope (%)	Imp. (%)	PERN N	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
172	33.1	4.8	0.0	0.080												100.0		
173	24.2	5.4	0.0	0.080												100.0		
174	22.4	5.3	8.7	0.075						17.4						82.5		
175	28.2	5.1	0.0	0.080												100.0		
176	31.5	2.8	0.0	0.080												100.0		
177	25.5	4.7	0.0	0.080												100.0		
178	25.5	4.5	0.0	0.080												100.0		
179	24.2	5.3	0.0	0.080												100.0		
180	29.9	5.8	0.0	0.080												100.0		
181	27.6	3.2	0.0	0.080												100.0		
182	28.8	7.2	0.0	0.080												100.0		
183	26.1	9.4	0.0	0.080												100.0		
184	20.8	6.6	0.0	0.080												100.0		
185	9.6	4.8	36.1	0.058				31.4		61.3							7.2	
186	29.7	5.8	0.0	0.080												100.0		
187	19.9	6.0	44.6	0.053				15.3		75.9							8.8	
188	26.8	4.7	0.0	0.080												100.0		
189	22.6	5.9	0.0	0.080												100.0		
190	25.3	5.5	0.0	0.080												100.0		
191	30.7	6.3	0.0	0.080												100.0		
192	23.5	5.3	4.7	0.077				7.1		9.4						83.4		
193	13.2	5.4	40.6	0.056				21.5		73.1							5.4	
194	30.7	6.5	25.3	0.065						44.6						51.3	4.0	
195	27.8	4.5	0.0	0.080												100.0		
196	28.9	5.2	0.0	0.080												100.0		

					Percentage of the catchment (%)													
ID	Area (ha)	Slope (%)	Imp. (%)	PERN N	Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
197	18.3	5.7	0.0	0.080												100.0		
198	31.3	6.7	0.0	0.080												100.0		
199	29.9	6.6	0.0	0.080												100.0		
200	30.0	3.9	0.0	0.080												100.0		
201	29.1	5.4	0.0	0.080												100.0		
202	22.9	5.3	45.3	0.053				19.4		55.6						1.6	23.4	
203	29.3	4.7	0.0	0.080												100.0		
204	29.8	9.4	44.9	0.053						77.7			14.3				8.0	
205	16.7	5.6	0.0	0.080												100.0		
206	29.6	6.5	0.0	0.080												100.0		
207	28.4	6.3	3.1	0.078						4.8						94.2	0.9	
208	34.2	4.0	0.0	0.080												100.0		
209	25.3	6.0	0.0	0.080												100.0		
210	12.9	8.4	48.8	0.051						82.0			7.7				10.4	
211	29.1	4.6	0.0	0.080												100.0		
212	29.0	6.3	17.6	0.069				0.7		34.4						64.3	0.5	
213	33.2	4.7	0.0	0.080												100.0		
214	24.8	5.9	49.8	0.050						79.6			7.1				13.3	
215	5.8	4.5	24.7	0.065		13.7		53.6		25.1							7.1	
216	28.2	4.5	21.5	0.057											89.2		10.8	
217	23.3	4.0	22.9	0.057											86.9		13.1	
218	24.5	4.6	24.2	0.056											84.7		15.3	
219	25.0	6.7	4.3	0.075				77.5							21.0		1.5	
220	31.2	4.6	20.5	0.058									0.8		89.9		9.3	
221	22.0	5.4	23.8	0.059		5.1		16.9							62.0		16.0	

					Percentage of the catchment (%)													
ID	Area (ha)	Slope (%)	Imp. (%)	PERN N	Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
222	26.7	7.1	20.2	0.060				17.4							69.6		13.1	
223	25.8	15.6	6.7	0.073				70.4							26.0		3.7	
224	25.2	4.8	22.6	0.059		1.6		8.7					9.3		64.0		16.3	
225	26.8	4.6	45.3	0.047		1.6						21.9			52.5		24.0	
226	18.5	4.0	19.9	0.058											91.9		8.1	
227	27.7	6.3	20.2	0.060	0.7			13.1							75.1		11.2	
228	11.3	4.0	15.1	0.060											99.9			
229	10.8	6.6	5.7	0.077				92.4									7.5	
230	27.0	5.1	18.3	0.060				3.5					8.8		79.0		8.6	
231	28.1	7.2	10.3	0.068				47.3							48.7		4.0	
232	28.4	6.4	10.5	0.071				56.7					7.7		27.0		8.6	
233	16.0	7.7	17.6	0.062				20.6							69.9		9.5	
234	20.8	4.5	26.8	0.055								11.2			82.2		6.6	
235	22.3	9.3	23.3	0.057				3.0							82.5		14.6	
236	27.5	20.0	4.1	0.075				72.8							27.1			
237	24.6	5.9	24.9	0.057				5.9							76.1		17.9	
238	24.5	26.5	0.6	0.079				95.8							4.2			
239	28.3	11.1	13.4	0.063				16.4							82.3		1.4	
240	11.0	5.9	24.9	0.056											82.5		16.7	
241	26.3	5.5	20.4	0.060				8.8						4.1	69.5		13.0	4.6
242	28.2	6.8	17.4	0.062				19.2							72.0		8.8	
243	28.4	5.0	15.4	0.060											99.3		0.7	
244	26.8	6.6	3.8	0.077				88.6							7.9		3.5	
245	22.7	36.6	0.0	0.080				100.0										
246	27.0	10.1	10.4	0.068				40.7							56.7		2.5	

					Percentage of the catchment (%)													
ID	Area (ha)	Slope (%)	Imp. (%)	PERN N	Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
247	14.4	8.0	9.8	0.071				61.2							32.1		6.6	
248	31.4	4.7	15.7	0.060											98.7		1.2	
249	14.4	6.3	12.2	0.067				44.1							49.6		6.3	
250	27.6	4.9	15.0	0.060											100.0			
251	19.8	11.6	14.9	0.060				0.8							99.2			
252	24.5	7.6	10.9	0.067				32.9					7.3		56.6		3.2	
253	26.4	4.2	19.3	0.058											92.8		7.2	
254	9.3	7.5	14.1	0.065				30.2							63.7		6.1	
255	15.3	20.2	14.4	0.065		1.8		34.5							57.2		6.5	
256	27.5	13.3	13.0	0.066				38.4							55.3		6.2	
257	29.5	7.1	20.5	0.061		1.2		20.8							64.4		13.6	
258	20.7	40.6	0.0	0.080				100.0										
259	25.0	6.5	16.2	0.060											92.5		3.1	4.4
260	14.4	4.6	15.1	0.064				27.7							65.2		7.1	
261	12.8	18.1	10.5	0.066				29.8							70.2			
262	23.2	5.6	14.9	0.065				3.1						34.8	46.8		8.1	7.2
263	34.0	41.2	0.5	0.080				99.3									0.7	
264	27.4	4.1	20.4	0.058											91.0		9.0	
265	26.6	7.8	18.4	0.059											94.3		5.7	
266	25.2	4.8	17.5	0.059											90.8	4.0	5.2	
267	25.0	37.6	0.9	0.079				98.8									1.2	
268	29.6	4.2	14.4	0.066									39.2		52.0		8.8	
269	29.8	4.8	17.3	0.060											91.9		4.7	3.5
270	27.4	5.8	16.2	0.060											98.0		2.0	
271	29.7	17.6	14.1	0.064		1.8		23.2							71.8		3.2	

					Percentage of the catchment (%)													
ID	Area (ha)	Slope (%)	Imp. (%)	PERN N	Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
272	27.8	8.1	23.1	0.057											86.4		13.6	
273	28.6	4.5	18.8	0.062									0.6		60.0	26.4	13.0	
274	27.4	5.4	18.4	0.059											94.3		5.7	
275	27.4	6.8	19.5	0.059				3.0					1.5		87.0		8.5	
276	6.2	11.8	17.7	0.060				6.5							87.3		6.1	
277	28.4	7.9	20.2	0.058											91.4		8.6	
278	14.9	21.8	5.4	0.073				64.3							35.7			
279	29.1	9.5	16.1	0.060											98.2		1.8	
280	24.3	5.2	16.0	0.060											93.9		2.6	3.5
281	22.1	3.7	18.7	0.058											93.9		6.1	
282	11.3	11.9	16.2	0.063				24.0							68.0		8.0	
283	23.9	3.0	15.0	0.060											99.7			
284	21.2	7.2	18.8	0.058											93.7		6.3	
285	23.4	10.8	12.5	0.065				30.1							66.6		3.3	
286	12.0	3.6	17.9	0.059											95.1		4.9	
287	32.6	15.9	13.0	0.065				32.8					0.6		61.5		5.0	
288	11.3	15.5	22.0	0.058				4.1							82.4		12.8	
289	30.3	6.5	14.9	0.060											98.6			1.3
290	27.5	29.7	0.0	0.080				100.0										
291	21.4	6.2	17.5	0.059											95.9		4.1	
292	14.3	25.7	0.0	0.080				100.0										
293	17.3	5.4	17.3	0.059											96.2		3.8	
294	25.1	21.7	0.5	0.079				96.4							3.6			
295	29.5	16.1	8.8	0.068				41.6							58.4			
296	27.4	5.0	16.9	0.059											96.9		3.1	

					Percentage of the catchment (%)													
ID	Area (ha)	Slope (%)	Imp. (%)	PERN N	Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
297	17.7	5.6	22.2	0.059				11.3							73.9		14.8	
298	25.4	4.2	15.0	0.060											100.0			
299	22.8	5.1	18.3	0.059											94.5		5.5	
300	27.1	7.5	18.5	0.059											94.1		5.9	
301	24.8	9.5	23.2	0.057											86.3		13.7	
302	27.3	5.8	17.2	0.059											96.3		3.7	
303	23.6	5.9	18.8	0.058											93.7		6.3	
304	26.3	5.8	8.3	0.070											41.3	51.8	2.8	4.1
305	28.7	8.4	13.3	0.065				32.2							62.7		5.1	
306	25.0	7.0	18.7	0.058											93.9		6.1	
307	29.1	13.4	14.5	0.065				31.9							61.0		7.1	
308	15.7	4.7	15.0	0.060											100.0			
309	5.3	7.0	15.0	0.060											100.0			
310	25.4	5.2	18.1	0.060				7.1							85.9		7.0	
311	29.4	6.1	18.6	0.059											93.5		6.1	
312	26.4	4.0	12.6	0.066		1.9							33.9		60.8		3.5	
313	16.9	10.9	15.4	0.064				32.0							59.3		8.7	
314	24.8	11.6	11.0	0.066				34.5							63.5		2.0	
315	26.2	10.9	14.2	0.064				23.9							71.4		4.7	
316	20.8	8.9	19.2	0.059				7.4							83.8		8.8	
317	27.4	7.6	22.1	0.058				5.3							81.6		13.1	
318	28.1	10.6	2.6	0.077				85.6							13.7		0.7	
319	24.9	9.9	18.3	0.060				10.5					0.6		80.6		8.3	
320	21.6	8.3	18.4	0.061				20.1							69.2		10.7	
321	15.1	10.2	12.4	0.067				42.9							50.8		6.3	

					Percentage of the catchment (%)													
ID	Area (ha)	Slope (%)	Imp. (%)	PERN N	Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
322	24.1	7.5	24.5	0.056											84.1		15.9	
323	26.0	8.1	18.4	0.060				11.8							79.2		8.7	
324	23.0	6.5	25.9	0.056											81.5		18.2	
325	17.3	8.9	13.6	0.068				50.3							39.0		10.4	
326	29.9	10.0	8.7	0.071				58.2							37.8		4.1	
327	26.9	6.7	5.2	0.076				88.3							5.9		5.8	
328	8.3	7.3	12.3	0.071				71.9							14.5		13.5	
329	5.6	10.5	0.0	0.080				100.0										
330	24.0	10.9	3.6	0.075				77.5							22.1			
331	12.4	5.4	7.4	0.074				81.7							10.5		7.8	
332	23.2	5.3	22.9	0.057		0.7		1.0							85.3		13.1	
333	27.7	15.2	0.0	0.080				100.0										
334	33.3	6.6	12.4	0.068				49.9							42.0		8.1	
335	28.6	8.3	16.2	0.064				25.5					0.8		59.8		9.7	4.1
336	14.2	6.7	19.4	0.062				20.7							54.5		15.0	9.9
337	29.5	8.0	2.4	0.079				95.5									3.1	1.3
338	18.2	7.6	10.8	0.068				48.7							46.1		5.1	
339	23.7	4.5	11.9	0.068				14.0					35.9		40.0		7.9	2.2
340	21.2	11.4	6.8	0.074				72.7							20.0		5.1	2.2
341	26.7	6.4	21.1	0.057		0.5									89.7		9.8	
342	29.6	7.1	13.1	0.069	0.7			29.3					27.7		32.0		10.3	
343	22.6	6.3	14.5	0.064				24.5							65.5		6.3	3.7
344	26.8	8.4	14.2	0.064				23.7							69.9		4.9	1.5
345	24.3	4.7	21.1	0.058									4.0		82.9		11.5	1.5
346	23.7	7.1	19.9	0.058											90.1		8.5	1.4

					Percentage of the catchment (%)													
ID	Area (ha)	Slope (%)	Imp. (%)	PERN N	Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
347	20.7	13.1	0.9	0.079				98.8									1.2	
348	28.7	15.9	0.4	0.080				99.5									0.5	
349	25.2	13.6	0.5	0.080				99.3									0.7	
350	25.3	12.8	0.3	0.080				99.6									0.4	
351	23.8	19.1	0.0	0.080				100.0										
352	22.2	13.1	0.4	0.080				99.5									0.5	
353	21.5	17.5	0.0	0.080				100.0										
354	14.5	16.8	4.3	0.077				88.4							7.3		4.3	
355	20.4	11.1	0.0	0.080				100.0										
356	14.3	12.6	4.7	0.076				82.8							13.6		3.6	
357	25.1	13.0	11.0	0.067				40.6							55.9		3.5	
358	25.1	15.2	0.0	0.080				100.0										
359	15.3	7.7	3.7	0.078				95.0									4.9	
360	6.4	10.6	2.3	0.079				96.9									3.1	
361	12.6	15.9	2.4	0.079				96.8									3.2	
362	28.6	14.0	4.0	0.078				94.4									5.3	0.4
363	28.9	15.8	0.0	0.080				100.0										
364	30.7	17.5	0.8	0.080				99.0									1.0	
365	11.8	28.6	4.3	0.077				94.3									5.7	
366	25.4	14.2	0.0	0.080				100.0										
367	23.2	17.9	2.8	0.078				93.0									3.8	3.2
368	15.7	11.3	3.9	0.078				94.8									5.2	
369	4.2	29.2	8.3	0.075				88.9									11.1	
370	30.0	10.8	0.0	0.080				100.0										
371	27.8	27.7	0.0	0.080				100.0										

					Percentage of the catchment (%)													
ID	Area (ha)	Slope (%)	Imp. (%)	PERN N	Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
372	25.5	34.0	0.0	0.080				100.0										
373	29.7	13.1	2.9	0.078				90.9									3.8	5.3
374	21.9	20.6	0.0	0.080				100.0										
375	18.1	18.3	1.8	0.079				97.5									2.5	
376	27.4	40.6	0.0	0.080				100.0										
377	4.4	27.5	0.0	0.080				100.0										
378	30.1	12.0	6.9	0.076				85.9									9.2	4.9
379	27.2	26.5	0.0	0.080				96.6										3.4
380	17.9	36.7	0.0	0.080				100.0										
381	15.9	21.2	0.0	0.080				100.0										
382	25.5	10.0	0.8	0.080				98.9									1.1	
383	33.7	40.7	0.0	0.080				100.0										
384	4.5	21.2	0.0	0.080				100.0										
385	29.4	44.0	0.0	0.080				100.0										
386	27.7	38.9	0.0	0.080				100.0										
387	14.3	25.3	0.0	0.080				100.0										
388	26.6	36.7	0.0	0.080				100.0										
389	25.6	35.6	0.0	0.080				100.0										
390	25.0	43.0	0.0	0.080				100.0										
391	15.5	21.5	0.0	0.080				100.0										
392	11.7	30.2	0.0	0.080				100.0										
393	14.2	33.1	0.0	0.080				100.0										
394	14.9	40.4	0.0	0.080				100.0										
395	30.1	44.6	0.0	0.080				100.0										
396	29.8	29.1	0.0	0.080				100.0										

ID	Area (ha)	Slope (%)	Imp. (%)	PERN N	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
397	25.1	32.2	0.0	0.080				100.0										
398	25.3	31.4	0.0	0.080				100.0										
399	26.1	41.8	0.0	0.080				100.0										
400	33.2	39.7	0.0	0.080				100.0										
401	29.4	43.6	0.0	0.080				100.0										
402	25.1	43.5	0.0	0.080				100.0										
403	25.0	36.7	0.0	0.080				100.0										
404	9.5	33.7	0.0	0.080				100.0										
405	4.3	36.5	0.0	0.080				100.0										
406	31.4	45.7	0.0	0.080				100.0										
407	29.1	41.4	0.0	0.080				100.0										
408	29.0	39.9	9.9	0.072										93.0			7.0	
409	21.1	30.5	1.1	0.079				98.5									1.5	
410	29.4	42.6	5.6	0.075										99.1			0.9	
411	25.3	34.9	2.3	0.079				96.9									3.1	
412	13.8	30.4	0.0	0.080				100.0										
413	25.3	17.2	0.3	0.080				99.5									0.5	
414	27.2	26.7	5.4	0.075										99.5			0.5	
415	20.5	25.7	1.7	0.079				97.7									2.3	
416	26.3	25.7	0.0	0.080				100.0										
417	27.6	30.0	5.7	0.075										99.0			1.0	
418	26.6	15.3	10.6	0.072										92.0			8.0	
419	29.8	32.3	6.2	0.074										98.3			1.7	
420	25.8	37.1	0.1	0.080				99.9										
421	29.6	22.2	5.9	0.075				9.4						88.7			1.9	

					Percentage of the catchment (%)													
ID	Area (ha)	Slope (%)	Imp. (%)	PERN N	Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
422	8.4	34.1	0.0	0.080				100.0										
423	25.3	33.2	1.6	0.078				67.1						32.9				
424	16.7	31.5	0.0	0.080				100.0										
425	23.3	29.6	0.0	0.080				99.4						0.6				
426	23.2	20.9	0.6	0.079				87.8						12.2				
427	7.7	19.9	5.0	0.075										100.0				
428	29.5	15.9	7.2	0.074										96.8			3.2	
429	25.0	32.3	5.0	0.075										100.0				
430	16.5	43.1	0.1	0.080				99.8										
431	20.5	25.9	0.0	0.080				100.0										
432	6.7	12.9	5.0	0.075										100.0				
433	25.0	18.4	5.0	0.075										100.0				
434	25.1	26.0	0.0	0.080				100.0										
435	29.4	27.5	0.0	0.080				100.0										
436	26.2	30.3	3.5	0.078				95.4									4.6	
437	14.1	32.6	9.2	0.073				6.9						86.6			6.5	
438	19.1	14.0	5.0	0.075										100.0				
439	28.8	14.5	7.0	0.074										97.2			2.8	
440	20.3	15.6	5.0	0.075										100.0				
441	25.3	31.9	5.8	0.075										98.8			1.2	
442	20.9	31.2	2.6	0.077				48.9						51.1				
443	19.7	12.9	7.2	0.074										96.8			3.2	
444	29.4	20.7	0.0	0.080				100.0										
445	26.6	12.4	4.4	0.077				94.2									5.8	
446	26.9	20.6	1.1	0.079				98.5									1.5	

ID	Area (ha)	Slope (%)	Imp. (%)	PERN N	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
447	15.4	15.2	5.0	0.075										100.0				
448	23.5	23.6	1.1	0.079				98.5									1.5	
449	27.2	18.0	1.1	0.079				98.5									1.5	
450	15.4	18.8	0.0	0.080				100.0										
451	9.8	12.8	6.7	0.074										97.6			2.4	
452	26.1	30.8	4.6	0.077				93.8									6.2	
453	24.4	25.9	2.2	0.079				97.0									3.0	
454	27.8	36.6	7.2	0.074				2.5						94.2			3.3	
455	25.8	18.5	2.5	0.078				50.4						49.6				
456	29.5	13.4	2.3	0.079				97.0									3.0	
457	27.6	14.1	5.0	0.075										100.0				
458	27.7	11.5	7.2	0.074										96.9			3.1	
459	22.2	12.4	4.5	0.077				67.4						28.6			4.0	
460	30.4	18.1	0.8	0.080				99.0									1.0	
461	26.4	13.8	1.7	0.079				97.7									2.3	
462	25.2	13.6	6.7	0.074				6.3						90.7			2.9	
463	28.0	16.8	13.6	0.071				39.0						46.0			15.0	
464	6.2	13.2	6.9	0.075				60.1						32.9			7.0	
465	26.0	15.0	0.0	0.080				100.0										
466	27.3	14.9	1.9	0.079				95.8						1.9			2.4	
467	9.3	11.9	6.2	0.075				48.3						46.6			5.2	
468	25.1	19.4	0.0	0.080				100.0										
469	29.5	17.6	0.0	0.080				100.0										
470	25.5	25.3	0.0	0.080				100.0										
471	27.7	11.8	4.1	0.077				87.0						8.2			4.9	

ID	Area (ha)	Slope (%)	Imp. (%)	PERN N	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
472	27.9	17.1	2.3	0.079				97.0									3.0	
473	6.9	13.2	0.0	0.080				100.0										
474	26.7	14.0	0.0	0.080				100.0										
475	28.9	19.5	0.7	0.080				99.1									0.9	
476	19.5	33.8	0.0	0.080				100.0										
477	21.8	14.6	0.0	0.080				100.0										
478	25.0	19.6	0.0	0.080				100.0										
479	28.1	13.6	0.0	0.080				100.0										
480	16.8	25.9	0.0	0.080				100.0										
481	27.8	18.5	0.0	0.080				100.0										
482	21.6	19.8	0.9	0.079				98.7									1.3	
483	28.7	26.5	0.3	0.080				99.6									0.4	
484	17.5	22.3	0.0	0.080				100.0										
485	21.0	18.3	0.0	0.080				100.0										
486	14.2	7.9	0.0	0.080												100.0		
487	33.2	6.0	0.0	0.080												100.0		
488	20.8	6.0	0.0	0.080												100.0		
489	12.2	9.4	35.6	0.059				31.5		57.0							9.4	2.1
490	28.8	7.2	5.7	0.077				17.8		11.4						59.4		11.3
491	25.9	7.5	20.5	0.068				58.9		31.0							6.7	3.4
492	19.7	4.8	44.8	0.053				14.7		76.9							8.5	
493	12.5	6.3	15.0	0.060											100.0			
494	26.1	7.6	0.0	0.080												100.0		
495	30.0	6.7	5.6	0.077				92.5									7.5	
496	17.2	7.0	2.6	0.078				96.5									3.5	

					Percentage of the catchment (%)													
ID	Area (ha)	Slope (%)	Imp. (%)	PERN N	Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
497	31.4	46.3	0.0	0.080				100.0										
498	22.1	7.0	13.0	0.067		0.8								52.5	39.6		5.4	1.5
499	23.6	5.0	18.1	0.059											94.9		5.1	
500	20.6	5.0	0.0	0.080												100.0		
501	18.9	4.4	13.9	0.064				25.3							68.7		4.9	1.2
502	20.5	9.5	23.7	0.060				32.2				12.6			47.3		7.8	
503	15.7	2.8	0.0	0.080												100.0		
504	24.6	5.1	0.0	0.080												100.0		
505	15.4	9.1	13.2	0.062											88.1			11.9
506	24.7	6.3	0.0	0.080												100.0		
507	17.8	34.6	0.0	0.080				100.0										
508	23.1	25.0	0.0	0.080				100.0										
509	21.6	38.2	2.4	0.079				96.8									3.2	
510	13.8	36.3	1.8	0.079				97.6									2.4	
511	22.7	14.2	5.8	0.075										98.9			1.1	
512	17.5	5.0	8.3	0.070				25.1					17.3		48.5		1.4	7.7
513	14.2	5.3	14.5	0.064				30.8							62.4		6.9	
514	23.3	31.4	0.0	0.080				100.0										
515	13.9	3.0	2.9	0.078												96.1	3.9	
516	7.9	8.6	19.5	0.058											92.4		7.5	
517	20.1	5.1	62.8	0.042				8.5	49.0				17.6				24.9	
518	15.7	4.4	37.0	0.058						65.3			2.6			26.3	5.8	
519	15.1	4.9	31.9	0.061						55.0						39.1	5.8	
520	17.6	5.9	52.8	0.048						85.6						1.1	13.3	
521	14.3	6.2	51.3	0.049	0.9					82.8			4.2				12.1	

ID	Area (ha)	Slope (%)	Imp. (%)	PERN N	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
522	23.2	5.1	52.0	0.049						89.1						1.0	9.9	
523	14.0	8.3	11.1	0.073												85.3	14.7	
524	26.7	4.9	46.5	0.052						82.2			10.6				7.1	
525	15.5	4.0	53.1	0.048						86.9							12.8	
526	14.7	5.8	17.6	0.059											95.7		4.3	
527	23.5	5.5	18.3	0.059											94.6		5.4	
528	17.1	6.5	19.3	0.058											92.8		7.2	
529	13.4	4.5	17.9	0.059											95.2		4.8	
530	13.8	15.0	18.9	0.059				1.9							91.1		7.0	
531	11.4	11.6	22.1	0.057											88.1		11.9	
532	18.2	22.4	10.8	0.066				28.9							71.0			
533	14.5	7.5	28.8	0.054											76.9		23.1	
534	9.3	10.3	22.1	0.057				3.1							84.3		12.6	
535	13.1	6.4	23.0	0.057											86.6		13.4	
536	15.4	5.4	22.0	0.057											88.3		11.7	
537	5.0	5.4	16.8	0.059											97.0		3.0	
538	6.4	4.4	16.7	0.059											97.2		2.8	
539	6.5	11.9	17.2	0.059											96.4		3.6	
540	16.0	5.3	18.5	0.059											94.2		5.8	
541	22.7	4.6	41.0	0.055						74.4						20.6	5.0	
542	16.2	5.6	16.3	0.059											97.8		2.2	
543	18.5	6.5	4.9	0.077												93.5	6.5	
544	14.8	3.2	23.2	0.058									13.3		69.7		17.0	
545	22.9	5.2	8.3	0.073				74.0							18.8		7.3	
546	13.2	4.4	18.6	0.059											94.0		6.0	

					Percentage of the catchment (%)													
ID	Area (ha)	Slope (%)	Imp. (%)	PERN N	Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
547	29.8	5.3	15.7	0.060											98.9		1.1	
548	22.6	9.8	20.0	0.058				1.3							90.0		8.7	
549	17.2	8.1	22.6	0.057				1.4							85.7		13.0	
550	13.1	2.6	0.0	0.080												100.0		
551	11.3	8.3	1.6	0.078											10.4	85.2		4.2
552	17.7	5.1	15.0	0.060											100.0			
553	11.7	5.6	21.7	0.067						40.9			16.7			40.7	1.7	
554	7.2	4.8	55.0	0.047						79.6							20.3	
555	17.7	6.8	17.9	0.059											95.2		4.8	
556	19.3	11.0	17.8	0.059											95.4		4.6	
557	12.5	4.3	18.6	0.058											93.9		6.1	
558	24.9	2.7	0.0	0.080												99.5		0.5
559	26.5	4.6	0.0	0.080												100.0		
560	5.1	8.5	22.4	0.057											87.7		12.3	
561	23.6	5.8	0.0	0.080												100.0		
562	21.1	6.4	0.0	0.080												100.0		
563	19.9	5.3	0.0	0.080												100.0		
564	15.7	6.5	42.4	0.055						81.5			16.4				2.2	
565	17.6	5.3	53.7	0.048	1.5					86.0							12.5	
566	27.3	3.4	17.4	0.059											96.1		3.9	
567	13.7	3.8	28.2	0.055											78.0		22.0	
568	10.8	8.8	29.1	0.056				15.2				15.5			60.1		9.2	
569	17.1	11.8	9.3	0.068				41.7							57.4		0.9	
570	14.1	13.7	7.2	0.074				76.7							17.1		6.2	
571	14.1	22.7	0.3	0.080				99.6										

ID	Area (ha)	Slope (%)	Imp. (%)	PERN N	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio- rity	Rec	Rural	Rur. Res.	Spe- cial	Road	Water
572	12.9	41.3	0.3	0.080				99.6										
573	13.5	33.2	0.0	0.080				100.0										
574	11.8	35.0	0.0	0.080				100.0										
575	9.2	22.9	0.0	0.080				100.0										
576	8.1	32.3	0.0	0.080				100.0										
577	6.2	34.0	0.0	0.080				100.0										
578	18.3	17.2	2.3	0.078				54.2						45.8				
579	14.2	32.2	5.0	0.075										100.0				
580	12.2	28.8	3.9	0.076				21.2						78.8				
581	16.7	13.3	5.0	0.075										100.0				
582	14.5	17.8	5.0	0.075										100.0				
583	13.2	36.0	7.2	0.074										96.8			3.2	
584	10.3	18.4	8.6	0.073										94.8			5.2	
585	16.0	14.5	6.8	0.074										97.4			2.6	
586	17.4	12.7	6.2	0.074										98.0			1.7	
587	8.2	12.2	5.2	0.075										99.7				
588	9.1	13.4	5.0	0.075										100.0				
589	12.2	14.7	5.0	0.075										100.0				
590	10.9	23.8	0.0	0.080				100.0										
591	17.9	39.8	2.8	0.078				96.3									3.7	
592	16.6	44.9	0.0	0.080				100.0										
593	18.9	17.5	2.5	0.078				96.6									3.4	
594	7.8	25.2	0.0	0.080				100.0										
595	13.4	31.1	0.0	0.080				100.0										
596	14.8	27.0	0.0	0.080				100.0										

ID	Area (ha)	Slope (%)	Imp. (%)	PERN N	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
597	14.3	33.8	0.0	0.080				100.0										
598	15.5	35.9	0.0	0.080				100.0										
599	10.9	26.4	5.6	0.072				62.3							37.7			
600	6.9	13.9	19.6	0.059									7.4		83.0		9.6	
601	8.5	12.7	19.5	0.058											92.5		7.5	
602	12.5	8.0	22.7	0.058				11.1							73.4		15.5	
603	11.5	10.0	16.2	0.062				15.4							78.7		5.9	
604	6.3	20.8	11.3	0.073				76.5						9.0			14.5	
605	24.2	18.4	0.5	0.080				99.3									0.7	
606	19.2	26.4	0.0	0.080				100.0										
607	15.9	32.3	0.0	0.080				100.0										
608	18.2	36.6	0.0	0.080				100.0										
609	13.5	11.0	0.4	0.080				99.5										
610	14.5	17.9	0.0	0.080				100.0										
611	8.8	11.3	0.0	0.080				100.0										
612	9.1	17.7	0.0	0.080				100.0										
613	13.7	10.6	1.9	0.079				96.1							1.6		2.3	
614	10.0	15.1	0.0	0.080				100.0										
615	19.4	6.5	22.6	0.057											87.3		12.6	
616	5.8	3.1	10.5	0.074												80.5	14.1	4.3
617	24.3	4.6	0.0	0.080												100.0		
618	20.8	6.8	14.0	0.065				2.6					12.0	28.2	50.6		6.6	
619	29.7	6.1	6.8	0.076				91.0									9.0	
620	9.0	4.2	54.1	0.048						67.8						5.3	26.9	
621	18.1	15.4	5.0	0.075										100.0				

ID	Area (ha)	Slope (%)	Imp. (%)	PERN N	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
622	17.4	14.1	13.4	0.065				31.2							63.7		5.1	
623	17.1	5.4	16.5	0.060										3.2	87.7		4.3	4.9
624	25.1	25.1	0.0	0.080				100.0										
625	12.3	7.1	0.0	0.080				100.0										
626	18.6	32.3	7.1	0.074				6.1						90.5			3.4	
627	14.3	9.2	8.7	0.075				88.3									11.7	
628	17.8	10.0	22.2	0.058				1.1					3.7		82.0		13.2	
629	24.2	4.1	16.5	0.059											97.5		2.5	
630	13.1	10.2	15.8	0.064				31.6							59.2		9.2	
631	18.1	14.3	0.0	0.080				100.0										
632	20.2	5.5	0.0	0.080												100.0		
633	15.5	13.2	14.7	0.064				28.7							64.6		6.7	
634	14.8	21.0	0.0	0.080				100.0										
635	2.9	29.0	0.0	0.080				100.0										
636	7.4	39.0	0.0	0.080				100.0										
637	14.1	12.1	0.0	0.080				100.0										
638	19.3	7.4	5.5	0.074				73.6							24.0		2.5	
639	18.8	7.4	9.5	0.072				63.9							20.0		8.6	7.4
640	9.3	18.4	2.1	0.077				85.8							14.2			
641	19.5	7.2	16.1	0.062										18.7	76.3		4.9	
642	18.8	20.2	0.0	0.080				100.0										
643	21.9	5.5	20.5	0.058											90.8		9.2	
644	17.3	3.7	0.0	0.080												100.0		
645	10.9	4.1	0.0	0.080												100.0		
646	26.4	6.5	0.0	0.080												100.0		

ID	Area (ha)	Slope (%)	Imp. (%)	PERN N	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
647	18.6	5.8	0.0	0.080												100.0		
648	8.1	9.1	0.0	0.080												100.0		
649	16.0	5.9	29.9	0.062				37.6					18.9			3.6	39.9	
650	25.6	7.4	30.3	0.062				41.8		28.1			8.4				21.7	
651	11.5	5.5	0.0	0.080												100.0		
652	14.9	7.0	49.9	0.050				2.2		83.4						3.5	10.9	
653	19.0	20.9	2.9	0.078				96.1									3.9	
654	16.6	5.3	0.0	0.080												100.0		
655	13.3	34.7	0.0	0.080				100.0										
656	25.9	7.1	12.6	0.067				41.8							51.8		6.4	
657	18.4	21.1	0.0	0.080				100.0										
658	21.8	12.6	1.5	0.079				98.1									1.9	
659	12.9	7.3	19.7	0.063				21.4					15.4		46.3		17.0	
660	13.4	38.3	2.7	0.076				81.7							18.3			
TOTAL	14149				0%	0%	0%	33%	1%	5%	0%	0%	1%	6%	22%	29%	4%	0%

A4 URBS parameters ultimate catchment conditions

Table A.3 - Adopted URBS subcatchment parameters for ultimate catchment conditions

ID	Area (ha)	Slope (%)	Imp. (%)	PERN 'n'	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
1	14.2	6.0	13.6	0.066				38.9							53.7		7.4	
2	5.4	10.1	7.7	0.075				80.5									10.3	9.3
3	25.2	5.1	11.4	0.073				86.1	6.1								7.8	
4	30.6	6.4	12.2	0.073				83.8	0.4								15.8	
5	16.0	4.9	23.5	0.066		15.3		41.5		26.4			6.8				3.6	6.5
6	5.4	7.3	15.8	0.068				43.1							21.9	10.8	16.7	7.6
7	22.0	6.6	19.9	0.058											91.8		8.2	
8	11.2	7.7	21.1	0.060				13.9							67.1		14.7	4.3
9*	16.4	7.1	4.9	0.075				67.7							21.8		2.1	8.4
10*	6.6	8.7	19.4	0.064				29.4							36.4		18.6	15.6
11	8.0	8.6	2.6	0.078				87.7									3.5	8.9
12	26.8	4.6	0.0	0.080												100.0		
13	26.9	5.9	0.0	0.080												100.0		
14	24.9	5.7	0.0	0.080												100.0		
15	25.6	5.9	42.2	0.055						78.8			4.5			13.0	3.7	
16	28.1	4.4	0.0	0.080												100.0		
17	34.3	5.9	3.0	0.078						3.4						94.9	1.6	
18	23.9	5.9	0.0	0.080												100.0		
19	25.4	3.5	0.0	0.080												100.0		
20	30.5	5.4	0.2	0.080												99.8		
21	25.0	4.6	0.0	0.080												100.0		

					Percentage of the catchment (%)													
ID	Area (ha)	Slope (%)	Imp. (%)	PERN **'n'**	Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
22	21.0	6.0	0.0	0.080												100.0		
23	31.5	5.0	0.0	0.080												100.0		
24	25.3	5.7	0.0	0.080												100.0		
25	29.2	5.4	0.0	0.080												100.0		
26	26.2	6.1	0.0	0.080												100.0		
27	14.6	4.9	0.0	0.080												100.0		
28	18.8	3.7	0.0	0.080												100.0		
29	20.9	5.6	0.0	0.080												100.0		
30	25.3	6.5	0.0	0.080												100.0		
31	14.1	5.9	0.0	0.080												100.0		
32	20.0	6.0	0.0	0.080												100.0		
33	25.5	6.7	0.0	0.080												100.0		
34	17.7	6.7	0.0	0.080												100.0		
35	29.7	5.9	0.0	0.080												100.0		
36	19.9	6.7	0.0	0.080												100.0		
37	30.3	7.2	0.0	0.080												100.0		
38	21.3	7.1	0.0	0.080												100.0		
39	10.4	8.5	0.0	0.080												100.0		
40	24.2	6.1	0.0	0.080												100.0		
41	28.0	6.5	0.0	0.080												100.0		
42	25.4	4.4	0.0	0.080												100.0		
43	30.3	3.9	0.0	0.080												100.0		
44	29.9	6.9	0.0	0.080												100.0		
45	19.2	3.8	0.0	0.080												100.0		
46	23.8	6.6	0.0	0.080												100.0		

ID	Area (ha)	Slope (%)	Imp. (%)	PERN 'n'	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
47	25.6	5.0	0.0	0.080												100.0		
48	25.1	5.6	0.0	0.080												100.0		
49	25.0	6.2	0.0	0.080												100.0		
50	13.1	7.2	0.0	0.080												100.0		
51	26.6	7.8	0.0	0.080												100.0		
52	25.0	4.5	0.0	0.080												100.0		
53	25.4	4.7	0.0	0.080												100.0		
54	23.3	7.4	6.2	0.076												91.7	8.3	
55	8.5	14.8	17.8	0.062		2.1		24.4							64.0		9.5	
56	19.9	6.5	3.4	0.078												95.5	4.5	
57	17.5	6.7	22.2	0.067				52.1		40.5							2.6	4.8
58	24.7	5.8	0.0	0.080												100.0		
59	23.5	6.5	1.1	0.079												98.6	1.4	
60	20.4	8.7	4.8	0.077												93.6	6.4	
61	26.5	6.9	21.9	0.067					11.4							73.0	15.6	
62	29.1	7.7	14.8	0.071					6.7							81.6	11.7	
63	12.2	6.9	76.9	0.033					45.7				6.6				47.7	
64	32.8	3.4	52.2	0.049						90.1							9.5	
65	26.5	5.0	6.0	0.076						8.7						89.0	2.3	
66	22.1	4.3	47.7	0.051						90.9			6.1				3.0	
67	22.3	5.1	0.0	0.080												100.0		
68	17.1	5.7	3.9	0.078												94.8	5.2	
69	24.1	5.8	36.8	0.058				54.8	23.6				1.0				20.7	
70	25.5	5.9	55.0	0.046				37.6	54.8								7.6	
71	28.3	2.4	84.8	0.028				4.0	85.4								10.6	

					Percentage of the catchment (%)													
ID	Area (ha)	Slope (%)	Imp. (%)	PERN 'n'	Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
72	14.1	6.2	0.1	0.080				99.9										
73	25.4	6.4	83.2	0.029				3.0	69.6								27.4	
74	26.4	5.3	49.9	0.050						80.0			6.8				13.2	
75	22.2	6.9	43.8	0.054						72.4			17.5				10.1	
76	27.6	6.6	2.6	0.078				96.6									3.4	
77	23.0	6.4	9.5	0.074				88.4	5.0								6.6	
78	20.7	3.0	6.2	0.076				91.6									7.9	
79	26.7	3.0	33.8	0.059				62.5	37.5									
80	24.6	4.9	28.9	0.062				66.8	27.0								6.2	
81	25.8	2.3	85.9	0.028				3.0	87.8								9.3	
82	25.6	8.8	4.0	0.078				86.7									5.4	8.0
83	24.9	2.5	84.8	0.028				3.6	83.1								13.3	
84	25.0	5.8	0.0	0.080				96.5										3.5
85	27.1	4.8	7.8	0.075				90.1	2.8								7.1	
86	33.1	4.4	48.5	0.051						82.0			6.0			2.0	10.0	
87	22.1	4.6	46.4	0.052						57.8			13.8			5.0	23.4	
88	21.8	5.6	48.2	0.051						81.9			5.7			2.8	9.6	
89	7.6	5.8	9.2	0.074				87.7									12.3	
90	25.9	6.9	0.2	0.080				99.8										
91	26.5	6.6	4.9	0.077				93.5									6.5	
92	29.7	5.0	21.8	0.067									0.4		0.4	70.1	29.0	
93	23.9	3.5	1.3	0.079												98.0	1.8	
94	28.4	4.0	1.6	0.079												97.8	2.2	
95*	29.4	4.2	7.9	0.075		4.9									2.6	85.7	6.8	
96	28.7	3.2	0.0	0.080												100.0		

ID	Area (ha)	Slope (%)	Imp. (%)	PERN 'n'	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
97	15.0	3.3	0.0	0.080												100.0		
98	25.5	3.9	2.2	0.079												97.0	3.0	
99	28.2	3.8	0.0	0.080												100.0		
100	25.1	3.4	0.0	0.080												100.0		
101*	27.2	4.5	63.6	0.041			68.8			1.2						19.4	10.6	
102	29.7	4.3	0.9	0.079												98.8	1.2	
103	27.8	7.6	16.8	0.066				23.3							33.6	23.2	15.6	4.3
104	25.7	3.8	0.0	0.080												100.0		
105	17.6	4.1	0.0	0.080												100.0		
106	5.4	8.1	16.0	0.062				19.6							73.7		6.6	
107	28.9	4.2	0.0	0.080												100.0		
108	29.8	3.8	0.0	0.080												100.0		
109	27.4	4.2	19.5	0.058											92.6		7.4	
110	29.9	8.9	16.9	0.061				10.2							84.1		5.7	
111	27.5	6.2	17.0	0.059											96.7		3.3	
112	25.8	4.0	0.0	0.080												100.0		
113	25.9	3.4	0.0	0.080												100.0		
114	29.4	6.6	15.8	0.060				4.4							93.1		2.5	
115	29.1	4.6	0.0	0.080												100.0		
116	20.4	4.6	19.9	0.058											91.9		8.1	
117*	24.9	4.8	75.7	0.034			88.3						0.6			4.4	6.7	
118	30.1	4.0	15.3	0.062									14.3		81.6		4.1	
119	23.1	7.1	23.0	0.057											86.6		13.4	
120*	28.9	5.4	77.8	0.033			82.0			5.1							12.8	
121*	11.2	5.2	64.9	0.041			72.6									18.3	9.1	

ID	Area (ha)	Slope (%)	Imp. (%)	PERN **'n'**	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
122	17.0	4.7	0.0	0.080												100.0		
123	19.4	5.9	0.0	0.080												100.0		
124	27.3	4.4	19.0	0.058											93.4		6.6	
125	29.2	5.6	0.0	0.080												100.0		
126	35.8	4.0	0.0	0.080												100.0		
127	13.8	5.8	11.5	0.069				54.0							38.4		7.6	
128	24.2	3.4	0.0	0.080												100.0		
129	14.8	4.1	0.0	0.080												100.0		
130	15.1	3.6	5.9	0.076												92.2	7.8	
131	26.9	4.6	22.0	0.057											88.3		11.7	
132	26.8	4.9	23.2	0.057											86.1		13.7	
133	18.1	5.4	20.1	0.058											91.5		8.5	
134	23.2	4.7	18.9	0.058											93.5		6.5	
135	23.4	7.0	22.7	0.057											87.2		12.8	
136	24.4	6.3	23.7	0.056											85.5		14.5	
137	9.5	8.8	18.8	0.058											93.6		6.4	
138	24.1	5.6	0.0	0.080												100.0		
139	19.9	3.9	1.9	0.079												97.5	2.5	
140	7.2	2.1	0.0	0.080												100.0		
141	26.8	7.8	0.0	0.080												100.0		
142	24.5	4.2	0.0	0.080												100.0		
143	13.9	4.6	0.0	0.080												100.0		
144	25.0	4.0	0.0	0.080												100.0		
145	16.4	4.2	4.7	0.077												93.7	6.3	
146	28.4	3.7	0.0	0.080												100.0		

ID	Area (ha)	Slope (%)	Imp. (%)	PERN 'n'	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
147	6.8	6.5	23.0	0.057											86.7		13.3	
148	23.9	4.5	1.1	0.079												98.5	1.5	
149	27.1	6.1	0.0	0.080												100.0		
150	25.5	6.2	2.7	0.078												96.4	3.6	
151	27.1	5.7	1.9	0.079												97.5	2.5	
152	10.3	3.7	0.0	0.080												100.0		
153	28.4	6.9	8.5	0.073				3.0							21.3	68.7	7.1	
154	26.1	4.4	0.0	0.080												100.0		
155	28.0	4.2	0.0	0.080												100.0		
156	23.8	6.0	0.0	0.080												100.0		
157	24.9	5.6	0.0	0.080												100.0		
158	24.5	7.9	0.0	0.080												100.0		
159	31.2	5.1	0.0	0.080												100.0		
160	13.4	4.9	0.0	0.080												100.0		
161*	24.7	5.2	75.2	0.034			84.0			2.0						4.7	9.3	
162	28.6	3.7	0.0	0.080												100.0		
163	25.4	6.2	0.0	0.080												100.0		
164	27.5	4.8	0.0	0.080												100.0		
165	14.1	4.6	0.0	0.080												100.0		
166*	31.6	5.5	51.9	0.049			16.6			61.9			7.0			4.4	10.2	
167	28.6	5.9	0.0	0.080												100.0		
168	29.7	5.0	0.0	0.080												100.0		
169	20.7	5.3	0.0	0.080												100.0		
170	25.1	5.2	0.0	0.080												100.0		
171	21.1	4.6	0.0	0.080												100.0		

ID	Area (ha)	Slope (%)	Imp. (%)	PERN 'n'	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
172	33.1	4.8	0.0	0.080												100.0		
173	24.2	5.4	0.0	0.080												100.0		
174	22.4	5.3	8.7	0.075						17.4						82.5		
175	28.2	5.1	0.0	0.080												100.0		
176	31.5	2.8	0.0	0.080												100.0		
177	25.5	4.7	0.0	0.080												100.0		
178	25.5	4.5	0.0	0.080												100.0		
179	24.2	5.3	0.0	0.080												100.0		
180	29.9	5.8	0.0	0.080												100.0		
181	27.6	3.2	0.0	0.080												100.0		
182	28.8	7.2	0.0	0.080												100.0		
183	26.1	9.4	0.0	0.080												100.0		
184	20.8	6.6	0.0	0.080												100.0		
185	9.6	4.8	36.1	0.058				31.4		61.3							7.2	
186	29.7	5.8	0.0	0.080												100.0		
187	19.9	6.0	44.6	0.053				15.3		75.9							8.8	
188	26.8	4.7	0.0	0.080												100.0		
189	22.6	5.9	0.0	0.080												100.0		
190	25.3	5.5	0.0	0.080												100.0		
191	30.7	6.3	0.0	0.080												100.0		
192	23.5	5.3	4.7	0.077				7.1		9.4						83.4		
193	13.2	5.4	40.6	0.056				21.5		73.1							5.4	
194	30.7	6.5	25.3	0.065						44.6						51.3	4.0	
195	27.8	4.5	0.0	0.080												100.0		
196	28.9	5.2	0.0	0.080												100.0		

					Percentage of the catchment (%)													
ID	Area (ha)	Slope (%)	Imp. (%)	PERN **'n'**	Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
197	18.3	5.7	0.0	0.080												100.0		
198	31.3	6.7	0.0	0.080												100.0		
199	29.9	6.6	0.0	0.080												100.0		
200	30.0	3.9	0.0	0.080												100.0		
201	29.1	5.4	0.0	0.080												100.0		
202	22.9	5.3	45.3	0.053				19.4		55.6						1.6	23.4	
203	29.3	4.7	0.0	0.080												100.0		
204	29.8	9.4	44.9	0.053						77.7			14.3				8.0	
205	16.7	5.6	0.0	0.080												100.0		
206	29.6	6.5	0.0	0.080												100.0		
207	28.4	6.3	3.1	0.078						4.8						94.2	0.9	
208	34.2	4.0	0.0	0.080												100.0		
209	25.3	6.0	0.0	0.080												100.0		
210	12.9	8.4	48.8	0.051						82.0			7.7				10.4	
211	29.1	4.6	0.0	0.080												100.0		
212	29.0	6.3	17.6	0.069				0.7		34.4						64.3	0.5	
213	33.2	4.7	0.0	0.080												100.0		
214	24.8	5.9	49.8	0.050						79.6			7.1				13.3	
215	5.8	4.5	24.7	0.065		13.7		53.6		25.1							7.1	
216	28.2	4.5	21.5	0.057											89.2		10.8	
217	23.3	4.0	22.9	0.057											86.9		13.1	
218	24.5	4.6	24.2	0.056											84.7		15.3	
219	25.0	6.7	4.3	0.075				77.5							21.0		1.5	
220	31.2	4.6	20.5	0.058									0.8		89.9		9.3	
221	22.0	5.4	23.8	0.059		5.1		16.9							62.0		16.0	

ID	Area (ha)	Slope (%)	Imp. (%)	PERN 'n'	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
222	26.7	7.1	20.2	0.060				17.4							69.6		13.1	
223	25.8	15.6	6.7	0.073				70.4							26.0		3.7	
224	25.2	4.8	22.6	0.059		1.6		8.7					9.3		64.0		16.3	
225*	26.8	4.6	72.8	0.034		1.6						61.2			13.2		24.0	
226*	18.5	4.0	84.2	0.029								91.9					8.1	
227	27.7	6.3	20.2	0.060	0.7			13.1							75.1		11.2	
228*	11.3	4.0	85.0	0.028								99.9						
229*	10.8	6.6	51.9	0.049		92.4											7.5	
230*	27.0	5.1	25.6	0.057				3.5				10.4	8.8		68.7		8.6	
231	28.1	7.2	10.3	0.068				47.3							48.7		4.0	
232*	28.4	6.4	38.8	0.054		56.7							7.7		27.0		8.6	
233	16.0	7.7	17.6	0.062				20.6							69.9		9.5	
234*	20.8	4.5	78.7	0.031								85.4			8.1		6.6	
235	22.3	9.3	23.3	0.057				3.0							82.5		14.6	
236	27.5	20.0	4.1	0.075				72.8							27.1			
237	24.6	5.9	24.9	0.057				5.9							76.1		17.9	
238	24.5	26.5	0.6	0.079				95.8							4.2			
239	28.3	11.1	13.4	0.063				16.4							82.3		1.4	
240	11.0	5.9	24.9	0.056											82.5		16.7	
241	26.3	5.5	20.4	0.060				8.8						4.1	69.5		13.0	4.6
242	28.2	6.8	17.4	0.062				19.2							72.0		8.8	
243*	28.4	5.0	79.9	0.030								92.0			7.2		0.7	
244*	26.8	6.6	48.1	0.050		88.6									7.9		3.5	
245	22.7	36.6	0.0	0.080				100.0										
246	27.0	10.1	10.4	0.068				40.7							56.7		2.5	

ID	Area (ha)	Slope (%)	Imp. (%)	PERN 'n'	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
247	14.4	8.0	9.8	0.071				61.2							32.1		6.6	
248*	31.4	4.7	61.0	0.039								64.7			34.0		1.2	
249	14.4	6.3	12.2	0.067				44.1							49.6		6.3	
250*	27.6	4.9	78.4	0.031								90.6			9.4			
251	19.8	11.6	14.9	0.060				0.8							99.2			
252	24.5	7.6	10.9	0.067				32.9					7.3		56.6		3.2	
253	26.4	4.2	19.3	0.058											92.8		7.2	
254	9.3	7.5	14.1	0.065				30.2							63.7		6.1	
255	15.3	20.2	14.4	0.065		1.8		34.5							57.2		6.5	
256	27.5	13.3	13.0	0.066				38.4							55.3		6.2	
257	29.5	7.1	20.5	0.061		1.2		20.8							64.4		13.6	
258	20.7	40.6	0.0	0.080				100.0										
259	25.0	6.5	16.2	0.060											92.5		3.1	4.4
260	14.4	4.6	15.1	0.064				27.7							65.2		7.1	
261	12.8	18.1	10.5	0.066				29.8							70.2			
262	23.2	5.6	14.9	0.065				3.1						34.8	46.8		8.1	7.2
263	34.0	41.2	0.5	0.080				99.3									0.7	
264	27.4	4.1	20.4	0.058											91.0		9.0	
265	26.6	7.8	18.4	0.059											94.3		5.7	
266*	25.2	4.8	17.6	0.059											90.8	4.0	5.2	
267	25.0	37.6	0.9	0.079				98.8									1.2	
268	29.6	4.2	14.4	0.066									39.2		52.0		8.8	
269	29.8	4.8	17.3	0.060											91.9		4.7	3.5
270	27.4	5.8	16.2	0.060											98.0		2.0	
271	29.7	17.6	14.1	0.064		1.8		23.2							71.8		3.2	

ID	Area (ha)	Slope (%)	Imp. (%)	PERN 'n'	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
272	27.8	8.1	23.1	0.057											86.4		13.6	
273	28.6	4.5	18.8	0.062									0.6		60.0	26.4	13.0	
274	27.4	5.4	18.4	0.059											94.3		5.7	
275	27.4	6.8	19.5	0.059				3.0					1.5		87.0		8.5	
276	6.2	11.8	17.7	0.060				6.5							87.3		6.1	
277	28.4	7.9	20.2	0.058											91.4		8.6	
278	14.9	21.8	5.4	0.073				64.3							35.7			
279	29.1	9.5	16.1	0.060											98.2		1.8	
280	24.3	5.2	16.0	0.060											93.9		2.6	3.5
281	22.1	3.7	18.7	0.058											93.9		6.1	
282	11.3	11.9	16.2	0.063				24.0							68.0		8.0	
283	23.9	3.0	15.0	0.060											99.7			
284	21.2	7.2	18.8	0.058											93.7		6.3	
285	23.4	10.8	12.5	0.065				30.1							66.6		3.3	
286	12.0	3.6	17.9	0.059											95.1		4.9	
287	32.6	15.9	13.0	0.065				32.8					0.6		61.5		5.0	
288	11.3	15.5	22.0	0.058				4.1							82.4		12.8	
289*	30.3	6.5	15.9	0.060		2.9									95.7			1.3
290	27.5	29.7	0.0	0.080				100.0										
291	21.4	6.2	17.5	0.059											95.9		4.1	
292	14.3	25.7	0.0	0.080				100.0										
293	17.3	5.4	17.3	0.059											96.2		3.8	
294	25.1	21.7	0.5	0.079				96.4							3.6			
295	29.5	16.1	8.8	0.068				41.6							58.4			
296	27.4	5.0	16.9	0.059											96.9		3.1	

					Percentage of the catchment (%)													
ID	Area (ha)	Slope (%)	Imp. (%)	PERN 'n'	Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
297	17.7	5.6	22.2	0.059				11.3							73.9		14.8	
298	25.4	4.2	15.0	0.060											100.0			
299	22.8	5.1	18.3	0.059											94.5		5.5	
300	27.1	7.5	18.5	0.059											94.1		5.9	
301	24.8	9.5	23.2	0.057											86.3		13.7	
302	27.3	5.8	17.2	0.059											96.3		3.7	
303	23.6	5.9	18.8	0.058											93.7		6.3	
304*	26.3	5.8	16.3	0.068		23.0									18.4	51.8	2.8	4.1
305	28.7	8.4	13.3	0.065				32.2							62.7		5.1	
306	25.0	7.0	18.7	0.058											93.9		6.1	
307	29.1	13.4	14.5	0.065				31.9							61.0		7.1	
308	15.7	4.7	15.0	0.060											100.0			
309	5.3	7.0	15.0	0.060											100.0			
310	25.4	5.2	18.1	0.060				7.1							85.9		7.0	
311	29.4	6.1	18.6	0.059											93.5		6.1	
312	26.4	4.0	12.6	0.066		1.9							33.9		60.8		3.5	
313*	16.9	10.9	15.4	0.064				32.0							59.3		8.7	
314*	24.8	11.6	11.0	0.066				34.5							63.5		2.0	
315*	26.2	10.9	14.2	0.064				23.9							71.4		4.7	
316*	20.8	8.9	19.2	0.059				7.4							83.8		8.8	
317*	27.4	7.6	22.1	0.058				5.3							81.6		13.1	
318	28.1	10.6	2.6	0.077				85.6							13.7		0.7	
319*	24.9	9.9	18.3	0.060				10.5					0.6		80.6		8.3	
320*	21.6	8.3	18.4	0.061				20.1							69.2		10.7	
321	15.1	10.2	12.4	0.067				42.9							50.8		6.3	

ID	Area (ha)	Slope (%)	Imp. (%)	PERN **'n'**	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
322	24.1	7.5	24.5	0.056											84.1		15.9	
323*	26.0	8.1	18.4	0.060				11.8							79.2		8.7	
324	23.0	6.5	25.9	0.056											81.5		18.2	
325	17.3	8.9	13.6	0.068				50.3							39.0		10.4	
326*	29.9	10.0	8.7	0.071				58.2							37.8		4.1	
327	26.9	6.7	5.2	0.076				88.3							5.9		5.8	
328*	8.3	7.3	12.3	0.071				71.9							14.5		13.5	
329	5.6	10.5	0.0	0.080				100.0										
330*	24.0	10.9	3.6	0.075				77.5							22.1			
331*	12.4	5.4	7.4	0.074				81.7							10.5		7.8	
332	23.2	5.3	22.9	0.057		0.7		1.0							85.3		13.1	
333	27.7	15.2	0.0	0.080				100.0										
334	33.3	6.6	12.4	0.068				49.9							42.0		8.1	
335*	28.6	8.3	16.2	0.064				25.5					0.8		59.8		9.7	4.1
336	14.2	6.7	19.4	0.062				20.7							54.5		15.0	9.9
337	29.5	8.0	2.4	0.079				95.5									3.1	1.3
338	18.2	7.6	10.8	0.068				48.7							46.1		5.1	
339	23.7	4.5	11.9	0.068				14.0					35.9		40.0		7.9	2.2
340	21.2	11.4	6.8	0.074				72.7							20.0		5.1	2.2
341	26.7	6.4	21.1	0.057		0.5									89.7		9.8	
342	29.6	7.1	13.1	0.069	0.7			29.3					27.7		32.0		10.3	
343	22.6	6.3	14.5	0.064				24.5							65.5		6.3	3.7
344	26.8	8.4	14.2	0.064				23.7							69.9		4.9	1.5
345	24.3	4.7	21.1	0.058									4.0		82.9		11.5	1.5
346	23.7	7.1	19.9	0.058											90.1		8.5	1.4

ID	Area (ha)	Slope (%)	Imp. (%)	PERN 'n'	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
347	20.7	13.1	0.9	0.079				98.8									1.2	
348	28.7	15.9	0.4	0.080				99.5									0.5	
349	25.2	13.6	0.5	0.080				99.3									0.7	
350	25.3	12.8	0.3	0.080				99.6									0.4	
351	23.8	19.1	0.0	0.080				100.0										
352	22.2	13.1	0.4	0.080				99.5									0.5	
353	21.5	17.5	0.0	0.080				100.0										
354*	14.5	16.8	4.3	0.077				88.4							7.3		4.3	
355	20.4	11.1	0.0	0.080				100.0										
356*	14.3	12.6	4.7	0.076				82.8							13.6		3.6	
357*	25.1	13.0	11.0	0.067				40.6							55.9		3.5	
358	25.1	15.2	0.0	0.080				100.0										
359	15.3	7.7	3.7	0.078				95.0									4.9	
360	6.4	10.6	2.3	0.079				96.9									3.1	
361	12.6	15.9	2.4	0.079				96.8									3.2	
362	28.6	14.0	4.0	0.078				94.4									5.3	0.4
363	28.9	15.8	0.0	0.080				100.0										
364	30.7	17.5	0.8	0.080				99.0									1.0	
365	11.8	28.6	4.3	0.077				94.3									5.7	
366	25.4	14.2	0.0	0.080				100.0										
367	23.2	17.9	2.8	0.078				93.0									3.8	3.2
368	15.7	11.3	3.9	0.078				94.8									5.2	
369	4.2	29.2	8.3	0.075				88.9									11.1	
370	30.0	10.8	0.0	0.080				100.0										
371	27.8	27.7	0.0	0.080				100.0										

					Percentage of the catchment (%)													
ID	Area (ha)	Slope (%)	Imp. (%)	PERN 'n'	Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
372	25.5	34.0	0.0	0.080				100.0										
373	29.7	13.1	2.9	0.078				90.9									3.8	5.3
374	21.9	20.6	0.0	0.080				100.0										
375	18.1	18.3	1.8	0.079				97.5									2.5	
376	27.4	40.6	0.0	0.080				100.0										
377	4.4	27.5	0.0	0.080				100.0										
378	30.1	12.0	6.9	0.076				85.9									9.2	4.9
379	27.2	26.5	0.0	0.080				96.6										3.4
380	17.9	36.7	0.0	0.080				100.0										
381	15.9	21.2	0.0	0.080				100.0										
382	25.5	10.0	0.8	0.080				98.9									1.1	
383	33.7	40.7	0.0	0.080				100.0										
384	4.5	21.2	0.0	0.080				100.0										
385	29.4	44.0	0.0	0.080				100.0										
386	27.7	38.9	0.0	0.080				100.0										
387	14.3	25.3	0.0	0.080				100.0										
388	26.6	36.7	0.0	0.080				100.0										
389	25.6	35.6	0.0	0.080				100.0										
390	25.0	43.0	0.0	0.080				100.0										
391	15.5	21.5	0.0	0.080				100.0										
392	11.7	30.2	0.0	0.080				100.0										
393	14.2	33.1	0.0	0.080				100.0										
394	14.9	40.4	0.0	0.080				100.0										
395	30.1	44.6	0.0	0.080				100.0										
396	29.8	29.1	0.0	0.080				100.0										

ID	Area (ha)	Slope (%)	Imp. (%)	PERN 'n'	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
397	25.1	32.2	0.0	0.080				100.0										
398	25.3	31.4	0.0	0.080				100.0										
399	26.1	41.8	0.0	0.080				100.0										
400	33.2	39.7	0.0	0.080				100.0										
401	29.4	43.6	0.0	0.080				100.0										
402	25.1	43.5	0.0	0.080				100.0										
403	25.0	36.7	0.0	0.080				100.0										
404	9.5	33.7	0.0	0.080				100.0										
405	4.3	36.5	0.0	0.080				100.0										
406	31.4	45.7	0.0	0.080				100.0										
407	29.1	41.4	0.0	0.080				100.0										
408	29.0	39.9	9.9	0.072										93.0			7.0	
409	21.1	30.5	1.1	0.079				98.5									1.5	
410	29.4	42.6	5.6	0.075										99.1			0.9	
411	25.3	34.9	2.3	0.079				96.9									3.1	
412	13.8	30.4	0.0	0.080				100.0										
413	25.3	17.2	0.3	0.080				99.5									0.5	
414	27.2	26.7	5.4	0.075										99.5			0.5	
415	20.5	25.7	1.7	0.079				97.7									2.3	
416	26.3	25.7	0.0	0.080				100.0										
417	27.6	30.0	5.7	0.075										99.0			1.0	
418	26.6	15.3	10.6	0.072										92.0			8.0	
419	29.8	32.3	6.2	0.074										98.3			1.7	
420	25.8	37.1	0.1	0.080				99.9										
421	29.6	22.2	5.9	0.075				9.4						88.7			1.9	

					Percentage of the catchment (%)													
ID	Area (ha)	Slope (%)	Imp. (%)	PERN 'n'	Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
422	8.4	34.1	0.0	0.080				100.0										
423	25.3	33.2	1.6	0.078				67.1						32.9				
424	16.7	31.5	0.0	0.080				100.0										
425	23.3	29.6	0.0	0.080				99.4						0.6				
426	23.2	20.9	0.6	0.079				87.8						12.2				
427	7.7	19.9	5.0	0.075										100.0				
428	29.5	15.9	7.2	0.074										96.8			3.2	
429	25.0	32.3	5.0	0.075										100.0				
430	16.5	43.1	0.1	0.080				99.8										
431	20.5	25.9	0.0	0.080				100.0										
432	6.7	12.9	5.0	0.075										100.0				
433	25.0	18.4	5.0	0.075										100.0				
434	25.1	26.0	0.0	0.080				100.0										
435	29.4	27.5	0.0	0.080				100.0										
436	26.2	30.3	3.5	0.078				95.4									4.6	
437	14.1	32.6	9.2	0.073				6.9						86.6			6.5	
438	19.1	14.0	5.0	0.075										100.0				
439	28.8	14.5	7.0	0.074										97.2			2.8	
440	20.3	15.6	5.0	0.075										100.0				
441	25.3	31.9	5.8	0.075										98.8			1.2	
442	20.9	31.2	2.6	0.077				48.9						51.1				
443	19.7	12.9	7.2	0.074										96.8			3.2	
444	29.4	20.7	0.0	0.080				100.0										
445	26.6	12.4	4.4	0.077				94.2									5.8	
446	26.9	20.6	1.1	0.079				98.5									1.5	

ID	Area (ha)	Slope (%)	Imp. (%)	PERN 'n'	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
447	15.4	15.2	5.0	0.075										100.0				
448	23.5	23.6	1.1	0.079				98.5									1.5	
449	27.2	18.0	1.1	0.079				98.5									1.5	
450	15.4	18.8	0.0	0.080				100.0										
451	9.8	12.8	6.7	0.074										97.6			2.4	
452	26.1	30.8	4.6	0.077				93.8									6.2	
453	24.4	25.9	2.2	0.079				97.0									3.0	
454	27.8	36.6	7.2	0.074				2.5						94.2			3.3	
455	25.8	18.5	2.5	0.078				50.4						49.6				
456	29.5	13.4	2.3	0.079				97.0									3.0	
457	27.6	14.1	5.0	0.075										100.0				
458	27.7	11.5	7.2	0.074										96.9			3.1	
459	22.2	12.4	4.5	0.077				67.4						28.6			4.0	
460	30.4	18.1	0.8	0.080				99.0									1.0	
461	26.4	13.8	1.7	0.079				97.7									2.3	
462	25.2	13.6	6.7	0.074				6.3						90.7			2.9	
463	28.0	16.8	13.6	0.071				39.0						46.0			15.0	
464	6.2	13.2	6.9	0.075				60.1						32.9			7.0	
465	26.0	15.0	0.0	0.080				100.0										
466	27.3	14.9	1.9	0.079				95.8						1.9			2.4	
467	9.3	11.9	6.2	0.075				48.3						46.6			5.2	
468	25.1	19.4	0.0	0.080				100.0										
469	29.5	17.6	0.0	0.080				100.0										
470	25.5	25.3	0.0	0.080				100.0										
471	27.7	11.8	4.1	0.077				87.0						8.2			4.9	

ID	Area (ha)	Slope (%)	Imp. (%)	PERN 'n'	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
472	27.9	17.1	2.3	0.079				97.0									3.0	
473	6.9	13.2	0.0	0.080				100.0										
474	26.7	14.0	0.0	0.080				100.0										
475	28.9	19.5	0.7	0.080				99.1									0.9	
476	19.5	33.8	0.0	0.080				100.0										
477	21.8	14.6	0.0	0.080				100.0										
478	25.0	19.6	0.0	0.080				100.0										
479	28.1	13.6	0.0	0.080				100.0										
480	16.8	25.9	0.0	0.080				100.0										
481	27.8	18.5	0.0	0.080				100.0										
482	21.6	19.8	0.9	0.079				98.7									1.3	
483	28.7	26.5	0.3	0.080				99.6									0.4	
484	17.5	22.3	0.0	0.080				100.0										
485	21.0	18.3	0.0	0.080				100.0										
486	14.2	7.9	0.0	0.080												100.0		
487	33.2	6.0	0.0	0.080												100.0		
488	20.8	6.0	0.0	0.080												100.0		
489	12.2	9.4	35.6	0.059				31.5		57.0							9.4	2.1
490	28.8	7.2	5.7	0.077				17.8		11.4						59.4		11.3
491	25.9	7.5	20.5	0.068				58.9		31.0							6.7	3.4
492	19.7	4.8	44.8	0.053				14.7		76.9							8.5	
493*	12.5	6.3	40.6	0.048								36.6			63.4			
494	26.1	7.6	0.0	0.080												100.0		
495	30.0	6.7	5.6	0.077				92.5									7.5	
496	17.2	7.0	2.6	0.078				96.5									3.5	

ID	Area (ha)	Slope (%)	Imp. (%)	PERN 'n'	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
497	31.4	46.3	0.0	0.080				100.0										
498	22.1	7.0	13.0	0.067		0.8								52.5	39.6		5.4	1.5
499	23.6	5.0	18.1	0.059											94.9		5.1	
500	20.6	5.0	0.0	0.080												100.0		
501	18.9	4.4	13.9	0.064				25.3							68.7		4.9	1.2
502*	20.5	9.5	23.7	0.060				32.2				12.6			47.3		7.8	
503	15.7	2.8	0.0	0.080												100.0		
504	24.6	5.1	0.0	0.080												100.0		
505	15.4	9.1	13.2	0.062											88.1			11.9
506	24.7	6.3	0.0	0.080												100.0		
507	17.8	34.6	0.0	0.080				100.0										
508	23.1	25.0	0.0	0.080				100.0										
509	21.6	38.2	2.4	0.079				96.8									3.2	
510	13.8	36.3	1.8	0.079				97.6									2.4	
511	22.7	14.2	5.8	0.075										98.9			1.1	
512*	17.5	5.0	8.3	0.070				25.1					17.3		48.5		1.4	7.7
513	14.2	5.3	14.5	0.064				30.8							62.4		6.9	
514	23.3	31.4	0.0	0.080				100.0										
515	13.9	3.0	2.9	0.078												96.1	3.9	
516	7.9	8.6	19.5	0.058											92.4		7.5	
517	20.1	5.1	62.8	0.042				8.5	49.0				17.6				24.9	
518*	15.7	4.4	56.6	0.046			65.3						2.6			26.3	5.8	
519*	15.1	4.9	48.4	0.051			55.0									39.1	5.8	
520	17.6	5.9	52.8	0.048						85.6						1.1	13.3	
521	14.3	6.2	51.3	0.049	0.9					82.8			4.2				12.1	

ID	Area (ha)	Slope (%)	Imp. (%)	PERN **‘n’**	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
522	23.2	5.1	52.0	0.049						89.1						1.0	9.9	
523	14.0	8.3	11.1	0.073												85.3	14.7	
524	26.7	4.9	46.5	0.052						82.2			10.6				7.1	
525	15.5	4.0	53.1	0.048						86.9							12.8	
526	14.7	5.8	17.6	0.059											95.7		4.3	
527	23.5	5.5	18.3	0.059											94.6		5.4	
528	17.1	6.5	19.3	0.058											92.8		7.2	
529	13.4	4.5	17.9	0.059											95.2		4.8	
530	13.8	15.0	18.9	0.059				1.9							91.1		7.0	
531	11.4	11.6	22.1	0.057											88.1		11.9	
532	18.2	22.4	10.8	0.066				28.9							71.0			
533	14.5	7.5	28.8	0.054											76.9		23.1	
534	9.3	10.3	22.1	0.057				3.1							84.3		12.6	
535	13.1	6.4	23.0	0.057											86.6		13.4	
536	15.4	5.4	22.0	0.057											88.3		11.7	
537	5.0	5.4	16.8	0.059											97.0		3.0	
538	6.4	4.4	16.7	0.059											97.2		2.8	
539	6.5	11.9	17.2	0.059											96.4		3.6	
540	16.0	5.3	18.5	0.059											94.2		5.8	
541*	22.7	4.6	63.3	0.042			74.4									20.6	5.0	
542	16.2	5.6	16.3	0.059											97.8		2.2	
543	18.5	6.5	4.9	0.077												93.5	6.5	
544	14.8	3.2	23.2	0.058									13.3		69.7		17.0	
545*	22.9	5.2	45.2	0.051		74.0									18.8		7.3	
546	13.2	4.4	18.6	0.059											94.0		6.0	

ID	Area (ha)	Slope (%)	Imp. (%)	PERN 'n'	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
547*	29.8	5.3	74.1	0.033								83.4			15.5		1.1	
548	22.6	9.8	20.0	0.058				1.3							90.0		8.7	
549	17.2	8.1	22.6	0.057				1.4							85.7		13.0	
550	13.1	2.6	0.0	0.080												100.0		
551	11.3	8.3	1.6	0.078											10.4	85.2		4.2
552*	17.7	5.1	15.4	0.060											99.5			
553	11.7	5.6	21.7	0.067						40.9			16.7			40.7	1.7	
554	7.2	4.8	55.0	0.047						79.6							20.3	
555	17.7	6.8	17.9	0.059											95.2		4.8	
556	19.3	11.0	17.8	0.059											95.4		4.6	
557	12.5	4.3	18.6	0.058											93.9		6.1	
558	24.9	2.7	0.0	0.080												99.5		0.5
559	26.5	4.6	0.0	0.080												100.0		
560*	5.1	8.5	22.4	0.057											87.7		12.3	
561	23.6	5.8	0.0	0.080												100.0		
562	21.1	6.4	0.0	0.080												100.0		
563	19.9	5.3	0.0	0.080												100.0		
564	15.7	6.5	42.4	0.055						81.5			16.4				2.2	
565	17.6	5.3	53.7	0.048	1.5					86.0							12.5	
566*	27.3	3.4	84.6	0.028								96.1					3.9	
567*	13.7	3.8	82.8	0.030								78.0					22.0	
568*	10.8	8.8	29.1	0.056				15.2				15.5			60.1		9.2	
569	17.1	11.8	9.3	0.068				41.7							57.4		0.9	
570*	14.1	13.7	7.2	0.074				76.7							17.1		6.2	
571	14.1	22.7	0.3	0.080				99.6										

ID	Area (ha)	Slope (%)	Imp. (%)	PERN 'n'	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
572	12.9	41.3	0.3	0.080				99.6										
573	13.5	33.2	0.0	0.080				100.0										
574	11.8	35.0	0.0	0.080				100.0										
575	9.2	22.9	0.0	0.080				100.0										
576	8.1	32.3	0.0	0.080				100.0										
577	6.2	34.0	0.0	0.080				100.0										
578	18.3	17.2	2.3	0.078				54.2						45.8				
579	14.2	32.2	5.0	0.075										100.0				
580	12.2	28.8	3.9	0.076				21.2						78.8				
581	16.7	13.3	5.0	0.075										100.0				
582	14.5	17.8	5.0	0.075										100.0				
583	13.2	36.0	7.2	0.074										96.8			3.2	
584	10.3	18.4	8.6	0.073										94.8			5.2	
585	16.0	14.5	6.8	0.074										97.4			2.6	
586	17.4	12.7	6.2	0.074										98.0			1.7	
587	8.2	12.2	5.2	0.075										99.7				
588	9.1	13.4	5.0	0.075										100.0				
589	12.2	14.7	5.0	0.075										100.0				
590	10.9	23.8	0.0	0.080				100.0										
591	17.9	39.8	2.8	0.078				96.3									3.7	
592	16.6	44.9	0.0	0.080				100.0										
593	18.9	17.5	2.5	0.078				96.6									3.4	
594	7.8	25.2	0.0	0.080				100.0										
595	13.4	31.1	0.0	0.080				100.0										
596	14.8	27.0	0.0	0.080				100.0										

					Percentage of the catchment (%)													
ID	Area (ha)	Slope (%)	Imp. (%)	PERN 'n'	Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
597	14.3	33.8	0.0	0.080				100.0										
598	15.5	35.9	0.0	0.080				100.0										
599	10.9	26.4	5.6	0.072				62.3							37.7			
600	6.9	13.9	19.6	0.059									7.4		83.0		9.6	
601	8.5	12.7	19.5	0.058											92.5		7.5	
602	12.5	8.0	22.7	0.058				11.1							73.4		15.5	
603	11.5	10.0	16.2	0.062				15.4							78.7		5.9	
604	6.3	20.8	11.3	0.073				76.5						9.0			14.5	
605	24.2	18.4	0.5	0.080				99.3									0.7	
606	19.2	26.4	0.0	0.080				100.0										
607	15.9	32.3	0.0	0.080				100.0										
608	18.2	36.6	0.0	0.080				100.0										
609	13.5	11.0	0.4	0.080				99.5										
610	14.5	17.9	0.0	0.080				100.0										
611	8.8	11.3	0.0	0.080				100.0										
612	9.1	17.7	0.0	0.080				100.0										
613*	13.7	10.6	1.9	0.079				96.1							1.6		2.3	
614	10.0	15.1	0.0	0.080				100.0										
615*	19.4	6.5	33.4	0.052								15.3			71.9		12.6	
616	5.8	3.1	10.5	0.074												80.5	14.1	4.3
617	24.3	4.6	0.0	0.080												100.0		
618	20.8	6.8	14.0	0.065				2.6					12.0	28.2	50.6		6.6	
619	29.7	6.1	6.8	0.076				91.0									9.0	
620	9.0	4.2	54.2	0.048						67.9						5.2	27.0	
621	18.1	15.4	5.0	0.075										100.0				

ID	Area (ha)	Slope (%)	Imp. (%)	PERN 'n'	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio-rity	Rec	Rural	Rur. Res.	Spe-cial	Road	Water
622	17.4	14.1	13.4	0.065				31.2							63.7		5.1	
623	17.1	5.4	16.5	0.060										3.2	87.7		4.3	4.9
624	25.1	25.1	0.0	0.080				100.0										
625	12.3	7.1	0.0	0.080				100.0										
626	18.6	32.3	7.1	0.074				6.1						90.5			3.4	
627	14.3	9.2	8.7	0.075				88.3									11.7	
628*	17.8	10.0	22.2	0.058				1.1					3.7		82.0		13.2	
629	24.2	4.1	16.5	0.059											97.5		2.5	
630	13.1	10.2	15.8	0.064				31.6							59.2		9.2	
631	18.1	14.3	0.0	0.080				100.0										
632	20.2	5.5	0.0	0.080												100.0		
633	15.5	13.2	14.7	0.064				28.7							64.6		6.7	
634	14.8	21.0	0.0	0.080				100.0										
635	2.9	29.0	0.0	0.080				100.0										
636	7.4	39.0	0.0	0.080				100.0										
637	14.1	12.1	0.0	0.080				100.0										
638*	19.3	7.4	5.5	0.074				73.6							24.0		2.5	
639*	18.8	7.4	9.5	0.072				63.9							20.0		8.6	7.4
640	9.3	18.4	2.1	0.077				85.8							14.2			
641	19.5	7.2	16.1	0.062										18.7	76.3		4.9	
642	18.8	20.2	0.0	0.080				100.0										
643	21.9	5.5	20.5	0.058											90.8		9.2	
644	17.3	3.7	0.0	0.080												100.0		
645	10.9	4.1	0.0	0.080												100.0		
646	26.4	6.5	0.0	0.080												100.0		

ID	Area (ha)	Slope (%)	Imp. (%)	PERN ‘n’	Percentage of the catchment (%)													
					Centre	Com. Fac.	Emerg. Com.	Env. Man. Conv.	Ind.	Low Dens. Res.	Low Med. Dens. Red.	Prio- rity	Rec	Rural	Rur. Res.	Spe- cial	Road	Water
647	18.6	5.8	0.0	0.080												100.0		
648	8.1	9.1	0.0	0.080												100.0		
649	16.0	5.9	29.9	0.062				37.6					18.9			3.6	39.9	
650	25.6	7.4	30.3	0.062				41.8		28.1			8.4				21.7	
651	11.5	5.5	0.0	0.080												100.0		
652	14.9	7.0	49.9	0.050				2.2		83.4						3.5	10.9	
653	19.0	20.9	2.9	0.078				96.1									3.9	
654	16.6	5.3	0.0	0.080												100.0		
655	13.3	34.7	0.0	0.080				100.0										
656*	25.9	7.1	12.6	0.067				41.8							51.8		6.4	
657	18.4	21.1	0.0	0.080				100.0										
658	21.8	12.6	1.5	0.079				98.1									1.9	
659	12.9	7.3	19.7	0.063				21.4					15.4		46.3		17.0	
660	13.4	38.3	2.7	0.076				81.7							18.3			
TOTAL	14149				0%	1%	1%	32%	1%	4%	0%	1%	1%	6%	21%	29%	4%	0%

* ultimate catchment conditions <> existing catchment conditions

Appendix B - TUFLOW model configuration

Contents

List of Figures

List of Tables

B1 Hydraulic roughness maps

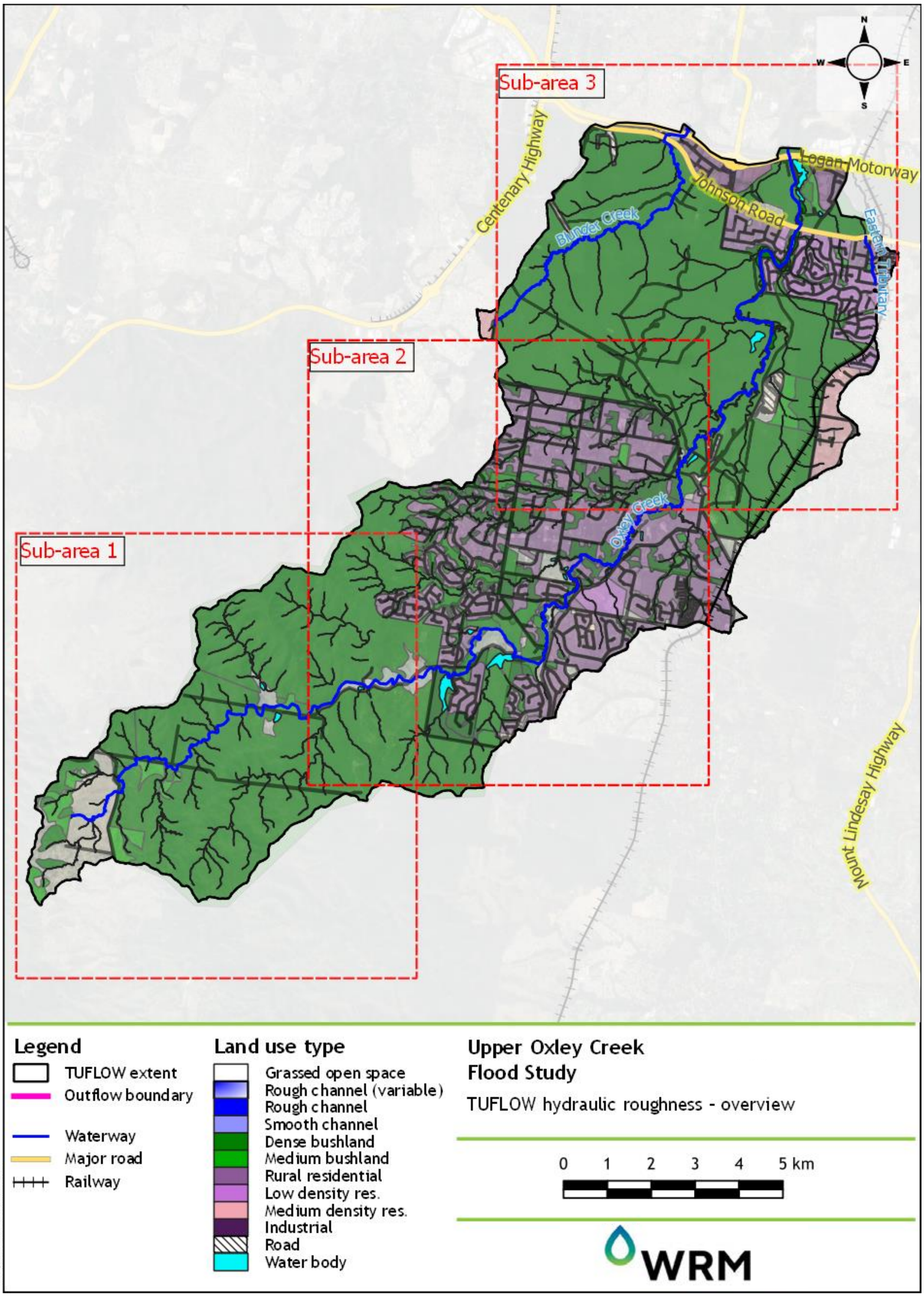

Figure B.1 - Distribution of hydraulic roughness (Manning's 'n') values (total extent)

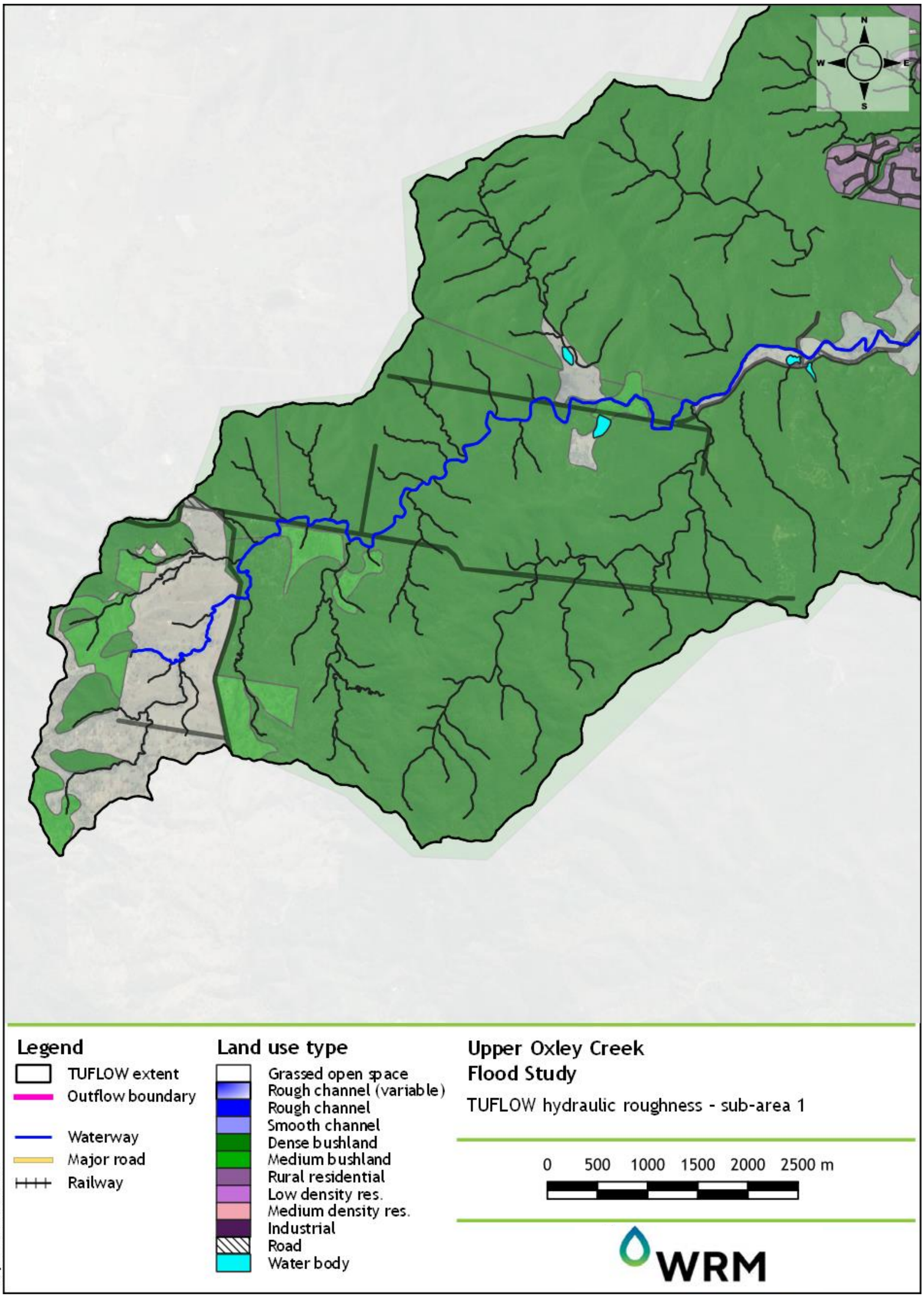

Figure B.2 - Distribution of hydraulic roughness (Manning's 'n') values (sub-area 1)

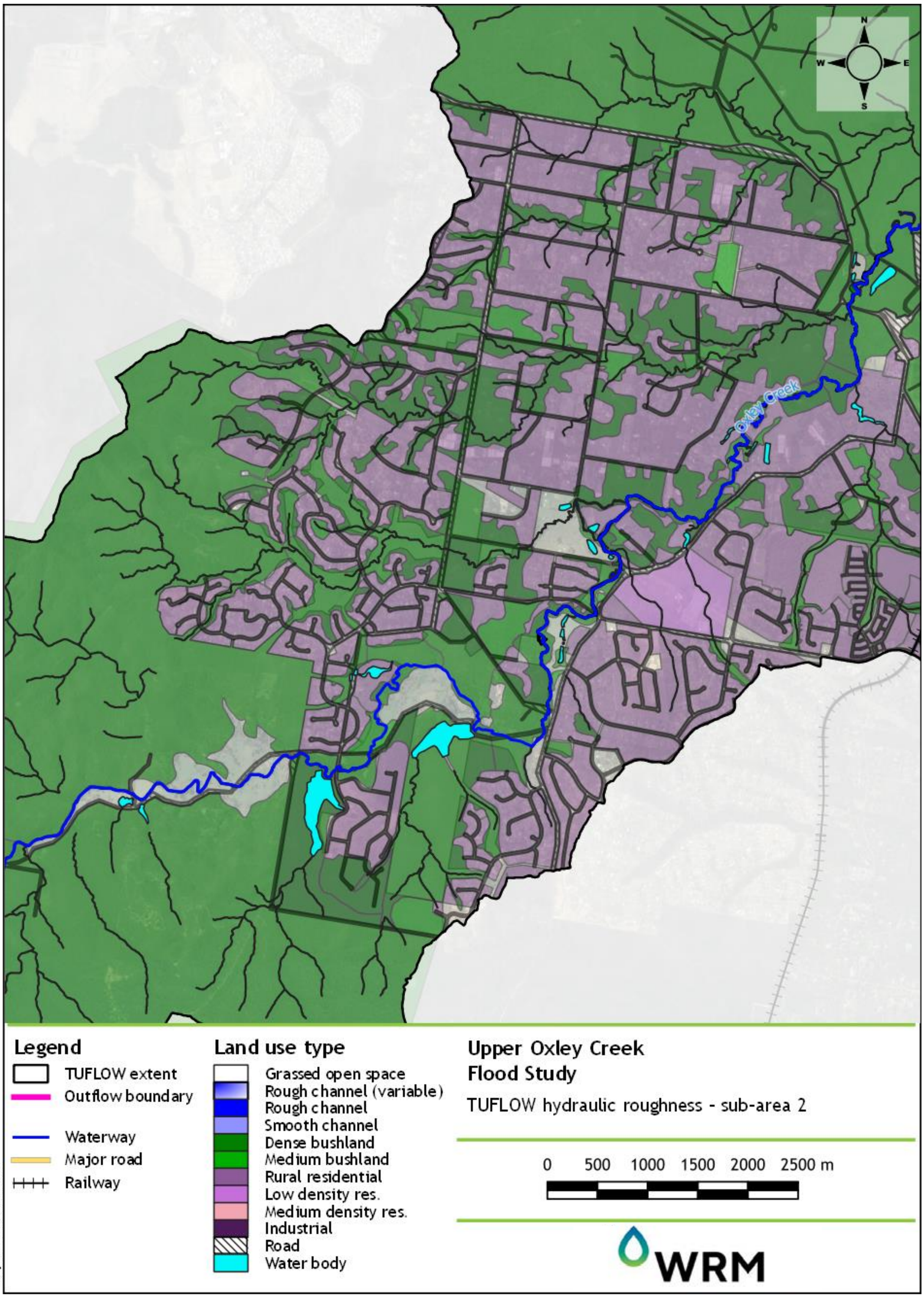

Figure B.3 - Distribution of hydraulic roughness (Manning's 'n') values (sub-area 2)

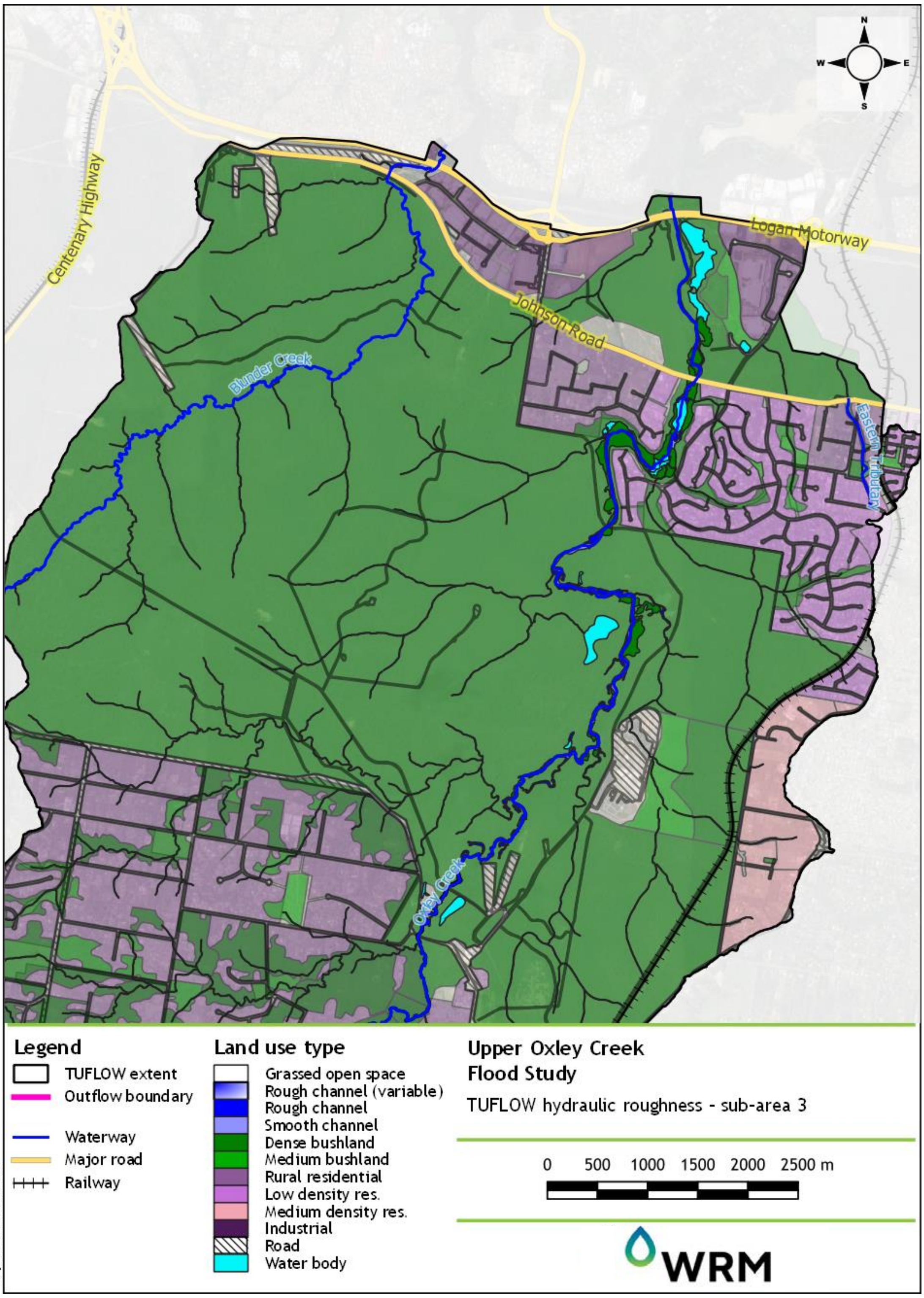

Figure B.4 - Distribution of hydraulic roughness (Manning's 'n') values (sub-area 3)

B2 Hydraulic structure locations

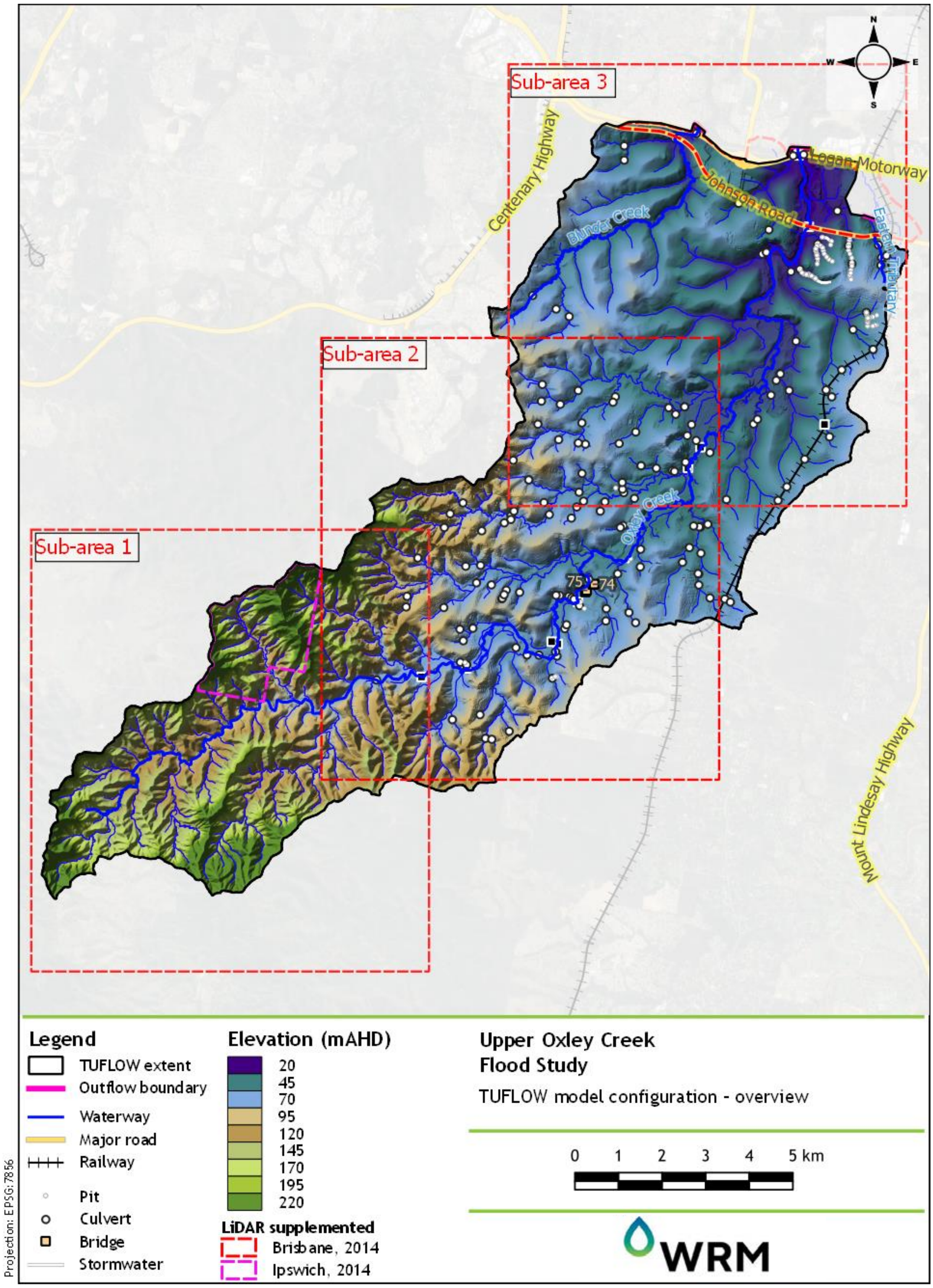

Figure B.5 - Locations of hydraulic structures in the hydraulic model (total extent)

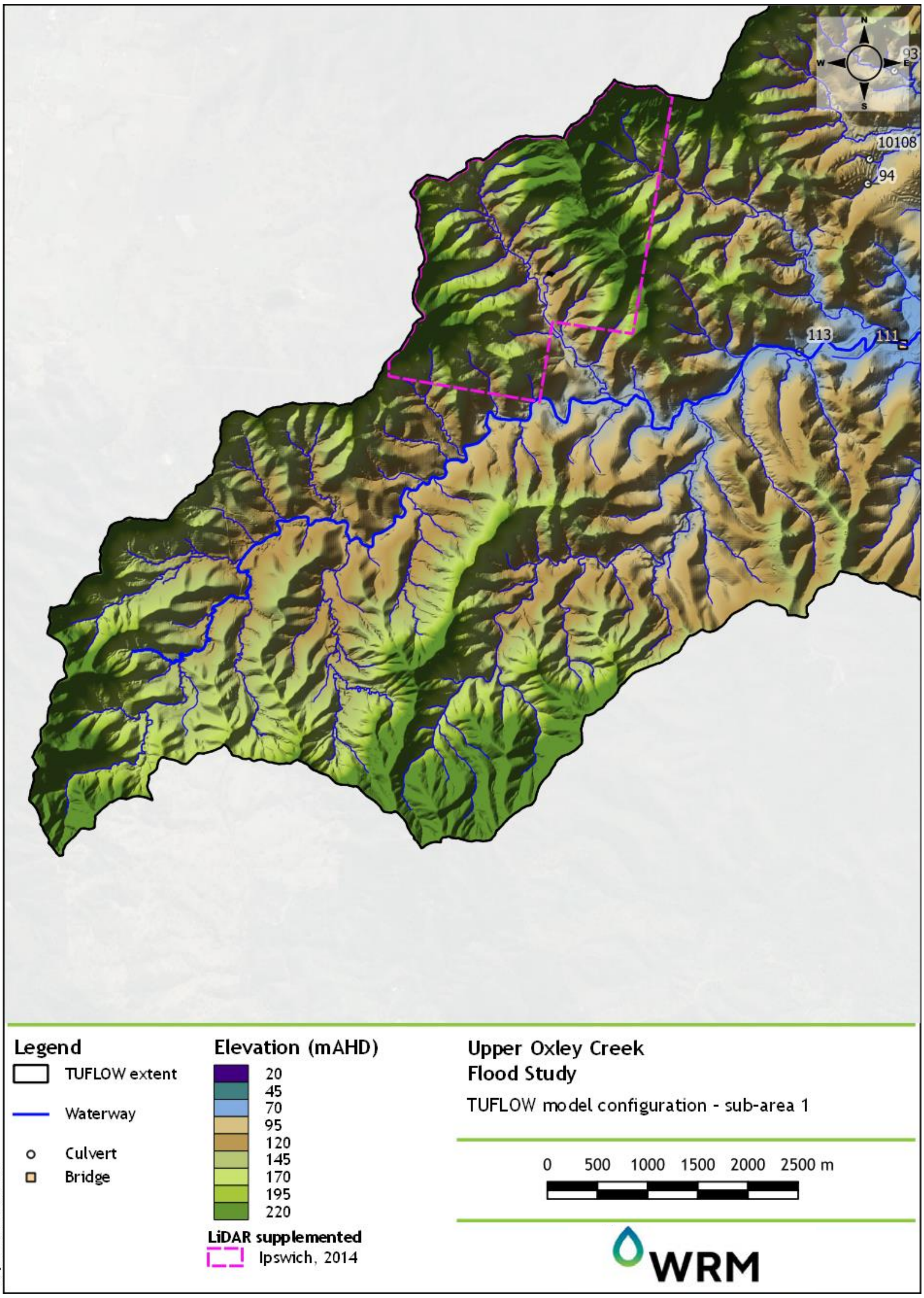

Figure B.6 - Locations of hydraulic structures in the hydraulic model (sub-area 1)

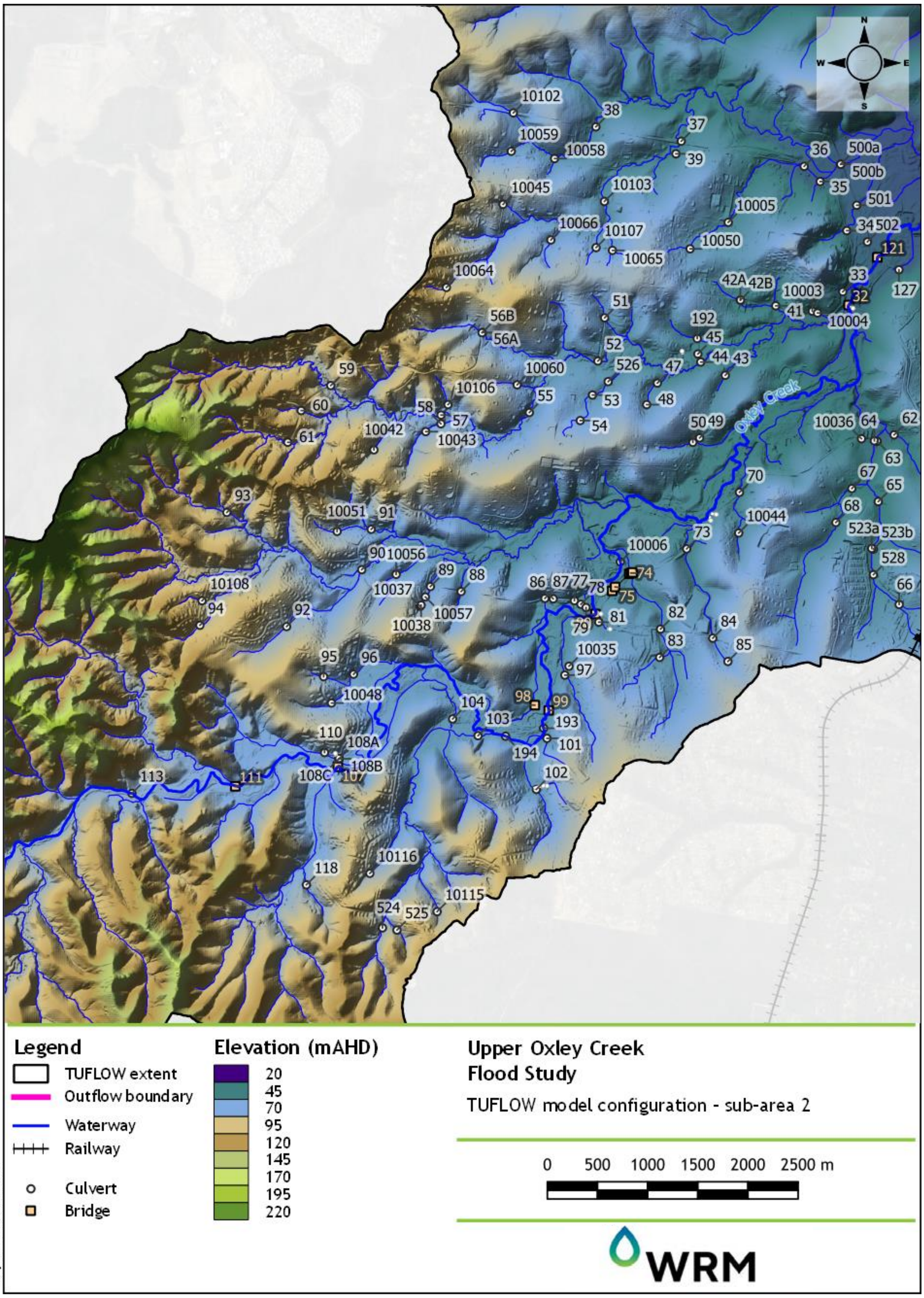

Figure B.7 - Locations of hydraulic structures in the hydraulic model (sub-area 2)

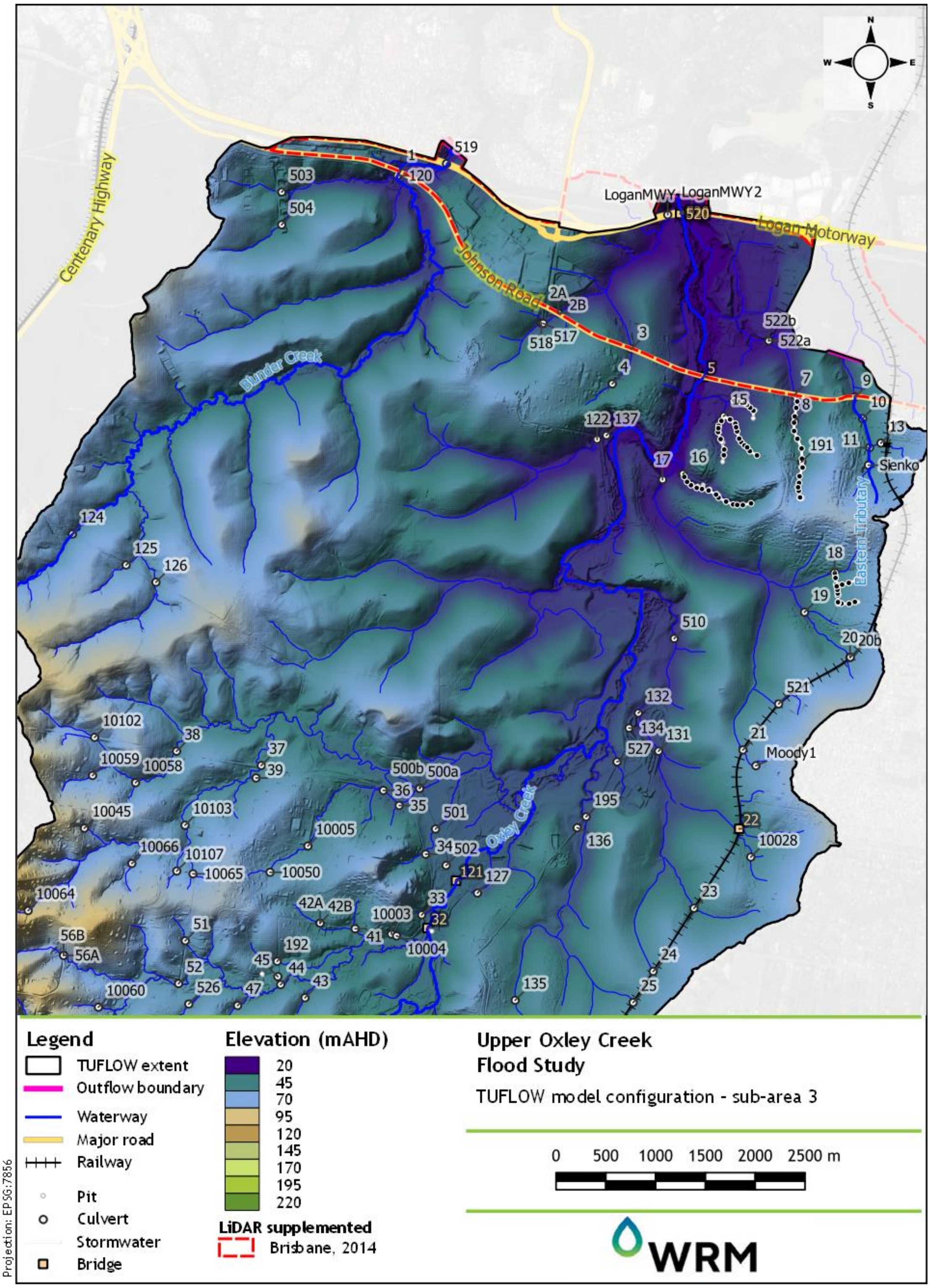

Figure B.8 - Locations of hydraulic structures in the hydraulic model (sub-area 3)

B3 Hydraulic structure details

Table B.1 - Configuration of cross-drainage culvert structures in the TUFLOW model

Structure ID	Easting	Northing	Culvert type [a]	Width / diameter (m)	Height (m)	Length (m)	No. of barrels	U/S invert level (mAHD)	D/S invert level (mAHD)	Comment	Source
1	496967.6	6943065	R	3	2.4	14.6	5	28.1	28		LCC database
2A	498557.7	6941647	R	1.2	1.2	38.0	3	34.52	34.52		LCC survey
2B	498558.7	6941646	R	1.35	0.825	37.9	2	34.52	34.52		LCC survey
3	499290.5	6941285	C	1.05	0	13.1	2	36.17	35.98		LCC survey
4	499100.5	6940936	C	1.05	0	17.3	6	42.13	41.9		WRM survey
7	500929.9	6940826	C	1.35	0	15.1	2	31	30.9		LCC database
8	500926.4	6940564	C	1.35	0	17.0	2	36.1	35.82		WRM survey
9	501536.7	6940804	C	1.5	0	12.3	2	39.4	38.8		LCC survey
10	501613.4	6940587	R	1.9	1.4	21.2	2	41.9	41.83		LCC database
11	501682.9	6940296	C	0.9	0	20.9	4	47.75	47.5		LCC database
13	501797.4	6940341	R	1.5	1.5	17.9	1	52.8	52.5		LCC database
15	500220	6940612	C	1.5	0	10.5	2	25.49	25.46		WRM survey
16	499810.7	6940033	C	1.5	0	30.8	2	25.58	25.58		WRM survey
17	499605.2	6939975	R	3.6	1.2	19.1	3	22.05	21.95		WRM survey
18	501333.6	6939040	C	1.05	0	20.5	3	46.72	46.51		LCC survey
19	501030.3	6938644	C	1.2	0	18.6	5	38.61	38.42		LCC survey
20	501487.2	6938190	R	1.2	1.2	11.7	1	58	57.3	Inverts assumed	LCC survey
20b	501489.1	6938192	R	0.6	0.6	11.4	4	58	57.3	Inverts assumed	LCC survey
21	500411.9	6937262	R	1.5	0.7	8.4	2	55.6	55.4	Inverts assumed	LCC survey
23	499920.7	6935673	R	2.1	2.1	19.1	1	46.66	46.6	Inverts assumed	LCC survey
24	499511.4	6935039	R	1.5	1	7.5	1	53.9	53.8	Inverts assumed	LCC survey

Structure ID	Easting	Northing	Culvert type [a]	Width / diameter (m)	Height (m)	Length (m)	No. of barrels	U/S invert level (mAHD)	D/S invert level (mAHD)	Comment	Source
25	499310.2	6934727	R	0.9	0.9	27.9	1	53.2	53.1	Inverts assumed	LCC survey
28	498089.6	6932466	R	1.5	0.75	13.2	1	58.15	58.1		LCC survey
33	497187.5	6935606	R	0.6	0.3	15.8	1	41.2	41.05		LCC database
34	497226.9	6936215	R	1.2	0.6	10.7	2	40.71	40.62		LCC survey
35	496962	6936704	R	1.2	0.6	10.5	2	39.52	39.48		LCC survey
36	496802.6	6936855	R	1.2	0.6	10.6	3	39.56	39.41		LCC survey
37	495577.7	6937106	C	1.65	0	13.9	8	47.71	47.61		LCC survey
38	494726.8	6937249	C	1.35	0	9.6	9	51.81	51.65		LCC survey
39	495524.4	6936980	C	0.6	0	16.0	2	50.15	50.1		LCC survey
41	496519.2	6935467	R	1.8	0.6	9.8	3	43.16	43.05		LCC survey
42A	496236.5	6935514	R	1.2	0.45	0.0	2	47.71	47.62		LCC survey
42B	496236.5	6935514	C	0.45	0	0.0	1	47.71	47.62		LCC survey
43	496016.3	6934774	C	0.45	0	6.6	3	50.1	50		LCC survey
44	495771.8	6934906	C	0.75	0	12.3	3	47.17	47.09		LCC survey
47	495339.6	6934696	C	0.9	0	66.6	3	51.41	50.17		LCC survey
48	495233.2	6934482	C	0.75	0	53.0	2	58.75	57.03		LCC database
49	495760.6	6934151	C	0.6	0	13.5	1	50.29	50.11		LCC survey
50	495693.3	6934106	C	0.825	0	8.9	2	50.28	50.18		LCC survey
51	494814.2	6935347	C	0.45	0	12.7	2	58.68	58.53		LCC survey
52	494746.9	6934916	C	1.35	0	16.6	4	53.52	53.49		LCC survey
53	494693.1	6934578	R	0.45	1.2	11.1	2	59.66	59.5		LCC database
54	494570.7	6934323	C	0.9	0	9.7	3	67.24	67.1		LCC database
55	494063.9	6934404	C	1.5	0	9.1	3	60.6	60.5		WRM survey
56A	493593.6	6935201	C	1.35	0	22.8	2	66.55	66.25		LCC survey
56B	493592.7	6935199	C	1.65	0	22.4	1	66.55	66.25		LCC survey

Structure ID	Easting	Northing	Culvert type [a]	Width / diameter (m)	Height (m)	Length (m)	No. of barrels	U/S invert level (mAHD)	D/S invert level (mAHD)	Comment	Source
57	493183.6	6934378	R	10	2.18	10.5	1	67.71	67.67		LCC survey
58	493182.6	6934291	C	1.2	0	22.6	1	67.98	67.89		LCC survey
59	492084.5	6934672	C	1.8	0	27.0	3	77.2	76.8		LCC database
60	491789.7	6934423	C	1.35	0	29.0	1	86.1	85.3		LCC database
61	491656.2	6934107	C	1.2	0	23.7	4	87.9	87.3		LCC database
62	497699.2	6934181	C	0.75	0	10.7	6	42.45	42.35		LCC database
63	497529.8	6934117	C	0.9	0	9.9	6	41.41	41.21		LCC survey
64	497502.2	6934122	R	2.1	0.75	9.8	2	41.58	41.51		LCC survey
65	497541.1	6933516	C	0.9	0	11.1	10	45.1	44.9	Inverts assumed	LCC database
66	497749.5	6932491	R	1.2	1	32.3	3	54.2	53.93	new for 2022	LCC database
67	497277.9	6933647	C	0.9	0	11.6	8	45.4	45	Inverts assumed	LCC database
68	497118.8	6933308	C	0.9	0	10.5	7	49.1	49.04		LCC database
70A	496161.1	6933607	C	0.45		17.4	2	46.41	46.36	pre-2022	LCC survey
70B	496157.7	6933608	C	1.05	0	18.5	4	46.48	46.35	new for 2022	LCC survey
73A	495637.4	6933041	C	0.45		11.2	2	47.85	47.32	pre-2022	LCC survey
73B	495631.5	6933045	R	2.4	1.8	25.8	3	47.71	47.3	new for 2022	LCC survey
74	495079.8	6932804	C	0.45		11.4	4	51.62	51.56	pre-2022	LCC survey
74D	495023	6932773	C	0.375		11.6	1	52.26	52.10	pre-2022	LCC survey
74A [a]	495074.1	6932803	R	3.9	3	21.4	5	51.91	51.87	new for 2022	LCC survey
74B [a]	495076.1	6932804	R	3.6	3	19.5	5	51.61	51.57	new for 2022	LCC survey
74C [a]	495078.1	6932805	R	3.6	2.7	21.3	5	51.61	51.57	new for 2022	LCC survey
75A [a]	494904.2	6932645	R	3.6	2.15	18.1	15	52.23	52.15	new for 2022	LCC survey
75B [a]	494906	6932648	R	3.6	2.35	17.1	10	52.43	52.35	new for 2022	LCC survey
77	494512.8	6932530	R	2.7	0.75	11.4	7	53.96	53.88		LCC survey
78	494577.5	6932494	R	2.7	0.6	10.0	3	53.87	53.79		LCC survey

Structure ID	Easting	Northing	Culvert type [a]	Width / diameter (m)	Height (m)	Length (m)	No. of barrels	U/S invert level (mAHD)	D/S invert level (mAHD)	Comment	Source
79	494628.8	6932461	R	2.7	0.75	10.9	3	53.73	53.62		LCC survey
81	494755.5	6932315	C	0.9	0	18.4	4	53.63	53.11		LCC database
82	495371	6932246	C	2.1	0	17.6	4	54.51	54.35		LCC database
83	495362.4	6931964	R	1.2	0.9	9.9	3	56.96	56.91	new for 2022	LCC database
84	495891.6	6932156	C	1.5	0	18.9	2	60.63	60.41		LCC survey
85	496042.7	6931924	R	0.9	0.45	20.7	6	66.04	65.95		LCC database
86	494302.1	6932548	C	0.675	0	17.8	1	55.98	55.93		LCC database
87	494218.9	6932552	C	0.9	0	12.5	1	55.7	55.66		LCC database
88	493383.5	6932620	C	1.2	0	14.2	2	59	58.9		LCC database
89	493077.7	6932670	C	1.2	0	20.3	1	62.85	62.7		LCC database
90	492393.2	6932838	R	3.6	1.8	12.5	4	63.78	63.6		WRM survey
91	492487.8	6933240	C	1.65	0	18.8	2	62.77	62.61		LCC survey
92	491644.4	6932271	C	1.35	0	14.1	3	74.74	74.65		LCC survey
93	491048.7	6933408	R	1.8	1.5	28.5	3	81.45	81.22		LCC database
94	490780.4	6932284	C	1.5	0	19.2	4	89.35	89.33		LCC database
95	492013.7	6931772	C	1.05	0	16.2	2	69.9	69.8		WRM survey
96	492311.5	6931797	C	0.3	0	11.4	1	63.23	62.93		LCC survey
97	494417.5	6931788	C	0.9	0	14.8	6	56.38	56.21		LCC survey
98	493635	6932029	R	1.2	0.6	0.0	1	75.7	75.6	new for 2022	LCC database
101	494239.3	6931158	C	1.2	0	15.6	1	58.51	58.35		LCC survey
102	494133.3	6930650	R	2.4	1.2	32.5	3	59.8	59.45		WRM survey
103	493552.4	6931184	C	0.9	0	7.7	1	58.81	58.75		LCC survey
104	493299.1	6931351	C	0.45	0	7.8	4	59.81	59.79		LCC survey
108A	492166.9	6930953	C	3	0	26.1	1	66.94	66.87	new for 2022	LCC survey
108B	492167.2	6930955	C	3	0	25.2	3	66.94	66.87	new for 2022	LCC survey

Structure ID	Easting	Northing	Culvert type [a]	Width / diameter (m)	Height (m)	Length (m)	No. of barrels	U/S invert level (mAHD)	D/S invert level (mAHD)	Comment	Source
108C	492167.5	6930957	C	1.95	0	26.4	1	66.94	66.87	new for 2022	LCC survey
110	492022.8	6931017	C	1.05	0	16.6	2	68.29	68.19		LCC database
113	490103.3	6930610	C	1.8	0	7.0	1	72.91	72.89		LCC survey
118	491841.3	6929699	C	1.2	0	26.9	2	71.29	70.85	new for 2022	LCC database
120	496944	6943026	C	1.2	0	16.2	4	27.33	27.18		LCC survey
122	498948.4	6940379	C	1.2	0	10.8	2	25.76	25.59		LCC survey
124	493681.5	6939429	R	2.4	1.2	13.0	1	56.65	56.24		LCC survey
125	494220.7	6939118	R	1.8	0.9	16.2	1	58.83	58.53		LCC survey
126	494519.9	6938945	R	2.7	0.9	14.1	2	58.69	58.62		LCC survey
127	497747.2	6935825	C	0.6	0	13.9	2	39.73	39.41		LCC survey
131	499564.8	6937249	R	3.6	1.8	34.0	9	33.43	33.35		LCC survey
132	499361.9	6937632	R	3.6	1.5	30.7	9	32.51	32.49		LCC survey
134	499268.5	6937481	C	0.6	0	28.2	1	36.87	35.77		LCC survey
135	498126.1	6934749	C	0.9	0	11.2	2	47.06	47.01		LCC survey
136	498748.5	6936481	R	3.6	1.2	11.0	2	36.66	36.62		LCC survey
137	499042.3	6940419	R	1.5	0.75	10.8	2	23.42	23.38		LCC survey
191	501002.4	6940153	C	1.05	0	15.8	2	48.93	48.67		WRM survey
192	495737	6935140	C	0.375	0	20.7	3	48.79	48.62		LCC survey
193	494206.3	6931259	C	0.9	0	8.9	2	56.68	56.43		LCC survey
194	493826.4	6931180	C	0.9	0	7.9	2	58.14	58.03		LCC survey
195	498837.8	6936590	R	3.6	1.2	11.2	1	36.38	36.28		LCC database
500a	497166.9	6936876	R	2.4	0.95	9.7	1	38.21	38.03		LCC survey
500b	497167	6936876	R	2.4	0.75	9.7	2	38.21	38.03		LCC survey
501	497326.2	6936468	C	0.75	0	15.3	4	39.07	38.81		LCC survey
502	497433.1	6936103	C	0.6	0	15.2	1	39.63	39.36		LCC survey

Structure ID	Easting	Northing	Culvert type [a]	Width / diameter (m)	Height (m)	Length (m)	No. of barrels	U/S invert level (mAHD)	D/S invert level (mAHD)	Comment	Source
503	495783	6942862	R	5.2	0.45	127.6	1	40.7	38.5		Inaccessible
504	495781.9	6942533	R	7.2	0.45	78.8	1	43.9	42.2		Inaccessible
510	499722.7	6938380	C	0.6	0	9.8	1	30.58	30.55		LCC survey
517	498406.4	6941543	C	1.05	0	10.2	1	36.19	36.16		LCC survey
518	498387.8	6941547	C	1.05	0	9.5	1	36.62	36.42		LCC survey
519	497436.7	6943146	R	3.6	3.6	51.1	5	25.1	25		LCC database
521	500770.3	6937723	R	1.5	0.7	9.6	2	57.2	57	Inverts assumed	LCC survey
522a	500672.2	6941370	R	2.4	0.9	21.0	4	23.49	23.36		LCC survey
522b	500671.6	6941369	R	2.7	1.1	21.0	3	23.49	23.36		LCC survey
523a	497476.2	6933050	C	0.9	0	14.7	4	48.57	48.46	new for 2022	AsCon drawings
523b	497492.8	6933043	R	1.5	0.6	6.2	6	50	49.95	new for 2022	AsCon drawings
524	492600	6929271	R	2.4	1.2	7.5	1	74.026	73.953	new for 2022	AsCon drawings
525	492744.5	6929249	R	0.9	0.45	12.2	1	78.65	78.502	new for 2022	AsCon drawings
526	494849.3	6934711	C	0.45	0	3.0	1	57.6	57.4		LCC database
527	499148.6	6937142	R	1.5	0.75	15.7	1	36	35.82		LCC database
528	497492.8	6932788	R	2.4	0.9	45.7	3	49.7	49.51	new for 2022	AsCon drawings
529	498216.7	6932396	C	0.3	0	5.2	3	59.75	59.7		LCC database
10003	496883.5	6935413	R	1.2	0.375	17.6	1	42.25	42.2		LCC database
10004	496935.5	6935395	R	0.9	0.45	11.6	1	41.5	41.3		LCC database
10005	496045.6	6936297	R	1.2	0.6	9.9	4	50.81	50.71		LCC survey
10006	494970.5	6932916	R	1.2	0.3	7.7	6	49.47	49.47		LCC database
10028	500490.8	6936186	C	1.2	0	13.3	3	48.44	48.38		LCC database
10035	494458.8	6931877	C	0.6	0	12.4	2	58.1	58		LCC survey
10036	497373.9	6934142	C	0.6	0	10.7	1	43.2	43		LCC survey
10037	492976.1	6932474	C	0.9	0	13.6	2	70.81	70.69		LCC survey

Structure ID	Easting	Northing	Culvert type [a]	Width / diameter (m)	Height (m)	Length (m)	No. of barrels	U/S invert level (mAHD)	D/S invert level (mAHD)	Comment	Source
10038	492985	6932485	C	0.9	0	14.3	2	70.7	70.5		LCC survey
10042	492514.8	6934032	C	1.05	0	16.7	1	79.15	78.95		LCC database
10043	493031.2	6934213	C	1.5	0	22.0	1	70.1	69.9		LCC database
10044	496150.2	6933204	C	1.05	0	15.5	3	52.85	52.75		LCC database
10045	493801.5	6936476	C	0.9	0	12.3	2	72.27	71.84		LCC survey
10048	492091.7	6931510	C	1.35	0	14.7	2	68.65	68.55		LCC database
10050	495665.6	6936034	C	0.9	0	17.0	1	57.5	57.42		LCC database
10051	492147.9	6933219	C	1.05	0	22.1	1	72.2	72	Inverts assumed	LCC database
10056	492736.2	6932791	C	1.2	0	19.7	3	63.3	63.13		LCC database
10057	493027.3	6932566	C	0.825	0	22.1	3	66.98	66.25		LCC database
10058	494315.2	6936933	C	0.75	0	10.7	2	57.43	57.19		LCC survey
10059	493883.7	6937005	C	1.05	0	10.2	2	63.08	62.97		LCC survey
10060	493942.3	6934679	C	1.05	0	16.0	1	66.21	66.11		LCC database
10064	493237.1	6935649	C	0.9	0	18.8	1	89.2	88.92		LCC database
10065	494892	6936018	C	1.05	0	10.1	1	62.78	62.78		LCC database
10066	494278.3	6936122	C	1.8	0	10.2	2	63.8	63.71		LCC database
10102	493904.1	6937388	C	1.35	0	12.6	4	63.46	63.41		LCC survey
10103	494811.7	6936506	C	1.2	0	14.0	7	54.81	54.72		LCC survey
10106	493252.9	6934483	C	0.9	0	24.7	1	68.5	67.9		LCC survey
10107	494728.9	6936046	C	0.45	0	9.9	1	65.43	65.42	Inverts assumed	LCC database
10108	490801.6	6932529	C	0.9	0	22.4	2	88.24	87.61		LCC database
10115	493144.4	6929432	C	0.9	0	48.0	4	78.7	76.2		LCC survey
10116	492474.1	6929813	C	0.9	0	0.0	1	74.53	74.42	new for 2022	LCC database
Moody1	500542.2	6937103	C	0.6	0	13.6	1	59.45	59.4		LCC database
Sienko	501671.1	6940120	C	0.9	0	33.8	2	51.65	51.48		LCC database

Structure ID	Easting	Northing	Culvert type [a]	Width / diameter (m)	Height (m)	Length (m)	No. of barrels	U/S invert level (mAHD)	D/S invert level (mAHD)	Comment	Source
LoganMWY	499657.3	6942633	C	2.4	0	59.3	3	19.2	19		LCC database
LoganMWY2	499898.2	6942661	C	1.2	0	63.9	1	17.6	17.25		LCC database

[a] - modelled as bridge structure

B4 Stormwater network

Table B.2 - Configuration of stormwater network in the TUFLOW model

Structure ID	Easting	Northing	Culvert type	Width / diameter (m)	Length (m)	No. of barrels	U/S invert level (mAHD)	D/S invert level (mAHD)	Source
10012	501004.4	6940145	C	0.375	80.8	1	48.9	46.71	LCC database
10013	501002.5	6940236	C	0.375	102.8	1	46.71	44.87	LCC database
10014	501007.8	6940100	C	0.375	11.4	1	50.45	48.9	LCC database
10015	500995.5	6940052	C	0.375	92.6	1	55.94	50.45	LCC database
10016	500977.9	6939975	C	0.375	67.3	1	59.38	55.94	LCC database
10017	500970.6	6939920	C	0.375	45.0	1	61.57	59.38	LCC database
10018	500969	6939880	C	0.375	37.0	1	63.61	61.57	LCC database
10019	500978.9	6939829	C	0.3	66.9	1	66.68	63.61	LCC database
10020	500979.7	6940336	C	0.375	106.0	1	44.87	41.55	LCC database
10021	500942.1	6940424	C	0.375	85.1	1	41.55	39.4	LCC database
10022	500925.5	6940505	C	0.375	84.5	1	38.8	35.42	LCC database
10023	500928.9	6940578	C	0.45	62.8	1	35.42	34.28	LCC database
10025	500939.9	6940652	C	0.45	88.0	1	34.28	32.67	LCC database
10026	500952.4	6940727	C	0.525	64.7	1	32.67	32.02	LCC database
10027	500945	6940786	C	0.525	59.5	1	32.02	31.92	LCC database
10067	500517.2	6940239	C	0.3	83.8	1	45.012	42.22	LCC database
10068	500467.8	6940280	C	0.3	45.5	1	42.22	41.6	LCC database
10069	500441.1	6940308	C	0.3	34.0	1	40.356	38.939	LCC database
10070	500411.3	6940334	C	0.3	45.5	1	38.542	36.474	LCC database
10071	500384.7	6940368	C	0.3	39.5	1	36.174	34.367	LCC database
10072	500363.9	6940423	C	0.3	76.5	1	32.8	30.86	LCC database
10073	500348.4	6940480	C	0.3	44.0	1	30.857	28.75	LCC database
10074	500339.6	6940518	C	0.3	37.5	1	28.75	27.822	LCC database
10075	500309.3	6940557	C	0.3	70.5	1	27.822	26.79	LCC database

Structure ID	Easting	Northing	Culvert type	Width / diameter (m)	Length (m)	No. of barrels	U/S invert level (mAHD)	D/S invert level (mAHD)	Source
10076	500258.2	6940590	C	0.3	54.6	1	26.79	25.941	LCC database
10077	500211.4	6940580	C	0.45	44.5	1	26.15	25.8	LCC database
10078	500181.8	6940540	C	0.45	58.5	1	26.41	26.15	LCC database
10079	500166.8	6940503	C	0.45	24.0	1	26.68	26.59	LCC database
10080	500164.3	6940472	C	0.45	38.2	1	27.32	27.15	LCC database
10081	500175.3	6940417	C	0.375	75.2	1	28.253	27.399	LCC database
10082	500193.8	6940366	C	0.3	34.5	1	29.079	28.328	LCC database
10083	500212	6940314	C	0.3	76.9	1	31.73	29.079	LCC database
10084	500222.6	6940248	C	0.3	56.6	1	34.427	31.73	LCC database
10085	500214.5	6940187	C	0.3	65.2	1	37.261	34.427	LCC database
10086	499837.4	6939978	C	0.45	57.0	1	25.966	25.707	LCC database
10087	499870.6	6939936	C	0.45	53.8	1	26.769	25.966	LCC database
10088	499919	6939905	C	0.45	61.6	1	27.82	27.05	LCC database
10089	499974.2	6939886	C	0.45	54.0	1	28.502	27.827	LCC database
10090	500033.9	6939873	C	0.45	70.1	1	30.885	29.51	LCC database
10091	500104.7	6939845	C	0.45	85.3	1	32.31	30.89	LCC database
10092	500155	6939809	C	0.375	41.0	1	34.729	33.635	LCC database
10093	500205.8	6939774	C	0.375	81.7	1	36.908	34.729	LCC database
10094	500278.6	6939740	C	0.375	83.4	1	39.687	36.908	LCC database
10095	500334.2	6939723	C	0.375	35.8	1	39.962	39.687	LCC database
10096	500382.9	6939720	C	0.375	60.0	1	43.366	41.2	LCC database
10097	500452.5	6939728	C	0.375	86.5	1	46.489	43.366	LCC database
10098	499825.9	6940007	C	0.45	9.8	0	25.707	25.63	LCC database
10099	494220.5	6930686	C	1.2	39.0	1	61.53	60.9	LCC database
10100	494163.6	6930677	C	1.35	78.8	1	60.87	59.52	LCC database

Structure ID	Easting	Northing	Culvert type	Width / diameter (m)	Length (m)	No. of barrels	U/S invert level (mAHD)	D/S invert level (mAHD)	Source
10101	494767.7	6932399	C	0.525	22.5	2	54.27	54.06	LCC database
10110	494859.5	6932248	C	0.375	15.4	1	56.14	56.09	LCC database
109	492130	6931001	C	0.375	16.9	1	67.82	67.74	LCC database
31	497284.2	6935455	C	0.45	27.6	1	40.24	40.12	LCC database
37984	500155.9	6939822	C	0.375	28.2	0	33	32.31	LCC database
46	495587.7	6935006	C	0.525	17.7	1	50.06	49.6	LCC database
71	495907.5	6933392	C	0.45	39.8	1	50.8	50.51	LCC database
72	495866.5	6933342	C	0.525	29.7	1	51.06	50.86	LCC database
SD16799	500991.3	6939794	C	0.375	12.9	1	67.47	66.68	LCC database
SD16800	500985.1	6939795	C	0.375	2.9	1	67.5	66.68	LCC database
SD17969	501363.1	6938724	C	0.375	3.5	1	53.22	52.9	LCC database
SD17970	501364.8	6938735	C	0.375	19.6	1	52.9	52	LCC database
SD17971	501368.1	6938741	C	0.375	8.2	1	52	52	LCC database
SD17972	501366	6938780	C	0.525	69.6	1	52	50.85	LCC database
SD17974	501365	6938823	C	0.525	18.2	1	50.85	50.77	LCC database
SD17975	501362.5	6938851	C	0.525	36.9	1	50.77	49.79	LCC database
SD17977	501357	6938886	C	0.525	35.6	1	49.79	49.2	LCC database
SD17980	501350.9	6938913	C	0.525	19.4	1	49.2	48.56	LCC database
SD17981	501356.9	6938918	C	0.45	19.0	1	49.4	48.56	LCC database
SD17982	501345	6938955	C	0.75	66.7	1	48.56	47.99	LCC database
SD17983	501339.8	6939000	C	0.75	24.3	1	47.99	47.56	LCC database
SD17984	501336.8	6939009	C	0.375	8.0	1	48.24	47.56	LCC database
SD17985	501340.2	6939010	C	0.375	6.8	1	48.65	47.56	LCC database
SD17986	501336.3	6939024	C	0.75	22.8	1	47.56	47	LCC database
SD17988	501328.9	6939037	C	0.75	12.0	1	47	46.51	LCC database

Structure ID	Easting	Northing	Culvert type	Width / diameter (m)	Length (m)	No. of barrels	U/S invert level (mAHD)	D/S invert level (mAHD)	Source
SD18021	501566.5	6938972	C	0.375	19.6	1	59.09	58.13	LCC database
SD18022	501516.1	6938954	C	0.375	87.5	1	58.13	54.33	LCC database
SD18024	501441.7	6938930	C	0.375	69.1	1	54.33	51.45	LCC database
SD18025	501411.8	6938921	C	0.375	7.1	1	52.27	51.45	LCC database
SD18026	501386.8	6938917	C	0.375	43.5	1	51.45	49.4	LCC database
SD18028	501375.1	6938912	C	0.375	9.9	1	49.8	49.7	LCC database
SD18029	501367.8	6938913	C	0.375	5.3	1	49.7	49.4	LCC database
SD19222	501552.9	6938747	C	0.3	34.0	1	59.06	58.36	LCC database
SD19224	501507	6938738	C	0.375	60.7	2	58.36	56.52	LCC database
SD19225	501439.6	6938730	C	0.375	77.2	2	56.52	52.63	LCC database
SD19231	501385.5	6938734	C	0.375	31.5	1	52.63	52	LCC database
SD44384	500553.4	6940215	C	0.3	6.1	1	45.48	45.13	LCC database
SD44385	500480.7	6940257	C	0.3	7.7	1	42.68	42.33	LCC database
SD44388	500427	6940314	C	0.3	6.8	1	39.41	39.06	LCC database
SD44390	500372.2	6940384	C	0.3	6.3	1	35.28	34.93	LCC database
SD44392	500350.9	6940458	C	0.3	6.6	1	31.43	31.08	LCC database
SD44397	500333	6940530	C	0.3	14.5	1	28.1	27.822	LCC database
SD44398	500282	6940572	C	0.3	12.0	1	27.2	26.79	LCC database
SD44425	500009.9	6939910	C	0.3	22.0	1	28.95	28.781	LCC database
SD44426	500003.9	6939890	C	0.3	16.8	1	28.781	28.652	LCC database
SD44436	500516.7	6940629	C	0.6	75.5	1	35.598	33.977	LCC database
SD44437	500501.4	6940682	C	0.675	43.0	1	33.902	31.795	LCC database
SD44438	500468.8	6940711	C	0.675	43.0	1	31.473	29.316	LCC database
SD44439	500440.4	6940737	C	0.675	37.0	1	28.416	27.505	LCC database
SD44440	500398.8	6940753	C	1.05	61.5	1	26.805	26.332	LCC database

Structure ID	Easting	Northing	Culvert type	Width / diameter (m)	Length (m)	No. of barrels	U/S invert level (mAHD)	D/S invert level (mAHD)	Source
SD44441	500347.5	6940763	C	1.05	41.6	1	26.332	26.012	LCC database
SD44442	500526.8	6940669	C	0.45	18.4	1	34.105	33.91	LCC database
SD44443	500319	6940766	C	1.35	13.0	1	25.712	25.686	LCC database

B5 Stormwater pits

Table B.3 - Configuration of stormwater inlet pits

Pit ID	Easting	Northing	Pit type	Surface level (mAHD)	Invert level (mAHD)	Source
pit3	500152	6939837	0.9x0.6	33.97	32.52	LCC database
pit5	500013	6939920	0.9x0.6	30.83	28.95	LCC database
pit9	499901	6939923	0.9x0.6	27.71		LCC database
pit13	500007	6939899	0.9x0.6	29.58	28.78	LCC database
pit15	499859	6939952	0.9x0.6	27.12		LCC database
pit17	500170	6939819	0.9x0.6	34.72		LCC database
pit19	500079	6939881	0.9x0.6	32.10		LCC database
pit21	499958	6939911	0.9x0.6	28.11		LCC database
pit23	500176	6940448	0.9x0.6	28.27		LCC database
pit26	500348	6940456	0.9x0.6	32.48	31.43	LCC database
pit27	500281	6940567	0.9x0.6	27.95	27.2	LCC database
pit30	500201	6940558	0.9x0.6	27.22	26.36	LCC database
pit34	500480	6940253	0.9x0.6	43.80	42.68	LCC database
pit35	500370	6940382	0.9x0.6	36.16	35.28	LCC database
pit36	500212	6940349	0.9x0.6	30.56		LCC database
pit41	500216	6940275	0.9x0.6	33.19		LCC database
pit43	500173	6940500	0.9x0.6	27.49		LCC database
pit44	500426	6940311	0.9x0.6	40.51	39.41	LCC database
pit47	500199	6940382	0.9x0.6	29.70	28.34	LCC database
pit49	500199	6940350	0.9x0.6	30.33	29.08	LCC database
pit54	500208	6940154	0.9x0.6	38.64	37.26	LCC database
pit56	500554	6940212	0.9x0.6	46.65	45.48	LCC database
pit57	500947	6940695	0.9x0.6	33.90	32.67	LCC database
pit58	500925	6940463	0.9x0.6	39.63	39.4	LCC database
pit60	501004	6940185	0.9x0.6	48.28	46.71	LCC database
pit61	500997	6939791	0.9x0.6	67.71	67.47	LCC database
pit62	500966	6939933	0.9x0.6	60.99	60.56	LCC database
pit63	500932	6940609	0.9x0.6	35.70	34.28	LCC database
pit65	500980	6940009	0.9x0.6	57.10	55.94	LCC database
pit67	501005	6940105	0.9x0.6	51.34	48.9	LCC database
pit68	500970	6939857	0.9x0.6	64.51	63.84	LCC database
pit69	501001	6940288	0.9x0.6	45.26	44.87	LCC database
pit70	500957	6940759	0.9x0.6	33.31	32.02	LCC database
pit71	500985	6939794	0.9x0.6	67.48	67.25	LCC database

Pit ID	Easting	Northing	Pit type	Surface level (mAHD)	Invert level (mAHD)	Source
pit73	500959	6940385	0.9x0.6	42.10	41.55	LCC database
pit74	500955	6939896	0.9x0.6	62.68	62.11	LCC database
pit76	500976	6939942	0.9x0.6	60.56	59.38	LCC database
pit77	500536	6940672	0.9x0.6	35.60	34.11	LCC database
pit84	500515	6940591	0.9x0.6	37.33	35.6	LCC database
pit85	501570	6938748	0.9x0.6	60.04	59.9	LCC database
pit87	501539	6938750	0.9x0.6	59.14	58.77	LCC database
pit89	501482	6938727	0.9x0.6	57.36	57.16	LCC database
pit90	501483	6938727	0.9x0.6	57.42	57.16	LCC database
pit93	501375	6938734	0.9x0.6	53.01	53	LCC database
pit94	501363	6938722	0.9x0.6	53.48	53.22	LCC database
pit95	501364	6938726	0.9x0.6	53.40	52.9	LCC database
pit98	501364	6938812	0.9x0.6	51.79	51.61	LCC database
pit101	501368	6938862	0.9x0.6	50.85	50.8	LCC database
pit103	501361	6938899	0.9x0.6	50.29	50	LCC database
pit104	501362	6938890	0.9x0.6	50.43	50.7	LCC database
pit108	501336	6939005	0.9x0.6	48.75	48.24	LCC database
pit109	501342	6939007	0.9x0.6	48.74	48.65	LCC database
pit111	501576	6938975	0.9x0.6	59.54	59.09	LCC database
pit114	501484	6938937	0.9x0.6	55.70	55.72	LCC database
pit116	501415	6938921	0.9x0.6	52.64	52.27	LCC database
pit117	501369	6938916	0.9x0.6	49.86	50.3	LCC database
pit118	501380	6938913	0.9x0.6	50.14	49.8	LCC database
pit119	501370	6938912	0.9x0.6	49.88	49.7	LCC database
pit120	501338	6939037	0.9x0.6	48.51	48	LCC database
pit121	494239	6930685	1.7x0.6	-0.05		LCC database
pit48	500330	6940523	0.9x0.6	29.16	28.1	LCC database
pit122	494201	6930688	0.9x0.6	-0.05		LCC database
pit66	500925	6940547	0.9x0.6	37.82	35.42	LCC database
pit123	495927	6933388	0.9x0.6	-0.05		LCC database
pit124	495871	6933328	0.9x0.6	-0.05		LCC database
pit125	494777	6932398	0.9x0.6	-0.05		LCC database
pit126	494868	6932246	0.9x0.6	-0.05		LCC database
pit127	492130	6931008	0.9x0.6	-0.05		LCC database
pit128	497289	6935442	0.9x0.6	-0.05		LCC database
pit129	495586	6935014	0.9x0.6	-0.05		LCC database
pit130	500325	6940766	0.9x0.6	-0.05		LCC database

B6 Stormwater manholes

Table B.4 - Configuration of manholes

Manhole ID	Easting	Northing	Diameter (m)	Invert level (mAHD)	Source
mh1	500947.5	6940695	1.05	32.67	LCC database
mh2	500925.5	6940463	1.05	39.4	LCC database
mh3	501004.4	6940185	1.05	46.71	LCC database
mh4	500997.3	6939791	1.05	67.47	LCC database
mh5	500932.3	6940609	1.05	34.28	LCC database
mh6	500958.8	6940385	1.05	41.55	LCC database
mh7	500975.6	6939942	1.05	59.38	LCC database
mh8	500980.1	6940009	1.05	55.94	LCC database
mh9	500925.5	6940547	1.05	35.42	LCC database
mh10	501004.5	6940105	1.05	48.9	LCC database
mh11	501000.7	6940288	1.05	44.87	LCC database
mh12	500957.3	6940759	1.05	32.02	LCC database
mh13	500984.9	6939794	1.05	67.25	LCC database
mh14	500224.5	6940277	1.05	31.73	LCC database
mh15	500394.9	6940351	1.05	36.17	LCC database
mh16	500162.5	6940452	1.05	27.32	LCC database
mh17	500353.4	6940460	1.05	30.86	LCC database
mh18	500985.4	6939796	1.05	66.68	LCC database
mh19	500972.4	6939862	1.05	63.61	LCC database
mh20	500553.2	6940218	1.05	45.01	LCC database
mh21	500427.7	6940318	1.05	38.54	LCC database
mh22	500335.9	6940536	1.05	27.82	LCC database
mh23	500196	6940564	1.05	26.15	LCC database
mh24	501011	6940095	1.05	50.45	LCC database
mh25	500517.9	6940667	1.05	33.9	LCC database
mh26	500484.9	6940697	1.05	31.47	LCC database
mh27	500452.6	6940726	1.05	28.42	LCC database
mh28	500965.5	6939898	1.05	61.57	LCC database
mh29	501400.9	6938731	1.05	52.63	LCC database
mh30	501370.1	6938738	1.05	52	LCC database
mh31	501366.1	6938745	1.05	52	LCC database
mh32	501535.9	6938747	1.05	58.36	LCC database
mh33	501478.2	6938728	1.05	56.52	LCC database
mh34	501348.5	6938922	1.05	48.56	LCC database
mh35	501365.3	6938914	1.05	49.4	LCC database
mh36	501338.1	6939012	1.05	47.56	LCC database

Manhole ID	Easting	Northing	Diameter (m)	Invert level (mAHD)	Source
mh37	501334.6	6939035	1.05	47	LCC database
mh38	501557.1	6938969	1.05	58.13	LCC database
mh39	501365.8	6938814	1.05	50.85	LCC database
mh40	501364.2	6938832	1.05	50.77	LCC database
mh41	501360.7	6938869	1.05	49.79	LCC database
mh42	501353.2	6938904	1.05	49.2	LCC database
mh43	501341.6	6938988	1.05	47.99	LCC database
mh44	501475.1	6938938	1.05	54.33	LCC database
mh45	501408.3	6938921	1.05	51.45	LCC database
mh46	500313.6	6939725	1.05	39.69	LCC database
mh47	500354.7	6939721	1.05	39.96	LCC database
mh48	500000.5	6939881	1.05	28.5	LCC database
mh49	500167.9	6939793	1.05	34.73	LCC database
mh50	499890	6939919	1.05	26.77	LCC database
mh51	500243.6	6939754	1.05	36.91	LCC database
mh52	500411.1	6939720	1.05	43.37	LCC database
mh53	500067.2	6939866	1.05	30.89	LCC database
mh54	500494	6939736	1.05	46.49	LCC database
mh55	500142.1	6939824	1.05	32.31	LCC database
mh56	499851.2	6939953	1.05	25.97	LCC database
mh57	500220.8	6940220	1.05	34.43	LCC database
mh58	500188.1	6940382	1.05	28.25	LCC database
mh59	500481.1	6940261	1.05	42.22	LCC database
mh60	500374.5	6940386	1.05	34.37	LCC database
mh61	500343.4	6940500	1.05	28.75	LCC database
mh62	499948	6939892	1.05	27.82	LCC database
mh63	499823.5	6940003	1.05	25.71	LCC database
mh64	500282.7	6940578	1.05	26.79	LCC database
mh65	500167.6	6940515	1.05	26.41	LCC database
mh66	500454.5	6940299	1.05	40.36	LCC database
mh67	500166	6940491	1.05	27.28	LCC database
mh68	500428.2	6940747	1.2	26.81	LCC database
mh69	500369.4	6940759	1.2	26.33	LCC database
mh70	500325.5	6940766	1.5	25.71	LCC database

Appendix C - Box plots of 1% AEP peak flood levels at key locations

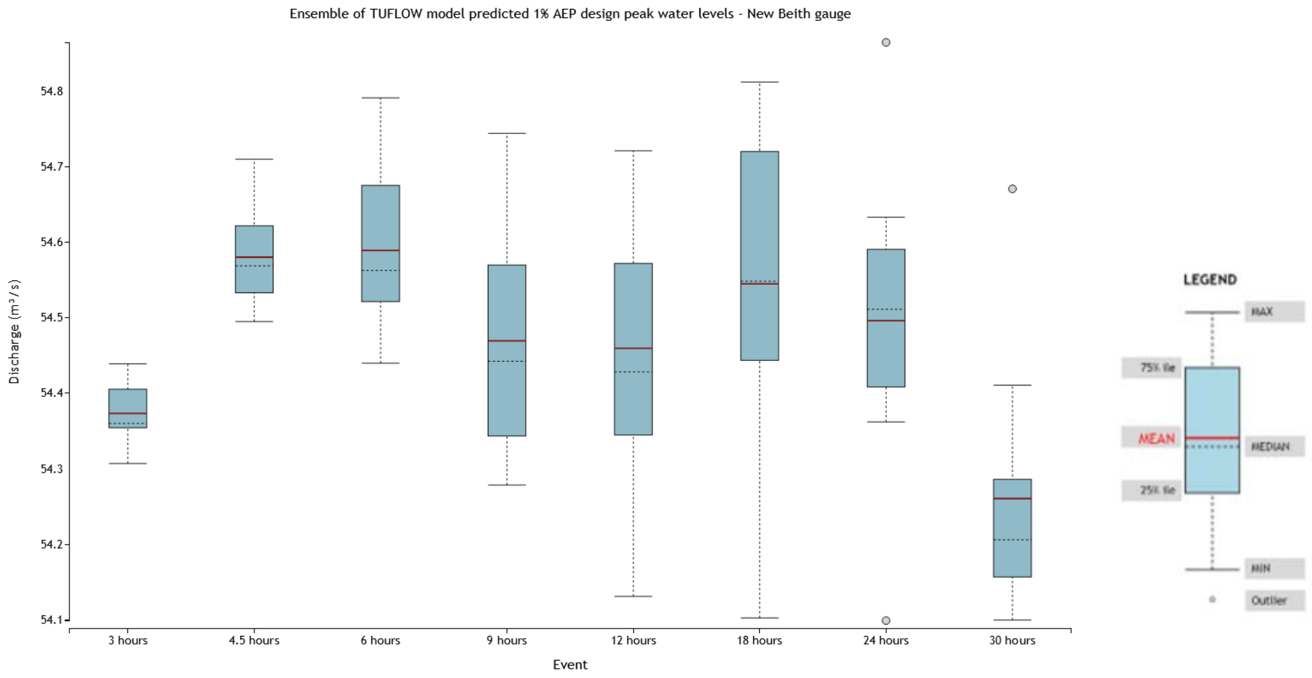

Figure C.1 - Box plot showing the ensemble of TUFLOW model predicted 1% AEP design peak water levels, Oxley Creek at New Beith AL gauge

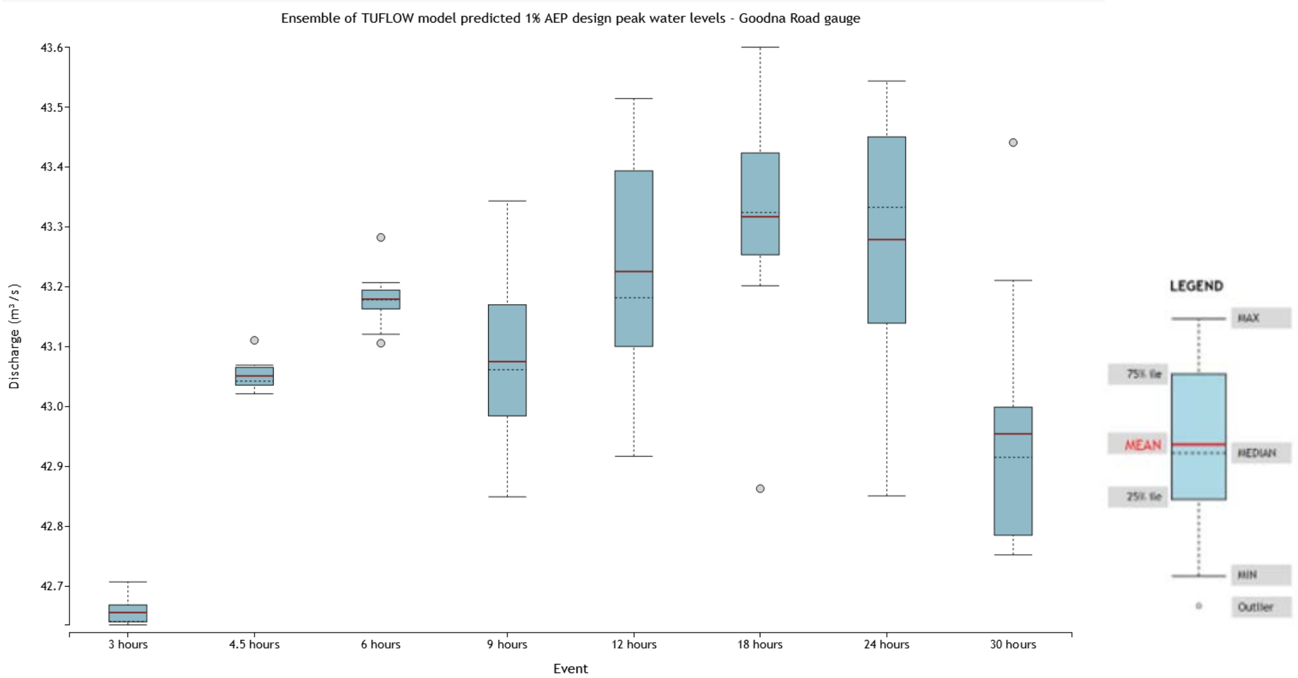

Figure C.2 - Box plot showing the ensemble of TUFLOW model predicted 1% AEP design peak water levels, Oxley Creek at Goodna Road

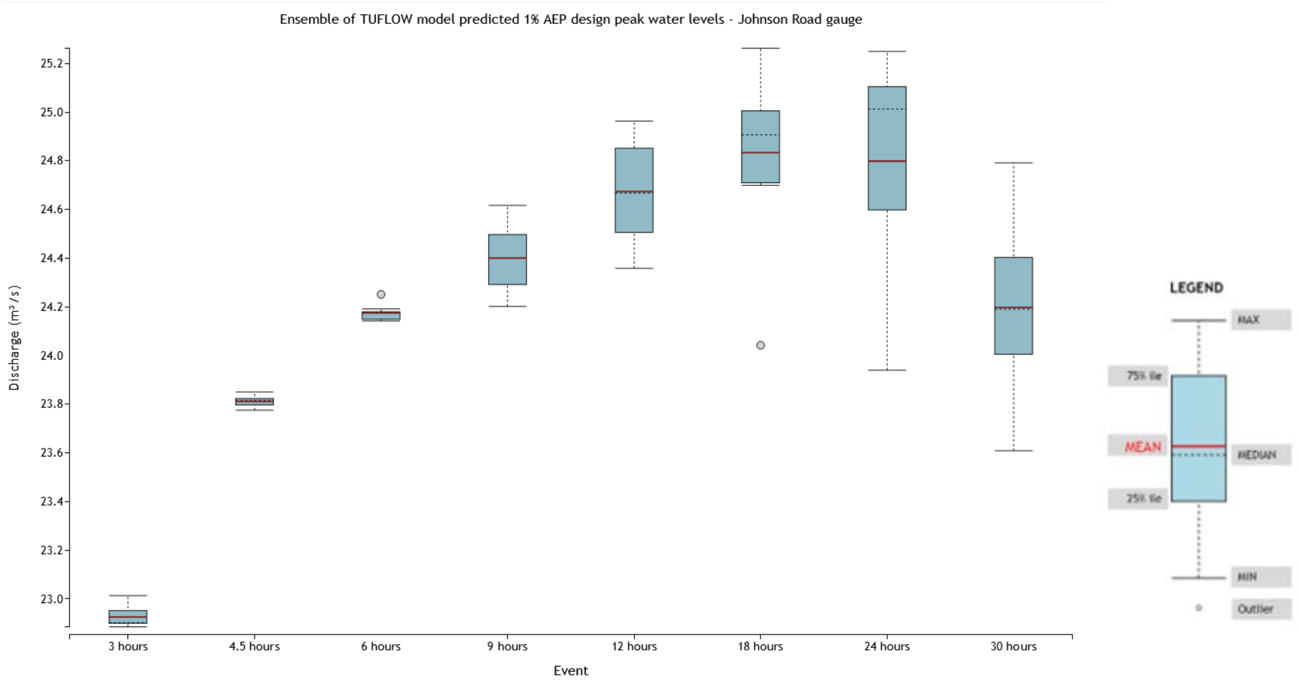

Figure C.3 - Box plot showing the ensemble of TUFLOW model predicted 1% AEP design peak water levels, Oxley Creek at Johnson Road

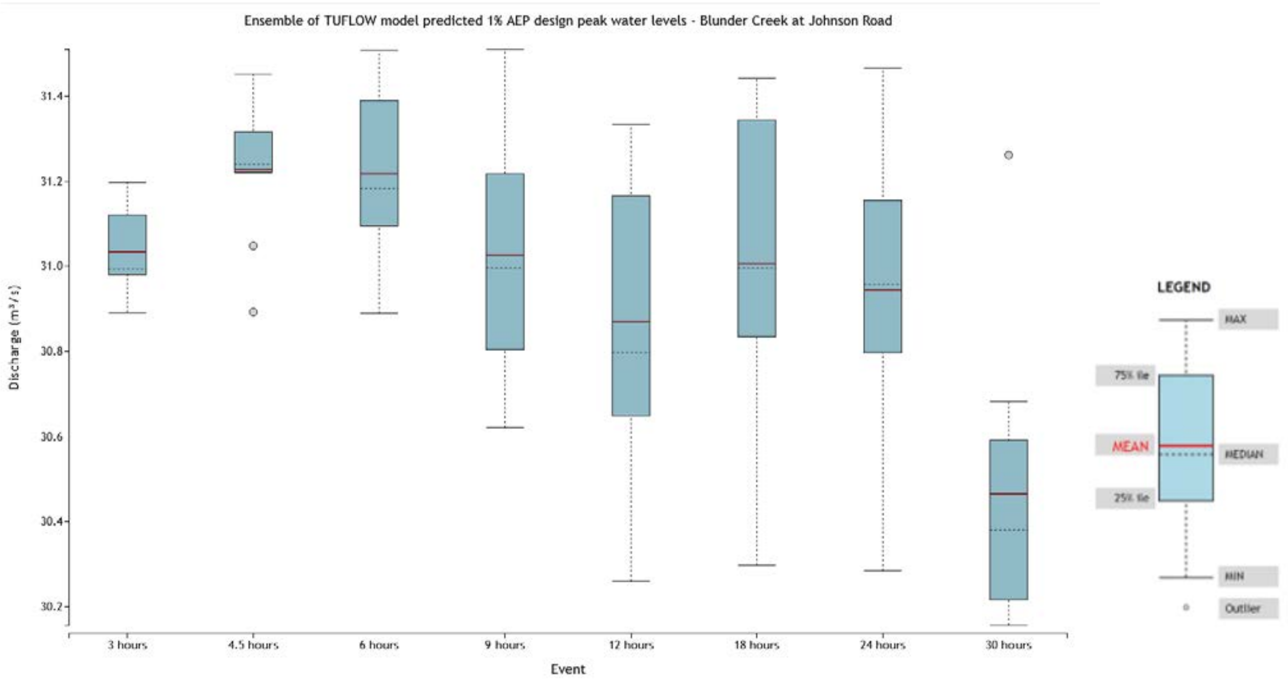

Figure C.4 - Box plot showing the ensemble of TUFLOW model predicted 1% AEP design peak water levels, Blunder Creek at Johnson Road

Appendix D - Flood maps