Logan and Albert Rivers Flood Study

Finalisation Project

Logan City Council

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1 Introduction

1.1 BACKGROUND

Logan City Council (LCC) engaged WRM Water and Environment Pty Ltd (WRM) to develop, calibrate and validate hydrologic and hydraulic models of the Logan and Albert rivers catchment. These models will be used by LCC to estimate design discharges, flood levels, depths, velocities and flood hazard along the Logan and Albert rivers.

LCC engaged WRM to undertake the following:

- Set up and calibrate an XP-RAFTS hydrologic and TUFLOW hydraulic model against available data for the January 1974, April 1990, January 2013 and March 2017 flood events;
- Undertake validation of the February 2022 flood event utilising the latest 2021 LiDAR topographic data for the floodplain;
- 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 Design Flood (PMPDF) event for the current climate (2020) rainfall and tidal estimates;
- Apply the Future Climate (2090) estimates of rainfall and tidal conditions 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 (AR&R 2019) (Ball et. Al, 2019).

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

1.2 LOGAN AND ALBERT RIVERS CATCHMENT DESCRIPTION

The Logan River has its headwaters in the McPherson Ranges along the Queensland/New South Wales border and flows in a generally north-easterly direction towards the coast where it discharges into Moreton Bay at Jacobs Well. The Logan River catchment has a total area of approximately 3,856 km^2. The significant tributaries of the Logan River include Teviot Brook, Slacks and Scrubby Creeks and the Albert River. Teviot Brook has a catchment area of 694 km^2 at its confluence with the Logan River near Cedar Pocket. Slacks and Scrubby Creeks join the Logan River at Tanah Merah and have a combined catchment area of some 121 km^2 to the confluence. The Albert River has a catchment area of 781 km^2 and discharges into the Logan River at Eagleby.

The topography of the catchment varies from steep hills, valleys and mountainous terrain in the upper catchment to wide, flat floodplains in the middle and lower reaches of the river. Catchment elevations range from approximately 1,350 mAHD in the McPherson Ranges to less than 2 mAHD at the river mouth. The catchment is scattered with many small storages in the form of farm dams, several on-river weirs and two major dams, Maroon Dam on Burnett Creek and Wyaralong Dam on Teviot Brook. The major land uses are forest and pasture in the upper catchment and pasture and rural residential in the middle and lower catchments. Major urban centres are located at Logan City and Beenleigh on the north and south banks of the lower Logan River.

2 Study methodology

2.1 HYDROLOGIC MODEL DEVELOPMENT

An XP-RAFTS runoff routing model (Innovyze, 2019) was developed for the Logan and Albert Rivers catchment to its outlet at Moreton Bay. The XP-RAFTS hydrologic model was calibrated against the January 1974, April 1990, January 2013 and March 2017 flood events. The aim of the calibration was to match predicted peak discharges with recorded peak discharges at the following stream gauges:

- Teviot Brook at the Overflow (GS 145012a);
- Logan River at Round Mountain (GS 145008a);
- Logan River at Yarrahappini (GS 145014a);
- Albert River at Bromfleet (GS 145102a); and
- Albert River at Wolffdene (GS 145196a).

Calibration of the hydrological model at other gauging stations (Logan River at Macleans Bridge, Logan Village, Waterford, Parklands and Riedel Road) is not possible due to the lack of accurate rating curves, and the influence of tailwater.

The XP-RAFTS model was validated against recorded discharges for the February 2022 event to confirm the adopted model parameters.

2.2 HYDRAULIC MODEL DEVELOPMENT

A TUFLOW two-dimensional (2D) hydrodynamic model (BMT, 2019) was developed for the Logan and Albert rivers and its tributaries. The updated model includes embedded one-dimensional (1D) elements representing culverts. The hydraulic model extends upstream along the Logan River to Gleneagle, and along the Albert River to Birnam. The following two hydraulic models were developed for this study:

- **'Fast Model'** – This model was configured with a grid cell size of 20 m. The purpose of this model is to allow the selection of critical design storms, which was then be simulated using a finer 'detailed model'.
- **'Detailed Model' –** This model was configured with a grid cell size of 10 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 Model' and 'Detailed Model' were calibrated (2018-03-AD_iSP) to match recorded water levels for the January 1974, April 1990, January 2013 and March 2017 flood events at the following stream gauges (if data is available):

- Logan River at Yarrahappini (GS 145014a);
- Logan River at Maclean Bridge (GS40935);
- Logan River at Logan Village (GS540596);
- Logan River at Waterford (GS40878);
- Slacks Creek at Loganlea Road (GS40091);
- Logan River at Parklands (GS540645);
- Albert River at Bromfleet (GS145102a);
- Albert River at Wolffdene (GS 145196a); and

- Albert River at Beenleigh (GS540644).

The 'Fast Model' and 'Detailed Model' were also calibrated against surveyed debris marks for the January 2013 and March 2017 flood events.

WRM undertook a validation of the hydraulic model for the February 2022 event at stream gauges and debris marks. No model parameters were adjusted as this was a validation event only.

2.3 MODEL CALIBRATON

Predicted inflow hydrographs from the hydrologic model were used as input to the hydraulic models. 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 flood events. Rating curves for stream gauges were combined with the results of the TUFLOW model to allow the calibration of the hydrologic model. The calibration process involved adjusting model parameters to achieve a set of parameters to utilise in the design event modelling. A model validation step was undertaken to model the February 2022 flood event with the adopted set of calibration parameters. This validation step ensures confidence in the model.

For the January 2013 and March 2017 flood events, the hydraulic model predictions were also compared against surveyed peak flood levels across the Logan and Albert rivers floodplains. The hydrologic model was calibrated to two key gauges located near the upstream boundary of the hydraulic model (Yarrahappini and Bromfleet). These gauges have reliable rating curves, and are unaffected by tidal influences or significant attenuation due to floodplain storage.

The calibration of the model downstream of these two gauges was undertaken in the hydraulic model. Due to the significant amount of tidal influence and floodplain storage in the lower Logan River system it was not possible to jointly calibrate the hydrologic model to match the hydraulic model.

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 model calibration and validation method 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 Logan River catchment for the 50% (1 in 1.44), 20% (1 in 5), 10% (1 in 10), 5% (1 in 20), 1% (1 in 100), 0.5% (1 in 200), 0.2% (1 in 500) and 0.05% (1 in 2,000) AEP and the PMPDF events for the Current Climate (2020). In addition, the Future Climate (2090) estimates were derived for the 20% (1 in 5), 10% (1 in 10), 5% (1 in 20), 1% (1 in 100), 0.5% (1 in 200) and 0.2% (1 in 500) AEP events.

Design event hydrology has been undertaken in accordance with the AR&R 2019 (Ball et al, 2019) guidelines. A summary of the proposed methodology and inputs adopted to estimate design discharges is provided in Section 9 of this report.

The XP-RAFTS model design event discharges were reconciled against FFA estimates at the following four gauges:

- Teviot Brook at the Overflow (GS 145012a);
- Logan River at Yarrahappini (GS 145014a);
- Albert River at Bromfleet (GS 145102a); and
- Albert River at Wolffdene (GS 145196a).

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 the Logan River and its tributaries for events ranging from the 50% AEP to the PMPDF event, for both the current climate and future climate scenarios. The hydraulic model was configured to produce maximum water surface levels, depth, velocities, depth-velocity products and flood hazard 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 be 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 median 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 ‘median’ results for each event. These design storms were then be 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 Logan-Albert River Flood Study Peer Review (2014)

The Logan-Albert River flood study was initially completed by Engeny in 2011 (on behalf of LCC). In 2014, WRM was engaged by Logan City Council (LCC) to implement peer review findings and reconfigure the hydrologic and hydraulic models of the Logan River catchment, referred to as the LCC (2014) models (WRM, 2014). Hydrologic modelling was undertaken using XP-RAFTS while hydraulic modelling was undertaken using the TUFLOW (BMT WBM, 2016) software package.

The LCC (2014) TUFLOW model incorporated key hydraulic structures including culverts and bridges within the Logan River catchment, including those located within the Slacks Creek catchment. The hydraulic structure information contained in this model was used to assist in the development of the Logan and Albert rivers hydraulic model for the current study.

3.1.2 Slacks and Scrubby Creeks Flood Study Peer Review (2015)

In 2015, WRM was engaged by Logan City Council (LCC) to peer review and reconfigure hydrologic and hydraulic models of the Slacks Creek and Scrubby Creek catchments, referred to as the LCC (2015) models (WRM, 2015). Hydrologic modelling was undertaken using XP-RAFTS while hydraulic modelling was undertaken using the TUFLOW (BMT WBM, 2016) software package.

The LCC (2015) TUFLOW model incorporated key hydraulic structures including culverts, trunk stormwater pipes and bridges within the Slacks and Scrubby creeks catchment. The hydraulic structure information contained in this model was used to assist in the development of the Logan and Albert rivers hydraulic model for the current study.

3.1.3 M1 Motorway Upgrade Hydraulic Study (2016 to 2017)

From 2016 to 2017, TMR engaged WRM to undertake a flood and cross-drainage study of the M1 Motorway corridor between Springwood Road and the Logan Motorway (in three separate study package areas) (WRM, 2017). Separate TUFLOW models of the three TMR study areas were developed, based on the LCC (2015) TUFLOW model for Slacks and Scrubby creeks.

The TUFLOW models developed for this study incorporated key existing hydraulic structures including culverts, trunk stormwater pipes, bridges and detention basins upstream and downstream of the M1 Motorway. The hydraulic structure information contained in this model was used to assist in the development of the Logan and Albert rivers hydraulic model for the current study.

3.1.4 Slacks and Scrubby Creeks Flood Study (2017 to 2018)

From 2017 to 2018, LCC engaged WRM to develop and calibrate a detailed catchment-wide hydrologic and hydraulic model of the Slacks and Scrubby creeks catchment (LCC, 2018). Design event modelling for this study was undertaken in accordance with AR&R 2016 (now the AR&R 2019) guidelines.

The Slacks and Scrubby Creek TUFLOW model developed for the study includes significant detail on trunk stormwater drainage and key cross drainage structures. Some hydraulic structures included in the LCC (2018) TUFLOW model were incorporated to the Logan and Albert rivers hydraulic model for the current study.

3.1.5 Logan and Albert Flood Study (2021)

Following the release of the Australian Rainfall & Runoff 2019 (ARR 2019) (Ball et al, 2019) guideline, WRM was commissioned by LCC to undertake an updated flood study of the Logan and Albert Rivers catchment.

- The XP-RAFTS hydrologic model and TUFLOW hydraulic models developed as part of the WRM (2014) flood study were updated to incorporate the latest AR&R 2019 methodology including the ensemble of temporal patterns approach for design event modelling. The XP-RAFTS and TUFLOW models were re-calibrated to the 1974, 1990 and 2013 events. The models were also calibrated to the 2017 event.
- Two separate TUFLOW hydraulic models were developed for this study. A 'fast model' with a grid cell size of 20 m was developed to allow the rapid simulation of all design storm temporal patterns for a range of durations. The results from the 'fast model' were used to identify 'representative design storms' for each storm duration to be simulated using the 'detailed model', which has a grid cell size of 10 m. Using this approach, detailed hydraulic model outputs including flood mapping were produced within a reasonable timeframe while accounting for the rigorous requirements of the ARR 2019 design event modelling methodology.
- Sensitivity analyses were also undertaken to assess the impact of climate change, culvert blockage and storm surge on the model results.

Note that that the Logan and Albert Flood Study Finalisation Project (this document) is considered a minor update to the substantial work described above, and completed as part of the Logan and Albert Flood Study 2021.

3.2 TOPOGRAPHIC DATA

Figure 3.1 shows the extents of the various topographic data for this study.

3.2.1 LiDAR survey data

LCC provided LiDAR survey data (flown in December 2021 and provided to LCC in July 2022) covering the majority of the Logan and Albert rivers hydraulic model extent. This data is referred to in this report as 2021 LiDAR data. This LiDAR campaign replaced the LCC 2017 LiDAR data. The LCC 2021 LiDAR was provided in both LAS point cloud and as regularised elevation points in one metre horizontal intervals. This data was used to generate a digital elevation model (DEM) for modelling and mapping purposes. Upon inspection of the LCC 2021 LiDAR data, some areas within the proposed hydraulic model extent are not covered by the data, including:

- Some floodplain areas in the upper eastern reaches of the Albert River;
- Some floodplain areas in the upper western reaches of the Logan River; and
- Some floodplain areas near at the Logan River mouth.

LCC previously provided LiDAR survey data (flown in May 2013) for the 2014 Logan and Alberts Rivers flood study (WRM, 2014). This data is referred to in this report as the 2013 LiDAR data. The 2013 LiDAR data was used to generate a DEM for modelling and mapping purposes, and to supplement the areas in the upper reaches of the Logan and Albert Rivers that are not covered by the 2017 or 2021 LiDAR data.

LiDAR survey data from the Queensland Government's ELVIS spatial information services was also obtained from the ELVIS website. This data (dated 2014) is referred to in this report as the 2014 LiDAR data. The 2014 LiDAR data was used to generate a DEM for modelling and mapping purposes, and to supplement the areas near the Logan River mouth (within the CoGC LGA) that are not covered by the 2013, 2017 and 2021 LiDAR data.

3.2.2 Bathymetric survey data

The bathymetry (i.e. the bed of the river channel) in the lower reaches of the Logan and Albert rivers was surveyed in detail in 2010 by LCC. It was suspected that significant bed movement may have occurred following the January 2013 flood event. Therefore, additional bathymetric survey in localised areas within the lower reaches of the Logan and Albert rivers was obtained in December 2013. This additional survey data indicated that the bed of the lower reaches of the Logan and Albert Rivers had been lowered, on average, by about 0.5 m following the January 2013 flood.

The combined bathymetry data obtained in 2010 and 2013 is referred to in this report as the 2013 bathymetry data. The 2013 bathymetry data consisted of bed scanning (boat survey) and cross section survey. The boat survey covers the Logan River channel from Riedel Road up to Stockleigh, and the Albert River channel from the Logan River confluence up to Wolffdene. Cross section survey data was available for the Logan River channel between Stockleigh and Yarrahappini, and for the Albert River channel between Wolffdene and Bromfleet. The 2013 bathymetry data was used for hydraulic modelling in the WRM (2014) study.

From June to August 2019, additional bathymetric survey for the Logan and Albert rivers was undertaken by RPS Australia Pty Ltd. This data is referred to in this report as the 2019 bathymetry data. The 2019 bathymetry data also consist of bed scanning (boat survey) and cross section survey. The extent of the 2019 bathymetry data is similar to the 2013 bathymetry data. The 2019 boat survey data has a horizontal accuracy of approximately ±1.0 m and a vertical accuracy of approximately ±0.2 m. The cross-section survey has horizontal and vertical accuracies of approximately ±0.05 m.

For the current study, the 2013 bathymetry survey was used in the hydraulic model for model calibration against the January 1974, April 1990, January 2013 flood events. The 2019 bathymetry data was used in the hydraulic model for model calibration against the March 2017 and February 2022 flood event and was used for design event modelling.

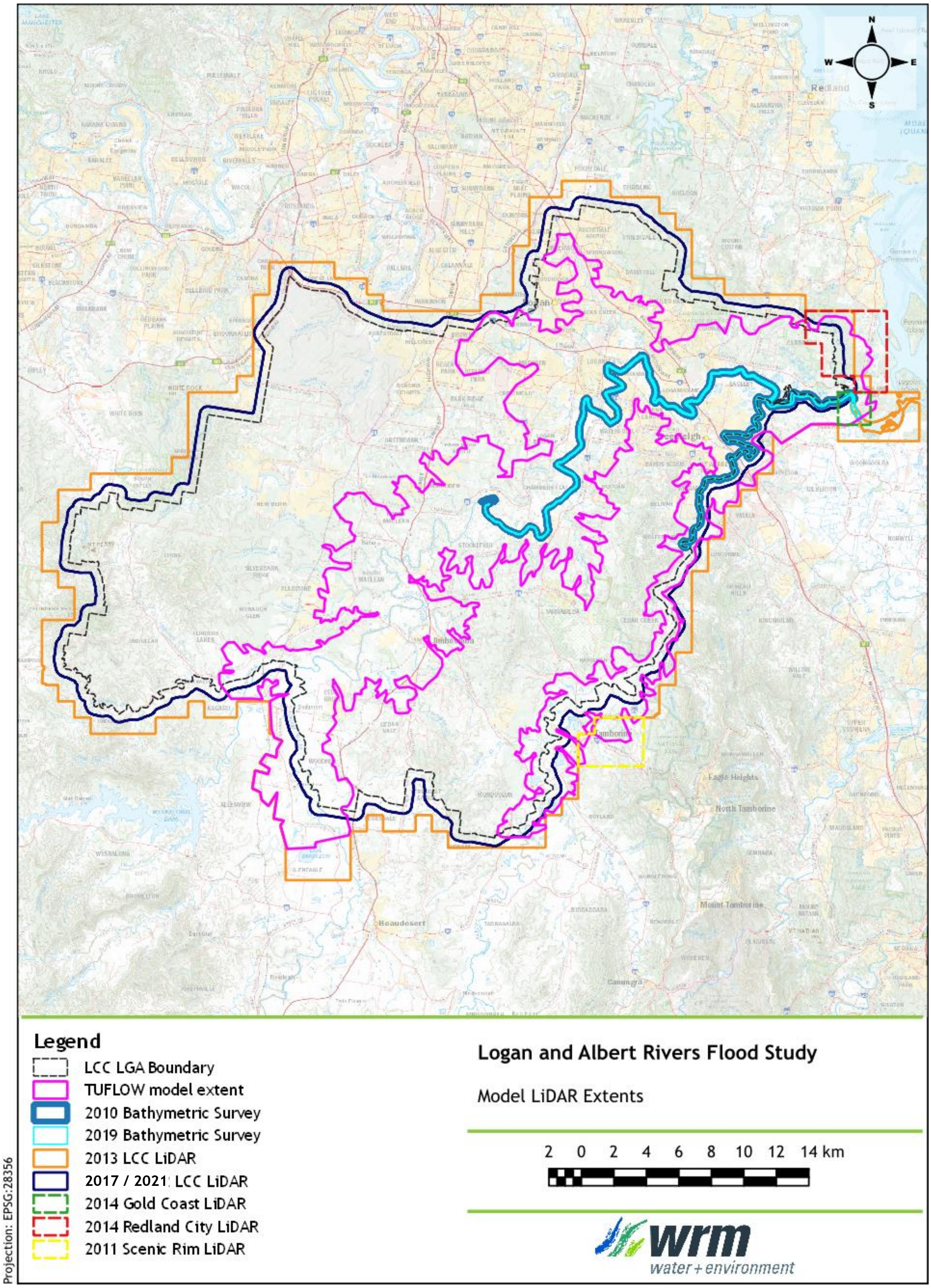

Figure 3.1 – Extent of topographical data used for this study

3.3 COUNCIL 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 key bridges and culverts located throughout the Logan and Albert rivers catchment. The data also contains key details for culvert structures including dimensions and invert levels, however details of the bridges (except for their locations) are limited.

3.4 AS-CONSTRUCTED DRAWINGS

LCC supplied WRM with as-constructed drawings for 14 bridges throughout the Logan and Albert rivers catchment. These drawings were used to configure the bridges in the hydraulic model.

3.5 COUNCIL'S BRIDGE SURVEY

LCC undertook site survey on 13 bridge structures throughout the Logan and Albert rivers catchment whereas constructed drawings are not available. These drawings were used to configure the bridges in the hydraulic model.

3.6 RAINFALL DATA

3.6.1 Pluviograph data

Table 3.1 shows the available pluviograph data from rainfall stations within and adjacent to the Logan River catchment for the January 1974, April 1990, January 2013, March 2017 and February 2022 events. Figure 3.2, Figure 3.3, Figure 3.4, and Figure 3.5 show the locations of these pluviograph stations.

Table 3.1 - Pluviograph Data Availability for the Logan-Albert Catchment

Station No.	Station Owner	Station Name	Pluviograph Data Available				
			1974	1990	2013	2017	2022
6263 / 540596	LCC	Logan Village Alert			Y	Y	Y
6266 / 540598	LCC	Bahrs Scrub Alert			Y	Y	Y
40004	BOM	Amberley Aero	Y				
40014	BOM	Beaudesert Cryna	Y	Y			
40094	BOM	Harrisville PO		Y			
40135	BOM	Moogerah Dam	Y	Y			
40178	BOM	Rathdowney Post Office	Y	Y			
40192	BOM	Springbrook Forestry	Y				
40197	BOM	Mount Tamborine Fern St	Y	Y			
40211	BOM	Archerfield Aero		Y			Y
40312	BOM	New Beith	Y				
40335	BOM	Mt Tamborine Alert					Y
40341	BOM	Wongawallan Alert					Y
40345	BOM	Luscombe Alert					Y
40376	BOM	Tyungun Alert					Y

Station No.	Station Owner	Station Name	Pluviograph Data Available				
			1974	1990	2013	2017	2022
40406	BOM	Beenleigh Bowls Club	Y	Y			
40416	BOM	Clearview TM					Y
40454	BOM	Jimboomba (Glenlogan)	Y				
40457	BOM	Wacol Dpi	Y				
40460	BOM	Mount Cotton Farm	Y				
40659	BOM	Greenbank Thompson Road		Y			
40677	BOM	Maroon Dam		Y			
40715	BOM	Shailer Park Oregon Drive		Y			
40784	BOM	Calamvale Alert					Y
40785	BOM	Carole Park Alert					Y
40786	BOM	Jingle Downs				Y	Y
40788	BOM	Johnson Rd			Y		Y
40794	BOM	Greenbank Alert			Y	Y	Y
40844	BOM	Beechmont Alert					Y
40845	BOM	Binna Burra Alert					Y
40847	BOM	Hinze Dam HW Alert					Y
40848	BOM	Lower Springbrook Alert					Y
40865	BOM	Cannon Cove TM					Y
40867	BOM	Kalbar TM					Y
40874	BOM	Brisbane Rd Alert					Y
40876	BOM	Wilsons Peak				Y	Y
40878	BOM	Waterford Alert			Y	Y	Y
40882	BOM	Numinbah Alert					Y
40930	BOM	Laheys Lookout				Y	
40931	BOM	O'Reillys				Y	Y
40932	BOM	Darlington				Y	Y
40933	BOM	Foxley				Y	Y
40934	BOM	Romani Alert			Y	Y	
40935	BOM	Maclean Bridge			Y	Y	Y
40936	BOM	Lumeah				Y	Y
40937	BOM	Benobble Alert				Y	Y
40938	BOM	Bromfleet				Y	Y
40939	BOM	Beaudesert				Y	Y

Station No.	Station Owner	Station Name	Pluviograph Data Available				
			1974	1990	2013	2017	2022
40941	BOM	Kooralbyn				Y	Y
40942	BOM	Palen Creek				Y	Y
40944	BOM	Rudds Ln				Y	Y
40946	BOM	Rathdowney Alert				Y	Y
40948	BOM	Knapps Peak				Y	Y
40949	BOM	Boonah Alert				Y	Y
40983	BOM	Beaudesert Drumley St			Y		Y
145003	DERM	Forest Home			Y		Y
145008 / 40945	DERM	Round Mountain			Y	Y	Y
145010 / 40943	DERM	Dieckmans Bridge			Y	Y	Y
145011 / 40947	DERM	Croftby			Y	Y	Y
145012	DERM	The Overflow		Y			
145014 / 40940	DERM	Yarahappinni			Y	Y	Y
145026	DERM	Tramway Lane			Y		
145027	DERM	Ward Road			Y		
145031	DERM	Coulsons			Y		
146015	DERM	Numinbah Valley			Y		
145196 / 40761	DERM	Wolffdene			Y	Y	Y
540023	BOM	Cainbable	Y				
540054	BOM	Little Nerang Dam Alert					Y
540065	BOM	Peak Crossing Alert					Y
540078	BOM / LCC	First Ave			Y	Y	Y
540079	BOM / LCC	Reserve Park			Y	Y	Y
540091	BOM / LCC	Loganlea Rd			Y	Y	Y
540125	BOM	Eight Mile Plains Alert					Y
540151	BOM	Kalbar Weir Alert					Y
540154	BOM	Harrisville Alert					Y
540173	BOM	Tarome Alert-					Y
540195	BOM	Washpool Alert					Y
540233	BOM / LCC	Millars Rd			Y	Y	Y
540234	BOM / LCC	Gowan Rd			Y	Y	Y
540235	BOM / LCC	Wine Glass			Y	Y	Y
540236	BOM / LCC	Riedel Road			Y	Y	Y
540237	BOM / LCC	Bega Rd			Y	Y	Y

Station No.	Station Owner	Station Name	Pluviograph Data Available				
			1974	1990	2013	2017	2022
540255	BOM / LCC	Carbrook			Y	Y	Y
540581	BOM	Springbrook TM		Y			
540644	BOM	Beenleigh				Y	Y
540645	BOM	Parklands				Y	Y
540646	BOM	Oxley Creek				Y	Y
540675	BOM	Schmidts Rd				Y	Y
540688	BOM	Lower Quinzeh				Y	Y
540689	BOM	Flagstone Ck (Jimboomba)				Y	Y
540690	BOM	Kilmoyla Rd				Y	Y
540691	BOM	Tamboring				Y	Y
540692	BOM	Waller Rd				Y	Y
540700	BOM	Spring Creek Road Alert					Y
540707	BOM	White Swamp Alert					Y
540712	BOM	Maroon Dam Inflow Alert					Y
540713	BOM	Harpers Crossing Alert					Y
540714	BOM	Kooralbyn Bridge Alert					Y
540715	BOM	Double Crossing Rd Alert					Y
540726	BOM	Upper Quinzeh				Y	
540729	BOM	North Tamborine Alert					Y
540787	BOM	Park Ridge (Stoney Camp Rd) Alert					Y
540790	BOM	Cedar Creek (Plunkett Rd) Alert					Y
540796	BOM	Darlington School Alert					Y
541020	BOM	Upper Burnett	Y				

3.6.2 Daily rainfall data

Historical rainfall records from Commonwealth Bureau of Meteorology (BoM) stations within and in the vicinity of the Logan River catchment were provided by LCC and the BOM for the January 1974, April 1990, January 2013, March 2017 and February 2022 flood events. Table 3.2 shows the available rainfall data for the 1974, 1990, 2013, 2017 and 2022 events. Figure 3.2, Figure 3.3, Figure 3.4, and Figure 3.5 show the locations of these daily rainfall stations.

Table 3.2 - Daily Rainfall Data Availability for the Logan-Albert Catchment

Station No.	Station Name	Daily Rainfall Data Available				
		1974	1990	2013	2017	2022
40000	Abbotsford	Y				
40012	Barney View	Y				
40015	Beechmont		Y			
40024	Boonah (Stark Ave)	Y	Y			
40042	Canungra (Finch Ave)	Y	Y	Y	Y	
40044	Darlington	Y				
40080	Foxley		Y			
40094	Harrisville PO				Y	
40097	Hillview (Christmas Ck)	Y				
40104	Kalbar PO (Englesberg Village)	Y	Y	Y	Y	
40107	Bruff Hill	Y				
40135	Moogerah Dam				Y	
40139	Mount Alford	Y		Y	Y	
40141	Mount Cotton West	Y	Y	Y		
40150	Mundoolun	Y	Y			
40156	Toolamba	Y	Y			
40160	Nerang (Gilston Rd)	Y				
40162	Numinbah State Farm	Y	Y			
40166	Oxenford (Oberon Way)	Y				
40167	Palen Creek Correctional	Y				
40178	Rathdowney PO				Y	
40181	Roadvale	Y				
40182	Green Mountains	Y				
40185	Russell Island	Y	Y			
40190	Southport	Y	Y			
40196	Tallebudgera	Y	Y			
40197	Mt Tamborine Fern St				Y	
40198	Tarome	Y	Y	Y	Y	
40211	Archerfield Airport				Y	Y
40244	Sunnybank Bowls Club	Y	Y	Y	Y	
40266	Aratula	Y	Y			
40269	Karragarra Island	Y	Y			
40290	Maroon	Y	Y	Y	Y	

Station No.	Station Name	Daily Rainfall Data Available				
		1974	1990	2013	2017	2022
40291	Redland bay QLD Uni Farm	Y	Y			
40306	Loganlea	Y				
40314	Ripley Valley	Y	Y			
40319	Rocky Point Sugar Mill	Y	Y			
40335	Mt Tamborine Alert			Y	Y	Y
40341	Wongawallan Alert			Y	Y	Y
40342	Chigigum Farm	Y				
40345	Luscombe Alert			Y	Y	Y
40376	Tyungun Alert			Y	Y	Y
40394	Mount Barney	Y	Y	Y	Y	
40402	Fortland	Y	Y			
40404	Glenapp	Y				
40407	Lumeah	Y	Y			
40410	Jacobs Well	Y				
40411	Romani	Y	Y			
40413	Central Kerry	Y	Y			
40416	Clearview				Y	Y
40429	Rochedale South	Y	Y			Y
40439	Springbrook (Alpine Panorama)	Y				Y
40471	Couran Cove	Y				
40485	Wilsons Peak	Y	Y	Y	Y	
40487	Binna Burra	Y	Y			
40490	Carneys Creek	Y	Y	Y	Y	
40523	Border Gate	Y	Y			
40524	Little Nerang Dam	Y	Y			Y
40534	Wunburra	Y	Y			
40535	Cainbable	Y				Y
40538	Tabragalba	Y	Y			
40542	Macleans Bridge		Y		Y	Y
40550	Natural Bridge	Y	Y			
40583	Widgee	Y	Y	Y	Y	
40606	Upper Mudgeeraba Water				Y	
40607	Springbrook Rd				Y	Y
40610	Darlington		Y			Y

Station No.	Station Name	Daily Rainfall Data Available				
		1974	1990	2013	2017	2022
40659	Greenbank Thompson Rd				Y	
40677	Maroon Dam				Y	Y
40714	Round Mountain TM		Y		Y	Y
40738	Bromfleet				Y	Y
40754	Rathdowney				Y	Y
40762	Yarrahappini TM		Y		Y	Y
40768	Jimboomba Millstream Road		Y	Y	Y	
40784	Calamvale Alert			Y	Y	Y
40785	Carole Park Alert			Y	Y	Y
40788	Forestdale			Y	Y	Y
40792	Ripley Alert			Y		
40793	Lyons Alert			Y		
40794	Greenbank Alert			Y		Y
40832	Forest Home				Y	Y
40841	Croftby				Y	Y
40844	Beechmont Alert				Y	Y
40845	Binna Burra Alert			Y	Y	Y
40846	Clearview Alert			Y	Y	Y
40847	Hinze Dam HW Alert				Y	Y
40854	Logan City Water Treatment Plant				Y	
40865	Cannon Cove				Y	Y
40867	Kalbar TM			Y	Y	Y
40874	Brisbane Road Alert				Y	Y
40882	Numinbah Alert			Y	Y	Y
40930	Laheys Lookout Alert			Y		Y
40931	O'Reillys Alert			Y		Y
40933	Foxley Alert			Y		Y
40934	Romani Alert			Y		
40936	Lumeah Alert			Y		Y
40937	Benobble Alert			Y		Y
40938	Bromfleet Alert			Y		Y
40942	Palen Ck Alert			Y		Y
40944	Rudds Lane Alert		Y	Y		Y
40948	Knapps Peak Alert			Y		Y

Station No.	Station Name	Daily Rainfall Data Available				
		1974	1990	2013	2017	2022
40949	Boonah Alert			Y		Y
40964	Regents Park				Y	
40973	Windaroo			Y	Y	
40983	Beaudesert Drumley St			Y	Y	Y
40985	Bellbird Park (Purser Rd)				Y	Y
41046	The Head	Y	Y	Y		Y
41085	Queen Mary Falls		Y		Y	Y
41134	Top Plains		Y			
41208	Spring Creek		Y			Y
41464	Oakington			Y	Y	Y
56023	Old Koreelah		Y		Y	Y
57020	Urbenville PO		Y			
57024	Woodenbong		Y	Y	Y	
57026	Old Koreelah		Y*			
57085	Old Bonalbo		Y			
58005	Brays Ck (Misty Mountain)			Y	Y	Y
58016	Unumgar			Y	Y	
58032	Kyogle PO			Y		
58044	Nimbin Post Office				Y	
58109	Tyalgum			Y		
58113	Green Pigeon			Y	Y	Y
58129	Kunghar		Y		Y	Y
58141	Loadstone		Y			
58148	Lillian Rock (Williams Rd)				Y	Y
58158	Murwillumbah (Bray Park)				Y	Y
58167	Uki (Tweed River)				Y	Y
58180	Nimbin (Goolmangar Ck)			Y	Y	Y
58186	Murwillumbah (Tweed River)				Y	
58193	Eungella (Oxley River)			Y	Y	Y
58194	Dairy Flat		Y	Y	Y	
58195	Wiangaree PO				Y	
58204	Boat Harbour (Rous River)			Y	Y	Y

3.6.3 Rainfall isohyet mapping

The daily total rainfalls and pluviography data from the stations identified in Table 3.1 and Table 3.2 were used to create isohyet maps for the January 1974, April 1990, January 2013, March 2017 and February 2022 historical events.

Figure 3.2, Figure 3.3, Figure 3.4, Figure 3.5 and Figure 3.6 show the rainfall isohyet maps and coverage of available rainfall data and pluviographs for each event. These isohyet maps were derived based on five-day rainfall totals for the 1974 event, six-day rainfall totals for the 1990 and 2013 events, two-day rainfall totals for the 2017 event and 8-day rainfall totals for the 2022 event.

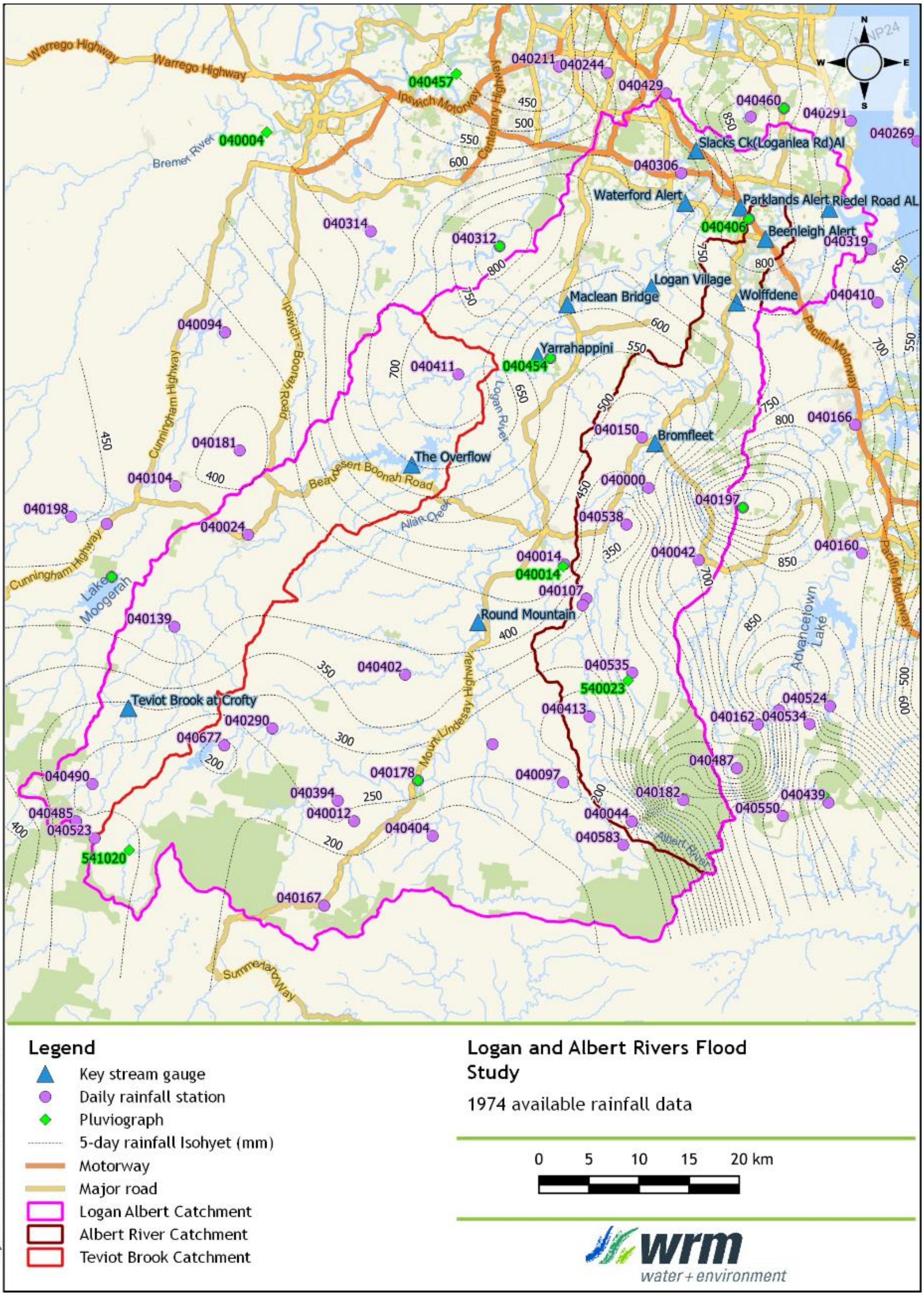

Figure 3.2 - Available rainfall data and 5-day rainfall isohyets (0900hrs 24/01/1974 to 0900hrs 28/01/1974), January 1974 event

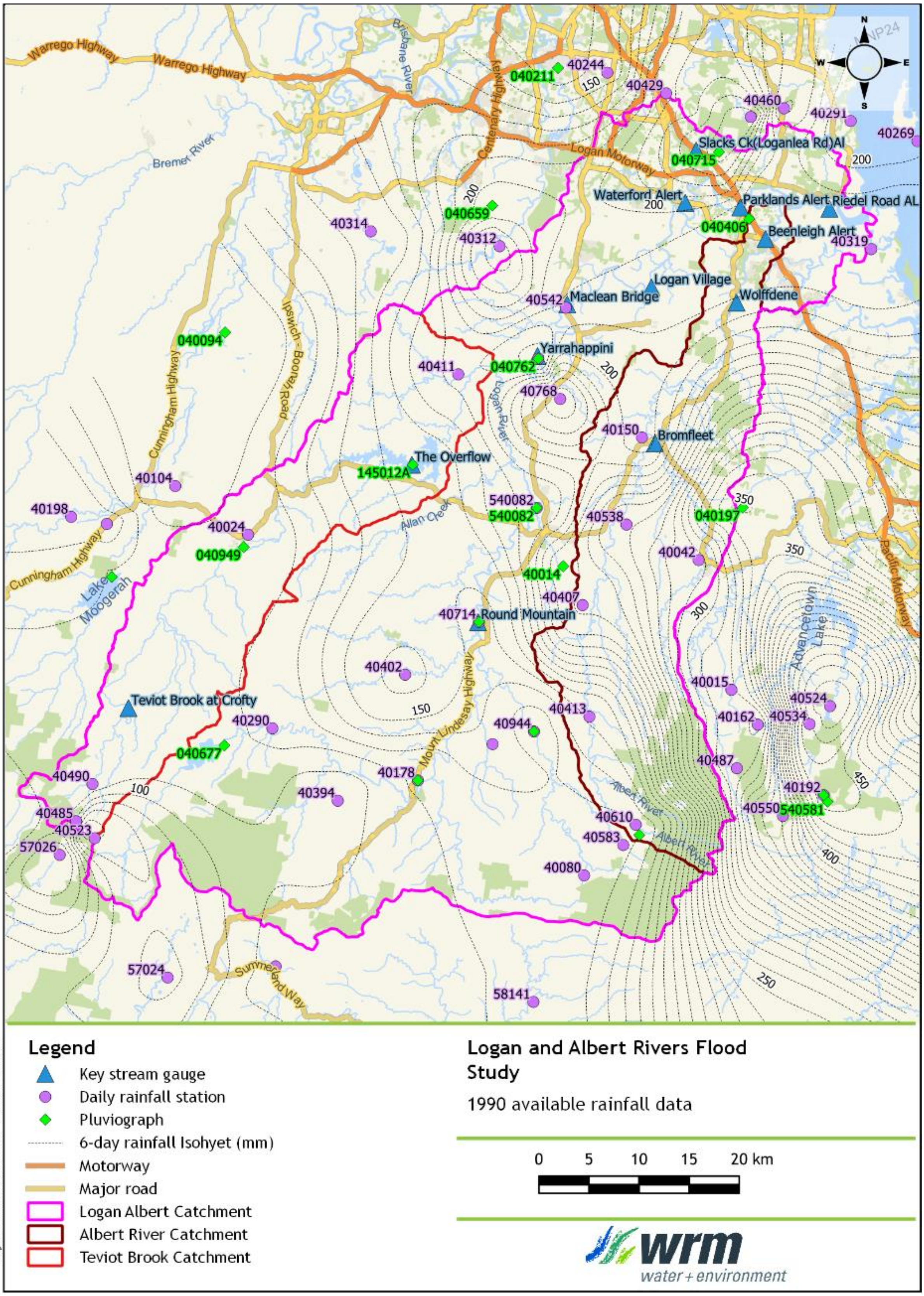

Figure 3.3 - Available rainfall data and 6-day rainfall isohyets (0900hrs 03/04/1990 to 0900hrs 09/04/1990), April 1990 event

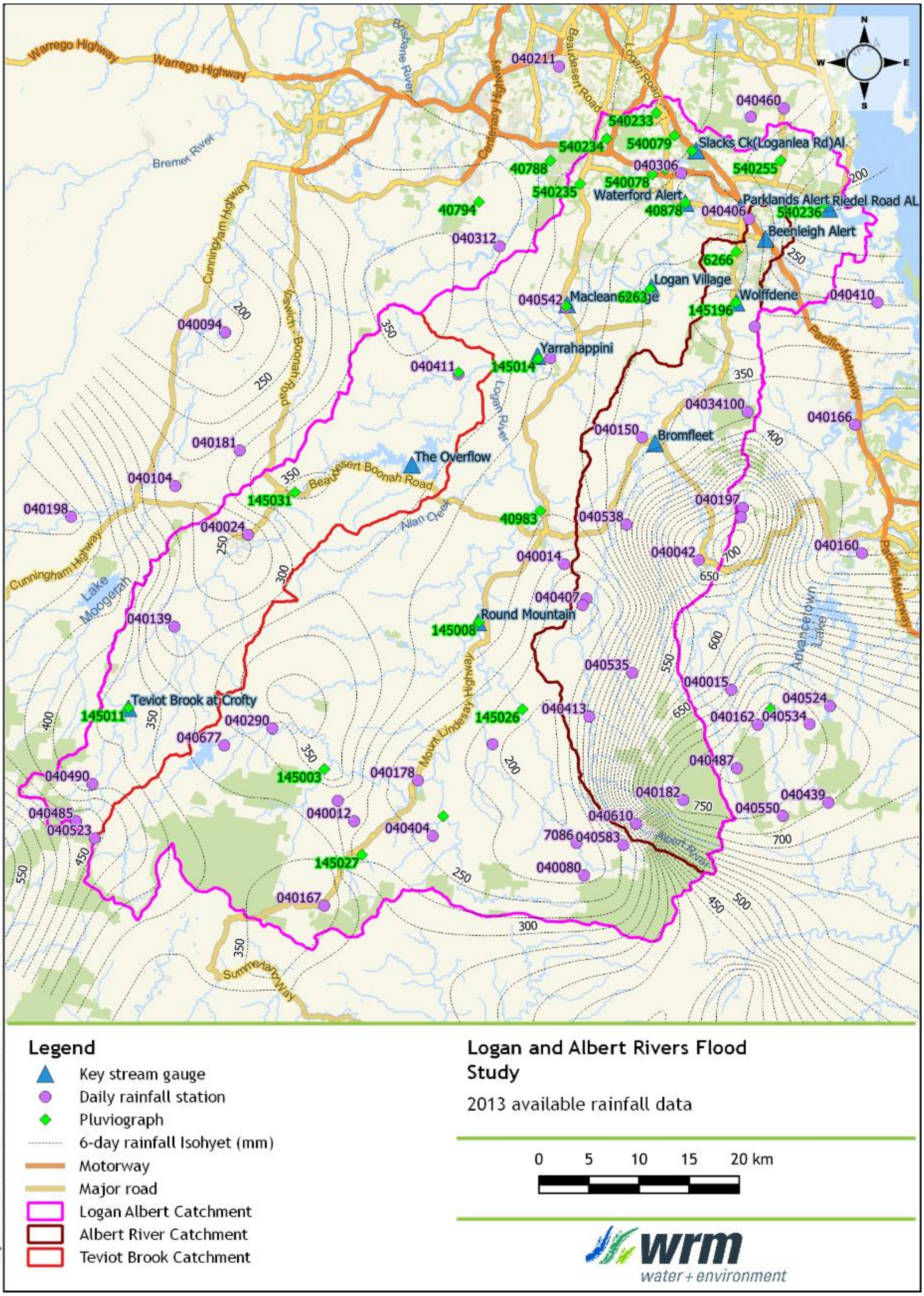

Figure 3.4 - Available rainfall data and 6-day rainfall isohyets (0900hrs 24/01/2013 to 0900hrs 30/01/1974), January 2013 event

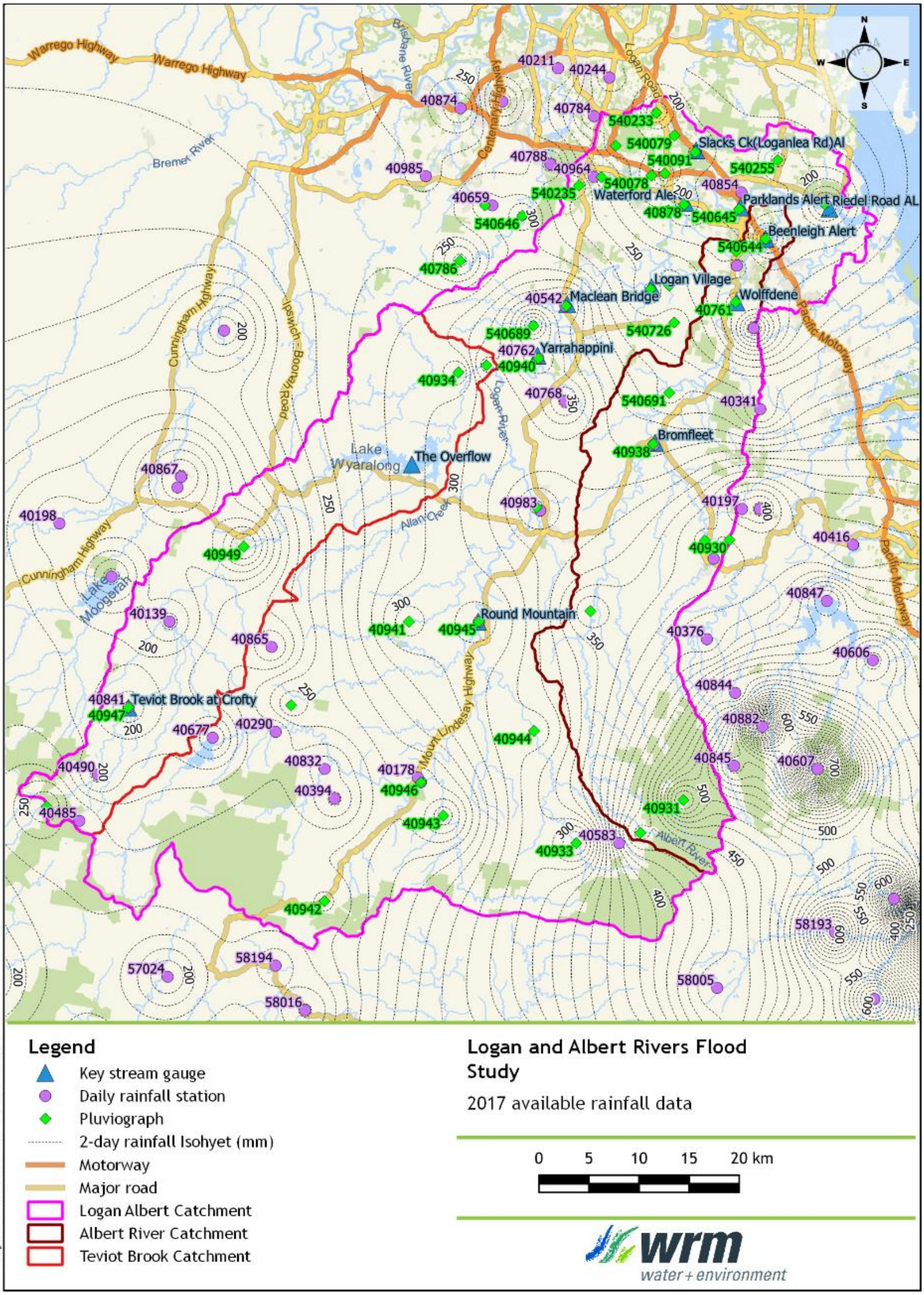

Figure 3.5 - Available rainfall data and 2-day rainfall isohyets (0900hrs 29/03/2017 to 0900hrs 31/03/2017), March 2017 event

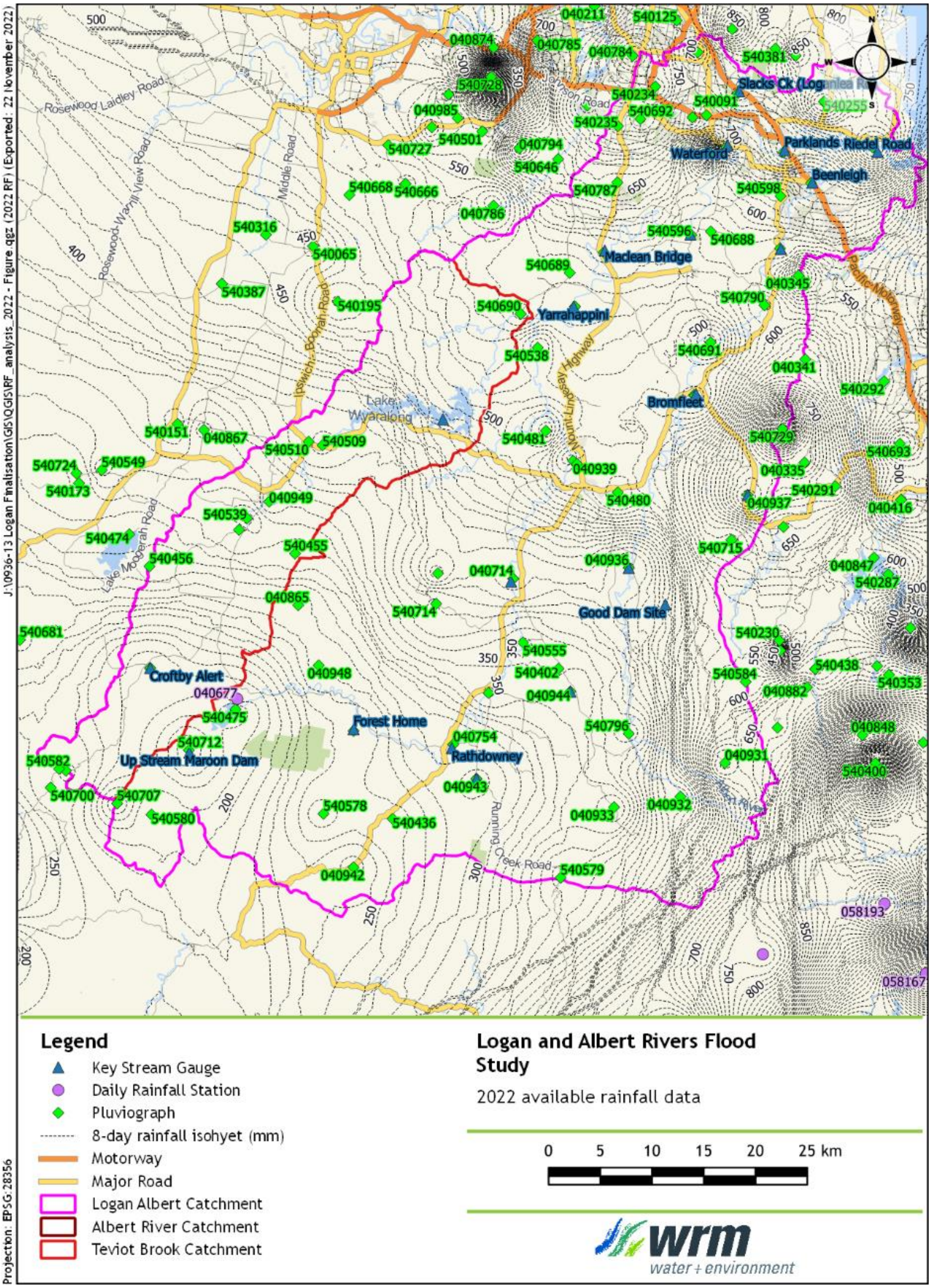

Figure 3.6 - Available rainfall data and 8-day rainfall isohyets (0000hrs 21/02/2022 to 0900hrs 1/03/2022), February 2022 event

3.7 STREAMFLOW DATA

The key stream gauging stations used for calibration of the Logan-Albert River catchment hydrologic models are listed below. Data from numerous other stream gauges within the catchment was used to verify the general timing and shape of predicted hydrographs for the calibration events; however the main emphasis of calibration was placed on the following gauges:

- Upper Logan River Catchment:
  - Logan River at Round Mountain (DNRM GS 145008A)
  - Logan River at Yarrahappini (DNRM GS 145014A)
- Teviot Brook Catchment:
  - Teviot Brook at The Overflow (DNRM GS 145012A)
- Albert River Catchment:
  - Albert River at Bromfleet (DNRM GS 145102B)
  - Albert River at Wolffdene (DNRM GS 145196A)
- Lower Logan River Catchment:
  - Logan River at Maclean Bridge Alert (BOM GS 040936)
  - Logan River at Logan Village (LCC GS 6263)
  - Logan River at Waterford Alert (BOM GS 040878)

The stream gauge locations are shown in Figure 3.2, Figure 3.3, Figure 3.4, Figure 3.5 and Figure 3.6. Table 3.3 shows the availability of stream flow data at the key gauge sites for each calibration event.

Table 3.3 - Stream gauge data availability for the Logan River catchment

Station No.	Station Name	Stream name	Streamflow data available				
			1974	1990	2013	2017	2022
145008A	Round Mountain	Logan River	Y	Y	Y	Y	Y
145014A	Yarrahappini	Logan River	Y	Y	Y	Y	Y
145012A	The Overflow	Teviot Brook	Y	Y	N	N	N
145102B	Bromfleet	Albert River	Y	Y	Y	Y	Y
145196A	Wolffdene	Albert River	Y	Y	N	Y	Y
040935	Maclean Bridge Alert	Logan River	N	Y	Y	Y	Y
6263	Logan Village	Logan River	N	N	Y	Y	Y
040878	Waterford Alert	Logan River	Y [a]	Y	Y	Y	Y

[a] - Partial hydrograph only

3.8 RATING CURVES

Rating curves for the key stream gauging stations outlined in Table 3.3 were reviewed as part of this study. The majority of the stream gauges are operated by DNRM, and have rating curves that are regularly updated based on gauged flows and changes in the waterway cross section at the gauge location. The maximum gauged height and / or gauged discharge for each of the gauge stations is shown in Table 3.4.

The stream gauges located at Maclean Bridge, Logan Village and Waterford are operated by the BOM or LCC and do not have rating curves based on gauged flows. Rating curves for these stations have largely been developed as part of previous studies or by hydraulic modelling undertaken by the gauge owner.

Table 3.4 – Stream gauge data and rating curves for the Logan River catchment

Station No.	Station Name	Stream name	Rating Table Source	Max. Gauged Height (m)	Max. Gauged Flow (m^3/s)
145008A	Round Mountain	Logan River	DNRM	14.88	1,047
145014A	Yarrahappini [a]	Logan River	DNRM	19.80	2,844
145012A	The Overflow	Teviot Brook	DNRM	9.67	390
145102B	Bromfleet	Albert River	DNRM	14.86	675
145196A	Wolffdene	Albert River	DNRM	10.86	1,214
040935	Maclean Bridge Alert	Logan River	BOM	-	-
6263	Logan Village	Logan River	LCC	-	-
040878	Waterford Alert	Logan River	BOM	-	-

[a] – The maximum gauged flow and maximum gauged water level at Yarrahappini were gauged at different times (i.e. different flood events)

3.8.1 Logan River at Round Mountain (DNRM GS 145008A)

Figure 3.7 shows the available and adopted rating curves for Round Mountain. The current DNRM rating curve for Round Mountain is based on gauged data up to 1,047 m^3/s at a 14.88 m gauge height. The rating has been extrapolated beyond this point by both DNRM and BOM. It is noted that the rating curve for Round Mountain is unchanged from the WRM (2014) study. The rating curve for this station has changed considerably between 1974 and 2013, potentially indicating changes in the waterway cross section at the site.

It is of note that hydrologic model predicts substantially higher discharges than the DNRM rating curve for water levels greater than 15 mGH. The smaller discharges predicted by the DNRM rating curves for such floods (January 1974 and January 2013) do not correlate with discharges at the downstream Yarrahappini stream gauge. An inspection of the DNRM floodplain cross section of the gauge site indicates that at water levels in excess of 15 mGH, significant flow would occur in the floodplain, facilitating large increases in discharge at comparatively minor increases in water level. Due to this fact, the BOM (2008) rating curve is considered to give better estimates of discharge at the gauge for larger floods. All of the hydraulic models developed for the Logan and Albert Rivers for various studies including the Engeny (2011), WRM (2014) and the current study do not extend upstream far enough to include the Round Mountain gauge, so model results cannot be used to confirm the BOM (2008) rating curve.

The following rating curves were adopted for the Round Mountain stream gauge:

- For estimating of discharges during the January 1974 event, DNRM Table-22 was adopted up to the highest gauges flow (1,047 m^3/s at a 14.88 m gauge height). Above this flow the adopted rating curve transitions to the BOM (2008) rating curve.
- For estimating of discharges during the April 1990 event, DNRM Table-35 was adopted up to the highest gauged flow. Above this flow the adopted rating curve transitions to the BOM (2008) rating curve.
- For estimating of discharges during the January 2013 event and the March 2017 event, DNRM Table-36 was adopted up to the highest gauged flow. Above this flow the adopted rating curve transitions to the BOM (2008) rating curve.

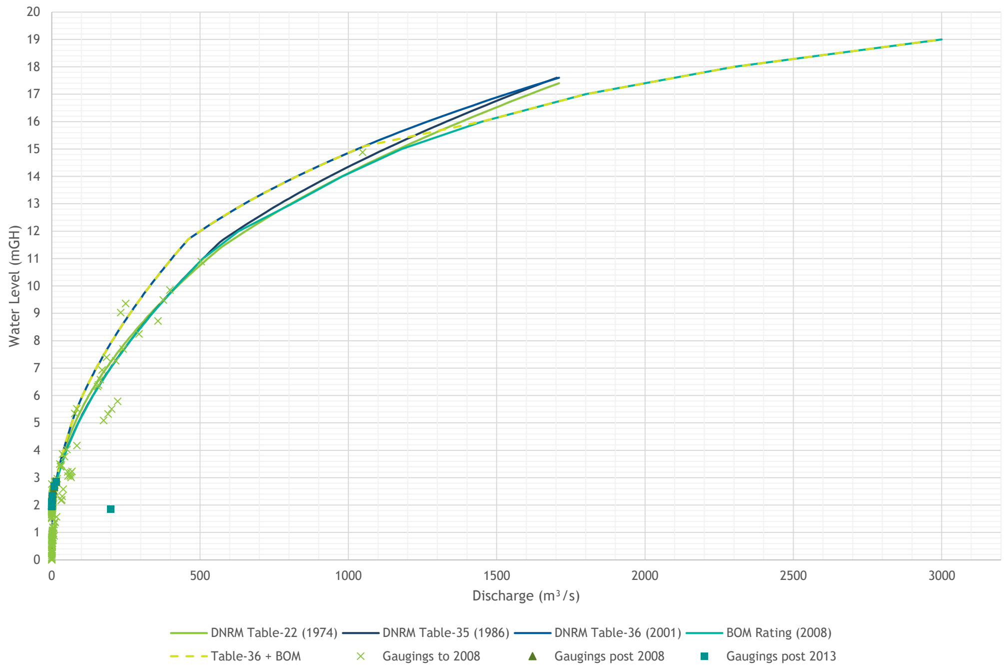

Figure 3.7 - Available rating curves, Logan River at Round Mountain (DNRM GS 145008A)

3.8.2 Logan River at Yarrahappini (DNRM GS 145014A)

Figure 3.8 shows the available and adopted rating curves for Yarrahappini. The current DNRM rating curve for Yarrahappini is based on gauged data up to 2,844 m^3/s at 18.36 m gauge height. The rating curve has been extrapolated above this point by DNRM and BOM. The DNRM rating curve for this station was adjusted slightly between 1999 and 2012, based on a gauging of 1,029 m^3/s at 15.318 mGH, taken in January 2011. The DNRM rating curve was adjusted again between 2012 and 2017, based on gaugings taken in March and April of 2017 during the recession of the March 2017 flood event. As a result, the 2017 gaugings are influenced by the hysteresis of the receding limb of the flood.

The rating curve generated from the calibrated Logan-Albert Rivers hydraulic model developed as part of this study results match well with DNRM's latest rating (Table 37) for discharges less than 1,000 m^3/s. The hydraulic model is unlikely to be as accurate as the DNRM rating curves for flood events confined within the river 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 DNRM rating curve at very high discharges.

The following rating curves were adopted for the Yarrahappini stream gauge:

- For estimating of discharges during the January 1974 event and April 1990 event, DNRM Table-24 was adopted to the highest gauges flow prior to March 2017 (2,844 m^3/s at 18.36 mGH). Above this flow, the adopted rating curve transitions to the hydraulic model rating curve.
- For estimating of discharges during the January 2013 event, DNRM Table-34 was adopted to the highest gauged flow (2,844 m^3/s at 18.36 mGH). Above this flow, the adopted rating curve transitions to the hydraulic model rating curve.
- For estimating of discharges during the March 2017 event, DNRM Table-37 was adopted to the highest gauged flow (2,844 m^3/s at 18.36 mGH). Above this flow, the rating curve transitions to the hydraulic model rating curve.

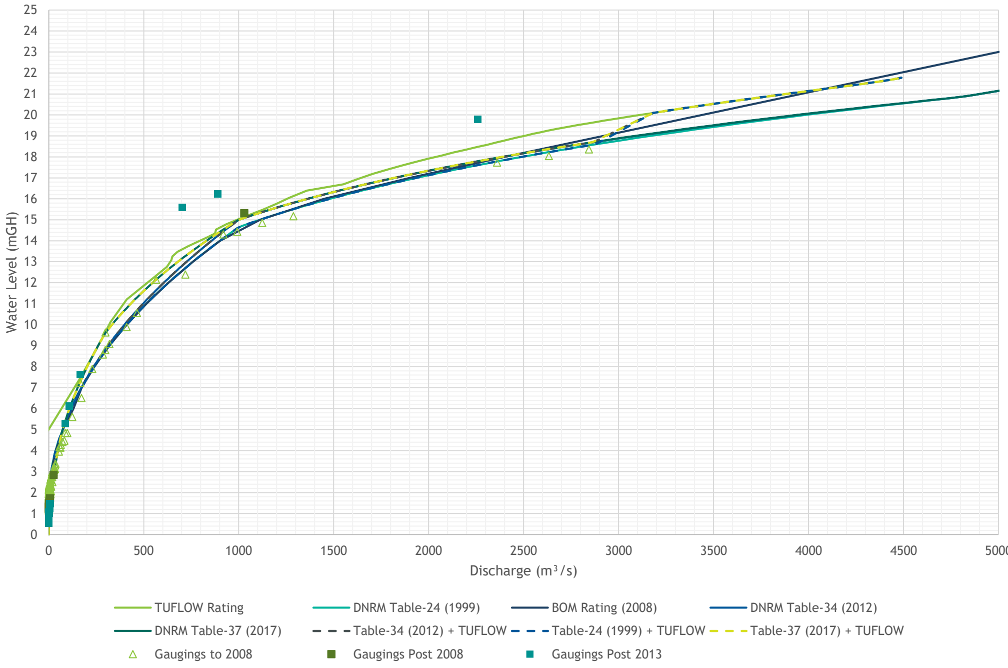

Figure 3.8 - Available rating curves, Logan River at Yarrahappini (DNRM GS 145014A)

Note that there are significant differences between gaugings made prior to 2008, and gaugings made after 2013. The calibrated hydraulic model rating curve bisects the two sets of gaugings at higher flows and is therefore considered acceptable. The transition from the DNRM rating to the TUFLOW rating curve occurs between 2,844 m^3/s and 3,200 m^3/s. Altering this transition would result in only minor changes to the recorded discharge hydrographs for the selected calibration events.

3.8.3 Teviot Brook at the Overflow (DNRM GS 145012A)

Figure 3.9 shows the available and adopted rating curves for The Overflow. SunWater undertook a detailed review of the rating curve for The Overflow as part of their Wyaralong Dam hydrology investigations (SunWater, 2007). The SunWater (2007) study included the following:

- A review of all available rating curves for the station from both DNRM and BOM;
- Construction of a hydraulic model to investigate the accuracy of available rating curves at high flows; and
- Generation of a composite rating curve combining the actual gauged flows with the results of the hydraulic modelling.

The SunWater (2007) rating curve was adopted for this study for estimation of discharges for all calibration events. It is of note that all rating curves reviewed were the same up to the maximum gauged flow of 390 m^3/s at 9.67 mGH. The Overflow gauging station has been closed following the construction of Wyaralong Dam in 2009. As such, there have been no updates to The Overflow rating curves since this time.

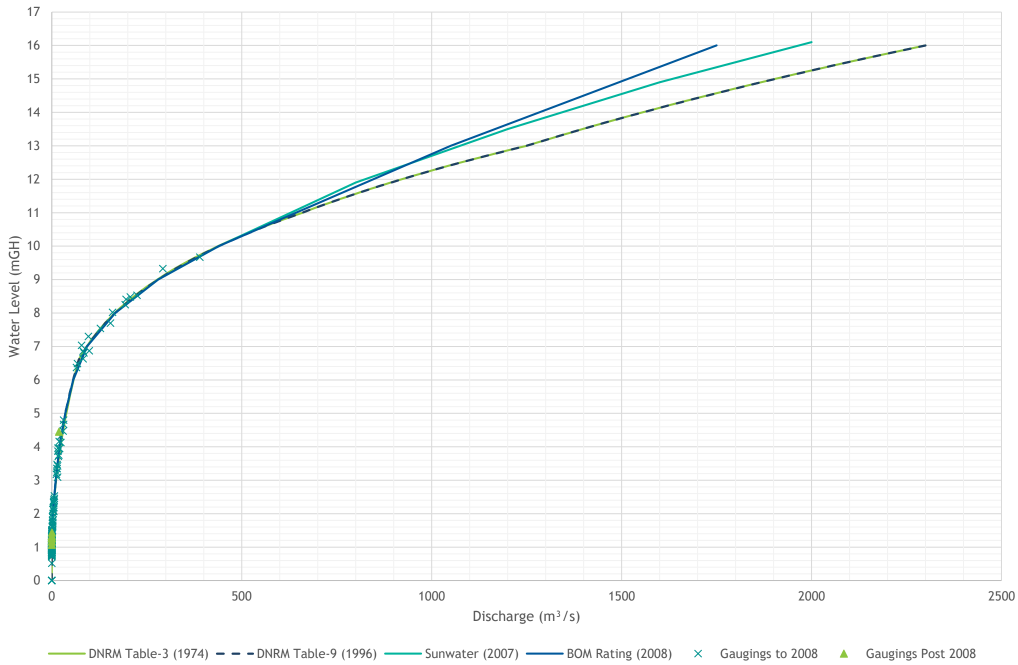

Figure 3.9 - Available rating curves, Teviot Brook at The Overflow (DNRM GS 145012A)

3.8.4 Albert River at Bromfleet (DNRM GS 145102A)

Figure 3.10 shows the available and adopted rating curves for Bromfleet. The current DNRM rating curve for Bromfleet (Table-30) is based on a series of gaugings up to 675 m^3/s at 14.86 mGH. The rating curve has been extrapolated above this point. The current rating curve has remained unchanged since its adoption in October 2017. The rating curve for Bromfleet has changed several times between 1974 and 2017, suggesting that some change in the waterway cross section at the site has occurred.

It is of note that the rating curve generated from the hydraulic model results matches well with the DNRM and BOM ratings at discharges greater than 1300 m^3/s, but appears to over predict discharges at lower water levels. The hydraulic model may not be as accurate as the DNRM rating curves for flood events confined within the river banks. However, the rating curve produced by the calibrated hydraulic model for floods larger than the highest gauged flow (involving significant floodplain flow) are likely to be more accurate at very high discharges than the extrapolated DNRM rating curve.

The following rating curves were adopted for the Bromfleet stream gauge:

- For estimating of discharges during the January 1974 and April 1990 events, DNRM Table-96 was adopted to the highest gauged flow prior to January 2012 (578 m^3/s at 12.24 mGH). Above this flow, the adopted rating curve transitions to the hydraulic model rating curve.
- For estimating of discharges during the January 2013 event, DNRM Table-97 was adopted to the highest gauged flow in January 2012 (675 m^3/s at 14.861 mGH). Above this flow, the adopted rating curve transitions to the hydraulic model rating curve.
- For estimating of discharges during the March 2017 event, DNRM Table-30 was adopted to the highest gauged flow. Above this flow, the adopted rating curve transitions to the hydraulic model rating curve.

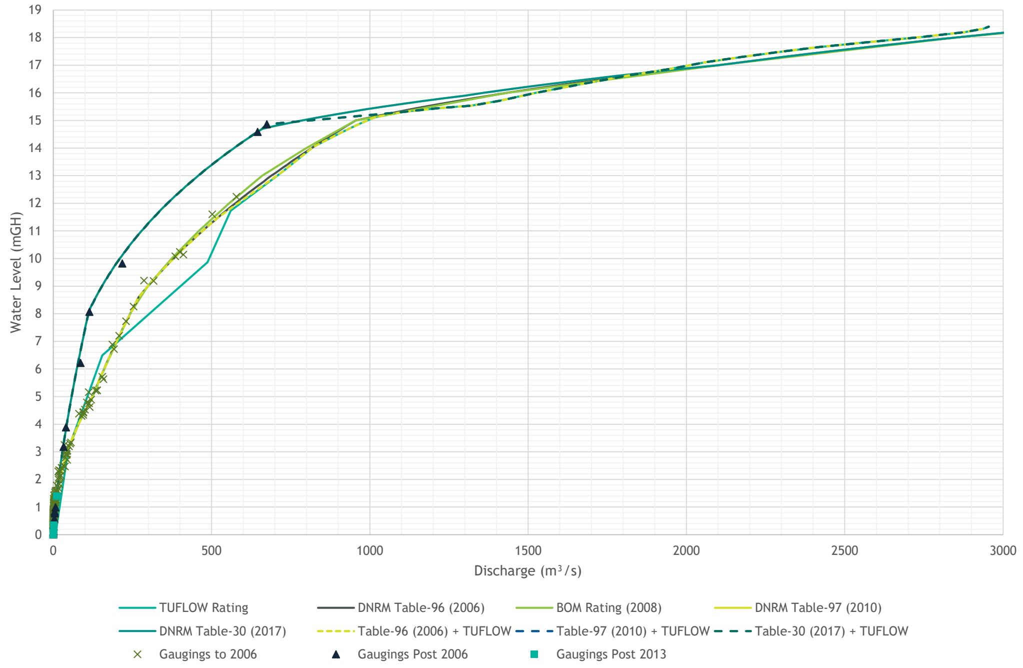

Figure 3.10 - Available rating curves, Albert River at Bromfleet (DNRM GS 145102B)

3.8.5 Albert River at Wolffdene (DNRM GS 145196A / BOM GS 40761)

Figure 3.11 shows the available and adopted rating curves for Wolffdene. The most recent DNRM rating curve for Wolffdene is based on gauged data up to 1,214 m^3/s at 10.855 mGH. The rating has been extrapolated above this point by both DNRM and BOM. It is noted that the BOM (2008) rating curve predicts lower discharges than the DNRM rating curve at flows higher than the largest gauging.

The rating curve generated from the hydraulic model appears to under predict discharges at flows below the largest gauging. The hydraulic model may not be as accurate as the DNRM rating curve for flood events confined within the river banks. At flows above the largest gauged discharge, the hydraulic model underestimates discharges when compared to the DNRM extrapolated rating curve, and over estimates discharges when compared to the BOM extrapolated rating curve. It is expected that above the largest gauging, the hydraulic model gives a better estimate of the water level discharge relationship due to the representation of the floodplain.

A synthetic rating curve has been adopted for the Wolffdene gauging station, based on DNRM Table-2 up to the highest gauged discharge of 1,214 m^3/s, transitioning to the hydraulic model rating curve. The synthetic rating curve was adopted for estimating discharges for all calibration events.

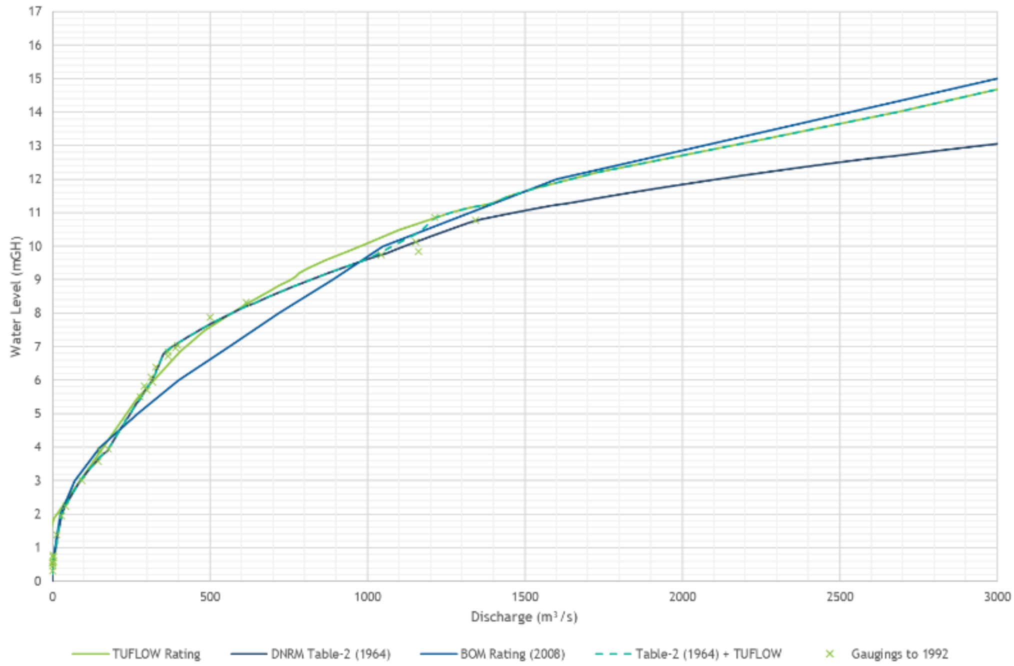

Figure 3.11 - Available rating curves, Albert River at Wolffdene (DNRM GS 145196A)

3.8.6 Logan River at Maclean Bridge (BOM GS 040935)

Figure 3.12 shows the adopted rating curve for Maclean Bridge. A DNRM rating curve is not available for this gauging site. The BOM (2008) rating curve has been derived based on a correlation between recorded water levels and BOM's URBS model results. The calibrated hydraulic model was used to develop a rating curve for the Maclean Bridge gauging station for flood events with magnitudes of up to and including the 100 Year ARI flood.

The hydraulic model rating curve significantly underestimates discharge compared to the BOM (2008) rating curve. However, the rating curve developed using the calibrated hydraulic model accounts for the physical characteristics of the channel and floodplain at the gauge location. Therefore, the rating curve for the gauge site developed from the hydraulic model has been adopted for estimating discharges for all calibration events.

The stream gauge at Maclean Bridge has been relocated several times throughout its history. During the 1974 flood event, the Maclean Bridge gauge was located about 700 m downstream of the current gauge location. This is confirmed in the study undertaken by Cameron, McNamara & Partners Pty Ltd in 1975; Report on Flood Hydrology of Logan River with Particular Reference to the January 1974 Flood (CMP, 1975).

The previous location of the gauge has been taken into account with respect to the calibration of the Logan River model for the 1974 flood event. The relocation of the gauge has no potential impacts on design event flood levels.

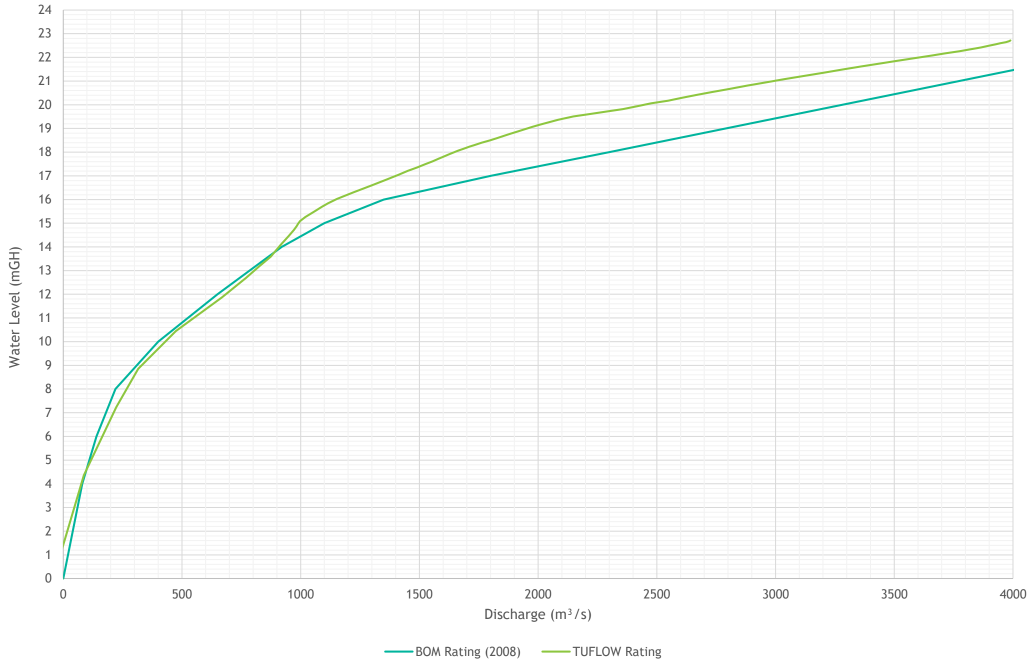

Figure 3.12 - Available rating curves, Logan River at Maclean Bridge (BOM GS 040935)

3.8.7 Logan River at Logan Village (LCC GS 6263)

Figure 3.13 shows the adopted rating curve for the Logan River at Logan Village. Neither a DNRM nor a BOM 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 estimating discharges for all calibration events. It should be noted that the Logan Village gauge location is tidally affected, and discharges at most gauge heights will be affected by tidal behaviour in the mouth of the Logan River.

3.8.8 Logan River at Waterford (BOM GS 040878)

Figure 3.14 shows the adopted rating curve for the Logan River at Waterford. A DNRM rating curve is not available for this site. The BOM (2008) rating curve at Waterford has been derived based on a correlation between recorded water levels and BOM's URBS model results. It is considered that the hydraulic model results will provide a more accurate rating curve for the Waterford Gauge. The rating curve for the gauge site developed from hydraulic model results has been adopted for estimating discharges for all calibration events. It should be noted that the Waterford gauge location is tidally affected, and discharges at most gauge heights will be affected by tidal behaviour at the mouth of the Logan River.

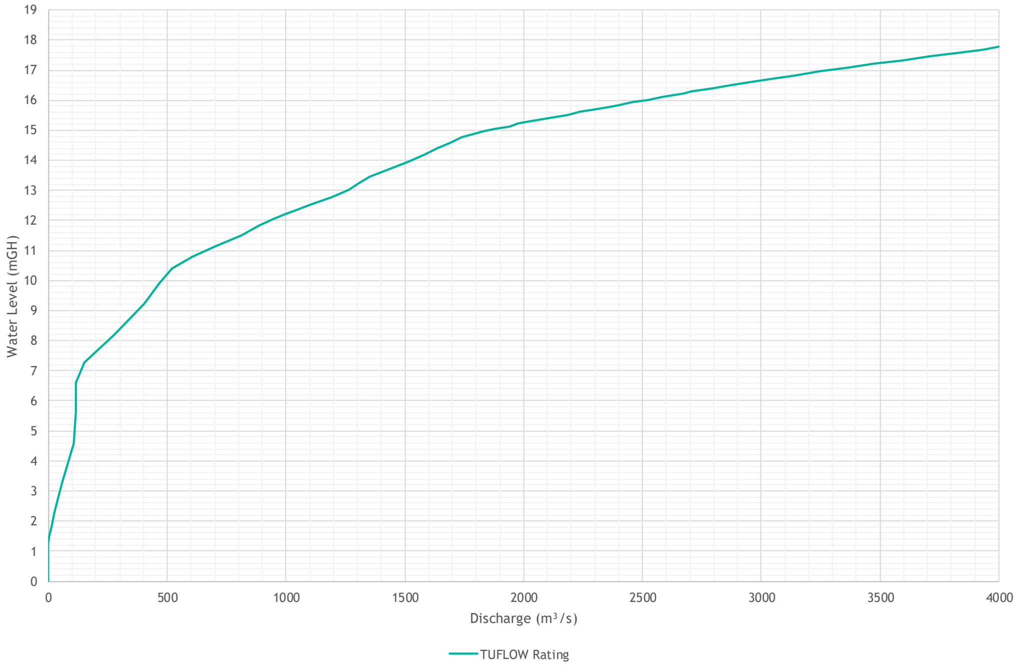

Figure 3.13 - Available rating curves, Logan River at Logan Village (LCC GS 6263)

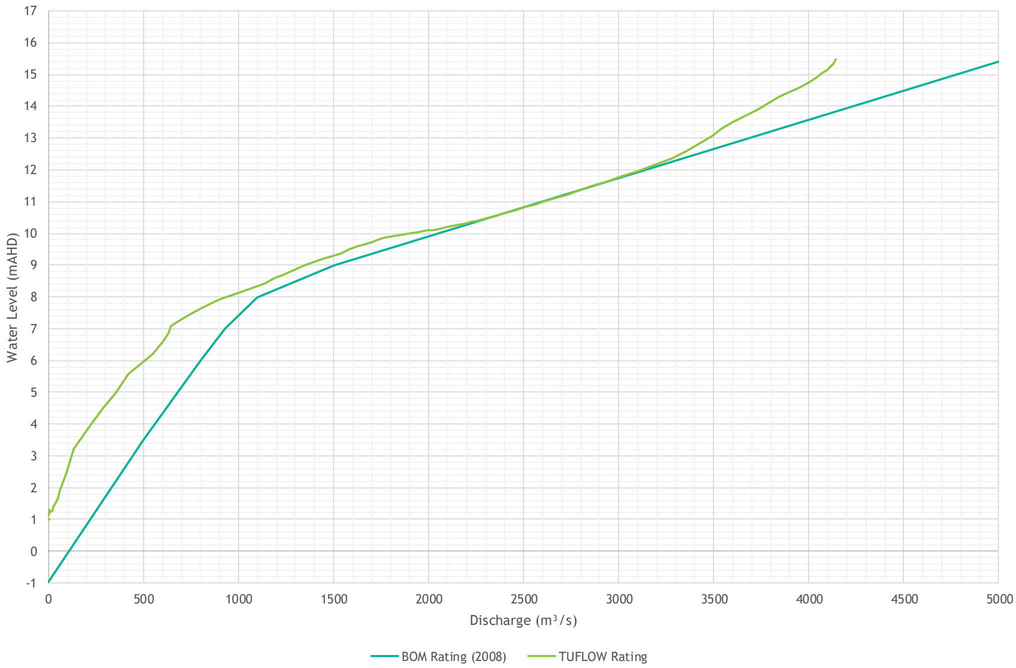

Figure 3.14 - Available rating curves, Logan River at Waterford (BOM GS 040878)

3.9 DAM STAGE-STORAGE AND OUTLET RATING CURVES

3.9.1 Maroon Dam

The stage-storage-discharge relationship for Maroon Dam has remained unchanged from the WRM (2014) study and is shown in Table 3.5. Stage-storage and spillway elevation data for Maroon Dam were provided by Seqwater based off survey undertaken in 1996. The following is of note with regards to the Maroon Dam spillway arrangement:

- The Maroon Dam maximum operating level is 207.14 mAHD, however the spillway invert level is 217.5 mAHD, 10.36 m higher.
- Seqwater has advised that they are unaware of any spillway discharges from Maroon Dam since it was constructed.

Seqwater provided the following advice on the operation of Maroon Dam during flood events:

- Seqwater provided the following advice on the operation of Maroon Dam during flood events:
- When the water level in the dam is below 207.14 mAHD, inflows of up to and including 4 ML/day (0.05 m^3/s) require an equivalent release rate. For inflows above 4 ML/day, the release rate is capped at 4 ML/day.
- When the water level increases above 207.14 mAHD, releases can be increased to match inflows, up to a maximum release rate of 2,500 ML/day (28 m^3/s).

For the purposes of hydrologic modelling, it has been assumed that water will be released from the dam at 28 m^3/s whenever the dam water level is above 207.14 mAHD. This simplification is considered acceptable for modelling of flood events, which will typically generate inflows to the dam of greater than 28 m^3/s.

3.9.2 Wyaralong Dam

Table 3.6 shows the stage-storage-discharge relationship for Wyaralong Dam. Wyaralong Dam is the largest storage in the Logan River catchment area. Stage-storage and spillway elevation data for Wyaralong Dam was provided by Seqwater, the operators of the dam.

It is of note that the water level gauge in Wyaralong Dam failed during the January 2013 event, so the performance of the hydrologic model, and accuracy of the adopted spillway rating curve could not be verified for this event. Wyaralong Dam was constructed in 2010, and therefore has not formed part of the January 1974 and April 1990 hydrologic models.

The performance of the hydrologic model and the accuracy of the adopted spillway rating curve was verified against the recorded water levels at the Wyaralong Dam gauge during the March 2017 event (see Section 5.7.4). The March 2017 calibration results indicate that the hydraulic model overestimates peak discharges at the spillway using the Seqwater stage-discharge rating curve for the spillway. The accuracy of the stage-discharge rating curve during events smaller than the March 2017 event is unknown.

Table 3.5 – Adopted stage-storage-spillway discharge relationship, Maroon Dam

Storage (ML)	Release Rate (m^3/s)	Spillway Discharge (m^3/s)	Total Discharge (m^3/s)
0	0	0	0
479	0	0	0
2449	0	0	0
6073	0	0	0
11560	0	0	0
19350	0	0	0
29210	0	0	0
41198	0	0	0
44319	0	0	0
44353	28	0	28
51311	28	0	28
58767	28	0	28
66742	28	0	28
75319	28	0	28
84563	28	0	28
86301	28	0	28
86789	28	12	40
96334	28	693	721
108699	28	3889	3917
110429	28	4542	4570

Table 3.6 – Adopted stage-storage-spillway discharge relationship, Maroon Dam

Stage (mAHD)	Storage (ML)	Spillway Discharge (m^3/s)
35	0	0
37.5	31	0
40	264	0
42.5	1015	0
45	2800	0
47.5	6243	0
50	11624	0
52.5	19668	0
55	30980	0
57.5	46078	0
60	65575	0
62.5	90154	0
63.6	102883	0
65	120912	417.7
67.5	158955	2425.4
70	205034	6,683.7*
72.5	260548	
75	326900	
77.5	403792	
80	491004	

'*' - No spillway rating data supplied above 70.5 mAHD

3.10 SURVEYED PEAK FLOOD LEVELS

3.10.1 January 2013 event

A total of 231 surveyed flood debris marks were available throughout the Logan and Albert River floodplains for the January 2013 event. The locations of these debris marks are shown in Figure 3.14. The surveyed flood levels at these locations are given in Table 3.7.

Table 3.7 - Surveyed flood levels (debris marks) Logan and Albert River floodplains, January 2013 event

Debris Mark	Surveyed peak flood level (mAHD)	Debris Mark	Surveyed peak flood level (mAHD)	Debris Mark	Surveyed peak flood level (mAHD)
L1	22.67	L29	12.83	L57	7.28
L2	22.68	L30	5.06	L58	7.03
L3	22.55	A31	3.88	L59	7.03
L4	22.59	A32	3.66	L60	7.29
L5	22.95	A33	3.07	L61	7.27
L6	24.54	L34	3.56	L62	7.29
L7	26.62	L35	3.01	L63	7.32
L8	23.79	A36	2.84	L64	5.99
L9	17.44	L37	3.59	L65	7.34
L10	17.51	L38	16.64	L66	7.26
L11	20.81	L39	4.45	L67	7.23
L12	19.53	L40	6.47	L68	7.49
L13	27.12	L41	4.42	L69	7.42
L14	24.89	L42	4.49	L70	14.71
L15	24.94	L43	3.61	L71	7.24
L16	22.26	L44	7.33	L72	6.28
L17	22.31	L45	2.96	L73	6.64
L18	26.25	L46	3.47	L74	5.35
L19	29.76	L47	3.31	L75	5.77
L20	28.79	L48	5.87	L76	5.17
L21	27.85	L49	4.01	L77	5.21
L22	21.57	L50	7.32	L78	5.41
L23	14.27	L51	7.41	L79	5.44
L24	13.55	L52	7.53	L80	5.88
L25	13.42	L53	7.58	L81	5.31
L26	18.09	L54	11.41	L82	5.23
L27	16.10	L55	7.31	L83	5.38
L28	21.89	L56	9.11	L84	5.35
L85	5.36	L120	8.68	L155	22.08
L86	5.22	L121	7.86	L156	22.08
L87	5.21	L122	8.13	A157	31.93
L88	5.22	L123	8.14	A158	31.88

Debris Mark	Surveyed peak flood level (mAHD)	Debris Mark	Surveyed peak flood level (mAHD)	Debris Mark	Surveyed peak flood level (mAHD)
L89	5.08	L124	7.39	A159	31.95
L90	8.81	L125	6.97	A160	31.84
L91	8.79	L126	17.15	A161	32.05
L92	5.74	L127	17.16	A162	32.13
L93	5.78	L128	17.08	A163	34.41
L94	5.27	L129	19.19	A164	34.34
L95	5.67	L130	9.78	A165	43.83
A96	10.79	L131	9.78	A166	65.62
A97	10.87	L132	5.58	L167	32.08
A98	11.46	L133	5.57	L168	32.02
A99	8.29	L134	5.25	L169	31.12
A100	8.29	L135	5.25	L170	31.8
A101	10.21	L136	21.71	L171	23.94
A102	9.44	L137	21.62	L172	24.61
A103	12.88	L138	21.85	173	42.72
A104	13.35	L139	21.63	174	42.81
A105	13.34	L140	16.31	175	42.52
L106	20.50	A141	19.18	L176	21.72
L107	17.24	A142	19.03	L177	22.46
L108	17.01	A143	19.06	L178	22.66
L109	16.29	A144	14.58	L179	27.6
L110	16.22	A145	14.67	L180	10.59
L111	13.71	A146	15.69	L181	9.79
L112	12.05	A147	14.99	A182	10.11
L113	10.64	A148	12.29	A183	10.24
L114	9.05	L149	11.48	A184	11.24
L115	15.24	L150	11.57	A185	7.78
L116	8.76	L151	9.95	A186	7.82
L117	8.60	L152	21.11	L187	23.11
L118	8.61	L153	21.19	L188	13.00
L119	9.18	L154	13.77	L189	13.00
L190	16.79	L204	7.81	L218	21.72
L191	18.85	L205	87.01	L219	21.75
L192	15.48	L206	21.11	L220	21.73
L193	15.75	L207	21.15	L221	21.67
L194	9.31	L208	21.23	L222	21.62
L195	29.88	L209	21.2	L223	23.99
196	44.38	L210	21.3	L224	35.70
197	44.37	L211	21.34	A225	44.20
198	44.44	L212	21.39	226	0.00

Debris Mark	Surveyed peak flood level (mAHD)	Debris Mark	Surveyed peak flood level (mAHD)	Debris Mark	Surveyed peak flood level (mAHD)
199	44.39	L213	21.45	227	0.00
200	44.42	L214	21.53	228	0.00
L201	8.65	L215	21.56	229	0.00
L202	8.10	L216	21.65	230	0.00
L203	8.12	L217	21.71	231	0.00

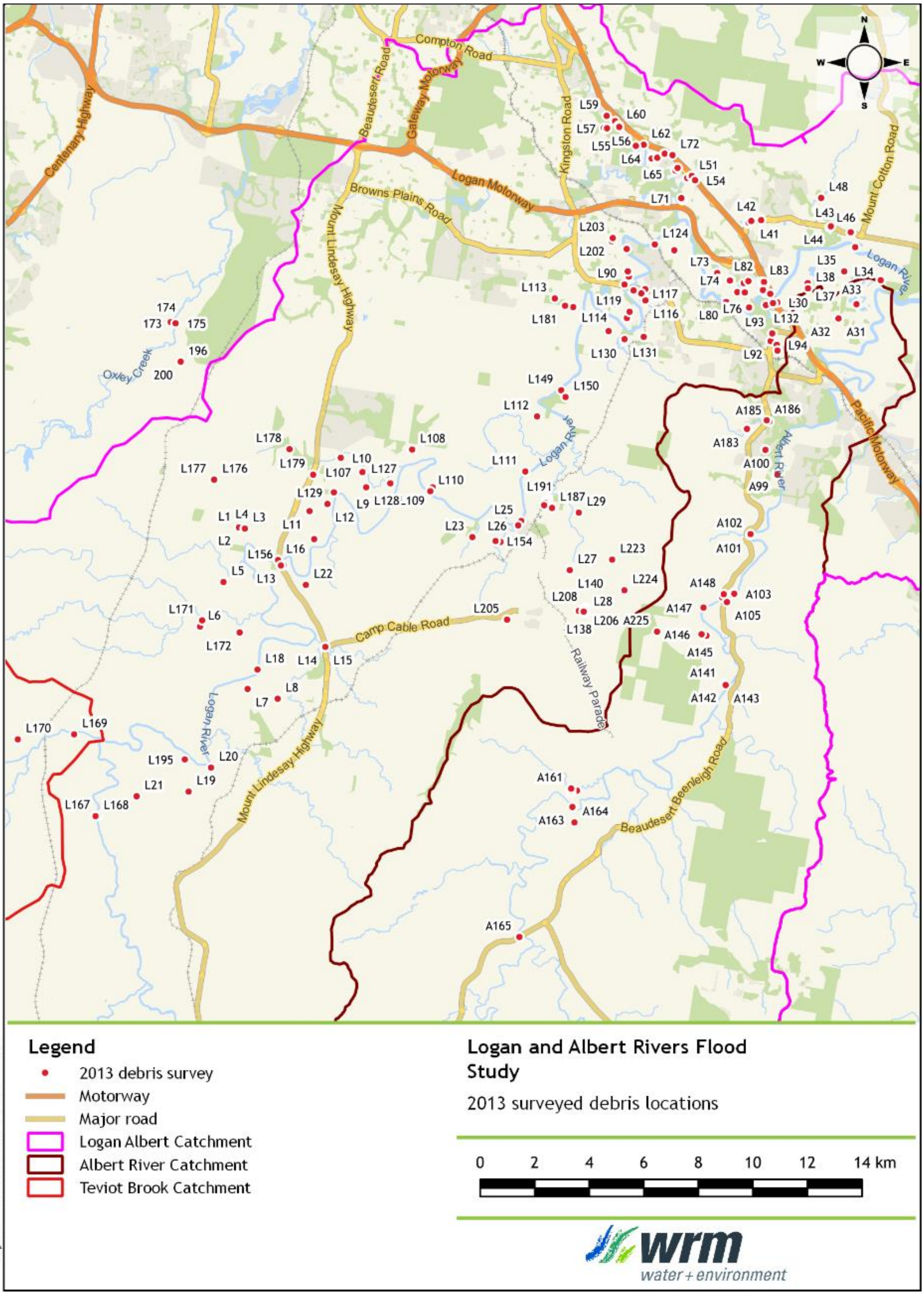

Figure 3.15 - Locations of surveyed peak flood levels throughout the Logan and Albert Rivers floodplain (debris marks), January 2013 event

3.10.2 March 2017 event

A total of 217 surveyed flood debris marks were available throughout the Logan and Albert River floodplains for the March 2017 event. The survey points corresponding to the Logan River are debris marks 1 to 137, with the corresponding survey points for the Albert River are represented by debris marks 138 to 217. The locations of the debris marks are shown in Figure 3.16. The surveyed flood levels at these locations are given in Table 3.8.

Table 3.8 - Surveyed flood levels (debris marks) Logan and Albert River floodplains, March 2017 event

Debris Mark	Surveyed peak flood level (mAHD)	Debris Mark	Surveyed peak flood level (mAHD)	Debris Mark	Surveyed peak flood level (mAHD)
L1	5.86	L29	24.61	L57	9.18
L2	6.15	L30	24.68	L58	9.12
L3	6.16	L31	24.88	L59	9.21
L4	6.17	L32	23.97	L60	9.31
L5	6.57	L33	27.30	L61	9.33
L6	6.62	L34	27.33	L62	9.35
L7	7.31	L35	26.27	L63	9.96
L8	8.27	L36	27.23	L64	9.88
L9	8.26	L37	4.43	L65	10.21
L10	24.85	L38	4.35	L66	10.41
L11	24.84	L39	5.24	L67	11.64
L12	33.21	L40	5.17	L68	10.46
L13	28.42	L41	4.39	L69	10.47
L14	28.44	L42	5.25	L70	10.55
L15	28.59	L43	5.27	L71	10.95
L16	26.33	L44	5.82	L72	11.57
L17	30.63	L45	5.65	L73	12.13
L18	27.16	L46	6.22	L74	10.19
L19	27.12	L47	6.21	L75	9.99
L20	27.20	L48	6.22	L76	9.95
L21	27.18	L49	6.19	L77	10.04
L22	27.01	L50	6.14	L78	10.02
L23	27.22	L51	6.29	L79	9.35
L24	27.15	L52	6.90	L80	8.73
L25	27.19	L53	6.83	L81	7.64
L26	25.23	L54	7.67	L82	6.63
L27	71.03	L55	9.19	L83	6.59
L28	24.78	L56	8.15	L84	9.93
L85	9.99	L120	17.31	A155	15.91
L86	12.09	L121	23.44	A156	16.09
L87	12.08	L122	20.84	A157	16.08
L88	12.09	L123	24.48	A158	16.12

Debris Mark	Surveyed peak flood level (mAHD)	Debris Mark	Surveyed peak flood level (mAHD)	Debris Mark	Surveyed peak flood level (mAHD)
L89	8.94	L124	21.79	A159	16.19
L90	8.23	L125	22.60	A160	14.37
L91	8.22	L126	21.66	A161	12.68
L92	8.21	L127	19.20	A162	12.69
L93	9.10	L128	19.28	A163	13.29
L94	8.23	L129	19.34	A164	12.06
L95	8.22	L130	19.25	A165	1.80
L96	8.23	L131	19.20	A166	11.05
L97	8.13	L132	19.31	A167	11.22
L98	8.22	L133	19.28	A168	10.99
L99	8.23	L134	7.93	A169	11.22
L100	8.21	L135	8.25	A170	10.47
L101	8.11	L136	8.23	A171	10.50
L102	8.24	L137	9.06	A172	10.55
L103	8.27	A138	35.28	A173	10.47
L104	8.14	A139	35.29	A174	10.32
L105	8.25	A140	33.37	A175	9.89
L106	8.26	A141	33.38	A176	9.92
L107	8.09	A142	33.59	A177	9.91
L108	11.13	A143	35.77	A178	9.92
L109	11.33	A144	33.33	A179	9.72
L110	11.58	A145	27.61	A180	8.74
L111	14.54	A146	22.95	A181	8.75
L112	14.72	A147	22.01	A182	8.77
L113	14.65	A148	20.88	A183	6.62
L114	15.66	A149	20.84	A184	6.62
L115	16.13	A150	18.10	A185	6.62
L116	15.14	A151	18.19	A186	6.62
L117	14.69	A152	19.16	A187	6.62
L118	11.99	A153	17.36	A188	6.62
L119	12.05	A154	16.94	A189	6.62
A190	7.16	A200	4.77	A210	4.18
A191	7.27	A201	3.92	A211	4.18
A192	7.03	A202	3.70	A212	4.23
A193	5.92	A203	4.06	A213	4.69
A194	6.61	A204	4.17	A214	4.47
A195	6.39	A205	4.59	A215	5.12
A196	24.40	A206	4.57	A216	6.16
A197	24.39	A207	4.20	A217	5.81
A198	4.99	A208	4.19		

Debris Mark	Surveyed peak flood level (mAHD)	Debris Mark	Surveyed peak flood level (mAHD)	Debris Mark	Surveyed peak flood level (mAHD)
A199	4.75	A209	4.20		

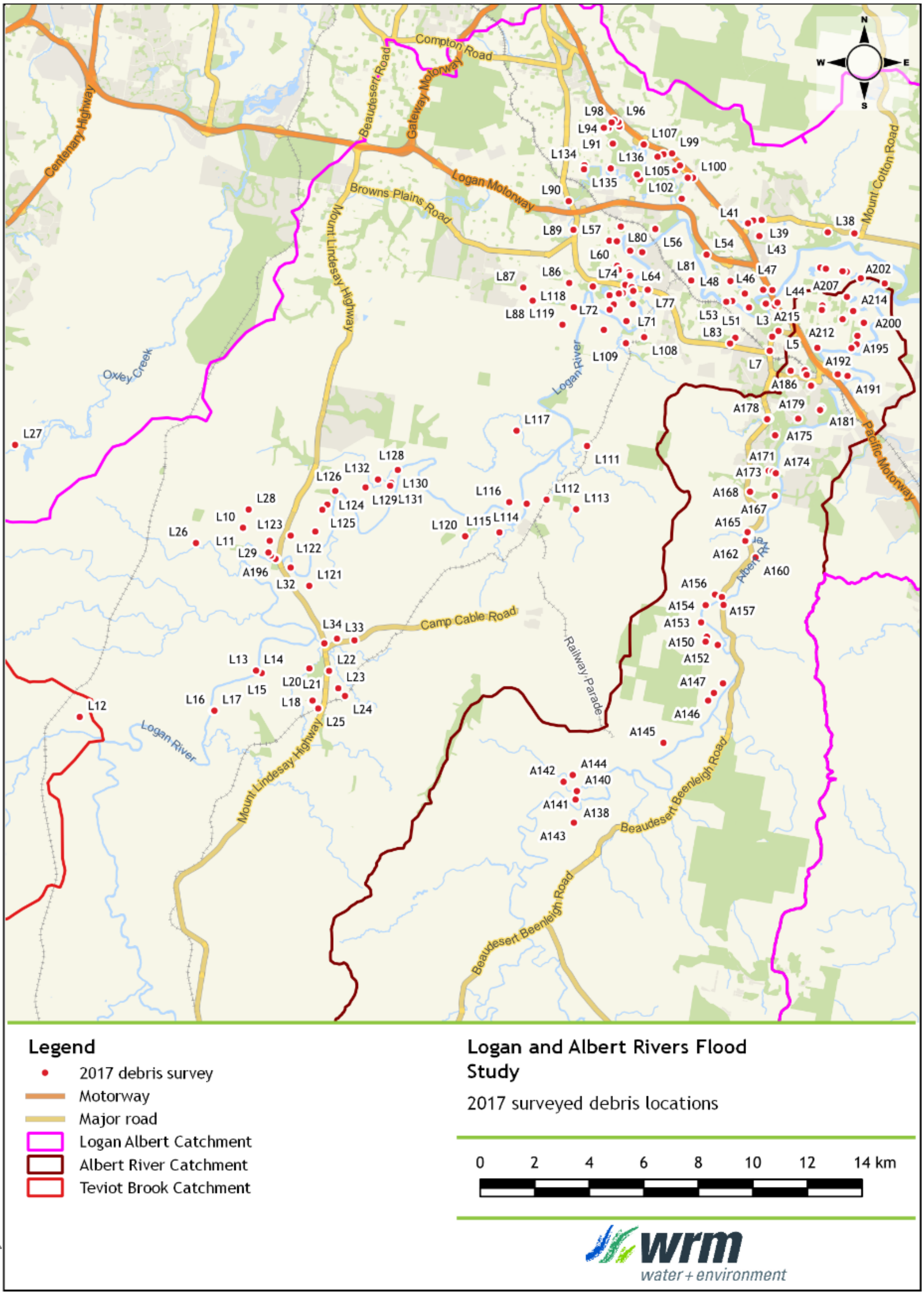

Figure 3.16 - Locations of surveyed peak flood levels throughout the Logan and Albert Rivers floodplain (debris marks), March 2017 event

3.10.3 February 2022 event

A total of 225 surveyed flood debris marks were available throughout the Logan and Albert River floodplains for the February 2022 event. The locations of the debris marks are shown in Figure 3.17. The surveyed flood levels at these locations are given in Table 3.9.

Table 3.9 - Surveyed flood levels (debris marks) Logan and Albert River floodplains, February 2022 event

Debris Mark	Surveyed peak flood level (mAHD)	Debris Mark	Surveyed peak flood level (mAHD)	Debris Mark	Surveyed peak flood level (mAHD)
1	5.13	85	24.80	163	11.95
2	5.77	86	21.96	164	11.95
3	6.03	87	21.93	165	11.83
4	3.62	88	22.67	166	8.88
5	6.62	89	9.92	167	27.24
6	6.63	90	8.87	168	32.76
7	6.64	91	8.90	169	32.87
8	6.59	92	9.01	170	26.72
9	6.81	93	8.88	171	28.86
10	7.72	94	8.91	172	30.16
11	9.34	95	8.31	173	27.33
12	9.26	96	6.74	174	27.31
13	9.05	97	7.12	175	27.31
14	9.68	98	7.01	176	12.67
15	9.93	99	6.83	177	11.19
16	9.55	100	6.62	178	10.08
18	11.63	101	7.42	179	6.23
19	11.53	102	7.35	180	6.64
20	12.42	103	5.74	181	7.22
21	14.89	104	5.62	182	7.11
22	15.99	105	5.75	183	7.11
23	17.08	106	5.00	184	7.14
24	20.50	107	5.00	185	7.19
25	20.48	108	5.03	186	7.22
26	20.52	109	5.72	187	3.48
27	26.61	110	5.73	188	3.48
28	35.74	111	8.81	189	2.89
29	35.92	112	8.87	190	3.86
30	45.03	113	9.09	191	4.26
31	44.99	114	8.88	192	4.62
32	7.70	115	8.86	193	14.91
34	7.71	116	8.87	194	14.90

Debris Mark	Surveyed peak flood level (mAHD)	Debris Mark	Surveyed peak flood level (mAHD)	Debris Mark	Surveyed peak flood level (mAHD)
36	8.27	117	8.85	196	14.40
37	8.27	118	8.87	197	8.40
38	8.32	119	8.91	198	8.45
40	6.66	120	8.91	199	7.67
41	6.63	121	8.86	200	28.73
42	4.88	122	8.89	201	27.09
43	5.10	123	8.87	203	31.68
44	5.13	124	8.86	204	31.66
45	4.74	125	8.85	205	32.64
46	5.00	126	8.88	206	27.37
47	4.83	127	8.91	207	27.30
48	5.07	128	8.85	208	27.30
49	7.58	129	8.87	209	27.28
50	11.04	130	12.59	210	27.32
51	11.03	131	12.53	213	8.44
52	10.98	132	12.66	214	8.41
53	11.01	133	12.61	217	8.82
54	11.44	134	12.71	219	8.81
55	11.04	135	12.68	220	5.75
56	10.05	136	12.66	221	8.40
57	9.82	137	12.63	222	8.40
58	10.05	138	13.12	223	9.05
59	10.70	139	15.31	224	8.40
60	11.01	140	15.32	225	8.45
61	24.38	141	18.82	226	8.45
63	25.10	142	18.54	227	8.30
64	10.81	143	18.48	228	6.50
65	10.81	144	18.04	229	6.50
66	10.69	145	19.37	230	7.20
67	10.70	146	19.52	231	7.30
68	11.00	147	19.62	232	8.30
69	11.00	148	20.09	234	14.30
70	11.00	149	21.91	235	14.35
71	11.06	150	19.40	236	17.65
72	11.04	151	19.47	237	20.10
73	10.96	152	15.96	238	20.15
74	11.03	153	21.99	239	10.10
75	11.02	154	15.11		
76	24.51	155	15.21		
78	24.56	156	16.74		

Debris Mark	Surveyed peak flood level (mAHD)	Debris Mark	Surveyed peak flood level (mAHD)	Debris Mark	Surveyed peak flood level (mAHD)
79	24.68	157	16.57		
80	24.56	158	16.39		
81	22.52	159	15.20		
82	24.51	160	16.23		
83	24.18	161	15.19		
84	24.97	162	13.82		

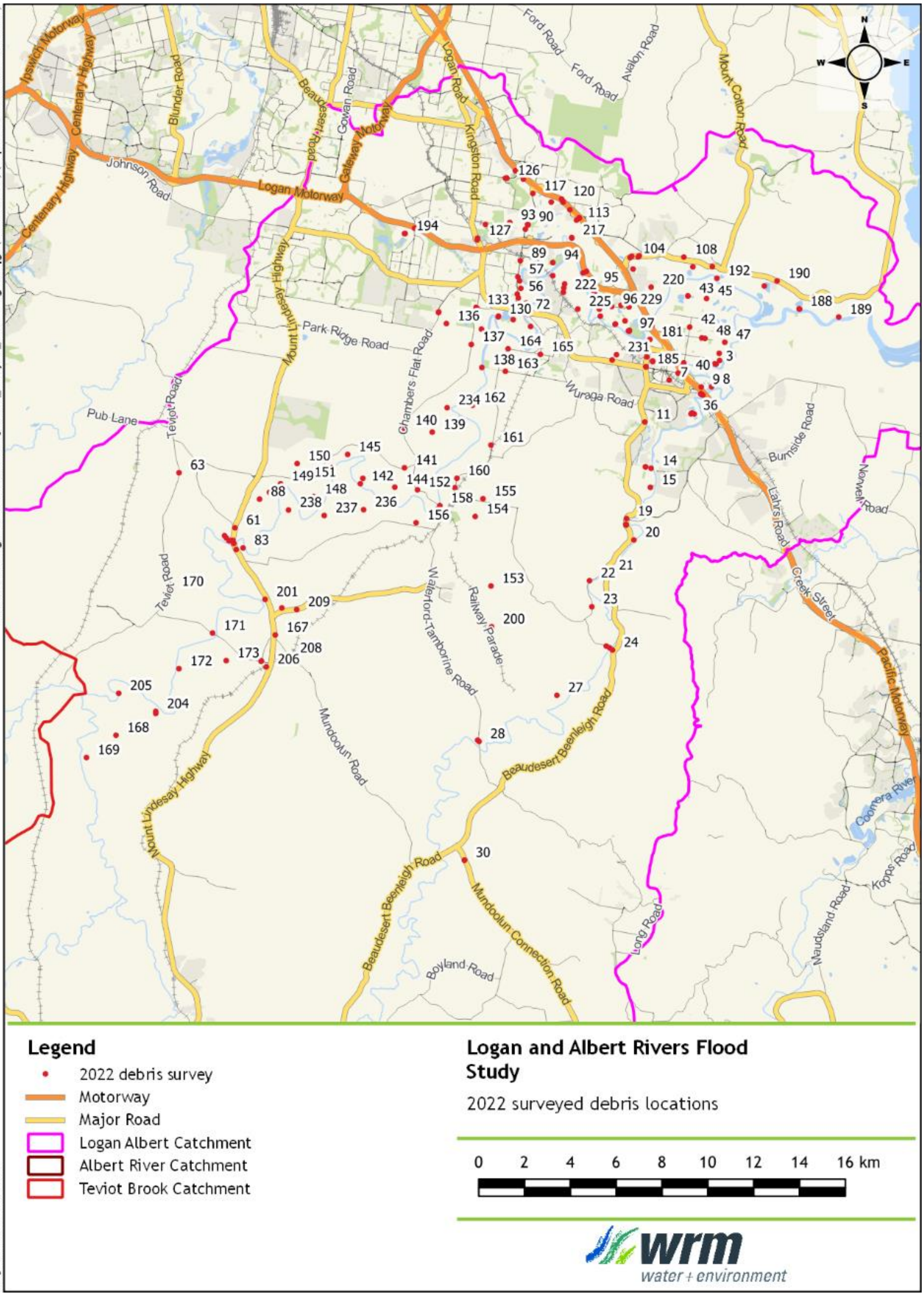

Figure 3.17 - Locations of surveyed peak flood levels throughout the Logan and Albert Rivers floodplain (debris marks), February 2022 event

4 Hydrologic model development

4.1 OVERVIEW

An XP-RAFTS runoff routing model (Innovyze, 2019) was developed for the Logan and Albert Rivers catchment to its outlet at Moreton Bay. The XP-RAFTS hydrologic model was calibrated against the January 1974, April 1990, January 2013 and March 2017 flood events. XP-RAFTS models was developed for the following scenarios:

- **Existing catchment conditions** – Model parameters based on existing development within the catchment. This model was used for model calibration to historical events.
- **Ultimate catchment conditions** – 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.

The XP-RAFTS hydrologic model was calibrated to the January 1974, April 1990, January 2013 and March 2017 flood events. Details of the XP-RAFTS model calibration methodology and results are described in Section 5 of this report. The proposed methodology for the use of the calibrated XP-RAFTS models to estimate design discharges is described in Section 8 of this report.

4.2 XP-RAFTS MODEL CONFIGURATION

4.2.1 Spatial configuration

Figure 4.1 to Figure 4.5 show the configuration of the Logan-Albert River XP-RAFTS hydrologic model. The XP-RAFTS model covers an area of 3,879 km^2 and includes the entire catchment of the Logan River to its outlet at Moreton Bay. The model includes the catchments of the Logan River's major tributaries including Teviot Brook and the Albert River. The model consists of 268 subcatchments, which range in size from 256 ha to 3,467 ha, with an average subcatchment area of 1,447 ha.

4.2.2 Subcatchment parameters

The XP-RAFTS model uses a single subcatchment approach to determine runoff hydrographs, based on the overall subcatchment parameters (fraction impervious, hydraulic roughness and slope). Subcatchment fraction impervious and roughness (Manning's 'n') were weighted based on the various land-use types in each subcatchment. The following is of note:

- For the existing catchment conditions XP-RAFTS model, land-use types were determined based on Google Earth aerial photographs.
- For the ultimate conditions catchment conditions XP-RAFTS model, land-use types were be determined based on the current LCC, Scenic Rim Regional Council (SRRC) and Gold Coast City Council (GCC) planning schemes

Subcatchment slopes were determined based on the supplied LiDAR by LCC.

The adopted fraction impervious and roughness (Manning's 'n') 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 Manning's 'n') for each subcatchment are given in Table A.2 for existing catchment conditions.

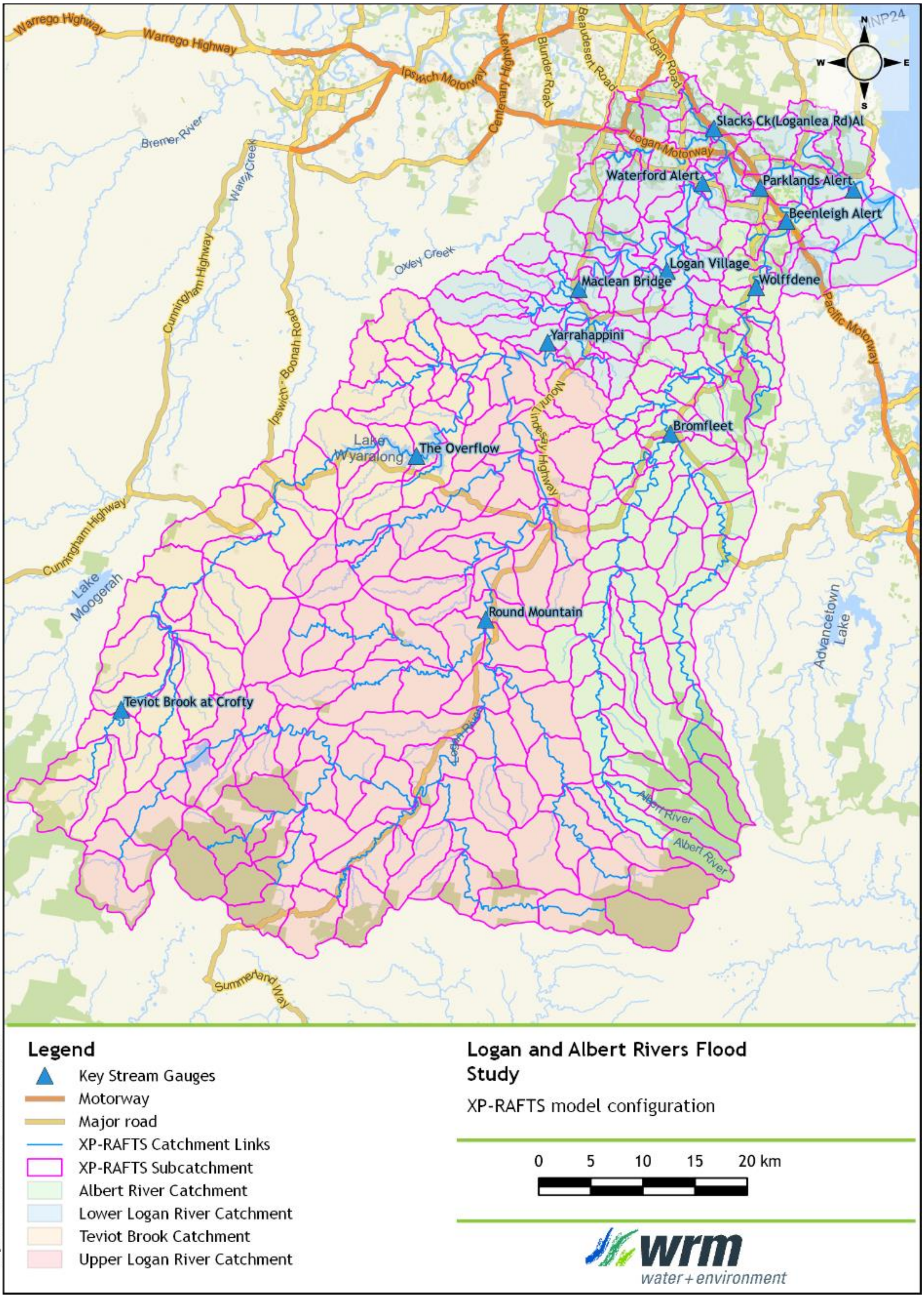

Figure 4.1 – Logan and Albert Rivers XP-RAFTS model configuration

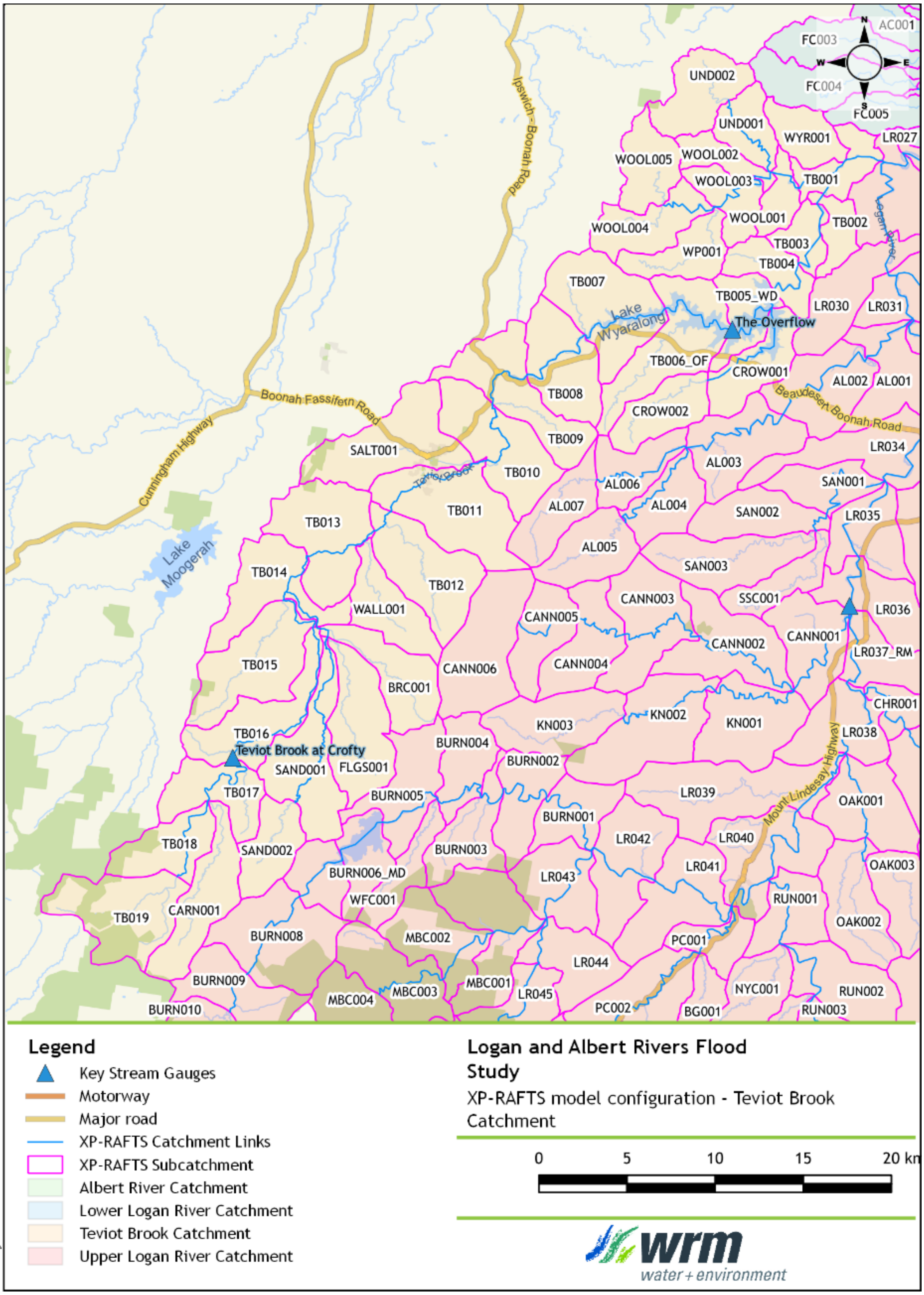

Figure 4.2 – Logan and Albert Rivers XP-RAFTS model configuration, focussing on Teviot Brook catchment

Figure 4.3 – Logan and Albert Rivers XP-RAFTS model configuration, focussing on the upper Logan River catchment

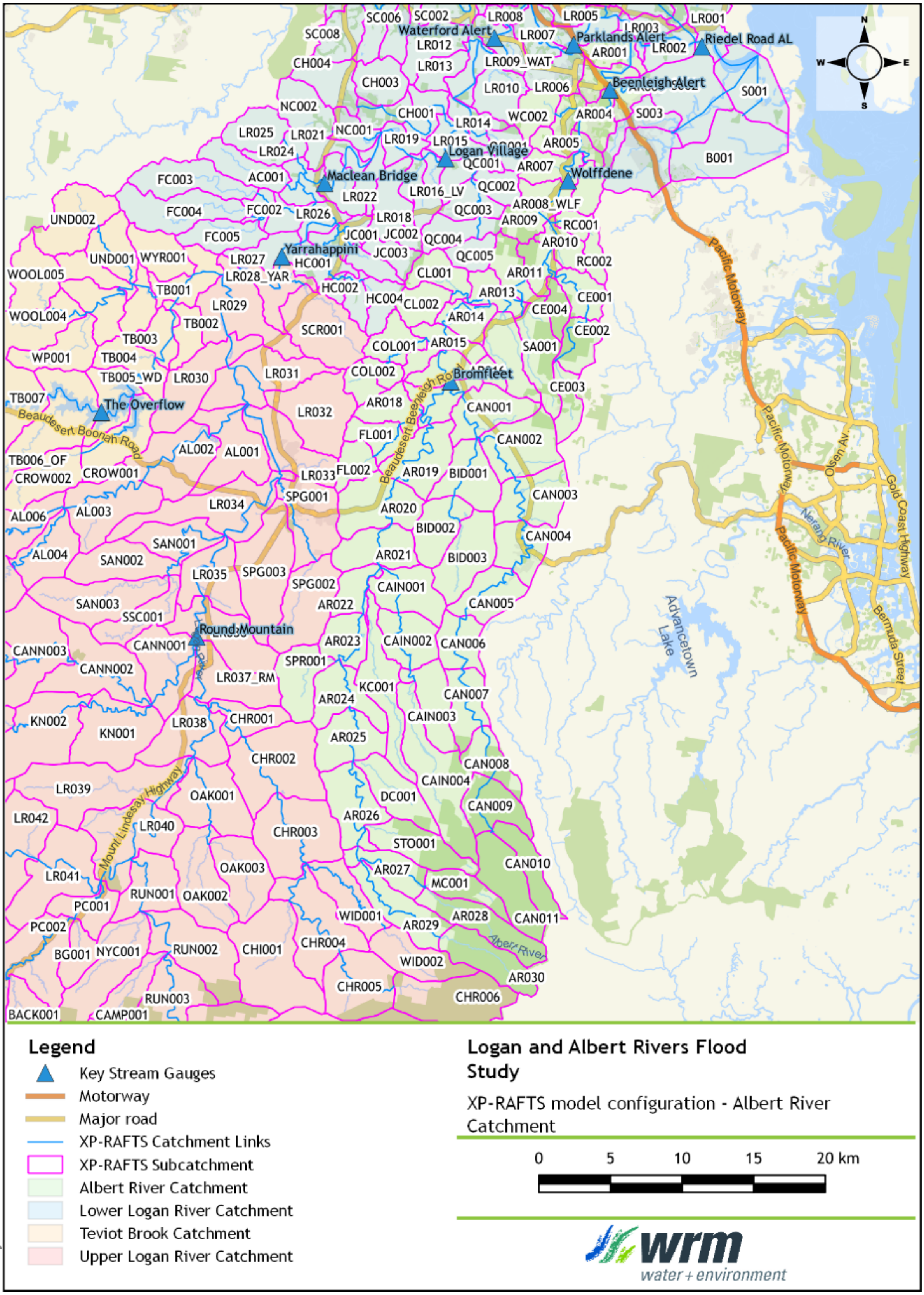

Figure 4.4 – Logan and Albert Rivers XP-RAFTS model configuration, focussing on the Albert River catchment

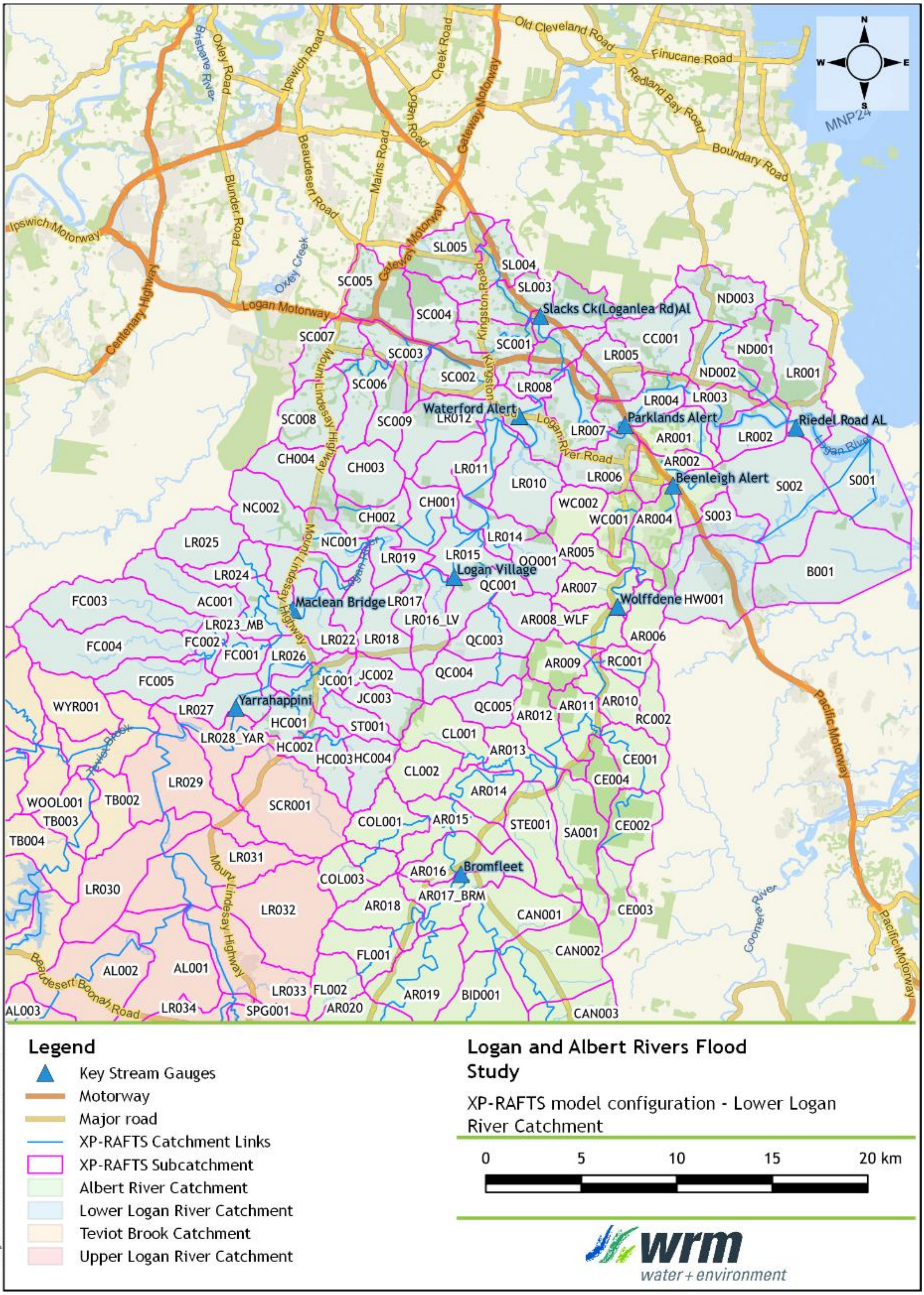

Figure 4.5 – Logan and Albert Rivers XP-RAFTS model configuration, focussing on the lower Logan River catchment

4.2.3 Losses

Initial and continuing losses were configured based on an adopted relationship with the percentage imperviousness of the model subcatchments. Subcatchment losses were determined based on the calibration process (described in Section 5).

4.2.4 Channel routing parameters

Channel routing was configured by specifying a 'K' and 'X' value for each routing link. A routing link 'X' value of 0.25 was adopted for all routing links within the model. The 'K' values represent estimated flow travel times (in hours) and were calculated based on based on average recorded flood peak travel times between gauges in the catchment. The adopted routing link parameters are shown in Table A.3 in Appendix A.

5 Hydrologic model calibration

5.1 OVERVIEW

This study is an update to and finalisation of the Logan and Albert Flood Study (WRM, 2021). As part of this study, the parameter values derived during the calibration phase were validated against the February 2022 flood event. Validation of hydrologic model parameters is a vital part of ensuring model health and robustness. Model calibration relies on estimating the parameters from historical observations. Data availability and quality changes over time and finding the optimal parameters for a model requires a level of judgement. Testing the selected model parameters on a completely independent event, as discussed in Section 5.7.5, is a vital step to ensure the validity of adopted model parameters.

5.2 METHODOLOGY

The emphasis of the model calibration was to achieve the best possible fit between the predicted and rated discharge hydrographs (recorded peak water levels converted to discharges using rating curves) at the following five key gauging stations:

- Teviot Brook at the Overflow (GS 145012a);
- Logan River at Round Mountain (GS 145008a);
- Logan River at Yarrahappini (GS 145014a);
- Albert River at Bromfleet (GS 145102a); and
- Albert River at Wolffdene (GS 145196a).

That is because these gauges are located closest to the upstream inflows to the hydraulic model on the three major streams, or have reliable rating curves. All other inflows to the hydraulic model downstream of Bromfleet and Yarrhappini are local inflows (single subcatchment inflows), meaning that all routing downstream of these gauges will be undertaken with great accuracy by the hydraulic model.

The hydrologic model calibration at all other gauges was optimised as much as possible without compromising the calibration at the five key gauges. A reliable calibration of the hydrologic model cannot be achieved at other gauging stations (Logan River at Macleans Bridge, Logan Village, Waterford, Parklands and Riedel Road) due to the lack of accurate rating curves, and the influence of tailwater.

A single set of XP-RAFTS model parameters (Bx, routing link, subcatchment PERN, imperviousness, slope) were adopted and maintained for all calibration and verification events. The model parameters were adjusted to achieve the best calibration across all events, resulting in a compromise between model accuracy and model simplicity. It is noted that calibration of the models for individual events can be improved by adopting a different set of model parameters for each of the different events.

Rainfall losses were adjusted to achieve the best possible hydrograph shapes and flood volumes. A uniform initial loss and continuing loss rate were adopted for each flood event. It is noted that calibration of the models for individual events can be improved by adopting a set of variable loss rates within the catchment for each of the different events.

The hydrologic model calibration and validation results presented below have been used in the hydraulic model calibration to confirm the adequacy of the hydrology calibration in the lower reaches of the Logan River. Hence the hydrology calibration results presented here for the lower reaches of the Logan River may not look suitable, however they have been confirmed in the hydraulic model.

5.3 CALIBRATON EVENTS & VALIDATION

The updated hydrologic model was calibrated against the January 1974, April 1990, January 2013 and March 2017 events. The analysis period of each event was as follows:

- January 1974: 24/01/1974 0900 hours to 30/01/1974 1500 hours (6 days 6 hours);
- April 1990: 03/04/1990 0900 hours to 10/04/1990 2100 hours (7 days 12 hours);
- January 2013: 24/01/2013 0900 hours to 31/01/2013 2100 hours (7 days 12 hours); and
- March 2017: 29/03/2017 0900 hours to 03/04/2017 0900 hours (5 days).
- February 2022: 21/02/2022 0000 hours to 03/03/2022 0900 hours (10 days 9 hours).

The selected events cover a wide range of discharges across all of the modelled catchments. 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 discussed in Section 3.8.

Table 5.1 - Recorded peak discharges during the calibration events

Gauging station name	Gauging station no.	Watercourse	Rated peak discharge (m^3/s) [a]				
			January 1974	April 1990	January 2013	March 2017	Feb 2022
The Overflow	145012a	Teviot Brook	1,082	224	n/a	n/a	n/a
Round Mountain	145008a	Logan River	1,269	588	1,109	1,681	1,247
Yarrahapinni	145014a	Logan River	3,677	1,032	2,215	3,152	3,100
Bromfleet	145102a	Albert River	1,688	661	1,394	2,361	2,013
Wolffdene	145196a	Albert River	2,199	617	n/a	2,445	1,779

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

5.4 ADOPTED MODEL PARAMETERS

The adopted subcatchment and routing link parameters are described in Section 4.2 and Appendix A. A subcatchment storage coefficient multiplication factor ‘Bx’ of 1.0 was adopted for all events.

5.5 ASSIGNMENT OF TOTAL RAINFALLS AND TEMPORAL PATTERNS

Total rainfalls and temporal patterns were initially assigned to the model subcatchments based on the proximity of each subcatchment to the nearest pluviograph or daily rainfall station using. Where recorded daily data was used, the temporal pattern from the nearest pluviography station was applied to the daily rainfall data.

Some adjustment of pluviograph assignment was required to improve the Albert River calibration for the January 2013, March 2017 and February 2022 events. The following is of note:

- For the January 2013 event, inspection of the recorded rainfall and streamflow data for the Upper Albert River catchment indicated that the temporal pattern initially applied to this part of the catchment (Tramway Lane and Beaudesert Drumley Street) did not reflect the temporal distribution of rainfalls experienced in the upper Albert River catchment, and that the Numinbah Valley pluviograph temporal pattern gave better model calibration results, and was considered more appropriate.

- For the March 2017 event, inspection of the recorded rainfall and streamflow data for the Upper Albert River catchment (indicated that the temporal pattern initially applied to this part of the catchment (Darlington, Rudds Lane, Lumeah and Bernoble) did not reflect the temporal distribution of rainfalls experienced in the upper Albert River catchment, and that the O'Reillys pluviograph temporal pattern gave better model calibration results, and was considered more appropriate.
- For the February 2022 event, it was noted that there was a heavy storm burst very late in the event that only affected the southeastern side of the Albert River catchment. The pluviography assignment was adjusted to ensure that stations which recorded the late spike of intense rainfall were not assigned to RAFTS subcatchments on the northwestern side of the catchment. Some rainfall totals applied to RAFTS subcatchments were also adjusted to reflect the late rainfall burst not affecting the entire catchment.

5.6 INITIAL AND CONTINUING LOSSES

Initial (IL) and continuing (CL) losses were configured based on an adopted relationship with the percentage imperviousness of the model subcatchments. The initial and continuing losses adopted in each calibration event are shown in Table 5.2.

It is of note that for areas that are between zero and 30% impervious, higher losses were adopted for the Albert River catchment compared to the Logan River catchment. This is due to the higher proportion of forested areas within the upper Albert River catchment compared to the upper Logan River catchment.

Table 5.2 - Initial (IL) and continuing (CL) losses for historical events

Percentage impervious (%)	1974 event		1990 event		2013 event		2017 event		2022 event	
	IL (mm)	CL (mm/h)	IL (mm)	CL (mm/h)	IL (mm)	CL (mm/h)	IL (mm)	CL (mm/h)	IL (mm)	CL (mm/h)
0-30_AR [a]	45.0	2.2	45.0	3.5	175	3.0	100.0	2.5	100.0	1.2
0-30	35.0	2.0	25.0	2.2	140	2.4	80.0	2.2	80.0	1.2
30-40	30.0	1.5	20.0	1.5	100	1.5	40.0	1.5	40.0	0.9
40-50	25.0	1.3	15.0	1.3	80	1.3	30.0	1.3	30.0	0.8
50-60	20.0	1.0	10.0	1.0	50	1.0	20.0	1.0	20.0	0.7
60-75	15.0	0.8	5.0	0.8	30	0.8	10.0	0.8	10.0	0.6
75+	10.0	0.5	0.0	0.5	10	0.5	5.0	0.5	5.0	0.5

[a] - Higher losses were adopted for the Albert River (AR) catchment due to the higher proportion of forested areas within the upper Albert River catchment compared to the upper Logan River catchment.

5.7 CALIBRATION AND VALIDATION RESULTS

5.7.1 January 1974 calibration event

Table 5.3 shows a comparison of rated peak discharges and modelled peak discharges at key gauging stations for the January 1974 event. Figure 5.1 to Figure 5.5 compare rated and modelled discharge hydrographs at key gauging stations for the January 1974 event.

Table 5.3 – Rated and modelled peak discharges at key gauging stations, January 1974 flood event

Gauging station name	Gauging station no.	Watercourse	Peak discharge (m^3/s)		Difference (%)
			Rated [a]	Modelled	
The Overflow	145012a	Teviot Brook	1,082	1,113	2.9%
Round Mountain	145008a	Logan River	1,269	1,933	52.4%
Yarrahapinni	145014a	Logan River	3,677	4,394	19.5%
Bromfleet	145102a	Albert River	1,688	1,704	0.9%
Wolffdene	145196a	Albert River	2,524	2,165	-17%
Macleans Bridge	40935	Logan River	n/a	4,434	n/a
Logan Village	6263	Logan River	n/a	4,429	n/a

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

The following is of note with regards to the January 1974 calibration:

- The January 1974 flood can be considered a large event in the Teviot Brook, Albert River and Upper and Lower Logan catchments.
- In Teviot Brook the calibration is good, with the predicted hydrograph at The Overflow accurately reproducing rated peak discharges, flood volumes and flood timing.
- The Upper Logan River calibration for the January 1974 event is generally acceptable, with the predicted hydrograph at Round Mountain returning a peak discharge and volume that are larger than the rated hydrograph indicates. The predicted hydrograph at Yarrahappini matches the rated hydrograph well for shape and volume, but the predicted peak discharge at Yarrahappini is larger than the rated hydrograph.
- The overestimation of flow at Yarrahappini is a result of attempting to maximise the predicted flood volume, and improve the hydraulic model calibration in the lower reaches of the Logan River. A better match with recorded peak flows at Yarrahappini can be achieved, but this would result in a worse calibration of the hydraulic model in the lower reaches of the Logan River.
- If the recorded hydrograph at Round Mountain is adopted in the model, the peak discharge and volume from the recorded hydrograph at Yarrahapinni cannot be replicated. As discussed in Section 3.8.1, it is considered likely that the rating curve at Round Mountain substantially underestimates discharges during large flood events such as January 1974.
- The January 1974 Albert River model verification is considered acceptable, with the predicted hydrograph at Bromfleet matching well with the rated peak discharge, flood volume and timing. The model underestimates flood discharges at Wolffdene, but adjusting rainfall losses to improve the calibration at Wolffdene results in poorer calibration at Bromfleet.
- The January 1974 verification for the Lower Logan is considered acceptable. There are no data available for Macleans Bridge or Logan Village, and the peak discharge at Waterford has been determined from a surveyed debris mark, which may not accurately reflect the actual peak water level at the gauge.
- It is also considered likely that the XP-RAFTS model cannot adequately represent the large amount of floodplain storage available in the lower Logan River, and therefore cannot replicate the attenuation of the flood hydrograph downstream of Yarrahappini. The predicted hydrograph generated by the hydrologic model has been confirmed by the hydraulic model calibration results.

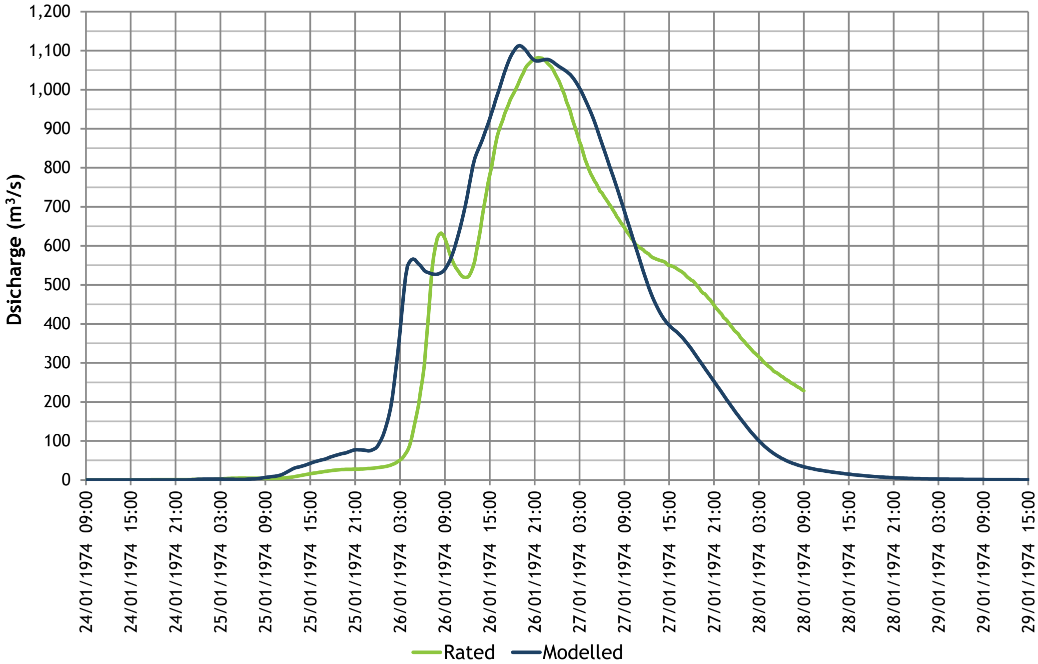

Figure 5.1 - Modelled and rated flows in Teviot Brook at the Overflow (DNRM GS 145012a), January 1974

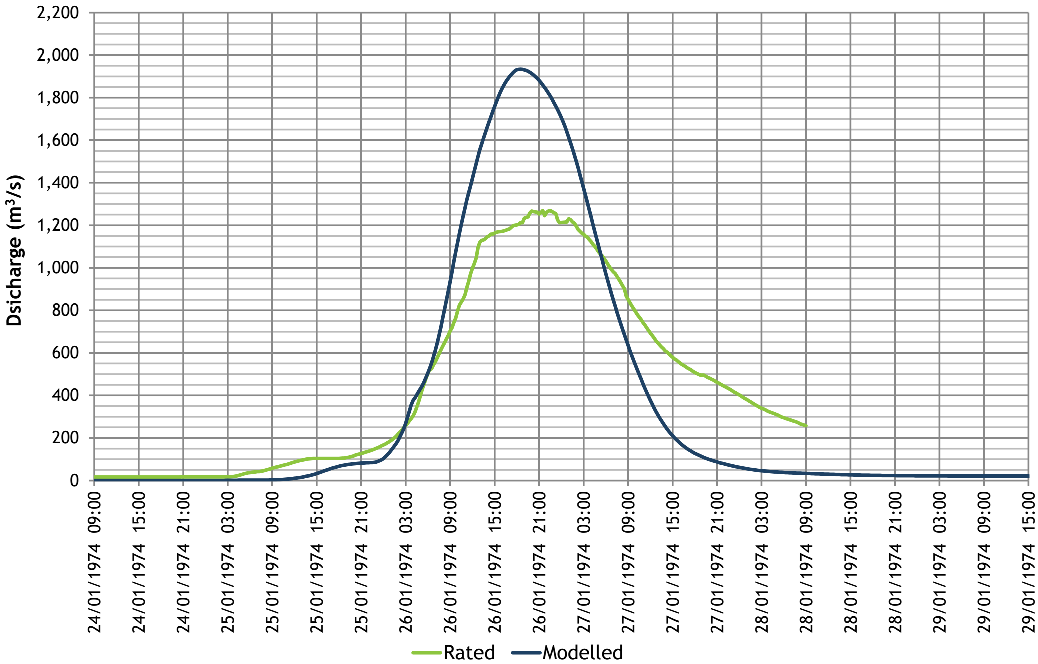

Figure 5.2 - Modelled and rated flows in the Logan River at Round Mountain (DNRM GS 145008a), January 1974

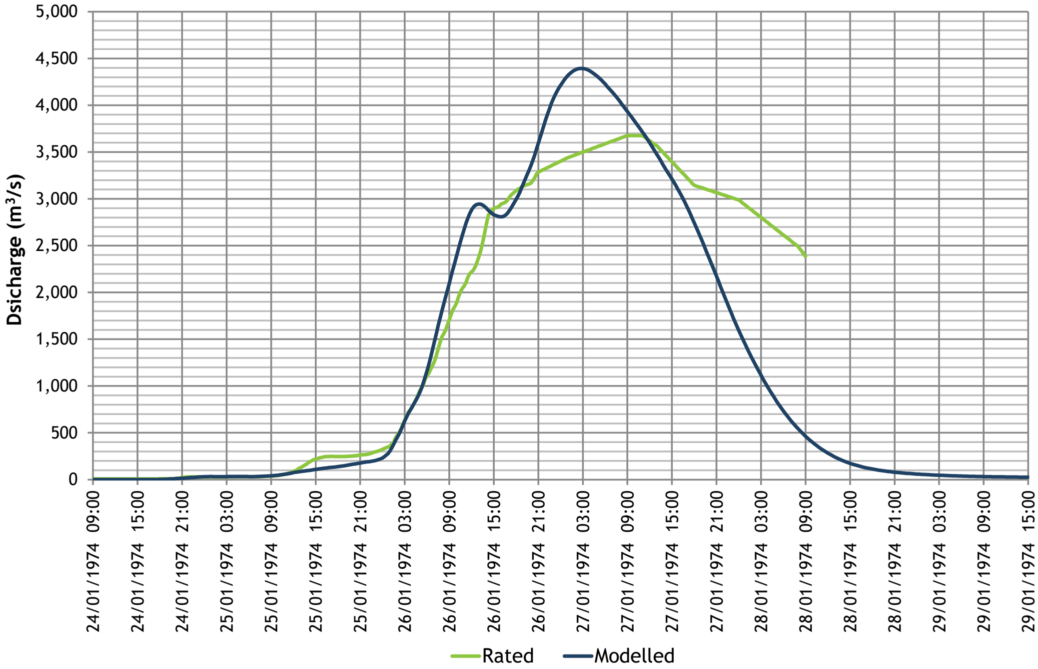

Figure 5.3 - Modelled and rated flows in the Logan River at Yarrahappini (DNRM GS 145014a), January 1974

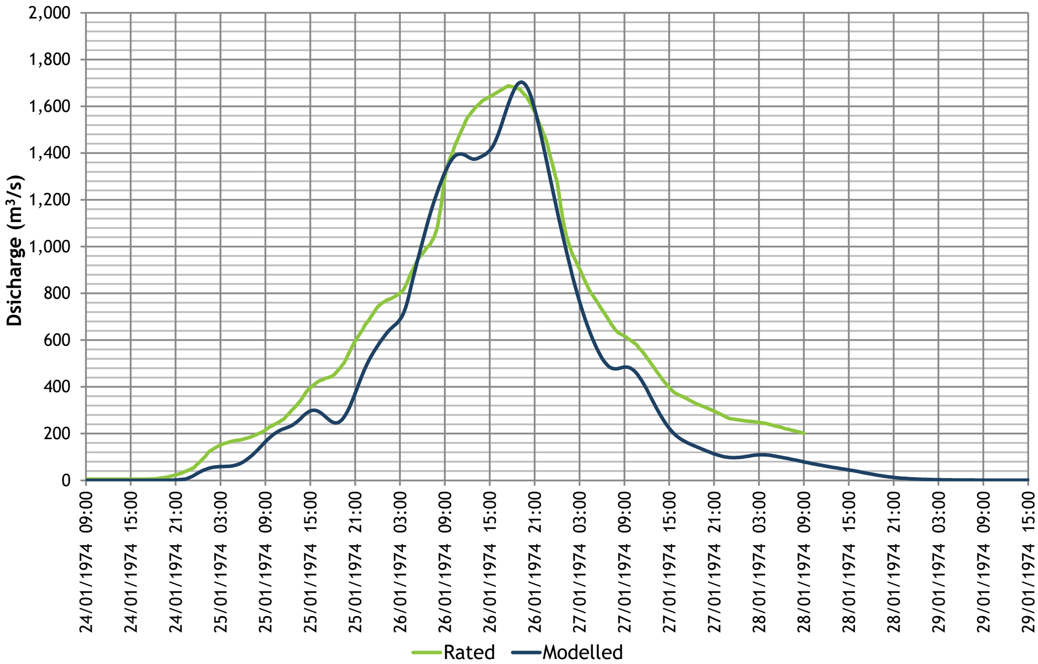

Figure 5.4 - Modelled and rated flows in the Albert River at Bromfleet (DNRM GS 145102a), January 1974

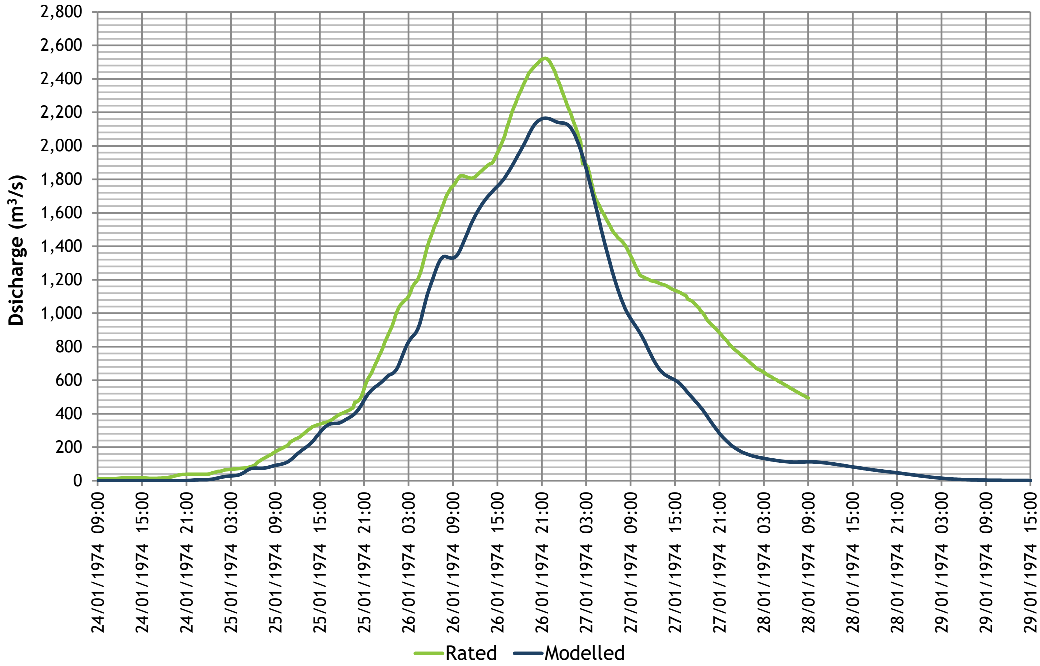

Figure 5.5 - Modelled and rated flows in the Albert River at Wolffdene (DNRM GS 145196a), January 1974

5.7.2 April 1990 calibration event

Table 5.4 shows a comparison of rated and modelled peak discharges at key gauging stations for the April 1990 event. Figure 5.6 to Figure 5.13 compare rated and modelled discharge hydrographs at key gauging stations for the April 1990 event.

Table 5.4 - Rated and modelled peak discharges at key gauging stations, April 1990 flood event

Gauging station name	Gauging station no.	Watercourse	Peak discharge (m³/s)		Difference (%)
			Rated [a]	Modelled	
The Overflow	145012a	Teviot Brook	224	313	40.0%
Round Mountain	145008a	Logan River	588	987	67.8%
Yarrahapinni	145014a	Logan River	1,032	1,350	30.8%
Bromfleet	145102a	Albert River	661	630	-4.6%
Wolffdene	145196a	Albert River	771	853	10.6%
Macleans Bridge [b]	40935	Logan River	957	1,329	38.8%
Logan Village	6263	Logan River	n/a	1,313	n/a
Waterford	40878	Logan River	n/a	1,295	n/a

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

[b] - The peak of the flood was not reached at Macleans Bridge. This gauge appears to have malfunctioned prior to the flood peak.

The following is of note with regards to the April 1990 calibration:

- The April 1990 flood can be considered a small event in the Teviot Brook and Upper Logan catchments; and a moderate event in the Albert and Lower Logan catchments.
- In Teviot Brook, the calibration is poor, with predicted hydrographs at the Overflow returning peak discharges well above the rated hydrographs. The predicted flood peak at the Overflow also occurs some three hours earlier than the rated flood peak. In addition, the shape of the predicted hydrograph does not resemble the rated hydrograph, and it appears there may be some error in the recorded data based on the flat spots in the hydrograph. The calibration in Teviot Brook at the Overflow can be improved by adjusting the losses for the Logan River catchment. However, adjusting rainfall losses to improve the calibration at Teviot Brook results in poorer calibration at Yarrahappini.
- The Upper Logan calibration for the April 1990 event is also poor, with predicted hydrographs at both Round Mountain and Yarrahappini returning peak discharges well above the rated hydrographs. If the rated hydrograph at Round Mountain is adopted in the model (i.e. matched), the predicted hydrograph at Yarrahappini matches very well with the rated hydrograph, indicating that model parameters are acceptable, and the problem is occurring due to the unrepresentative input rainfall data upstream of Round Mountain.
- The Albert River model calibration is acceptable, with the predicted hydrograph at Bromfleet matching adequately with the rated hydrograph for shape, timing and flood volume, while the modelled peak discharge is only slightly less than the rated peak discharge. The predicted flood peak at Wolffdene is higher than the recorded hydrograph, and the predicted hydrograph displays less attenuation than the recorded data. Adjusting rainfall losses to improve the calibration at Wolffdene results in poorer calibration at Bromfleet.
- The April 1990 calibration for the Lower Logan is also poor. The Maclean Bridge gauge did not pick up the peak or the falling limb of the flood hydrograph, as the gauge appears to have failed at approximately midnight on 5 April. The predicted hydrograph at Maclean Bridge substantially over predicts the recorded peak discharge.
- Adopting the Round Mountain recorded hydrograph in the model results in a predicted peak discharge at Yarrahappini of 1,073 m^3/s, which correlates well to the estimated rated peak discharge of 1,032 m^3/s.
- The issues associated with calibration in the Upper Logan and Albert River models appear to be associated with unrepresentative input rainfall data. The April 1990 event was relatively minor, and rainfall varied significantly both spatially and temporally across the catchment. It is considered likely that the dearth of pluviograph availability (only five available pluviographs within the Logan-Albert catchment) has impacted on the calibration results.
- It should be noted that by considering each gauge in isolation, and developing separate model parameters (including rainfall losses) for each gauge, reasonable matches with recorded data can be achieved. However, this approach does not allow catchment wide model parameters to be developed for use in estimating design flood events.
- The calibration results described in Section 7.4 indicates that when the discharges predicted by the XP-RAFTS model for the January 1990 event (with the recorded hydrograph adopted at Round Mountain) are input to the hydraulic model, a good match with recorded water levels is achieved at Yarrahappini, Macleans Bridge, Waterford and Bromfleet.

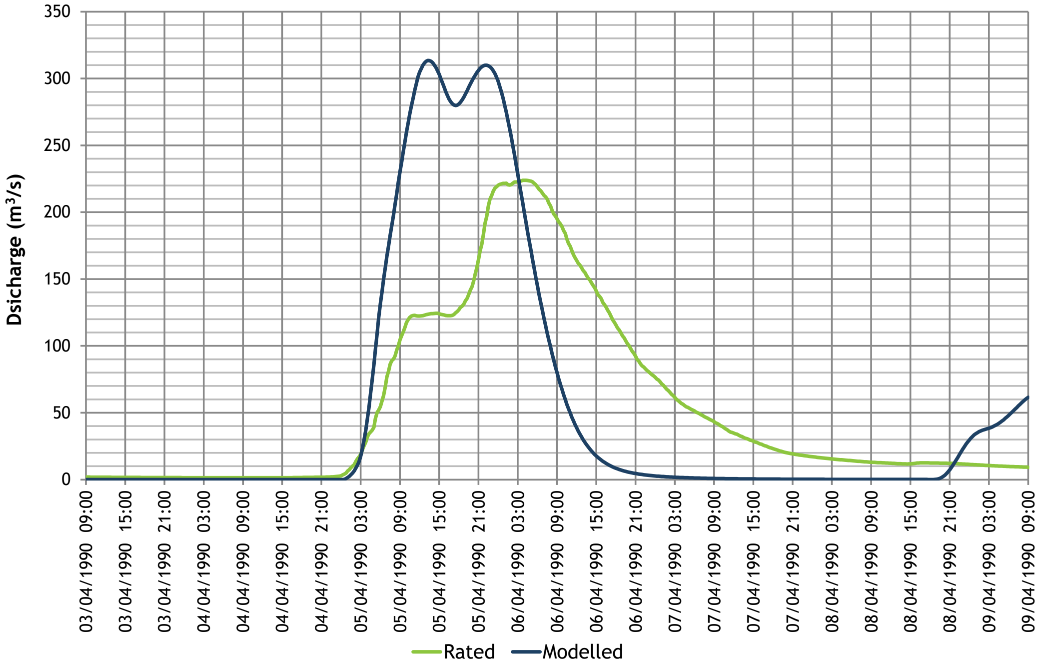

Figure 5.6 - Modelled and rated flows in Teviot Brook at the Overflow (DNRM GS 145012a), April 1990

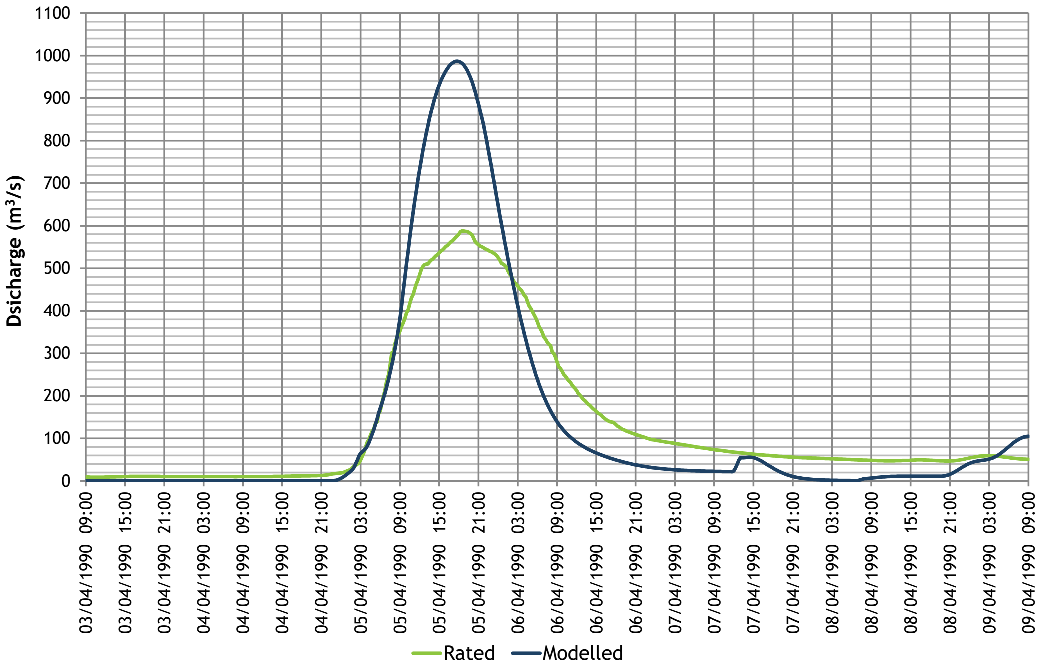

Figure 5.7 - Modelled and rated flows in the Logan River at Round Mountain (DNRM GS145008a), April 1990

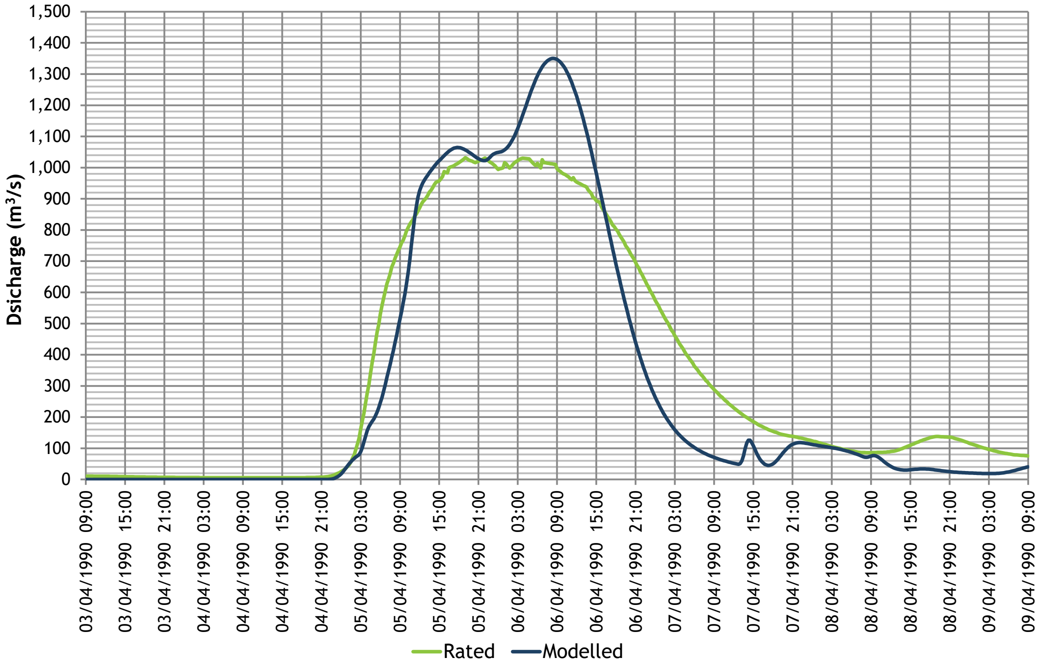

Figure 5.8 - Modelled and rated flows in the Logan River at Yarrahappini (DNRM GS 145014a), April 1990

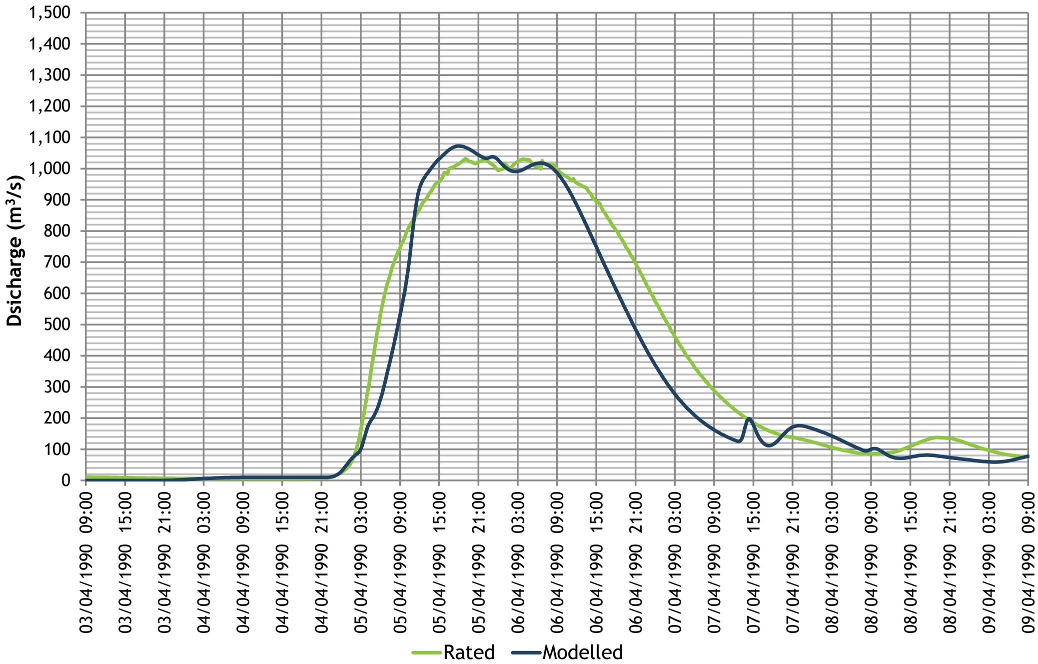

Figure 5.9 - Modelled and rated flows in the Logan River at Yarrahappini (DNRM GS 145014a), April 1990, matching recorded hydrograph at Round Mountain

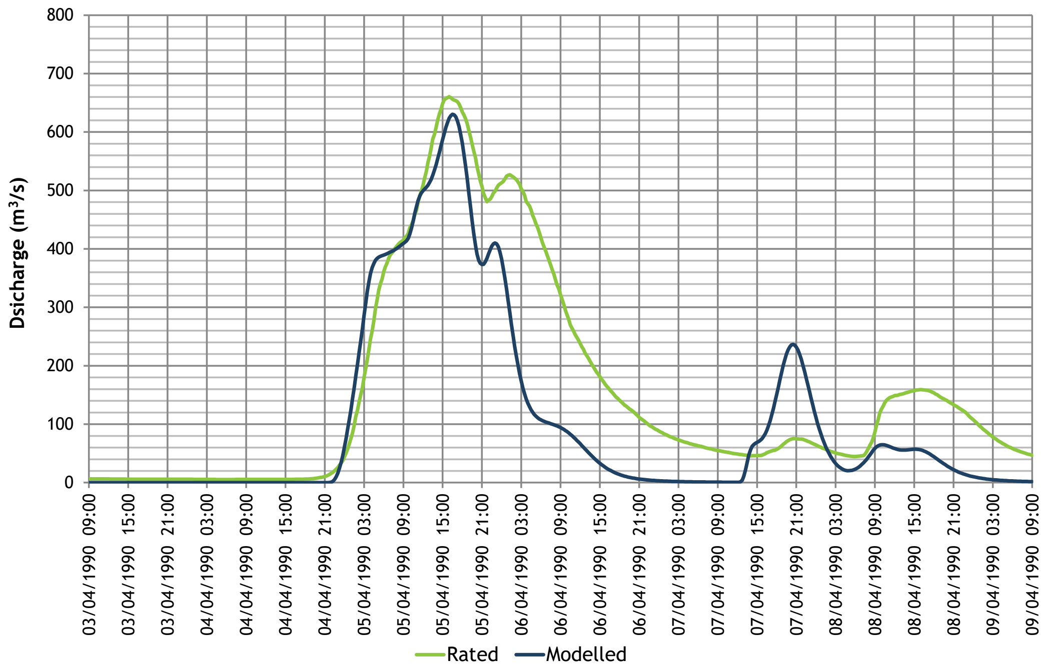

Figure 5.10 - Modelled and rated flows in the Albert River at Bromfleet (DNRM GS 145102a), April 1990

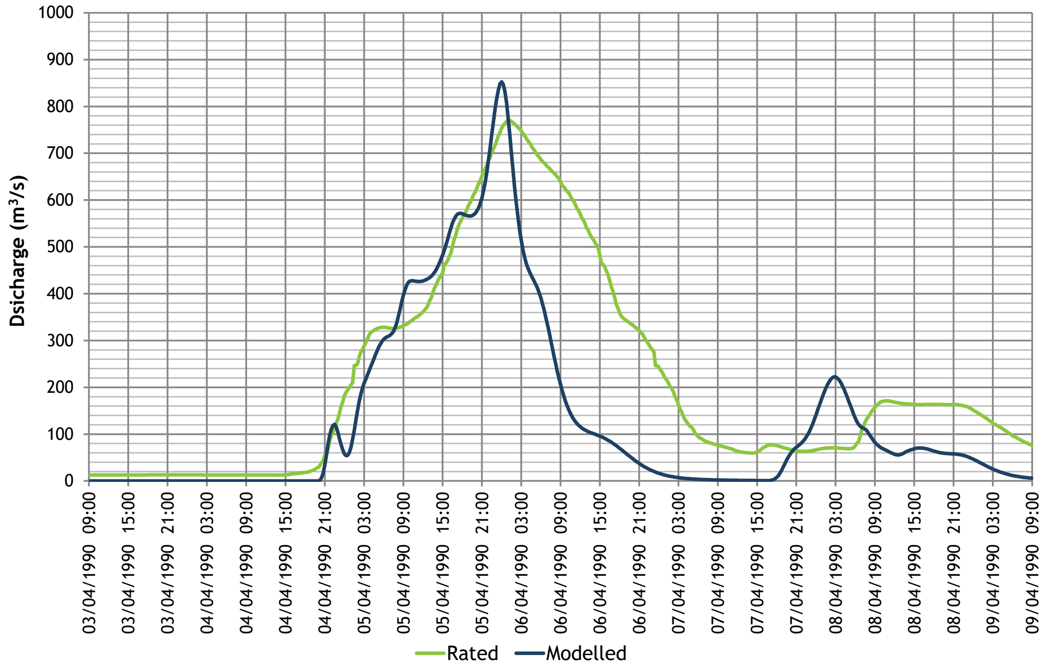

Figure 5.11 - Modelled and rated flows in the Albert River at Wolffdene (DNRM GS 145196a), April 1990

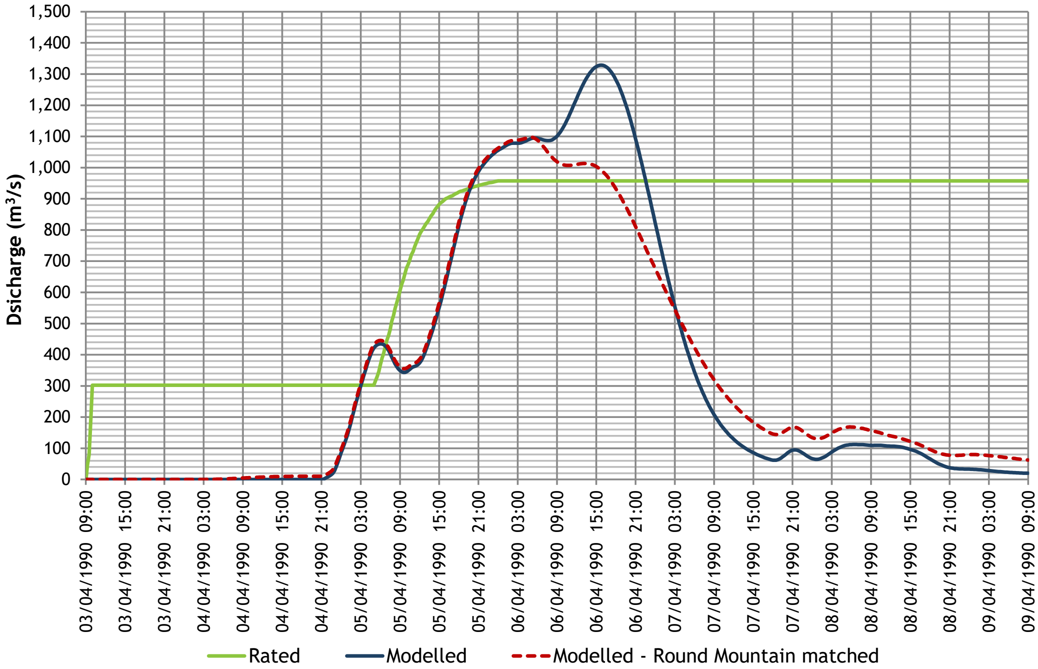

Figure 5.12 - Modelled and rated flows in the Logan River at Maclean Bridge (BOM GS 040935), April 1990

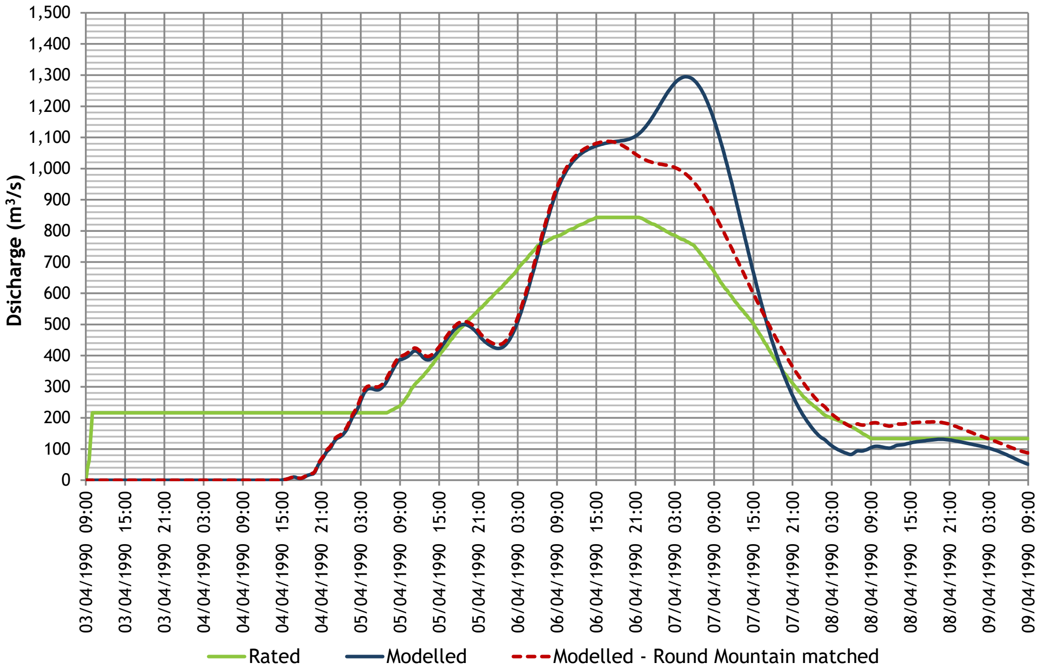

Figure 5.13 - Modelled and rated flows in the Logan River at Waterford (BOM GS 040878), April 1990

5.7.3 January 2013 calibration event

Table 5.5 shows a comparison of rated and modelled peak discharges at key gauging stations for the January 2013 event. Figure 5.14 to Figure 5.19 compare rated and modelled discharge hydrographs at key gauging stations for the January 2013 event.

Table 5.5 - Rated and modelled peak discharges at key gauging stations, January 2013 flood event

Gauging station name	Gauging station no.	Watercourse	Peak discharge (m^3/s)		Difference (%)
			Rated [a]	Modelled	
The Overflow	145012a	Teviot Brook	n/a	816	n/a
Round Mountain	145008a	Logan River	1,109	1,490	34.4%
Yarrahapinni	145014a	Logan River	2,215	2,181	-1.5%
Bromfleet	145102a	Albert River	1,403	1,353	-3.6%
Wolffdene	145196a	Albert River	n/a	1,398	n/a
Macleans Bridge	40935	Logan River	1,708	2,153	26.0%
Logan Village	6263	Logan River	1,694	1,809	6.8%
Waterford	40878	Logan River	942	1,286	36.5%

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

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

- The January 2013 flood can be considered a large event in the Teviot Brook and Albert River, and a moderate event in the Upper and Lower Logan catchments;
- There is no calibration data available at the key stream gauges in Teviot Brook, and the water level recorder in Wyaralong Dam failed during the January 2013 event. The timing and shape of predicted flood hydrograph matches well with the rated hydrograph at the stream gauge at Croftby (DRNM GS 145011a);
- The Upper Logan calibration for the January 2013 event is generally good, with the predicted hydrograph at Round Mountain returning a peak discharge and volume that are larger than the rated hydrograph indicates. The predicted hydrograph at Yarrahappini matches the rated hydrograph well for peak discharge and hydrograph shape. However, the modelled flood peak at Yarrahappini occurs some six hours earlier than the rated flood peak. The predicted flood volume at Yarrahappini at the receding stage of the flood is less than the rated hydrograph. Adjusting the routing parameters upstream of Yarrahappini would improve the calibration at this gauge with regards to the timing of the peak, but this would result in a worse calibration result at this gauge for other events.
- If the rated hydrograph at Round Mountain is adopted in the model, the peak discharge and volume from the rated hydrograph at Yarrahapinni cannot be replicated. As discussed in Section 3.8.1, it is considered likely that the rating curve at Round Mountain substantially underestimated discharges during large flood events such as January 2013.
- The January 2013 Albert River model verification is good, with the predicted hydrograph at Bromfleet matching very well with the rated flood volume, peak discharge, hydrograph shape and timing. The Wolffdene gauge failed during the January 2013 event. The timing and shape of predicted flood hydrographs at secondary gauge sites at Lumeah (DNRM GS 145101d) and the Gorge (DNRM GS 145103a) matches well with the recorded hydrographs.
- The January 2013 calibration for the Lower Logan is considered acceptable. The rated hydrograph at Maclean Bridge is based on manual gauge readings, and

although the peak of the flood is recorded well, there is no record of the rising limb. The predicted discharge hydrograph at Maclean Bridge matches the timing of the rated peak well, however the peak discharge is slightly overestimated. The predicted hydrographs at Logan Village and Waterford appear to overestimate the peak discharge, however as discussed above this is due to the fact that the XP-RAFTS model cannot adequately represent the large amount of floodplain storage available in the lower Logan River. Adopting the rated hydrograph at Yarrahappini in the model does not improve the calibration at Logan Village and Waterford.

- The calibration results described in Section 7.5 indicates that when the discharges predicted by the XP-RAFTS model for the January 2013 event are input to the hydraulic model, a reasonable match with recorded water levels at Logan Village and Waterford is achieved.

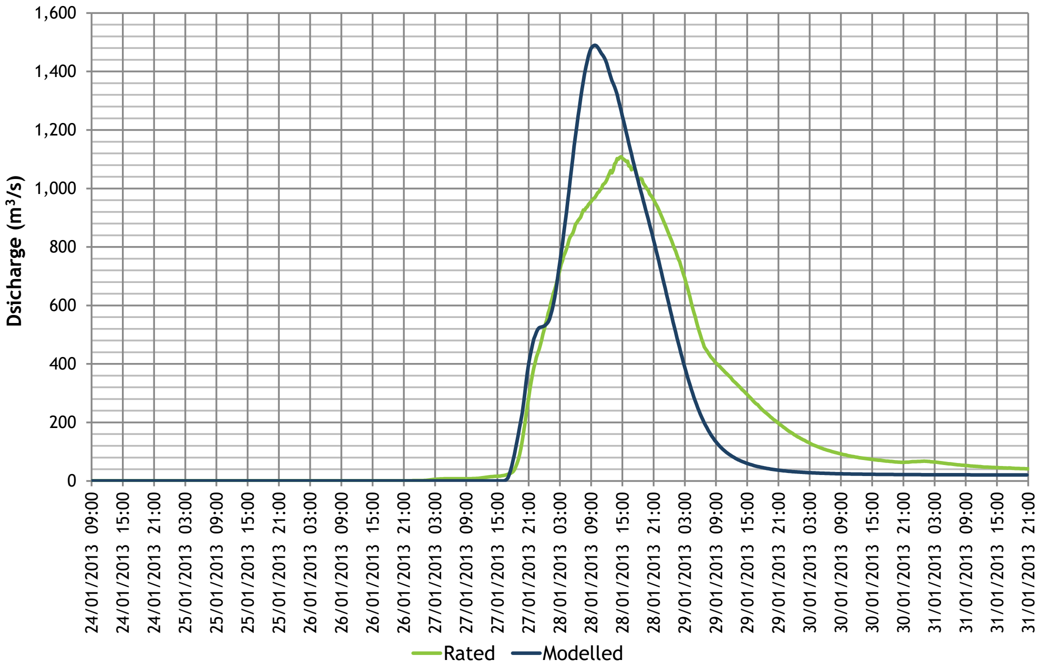

Figure 5.14 - Modelled and rated flows in the Logan River at Round Mountain (DNRM GS 145008a), January 2013

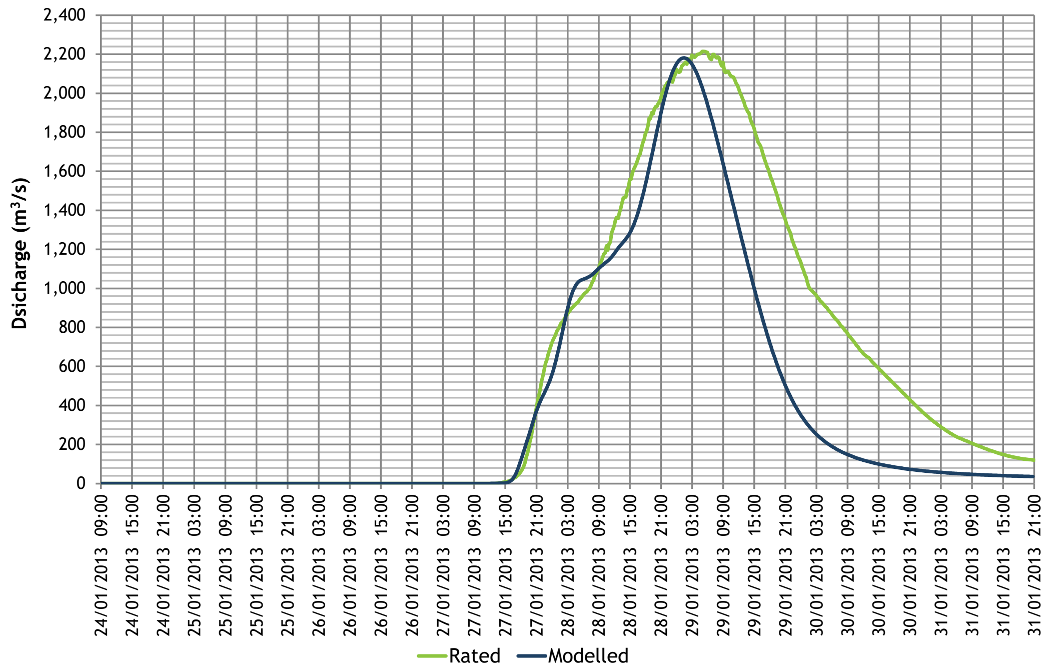

Figure 5.15 - Modelled and rated flows in the Logan River at Yarrahappini (DNRM GS 145014a), January 2013

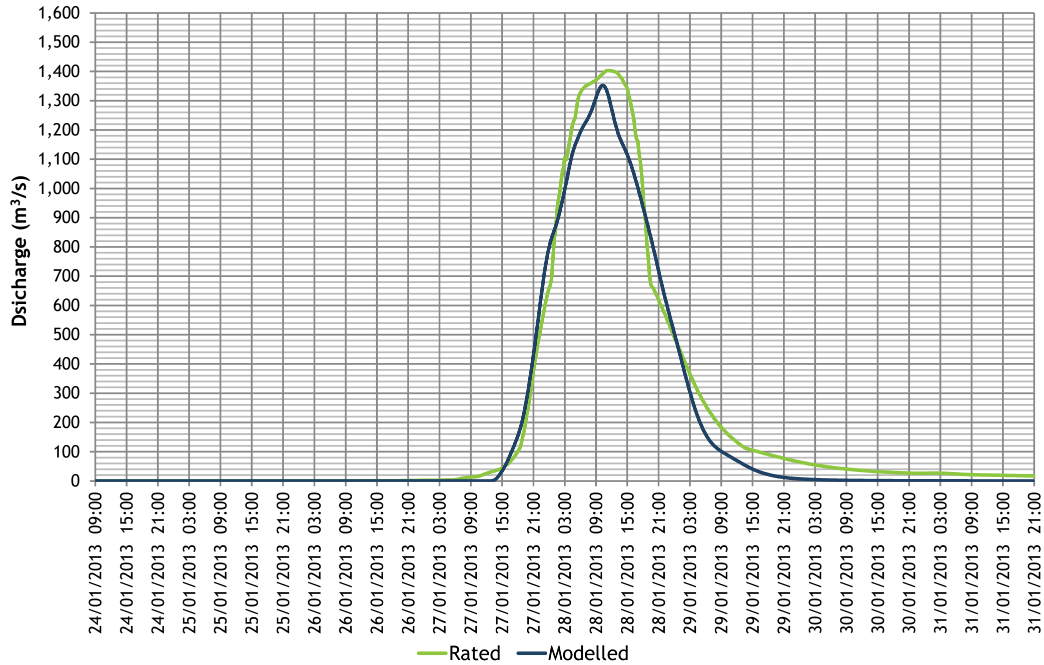

Figure 5.16 - Modelled and rated flows in the Albert River at Bromfleet (DNRM GS 145102a), January 2013

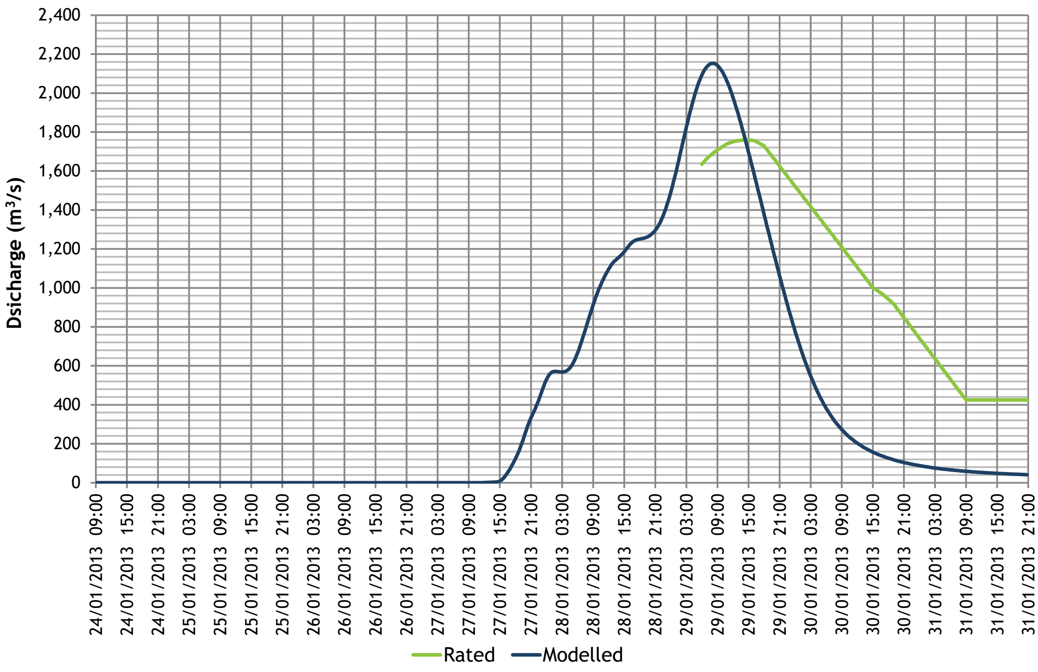

Figure 5.17 - Modelled and rated flows in the Logan River at Maclean Bridge (BOM GS 040935), January 2013

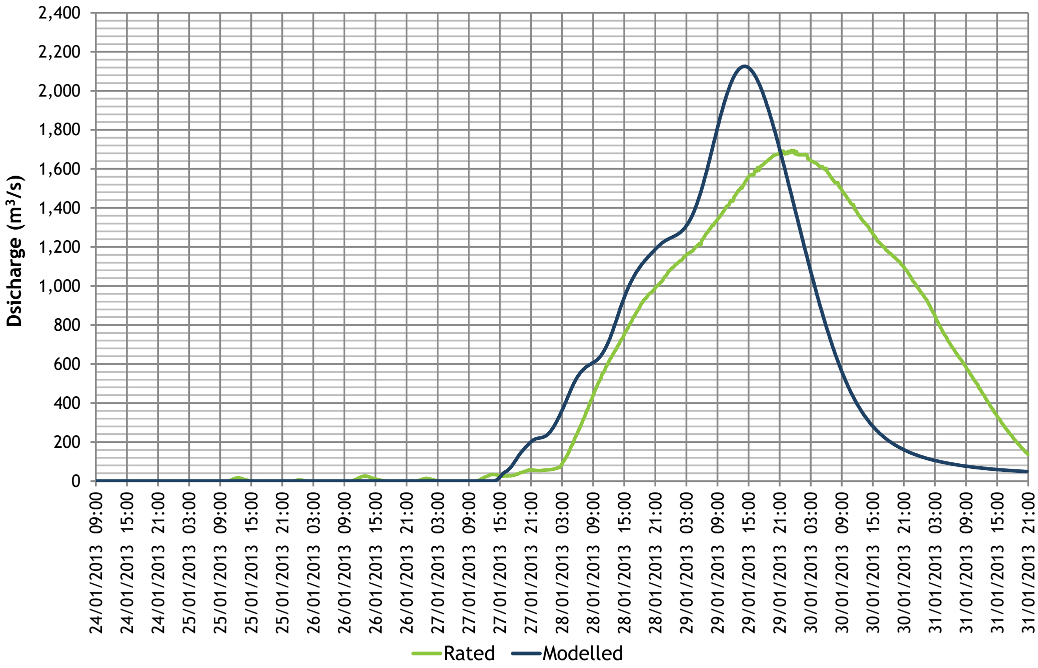

Figure 5.18 - Modelled and rated flows in the Logan River at Logan Village (LCC GS 6263) (BOM GS 040935), January 2013

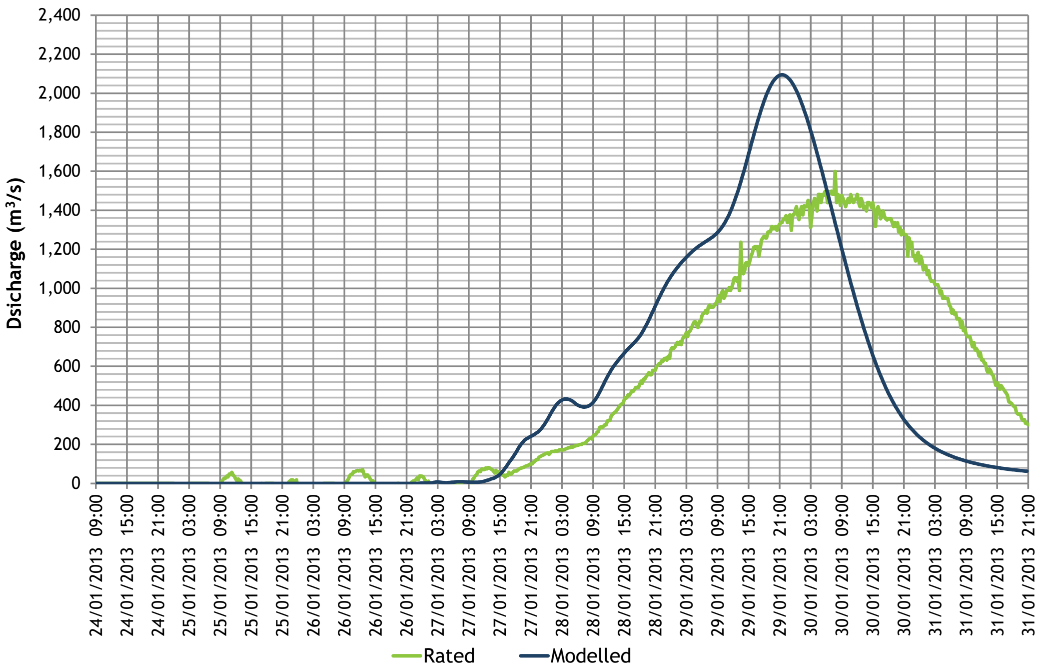

Figure 5.19 - Modelled and rated flows in the Logan River at Waterford (BOM GS 040878), January 2013

5.7.4 March 2017 calibration event

Table 5.6 shows a comparison of rated and modelled peak discharges at key gauging stations for the March 2017 event. Figure 5.20 to Figure 5.27 compare rated and modelled discharge hydrographs at key gauging stations for the March 2017 event. Figure 5.20 also compares the rated and predicted dam water level hydrographs at the Wyaralong Dam spillway during the March 2017 event.

Table 5.6 - Recorded and modelled peak discharges at key gauging stations, March 2017 flood event

Gauging station name	Gauging station no.	Watercourse	Peak discharge (m^3/s)		Difference (%)
			Rated [a]	Modelled	
The Overflow	145012a	Teviot Brook	n/a	754	n/a
Round Mountain	145008a	Logan River	1,681	2,919	73.6%
Yarrahapinni	145014a	Logan River	3,152	3,417	8.4%
Bromfleet	145102a	Albert River	2,384	2,741	16.2%
Wolffdene	145196a	Albert River	2,445	2,667	9.1%
Macleans Bridge	40935	Logan River	2,802	3,366	20.1%
Logan Village	6263	Logan River	2,699	3,327	23.3%
Waterford	40878	Logan River	2,337	3,278	40.3%

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

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

- The March 2017 flood can be considered a large event in both the Logan River and the Albert River.
- The calibration in Teviot Brook is generally acceptable:
  - At the Wyaralong Dam spillway, the modelled spillway discharge hydrograph matches rated hydrograph for shape and flood volume. However, the model appears to overestimate the peak spillway outflow. The timing of the flood peak at the dam spillway also occurs some five hours later than the rated flood peak.
  - The reason for the hydrologic model overestimating outflows at the Wyaralong Dam spillway is likely due to the limited available rainfall data. The delayed timing of the peak spillway outflow is likely due to the XP-RAFTS model slightly overestimated travel times within the dam waterbody.
  - The timing and shape of predicted flood hydrographs at secondary gauge sites at Croftby (DRNM GS 145011a) and Coulson (DNRM GS 145031a) match well with the rated hydrographs.
- The Upper Logan calibration for the March 2017 event is generally acceptable, with the predicted hydrograph at Round Mountain returning a peak discharge and volume that are larger than the rated hydrograph indicates. The modelled hydrograph at Yarrahappini generally matches the shape of the rated hydrograph, but the model appears to overestimate the peak discharge at this gauge. The modelled peak discharge at this gauge is smaller than the rated peak discharge. The modelled flood peak at Yarrahappini occurs some three hours later than the rated flood peak. The predicted flood volume at Yarrahappini is less than the rated hydrograph. Adjusting the routing parameters upstream of Yarrahappini would improve the calibration at this gauge with regards to the timing of the peak, but this would result in a worse calibration result at this gauge for other events.
- If the rated hydrograph at Round Mountain is adopted in the model, the peak discharge and volume from the recorded hydrograph at Yarrahapinni cannot be replicated. As discussed in Section 3.8.1, it is considered likely that the rating curve at Round Mountain substantially underestimated discharges during large flood events such as March 2017.
- The March 2017 Albert River model calibration is acceptable, with the modelled hydrograph at Bromfleet matching very well with the rated hydrograph for flood volume, hydrograph shape and timing. The modelled hydrograph at Wolffdene also match well with the rated hydrograph for flood volume, hydrograph shape and timing. The predicted flood peaks at Bromfleet and Wolffdene are higher than the recorded hydrograph, and the predicted hydrograph displays less attenuation than the recorded data at both gauges.
- The March 2017 calibration for the Lower Logan is considered acceptable. The modelled hydrograph at Maclean Bridge matches well with the shape and timing of the recorded hydrograph, however the peak discharge is slightly overestimated. The predicted hydrographs at Logan Village and Waterford appear to overestimate the peak discharge, however as discussed above this is due to the fact that the XP-RAFTS model cannot adequately represent the large amount of floodplain storage available in the lower Logan River. Adopting the recorded hydrograph at Yarrahappini in the model does not improve the calibration at Logan Village and Waterford.
- The calibration results described in Section 7.6 indicates that when the discharges predicted by the XP-RAFTS model for the March 2017 event are input to the hydraulic model, a good match with recorded water levels at Maclean Bridge, Logan Village and Waterford is achieved.

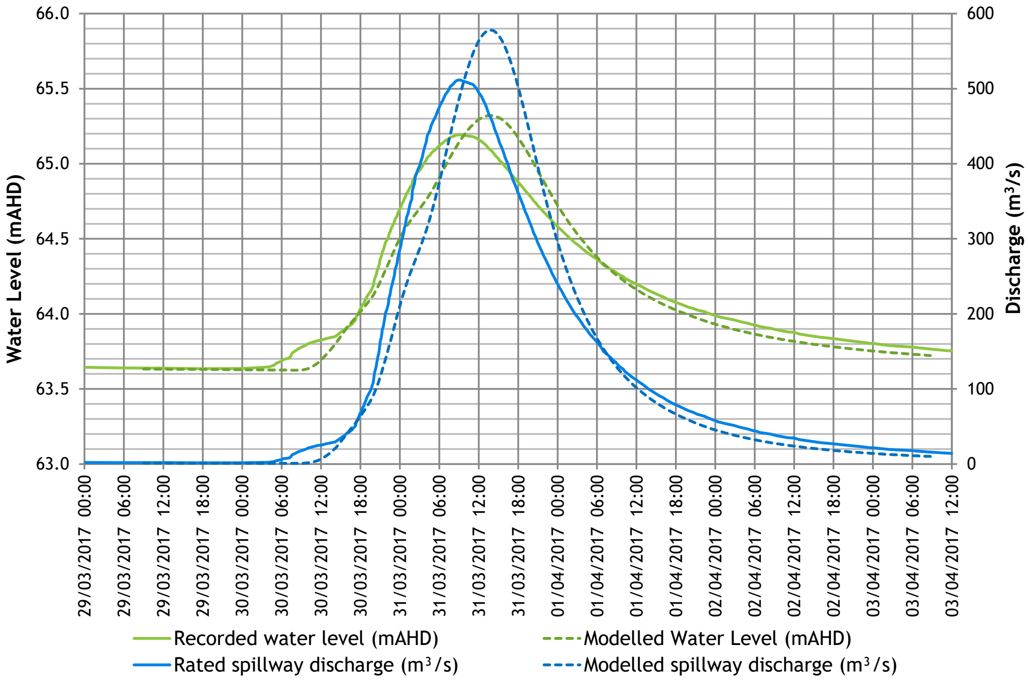

Figure 5.20 - Modelled and rated flows and recorded dam water levels at the Wyaralong Dam Spillway (BOM GS 145033a), March 2017

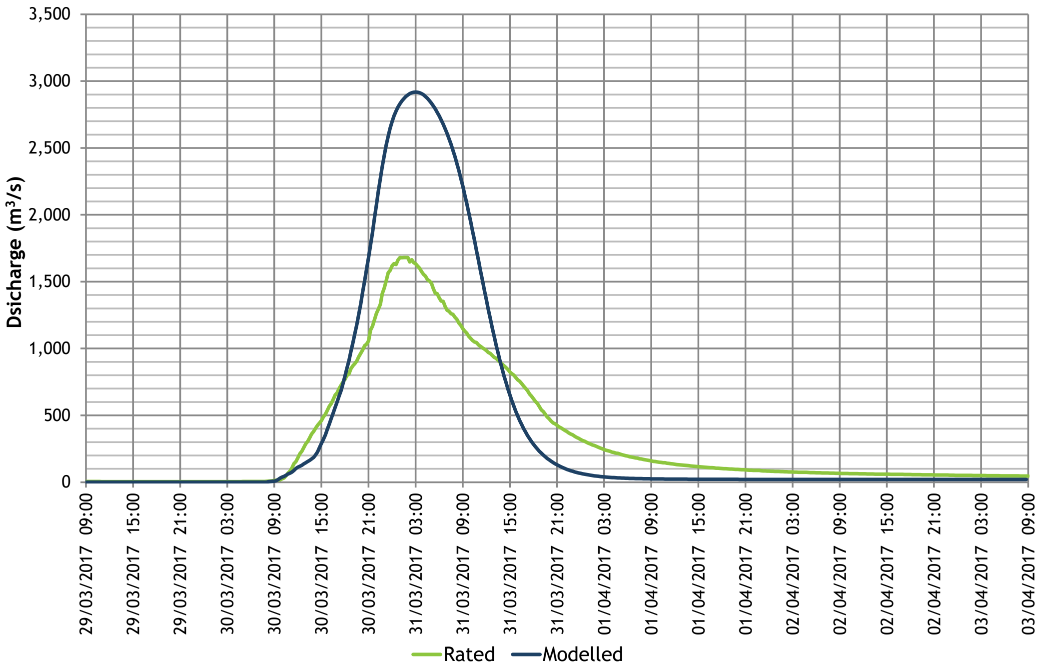

Figure 5.21 - Modelled and rated flows in the Logan River at Round Mountain (DNRM GS 145008a), March 2017

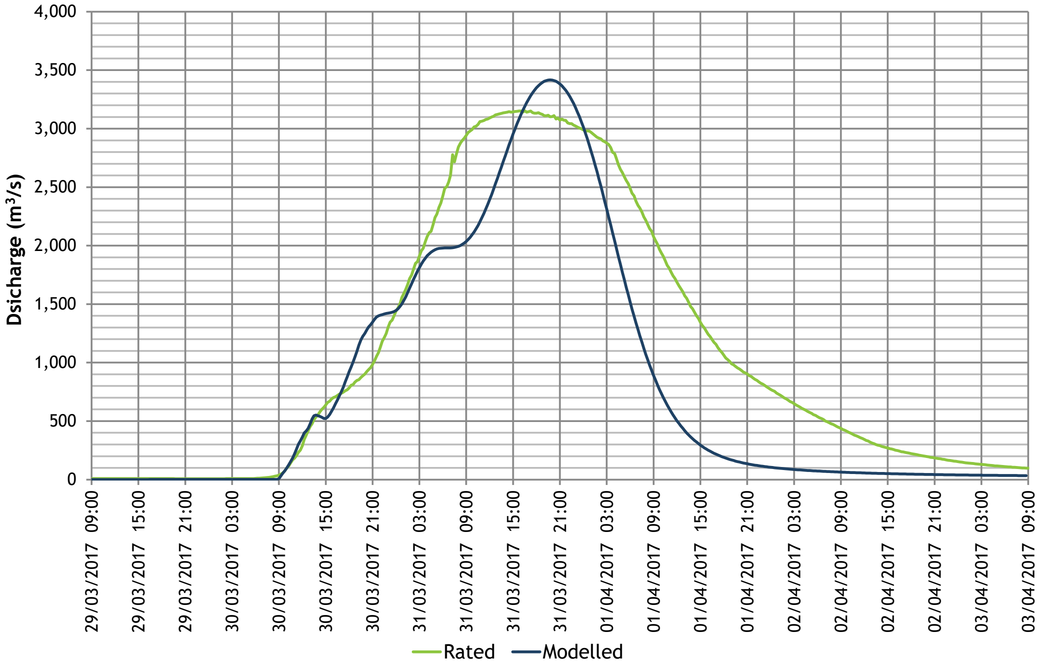

Figure 5.22 - Modelled and rated flows in the Logan River at Yarrahappini (DNRM GS 145014a), March 2017

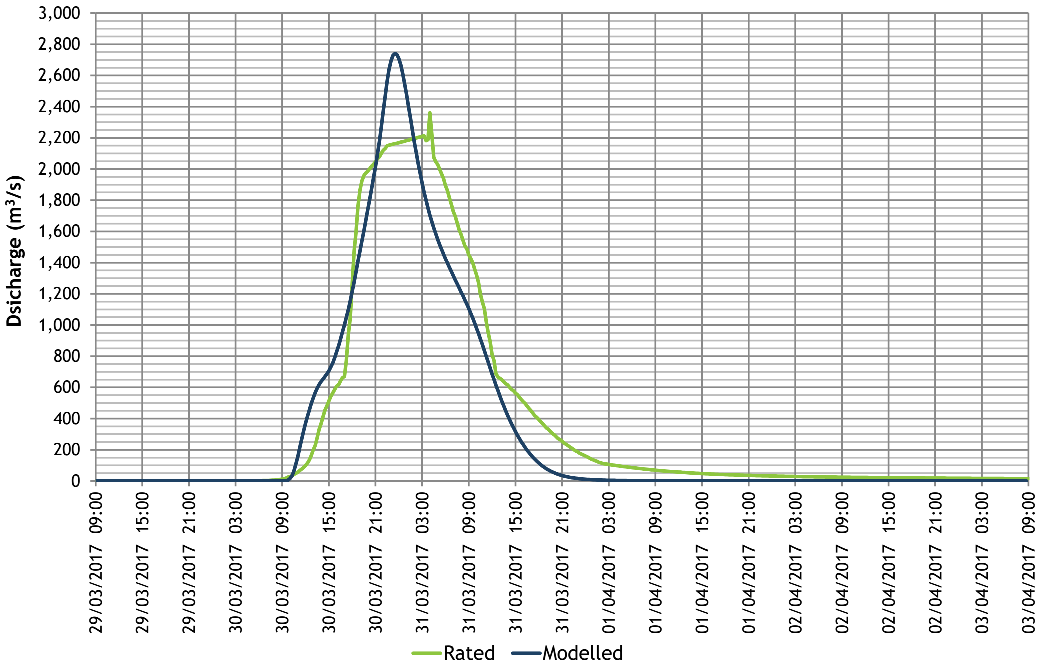

Figure 5.23 - Modelled and rated flows in the Albert River at Bromfleet (DNRM GS 145102a), March 2017

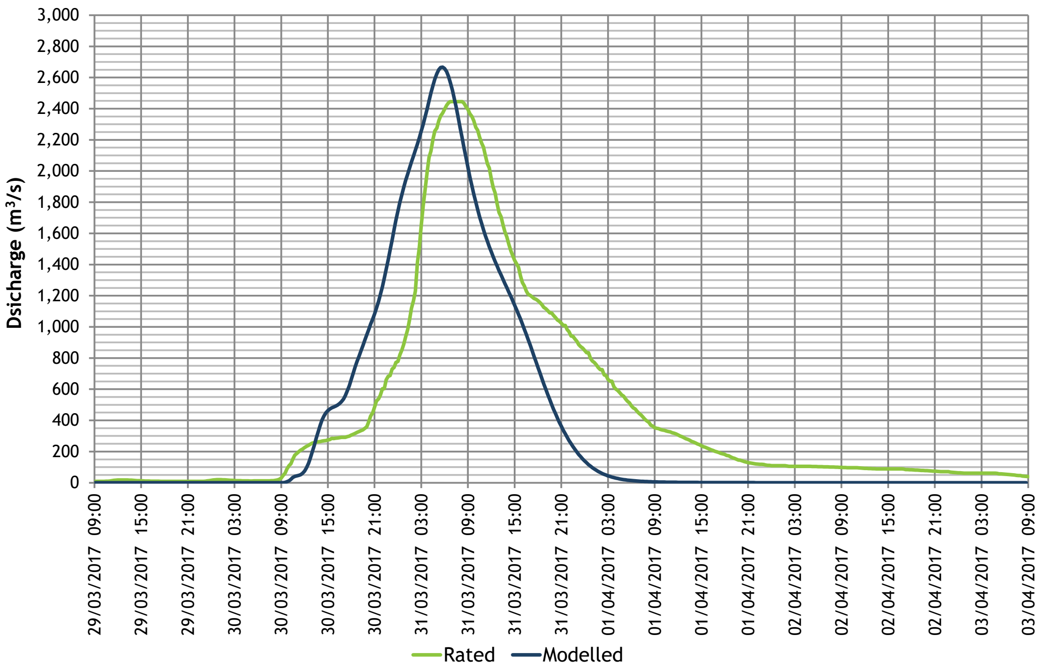

Figure 5.24 - Modelled and rated flows in the Albert River at Wolffdene (DNRM GS 145196a), March 2017

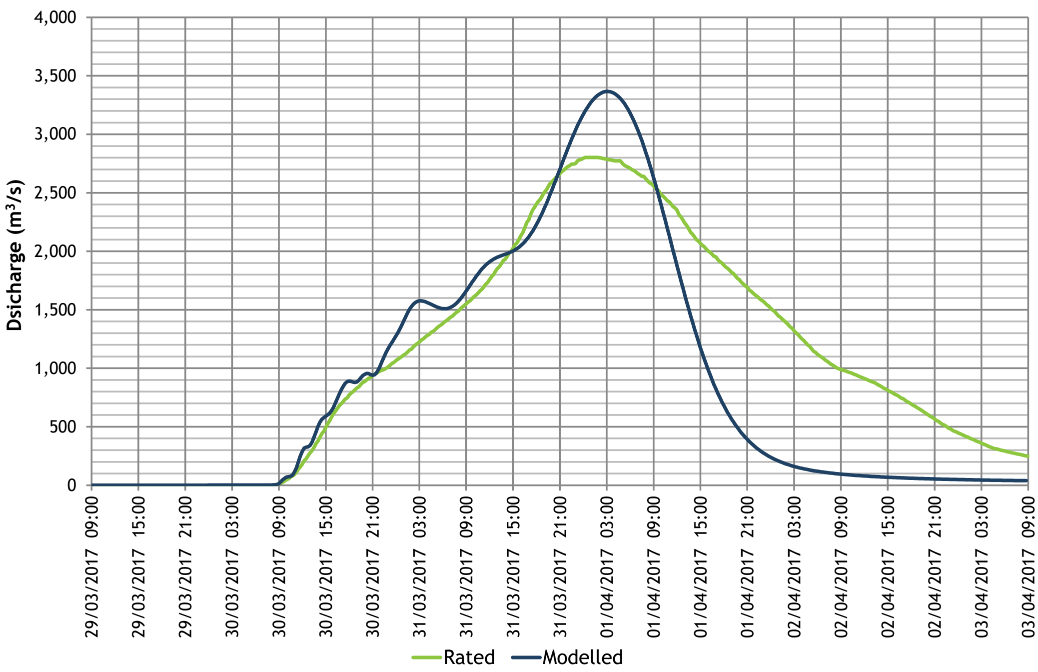

Figure 5.25 - Modelled and rated flows in the Logan River at Maclean Bridge (BOM GS 040935), March 2017

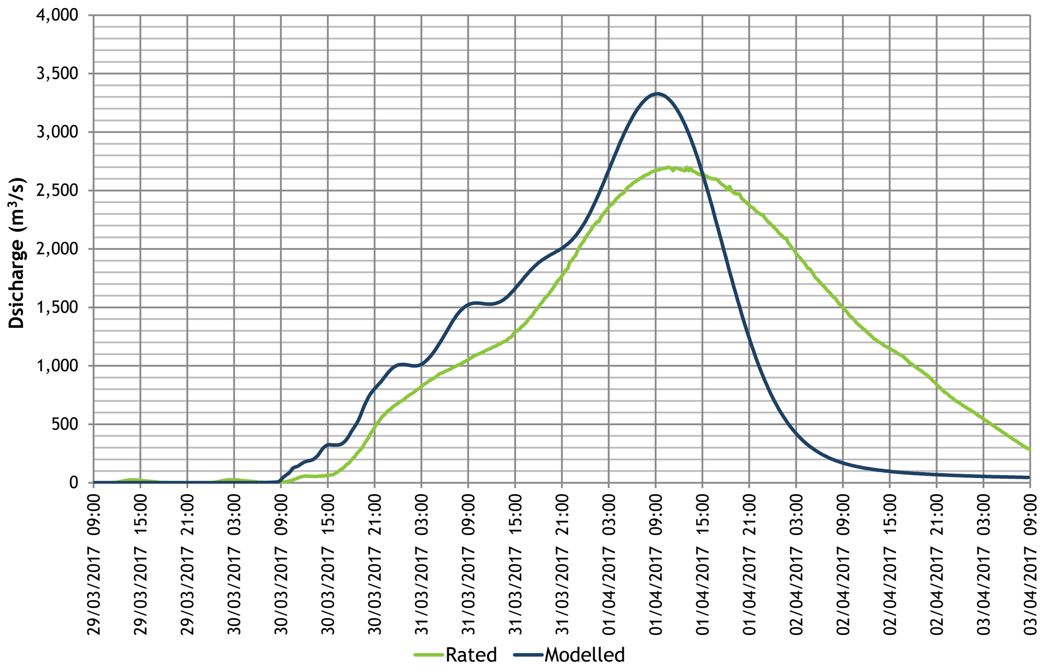

Figure 5.26 - Modelled and rated flows in the Logan River at Logan Village (LCC GS 6263) (BOM GS 040935), March 2017

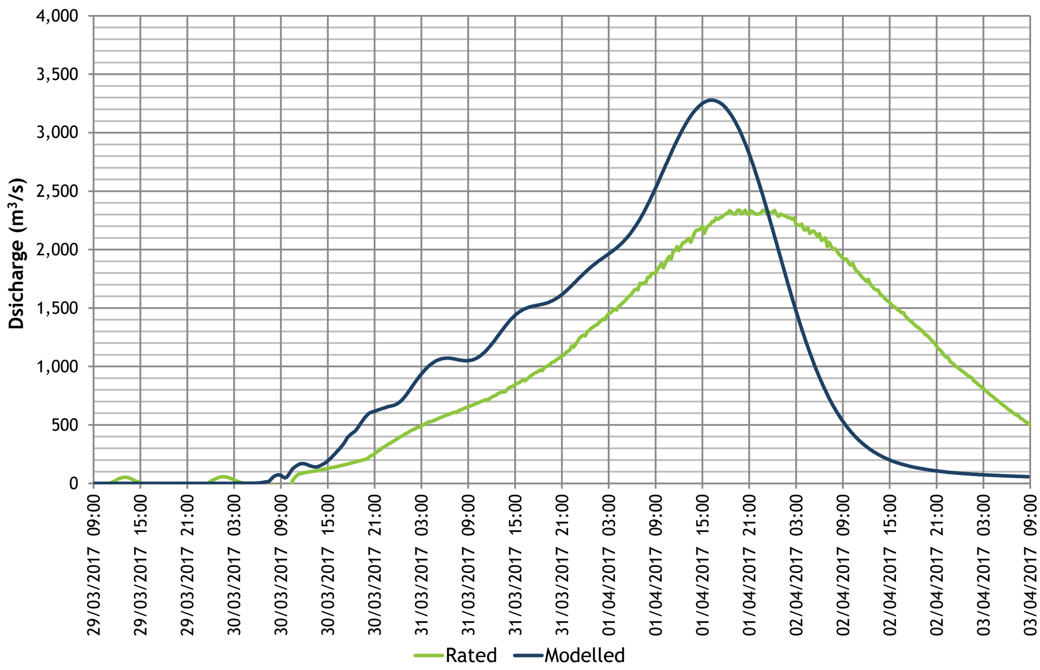

Figure 5.27 - Modelled and rated flows in the Logan River at Waterford (BOM GS 040878), March 2017

5.7.5 February 2022 validation event

Table 5.7 shows a comparison of rated and modelled peak discharges at key gauging stations for the February 2022 event. Figure 5.28 to Figure 5.35 compare rated and modelled discharge hydrographs at key gauging stations for the February 2022 event. Figure 5.28 also compares the rated and predicted dam water level hydrographs at the Wyaralong Dam spillway during the February 2022 event.

Table 5.7 – Recorded and modelled peak discharges at key gauging stations, February 2022 flood event

Gauging station name	Gauging station no.	Watercourse	Peak discharge (m^3/s)		Difference (%)
			Rated [a]	Modelled	
Round Mountain	145008a	Logan River	1,247	1,866	50%
Yarrahapinni	145014a	Logan River	3,100	3,065	-1%
Bromfleet	145102a	Albert River	2,013	1,869	-7%
Wolffdene	145196a	Albert River	1,779	2,390	34%
Macleans Bridge	40935	Logan River	2,790[b]	3,050	9%
Logan Village	6263	Logan River	3,075	3,050	-1%
Waterford	40878	Logan River	2,790	3,066	10%

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

[b] - Macleans Bridge gauge malfunctioned and did not record the peak of the flood

The following is of note with regards to the February 2022 validation:

- The February 2022 flood can be considered a large event in both the Logan River and the Albert River.
- The validation in Teviot Brook is generally acceptable:
  - At the Wyaralong Dam spillway, the modelled spillway discharge hydrograph matches rated hydrograph for shape and flood volume. However, the model appears to overestimate the peak spillway outflow. The timing of the flood peak at the dam spillway also occurs some five hours later than the rated flood peak.
  - The timing and shape of predicted flood hydrographs at secondary gauge sites at Croftby (DRNM GS 145011a) and Coulson (DNRM GS 145031a) match well with the rated hydrographs.
  - The February 2022 validation in Wyaralong Dam is similar to the validation results for the March 2017 event.
- The Upper Logan validation for the February 2022 event is generally acceptable, with the predicted hydrograph at Round Mountain returning a peak discharge and volume that are larger than the rated hydrograph indicates. The modelled hydrograph at Yarrahappini generally matches the shape, timing and peak of the rated hydrograph, but predicted flood volume at Yarrahappini is less than the rated hydrograph. The underprediction of flood volume could be an issue with hysteresis recorded during the receding limb of the flood.
- If the rated hydrograph at Round Mountain is adopted in the model, the peak discharge and volume from the recorded hydrograph at Yarrahapinni cannot be replicated. As discussed in Section 3.8.1, it is considered likely that the rating curve at Round Mountain substantially underestimated discharges during large flood events such as February 2022.
- The February 2022 Albert River model validation is acceptable, and represents a compromise between the observed flows at Bromfleet and flows at Wolffdene. The

modelled hydrograph at Bromfleet matches the shape and timing of the observed hydrograph well, but underestimates the rated peak flow. However, the modelled hydrograph at Wolffdene significantly overestimates the peak flow compared to the observed hydrograph. It should be noted that the rated peak discharge at Wolffdene is 234 m^3/s less than the rated peak discharge at Bromfleet. It is of note that rated flows for the other calibration events increase between Bromfleet and Wolffdene. Considering the timing and intensity of rainfall between Bromfleet and Wolffdene during the February 2022 event, it is extremely unlikely that the peak discharge in the Albert River decreased between Bromfleet and Wolffdene. Therefore it is considered likely that the gauge record at Wolffdene is incorrect.

- The February 2022 validation for the Lower Logan is considered acceptable. The modelled hydrograph at Maclean Bridge matches well with the shape and timing of the recorded hydrograph, however the peak discharge is overestimated. The modelled hydrograph at Waterford also appear to overestimate the peak discharge, however as discussed above this is due to the fact that the XP-RAFTS model cannot adequately represent the large amount of floodplain storage available in the lower Logan River.
- The validation results described in Section 7.6 indicates that when the discharges predicted by the XP-RAFTS model for the February 2022 event are input to the hydraulic model, a good match with recorded water levels at Maclean Bridge, Logan Village and Waterford is achieved.

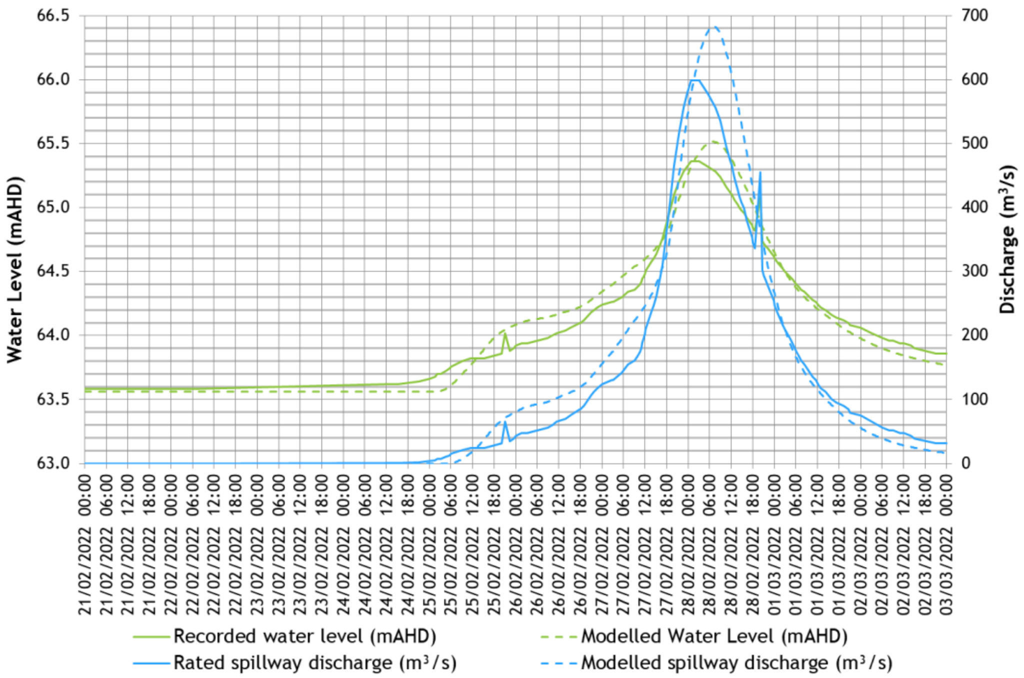

Figure 5.28 - Modelled and rated flows and recorded dam water levels at the Wyaralong Dam Spillway (BOM GS 145033a), February 2022

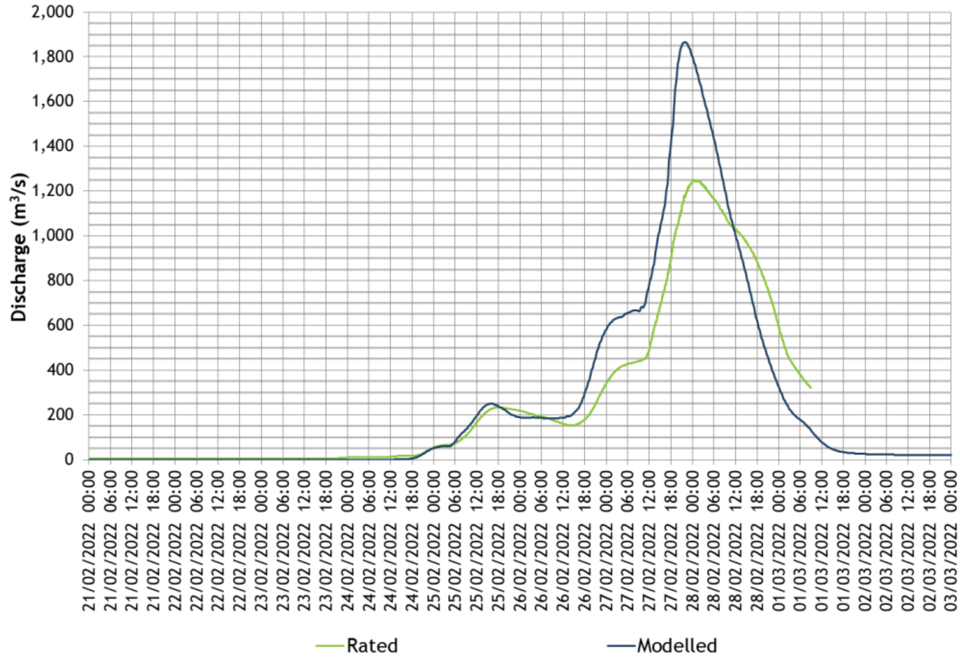

Figure 5.29 - Modelled and rated flows in the Logan River at Round Mountain (DNRM GS 145008a), February 2022

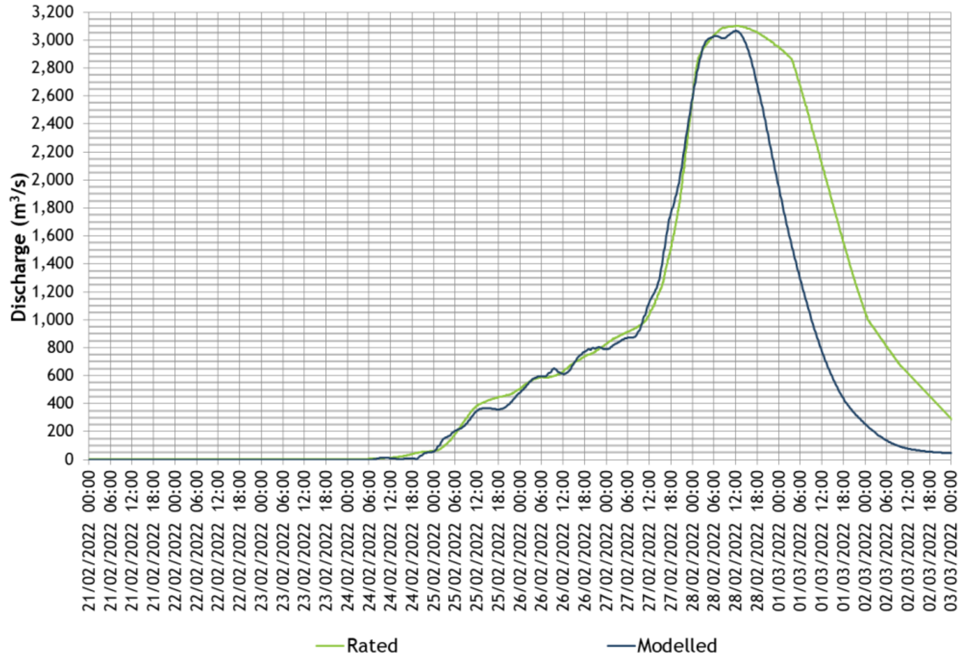

Figure 5.30 - Modelled and rated flows in the Logan River at Yarrahappini (DNRM GS 145014a), February 2022

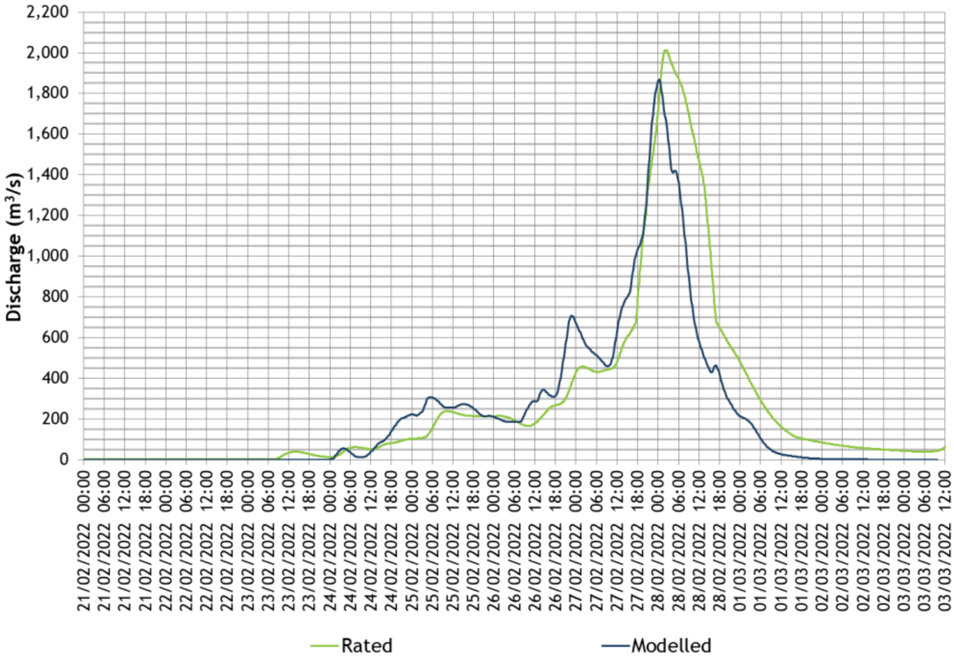

Figure 5.31 - Modelled and rated flows in the Albert River at Bromfleet (DNRM GS 145102a), February 2022

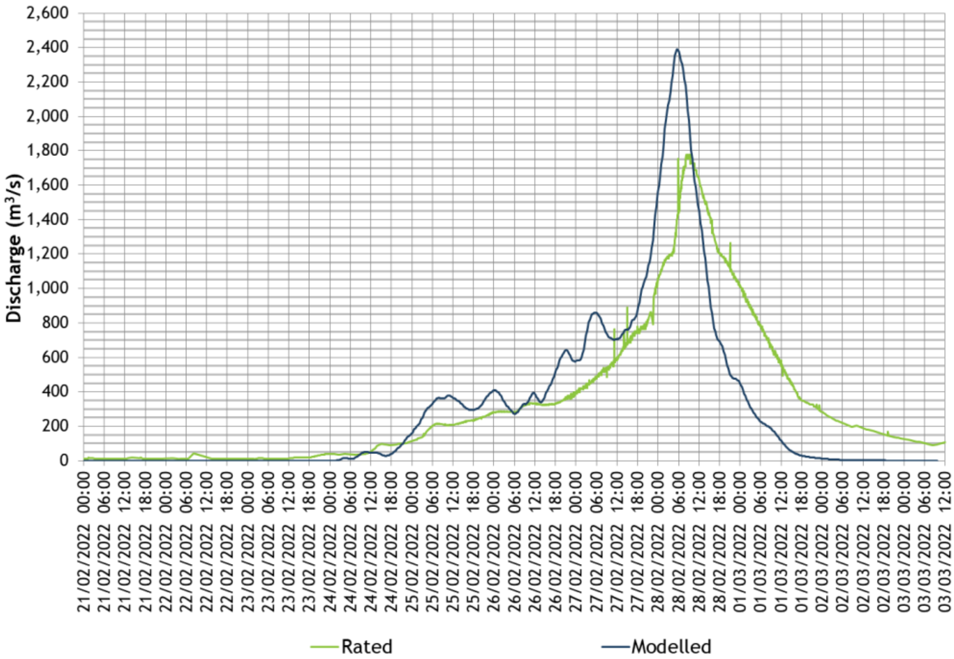

Figure 5.32 - Modelled and rated flows in the Albert River at Wolffdene (DNRM GS 145196a), February 2022

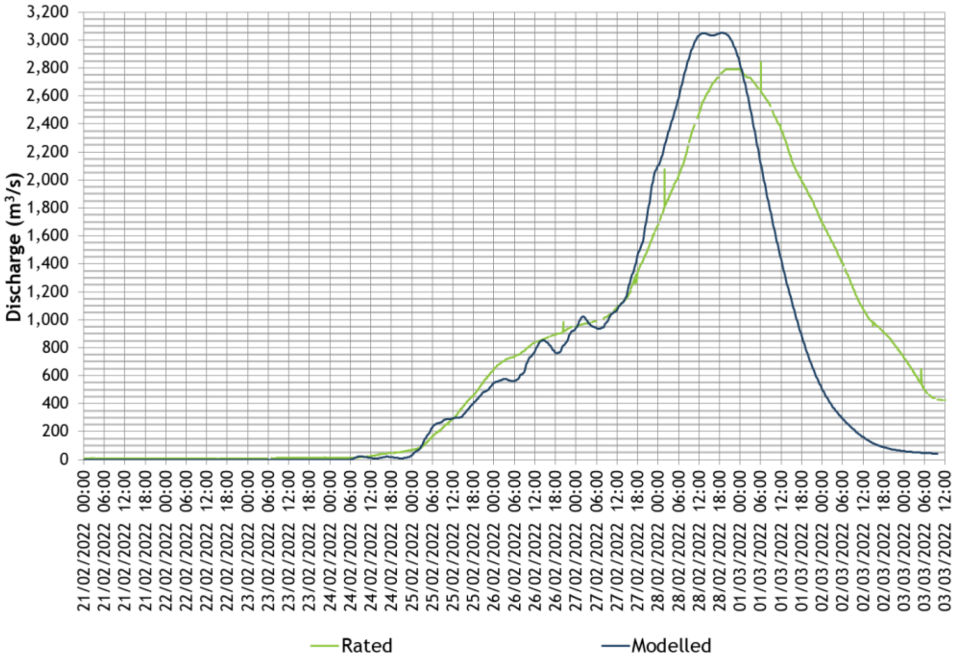

Figure 5.33 - Modelled and rated flows in the Logan River at Maclean Bridge (BOM GS 040935), February 2022

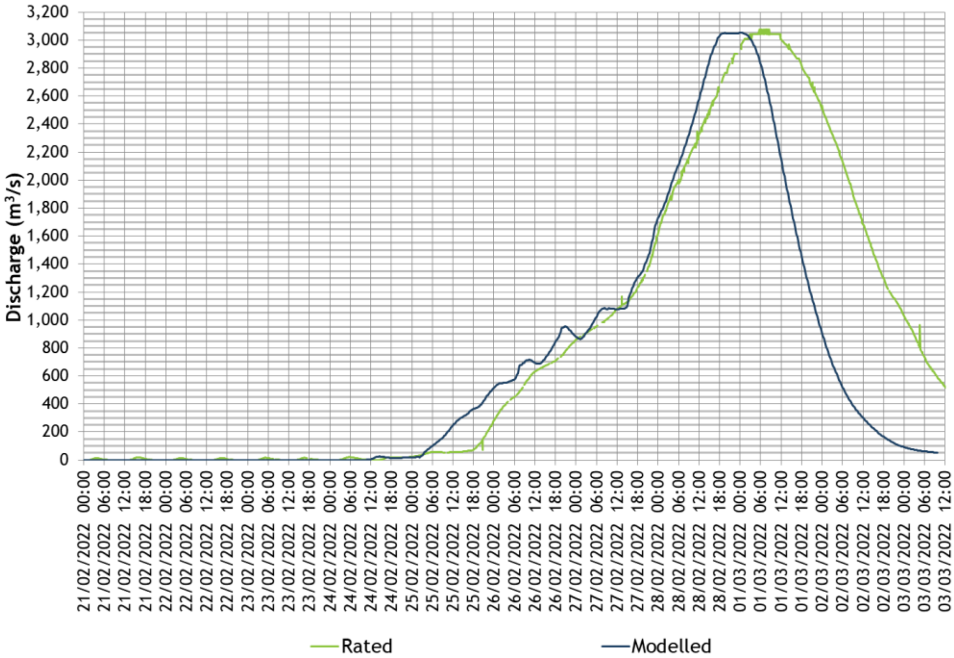

Figure 5.34 - Modelled and rated flows in the Logan River at Logan Village (LCC GS 6263) (BOM GS 040935), February 2022

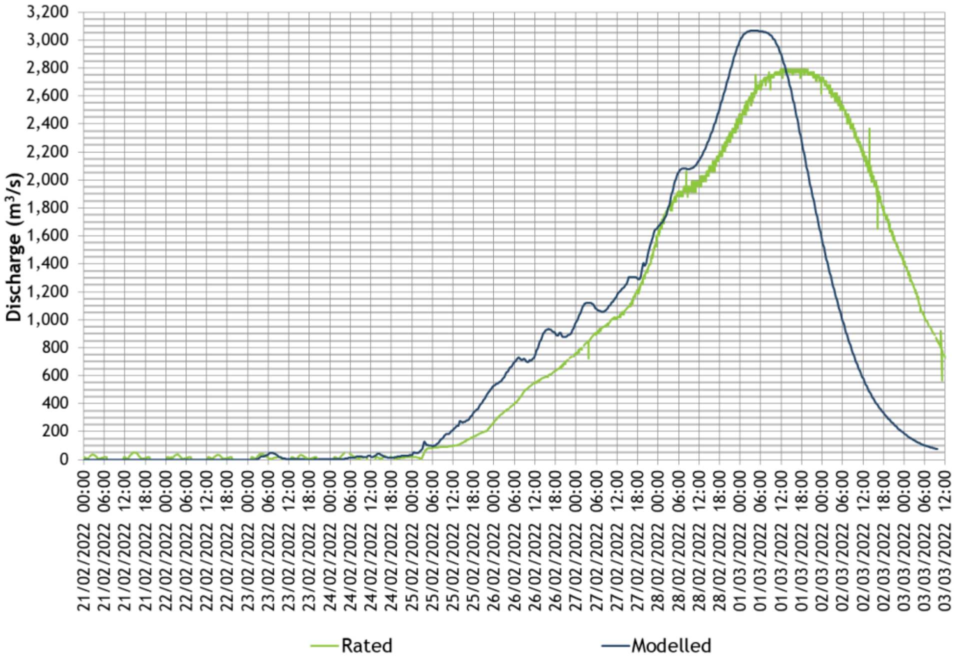

Figure 5.35 - Modelled and rated flows in the Logan River at Waterford (BOM GS 040878), February 2022

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 Logan and Albert rivers 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 2018-03-AD 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 the Logan and Albert rivers and their tributaries.

The discharges estimated using the XP-RAFTS hydrologic model were adopted as inflows to the TUFLOW hydraulic model. The XP-RAFTS hydrograph inputs used were a combination of total inflow hydrographs at the upstream boundaries of the model, with local inflow hydrographs for all downstream subcatchments within the model boundary.

6.2 SPATIAL CONFIGURATION AND GRID CELL SIZE

Figure 6.1 shows the Logan and Albert Rivers TUFLOW model configuration. The model covers an area of 453 km^2 and includes the Logan River from Gleneagle to the just upstream of the river mouth, and the Albert River from Birnam to the Logan River confluence. The following two TUFLOW models were developed. These models were:

- **'Fast Model'** – This model was configured with a grid cell size of 20 m. The purpose of this model is to allow the selection of critical design storms and then minimise the number of design event simulations is required to be run using a finer 'detailed model'.
- **'Detailed Model'** – This model was configured with a grid cell size of 10 m. The purpose of this model is to run the critical design storms selected using the 'Fast Model' to obtain the design outputs.

A grid cell size of 10 m is considered to be most suitable for generating the design outputs for this study. However, the 'Fast Model' (with a 20 m grid) was required for this study to more efficiently implement the 'ensemble' method of design event modelling described in AR&R 2019. This approach is described in more detail in Sections 9.4.1 and 10.2.

6.3 TOPOGRAPHY

6.3.1 Base model topography

For the purpose of calibrating of the hydraulic model to the January 1974, April 1990 and January 2013 events, the base model topography was configured using the 2013 LiDAR data. The 2014 LiDAR data was also used for some floodplain areas near the downstream end of the model that are not covered by the 2013 LiDAR data.

For the purpose of calibrating of the hydraulic model to the March 2017 events, and for undertaking design event hydraulic modelling, the base model topography was configured using the 2017 and 2021 LiDAR data. The 2014 LiDAR data was also used for some floodplain areas near the downstream end of the model that are not covered by the 2017 or 2021 LiDAR data. The 2021 LiDAR data was used in the design model runs in preference to the earlier data. There were locations where incongruities occurred with the 2021 LiDAR data. For example the 2021 LiDAR had captured standing water and the reflection of the water surface had infilled what had been a low point present in 2017 LiDAR. When this occurred, the 2017 dataset replaced the LAS data that categorised as a water reflection.

6.3.2 GDA 2020 Conversion

As part of the finalisation of the model, the files used within the model were converted from their existing projection on the GDA 94 datum. All geospatial components of the hydraulic model were updated to the GDA 2020 datum. This reflects the tectonic motion of Australia and has no impact on the production of modelled results.

6.3.3 Channel bathymetry

For the purpose of calibrating of the hydraulic model to the January 1974, April 1990 and January 2013 events, the bathymetry of the lower reaches of the Logan River (up to Stockleigh) and Albert River (up to Wolffdene) were configured based on the 2013 bathymetry data.

For the purpose of calibrating of the hydraulic model to the March 2017 events, and for undertaking design event hydraulic modelling, the bathymetry of the lower reaches of the Logan River (up to Stockleigh) and Albert River (up to Wolffdene) were configured based on the 2019 bathymetry data.

For the Logan River channel upstream of Stockleigh, and the Albert River channel upstream of Wolffdene, a series of 'z-shape' objects were used to improve the representation of channel inverts along these upper reaches. For the January 1974, April 1990 and January 2013 calibration models, the z-shapes were configured based on surveyed cross sections obtained from the 2013 bathymetric survey. For the March 2017 calibration model, the February 2022 validation model and for design event hydraulic modelling, the z-shapes were configured based on surveyed cross sections obtained from the 2019 bathymetric survey.

6.4 INFLOW AND OUTFLOW BOUNDARIES

6.4.1 Inflow boundaries

Figure 6.1 shows the locations of inflow boundaries adopted in the TUFLOW model. The model has a total of 96 inflow boundaries, including 24 total and 72 local inflow boundaries. The TUFLOW model inflow boundaries were configured using 2D surface-area (SA) polygons. Using this approach, flows are initially applied to the lowest point within each SA polygon, then gradually applied over a larger area within the SA polygon as the discharge increases. Total and local inflow hydrographs generated from the XP-RAFTS model were adopted as inflows at the 2D SA inflow boundaries.

6.4.2 Outflow boundaries

Figure 6.1 shows the locations of the outflow boundary adopted in the TUFLOW model. The outflow boundary of the TUFLOW model is located in the Logan River approximately 2.2 km downstream of the Serpentine Creek confluence (approximately 5 km upstream of the Logan River mouth). This outflow boundary extends to the southwest across the southern Logan River floodplain downstream of the Albert River confluence, to provide an outlet for overflows from the lower Logan River floodplain during large flood events.

There is no stream gauge at the TUFLOW model's downstream boundary location. For the 1990, 2013 and 2017 calibration events, water level hydrographs recorded at the Riedel Road AL (GS 540236) gauging station were adopted at the primary outflow boundary of the model. This was deemed appropriate due to the proximity of the gauging station to the primary outflow model boundary location. The following is of note:

- For the 1974 calibration event, a water level hydrograph was derived for the primary outflow boundary, based on the water level hydrograph shape just upstream of the outflow boundary, and a maximum water level equal to the surveyed debris level of 2.6 mAHD near the primary outflow boundary location.

- For the February 2022 event, a synthetic tidal boundary was adopted based on recorded tidal water levels during the event.
- For design events, a fixed or time varying tidal tailwater was adopted for the primary outflow boundary depending on the AEP being modelled. The adopted tailwater boundary conditions for design events are provided in Section 10.3.5.

6.5 HYDRAULIC ROUGHNESS

6.5.1 Overview

Hydraulic roughness in the TUFLOW model is represented by Manning's 'n' roughness coefficients. 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. The distribution of landuses within the hydraulic model extent was identified using aerial photography.

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.

Table 6.1 shows a summary of the adopted hydraulic roughness (Manning's 'n') coefficients used for each landuse type in the hydraulic model. Figure B.1 to Figure B.5 in Appendix B are maps showing the distribution of landuses within the hydraulic model extent.

6.5.2 Channel roughness

For river channels, Manning's 'n' were varied with depth. This approach reflects the variation in vegetation density at various depths within the river channels. Figure 6.2 illustrates the four 'depth regions' within each river 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', the presence of tree canopies would increase the hydraulic roughness further (compared to depth region n2).
- At depth region 'n4', water would flow above the vegetation level, so the hydraulic roughness for this depth region would be lower than in region n3.

For river channels, slightly different Manning's 'n' values were adopted for each channel type between the fast model (20 m grid) and the detailed model (10 m grid). Due to the finer grid resolution, channel capacities are generally higher in the finer (10 m grid) detailed model compared to the coarser (20 m grid) fast model. Therefore, the adopted river channel Manning's 'n' values in the detailed model are slightly higher than in the fast model. This approach is required so that both the detailed model and the fast model would produce similar results when applied equal inflows. If the same Manning's 'n' values were adopted for river channels between the fast model and the detailed model, the detailed model would produce significantly lower peak flood levels than the fast model.

Table 6.2 shows the adopted hydraulic roughness (Manning's 'n') coefficients used for each channel type in the 20 m grid 'fast model'. Table 6.3 shows the adopted hydraulic roughness (Manning's 'n') coefficients used for each channel type in the 10 m grid 'detailed model'. The distinction between 'smooth', 'rough' and 'very rough' channel sections were determined based on vegetation density and water surface areas observed from aerial photos and Google Street View images.

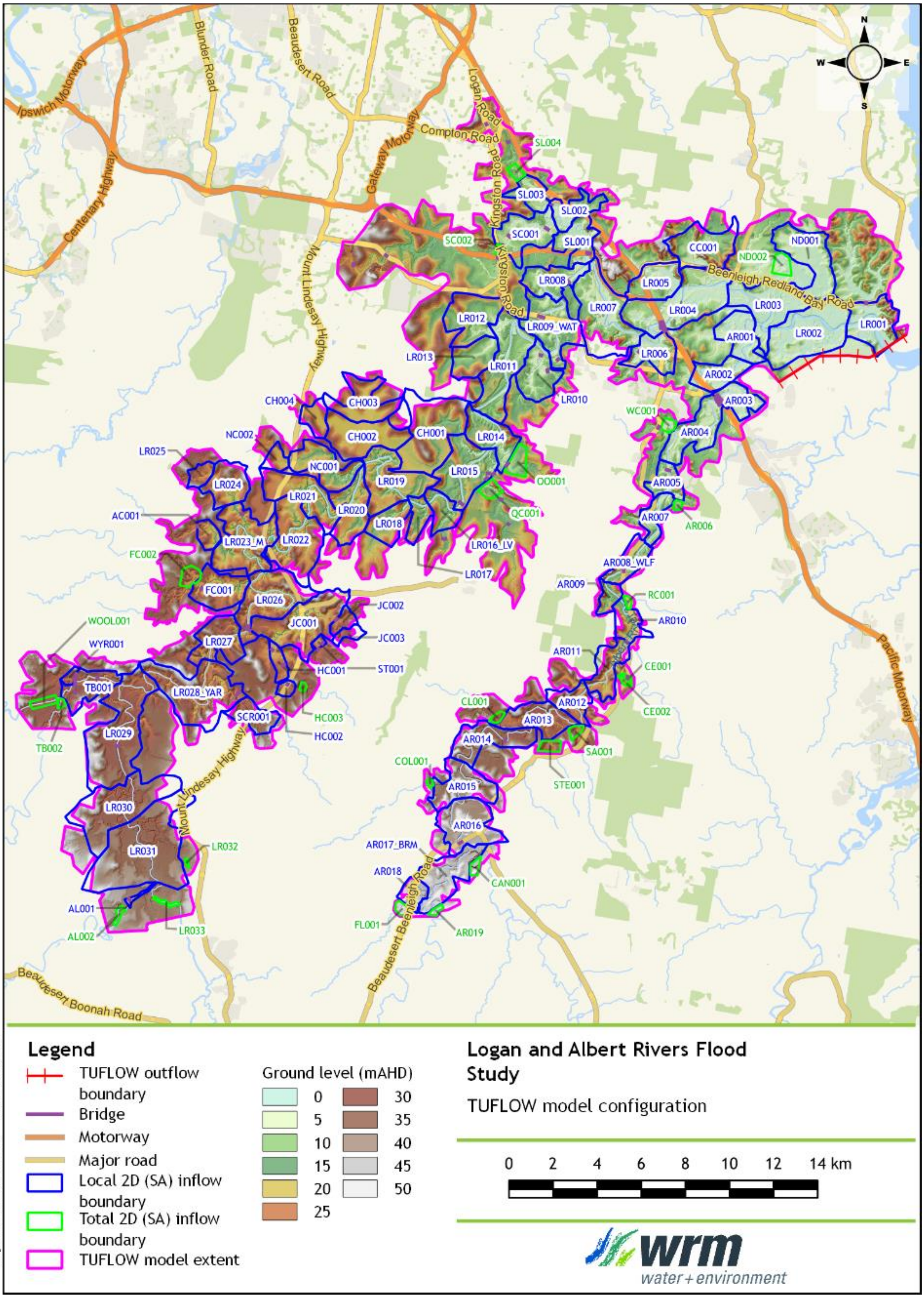

Figure 6.1 – TUFLOW model extent

6.5.3 Floodplain roughness

Similar to the approach adopted for river channels, Manning's 'n' values for open floodplain areas (open space, lower region farmlands and lower urban floodplain) were also varied with depth. Figure 6.3 illustrates the four 'depth regions' within each river channel. The following is of note:

- At the lower depth region (region 'n1'), hydraulic roughness would be relatively high due to the presence of grass, crops, shrubs, fences and/or sporadic trees.
- At higher depth region (region 'n2'), water would flow above the vegetation/fence level, so the hydraulic roughness for this depth region would be lower than in region n1.

For open floodplain areas, the model grid cell size has a less significant impact on model results compared to river channels. Therefore, the same Manning's 'n' values for open floodplain areas were adopted for both the fast model (20 m grid) and the detailed model (10 m grid). Table 6.2 shows the adopted hydraulic roughness (Manning's 'n') coefficients adopted for open floodplains areas.

Table 6.1 – Adopted hydraulic roughness coefficients

Landuse	Manning's 'n' coefficient
Rural residential	0.0550
Low density residential	0.2000
Medium density residential	0.2500
High density residential	0.3000
Medium density bushland	0.0800
Dense bushland	0.0900
Very dense bushland	0.1500
Industrial	0.3000
Road	0.0200
Waterbody	0.0200
Logan River - smooth	Depth-varying (see Table 6.2 and Table 6.3)
Logan River - rough	Depth-varying (see Table 6.2 and Table 6.3)
Logan River - very rough	Depth-varying (see Table 6.2 and Table 6.3)
Logan River - middle reach	Depth-varying (see Table 6.2 and Table 6.3)
Logan River - lower reach	Depth-varying (see Table 6.2 and Table 6.3)
Logan River - tidal reach	Depth-varying (see Table 6.2 and Table 6.3)
Albert River - upper reach	Depth-varying (see Table 6.2 and Table 6.3)
Albert River - lower reach	Depth-varying (see Table 6.2 and Table 6.3)
Open space	Depth-varying (see Table 6.4)
Lower region farmlands	Depth-varying (see Table 6.4)
Lower urban floodplain	Depth-varying (see Table 6.4)

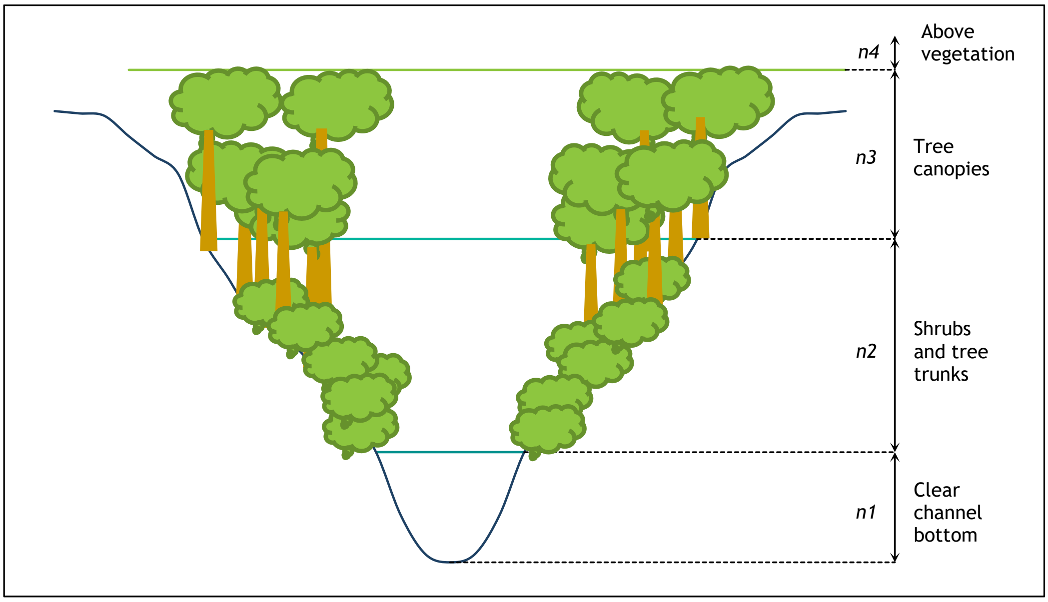

Figure 6.2 - Illustration of depth-varying Manning's n' for river channels

Table 6.2 - Adopted hydraulic roughness coefficients for river channels in the 20 m grid 'fast model'

Depth band	Logan River smooth		Logan River rough		Logan River very rough		Logan River middle reach	
	Depth (m)	Manning's 'n'	Depth (m)	Manning's 'n'	Depth (m)	Manning's 'n'	Depth (m)	Manning's 'n'
n1	< 8	0.030	< 1	0.030	< 1	0.030	< 1	0.030
n2	8 to 18	0.070	1 to 14	0.085	1 to 14	0.085	1 to 12	0.060
n3			14 to 16	0.120	14 to 20	0.120	12 to 18	0.075
n4	> 18	0.020	> 16	0.060	> 20	0.060	> 18	0.050

Table 6.2 (cont.) - Adopted hydraulic roughness coefficients for river channels in the 20 m grid 'fast model'

Depth band	Logan River lower reach		Logan River tidal reach		Albert River upstream		Albert River downstream	
	Depth (m)	Manning's 'n'	Depth (m)	Manning's 'n'	Depth (m)	Manning's 'n'	Depth (m)	Manning's 'n'
n1	< 1	0.030	< 1	0.030	< 1	0.030	< 1	0.030
n2	1 to 12	0.045	1 to 12	0.035	1 to 12	0.030	1 to 10	0.040
n3					12 to 16	0.120	10 to 14	0.120
n4	> 12	0.020	> 12	0.020	> 16	0.060	> 14	0.060

Table 6.3 - Adopted hydraulic roughness coefficients for river channels in the 10 m grid 'detailed model'

Depth band	Logan River smooth		Logan River rough		Logan River very rough		Logan River middle reach	
	Depth (m)	Manning's 'n'	Depth (m)	Manning's 'n'	Depth (m)	Manning's 'n'	Depth (m)	Manning's 'n'
n1	< 8	0.045	< 1	0.030	< 1	0.030	< 1	0.030
n2	8 - 18	0.080	1 - 14	0.095	1 - 14	0.100	1 - 12	0.070
n3			14 - 16	0.120	14 - 20	0.140	12 - 18	0.075
n4	> 18	0.020	> 16	0.060	> 20	0.060	> 18	0.050

Table 6.3 (cont.) - Adopted hydraulic roughness coefficients for river channels in the 10 m grid 'detailed model'

Depth band	Logan River lower reach		Logan River tidal reach		Albert River upstream		Albert River downstream	
	Depth (m)	Manning's 'n'	Depth (m)	Manning's 'n'	Depth (m)	Manning's 'n'	Depth (m)	Manning's 'n'
n1	< 1	0.030	< 1	0.030	< 1	0.030	< 1	0.030
n2	1 - 12	0.060	1 - 12	0.045	1 - 12	0.050	1 - 10	0.060
n3					12 - 16	0.120	10 - 14	0.120
n4	> 12	0.030	> 12	0.025	> 16	0.060	> 14	0.060

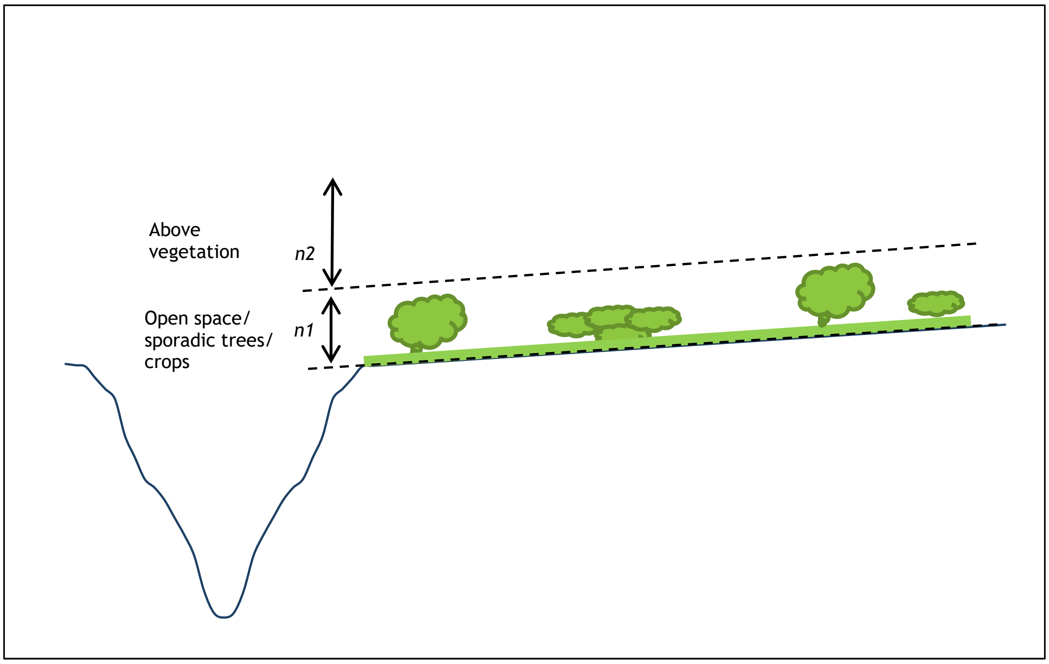

Figure 6.3 – Illustration of depth-varying Manning's n' for open floodplains

Table 6.4 - Adopted hydraulic roughness coefficients for open floodplains

Depth band	Open space		Lower region farmlands		Lower urban floodplain	
	Depth (m)	Manning's 'n'	Depth (m)	Manning's 'n'	Depth (m)	Manning's 'n'
n1	< 2	0.045	< 2	0.06	< 1	0.04
n2	> 2	0.020	> 2	0.02	> 1	0.02

6.6 HYDRAULIC STRUCTURES

6.6.1 Overview

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

- 216 culverts, made up of 128 Reinforced Concrete Pipes (RCPs) and 88 Reinforced Concrete Box Culverts (RCBCs); and
- 80 bridge structures.

The locations of these structures are shown in Figure B.6 to Figure B.13 in Appendix B. Details of these structures are shown in Table B.1 and Table B.2 in Appendix B for culverts and bridges respectively.

6.6.2 Stormwater culverts

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' based off the 20 m grid cell size of the 'Fast Model' to ensure inflow and outflow characteristics were modelled consistently between the ‘Fast Model’ and ‘Detailed Model’. The following is of note with regards to the configuration of stormwater culverts:

- For most areas in the hydraulic model, details of stormwater culverts were obtained from the Engeny (2011) and WRM (2014) hydraulic models. Details of these culverts were confirmed using the Council’s GIS database of hydraulic structures.
- For areas along the M1 Motorway (Pacific highway), details of stormwater culverts were obtained from the M1 Motorway hydraulic model WRM (2017).
- For areas within the Slacks and Scrubby creeks catchment, details of stormwater culverts were obtained from the Slacks and Scrubby Creeks hydraulic model (LCC, 2018). Note that the LCC (2018) hydraulic model contains a large number of trunk stormwater pipe networks. These trunk stormwater pipes were not included in the hydraulic model for the current study.

Some of the 216 culverts did not exist for earlier calibration events. Council’s GIS database of hydraulic structures provides information on the year of construction for existing structures within the LCC LGA. This information was used to identify the culverts to be included or excluded for each event being modelled.

6.6.3 Bridges

A total of 80 bridges were included in the hydraulic model. Bridges were represented in the hydraulic model using two-dimensional ‘layered flow constrictions’. Using this approach, bridges are modelled as partial blockages to incoming flows. These blockages were determined as percentages based on the configuration of bridge piers, deck and guard rails of each bridge.

The adopted percentage blockage due to the bridge piers is generally between 0% and 10% 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), while guard rails were considered as partial blockages. The adopted percentage blockage for guard rails range from 20% to 50% depending on the guard rail configuration at each bridge.

Details of most bridges in the TUFLOW model were obtained from hydraulic models developed from previous studies. Additional bridges (not included in previous studies) model were configured based on as-constructed drawings provided by LCC and Council’s bridge survey data.

LCC also provided drawings for the following four recent bridge works (post-2017):

- Edward O’Neil Bridge Replacement (Kilmoylar Road, Jimboomba);
- Miller Road Bridge Replacement;
- Chardon Bridge Replacement;
- Kingston Road Pedestrian Bridge (Scrubby Creek); and

These four bridges were included for the hydraulic model for design events, but excluded for the hydraulic model for calibration events.

7 Hydraulic model calibration

7.1 OVERVIEW

This report is the final phase of the over-arching Logan and Albert Flood Study (WRM, 2021). As such and as discussed in Section 5.1, this report documents the validation results from the February 2022 flood event. The adopted model parameters on a completely independent event, as discussed in Section 7.7, demonstrates the validity and robustness of the hydraulic model.

7.2 METHODOLOGY

Inflow hydrographs for the January 1974, April 1990, January 2013, March 2017 and February 2022 events were generated from the calibrated XP-RAFTS hydrologic model and used as input to the TUFLOW hydraulic model. The hydraulic model results were then compared with recorded water level hydrographs from the available stream gauges for all four events. The hydraulic model results for the January 1974, January 2013, March 2017 and February 2022 events were also compared with surveyed debris marks throughout the Logan-Albert rivers catchment. This 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 in the lower reaches of the Logan River.

7.3 JANUARY 1974 CALIBRATION

7.3.1 Overview

Inflow hydrographs from the calibrated January 1974 hydrologic model were used as input to the TUFLOW model. Results from the hydraulic model were compared with recorded water level hydrographs at Yarrahappini, Bromfleet and Wolffdene, and surveyed peak flood levels at Maclean Bridge and Waterford, which were obtained from the BOM brochure Flood Warning System for the Logan and Albert Rivers (BOM, 2011).

There is some uncertainty surrounding the accuracy of the peak flood level at the Waterford gauge reported in BOM (2011) as it is based on debris marks. Also, the peak flood level reported in BOM (2011) at the Maclean Bridge gauge was actually recorded at a previous flood warning gauge location about 700 m downstream of the current gauge location. This is confirmed in the study undertaken by Cameron, McNamara & Partners Pty Ltd in 1975; Report on Flood Hydrology of Logan River with Particular Reference to the January 1974 Flood (CMP, 1975).

7.3.2 1974 calibration results

Table 3.1 summarises the recorded peak water levels at key locations within the model, and compares them with peak water levels estimated by the hydraulic model. Figure 7.1, Figure 7.2 and Figure 7.3 show the recorded and predicted water level hydrographs at Yarrahappini, Bromfleet and Wolffdene respectively.

The following is of note with regards to the calibration results:

- In the Logan River:
    - The modelled water level hydrographs matches well with the recorded hydrograph shape, timing and flood volume at Yarrahappini. However, the model overestimates the peak flood level at this gauge, which is likely due to the XP-RAFTS model overestimating the peak discharge at this gauge.

- Recorded peak water levels downstream of Waterford for the January 1974 event were estimated from model calibration plots in AWE (1997). The AWE (1997) recorded water levels were obtained from debris surveys conducted by the Queensland Surveyor General's Office, Beaudesert Shire Council and Albert Shire Council following the January 1974 flood event. Figure 7.4 compares longitudinal profiles of modelled peak water levels along the Logan River between Logan Reserve and the river mouth and compares it with the surveyed debris marks from AWE (1997). The following is of note:
    - The modelled peak water level at Waterford matches the lowest surveyed debris mark at this gauge (12.60 mAHD).
    - The modelled peak water levels between Waterford and the M1 Motorway are generally close to the lowest surveyed debris marks along this reach.
    - The modelled peak water levels in the lower reaches of the Logan River (downstream of the Albert River confluence) also generally agree with the surveyed peak flood levels.
    - The model appears to substantially underestimate peak flood levels between the M1 Motorway and the confluence of the Logan River and the Albert River confluence.
- The reason for the model substantially underestimating peak flood levels between the M1 Motorway and the Albert River confluence is unclear, but it is possibly due to:
    - The representation of the Logan River bed in the hydraulic model (i.e. the river bed profile was different during the 1974 event).
    - Denser vegetation on the floodplains along this reach during the 1974 event.
- Adjusting the hydraulic roughness parameters to improve the 1974 calibration in this reach would result in worse calibration results for the 2013 and 2017 events (based on comparisons against surveyed debris marks for those events).

- In the Albert River:
    - The modelled water level hydrographs match well with the recorded hydrograph shape, timing and flood volume at Bromfleet and Wolffdene. The model also matches the recorded peak flood level at Bromfleet, but overestimates the peak flood level at Wolffdene.
    - Adjusting the hydraulic roughness parameters at Wolffdene to improve the calibration result at this gauge would result in worse calibration results for the other events. The adopted hydraulic roughness parameters provide a reasonable compromise between all calibration events.

Table 7.1 - Recorded and modelled peak water levels, January 1974 flood event

	Recorded peak water level (mAHD)	Fast (20 m grid) model		Detailed (10 m grid) model	
		Modelled peak water level (mAHD)	Difference (m)	Modelled peak water level (mAHD)	Difference (m)
Yarrahappini Gauge	31.22	31.50	0.28	31.52	0.31
Maclean Bridge Gauge (1972 Location)	24.87	25.07	0.20	25.05	0.18
Waterford Gauge	12.60 - 13.20	12.46	-0.14 to -0.74	12.53	-0.07 to -0.67

Bromfleet Gauge	44.56	44.61	0.05	44.54	-0.02
Wolffdene Gauge	13.70	13.38	-0.32	13.33	-0.37

[a] – Estimated based on surveyed debris marks (AWE, 1997)

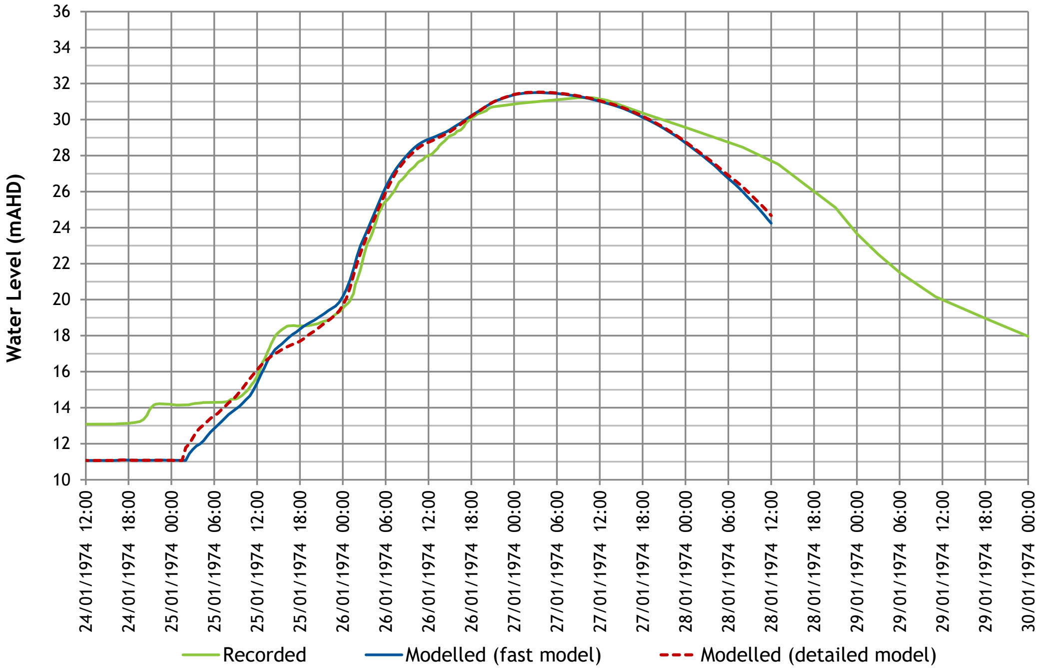

Figure 7.1 - Modelled and recorded water level hydrographs in the Logan River at Yarrahappini (DNRM GS 145014a), January 1974 flood event

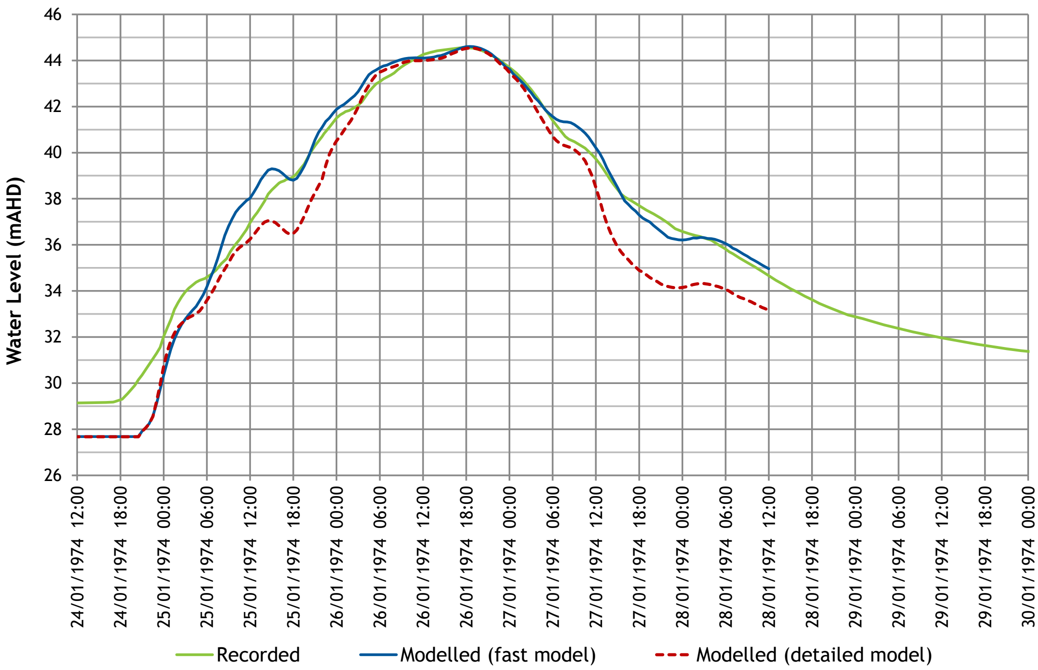

Figure 7.2 - Modelled and recorded water level hydrographs in the Albert River at Bromfleet (DNRM GS 145102a), January 1974

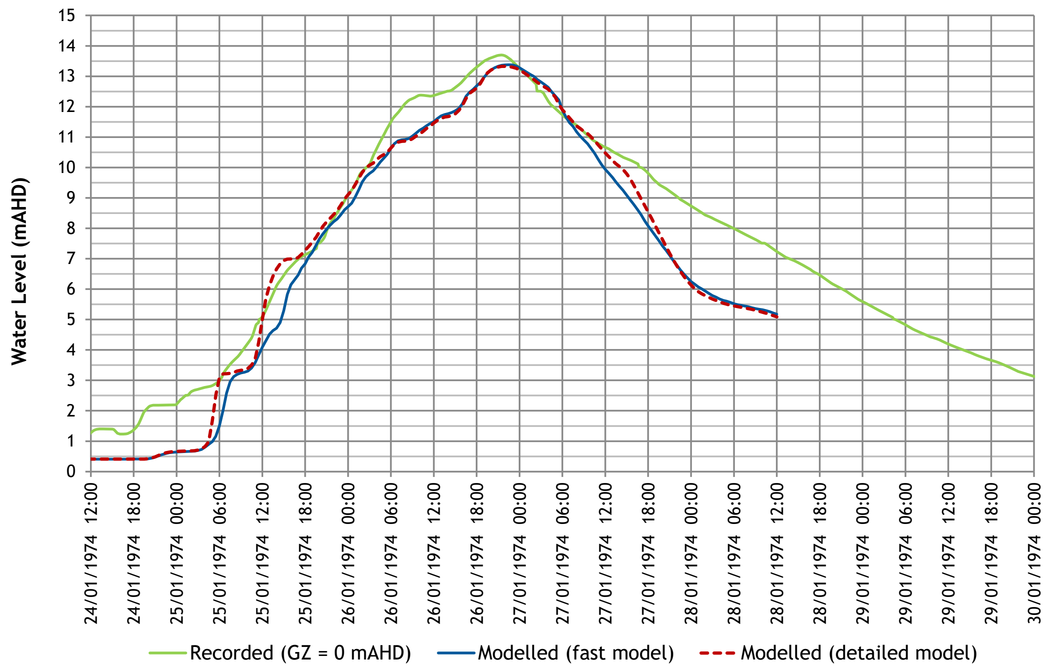

Figure 7.3 – Modelled and recorded water level hydrographs in the Albert River at Wolffdene (DNRM GS 145196a), January 1974

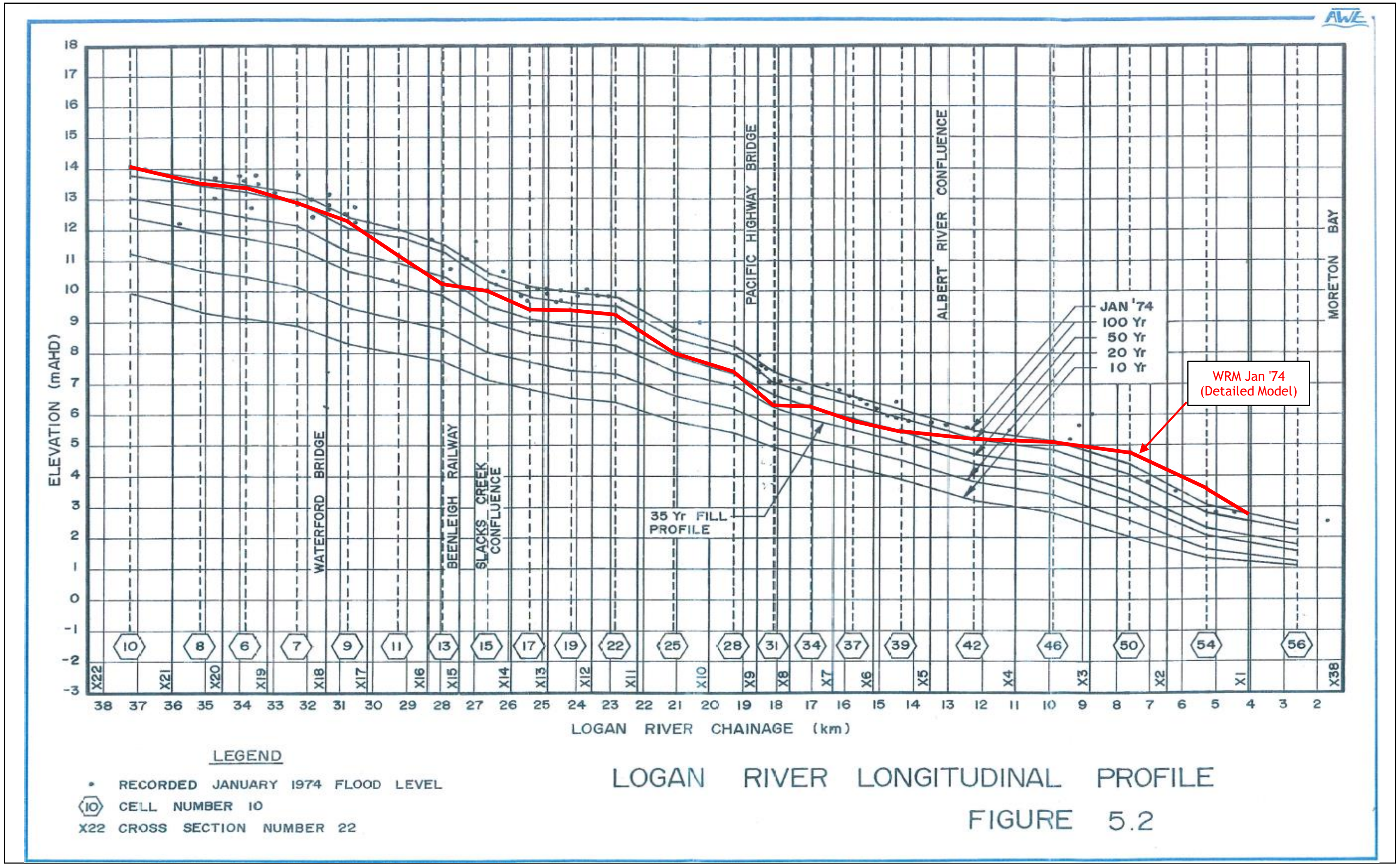

Figure 7.4 – Longitudinal profile of modelled peak water levels (from the 10 m grid detailed model) and comparison against surveyed debris marks, 1974 flood event

7.4 APRIL 1990 CALIBRATION

7.4.1 Overview

Inflow hydrographs for the hydraulic model for the April 1990 event were generated from the calibrated April 1990 hydrologic model, with flows in the Logan River at Round Mountain and Teviot Brook at the Overflow matched to the recorded flows. This was considered necessary due to the inability of the hydrologic model to accurately replicate recorded hydrographs at Round Mountain, The Overflow and Yarrahappini due to insufficient rainfall data. Results from the hydraulic model were compared with recorded water level hydrographs at Yarrahappini, Maclean Bridge, Waterford, Bromfleet and Wolffdene.

7.4.2 1990 calibration results

Table 7.2 summarises the recorded peak water levels at the above locations, and compares them with peak water levels estimated by the hydraulic model. Figure 7.5, Figure 7.6, Figure 7.7, Figure 7.8 and Figure 7.9 show the recorded and predicted water level hydrographs at Yarrahappini, Maclean Bridge, Waterford, Bromfleet and Wolffdene respectively. The following is of note with regards to the calibration results:

- The 1990 flood event is a relatively minor flood event compared to the 1974 event, and was typically confined within the main Logan and Albert River channels, with very little overbank flow.
- In the Logan River:
  - The modelled water level hydrographs generally match the recorded hydrograph shape, timing and flood volume at Yarrahappini, Maclean Bridge and Waterford. However, the modelled flood peak at Waterford occurs some six hours earlier than the modelled flood peak.
  - The fast model matches the recorded peak flood level at Yarrahappini, while the detailed model underestimates the peak flood level at this gauge. The reason for the detailed model underestimating the peak flood level at Yarrahappini is likely due to a higher channel capacity in the detailed (10 m grid) model compared to the fast (20 m grid) model.
  - Both the fast and detailed models overestimate the peak flood level at Maclean Bridge, but match the recorded peak flood level at Waterford.
  - Adjusting the hydraulic roughness parameters at Maclean Bridge to improve the calibration result at this gauge would result in worse calibration results for the other events. The adopted hydraulic roughness parameters provide a reasonable compromise between all calibration events.
- In the Albert River:
  - The fast model substantially overestimates the recorded peak flood level at Bromfleet, while the detailed model matches the recorded peak flood level and hydrograph shape at this gauge. The fast model matched the peak flood level at Wolffdene, while the detailed model overestimates the peak flood level at this gauge.
  - The reason for the fast model substantially underestimating the peak flood level at Bromfleet is likely due to the 20 m grid size adopted for this model, which is not adequately representing the behaviour of small floods such as the 1990 event in the upper Logan River channel. The 10 m grid detailed model simulates the behaviour of 1990 flood well in the upper Logan River channel very well, due to the 10 m grid size more adequately representing the channel capacity of the Logan River in this section.

- The reason for the detailed model overestimating the peak flood level at Wolffdene is likely due to the XP-RAFTS model overestimating the peak discharge at this gauge.
- A recorded peak water level of 4.0 mAHD is reported in AWE (1997) at the Eagleby BOM flood warning gauge, just downstream of the Pacific Motorway. The peak flood level predicted by the hydraulic model at this location is about 3.98 mAHD. No other recorded water level data are available for the 1990 event.

Table 7.2 - Recorded and modelled peak water levels, April 1990 flood event

Location	Recorded peak water level (mAHD)	Fast (20 m grid) model		Detailed (10 m grid) model	
		Modelled peak water level (mAHD)	Difference (m)	Modelled peak water level (mAHD)	Difference (m)
Yarrahappini Gauge	25.22	25.19	-0.03	24.95	-0.27
Maclean Bridge Gauge (current Location)	17.86	18.13	0.27	18.16	0.30
Waterford Gauge	7.30	7.35	0.05	7.34	0.04
Bromfleet Gauge	40.83	42.10	1.28	40.89	0.06
Wolffdene Gauge	8.82	8.85	0.03	9.13	0.31

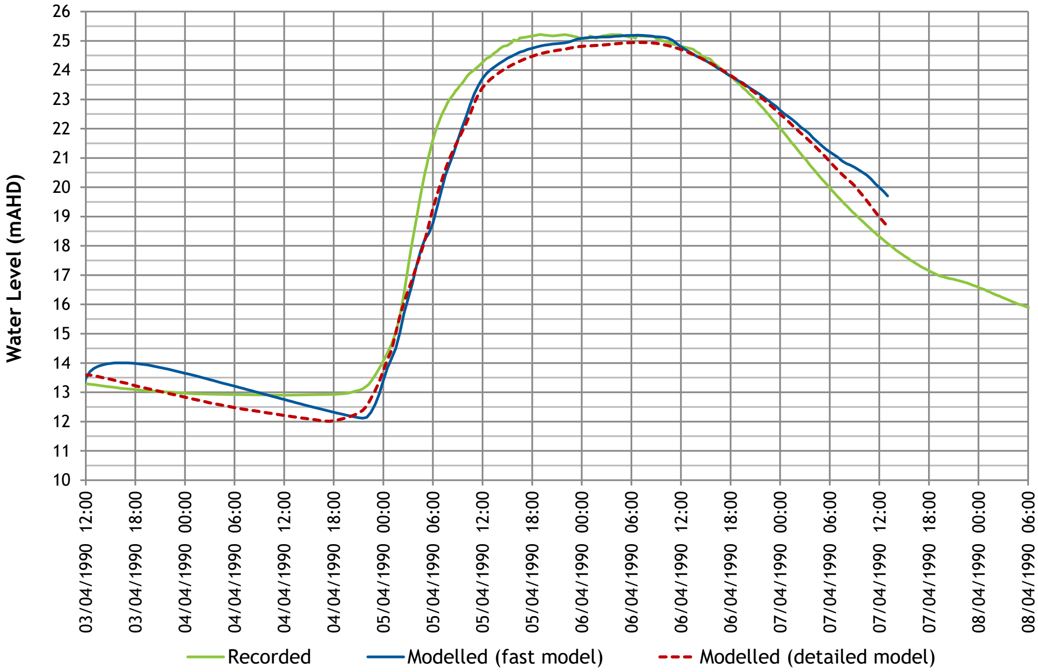

Figure 7.5 - Modelled and recorded water level hydrographs in the Logan River at Yarrahappini (DNRM GS 145014a), April 1990 flood event

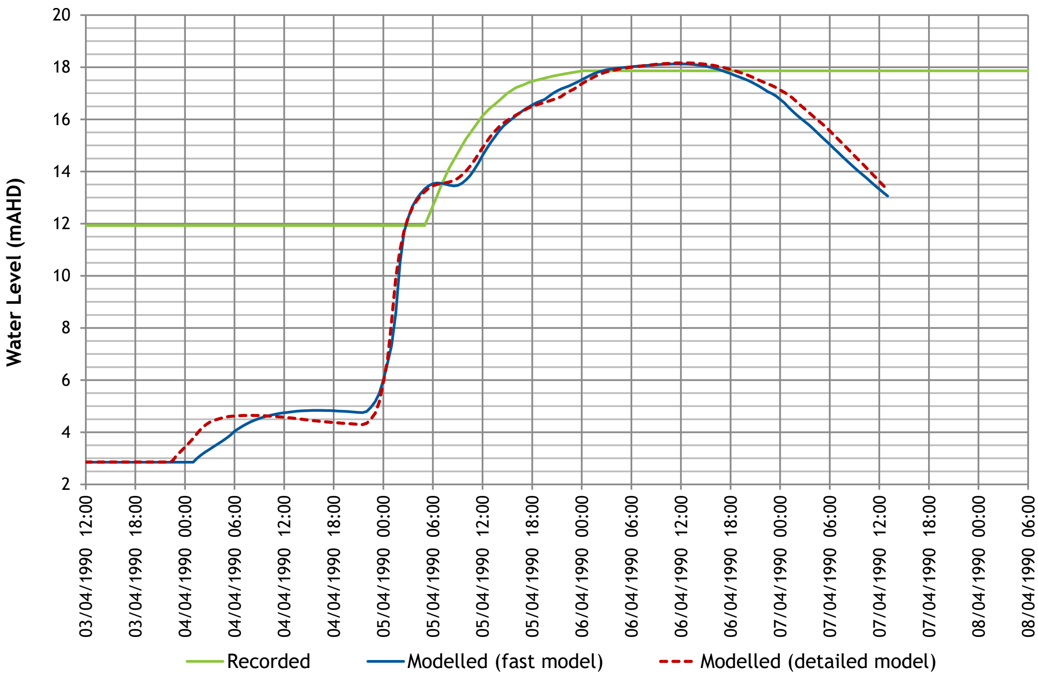

Figure 7.6 – Modelled and recorded water level hydrographs in the Logan River at Maclean Bridge (BOM GS 040935), April 1990 flood event

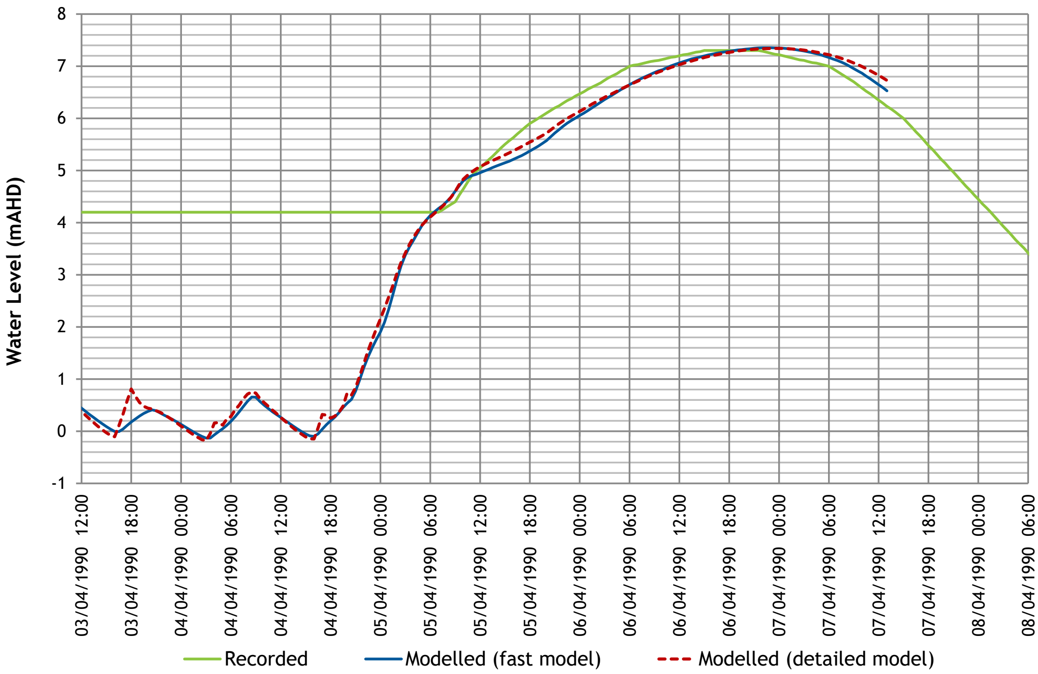

Figure 7.7 – Modelled and recorded water level hydrographs in the Logan River at Waterford (BOM GS 040878), April 1990 flood event

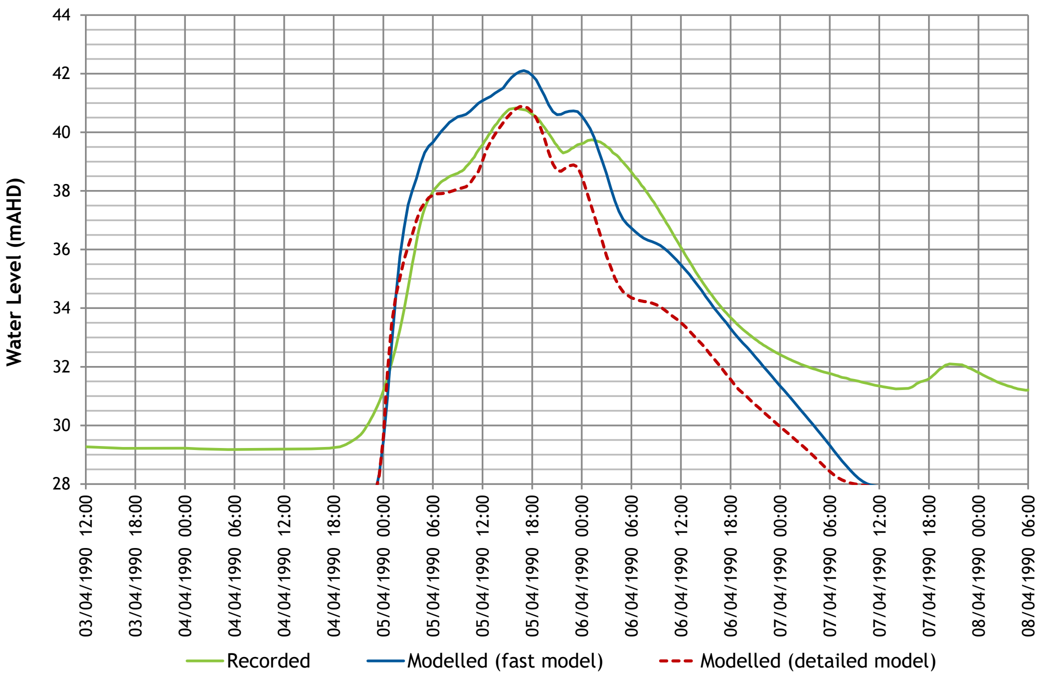

Figure 7.8 - Modelled and recorded water level hydrographs in the Albert River at Bromfleet (DNRM GS 145102a), April 1990 flood event

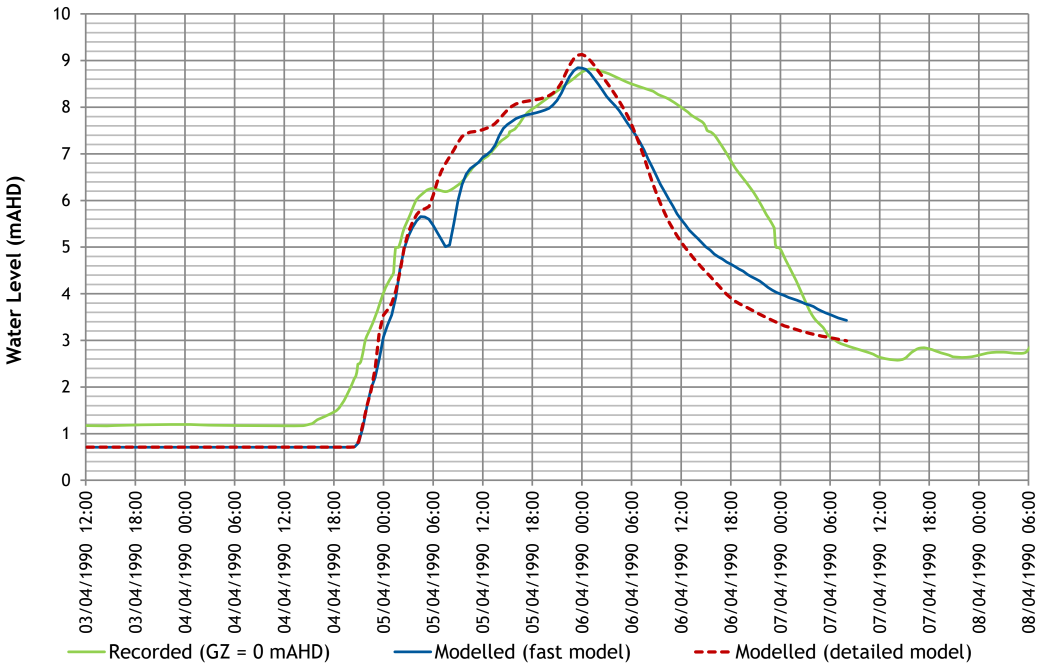

Figure 7.9 - Modelled and recorded water level hydrographs in the Albert River at Wolffdene (DNRM GS 145196a), April 1990 flood event

7.5 JANUARY 2013 CALIBRATION

7.5.1 Overview

Inflow hydrographs for the hydraulic model for the January 2013 event were generated from the calibrated January 2013 hydrologic model. Results from the hydraulic model were compared with recorded water level hydrographs at Yarrahappini, Maclean Bridge, Logan Village, Waterford and Bromfleet, as well as with surveyed debris marks throughout the Logan and Albert River catchments.

7.5.2 2013 calibration results

Table 7.3 summarises the recorded peak water levels at the above gauging stations, and compares them with peak water levels estimated by the hydraulic model. Figure 7.10, Figure 7.11, Figure 7.12, Figure 7.13 and Figure 7.14 show the recorded and predicted water level hydrographs at Yarrahappini, Maclean Bridge, Logan Village, Waterford and Bromfleet respectively.

Figure 7.15 and Figure 7.16 show the differences between the modelled peak flood levels and surveyed debris marks at the debris locations within the model extent. Table C.1 in Appendix C shows further details on the surveyed debris marks including eastings and northings and comparisons between surveyed debris levels and the modelled peak water levels at each location.

The following is of note with regards to the calibration results:

- In the Logan River:
  - The modelled water level hydrographs (for both the fast and detailed models) match well with the shape of the recorded hydrographs at Yarrahappini, Maclean Bridge, Logan Village and Waterford.
  - The timing of the peak also match well with the recorded hydrograph at Yarrahappini, Maclean Bridge and Logan Village. However, the modelled flood peak at Waterford occurs some six hours earlier than the recorded peak.
  - The modelled peak water level at Yarrahappini (for both the fast and detailed models) matches well with the recorded peak water level.
  - The model appears to underestimate the peak flood level at Waterford. However, the recorded water level hydrograph for Waterford shows a spike in water level (9.25 mAHD) at about 0745 hours on 30 January. Based on the small fluctuations in water level at the peak of the flood, the peak water level at Waterford is more likely to be approximately 9.0 mAHD, which corresponds well with the modelled peak flood level of 8.95 mAHD (for the detailed model).
  - Further comparison of predicted water surface levels with surveyed debris marks in the vicinity of Waterford indicate that the modelled peak flood levels match well with the surveyed flood levels at this gauge. This indicates that the model predicts peak water levels at Waterford reasonably well when considering all of the available data.
  - The peak flood extent for the January 2013 event is generally consistent with the locations of the surveyed debris marks throughout the Logan River catchment.
  - The detailed model underestimates the peak flood levels at Maclean Bridge and Logan Village. Further comparison of predicted water surface levels with surveyed debris marks indicate that the model is underestimating peak water levels by 0.3 m to 0.5 m between Mount Lyndsay Highway and Norris Creek. Peak flood levels upstream of Mount Lyndsay Highway and downstream of Norris Creek generally match well with the surveyed debris marks.

    - The reason for the model underestimating flood levels between Mount Lyndsay Highway and Norris Creek is not clear. Adjusting the hydraulic roughness in this channel reach to improve the 2013 calibration would produce worse results for other events. It is possible that some form of blockage developed within this reach of the river during the January 2013 flood event, and that this blockage has not been represented in the available survey data.
    - The modelled peak water levels between Waterford and the M1 Motorway (including the Slacks Creek area) generally match well with the surveyed debris marks.
    - The hydraulic model appears to overestimate peak flood levels in the Logan River downstream of the Pacific Motorway by between 0.2 m and 0.6 m. The reason for the hydraulic model over predicting levels in the lower reaches of the Logan River is not clear, however it is possibly due to the following issues:
        - Tidal effects in the lower Logan River that are not adequately represented in the hydraulic model, however the use of the recorded water level hydrograph at the Riedel Road stream gauge as the downstream boundary conditions should preclude this from being an issue;
        - Mobilisation of the Logan River bed in the lower reaches during the January 2013 flood event. Bathymetry survey before and after the January 2013 flood event highlighted substantial changes in bed levels in the lower Logan River. Therefore it is considered likely that during significant flood events a layer of silt within the river bed becomes mobile, increasing channel conveyance; and
        - Debris marks not representing the peak flood level. It is possible that the surveyed debris marks do not reflect the peak water level in the lower reaches.
- In the Albert River:
    - The modelled water level hydrograph (for both the fast and detailed models) at Bromfleet matches the shape, timing and peak water level of the recorded hydrograph. The detailed hydraulic model estimates a peak water level of 11.09 mAHD at Wolffdene gauge for the January 2013 event.
    - The peak flood extent for the January 2013 event is generally consistent with the locations of the surveyed debris marks throughout the Albert River catchment.
    - The modelled peak flood levels in the upper reaches of the Albert River upstream of Wolffdene are generally in good agreement with the surveyed debris marks.
    - The hydraulic model appears to substantially overestimate peak flood levels between Wolffdene and Beenleigh (the M1 Motorway) by up to 0.8 m. The reason for this is not clear, but is most likely due to the adopted hydraulic roughness of this channel reach. However, adjusting the hydraulic roughness along this river reach would result in worse calibration results for the larger 2017 flood event.

Table 7.3 - Recorded and modelled peak water levels, January 2013 flood event

Location	Recorded peak water level (mAHD)	Fast (20 m grid) model		Detailed (10 m grid) model	
		Modelled peak water level (mAHD)	Difference (m)	Modelled peak water level (mAHD)	Difference (m)
Yarrahappini Gauge	28.18	28.28	0.10	28.19	0.01
Maclean Bridge Gauge (current Location)	21.70	21.38	-0.32	21.38	-0.32
Logan Village Gauge	14.16	14.15	-0.01	13.88	-0.28
Waterford Gauge	9.25	8.88	-0.38	8.95	-0.30
Bromfleet Gauge	43.88	44.00	0.12	43.84	-0.04

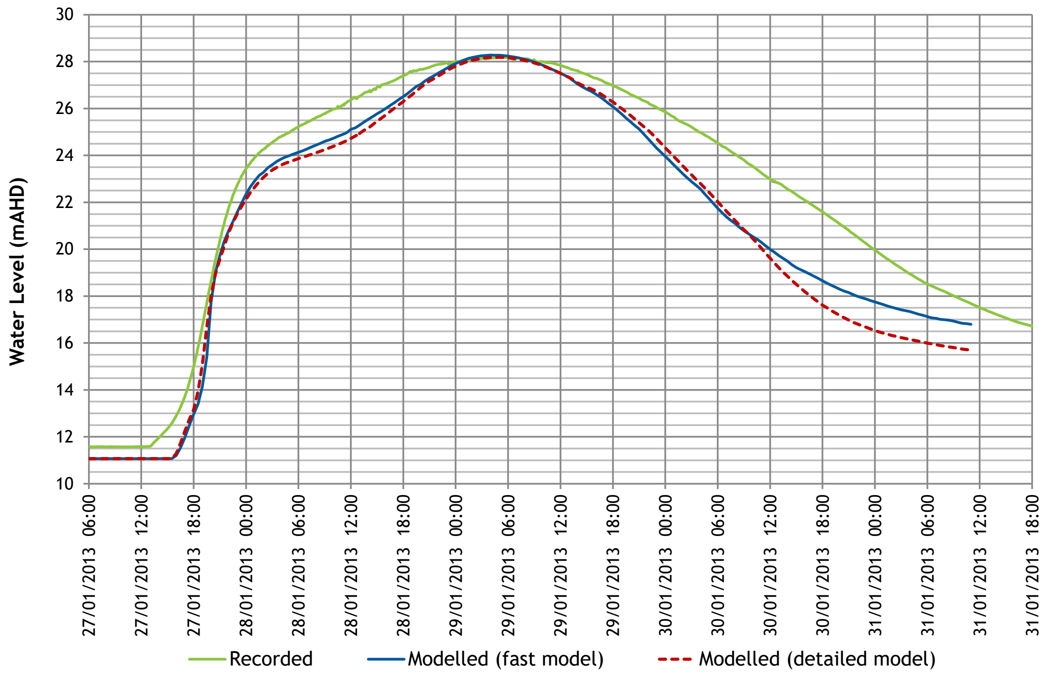

Figure 7.10 - Modelled and recorded water level hydrographs in the Logan River at Yarrahappini (DNRM GS 145014a), January 2013 flood event

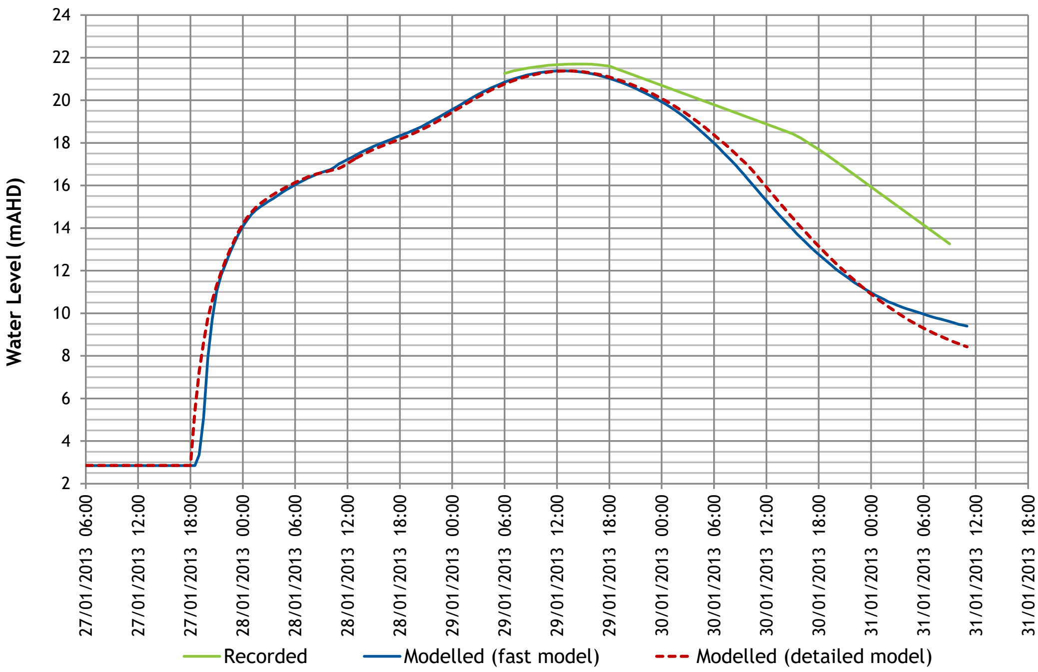

Figure 7.11 - Modelled and recorded water level hydrographs in the Logan River at Maclean Bridge (BOM GS 040935), January 2013 flood event

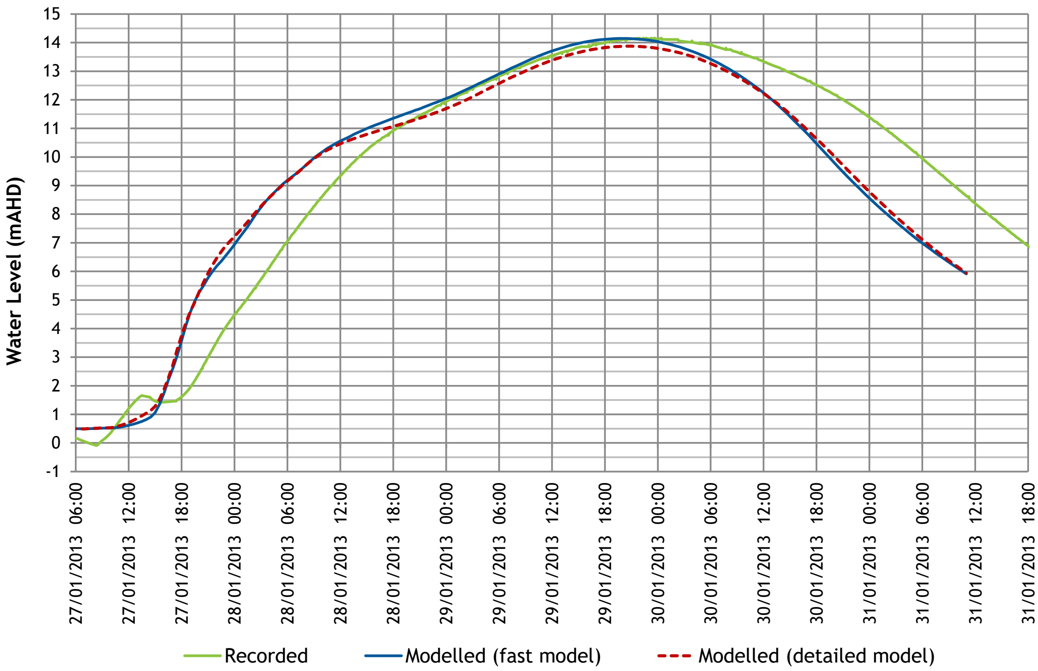

Figure 7.12 - Modelled and recorded water level hydrographs in the Logan River at Logan Village (LCC GS 6263), January 2013 flood event

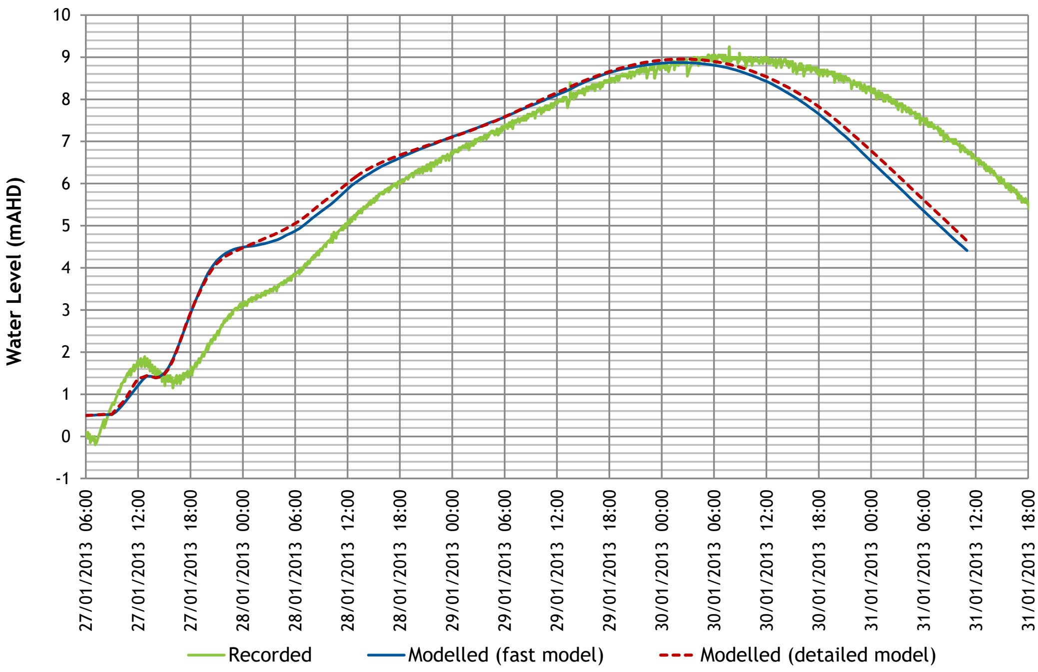

Figure 7.13 - Modelled and recorded water level hydrographs in the Logan River at Waterford (BOM GS 040878), January 2013 flood event

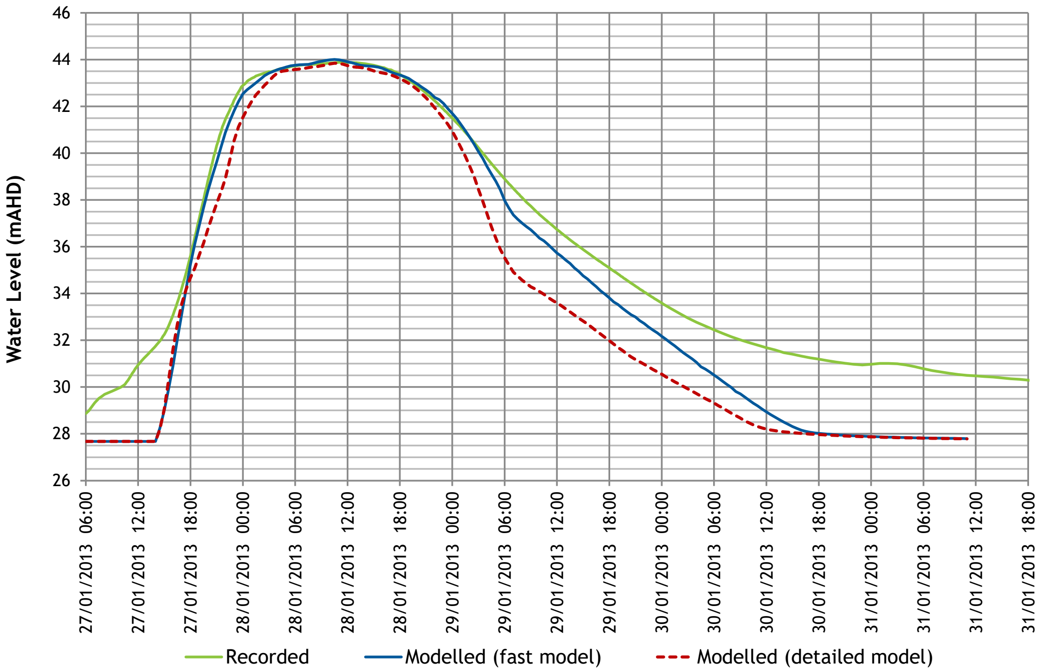

Figure 7.14 - Modelled and recorded water level hydrographs in the Albert River at Bromfleet (DNRM GS 145102a), January 2013 flood event

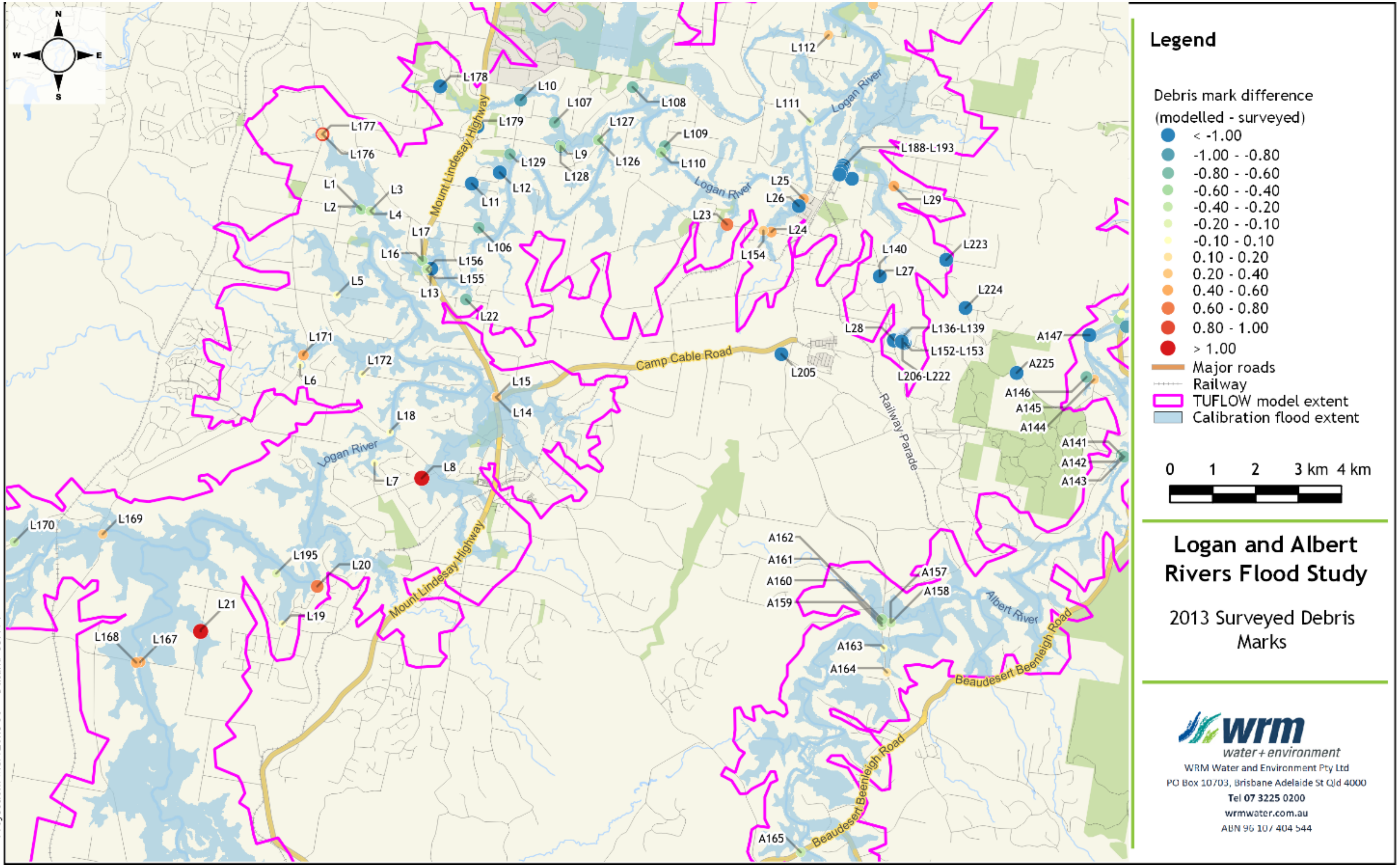

Figure 7.15 - Differences between modelled peak water levels and surveyed debris marks at the upper reaches of the Logan and Albert rivers, January 2013 flood event

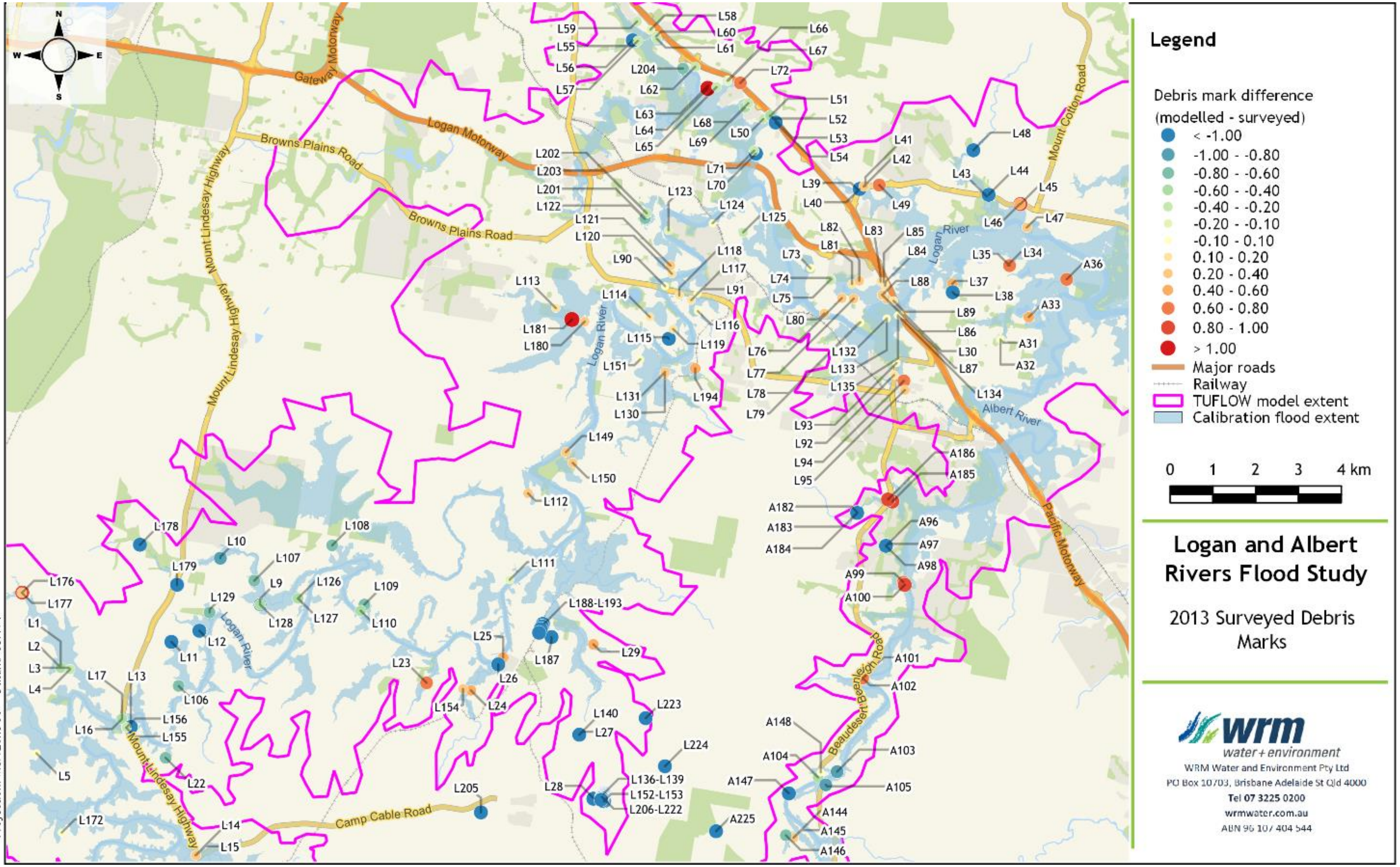

Figure 7.16 – Differences between modelled peak water levels and surveyed debris marks at the lower reaches of the Logan and Albert rivers, January 2013 flood event

7.6 MARCH 2017 CALIBRATION

7.6.1 Overview

Inflow hydrographs for the hydraulic model for the March 2017 event were generated from the calibrated March 2017 hydrologic model. Results from the hydraulic model were compared with recorded water level hydrographs at Yarrahappini, Maclean Bridge, Logan Village, Waterford, Parklands, Bromfleet, Wolffdene and Beenleigh as well as with surveyed debris marks throughout the Logan and Albert River catchments.

7.6.2 2017 calibration results

Table 7.4 summarises the recorded peak water levels at the above gauging stations, and compares them with peak water levels estimated by the hydraulic model. Figure 7.17, Figure 7.18, Figure 7.19, Figure 7.20, Figure 7.21, Figure 7.22, Figure 7.23, Figure 7.22, Figure 7.23 and Figure 7.24 show the recorded and predicted water level hydrographs at Yarrahappini, Maclean Bridge, Logan Village, Waterford, Parklands, Bromfleet, Wolffdene and Beenleigh respectively.

Figure 7.25 and Figure 7.26 show the differences between the modelled peak flood levels and surveyed debris marks at the debris locations within the model extent. Table C.2 in Appendix C shows further details on the surveyed debris marks including eastings and northings and comparisons between surveyed debris levels and the modelled peak water levels at each location.

The following is of note with regards to the calibration results:

- In the Logan River:
  - The modelled water level hydrographs (for both the fast and detailed models) match well with the shape of the recorded hydrographs at Yarrahappini, Maclean Bridge, Logan Village, Waterford and Parklands. The modelled peak water level (for both the fast and detailed models) also match well with the recorded peak water levels.
  - The timing of the modelled flood peak at Maclean Bridge and Logan Village match well with the recorded hydrograph. However, the flood peak occurs a few hours later then the recorded flood peak at Yarrahappini, and a few hours earlier than the recorded flood peak at Waterford and Parklands.
  - The discrepancy between the modelled and recorded timing of the flood peaks at Yarrahappini is due to the XP-RAFTS model inflow hydrograph. The timing of the modelled flood peak the in the XP-RAFTS model discharge hydrograph at Yarrahappini occurs later than the recorded flood peak.
  - The peak flood extent for the March 2017 event is generally consistent with the locations of the surveyed debris marks throughout the Logan River catchment. The modelled peak flood levels (for both the fast and detailed models) are generally in good agreement with the surveyed debris marks throughout the Logan River catchment.
- In the Albert River:
  - The modelled water level hydrograph (for both the fast and detailed models) at Bromfleet match well with the recorded hydrograph shape and timing as well as the peak flood level.
  - The modelled water level hydrographs at Wolffdene and Beenleigh generally match the recorded hydrograph shape and timing, but the rising limb of the modelled hydrographs occur earlier than the recorded hydrograph. However, this is likely due to the XP-RAFTS model not adequately representing the attenuation of flows between Bromfleet and Beenleigh.
  - Both the fast and detailed models match the peak water level at Beenleigh, but overestimate the peak water level at Wolffdene.

- The reason for the model overestimating peak water level at Wolffdene is possibly due to the adopted hydraulic roughness in this channel reach. However, adjusting the hydraulic roughness to improve the 2017 calibration at Wolffdene would result in worse calibration result for other events (especially when comparing against surveyed debris marks in the floodplain).
- There is also an inconsistency between the recorded peak water level at the Wolffdene gauging station (13.55 mAHD) and a surveyed debris mark immediately northwest of gauge (14.373 mAHD). The peak water level estimated by the fast and detailed models at Wolffdene are 14.09 mAHD and 14.00 mAHD respectively.
- Further comparison of predicted water surface levels with surveyed debris marks along the Albert River indicate that the modelled peak water levels (for both the fast and detailed models) are generally in good agreement with surveyed debris marks throughout the Albert River catchment. The peak flood extent for the March 2017 event is generally consistent with the locations of the surveyed debris marks throughout the Albert River catchment.

Table 7.4 - Recorded and modelled peak water levels, March 2017 flood event

Location	Recorded peak water level (mAHD)	Fast (20 m grid) model		Detailed (10 m grid) model	
		Modelled peak water level (mAHD)	Difference (m)	Modelled peak water level (mAHD)	Difference (m)
Yarrahappini Gauge	30.42	30.40	-0.02	30.43	0.01
Maclean Bridge Gauge (current Location)	23.97	23.86	-0.11	23.86	-0.11
Logan Village Gauge	15.91	16.05	0.14	15.84	-0.07
Waterford Gauge	10.35	10.37	0.02	10.36	0.01
Parklands Gauge	6.19	6.28	0.09	6.25	0.06
Bromfleet Gauge	45.78	45.64	-0.14	45.63	-0.15
Wolffdene Gauge	13.55	14.09	0.54	14.00	0.45
Beenleigh Gauge	8.02	7.93	-0.09	7.92	-0.10

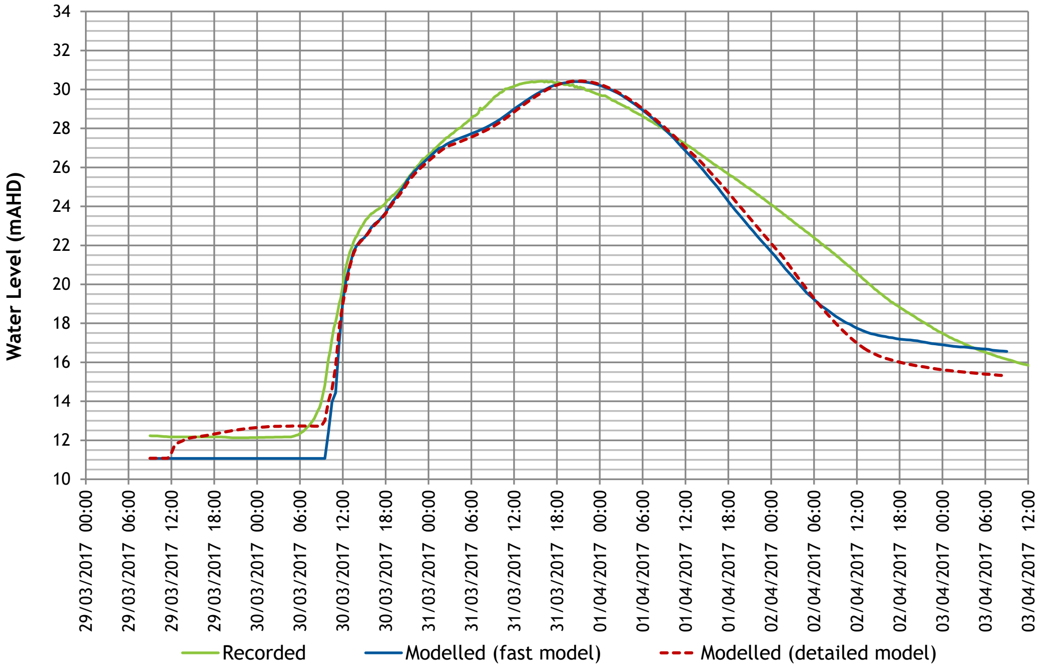

Figure 7.17 – Modelled and recorded water level hydrographs in the Logan River at Yarrahappini (DNRM GS 145014a), March 2017 flood event

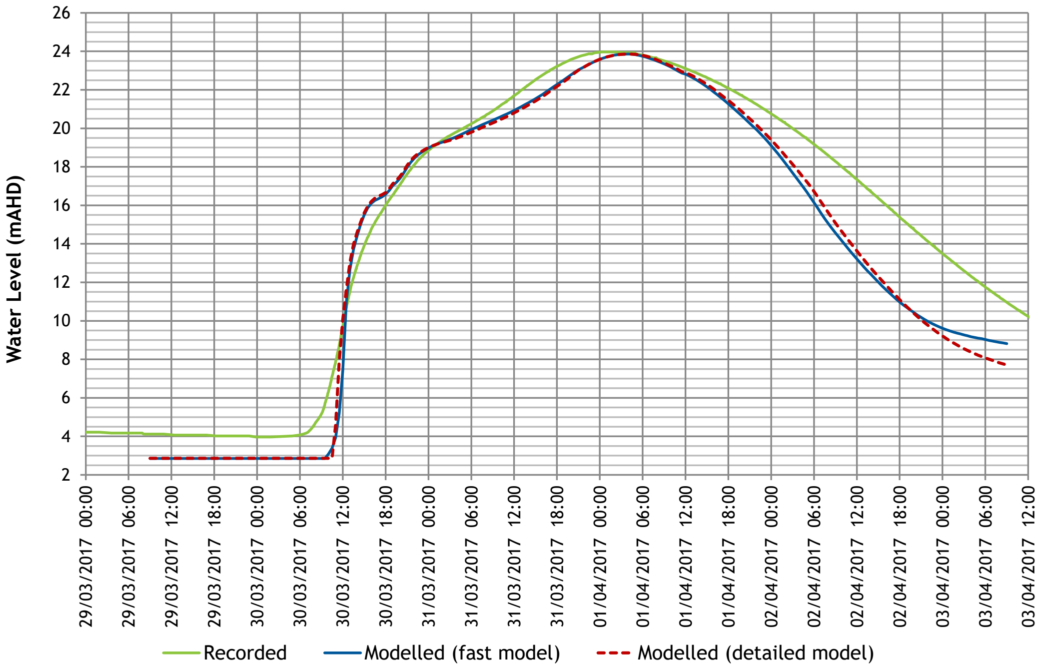

Figure 7.18 – Modelled and recorded water level hydrographs in the Logan River at Maclean Bridge (BOM GS 040935), March 2017 flood event

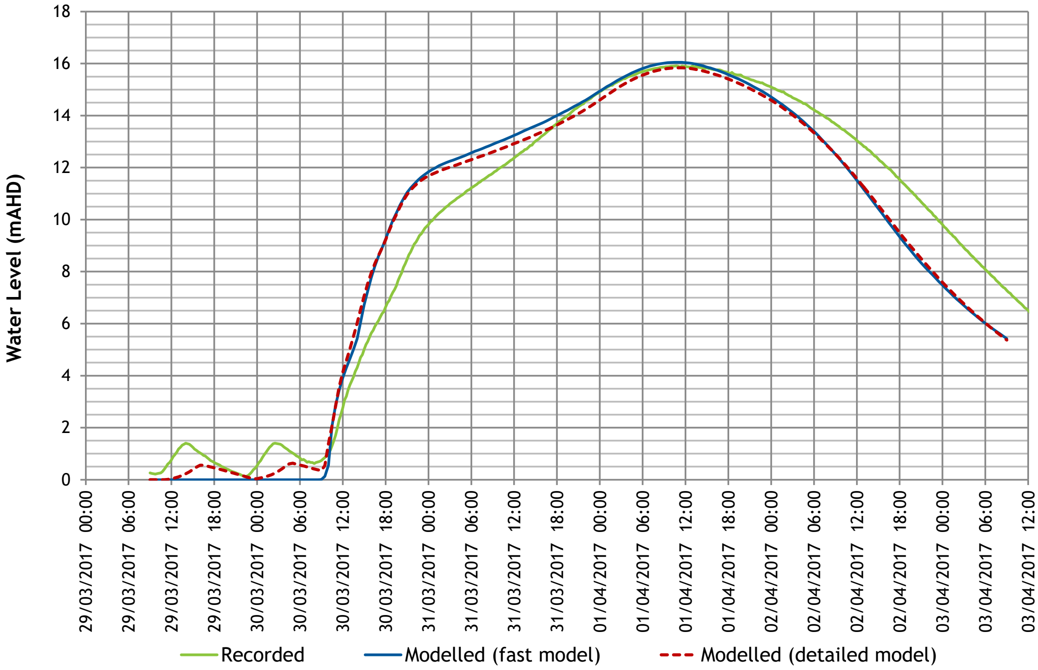

Figure 7.19 - Modelled and recorded water level hydrographs in the Logan River at Logan Village (LCC GS 6263), March 2017 flood event

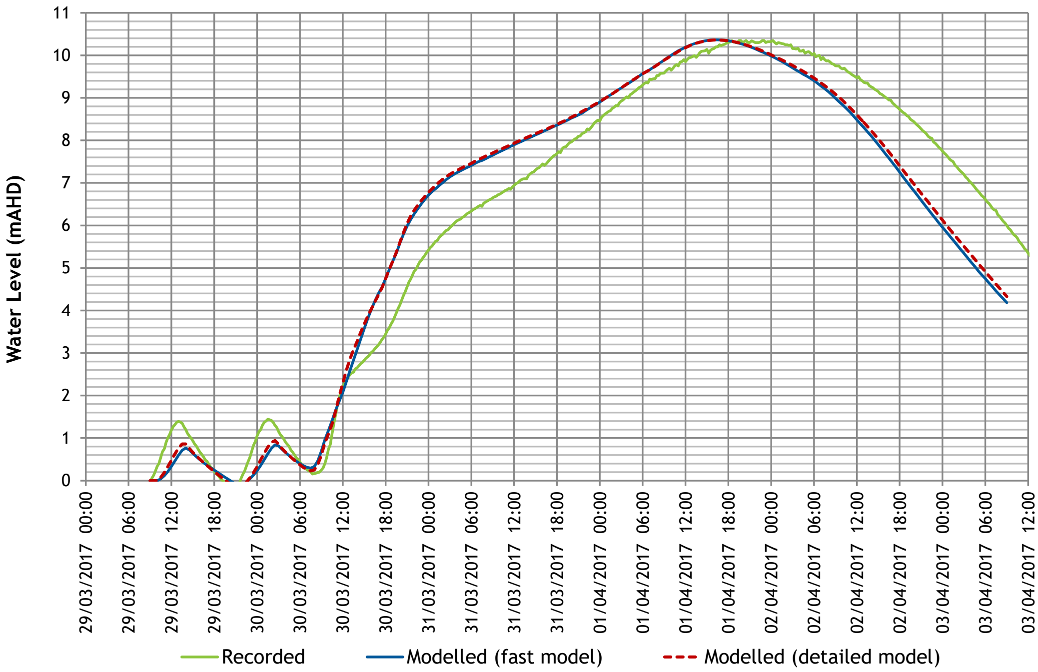

Figure 7.20 - Modelled and recorded water level hydrographs in the Logan River at Waterford (BOM GS 040878), March 2017 flood event

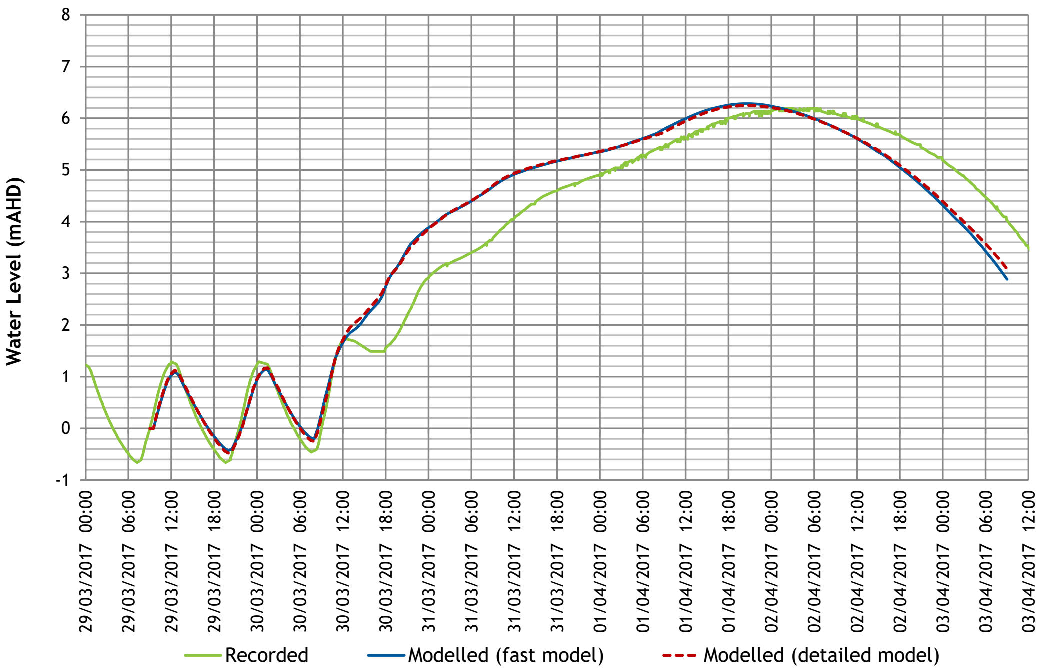

Figure 7.21 - Modelled and recorded water level hydrographs in the Logan River at Parklands (BOM GS 540645), March 2017 flood event

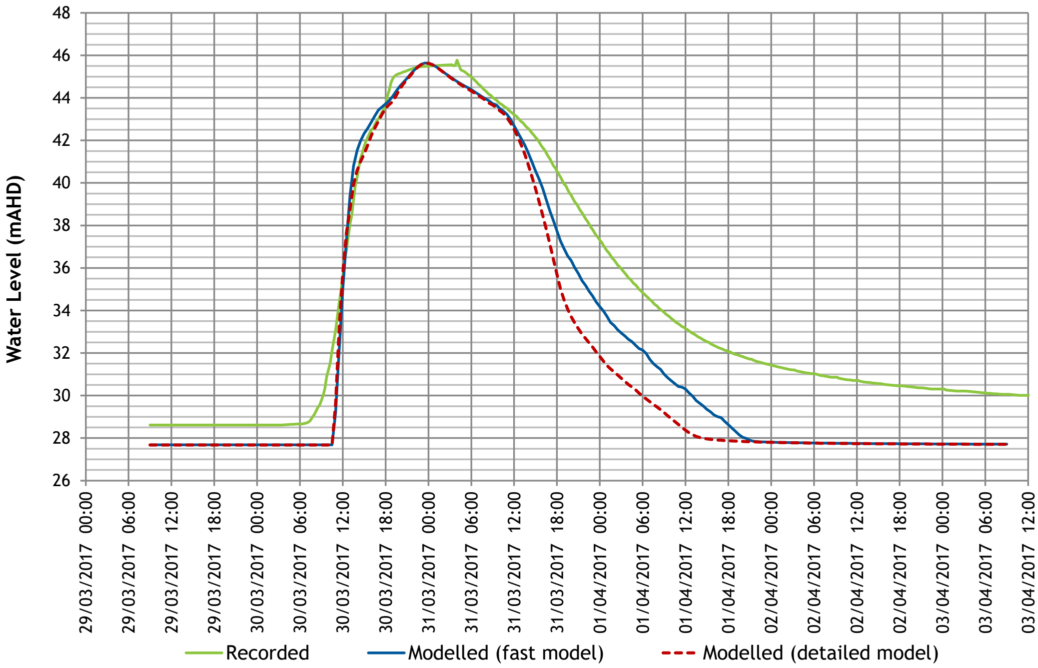

Figure 7.22 - Modelled and recorded water level hydrographs in the Albert River at Bromfleet (DNRM GS 145102a), March 2017 flood event

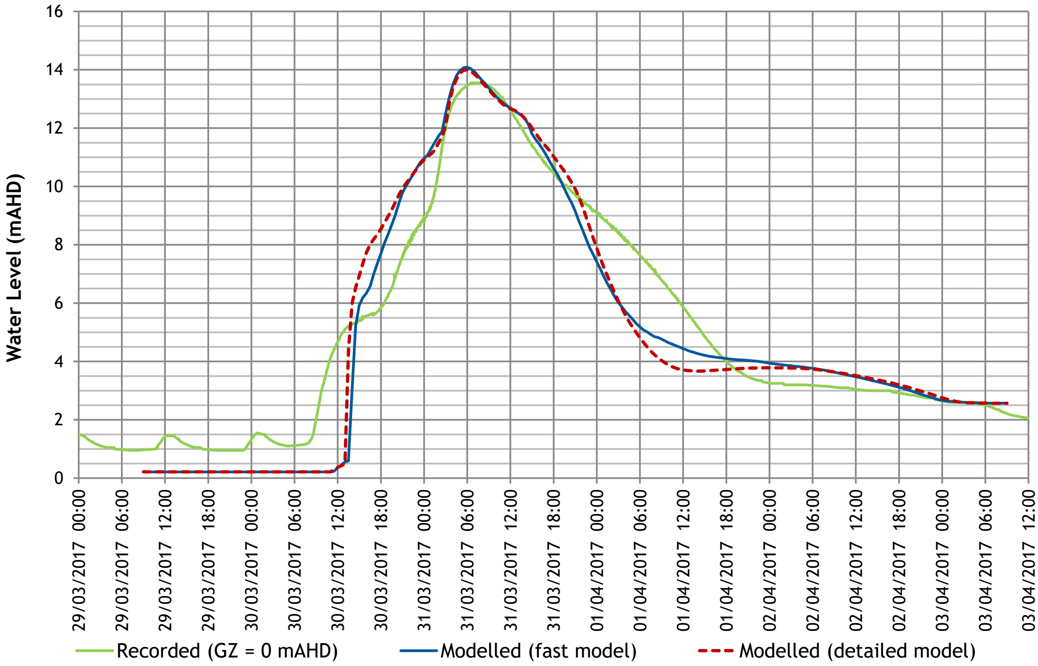

Figure 7.23 - Modelled and recorded water level hydrographs in the Albert River at Wolffdene (DNRM GS 145196a), March 2017 flood event

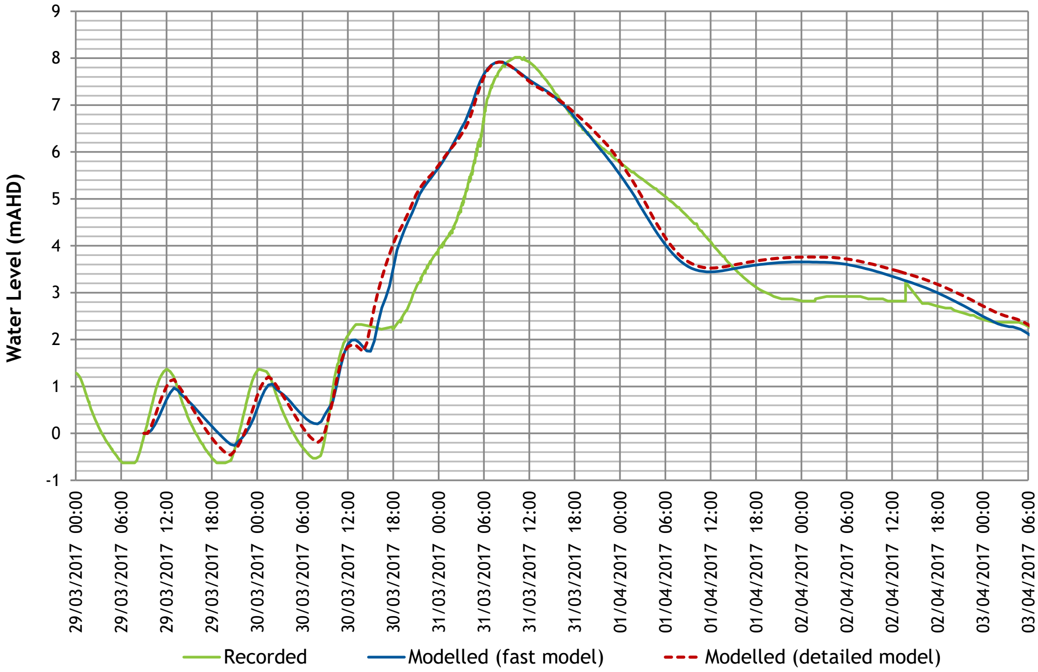

Figure 7.24 - Modelled and recorded water level hydrographs in the Albert River at Beenleigh (BOM GS GS540644), March 2017 flood event

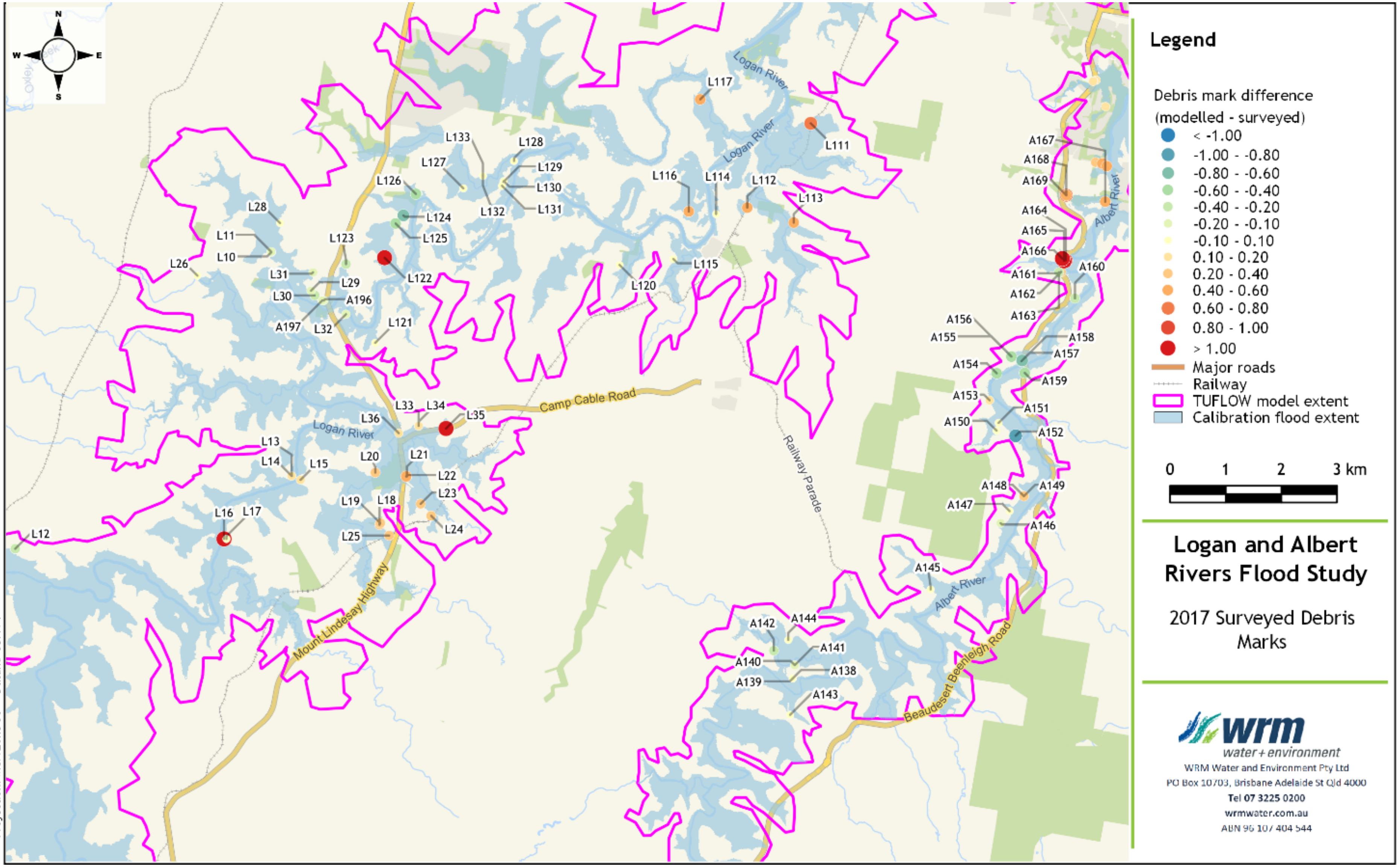

Figure 7.25 - Differences between modelled peak water levels and surveyed debris marks at the upper reaches of the Logan and Albert rivers, March 2017 flood event

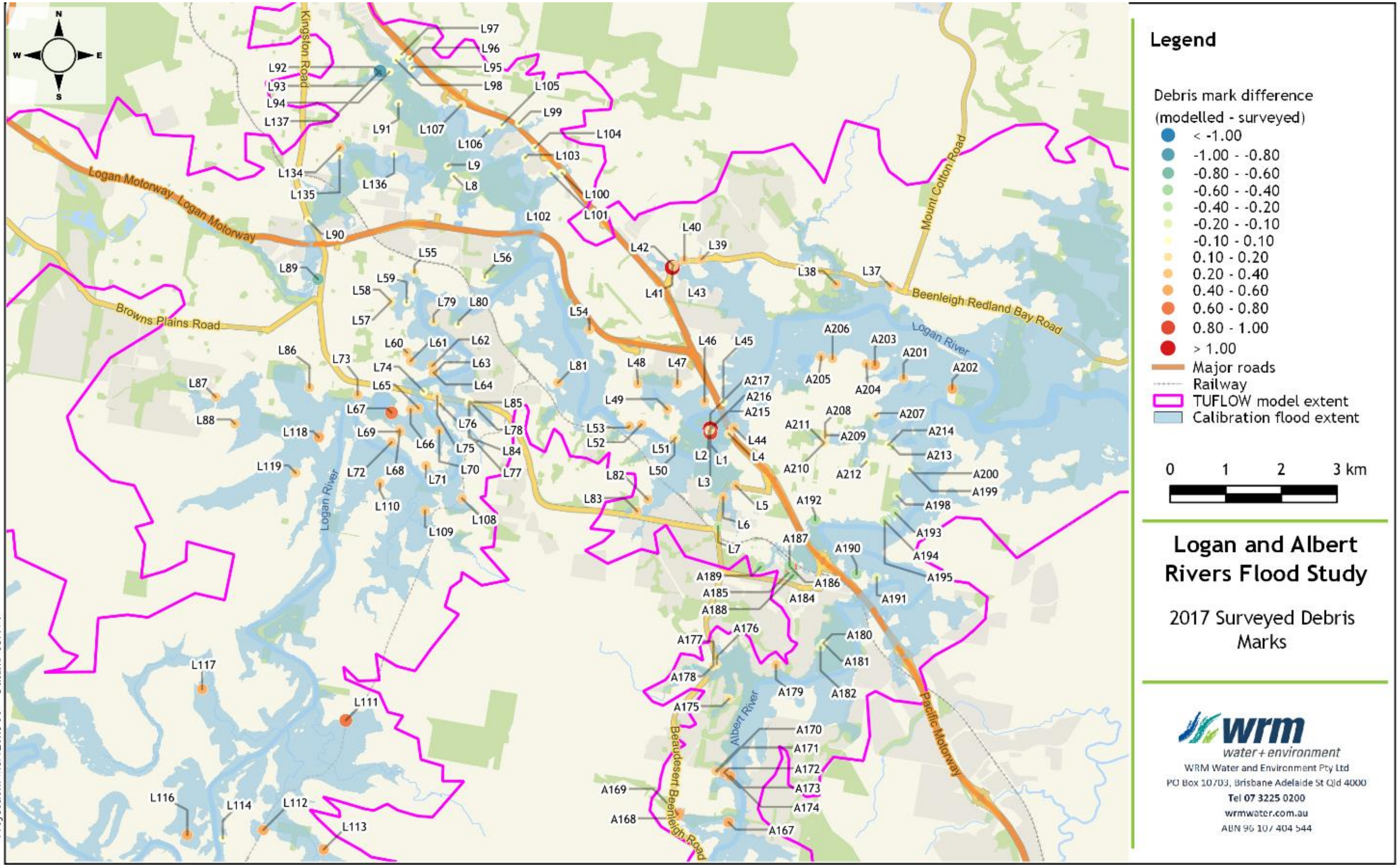

Figure 7.26 – Differences between modelled peak water levels and surveyed debris marks at the lower reaches of the Logan and Albert rivers, March 2017 flood event

7.7 FEBRUARY 2022 MODEL VALIDATION

7.7.1 Overview

Inflow hydrographs for the hydraulic model for the February 2022 event were generated from the calibrated February 2022 hydrologic model. As this was a validation exercise, no calibration parameters were adjusted in either the hydrologic or hydraulic models. In other words, the parameters used in the derivation of the design event model results were used here. Results from the hydraulic model were compared with recorded water level hydrographs at Yarrahappini, Maclean Bridge, Logan Village, Waterford, Parklands, Bromfleet, Wolffdene and Beenleigh as well as with surveyed debris marks throughout the Logan and Albert River catchments.

7.7.2 2022 Validation Results

Table 7.5 summarises the recorded peak water levels at the above gauging stations, and compares them with peak water levels estimated by the hydraulic model. Figure 7.28 through to Figure 7.35 show the recorded and predicted water level hydrographs at Yarrahappini, Maclean Bridge, Logan Village, Waterford, Parklands, Bromfleet, Wolffdene and Beenleigh.

Figure 7.36 and Figure 7.37 show the differences between the modelled peak flood levels and surveyed debris marks at the debris locations within the model extent. A histogram of differences plotted Figure 7.36 and Figure 7.37 is shown in Figure 7.27. Table C.3 in Appendix C shows further details on the surveyed debris marks including eastings and northings and comparisons between surveyed debris levels and the modelled peak water levels at each location.

Figure 7.40 and Figure 7.41 compares longitudinal profiles of modelled peak water levels along the Logan and Albert rivers and compares to available it with the peak gauged and select surveyed debris marks. For ease of reference, the 10% and 1% design surface is shown alongside the validation model results.

Table 7.5 – Recorded and modelled peak water levels, February 2022 flood event

Location	Recorded peak water level (mAHD)	Detailed (10 m grid) model	
		Modelled peak water level (mAHD)	Difference (m)
Yarrahappini Gauge	30.17	30.20	0.03
Maclean Bridge Gauge (current Location)	23.95	24.06	0.11
Logan Village Gauge	16.46	16.19	-0.27
Waterford Gauge	11.15	10.89	-0.26
Parklands Gauge	6.64	6.36	-0.18
Bromfleet Gauge	45.21	44.80	-0.41
Wolffdene Gauge	12.3	13.69	1.39
Beenleigh Gauge	7.42	7.61	0.19

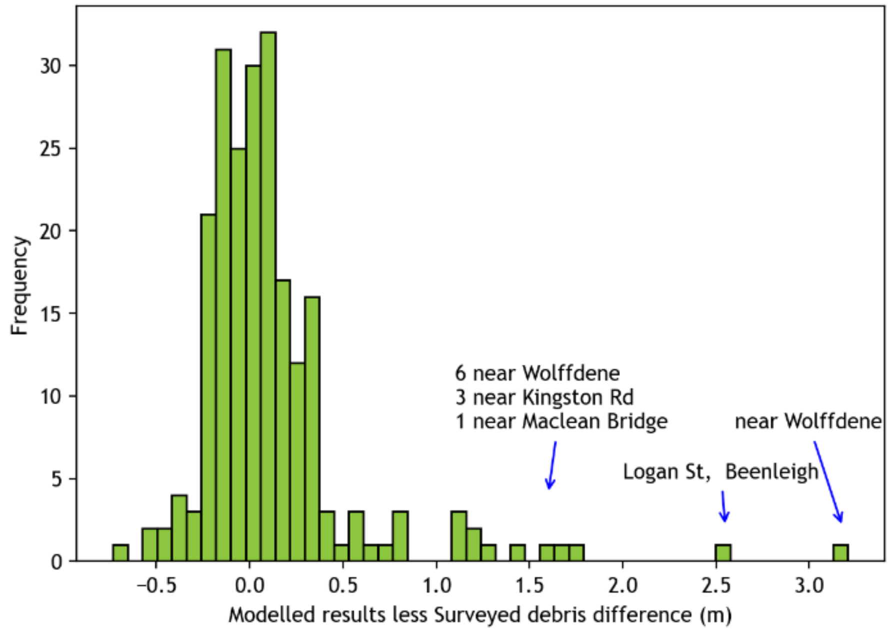

Figure 7.27 - Comparison of surveyed debris marks and 2022 validation model results refer to Figure 7.36 and Figure 7.37

The following is of note with regard to the validation results:

- In the Logan River:
  - The modelled water level hydrographs match the rising limb of the shape of the recorded hydrographs at Yarrahappini, Maclean Bridge, Logan Village, Waterford and Parklands. The decay of the falling limb indicates an adjustment of routing, baseflow or roughness parameters may improve the post peak volumes. The peak water level are in very good agreement with the recorded peak water levels.
  - The timing of the modelled flood peak at Logan Village, Waterford and Parklands acceptably match the recorded hydrograph. However, the arrival of the recorded flood peak occurs a few hours later then the modelled flood peak, this suggests more complex routing mechanisms may be contributing volume at the trailing limb of the hydrograph.
  - The peak flood extent for the February 2022 event agrees with the locations of the surveyed debris marks throughout the Logan River catchment. The modelled peak flood levels are in good agreement with the surveyed debris marks throughout the Logan River catchment.
- In the Albert River:
  - The modelled water level hydrograph at Bromfleet match well with the recorded hydrograph shape and timing, however it is underestimating the peak flood level by approximately 0.41 m. The underestimation in flood level is due to the underestimation of flow in the XP-RAFTS model for this event. It is of note that matching the RAFTS model discharges and observed peak water level at Bromfleet for this event will result in a significantly worse validation at Wolffdene.
  - The models performance near to Wolffdene in the mid to lower Albert River does show a discrepancy that is difficult resolve solely within the model parameters related to routing and energy loss. The detailed models match the surveyed debris marks available and the peak water level at Beenleigh, but overestimate the peak water level at Wolffdene. Similar to that reported

in 2017, there remains an inconsistency between the recorded peak water level at the Wolffdene gauging station and a surveyed debris mark immediately northwest of gauge. As identified in Section 5.7.5, it appears that the Wolffdene stream gauge did not accurately record the peak of the flood event during the February 2022 event, or there is some error with sensor or gauge datum.

- The modelled water level hydrographs at Wolffdene and Beenleigh approximate the recorded hydrograph's shape and timing, but the rising limb of the modelled hydrographs indicates higher volumes occurring earlier than in the recorded hydrograph. There are many possible reasons for why this artefact continues to be observed. Possible reasons could be: localised storm bursts near to the pluvio stations being distributed too broadly through the valley leading to greater inflow volumes; river gauging resolution misreporting increments; or, lower roughness values occurring once vegetation becomes deeply submerged during large flood events.
- One of the reasons for the model overestimating peak water level at Wolffdene is the adopted hydraulic roughness in this channel reach. However, this was a validation exercise and so adjusting the hydraulic roughness was not undertaken. Regardless, adjusting parameters near to Wolffdene would worsen calibration result for other events (especially when comparing against surveyed debris marks in the floodplain).
- Further comparison of predicted water surface levels with surveyed debris marks along the Albert River indicate that the modelled peak water levels are generally in good agreement with surveyed debris marks throughout the Albert River catchment. The peak flood extent for the February 2022 event is generally consistent with the locations of the surveyed debris marks throughout the Albert River catchment.

7.7.3 Conclusions

The modelling of the February 2022 event indicates that this regional model provides very good agreement with the observations at gauging stations and surveyed debris marks. Further work could investigate weighting calibration to more recent events and accepting that a single set of hydrologic and hydraulic calibration parameters may need to vary for older events. The performance of the model compared to 220 surveyed debris marks and to eight river level gauging stations across the hydraulic model domain of 460 km^2.

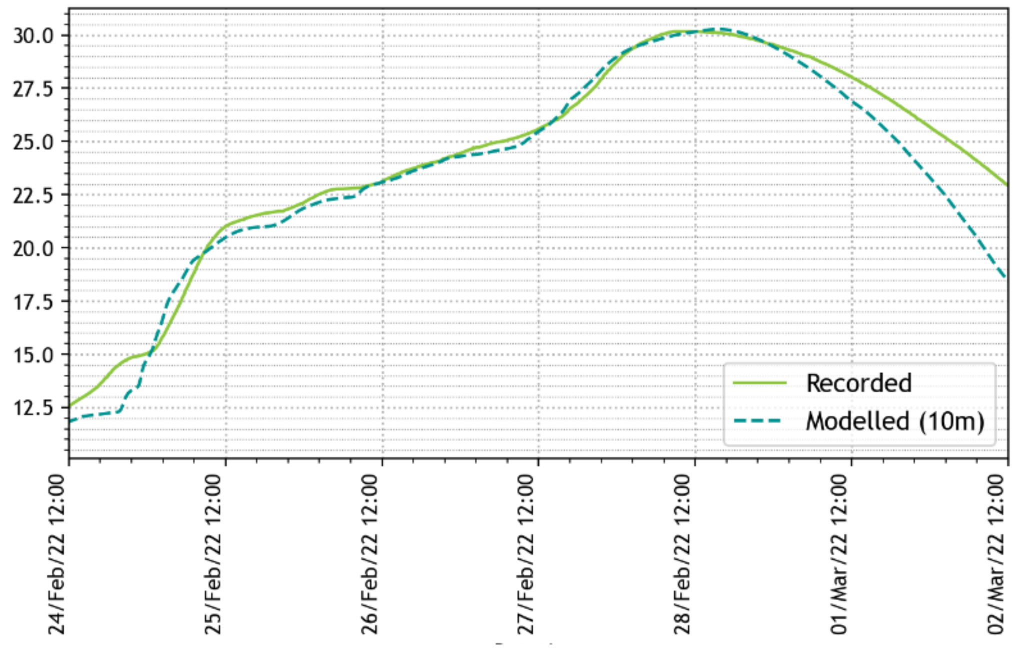

Figure 7.28 – Modelled and recorded water level hydrographs in the Logan River at Yarrahappini (DNRM GS 145014a), February 2022 flood event

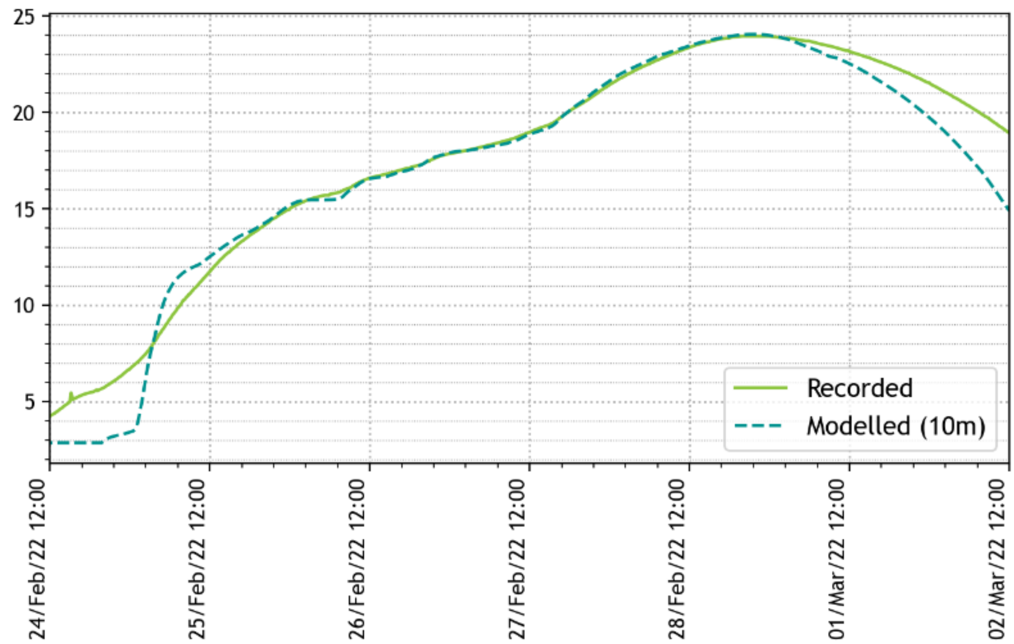

Figure 7.29 – Modelled and recorded water level hydrographs in the Logan River at Maclean Bridge (BOM GS 040935), February 2022 flood event

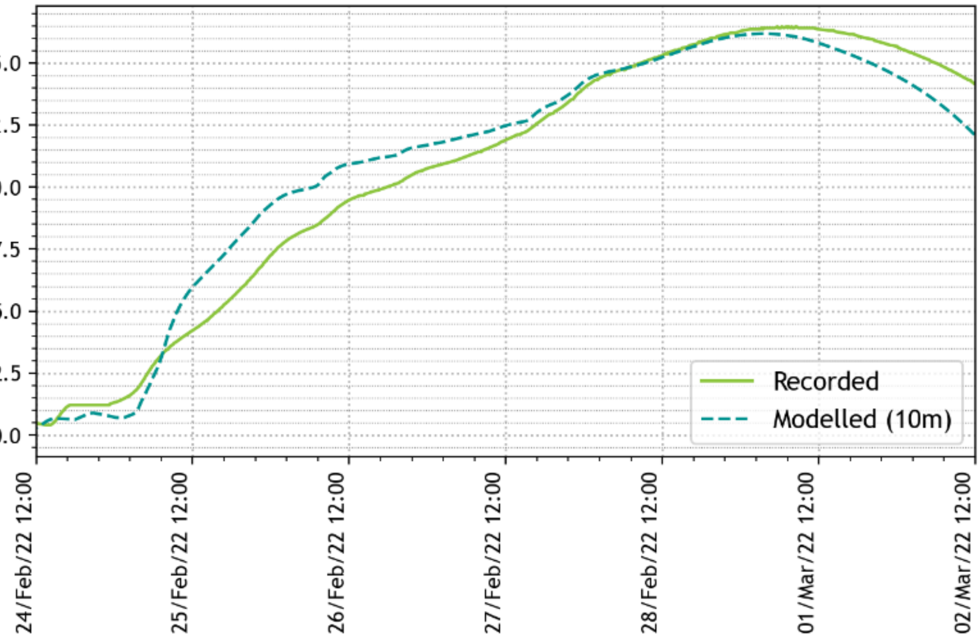

Figure 7.30 – Modelled and recorded water level hydrographs in the Logan River at Logan Village (LCC GS 6263), February 2022 flood event

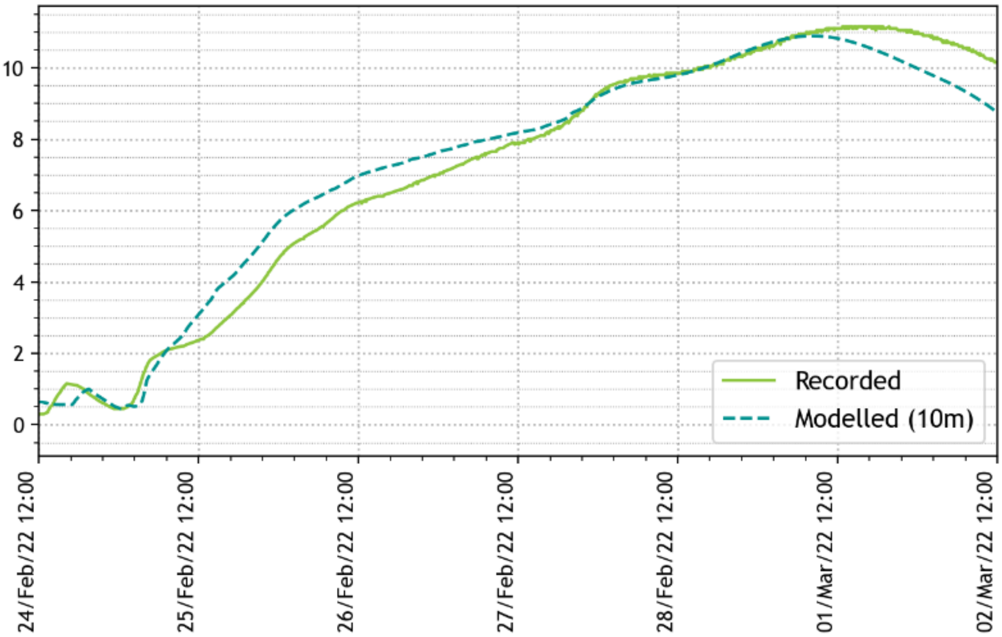

Figure 7.31 - Modelled and recorded water level hydrographs in the Logan River at Waterford (BOM GS 040878), February 2022 flood event

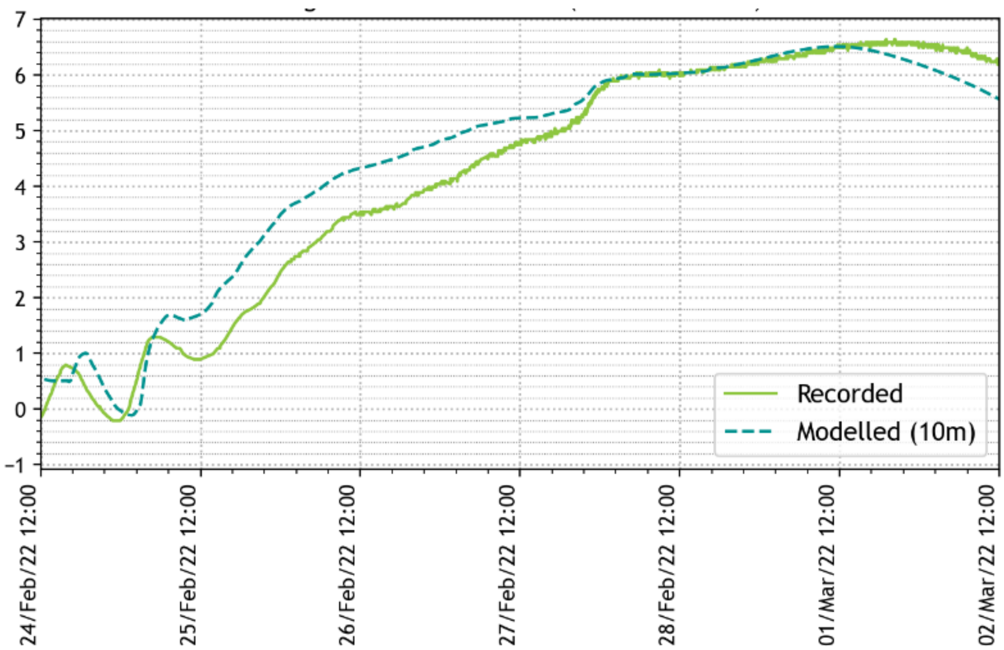

Figure 7.32 – Modelled and recorded water level hydrographs in the Logan River at Parklands (BOM GS 540645), February 2022 flood event

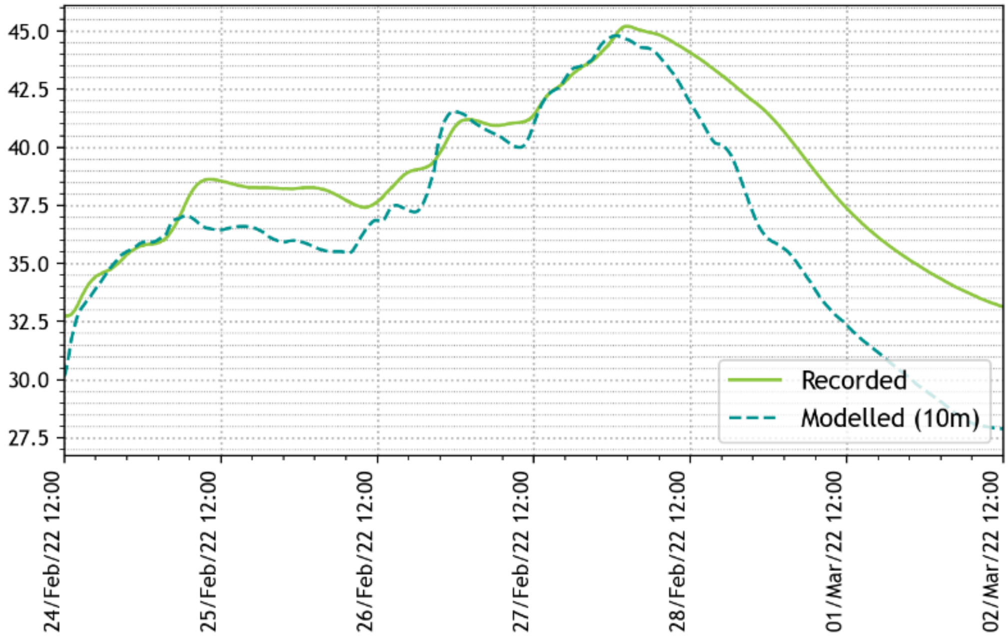

Figure 7.33 – Modelled and recorded water level hydrographs in the Albert River at Bromfleet (DNRM GS 145102a), February 2022 flood event

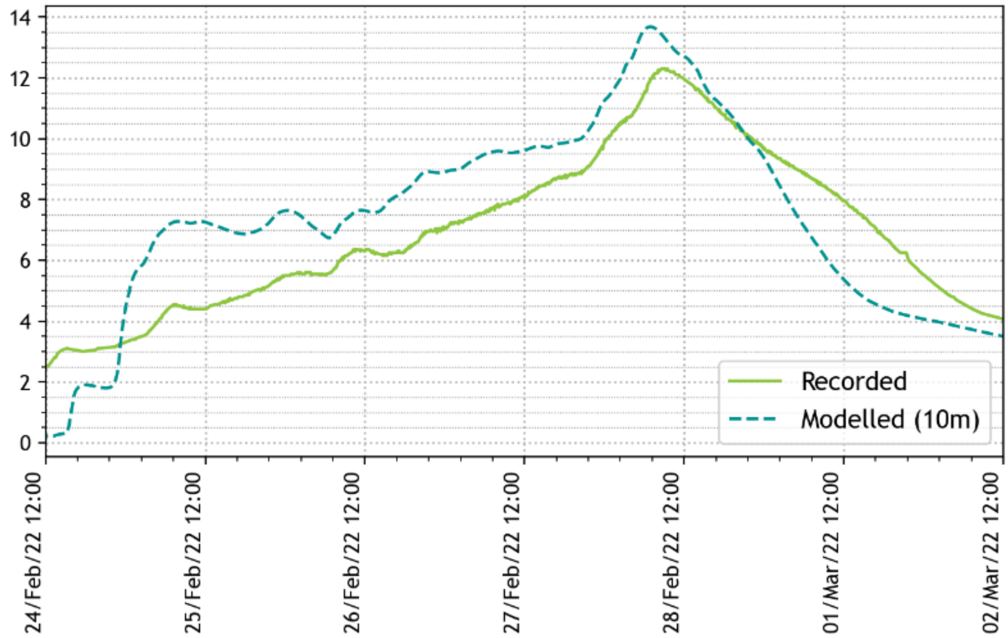

Figure 7.34 – Modelled and recorded water level hydrographs in the Albert River at Wolffdene (DNRM GS 145196a), February 2022 flood event

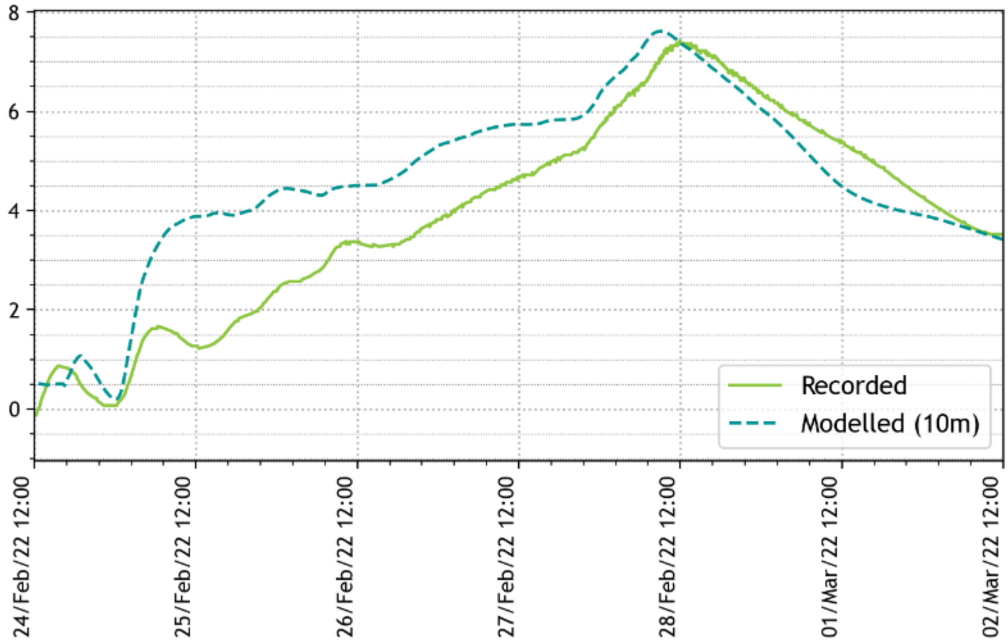

Figure 7.35 – Modelled and recorded water level hydrographs in the Albert River at Beenleigh (BOM GS GS540644), February 2022 flood event

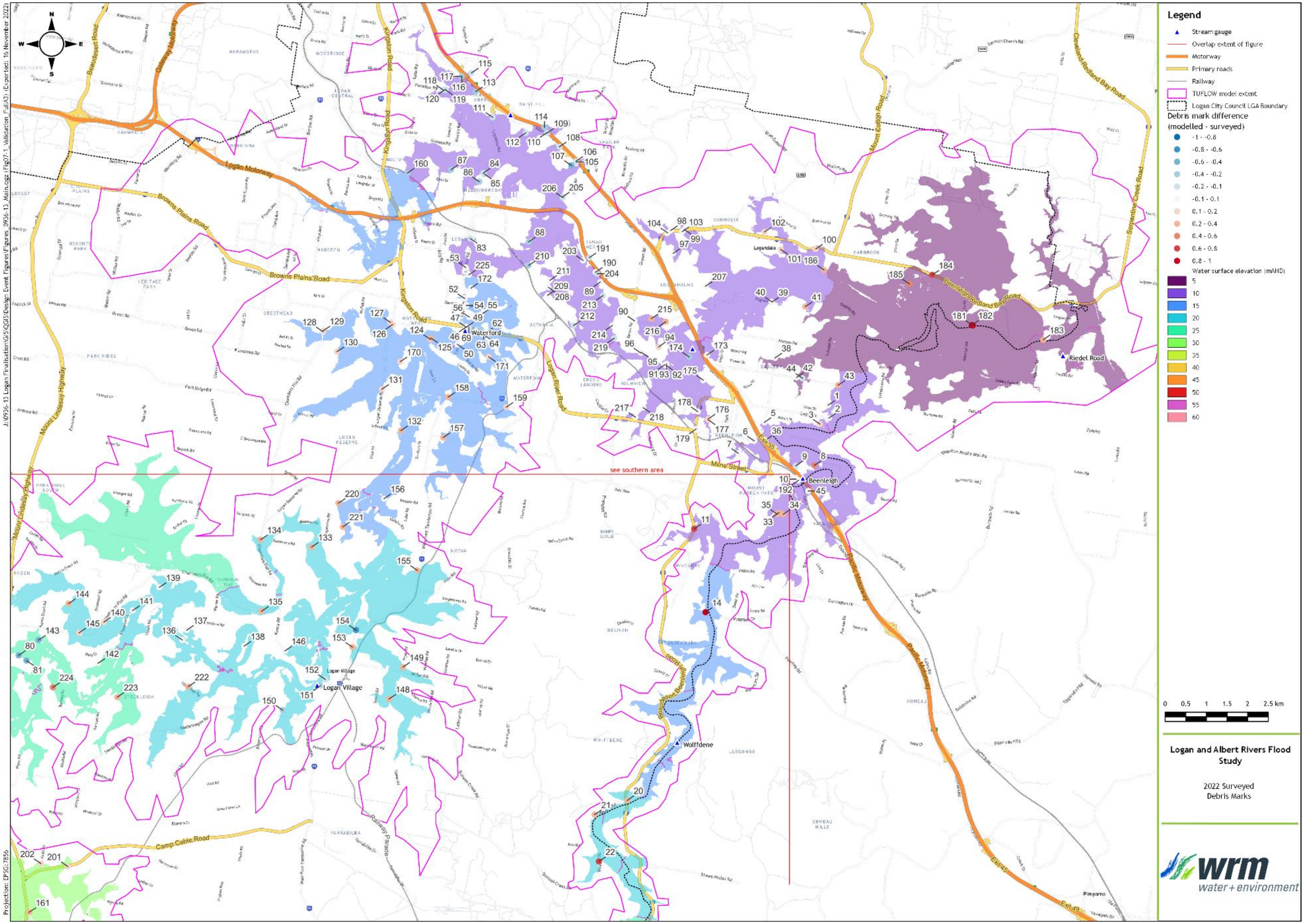

Figure 7.36 Differences between modelled peak water levels and surveyed debris marks at the lower reaches of the Logan and Albert rivers, February 2022 flood event

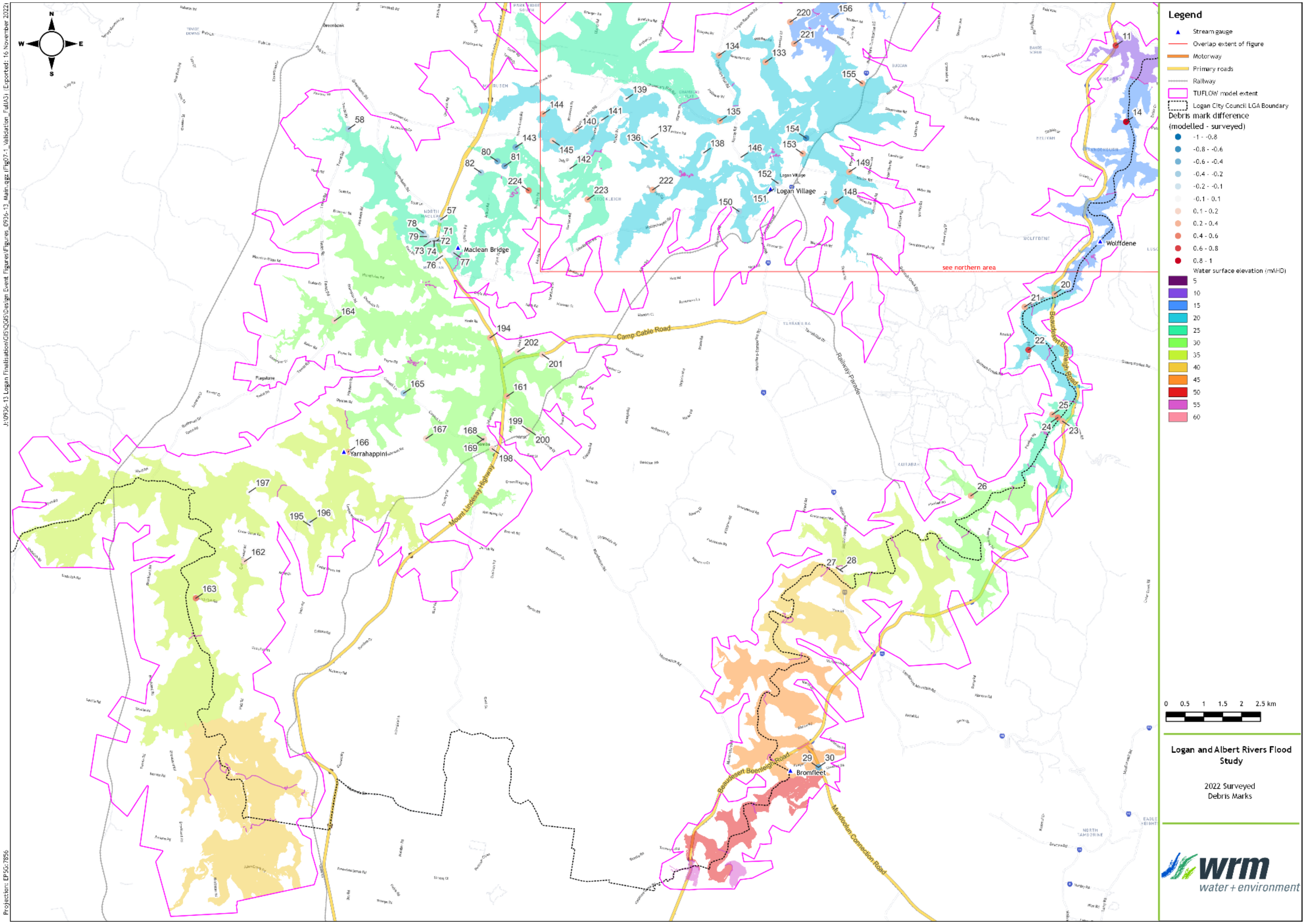

Figure 7.37 Differences between modelled peak water levels and surveyed debris marks at the lower reaches of the Logan and Albert rivers, February 2022 flood event

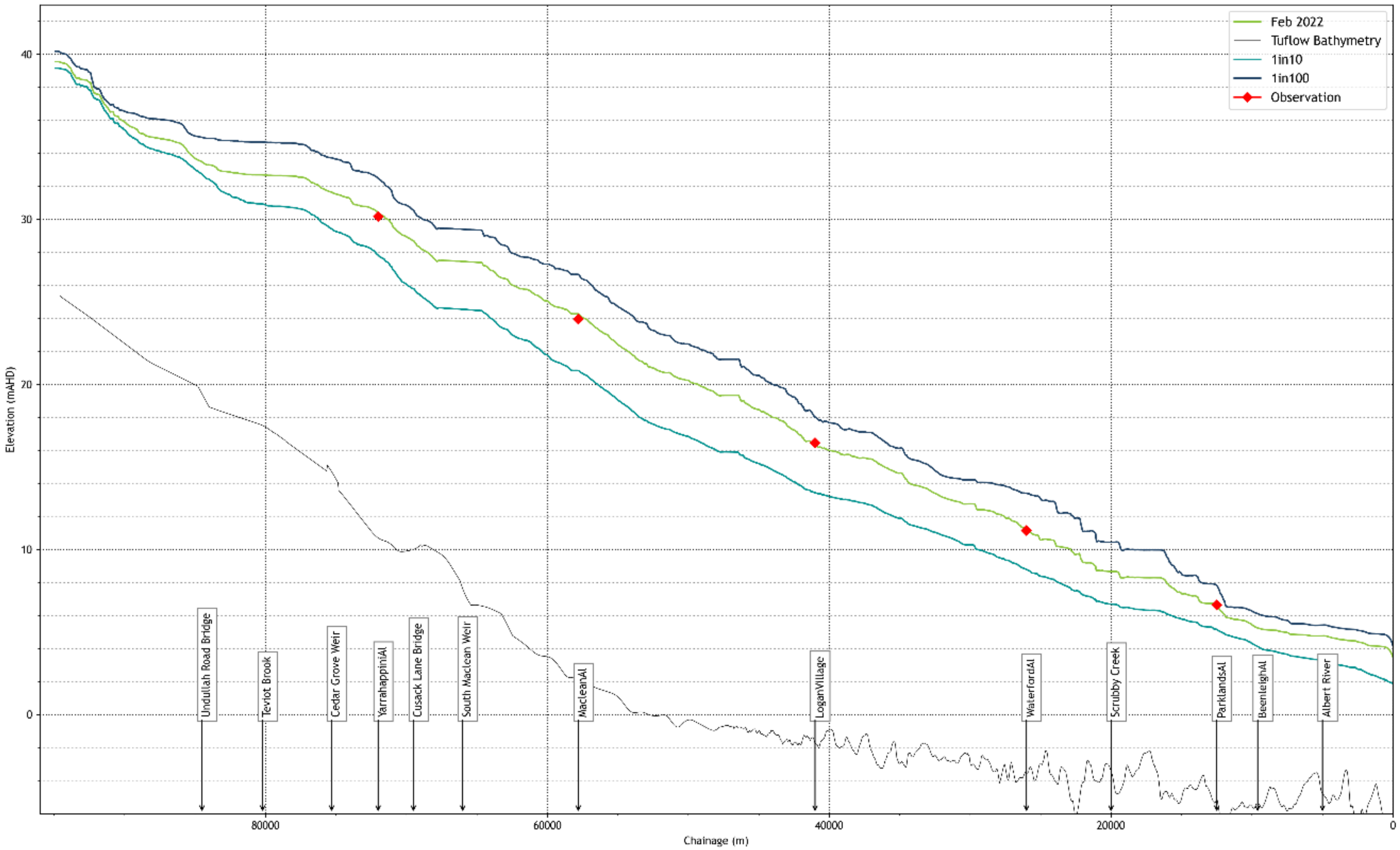

Figure 7.38 Longitudinal profile of modelled peak water levels (from 10m grid detailed model) compared with peak water observations in the Logan River, February 2022 flood event

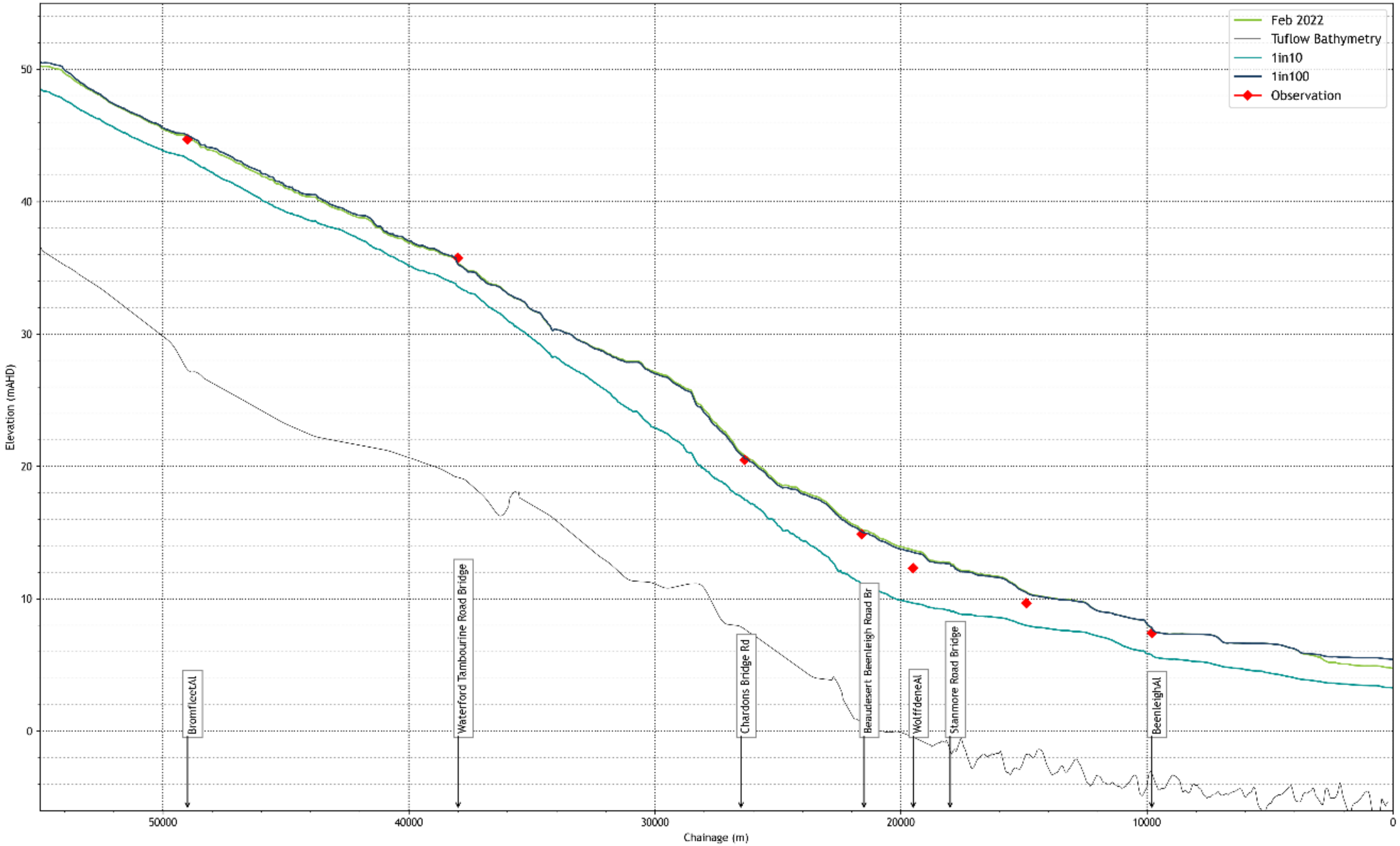

Figure 7.39 Longitudinal profile of modelled peak water levels (from 10m grid detailed model) compared with peak water observations in the Albert River, February 2022 flood event

7.8 CALIBRATION SUMMARY

The calibration and validation exercise confirms that the hydrologic model produces discharges that generally result in good reproduction of historical peak water levels for the January 1974, April 1990, January 2013 March 2017 and February 2022 events.

The April 1990 calibration results indicate that in-channel flows are represented adequately by the hydraulic model. The peak flood extents for the January 2013 and March 2017 events are generally consistent with the locations of the surveyed debris marks throughout the Logan and Albert rivers catchment, indicating that overbank flows are generally represented adequately by the hydraulic model. Both the fast (20 m grid) model and the detailed (10 m grid) model produce similar results.

The hydraulic model generally under predicts peak water levels in the lower reaches of the Logan River between Waterford and the Albert River confluence for the January 1974 event. However, modelled peak water levels in this reach for the January 2013 and March 2017 events are generally higher than (but close to) the surveyed debris marks for these events. The reason for the inconsistency in modelled peak water levels in this reach for the 1974 event compared to the other events is unknown but is possibly due to the representation of the river bed along this reach for the 1974 event.

With regards to the selection of floodplain hydraulic roughness (Manning's 'n'), more importance was placed on matching the January 2013 and March 2017 peak flood levels at surveyed debris marks than for the 1974 event.

7.9 SENSITIVITY ASSESSMENT FOR THE JANUARY 1974 CALIBRATION

7.9.1 Overview

The longitudinal plot shown in Figure 7.4 indicate that for the January 1974 event, the modelled peak flood levels in the Logan River between Logan Reserve and Waterford match reasonably well with the surveyed debris marks. However, the modelled peak flood levels between Waterford and the Albert River confluence are generally lower compared to the surveyed flood debris marks. Overall, the 1974 calibration result between Yarrahappini and Waterford is considered good but predicted water levels downstream of Waterford appear to be underestimated

A sensitivity assessment was undertaken to test the sensitivity of the hydraulic model calibration result for the 1974 flood event to increasing the adopted Manning's 'n' values along the lower reach of the Logan River. This analysis was undertaken to determine if changes to channel hydraulic roughness can improve the match between modelled peak flood levels and surveyed debris marks downstream of Waterford. The impact of this change on the calibration results for the 1990, 2013 and 2017 events was also assessed.

7.9.2 Methodology

In the hydraulic model, Manning's 'n' for river channels were varied with depth. Further details of this approach are provided in WRM (2020).

For this sensitivity assessment, the adopted channel Manning's 'n' values for the "middle", "lower" and "tidal" reaches of the Logan River were factored up by 50% (i.e. multiplied by 1.5) as shown in Table 1. Channel Manning's 'n' values for channel types other than the three mentioned above, as well as floodplain Manning's 'n' values were unchanged.

Table 7.6 – Comparison between the adopted Manning's 'n' coefficients for the base case 1974 event calibration and the adjusted coefficients for the 1974 sensitivity scenario

Range	Logan River middle reach		Logan River lower reach		Logan River tidal reach	
	Elevation (mAHD)	Manning's 'n'	Elevation (mAHD)	Manning's 'n'	Elevation (mAHD)	Manning's 'n'
Manning's 'n' coefficients adopted for the base case 1974 event calibration						
n1	< 1	0.030	< 1	0.030	< 1	0.030
n2	1 to 12	0.070	1 to 12	0.060	1 to 12	0.045
n3	12 to 18	0.075				
n4	> 18	0.050	> 12	0.030	> 12	0.025
Adjusted Manning's 'n' coefficients for the 1974 event sensitivity assessment						
n1	< 1	0.045	< 1	0.045	< 1	0.045
n2	1 to 12	0.105	1 to 12	0.090	1 to 12	0.068
n3	12 to 18	0.113				
n4	> 18	0.075	> 12	0.045	> 12	0.038

The 10 m grid detailed model (with the updated Manning's 'n' values) was then re-run for the January 1974 calibration event, as well as the April 1990, January 2013 and March 2017 calibration events. These model runs are referred to in this memo as the sensitivity scenarios.

For each event, the impact of increasing channel Manning's 'n' values was assessed by comparing longitudinal profiles of peak water levels along the Logan River between the WRM (2020) and the sensitivity scenario results.

7.9.3 Results

7.9.3.1 Impact on the 1974 flood event calibration results

Figure 7.40 shows longitudinal profiles of modelled peak water levels along the Logan River (between Waterford and the Albert River confluence) from the base case calibration and scenario the sensitivity scenario for the 1974 event and compares them with the surveyed debris marks from the AWE (1997) study. The results show that:

- Predicted peak water levels along the Logan River between Waterford and the Albert River confluence for the sensitivity scenario are generally about 0.3 to 0.4 m higher than the WRM (2020) calibration result;
- This results in a generally better fit to surveyed debris marks, although the predicted peak Logan River flood surface at the M1 Motorway is only about 0.2 m higher for the sensitivity event than for the base case calibration; and
- Overall, factoring up the channel Manning's 'n' results in an improved calibration result for the January 1974 event.

7.9.3.2 Impact on the 1990, 2013 and 2017 flood event calibration results

Figure 7.41 compares longitudinal profiles of modelled peak water levels along the Logan River (between Waterford and the Albert River confluence) between the base case calibration results and the sensitivity scenario results for the 1990, 2013 and 2017 events. The results show that by increasing channel Manning's 'n' to improve the 1974 calibration results:

- Peak water levels along the Logan River would generally be increased by about 0.5 m. Increased of higher than 0.5 m are predicted in some locations.

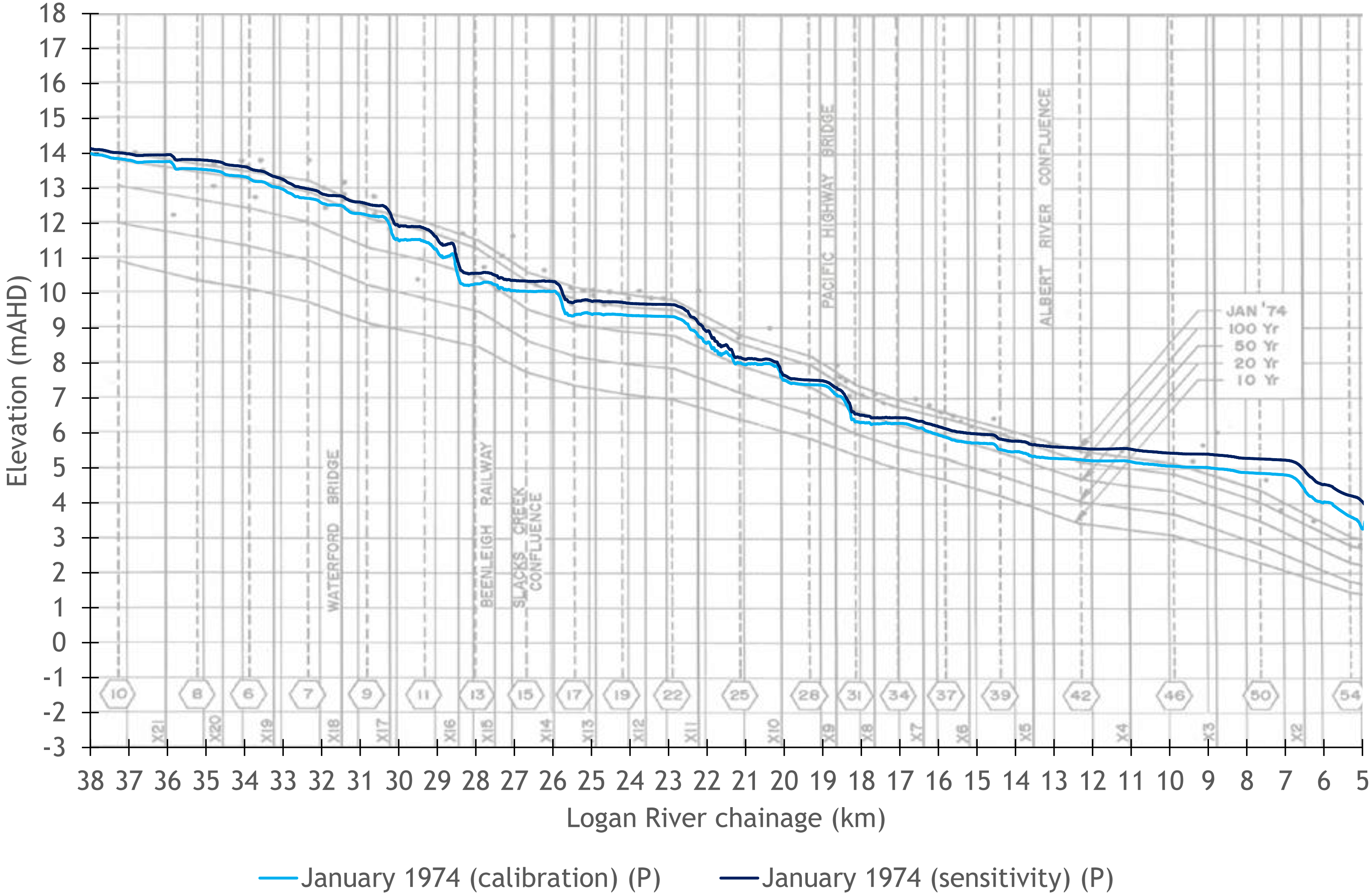

Figure 7.40 – Longitudinal profile of modelled peak water levels for base case calibration scenario and the Manning's 'n' sensitivity scenario compared to surveyed debris marks, January 1974 flood event

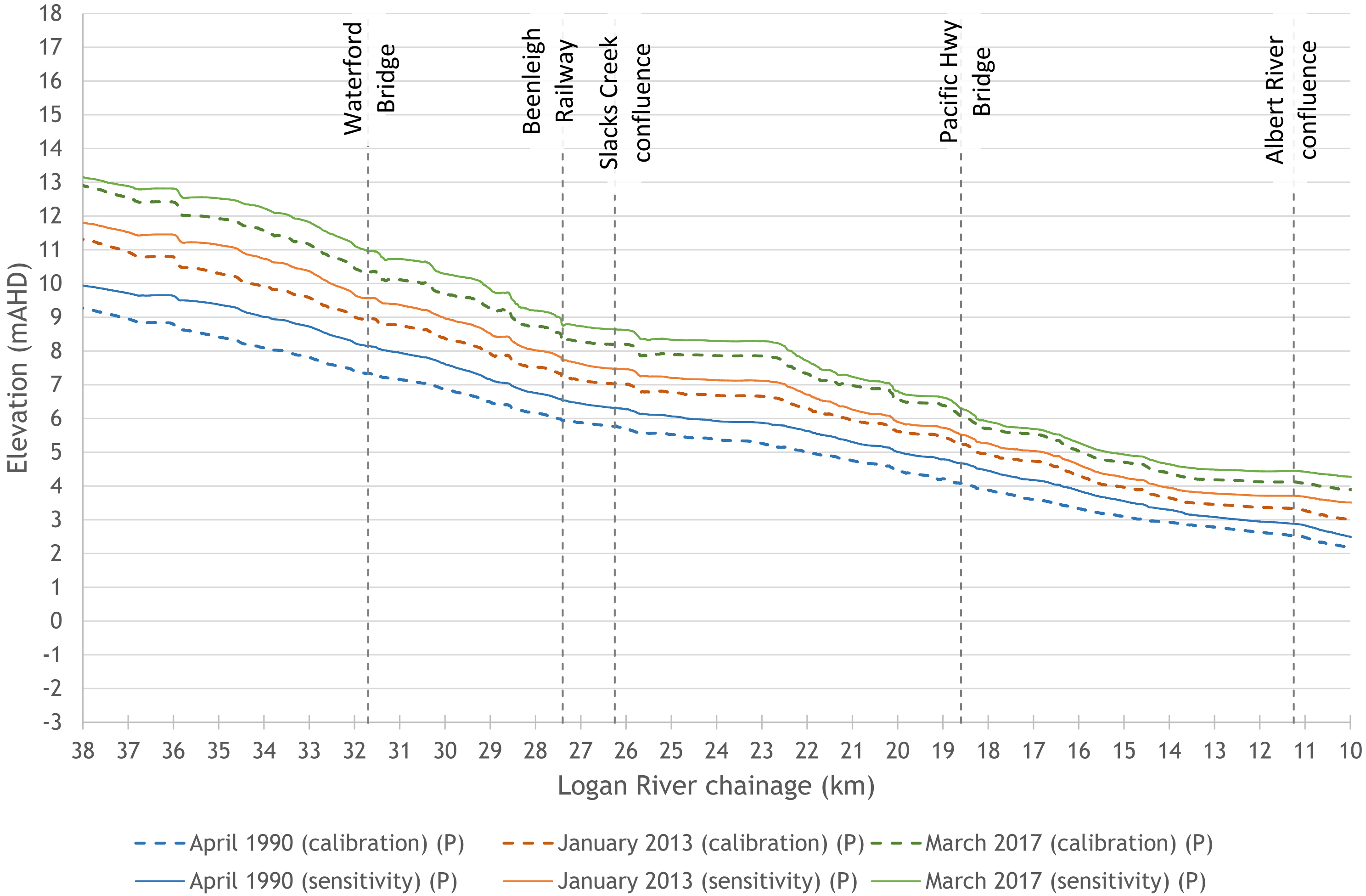

Figure 7.41 – Longitudinal profile of modelled peak water levels for the channel Manning's 'n' sensitivity scenario compared to the base case calibration results for the April 1990, January 2017 and March 2017 flood events

- The predicted increased in peak water levels for these three events are higher than predicted for the 1974 event. This is likely due to the 1974 vent being a larger flood event, engaging more Logan River floodplain conveyance, compared to the 1990, 2013 and 2017 events, which are more greatly influenced by Logan River channel conveyance.
- For the 1990 calibration event:
    - The base case calibration results showed a good match between predicted and recorded peak water levels at the Waterford gauge, with the predicted peak water level approximately 0.04 m higher than the recorded peak water level.
    - The sensitivity scenario increases peak flood levels along the Logan River including at Waterford by about 0.5 m on average. Therefore, the sensitivity scenario produces a worse calibration result than the WRM (2020) study for this event.
- For the 2013 and 2017 calibration events:
    - The base case calibration results showed that modelled peak water levels downstream of Waterford generally match well with the surveyed debris marks, with the predicted peak levels generally slightly higher than the surveyed debris marks.
    - The sensitivity scenario increases peak flood levels along the Logan River including at Waterford by about 0.5 m on average. Therefore, the sensitivity scenario produces a worse calibration result than the WRM (2020) study for these events.

7.9.4 Conclusions

The sensitivity assessment results show that while a factoring up channel Manning's 'n' does result in an improved calibration for the 1974 event, doing so would adversely impact the April 1990, January 2013, and March 2017 flood event calibrations.

Given the satisfactory calibration result between Yarrahappini and Waterford, the reasons for the underestimation of flood levels downstream Waterford is not known. It is possible that it is due to differences in channel bathymetry, floodplain topography and land-use in 1974 compared to what the latest topographical data and aerial imagery shows.

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). The FFA was undertaken using the FLIKE software (version 5.0.251.0) in accordance with guidelines in Book 3, Chapter 2 of AR&R 2019 (Ball et al, 2019).

The following gauges were selected for FFA due to their key locations within the catchment and length (over 30 years) of historical record:

- Teviot Brook at The Overflow (DNRM GS 145012a);
- Logan River at Yarrahappini (DNRM GS 145014a);
- Albert River at Bromfleet (DNRM GS 145102b); and
- Albert River at Wolffdene (DNRM GS 145196a).

Round Mountain was not selected for FFA due to concerns regarding the accuracy of the rating curves for higher discharges.

Annual series and peak over threshold (POT) series analyses were undertaken based on fitting Log-Pearson Type III (LPIII) distributions to the respective data series at the above four locations.

8.2 AVAILABLE DATA

8.2.1 Peak annual data

The peak annual gauge heights and discharges recorded at the selected gauge sites were obtained from the DNRM website. Where an annual peak height at a gauge site was within the range of modification of the adopted rating curves described in Section 3.8 (i.e. the peak flood height exceeded the highest gauging at that rating curve) the discharge was estimated using the extended TUFLOW rating curves adopted for this study (refer to Section 3.8). Where an annual peak height was below the range of modification, the corresponding peak discharge given by the DERM website was adopted. A summary of the available peak series data for each gauge is given in Table 8.1. The following is of note with regards to Table 8.1:

- The annual data is presented for water years (i.e. September to August).
- The Overflow gauging station was decommissioned in October 2010 following the construction of Wyaralong Dam.
- The influence of Wyaralong Dam (constructed in 2010) on the Yarrahappini FFA was investigated by comparing FFA results at this gauge using annual series data including and excluding the period following the dam's construction (2011 to 2019). It was found that the annual series FFA results at Yarrahappini when all data is included (51 years of data) are similar, but slightly higher compared to the FFA results with the post-dam period excluded (42 years of data). This is due to the two significant flood events in the Logan River which occurred after the dam's construction (the January 2013 and March 2017 events). On this basis, the entire data set available for the Yarrahappini gauge (including the post-dam period) was included for the FFA.
- The Wolffdene gauging station was owned by DNRM until it was decommissioned in May 2004. This gauge was re-activated in 2006 under the ownership of LCC. Data for this gauge is missing for the entire 2004 to 2005 water year (September to August).

Table 8.1 – Recorded and modelled peak water levels, March 2017 flood event

Gauging station name	Gauging station no.	Catchment	Period of gauge record	Years without record	Years of available data
The Overflow	145012a	Teviot Brook	1966 - 2010	0	45
Yarrahappini	145014a	Upper Logan	1969 - 2019	0	51
Bromfleet	145102a	Albert River	1920 - 2019	0	100
Wolffdene	145196a	Albert River	1969 - 2019	1	50

8.2.2 Peak over threshold (POT) data

POT series were derived using continuous water level data for the period and gauges shown in Table 8.1. Guidelines and recommendations in AR&R 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 AR&R 2019 for fitting an LPIII distribution to a POT series. 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 AR&R 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 interdepency periods ranging from 11 to 12 days between the four selected gauge sites. The resulting peak flow series were then filtered further by removing the lowest ranked flows until the number of data points (m) equal the number of data years (n).

8.2.3 Other historical data

No historical flood data (pre-dating the period of record) was available at any of the selected gauge sites for the study. It is of note that FFA undertaken for Yarrahappini, Bromfleet and Wolffdene in the AWE (1997) study included some historical data, however this data was not available for use in this study.

8.3 ANALYSIS AND RESULTS

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

- For the Overflow, Yarrahappini and Bromfleet gauges, a Log Pearson Type III distribution was adopted with the Bayesian inference method. Potentially influential low flows (PILFs) were censored from the annual series using the multiple Grubbs Beck test prior to fitting the LPIII distribution. No data was censored from the POT series.
- For the Wolffdene gauge, a Log Pearson Type III distribution was adopted with the L-Moment method. This method resulted in a much better fit between the expected flood quantile and the recorded data at this gauge, and it also produced design discharges that are more consistent with the FFA results at Bromfleet. Low flows smaller than 25 m^3/s were censored from the annual series prior to fitting the LPIII distribution at this gauge. No data was censored from the POT series.

Table 8.2 to Table 8.5 show the flood frequency distributions for each gauge, including the 5% and 95% confidence limits obtained for the results. Figure 9.2 to Figure 9.5 show plots of the flood frequency distribution results for each gauge. The following is of note with regards to the FFA results:

- The FFA results at The Overflow show that:
    - For the annual series, the estimated 2% AEP discharge ranges from 809 m^3/s and 3,908 m^3/s. The estimated 1% AEP discharge ranges from 999 m^3/s to 6,800 m^3/s. The fitted LPIII values for the 2% and 1% AEP events are 1,491 m^3/s and 2,043 m^3/s.
    - For the POT series, the fitted LPIII values are higher than the annual series values for the 50%, 20%, 2% and 1% AEP events. The fitted LPIII values are lower than the annual series values for the 10% and 5% AEP events.
- The FFA results at Yarrahappini show that:
    - For the annual series, the estimated 2% AEP discharge ranges from 2,598 m^3/s and 7,433 m^3/s. The estimated 1% AEP discharge ranges from 3,076 m^3/s to 11,076 m^3/s. The fitted LPIII values for the 2% and 1% AEP events are 3,927 m^3/s and 4,960 m^3/s.
    - For the POT series, the fitted LPIII values are higher than the annual series values for the 50% event. The fitted LPIII values are lower than the annual series values for all other events.
- The FFA results at Bromfleet show that:
    - For the annual series, the estimated 2% AEP discharge ranges from 809 m^3/s and 3,908 m^3/s. The estimated 1% AEP discharge ranges from 999 m^3/s to 6,800 m^3/s. The fitted LPIII values for the 2% and 1% AEP events are 1,491 m^3/s and 2,043 m^3/s.
    - For the POT series, the fitted LPIII values are higher than the annual series values for the 50%, 20%, 2% and 1% AEP events. The fitted LPIII values are lower than the annual series values for the 10% and 5% AEP events.
- The FFA results at Wolffdene show that:
    - For the annual series, the estimated 2% AEP discharge ranges from 1,113 m^3/s and 4,880 m^3/s. The estimated 1% AEP discharge ranges from 1,263 m^3/s to 7,570 m^3/s. The fitted LPIII values for the 2% and 1% AEP events are 2,261 m^3/s and 2,932 m^3/s.
    - For the POT series, the fitted LPIII values are higher than the annual series values for all events up to and including 1% AEP.
- The flood frequency distributions at The Overflow, Yarrahappini and Wolffdene are based on 45, 51 and 50 years of data, respectively. As such, there is a high degree of uncertainty attached to the 1% AEP, and to a lesser extent the 2% AEP discharge estimates at these locations.
- The flood frequency distribution at Bromfleet is based on 100 years of data, and as such the 2% AEP discharge estimate can be considered acceptable, however the 1% AEP discharge estimate still contains a significant level of uncertainty.
- The FFA results for Wolffdene are not consistent with the FFA results at Bromfleet for events up to and including the 10% AEP (i.e. the Wolffdene discharges are lower than the Bromfleet discharges for events up to and including 10% AEP). This is likely due to the significantly shorter period of record at Wolffdene compared with Bromfleet.

Table 8.2 - Flood frequency analysis results, Teviot Brook at The Overflow (DNRM GS 145012a)

AEP (%)	Annual series			POT series		
	5% confidence limit	Expected quantile	95% confidence limit	5% confidence limit	Expected quantile	95% confidence limit
50	48	76	121	131	159	192
20	190	294	457	256	335	489
10	351	553	946	379	545	908
5	542	898	1,829	545	859	1,770
2	809	1,491	3,908	828	1,520	4,133
1	999	2,043	6,800	1,083	2,304	7,831

Table 8.3 - Flood frequency analysis results, Logan River at Yarrahappini (DNRM GS 145014a)

AEP (%)	Annual series			POT series		
	5% confidence limit	Expected quantile	95% confidence limit	5% confidence limit	Expected quantile	95% confidence limit
50	285	400	568	556	631	722
20	841	1,147	1,592	919	1,110	1,371
10	1,351	1,861	2,618	1,249	1,603	2,152
5	1,896	2,687	4,163	1,652	2,259	3,343
2	2,598	3,927	7,433	2,295	3,478	5,966
1	3,076	4,960	11,076	2,918	4,763	9,039

Table 8.4 - Flood frequency analysis results, Albert River at Bromfleet (DNRM GS 145102a)

AEP (%)	Annual series			POT series		
	5% confidence limit	Expected quantile	95% confidence limit	5% confidence limit	Expected quantile	95% confidence limit
50	231	289	363	365	406	453
20	600	732	894	638	746	893
10	900	1,094	1,342	903	1,113	1,453
5	1,199	1,464	1,860	1,237	1,617	2,289
2	1,550	1,951	2,703	1,799	2,587	4,088
1	1,782	2,309	3,452	2,377	3,647	6,286

Table 8.5 – Flood frequency analysis results, Albert River at Wolffdene (DNRM GS 145196a)

AEP (%)	Annual series			POT series		
	5% confidence limit	Expected quantile	95% confidence limit	5% confidence limit	Expected quantile	95% confidence limit
50	161	245	367	218	306	429
20	427	645	960	468	688	1,019
10	655	1,037	1,630	672	1,078	1,766
5	870	1,508	2,655	878	1,582	3,002
2	1,113	2,261	4,880	1,139	2,470	5,973
1	1,263	2,932	7,570	1,332	3,353	10,001

8.4 COMPARISON WITH THE PREVIOUS WRM (2014) STUDY

WRM previously undertook a FFA at The Overflow, Yarrahappini, Bromfleet and Wolffdene as part of the 2014 Logan and Albert Rivers Flood Study (WRM, 2014). Table 8.6 to Table 8.9 compare the estimates in the WRM (2014) study with the results of the current study. When comparing these results, the following should be noted:

- For events smaller than 10% AEP (10 years), the WRM (2014) FFA was undertaken for the 39% AEP (2 years) and 18% AEP (5 years) events, whereas the FFA for the current study was undertaken for the 50% AEP (1.44 years) and 20% AEP (4.48 years) events. These two frequent events are similar, but not identical between the two studies. Therefore these events have been included for comparison in Table 8.6 to Table 8.9.
- The FFAs at The Overflow from both studies are in reasonable agreement for all AEPs.
- The FFAs at Yarrahappini from both studies are in reasonable agreement for all AEPs. The FFA peak discharges in the current study are consistently slightly higher than the WRM (2014) study. This is likely due to the following reasons:
    - The FFA for the current study includes 10 additional years of data compared to the WRM (2014) study. This additional data represents the period after the construction of Wyaralong Dam (constructed in 2011), which includes two large events (January 2013 and March 2017) which were not included in the WRM (2014) FFA.
    - The adopted rating curve at Yarrahappini is different between the current study and the WRM (2014) study. The Yarrahappini rating curve adopted for the current study is likely to be more accurate than the WRM (2014) rating curve due to the higher resolution hydraulic model used to derive it (10 m grid versus 20 m grid).
- The FFAs at Bromfleet from both studies are in reasonable agreement for all AEPs. The slight difference in the FFA discharges from the two studies is likely due to the additional data included in the current study (six additional years) as well as an updated rating curve adopted at Bromfleet in current study. The Bromfleet rating curve adopted for the current study is likely to be more accurate due to the higher resolution hydraulic model used to derive it.
- The FFAs at Wolffdene from both studies are in reasonable agreement for most AEPs. The FFA peak discharges in the current study are generally higher than the WRM (2014) study. Again, the difference in the FFA discharges from the two studies is likely due to the additional data included in the current study (13 additional

years), as well as an updated rating curve adopted at Wolffdene in current study. The Bromfleet rating curve adopted for the current study is likely to be more accurate due to the higher resolution hydraulic model used to derive it.

Table 8.6 - Comparison of annual series flood frequency analysis, Teviot Brook at The Overflow (DNRM GS 145012a)

WRM (2014) study		Current study	
AEP (%)	Estimated peak discharge (m^3/s)	AEP (%)	Estimated peak discharge (m^3/s)
39	82	50	76
18	273	20	294
10	500	10	553
5	822	5	898
2	1,435	2	1,491
1	2,079	1	2,043

Table 8.7 - Comparison of annual series flood frequency analysis, Logan River at Yarrahappini (DNRM GS 145014a)

WRM (2014) study		Current study	
AEP (%)	Estimated peak discharge (m^3/s)	AEP (%)	Estimated peak discharge (m^3/s)
39	375	50	400
18	1,020	20	1,147
10	1,653	10	1,861
5	2,434	5	2,687
2	3,723	2	3,927
1	4,918	1	4,960

Table 8.8 - Comparison of annual series flood frequency analysis, Albert River at Bromfleet (DNRM GS 145102a)

WRM (2014) study		Current study	
AEP (%)	Estimated peak discharge (m^3/s)	AEP (%)	Estimated peak discharge (m^3/s)
39	294	50	289
18	681	20	732
10	1,009	10	1,094
5	1,374	5	1,464
2	1,921	2	1,951
1	2,384	1	2,309

Table 8.9 – Comparison of annual series flood frequency analysis, Albert River at Wolffdene (DNRM GS 145196a)

WRM (2014) study		Current study	
AEP (%)	Estimated peak discharge (m^3/s)	AEP (%)	Estimated peak discharge (m^3/s)
39	185	50	245
18	529	20	645
10	885	10	1,037
5	1,338	5	1,508
2	2,105	2	2,261
1	2,829	1	2,932

9 Estimation of design flood discharges

9.1 METHODOLOGY

This section describes the adopted methodology to estimate design discharges throughout the Logan and Albert rivers catchment. A summary of the adopted design hydrology methodology for this study is given in Table 9.1.

The calibrated XP-RAFTS model was used to estimate design flood discharges throughout the Logan and Albert rivers catchment in accordance with the AR&R 2019 guidelines. The XP-RAFTS model design event discharges were reconciled against FFA estimates at the four gauging stations described in Section 8.

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 PMPDF event.

Subcatchment parameters (fraction impervious and Manning's n) for the XP-RAFTS model for design events were derived based ultimate catchment conditions (based on landuses identified in the LCC, GCCC and SRRC planning schemes). The XP-RAFTS model for design events is referred to as the ultimate conditions XP-RAFTS model.

Table 9.1 – Summary of methodology for design event analysis

Design flood parameter	AEP (1 in X)	Source/method	Comment
Rainfall depth	≤ 100	AR&R 2019	Industry standard.
	> 100 to 2000	AR&R 2019	Industry standard.
	PMPDF	BoM GSDM	Industry standard approach for durations ≤ 6 hours.
		BoM GTSMR	Industry standard approach for durations > 6 hours.
Areal Reduction Factor (ARF)	≤ 2000	AR&R 2019	Industry standard.
	PMFDF	BoM GTSMR	Industry standard.
Temporal pattern	≤ 200	AR&R 2019	A point location at the centroid of the total Logan River catchment to produce 'point' temporal patterns for durations ≤ 12 hours. (Note that the entire Logan-Albert rivers catchment is within the East Coast North temporal pattern region) 'Areal' temporal patterns for the total Logan River catchment for durations ≥ 12 hours.
	PMPDF	BoM GSDM	Industry standard approach for durations ≤ 6 hours.
		BoM GTSMR	Industry standard approach for durations > 6 hours.
Spatial distribution	≤ 2000	Multiple locations	Intensity-Frequency-Duration (IFD) data obtained for multiple locations within the catchment, in order to account for variation in design rainfall throughout the catchment.
	PMPDF	BoM GTSMR	Adopt PMP spatial distribution for events greater than 2000 year ARI as recommended by AR&R 2019.
Rainfall losses	≤ 100	AR&R 2019	Adopted rainfall losses were determined by reconciliation with Flood Frequency Analysis (FFA) results, and then adjusted on a subcatchment basis based subcatchment imperviousness.
	> 100 to PMPDF	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 AR&R 2019 (Ball et al, 2019).

Rainfall intensity-frequency-duration (IFD) data was be obtained and applied in the model for multiple locations throughout the catchment, in order to account for variation in design rainfalls. The adopted 50% to 0.05% AEP design rainfall depths are shown in Appendix D.

9.2.2 PMPDF 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 longer than 6 hours were estimated using the standard methodology given in the Generalised Tropical Storm Method – Revised Edition – GTSMR (BoM, 2005), based on the on the total Logan River catchment to its outlet. The adopted PMP design rainfall depths are shown in Appendix D.

9.3 AREAL REDUCTION FACTOR

For the XP-RAFTS model reconciliation process with the FFA, areal reduction factors (ARFs) were calculated based on the catchment area at each stream gauge. For design event discharge estimation, ARFs were calculated based on the catchment area draining to the confluence between the Logan and Albert rivers. All ARFs were calculated in accordance with the AR&R 2019 guidelines and vary according to storm duration and AEP. Table 9.2 shows the adopted ARFs for the 1% AEP event only.

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 AR&R 2019 data hub for the 'East Coast North' region, which is appropriate for the entire Logan River catchment. For durations up to and inlcuidng 9 hours, 'point' temporal patterns were obtained based on a point location at the centroid of the total Logan River catchment. 'Areal' temporal patterns for the Logan River catchment to the Albert River confluence were adopted for durations equal to or longer than 12 hours.

The AR&R 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 XP-RAFTS 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 storms for each duration was selected for simulation using the 'detailed model'. This process is discussed in more detail in Section 10.2.

An ensemble analysis to select critical design storms was not undertaken using the XP-RAFTS model. Ensemble analysis on the XP-RAFTS model results was done only to determine the peak discharges at key locations and for the reconciliation process with Flood Frequency Analysis. The selection of representative design storms was undertaken spatially at all locations in the TUFLOW model domain using the "fast model" results.

Table 9.2 - Adopted areal reduction factors for the 1% AEP event for varying durations

Catchment	Area (km^2)	Adopted for design events (Y/N)	Areal reduction factor for the 1% AEP event, for various durations													
			3 hours	4.5 hours	6 hours	9 hours	12 hours	18 hours	24 hours	36 hours	48 hours	72 hours	96 hours	120 hours	144 hours	168 hours
Confluence of Logan and Albert Rivers	3,730	Y	0.467	0.548	0.636	0.716	0.740	0.791	0.842	0.864	0.878	0.895	0.906	0.913	0.919	0.923
Teviot Brook at The Overflow	501	N [a]	0.694	0.742	0.797	0.845	0.859	0.887	0.915	0.930	0.939	0.949	0.954	0.958	0.961	0.964
Logan River at Yarrahappini	2,414	N [a]	0.526	0.599	0.678	0.750	0.841	0.817	0.863	0.882	0.894	0.909	0.919	0.925	0.930	0.934
Albert River at Bromfleet	544	N [a]	0.687	0.736	0.791	0.841	0.855	0.884	0.914	0.928	0.937	0.947	0.953	0.957	0.960	0.962
Albert River at Wolffdene	720	N [a]	0.661	0.714	0.773	0.827	0.841	0.874	0.907	0.922	0.931	0.941	0.947	0.952	0.955	0.958

[a] - Used in FFA reconciliation

These selected representative design storms were then run using the detailed model. This selection process is described in Section 10.4.

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

Initially, temporal patterns for the 0.5% to 0.05% AEP events were obtained from the following sources as per the recommendation in AR&R 2019:

- Temporal patterns for durations up to and including 12 hours were obtained from the Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method (GSDM) (BoM, 2003); and
- Temporal patterns for durations longer than 12 hours were obtained for Coastal AVM storms from the Generalised Tropical Storm method – Revised Edition (GTSMR) (BoM, 2005).

Preliminary hydraulic model results 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 (AR&R 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 (AR&R 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 AR&R 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 AR&R 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 AR&R 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 PMPDF event

The temporal patterns for durations up to and including 12 hours were obtained from the Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method (GSDM) (BoM, 2003).

Temporal patterns for durations longer than 12 hours were obtained for Coastal AVM storms from the Generalised Tropical Storm method – Revised Edition (GTSMR) (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 38 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 38 locations are shown in Appendix D.

Table 9.3 compares 1% AEP areally reduced rainfall depths at eight representative locations (referred as Loc 1 to Loc 36) within the Logan and Albert Rivers catchment. These include Loc 1 and 4 (in the Teviot Brook catchment), Loc 7, 15 and 19 (in the upper Logan River catchment), Loc 22 and 27 (in the Albert River catchment) and Loc 36 in the lower reaches of the Logan River catchment. It shows that:

- 1% AEP design rainfall depths within the Albert River catchment are generally higher than those within the Logan River and Teviot Brook catchments;

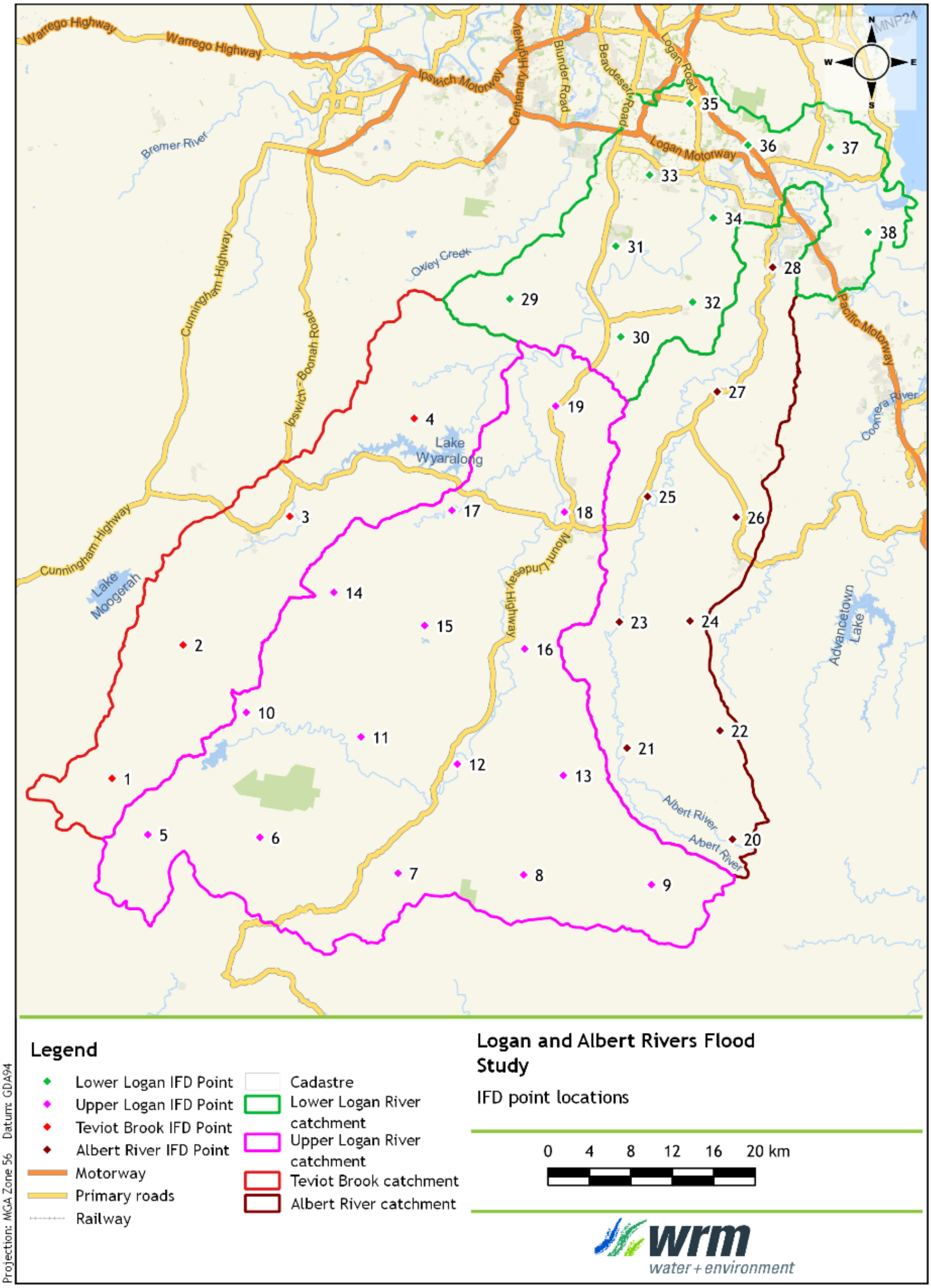

Figure 9.1 – Adopted representative IFD point locations for estimation of design rainfalls

- 1% AEP design rainfall depths are highest in the upper reaches of the Albert River catchment; and
- 1% AEP design rainfall depths within the middle and lower parts of the Logan River catchment are generally higher than those in the upper parts of the Logan River catchment.

Table 9.3 – Comparison of 1% AEP areally reduced rainfall depths at representative locations within the Logan and Albert Rivers catchment

Duration (hours)	1% AEP areally reduced design rainfall depths (mm)							
	Loc 1	Loc 4	Loc 7	Loc 15	Loc 19	Loc 22	Loc 27	Loc 36
6	93	96	93	90	100	140	114	126
12	139	145	141	133	154	229	178	195
24	211	222	209	197	238	358	274	298
48	291	308	277	264	330	483	375	415
72	341	362	317	304	387	553	433	489

9.5.2 PMPDF event

Spatial distribution of rainfall for storm durations between 1 hour and 6 hours is accounted for in the Generalised Tropical Storm method – Revised Edition (BoM, 2005) rainfall depth estimation methodology.

Spatial distribution of rainfall for storm durations longer than 6 hours is accounted for in the Generalised Tropical Storm method – Revised Edition (BoM, 2005) rainfall depth estimation methodology.

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. Four sets of ILs and CLs were derived for the following four distinct regions within the Logan River catchment:

- The Upper Logan River catchment;
- The Teviot Brook catchment;
- The Albert River catchment; and
- The Lower Logan River catchment.

ILs and CLs for the upper Logan River, Teviot Brook and Albert River regions were determined by adjusting the ILs and CLs until a good match is achieved between the XP-RAFTS design peak discharges and the FFA peak discharges estimated for the stream gauge in each region. The Upper Logan River design rainfall losses were adopted for the Lower Logan River model as there are no gauges suitable for FFA in the Lower Logan River catchment. The following is of note:

- ILs and CLs for each subcatchment were determined based on an adopted relationship with the percentage imperviousness of the model subcatchments.
- For subcatchments with fraction impervious of 0% to 30, the ILs and CLs determined from the XP-RAFTS – FFA reconciliation process were adopted.
- For subcatchments fraction imperviousness of more than 75%, minimum losses were be adopted (to be determined in the design event modelling stage).
- ILs for other subcatchments (with fraction imperviousness of between 30% and 75%) were interpolated based on the subcatchment fraction imperviousness.

Table 9.4 and Table 9.5 show the final (adopted) ILs and CLs respectively for each region for all AEPs up to and including the 1% AEP event. Table 9.4 and Table 9.5 also show the range of calibration losses adopted for each catchment.

Higher initial and continuing losses were adopted for the Albert River catchment compared to the Logan River and Teviot Brook catchments, particularly for subcatchments with fraction impervious of 0% to 30%. This was necessary to achieve XP-RAFTS model design discharges of the same order as those given by the FFA. This approach was also necessary to achieve a good calibration of the hydraulic model as described in Section 6, because of the higher proportion of forested areas within the upper Albert River catchment compared to the upper Logan River catchment.

Table 9.4 – Adopted initial loss values, 50% to 1% AEP events

Percentage Impervious (%)	Calibration initial loss range (mm)	Adopted initial loss (mm)					
		50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
Teviot Brook subcatchments							
0-30	25 - 140	40.0	30.0	20.0	0.0	0.0	0.0
30-40	20 - 100	36.0	27.0	18.0	0.0	0.0	0.0
40-50	15 - 80	27.0	20.0	14.0	0.0	0.0	0.0
50-60	10 - 50	19.0	14.0	9.0	0.0	0.0	0.0
60-75	5 - 30	8.0	6.0	4.0	0.0	0.0	0.0
75+	0 - 10	2.0	1.0	0.5	0.0	0.0	0.0
Logan River subcatchments							
0-30	25 - 140	30.0	30.0	20.0	15.0	10.0	0.0
30-40	20 - 100	27.0	27.0	18.0	13.0	9.0	0.0
40-50	15 - 80	20.0	20.0	14.0	10.0	7.0	0.0
50-60	10 - 50	14.0	14.0	9.0	7.0	5.0	0.0
60-75	5 - 30	6.0	6.0	4.0	3.0	2.0	0.0
75+	0 - 10	1.0	1.0	0.8	0.4	0.2	0.0
Albert River subcatchments							
0-30	45 - 175	60.0	60.0	50.0	50.0	30.0	20.0
30-40	20 - 100	54.0	54.0	45.0	45.0	27.0	18.0
40-50	15 - 80	42.0	42.0	35.0	34.0	21.0	14.0
50-60	10 - 50	29.0	29.0	24.0	24.0	14.0	9.0
60-75	5 - 30	14.0	14.0	12.0	11.0	7.0	4.0
75+	0 - 10	5.0	5.0	4.0	3.0	2.0	1.0

Table 9.5 – Adopted continuing loss values, 50% to 1% AEP events

Percentage Impervious (%)	Calibration continuing loss range (mm/h)	Adopted continuing loss (mm/h)					
		50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
Teviot Brook subcatchments							
0-30	2.0 - 2.4	3.0	2.5	2.0	1.0	0.5	0.5
30-40	1.5	1.5	2.3	1.8	0.9	0.5	0.5
40-50	1.3	1.3	1.8	1.4	0.7	0.4	0.4
50-60	1.0	1.0	1.3	1.1	0.6	0.3	0.3
60-75	0.8	0.8	0.8	0.6	0.3	0.2	0.2
75+	0.5	0.5	0.4	0.3	0.2	0.1	0.1
Logan River subcatchments							
0-30	2.0 - 2.4	2.8	2.8	2.5	1.9	1.0	0.2
30-40	1.5	1.5	1.5	1.3	1.0	0.5	0.2
40-50	1.3	1.3	1.3	1.2	0.9	0.5	0.2
50-60	1.0	1.0	1.0	0.9	0.7	0.4	0.1
60-75	0.8	0.8	0.8	0.7	0.5	0.3	0.1
75+	0.5	0.5	0.5	0.4	0.3	0.2	0.1
Albert River subcatchments							
0-30	2.2 - 3.5	3.0	3.0	3.0	2.5	2.5	2.0
30-40	1.5	1.5	1.5	1.5	1.3	1.3	1.0
40-50	1.3	1.3	1.3	1.3	1.1	1.1	0.9
50-60	1.0	1.0	1.0	1.0	0.8	0.8	0.7
60-75	0.8	0.8	0.8	0.8	0.7	0.7	0.5
75+	0.5	0.5	0.5	0.5	0.4	0.4	0.3

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. The CLs for these events were unchanged from the 50% to 1% AEP events.

9.6.3 PMPDF event

A 0.0 mm initial loss was adopted for the PMPDF event. The CLs for this event were unchanged from the 50% to 1% AEP events.

9.7 FUTURE CLIMATE SCENARIO (2090)

To obtain climate change scenario design flow hydrographs, design rainfall in the XP-RAFTS hydrologic model was increased by a factor of 1.095 (9.5% increase) in accordance with guidelines in Book 1 Chapter 6 of the 2016 ARR (Ball et al, 2019). The adopted multiplication factor is based on the RCP4.5 climate change projection, a planning horizon of year 2090 and a projected warming of 1.862 degrees Celsius.

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

9.8 RECONCILIATION WITH FLOOD FREQUENCY ANALYSIS RESULTS

Table 9.6 to Table 9.9 compare the XP-RAFTS model estimated peak design discharges at The Overflow, Yarrahappini, Bromfleet and Wolffdene with the peak discharge estimates obtained from the FFA described in Section 8 of this report. Both the annual series and peak-over-threshold (POT) series FFA results are shown in Table 9.6 to Table 9.9. Figure 9.2 to Figure 9.5 show the XP-RAFTS model peak design discharges plotted against the adopted flood frequency distribution curves and recorded peak series data at each location. The following is of note:

- For the purpose of reconciling XP-RAFTS design discharge estimates with the FFA, appropriate ARFs were adopted based on the catchment area of each gauging station selected for the FFA and reconciliation.
- Wyaralong Dam was removed from the XP-RAFTS model for the purpose of reconciling design discharge estimates at Yarrahappini with the FFA estimates.
- For events up to and including 10% AEP, design rainfall losses (described in Section 9.6) were derived by considering both the annual series and POT series results. For events rarer than 10% AEP, only the annual series FFA results were considered. This approach is consistent with guidelines in Book 3 – Chapter 2.2.2.3 of AR&R, which recommend using the POT series approach for more frequent events up to 10% AEP, and the using the annual series for events rarer than 10% AEP.
- For Teviot Brook at The Overflow:
    - The design peak discharges estimated by the XP-RAFTS model correspond well to the flood frequency discharge estimates from the 50% AEP up to the 5% AEP event.
    - For AEPs rarer than 5% AEP, the XP-RAFTS model discharge estimates are lower than those predicted by the FFA. However, the FFA estimates for AEPs in this range have reasonably high degree of uncertainty due to the relatively short peak annual data series (45 years), and the XP-RAFTS discharge estimates are well within the flood frequency confidence limits.
    - Note that the adopted losses for the Teviot Brook catchment were already minimised (zero IL for events rarer than 10% AEP). However, this was not enough to match the FFA discharge estimates for large events.
- For the Logan River at Yarrahappini, the design peak discharges estimated by the XP-RAFTS model correspond well to the flood frequency discharge estimates for all AEPs up to the 1% AEP flood.
- For the Albert River at Bromfleet:
    - The design peak discharges estimated by the XP-RAFTS model correspond very well to the flood frequency discharge estimates for all AEPs up to the 1% AEP flood.
    - This is of some significance as Bromfleet has the longest annual series (100 years of data), meaning that discharge estimates for events up to and including 2% AEP are reasonably certain.
- For the Albert River at Wolffdene:
    - The design peak discharges estimated by the XP-RAFTS model correspond well to the flood frequency discharge estimates from the 50% AEP up to the 5% AEP event.
    - For AEPs rarer than 5% AEP, the XP-RAFTS model discharge estimates are lower than those predicted by the FFA. However, the FFA estimates for AEPs in this range have reasonably high degree of uncertainty due to the

relatively short peak annual data series (50 years), and the XP-RAFTS discharge estimates are well within the flood frequency confidence limits.

  - The XP-RAFTS model design peak discharges at Wolffdene were produced using the same design rainfall losses (refer to Section 9.6) derived from reconciliation of the model at the Bromfleet gauge (which has 100 years of data). Given the high degree of certainty in the FFA results at Bromfleet, the XP-RAFTS model is considered to produce reasonably accurate discharges at Wolffdene using the same design losses derived for Bromfleet.

- The adopted design losses (shown in Section 9.6) decrease with decreasing AEP (increasing event magnitude):
  - This approach is considered reasonable because for larger events, the main storm burst is likely to occur after a period of rainfall that would saturate the catchment prior to the arrival of the burst.
  - At the four gauges assessed, it was not possible for the XP-RAFTS model to match the 50% AEP discharges estimates from the POT series FFA without adopting lower losses than the 20% AEP event. However, the XP-RAFTS model 50% AEP peak discharges at these four gauges are between the annual series and POT series FFA discharge estimates and are therefore within the expected range of design discharges for this event.

Table 9.6 - Comparison of XP-RAFTS model and Flood Frequency Analysis estimated peak design discharges, Teviot Brook at The Overflow

AEP (%)	Estimated peak discharge (m^3/s)		
	XP-RAFTS model [a]	FFA (annual series)	FFA (POT series)
50	104	76	159
20	355	294	335
10	570	553	545
5	854	898	859
2	1,130	1,491	1,520
1	1,522	2,043	2,304

[a] - Peak design discharges reported are based on the application of an ARF for the catchment area upstream of The Overflow gauging station.

Table 9.7 – Comparison of XP-RAFTS model and Flood Frequency Analysis estimated peak design discharges, Logan River at Yarrahappini

AEP (%)	Estimated peak discharge (m^3/s)		
	XP-RAFTS model [a]	FFA (annual series)	FFA (POT series)
50	493	400	631
20	1,166	1,147	1,110
10	1,857	1,861	1,603
5	2,701	2,687	2,259
2	3,942	3,927	3,478
1	4,985	4,960	4,763

[a] – Peak design discharges reported are based on the application of an ARF for the catchment area upstream of the Yarrahappini gauging station.

Table 9.8 – Comparison of XP-RAFTS model and Flood Frequency Analysis estimated peak design discharges, Albert River at Bromfleet

AEP (%)	Estimated peak discharge (m^3/s)		
	XP-RAFTS model [a]	FFA (annual series)	FFA (POT series)
50	307	289	406
20	749	732	746
10	1,100	1,094	1,113
5	1,496	1,464	1,617
2	1,927	1,951	2,587
1	2,328	2,309	3,647

[a] – Peak design discharges reported are based on the application of an ARF for the catchment area upstream of the Bromfleet gauging station.

Table 9.9 – Comparison of XP-RAFTS model and Flood Frequency Analysis estimated peak design discharges, Albert River at Wolffdene

AEP (%)	Estimated peak discharge (m^3/s)		
	XP-RAFTS model [a]	FFA (annual series)	FFA (POT series)
50	261	245	306
20	689	645	688
10	1,061	1,037	1,078
5	1,491	1,508	1,582
2	1,975	2,261	2,470
1	2,419	2,932	3,353

[a] – Peak design discharges reported are based on the application of an ARF for the catchment area upstream of the Wolffdene gauging station.

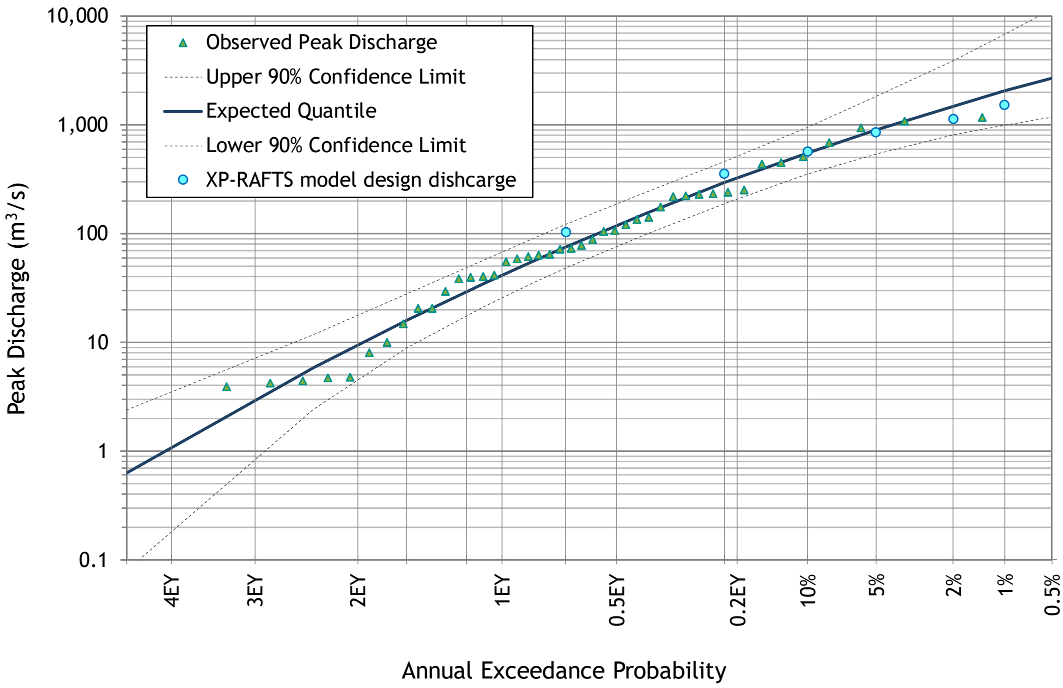

Figure 9.2 - Comparison of XP-RAFTS model design discharges and annual series flood frequency distribution, Teviot Brook at The Overflow

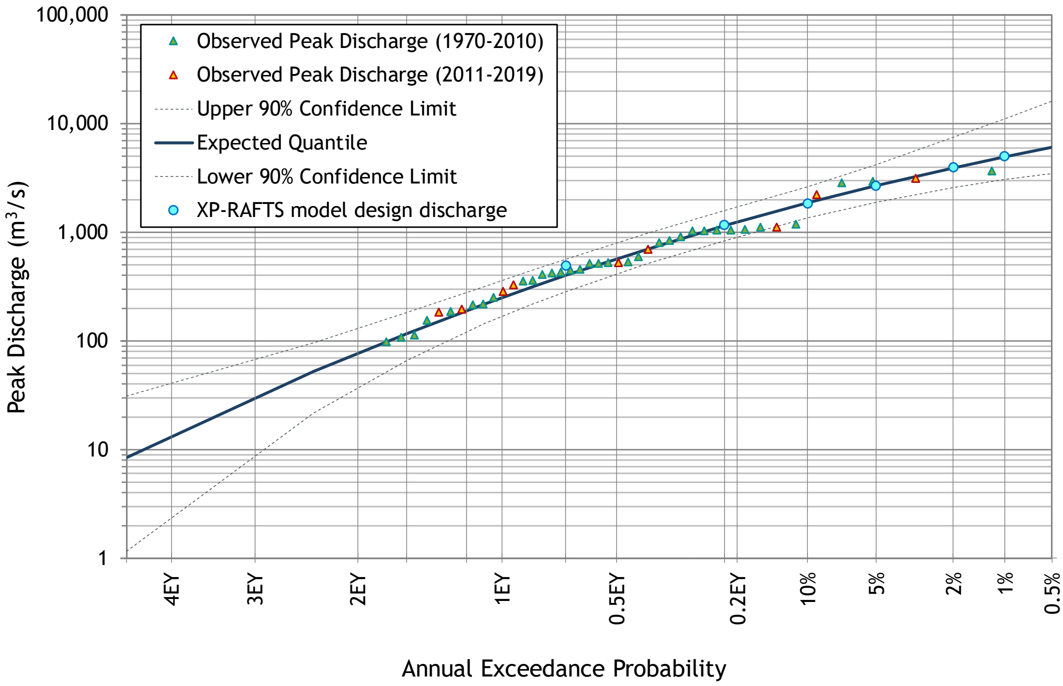

Figure 9.3 - Comparison of XP-RAFTS model design discharges and annual series flood frequency distribution, Logan River at Yarrahappini

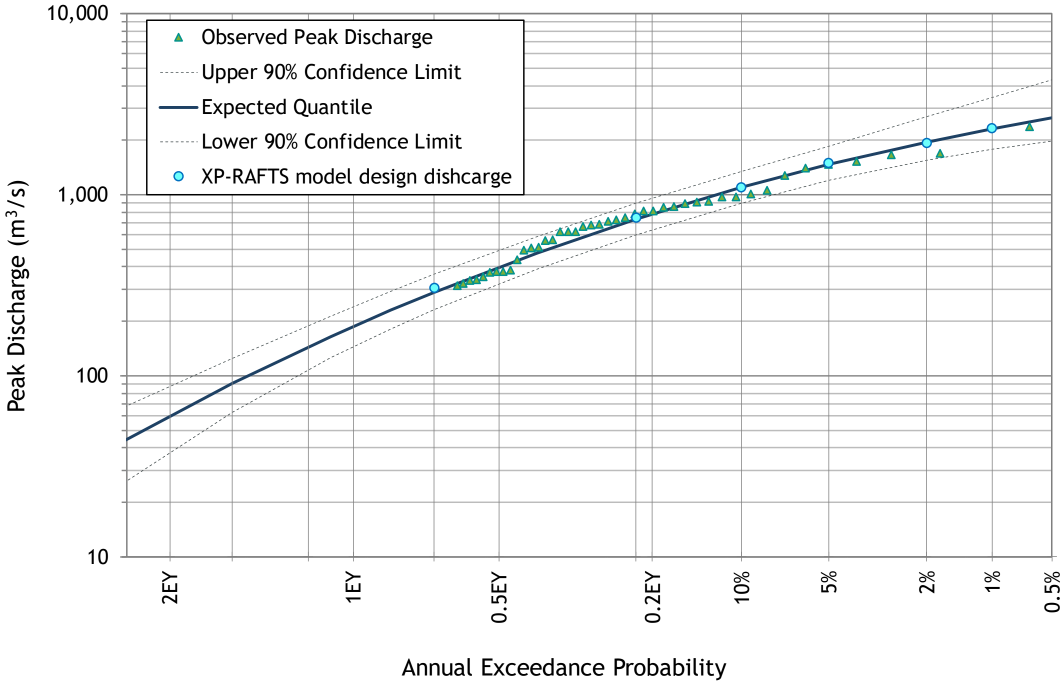

Figure 9.4 - Comparison of XP-RAFTS model design discharges and annual series flood frequency distribution, Albert River at Bromfleet

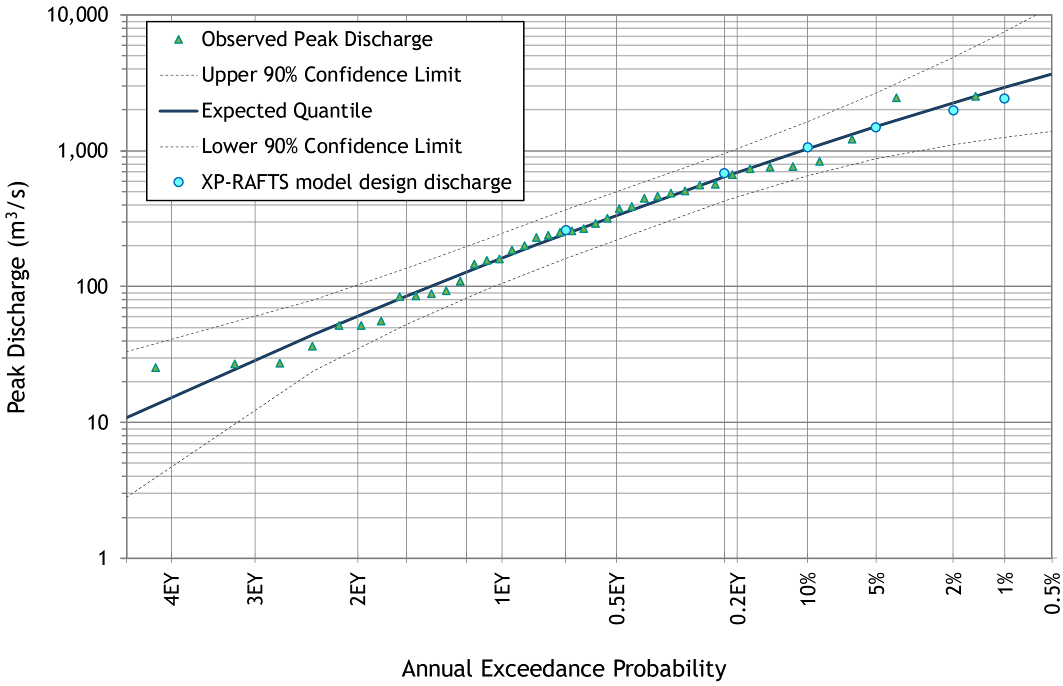

Figure 9.5 - Comparison of XP-RAFTS model design discharges and annual series flood frequency distribution, Albert River at Wolffdene

9.9 DESIGN DISCHARGES – CURRENT CLIMATE (2020)

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

Table 9.10 and Table 9.11 show the XP-RAFTS model predicted 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 XP-RAFTS model are as follows:
    - Peak discharges at the Overflow range from 58 m^3/s for the 50% AEP event to 1,151 m^3/s for the 1% AEP event;
    - Peak discharges at Yarrahappini range from 401 m^3/s for the 50% AEP event to 4,966 m^3/s for the 1% AEP event;
    - Peak discharges at Bromfleet range from 216 m^3/s for the 50% AEP event to 1,927 m^3/s for the 1% AEP event;
    - Peak discharges at Wolffdene range from 213 m^3/s for the 50% AEP event to 2,158 m^3/s for the 1% AEP event;
    - Peak discharges at Maclean Bridge range from 393 m^3/s for the 50% AEP event to 4,941 m^3/s for the 1% AEP event;
    - Peak discharges at Waterford range from 379 m^3/s for the 50% AEP event to 4,878 m^3/s for the 1% AEP event; and
    - Peak discharges at the Logan River mouth range from 384 m^3/s for the 50% AEP event to 5,384 m^3/s for the 1% AEP event; and
- The XP-RAFTS model critical durations for key locations throughout the catchment are as follows:
    - The Overflow: 120 hours for the 50% AEP event, 24 hours for all other AEPs;
    - Yarrahappini: 24 hours for the 50% to 10% AEP events, 36 hours for the 5% to 1% AEP events;
    - Bromfleet: 120 hours for the 50% AEP event, 36 hours for the 20% and 10% AEP events, 18 hours for the 5% to 1% AEP events;
    - Wolffdene: 120 hours for the 50% AEP event, 36 hours for all other events;
    - Maclean Bridge: 24 hours for the 50% to 10% AEP events, 36 hours for the 5% to 1% AEP events;
    - Waterford: 24 hours for the 50% to 10% AEP events, 36 hours for the 5% to 1% AEP events;
    - Logan River mouth: 24 hours for the 50% and 10% AEP events, 36 hours for the 20% AEP events, 72 hours for the 5% to 1% AEP events.

Table 9.10 – Logan River XP-RAFTS model predicted design discharges at key locations, 50% (1 in 2) AEP to 1% (1 in 100) AEP events

Location	Stream Name	Peak XP-RAFTS Model Design Discharge (m^3/s)					
		50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
The Overflow	Teviot Brook	58	255	461	743	1,000	1,151
Yarrahappini	Logan River	401	1,082	1,794	2,740	3,985	4,966
Maclean Bridge	Logan River	393	1,064	1,771	2,719	3,961	4,941
Waterford	Logan River	379	1,035	1,730	2,676	3,908	4,878
Bromfleet	Albert River	216	559	846	1,188	1,579	1,927
Wolffdene	Albert River	213	584	928	1,336	1,751	2,158
Confluence of Logan and Albert rivers	Logan River	376	1,019	1,709	2,713	4,099	5,319
Logan River Mouth	Logan River	384	1,010	1,696	2,723	4,129	5,384

Table 9.11 – Logan River XP-RAFTS model predicted critical storm durations at key locations, 50% (1 in 2) AEP to 1% (1 in 100) AEP events

Location	Stream Name	Peak XP-RAFTS Critical Storm Durations (hours)					
		50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
The Overflow	Teviot Brook	120	24	24	24	24	24
Yarrahappini	Logan River	24	24	24	36	36	36
Maclean Bridge	Logan River	24	24	24	36	36	36
Waterford	Logan River	24	24	24	36	36	36
Bromfleet	Albert River	120	36	36	18	18	18
Wolffdene	Albert River	120	36	36	36	36	36
Confluence of Logan and Albert rivers	Logan River	24	24	24	72	72	72
Logan River Mouth	Logan River	24	36	24	72	72	72

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 XP-RAFTS model predicted peak discharges and critical durations for the 0.5% (1 in 200), 0.2% (1 in 500) and 0.05% (1 in 2,000) AEP events. The following is of note:

- The peak design discharges estimated by the XP-RAFTS model are as follows:
  - Peak discharges at the Overflow range from 1,320 m^3/s for the 0.5% AEP event to 1,945 m^3/s for the 0.05% AEP event;
  - Peak discharges at the Yarrahappini range from 5,438 m^3/s for the 0.5% AEP event to 7,722 m^3/s for the 0.05% AEP event;
  - Peak discharges at the Bromfleet range from 2,146 m^3/s for the 0.5% AEP event to 3,005 m^3/s for the 0.05% AEP event;
  - Peak discharges at the Wolffdene range from 2,446 m^3/s for the 0.5% AEP event to 3,553 m^3/s for the 0.05% AEP event;

    - Peak discharges at Maclean Bridge range from 5,403 m^3/s for the 0.5% AEP event to 7,675 m^3/s for the 0.05% AEP event;
    - Peak discharges at Waterford range from 5,335 m^3/s for the 0.5% AEP event to 7,580 m^3/s for the 0.05% AEP event; and
    - Peak discharges at the Logan River mouth range from 6,552 m^3/s for the 0.5% AEP event to 9,553 m^3/s for the 0.05% AEP event.
- The XP-RAFTS model critical durations for key locations throughout the catchment are as follows:
    - The Overflow: 48 hours for the 0.5% to 0.05% AEP events;
    - Yarrahappini: 36 hours for the 0.5% to 0.05% AEP events;
    - Bromfleet: 24 hours for the 0.5% to 0.05% AEP events;
    - Wolffdene: 48 hours for the 0.5% to 0.05% AEP events;
    - Maclean Bridge: 36 hours for the 0.5% to 0.05% AEP events;
    - Waterford: 36 hours for the 0.5% to 0.05% AEP events; and
    - Logan River mouth: 96 hours for the 0.5% to 0.05% AEP events.

9.9.3 PMPDF event

Table 9.12 and Table 9.13 show the XP-RAFTS model predicted peak discharges and critical durations for the PMPDF event. The following is of note:

- The PMPDF peak discharge at The Overflow is 5,412 m^3/s and the critical duration is 24 hours;
- The PMPDF peak discharge at Yarrahappini is 5,412 m^3/s and the critical duration is 24 hours;
- The PMPDF peak discharge at Bromfleet is 6,711 m^3/s and the critical duration is 18 hours;
- The PMPDF peak discharge at Wolffdene is 7,513 m^3/s and the critical duration is 24 hours;
- The PMPDF peak discharge at Maclean Bridge is 18,820 m^3/s and the critical duration is 36 hours;
- The PMPDF peak discharge at Waterford is 18,587 m^3/s and the critical duration is 36 hours; and
- The PMPDF peak discharge at the Logan River mouth is 21,436 m^3/s and the critical duration is 72 hours.

Table 9.12 – Logan River XP-RAFTS model predicted design discharges at key locations, 0.5% (1 in 200) AEP to 0.05% (1 in 2,000) AEP and the PMPDF event

Location	Stream Name	Peak XP-RAFTS model design discharge (m³/s)			
		0.5% AEP	0.2% AEP	0.05% AEP	PMPDF
The Overflow	Teviot Brook	1,320	1,554	1,945	5,412
Yarrahappini	Logan River	5,438	6,315	7,722	18,989
Maclean Bridge	Logan River	5,403	6,274	7,675	18,820
Waterford	Logan River	5,335	6,194	7,580	18,587
Bromfleet	Albert River	2,146	2,481	3,005	6,711
Wolffdene	Albert River	2,446	2,872	3,553	7,513
Confluence of Logan and Albert rivers	Logan River	6,365	7,461	9,263	21,340
Logan River Mouth	Logan River	6,552	7,686	9,553	21,436

Table 9.13 – Logan River XP-RAFTS model predicted critical storm durations at key locations, 0.5% (1 in 200) AEP to 0.05% (1 in 2,000) AEP and the PMPDF event

Location	Stream Name	Peak XP-RAFTS Critical Storm Durations (hours)			
		0.5% AEP	0.2% AEP	0.05% AEP	PMPDF
The Overflow	Teviot Brook	48	48	48	24
Yarrahappini	Logan River	36	36	36	24
Maclean Bridge	Logan River	36	36	36	36
Waterford	Logan River	36	36	36	36
Bromfleet	Albert River	24	24	24	18
Wolffdene	Albert River	48	48	48	24
Confluence of Logan and Albert rivers	Logan River	96	96	96	72
Logan River Mouth	Logan River	96	96	96	72

9.10 DESIGN DISCHARGES - FUTURE CLIMATE (2090)

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

Table 9.14 and Table 9.15 show the XP-RAFTS 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 XP-RAFTS model are as follows:
  - Peak discharges at the Overflow range from 314 m³/s for the 20% AEP event to 1,275 m³/s for the 1% AEP event;
  - Peak discharges at Yarrahappini range from 1,327 m³/s for the 20% AEP event to 5,488 m³/s for the 1% AEP event;
  - Peak discharges at Bromfleet range from 689 m³/s for the 20% AEP event to 2,201 m³/s for the 1% AEP event;
  - Peak discharges at Wolffdene range from 726 m³/s for the 20% AEP event to 2,434 m³/s for the 1% AEP event;

- Peak discharges at Maclean Bridge range from 1,306 m^3/s for the 20% AEP event to 5,518 m^3/s for the 1% AEP event;
- Peak discharges at Waterford range from 1,265 m^3/s for the 20% AEP event to 5,431 m^3/s for the 1% AEP event; and
- Peak discharges at the Logan River mouth range from 384 m^3/s for the 50% AEP event to 5,384 m^3/s for the 1% AEP event; and

- The XP-RAFTS model critical durations for key locations throughout the catchment are generally unchanged from the current climate XP-RAFTS model results, with the exception of at Bromfleet, where future climate critical durations have changed, likely due to the interaction between the flood waves in Canungra Creek and the Albert River, which join immediately upstream of the gauge,

Table 9.14 - Logan River XP-RAFTS model predicted future climate design discharges at key locations, 20% (1 in 5) AEP to 1% (1 in 100) AEP events

Location	Stream Name	Peak XP-RAFTS Model Design Discharge (m^3/s)				
		20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
The Overflow	Teviot Brook	314	534	829	1,107	1,275
Yarrahappini	Logan River	1,327	2,081	3,113	4,494	5,488
Maclean Bridge	Logan River	1,306	2,053	3,079	4,426	5,518
Waterford	Logan River	1,265	2,006	3,153	4,340	5,431
Bromfleet	Albert River	689	1,020	1,402	1,794	2,187
Wolffdene	Albert River	726	1,121	1,563	2,036	2,434
Confluence of Logan and Albert rivers	Logan River	1,248	2,051	3,161	4,597	5,941
Logan River Mouth	Logan River	1,233	1,995	3,168	4,617	5,940

Table 9.15 - Logan River XP-RAFTS model predicted future climate critical storm durations at key locations, 20% (1 in 5) AEP to 1% (1 in 100) AEP events

Location	Stream Name	Peak XP-RAFTS Critical Storm Durations (hours)				
		20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
The Overflow	Teviot Brook	24	24	24	24	24
Yarrahappini	Logan River	24	24	36	36	36
Maclean Bridge	Logan River	24	24	36	36	36
Waterford	Logan River	24	24	36	36	36
Bromfleet	Albert River	24	24	24	24	18
Wolffdene	Albert River	36	36	36	24	36
Confluence of Logan and Albert rivers	Logan River	24	36	72	72	72
Logan River Mouth	Logan River	24	48	72	72	72

9.10.2 0.5% (1 in 200) AEP and 0.2% (1 in 500) AEP design events

Table 9.16 shows the XP-RAFTS 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 9.16 - Logan River XP-RAFTS model 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	Stream Name	Design discharge (m^3/s)		Critical Duration (hours)	
		0.5% AEP	0.2% AEP	0.5% AEP	0.2% AEP
The Overflow	Teviot Brook	1,485	1,746	36	36
Yarrahappini	Logan River	6,161	7,145	36	36
Maclean Bridge	Logan River	6,203	7,193	36	36
Waterford	Logan River	6,089	7,040	48	48
Bromfleet	Albert River	2,381	2,747	24	24
Wolffdene	Albert River	2,744	3,201	36	36
Confluence of Logan and Albert rivers	Logan River	6,780	7,892	72	72
Logan River Mouth	Logan River	6,758	7,988	72	72

9.11 IMPACT OF WYARALONG DAM ON DESIGN DISCHARGES

Wyaralong Dam was constructed in 2011 and is an un-gated dam. The impact Wyaralong Dam on design discharges was assessed in the WRM (2014) study.

The LCC (2014) XP-RAFTS model indicates that Wyaralong Dam has reduced peak design discharges at all locations downstream of the dam in the Logan River and Teviot Brook for all design events up to and including the 1% AEP event. However, the reduction in peak design discharges due to the dam is not particularly significant, with the peak 39% AEP design discharges being reduced by up to 12% at all locations upstream of the Logan River mouth. The peak 1% AEP design discharges are reduced by up to 5% at all locations upstream of the Logan River mouth.

Wyaralong Dam does not impact on design discharges in Teviot Brook upstream of the dam location, or on design discharges in the Albert River.

The impact of Wyaralong Dam on design discharges based on the updated XP-RAFTS model is not expected to change significantly from those observed in the WRM (2014) study.

10 Design event hydraulic modelling

10.1 OVERVIEW

The calibrated TUFLOW model was used to estimate flood levels, depths, velocities and flood hazard in the Logan and Albert rivers and floodplains 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 PMPDF event, for a range of storm durations up to 168 hours. Future climate flood events were simulated

Sensitivity testing was also be undertaken for the 1% (1 in 100) AEP event to assess the impact of removing culvert blockages and the impact higher tailwater levels.

This section describes the methodology adopted to produce the desired outputs from the hydraulic model throughout the Logan and Albert rivers catchment.

10.2 DESIGN MODELLING APPROACH

10.2.1 Adopted approach

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

- **'Fast Model'** – This model was configured with a grid cell size of 20 m. The purpose of this model is to allow the selection of critical AR&R 2019 design storms, which was then simulated using a finer 'detailed model'.
- **'Detailed Model' –** This model was configured with a grid cell size of 10 m. The purpose of this model is to run 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 XP-RAFTS model. The TUFLOW asc_to_asc utility was used to extract the median depths, water levels, velocities and flood hazards for each cell in the model for each design event and storm duration. A max-max selection of the median 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 above is a slight variation on the AR&R 2019 guidelines, which refer to mapping the mean water surfaces. However, there is a known issue with calculating mean grids using the TUFLOW asc_to_asc utility:

- 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; and
- The TUFLOW asc_to_asc utility only returns a mean value when all 10 of the input grids have a numeric value at a cell.

The above issue means that the mean result grids, and the resulting max-max 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 the critical duration. In fact, this methodology will present a 'minimum' extent of flooding, as it effectively discards results for cells that are not wet by all 10 ensemble temporal patterns.

The TUFLOW asc_to_asc utility produced the following outputs from the 20 m grid 'Fast Model' results:

- A median water surface grid;

- A source grid identifying which design storm was adopted at each location; and
- A spreadsheet listing the design storms that were used to produce the median water surface grid.

The median 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. These representative design storms would be considered as the 'representative design storms'.

The calibrated 'Detailed Model' (with a 10 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.

10.2.2 Simulation of all design storms for the 1% AEP event

In this study, the 'Detailed Model' was also run for all 10 ensemble temporal patterns for each storm duration for the 1% AEP event (current climate only). This will allow LCC to undertake a more detailed assessment of design peak flood levels at specific locations within the model.

For the purpose of this study, the max-max water surface grids adopted for mapping for the 1% AEP event were derived from the 'representative design storms' only in accordance with the methodology outlined in Section 10.2.2. However, the 'Detailed Model' results for all 10 ensemble temporal patterns for each storm duration for the 1% AEP event were used to generate box and whisker plots (box plots) of 1% AEP design peak flood levels at key gauge locations as described in Section 10.6.2 of this report.

10.3 HYDRAULIC MODEL CONFIGURATION

10.3.1 Topography

The model topography adopted for the 2017 calibration and 2022 validation 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 Luscombe Weir on the Albert River is a City of Gold Coast asset and is scheduled to be removed in 2022/23. At the direction of LCC, this structure was removed from the bathymetry survey for the model.

10.3.2 Hydraulic structures

All of the culverts and bridges included in the calibration event TUFLOW model for the recent 2017 calibration event were also included in the TUFLOW model for design events. However, the TUFLOW model for design events includes the following additional bridges:

- Edward O'Neil Bridge Replacement (Kilmoylar Road, Jimboomba);
- Miller Road Bridge replacement;
- Chardon Bridge Replacement; and
- Kingston Road Pedestrian Bridge (Scrubby Creek).

Blockage of hydraulic structures (culverts and bridges) for design events was determined based on guidelines in Book 6 – Chapter 6 of AR&R 2019 (Ball et al, 2019). The following is of note with regards to the proposed design blockage factors:

- 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 within the model extent was determined as "Medium", based on assessment of the following:

- An "L_{10}" value of 10 m was adopted. This was estimated as 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 "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.
- 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 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.

Based on the "Medium" debris potential classification, the blockages in Table 10.1 were adopted for culverts for design event modelling. The Blockage Category was applied based on the location within the model domain and width of the culvert. Blockage Category A was applied to all culverts as part of a sensitivity test was performed to determine the impact of blockage on the 1% AEP simulations.

Table 10.1 - Design event culvert blockage

Event	Blockage Category A	Blockage Category B	Blockage Category C
20% AEP inclusive	0%	10%	10%
10% AEP	0%	10%	10%
5% AEP	0%	10%	20%
2% AEP	0%	20%	50%
1% AEP	0%	50%	70%
0.5% (1in 200) AEP	0%	50%	70%
0.2% (1in 500) AEP	0%	50%	100%
1 in 2000 AEP	0%	70%	100%

Blockage Category A: W > 3*L_{10}
Blockage Category B: L10 ≤ W ≤ 3*L_{10}
Blockage Category C: Control Dimension Inlet Clear Width (W) < L_{10}

- For bridges:
    - A blockage factor of 50% was adopted to represent pier blockage for bridges with under croft clearance widths of less than 10 m (<L_{10}). About 40% of bridges in the model fall within this category.
    - A pier blockage factor of 10% was adopted to represent pier blockage for bridges with under croft clearance widths of between 10 m and 30 m (L_{10} to 3 x L_{10}). About 60% of bridges in the model fall within this category.
    - A blockage factor of 100% was adopted for guard rails and hand rails.

10.3.3 Hydraulic roughness

Based on the LCC, GCCC and SCRC planning schemes, some undeveloped areas within the Logan and Albert rivers catchment are zoned for future development. Although these areas may undergo significant urbanisation, it is assumed that the waterway channels in these areas will be maintained close to existing conditions. Therefore, the hydraulic roughness mapping adopted for the 2017 calibration event were also adopted for the design events without changes.

A sensitivity test was undertaken to assess the potential impact of waterway restoration with LCC, with a Manning's 'n' value of 0.15 applied to waterway corridors throughout the LCC LGA.

10.3.4 Inflow boundaries

The locations of 2D (SA) inflow boundaries in the hydraulic model were unchanged from the calibration event TUFLOW model. Local inflow hydrographs generated from the XP-RAFTS model for ultimate catchment conditions were adopted as inflows 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.

10.3.5 Outflow boundaries

Design event tailwater method and peak level varied based on the AEP being modelled. Table 10.2 and Table 10.3 shows the adopted tailwater levels for all design events. Table 10.2 also shows the adopted tailwater levels for two sensitivity analysis scenarios. These two sensitivity scenarios are described in detail in Section 10.8.

The mean high water springs (MHWS) tide level was obtained from Department of Transport and Road (TMR) Queensland Tide Tables (TMR, 2020), and was adjusted by 0.8m to account for sea level rise in the 2090 future climate scenario.

The current climate and future climate 5% AEP storm surge levels for Rocky Point (in the marine channel at the mouth of the Logan River) reported in the Gold Coast City Council Storm Tide Study Final Report Addendum (GHD, 2013) were adopted for the study, and applied as the peak level for the storm surge tidal sequence applied at the downstream boundary of the model. This is consistent with the approach adopted for recent City of Gold Coast modelling of the Logan River and Woongoolba floodplain.

Adopted levels and boundary conditions for each design event are set out below.

10.3.6 Events up to and including 5% AEP

A fixed MHWS boundary condition was adopted for these events. A MHWS level of 0.99 mAHD was adopted for the current climate condition. A MHWS level of 1.79 mAHD was adopted for the 2090 climate change scenario.

10.3.7 2% AEP to 1 in 2,000 AEP events

A time varying 5% AEP storm surge tidal boundary was adopted for these events, with the peak of the storm surge adjusted so that it coincides with peak of the flood wave at Reidel Road.

The peak 5% AEP storm surge level adopted for the current climate is 1.88 mAHD. The peak for the 2090 climate change scenario is 2.76 mAHD.

10.3.8 PMPDF design event

A time varying 1% AEP storm surge tidal boundary was adopted for these events, with the peak of the storm surge adjusted so that it coincides with peak of the flood wave at Reidel Road.

The peak 1% AEP storm surge level adopted for the current climate is 2.07 mAHD.

10.3.9 Sensitivity 5% AEP flood with 1% AEP storm surge

To investigate the joint probability zone of storm surge on flood behaviour, a 5% AEP flood was simulated with 1% AEP time varying storm surge tidal boundary. The same process was adopted for timing the peak of the 1% AEP storm surge as outlined in Section 10.3.7 above.

Figure 10.1 provides a simple representation of this joint probability zone and the uncertainty about whether it is influenced by tidal boundary or storm selection.

The peak 1% AEP storm surge level adopted for the current climate is 2.07 mAHD.

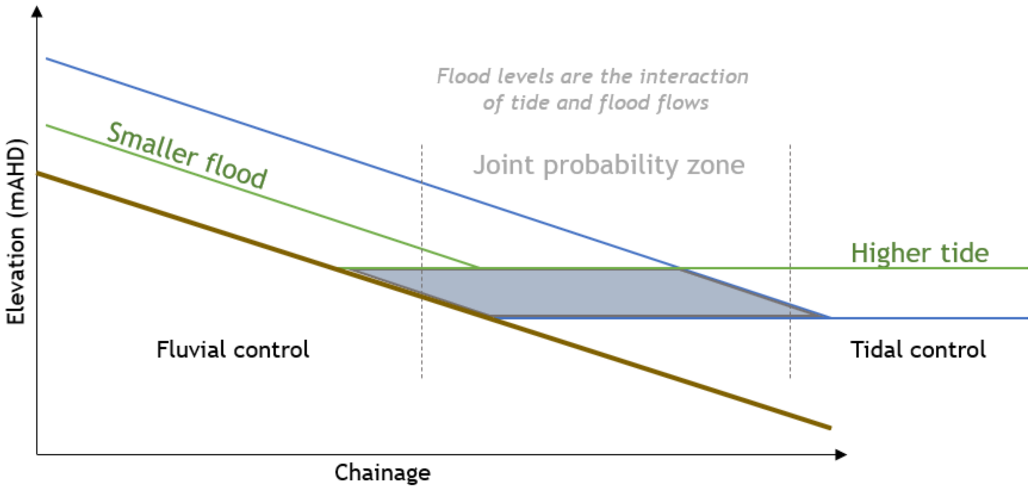

Figure 10.1 – Joint probability zone at tidal margin

Table 10.2 – Adopted tailwater conditions for current climate (2020) design events

Design event	Adopted tailwater level (mAHD)	Time varying and peaks with flood?	Tailwater conditions
Base case scenarios			
50% AEP	0.99	No	MHWS - static
20% AEP	0.99	No	MHWS - static
10% AEP	0.99	No	MHWS - static
5% AEP	0.99	No	MHWS - static
2% AEP	1.88	Yes	5% Storm surge
1% AEP	1.88	Yes	5% Storm surge
0.5% AEP	1.88	Yes	5% Storm surge
0.2% AEP	1.88	Yes	5% Storm surge
0.05% AEP	1.88	Yes	5% Storm surge
PMPDF	2.07	Yes	1% Storm surge
Sensitivity scenarios			
5% AEP + 1% Storm Surge	2.07	Yes	1% Storm surge
1% AEP + No Blockage	1.88	Yes	5% Storm surge

Table 10.3 – Adopted tailwater conditions for future climate (2090) design events

Design event	Adopted tailwater level (mAHD)	Time varying and peaks with flood?	Tailwater conditions
Base case scenarios			
20% AEP	1.79	No	MHWS
10% AEP	1.79	No	MHWS
5% AEP	1.79	No	MHWS
2% AEP	2.76	Yes	5% Storm surge
1% AEP	2.76	Yes	5% Storm surge
0.5% AEP	2.76	Yes	5% Storm surge
0.2% AEP	2.76	Yes	5% Storm surge

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 median water surface grids for produced by the 20 m grid 'Fast Model' and the corresponding source grids were analysed for each duration to determine one dominant design storm for that 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 median 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 median water surface grids from all durations in each event from the 'fast model' results.
- Figure 10.2 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 10.3 shows the distribution of median design storms throughout the hydraulic model extent for the 1% AEP event 48-hour duration from the 'fast model' results:
    - Figure 10.3 shows that at areas where the 48-hour storm is expected to be critical (the middle and lower reaches of the Albert River), design storm #10 is the median design storm.
    - Design storm #10 was therefore selected as the representative design storm for the 1% AEP event 48-hour duration and was then included in the design event simulations using the 'detailed model'.

Table 10.4 shows 'representative design storms' selected using the procedure outlined above. Only these representative design storms were simulated using the 10 m grid 'detailed model' for Current Climate (2020) scenario. The representative design storms selected for the 1% AEP were also simulated for the 0.5% to 0.05% AEP events, with the reasoning for this provided in Section 9.4.2.

Table 10.4 – Representative design storms Current Climate (2020) selected for the 'detailed model'

Storm duration	Design event representative temporal pattern									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.05% AEP	PMPDF
9 hours	-	-	-	-	2	2	-	-	-	-
12 hours	8	10	2	3	3	1	1	1	1	1
18 hours	6	5	3	5	5	5	5	5	5	5
24 hours	1	9	8	8	8	6	6	6	6	6
36 hours	9	10	4	9	2	2	2	2	2	2
48 hours	10	3	6	3	10	10	10	10	10	10
72 hours	2	2	2	6	2	2	2	2	2	2
96 hours	8	5	2	5	5	5	5	5	5	5
120 hours	7	6	8	6	8	8	8	8	8	8
144 hours	10	10	7	9	9	10	10	10	10	-
168 hours	3	3	8	5	5	5	5	5	5	-

Note that the hydraulic model (both the fast and detailed models) were simulated only for durations equal to and longer than 12 hours. An additional 9 hour duration storm was simulated for the 2% and 1% AEP events. The hydraulic model results (described in Section 10.6 indicate that this range of durations was sufficient to capture the critical storm durations at all areas within the hydraulic model. In addition, this study is a regional flood study covering the lower reaches of the Logan River where storm durations longer than 12 hours are dominant. On this basis, it was not considered necessary to run the hydraulic model for durations shorter than 12 hours.

10.4.2 Future Climate representative design storms

Table 10.5 shows 'representative design storms' selected for the Future Climate (2090) scenario. Only these representative design storms were simulated using the 10 m grid 'detailed model'. The adopted temporal patterns for the future climate scenario are the same as the current climate scenario. This ensures consistency between the current climate and future climate scenarios, and avoids potential for discontinuity in the water surfaces between AEPs.

To confirm that representative temporal patters remain generally unchanged between current climate and future climate, the distribution of median design storms throughout the hydraulic model extent for the future climate 1% AEP event 48-hour duration from the 'fast model' was mapped (refer Figure 10.5). Figure 10.5 clearly shows a similar distribution of median temporal pattern to the current climate (refer Figure 10.3 and Figure 10.4). Figure 10.5 shows that storm #10 remains the representative temporal pattern for the 48-hour storm, for both current climate and future climate. Therefore, adopting the same representative temporal patterns or current and future climate scenarios is appropriate.

Table 10.5 – Future Climate representative design storms selected

Storm duration	Design event representative temporal pattern						
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
9 hours	-	-	-	2	2	-	-
12 hours	10	2	3	3	1	1	1
18 hours	5	3	5	5	5	5	5
24 hours	9	8	8	8	6	6	6
36 hours	10	4	9	2	2	2	2
48 hours	3	6	3	10	10	10	10
72 hours	2	2	6	2	2	2	2
96 hours	5	2	5	5	5	5	5
120 hours	6	8	6	8	8	8	8
144 hours	10	7	9	9	10	10	10
168 hours	3	8	5	5	5	5	5

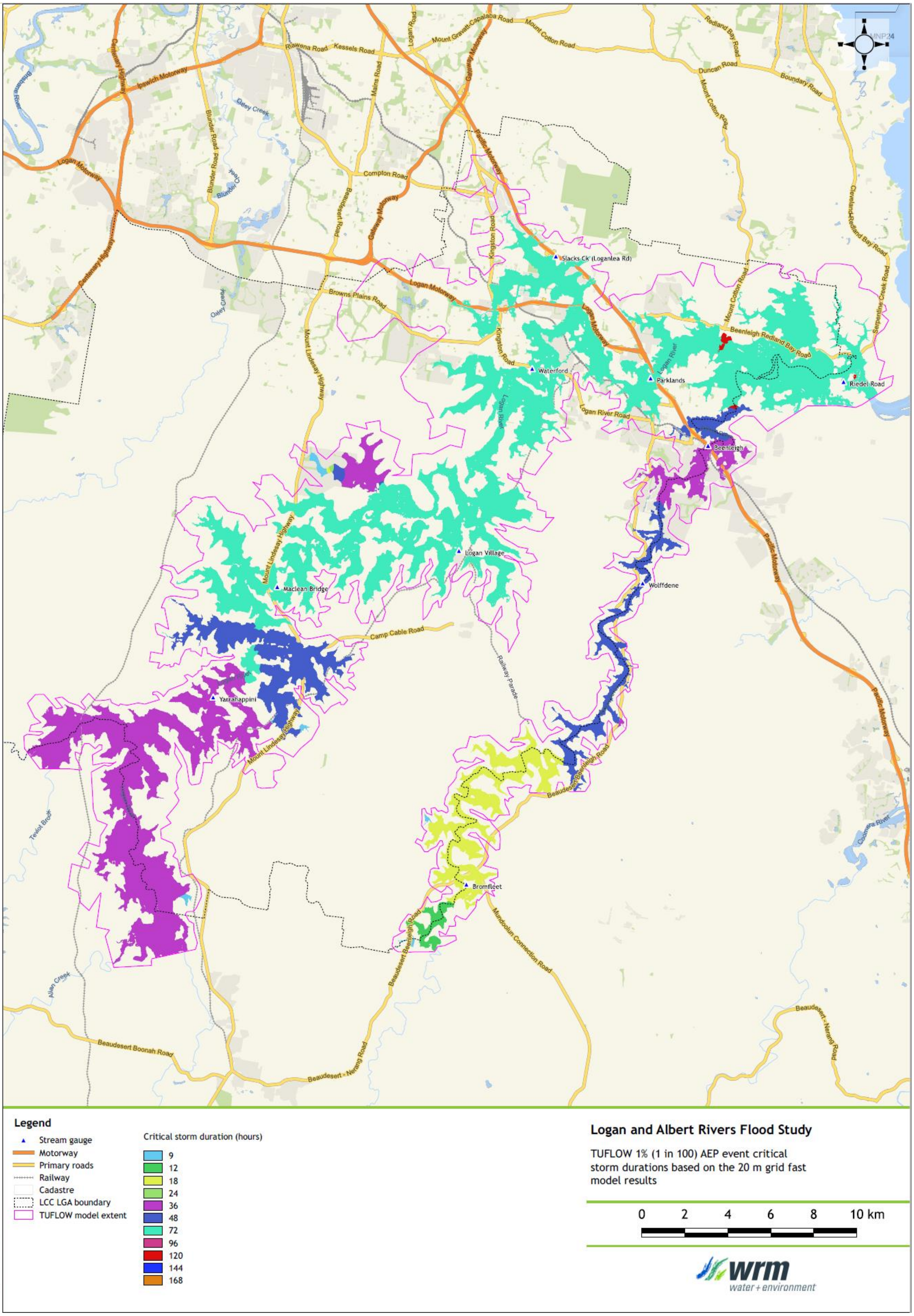

Figure 10.2 - Expected critical storm durations for the current climate 1% AEP event based on the 20 m grid 'Fast Model' results

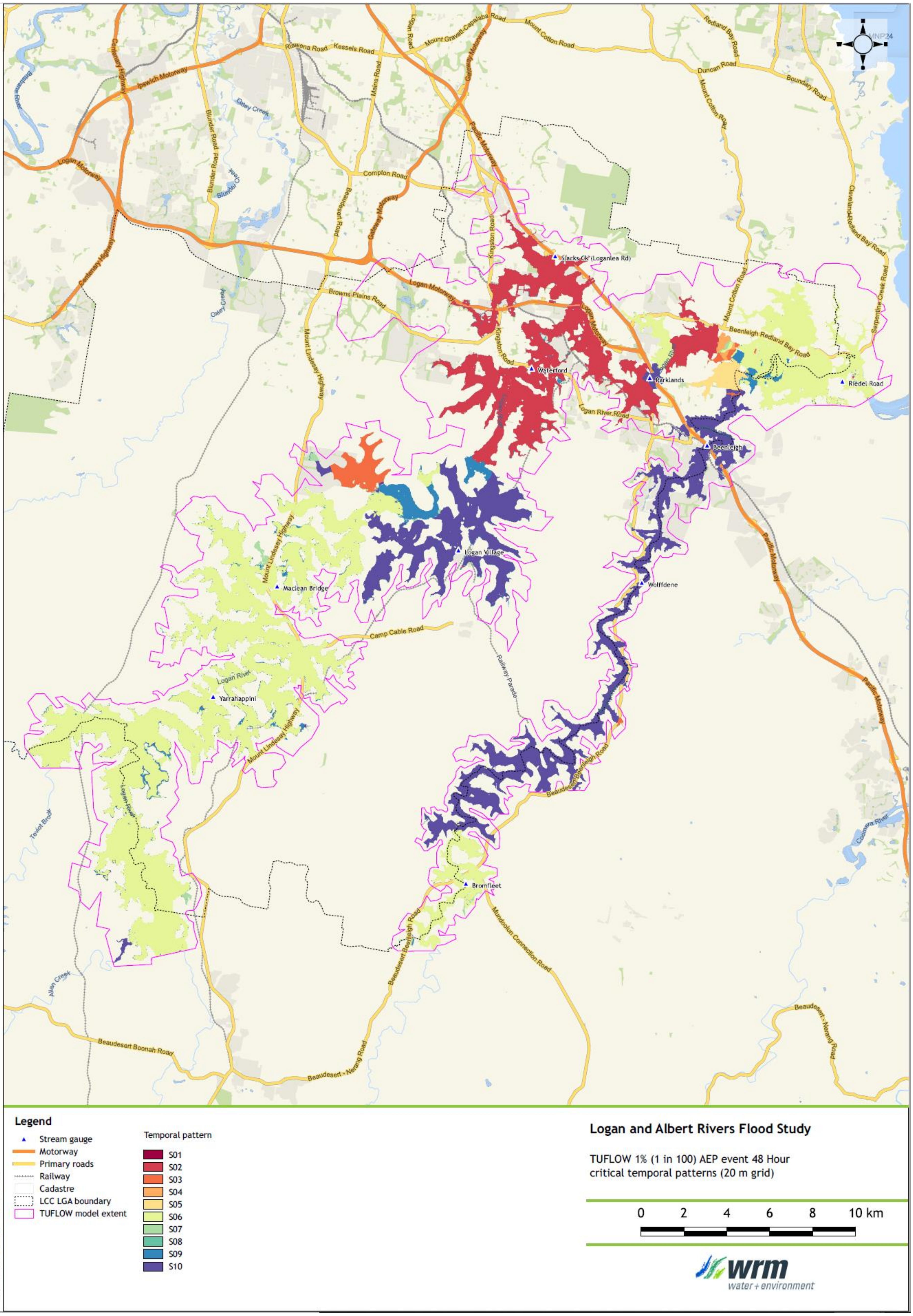

Figure 10.3 – Distribution of median design temporal patterns for the current climate 1% AEP 48-hour storm duration, for the 20 m grid 'Fast Model'

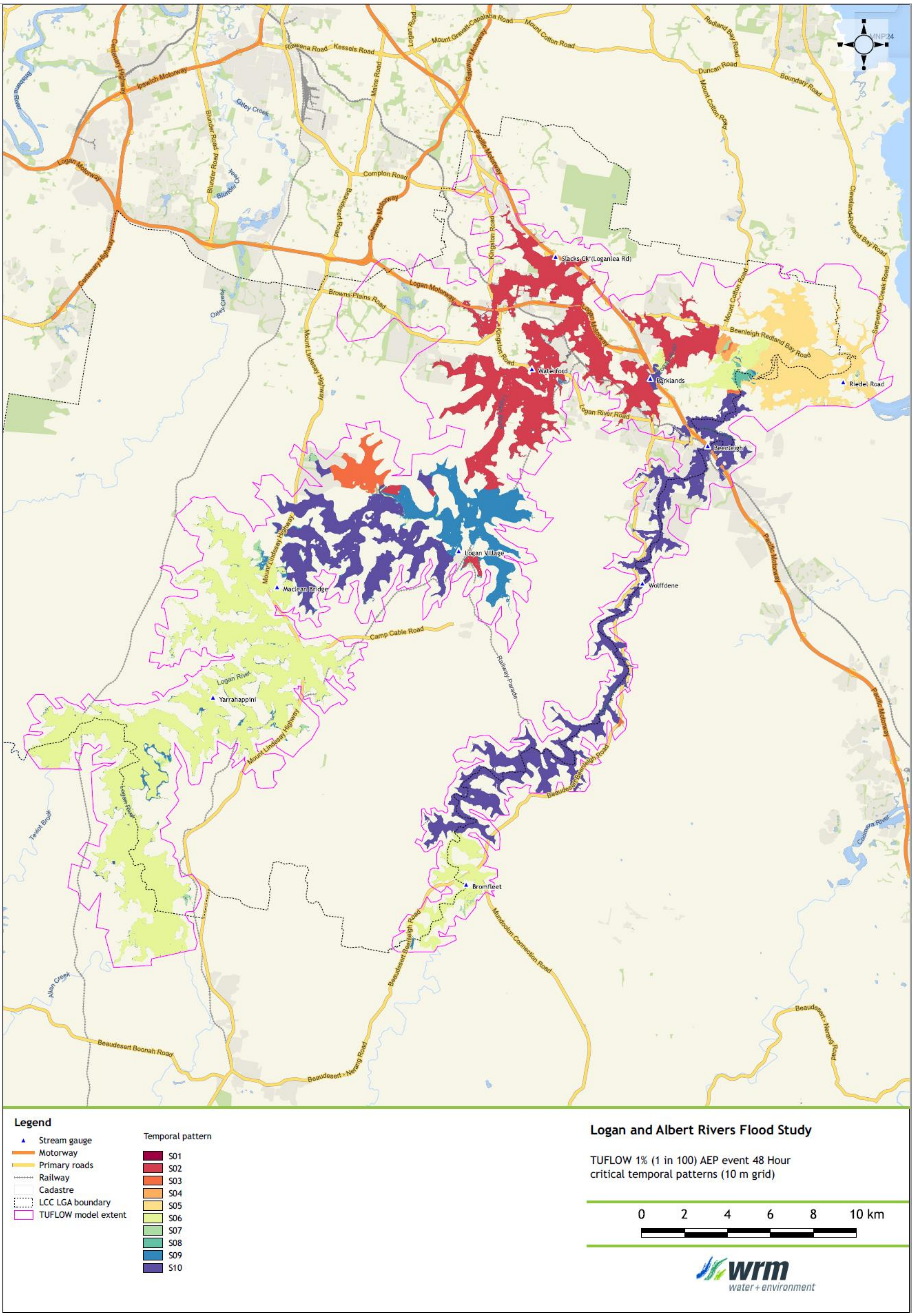

Figure 10.4 – Distribution of median design temporal patterns for the current climate 1% AEP 48-hour storm duration, for the 10 m grid 'Detailed Model'

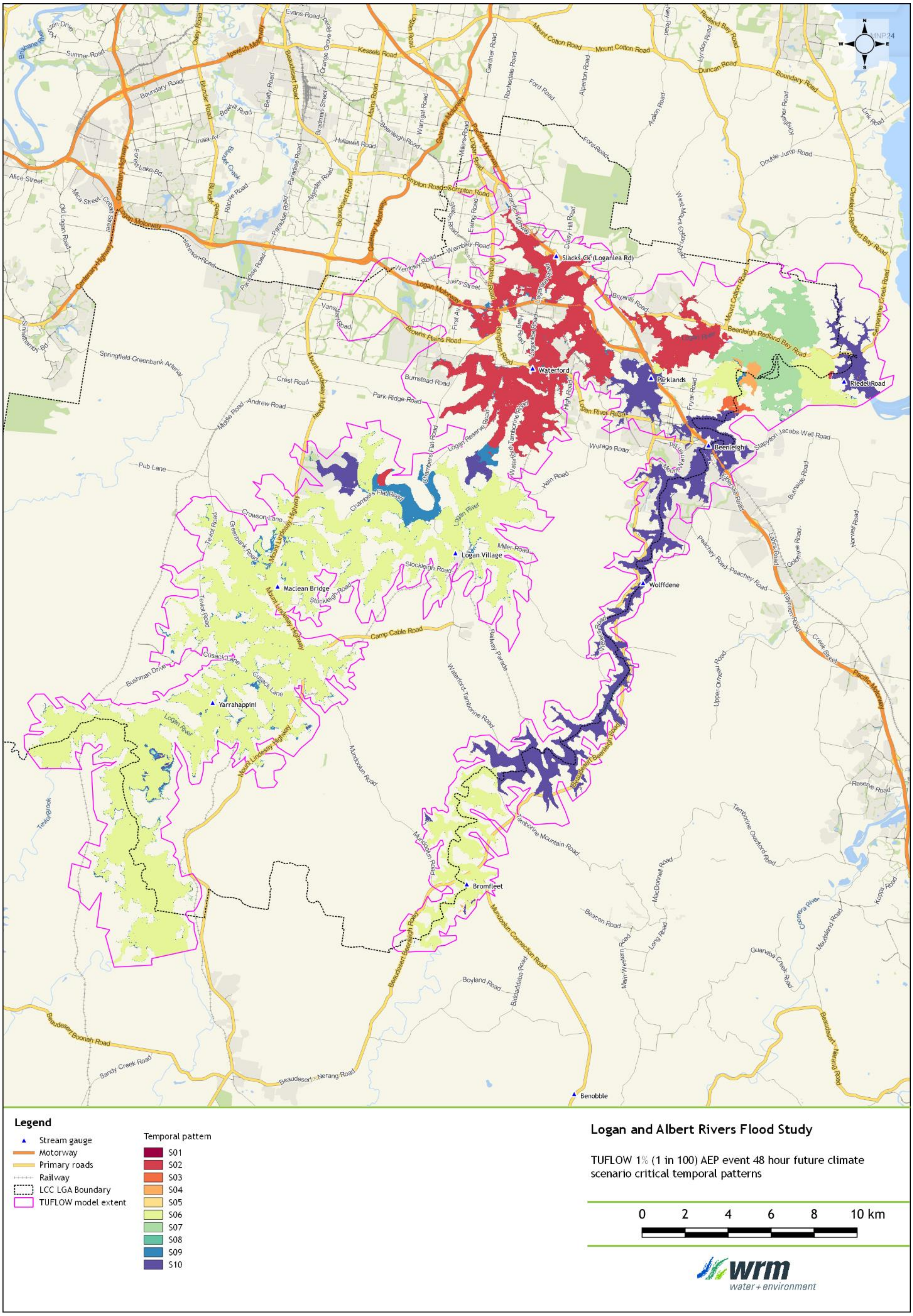

Figure 10.5 – Distribution of median design temporal patterns for the future climate 1% AEP 48-hour storm duration, for the 20 m grid 'Fast Model'

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 20 m grid 'fast model' and for the representative design storms for the 10 m grid 'detailed model':

- Peak water surface levels;
- Peak flood depth;
- Peak velocity;
- Critical storm duration;
- Peak velocity x depth (dV) product;
- Flood hazard classifications for the following four flood hazard criteria:
    - Flood hazard category based on the QUDM (2017) guideline;
    - 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 (including map of chainage) was 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 Logan and Albert rivers within the LCC LGA.

Note that 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 median 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 AR&R 2019.

10.5.3 Flood mapping Current Climate and Future Climate design

Appendix F of the report contains flood maps in A3 size and pdf format. Due to the large area covered by the hydraulic model, flood mapping for the study area was split into two areas referred to as the northern and southern areas. Mapping is provided for the current climate and future climate scenarios for:

- Design peak flood levels;
- Design peak flood depths;
- Design peak flood velocities;
- Critical storm duration maps;
- Depth x velocity (dV) products; and
- AEMI (2014) flood hazard classifications.

Sensitivity analyses results (described in Section 10.8), including:

- Flood level impact maps showing the impact of the 1% AEP storm surge tailwater level on 5% AEP design flood levels (2 maps);
- Flood level impact maps showing the impact of removing culvert blockage on 1% AEP design flood levels (2 maps).

10.6 SUMMARY OF CURRENT CLIMATE DESIGN FLOOD LEVELS

10.6.1 Overview

Table 10.6 summarises the estimated design flood levels at a number of key locations throughout the catchment for events ranging from 50% (1 in 2) AEP to PMPDF events.

Table 10.7shows the corresponding critical storm durations based on the 'detailed' TUFLOW model results.

Figure 10.6 and Figure 10.7 show the predicted max-max water surfaces for the 10% (1 in 10) AEP event. Figure 10.8 and Figure 10.9 show the predicted max-max water surfaces for the 1% (1 in 100) AEP event.

Figure 10.10 and Figure 10.11 are longitudinal section plots showing the TUFLOW model bathymetry and design event peak water surface levels along the length of the Logan and Albert rivers respectively.

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:

- Figure 10.10 starts at chainage 3 km, as flood levels downstream of this point are strongly influenced by the adopted tailwater boundary conditions.
- 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 5% (1 in 20) and 1% (1 in 100) AEP events only. Flood mapping for all other events and for all other output types are provided in Appendix F.
- Design flood levels at Waterford range from 4.11 mAHD for the 50% AEP to 13.23 mAHD for the 1% AEP event. The January 1974 recorded peak flood level at Waterford is between 12.60 mAHD to 13.20 mAHD (based on surveyed debris marks), and the March 2017 recorded flood level is 10.35 mAHD.
- Design flood levels at Logan Village range from 7.62 mAHD for the 50% AEP to 18.03 mAHD for the 1% AEP event. The January 2013 recorded peak flood level at Logan Village is 14.16 mAHD, and the March 2017 recorded flood level is 15.91 mAHD.
- Design flood levels at Maclean Bridge range from 13.15 mAHD for the 50% AEP to 26.38 mAHD for the 1% AEP event. The January 2013 recorded peak flood level at Maclean Bridge is 21.70 mAHD, and the March 2017 recorded flood level is 23.97 mAHD.
- Design flood levels at Yarrahappini range from 21.19 mAHD for the 50% AEP to 32.54 mAHD for the 1% AEP event. The January 1974 recorded peak flood level at Yarrahappini is 31.22 mAHD, and the March 2017 recorded flood level is 30.42 mAHD.
- Design flood levels at Wolffdene range from 6.24 mAHD for the 50% AEP to 13.50 mAHD for the 1% AEP event. The January 1974 recorded peak flood level at Wolffdene is 13.70 mAHD, and the March 2017 recorded flood level is 13.55 mAHD.

- Design flood levels at Bromfleet range from 36.21 mAHD for the 50% AEP to 44.93 mAHD for the 1% AEP event. The January 1974 recorded peak flood level at Wolffdene is 44.56 mAHD, and the March 2017 recorded flood level is 45.78 mAHD.

To illustrate the variation in peak water levels from the ensemble of 10 temporal patterns for each storm duration for the 1% AEP, Figure E.1 to Figure E.7 (in Appendix E) provide box and whisker plots (box plots) showing the distribution of peak water levels in the Logan and Albert Rivers for the 1% AEP event at the following key gauge locations:

- Logan River at Yarrahappini, Maclean Bridge, Logan Village, Waterford and Parklands; and
- Albert River at Bromfleet and Wolffdene.

For each duration, the rectangle box represents the 25%ile and 75%ile (1st and 3rd quartile, the interquartile range or IQR) bound of the estimate. The horizontal line at the top and bottom (whiskers) represents the upper and lower estimates for 1.5 times of the IQR. The horizontal red line within the box is the mean value. The horizontal black dashed line within the box is the median value. For comparison.

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:

- Logan River 0.5% AEP flood level are typically between 0.2 m and 0.5 m higher than 1% AEP flood levels. Logan River 0.2% AEP flood level are typically between 0.7 m and 1.3 m higher than 1% AEP flood levels. Logan River 0.05% AEP flood level are typically between 1.5 m and 2.6 m higher than 1% AEP flood levels.
- Albert River 0.5% AEP flood level are typically between 0.2 m and 0.7 m higher than 1% AEP flood levels. Albert River 0.2% AEP flood level are typically between 0.5 m and 1.6 m higher than 1% AEP flood levels. Albert River 0.05% AEP flood level are typically between 0.9 m and 2.6 m higher than 1% AEP flood levels.

10.6.4 PMPDF design event

The design flood levels for the PMPDF event are summarised as follows:

- Logan River PMPDF flood level are typically between 4.9 m and 7.0 m higher than 1% AEP flood levels.
- Albert River PMPDF flood level are typically between 2.7 m and 5.9 m higher than 1% AEP flood levels.

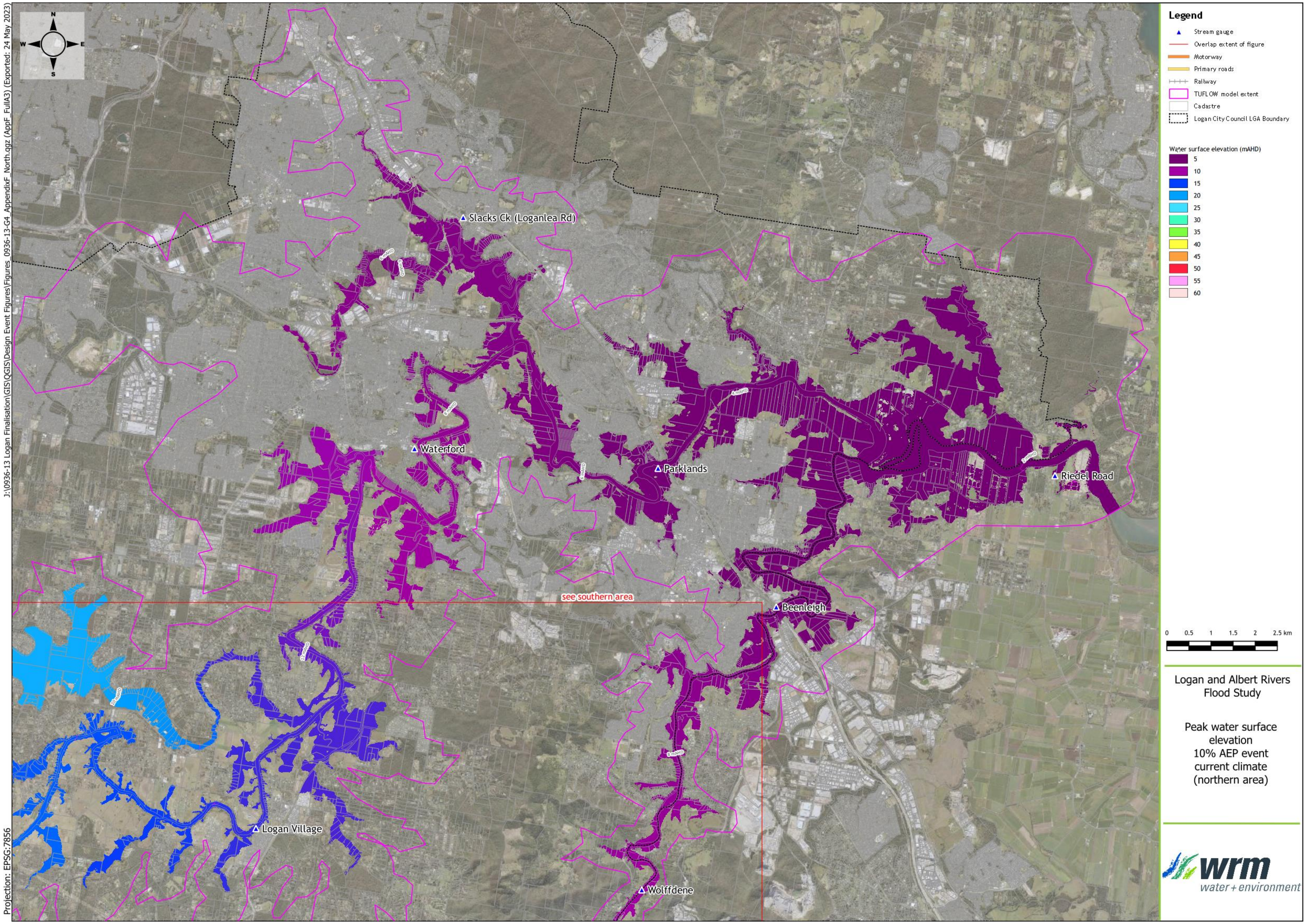

Figure 10.6 – 10% (1 in 10) AEP peak water surface, maximum of all simulated durations, current climate, northern model area

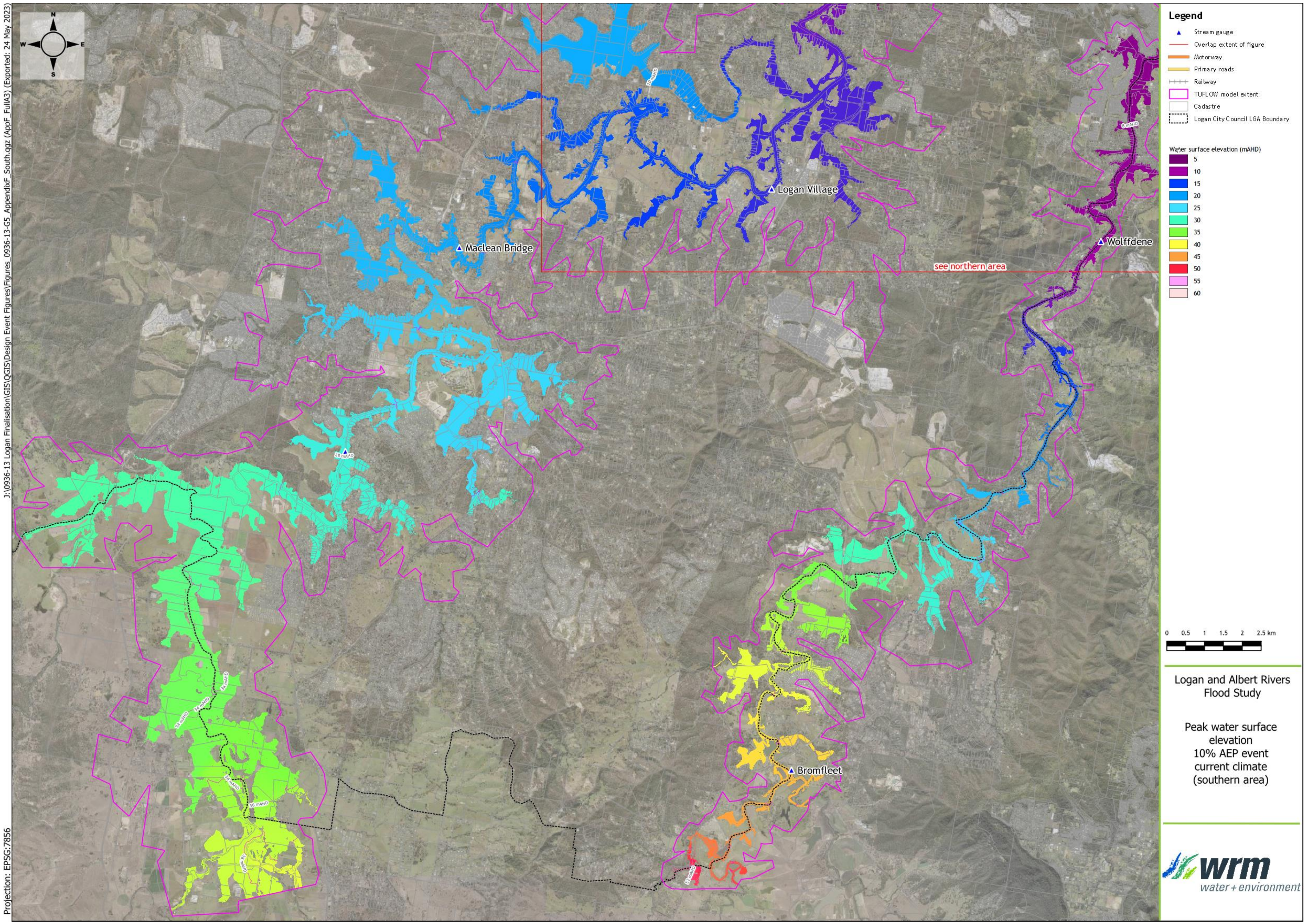

Figure 10.7 - 10% (1 in 10) AEP peak water surface, maximum of all simulated durations, current climate, southern model area

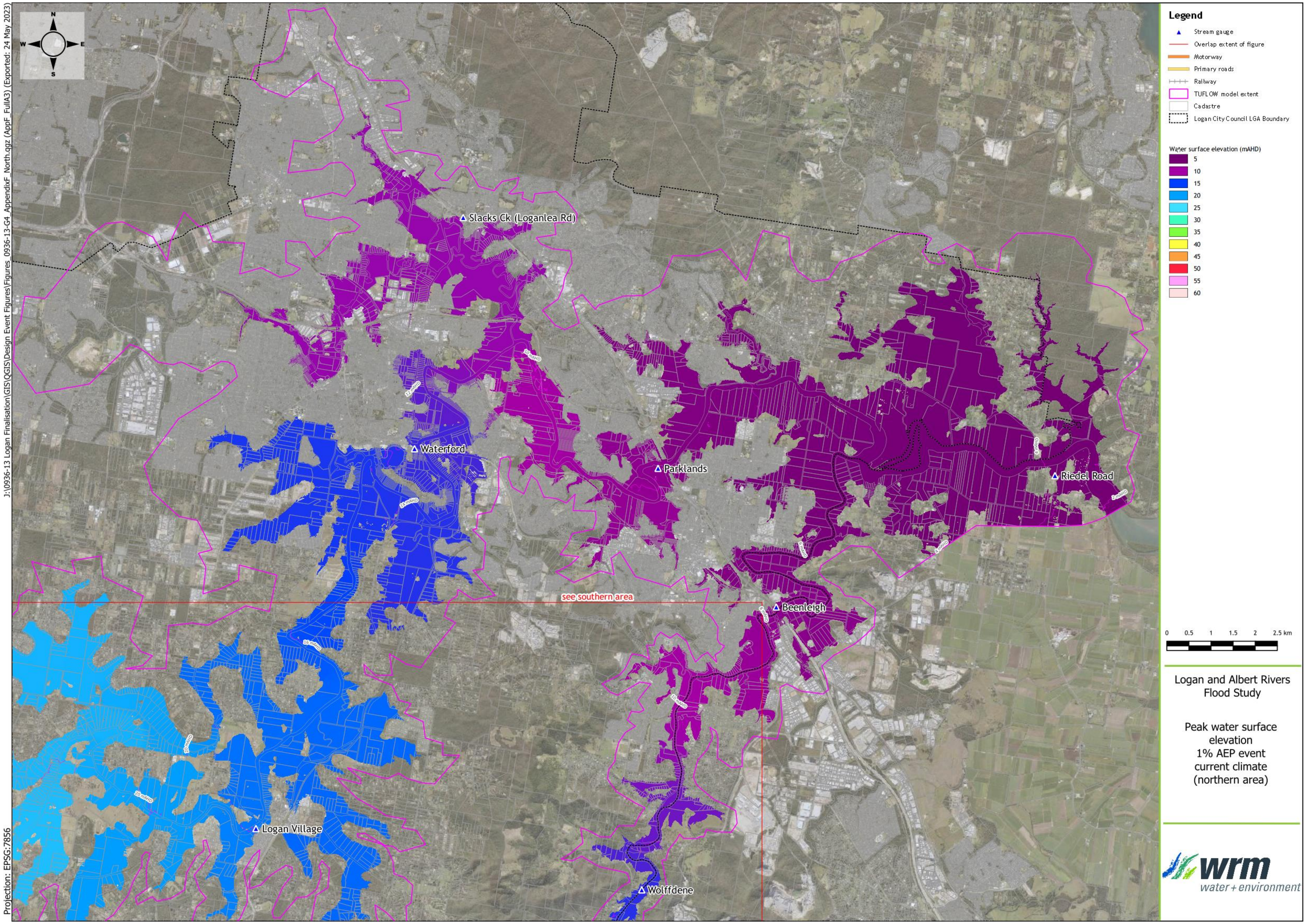

Figure 10.8 - 1% (1 in 100) AEP peak water surface, maximum of all simulated durations, current climate, northern model area

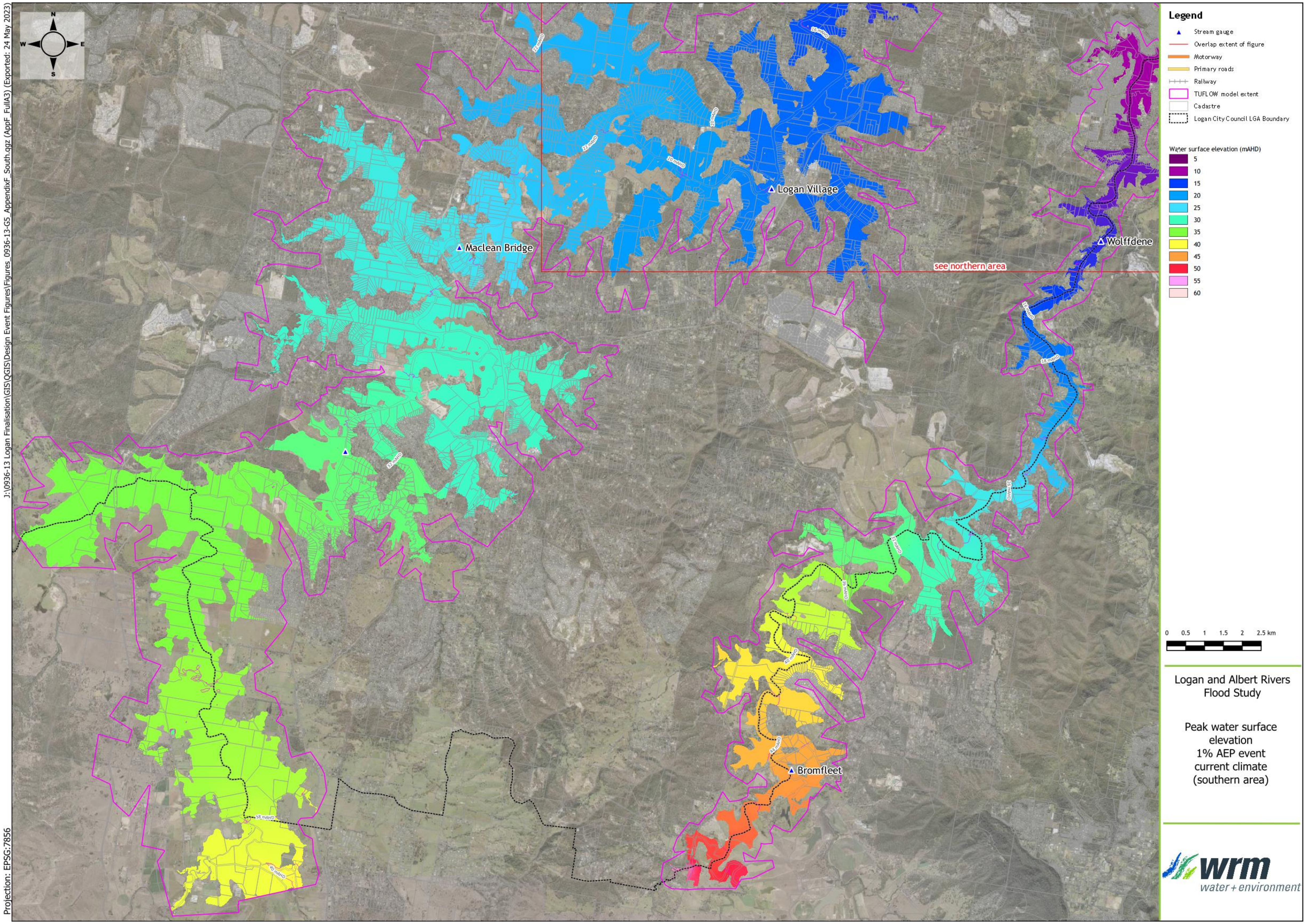

Figure 10.9 - 1% (1 in 100) AEP peak water surface, maximum of all simulated durations, current climate, southern model area

Table 10.6 – Estimated Logan-Albert River Current Climate (2020) design peak flood levels – Current Climate 2020

Location	Peak design water level (mAHD)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.05% AEP	PMPDF
Logan River										
Pacific Motorway	1.92	3.75	5.04	5.92	6.78	7.47	7.81	8.35	9.20	12.45
Scrubby Creek	5.37	6.04	6.10	7.95	9.37	10.43	10.92	11.72	12.98	17.42
Waterford GS	4.11	6.81	8.59	10.11	11.81	13.23	13.70	14.40	15.35	19.27
Logan Village AL	7.62	11.10	13.44	15.51	17.10	18.03	18.38	19.05	20.05	23.80
Maclean Bridge GS	13.15	17.59	20.67	23.06	25.09	26.38	26.83	27.48	28.30	31.59
Mt Lindesay Highway	13.57	17.89	20.96	23.37	25.44	26.75	27.20	27.86	28.69	31.96
Cusack Lane	19.61	22.98	25.76	28.02	29.43	30.41	30.78	31.40	32.14	35.28
Yarrahappini AL	21.19	25.20	27.89	30.01	31.46	32.54	32.95	33.64	34.51	37.94
Upstream Cedar Grove Weir	24.11	27.65	29.81	31.55	32.86	33.90	34.27	34.91	35.75	39.42
Teviot Brook	26.65	29.66	31.02	32.45	33.69	34.70	35.08	35.75	36.66	40.90
Undullah Road	30.51	33.50	34.16	34.80	35.44	36.06	36.28	36.79	37.52	41.13
Albert River										
Logan River	1.33	2.22	3.30	3.71	4.80	5.46	5.77	6.13	6.58	8.70
Pacific Motorway	2.99	4.83	5.56	6.43	6.89	7.48	7.92	8.46	9.18	11.63
Stanmore Road	5.07	7.33	8.70	10.22	10.94	11.83	12.41	13.02	13.87	17.00
Wolffdene GS	6.24	8.45	9.67	11.43	12.42	13.50	14.26	15.08	16.10	19.32
Beaudesert Beenleigh Rd (DS Crossing)	7.99	10.30	11.33	13.15	14.11	15.14	15.80	16.56	17.50	20.98
Chardons Bridge Road	14.11	16.32	17.56	19.04	19.62	20.71	21.11	21.56	22.21	25.00
Waterford Tamborine Road	28.52	31.85	33.90	35.00	35.51	35.85	36.03	36.28	36.53	38.08
Beaudesert Beenleigh Rd (US Crossing)	35.86	40.39	42.65	43.09	43.85	44.33	44.55	44.90	45.38	48.35
Bromfleet GS	36.21	40.88	43.14	43.63	44.44	44.93	45.12	45.42	45.83	48.66
Canungra Creek	36.55	41.19	43.47	44.00	44.74	45.17	45.35	45.63	46.04	48.77

Table 10.7 - Estimated Logan-Albert River Current Climate (2020) critical storm durations

Location	Critical duration									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.05% AEP	PMPDF
Logan River										
Pacific Motorway	48h	48h	36h	48h	48h	72h	72h	72h	72h	36h
Scrubby Creek	12h	24h	36h	48h	48h	72h	72h	72h	72h	36h
Waterford GS	48h	48h	36h	48h	48h	72h	72h	72h	72h	36h
Logan Village AL	48h	48h	36h	48h	48h	72h	72h	72h	72h	36h
Maclean Bridge GS	48h	48h	36h	48h	48h	72h	72h	72h	72h	36h
Mt Lindesay Highway	48h	48h	36h	48h	48h	72h	72h	72h	72h	36h
Cusack Lane	48h	48h	36h	48h	48h	72h	72h	72h	36h	36h
Yarrahappini AL	48h	48h	36h	48h	36h	36h	36h	36h	36h	36h
Upstream Cedar Grove Weir	48h	48h	36h	48h	36h	36h	36h	36h	36h	36h
Teviot Brook	48h	48h	36h	48h	36h	36h	36h	36h	36h	36h
Undullah Road	48h	48h	36h	48h	36h	36h	36h	36h	36h	36h
Albert River										
Logan River	48h	96h	120h	96h	120h	120h	120h	120h	120h	48h
Pacific Motorway	48h	48h	36h	48h	36h	36h	48h	48h	48h	24h
Stanmore Road	48h	48h	36h	48h	36h	48h	48h	48h	48h	24h
Wolffdene GS	48h	48h	36h	48h	36h	48h	48h	48h	48h	24h
Beaudesert Beenleigh Rd (DS Crossing)	48h	48h	36h	48h	36h	48h	48h	48h	48h	24h
Chardons Bridge Road	48h	48h	36h	48h	48h	48h	48h	48h	48h	18h
Waterford Tamborine Road	48h	48h	36h	48h	18h	18h	24h	24h	18h	18h
Beaudesert Beenleigh Rd (US Crossing)	48h	48h	36h	48h	18h	18h	24h	24h	24h	18h
Bromfleet GS	48h	48h	36h	48h	18h	18h	24h	24h	24h	18h
Canungra Creek	48h	48h	36h	48h	18h	18h	24h	24h	24h	18h

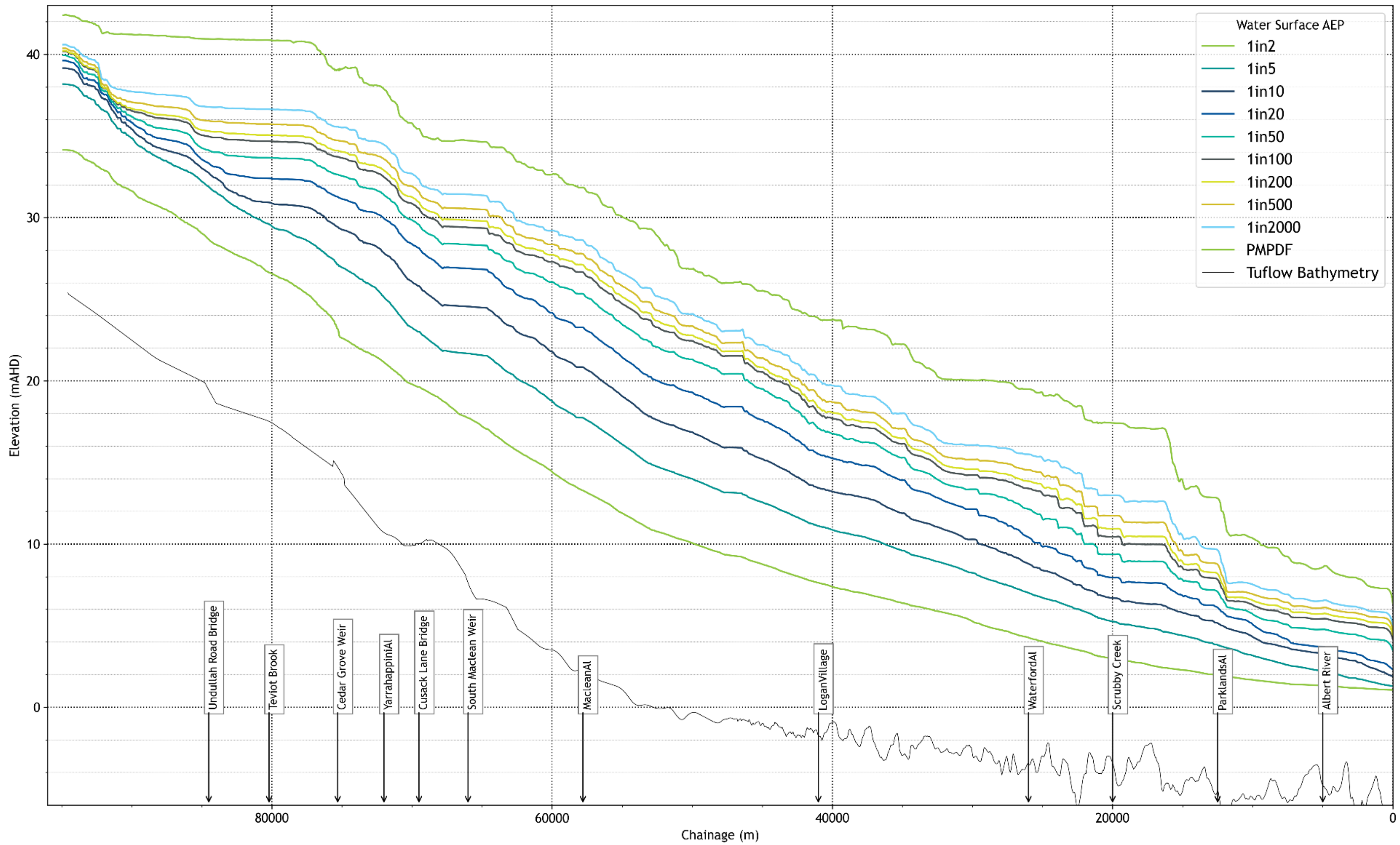

Figure 10.10 – Longitudinal section of TUFLOW model bathymetry and peak design event water surface levels along the Logan River

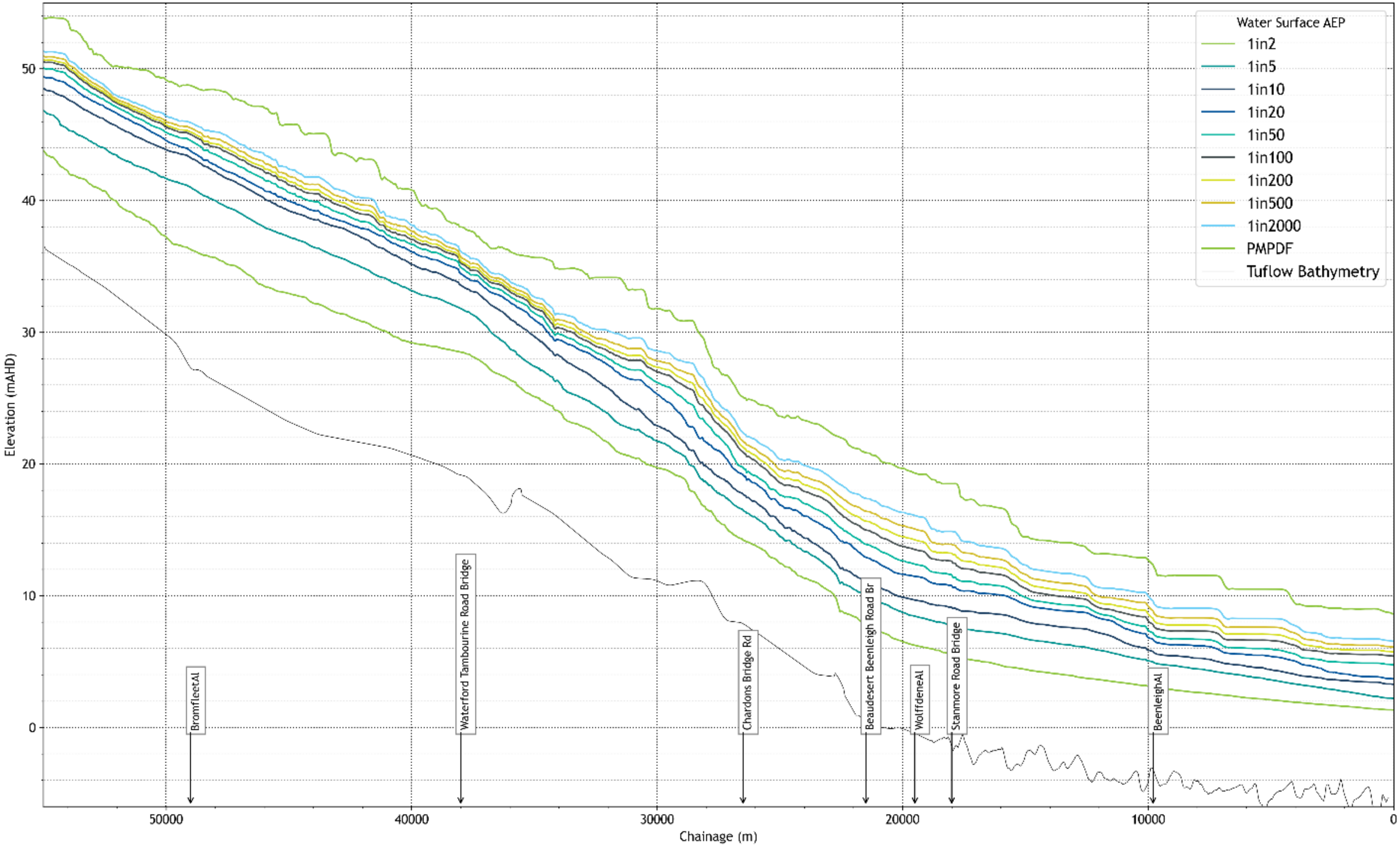

Figure 10.11 – Longitudinal section of TUFLOW model bathymetry and peak design event water surface levels along the Albert River

10.7 SUMMARY OF FUTURE CLIMATE DESIGN FLOOD LEVELS

10.7.1 Overview

Table 10.8 summarises the estimated design flood levels at a number of key locations throughout the catchment for events ranging from 20% (1 in 5) AEP to PMPDF events. Table 10.9 shows the corresponding critical storm durations based on the 'detailed' TUFLOW model results.

Figure 10.12 and Figure 10.13 show the predicted max-max water surfaces for the 10% (1 in 10) AEP event. Figure 10.14 and Figure 10.15 show the predicted max-max water surfaces for the 1% (1 in 100) AEP event.

Figure 10.16 and Figure 10.17 are longitudinal section plots showing the TUFLOW model bathymetry and design event peak water surface levels along the length of the Logan and Albert rivers respectively.

10.7.2 20% (1 in 5) to 1% (1 in 100) AEP design events

The design flood levels for the 20% (1 in 5) to 1% (1 in 100) AEP events are summarised as follows:

- Figure 10.10 starts at chainage 3 km, as flood levels downstream of this point are strongly influenced by the adopted tailwater boundary conditions.
- 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 5% (1 in 20) and 1% (1 in 100) AEP events only. Flood mapping for all other events and for all other output types are provided in Appendix F.
- Design flood levels at Waterford range from 7.43 mAHD for the 20% AEP to 13.66 mAHD for the 1% AEP event. The January 1974 recorded peak flood level at Waterford is between 12.60 mAHD to 13.20 mAHD (based on surveyed debris marks), and the March 2017 recorded flood level is 10.35 mAHD.
- Design flood levels at Logan Village range from 11.83 mAHD for the 20% AEP to 18.37 mAHD for the 1% AEP event. The January 2013 recorded peak flood level at Logan Village is 14.16 mAHD, and the March 2017 recorded flood level is 15.91 mAHD.
- Design flood levels at Maclean Bridge range from 18.57 mAHD for the 20% AEP to 26.83 mAHD for the 1% AEP event. The January 2013 recorded peak flood level at Maclean Bridge is 21.70 mAHD, and the March 2017 recorded flood level is 23.97 mAHD.
- Design flood levels at Yarrahappini range from 26.26 mAHD for the 20% AEP to 32.98 mAHD for the 1% AEP event. The January 1974 recorded peak flood level at Yarrahappini is 31.22 mAHD, and the March 2017 recorded flood level is 30.42 mAHD.
- Design flood levels at Wolffdene range from 9.09 mAHD for the 20% AEP to 14.10 mAHD for the 1% AEP event. The January 1974 recorded peak flood level at Wolffdene is 13.70 mAHD, and the March 2017 recorded flood level is 13.55 mAHD.
- Design flood levels at Bromfleet range from 41.98 mAHD for the 20% AEP to 45.16 mAHD for the 1% AEP event. The January 1974 recorded peak flood level at Wolffdene is 44.56 mAHD, and the March 2017 recorded flood level is 45.78 mAHD.

To illustrate the variation in peak water levels from the ensemble of 10 temporal patterns for each storm duration for the 1% AEP, Figure E.1 to Figure E.7 (in Appendix E) provide box and whisker plots (box plots) showing the distribution of peak water levels in the Logan and Albert Rivers for the 1% AEP event at the following key gauge locations:

- Logan River at Yarrahappini, Maclean Bridge, Logan Village, Waterford and Parklands; and
- Albert River at Bromfleet and Wolffdene.

For each duration, the rectangle box represents the 25%ile and 75%ile (1st and 3rd quartile, the interquartile range or IQR) bound of the estimate. The horizontal line at the top and bottom (whiskers) represents the upper and lower estimates for 1.5 times of the IQR. The horizontal red line within the box is the mean value. The horizontal black dashed line within the box is the median value. For comparison.

10.7.3 0.5% (1 in 200) to 0.02% (1 in 500) 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:

- Logan River 0.5% AEP flood level are typically between 0.2 m and 0.5 m higher than 1% AEP flood levels. Logan River 0.2% AEP flood level are typically between 0.7 m and 1.3 m higher than 1% AEP flood levels. Logan River 0.05% AEP flood level are typically between 1.5 m and 2.6 m higher than 1% AEP flood levels.
- Albert River 0.5% AEP flood level are typically between 0.2 m and 0.7 m higher than 1% AEP flood levels. Albert River 0.2% AEP flood level are typically between 0.5 m and 1.6 m higher than 1% AEP flood levels. Albert River 0.05% AEP flood level are typically between 0.9 m and 2.6 m higher than 1% AEP flood levels.

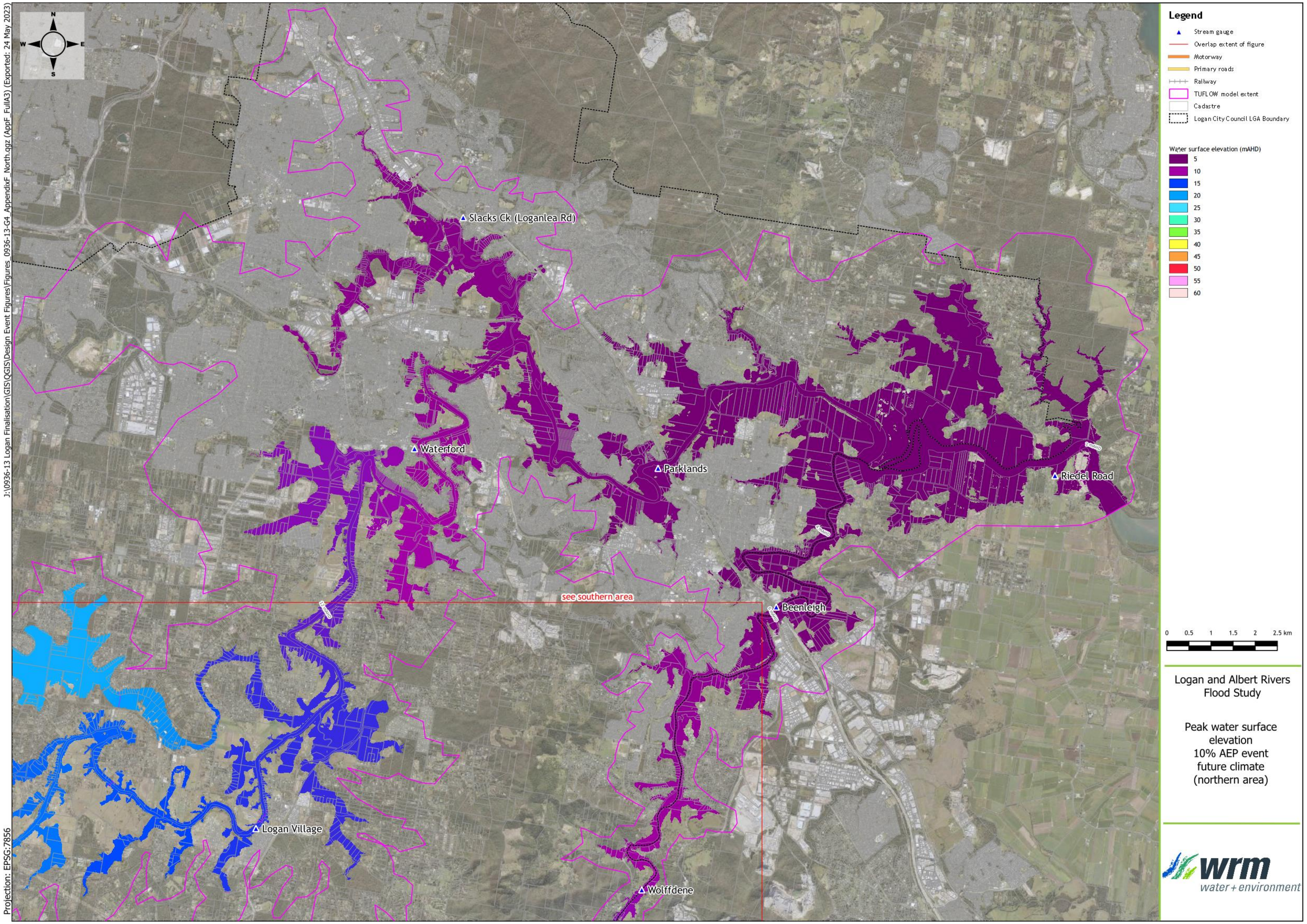

Figure 10.12- 10% (1 in 10) AEP peak water surface, maximum of all simulated durations, future climate, northern model area

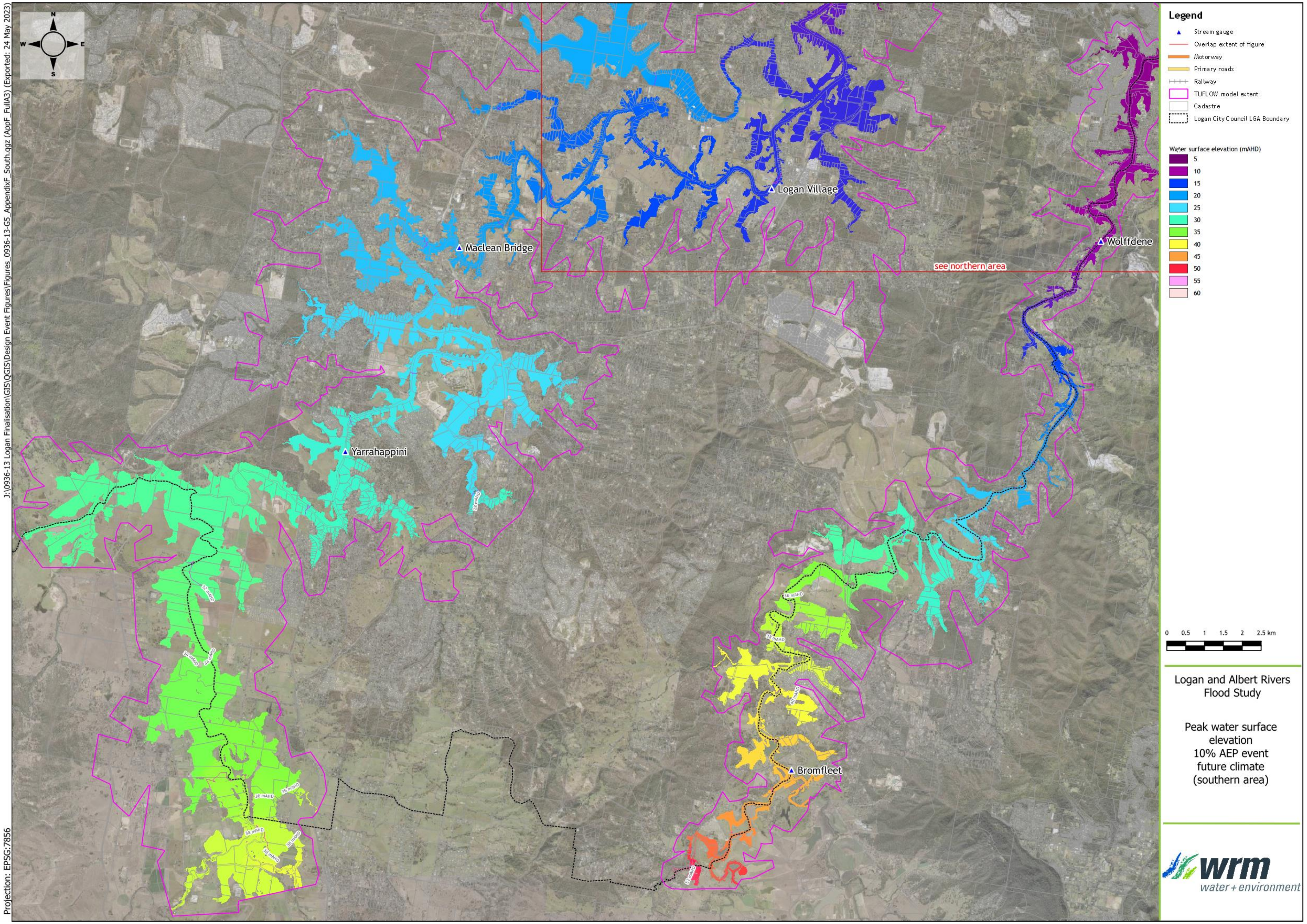

Figure 10.13 - 10% (1 in 10) AEP peak water surface, maximum of all simulated durations, future climate, southern model area

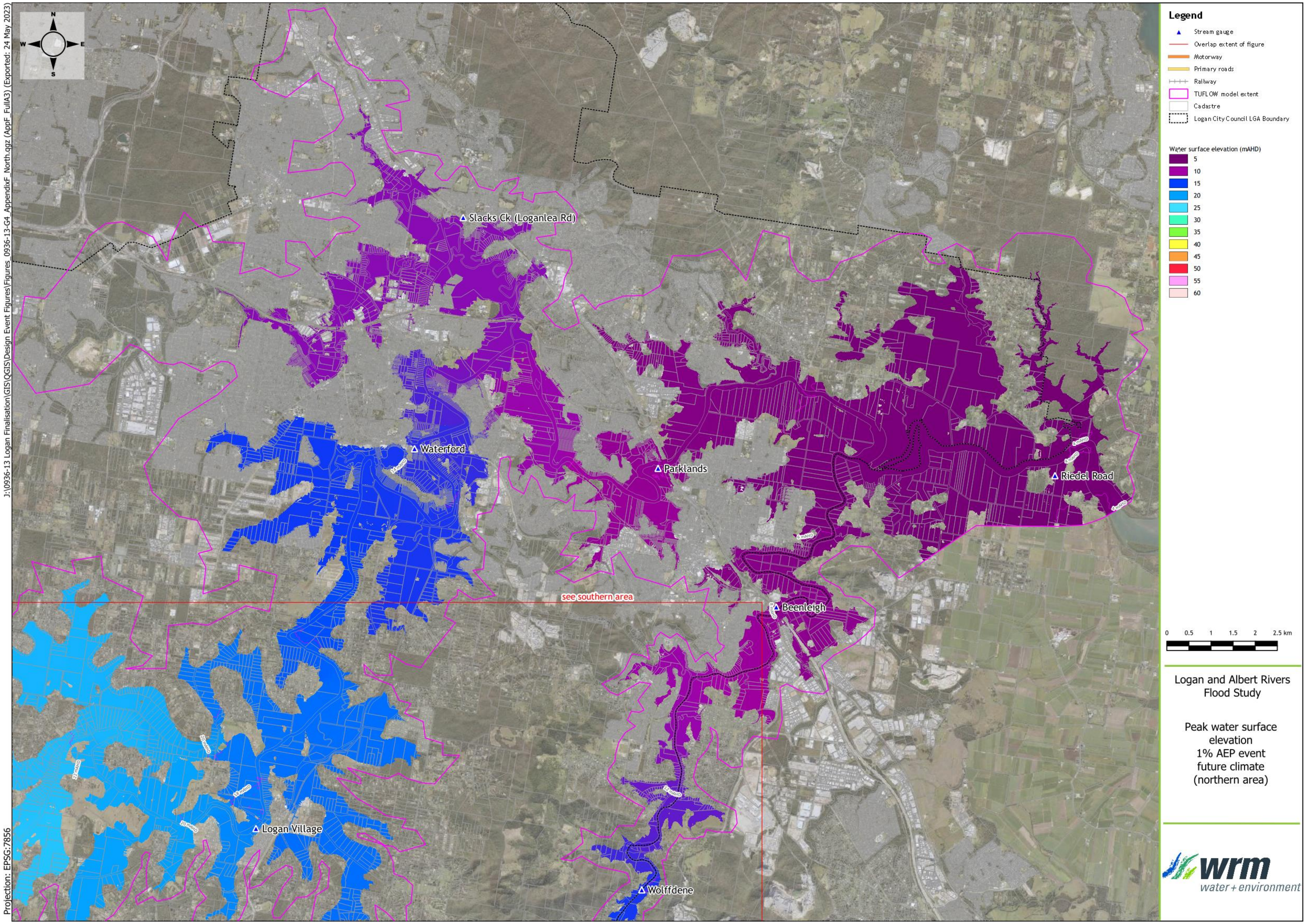

Figure 10.14 - 1% (1 in 100) AEP peak water surface, maximum of all simulated durations, future climate, northern model area

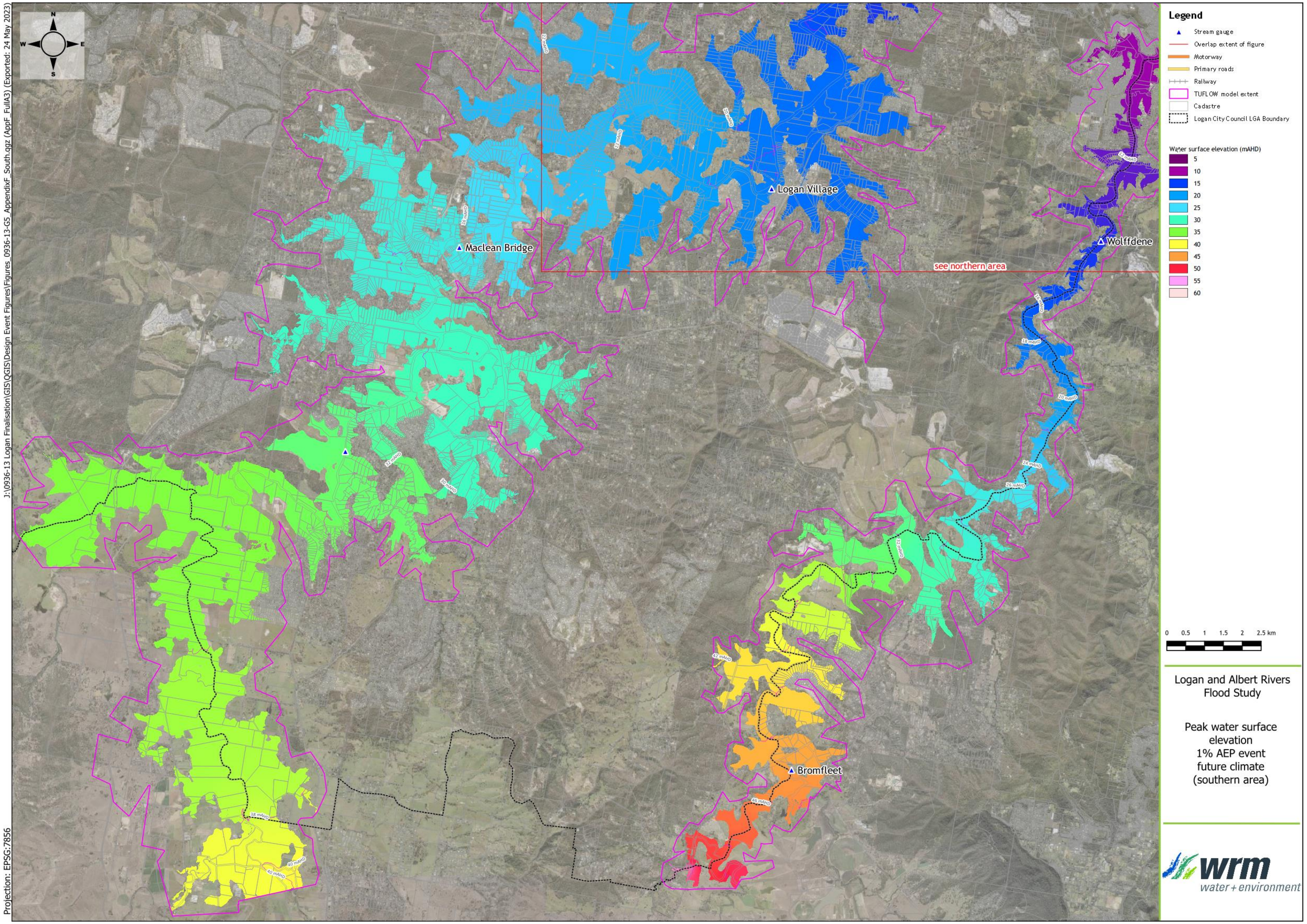

Figure 10.15 - 1% (1 in 100) AEP peak water surface, maximum of all simulated durations, future climate, southern model area

Table 10.8 – Estimated Logan-Albert River Future Climate (2090) design peak flood levels

Location	Future Climate 2090 -Peak design water level (mAHD)						
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
Logan River							
Pacific Motorway	4.33	5.31	6.18	7.05	7.77	8.21	8.80
Scrubby Creek	6.16	6.32	8.39	9.79	10.87	11.53	12.42
Waterford GS	7.43	9.05	10.61	12.40	13.66	14.25	14.94
Logan Village AL	11.83	14.07	16.07	17.50	18.37	18.92	19.64
Maclean Bridge GS	18.57	21.47	23.83	25.66	26.83	27.39	28.00
Mt Lindesay Highway	18.86	21.77	24.16	26.02	27.20	27.77	28.38
Cusack Lane	23.86	26.50	28.58	29.88	30.81	31.33	31.88
Yarrahappini AL	26.26	28.57	30.58	31.96	32.98	33.52	34.19
Upstream Cedar Grove Weir	28.40	30.37	32.05	33.33	34.31	34.81	35.44
Teviot Brook	30.10	31.42	32.92	34.13	35.12	35.65	36.32
Undullah Road	33.76	34.36	35.03	35.70	36.37	36.76	37.31
Albert River							
Logan River	2.83	3.60	4.03	5.16	5.73	6.02	6.34
Pacific Motorway	5.27	5.86	6.72	7.20	7.83	8.27	8.80
Stanmore Road	8.06	9.32	10.68	11.42	12.30	12.81	13.43
Wolffdene GS	9.09	10.30	12.11	13.01	14.10	14.80	15.58
Beaudesert Beenleigh Rd (DS Crossing)	10.90	11.89	13.81	14.69	15.67	16.33	17.01
Chardons Bridge Road	17.05	18.19	19.42	20.47	21.03	21.41	21.87
Waterford Tamborine Road	32.91	34.47	35.29	35.73	36.03	36.20	36.46
Beaudesert Beenleigh Rd (US Crossing)	41.49	42.82	43.54	44.14	44.59	44.81	45.16
Bromfleet GS	41.98	43.38	44.10	44.75	45.16	45.34	45.63
Canungra Creek	42.29	43.75	44.43	45.01	45.39	45.56	45.85

Table 10.9 - Estimated Logan-Albert River Future Climate (2090) critical storm durations

Location	Future Climate 2090 -Peak design water level (mAHD)						
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
Logan River							
Pacific Motorway	48h	96h	48h	72h	72h	72h	72h
Scrubby Creek	48h	96h	48h	72h	72h	72h	72h
Waterford GS	48h	36h	48h	72h	72h	72h	72h
Logan Village AL	48h	36h	48h	48h	72h	72h	72h
Maclean Bridge GS	48h	36h	48h	48h	72h	72h	72h
Mt Lindesay Highway	48h	36h	48h	48h	72h	72h	72h
Cusack Lane	48h	36h	48h	48h	72h	72h	72h
Yarrahappini AL	48h	36h	48h	36h	36h	36h	36h
Upstream Cedar Grove Weir	48h	36h	48h	36h	36h	36h	36h
Teviot Brook	48h	36h	48h	36h	36h	36h	36h
Undullah Road	48h	36h	36h	36h	36h	36h	36h
Albert River							
Logan River	96h	120h	120h	120h	120h	120h	120h
Pacific Motorway	48h	36h	48h	36h	48h	48h	48h
Stanmore Road	48h	36h	48h	36h	48h	48h	48h
Wolffdene GS	48h	36h	48h	24h	48h	48h	48h
Beaudesert Beenleigh Rd (DS Crossing)	48h	36h	48h	24h	48h	48h	48h
Chardons Bridge Road	48h	36h	48h	24h	48h	48h	48h
Waterford Tamborine Road	48h	36h	48h	24h	18h	24h	24h
Beaudesert Beenleigh Rd (US Crossing)	48h	36h	24h	24h	18h	24h	24h
Bromfleet GS	48h	36h	24h	24h	18h	24h	24h
Canungra Creek	48h	36h	24h	24h	18h	24h	24h

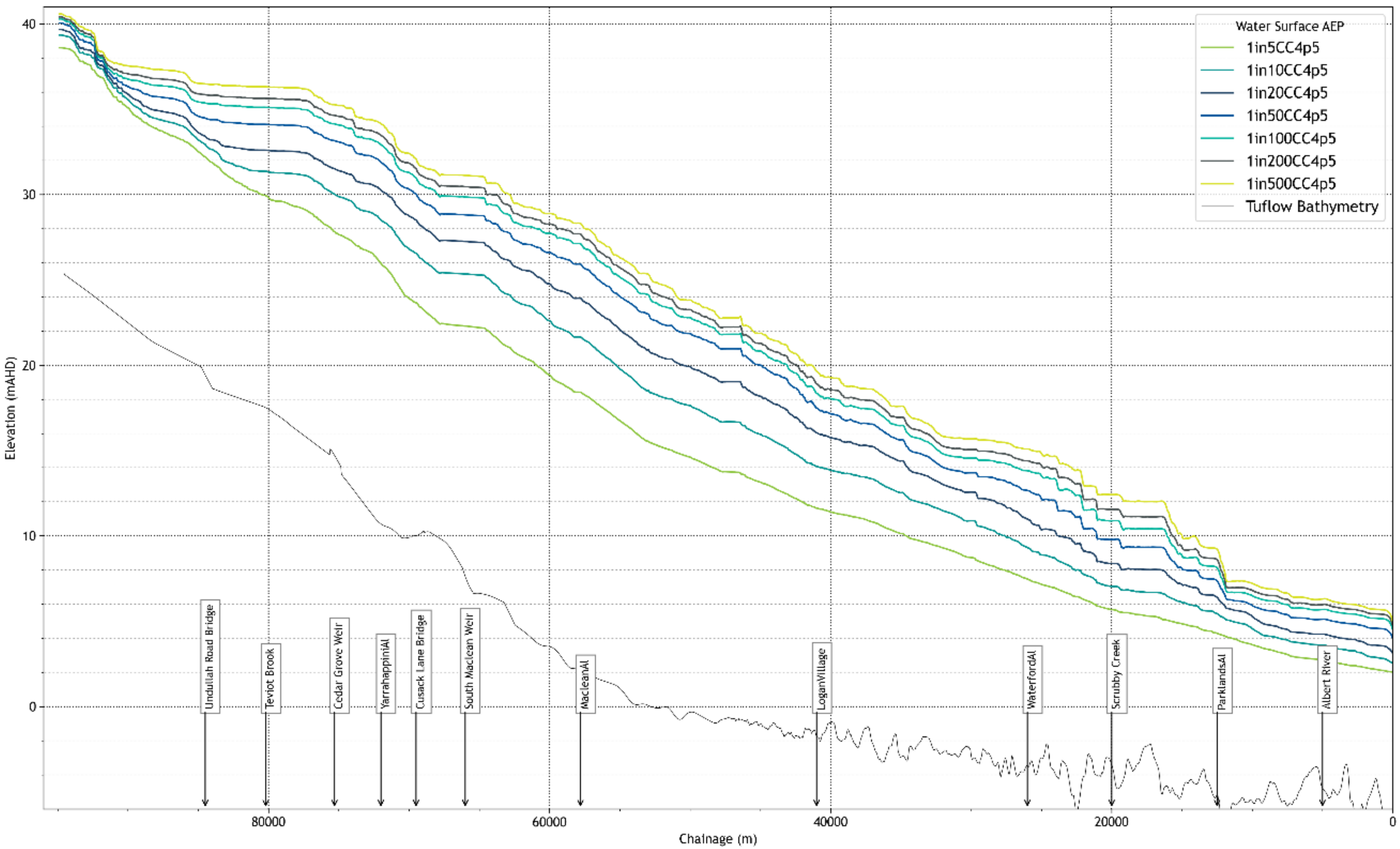

Figure 10.16 - Longitudinal section of TUFLOW model bathymetry and peak design event water surface levels along the Logan River

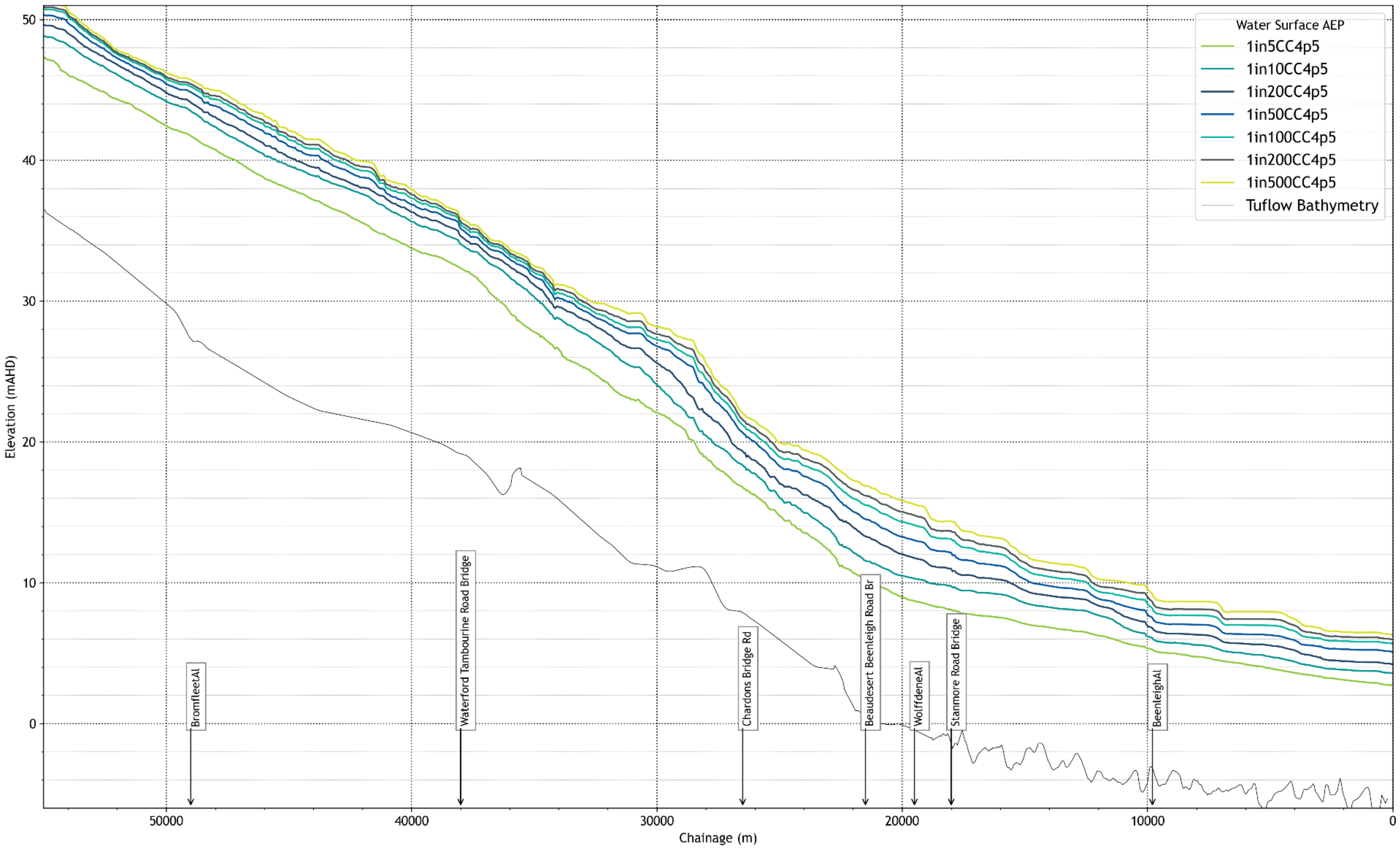

Figure 10.17 – Longitudinal section of TUFLOW model bathymetry and peak design event water surface levels along the Albert River

10.8 SENSITIVITY ANALYSIS RESULTS

10.8.1 Overview

The following three sensitivity analyses were undertaken:

- The impact of adopting the 1% AEP storm surge tailwater level instead of MHWS on 5% AEP design flood levels;
- The impact of removing culvert blockage on 1% AEP peak flood levels; and
- The impact of waterway restoration on 1% AEP and 20% AEP events.

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

10.8.2 Impact of storm surge on design flood levels

For the 5% AEP event, adopting a 1% AEP storm surge tailwater level (2.07 mAHD) results in increased flood levels over the base case simulations (tailwater level of 0.99 mAHD) as follows:

- Increases of between 1.0 m and 2.5 m in the Logan River from the downstream boundary to Riedel Road (3 km upstream of the downstream boundary);
- Increases of between 0.1 m and 0.3 m in the Logan River from Riedel Road to Ferry Road (5 km upstream of the downstream boundary);
- Increases of about 0.05 m at the confluence of the Albert and Logan Rivers (7.5 km upstream of the downstream boundary);
- Increases of about 0.01 m at in the Logan River at Wharf Road (10.5 km upstream of the downstream boundary); and
- Increases of about 0.01 m at in the Albert River at Pacific Motorway (13 km upstream of the downstream boundary).

10.8.3 Impact of removing culvert blockage on design flood levels

For the 1% AEP event, removing culvert blockage (from typically 50% to zero) generally results in negligible change in peak flood levels (less than 0.01 m impact) in most areas of the model except for the following:

- Two backwater areas along the Logan Motorway where the removal of design blockage allows more floodwater to enter the backwater zones, increasing flood levels by between 0.01 m and 0.3 m.
- Reductions in flood level upstream of the Gold Coast rail line of between 0.1m and 0.5m in two backwater zones where the reduced blockage allow water that has overflowed into the backwater zones via surface flow to drain more freely via the unblocked culverts.
- Increased flood levels of up to 0.05 m in the Albert River backwater area near Beenleigh Station and the Beenleigh Marketplace due to the unblocked culverts allowing more floodwater to the enter the backwater zone.
- Increased flood levels of up to 0.05 m in the backwater zone in Chambers Flat at Carter Road due to the unblocked culverts allowing more floodwater to the enter the backwater zone.

10.8.4 Impact of waterway restoration on design flood levels

Increasing Manning's 'n' hydraulic roughness in the LCC waterway corridors to 0.15 (to simulate dense vegetation) generally results in increases in peak flood levels in most areas of the model as follows:

- Two backwater areas along the Logan Motorway where the removal of design blockage allows more floodwater to enter the backwater zones, increasing flood levels by between 0.01 m and 0.3 m.
- Reductions in flood level upstream of the Gold Coast rail line of between 0.1m and 0.5m in two backwater zones where the reduced blockage allow water that has overflowed into the backwater zones via surface flow to drain more freely via the unblocked culverts.
- Increased flood levels of up to 0.05 m in the Albert River backwater area near Beenleigh Station and the Beenleigh Marketplace due to the unblocked culverts allowing more floodwater to the enter the backwater zone.
- Increased flood levels of up to 0.05 m in the backwater zone in Chambers Flat at Carter Road due to the unblocked culverts allowing more floodwater to the enter the backwater zone.

11 Summary and conclusions

11.1 OVERVIEW

XP-RAFTS hydrologic and TUFLOW hydraulic models were developed for the Logan and Albert rivers catchment. The models were calibrated against the January 1974, April 1990, January 2013 and March 2017 flood events. An additional validation model run was completed for February 2022.

The calibrated XP-RAFTS and TUFLOW models was used to estimate design discharges, flood levels, depths, velocities and flood hazard in the Slacks and Scrubby creeks 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 PMPDF event.

11.2 HYDROLOGIC MODEL DEVELOPMENT

XP-RAFTS models were developed for 'existing catchment conditions' (for model calibration purposes). An XP-RAFTS model for 'ultimate catchment conditions' was developed for design event modelling.

The XP-RAFTS model uses a single subcatchment approach to determine runoff hydrographs, based on the overall weighted subcatchment parameters (fraction impervious, roughness and slope). The model consists of 268 subcatchments, which range in size from 256 ha to 3,467 ha, with an average subcatchment area of 1,447 ha.

Channel routing in the XP-RAFTS model was configured based on specifying a 'K' and 'X' value for each routing link. The 'K' values represent estimated flow travel times (in hours) and were calculated based on based on average recorded flood peak travel times between gauges in the catchment.

11.3 HYDRAULIC MODEL DEVELOPMENT

The Logan and Albert rivers hydraulic model covers an area of 453 km^2 and includes the Logan River from Gleneagle to the just upstream of the river mouth, and the Albert River from Birnam to the Logan River confluence. All hydraulic modelling was undertaken using the TUFLOW Build 2018-03-AD HPC-GPU solver.

Two TUFLOW models were developed. These models were:

- **'Fast Model'** – Configured with a grid cell size of 20 m, this model was used to select the critical design storms to be run using a finer 'detailed model'.
- **'Detailed Model'** – Configured with a grid cell size of 10 m, this model simulates the critical design storms selected using the 'Fast Model' to obtain the design outputs.

The model inflow boundaries were configured using 2D surface-area (SA) polygons. The model has a total of 96 inflow boundaries, including 24 total and 72 local inflow boundaries. The TUFLOW model inflow boundaries were configured using 2D surface-area (SA) polygons. Total and local inflow hydrographs generated from the XP-RAFTS model were adopted as inflows at the 2D SA inflow boundaries.

The TUFLOW model has a single outflow boundary located in the Logan River approximately 2.2 km downstream of the Serpentine Creek confluence (approximately 5 km upstream of the Logan River mouth). This outflow boundary extends to the southwest across the southern Logan River floodplain downstream of the Albert River confluence, to provide an outlet for overflows from the lower Logan River floodplain during large flood events.

For design events, a fixed tailwater or tidal storm surge was adopted for the primary outflow boundary dependant on the AEP being modelled.

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 216 culverts (128 RCPs and 88 RCBCs) and 80 bridges structures. 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, recorded peak flood levels and surveyed debris marks for the January 1974, April 1990, January 2013 and March 2017 flood events.

For the purpose of calibrating of the hydraulic model to the January 1974, April 1990 and January 2013 events, the base model topography was configured using the 2013 LiDAR data and the 2013 Bathymetry data. For the purpose of calibrating of the hydraulic model to the March 2017 events, and for undertaking design event hydraulic modelling, the base model topography was configured using the 2017 LiDAR data and the 2019 Bathymetry data.

The calibration confirms that the calibrated hydrologic model produces discharges that generally result in good reproduction of historical peak water levels for the January 1974, April 1990, January 2013 and March 2017 events.

The April 1990 calibration results indicate that in-channel flows are represented adequately by the hydraulic model. The peak flood extents for the January 2013 and March 2017 events are generally consistent with the locations of the surveyed debris marks throughout the Logan and Albert rivers catchment, indicating that overbank flows are generally represented adequately by the hydraulic model. Both the fast (20 m grid) model and the detailed (10 m grid) model produce similar results.

The hydraulic model generally under predicts peak water levels in the lower reaches of the Logan River between Waterford and the Albert River confluence for the January 1974 event. However, modelled peak water levels in this reach for the January 2013 and March 2017 events are generally higher than (but close to) the surveyed debris marks for these events. The reason for the inconsistency in modelled peak water levels in this reach for the 1974 event compared to the other events is unknown but is possibly due to the representation of the river bed along this reach for the 1974 event.

An additional validation model run was completed for February 2022 flood event. The model topography was updated to utilise the 2021 LiDAR data where possible. The model validation showed excellent agreement in most areas of the model where gauging and surveyed debris was collected.

Across the calibration and validation model runs the model struggled to match the reported values at the Wolffdene gauge. Various reasons beyond model parameter adjustment should be considered to help explain why the model struggles in such a localised area and performs well elsewhere.

11.5 DESIGN FLOOD DISCHARGES

The calibrated XP-RAFTS model was used to estimate design flood discharges throughout the Logan and Albert rivers catchment in accordance with the AR&R 2019 guidelines. The

XP-RAFTS model design event discharges were reconciled against FFA estimates at the four gauging stations within the Logan and Albert rivers catchment.

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 PMPDF event.

Subcatchment parameters (fraction impervious and Manning's n) for the XP-RAFTS model for design events were derived based ultimate catchment conditions (based landuses identified in the LCC, GCCC and SRRC planning schemes).

Design flood discharges were also estimated for the future climate scenario based on RCP 4.5 for the 2090 climate horizon. An increase in rainfall intensity of 9.5% is predicted for the future climate scenario

11.6 FLOOD FREQUENCY ANALYSIS

Design Flood discharges were estimated by flood frequency analysis (FFA) using the FLIKE software (version 5.0.251.0) in accordance with guidelines in Book 3, Chapter 2 of AR&R 2019 (Ball et al, 2019). FFA was undertaken at the following key gauging stations within the catchment with more than 30 years of historical record:

- Teviot Brook at The Overflow (DNRM GS 145012a);
- Logan River at Yarrahappini (DNRM GS 145014a);
- Albert River at Bromfleet (DNRM GS 145102b); and
- Albert River at Wolffdene (DNRM GS 145196a).

The XP-RAFTS model estimated design peak discharges at the above stations were compared with the peak discharge estimates obtained from the FFA to assess the consistency between the two sets of discharge estimates and reconcile any differences between estimates from the two methods. The results of the comparison are summarised below:

- In Teviot Brook, the design peak discharges at The Overflow estimated by the XP-RAFTS model correspond well to the flood frequency discharge estimates from the 50% AEP up to the 5% AEP event. For AEPs rarer than 5% AEP, the XP-RAFTS model discharge estimates are lower than those predicted by the FFA, but the XP-RAFTS discharge estimates are well within the flood frequency confidence limits.
- In the Logan River, the design peak discharges estimated by the XP-RAFTS model at Yarrahappini correspond well to the flood frequency discharge estimates for all AEPs up to the 1% AEP flood.
- In the Albert River:
    - the design peak discharges estimated by the XP-RAFTS model at Bromfleet correspond very well to the flood frequency discharge estimates for all AEPs up to the 1% AEP flood. The design peak discharges estimated by the XP-RAFTS model at Wolffdene correspond well to the flood frequency discharge estimates from the 50% AEP up to the 5% AEP event.
    - For AEPs rarer than 5% AEP, the XP-RAFTS model discharge estimates are lower than those predicted by the FFA. However, the FFA estimates for AEPs in this range have reasonably high degree of uncertainty due to the relatively short peak annual data series (50 years), and the XP-RAFTS discharge estimates are well within the flood frequency confidence limits.

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 Logan and Albert rivers and floodplains 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 PMPDF event, for a range of storm durations up to 120 hours.

The 'Fast Model' was used to select the representative AR&R 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 median depths, water levels, velocities and flood hazards for each cell in the model for each design event and storm duration. A max-max selection of the median 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 of this report. Longitudinal profiles of design peak water levels along the Logan and Albert rivers are also provided in this report.

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Appendix A – XP-RAFTS model configuration

A1 XP-RAFTS subcatchment parameters

Table A.1 – Adopted percentage impervious and Manning's 'n' values for each landuse type

Land-use type (refer to Council planning scheme)	Percentage impervious (%)	Manning's '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

Table A.2 – Adopted subcatchment parameters for existing catchment conditions

Subcatchment name	Total area (ha)	Percentage impervious (%)	Catchment slope (%)	Catchment Manning's 'n'
AC001	1131	26.03	5.7	0.059
AL001	2005	6.92	1.5	0.074
AL002	2189	6.25	3.0	0.074
AL003	2254	5.97	5.0	0.074
AL004	1434	6.05	5.0	0.074
AL005	1691	5.92	4.0	0.074
AL006	1403	5.33	5.0	0.075
AL007	1589	6.35	3.0	0.074
AR001	825	32.69	2.3	0.060
AR002	652	43.05	4.4	0.054
AR003	540	47.15	4.3	0.050
AR004	754	29.28	3.5	0.060
AR005	702	27.58	8.9	0.060
AR006	601	83.46	14.9	0.029
AR007	838	11.65	12.7	0.070
AR008_WLF	693	7.99	13.7	0.073
AR009	713	6.08	9.8	0.074

Subcatchment name	Total area (ha)	Percentage impervious (%)	Catchment slope (%)	Catchment Manning's 'n'
AR010	702	23.99	14.8	0.062
AR011	736	11.10	7.1	0.068
AR012	940	5.84	8.3	0.074
AR013	761	9.50	4.2	0.070
AR014	822	10.28	3.7	0.071
AR015	971	10.69	5.8	0.069
AR016	1103	13.51	5.7	0.066
AR017_BRM	917	6.40	4.6	0.074
AR018	962	9.15	10.8	0.071
AR019	1653	5.90	1.6	0.075
AR020	1951	6.88	3.4	0.074
AR021	1466	6.30	3.0	0.074
AR022	788	6.46	3.0	0.074
AR023	1034	6.05	4.0	0.074
AR024	1404	6.29	6.0	0.074
AR025	1492	6.90	5.3	0.074
AR026	1730	6.76	4.0	0.074
AR027	1063	6.10	5.0	0.075
AR028	1635	0.62	8.5	0.079
AR029	1605	6.80	6.0	0.074
AR030	1523	0.54	11.0	0.080
B001	2587	10.68	0.8	0.072
BACK001	2314	3.62	11.0	0.077
BG001	763	6.44	6.0	0.074
BID001	1509	5.99	5.5	0.074
BID002	1316	5.85	3.0	0.075
BID003	1720	5.79	8.5	0.075
BRC001	1832	5.95	2.5	0.074
BURN001	1439	7.10	4.0	0.074
BURN002	1611	6.35	9.0	0.074
BURN003	1632	5.90	7.0	0.075
BURN004	1407	6.17	4.0	0.074
BURN005	2022	6.16	5.0	0.074
BURN006_MD	1284	3.68	8.0	0.077
BURN007	1089	5.20	11.0	0.075
BURN008	3052	5.15	15.0	0.075
BURN009	2232	3.79	9.0	0.077
BURN010	2903	0.97	5.0	0.079
CAIN001	1476	5.50	6.0	0.075
CAIN002	1360	4.91	6.0	0.075
CAIN003	1332	7.04	7.0	0.074
CAIN004	2881	5.33	5.5	0.075

Subcatchment name	Total area (ha)	Percentage impervious (%)	Catchment slope (%)	Catchment Manning's 'n'
CAMP001	981	6.61	8.0	0.074
CAN001	1509	6.62	5.9	0.074
CAN002	1925	9.13	5.5	0.071
CAN003	1638	8.00	7.0	0.073
CAN004	1270	11.98	6.0	0.069
CAN005	1282	6.65	7.0	0.074
CAN006	1088	6.45	6.0	0.074
CAN007	1223	7.33	8.0	0.074
CAN008	983	3.82	8.5	0.077
CAN009	1326	0.93	10.0	0.079
CAN010	1082	0.06	10.0	0.080
CAN011	1792	0.17	10.0	0.080
CANN001	1997	6.73	3.0	0.074
CANN002	2533	13.68	4.0	0.068
CANN003	2454	7.33	3.0	0.073
CANN004	1882	6.26	5.0	0.074
CANN005	1521	6.79	6.0	0.074
CANN006	2910	6.90	3.0	0.074
CARN001	2160	7.08	5.0	0.074
CC001	1330	17.73	6.8	0.067
CE001	863	6.88	4.5	0.074
CE002	897	4.41	6.4	0.076
CE003	766	20.40	6.0	0.063
CE004	505	1.47	8.1	0.079
CH001	795	26.33	2.2	0.058
CH002	611	15.14	1.3	0.066
CH003	1027	29.42	2.2	0.058
CH004	1152	23.01	2.5	0.058
CHI001	3311	6.35	6.5	0.074
CHR001	985	5.82	4.0	0.075
CHR002	3057	6.82	5.0	0.074
CHR003	2714	6.31	5.0	0.074
CHR004	2472	6.76	6.0	0.074
CHR005	2066	5.11	8.0	0.075
CHR006	2495	0.93	10.0	0.079
CL001	940	13.73	14.4	0.064
CL002	848	11.79	12.4	0.067
COL001	892	8.09	8.8	0.072
COL002	396	10.26	14.1	0.070
COL003	537	7.28	14.0	0.074
CRON001	1370	0.00	11.0	0.080
CROW001	1578	5.94	4.0	0.074

Subcatchment name	Total area (ha)	Percentage impervious (%)	Catchment slope (%)	Catchment Manning's 'n'
CROW002	1482	5.17	5.3	0.075
DC001	1394	6.48	7.5	0.074
FC001	508	17.15	3.0	0.061
FC002	386	28.86	3.0	0.059
FC003	1653	16.79	8.8	0.070
FC004	1963	20.40	9.4	0.068
FC005	1063	39.57	4.5	0.054
FL001	807	5.91	8.3	0.074
FL002	686	6.50	5.9	0.074
FLGS001	2459	6.01	2.0	0.074
HC001	657	22.82	2.2	0.062
HC002	256	18.72	5.7	0.060
HC003	528	19.70	7.0	0.058
HC004	727	16.70	11.5	0.060
HW001	1758	49.27	4.8	0.048
JC001	670	36.37	3.4	0.055
JC002	592	15.40	11.0	0.062
JC003	590	15.16	15.8	0.061
KC001	1840	6.45	3.0	0.074
KN001	2397	6.05	4.0	0.074
KN002	3034	6.23	3.5	0.074
KN003	2215	6.30	4.0	0.074
LR001	1730	8.20	3.5	0.072
LR002	776	8.23	1.8	0.073
LR003	594	9.46	1.6	0.073
LR004	856	26.28	3.3	0.063
LR005	833	52.22	4.1	0.048
LR006	975	53.52	5.3	0.048
LR007	954	35.66	4.2	0.058
LR008	330	36.37	2.7	0.058
LR009_WAT	818	42.45	3.4	0.053
LR010	1185	19.03	4.1	0.062
LR011	747	21.62	3.3	0.065
LR012	1148	39.79	2.1	0.055
LR013	648	43.68	2.1	0.054
LR014	625	15.52	3.9	0.065
LR015	804	21.72	3.7	0.063
LR016_LV	744	23.80	7.1	0.058
LR017	381	19.12	4.0	0.061
LR018	891	15.77	4.2	0.063
LR019	586	10.48	3.6	0.069
LR020	603	13.38	3.8	0.065

Subcatchment name	Total area (ha)	Percentage impervious (%)	Catchment slope (%)	Catchment Manning's 'n'
LR021	699	32.56	3.3	0.057
LR022	842	16.90	4.0	0.062
LR023_MB	771	14.30	4.1	0.065
LR024	567	19.97	3.0	0.060
LR025	1059	21.95	4.4	0.058
LR026	618	19.59	4.6	0.064
LR027	894	27.60	3.6	0.060
LR028_YAR	1122	16.68	4.7	0.064
LR029	2310	10.82	3.5	0.070
LR030	2028	6.10	0.6	0.074
LR031	2195	7.96	3.9	0.073
LR032	2272	9.11	6.1	0.071
LR033	1766	11.96	2.0	0.070
LR034	2603	8.37	3.9	0.073
LR035	1702	6.58	3.0	0.074
LR036	2057	6.54	3.6	0.074
LR037_RM	1674	6.15	4.5	0.074
LR038	1937	6.85	3.0	0.074
LR039	3467	6.23	2.0	0.074
LR040	2672	7.27	2.0	0.074
LR041	2540	6.52	3.5	0.074
LR042	2453	6.75	5.0	0.074
LR043	1867	5.75	9.0	0.075
LR044	1725	7.02	6.5	0.074
LR045	1710	4.25	22.0	0.076
LR046	1817	2.70	10.0	0.078
MBC001	2670	1.94	13.0	0.078
MBC002	1920	2.52	10.0	0.078
MBC003	2178	1.05	12.0	0.079
MBC004	2370	0.00	12.0	0.080
MC001	946	3.04	12.0	0.078
NC001	589	20.06	2.8	0.059
NC002	1166	24.75	3.1	0.060
ND001	719	5.50	2.8	0.076
ND002	869	7.75	2.2	0.075
ND003	967	31.97	5.5	0.057
NYC001	2387	5.97	6.5	0.075
OAK001	2141	5.68	3.0	0.075
OAK002	2135	6.10	4.6	0.074
OAK003	1729	5.75	4.0	0.075
OO001	658	9.69	11.9	0.069
PC001	990	5.73	4.0	0.075

Subcatchment name	Total area (ha)	Percentage impervious (%)	Catchment slope (%)	Catchment Manning's 'n'
PC002	2557	6.85	5.0	0.074
PC003	1033	5.23	15.0	0.075
PC004	2821	6.59	12.0	0.075
QC001	723	23.41	3.3	0.058
QC002	603	13.00	9.6	0.065
QC003	797	26.11	4.7	0.060
QC004	936	17.08	3.5	0.067
QC005	630	7.19	2.6	0.074
RC001	385	6.87	12.4	0.074
RC002	441	6.67	20.5	0.074
RUN001	1498	6.20	3.0	0.074
RUN002	2419	5.99	7.0	0.075
RUN003	1899	6.71	6.0	0.074
RUN004	2077	6.25	6.0	0.075
RUN005	2284	4.88	8.0	0.076
RUN006	3226	0.00	7.5	0.080
S001	1916	14.63	1.1	0.069
S002	2346	22.27	1.4	0.065
S003	893	64.88	4.3	0.040
SA001	1443	9.41	6.7	0.072
SALT001	2915	10.05	6.0	0.072
SAN001	1262	5.77	4.0	0.075
SAN002	1656	5.52	4.5	0.075
SAN003	2231	5.17	3.0	0.075
SAND001	2625	6.85	2.5	0.074
SAND002	1422	5.90	4.0	0.075
SC001	844	49.14	2.6	0.050
SC002	981	49.19	2.4	0.050
SC003	667	42.86	3.0	0.054
SC004	763	33.89	2.4	0.059
SC005	1119	38.98	4.0	0.056
SC006	885	29.06	3.0	0.060
SC007	807	50.36	3.3	0.049
SC008	1097	45.59	2.9	0.052
SC009	645	38.15	2.4	0.053
SCR001	2285	15.71	11.9	0.063
SL001	582	40.95	3.9	0.055
SL002	825	31.44	7.0	0.061
SL003	873	51.74	3.5	0.049
SL004	886	60.15	3.8	0.044
SL005	1050	44.08	4.6	0.053
SPG001	1946	23.92	1.4	0.064

Subcatchment name	Total area (ha)	Percentage impervious (%)	Catchment slope (%)	Catchment Manning's 'n'
SPG002	2069	6.12	4.0	0.074
SPG003	2653	8.12	4.0	0.073
SPR001	1375	5.89	4.0	0.074
SSC001	1141	5.45	2.5	0.075
ST001	513	25.57	8.8	0.058
STE001	1254	14.49	6.5	0.066
STO001	1497	3.69	8.0	0.077
TB001	1113	19.26	1.3	0.067
TB002	758	6.83	1.4	0.074
TB003	810	5.50	4.0	0.075
TB004	1178	5.24	6.0	0.075
TB005_WD	1206	5.88	8.0	0.075
TB006_OF	2883	7.00	3.5	0.074
TB007	2944	7.51	9.0	0.074
TB008	2217	7.49	5.5	0.074
TB009	2551	7.41	5.0	0.074
TB010	2716	8.03	6.5	0.073
TB011	3076	9.46	6.0	0.072
TB012	2628	7.11	4.0	0.074
TB013	2787	6.55	9.0	0.074
TB014	2190	6.74	5.0	0.074
TB015	2822	6.02	4.0	0.074
TB016	2181	6.91	2.5	0.074
TB017	1709	7.35	4.0	0.074
TB018	1594	5.63	8.0	0.075
TB019	2802	4.55	14.0	0.077
UND001	1130	35.72	2.3	0.058
UND002	1797	6.81	3.4	0.074
WALL001	1657	6.74	6.0	0.074
WC001	520	40.10	6.8	0.056
WC002	762	28.50	8.8	0.063
WFC001	1118	5.31	7.0	0.075
WID001	1360	6.37	4.0	0.074
WID002	1462	5.25	10.0	0.075
WOOL001	745	11.22	2.6	0.072
WOOL002	775	29.54	3.4	0.060
WOOL003	1144	12.55	3.8	0.069
WOOL004	1623	6.76	4.3	0.075
WOOL005	1448	3.24	3.9	0.077
WP001	1350	6.15	4.1	0.075
WYR001	1125	25.24	3.0	0.065

A2 XP-RAFTS routing link parameters

Table A.3 - Adopted XP-RAFTS routing parameters

Link name	Upstream catchment	Downstream catchment	Link type (routing / lagging)	K	X
LAC001	AC001	JLR010	Routing	0.907	0.25
LAL001	AL001	JLR004	Lagging	0.000	0.00
LAL002	AL002	AL001	Routing	1.789	0.25
LAL003	AL003	AL002	Routing	3.483	0.25
LAL004	AL004	AL003	Routing	4.036	0.25
LAL005	AL005	AL004	Routing	3.443	0.25
LAL006	AL006	AL004	Lagging	0.000	0.00
LAL007	AL007	AL006	Routing	3.534	0.25
LAR001	AR001	JLR017	Routing	0.138	0.25
LAR002	AR002	AR001	Routing	0.473	0.25
LAR003	AR003	AR002	Routing	0.837	0.25
LAR004	AR004	AR003	Routing	0.637	0.25
LAR005	AR005	JAR011	Routing	0.344	0.25
LAR006	AR006	AR007	Routing	0.402	0.25
LAR007	AR007	AR005	Routing	0.310	0.25
LAR008_WLF	AR008_WLF	AR007	Routing	0.833	0.25
LAR009	AR009	AR008_WLF	Routing	0.624	0.25
LAR010	AR010	AR009	Routing	0.238	0.25
LAR011	AR011	JAR010	Routing	0.491	0.25
LAR012	AR012	JAR009	Routing	0.431	0.25
LAR013	AR013	AR012	Routing	0.562	0.25
LAR014	AR014	JAR007	Routing	0.167	0.25
LAR015	AR015	AR014	Routing	1.378	0.25
LAR016	AR016	JAR006	Routing	0.126	0.25
LAR017_BRM	AR017_BRM	AR016	Routing	0.743	0.25
LAR018	AR018	JAR004	Lagging	0.000	0.00
LAR019	AR019	JAR004	Routing	0.492	0.25
LAR020	AR020	AR019	Routing	2.000	0.25
LAR021	AR021	AR020	Routing	0.881	0.25
LAR022	AR022	AR021	Routing	0.845	0.25
LAR023	AR023	JAR003	Routing	0.469	0.25
LAR024	AR024	AR023	Routing	1.288	0.25
LAR025	AR025	AR024	Routing	0.984	0.25
LAR026	AR026	AR025	Routing	1.151	0.25
LAR027	AR027	JAR002	Routing	0.363	0.25
LAR028	AR028	JAR001	Lagging	0.000	0.00
LAR029	AR029	AR027	Routing	0.273	0.25
LAR030	AR030	AR029	Routing	2.278	0.25

Link name	Upstream catchment	Downstream catchment	Link type (routing / lagging)	K	X
LB001	B001	S001	Routing	1.989	0.25
LBACK001	BACK001	PC003	Lagging	0.000	0.00
LBG001	BG001	PC002	Lagging	0.000	0.00
LBID001	BID001	JCAN002	Lagging	0.000	0.00
LBID002	BID002	BID001	Routing	1.084	0.25
LBID003	BID003	BID002	Routing	0.557	0.25
LBRC001	BRC001	JTB001	Routing	0.950	0.25
LBURN001	BURN001	LR042	Routing	1.234	0.25
LBURN002	BURN002	BURN001	Routing	1.762	0.25
LBURN003	BURN003	BURN002	Routing	1.319	0.25
LBURN004	BURN004	BURN003	Routing	0.594	0.25
LBURN005	BURN005	BURN004	Routing	1.110	0.25
LBURN006_MD	BURN006_MD	BURN005	Routing	1.115	0.25
LBURN007	BURN007	BURN006_MD	Routing	0.891	0.25
LBURN008	BURN008	BURN007	Routing	0.948	0.25
LBURN009	BURN009	BURN008	Routing	1.581	0.25
LBURN010	BURN010	BURN009	Routing	0.744	0.25
LCAIN001	CAIN001	AR022	Lagging	0.000	0.00
LCAIN002	CAIN002	CAIN001	Routing	0.939	0.25
LCAIN003	CAIN003	CAIN002	Routing	1.273	0.25
LCAIN004	CAIN004	CAIN003	Routing	0.305	0.25
LCAMP001	CAMP001	RUN003	Lagging	0.000	0.00
LCAN001	CAN001	JAR005	Routing	0.580	0.25
LCAN002	CAN002	JCAN002	Lagging	0.000	0.00
LCAN003	CAN003	CAN002	Routing	1.283	0.25
LCAN004	CAN004	CAN003	Routing	1.163	0.25
LCAN005	CAN005	CAN004	Routing	1.500	0.25
LCAN006	CAN006	CAN005	Routing	1.465	0.25
LCAN007	CAN007	CAN006	Routing	1.215	0.25
LCAN008	CAN008	CAN007	Routing	1.364	0.25
LCAN009	CAN009	CAN008	Routing	0.992	0.25
LCAN010	CAN010	JCAN001	Lagging	0.000	0.00
LCAN011	CAN011	JCAN001	Lagging	0.000	0.00
LCANN001	CANN001	LR037_RM	Lagging	0.000	0.00
LCANN002	CANN002	CANN001	Routing	2.035	0.25
LCANN003	CANN003	CANN002	Routing	2.484	0.25
LCANN004	CANN004	CANN003	Routing	2.059	0.25
LCANN005	CANN005	CANN004	Routing	1.293	0.25
LCANN006	CANN006	CANN005	Routing	1.568	0.25
LCARN001	CARN001	TB018	Lagging	0.000	0.00
LCC001	CC001	JLR016	Routing	0.371	0.25
LCE001	CE001	JCE001	Routing	0.179	0.25

Link name	Upstream catchment	Downstream catchment	Link type (routing / lagging)	K	X
LCE002	CE002	CE001	Routing	1.278	0.25
LCE003	CE003	CE002	Routing	1.260	0.25
LCE004	CE004	JCE001	Routing	0.181	0.25
LCH001	CH001	LR015	Routing	0.810	0.25
LCH002	CH002	CH001	Routing	2.283	0.25
LCH003	CH003	JCH001	Routing	0.826	0.25
LCH004	CH004	JCH001	Routing	0.724	0.25
LCHI001	CHI001	JCHR001	Lagging	0.000	0.00
LCHR001	CHR001	JLR002	Lagging	0.000	0.00
LCHR002	CHR002	CHR001	Routing	1.522	0.25
LCHR003	CHR003	CHR002	Routing	1.529	0.25
LCHR004	CHR004	CHR003	Routing	1.940	0.25
LCHR005	CHR005	JCHR001	Routing	2.245	0.25
LCHR006	CHR006	CHR005	Routing	1.761	0.25
LCL001	CL001	JAR007	Routing	0.539	0.25
LCL002	CL002	CL001	Routing	0.395	0.25
LCOL001	COL001	JAR006	Routing	0.498	0.25
LCOL002	COL002	COL001	Routing	0.849	0.25
LCOL003	COL003	COL002	Routing	0.446	0.25
LCRON001	CRON001	LR046	Lagging	0.000	0.00
LCROW001	CROW001	JTB005	Lagging	0.000	0.00
LCROW002	CROW002	CROW001	Routing	2.050	0.25
LDC001	DC001	AR026	Lagging	0.000	0.00
LFC001	FC001	JLR009	Lagging	0.000	0.00
LFC002	FC002	FC001	Routing	1.870	0.25
LFC003	FC003	FC002	Routing	0.943	0.25
LFC004	FC004	JFC001	Routing	0.576	0.25
LFC005	FC005	JFC001	Routing	0.300	0.25
LFL001	FL001	AR018	Routing	0.711	0.25
LFL002	FL002	FL001	Routing	0.840	0.25
LFLGS001	FLGS001	JTB002	Lagging	0.000	0.00
LHC001	HC001	JJC001	Routing	1.207	0.25
LHC002	HC002	HC001	Routing	1.725	0.25
LHC003	HC003	HC002	Routing	0.540	0.25
LHC004	HC004	HC003	Routing	1.004	0.25
LHW001	HW001	JS001	Lagging	0.000	0.00
LJAR001	JAR001	AR029	Routing	1.448	0.25
LJAR002	JAR002	AR026	Routing	1.785	0.25
LJAR003	JAR003	AR022	Routing	0.518	0.25
LJAR004	JAR004	JAR005	Routing	0.808	0.25
LJAR005	JAR005	AR017_BRM	Routing	0.081	0.25
LJAR006	JAR006	AR015	Routing	0.611	0.25

Link name	Upstream catchment	Downstream catchment	Link type (routing / lagging)	K	X
LJAR007	JAR007	JAR008	Routing	0.288	0.25
LJAR008	JAR008	AR013	Routing	0.401	0.25
LJAR009	JAR009	AR011	Routing	0.249	0.25
LJAR010	JAR010	AR010	Routing	0.041	0.25
LJAR011	JAR011	AR004	Routing	0.748	0.25
LJC001	JC001	JLR008	Routing	0.099	0.25
LJC002	JC002	JJC002	Routing	1.306	0.25
LJC003	JC003	JC002	Routing	0.480	0.25
LJCAN001	JCAN001	CAN009	Routing	1.037	0.25
LJCAN002	JCAN002	CAN001	Routing	0.951	0.25
LJCE001	JCE001	JAR009	Routing	0.160	0.25
LJCH001	JCH001	CH002	Routing	0.040	0.25
LJCHR001	JCHR001	CHR004	Routing	1.106	0.25
LJFC001	JFC001	FC002	Routing	0.561	0.25
LJJC001	JJC001	JC001	Routing	0.378	0.25
LJJC002	JJC002	JJC001	Routing	0.210	0.25
LJLR001	JLR001	LR040	Routing	2.010	0.25
LJLR002	JLR002	LR038	Routing	0.389	0.25
LJLR003	JLR003	LR034	Routing	0.200	0.25
LJLR004	JLR004	JLR005	Routing	1.200	0.25
LJLR005	JLR005	LR031	Routing	0.250	0.25
LJLR006	JLR006	LR029	Routing	0.800	0.25
LJLR007	JLR007	LR028_YAR	Routing	0.300	0.25
LJLR008	JLR008	JLR009	Routing	1.271	0.25
LJLR009	JLR009	LR026	Routing	0.429	0.25
LJLR010	JLR010	JLR011	Routing	0.482	0.25
LJLR011	JLR011	LR023_MB	Routing	1.038	0.25
LJLR012	JLR012	LR014	Routing	0.805	0.25
LJLR013	JLR013	LR011	Routing	0.584	0.25
LJLR014	JLR014	LR007	Routing	2.003	0.25
LJLR015	JLR015	JLR016	Routing	0.503	0.25
LJLR016	JLR016	LR004	Routing	0.393	0.25
LJLR017	JLR017	LR003	Routing	0.196	0.25
LJRUN001	JRUN001	RUN001	Routing	1.465	0.25
LJS001	JS001	S002	Routing	1.360	0.25
LJSC001	JSC001	SC006	Routing	0.738	0.25
LJSC002	JSC002	SC003	Routing	0.437	0.25
LJSL001	JSL001	SL002	Routing	0.388	0.25
LJSPG001	JSPG001	SPG001	Routing	1.005	0.25
LJTB001	JTB001	TB014	Routing	0.756	0.25
LJTB002	JTB002	BRC001	Routing	0.240	0.25
LJTB003	JTB003	TB013	Routing	0.221	0.25

Link name	Upstream catchment	Downstream catchment	Link type (routing / lagging)	K	X
LJTB004	JTB004	TB011	Routing	0.280	0.25
LJTB005	JTB005	TB005_WD	Routing	0.503	0.25
LJTB006	JTB006	JTB007	Routing	0.492	0.25
LJTB007	JTB007	TB001	Routing	1.080	0.25
LKC001	KC001	JAR003	Lagging	0.000	0.00
LKN001	KN001	CANN002	Lagging	0.000	0.00
LKN002	KN002	KN001	Routing	2.230	0.25
LKN003	KN003	KN002	Routing	2.407	0.25
LLR001	LR001	S001	Routing	1.181	0.25
LLR002	LR002	LR001	Routing	1.248	0.25
LLR003	LR003	LR002	Routing	1.715	0.25
LLR004	LR004	JLR017	Routing	1.329	0.25
LLR005	LR005	JLR015	Lagging	0.000	0.00
LLR006	LR006	JLR015	Routing	1.229	0.25
LLR007	LR007	LR006	Routing	0.484	0.25
LLR008	LR008	JLR014	Lagging	0.000	0.00
LLR009_WAT	LR009_WAT	LR008	Routing	1.599	0.25
LLR010	LR010	LR009_WAT	Routing	1.481	0.25
LLR011	LR011	LR010	Routing	0.360	0.25
LLR012	LR012	JLR013	Routing	0.621	0.25
LLR013	LR013	LR012	Lagging	0.000	0.00
LLR014	LR014	JLR013	Routing	2.007	0.25
LLR015	LR015	JLR012	Routing	0.286	0.25
LLR016_LV	LR016_LV	LR015	Routing	1.506	0.25
LLR017	LR017	LR016_LV	Routing	0.668	0.25
LLR018	LR018	LR017	Routing	0.406	0.25
LLR019	LR019	LR018	Lagging	0.000	0.00
LLR020	LR020	LR019	Routing	1.354	0.25
LLR021	LR021	LR020	Routing	0.854	0.25
LLR022	LR022	LR021	Routing	1.723	0.25
LLR023_MB	LR023_MB	LR022	Routing	1.185	0.25
LLR024	LR024	JLR011	Routing	0.880	0.25
LLR025	LR025	LR024	Routing	1.026	0.25
LLR026	LR026	JLR010	Routing	1.160	0.25
LLR027	LR027	JLR008	Routing	1.919	0.25
LLR028_YAR	LR028_YAR	LR027	Routing	1.076	0.25
LLR029	LR029	JLR007	Routing	1.500	0.25
LLR030	LR030	JLR006	Routing	2.000	0.25
LLR031	LR031	LR030	Routing	1.000	0.25
LLR032	LR032	JLR005	Routing	1.322	0.25
LLR033	LR033	JLR004	Lagging	0.000	0.00
LLR034	LR034	LR033	Routing	2.000	0.25

Link name	Upstream catchment	Downstream catchment	Link type (routing / lagging)	K	X
LLR035	LR035	JLR003	Routing	3.000	0.25
LLR036	LR036	LR035	Routing	2.946	0.25
LLR037_RM	LR037_RM	LR036	Routing	1.814	0.25
LLR038	LR038	LR037_RM	Routing	2.269	0.25
LLR039	LR039	JLR002	Routing	1.337	0.25
LLR040	LR040	LR039	Routing	1.381	0.25
LLR041	LR041	JLR001	Routing	1.223	0.25
LLR042	LR042	LR041	Routing	2.018	0.25
LLR043	LR043	BURN001	Lagging	0.000	0.00
LLR044	LR044	LR043	Routing	1.623	0.25
LLR045	LR045	LR044	Routing	0.760	0.25
LLR046	LR046	LR045	Routing	1.763	0.25
LMBC001	MBC001	LR044	Lagging	0.000	0.00
LMBC002	MBC002	MBC001	Routing	0.904	0.25
LMBC003	MBC003	MBC002	Routing	1.269	0.25
LMBC004	MBC004	MBC003	Routing	1.427	0.25
LMC001	MC001	JAR001	Lagging	0.000	0.00
LNC001	NC001	LR020	Lagging	0.000	0.00
LNC002	NC002	NC001	Routing	1.817	0.25
LND001	ND001	LR002	Routing	0.652	0.25
LND002	ND002	ND001	Routing	0.378	0.25
LND003	ND003	ND002	Routing	2.502	0.25
LNYC001	NYC001	JRUN001	Lagging	0.000	0.00
LOAK001	OAK001	LR039	Lagging	0.000	0.00
LOAK002	OAK002	OAK001	Routing	1.518	0.25
LOAK003	OAK003	OAK002	Routing	0.447	0.25
LOO001	OO001	JLR012	Routing	1.069	0.25
LPC001	PC001	LR041	Lagging	0.000	0.00
LPC002	PC002	PC001	Routing	1.356	0.25
LPC003	PC003	PC002	Routing	2.185	0.25
LPC004	PC004	PC003	Routing	1.498	0.25
LQC001	QC001	LR015	Routing	1.148	0.25
LQC002	QC002	QC001	Routing	0.812	0.25
LQC003	QC003	QC002	Lagging	0.000	0.00
LQC004	QC004	QC003	Routing	1.515	0.25
LQC005	QC005	QC004	Routing	0.711	0.25
LRC001	RC001	JAR010	Routing	0.093	0.25
LRC002	RC002	RC001	Routing	0.599	0.25
LRUN001	RUN001	JLR001	Lagging	0.000	0.00
LRUN002	RUN002	JRUN001	Lagging	0.000	0.00
LRUN003	RUN003	RUN002	Routing	1.504	0.25
LRUN004	RUN004	RUN003	Routing	2.133	0.25

Link name	Upstream catchment	Downstream catchment	Link type (routing / lagging)	K	X
LRUN005	RUN005	RUN004	Routing	2.475	0.25
LRUN006	RUN006	RUN005	Routing	2.255	0.25
LS002	S002	S001	Routing	1.732	0.25
LS003	S003	JS001	Lagging	0.000	0.00
LSA001	SA001	AR013	Routing	0.246	0.25
LSALT001	SALT001	JTB004	Lagging	0.000	0.00
LSAN001	SAN001	LR035	Lagging	0.000	0.00
LSAN002	SAN002	SAN001	Routing	3.381	0.25
LSAN003	SAN003	SAN002	Routing	0.846	0.25
LSAND001	SAND001	JTB002	Lagging	0.000	0.00
LSAND002	SAND002	SAND001	Routing	3.571	0.25
LSC001	SC001	JSL001	Lagging	0.000	0.00
LSC002	SC002	SC001	Routing	0.949	0.25
LSC003	SC003	SC002	Routing	1.209	0.25
LSC004	SC004	SC003	Routing	0.026	0.25
LSC005	SC005	JSC002	Routing	0.273	0.25
LSC006	SC006	JSC002	Routing	0.453	0.25
LSC007	SC007	JSC001	Routing	0.074	0.25
LSC008	SC008	JSC001	Routing	0.231	0.25
LSC009	SC009	JSC002	Routing	0.091	0.25
LSCR001	SCR001	JLR007	Routing	1.373	0.25
LSL001	SL001	JLR014	Routing	0.046	0.25
LSL002	SL002	SL001	Routing	0.477	0.25
LSL003	SL003	JSL001	Lagging	0.000	0.00
LSL004	SL004	SL003	Routing	0.646	0.25
LSL005	SL005	SL004	Routing	0.538	0.25
LSPG001	SPG001	JLR003	Lagging	0.000	0.00
LSPG002	SPG002	JSPG001	Routing	2.284	0.25
LSPG003	SPG003	JSPG001	Lagging	0.000	0.00
LSPR001	SPR001	AR024	Lagging	0.000	0.00
LSSC001	SSC001	SAN003	Lagging	0.000	0.00
LST001	ST001	JJC002	Routing	0.756	0.25
LSTE001	STE001	JAR008	Routing	0.413	0.25
LSTO001	STO001	JAR002	Lagging	0.000	0.00
LTB001	TB001	JLR006	Lagging	0.000	0.00
LTB002	TB002	JTB006	Routing	0.718	0.25
LTB003	TB003	TB002	Routing	0.184	0.25
LTB004	TB004	TB003	Routing	1.321	0.25
LTB005_WD	TB005_WD	TB004	Routing	1.008	0.25
LTB006_OF	TB006_OF	JTB005	Routing	1.477	0.25
LTB007	TB007	TB006_OF	Routing	1.704	0.25
LTB008	TB008	TB007	Routing	1.690	0.25

Link name	Upstream catchment	Downstream catchment	Link type (routing / lagging)	K	X
LTB009	TB009	TB008	Routing	1.530	0.25
LTB010	TB010	TB009	Routing	1.099	0.25
LTB011	TB011	TB010	Routing	1.531	0.25
LTB012	TB012	JTB004	Routing	1.730	0.25
LTB013	TB013	TB012	Routing	0.495	0.25
LTB014	TB014	JTB003	Routing	1.066	0.25
LTB015	TB015	JTB001	Routing	0.173	0.25
LTB016	TB016	TB015	Routing	0.901	0.25
LTB017	TB017	TB016	Routing	3.158	0.25
LTB018	TB018	TB017	Routing	1.718	0.25
LTB019	TB019	TB018	Routing	1.617	0.25
LUND001	UND001	WOOL002	Lagging	0.000	0.00
LUND002	UND002	UND001	Routing	1.766	0.25
LWALL001	WALL001	JTB003	Lagging	0.000	0.00
LWC001	WC001	JAR011	Routing	0.043	0.25
LWC002	WC002	WC001	Routing	0.565	0.25
LWFC001	WFC001	BURN005	Lagging	0.000	0.00
LWID001	WID001	CHR004	Lagging	0.000	0.00
LWID002	WID002	WID001	Routing	2.779	0.25
LWOOL001	WOOL001	JTB006	Routing	1.172	0.25
LWOOL002	WOOL002	WOOL001	Routing	0.570	0.25
LWOOL003	WOOL003	WOOL002	Routing	0.407	0.25
LWOOL004	WOOL004	WOOL003	Routing	1.399	0.25
LWOOL005	WOOL005	WOOL004	Routing	1.148	0.25
LWP001	WP001	WOOL004	Lagging	0.000	0.00
LWYR001	WYR001	JTB007	Lagging	0.000	0.00

Appendix B - TUFLOW model configuration

B1 Hydraulic roughness maps

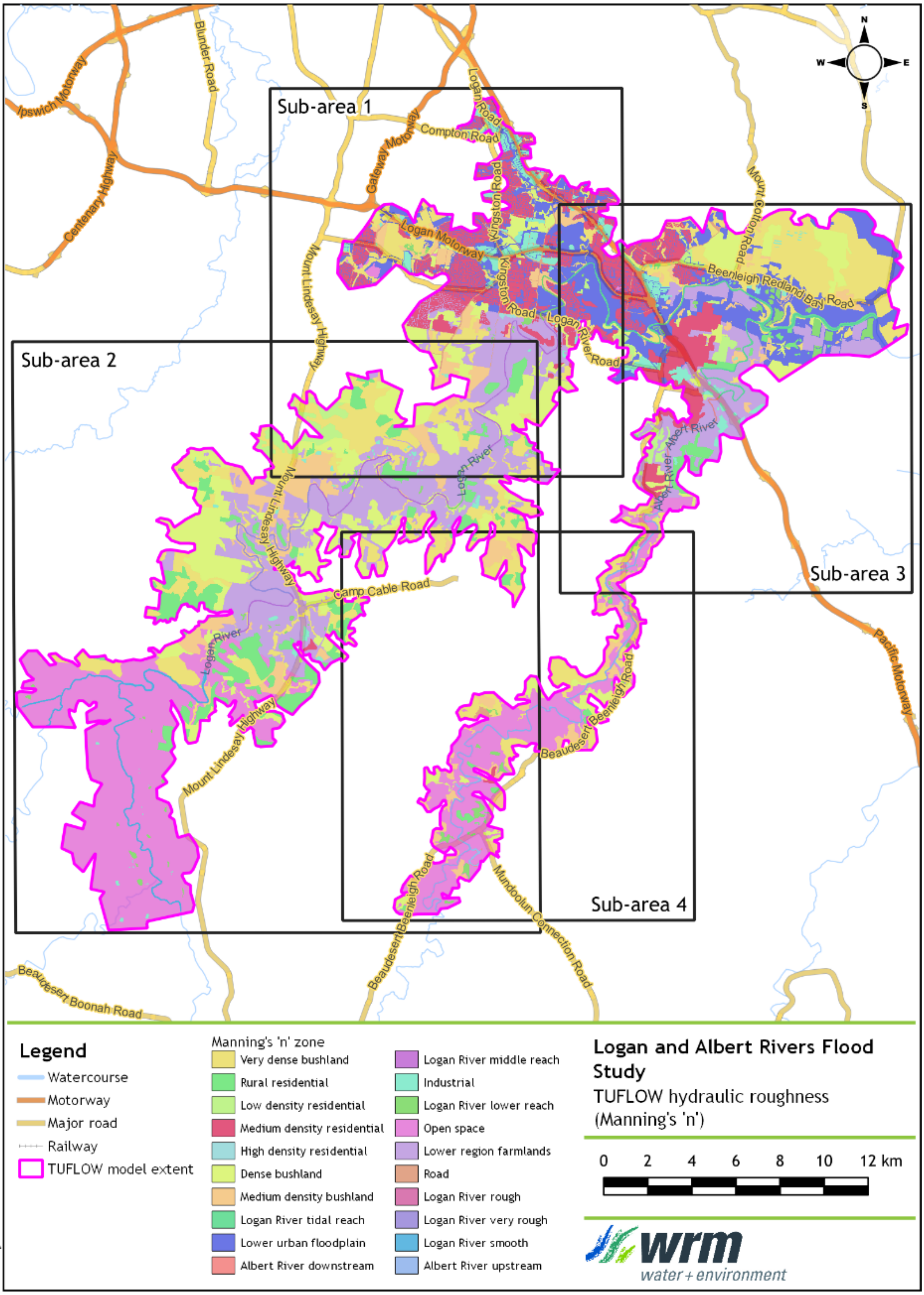

Figure B.1 – Distribution of hydraulic roughness (Manning's 'n') values (total extent)

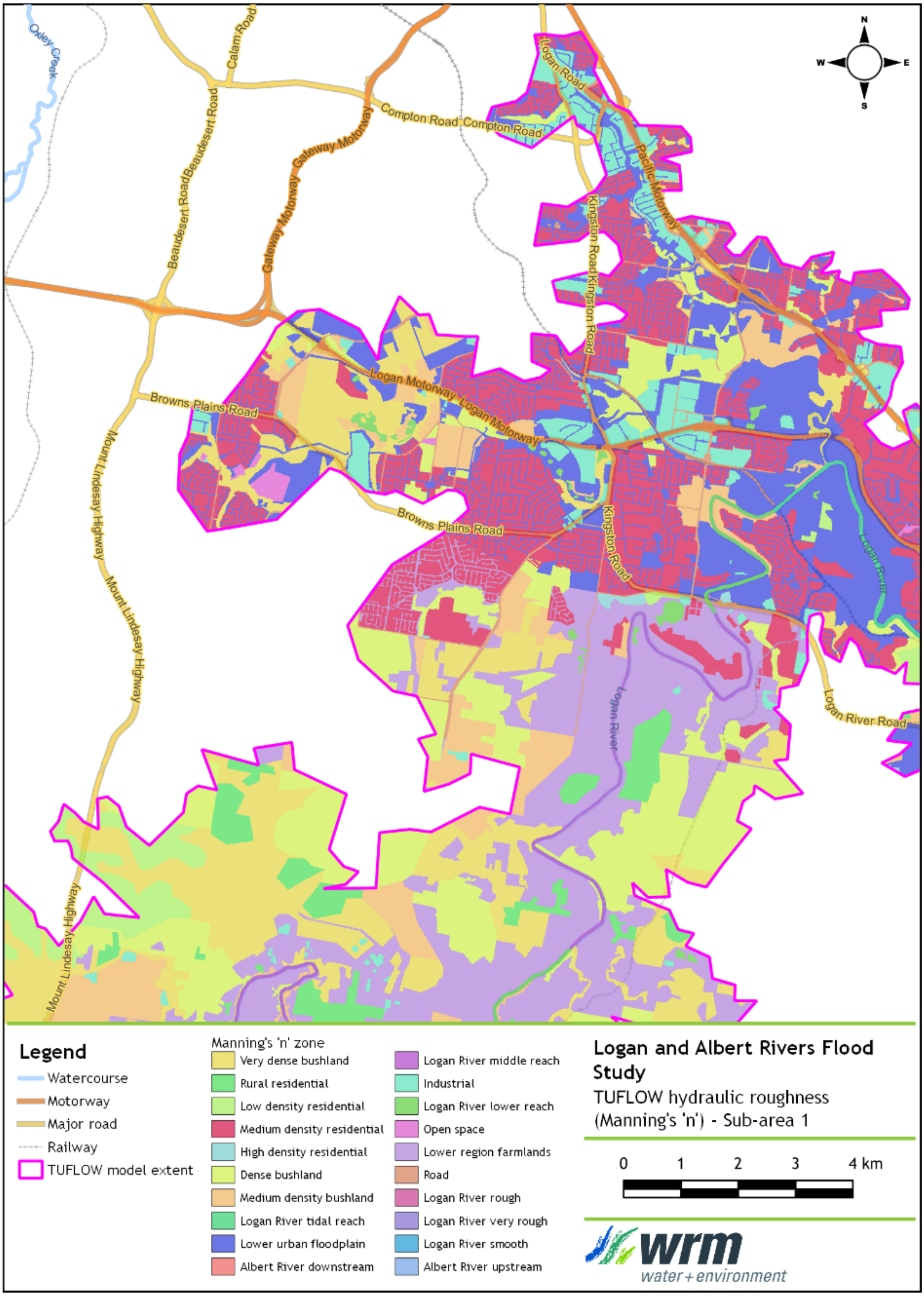

Figure B.2 – Distribution of hydraulic roughness (Manning's 'n') values (Sub-area 1)

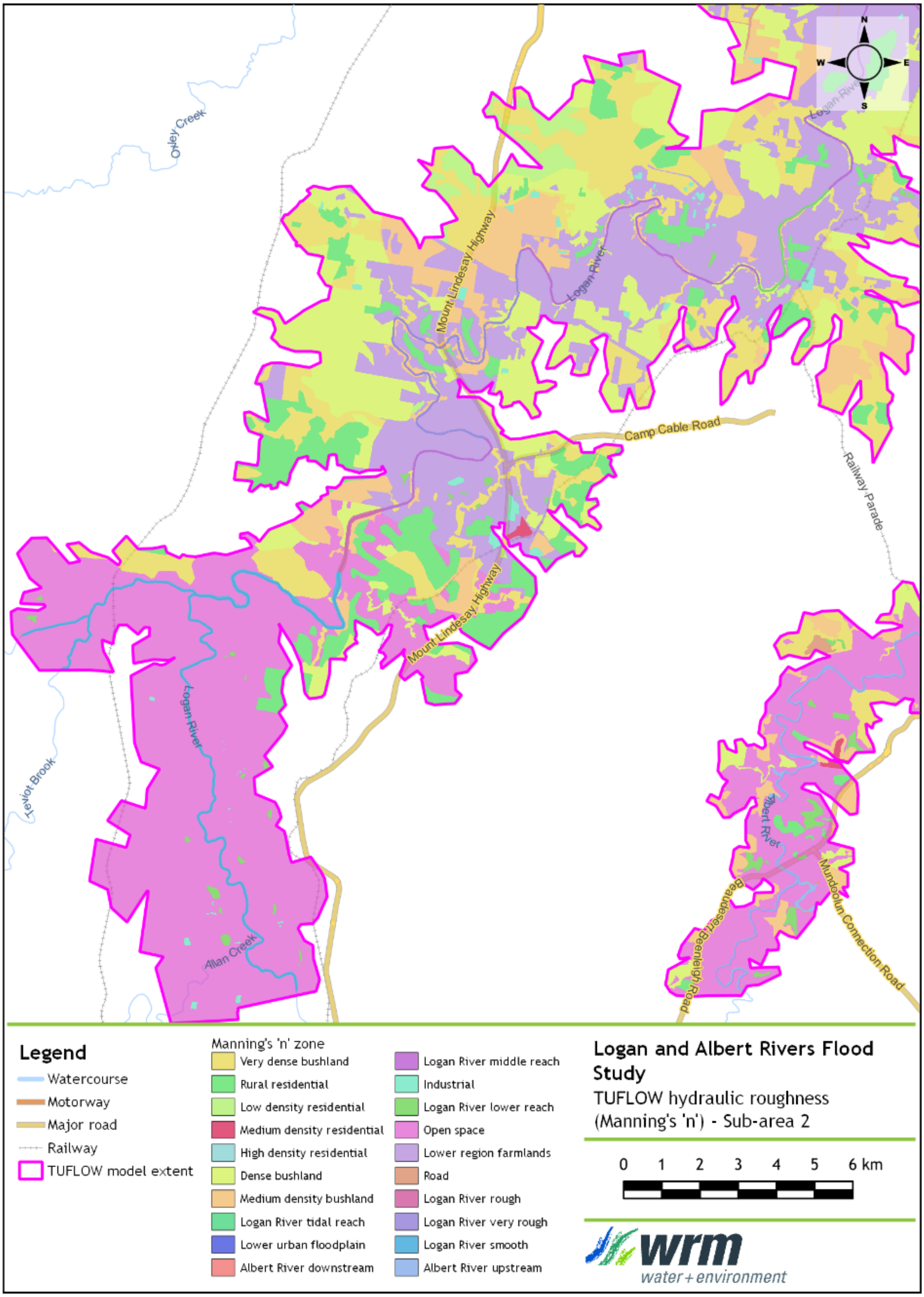

Figure B.3 – Distribution of hydraulic roughness (Manning's 'n') values (Sub-area 2)

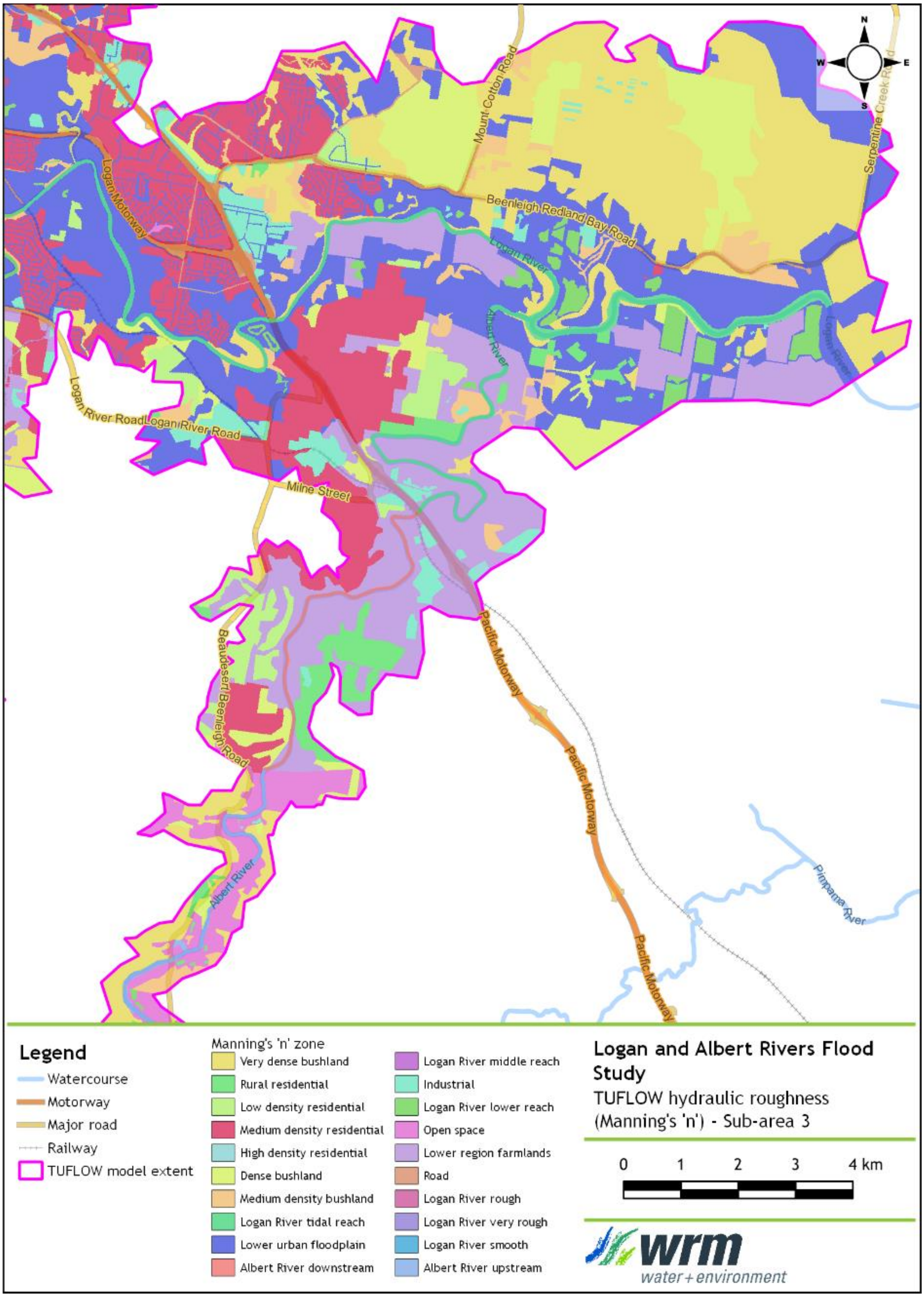

Figure B.4 – Distribution of hydraulic roughness (Manning's 'n') values (Sub-area 3)

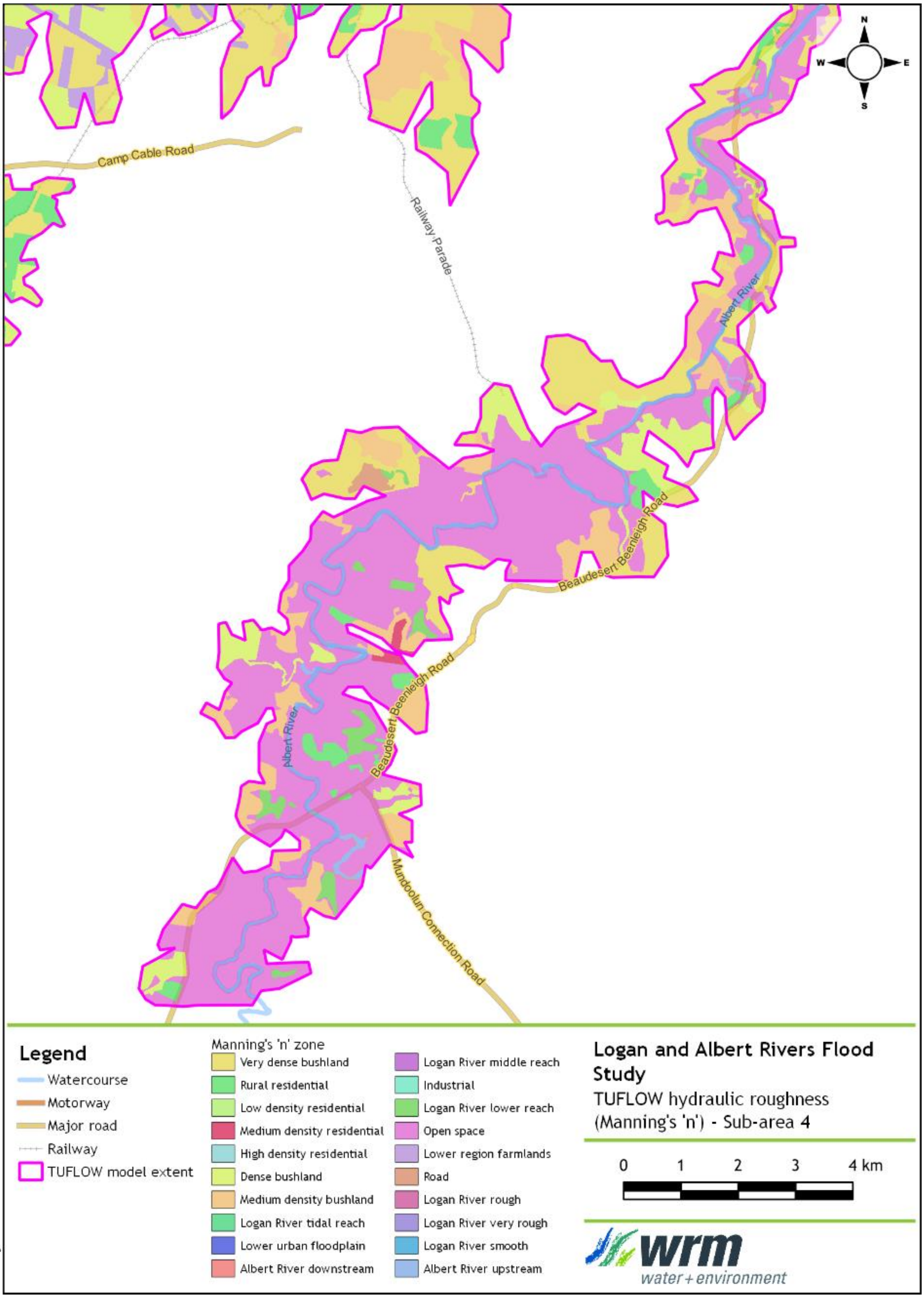

Figure B.5 – Distribution of hydraulic roughness (Manning's 'n') values (Sub-area 4)

B2 Hydraulic structure locations and details

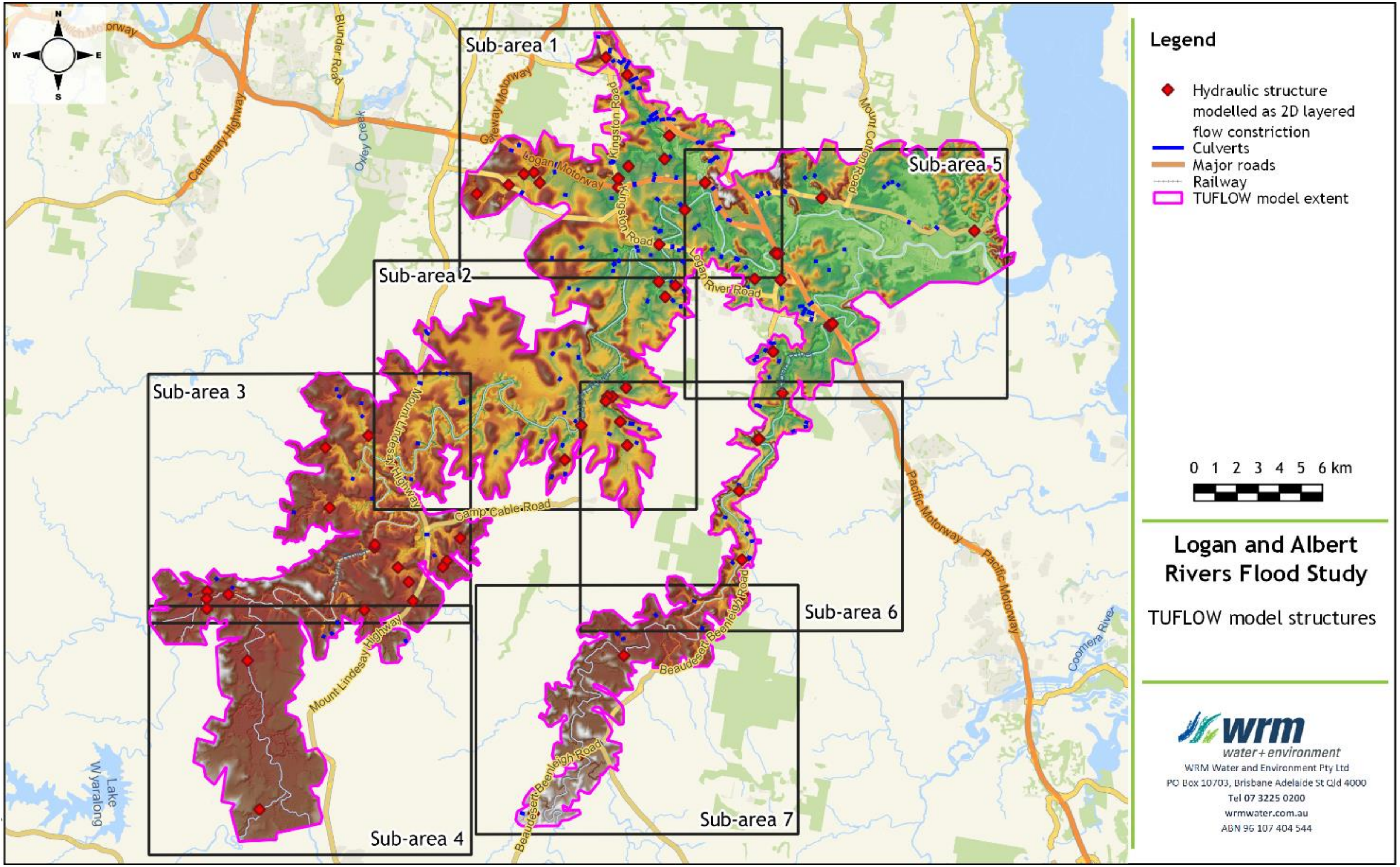

Figure B.6 – Locations of hydraulic structures in the hydraulic model (general figure)

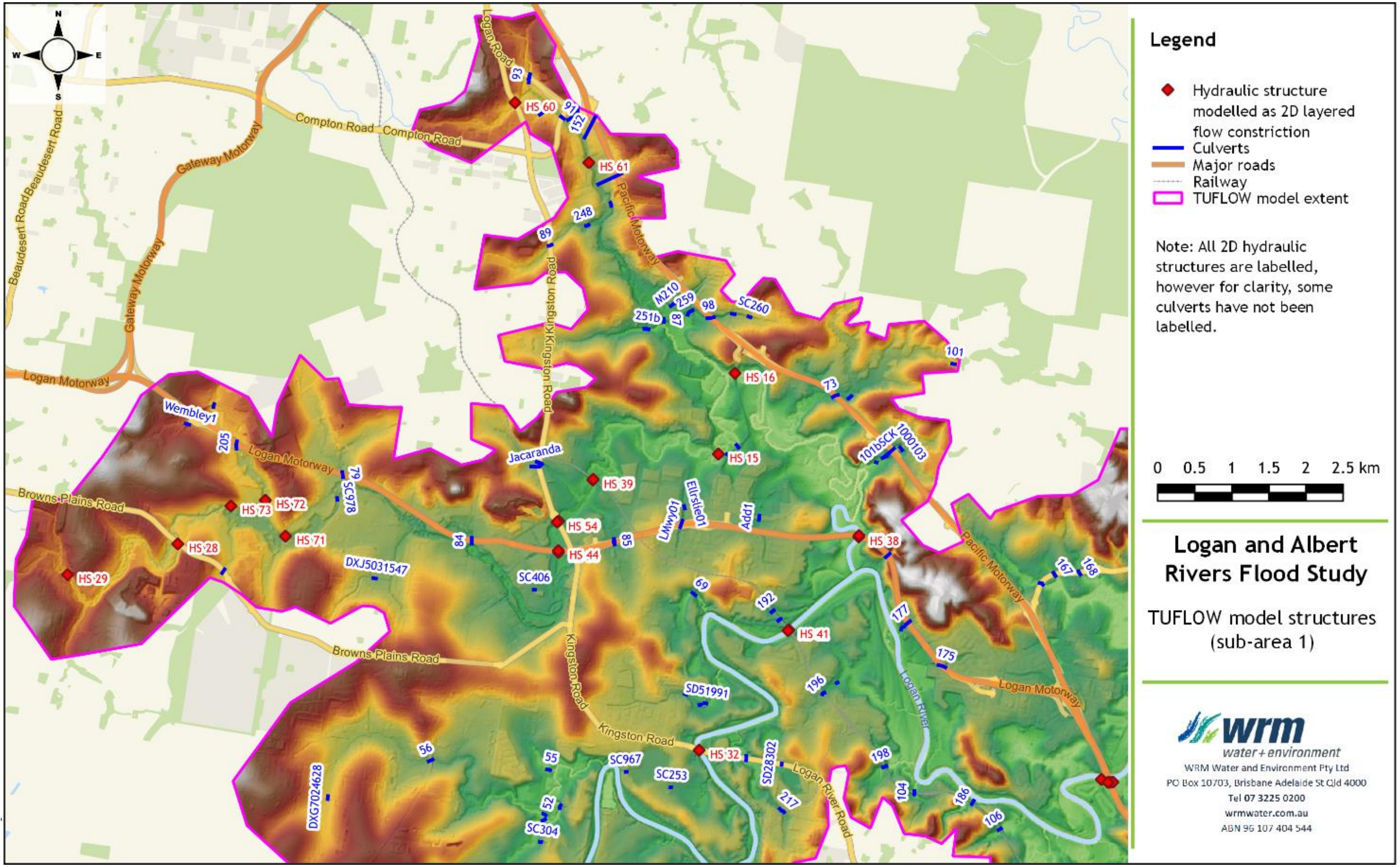

Figure B.7 – Locations of hydraulic structures in the hydraulic model (sub-area 1)

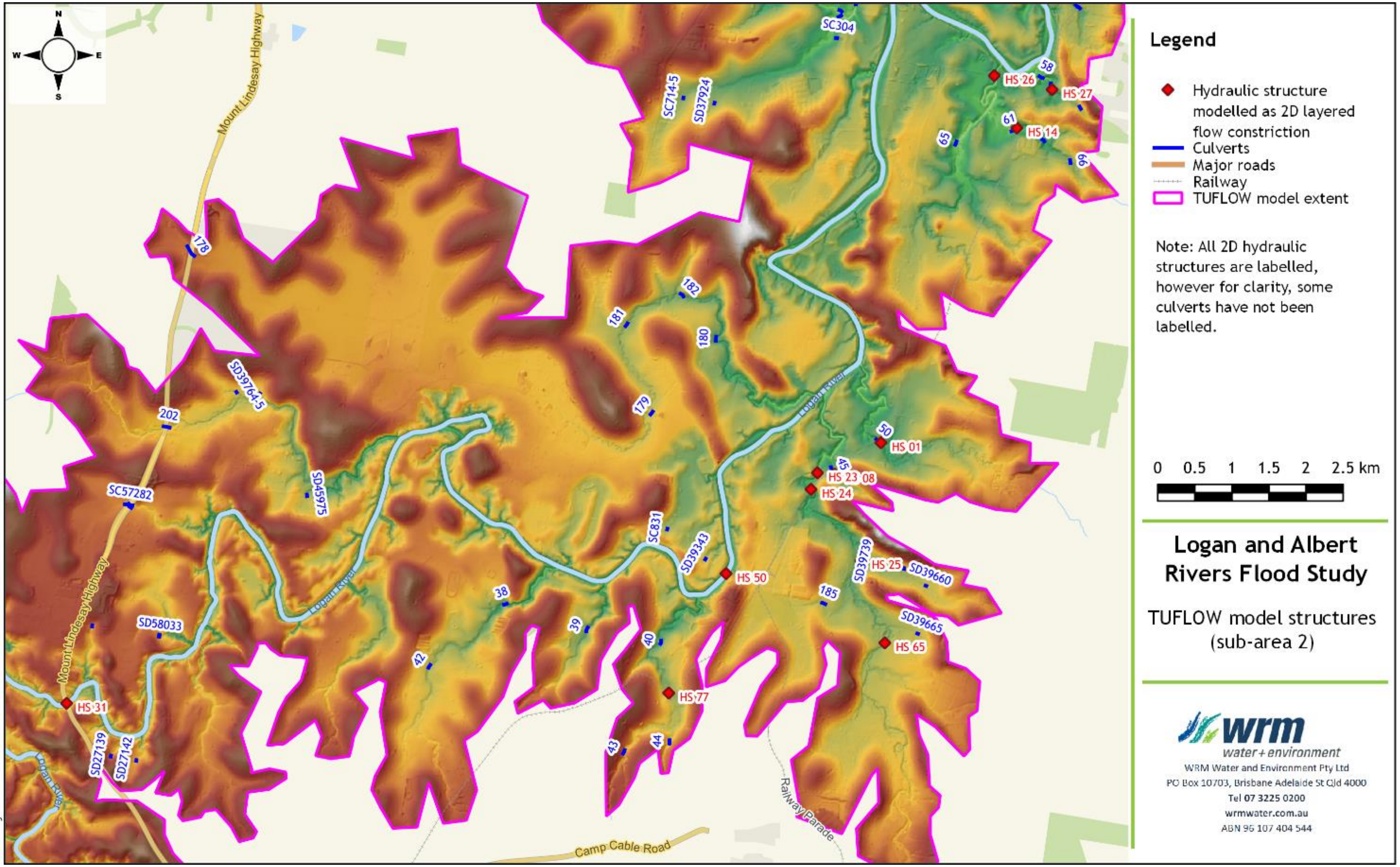

Figure B.8 – Locations of hydraulic structures in the hydraulic model (sub-area 2)

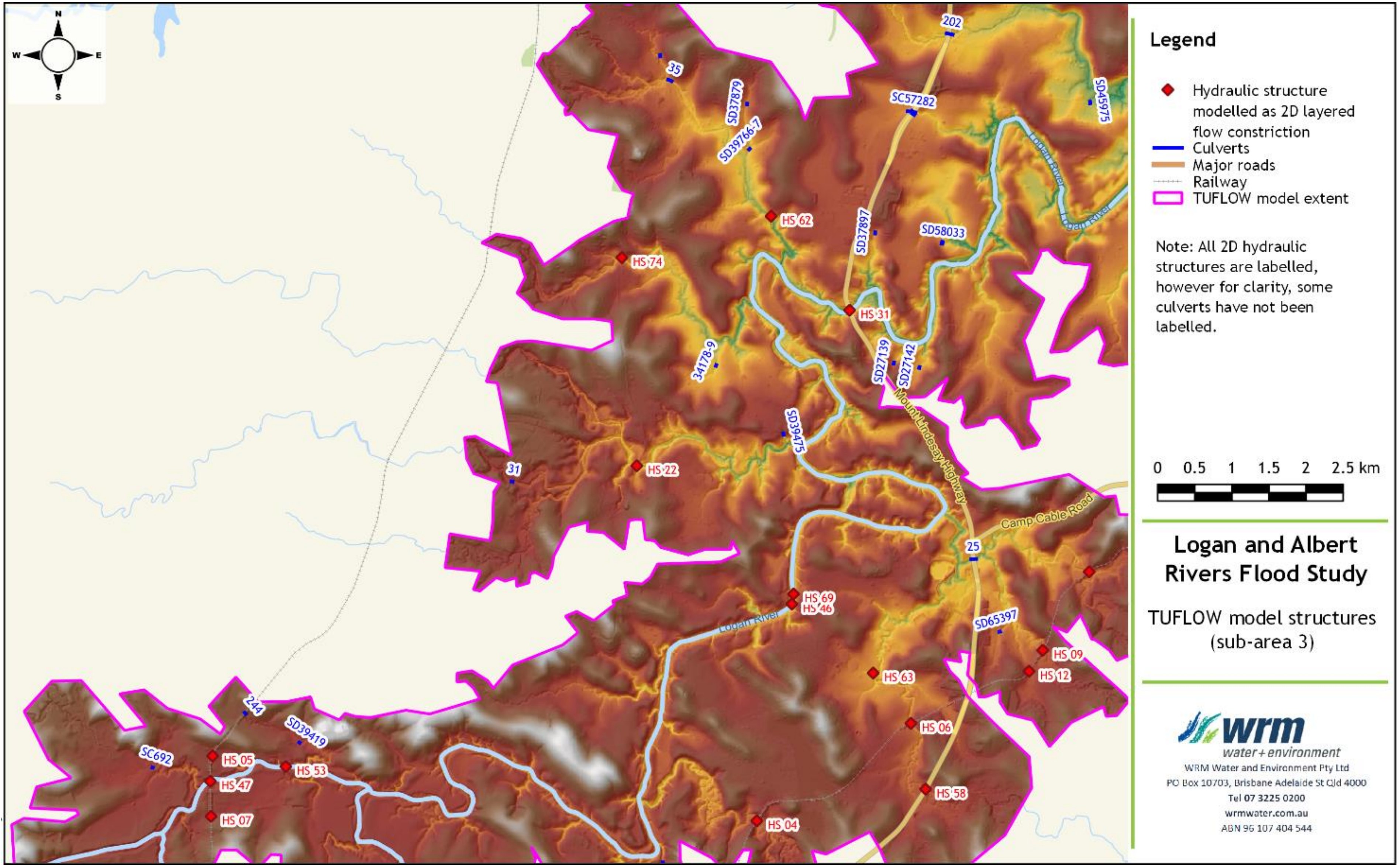

Figure B.9 – Locations of hydraulic structures in the hydraulic model (sub-area 3)

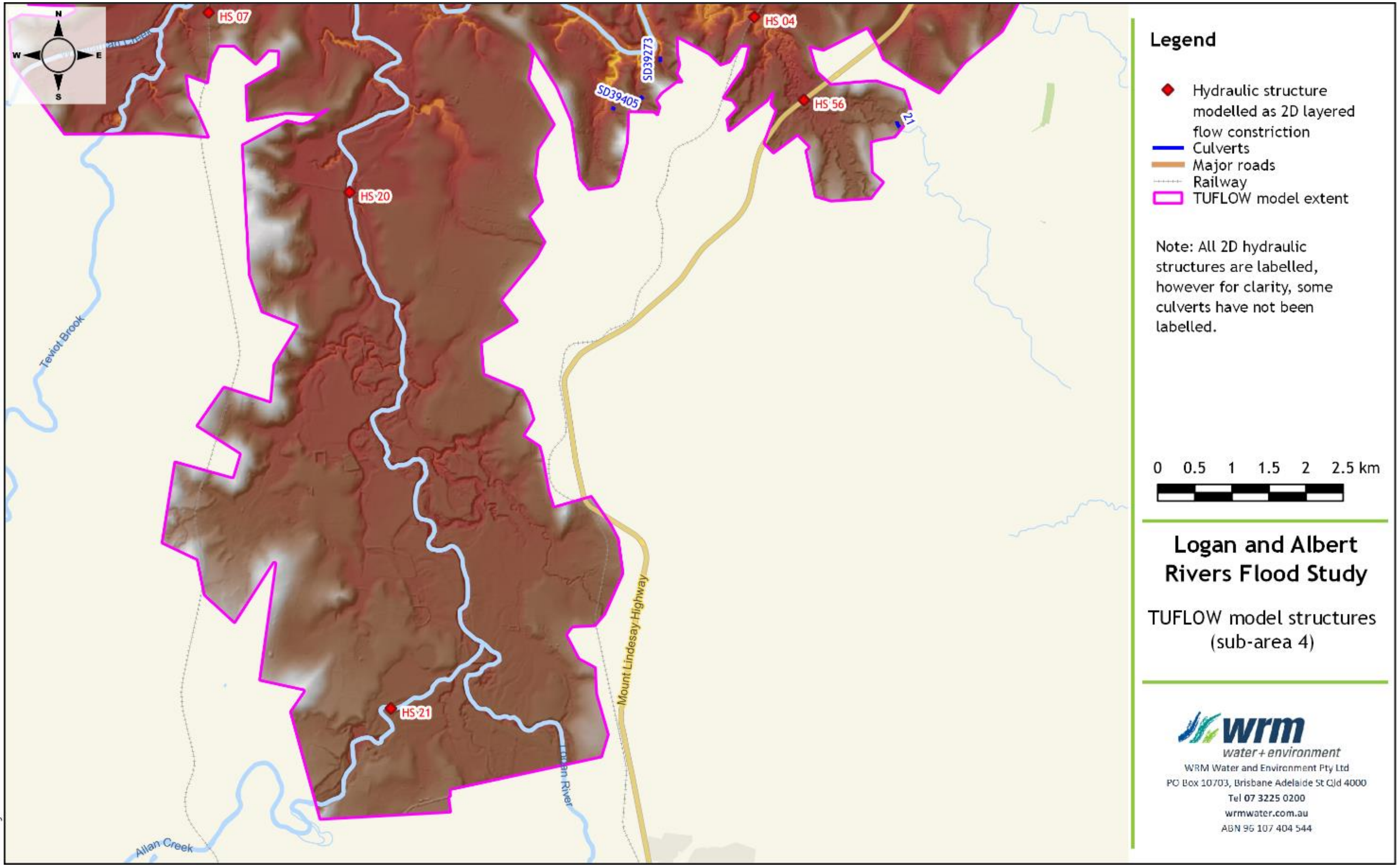

Figure B.10 – Locations of hydraulic structures in the hydraulic model (sub-area 4)

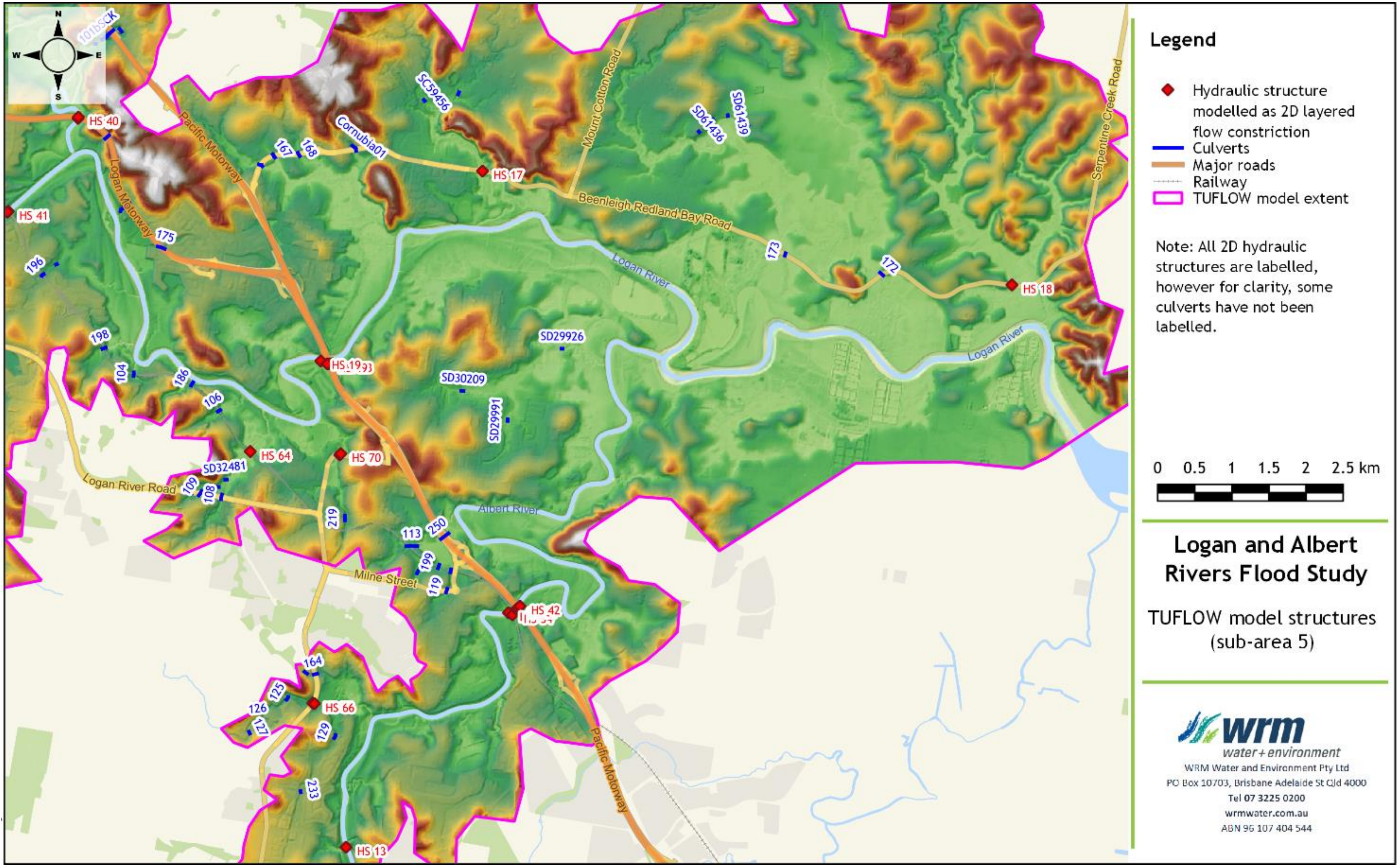

Figure B.11 – Locations of hydraulic structures in the hydraulic model (sub-area 5)

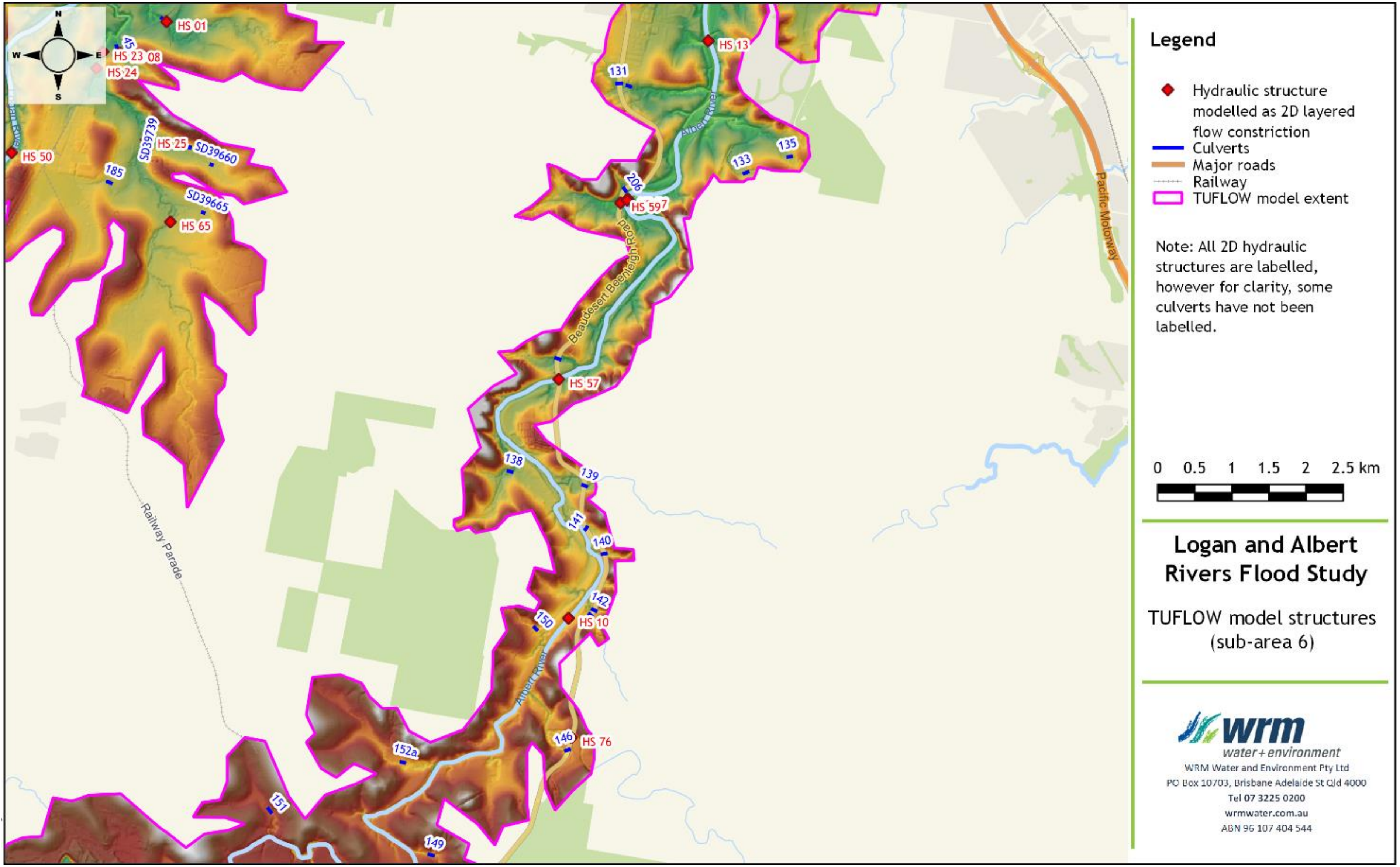

Figure B.12 – Locations of hydraulic structures in the hydraulic model (sub-area 6)

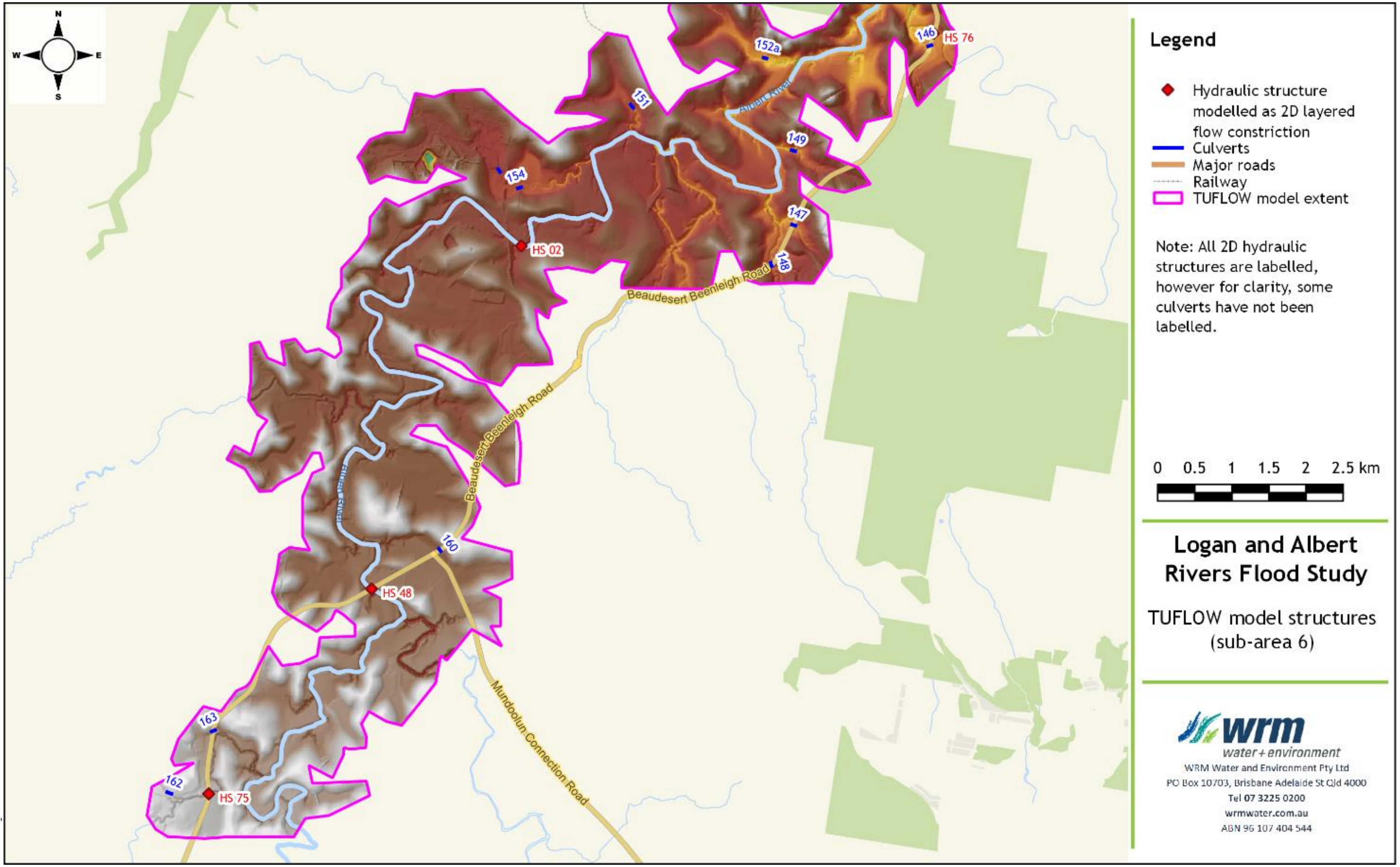

Figure B.13 – Locations of hydraulic structures in the hydraulic model (sub-area 7)

Table B.1 - Configuration of culverts in the hydraulic model

Structure ID	Easting	Northing	Culvert type	Width / diameter (m)	Height (m)	Length (m)	No. of barrels	U/S invert level (mAHD)	D/S invert level (mAHD)	Present in events
21	501,879	6,918,282	RCP	1.65	0	12.3	4	40.33	40.28	2022, 2017, 2013 & 1990
25	502,868	6,923,260	RCP	5.35	0	53.5	2	11.15	11.1	All
31	496,644	6,924,305	RCBC	3.6	3.6	15	2	25.292	25.192	2022,2017 & 2013
35	498,773	6,929,713	RCP	1.8	0	14.9	6	19.4	19.23	All
36	504,570	6,929,475	RCP	1.2	0	9.85	5	6.89	6.74	All
38	507,114	6,927,947	RCP	1.52	0	16	4	6.26	5.97	All
39	508,211	6,927,608	RCP	1.83	0	14.87	2	8.67	8.53	All
40	509,211	6,927,434	RCBC	2.73	2.45	8.6	2	7.78	7.61	All
42	506,086	6,927,111	RCP	1.4	0	11.7	2	12.61	12.4	All
43	508,712	6,925,957	RCP	1.37	0	14.4	4	19.36	19.21	All
44	509,326	6,926,092	RCP	1.37	0	12.27	1	17.83	17.67	All
45	511,508	6,929,774	RCP	1.5	0	18.5	2	5.96	5.86	All
50	512,127	6,930,161	RCP	3.5	0	33	2	4.2	4	All
52	511,840	6,936,053	RCP	1.83	0	9.56	2	0.98	0.88	All
53	511,622	6,935,873	RCP	2.7	0	14	9	1.44	1.38	All
54	511,633	6,935,949	RCP	2.7	0	14	9	1.44	1.38	All
55	511,686	6,936,552	RCP	2.1	0	14.7	3	1.57	1.49	All
56	510,096	6,936,677	RCBC	3.32	2.1	12	7	8.96	8.93	All
58	514,337	6,935,050	RCP	1.65	0	46.27	3	2	1.9	2022, 2017, 2013 & 1990
59	514,465	6,934,953	RCP	1.5	0	9.2	2	3.09	2.97	All
61	513,956	6,934,330	RCP	1.6	0	12	2	2.56	2.34	All
63	514,369	6,934,200	RCBC	3.6	1.4	20.7	1	6.4	6.3	2022, 2017, 2013 & 1990
64	514,862	6,934,639	RCP	1.8	1.5	20	2	14.77	14.22	2022, 2017, 2013 & 1990
65	513,188	6,934,163	RCP	0.6	0	9.8	3	2.04	1.85	2022, 2017, 2013 & 1990
66	514,731	6,933,914	RCBC	2.43	1.22	8.6	1	10.85	10.82	All
68	514,352	6,936,709	RCP	2.25	0	65	6	2.5	2.4	2022, 2017 & 2013
69	513,646	6,938,919	RCP	1.35	0	42.7	6	2.72	2.5	2022, 2017, 2013 & 1990
73	515,551	6,941,592	RCBC	2.4	2.16	55.4	6	5.57	5.29	All
79	508,910	6,940,529	RCBC	3.6	2.7	60.5	5	9.963	9.66	2022, 2017, 2013 & 1990
80	507,301	6,939,227	RCBC	2.7	1.5	40	5	16.52	16.32	All
84	510,650	6,939,638	RCP	1.2	0	61.5	4	6.824	6.44	2022, 2017, 2013 & 1990
85	512,567	6,939,623	RCBC	1.8	0.75	53.5	5	8.415	8.051	2022, 2017, 2013 & 1990
86	511,556	6,940,685	RCBC	2.85	2	50.81	1	7.077	7.076	All
87	513,243	6,942,607	RCBC	2.4	2.4	24	3	3.5	3	2022, 2017, 2013 & 1990
88	512,528	6,944,171	RCBC	3.7	3.7	23	3	7.178	6.982	2022, 2017, 2013 & 1990
89	511,707	6,943,618	RCBC	2.4	1.2	25	5	13.5	13	All
91	511,872	6,945,341	RCBC	3.05	3.735	31.8	7	10.62	10.59	2022, 2017, 2013 & 1990
93	511,428	6,945,892	RCBC	2.4	2.1	69	2	16.5	16	All
93	511,428	6,945,892	RCBC	3.05	2.5	69	2	16.397	16.019	All
94	512,512	6,944,514	RCP	1.65	0	341.9	3	14.35	12.01	All
98	513,870	6,942,641	RCP	1.8	0	72	4	6.78	5.83	All
99	513,561	6,942,964	RCP	1.8	0	57	4	6.85	6.54	All
100	515,749	6,941,571	RCBC	2.1	0.9	21.7	4	7.042	6.844	All
101	517,148	6,942,020	RCP	1.8	0	20.3	2	16.5	16	All
103	516,218	6,936,592	RCP	1.2	0	32	1	1.736	1.503	All
104	516,620	6,936,242	RCP	1.8	0	28	3	1.682	1.56	2022, 2017, 2013 & 1990
105	517,308	6,936,160	RCP	1.8	0	26	2	1.25	1.1	All
106	517,768	6,935,748	RCBC	2.43	2.43	27.4	1	1.47	1.4	All
108	517,800	6,934,588	RCBC	3	2.4	26	2	3	2.9	2022, 2017, 2013 & 1990
109	517,516	6,934,637	RCP	1.85	0	64	4	4.77	2.51	2022, 2017, 2013 & 1990
113	520,368	6,933,927	RCP	1.65	0	64	6	1.38	1.06	2022, 2017, 2013 & 1990
114	520,536	6,933,764	RCP	1.5	0	58	5	1.25	1.134	2022, 2017 & 2013
119	520,837	6,933,325	RCBC	2.4	2.4	31.6	3	3.5	3.4	All
122	520,446	6,933,574	RCP	1.8	0	18.6	1	2.38	2.28	All
125	518,691	6,931,871	RCBC	3.6	2.4	12.9	6	6.42	6.35	2022, 2017 & 2013

Structure ID	Easting	Northing	Culvert type	Width / diameter (m)	Height (m)	Length (m)	No. of barrels	U/S invert level (mAHD)	D/S invert level (mAHD)	Present in events
126	518,302	6,931,569	RCBC	0.6	0.375	10.1	6	8.15	8.12	2022, 2017 & 2013
127	518,178	6,931,411	RCP	0.675	0	9.8	3	10.83	10.78	2022, 2017, 2013 & 1990
129	519,333	6,931,356	RCP	1.2	0	32	4	6.1	6	2022, 2017, 2013 & 1990
130	518,410	6,929,255	RCP	2.1	0	17.3	4	8.05	7.92	2022, 2017, 2013 & 1990
131	518,278	6,929,291	RCBC	2.1	1.2	42.6	4	9.5	9	All
133	519,989	6,928,089	RCBC	1.2	0.9	13.4	4	13.37	13.31	All
135	520,578	6,928,305	RCP	1.2	0	35.9	5	13.99	13.19	All
137	517,452	6,925,581	RCP	1.95	0	21.6	5	6.42	6.29	All
138	516,808	6,924,062	RCP	1.35	0	13	4	8.5	8	All
139	517,813	6,923,870	RCBC	3	2.7	13.5	3	10.67	10.64	All
140	518,077	6,922,952	RCP	2.7	0	21.6	2	11.97	11.86	All
141	517,834	6,923,295	RCP	1.5	0	19.45	1	11.69	11.14	All
142	517,942	6,922,192	RCBC	2.1	2.17	33.1	3	15.12	14.95	2022, 2017, 2013 & 1990
143	517,896	6,922,123	RCBC	2.4	2.5	40.5	5	14.62	14.43	2022, 2017, 2013 & 1990
146	517,582	6,920,307	RCBC	2.63	3.1	20.8	3	18.95	18.88	All
147	515,748	6,917,889	RCBC	2.75	2.2	28.95	5	20.75	20.35	All
148	515,443	6,917,358	RCBC	2.1	1.28	14.45	5	25.52	25.5	All
149	515,744	6,918,892	RCP	1.5	0	24.7	2	18.8	18.07	2022, 2017, 2013 & 1990
150	517,153	6,921,944	RCP	1.2	0	9.76	6	17.35	17.2	All
151	513,566	6,919,492	RCP	1.2	0	10.5	5	24.5	24	All
152	512,244	6,945,211	RCP	1.5	0	305	2	17.97	16.83	2022, 2017 & 2013
154	512,050	6,918,392	RCBC	3.03	1.2	8.55	5	24.89	24.85	All
155	511,776	6,918,624	RCP	0.525	0	6	2	27.5	27	All
160	510,976	6,913,510	RCP	2.1	0	40	3	38.5	38.45	2022, 2017 & 2013
162	507,329	6,910,234	RCP	1.35	0	12.3	2	52.19	51.96	All
163	507,923	6,911,072	RCP	1.5	0	11.3	2	44.31	44.26	All
164	519,069	6,932,199	RCP	1.25	0	23.3	1	6.92	6.48	All
165	518,938	6,932,218	RCP	0.975	0	17.2	4	12.19	11.29	2022, 2017 & 2013
166	518,331	6,939,059	RCBC	2.7	2.1	38.35	5	1.91	1.759	2022, 2017 & 2013
167	518,508	6,939,185	RCP	1.35	0	39.002	3	1.759	1.151	2022, 2017 & 2013
168	518,842	6,939,204	RCP	1.8	0	33.053	5	2.372	2.2	2022, 2017 & 2013
172	526,702	6,937,592	RCP	1.5	0	19.75	4	0.26	0.13	All
173	525,402	6,937,856	RCBC	2.135	2.19	12.23	7	0.39	0.24	All
175	516,990	6,937,949	RCBC	2.4	1.5	53.1	2	8.8	8.5	2022, 2017, 2013 & 1990
176	516,535	6,938,532	RCBC	2.4	2.4	40.5	1	7.251	5.72	2022, 2017, 2013 & 1990
177	516,533	6,938,534	RCP	1.05	0	54	2	5.051	4.806	2022, 2017, 2013 & 1990
178	502,866	6,932,703	RCBC	3	0.5	0	7	24.28	23.72	All
179	509,085	6,930,524	RCBC	2.4	1.3	13.5	7	14.08	14.01	All
180	509,954	6,931,527	RCBC	2.6	0.9	9.9	1	6.76	6.65	All
181	508,747	6,931,715	RCBC	3	1.85	12.3	3	10.22	10.09	All
182	509,498	6,932,116	RCBC	2.6	1.6	16	2	9.05	9.01	2022, 2017, 2013 & 1990
183	502,045	6,929,291	RCBC	2.078	1.52	18	4	20.51	20.48	All
185	511,405	6,927,959	RCP	1.65	0	9.9	4	13.82	13.72	All
186	517,405	6,936,112	RCP	0.6	0	12.2	2	6.4	6.35	All
192	514,715	6,938,693	RCBC	3	2.7	7.2	1	5.61	5.54	All
193	514,808	6,938,577	RCBC	3	3	7.2	1	5.96	5.88	All
196	515,387	6,937,583	RCP	1.35	0	17.6	4	7.088	6.912	2022, 2017, 2013 & 1990
197	515,389	6,937,581	RCP	0.75	0	21.4	1	6.234	5.977	2022, 2017, 2013 & 1990
198	516,219	6,936,592	RCBC	4.3	4.3	13	1	2.627	2.5	All
199	520,729	6,933,650	RCP	0.75	0	30	3	2.633	2.513	2022, 2017 & 2013
200	520,892	6,933,592	RCP	2.1	0	24	5	1.83	1.782	2022, 2017 & 2013
204	507,478	6,940,898	RCBC	3	3	17.5	6	14.464	14.464	2022, 2017, 2013 & 1990
205	507,480	6,940,948	RCBC	3	3	50	6	14.464	14.464	2022, 2017, 2013 & 1990
206	518,355	6,927,860	RCP	1.65	0	32	2	4.71	4.39	2022, 2017, 2013 & 1990
208	513,527	6,942,931	RCP	1.8	0	10.98	5	6.396	6.286	2022, 2017, 2013 & 1990
209	513,485	6,942,918	RCBC	1.8	1.8	14.173	5	5.873	5.809	2022, 2017, 2013 & 1990
210	513,448	6,942,900	RCBC	1.5	0.9	18	11	5.695	5.5	2022, 2017 & 2013

Structure ID	Easting	Northing	Culvert type	Width / diameter (m)	Height (m)	Length (m)	No. of barrels	U/S invert level (mAHD)	D/S invert level (mAHD)	Present in events
211	513,423	6,942,637	RCBC	3.3	2.7	24	6	4	3.9	2022, 2017, 2013 & 1990
217	514,819	6,936,009	RCBC	3	3.08	10	5	7.7	7.6	2022, 2017 & 2013
219	519,467	6,934,302	RCP	1.8	0	30	3	4.5	4.4	All
223	507,172	6,941,461	RCP	1.85	0	17.5	8	17.66	17.6	2022, 2017 & 2013
225	516,260	6,939,439	RCBC	3	3.3	61.5	1	15.94	12.66	2022, 2017, 2013 & 1990
226	516,452	6,938,463	RCP	0.675	0	12.7	1	4.5	4	2022, 2017, 2013 & 1990
227	513,006	6,942,491	RCBC	3.1	1.5	23.78	2	3.593	3.578	2022, 2017, 2013 & 1990
233	518,869	6,930,615	RCP	1.65	0	18.4	3	8.85	8.82	2022, 2017 & 2013
240	514,792	6,938,567	RCBC	3.05	3.05	7.2	1	6.04	5.96	All
241	514,699	6,938,681	RCBC	3.05	2.74	7.2	1	5.68	5.61	All
245	511,583	6,945,390	RCBC	3.6	1.2	21	1	15.7	15.5	2022, 2017, 2013 & 1990
246	512,013	6,945,357	RCBC	3.6	3	163	1	14.4	11.65	2022, 2017 & 2013
247	512,079	6,945,434	RCBC	3.6	3.6	26.9	1	14.5	14.4	2022, 2017 & 2013
248	512,209	6,943,886	RCBC	1.8	1.2	14	4	8.376	8.28	2022, 2017 & 2013
249	517,375	6,934,653	RCBC	1.2	0.75	29	4	6.5	6.4	2022, 2017, 2013 & 1990
250	520,811	6,934,058	RCBC	2.4	1.8	142	9	1.5	1.22	All
252	510,871	6,946,514	RCBC	2.1	2.1	35.4	3	27.5	27	All
256	511,421	6,945,838	RCBC	3.45	3.51	12	3	13.98	13.96	2022, 2017 & 2013
258	513,573	6,942,706	RCBC	2.1	2.1	12.1	4	3.854	3.794	2022, 2017, 2013 & 1990
259	513,608	6,942,734	RCBC	2.1	2.1	17.3	4	4.2	4.005	2022, 2017 & 2013
264	520,613	6,928,507	RCP	1.2	0	31.2	5	13.59	12.91	All
1000103	516,441	6,940,878	RCP	1.8	0	50.57	4	5.084	4.865	2022, 2017 & 2013
10000101	516,105	6,940,695	RCP	1.2	0	6	2	1.39	1.35	2017 & 2013
10000103	516,314	6,940,854	RCP	1.8	0	72.29	3	4.6	3.538	2017 & 2013
11000102	516,235	6,940,788	RCP	2.75	2.3	117.2	2	3.411	3.35	2017 & 2013
101bSCK	516,240	6,940,783	RCBC	2.5	2.6	117.2	1	3.411	3.35	2017 & 2013
152a	515,361	6,920,141	RCP	0.9	0	7	1	21.5	21	2017, 2013 & 1990
251b	513,006	6,942,494	RCBC	3.1	1.7	23.78	1	3.593	3.578	2017, 2013 & 1990
34178-9	499,395	6,925,868	RCP	1.05	0	9.75	2	16.24	16.15	All
85bb	512,574	6,939,624	RCBC	1.8	1	53.5	4	8.415	8.051	2017, 2013 & 1990
86bb	511,558	6,940,692	RCBC	2.75	1.8	50.81	2	7.077	7.076	All
94B	512,787	6,944,113	RCP	1.8	0	341.9	3	17	16	All
Add1	514,526	6,939,947	RCP	2.1	0	41.2	3	7.5	7.2	2017, 2013 & 1990
BRBRd01	519,614	6,939,269	RCP	1.5	0	33	3	4.1	3.36	2022, 2017 & 2013
Cornubia01	519,589	6,939,303	RCP	1.462	0	55	3	5.4	4.1	2022, 2017 & 2013
DXG7024628	508,709	6,936,176	RCBC	1.2	0.9	13.73	4	17.3	17	2017, 2013 & 1990
DXJ5031547	509,341	6,939,131	RCBC	2.1	1.5	15.161	8	10.85	10.8	2017, 2013 & 1990
Ellrslie01	513,518	6,940,090	RCBC	2.1	2.1	28	3	6.938	6.893	2022, 2017 & 2013
Jacaranda	511,530	6,940,640	RCP	1.05	0	-1	1	7.8	6.85	2022, 2017 & 2013
LMwy01	513,476	6,939,864	RCP	1.65	0	90	6	8.08	7.91	2022, 2017 & 2013
M210	513,387	6,942,844	RCP	1.8	0	149	9	4.6	4.15	2022, 2017 & 2013
SC1054	520,998	6,940,028	RCBC	3	1.8	32.5	3	3.25	3.12	2017 & 2013
SC223	513,536	6,937,568	RCBC	3	1.5	27.35	3	7.63	7.43	2022, 2017 & 2013
SC253	513,334	6,936,315	RCBC	0.6	0.375	4.88	1	9.2	9.03	2022, 2017 & 2013
SC260	514,395	6,942,655	RCBC	2.4	0.9	30	9	11.6	11.5	2022, 2017 & 2013
SC298	511,577	6,935,578	RCBC	1.2	0.6	12	1	7.11	7.05	2022, 2017 & 2013
SC304	511,577	6,935,578	RCBC	1.2	0.6	14.88	1	7.11	7.05	2022, 2017 & 2013
SC406	511,494	6,938,978	RCBC	0.75	0.3	18.5	2	8.86	8.67	2022, 2017 & 2013
SC57282	502,032	6,929,287	RCBC	2.1	1.8	103.7	4	20.85	20.3	2022, 2017 & 2013
SC59456	520,536	6,939,932	RCBC	2.7	2.1	18.22	2	2.54	2.48	2022, 2017 & 2013
SC599	503,801	6,930,783	RCBC	1.2	0.6	9	1	16.54	15.8	All
SC692	491,798	6,920,449	RCBC	1.2	0.9	5	4	26.82	26.54	2022, 2017 & 2013
SC714-5	509,512	6,934,771	RCBC	1.2	0.6	12	2	12.18	12.13	All
SC831	509,295	6,928,960	RCBC	0.9	0.45	10.98	3	13.55	13.5	2022, 2017 & 2013
SC879	498,641	6,930,044	RCBC	2.1	1.8	14.4	3	21.7	21.6	2022, 2017 & 2013
SC967	512,732	6,936,523	RCBC	2.1	1.5	13.42	1	10.02	9.64	2022, 2017 & 2013
SC978	508,836	6,940,200	RCBC	2.7	2.1	18	3	9.74	9.7	2022, 2017 & 2013
SD18333	518,843	6,939,205	RCP	1.5	0	13.69	3	1.5	1.5	2022, 2017 , 2013 & 1990
SD18334	518,504	6,939,189	RCP	1.35	0	18.28	2	1.35	1.35	All
SD18335	518,323	6,939,066	RCP	1.5	0	16.23	2	1.9	1.9	2022, 2017 , 2013 & 1990
SD19473	514,176	6,942,694	RCP	1.8	0	25	4	9.25	8.9	2022, 2017 , 2013 & 1990

Structure ID	Easting	Northing	Culvert type	Width / diameter (m)	Height (m)	Length (m)	No. of barrels	U/S invert level (mAHD)	D/S invert level (mAHD)	Present in events
SD19939	514,108	6,940,790	RCP	1.5	0	48.58	1	2.587	2.543	2022, 2017 & 2013
SD19941	514,235	6,940,911	RCP	1.4	0	27.61	1	2.554	1.879	2022, 2017 & 2013
SD27139	501,793	6,925,901	RCP	0.75	0	15.47	1	23.18	22.52	2022, 2017 & 2013
SD27142	502,136	6,925,841	RCP	0.75	0	11.55	3	19.95	19.83	2022, 2017 & 2013
SD28297	514,649	6,936,550	RCP	1.5	0	13	2	3.23	3.29	2022, 2017 & 2013
SD28302	514,829	6,936,625	RCP	0.675	0	16.6	1	10.04	10.03	2022, 2017 & 2013
SD28360	515,578	6,937,722	RCP	1.2	0	14	1	6.13	5.65	2022, 2017 , 2013 & 1990
SD29925	522,393	6,936,584	RCP	0.825	0	11	2	0.92	0.91	2022, 2017 & 2013
SD29926	522,393	6,936,584	RCP	0.6	0	11	3	0.92	0.91	2022, 2017 & 2013
SD29991	521,659	6,935,622	RCP	0.9	0	20	6	3.6	3.6	2022, 2017 , 2013 & 1990
SD30209	521,050	6,936,016	RCP	0.9	0	32.4	6	2.8	2.34	All
SD32478	517,757	6,934,720	RCP	1.35	0	15.7	2	3.94	2.07	All
SD32481	517,862	6,934,820	RCP	1.35	0	20.1	1	3.42	2.58	2022, 2017 , 2013 & 1990
SD37879	499,813	6,929,393	RCP	1.35	0	10	2	22.77	22.72	2022, 2017 , 2013 & 1990
SD37897	501,541	6,927,656	RCP	0.825	0	16	1	22.46	21.72	All
SD37924	509,932	6,934,701	RCP	0.6	0	13	1	12.88	12.45	All
SD39273	498,678	6,919,160	RCP	1.2	0	24	3	24.32	23.83	2022, 2017 , 2013 & 1990
SD39343	509,811	6,928,556	RCP	0.825	0	12.2	1	15.15	14.92	2022, 2017 & 2013
SD39402	498,426	6,918,642	RCP	1.2	0	11	3	32.68	31.02	2022, 2017 , 2013 & 1990
SD39405	498,043	6,918,499	RCP	0.9	0	11	2	31.92	30.83	2022, 2017 , 2013 & 1990
SD39419	493,779	6,920,785	RCP	0.9	0	8	3	28.25	27.78	2022, 2017 , 2013 & 1990
SD39475	500,304	6,924,943	RCP	0.825	0	18	1	24.92	22.77	2022, 2017 , 2013 & 1990
SD39660	512,784	6,928,196	RCP	1.2	0	10	5	14.49	14.45	2022, 2017 , 2013 & 1990
SD39665	512,672	6,927,551	RCP	0.9	0	10	4	14.61	14.61	2022, 2017 , 2013 & 1990
SD39737	512,489	6,928,429	RCP	1.2	0	15	1	16.36	16.04	2022, 2017 , 2013 & 1990
SD39738	512,369	6,928,444	RCP	0.75	0	26	1	15.31	14.61	2022, 2017 , 2013 & 1990
SD39739	512,099	6,928,501	RCP	0.75	0	20	1	12.03	11.71	2022, 2017 , 2013 & 1990
SD39764-5	503,487	6,930,806	RCP	1.2	0	11	2	15.52	15.33	All
SD39766-7	499,845	6,928,785	RCP	1.5	0	12	2	16.98	15.47	All
SD45975	504,438	6,929,414	RCP	1.5	0	29.33	1	11.58	11.21	2022 & 2017
SD51988	513,724	6,937,424	RCP	0.225	0	9.91	1	6.38	6.31	2022 & 2017
SD51989	513,735	6,937,427	RCP	0.225	0	10.99	1	6.3	6.27	2022 & 2017
SD51991	513,802	6,937,446	RCP	0.525	0	27.46	12	4.91	4.29	2022 & 2017
SD57233	502,054	6,929,255	RCP	0.825	0	25.79	1	20.78	20.39	All
SD58031	502,447	6,927,536	RCP	0.75	0	7.49	2	20.33	19.61	2022, 2017 , 2013 & 1990
SD58033	502,441	6,927,510	RCP	0.75	0	10.62	2	20.86	20.62	2022, 2017 , 2013 & 1990
SD61436	524,240	6,939,509	RCP	0.375	0	11.75	1	7.33	7.28	2022 & 2017
SD61437	524,432	6,939,671	RCP	0.45	0	12.66	2	5.22	5.12	2022 & 2017
SD61439	524,628	6,939,727	RCP	0.525	0	12.68	1	5.12	3.22	2022 & 2017
SD61440	524,899	6,939,588	RCP	0.525	0	11.66	1	6.17	6.06	2022 & 2017
SD65397	503,219	6,922,281	RCP	1.5	0	10	2	36.5	36.3	2022, 2017 , 2013 & 1990
SD6847	512,678	6,936,704	RCP	1.05	0	16.93	1	8.76	8.44	2022, 2017 , 2013 & 1990
Wembley1	506,817	6,941,210	RCBC	3	3	30	3	22.95	22.75	2022, 2017 , 2013 & 1990

Table B.2 - Configuration of bridges in the hydraulic model

Structure ID	Watercourse	Road	Length (m)	Width (m) [a]	Road deck level (mAHD)	Deck thickness (m)	Pier configuration [b]	Comments	Present in events
HS 01	Ooah Ck	Railway Line	119.37	< 10	9.12	1.03	Unknown		All
HS 02	Albert River	Albert River Pl	39.04	< 10	27.5	0.6	Unknown	Unknown Data - From Aerials	All
HS 03	Albert River	Martens St	102.37	11.2	5.9	1.9	Unknown		All
HS 04	Scrubby Ck	Railway Line	153	< 10	30.82	1.03	Unknown		All
HS 05	Unknown tributary	Railway Line	64.26	< 10	35.2	1	Unknown	Unknown Data - From Aerials	All
HS 06	Henderson Ck	Railway Line	87.29	< 10	26.47	1.03	Unknown		All
HS 07	Unknown tributary	Railway Line	60.89	< 10	34.86	1	Unknown		All
HS 08	Unknown tributary	Railway Line - Waterford-Tamborine Rd	38.61	< 10	11.27	1.03	Unknown		All
HS 09	Strachans Ck	Railway Line	49.5	< 10	28.67	1.03	Unknown		All
HS 10	Albert River	Chardon Bridge Rd	39.29	< 10	16.78	0.65	Unknown		All
HS 11	Jimboomba Ck	Railway Line	84.3	< 10	27.57	1.03	Unknown		All
HS 12	Unknown tributary	Ann Street	28	< 10	27.3	0.6	Unknown		All
HS 13	Albert River	Carter Park footpath	129.33	< 10	6.97	0.6	Unknown		2022, 2017, 2013 & 1990
HS 14	Cambogan Ck	Railway Line	78.09	< 10	7.7	0.64	Unknown		2022, 2017 & 2013
HS 15	Scrubby Ck	Queens Rd	123.13	< 10	6.09	0.91	Unknown		2022, 2017, 2013 & 1990
HS 16	Slacks Ck	Loganlea Rd	170.42	20	7.55	0.75	Unknown		2022, 2017, 2013 & 1990
HS 17	California Ck	Beenleigh Redland Bay Rd	68.43	< 10	5.72	1.03	Unknown		All
HS 18	Serpentine Ck	Beenleigh Redland Bay Rd	30.11	< 10	2	1.03	Unknown		All
HS 19	Logan River	Railway Line	244.65	< 10	9	1	Unknown		All
HS 20	Logan River	Undullah Rd	77.23	< 10	30.55	1.2	Unknown		All
HS 21	Allan Ck	Allan Creek Rd	68.03	< 10	39	1	Unknown		All
HS 22	Flagstone Ck	Teviot Rd	61.96	< 10	23.59	0.96	Unknown		All
HS 23	Quinzeh Ck	Waterford-Tamboring Rd	54.4	< 10	8.38	0.7	Unknown		All
HS 24	Quinzeh Ck	Railway line	46.11	< 10	10.97	1.03	Unknown		All
HS 25	Quinzeh Ck	Miller Rd Bridge	34.42	< 10	9.273	1.05	None		All
HS 26	Dairy Ck	Waterford-Tamboring Rd	42.45	< 10	6.89	0.76	Unknown		All
HS 27	Unknown tributary	Railway Line	37.82	< 10	8.47	1.03	Unknown		2022, 2017, 2013 & 1990
HS 28	Scrubby Ck	Browns Plains Rd	45.89	23.4	18.75	1.45	Unknown		2022, 2017, 2013 & 1990
HS 29	Scrubby Ck	Waller Rd	65.32	16.5	23.005	1.38	Unknown		All
HS 30	Scrubby Ck	Kingston Rd	61.09	4	8.47	0.6	Unknown		2022, 2017, 2013 & 1990
HS 31	Logan River	Mount Lindsay Hwy	130.95	< 10	21.15	0.85	Unknown		All
HS 32	Logan River	Kingston Rd	212.9	32	9.9	1	Unknown		All
HS 33	Logan River	Pacific Mwy	383.39	21.5	8.68	2.1	Unknown		All
HS 34	Albert River	Martens St	364.58	10.5	9.7	1.665	13 x unknown diameter pillars		All
HS 35	Albert River	Pacific Mwy	361.74	22.1	9.04	1.81	16 x 0.9 m diameter pillars		All
HS 36	Scrubby Ck	Logan Mwy	107.81	< 10	14.64	1.5	Unknown		2022, 2017, 2013 & 1990
HS 37	Albert River	Pacific Mwy	363.4	22.1	9.04	1.81	12 x 0.9 m diameter pillars		All
HS 38	Slacks Ck	Logan Mwy	133.14	< 10	12.43	1.3	Unknown		2022, 2017, 2013 & 1990
HS 39	Scrubby Ck	Railway Line	111.47	< 10	8.669	1.656	Unknown		2022, 2017, 2013 & 1990
HS 40	Slacks Ck	Logan Mwy	134.54	< 10	12.43	1.3	Unknown		2022, 2017, 2013 & 1990
HS 41	Logan River	Railway Line	141.43	< 10	10.89	1.65	Unknown		All

Structure ID	Watercourse	Road	Length (m)	Width (m) [a]	Road deck level (mAHD)	Deck thickness (m)	Pier configuration [b]	Comments	Present in events
HS 42	Albert River	Pacific Mwy	363.22	12.535	9.23	1.44	13 x 0.9 m diameter pillars		All
HS 43	Logan River	Pacific Mwy	381.96	< 10	8.68	2.1	Unknown		All
HS 44	Scrubby Ck	Logan Mwy	109.11	< 10	14.64	1.5	Unknown		2022, 2017, 2013 & 1990
HS 45	Scrubby Ck	Railway Line	111.47	< 10	8.669	1.656	Unknown		2022, 2017, 2013 & 1990
HS 46	Logan River	Cusack Ln	177.93	< 10	25.18	1.62	Unknown		All
HS 47	Teviot Brook	Railway Line	277.39	< 10	34.285	1.576	Unknown		All
HS 48	Albert River	Beaudesert Beenleigh Rd	112.25	< 10	43.44	0.878	Unknown		All
HS 49	Logan River	Pacific Mwy	385.68	21.5	9.19	2.1	Unknown		All
HS 50	Logan River	Pacific Mwy	164.9	< 10	16.446	2.785	Unknown		2022, 2017 & 2013
HS 51	Albert River	Stanmore Rd	101.78	< 10	10.34	0.86	Unknown		All
HS 52	Logan River	Railway Line	141.45	< 10	10.89	1.65	Unknown		All
HS 53	Teviot Brook	Kilmoylar Rd	31	< 10	26.037	1	3 x 1.2 m diameter pillars	Bridge upgraded from lower single lane	2017
HS 54	Scrubby Ck	Kingston Rd	61.7	28	7.4	0.45	Unknown		2022, 2017, 2013 & 1990
HS 55	Windaroo Ck	Beaudesert Beenleigh Rd	69.15	< 10	7.04	0.76	Unknown		All
HS 56	Scrubby Ck	Mount Lindsay Hwy	39.47	< 10	33.18	0.92	2 x 0.7 m diameter pillars		All
HS 57	Albert River	Beaudesert Beenleigh Rd	54.64	< 10	7.64	1.34	4 x 1.2 m diameter pillars		All
HS 58	Henderson Ck	Mount Lindsay Hwy	33.38	< 10	24.07	1.17	2 x 1.8 m diameter pillars		All
HS 59	Dunn Ck	Beaudesert Beenleigh Rd	55.86	< 10	9.764	0.596	2 x 1.0 m diameter pillars		All
HS 60	Slacks Ck	Kingston Rd	31.89	20	19.761	0.85	1 x 0.45 m octagonal pillar		All
HS 61	Slacks Ck	Moss St	31.65	10	0	0	Unknown		All
HS 62	Unknown tributary	Scott Ln	59.37	< 10	16.84	0.65	Unknown		All
HS 63	Henderson Ck	Cusack Ln	34.82	< 10	19.47	0.968	None	Upgraded in 2001 - No other information	2022,2017, 2013 & 1990
HS 64	Unknown tributary	Railway Line	91.32	< 10	5.2	0.33	4 x 0.3 m diameter pillars	DWG from 1984 - No other information	All
HS 65	Quinzeh Ck	Quinzeh Creek Rd	14.87	< 10	11.68	0.43	Nil - large box culverts	Survey from 2018. No other information	All
HS 66	Windaroo Ck	Beaudesert Beenleigh Rd	19.27	< 10	5.39	0.6	1 x 0.6 m wide pillar	Site Surveyed Aug19	All
HS 67	Albert River	Stanmore Rd	39	< 10	0.233	0.9	Nil - series of RCPs	Site Survey Aug19	All
HS 68	Unknown tributary	Logan St	19.99	< 10	2.28	1.58	Nil - series of RCPs	Site Survey Aug19	All
HS 69	Logan River	Cusack Ln	30.57	< 10	11.976	0.8	1 x 0.3 m wide pillar	Site Survey Aug19	All
HS 70	Unknown tributary	Logan St	21.37	< 10	3.017	0.5	Unknown	Site Survey Aug19	All
HS 71	Berrinba Wetlands	Footbridge	48.3	< 10	16.458	0.37	1 x pillar unknown dimensions	SiteSurveyAug19	2022 & 2017
HS 72	Berrinba Wetlands	Footbridge	22.11	< 10	13.823	0.7	None	Site Survey Aug19	2022 & 2017
HS 73	Scrubby Ck	Footbridge	23.01	< 10	13.597	0.9	None	Site Survey Aug19	2022 & 2017
HS 74	Albrade Ck	Teviot Rd	48.26	< 10	29.57	0.9	2 x 0.6 m diameter pillars	From 1994 no other information	All
HS 75	Flagstone Ck	Beaudesert Beenleigh Rd	34.05	< 10	51.261	0.6	3 x 0.62 m diameter pillars	Site Survey Aug19	All
HS 76	Cedar Ck	Beaudesert Beenleigh Rd	47.1	< 10	23.05	0.8	2 x 1.0 m diameter pillars	Site Survey Aug19	All
HS 77	Allans Ck	Railway Line	104.23	< 10	17	1.2	Unknown	Estimated from old dwgs	All

[a] - Bridge width not recorded for bridges less than 10m wide (one grid cell)

[b] - Unknown cells denote that pier configurations were not available and blockage factors were obtained by Engeny

Appendix C - Hydraulic model calibration results

C1 Comparison between modelled peak flood levels and surveyed debris marks

Table C.1 – Comparison between modelled peak flood levels and surveyed debris marks for the January 2013 flood event

Debris mark	River	Easting	Northing	Ground Level (mAHD)	Surveyed flood level (mAHD)	Comments	Modelled peak flood level (mAHD)	Difference (m)
L1	Logan	499,687	6,927,944	22.67	22.67		22.23	-0.44
L2	Logan	499,687	6,927,951	22.72	22.68		22.23	-0.45
L3	Logan	499,905	6,927,916	22.63	22.55		22.23	-0.32
L4	Logan	499,904	6,927,911	22.59	22.59		22.23	-0.36
L5	Logan	499,120	6,925,949	22.92	22.95		22.97	0.02
L6	Logan	498,260	6,924,316	24.48	24.54		24.53	-0.01
L7	Logan	500,004	6,922,027	26.80	26.62		26.67	0.05
L8	Logan	501,105	6,921,668	23.91	23.79	See footnote [a]	25.20	1.41
L9	Logan	504,347	6,929,423	17.27	17.44		16.58	-0.86
L10	Logan	503,419	6,930,507	17.29	17.51		16.58	-0.93
L11	Logan	502,275	6,928,552	20.72	20.81		19.71	-1.10
L12	Logan	502,929	6,928,813	19.64	19.53		18.52	-1.01
L13	Logan	501,328	6,926,565	27.08	27.12	See footnote [b]		-27.12
L14	Logan	502,836	6,923,565	24.54	24.89		25.20	0.31
L15	Logan	502,852	6,923,569	24.85	24.94		25.20	0.26
L16	Logan	501,124	6,926,756	21.38	22.26		21.87	-0.40
L17	Logan	501,120	6,926,753	21.66	22.31		21.87	-0.45
L18	Logan	500,364	6,922,736	26.24	26.25		26.23	-0.02
L19	Logan	497,843	6,918,259	29.36	29.76		29.68	-0.09
L20	Logan	498,663	6,919,142	28.56	28.79		29.47	0.68
L21	Logan	495,937	6,918,090	27.49	27.85		31.69	3.84
L22	Logan	502,140	6,925,844	21.21	21.57		20.96	-0.61
L23	Logan	508,240	6,927,597	14.24	14.27		14.90	0.63
L24	Logan	509,275	6,927,421	13.54	13.55		14.03	0.48
L25	Logan	510,032	6,928,190	14.09	13.42		13.93	0.51
L26	Logan	509,918	6,928,027	18.01	18.09	See footnote [b]		-18.09
L27	Logan	511,811	6,926,384	15.64	16.10	See footnote [b]		-16.10
L28	Logan	512,386	6,924,829	20.22	21.89	See footnote [b]		-21.89
L29	Logan	512,142	6,928,495	12.39	12.83		13.29	0.46
L30	Logan	519,417	6,936,207	5.17	5.06		5.26	0.20
A31	Albert	521,659	6,935,613	3.59	3.88		3.57	-0.31
A32	Albert	521,660	6,935,617	3.67	3.66		3.57	-0.09
A33	Albert	522,319	6,936,141	3.15	3.07		3.57	0.50
L34	Logan	521,828	6,937,353	3.56	3.56		3.74	0.18

Debris mark	River	Easting	Northing	Ground Level (mAHD)	Surveyed flood level (mAHD)	Comments	Modelled peak flood level (mAHD)	Difference (m)
L35	Logan	521,870	6,937,344	3.01	3.01		3.74	0.73
A36	Albert	523,205	6,937,022	2.81	2.84		3.45	0.61
L37	Logan	520,533	6,936,917	3.63	3.59		4.00	0.41
L38	Logan	520,541	6,936,722	16.63	16.64	See footnote [b]		-16.64
L39	Logan	518,335	6,939,104	3.88	4.45		4.73	0.28
L40	Logan	518,365	6,939,135	6.40	6.47	See footnote [b]		-6.47
L41	Logan	518,500	6,939,205	3.82	4.42		4.73	0.31
L42	Logan	518,463	6,939,194	4.20	4.49		4.73	0.24
L43	Logan	521,337	6,938,960	2.50	3.61		3.94	0.33
L44	Logan	521,380	6,938,999	7.52	7.33	See footnote [b]	3.94	-3.39
L45	Logan	522,125	6,938,783	2.94	2.96		3.93	0.97
L46	Logan	522,108	6,938,782	3.02	3.47		3.93	0.46
L47	Logan	522,273	6,938,233	3.38	3.31		3.60	0.29
L48	Logan	521,023	6,940,040	5.76	5.87		4.04	-1.83
L49	Logan	518,824	6,939,225	4.02	4.01		4.73	0.72
L50	Logan	516,116	6,940,771	7.33	7.32		7.04	-0.28
L51	Logan	516,269	6,940,830	7.35	7.41		7.04	-0.37
L52	Logan	516,270	6,940,850	7.05	7.53		7.04	-0.49
L53	Logan	516,284	6,940,849	6.99	7.58		7.04	-0.54
L54	Logan	516,403	6,940,687	11.41	11.41	See footnote [b]		-11.41
L55	Logan	513,137	6,942,553	7.34	7.31		7.04	-0.27
L56	Logan	513,061	6,942,609	9.09	9.11	See footnote [b]		-9.11
L57	Logan	513,178	6,942,596	7.10	7.28		7.04	-0.24
L58	Logan	513,472	6,942,856	7.19	7.26		7.14	-0.12
L59	Logan	513,164	6,943,049	7.44	7.37		7.15	-0.22
L60	Logan	513,607	6,942,698	6.70	7.29		7.04	-0.25
L61	Logan	513,623	6,942,644	6.89	7.27		7.04	-0.23
L62	Logan	514,522	6,941,991	6.82	7.29		7.04	-0.25
L63	Logan	514,825	6,941,548	7.36	7.32		7.04	-0.28
L64	Logan	514,815	6,941,484	6.00	5.99	See footnote [c]	7.04	1.05
L65	Logan	515,020	6,941,515	7.32	7.34		7.04	-0.30
L66	Logan	515,275	6,941,664	7.36	7.26		7.04	-0.22
L67	Logan	515,290	6,941,662	7.31	7.23		7.04	-0.19
L68	Logan	515,686	6,941,043	7.66	7.49		7.04	-0.45
L69	Logan	515,763	6,941,140	7.50	7.42		7.04	-0.38
L70	Logan	515,943	6,939,962	14.85	14.71	See footnote [b]	7.04	-7.67
L71	Logan	515,900	6,940,031	7.60	7.24		7.04	-0.20
L72	Logan	515,575	6,941,611	6.09	6.28		7.04	0.76
L73	Logan	517,217	6,937,284	5.74	6.64		6.66	0.02
L74	Logan	517,705	6,937,023	5.41	5.35		5.51	0.16

Debris mark	River	Easting	Northing	Ground Level (mAHD)	Surveyed flood level (mAHD)	Comments	Modelled peak flood level (mAHD)	Difference (m)
L75	Logan	517,679	6,937,008	5.93	5.77		5.51	-0.26
L76	Logan	517,949	6,936,584	5.29	5.17		5.51	0.34
L77	Logan	518,226	6,936,572	5.53	5.21		5.51	0.30
L78	Logan	518,365	6,936,019	5.44	5.41		5.54	0.13
L79	Logan	518,383	6,936,021	5.12	5.44		5.54	0.10
L80	Logan	517,542	6,936,226	6.05	5.88		6.12	0.24
L81	Logan	518,188	6,936,914	3.98	5.31		5.51	0.20
L82	Logan	518,356	6,936,989	5.31	5.23		5.51	0.28
L83	Logan	518,853	6,936,971	5.87	5.38		5.51	0.13
L84	Logan	518,964	6,936,871	5.25	5.35		5.51	0.16
L85	Logan	518,931	6,936,954	5.32	5.36		5.51	0.15
L86	Logan	518,984	6,936,570	5.28	5.22		5.47	0.25
L87	Logan	518,890	6,936,661	5.76	5.21		5.51	0.30
L88	Logan	518,893	6,936,658	5.61	5.22		5.51	0.29
L89	Logan	519,157	6,936,521	5.15	5.08		5.24	0.16
L90	Logan	513,818	6,936,863	8.84	8.81		8.90	0.09
L91	Logan	514,574	6,936,690	7.63	8.79		8.79	0.00
L92	Logan	519,171	6,934,786	5.71	5.74		5.88	0.14
L93	Logan	519,231	6,935,069	5.80	5.78		5.88	0.10
L94	Logan	519,399	6,934,652	4.06	5.27		5.88	0.61
L95	Logan	519,423	6,934,438	5.76	5.67		5.88	0.21
A96	Albert	518,984	6,930,794	10.59	10.79	See footnote [b]		-10.79
A97	Albert	518,991	6,930,808	10.42	10.87	See footnote [b]		-10.87
A98	Albert	518,980	6,930,796	11.76	11.46	See footnote [b]		-11.46
A99	Albert	519,387	6,929,947	8.30	8.29		9.07	0.78
A100	Albert	519,420	6,929,885	8.32	8.29		9.15	0.86
A101	Albert	518,417	6,927,677	3.97	10.21		10.32	0.11
A102	Albert	518,436	6,927,708	5.26	9.44		10.12	0.68
A103	Albert	517,838	6,925,520	11.84	12.88		12.08	-0.81
A104	Albert	517,393	6,925,388	13.23	13.35		12.79	-0.56
A105	Albert	517,572	6,925,213	13.52	13.34		12.54	-0.80
L106	Logan	502,443	6,927,524	20.51	20.50		19.71	-0.79
L107	Logan	504,212	6,929,982	15.58	17.24		16.58	-0.66
L108	Logan	506,032	6,930,808	17.05	17.01		16.33	-0.68
L109	Logan	506,786	6,929,424	16.33	16.29		15.61	-0.68
L110	Logan	506,699	6,929,281	16.27	16.22		15.70	-0.52
L111	Logan	510,182	6,930,004	13.66	13.71		13.59	-0.12
L112	Logan	510,613	6,932,023	12.03	12.05		12.43	0.38
L113	Logan	511,263	6,936,351	10.63	10.64		10.81	0.16

Debris mark	River	Easting	Northing	Ground Level (mAHD)	Surveyed flood level (mAHD)	Comments	Modelled peak flood level (mAHD)	Difference (m)
L114	Logan	513,461	6,936,141	9.11	9.05		9.17	0.12
L115	Logan	513,905	6,935,636	15.28	15.24	See footnote [b]		-15.24
L116	Logan	514,584	6,936,280	8.80	8.76		8.79	0.03
L117	Logan	514,428	6,936,537	8.74	8.60		8.79	0.19
L118	Logan	514,148	6,936,646	8.74	8.61		8.79	0.18
L119	Logan	514,004	6,935,862	9.20	9.18		9.32	0.14
L120	Logan	513,976	6,937,152	8.76	8.68		8.82	0.14
L121	Logan	513,940	6,937,346	7.36	7.86		8.23	0.37
L122	Logan	513,341	6,938,440	8.16	8.13		7.91	-0.22
L123	Logan	513,896	6,938,167	8.11	8.14		8.02	-0.11
L124	Logan	514,928	6,938,334	7.49	7.39		7.37	-0.02
L125	Logan	515,642	6,938,120	7.05	6.97		6.69	-0.29
L126	Logan	505,234	6,929,569	17.33	17.15		16.58	-0.57
L127	Logan	505,234	6,929,569	17.33	17.16		16.58	-0.58
L128	Logan	504,349	6,929,424	17.04	17.08		16.58	-0.50
L129	Logan	503,167	6,929,239	19.84	19.19		18.52	-0.67
L130	Logan	513,811	6,934,820	9.81	9.78		9.99	0.21
L131	Logan	513,819	6,934,859	9.26	9.78		9.99	0.21
L132	Logan	519,001	6,936,108	5.49	5.58		5.65	0.07
L133	Logan	519,001	6,936,108	5.49	5.57		5.65	0.08
L134	Logan	519,259	6,936,181	4.30	5.25		5.29	0.04
L135	Logan	519,259	6,936,181	4.30	5.25		5.29	0.04
L136	Logan	512,395	6,924,824	19.97	21.71	See footnote [b]		-21.71
L137	Logan	512,396	6,924,834	19.15	21.62	See footnote [b]		-21.62
L138	Logan	512,386	6,924,830	20.22	21.85	See footnote [b]		-21.85
L139	Logan	512,352	6,924,840	21.47	21.63	See footnote [b]		-21.63
L140	Logan	511,811	6,926,384	15.64	16.31	See footnote [b]		-16.31
A141	Albert	517,465	6,922,211	18.53	19.18		18.48	-0.70
A142	Albert	517,490	6,922,190	17.54	19.03		18.47	-0.56
A143	Albert	517,524	6,922,170	18.22	19.06		18.42	-0.64
A144	Albert	516,822	6,923,978	14.82	14.58		14.96	0.38
A145	Albert	516,823	6,923,980	14.74	14.67		14.96	0.29
A146	Albert	516,641	6,924,034	15.68	15.69		14.96	-0.73
A147	Albert	516,711	6,925,012	15.38	14.99		13.98	-1.01
A148	Albert	517,456	6,925,503	12.01	12.29		12.34	0.05
L149	Logan	511,498	6,932,984	11.86	11.48		11.88	0.40
L150	Logan	511,657	6,932,736	11.42	11.57		11.81	0.23
L151	Logan	513,235	6,935,154	10.05	9.95		9.99	0.04
L152	Logan	512,149	6,924,896	21.13	21.11	See footnote [b]		-21.11
L153	Logan	512,140	6,924,888	21.28	21.19	See footnote [b]		-21.19

Debris mark	River	Easting	Northing	Ground Level (mAHD)	Surveyed flood level (mAHD)	Comments	Modelled peak flood level (mAHD)	Difference (m)
L154	Logan	509,091	6,927,454	13.86	13.77		14.03	0.26
L155	Logan	501,215	6,926,552	21.39	22.08		21.72	-0.36
L156	Logan	501,225	6,926,555	20.07	22.08		21.72	-0.36
A157	Albert	512,067	6,918,295	32.12	31.93		31.59	-0.34
A158	Albert	512,074	6,918,296	32.02	31.88		31.59	-0.29
A159	Albert	511,861	6,918,226	31.93	31.95		31.59	-0.36
A160	Albert	511,856	6,918,286	32.02	31.84		31.59	-0.25
A161	Albert	511,853	6,918,376	32.20	32.05		31.59	-0.46
A162	Albert	511,863	6,918,372	32.18	32.13		31.59	-0.54
A163	Albert	511,907	6,917,698	32.23	34.41		34.49	0.08
A164	Albert	511,981	6,917,131	34.35	34.34		34.44	0.10
A165	Albert	509,964	6,912,928	43.91	43.83		43.47	-0.36
A166	Albert	505,602	6,904,877	0.00	65.62	See footnote [d]	N/A	
L167	Logan	494,523	6,917,373	31.13	32.08		32.57	0.49
L168	Logan	494,431	6,917,361	32.10	32.02		32.61	0.59
L169	Logan	493,646	6,920,360	29.31	31.12		31.32	0.20
L170	Logan	491,581	6,920,177	31.03	31.80		31.54	-0.26
L171	Logan	498,339	6,924,544	24.29	23.94		24.53	0.59
L172	Logan	499,712	6,924,098	24.68	24.61		24.53	-0.08
173	N/A	497,278	6,935,450	42.13	42.72	See footnote [d]	N/A	
174	N/A	497,185	6,935,486	42.82	42.81	See footnote [d]	N/A	
175	N/A	497,365	6,935,441	41.47	42.52	See footnote [d]	N/A	
L176	Logan	498,788	6,929,705	20.71	21.72		22.53	0.81
L177	Logan	498,776	6,929,704	20.66	22.46		22.72	0.26
L178	Logan	501,539	6,930,822	22.27	22.66	See footnote [b]		-22.66
L179	Logan	502,406	6,929,887	27.65	27.60	See footnote [b]		-27.60
L180	Logan	511,936	6,936,035	10.76	10.59		10.81	0.22
L181	Logan	511,638	6,936,084	8.22	9.79		10.81	1.02
A182	Albert	518,310	6,931,580	10.39	10.11	See footnote [b]		-10.11
A183	Albert	518,307	6,931,555	10.02	10.24	See footnote [b]		-10.24
A184	Albert	518,306	6,931,567	8.97	11.24	See footnote [b]		-11.24
A185	Albert	519,131	6,931,833	5.91	7.78		8.64	0.86
A186	Albert	519,029	6,931,880	7.20	7.82		8.64	0.82
L187	Logan	511,161	6,928,666	23.21	23.11	See footnote [b]		-23.11
L188	Logan	511,004	6,928,993	12.07	13.00		13.29	0.29
L189	Logan	511,005	6,928,993	12.07	13.00		13.29	0.29
L190	Logan	510,960	6,928,973	15.09	16.79	See footnote [e]	13.29	-3.50
L191	Logan	510,936	6,928,916	16.98	18.85	See footnote [e]	13.29	-5.56
L192	Logan	510,908	6,928,855	15.83	15.48	See footnote [b]		-15.48
L193	Logan	510,870	6,928,766	16.11	15.75	See footnote [b]		-15.75

Debris mark	River	Easting	Northing	Ground Level (mAHD)	Surveyed flood level (mAHD)	Comments	Modelled peak flood level (mAHD)	Difference (m)
L194	Logan	514,522	6,934,944	9.43	9.31		9.83	0.52
L195	Logan	497,702	6,919,441	29.93	29.88		29.71	-0.17
196	N/A	497,540	6,934,019	44.23	44.38	See footnote [d]	N/A	
197	N/A	497,545	6,934,021	44.21	44.37	See footnote [d]	N/A	
198	N/A	497,552	6,934,033	44.27	44.44	See footnote [d]	N/A	
199	N/A	497,552	6,934,033	44.27	44.39	See footnote [d]	N/A	
200	N/A	497,552	6,934,033	44.27	44.42	See footnote [d]	N/A	
L201	Logan	513,350	6,938,453	8.19	8.65		7.91	-0.74
L202	Logan	513,388	6,938,568	7.91	8.10		7.91	-0.19
L203	Logan	513,388	6,938,568	7.91	8.12		7.91	-0.21
L204	Logan	514,234	6,941,949	7.08	7.81		7.04	-0.77
L205	Logan	509,512	6,924,569	87.08	87.01	See footnote [b]		-87.01
L206	Logan	512,390	6,925,021	21.18	21.11	See footnote [b]		-21.11
L207	Logan	512,386	6,925,013	21.23	21.15	See footnote [b]		-21.15
L208	Logan	512,382	6,925,004	21.27	21.23	See footnote [b]		-21.23
L209	Logan	512,377	6,924,995	21.33	21.20	See footnote [b]		-21.20
L210	Logan	512,372	6,924,987	21.39	21.30	See footnote [b]		-21.30
L211	Logan	512,367	6,924,978	21.43	21.34	See footnote [b]		-21.34
L212	Logan	512,362	6,924,969	21.45	21.39	See footnote [b]		-21.39
L213	Logan	512,356	6,924,958	21.52	21.45	See footnote [b]		-21.45
L214	Logan	512,350	6,924,949	21.54	21.53	See footnote [b]		-21.53
L215	Logan	512,346	6,924,940	21.58	21.56	See footnote [b]		-21.56
L216	Logan	512,341	6,924,929	21.65	21.65	See footnote [b]		-21.65
L217	Logan	512,337	6,924,919	21.70	21.71	See footnote [b]		-21.71
L218	Logan	512,333	6,924,909	21.75	21.72	See footnote [b]		-21.72
L219	Logan	512,330	6,924,899	21.76	21.75	See footnote [b]		-21.75
L220	Logan	512,325	6,924,879	21.76	21.73	See footnote [b]		-21.73
L221	Logan	512,323	6,924,869	21.72	21.67	See footnote [b]		-21.67
L222	Logan	512,321	6,924,864	21.64	21.62	See footnote [b]		-21.62
L223	Logan	513,363	6,926,770	23.98	23.99	See footnote [b]		-23.99
L224	Logan	513,814	6,925,647	35.70	35.70	See footnote [b]		-35.70
A225	Albert	515,009	6,924,128	44.63	44.20	See footnote [b]		-44.20

[a] - Ground level at approximately Surveyed flood level

[b] - Significantly outside flood extent

[c] - Ground level higher than surveyed flood level

[d] - Outside study area

[e] - Debris mark against elevated retaining wall

Table C.2 - Comparison between modelled peak flood levels and surveyed debris marks for the March 2017 flood event

Debris mark	River	Easting	Northing	Ground Level (mAHD)	Surveyed flood level (mAHD)	Comments	Modelled peak flood level (mAHD)	Difference (m)
A138	Albert	512,022	6,917,970	35.48	35.28		35.29	0.00
A139	Albert	512,022	6,917,970	35.48	35.29		35.29	-0.01
A140	Albert	512,071	6,918,280	33.53	33.37		33.24	-0.13
A141	Albert	512,071	6,918,280	33.53	33.38		33.24	-0.13
A142	Albert	511,582	6,918,620	33.62	33.59	See footnote [a]	33.24	-0.34
A143	Albert	511,962	6,917,120	0.00	35.77		35.68	-0.09
A144	Albert	511,919	6,918,870	33.50	33.33		33.24	-0.09
A151	Albert	516,835	6,923,940	17.38	18.19		18.11	-0.07
A152	Albert	517,234	6,923,640	18.09	19.16	See footnote [b]	18.32	-0.84
A153	Albert	516,625	6,924,470	17.43	17.36	See footnote [a]	17.54	0.18
A154	Albert	516,791	6,925,100	17.09	16.94	See footnote [b]	16.46	-0.48
A155	Albert	517,128	6,925,500	15.96	15.91	See footnote [b]	15.52	-0.39
A156	Albert	517,136	6,925,490	15.30	16.09	See footnote [b]	15.52	-0.57
A157	Albert	517,366	6,925,380	16.11	16.08	See footnote [b]	15.49	-0.58
A158	Albert	517,387	6,925,400	15.78	16.12	See footnote [b]	15.51	-0.61
A159	Albert	517,446	6,925,110	16.22	16.19	See footnote [a]	15.71	-0.48
A160	Albert	518,620	6,926,850	14.37	14.37	See footnote [b]	13.98	-0.39
A167	Albert	519,327	6,929,110	11.11	11.22		11.70	0.48
A168	Albert	518,417	6,929,260	11.17	10.99		11.70	0.71
A169	Albert	518,418	6,929,260	10.69	11.22		11.70	0.48
A170	Albert	519,119	6,930,020	9.44	10.47		10.87	0.40
A171	Albert	519,103	6,930,030	10.30	10.50		10.87	0.37
A172	Albert	519,250	6,930,000	9.32	10.55		10.87	0.32
A173	Albert	519,258	6,930,000	10.20	10.47		10.87	0.40
A174	Albert	519,363	6,929,940	10.32	10.32		10.74	0.42
A175	Albert	519,338	6,931,330	10.20	9.89	See footnote [a]	10.08	0.19
A176	Albert	519,116	6,931,950	8.24	9.92		10.10	0.17
A183	Albert	520,678	6,933,150	6.24	7.07	See footnote [c]	6.58	-0.49
A184	Albert	520,652	6,933,150	6.51	7.05	See footnote [c]	6.58	-0.47
A185	Albert	520,406	6,933,590	6.34	7.03		6.58	-0.46
A186	Albert	520,445	6,933,690	4.54	5.86		6.58	0.71
A187	Albert	520,426	6,933,720	6.45	7.05		6.58	-0.47
A188	Albert	520,493	6,933,550	6.96	7.05		6.58	-0.48
A189	Albert	519,906	6,933,700	5.76	7.06		6.58	-0.49
A190	Albert	521,630	6,933,570	5.64	7.16		6.64	-0.51
A191	Albert	521,993	6,933,510	7.33	7.27		7.11	-0.16

Debris mark	River	Easting	Northing	Ground Level (mAHD)	Surveyed flood level (mAHD)	Comments	Modelled peak flood level (mAHD)	Difference (m)
A192	Albert	520,884	6,934,540	7.09	7.03		6.62	-0.41
A199	Albert	522,574	6,935,460	4.87	4.75		4.78	0.03
A200	Albert	522,589	6,935,460	4.85	4.77		4.78	0.02
A201	Albert	522,476	6,937,090	3.89	3.92		4.26	0.34
A202	Albert	523,352	6,936,900	3.73	3.70	See footnote [a]	4.20	0.50
A203	Albert	521,960	6,937,330	4.32	4.06	See footnote [a]	4.56	0.50
A204	Albert	521,808	6,937,350	3.76	4.17		4.56	0.38
A205	Albert	520,992	6,937,480	4.72	4.59		4.83	0.24
A206	Albert	521,198	6,937,440	4.29	4.57		4.84	0.27
A207	Albert	521,967	6,936,410	4.17	4.20		4.31	0.11
A208	Albert	521,066	6,936,020	3.10	4.19		4.31	0.12
A215	Albert	519,001	6,936,180	5.15	5.12	See footnote [a]	6.28	1.16
A216	Albert	518,975	6,936,140	6.39	6.16		6.13	-0.04
A217	Albert	519,003	6,936,110	5.77	5.81	See footnote [b]	6.67	0.86
A145	Albert	515,246	6,920,050	27.72	27.61		27.52	-0.10
A146	Albert	516,882	6,921,600	23.20	22.95	See footnote [a]	22.79	-0.15
A147	Albert	517,093	6,921,880	21.48	22.01		22.00	-0.01
A148	Albert	517,427	6,922,230	21.11	20.88		21.06	0.18
A149	Albert	517,427	6,922,230	21.11	20.84		21.06	0.22
A150	Albert	516,789	6,923,760	18.47	18.10		18.11	0.02
A161	Albert	518,290	6,927,470	12.36	12.68		13.02	0.34
A162	Albert	518,296	6,927,470	12.90	12.69		13.02	0.33
A163	Albert	518,244	6,927,460	13.30	13.29	See footnote [b]	13.02	-0.27
A164	Albert	518,401	6,927,740	0.75	12.06		12.87	0.81
A165	Albert	518,366	6,927,730	1.83	1.80	See footnote [a]	12.97	11.17
A166	Albert	518,325	6,927,780	11.09	11.05	See footnote [a]	12.93	1.88
A177	Albert	519,058	6,931,930	9.15	9.91		10.10	0.19
A178	Albert	519,046	6,931,920	8.96	9.92		10.10	0.18
A179	Albert	520,183	6,931,940	9.97	9.72	See footnote [a]	9.94	0.22
A180	Albert	521,033	6,932,330	8.74	8.74		8.66	-0.08
A181	Albert	521,033	6,932,330	8.74	8.75		8.66	-0.09
A182	Albert	520,983	6,932,260	8.79	8.77	See footnote [a]	8.66	-0.11
A193	Albert	522,325	6,934,670	6.18	5.92		5.70	-0.23
A194	Albert	522,136	6,934,520	6.60	6.61	See footnote [b]	6.08	-0.53
A195	Albert	522,136	6,934,530	6.19	6.39	See footnote [b]	6.08	-0.31
A196	Albert	501,061	6,926,800	24.37	24.40		24.24	-0.15
A197	Albert	501,026	6,926,800	24.41	24.39		24.25	-0.14
A198	Albert	522,354	6,934,980	5.02	4.99		4.82	-0.16
A209	Albert	521,068	6,936,090	4.26	4.20		4.31	0.11
A210	Albert	521,049	6,935,930	4.00	4.18		4.31	0.13

Debris mark	River	Easting	Northing	Ground Level (mAHD)	Surveyed flood level (mAHD)	Comments	Modelled peak flood level (mAHD)	Difference (m)
A211	Albert	521,049	6,935,930	4.00	4.18		4.31	0.13
A212	Albert	521,810	6,935,590	4.29	4.23	See footnote [a]	4.31	0.08
A213	Albert	522,248	6,935,880	4.95	4.69		4.41	-0.28
A214	Albert	522,199	6,935,890	4.82	4.47		4.41	-0.06
L1	Logan	519,003	6,936,110	5.77	5.86	See footnote [b]	6.67	0.81
L2	Logan	518,975	6,936,140	6.39	6.15		6.13	-0.02
L3	Logan	518,999	6,936,160	6.27	6.16		6.28	0.12
L4	Logan	519,333	6,936,090	6.29	6.17		6.32	0.15
L5	Logan	519,458	6,935,160	6.11	6.57		6.91	0.34
L6	Logan	519,231	6,934,950	5.76	6.62		6.91	0.29
L7	Logan	519,141	6,934,430	5.61	7.31		6.91	-0.40
L14	Logan	500,314	6,922,700	27.98	28.44		28.52	0.08
L15	Logan	500,519	6,922,610	29.08	28.59		28.76	0.17
L16	Logan	498,731	6,921,230	26.36	26.33	See footnote [a]	30.58	4.25
L17	Logan	498,788	6,921,230	30.54	30.63		30.59	-0.05
L18	Logan	502,367	6,921,560	26.81	27.16		27.43	0.27
L19	Logan	502,383	6,921,600	27.22	27.12	See footnote [a]	27.43	0.31
L20	Logan	502,267	6,922,780	27.16	27.20		27.43	0.23
L21	Logan	503,006	6,922,690	27.19	27.18		27.43	0.25
L22	Logan	502,989	6,922,690	27.16	27.01		27.43	0.42
L23	Logan	503,327	6,922,050	26.93	27.22		27.43	0.21
L30	Logan	500,852	6,926,920	24.30	24.68		24.46	-0.22
L31	Logan	500,813	6,927,460	24.90	24.88		24.69	-0.19
L32	Logan	501,582	6,926,480	23.17	23.97		23.86	-0.11
L33	Logan	503,279	6,923,870	27.30	27.30	See footnote [b]	27.43	0.13
L34	Logan	503,279	6,923,870	27.30	27.33		27.43	0.10
L35	Logan	503,920	6,923,810	26.36	26.27	See footnote [a]	27.43	1.15
L36	Logan	502,816	6,923,700	25.35	27.23		27.43	0.20
L37	Logan	522,244	6,938,740	4.20	4.43		4.69	0.26
L38	Logan	521,267	6,938,780	4.57	4.35		4.70	0.36
L39	Logan	518,844	6,939,230	4.66	5.24		5.54	0.30
L46	Logan	518,898	6,936,670	6.35	6.22	See footnote [a]	6.45	0.23
L47	Logan	518,408	6,936,990	6.30	6.21	See footnote [a]	6.45	0.25
L48	Logan	517,698	6,936,990	5.99	6.22		6.45	0.23
L49	Logan	518,227	6,936,530	6.68	6.19	See footnote [a]	6.45	0.26
L50	Logan	518,354	6,936,000	6.29	6.14	See footnote [a]	6.47	0.33
L51	Logan	518,382	6,936,020	5.13	6.29		6.47	0.18
L52	Logan	517,764	6,936,260	6.93	6.90		7.13	0.24
L53	Logan	517,547	6,936,230	6.88	6.83	See footnote [a]	7.09	0.26

Debris mark	River	Easting	Northing	Ground Level (mAHD)	Surveyed flood level (mAHD)	Comments	Modelled peak flood level (mAHD)	Difference (m)
L54	Logan	516,825	6,937,960	7.84	7.67		7.88	0.21
L55	Logan	513,681	6,938,990	8.76	9.19		9.31	0.12
L62	Logan	513,999	6,937,310	9.48	9.35	See footnote [a]	9.59	0.24
L63	Logan	514,042	6,937,190	9.85	9.96		10.11	0.15
L64	Logan	514,023	6,937,190	9.96	9.88	See footnote [a]	10.11	0.23
L65	Logan	513,753	6,936,550	9.93	10.21		10.45	0.24
L66	Logan	513,611	6,936,530	10.31	10.41		10.64	0.22
L67	Logan	513,266	6,936,470	11.17	11.64		12.33	0.70
L68	Logan	513,410	6,936,160	10.21	10.46		10.67	0.21
L69	Logan	513,425	6,936,130	10.07	10.47		10.67	0.20
L70	Logan	514,124	6,936,150	9.53	10.55		10.77	0.23
L71	Logan	513,886	6,935,520	10.98	10.95	See footnote [a]	11.31	0.36
L78	Logan	514,669	6,936,670	9.48	10.02		10.13	0.11
L79	Logan	514,024	6,938,100	8.65	9.35		9.53	0.18
L80	Logan	514,466	6,938,050	7.75	8.73		8.73	0.00
L81	Logan	516,262	6,937,010	8.42	7.64	See footnote [a]	7.86	0.23
L82	Logan	517,878	6,934,910	6.65	6.63	See footnote [a]	6.96	0.33
L83	Logan	517,686	6,934,700	6.56	6.59	See footnote [b]	6.96	0.37
L84	Logan	514,657	6,936,640	9.95	9.93	See footnote [a]	10.13	0.20
L85	Logan	514,662	6,936,630	9.26	9.99		10.13	0.13
L86	Logan	511,791	6,936,920	12.20	12.09		12.43	0.34
L87	Logan	510,107	6,936,750	11.88	12.08		12.43	0.35
L94	Logan	513,231	6,942,600	7.07	8.23		8.21	-0.03
L95	Logan	513,628	6,942,660	7.15	8.22		8.21	-0.02
L96	Logan	513,591	6,942,820	7.74	8.23		8.21	-0.02
L97	Logan	513,443	6,942,910	8.25	8.13		8.21	0.08
L98	Logan	513,346	6,942,810	7.09	8.22		8.21	-0.02
L99	Logan	515,559	6,941,670	7.81	8.23		8.21	-0.02
L100	Logan	516,328	6,940,780	7.64	8.21		8.21	-0.01
L101	Logan	516,132	6,940,780	8.38	8.11	See footnote [a]	8.21	0.09
L102	Logan	515,914	6,940,010	8.27	8.24	See footnote [a]	8.21	-0.03
L103	Logan	515,671	6,941,050	7.17	8.27		8.21	-0.07
L110	Logan	513,060	6,935,200	11.64	11.58	See footnote [a]	11.93	0.35
L111	Logan	512,445	6,930,940	14.63	14.54	See footnote [a]	15.19	0.64
L112	Logan	510,960	6,928,970	13.42	14.72		15.19	0.47
L113	Logan	512,047	6,928,620	14.70	14.65		15.19	0.54
L114	Logan	510,233	6,928,820	15.76	15.66		15.74	0.07
L115	Logan	509,234	6,927,770	16.28	16.13	See footnote [a]	16.12	-0.01
L116	Logan	509,594	6,928,880	13.60	15.14		15.65	0.50
L117	Logan	509,861	6,931,500	13.24	14.69		15.24	0.56

Debris mark	River	Easting	Northing	Ground Level (mAHD)	Surveyed flood level (mAHD)	Comments	Modelled peak flood level (mAHD)	Difference (m)
L118	Logan	511,960	6,936,030	12.08	11.99		12.43	0.44
L119	Logan	511,543	6,935,390	12.09	12.05		12.43	0.38
L126	Logan	503,216	6,929,290	20.79	21.66		21.11	-0.55
L127	Logan	504,326	6,929,420	17.80	19.20		19.24	0.04
L128	Logan	505,509	6,930,060	18.96	19.28		19.25	-0.03
L129	Logan	505,262	6,929,570	18.99	19.34		19.25	-0.08
L130	Logan	505,270	6,929,590	19.27	19.25	See footnote [a]	19.26	0.01
L131	Logan	505,229	6,929,480	19.19	19.20	See footnote [b]	19.25	0.05
L132	Logan	504,782	6,929,720	19.27	19.31		19.24	-0.06
L133	Logan	504,782	6,929,710	18.62	19.28		19.24	-0.04
L134	Logan	512,348	6,941,240	7.91	7.93	See footnote [b]	8.21	0.27
L135	Logan	512,333	6,941,090	7.71	8.25		8.21	-0.04
L8	Logan	514,386	6,940,720	8.22	8.27		8.21	-0.06
L9	Logan	514,276	6,940,900	7.09	8.26		8.21	-0.05
L10	Logan	499,839	6,927,930	24.39	24.85		24.69	-0.16
L11	Logan	499,834	6,927,940	24.21	24.84		24.69	-0.15
L12	Logan	493,850	6,921,000	33.27	33.21		32.92	-0.29
L13	Logan	500,314	6,922,700	27.98	28.42		28.52	0.10
L24	Logan	503,572	6,921,770	27.15	27.15	See footnote [b]	27.43	0.28
L25	Logan	502,591	6,921,310	27.41	27.19		27.43	0.24
L26	Logan	498,110	6,927,380	25.32	25.23		25.32	0.09
L27	Logan	491,482	6,930,980	70.73	71.03	See footnote [d]	N/A	
L28	Logan	500,041	6,928,610	24.84	24.78		24.69	-0.09
L29	Logan	500,765	6,927,030	24.58	24.61		24.46	-0.15
L40	Logan	518,535	6,939,210	5.50	5.17		5.54	0.37
L41	Logan	518,316	6,939,080	3.53	4.39	See footnote [b]	5.54	1.15
L42	Logan	518,342	6,939,110	4.93	5.25		5.54	0.29
L43	Logan	518,759	6,938,640	5.37	5.27	See footnote [a]	5.54	0.27
L44	Logan	519,424	6,936,200	5.95	5.82	See footnote [a]	6.06	0.23
L45	Logan	519,235	6,936,660	5.73	5.65	See footnote [a]	5.71	0.07
L56	Logan	514,945	6,938,900	8.26	8.15	See footnote [a]	8.22	0.06
L57	Logan	513,251	6,938,460	9.29	9.18	See footnote [a]	9.31	0.13
L58	Logan	513,259	6,938,470	9.01	9.12		9.30	0.18
L59	Logan	513,539	6,938,450	8.26	9.21		9.31	0.09
L60	Logan	513,549	6,937,550	9.61	9.31	See footnote [a]	9.59	0.27
L61	Logan	513,610	6,937,400	9.39	9.33	See footnote [a]	9.59	0.26
L72	Logan	513,270	6,935,940	11.35	11.57		11.92	0.35
L73	Logan	512,658	6,936,790	12.09	12.13		12.42	0.29
L74	Logan	513,848	6,936,850	10.20	10.19	See footnote [a]	10.23	0.04
L75	Logan	514,088	6,936,770	9.98	9.99		10.13	0.13

Debris mark	River	Easting	Northing	Ground Level (mAHD)	Surveyed flood level (mAHD)	Comments	Modelled peak flood level (mAHD)	Difference (m)
L76	Logan	514,136	6,936,630	9.99	9.95	See footnote [a]	10.13	0.18
L77	Logan	514,669	6,936,670	9.48	10.04		10.13	0.09
L88	Logan	510,451	6,936,270	12.08	12.09		12.43	0.34
L89	Logan	511,945	6,938,870	9.83	8.94		8.21	-0.73
L90	Logan	511,772	6,939,920	8.34	8.23	See footnote [a]	8.21	-0.03
L91	Logan	513,390	6,942,030	7.95	8.22		8.21	-0.01
L92	Logan	513,079	6,942,550	7.59	8.21		8.21	0.00
L93	Logan	513,061	6,942,610	9.09	9.10		8.21	-0.89
L104	Logan	515,848	6,941,230	8.25	8.14	See footnote [a]	8.21	0.06
L105	Logan	515,248	6,941,640	7.56	8.25		8.21	-0.05
L106	Logan	515,028	6,941,550	8.28	8.26	See footnote [a]	8.21	-0.05
L107	Logan	514,525	6,942,000	8.47	8.09		8.21	0.11
L108	Logan	514,536	6,934,930	10.77	11.13		11.46	0.33
L109	Logan	513,870	6,934,710	10.58	11.33		11.69	0.35
L120	Logan	507,977	6,927,630	17.37	17.31	See footnote [a]	17.32	0.02
L121	Logan	502,263	6,925,810	23.56	23.44		23.48	0.04
L122	Logan	502,484	6,927,800	19.30	20.84		22.17	1.34
L123	Logan	501,583	6,927,650	24.51	24.48		24.09	-0.40
L124	Logan	502,924	6,928,790	21.94	21.79		21.10	-0.69
L125	Logan	502,741	6,928,600	22.67	22.60	See footnote [a]	22.17	-0.43
L136	Logan	513,312	6,941,120	9.18	8.23		8.21	-0.02
L137	Logan	513,061	6,942,610	9.09	9.06		8.21	-0.85

[a] - Ground level higher than surveyed flood level

[b] - Ground level at approximately the surveyed flood level

[c] - Modelled peak flood level was obtained from approximately 350 m from this debris mark

[d] - Outside study area

Table C.3 - Comparison between modelled peak flood levels and surveyed debris marks for the February 2022 flood event

Debris mark	River	Easting	Northing	Ground Level (mAHD)	Surveyed flood level (mAHD)	Comments	Modelled peak flood level (mAHD)	Difference (m)
1	Albert	522347	6934977	4.97	5.13		5.18	0.05
2	Albert	522365	6934663	3.97	5.77		5.82	0.04
3	Albert	522148	6934521	6.05	6.03		6.13	0.10
4	Albert	522212	6934510	3.63	3.62		6.13	2.51
5	Albert	520803	6934560	5.52	6.62		6.63	0.01
6	Albert	520556	6934111	6.65	6.63		6.62	-0.01
7	Albert	520168	6933812	6.63	6.64		6.62	-0.02
8	Albert	522012	6933519	6.74	6.59		7.03	0.45
9	Albert	521564	6933508	5.82	6.81		6.65	-0.16
10	Albert	521570	6933184	6.34	7.72		7.78	0.05
11	Albert	519103	6931982	9.19	9.34		9.95	0.61
12	Albert	519127	6930025	9.24	9.26		10.70	1.44
13	Albert	519143	6930024	9.06	9.05		10.70	1.64
14	Albert	519377	6929962	9.69	9.68		10.51	0.84
15	Albert	519347	6929130	10.05	9.93		11.50	1.56
16	Albert	518279	6927513	9.52	9.55		12.76	3.21
17	Albert	518293	6927480	11.32	11.63		12.76	1.13
18	Albert	518304	6927767	11.41	11.53		12.75	1.23
19	Albert	518629	6926837	12.42	12.42		13.68	1.26
20	Albert	517482	6925401	14.22	14.89		15.20	0.31
21	Albert	516691	6925059	15.01	15.99		16.19	0.20
22	Albert	516793	6923922	16.49	17.08		17.78	0.70
23	Albert	517694	6922033	20.45	20.50		20.80	0.30
24	Albert	517570	6922131	20.34	20.48		20.91	0.43
25	Albert	517423	6922209	20.67	20.52		20.86	0.33
26	Albert	515269	6920059	25.88	26.61		26.94	0.33
27	Albert	511874	6918047	35.67	35.74		35.83	0.09
28	Albert	511812	6918102	35.91	35.92		35.88	-0.04
29	Albert	511237	6912864	0.00	45.03		44.59	-0.44
30	Albert	511235	6912871	0.00	44.99		44.58	-0.41
31	Albert	521549	6933202	7.62	7.70		7.78	0.07
32	Albert	521563	6933215	7.69	7.71		7.78	0.07
33	Albert	521158	6932376	8.30	8.27		8.55	0.28
34	Albert	521260	6932333	5.75	8.27		8.58	0.31
35	Albert	521118	6932336	8.31	8.32		8.69	0.37
36	Albert	520824	6934126	6.09	6.66		6.63	-0.04

Debris mark	River	Easting	Northing	Ground Level (mAHD)	Surveyed flood level (mAHD)	Comments	Modelled peak flood level (mAHD)	Difference (m)
37	Albert	520817	6934135	6.62	6.63		6.63	0.00
38	Albert	521062	6936123	4.86	4.88		4.95	0.07
39	Logan	520985	6937477	5.14	5.10		5.18	0.08
40	Logan	520980	6937483	3.92	5.13		5.18	0.05
41	Logan	521796	6937366	4.69	4.74		5.07	0.33
42	Albert	521586	6935649	4.92	5.00		4.95	-0.05
43	Albert	522590	6935461	4.77	4.83		5.16	0.33
44	Albert	521727	6935630	5.07	5.07		4.95	-0.12
45	Albert	521868	6932898	6.68	7.58		7.62	0.05
46	Logan	513570	6936864	11.04	11.04		10.90	-0.14
47	Logan	513583	6936864	11.05	11.03		10.90	-0.13
48	Logan	513577	6936878	10.96	10.98		10.92	-0.07
49	Logan	513585	6936872	10.97	11.01		10.90	-0.11
50	Logan	513363	6936450	11.40	11.44		11.52	0.09
51	Logan	513448	6936966	10.96	11.04		10.92	-0.12
52	Logan	513541	6937562	10.02	10.05		10.11	0.06
53	Logan	513563	6938315	9.81	9.82		9.79	-0.03
54	Logan	513585	6937394	10.01	10.05		10.11	0.06
55	Logan	513941	6937174	10.65	10.70		10.61	-0.08
56	Logan	513651	6937112	10.99	11.01		10.92	-0.09
57	Logan	501228	6927366	24.38	24.38		24.28	-0.11
58	Logan	498790	6929769	25.02	25.10		24.87	-0.23
59	Logan	513884	6936801	10.77	10.81		10.63	-0.18
60	Logan	513934	6936810	10.79	10.81		10.59	-0.22
61	Logan	514062	6936749	10.66	10.69		10.73	0.04
62	Logan	514059	6936733	10.68	10.70		10.70	-0.01
63	Logan	513998	6936700	10.92	11.00		10.98	-0.02
64	Logan	513989	6936695	10.99	11.00		10.99	-0.01
65	Logan	513974	6936698	10.94	11.00		10.99	-0.01
66	Logan	513935	6936729	11.01	11.06		10.99	-0.07
67	Logan	513845	6936776	11.01	11.04		10.91	-0.14
68	Logan	513841	6936793	10.92	10.96		10.91	-0.05
69	Logan	513640	6936864	3.03	11.03		10.90	-0.13
70	Logan	513614	6936821	10.99	11.02		10.90	-0.12
71	Logan	501137	6926821	24.40	24.51		24.37	-0.14
72	Logan	501027	6926806	24.49	24.56		24.43	-0.13
73	Logan	500968	6926795	24.35	24.68		24.54	-0.15
74	Logan	501060	6926811	24.55	24.56		24.42	-0.15
75	Logan	501176	6926681	22.44	22.52		24.30	1.78
76	Logan	501282	6926417	24.44	24.51		24.42	-0.09

Debris mark	River	Easting	Northing	Ground Level (mAHD)	Surveyed flood level (mAHD)	Comments	Modelled peak flood level (mAHD)	Difference (m)
77	Logan	501582	6926490	23.09	24.18		24.06	-0.12
78	Logan	500773	6927022	24.78	24.97		24.63	-0.34
79	Logan	500852	6926923	24.15	24.80		24.63	-0.17
80	Logan	502734	6928916	20.85	21.96		21.43	-0.54
81	Logan	502923	6928788	21.84	21.93		21.43	-0.51
82	Logan	502300	6928616	22.66	22.67		22.44	-0.24
83	Logan	513673	6939016	9.47	9.92		9.80	-0.12
84	Logan	513992	6940602	8.83	8.87		8.68	-0.19
85	Logan	514015	6940580	8.82	8.90		8.68	-0.22
86	Logan	513894	6940391	8.93	9.01		8.68	-0.33
87	Logan	513214	6940683	8.69	8.88		8.68	-0.20
88	Logan	515093	6938935	8.87	8.91		8.68	-0.24
89	Logan	516828	6937961	7.99	8.31		8.31	0.00
90	Logan	517657	6937019	6.71	6.74		6.72	-0.01
91	Logan	518391	6935955	7.00	7.12		7.19	0.07
92	Logan	518422	6935941	6.99	7.01		7.08	0.08
93	Logan	518432	6935982	6.30	6.83		6.75	-0.08
94	Logan	518243	6936391	6.50	6.62		6.72	0.11
95	Logan	517822	6936258	7.40	7.42		7.46	0.05
96	Logan	517805	6936243	7.55	7.35		7.46	0.11
97	Logan	518592	6938655	5.41	5.74		5.71	-0.03
98	Logan	518535	6939211	5.55	5.62		5.71	0.09
99	Logan	518862	6939232	5.56	5.75		5.71	-0.04
100	Logan	522047	6938762	4.46	5.00		5.12	0.11
101	Logan	521199	6938750	5.04	5.00		5.12	0.13
102	Logan	520806	6939175	5.02	5.03		5.20	0.17
103	Logan	518811	6939181	5.41	5.72		5.71	-0.01
104	Logan	518458	6939153	5.69	5.73		5.71	-0.02
105	Logan	516246	6940872	8.37	8.81		8.68	-0.13
106	Logan	516244	6940891	8.87	8.87		8.68	-0.19
107	Logan	516125	6940787	8.60	9.09		8.68	-0.41
108	Logan	515837	6941239	8.20	8.88		8.68	-0.20
109	Logan	515541	6941572	8.47	8.86		8.68	-0.18
110	Logan	515534	6941580	8.29	8.87		8.68	-0.19
111	Logan	514219	6941952	8.84	8.85		8.68	-0.17
112	Logan	515022	6941575	8.64	8.87		8.68	-0.19
113	Logan	513805	6942573	8.01	8.91		8.68	-0.23
114	Logan	515475	6941709	8.24	8.91		8.68	-0.23
115	Logan	513706	6943027	8.55	8.86		8.68	-0.19

Debris mark	River	Easting	Northing	Ground Level (mAHD)	Surveyed flood level (mAHD)	Comments	Modelled peak flood level (mAHD)	Difference (m)
116	Logan	513472	6942944	8.88	8.89		8.68	-0.21
117	Logan	513463	6942942	8.90	8.87		8.68	-0.19
118	Logan	513022	6942615	8.89	8.86		8.68	-0.18
119	Logan	513081	6942614	8.86	8.85		8.68	-0.17
120	Logan	513075	6942628	8.93	8.88		8.68	-0.20
121	Logan	511807	6940003	8.18	8.91		10.02	1.11
122	Logan	511799	6939952	8.28	8.85		10.02	1.17
123	Logan	511796	6939920	7.98	8.87		10.02	1.15
124	Logan	512709	6936573	11.85	12.59		12.74	0.15
125	Logan	512722	6936603	12.01	12.53		12.75	0.22
126	Logan	511794	6936932	12.71	12.66		12.79	0.13
127	Logan	511743	6936981	12.64	12.61		12.79	0.18
128	Logan	510107	6936758	12.86	12.71		12.79	0.08
129	Logan	510115	6936781	12.62	12.68		12.79	0.11
130	Logan	510449	6936274	12.76	12.66		12.79	0.13
131	Logan	511535	6935366	12.57	12.63		12.79	0.17
132	Logan	511995	6934361	13.07	13.12		13.33	0.22
133	Logan	509831	6931540	13.97	15.31		15.55	0.24
134	Logan	508596	6931719	14.84	15.32		15.56	0.24
135	Logan	508621	6929986	18.09	18.82		19.04	0.22
136	Logan	506698	6929290	18.47	18.54		18.56	0.02
137	Logan	506807	6929526	18.47	18.48		18.45	-0.03
138	Logan	508198	6929140	18.04	18.04		17.96	-0.08
139	Logan	506143	6930566	18.56	19.37		19.34	-0.04
140	Logan	504801	6929723	19.48	19.52		19.64	0.12
141	Logan	505495	6930001	18.26	19.62		19.68	0.06
142	Logan	504657	6928724	20.06	20.09		20.08	-0.01
143	Logan	503217	6929288	20.69	21.91		21.43	-0.49
144	Logan	503941	6930169	19.22	19.40		19.64	0.24
145	Logan	504196	6929461	19.17	19.47		19.64	0.17
146	Logan	509187	6929024	15.92	15.96		15.95	-0.02
148	Logan	511707	6927859	13.74	15.11		15.50	0.39
149	Logan	512047	6928633	15.15	15.21		15.50	0.29
150	Logan	509129	6927589	16.69	16.74		16.51	-0.23
151	Logan	510045	6928179	16.44	16.57		16.26	-0.31
152	Logan	510163	6928334	16.48	16.39		16.23	-0.16
153	Logan	510821	6929117	14.68	15.20		15.50	0.30
154	Logan	510908	6929529	16.21	16.23		15.50	-0.73
155	Logan	512394	6930976	15.15	15.19		15.50	0.31
156	Logan	511589	6932712	12.45	13.82		13.87	0.05

Debris mark	River	Easting	Northing	Ground Level (mAHD)	Surveyed flood level (mAHD)	Comments	Modelled peak flood level (mAHD)	Difference (m)
157	Logan	513023	6934193	11.94	11.95		12.15	0.20
158	Logan	513142	6935174	11.95	11.95		12.15	0.21
159	Logan	514549	6934930	11.68	11.83		11.94	0.10
160	Logan	512153	6940601	7.99	8.88		8.68	-0.20
161	Logan	502986	6922691	27.43	27.24		27.47	0.24
162	Logan	496039	6918319	32.72	32.76		32.90	0.14
163	Logan	494751	6917346	32.95	32.87		33.45	0.58
164	Logan	498419	6924689	25.51	26.72		26.84	0.12
165	Logan	500253	6922774	28.95	28.86		28.49	-0.37
166	Logan	498786	6921221	30.04	30.16		30.43	0.27
167	Logan	500848	6921573	27.21	27.33		27.47	0.15
168	Logan	502368	6921539	26.57	27.31		27.47	0.16
169	Logan	502377	6921568	27.28	27.31		27.47	0.17
170	Logan	511978	6936031	12.62	12.67		12.79	0.12
171	Logan	514123	6936147	9.41	11.19		11.30	0.11
172	Logan	513694	6937814	9.95	10.08		10.11	0.03
173	Logan	519414	6936194	6.25	6.23		6.27	0.04
174	Logan	518980	6936145	6.63	6.64		6.40	-0.24
175	Logan	519323	6935583	7.16	7.22		7.22	0.00
176	Logan	519445	6934646	5.74	7.11		7.22	0.12
177	Logan	519445	6934620	5.62	7.11		7.22	0.11
178	Logan	519189	6934821	6.52	7.14		7.22	0.08
179	Logan	519146	6934399	6.40	7.19		7.22	0.03
180	Logan	519150	6934383	7.22	7.22		7.22	0.01
181	Logan	525854	6936910	2.24	3.48		4.30	0.82
182	Logan	525831	6936916	2.05	3.48		4.31	0.83
183	Logan	527559	6936561	2.17	2.89		3.24	0.35
184	Logan	524870	6938134	3.89	3.86		4.54	0.68
185	Logan	524316	6937918	2.65	4.26		4.71	0.45
186	Logan	522249	6938252	4.59	4.62		4.96	0.33
190	Logan	516713	6938199	6.44	8.40		8.31	-0.09
191	Logan	516562	6938553	8.21	8.45		8.34	-0.12
192	Albert	521633	6933158	7.68	7.67		7.75	0.08
194	Logan	502542	6924243	26.98	27.09		27.45	0.36
195	Logan	497775	6919270	31.51	31.68		31.59	-0.09
196	Logan	497774	6919358	30.94	31.66		31.52	-0.14
197	Logan	496159	6920149	31.72	32.64		32.63	-0.01
198	Logan	502597	6921300	27.39	27.37		27.47	0.11
199	Logan	503567	6921789	27.23	27.30		27.47	0.18
200	Logan	503572	6921792	26.82	27.30		27.47	0.17

Debris mark	River	Easting	Northing	Ground Level (mAHD)	Surveyed flood level (mAHD)	Comments	Modelled peak flood level (mAHD)	Difference (m)
201	Logan	503923	6923801	27.30	27.28		27.47	0.19
202	Logan	503273	6923871	27.20	27.32		27.47	0.15
203	Logan	516411	6938485	6.71	8.44		8.34	-0.10
204	Logan	516752	6938164	6.48	8.41		8.31	-0.11
205	Logan	515914	6940025	7.85	8.82		8.68	-0.14
206	Logan	515922	6940006	8.82	8.81		8.68	-0.13
207	Logan	519378	6937861	5.67	5.75		5.71	-0.04
208	Logan	515572	6937832	8.33	8.40		8.31	-0.09
209	Logan	515551	6937638	8.29	8.40		8.31	-0.09
210	Logan	515089	6938363	8.97	9.05		8.72	-0.33
211	Logan	515607	6938003	8.37	8.40		8.31	-0.09
212	Logan	516181	6936910	8.15	8.45		8.29	-0.16
213	Logan	516895	6937633	8.36	8.45		8.31	-0.14
214	Logan	517120	6936908	8.15	8.30		8.26	-0.04
215	Logan	518066	6937075	6.48	6.50		6.72	0.22
216	Logan	518414	6936998	6.55	6.50		6.72	0.22
217	Logan	517680	6934686	7.16	7.20		7.27	0.07
218	Logan	517869	6934917	7.15	7.30		7.27	-0.03
219	Logan	517166	6936598	8.08	8.30		8.15	-0.15
220	Logan	510482	6932604	14.21	14.30		14.66	0.36
221	Logan	510588	6932030	14.43	14.35		14.66	0.31
222	Logan	506840	6928157	17.69	17.65		17.98	0.33
223	Logan	505122	6927902	20.03	20.10		20.31	0.21
224	Logan	503564	6928142	20.08	20.15		20.73	0.58
225	Logan	513642	6938137	10.09	10.10		10.11	0.01

Appendix D - Design rainfall depths

Table D.1 - Design rainfall depths - Location 1

Duration	Design Rainfall depths (mm)										
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	33.9	46.1	54.7	63.3	75.0	84.3	94.5	109	121	133	200
1.5 hour	38.3	52.0	61.7	71.5	85.0	95.7	107	124	137	151	260
2 hour	41.5	56.3	66.9	77.6	92.4	104	117	135	150	165	300
3 hour	46.4	63.0	74.8	87.0	104	118	132	152	169	186	360
4.5 hour	52.1	70.6	84.2	98.1	118	133	149	172	191	211	430
6 hour	56.7	77.1	92.0	107	129	146	164	189	210	231	480
9 hour	64.6	88.1	105	123	149	169	189	218	242	267	568
12 hour	71.3	97.7	117	137	166	188	211	244	270	298	640
18 hour	82.6	114	137	161	195	222	248	287	318	350	758
24 hour	92.1	128	154	182	219	250	280	324	358	395	854
30 hour	100	140	169	199	241	274	308	357	396	437	926
36 hour	107	151	183	215	260	296	333	386	428	473	989
48 hour	119	169	205	241	291	331	374	433	480	530	1124
72 hour	137	195	236	278	336	381	430	497	551	607	1348
96 hour	147	211	255	301	363	412	463	535	592	651	1539
120 hour	154	219	266	314	378	429	482	556	615	676	1629
144 hour	158	223	271	319	385	437	491	566	626	688	-
168 hour	159	223	271	320	386	438	493	569	629	692	-

Table D.2 - Design rainfall depths - Location 2

Duration	Design Rainfall depths (mm)										
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	34.2	46.8	55.6	64.3	76.2	85.5	96.0	111	124	137	200
1.5 hour	38.4	52.3	62.0	71.9	85.4	96.1	108	125	139	154	260
2 hour	41.3	56.1	66.6	77.3	92.1	104	116	135	150	166	300
3 hour	45.8	61.9	73.5	85.4	102	116	129	150	167	184	360
4.5 hour	50.8	68.5	81.4	94.8	114	129	144	167	186	205	430
6 hour	54.8	74.0	88.0	103	123	140	157	182	202	223	480
9 hour	61.6	83.3	99	116	140	160	178	207	229	253	568
12 hour	67.3	91.4	109	128	155	177	197	229	253	280	640
18 hour	76.9	105	127	149	180	206	231	267	296	327	758
24 hour	84.9	117	141	166	202	231	259	301	334	369	854
30 hour	92	128	154	182	221	253	286	333	372	412	926
36 hour	98	137	166	196	238	273	309	362	404	449	989
48 hour	108	152	185	219	267	305	348	407	456	507	1124
72 hour	122	175	213	253	308	352	401	469	525	583	1348
96 hour	132	189	230	273	334	382	433	505	564	626	1539
120 hour	138	197	240	285	348	398	450	525	585	649	1629
144 hour	141	201	245	291	354	406	458	534	594	658	-
168 hour	143	201	245	292	354	407	460	535	596	660	-

Table D.3 - Design rainfall depths - Location 3

Duration	Design Rainfall depths (mm)										
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	34.4	46.9	55.6	64.3	76.0	85.2	95.9	112	124	138	200
1.5 hour	38.4	52.2	61.9	71.7	85.0	95.5	108	125	139	155	260
2 hour	41.3	55.9	66.3	76.9	91.4	103	116	135	150	166	300
3 hour	45.6	61.5	73.0	84.8	101	114	129	149	166	184	360
4.5 hour	50.4	68.0	80.8	94.0	113	128	143	166	185	204	430
6 hour	54.4	73.4	87.3	102	122	139	155	180	200	222	480
9 hour	61.0	82.5	98	115	139	158	177	205	228	251	568
12 hour	66.5	90.4	108	127	153	175	195	227	252	278	640
18 hour	75.7	104	125	147	178	204	228	265	294	325	758
24 hour	83.3	115	139	164	199	228	256	298	331	367	854
30 hour	90	125	151	178	217	249	283	331	371	412	926
36 hour	95	134	162	191	234	268	306	359	404	450	989
48 hour	104	148	180	213	261	299	343	404	455	508	1124
72 hour	117	168	205	244	298	343	393	462	519	581	1348
96 hour	125	180	220	262	321	370	421	495	554	620	1539
120 hour	131	187	229	272	334	385	436	511	573	641	1629
144 hour	134	190	233	276	340	392	442	518	582	650	-
168 hour	135	191	233	276	340	393	443	518	584	652	-

Table D.4 - Design rainfall depths - Location 4

Duration	Design Rainfall depths (mm)										
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	34.3	47.0	55.9	64.7	76.6	86.0	96.6	112	125	139	200
1.5 hour	38.4	52.6	62.7	72.8	86.7	97.7	110	128	142	158	260
2 hour	41.4	56.8	67.8	78.9	94.3	107	120	139	155	172	300
3 hour	46.2	63.3	75.8	88.5	106	121	135	157	175	193	360
4.5 hour	51.8	71.2	85.3	99.9	120	137	153	178	198	218	430
6 hour	56.5	77.9	93.5	110	133	151	169	196	217	240	480
9 hour	64.6	89.4	108	127	153	175	195	226	251	277	568
12 hour	71.5	99.5	120	141	172	196	219	253	281	310	640
18 hour	83.0	117	141	167	203	232	259	301	334	369	758
24 hour	92.5	131	159	188	229	263	294	342	380	421	854
30 hour	100	143	174	207	252	289	328	383	428	476	926
36 hour	107	154	188	223	272	312	356	418	468	522	989
48 hour	119	171	210	249	305	351	402	474	532	595	1124
72 hour	134	195	240	286	351	404	463	546	614	688	1348
96 hour	143	209	257	308	379	437	498	587	660	739	1539
120 hour	148	216	267	320	395	455	517	608	683	765	1629
144 hour	151	220	271	326	401	462	525	617	693	776	-
168 hour	152	221	271	326	402	462	527	619	693	776	-

Table D.5 - Design rainfall depths - Location 5

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	33.8	45.9	54.2	62.4	73.7	82.4	91.8	106	117	129	200
1.5 hour	38.6	52.4	62.0	71.5	84.6	94.9	106	122	135	148	260
2 hour	42.2	57.4	68.1	78.8	93.4	105	117	135	149	164	300
3 hour	47.9	65.5	78.0	90.7	108	122	136	156	173	191	360
4.5 hour	54.8	75.4	90.3	105.0	126	143	159	183	203	223	430
6 hour	60.6	83.9	101.0	118	142	161	179	207	229	252	480
9 hour	70.5	98.7	119	140	170	193	214	247	274	302	568
12 hour	79.1	111.0	135	159	193	220	244	282	312	344	640
18 hour	93.8	133	162	192	233	266	295	340	377	415	758
24 hour	106.0	152	185	219	265	302	336	388	429	473	854
30 hour	117	168	204	241	292	333	372	430	476	525	926
36 hour	126	181	221	260	315	359	402	465	514	567	989
48 hour	142	204	248	292	352	400	449	518	573	631	1124
72 hour	164	236	285	334	402	455	511	588	648	711	1348
96 hour	177	255	308	360	432	488	548	628	692	758	1539
120 hour	185	265	321	375	450	508	570	653	719	787	1629
144 hour	189	271	327	383	460	520	582	668	736	806	-
168 hour	190	272	329	387	466	527	589	676	745	817	-

Table D.6 - Design rainfall depths - Location 6

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	34.2	46.4	54.9	63.3	74.8	83.8	92.6	106	117	128	200
1.5 hour	39.0	53.1	63.0	72.9	86.5	97.2	107	123	136	149	260
2 hour	42.7	58.4	69.4	80.5	95.9	108	119	137	151	166	300
3 hour	48.6	66.8	79.9	93.2	112	126	139	160	176	193	360
4.5 hour	55.6	77.2	92.8	109.0	131	149	164	188	207	227	430
6 hour	61.5	86.0	104.0	122	148	168	185	212	234	257	480
9 hour	71.7	101.0	123	145	176	202	221	254	280	307	568
12 hour	80.5	114.0	139	165	201	230	252	289	319	350	640
18 hour	95.5	137	167	199	241	276	303	348	384	421	758
24 hour	108.0	156	190	226	274	313	345	396	437	479	854
30 hour	119	172	210	249	302	343	382	440	485	533	926
36 hour	128	186	226	268	325	369	412	475	524	576	989
48 hour	144	208	254	299	361	410	460	529	584	641	1124
72 hour	166	240	291	341	410	464	521	598	658	721	1348
96 hour	180	259	313	366	439	495	556	637	701	767	1539
120 hour	188	269	325	381	456	515	577	661	726	794	1629
144 hour	192	275	332	388	466	527	589	675	742	811	-
168 hour	193	276	334	392	472	534	596	683	751	821	-

Table D.7 - Design rainfall depths - Location 7

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	33.1	44.6	52.7	60.8	71.9	80.8	88.5	101	111	121	200
1.5 hour	37.1	50.2	59.5	68.9	82.1	92.6	101	116	127	138	260
2 hour	40.0	54.4	64.7	75.1	89.8	102	111	127	139	152	300
3 hour	44.4	60.8	72.7	84.9	102	116	127	145	158	172	360
4.5 hour	49.5	68.3	82.2	96.5	117	133	145	165	181	197	430
6 hour	53.7	74.7	90.2	106	129	147	160	182	200	217	480
9 hour	60.9	85.4	104	123	149	171	185	211	231	251	568
12 hour	67.1	94.7	115	137	166	190	207	235	257	280	640
18 hour	77.8	111	135	160	195	222	242	276	302	329	758
24 hour	86.9	124	151	179	218	248	271	309	338	369	854
30 hour	95	136	165	195	237	269	297	340	374	407	926
36 hour	102	146	177	209	253	287	319	366	403	439	989
48 hour	114	163	197	232	279	316	354	405	446	487	1124
72 hour	131	187	225	262	314	354	397	454	499	546	1348
96 hour	143	202	242	280	335	377	422	481	527	577	1539
120 hour	150	211	252	290	347	391	436	496	543	593	1629
144 hour	154	217	257	296	354	398	443	504	550	600	-
168 hour	156	219	260	298	357	402	446	506	553	601	-

Table D.8 - Design rainfall depths - Location 8

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	33.6	45.4	53.7	62.0	73.6	82.8	89.7	102	111	121	200
1.5 hour	38.3	52.2	62.1	72.2	86.4	97.8	106	120	132	143	260
2 hour	41.8	57.5	68.8	80.3	96.8	110	119	135	148	160	300
3 hour	47.3	66.0	79.7	93.8	114	130	141	160	174	189	360
4.5 hour	53.9	76.3	92.8	110.0	134	154	166	188	206	223	430
6 hour	59.3	84.9	104.0	124	152	174	187	212	231	251	480
9 hour	68.6	99.3	122	146	180	207	221	251	274	297	568
12 hour	76.3	111.0	138	165	202	232	249	282	308	334	640
18 hour	89.3	131	162	195	238	272	292	332	362	393	758
24 hour	99.9	147	182	218	265	302	326	370	404	438	854
30 hour	109	160	198	236	286	325	357	406	445	484	926
36 hour	117	172	211	252	304	344	381	434	476	518	989
48 hour	129	190	232	276	331	374	416	475	520	566	1124
72 hour	147	214	261	306	366	411	460	523	572	622	1348
96 hour	159	230	278	325	387	434	486	552	602	654	1539
120 hour	166	240	289	337	402	451	503	570	622	674	1629
144 hour	170	246	297	346	413	464	515	584	636	690	-
168 hour	173	250	302	352	421	474	524	594	648	702	-

Table D.9 - Design rainfall depths - Location 9

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	37.7	51.0	60.4	69.8	82.8	93.1	100.0	113	123	133	200
1.5 hour	44.0	60.5	72.2	84.1	101.0	115.0	123	139	152	164	260
2 hour	49.2	68.5	82.4	96.6	117.0	133	143	162	176	190	300
3 hour	58.0	82.3	100.0	118.0	145	166	178	201	218	236	360
4.5 hour	69.2	100.0	123.0	147.0	180	208	222	250	272	294	430
6 hour	79.0	116.0	143.0	171	211	243	259	292	318	343	480
9 hour	95.9	142.0	177	214	263	303	322	363	395	426	568
12 hour	110.0	165.0	206	249	306	352	374	422	459	495	640
18 hour	135.0	203	254	307	375	429	457	516	561	606	758
24 hour	154.0	233	291	352	427	486	521	589	640	692	854
30 hour	170	258	321	387	469	531	579	656	715	774	926
36 hour	184	278	347	417	502	568	625	709	773	837	989
48 hour	206	310	385	462	553	623	692	785	856	928	1124
72 hour	234	352	435	520	619	694	775	879	959	1040	1348
96 hour	252	377	465	555	661	740	828	938	1020	1110	1539
120 hour	262	393	485	579	691	775	866	982	1070	1160	1629
144 hour	269	403	500	598	716	805	896	1020	1110	1210	-
168 hour	274	411	511	614	738	834	922	1050	1150	1240	-

Table D.10 - Design rainfall depths - Location 10

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	34.0	46.2	54.7	63.2	74.8	84.0	93.5	108	119	131	200
1.5 hour	38.1	51.7	61.3	71.0	84.4	95.0	106	122	135	149	260
2 hour	41.1	55.7	66.2	76.8	91.5	103	115	133	147	161	300
3 hour	45.5	61.8	73.5	85.6	102	116	129	149	164	181	360
4.5 hour	50.6	68.8	82.1	95.8	115	131	145	167	185	203	430
6 hour	54.8	74.6	89.2	104	126	143	159	183	202	222	480
9 hour	61.8	84.6	102	119	144	164	182	209	231	254	568
12 hour	67.9	93.3	112	132	160	182	202	232	257	282	640
18 hour	78.1	108	131	154	187	213	236	272	301	331	758
24 hour	86.7	121	146	172	209	239	265	306	339	372	854
30 hour	94	132	160	189	229	261	293	339	376	415	926
36 hour	101	142	172	203	246	280	316	367	408	450	989
48 hour	112	158	192	226	274	312	354	411	457	505	1124
72 hour	128	182	220	259	314	357	404	468	520	574	1348
96 hour	138	196	238	279	338	384	433	501	555	612	1539
120 hour	145	205	247	290	351	399	449	518	574	632	1629
144 hour	148	209	252	295	357	406	456	526	582	641	-
168 hour	150	209	253	295	358	407	458	528	584	643	-

Table D.11 – Design rainfall depths – Location 11

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	33.7	45.7	54.0	62.3	73.8	82.9	91.4	105	116	127	200
1.5 hour	37.8	51.3	60.9	70.6	84.0	94.8	104	120	132	145	260
2 hour	40.8	55.5	66.0	76.7	91.7	104	114	131	145	158	300
3 hour	45.2	61.8	73.9	86.3	104	118	130	149	164	179	360
4.5 hour	50.3	69.2	83.1	97.5	118	134	147	169	186	204	430
6 hour	54.5	75.4	90.8	107	130	148	162	186	204	224	480
9 hour	61.6	86.0	104	123	149	171	187	214	235	257	568
12 hour	67.8	95.0	115	136	166	190	208	238	262	286	640
18 hour	78.3	111	134	159	194	221	243	278	306	335	758
24 hour	87.1	124	150	178	216	247	272	312	343	376	854
30 hour	95	135	164	194	236	269	299	345	381	417	926
36 hour	102	145	176	208	252	287	322	372	411	450	989
48 hour	113	161	195	230	279	317	357	413	457	502	1124
72 hour	129	184	222	261	315	357	403	464	513	566	1348
96 hour	139	198	238	278	336	380	428	492	544	600	1539
120 hour	145	206	247	288	347	393	441	507	559	618	1629
144 hour	149	210	251	292	352	398	448	514	567	626	-
168 hour	150	211	252	292	352	399	450	516	569	627	-

Table D.12 – Design rainfall depths – Location 12

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	33.1	44.6	52.7	60.8	72.0	80.9	88.9	102	112	122	200
1.5 hour	36.7	49.7	58.9	68.2	81.2	91.7	101	115	127	138	260
2 hour	39.2	53.3	63.4	73.6	88.1	100	110	125	138	150	300
3 hour	43.0	58.8	70.2	82.1	99	112	123	141	155	169	360
4.5 hour	47.3	65.2	78.4	92.1	111	127	139	159	174	190	430
6 hour	50.9	70.7	85.3	101	122	140	152	174	191	208	480
9 hour	57.2	80.1	97	115	140	160	175	200	219	239	568
12 hour	62.7	88.5	108	128	156	178	194	222	243	265	640
18 hour	72.4	103	126	149	182	208	227	259	284	310	758
24 hour	80.9	115	141	167	203	232	254	291	319	348	854
30 hour	88	126	154	183	221	252	280	321	354	388	926
36 hour	95	136	166	196	237	270	302	347	383	420	989
48 hour	106	152	185	218	263	298	335	386	427	468	1124
72 hour	123	175	212	247	298	337	379	436	481	527	1348
96 hour	133	189	228	265	318	360	404	463	509	557	1539
120 hour	139	197	236	275	330	372	417	477	524	573	1629
144 hour	141	201	240	279	335	378	423	484	531	579	-
168 hour	142	201	240	280	336	379	425	485	532	580	-

Table D.13 – Design rainfall depths – Location 13

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	33.5	45.3	53.5	61.8	73.3	82.5	89.8	102	112	122	200
1.5 hour	37.7	51.4	61.2	71.1	85.1	96.5	105	120	131	142	260
2 hour	40.9	56.1	67.1	78.4	94.5	108	117	133	146	158	300
3 hour	45.7	63.6	76.6	90.2	109	125	136	155	169	184	360
4.5 hour	51.4	72.4	87.9	104.0	127	146	158	179	196	213	430
6 hour	56.1	79.7	97.3	116	142	163	176	200	218	237	480
9 hour	64.1	92.2	113	135	166	191	205	233	254	276	568
12 hour	70.9	103.0	126	151	185	213	229	260	284	309	640
18 hour	82.4	120	148	177	216	248	267	304	332	361	758
24 hour	92.0	135	166	198	241	275	298	339	371	403	854
30 hour	100	147	180	215	261	296	326	372	407	444	926
36 hour	107	157	193	229	277	314	348	398	437	476	989
48 hour	119	174	212	252	303	342	382	437	480	524	1124
72 hour	136	197	239	281	337	379	425	486	533	581	1348
96 hour	146	211	255	299	357	401	450	513	562	612	1539
120 hour	153	220	265	309	369	416	464	529	578	629	1629
144 hour	156	225	271	316	377	425	473	537	587	638	-
168 hour	158	227	274	319	382	431	477	542	592	643	-

Table D.14 – Design rainfall depths – Location 14

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	34.7	47.3	56.1	64.8	76.8	86.3	96.0	111	123	135	200
1.5 hour	39.2	53.4	63.5	73.8	87.9	99.2	110	127	141	155	260
2 hour	42.4	58.0	69.2	80.5	96.4	109	121	140	155	170	300
3 hour	47.5	65.2	78.1	91.2	110	125	138	160	176	194	360
4.5 hour	53.5	73.7	88.6	104.0	126	143	158	183	202	222	430
6 hour	58.4	80.9	97.4	115	139	158	175	202	223	245	480
9 hour	66.8	93.1	113	133	161	184	203	234	259	284	568
12 hour	73.9	104.0	125	148	180	206	228	262	289	318	640
18 hour	85.7	121	147	175	212	243	268	309	342	376	758
24 hour	95.6	136	166	196	239	273	303	349	386	425	854
30 hour	104	149	181	215	261	298	334	388	430	475	926
36 hour	111	159	195	231	281	321	361	420	467	516	989
48 hour	123	177	217	257	312	357	404	470	523	580	1124
72 hour	139	202	247	293	356	406	461	535	596	660	1348
96 hour	150	217	265	314	381	435	493	572	636	704	1539
120 hour	156	225	275	325	395	451	509	592	658	727	1629
144 hour	159	229	279	330	401	458	516	601	668	738	-
168 hour	160	230	280	331	401	458	516	604	670	741	-

Table D.15 – Design rainfall depths – Location 15

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	33.5	45.3	53.5	61.8	73.1	82.1	90.7	104	115	127	200
1.5 hour	37.2	50.5	59.9	69.4	82.6	93.1	103	118	131	144	260
2 hour	39.9	54.2	64.5	75.0	89.6	101	112	129	142	156	300
3 hour	43.8	59.9	71.6	83.6	101	114	126	145	160	175	360
4.5 hour	48.3	66.5	79.9	93.8	113	129	142	163	180	197	430
6 hour	52.1	72.1	86.9	102	124	142	156	179	197	216	480
9 hour	58.6	81.7	99	117	142	163	178	205	225	247	568
12 hour	64.2	90.1	109	130	158	180	198	227	250	274	640
18 hour	74.0	105	127	151	183	210	231	265	292	320	758
24 hour	82.3	117	142	168	205	234	258	297	328	359	854
30 hour	90	127	155	183	223	255	284	328	364	400	926
36 hour	96	137	166	196	239	272	306	355	393	434	989
48 hour	107	152	185	218	264	301	340	395	438	484	1124
72 hour	122	174	210	246	299	340	385	446	495	546	1348
96 hour	131	187	225	263	319	363	409	473	525	578	1539
120 hour	137	194	234	273	330	375	423	488	540	594	1629
144 hour	139	197	238	277	335	380	429	495	547	601	-
168 hour	139	198	238	277	335	380	430	496	548	602	-

Table D.16 – Design rainfall depths – Location 16

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	33.2	45.0	53.2	61.5	72.8	81.7	90.2	104	114	125	200
1.5 hour	36.8	50.1	59.5	69.0	82.3	92.9	103	118	130	142	260
2 hour	39.4	53.9	64.1	74.7	89.5	101	112	128	141	155	300
3 hour	43.4	59.6	71.3	83.5	101	115	126	145	159	175	360
4.5 hour	47.9	66.4	79.9	94.0	114	130	143	164	180	197	430
6 hour	51.8	72.1	87.2	103	125	143	157	180	198	216	480
9 hour	58.5	82.2	100	118	144	165	181	207	227	249	568
12 hour	64.4	91.0	111	132	160	184	201	230	253	277	640
18 hour	74.6	106	130	154	188	215	235	270	297	325	758
24 hour	83.3	119	145	173	210	240	264	303	334	366	854
30 hour	91	130	159	189	229	262	292	336	372	409	926
36 hour	98	140	171	202	246	280	314	363	402	443	989
48 hour	109	156	190	224	272	310	350	405	450	496	1124
72 hour	125	179	217	254	308	350	396	458	508	560	1348
96 hour	134	192	232	272	329	374	422	487	539	594	1539
120 hour	140	200	241	281	340	386	435	502	555	610	1629
144 hour	142	203	245	286	345	392	441	508	562	617	-
168 hour	143	203	245	286	345	392	443	509	562	617	-

Table D.17 – Design rainfall depths – Location 17

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	33.7	45.9	54.4	62.9	74.5	83.6	93.0	107	119	131	200
1.5 hour	37.6	51.3	61.0	70.8	84.4	95.2	106	122	136	149	260
2 hour	40.4	55.3	65.9	76.7	91.9	104	116	134	148	163	300
3 hour	44.8	61.5	73.6	86.1	104	118	131	151	167	184	360
4.5 hour	49.9	68.8	82.7	97.2	118	134	148	171	189	208	430
6 hour	54.1	75.1	90.5	107	129	148	163	188	208	228	480
9 hour	61.5	85.9	104	123	149	171	189	217	240	263	568
12 hour	67.8	95.3	116	137	167	191	211	242	268	294	640
18 hour	78.6	111	135	161	196	224	248	286	316	347	758
24 hour	87.7	125	152	181	220	251	279	322	357	393	854
30 hour	95	136	166	197	240	275	309	358	398	440	926
36 hour	102	146	179	212	258	295	334	389	433	480	989
48 hour	113	163	199	236	287	329	374	436	487	540	1124
72 hour	129	186	227	268	327	374	425	497	555	616	1348
96 hour	138	199	243	287	350	401	455	530	591	656	1539
120 hour	143	206	252	298	363	415	470	548	611	677	1629
144 hour	145	210	255	303	369	421	478	556	619	685	-
168 hour	146	210	256	303	369	421	479	557	620	686	-

Table D.18 – Design rainfall depths – Location 18

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	33.2	45.4	53.9	62.3	73.8	82.8	91.8	106	117	129	200
1.5 hour	36.9	50.7	60.4	70.2	83.8	94.6	105	121	134	147	260
2 hour	39.7	54.7	65.3	76.2	91.5	104	115	132	146	161	300
3 hour	44.0	60.9	73.2	85.8	104	118	130	150	166	182	360
4.5 hour	49.1	68.5	82.7	97.5	118	135	149	171	189	208	430
6 hour	53.5	75.0	90.9	108	131	150	165	189	209	229	480
9 hour	61.2	86.4	105	125	152	175	192	220	243	266	568
12 hour	67.9	96.4	118	140	170	196	215	247	272	299	640
18 hour	79.3	114	139	165	201	231	254	292	323	354	758
24 hour	89.0	128	156	186	227	260	287	331	366	402	854
30 hour	97	140	172	204	248	284	318	369	408	452	926
36 hour	105	151	184	219	267	305	344	400	444	492	989
48 hour	116	168	206	244	297	339	385	449	500	554	1124
72 hour	133	192	234	277	337	385	438	510	569	631	1348
96 hour	142	206	251	296	360	412	467	544	607	672	1539
120 hour	147	213	260	306	373	426	482	561	626	693	1629
144 hour	149	216	264	311	378	433	489	568	633	703	-
168 hour	149	216	264	311	378	434	490	569	634	706	-

Table D.19 - Design rainfall depths - Location 19

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	33.5	46.2	55.0	63.7	75.6	84.8	94.6	110	122	134	200
1.5 hour	37.4	51.8	61.9	72.1	86.2	97.3	109	126	140	154	260
2 hour	40.4	56.0	67.2	78.5	94.4	107	119	138	153	169	300
3 hour	45.1	62.9	75.7	88.9	107	123	136	158	175	193	360
4.5 hour	50.9	71.3	86.2	102.0	123	141	157	181	200	221	430
6 hour	55.9	78.7	95.3	113	137	157	174	201	222	245	480
9 hour	64.7	91.5	111	132	161	185	204	235	260	286	568
12 hour	72.2	103.0	125	149	181	208	230	265	293	323	640
18 hour	85.2	122	149	178	216	248	275	318	351	387	758
24 hour	96.0	138	169	202	246	282	313	362	402	443	854
30 hour	105	152	187	222	271	310	350	407	453	501	926
36 hour	113	164	201	240	293	335	380	444	496	550	989
48 hour	126	183	226	269	328	376	429	503	563	627	1124
72 hour	143	210	258	308	377	432	493	579	649	724	1348
96 hour	153	225	277	330	405	465	529	621	696	777	1539
120 hour	158	233	287	343	420	483	549	643	720	804	1629
144 hour	161	236	291	348	426	491	557	652	730	815	-
168 hour	162	237	291	349	426	492	559	654	731	816	-

Table D.20 - Design rainfall depths - Location 20

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	40.5	55.1	65.3	75.5	89.6	101.0	109.0	123	134	145	200
1.5 hour	47.7	65.8	78.6	91.6	110.0	125.0	135	152	166	179	260
2 hour	53.7	75.0	90.2	106.0	128.0	146	157	178	193	209	300
3 hour	64.1	91.1	111.0	131.0	160	183	197	223	242	262	360
4.5 hour	77.7	112.0	138.0	164.0	201	232	248	281	305	330	430
6 hour	89.8	131.0	162.0	194	238	275	293	331	360	390	480
9 hour	111.0	165.0	204	246	302	348	371	419	456	492	568
12 hour	130.0	194.0	241	291	357	410	437	493	536	580	640
18 hour	161.0	243	303	366	446	509	545	616	669	724	758
24 hour	187.0	283	353	426	516	587	632	714	777	840	854
30 hour	208	316	394	475	574	650	710	805	877	950	926
36 hour	227	344	429	516	621	702	774	878	957	1040	989
48 hour	256	388	484	581	696	784	870	988	1080	1170	1124
72 hour	296	447	556	668	796	893	998	1130	1240	1340	1348
96 hour	320	483	601	723	861	967	1080	1230	1340	1450	1539
120 hour	335	506	631	761	909	1020	1140	1300	1420	1540	1629
144 hour	346	523	653	790	948	1070	1190	1360	1490	1620	-
168 hour	353	534	670	815	982	1110	1230	1410	1550	1680	-

Table D.21 – Design rainfall depths – Location 21

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	34.2	46.3	54.7	63.3	75.1	84.6	91.8	104	114	124	200
1.5 hour	38.9	53.3	63.5	74.0	88.8	101.0	109	124	136	148	260
2 hour	42.4	58.7	70.5	82.6	99.9	114	124	141	154	167	300
3 hour	48.0	67.5	81.8	96.7	118	136	146	166	182	198	360
4.5 hour	54.7	78.1	95.4	114.0	140	161	173	197	215	233	430
6 hour	60.2	86.8	107.0	128	157	181	195	221	242	262	480
9 hour	69.5	101.0	125	151	186	214	229	260	284	309	568
12 hour	77.3	114.0	141	170	208	240	257	292	318	346	640
18 hour	90.1	133	165	199	243	279	300	341	372	404	758
24 hour	100.0	149	185	222	270	308	333	378	413	449	854
30 hour	109	162	200	240	291	330	362	413	452	492	926
36 hour	117	173	213	254	307	349	386	440	483	526	989
48 hour	129	190	233	277	333	377	420	480	527	574	1124
72 hour	145	212	259	306	367	413	463	529	580	632	1348
96 hour	155	226	275	324	387	435	488	557	610	664	1539
120 hour	161	235	285	335	401	451	504	574	629	684	1629
144 hour	165	240	292	343	410	462	515	586	641	698	-
168 hour	166	243	296	348	418	472	523	595	651	707	-

Table D.22 – Design rainfall depths – Location 22

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	36.1	48.9	57.9	67.0	79.6	89.7	96.6	109	119	129	200
1.5 hour	41.4	57.1	68.3	79.8	96.2	109.0	118	134	145	158	260
2 hour	45.6	63.8	77.0	90.6	110.0	126	136	154	168	181	300
3 hour	52.6	75.1	91.7	109.0	134	155	166	188	204	221	360
4.5 hour	61.5	89.5	110.0	132.0	164	190	202	229	250	270	430
6 hour	69.3	102.0	127.0	153	189	220	234	264	288	311	480
9 hour	83.0	124.0	155	188	232	269	285	323	351	380	568
12 hour	94.9	143.0	179	217	268	310	328	372	405	437	640
18 hour	115.0	175	219	266	326	375	399	452	491	531	758
24 hour	132.0	201	252	306	372	425	455	515	561	608	854
30 hour	146	223	279	338	409	465	506	574	627	680	926
36 hour	159	242	302	365	440	498	548	622	680	738	989
48 hour	178	271	338	407	488	550	612	696	761	826	1124
72 hour	204	309	384	461	550	618	692	788	861	936	1348
96 hour	219	330	410	491	586	658	738	840	918	998	1539
120 hour	226	340	423	508	607	683	764	870	951	1030	1629
144 hour	230	345	429	517	620	699	778	886	970	1060	-
168 hour	230	345	431	521	627	709	785	895	980	1070	-

Table D.23 - Design rainfall depths - Location 23

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	33.7	45.9	54.4	62.8	74.3	83.4	91.6	105	116	127	200
1.5 hour	37.8	51.8	61.7	71.7	85.7	96.9	106	122	134	147	260
2 hour	40.9	56.4	67.4	78.7	94.6	108	118	135	149	163	300
3 hour	45.7	63.5	76.5	89.9	109	124	136	156	172	188	360
4.5 hour	51.3	72.1	87.5	103.0	126	145	158	181	198	217	430
6 hour	56.2	79.5	96.8	115	140	161	175	201	220	241	480
9 hour	64.5	92.1	113	134	164	189	205	235	257	281	568
12 hour	71.6	103.0	126	151	184	212	230	263	288	315	640
18 hour	83.7	121	149	178	217	248	271	310	340	372	758
24 hour	93.8	136	167	199	243	278	304	348	383	419	854
30 hour	102	149	182	217	264	302	335	385	424	465	926
36 hour	110	160	196	233	282	322	360	415	458	503	989
48 hour	122	177	216	257	311	354	398	460	509	560	1124
72 hour	138	201	244	288	348	395	446	516	571	630	1348
96 hour	148	214	260	305	369	418	472	546	604	666	1539
120 hour	154	222	268	314	380	431	486	561	621	684	1629
144 hour	156	225	272	319	385	437	493	568	628	692	-
168 hour	157	226	273	320	386	439	495	569	629	692	-

Table D.24 - Design rainfall depths - Location 24

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	35.5	48.3	57.1	65.9	78.1	87.7	95.6	109	120	130	200
1.5 hour	40.5	55.7	66.5	77.5	92.9	105.0	115	131	144	156	260
2 hour	44.4	61.7	74.1	86.9	105.0	120	130	149	163	178	300
3 hour	50.7	71.5	86.8	103.0	125	144	156	178	195	212	360
4.5 hour	58.4	83.6	102.0	122.0	150	173	186	212	233	253	430
6 hour	65.0	94.0	116.0	138	170	197	212	241	264	287	480
9 hour	76.3	112.0	138	166	204	235	253	288	315	343	568
12 hour	85.9	126.0	157	189	232	267	287	327	357	388	640
18 hour	102.0	151	187	225	276	316	341	388	425	462	758
24 hour	115.0	170	211	254	309	353	383	437	479	522	854
30 hour	126	187	231	277	336	383	421	482	529	577	926
36 hour	135	200	247	296	359	408	452	518	569	622	989
48 hour	150	222	273	326	393	446	499	573	631	690	1124
72 hour	169	250	306	364	438	495	558	642	708	776	1348
96 hour	181	266	326	386	464	525	593	681	751	824	1539
120 hour	187	275	337	400	481	545	613	705	777	852	1629
144 hour	191	281	344	408	492	558	625	718	791	867	-
168 hour	193	284	348	414	500	567	632	725	799	874	-

Table D.25 - Design rainfall depths - Location 25

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	33.5	45.8	54.4	62.9	74.5	83.5	92.1	106	117	129	200
1.5 hour	37.5	51.7	61.7	71.8	85.7	96.8	107	123	136	149	260
2 hour	40.6	56.2	67.4	78.7	94.7	107	118	136	151	165	300
3 hour	45.5	63.5	76.6	90.1	109	125	137	158	174	191	360
4.5 hour	51.5	72.5	88.0	104.0	127	146	159	183	202	221	430
6 hour	56.6	80.3	97.9	116	142	163	178	205	226	247	480
9 hour	65.7	94.0	115	137	168	193	210	241	266	291	568
12 hour	73.5	106.0	130	155	190	218	238	273	301	329	640
18 hour	86.8	126	155	185	226	259	284	326	359	394	758
24 hour	97.9	142	175	209	255	292	322	370	408	448	854
30 hour	107	156	192	229	280	320	357	413	458	504	926
36 hour	115	168	207	247	300	343	386	448	498	549	989
48 hour	129	188	230	274	333	380	431	501	558	617	1124
72 hour	146	213	261	309	376	428	487	567	631	700	1348
96 hour	156	227	278	328	399	455	517	602	671	743	1539
120 hour	162	235	286	338	411	470	532	619	692	766	1629
144 hour	164	239	290	342	416	477	539	626	701	777	-
168 hour	164	239	291	342	416	478	540	626	704	780	-

Table D.26 - Design rainfall depths - Location 26

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	35.7	48.8	57.8	66.7	78.8	88.2	96.7	111	122	134	200
1.5 hour	40.6	56.0	66.9	77.8	93.0	105.0	115	132	145	159	260
2 hour	44.4	61.8	74.3	86.9	105.0	119	130	149	164	180	300
3 hour	50.8	71.5	86.6	102.0	124	142	155	178	195	214	360
4.5 hour	58.6	83.6	102.0	121.0	148	171	185	212	233	255	430
6 hour	65.5	94.1	115.0	138	169	195	211	241	265	289	480
9 hour	77.3	112.0	138	166	204	235	254	290	319	347	568
12 hour	87.5	128.0	158	190	233	268	290	331	364	396	640
18 hour	105.0	154	190	229	280	321	348	399	438	478	758
24 hour	119.0	175	216	259	317	363	395	453	498	545	854
30 hour	130	192	238	284	346	396	437	502	555	608	926
36 hour	140	207	255	305	371	423	471	543	601	660	989
48 hour	156	230	283	337	409	466	524	606	672	740	1124
72 hour	177	261	319	378	458	521	590	684	758	837	1348
96 hour	189	278	339	401	485	552	626	726	805	889	1539
120 hour	196	287	350	413	501	570	645	748	830	916	1629
144 hour	200	292	356	421	510	581	654	757	842	929	-
168 hour	202	294	359	424	515	586	656	758	845	932	-

Table D.27 – Design rainfall depths – Location 27

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	35.0	48.3	57.5	66.6	79.1	88.9	98.5	114	126	139	200
1.5 hour	39.5	54.8	65.7	76.6	91.8	104.0	115	133	148	163	260
2 hour	43.0	59.9	72.1	84.6	102.0	116	129	149	165	181	300
3 hour	48.6	68.3	82.6	97.5	118	136	150	173	192	211	360
4.5 hour	55.4	78.6	95.6	113.0	139	159	175	202	224	246	430
6 hour	61.4	87.5	107.0	127	156	179	197	227	251	275	480
9 hour	71.7	103.0	126	151	185	213	233	268	296	325	568
12 hour	80.6	116.0	143	171	209	241	264	304	336	368	640
18 hour	95.6	139	171	204	250	287	316	364	403	442	758
24 hour	108.0	158	194	232	283	325	359	415	459	505	854
30 hour	118	173	213	255	311	357	400	464	516	570	926
36 hour	127	186	230	274	335	383	434	505	562	623	989
48 hour	142	208	256	305	372	427	486	568	634	705	1124
72 hour	161	236	290	346	422	484	552	647	724	807	1348
96 hour	172	252	309	368	450	517	588	690	772	860	1539
120 hour	177	260	319	380	466	534	607	712	797	887	1629
144 hour	180	264	323	385	472	542	615	721	806	897	-
168 hour	181	264	324	385	473	543	616	722	807	897	-

Table D.28 – Design rainfall depths – Location 28

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	37.5	51.8	61.9	71.9	85.6	96.3	107.0	125	139	153	200
1.5 hour	42.7	59.5	71.5	83.8	101.0	114.0	128	148	164	182	260
2 hour	46.8	65.6	79.2	93.2	113.0	129	143	166	185	204	300
3 hour	53.4	75.5	91.7	109.0	132	152	169	196	217	239	360
4.5 hour	61.5	87.7	107.0	127.0	156	179	199	230	255	281	430
6 hour	68.4	98.1	120.0	143	175	202	224	258	286	315	480
9 hour	80.3	116.0	142	170	208	240	265	306	338	372	568
12 hour	90.5	131.0	161	192	236	271	300	346	383	422	640
18 hour	107.0	157	193	231	282	324	359	415	460	507	758
24 hour	121.0	178	219	262	320	367	409	473	525	580	854
30 hour	133	195	241	288	352	404	456	532	592	657	926
36 hour	142	210	259	311	380	435	496	580	648	721	989
48 hour	158	233	289	347	425	487	559	657	736	821	1124
72 hour	178	264	328	396	487	559	640	754	847	947	1348
96 hour	190	282	351	425	523	602	686	807	908	1020	1539
120 hour	196	291	363	441	542	626	711	836	941	1050	1629
144 hour	200	296	369	448	550	636	723	849	956	1070	-
168 hour	202	297	370	449	550	637	726	852	959	1070	-

Table D.29 - Design rainfall depths - Location 29

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	34.0	47.5	56.8	66.1	78.5	88.3	99.6	116	130	144	200
1.5 hour	38.1	53.1	63.7	74.4	89.0	101.0	113	132	148	164	260
2 hour	41.1	57.4	69.0	80.7	96.9	110	124	144	161	179	300
3 hour	46.0	64.2	77.3	90.7	109	124	140	163	181	201	360
4.5 hour	51.9	72.5	87.4	103.0	124	142	159	185	206	228	430
6 hour	57.1	79.7	96.2	113	137	157	176	204	227	250	480
9 hour	65.9	92.3	112	131	160	183	204	237	263	291	568
12 hour	73.6	103.0	125	148	179	205	230	266	296	327	640
18 hour	86.5	122	149	175	214	244	274	318	354	392	758
24 hour	97.2	138	168	199	243	278	313	365	406	450	854
30 hour	106	152	186	220	269	308	351	412	461	513	926
36 hour	114	164	201	238	292	334	384	452	507	567	989
48 hour	126	184	225	269	330	379	438	517	582	653	1124
72 hour	143	210	260	311	384	442	509	603	681	765	1348
96 hour	153	226	280	337	416	481	550	651	736	827	1539
120 hour	158	234	291	351	434	503	572	677	765	859	1629
144 hour	161	237	296	357	442	513	582	688	777	872	-
168 hour	162	238	296	357	442	514	584	689	779	873	-

Table D.30 - Design rainfall depths - Location 30

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	33.9	47.0	56.0	65.1	77.3	86.8	97.0	113	125	138	200
1.5 hour	38.0	52.8	63.2	73.8	88.4	100.0	112	130	144	159	260
2 hour	41.1	57.2	68.8	80.6	97.0	110	123	143	158	175	300
3 hour	46.0	64.4	77.7	91.5	111	126	141	163	181	200	360
4.5 hour	52.0	73.2	88.7	105.0	127	146	162	187	208	229	430
6 hour	57.2	80.8	98.2	116	142	162	180	208	231	254	480
9 hour	66.3	94.2	115	136	166	191	211	244	270	297	568
12 hour	74.2	106.0	129	153	187	215	238	275	304	335	640
18 hour	87.6	126	154	183	223	256	284	329	365	401	758
24 hour	98.7	142	174	208	253	291	324	375	417	460	854
30 hour	108	157	192	229	279	320	362	422	470	521	926
36 hour	116	169	207	247	301	346	394	461	515	572	989
48 hour	129	189	232	276	338	388	444	522	585	653	1124
72 hour	146	215	265	316	388	446	510	600	675	754	1348
96 hour	157	230	284	339	417	480	547	644	724	809	1539
120 hour	162	238	294	352	433	498	567	666	749	837	1629
144 hour	165	242	299	357	440	506	576	676	760	849	-
168 hour	165	242	300	358	441	507	577	677	761	849	-

Table D.31 - Design rainfall depths - Location 31

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	35.4	49.4	59.0	68.7	81.6	91.7	103.0	120	134	149	200
1.5 hour	39.9	55.7	66.9	78.2	93.7	106.0	119	139	155	172	260
2 hour	43.3	60.6	72.9	85.5	103.0	117	131	153	171	189	300
3 hour	48.7	68.3	82.5	97.1	117	134	150	175	195	216	360
4.5 hour	55.2	77.7	94.1	111.0	135	154	172	200	223	246	430
6 hour	60.8	85.7	104.0	123	149	171	191	221	246	272	480
9 hour	70.4	99.5	121	143	174	199	223	258	286	316	568
12 hour	78.6	111.0	135	160	195	224	250	290	322	355	640
18 hour	92.2	132	160	190	232	266	297	345	383	424	758
24 hour	103.0	148	181	215	262	301	338	393	438	485	854
30 hour	113	163	199	236	289	331	377	442	495	551	926
36 hour	121	175	214	255	312	358	411	484	543	607	989
48 hour	133	194	239	285	350	403	465	550	619	694	1124
72 hour	150	221	273	328	404	466	536	635	717	806	1348
96 hour	160	236	293	353	436	504	577	683	772	867	1539
120 hour	166	245	304	366	454	526	598	708	801	899	1629
144 hour	169	248	309	372	461	536	608	719	813	913	-
168 hour	171	249	310	373	462	537	611	721	815	915	-

Table D.32 - Design rainfall depths - Location 32

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	35.6	49.4	58.9	68.5	81.4	91.5	102.0	119	132	146	200
1.5 hour	40.2	56.1	67.3	78.7	94.4	107.0	119	139	154	171	260
2 hour	43.8	61.3	73.8	86.7	105.0	119	133	154	171	190	300
3 hour	49.5	69.7	84.4	99.6	121	138	154	179	198	219	360
4.5 hour	56.4	79.9	97.2	115.0	141	161	179	207	230	254	430
6 hour	62.4	88.8	108.0	128	157	180	200	231	256	282	480
9 hour	72.7	104.0	127	151	185	213	235	272	301	332	568
12 hour	81.6	117.0	144	171	209	240	266	307	340	375	640
18 hour	96.4	139	171	204	249	286	317	367	407	449	758
24 hour	109.0	158	194	231	282	324	361	419	465	513	854
30 hour	119	173	213	254	311	356	403	470	524	581	926
36 hour	127	186	229	274	335	384	438	513	574	638	989
48 hour	141	208	256	306	375	430	494	580	651	727	1124
72 hour	160	236	291	350	429	494	566	667	750	839	1348
96 hour	170	252	312	375	461	531	606	715	804	900	1539
120 hour	176	260	323	388	479	552	628	740	832	931	1629
144 hour	180	263	328	394	486	560	637	751	844	943	-
168 hour	181	264	328	395	487	561	639	753	846	945	-

Table D.33 – Design rainfall depths – Location 33

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	36.6	50.9	60.8	70.7	83.9	94.2	106.0	124	138	154	200
1.5 hour	41.4	57.7	69.3	81.0	96.9	109.0	123	144	161	178	260
2 hour	45.0	63.0	75.8	88.9	107.0	121	136	159	178	197	300
3 hour	50.9	71.4	86.2	101.0	123	140	157	183	204	226	360
4.5 hour	57.9	81.5	98.6	116.0	141	161	181	210	234	259	430
6 hour	63.9	90.1	109.0	129	157	179	201	233	259	286	480
9 hour	74.0	105.0	127	150	183	210	234	272	302	334	568
12 hour	82.6	117.0	143	169	206	236	263	306	339	375	640
18 hour	96.8	138	169	200	244	280	313	364	405	448	758
24 hour	108.0	156	190	226	276	317	356	415	462	512	854
30 hour	118	170	209	248	304	349	398	467	523	583	926
36 hour	126	183	225	268	328	377	434	510	574	642	989
48 hour	139	203	250	300	368	423	490	580	654	735	1124
72 hour	156	230	286	344	424	490	565	670	758	853	1348
96 hour	166	246	306	370	458	530	607	721	815	918	1539
120 hour	173	255	317	384	476	553	629	748	845	951	1629
144 hour	176	259	322	389	484	563	640	760	859	966	-
168 hour	179	260	323	390	484	564	642	762	861	968	-

Table D.34 – Design rainfall depths – Location 34

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	37.2	51.6	61.6	71.7	85.2	95.9	108.0	125	140	155	200
1.5 hour	42.2	58.9	70.8	82.8	99.4	113.0	127	147	164	182	260
2 hour	46.1	64.6	77.9	91.5	110.0	126	141	164	183	203	300
3 hour	52.3	73.7	89.3	105.0	128	146	164	191	212	235	360
4.5 hour	59.8	84.7	103.0	122.0	149	171	191	221	246	271	430
6 hour	66.1	94.1	115.0	136	166	191	213	246	273	302	480
9 hour	77.0	110.0	134	160	195	224	249	289	320	353	568
12 hour	86.2	124.0	151	180	220	252	281	326	361	398	640
18 hour	101.0	147	180	214	261	300	335	388	431	476	758
24 hour	114.0	165	203	242	296	339	380	442	492	544	854
30 hour	124	181	223	266	325	373	425	497	555	618	926
36 hour	133	195	240	287	351	403	462	543	609	680	989
48 hour	147	216	267	321	393	452	522	615	693	776	1124
72 hour	165	245	304	367	452	521	600	710	800	898	1348
96 hour	176	261	326	395	488	563	644	762	859	965	1539
120 hour	182	270	337	410	507	587	667	790	891	999	1629
144 hour	186	274	342	416	515	598	678	803	904	1010	-
168 hour	188	275	343	416	516	599	680	805	907	1020	-

Table D.35 - Design rainfall depths - Location 35

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	38.5	53.2	63.4	73.5	87.1	97.7	110.0	129	144	160	200
1.5 hour	43.7	60.7	72.7	84.8	101.0	114.0	129	151	168	187	260
2 hour	47.8	66.6	80.0	93.5	112.0	127	143	167	187	207	300
3 hour	54.2	75.9	91.4	107.0	130	147	166	193	215	239	360
4.5 hour	61.9	87.0	105.0	124.0	150	171	192	224	249	276	430
6 hour	68.4	96.4	117.0	138	167	191	214	249	277	306	480
9 hour	79.2	112.0	136	161	196	224	251	291	324	358	568
12 hour	88.4	126.0	153	181	221	253	282	328	365	403	640
18 hour	103.0	148	181	215	262	300	337	392	436	483	758
24 hour	115.0	167	204	242	296	340	383	447	498	552	854
30 hour	125	182	223	266	326	375	427	502	563	630	926
36 hour	134	195	240	287	352	405	465	549	618	694	989
48 hour	147	216	267	320	394	455	526	624	705	794	1124
72 hour	165	245	304	367	453	525	606	721	817	920	1348
96 hour	176	262	326	394	489	568	651	775	878	989	1539
120 hour	183	271	338	410	509	591	675	803	910	1030	1629
144 hour	187	276	344	417	518	601	685	815	922	1040	-
168 hour	190	278	345	418	519	601	686	815	922	1050	-

Table D.36 - Design rainfall depths - Location 36

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	38.4	53.1	63.3	73.6	87.4	98.3	111.0	129	144	160	200
1.5 hour	43.7	60.8	73.0	85.4	102.0	116.0	130	152	169	188	260
2 hour	47.8	66.8	80.6	94.6	114.0	130	146	170	189	210	300
3 hour	54.3	76.5	92.7	109.0	133	151	170	198	220	244	360
4.5 hour	62.3	88.2	107.0	127.0	154	177	198	230	256	283	430
6 hour	69.0	98.2	119.0	142	173	198	221	257	285	315	480
9 hour	80.4	115.0	140	166	203	233	260	302	335	369	568
12 hour	90.1	129.0	158	188	229	263	293	340	377	417	640
18 hour	106.0	153	188	223	273	313	350	406	451	499	758
24 hour	119.0	173	212	253	309	354	398	463	515	571	854
30 hour	129	189	232	278	340	390	444	521	583	650	926
36 hour	138	203	250	299	367	421	483	569	640	715	989
48 hour	152	225	279	335	411	473	546	646	728	817	1124
72 hour	171	254	317	383	473	546	629	745	842	946	1348
96 hour	183	271	339	412	510	590	676	801	904	1020	1539
120 hour	189	281	352	428	531	616	700	831	938	1050	1629
144 hour	193	286	357	436	540	628	710	845	953	1070	-
168 hour	195	287	359	437	541	629	711	848	957	1070	-

Table D.37 – Design rainfall depths – Location 37

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	39.7	54.9	65.4	76.0	90.4	102.0	114.0	133	148	164	200
1.5 hour	45.4	63.3	75.9	88.8	107.0	121.0	136	158	176	195	260
2 hour	49.9	69.8	84.2	98.9	119.0	136	152	177	197	219	300
3 hour	57.0	80.5	97.5	115.0	140	160	179	208	231	256	360
4.5 hour	65.7	93.3	113.0	134.0	164	188	210	243	271	299	430
6 hour	72.9	104.0	127.0	151	184	211	235	273	303	334	480
9 hour	85.2	122.0	150	178	217	250	278	321	357	393	568
12 hour	95.6	138.0	169	201	245	282	313	363	403	444	640
18 hour	113.0	163	200	239	292	335	374	433	482	531	758
24 hour	126.0	184	226	270	330	379	424	493	549	607	854
30 hour	137	201	248	297	363	417	473	553	618	688	926
36 hour	147	216	266	319	391	449	514	604	677	756	989
48 hour	162	239	296	356	438	503	579	684	769	862	1124
72 hour	182	270	336	407	502	578	665	787	888	996	1348
96 hour	194	288	360	437	540	624	714	844	953	1070	1539
120 hour	201	298	373	454	561	650	740	873	987	1110	1629
144 hour	205	303	379	463	571	662	751	886	1000	1120	-
168 hour	207	304	381	465	571	663	753	887	1000	1120	-

Table D.38 – Design rainfall depths – Location 38

Duration	Design Rainfall depths (mm)									
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP	PMP
1 hour	40.3	55.6	66.3	76.9	91.5	103.0	115.0	133	148	164	200
1.5 hour	46.3	64.4	77.3	90.4	109.0	123.0	137	159	177	196	260
2 hour	51.0	71.3	86.0	101.0	122.0	139	155	180	200	221	300
3 hour	58.5	82.6	100.0	118.0	144	165	184	213	236	261	360
4.5 hour	67.6	96.2	117.0	139.0	170	196	217	251	278	307	430
6 hour	75.2	108.0	132.0	157	192	221	245	283	313	345	480
9 hour	88.0	127.0	156	186	228	262	290	334	370	407	568
12 hour	98.8	143.0	176	210	257	296	327	377	418	460	640
18 hour	117.0	170	209	250	306	351	389	450	498	549	758
24 hour	131.0	191	236	282	345	395	440	509	565	624	854
30 hour	143	209	258	308	377	433	487	568	632	701	926
36 hour	152	224	276	331	405	465	527	617	688	765	989
48 hour	168	248	307	368	450	517	591	693	776	866	1124
72 hour	189	279	346	417	512	588	674	792	890	994	1348
96 hour	202	298	370	447	549	632	721	848	953	1060	1539
120 hour	209	308	383	464	570	657	747	878	987	1100	1629
144 hour	213	313	390	473	581	669	760	892	1000	1120	-
168 hour	215	315	393	477	585	671	764	895	1010	1120	-

Appendix E - Box plots of 1% AEP peak flood levels at key gauges

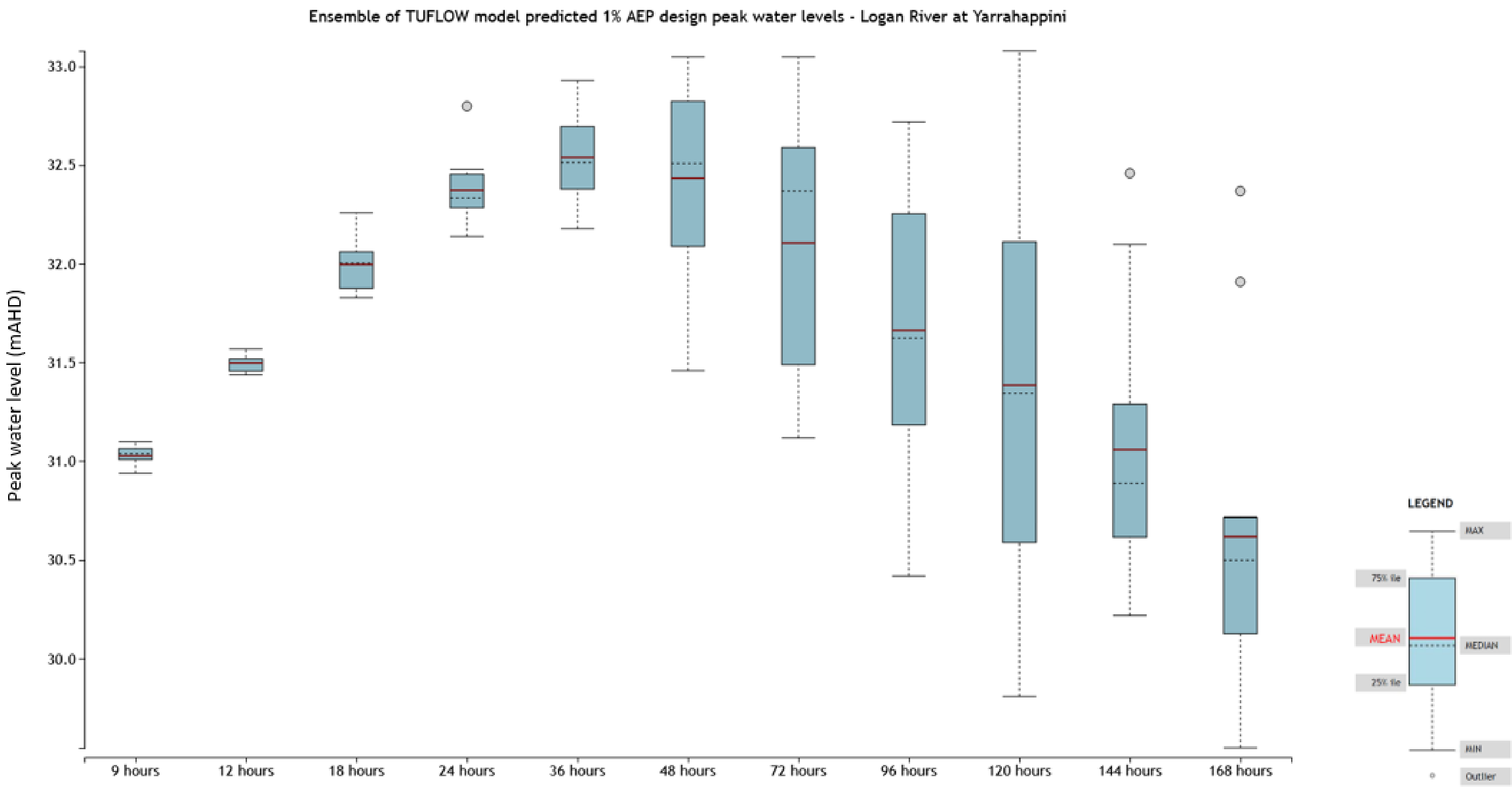

Figure E.1 – Box plot showing the ensemble of TUFLOW model predicted 1% AEP design peak water levels, Logan River at Yarrahappini

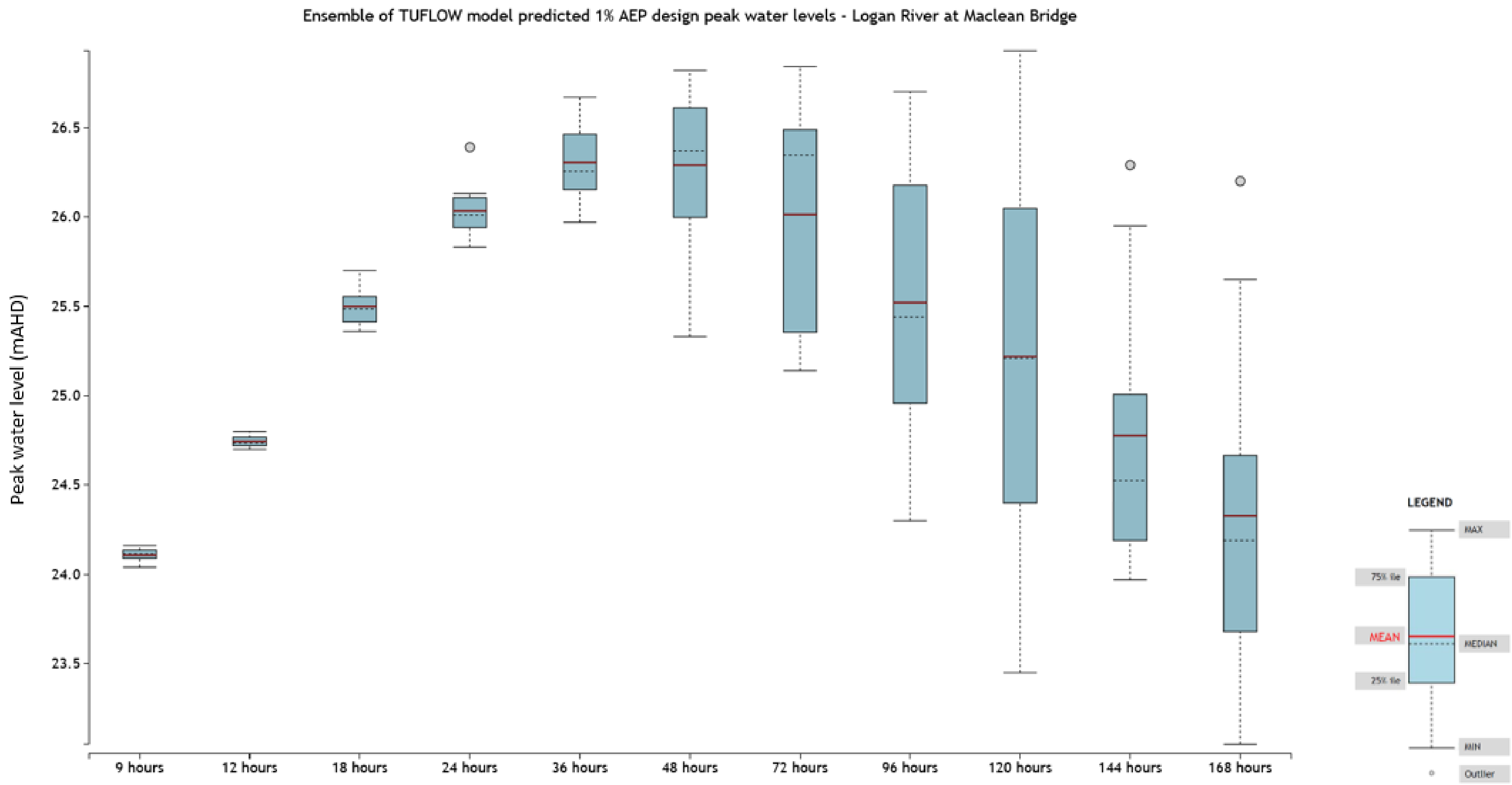

Figure E.2 - Box plot showing the ensemble of TUFLOW model predicted 1% AEP design peak water levels, Logan River at Maclean Bridge

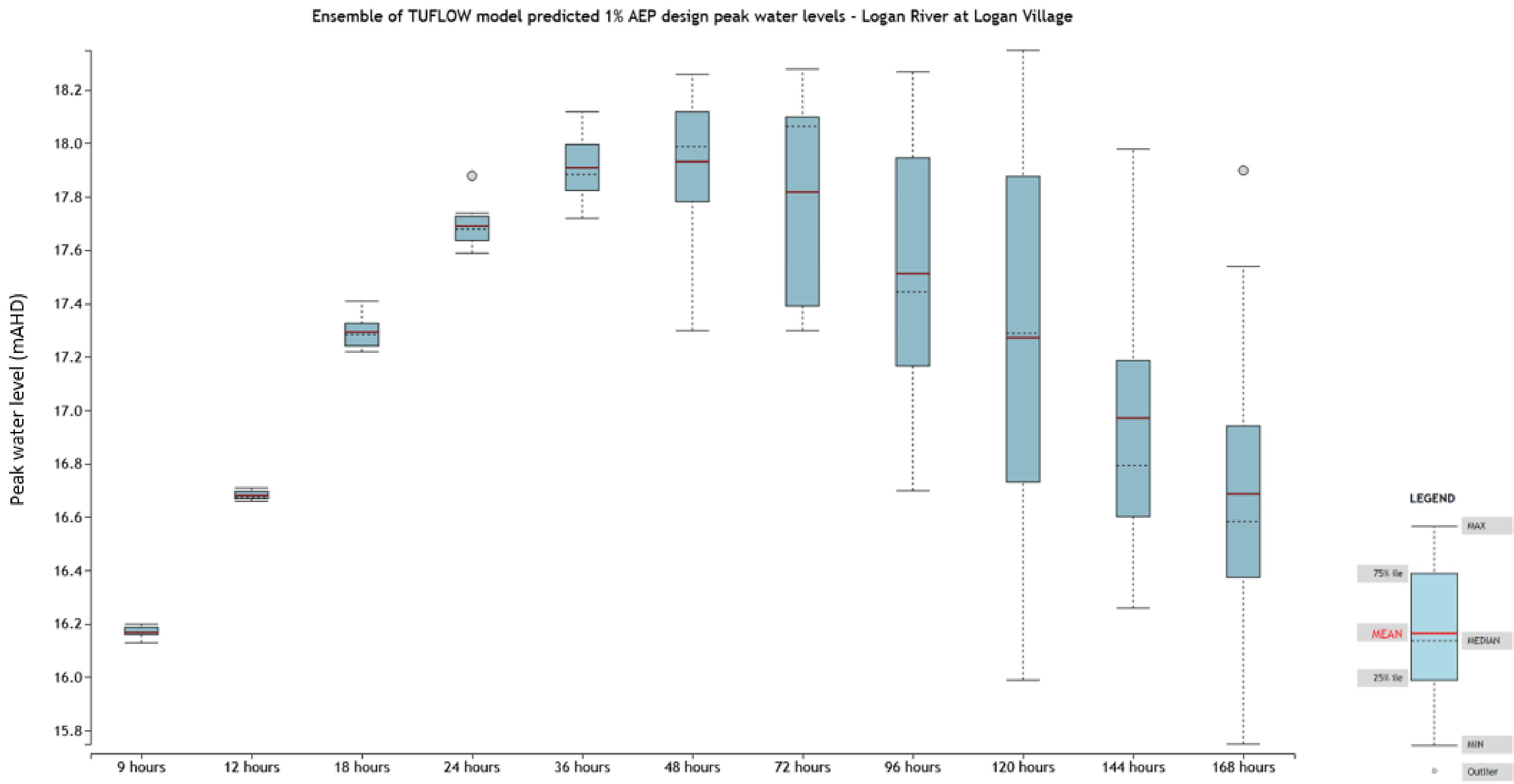

Figure E.3 - Box plot showing the ensemble of TUFLOW model predicted 1% AEP design peak water levels, Logan River at Logan Village

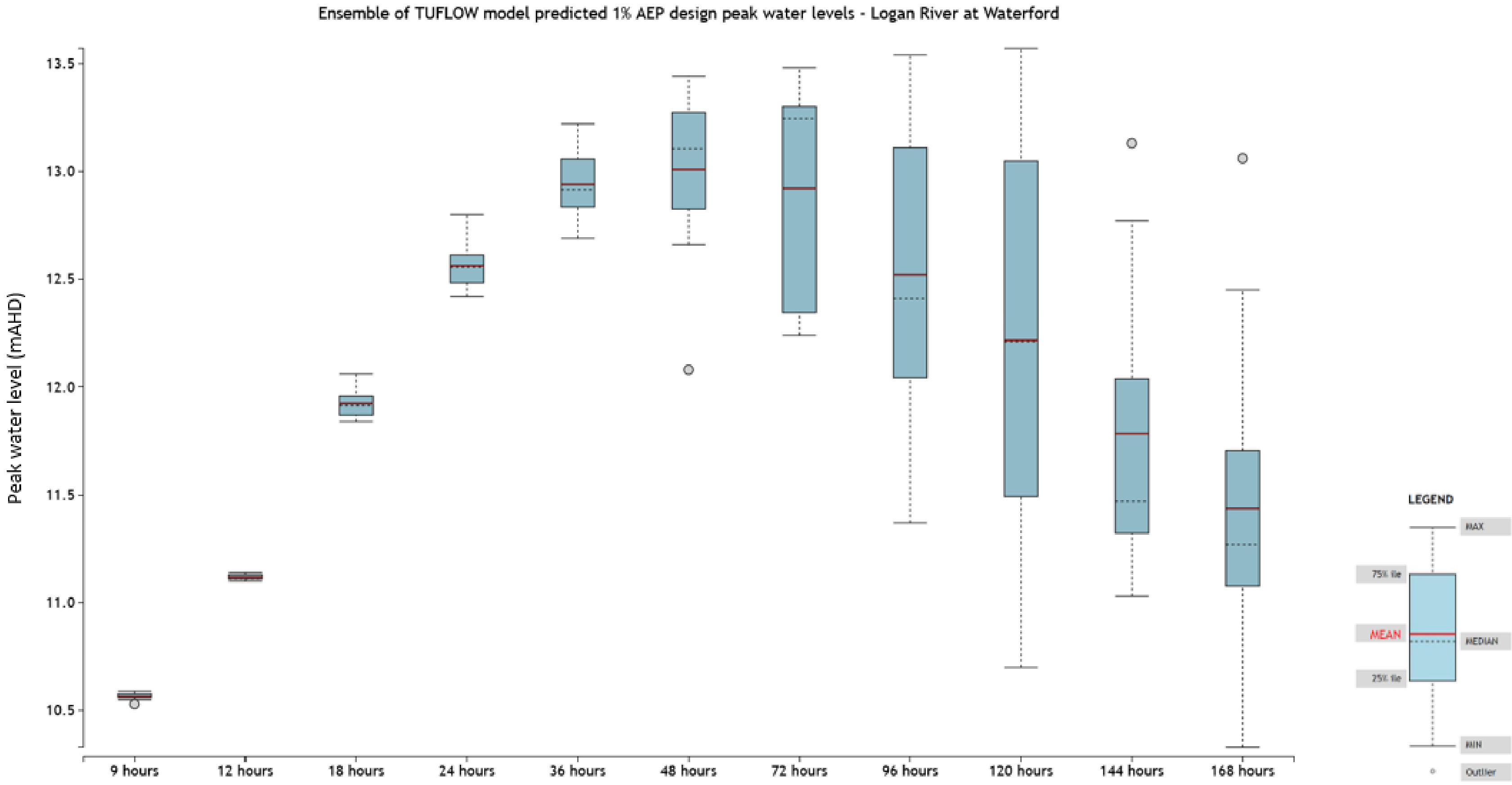

Figure E.4 – Box plot showing the ensemble of TUFLOW model predicted 1% AEP design peak water levels, Logan River at Waterford

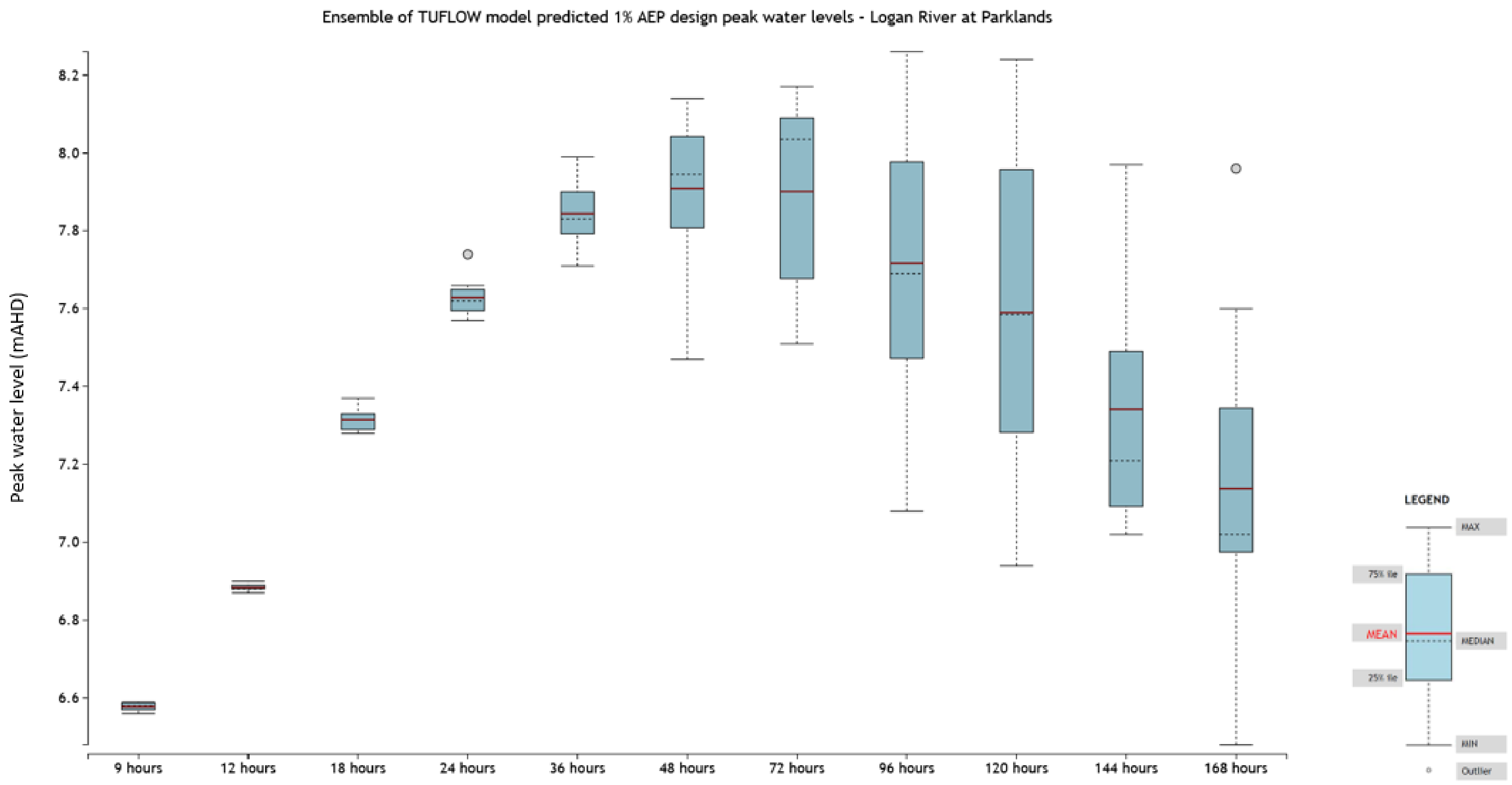

Figure E.5 – Box plot showing the ensemble of TUFLOW model predicted 1% AEP design peak water levels, Logan River at Parklands

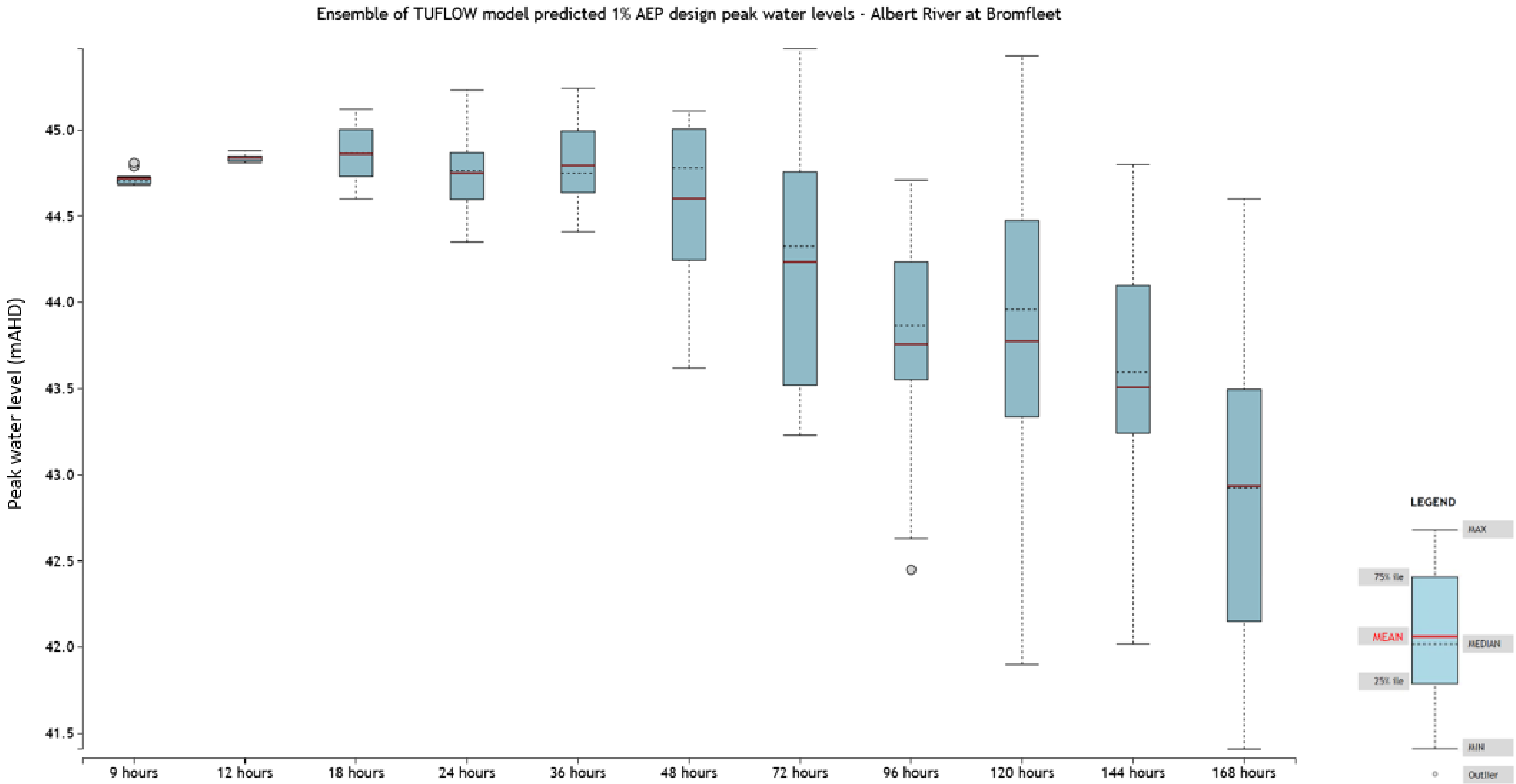

Figure E.6 - Box plot showing the ensemble of TUFLOW model predicted 1% AEP design peak water levels, Albert River at Bromfleet

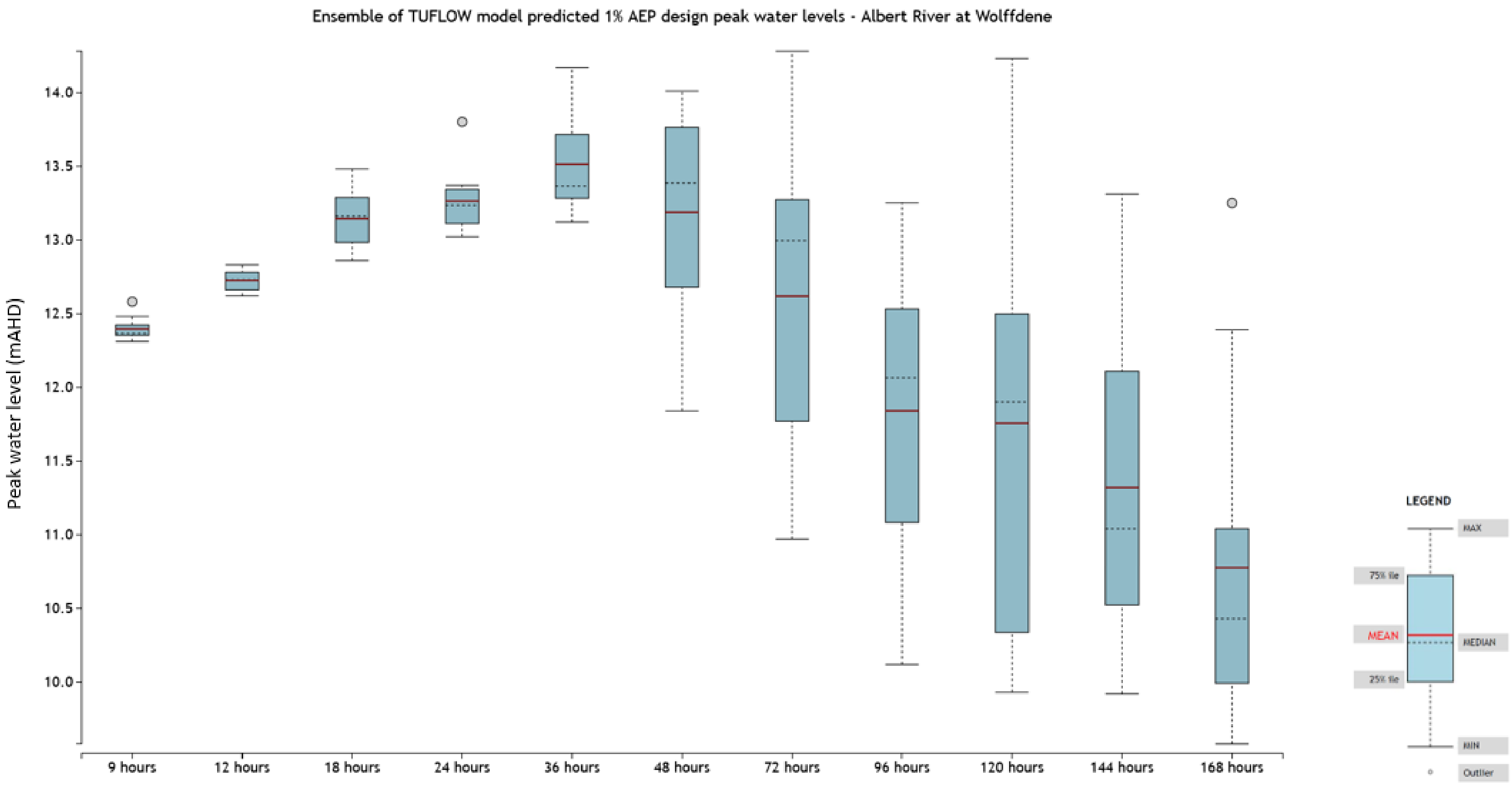

Figure E.7 - Box plot showing the ensemble of TUFLOW model predicted 1% AEP design peak water levels, Albert River at Wolffdene

Appendix F - Flood maps