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Little Bohle River Flood Study

Base-line Flooding Assessment

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Base-line Flooding Assessment

Prepared for

Townsville City Council

Prepared by

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A	04-May-2011	Final Copy	Stephen Downes Technical Director - Water	Original previously signed
B	14-Jun-2011	Revised Final Copy	Stephen Downes Technical Director - Water	

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Executive Summary

Townsville City Council (TCC) is presently undertaking the City Wide Flood Constraints Project to develop detailed flood models for the city.

Individual catchment areas have been identified for individual flood study areas as part of the overall project and the Little Bohle River has been identified as one of these study areas. Hydrologic and hydraulic models of the Little Bohle and surrounding catchments have been developed for the area.

These hydrologic and hydraulic models have been developed using the latest LiDAR topography data which was flown in 2009. This data has been used to develop an XP-RAFTS hydrologic model of the Little Bohle based on the model previously developed for the *Bohle Plains Flood Planning Study (BPFPS)*

Hydrologic models of the Black River, Saunders and Stony Creek catchments which flow through the hydraulic model domain have been updated from those developed for the *BPFPS.*

The LiDAR topography data was used as the basis to develop a MIKEFLOOD hydraulic model of the Little Bohle River area, extending past Rupertswood in the west, and including Black and Alice Rivers.

The models have been calibrated using stream flow data from the Little Bohle River and Bohle River - Hervey Range Road stream gauges for the March 1997 and January 2008 floods. For a majority of the study area, the 24 hour storm was determined as the critical duration flood. This has increased from the 3 hour event which was identified as critical during the *Bohle Plains Flood Planning Study* due to the increased contour detail available and the explicit representation of floodplain storage within the model. The catchments slopes have changed resulting in a longer critical duration for the catchment.

Flooding Impacts

The 2, 5, 10, 20, 50, 100 year ARI and Probable Maximum Precipitation (PMP) critical storms have been modelled to determine base line flood flows. Maximum flood envelopes have been developed for the 50 and 100 year ARI floods for a range of durations.

There are rural and rural residential properties located within the study area and the flooding impacts for each of the modelled events are described.

2 Year ARI Storm Event

- 7 rural property boundaries are affected along the Little Bohle River upstream of Pinnacle Quarry Road;
- 15 rural properties are affected along the Little Bohle River downstream of Pinnacle Quarry Road;
- 15 properties are affected by overland flow east of Granitevale Road. Flood depths are less than 0.1m;
- 3 rural properties north of Rupertswood are affected by overland flooding with flood depths up to 0.2m. Flood depths up to 2.5m occur within the watercourse on 1 of these properties;
- 1 rural property north of Rupertswood, bordering Alice River is affected by overland flooding with flood depths up to 0.3m. Flood depths up to 1.6m occur within the watercourses on the property.

5 Year ARI Storm Event

- 7 rural property boundaries are affected along the Little Bohle River upstream of Pinnacle Quarry Road.
- 15 rural properties are affected along the Little Bohle River downstream of Pinnacle Quarry Road;
- 15 properties are affected by overland flow east of Granitevale Road. Flood depths are less than 0.1m;
- 3 rural properties north of Rupertswood are affected by overland flooding with flood depths up to 0.3m. Flood depths up to 2.8m occur within the watercourse on 1 of these properties;
- 1 rural property north of Rupertswood, bordering Alice River is affected by overland flooding with flood depths up to 0.4m. Flood depths up to 1.7m occur within the watercourses on the property.

10 Year ARI Storm Event

- 7 rural property boundaries are affected along the Little Bohle River upstream of Pinnacle Quarry Road.

- 15 rural properties are affected along the Little Bohle River downstream of Pinnacle Quarry Road;
- 15 properties are affected by overland flow east of Granitevale Road. Flood depths are less than 0.1m;
- 3 rural properties north of Rupertswood are affected by overland flooding with flood depths up to 0.3m. Flood depths up to 2.8m occur within the watercourse on 1 of these properties;
- 1 rural property north of Rupertswood, bordering Alice River is affected by overland flooding with flood depths up to 0.4m. Flood depths up to 1.8m occur within the watercourses on the property.

20 Year ARI Storm Event

- 7 rural property boundaries are affected along the Little Bohle River upstream of Pinnacle Quarry Road;
- 15 rural properties are affected along the Little Bohle River downstream of Pinnacle Quarry Road. Results indicate existing buildings may be affected on 1 property;
- 15 properties are affected by overland flow east of Granitevale Road with flood depths less than 0.1m;
- 3 rural properties north of Rupertswood are affected by overland flooding with flood depths up to 0.4m. Flood depths up to 2.9m occur within the watercourse on 1 of these properties;
- 1 rural property north of Rupertswood, bordering Alice River is affected by overland flooding with flood depths up to 0.5m. Flood depths up to 1.9m occur within the watercourses on the property.

50 Year ARI Storm Event

- 7 rural property boundaries are affected along the Little Bohle River upstream of Pinnacle Quarry Road;
- 15 rural properties are affected along the Little Bohle River downstream of Pinnacle Quarry Road. Results indicate existing buildings may be affected on 2 properties;
- 15 properties are affected by overland flow east of Granitevale Road with flood depths up to 0.2m;
- 3 rural properties north of Rupertswood are affected by overland flooding with flood depths up to 0.4m. Flood depths up to 3m occur within the watercourse on 1 of these properties;
- 1 rural property north of Rupertswood, bordering Alice River is affected by overland flooding with flood depths up to 0.6m. Flood depths up to 1.9m occur within the watercourses on the property.

100 Year ARI Storm Event

- 7 rural property boundaries are affected along the Little Bohle River upstream of Pinnacle Quarry Road.
- 15 rural properties are affected along the Little Bohle River downstream of Pinnacle Quarry Road. Results indicate existing buildings may be affected on 3 properties;
- 15 properties are affected by overland flow east of Granitevale Road with flood depths up to 0.2m;
- 3 rural properties north of Rupertswood are affected by overland flooding with flood depths up to 0.4m. Flood depths up to 3m occur within the watercourse on 1 of these properties;
- 1 rural property north of Rupertswood, bordering Alice River is affected by overland flooding with flood depths up to 0.6m. Flood depths up to 2.0m occur within the watercourses on the property.

For all events the Little Bohle River floodwater does not contribute to the flow north over Hervey Range Road.

It should be noted that the results of the modelling indicate flood levels and extents within Rupertswood are influenced by drainage features which cannot be accurately represented in the model developed for this study. For this reason the flood model results within Rupertswood should not be relied upon and are considered indicative only.

In order to provide accurate flood levels and extents within Rupertswood, it is recommended that the model be refined in this area in the future. This refinement should include representing the drainage channels within the development as one-dimensional elements within the hydraulic model and increasing the resolution to ensure all local drainage features are represented.

A sensitivity analysis of various model parameters was also undertaken to determine the sensitivity of flood levels to increases in model roughness parameters, the timing of flood peaks and downstream boundary conditions. This analysis indicates the maximum Bohle River flood levels are particularly sensitive to the timing of the Little

Bohle River flows which can increase flood levels by more than 0.3m within the Bohle River. It is recommended a more detailed analysis of the impacts of these timing effects be undertaken as part of any future flood studies for the Bohle River.

Impacts of Potential Future Urbanisation

An assessment has been made of the impacts of potential future urbanisation of the catchment and maximum flood envelopes have been developed for the 50 and 100 year ARI events assuming full urbanisation of the area in accordance with Councils planning policy. The impacts of this potential urbanisation are similar for both the 50 and 100 year ARI events.

For the 50 year ARI event result indicate the flood levels within the Little Bohle River will increase by between 0 and 0.3m at the upper reaches near Rupertswood and between 0 and 0.25m along the length of the Little Bohle River for the 50 year ARI event. Flood levels within the drain that runs through the western section of Rupertswood will increase by up to 0.3m. Flood levels within Alice River will increase by more than 0.5m however the flow will be contained within the river banks and the impact on Rupertswood would be minimal.

Similarly for the 100 year ARI event The result indicate the flood levels within the Little Bohle River will increase by between 0 and 0.4m at the upper reaches near Rupertswood and between 0 and 0.25m along the length of the Little Bohle River with higher increases occurring downstream of the Middle Bohle junction. Flood levels within the drain that runs through the western section of Rupertswood will increase by up to 0.4m. Flood levels within Alice River will increase by more than 0.5m however the flow will be contained within the river banks and the impact on Rupertswood would be minimal.

Granitevale Road Area

Using the MIKEFLOOD model developed for this study, historic contour data representing floodplain conditions in 2000, were used to develop a pre-existing model in order to assess the impacts of various development stages within the eastern section of Rupertswood. The 50 and 5 year 24 hour critical duration events have been modelled for the following scenarios (which are further detailed in the report), to assess these impacts:

- **Pre-existing Undeveloped Scenario –** This scenario assumes the eastern portion of Rupertswood is not developed;
- **Weir Scenario** - This scenario represents the Rupertswood development prior to development of Kens Court; and
- **Existing Scenario** – This scenario represents the existing development including the changes to the drainage system to accommodate development of Kens Court.

The following table summarises the change in flow regime between the pre-existing scenario and the two development scenarios for the 50 year ARI event. The five sections represent locations where the peak flow rate has been determined as detailed in **Figure 29**. Section 1 represents the flow east over Granitevale Road. Section 2 and 3 represent the inflow to the detention basin from the south and west respectively, Sections 4 represents the flow out of the basin to the east and Section 5 represents the flow out of the detention basin and north over Hervey Range Road.

Section	Pre-Existing Scenario (m^3/s)	Weir Scenario (m^3/s)	Difference Weir – Pre-existing(m^3/s)	Existing Scenario (m^3/s)	Difference Existing – Pre-existing (m^3/s)
1	10.4	10.2	-0.2	1.2	-9.2
2	0	2.4	2.4	12.5	12.5
3	0.4	9.4	9	9.4	9
4	3.8	8.4	4.6	10.1	6.3
5	2.6	4.6	2	16.4	13.8

Assuming the development was constructed as detailed in the weir scenario, the table above shows that during the 50 year ARI event:

- the pre-existing flow over Granitevale Road is maintained however the increase in flow due to urbanisation results in an increase in peak flow of 2.4 m^3/s in Granitevale Road drain, over the check dam and north to the detention basin;
- peak flow from the catchment to the west is increased by 9 m^3/s. Previously this catchment overflowed into the main Rupertswood drainage channel however due to urbanisation the flow is increased and, a majority of this flow is directed into the detention basin;
- the detention basin does not adequately mitigate these increases in inflows and the flow north over Hervey Range Road is increased by 2 m^3/s while the flow east over Granitevale Road is increased by 4.6 m^3/s; and
- this increased flow over Hervey Range Road increases flood levels to the north by between 50 and 100mm over a significant area. With maximum flood level immediately north of Hervey Range Road increased by up to 140mm; and

Flood levels are increased by up to 0.1m north of Hervey Range Road during the 5 year ARI event.

With the existing development currently in place, the previous table shows that for the 50 year ARI existing scenario:

- the increases in peak flows into the detention basin from the west remains the same as the weir scenario and is 9 m3/s greater than pre-existing;
- removing the check dam from Granitevale Road drain increases the flow from the south by 12.5 m3/s and significantly reduces the flow across Granitevale Road, south of Kens Court;
- the capacity of the culvert installed under Granitevale Road cannot accommodate this increase and consequently the flow north over Hervey Range is again increased.
- the final peak flow over Hervey Range Road is 16.4 m3/s, which is more than 6 times the pre-existing flow; and
- the changes to the flow regime has increased maximum flood levels by up to 0.25m north of Hervey Range Road compared to the pre-existing scenario for the 50 year ARI event;

Flood levels are increased by up to 0.15m north of Hervey Range Road during the 5 year ARI event.

1.0 Introduction

1.1 Background

Townsville City Council (TCC) is presently undertaking the City Wide Flood Constraints Project to develop detailed flood models for the city.

Individual catchments have been identified for assessment and the Little Bohle River has been identified as one of these. AECOM has been engaged by TCC to develop hydrologic and hydraulic flood models of the Little Bohle River, to undertake a flood study for the Little Bohle River.

1.2 Study Area

The study covers the entire catchment area including the Pinnacle Range and Little Bohle River floodplain down to the junction with the Bohle River. Several areas which are not part of the Little Bohle River catchment are also included in the study. The area north of Hervey Range Road is included in order to quantify the flows that occur to the north of this roadway to provide boundary conditions for future flood assessment of properties located to the north. Also the residential estate of Rupertswood is included in this assessment.

A locality plan and model extent is shown in **Figure 1**.

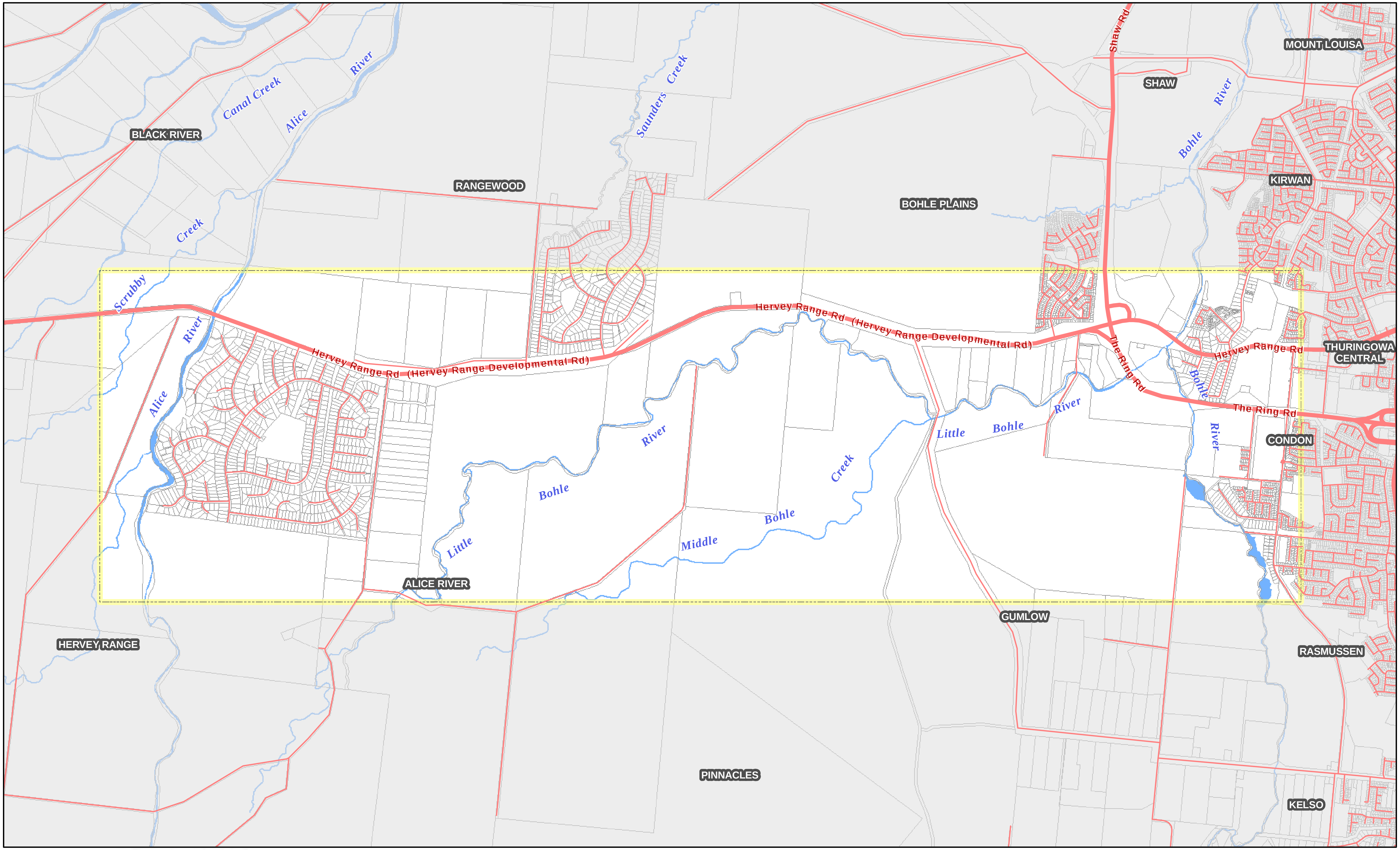
1.3 Study Approach

An XP-RAFTS hydrologic model was developed for the study area to quantify runoff from the catchment. A MIKEFLOOD hydraulic model was then developed to determine base line flooding that will occur as a result of rainfall runoff from the catchments. The hydrologic model is generally based on the previous model developed for the *Bohle Plains Flood Planning Study (BPFPS).* The approach adopted in this study is in line with councils flood study guidelines.

1.4 Scope of Works

The scope of works for this flood modelling study includes:

- Collation and review of available data relevant to flood model development;
- Site assessment;
- Revision of previously developed models;
- Calibration and/or verification of XP-RAFTS hydrologic models;
- Calculation of design storm flows for the 2, 5, 10, 20, 50, 100 year and PMF events;
- Calculation of storm flows for the 50 and 100 year ARI events with future catchment urbanisation;
- Development of a MIKEFLOOD model for the Little Bohle River study area;
- Calibration and/or verification of the MIKEFLOOD model;
- Calculation of the critical duration design flood for the 2, 5, 10, 20, 50, 100 year and PMF events;
- Calculation of peak flood envelopes for the 50 and 100 year ARI events;
- Calculation of peak flood envelopes for the 50 and 100 year ARI events;
- Investigation of the changes to the flow regime in the area of the intersection of Hervey Range Road and Granitevale Road as a result of development within eastern Rupertswood, construction of a detention basin and development to the east of Ganitevale Road;
- Preparation of a technical report to communicate the development and results of the modelling; and
- Provision of all digital model files and GIS layers in accordance with the TCC-AECOM Deed of Agreement for exchange of data.



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0 500 1,000 2,000 Metres

Legend

- Main Road
- Minor Road
- Watercourse
- Property Boundary
- Hydraulic Model Extent

LITTLE BOHLE FLOOD MODEL
Locality Plan and hydraulic model extent

Figure 1

2.0 Available Data

2.1 Bohle River Flood Modelling Studies

AECOM has conducted a number of previous flood studies in the area. The following sections describe the studies which have been undertaken and involved continued development of the hydrologic and hydraulic models that are relevant to this project.

2.1.1 Bohle River Floodplain Management Study, April 2001

The *Bohle River Floodplain Management Study (BRFMS)* modelled the hydrology and hydraulics of the Bohle River floodplain from Kelso Drive to its outlet at Halifax Bay. The study employed the RORB runoff-routing hydrologic model and the 1-dimensional hydraulic model MIKE 11. Survey of the Bohle River and floodplain conducted for the *BRFMS* was used in the current study as the basis for topography of the MIKE FLOOD model.

2.1.2 Ring Road Stages 2 & 3 – Bohle River Flooding, September 2006

Queensland Department of Main Roads commissioned Maunsell to determine accurate flood levels adjacent to the Townsville-Thuringowa Ring Road along with sizing bridge and flood mitigation options. The *BRFMS* MIKE 11 model was updated to a MIKE FLOOD model, in order to more accurately represent the 2-Dimensional floodplain hydraulics. MIKE FLOOD is coupled 1-Dimensional (MIKE11)/ 2-Dimensional (MIKE21) fully dynamic flood hydraulics model.

The MIKE 11 component was used to represent reaches of the Bohle River upstream and downstream of the 2D grid extent as well as structures within the grid. The MIKE 21 model grid extends from Gollogly Lane in the south to Mount Louisa in the north. The MIKE 21 model grid was adjusted to include as-constructed levels for developments within Kirwan. The MIKE FLOOD model for the Willowbank Estate Flood Modelling study contained an expanded list of catchment runoff inflows based on a detailed sub-catchment breakdown of the *BRFMS*; Bohle River 1 and Tchooratippa Creek (Kirwan and Condon) sub-catchments.

Flood levels obtained by this study for the 50 year event differ from those obtained from the *BRFMS* due to the refined representation of the 2D floodplain in the MIKE FLOOD and development in the northern Kirwan area which eliminated a surcharge flowpath to the Louisa Creek catchment. The MIKE FLOOD model was shown to achieve a better calibration than the previous MIKE11 model.

2.1.3 Liberty Rise Development Flooding Assessment, September 2008

A flooding assessment for the Liberty Rise overall development was previously completed by Maunsell for Parkside Joint Venture. MIKE FLOOD two-dimensional hydraulic modelling previously developed for the Ring Road Project and *BRFMS* was used as a basis for the assessment.

2.1.4 Kern Drain Trunk Drainage Assessment, January 2008

Townsville City Council commissioned AECOM to undertake this study to establish 50 Year ARI hydraulic grade lines for Kern Drain and to determine the impacts of as-built excavations of the drain. The investigation focussed on the timing of catchment flows from Kern Drain with various tailwater levels as a result of Bohle River flood flows.

As part of this study, the catchment hydrology assessment undertaken for the *BRFMS* was refined to incorporate all recent developments since the *BRFMS*, as well as to account for site specific investigations. The refined XP-RAFTS hydrologic model was verified to the previous RORB modelling of the catchments from the *BRFMS*.

2.1.5 Bohle Plains Flood Planning Report, April 2010

Modelling for the *Bohle Plains Flood Planning Report (BPFPR)* was undertaken to consolidate a range of projects undertaken since the *BRFMS* as well as updated digital contour data. The assessment included hydrological and hydraulic modelling of the Bohle River, Saunders Creek, Stony Creek and Black River catchments for the 50 year ARI flood event. The major changes to the hydrological modelling include changing from previously developed RORB model to XP-RAFTS. Major changes to the hydraulic model included updating the MIKE11 stand-alone model to a MIKE FLOOD 1D and 2D coupled model.

2.2 Rupertswood Hydraulic Assessment and Design Studies

The following reports are relevant to the detention basin.

2.2.1 Rupertswood – Drainage of Eastern Area – Saunders Creek Options Report, February 1994

The *Saunders Creek Options Report* was completed by McIntyre & Associates in February 1994, and details the investigation of options for the drainage and discharge of the stormwater runoff from the, as then, undeveloped area of eastern Rupertswood. Option 10 of the report includes a 30 ML detention basin in the north eastern corner of Rupertswood, and a comparison of developed and undeveloped flows at the Hervey Range Road boundary. These flows were given as 27.1 and 31.4 m^3/s respectively.

2.2.2 Rupertswood – Drainage of Eastern Area – Using a Detention Basin within Rupertswood - Design Report, May 1994

The *Using a Detention Basin within Rupertswood Design Report* was completed by McIntyre & Associates in May 1994, and is an extension of the *Saunders Creek Options Report* completed in February 1994. The report refines flow estimates and estimates of the required detention basin design.

2.2.3 Investigation to the Pre-Development and Post-Development Stormwater Flows – Granitevale Road Drain Report, February 2007

The *Granitevale Road Drain Report* was undertaken by UDP in February 2007 and details the investigation into the stormwater flows from the eastern side of the Rupertswood Estate. The objective of the report is to provide detailed design of the Granitevale Road Drain, to be incorporated into development approval applications for eastern Rupertswood.

2.2.4 LCJ Johnstone and Associates – Twelve (12) Rural Lot Subdivision - Granitevale Road Alice River

TCC provided details of the design of the 12 lot subdivision including Granitevale Road, Kens Court and associated drainage works prepared by LCJ Johnstone and Associates. The initial design included 4/1200x450 culverts installed adjacent to the check dam in the Granitevale Road drain to maintain the existing flow to the west of Granitevale Road. However a revision to this design moved this culvert north to the intersection of Hervey Range Road and Granitevale Road. A summary of the flows used in the design was included in the design drawings however no detail of the calculation of these flows was given. It is assumed the flows were derived from the UDP report described above.

2.3 Topographic Data

2.3.1 Survey Data

Topography data was provided by TCC in the form of contours and a Digital Elevation Map (DEM). Contours dated 2009 were provided at 0.25m vertical intervals along with a 2m gridded DEM subset of the raw LiDAR data.

0.25m contour data was also provided which was dated 2004. From communication with Council it is understood this contour data was obtained in 2000 and as such will be referred to as the 2000 contours within this document.

2.3.2 Aerial Photography

The aerial photography for the rural areas of Little Bohle River and the urban areas of Rupertswood were provided by the Townsville City Council. The aerial imagery was flown between 19 and 29 June 2009. The pixel sizes for the urban and rural areas are 0.125 m and 0.5 m respectively. The captured bands are RGB and near-infrared.

2.4 Hervey Range Road Drainage Plans

As-constructed plans of the culvert crossings of Hervey Range Road were provided by TCC. Plans were also provided for the Alice River Bridge crossing to allow representation in the hydraulic model. Plans of the Hervey Range Road Bridge over the Bohle River and the Ring Road bridges and culvert crossings obtained during the previous model development (described above) were used to obtain the geometry of these structures.

2.5 Rupertswood Drainage Plans

Plans of major culvert crossing within Rupertswood were provided by TCC to allow these structures to be represented in the hydraulic model**.**

2.6 Historical Climate Data

Historical rainfall from the Bureau of Meteorology (BOM) and stream gauging data from Department of Environment and Resource Management (DERM) was provided by Townsville City Council (TCC). In addition, rainfall data for select stations was sourced directly from DERM, as shown in **Table 1**.

Table 1 Summary of rainfall and stream gauge data

Site Number	Site Name	Source	Latitude (°S)	Longitude (°E)	Period of record	Observation
32040	Townsville Aero	BoM	19.25	146.77	March 1953-	Rainfall
32050	Yabulu Qld Nickel	BoM	19.2	146.61	Jan 1990-	Rainfall
532005	Mt Margaret Stand alone	DERM	19.368	146.603	March 85 -	Rainfall
532006	Gleesons Mill Stand alone	DERM	19.423	146.708	March 85 -	Rainfall
532007	Stag Creek Standalone	DERM	19.382	146.68	March 85 -	Rainfall
532041	The Pinnacles Alert	BoM	19.384	146.681	October 2000 -	Rainfall
532042	Mt Margaret Alert	BoM	19.346	146.601	May 2000 -	Rainfall
532044	Little Bohle River Alert	BoM	19.326	146.674	September 2002 -	Rainfall
118003A	Bohle River at Hervey Range Road	DERM	19.32	146.702	1985 -	Stream Flow, Rainfall
118004A	Little Bohle River at Middle Bohle Junction	DERM	19.328	146.677	1985 -	Stream Flow

3.0 Hydrology

3.1 Overview

The hydrologic modelling software XP-RAFTS was used to model the rainfall runoff from the Little Bohle River catchment and additional areas within the hydraulic model extent, including the catchments which drain the suburb of Rupertswood.

The suburb of Rupertswood drains to four separate catchments, Little Bohle River, Saunders Creek, Stony Creek and Black River. The existing Little Bohle River, Stony Creek, Saunders Creek and Black River XP-RAFTS models developed for the *BPFPS* were updated to include the detailed contours from new LiDAR data, land use changes and the requirement of inflow hydrographs at key locations in the hydraulic model.

The south-eastern corner of the hydraulic model also includes a section of the Middle Bohle River. The Middle Bohle sub-catchment detailed in the *BPFPS* did not significantly change due to the additional data and as such the Middle Bohle River sub-catchment was based on the model used for the *BPFPS.*

A map showing the extent of the Black River, Stony Creek, Saunders Creek, Little Bohle River and Middle Bohle River is shown in **Figure 2**. Detailed catchment maps are included in the next section.

The runoff from three separate scenarios was assessed using XP-RAFTS:

- pre-existing undeveloped case (development extent and topography based on 2000 contours);
- existing case (current development extent and topography based on 2009 contours); and
- potential future, urbanised scenario (potential future development extent with topography based on 2009 contours).

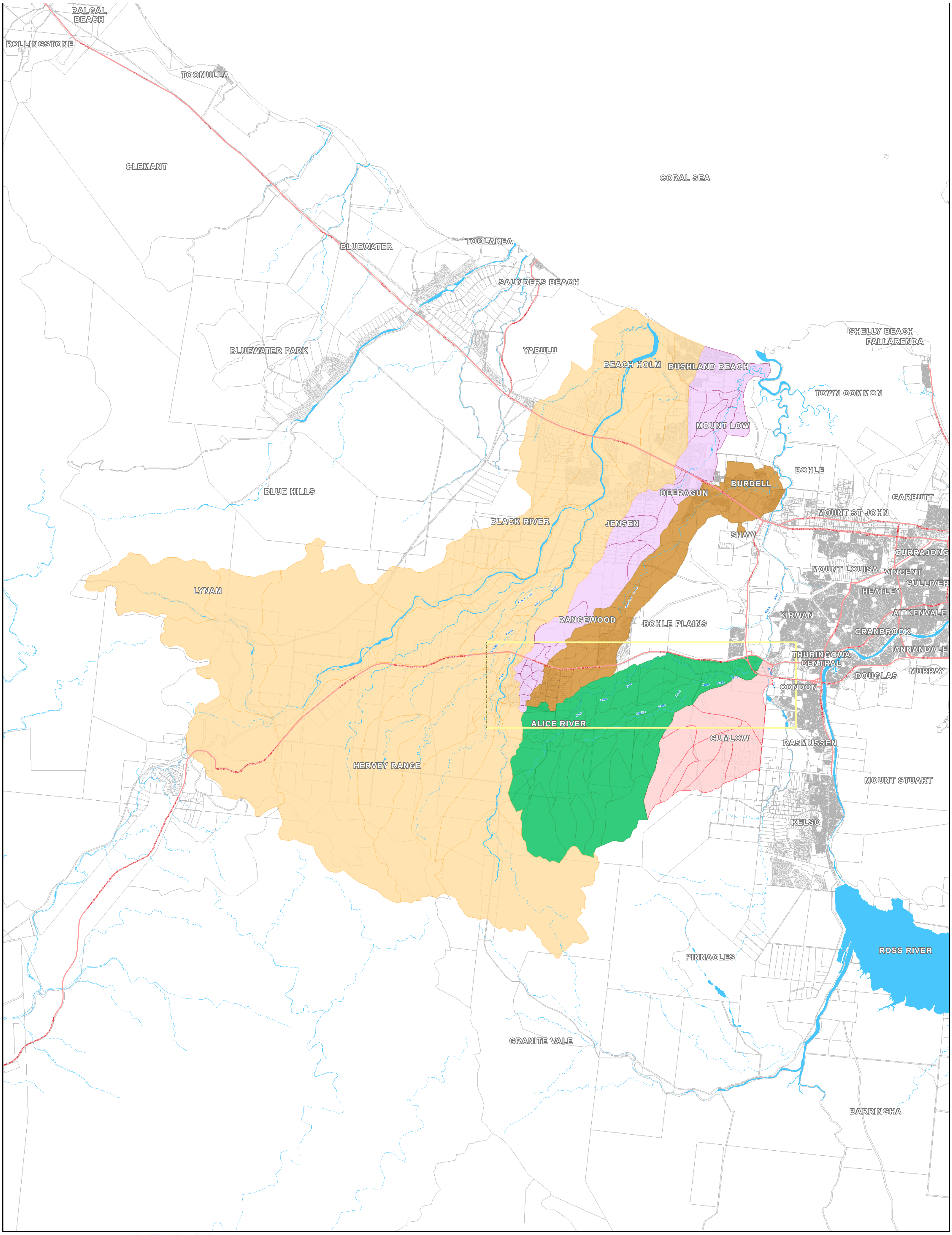
The Little Bohle River model and the catchments that drain Rupertswood are described separately.

3.2 Little Bohle River Catchment

3.2.1 Catchment Description

The Little Bohle River catchment is approximately 55 km^2 and is a tributary to the Bohle River. From the confluence with the Bohle River the Little Bohle River extends 14 km upstream and rises approximately 600m in a south westerly direction to its source in the Pinnacle Range. At present, the majority of the catchment is undeveloped with some rural residential and agricultural areas, including the Gumlow Quadrant. The Gumlow quadrant is generally defined as the area south of the Little Bohle River to the Pinnacle Range. This is detailed further in **Figure 11**.

The catchment map for Little Bohle River is shown in **Figure 3**. A detailed catchment map at TCC's the recommended map scales are shown in **Appendix C**.



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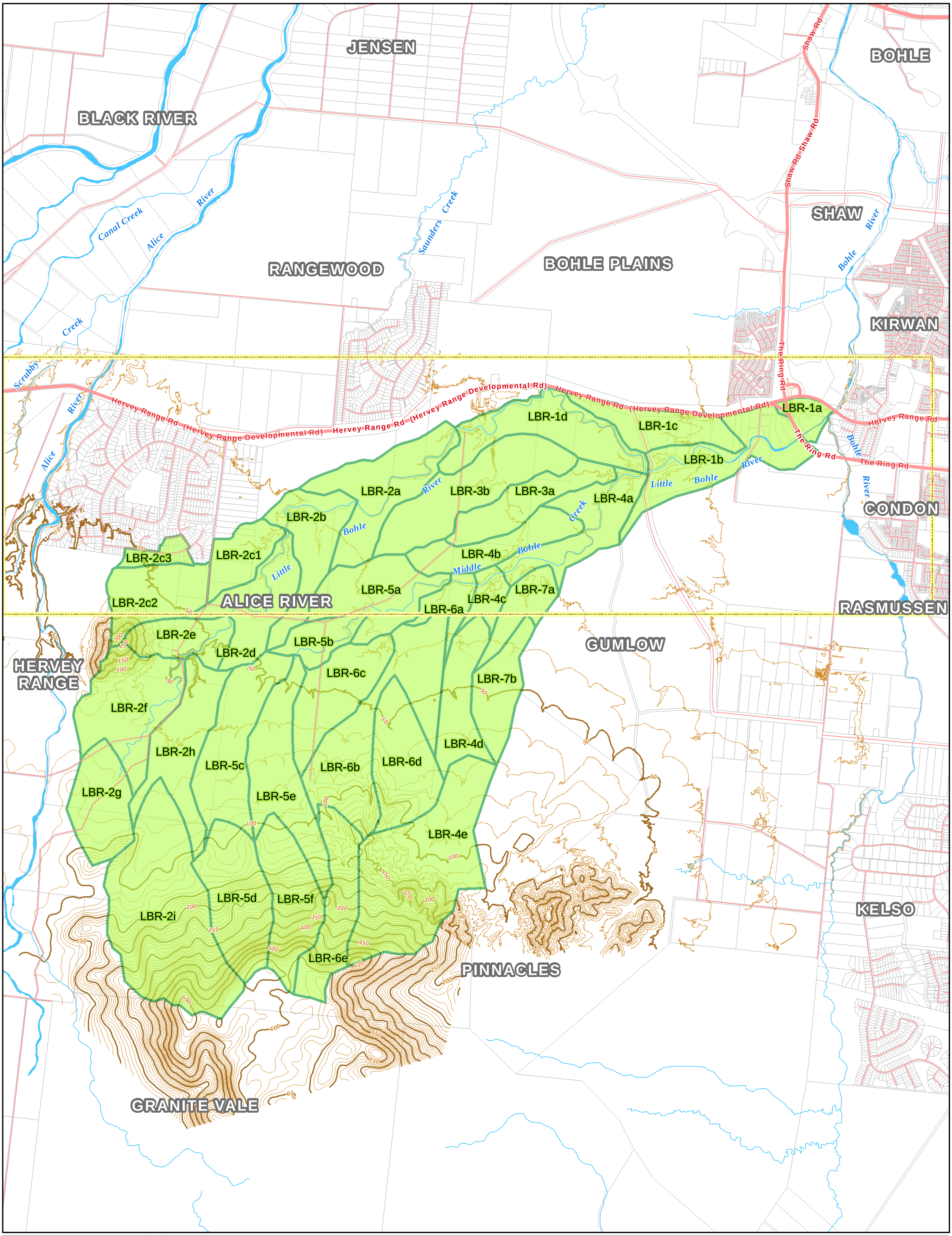
0 0.5 1 2 3 4 Kilometers

Legend

	Main Road		Middle Bohle Catchment
	Watercourse		Black River Catchment
	Property Boundary		Little Bohle Catchment
	Hydraulic Model Extent		Saunders Creek Catchment
			Stoney Creek Catchment

LITTLE BOHLE FLOOD MODEL
Hydrologic models

Figure 2



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Legend
- Property Boundary
- Hydraulic Model Extent
- Little Bohle Catchment
- Minor Contours (10m)
- Major Contours (50m)

LITTLE BOHLE FLOOD MODEL
Little Bohle River Catchment Map

Figure 3

3.2.2 Flood Frequency Analysis

Flood frequency analysis (FFA) was undertaken for the annual peak discharges for the 25 year record for the Little Bohle River Stream gauge using Log-Pearson III techniques from *Australian Rainfall and Runoff* (1998). **Table 2** presents the annual maxima of flood flows used in the FFA.

A partial series analysis was also undertaken to account for the additional events that occur during the wet season in order to more accurately determine the lower return period flows. For the partial series analysis the threshold flow rate was chosen as 50 m^3/s which increased the number of events from 25 years of record to 43 recorded events.

The results of the FFA are presented in **Table 2** for the 2, 5, 10, 20, 50 and 100 year ARI, with values for the 95% confidence interval.

Table 2 Flood Frequency Analysis

ARI	Fitted Value (m^3/s)	95% Confidence Interval	
		Lower Bound (m^3/s)	Upper Bound (m^3/s)
2	155 (Partial Series)	50	240
5	214 (Partial Series)	130	410
10	310	200	490
20	440	250	720
50	620	280	1220
100	770	280	1780

3.2.3 Existing Case Sub-catchment Parameters

The sub-catchments of the Little Bohle River were delineated based on the 0.25 m contour LiDAR data where available. Aerial photography was used to determine the percent impervious and roughness values.

Table 3 shows the parameters (area, roughness, catchment slope and percentage impervious) used to represent the individual sub-catchments in XP-RAFTS for the existing case (2009 contours).

Table 3 Existing Case Little Bohle River sub-catchment parameters

Sub-catchment	Total Area [ha]	Catchment Mannings 'n' [n value]	Percentage Impervious [%]	Catchment Slope [%]
LBR-1a	34	0.06	0	4.7
LBR-1b	188	0.06	1	3.5
LBR-1c	110	0.06	1	1.5
LBR-1d	179	0.06	4	4.0
LBR-1e	44	0.025	47	5.4
LBR-1f	13	0.025	29	0.6
LBR-1g	15	0.06	0	0.6
LBR-2a	189	0.06	4	2.1
LBR-2b	140	0.06	0	2.0
LBR-2c1	78	0.06	0	1.8
LBR-2c2	129	0.06	0	8.0
LBR-2c3	32	0.06	0	8.0
LBR-2d	139	0.06	0	2.7
LBR-2e	90	0.06	1	11.1
LBR-2f	209	0.06	0	9.5
LBR-2g	132	0.06	0	5.3
LBR-2h	167	0.06	0	2.8
LBR-2i	422	0.06	0	21.9
LBR-3a	114	0.06	0	1.6
LBR-3b	213	0.06	0	1.0
LBR-4a	147	0.06	0	4.2
LBR-4b	110	0.06	0	1.3
LBR-4c	39	0.06	0	3.7
LBR-4d	117	0.06	0	2.1
LBR-4e	373	0.06	0	20.6

Sub-catchment	Total Area [ha]	Catchment Mannings 'n' [n value]	Percentage Impervious [%]	Catchment Slope [%]
LBR-5a	161	0.06	0	2.3
LBR-5b	61	0.06	0	2.9
LBR-5c	192	0.06	0	2.6
LBR-5d	187	0.06	0	24.2
LBR-5e	191	0.06	0	6.0
LBR-5f	156	0.06	0	26.2
LBR-6a	50	0.06	0	3.2
LBR-6b	264	0.06	0	5.7
LBR-6c	150	0.06	0	1.9
LBR-6d	164	0.06	0	6.6
LBR-6e	145	0.06	0	24.5
LBR-7a	69	0.06	0	2.2
LBR-7b	103	0.06	0	1.9
LBR-N2	164	0.06	3	0.7
LBR-N3	36	0.06	0	0.5
LBR-N4	37	0.06	0	0.4
LBR-N5	72	0.06	0	0.3
LBR-N6	118	0.06	2	0.5
LBR-N7	58	0.025	14	1.7
LBR-N8	29	0.06	0	2.5
LBR-N9	57	0.025	9	2.6

3.2.4 Channel Routing

The Muskingum-Cunge routing method was used to route hydrographs between sub-catchments. The Muskingum-Cunge method requires a defined channel geometry and roughness to determine the appropriate hydrograph routing. The general channel geometry, link lengths and slopes were based on previous models used for the *BPFPS* and updated based on new catchment delineations and new contour data.

3.2.5 Model Calibration

The XP-RAFTS model was calibrated using the March 1997 event and then the same parameters were used to verify the model performance using the January 2008 event. These two storms were previously used to calibrate the model developed for the *BPFPS* and as such inflow data exists for the Bohle River boundary conditions.

The aim of this study is to provide flood levels for the Little Bohle River and this joint calibration was done to ensure the MIKEFLOOD model flood levels match those that have occurred for the above historical events

3.2.5.1 March 1997 event

The XP-RAFTS model for the Little Bohle River catchment was calibrated to the event on the 23-24 March 1997. It is estimated this event had a return period of just less than 5 year ARI.

For calibration, the rainfall data was taken from the Mt Margaret standalone station. Calibration was undertaken jointly using the XP-RAFTS model and the MIKEFLODO hydraulic model. The aim of this study is to provide flood levels for the Little Bohle River and this joint calibration was done to ensure the MIKEFLOOD model flood levels match those that have occurred for the above historical events. The XP-RAFTS model was calibrated to the timing and volume of flow and the flood levels were determined using the MIKEFLOO model. The XP-RAFTS results should be viewed in conjunction with the calibrated MIKEFLOOD model results shown in **Figures 15** and **Figure 16**.

Figure 4 shows the XP-RAFTS results. The results indicate differences in the timing of the hydrograph while the peak flow shows a reasonable match to the data. The comparison of flood levels obtained from the MIKEFLOOD model and shown in **Section 4.3.1** however, show good agreement with the shape, timing and peak level of the flood level timeseries data.

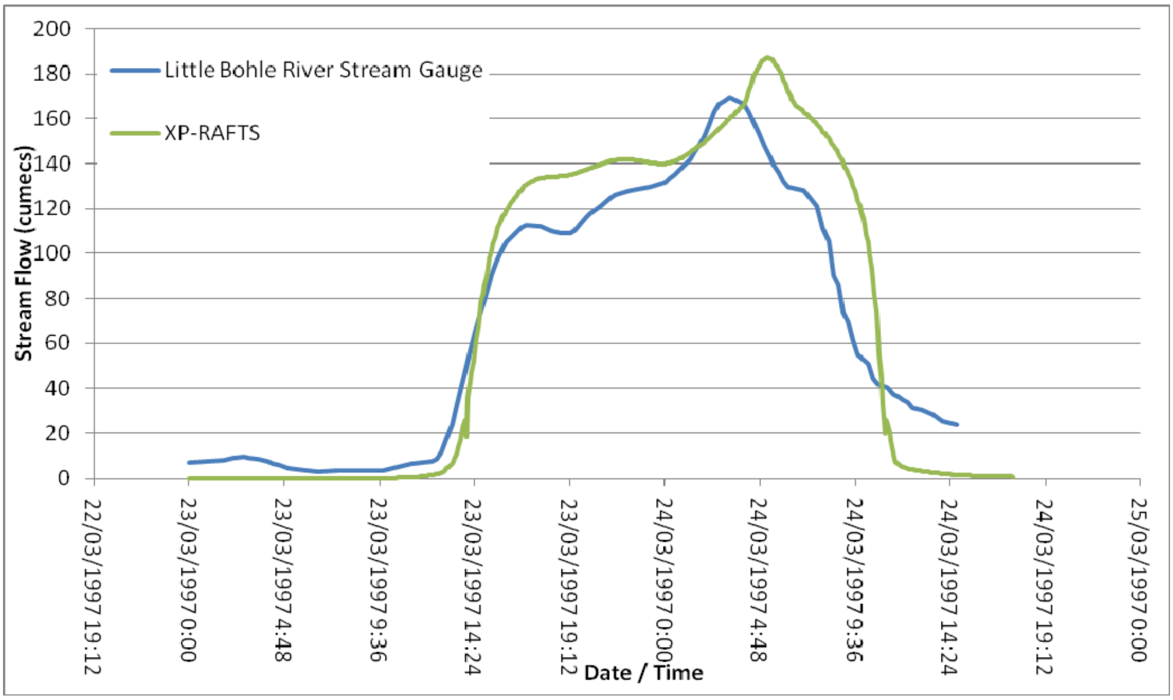


Figure 4 **March 1997 Calibration Event**

3.2.6 Verification

3.2.6.1 January 2008 event

The XP-RAFTS model for the Little Bohle River catchment was verified to a second historical event on the 14-16 January 2008. This event had a return period of between 2 and 5 year ARI. Again the rainfall data was taken from the Mt Margaret Alert station and a joint calibration was undertaken. The XP-RAFTS results should be viewed in conjunction with the calibrated MIKEFLOOD model results shown in **Figure 17** and **Figure 18**. The XP-RAFTS results in **Figure 5** show a reasonable match to, flood volume, peak flow and rising limb of the second peak. However the peak flow is overestimated for the first flood peak and the timing of the rising limb lags the data.

The comparison of flood levels obtained from the MIKEFLOOD model and shown in **Section 4.3.1** however, show good agreement with the shape, timing and peak level of the flood level timeseries data.

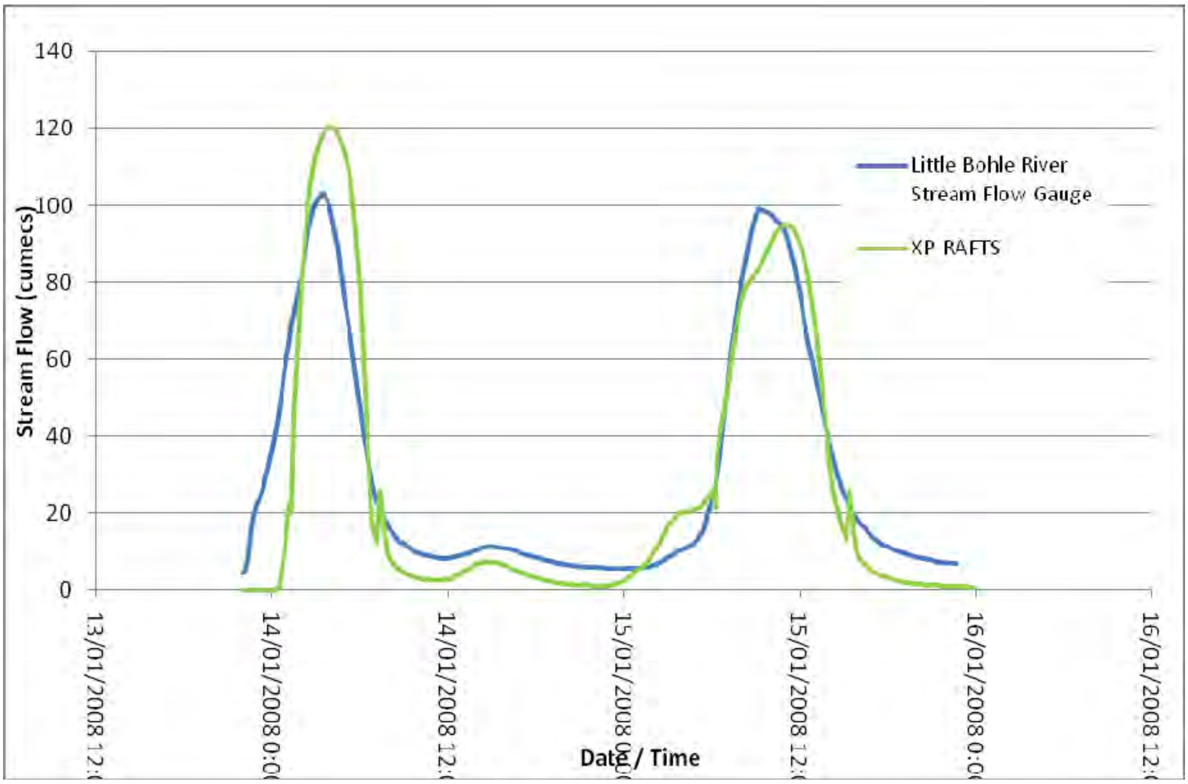


Figure 5 January 2008 Verification Event

3.2.7 Loss Parameters

XP-RAFTS uses an initial and continuing loss model to represent infiltration and storage of runoff in surface depressions. Through the calibration and verification process, initial and continuing loss values for the XP-RAFTS model were chosen. The loss values adopted for the pervious and impervious fractions are shown in **Table 4**.

Table 4 Adopted Rainfall Loss Parameters – Little Bohle River

	Initial Loss (mm)	Continuing Loss (mm/h)
Pervious area	25	2.5
Impervious area	1	0

3.3 Rupertswood Catchments

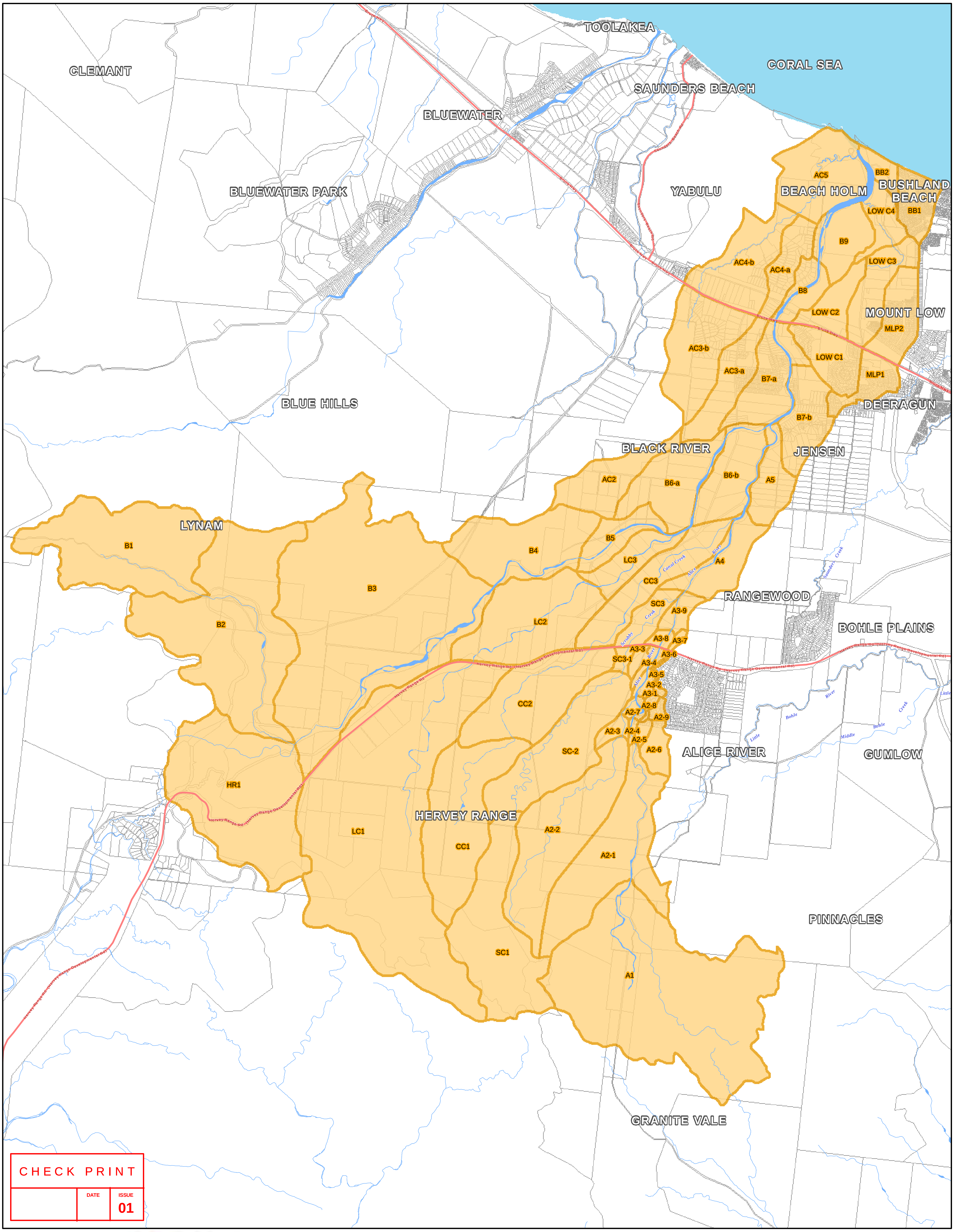
3.3.1 Catchment Description

Rupertswood is a rural residential estate located immediately east of Alice River. The runoff from this area drains to three separate main catchments. The western portion of the site drains to the Black River catchment. The middle and eastern portions of the estate drain north across Hervey Range Road to Stony Creek and Saunders Creek respectively.

Also a small area on the southern side of Rupertswood drains to the Little Bohle River however this section only details the three main catchments that drain the area.

The hydrologic models developed for these three catchments are based on those developed for the *BPFPS*. The catchment map for Black River is shown in **Figure 6**, the catchment map for Stony Creek is shown in **Figure 7** and the catchment map for Saunders Creek is shown in **Figure 8**.

The catchment breakup for all catchments draining through Rupertswood is shown in **Figure 9**. Detailed maps of each catchment at the recommended scales in TCC's flood guidelines are shown in **Appendix C**.



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N

Scale: 1:100,000
(when printed at A3)

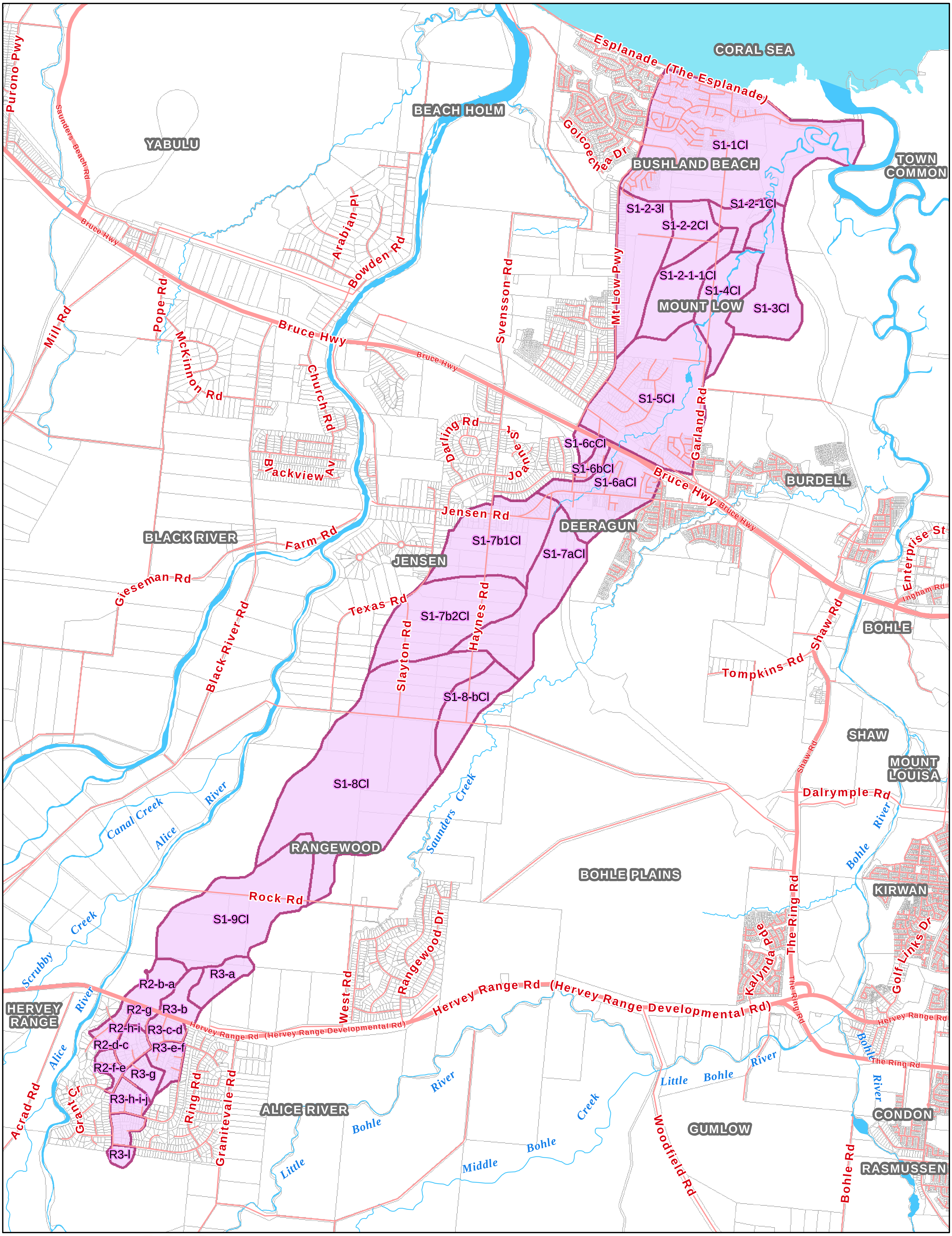
0 0.5 1 2 3 Kilometers

Legend

- Main Road
- Property Boundary
- Watercourse
- Black River Catchment

LITTLE BOHLE FLOOD MODEL
Black River Catchment Map

Figure 6



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Scale: 1:50,000
(when printed at A3)

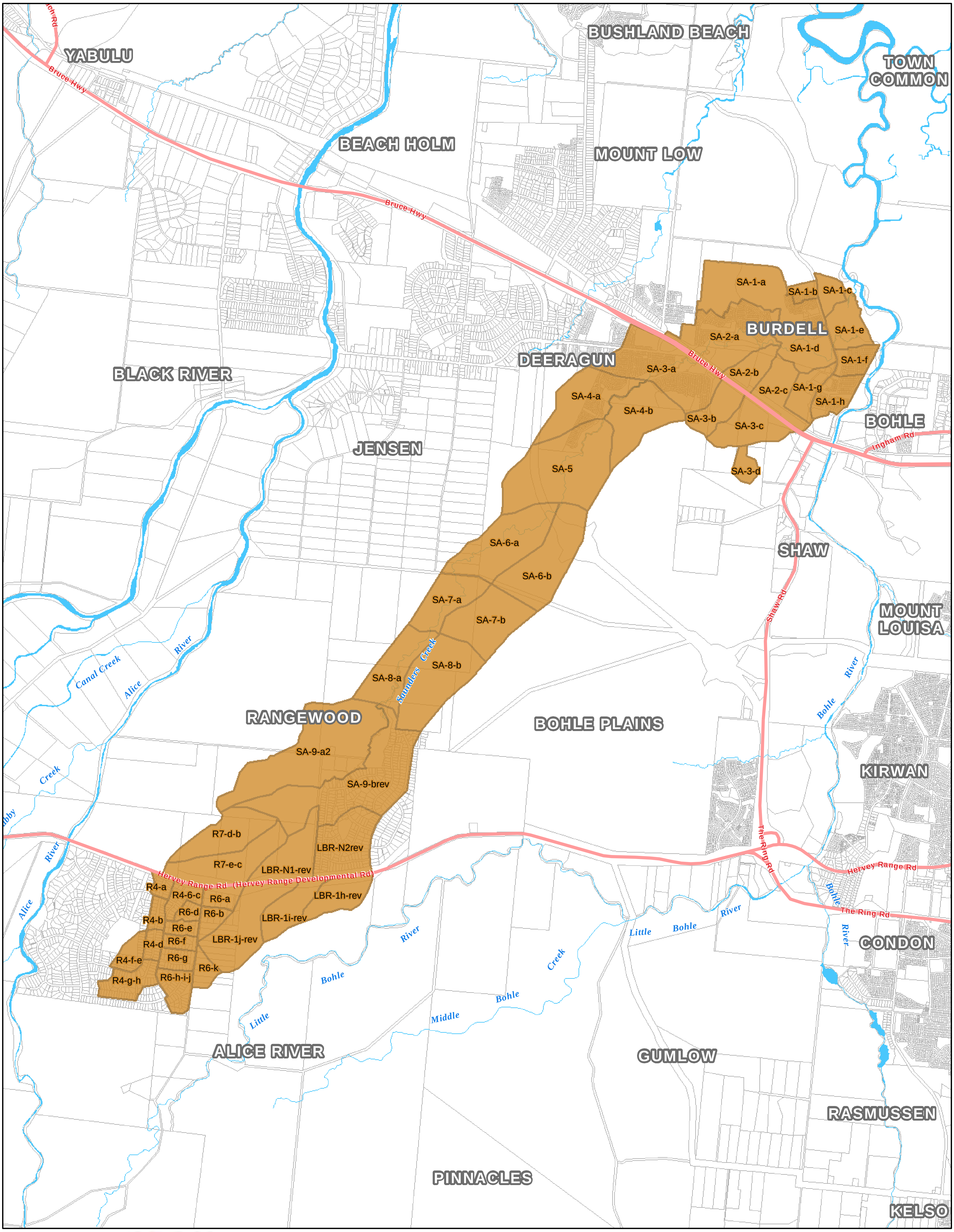
0 250 500 1,000 Metres

Legend

Stoney Creek Catchment

LITTLE BOHLE FLOOD MODEL
Stony Creek Catchment Map

Figure 7



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Scale: 1:50,000
(when printed at A3)

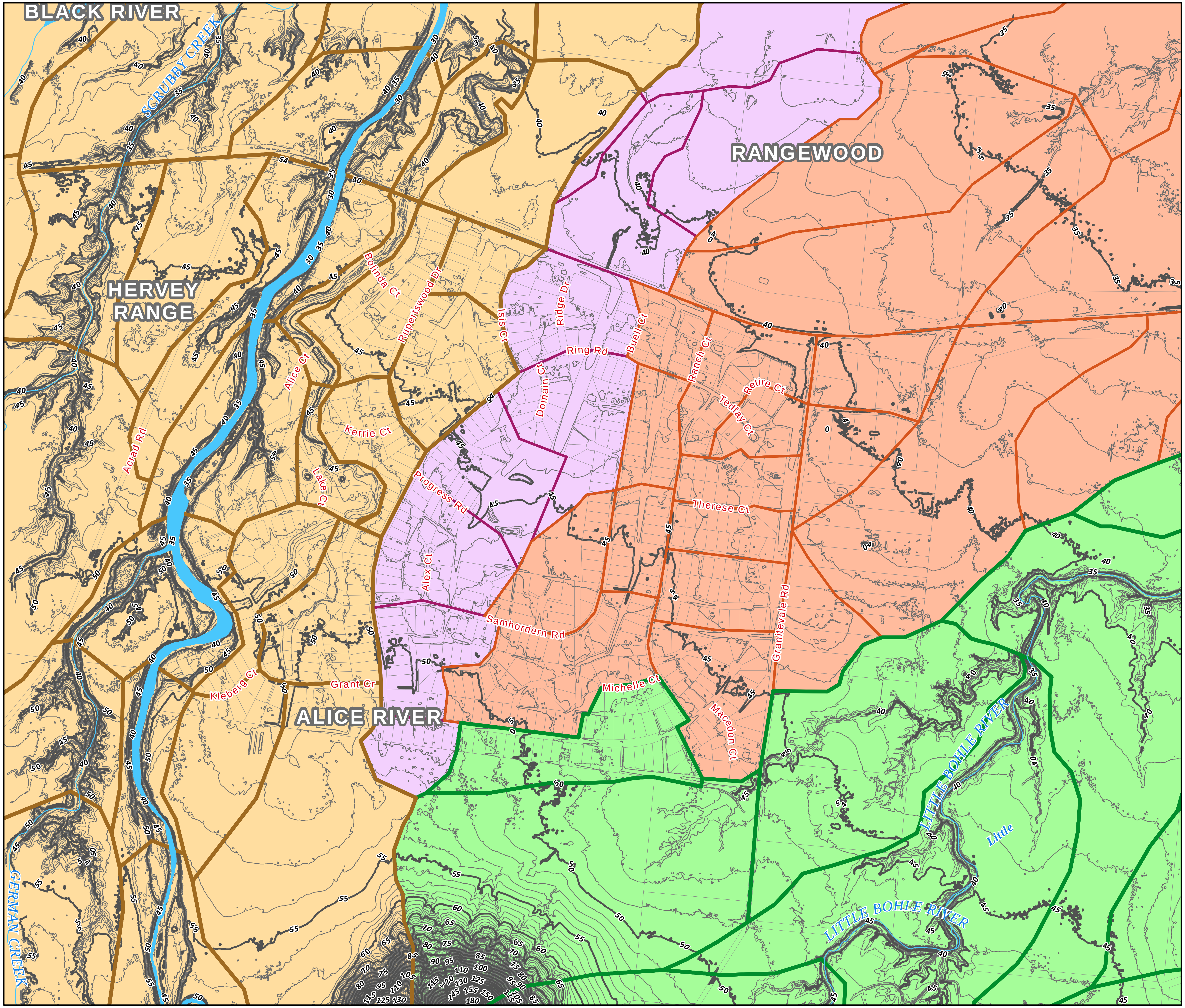
0 500 1,000 2,000 Meters

Legend

	Main Road		Property Boundary
	Watercourse		Saunders Creek Catchment

LITTLE BOHLE FLOOD MODEL
Saunders Creek Catchment Map

Figure 8



LITTLE BOHLE FLOOD MODEL
Rupertswood Catchment Delineation

Figure 9

Legend

- Black River Catchment
- Little Bohle Catchment
- Saunders Creek Catchment
- Stoney Creek Catchment
- Property Boundary
- Major Contours (5m)
- Minor Contours (1m)

N

Scale: 1:15,000 (when printed at A3)

0 150 300 600
Metres

PROJECT ID 60188958
LAST MODIFIED CFS 20-Feb-2011
FILE NAME 60188958G_WR_15

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3.3.2 Existing Case Sub-catchment Parameters

The sub-catchments were delineated based on the 0.25 m contour LiDAR data for the area. Aerial photography was used to determine the percent impervious and roughness values and catchment slopes were calculated using the Spatial Analysis Extension within ArcMap.

Table 5 to **Table 7** show the parameters (area, roughness, catchment slope and percentage impervious) used to represent the individual sub-catchments of Black River, Stony Creek and Saunders Creek XP-RAFTS models for the existing case (2009 contours).

The Black River, Stony Creek and Saunders Creek sub-catchments downstream of Rupertswood have been further delineated to allow determination of inflow hydrographs for the hydraulic model in the area downstream of Rupertswood. The parameters (area, slope, roughness and percent impervious) for sub-catchments downstream of the hydraulic model extent have for have not changed from *BPFPS*.

Table 5 Existing Case Black River Sub-Catchment Parameters

Sub-catchment	Total Area [ha]	Catchment Mannings 'n' [n value]	Percentage Impervious [%]	Catchment Slope [%]
A1	2668	0.05	0	6.0
A2-1	956	0.05	0	9.2
A2-2	957	0.05	0	6.5
A2-3	56	0.05	0	10.0
A2-4	19	0.04	0	12.2
A2-5	27	0.06	2	1.0
A2-6	108	0.06	1	1.5
A2-7	37	0.05	1	11.3
A2-8	20	0.05	6	1.7
A2-9	25	0.05	7	1.4
A3-1	42	0.05	2	8.0
A3-2	11	0.05	5	3.8
A3-3	38	0.06	0	1.0
A3-4	43	0.05	1	6.8
A3-5	7	0.06	3	4.8
A3-6	3	0.04	4	5.0
A3-7	17	0.06	0	6.1
A3-8	36	0.06	0	6.4
A3-9	92	0.035	0	4.2
A4	307	0.05	0	0.3
A5	288	0.045	0	0.4
AC2	365	0.038	0	1.6
AC3-a	399	0.035	0	0.4
AC3-b	608	0.05	0	0.3
AC4-a	231	0.05	0	0.4
AC4-b	522	0.05	0	0.3
AC5	564	0.05	0	0.3
B1	1217	0.07	0	9.3
B10	0	0.025	0	1.0
B11	0	0.025	0	1.0
B2	1832	0.06	0	8.6
B3	3106	0.05	0	8.0
B4	732	0.05	0	9.8
B5	229	0.05	0	0.3
B6-a	409	0.05	0	0.3
B6-b	409	0.05	0	0.3
B7-a	409	0.05	0	0.4
B7-b	387	0.05	0	0.4
B8	175	0.03	0	0.3

Sub-catchment	Total Area [ha]	Catchment Mannings 'n' [n value]	Percentage Impervious [%]	Catchment Slope [%]
B9	295	0.04	0	0.3
BB1	202	0.05	0	3.1
BB2	95	0.05	0	0.3
CC1	931	0.05	0	6.6
CC2	741	0.05	0	0.4
CC3	487	0.05	0	0.3
HR1	1495	0.05	0	6.4
LC1	3394	0.05	0	5.2
LC2	832	0.05	0	0.4
LC3	244	0.05	0	0.3
LOWC1	271	0.05	0	4.6
LOWC2	208	0.05	0	0.4
LOWC3	323	0.05	0	0.3
LOWC4	180	0.05	0	0.3
MLP1	186	0.05	0	0.3
MLP2	287	0.05	0	0.6
SC1	981	0.05	0	7.1
SC-2	763	0.05	0	4.8
SC3	201	0.05	0	0.4
SC3-1	38	0.06	0	6.1

Table 6 Existing Case Stony Creek Sub-catchment Parameters

Sub-catchment	Total Area [ha]	Catchment Mannings 'n' [n value]	Percentage Impervious [%]	Catchment Slope [%]
R2-b-a	38	0.06	0	0.8
R2-d-c	22	0.05	5	1.0
R2-f-e	15	0.05	6	1.0
R2-g	11	0.05	4	0.9
R2-h-i	24	0.05	5	1.0
R3-a	37	0.06	0	0.7
R3-b	29	0.06	0	1.0
R3-c-d	22	0.04	7	1.0
R3-e-f	27	0.05	5	0.9
R3-g	23	0.05	3	1.4
R3-h-i-j	24	0.05	6	1.2
R3-k	19	0.05	7	1.2
R3-l	11	0.05	3	1.2
S1-1CL	476	0.048	54	1.3
S1-2-1-1CL	104	0.05	70	0.7
S1-2-1CL	35	0.05	51	3.7
S1-2-2CL	52	0.05	57	5.0
S1-2-3CL	134	0.048	64	0.7
S1-3CL	127	0.05	62	0.7
S1-4CL	94	0.05	70	0.7
S1-5CL	280	0.0373	50	0.7
S1-6aCL	130	0.0373	23	0.7
S1-6b-Cl	15	0.0373	50	0.7
S1-6c-Cl	14	0.0373	50	0.7
S1-7aCL	169	0.05	4	2.7
S1-7b1Cl	169	0.05	16	0.7
S1-7b2Cl	187	0.05	10	0.7

Sub-catchment	Total Area [ha]	Catchment Mannings 'n' [n value]	Percentage Impervious [%]	Catchment Slope [%]
S1-8b	80	0.05	7	2.1
S1-8CL	613	0.05	3	2.9
S1-9CL-rev	247	0.05	18	0.7

Table 7 Existing Case Saunders Creek Sub-catchment Parameters

Sub-catchment	Total Area [ha]	Catchment Mannings 'n' [n value]	Percentage Impervious [%]	Catchment Slope [%]
R7-e-c	75	0.07	0	0.7
R7-d-b	65	0.06	0	0.8
R4-a	10	0.04	5	1.5
R4-b	11	0.05	19	1.1
R4-d	11	0.05	6	1.3
R4-f-e	19	0.05	5	0.7
R4-g-h	34	0.05	6	1.2
R4-6-c	19	0.05	3	1.2
R6-a	18	0.06	0	1.0
R6-d	9	0.05	4	1.3
R6-e	11	0.05	3	1.0
R6-f	11	0.05	6	1.0
R6-g	16	0.05	4	0.9
R6-h-i-j	27	0.05	5	0.9
R6-b	15	0.06	5	1.1
R6-k	16	0.06	2	0.7
LBR-N1-rev	57	0.06	1	0.7
LBR-N2rev	79	0.06	3	0.7
LBR-1h-rev	41	0.06	0	0.4
LBR-1i-rev	43	0.06	0	0.3
LBR-1j-rev	86	0.06	0	0.5
SA-8-a	66	0.065	1	0.5
SA-7-a	56	0.065	1	0.5
SA-7-b	82	0.065	1	0.5
SA-6-a	101	0.065	1	0.5
SA-6-b	101	0.065	1	0.6
SA-5	157	0.065	1	0.5
SA-4-a	80	0.065	13	0.5
SA-3-a	118	0.065	38	3.5
SA-2-a	109	0.05	31	0.5
SA-1-d	49	0.05	22	0.5
SA-1-e	38	0.05	1	0.5
SA-1-c	19	0.05	1	0.7
SA-2-c	45	0.05	70	0.6
SA-2-b	32	0.05	42	0.5
SA-3-c	55	0.05	50	4.3
SA3-b	36	0.05	1	5.9
SA-9-a2rev	186	0.065	1	0.5
SA-9-brev	171	0.065	12	1.0
SA-8-b	106	0.065	1	0.5
SA-4-b	78	0.065	1	5.3
SA-1-g	30	0.05	70	0.5
SA-1-h	32	0.05	66	0.5
SA-1-f	23	0.05	51	0.7

Sub-catchment	Total Area [ha]	Catchment Mannings 'n' [n value]	Percentage Impervious [%]	Catchment Slope [%]
SA-1-a	109	0.05	66	0.5
SA-1-b	11	0.05	52	0.6

3.3.3 Link Lagging

Link Lagging was used to route hydrographs between sub-catchments. An estimation of channel flow was based on nominal velocities of 0.5 m/s for rural areas and 1 m/s for urban areas. These velocities were verified against final results of the hydraulic modelling and were found to be suitable. Flow path lengths were based on channel geometries identified from contour data.

3.3.4 Initial and Continuing Loss Values

The XP-RAFTS model for the three catchments developed for the *BPFPS* use differing loss values throughout Rupertswood. These loss values were determine based on model calibration at location a significant distance downstream. The loss values used previously are summarised in **Table 8**.

Table 8 Loss values used in the *BPFPS*

Catchment	Initial Loss (mm)	Continuing Loss (mm)
Black River	30	2.5
Stony Creek	4	1.5
Saunders Creek	15	2.5

The catchment conditions within Rupertswood do not differ significantly between catchments and therefore consistent loss parameters should be specified for this area.

3.3.5 Sensitivity Analysis

To determine suitable loss parameters a sensitivity analysis was performed on the loss parameters used within the Rupertswood catchment. This sensitivity analysis assessed all three loss parameter sets and quantified the changes in flow downstream of Rupertswood and also the changes in peak and total flow at the downstream outlet of each watercourse. The results of the sensitivity analysis are shown in **Table 9**. The highlighted values in each column are the values used previously in the *BPFPS*.

Table 9 Sensitivity analysis of varying loss parameters within Rupertswood catchments

Losses	Initial loss 30 mm, Continuing Loss 2.5 mm/hr	Initial loss 4 mm, Continuing Loss 1.5 mm/hr	Initial loss 15 mm, Continuing Loss 2.5 mm/hr
Black River Catchment			
Peak @ Hervey Range Road (A3-4) m^3/s)	766	768	767
Peak @ Hervey Range Road (A3-6) m^3/s)	29	34	32
Peak @ Hervey Range Road (SC3-1) (m^3/s)	309	316	313
Peak @ downstream outlet (m^3/s)	3294	3318	3306
Volume @ downstream outlet (ML)	1739	1749	1742
Stony Creek Catchment			
Peak @ Hervey Range Rd (R2-d-c) (m^3/s)	7	8	8
Peak @ Hervey Range Rd (R2-g) (m^3/s)	6	7	7
Peak @ Hervey Range Rd (R3-c-d) (m^3/s)	23	28	26
Peak @ downstream outlet (m^3/s)	198		200
Volume @ downstream outlet (ML)	88	89	89
Saunders Creek Catchment			
Peak @ Hervey Range Rd (R4-a) (m^3/s)	13	16	15
Peak @ Hervey Range Rd (R4-6-c) (m^3/s)	15	20	18
Peak @ Hervey Range Rd (R6-a) (m^3/s)	19	25	23
Peak @ downstream outlet (m^3/s)	198	215	207
Volume @ downstream outlet (ML)	86	89	87

The loss parameters selected for these catchments are 15 mm initial loss and 2.5 mm/hr continuing loss.

Applying these loss values to the Rupertswood area of the three catchments and comparing against the catchment outflows from the *BPFPS* shows the overall volume of runoff for the Black River catchment is increased by 0.2% and the overall volume of runoff for the Stony Creek catchment is decreased by 0.5%. The Saunders Creek catchment previously used loss values of 15 mm initial loss and 2.5 mm continuing loss and therefore the overall volume downstream remains unchanged.

3.3.6 Loss Parameters

Loss values are considered acceptable and to summarise, the final loss values adopted for the pervious and impervious fractions are shown in **Table 10.**

Table 10 Adopted Rainfall Loss Parameters - Rupertswood

	Initial Loss (mm)	Continuing Loss (mm/hr)
Pervious area	15	2.5
Impervious area	1	0

3.3.7 Verification

The flows within the various catchments through Rupertswood were verified to the rational method and also compared to the results of the previous reports *Saunders Creek Options Report* by McIntyre & Associates (1994).

Rational Method

The XP-RAFTS model results were verified using the Rational Method for the Black River and Stony Creek catchments that flow through Rupertswood and also the western portion of the Saunders Creek catchment. Only the flows from the western portion of Saunders Creek were assessed as these flows are not influenced by flow over Granitevale road or the detention basin in the northeast corner of Rupertswood.

Table 11 shows the results of the Rational Method, compared to the results of XP-RAFTS. The time of concentration was calculated using three different methods where appropriate, Bransby Williams, Stream velocity method and the Kinematic Wave Equation.

The result of the verification show the peak discharge is reasonable agreement with the rational method calculations.

Table 11 Verification to Rational Method for Black and Stony Creek catchments

Catchment	D/S node	Peak discharge (m3/s)		Difference (%)
		XP-RAFTS	Rational Method	
Black River	A3-6	31.8	31.0	-2.5
Stony Creek	R3-c-d	27.4	27.2	-0.7
Saunders Creek – west portion	R4-a	16.6	17.3	-4

3.4 Design Rainfall

3.4.1 Design Rainfall Intensity

Design rainfall intensities, or Intensity Frequency Duration (IFD) data, were determined from Volume 2 of *Australian Rainfall and Runoff* (ARR, 1987). Inspection of the design intensity isopleths for the Little Bohle catchment and suburb of Rupertswood showed minimal variation within the catchment area. A single IFD was adopted for all catchments and these IFD parameters shown in **Table 12**. Standard techniques from ARR were used to determine rainfall intensities for durations up to 72 hours and up to a 100 year ARI event. The calculated IFD data is shown in **Table 13**.

Table 12 Adopted IFD input parameters

Parameter	Value
2 year ARI, 1 hour duration (mm/hr)	55.0
2 year ARI, 12 hour duration (mm/hr)	13.0
2 year ARI, 72 hour duration (mm/hr)	4.0
50 year ARI, 1 hour duration (mm/hr)	105.0
50 year ARI, 12 hour duration (mm/hr)	27.5
50 year ARI, 72 hour duration (mm/hr)	9.5
G	0.05
F2	3.93
F50	17.0

Table 13 Design Rainfall Intensities

Duration	1 Year ARI (mm/hr)	2 Year ARI (mm/hr)	5 Year ARI (mm/hr)	10 Year ARI (mm/hr)	20 Year ARI (mm/hr)	50 Year ARI (mm/hr)	100 Year ARI (mm/hr)
5 min	119	153	195	220	253	297	330
6 min	112	144	184	208	239	280	312
10 min	94	121	155	174	201	235	261
12 min	88	113	145	163	187	219	244
15 min	81	104	132	149	171	201	223
18 min	75	96	123	138	159	186	207
20 min	71	92	117	132	152	178	198
24 min	66	85	108	122	140	164	183
30 min	60	77	98	110	127	148	165
1 hr	42.7	55	70	79	91	106	118
1.5 hr	33.8	43.6	56	63	73	86	96
2 hr	28.6	36.9	47.7	54	62	73	82
3 hr	22.5	29.1	37.9	43.1	49.9	59	66
4.5 hr	17.7	23	30.1	34.3	39.9	47.3	53
6 hr	14.9	19.4	25.5	29.2	34	40.5	45.5
9 hr	11.8	15.3	20.3	23.3	27.2	32.5	36.6
12 hr	9.92	13	17.2	19.9	23.3	27.8	31.4
18 hr	7.69	10.1	13.6	15.7	18.5	22.2	25.1
24 hr	6.41	8.42	11.4	13.3	15.6	18.9	21.4
30 hr	5.54	7.3	9.95	11.6	13.7	16.6	18.9
36 hr	4.91	6.48	8.88	10.4	12.3	14.9	17.0
48 hr	4.04	5.34	7.37	8.65	10.3	12.5	14.3
72 hr	3.00	3.98	5.56	6.57	7.86	9.62	11.0

3.4.2 Probable Maximum Precipitation

The Generalised Short Duration Method (GSDM) and the Generalised Tropical Storm Method (GTSM) were used to determine the critical duration of the Probable Maximum Precipitation (PMP) for the Little Bohle River and the combined Black River, Saunders Creek and Stony Creek catchments. The GSDM was used to calculate the PMP for the 1 hour, 3 hour and 6 hour durations, while the GTSM was used to calculate the PMP for the 24 hour, 36 hour, 48 hour, 72 hour, 96 hour and 120 hour durations. The rainfall depths were applied to the XP-RAFTS models for the Little Bohle River, Black River, Stony Creek and Saunders Creek models respectively.

For both catchments, the Annual Exceedance Probability is approximately 10^-7, which equates to an Average Recurrence Interval of 10 million years.

The probable maximum precipitation depths for Little Bohle River and the combined catchments of Black River, Stony Creek and Saunders Creek are shown in **Table 14**.

Table 14 Probable Maximum Precipitation Depths

Duration (hrs)	Probable Maximum Precipitation (mm)	
	Little Bohle River	Combined Black River, Stony Creek and Saunders Creek
1	388	291
3	703	461
6	931	592
24	1630	1500
36	2000	1740
48	2340	2000
72	2940	2450
96	3300	2770
120	3450	2920

3.5 Design Results

The results in **Table 15** and **Table 16** show the peak flows through the Little Bohle River and across Hervey Range Road respectively with the critical duration flood highlighted. The results in **Table 15** show that the critical duration for the standard recurrence intervals is 24 hours for the 50 and 100 year events. This has increased from the 3 hour as determined in the *BPFPS* as the more detailed catchment breakup and topography data resulted in changed catchment slopes.

The flows at the downstream extent of the Little Bohle are approximately 10% higher than the 50 year flow and 5% higher than the 100 year flow calculated from the flood frequency analysis using the values obtained through calibration of the historical events. The record length is 25 years which limits the accuracy of the FFA for larger return periods as evidenced by the large confidence intervals for the design flows in **Table 2**. These flows are within the confidence intervals of the flood frequency analysis.

Comparison of the 50 year 3 hour duration events to the *BPFPS* results shows the peak 50 year 3 hour flow is 640m^3/s compared to 600m^3/s. Differing catchment roughness values were used compared to the *BPFPS* and also IFD parameters specific to the Little Bohle River catchment were used for this assessment, whereas direct rainfall was applied for the *BPFPS* design events calculated using Bohle River IFD parameters and an areal reduction factor.

Four durations had to be modelled to determine maximum flood envelopes for the 50 and 100 year ARI. The 1, 3, 12 and 24 hour durations were selected to ensure the maximum flood levels are captured throughout the catchment.

The 24 hour critical duration was confirmed from the hydraulic model results which indicate the 24 hour event generally causes the highest flood levels throughout the model, this is detailed further in **Section 4.4**. The critical duration for the PMP flood is generally 3 hours.

The results from XP-RAFTS for peak flows at Hervey Range Road from the main Rupertswood drainage channels are shown in **Table 16** for the critical duration 24 hour events. The critical duration for the PMP flood is 24 hours for A2-6, A3-4 and R4-6-c, and 1 hour for R3-c-d, R2-g and R4-a.

Table 15 Peak flows at the downstream extent of the Little Bohle River

Duration (hours)	Peak Flow (m3/s)		
	50 yr ARI	100 yr ARI	PMP
1	430	510	2830
3	640	740	3670
6	630	730	3170
12	640	740	-
24	690	810	3230
36	490	590	2590
48	-	-	2670
72	-	-	2540

Table 16 Peak flows at Hervey Range Road within Rupertswood

Catchment	Node	Peak flow (m3/s)						
		2 yr ARI	5 yr ARI	10 yr ARI	20 yr ARI	50 yr ARI	100 yr ARI	PMP
Black River	A3-6	12.1	19.1	23.3	29.2	32.8	38.8	136
Black River	A3-4	316.7	503.6	619.8	774.2	860.7	1015.6	3477
Stony Creek	R3-c-d	11.2	16.7	19.9	24.2	26.4	30.4	105
Stony Creek	R2-g	3.1	4.6	5.6	6.7	7.5	8.6	35
Saunders Creek	R4-6-c	9.0	13.7	16.4	20.1	22.0	25.5	76
Saunders Creek	R4-a	7.4	11.2	13.4	16.3	17.8	20.7	75

3.6 Pre-existing Undeveloped East Rupertswood Hydrology

The pre-existing case assesses the runoff from the eastern section of Rupertswood based on the 2000 contours, prior to the area being developed. The undeveloped sub-catchments are shown in **Figure 10**

3.6.1 Sub-catchment Parameters

The sub-catchment parameters used for the undeveloped scenario in Rupertswood are shown in **Table 17**.

Table 17 Pre-existing Case Sub-Catchment Parameters

Sub-catchment	Total Area [ha]	Catchment Mannings 'n' [n value]	Percentage Impervious [%]	Catchment Slope [%]
1a	15.6	0.065	0	0.9
1b	18.0	0.065	0	0.6
1c	26.9	0.065	0	0.7
1d	16.9	0.065	0	1.1
2a	38.8	0.065	0	0.8
2b	21.2	0.065	0	0.7
2c	15.0	0.065	0	0.9
3a	7.7	0.065	0	0.7
3b	20.2	0.065	0	0.8

3.6.2 Results and Verification

The results from the pre-existing undeveloped hydrologic modelling are shown in **Table 18**.

Table 18 Results from pre-existing scenario

Sub-catchment	Total Area [ha]	Peak Runoff [m^3/s]
1	77	11.8
2	75	11.2
3	27	4.5

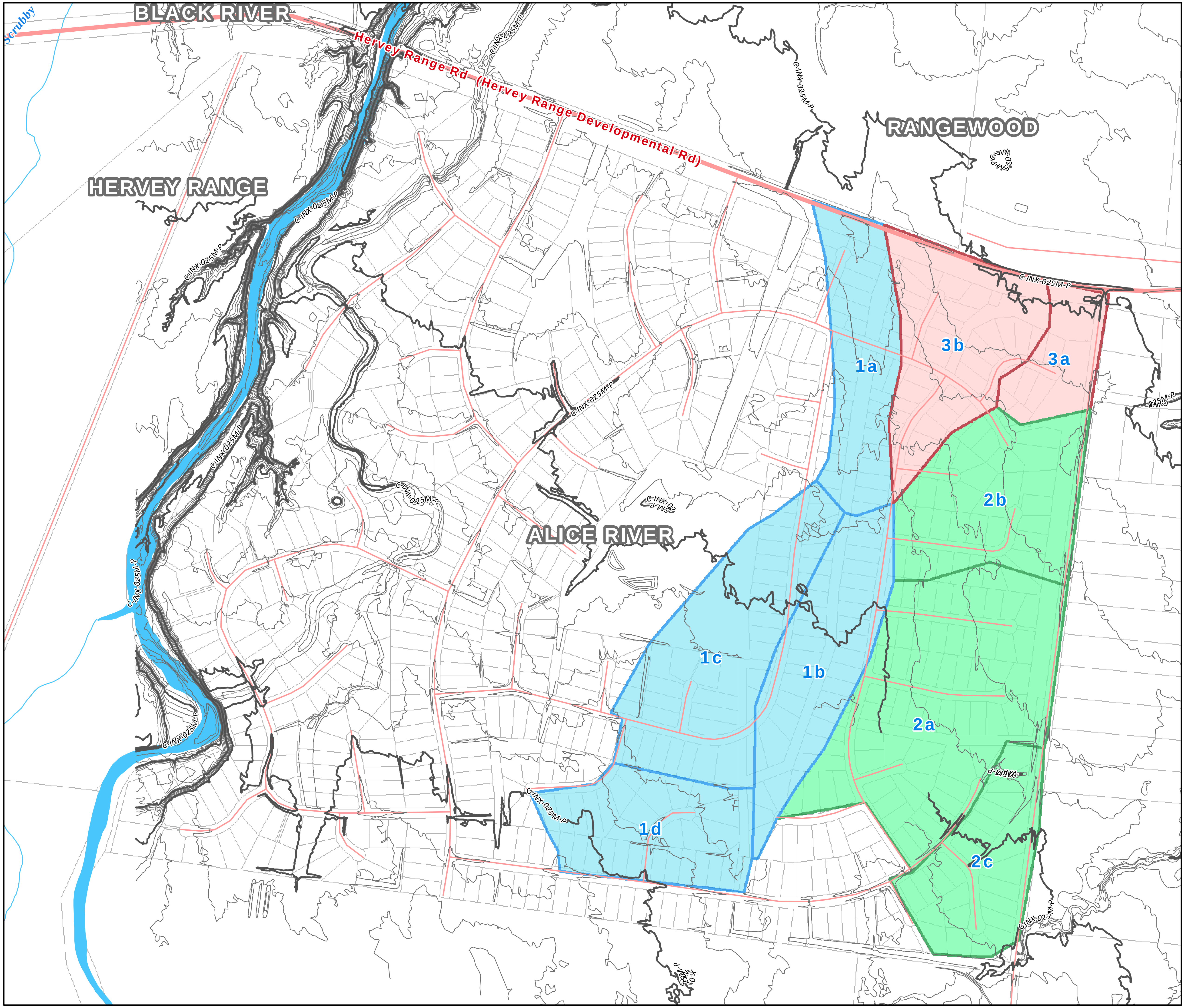
The undeveloped XP-RAFTS model was verified to the flows determined in the report *Using a Detention Basin within Rupertswood Design Report* McIntyre & Associates (1994). This report utilised a RORB hydrologic model to determine flows within the Saunders Creek catchment through Rupertswood. The undeveloped flows for catchment 1 (identified in **Drawing 6820/R10** of the M&A report) were compared and the same loss values were used for the other catchments.

The XP-RAFTS results give a peak runoff of 11.8 m^3/s compared to the 12.5 m^3/s for RORB a difference of 5.6%. This decrease can be partly attributed to the 3.8% difference in catchment area between the two models, 77 ha for XP-RAFTS and 80 ha for RORB. The catchment areas are slightly different as the XP-RAFTS catchment delineation was based on a more comprehensive set of contour data than used for the RORB model setup.

These results are in reasonable agreement given the differences in catchment area. A more detailed assessment of flows and discharges from the Saunders Creek catchment for the undeveloped scenario and the developed scenario including the detention basin in this area is included in **Section 6.0** based on the results of the hydraulic model.

Table 19 Verification of undeveloped runoff

	Catchment Area (ha)		Peak Discharge (m^3/s)		Difference (%)
	McIntyre RORB model	XP-RAFTS	McIntyre RORB model	XP-RAFTS	
Catchment 1	80	77	12.5	11.8	-5.6



LITTLE BOHLE FLOOD MODEL
Undeveloped Catchment Delineation

Figure 10

Legend

- Undeveloped Catchment 1
- Undeveloped Catchment 2
- Undeveloped Catchment 3
- Property Boundary
- Major Contours (5m)
- Minor Contours (1m)

N

Scale: 1:10,000 (when printed at A3)

0 100 200 400

Metres

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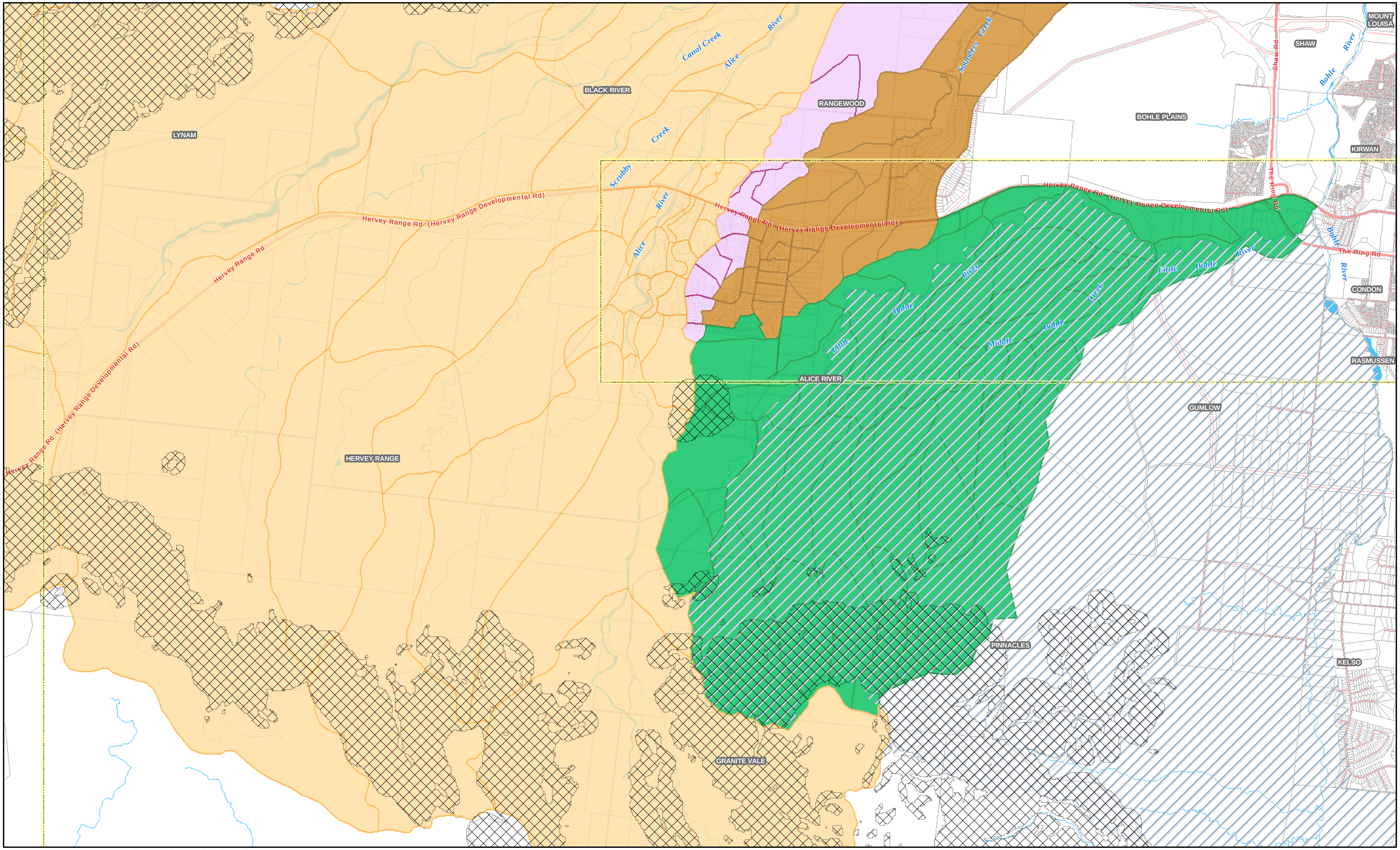
3.7 Future Urbanisation

The future urbanised scenario is based on the development of Bohle Plains. It is assumed that any area less than 15% slope, not currently developed and outside the Gumlow Quadrant is developable, as shown in **Figure 11**.

The area within and upstream of the hydraulic modelling extent for Saunders Creek and Stony Creek is already developed and therefore remains unchanged from the existing case.



LITTLE BOHLE FLOOD MODEL
Future Urbanisation Extent

Figure 11

Legend

- Minor Road
- Main Road
- Watercourse
- Property Boundary
- Black River Catchment
- Little Bohle Catchment
- Saunders Creek Catchment
- Stoney Creek Catchment
- Slope > 15%
- Gumlow
- Hydraulic Model Extent

Scale: 1:60,000
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0 500 1,000 2,000 Metres

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3.7.1 Sub-catchment Parameters

The sub-catchment parameters used to model the Little Bohle River for the urbanised case are shown in **Table 20**. The sub-catchment parameters used to model the urbanised case for Black River catchment are shown in **Table 21**. Only the sub-catchments relevant to this study are shown (i.e. sub-catchments within or upstream of the hydraulic model extent).

Any area outside Gumlow Quadrant and less than 15% slope was taken to be developed with 70% impervious area.

Table 20 Adjusted Sub-Catchments in Little Bohle River

Sub-catchment	Total Area [ha]	Catchment Mannings 'n' [n value]	Percentage Impervious [%]	Catchment Slope [%]
LBR-1a	34	0.06	0	4.7
LBR-1b	188	0.06	1	3.5
LBR-1c	110	0.06	70.0	1.5
LBR-1d	179	0.06	4	4.0
LBR-1e	44	0.025	53.0	5.4
LBR-1f	13	0.025	70.0	0.6
LBR-1g	15	0.06	70.0	0.6
LBR-2a	189	0.06	33.3	2.1
LBR-2b	140	0.06	10.0	2.0
LBR-2c1	78	0.06	70.0	1.8
LBR-2c2	129	0.06	70.0	8.0
LBR-2c3	32	0.06	17.2	8.0
LBR-2d	139	0.06	14.7	2.7
LBR-2e	90	0.06	48.3	11.1
LBR-2f	209	0.06	70.0	9.5
LBR-2g	132	0.06	70.0	5.3
LBR-2h	167	0.06	0	2.8
LBR-2i	422	0.06	0	21.9
LBR-3a	114	0.06	0	1.6
LBR-3b	213	0.06	0	1.0
LBR-4a	147	0.06	0	4.2
LBR-4b	110	0.06	0	1.3
LBR-4c	39	0.06	0	3.7
LBR-4d	117	0.06	0	2.1
LBR-4e	373	0.06	0	20.6
LBR-5a	161	0.06	0	2.3
LBR-5b	61	0.06	0	2.9
LBR-5c	192	0.06	0	2.6
LBR-5d	187	0.06	0	24.2
LBR-5e	191	0.06	0	6.0
LBR-5f	156	0.06	0	26.2
LBR-6a	50	0.06	0	3.2
LBR-6b	264	0.06	0	5.7
LBR-6c	150	0.06	0	1.9
LBR-6d	164	0.06	0	6.6
LBR-6e	145	0.06	0	24.5
LBR-7a	69	0.06	0	2.2
LBR-7b	103	0.06	0	1.9
LBR-N2	164	0.06	15.2	0.7
LBR-N3	36	0.06	70.0	0.5
LBR-N4	37	0.06	70.0	0.4
LBR-N5	72	0.06	70.0	0.3
LBR-N6	118	0.06	70.0	0.5

Sub-catchment	Total Area [ha]	Catchment Mannings 'n' [n value]	Percentage Impervious [%]	Catchment Slope [%]
LBR-N7	58	0.025	14	1.7
LBR-N8	29	0.06	41.8	2.5
LBR-N9	57	0.025	9	2.6

Table 21 Adjusted Sub-Catchments in Black River

Sub-catchment	Total area (ha)	Catchment Mannings 'n' [n value]	Percentage Impervious [%]	Catchment Slope [%]
A1	2668	0.05	31.8	6.0
A2-1	956	0.05	57.4	9.2
A2-2	957	0.05	63.3	6.5
A2-3	56	0.05	66.3	10.0
A2-5	27	0.06	51.8	1.0
A2-6	108	0.06	52.3	1.5
A2-7	37	0.05	38.1	11.3
A3-3	38	0.06	70.0	1.0
A3-7	17	0.06	70.0	6.1
SC1	981	0.05	26.2	7.1
SC2	763	0.05	70.0	4.8
SC31	38	0.06	70.0	6.1

3.7.2 Results

The urbanisation of the various areas increases the flows within the Little Bohle and Black River catchments.

The peak flow in the Little Bohle River is approximately 740 m^3/s and 860 m^3/s in the 50 year ARI and the 100 year ARI events respectively. This is increased from 690 m^3/s and 810 m^3/s in the base case.

The peak flows from the Black River catchment at Alice River Bridge and the culvert to the east of Alice River are shown in **Table 23**. The results show that the critical duration has changed from 24 to 1 hour for the Black River upstream of Rupertswood and the results also show a significant increase in runoff from the catchments of up to 75% upstream of Hervey Range Road, as shown in **Table 23**. This decrease in critical duration and increase in flows is due to the increased urbanisation of the Black River catchment upstream of Rupertswood.

As mentioned the Saunders and Stony Creek catchments upstream of Hervey Range Road are assumed to be fully developed so the flows within these catchments within Rupertswood do not change. Flows downstream of Rupertswood will potentially be increased due to future development that may occur north of Hervey Range Road, however these flow increases have not been included in this assessment.

Table 22 Peak flow downstream of Little Bohle River – Urbanised Case

Duration (hours)	Peak flow (m^3/s)			
	50 yr ARI	50yr ARI Base Case	100 yr ARI	100yr ARI Base Case
1	479	430	568	510
3	699	640	805	740
6	659	630	756	730
12	659	640	760	740
24	740	690	866	810

Table 23 Peak Flow at Hervey Range Road – Black River Urbanised Case

	Peak flow (m3/s)							
Node	A3-6				A3-4			
Duration	50 yr ARI	Base Case	100 yr ARI	Base Case	50 yr ARI	Base Case	100 yr ARI	Base Case
1 h	57		65		1278		1445	
3 h	51		58		1043		1200	
6 h	42		48		964		1108	
12 h	43		50		997		1153	
24 h	41	33	47	39	982	861	1138	1016

4.0 Hydraulic Model

4.1 Overview

A MIKEFLOOD model for the Little Bohle River catchment and surrounding areas has been established to provide baseline flood levels for the area. Rupertswood is also included in the model domain, which extends north of Hervey Range Road. This extension of the model to the north allows the calculation of flows over Hervey Range Road. The extent of the model is shown in **Figure 12.**

The broad floodplain was modelled in MIKE21 while structures and bridges were modelled in MIKE11. A MIKE21 topographic grid was created from digital elevation data as supplied by TCC. Structures were input into the MIKE11 model based on as constructed plans. Flow hydrographs generated in the hydrologic model were applied at boundaries and source points within the study area.

4.2 Model Establishment

4.2.1 MIIKEFLOOD Hydraulic Model

MIKE FLOOD is a numerical hydraulic model developed by the Danish Hydraulic Institute (DHI). It is a dynamically linked one-dimensional and two-dimensional flood modelling package, which dynamically couples the one-dimensional river hydraulics model, MIKE11, with the two-dimensional surface water model, MIKE21.

MIKE FLOOD also provides an appropriate method to include the hydraulics of structures such as bridges and culverts into a MIKE21 grid. Outputs from MIKE FLOOD include GIS compatible maps of water depth, water level and current speed, along with time series of these and other hydraulic parameters. The MIKE FLOOD model setup used for the flooding assessment of Little Bohle River is indicated in **Figure 12**.

4.2.2 Model Scenarios

The existing case model has been used as the basis to assess three development scenarios:

- Existing model – Based on 2009 contours and used to determine base line flooding;
- Pre-existing model – based on the 2000 contours within Rupertswood and used as a base-line to assess the impacts of the Rupertswood detention basin;
- Future urbanisation scenario – based on 2009 contours and future urbanisation hydrology and used to determine flood levels assuming the potential development of the catchment in the future.

The events that have been modelled are listed below:

- 2, 5, 10, 20 and PMP critical duration events to determine base line flooding ;
- the 1 hour, 3 hour, 12 hour and 24 hour duration 50 year ARI events to determine base line flooding;
- the 1 hour, 3 hour, 12 hour and 24 hour duration 100 year ARI events to determine base line flooding;
- the 1 hour, 3 hour, 12 hour and 24 hour duration 50 year ARI events assuming future urbanisation of the catchment;
- the 1 hour, 3 hour, 12 hour and 24 hour duration 100 year ARI events assuming future urbanisation of the catchment;
- 50 year ARI 24 hour duration simulations to determine the sensitivity of the model to various parameters; and
- 50 year ARI 24 hour duration event for the pre-existing scenario to assess the Rupertswood detention basin; MIKE FLOOD

4.2.3 Topography

The topographic grid for the two-dimensional component of the MIKE FLOOD model was developed from the detailed LiDAR survey, received from the Townsville City Council.

The topography developed for Little Bohle River is described by a digital elevation model (DEM) with elevations resolved to 10m grid cells. The average value within each 10m grid was chosen to represent the elevation of that cell with two areas of exception.

The maximum value in the 10m grid cells were selected for the grid cells that represent roads within the area. This is to ensure the hydraulic controls, and in particular Hervey Range Road, is accurately represented in the model.

Also the minimum value in the 10m grid cells was selected for the cells that represent watercourses including the Little Bohle River and various defined drainage paths throughout the model.

Figure 12 shows the topographic grid used for the MIKE 21 model for the base line existing scenario.

Pre-existing model

The pre-existing model was also developed primarily to assess the undeveloped flows off the eastern portion of Rupertswood, in order to investigate the performance of the detention basin in the northeast corner of the development.

There were several areas of changes to the topography for the pre-existing model grid. To create this grid, the 2000 contours were used to extract elevations for the areas where the topography has changed after 2004. These areas were stamped into the base mesh to represent the 2000 topography within the model domain. The areas that were altered include:

- Eastern section of Rupertswood;
- Rangewood
- Refuse Disposal site
- Kalynda Chase; and
- the area where the Ring Road is located including associated detention basins.

The areas where the topography has changed is shown in **Figure 13**.

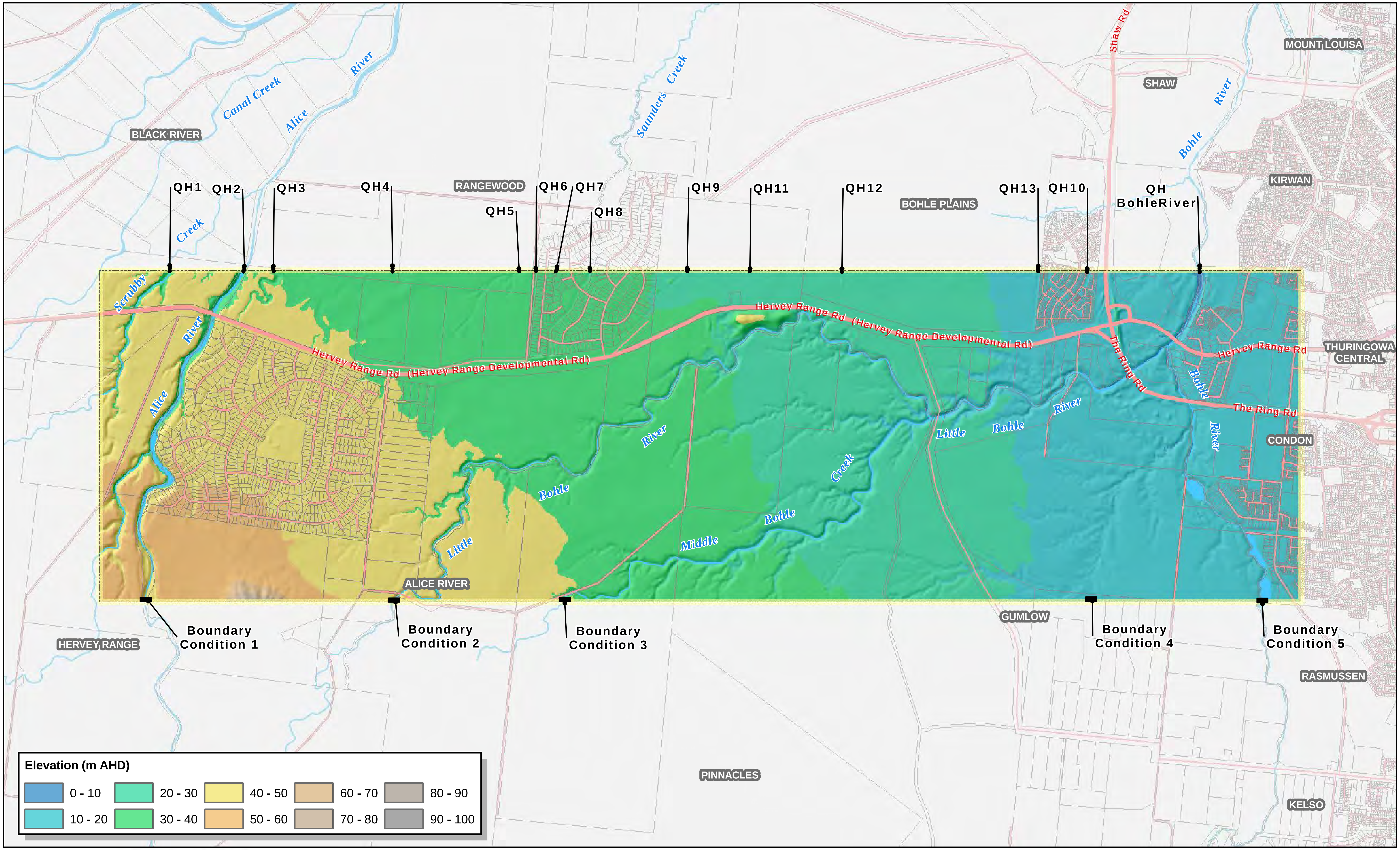
4.2.4 Roughness

The specific roughness values adopted for the MIKE 21 model are as shown in Table 4.1. The roughness distribution was determined using ortho-imagery sourced from Google Earth and observations during site inspections.

Figure 14 shows the distribution of roughness across the model grid.

Table 24 Hydraulic Roughness Values

Land Use	Manning's n Value
Bush Land	0.07
River Channel	0.03
Riparian Zone	0.08
Roads/Rail	0.025
Urban Areas	0.06
Open Space	0.05
Dense Forest	0.1



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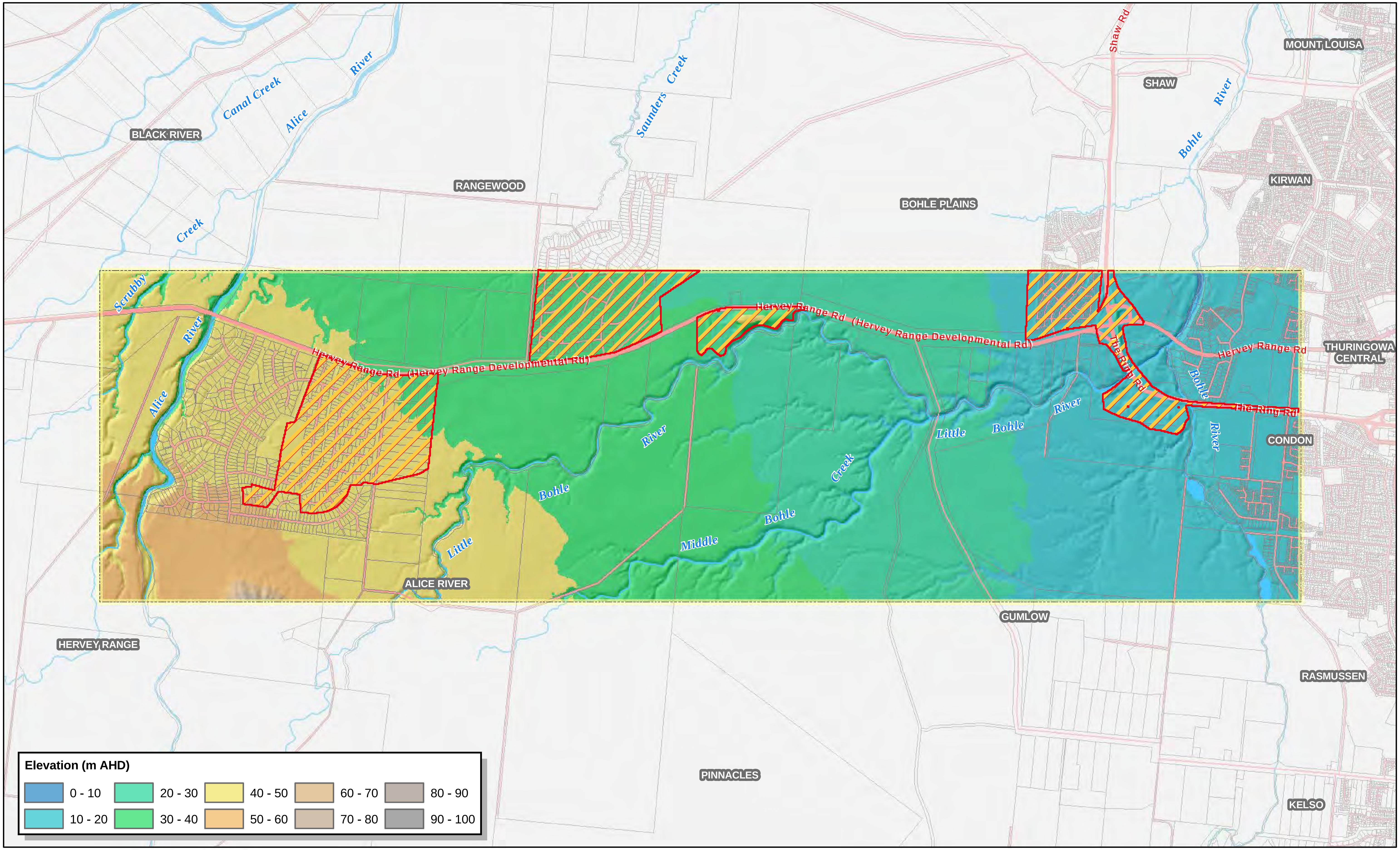
Legend

QH Locations	Property Boundary
Minor Road	Hydraulic Model Extent
Main Road	Boundary Conditions
Watercourse	

LITTLE BOHLE FLOOD MODEL
MIKEFLOOD Model Setup

Figure 12



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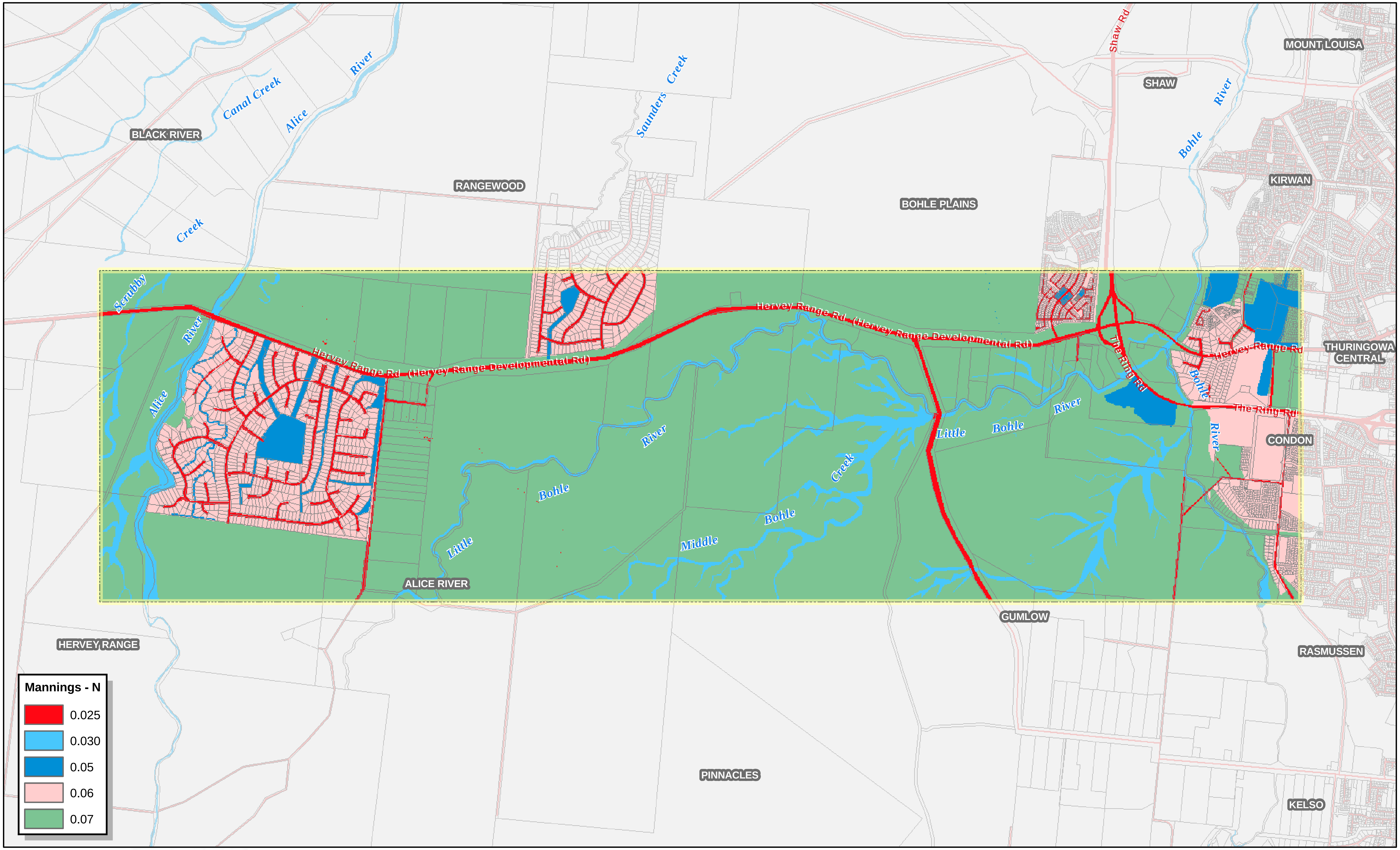
Legend

- OH Locations
- Minor Road
- Main Road
- Watercourse
- Changed Areas
- Property Boundary
- Hydraulic Model Extent
- Boundary Conditions

LITTLE BOHLE FLOOD MODEL
Topography changes from existing to pre-existing

Figure 13



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(when printed at A3)

0 500 1,000 2,000 Metres

Legend

- Minor Road
- Main Road
- Watercourse
- Property Boundary
- Hydraulic Model Extent

LITTLE BOHLE FLOOD MODEL
MIKEFLOOD Roughness map

Figure 14

4.2.5 Boundary Conditions

The various boundary conditions applied to the MIKE 21 model are shown in **Figure 12**. A number of inflow boundaries were included in the model to simulate the flow entering the model domain. These are labelled *Boundary Condition 1 – 5* in **Figure 12**. The main inflow boundaries are the Bohle River in the southeast of the model (*Boundary Condition 1*) and Alice River (*Boundary Condition* 1) in the southwest. The remainder of the inflows represent runoff from the various subcatchments identified during the hydrologic modelling.

Numerous stage-discharge boundaries were specified along the northern boundary of the model to simulate the flow northward out of the model domain. These boundaries were specified at watercourses and low points along the northern boundary where flow is concentrated. The stage discharge relationships were determined using cross sections from the LiDAR data and Mannings equation with assumptions of slope and normal depth based on the topographic data available.

Bohle River Inflow Boundary Conditions

The inflow hydrographs at the Bohle River boundary were extracted from the *BPFPS* model results for the events that had been modelled as part of the *BPFPS*, these events are shown in **Table 25.**

Table 25 - Events modelled for the *BPFPS*

Event	Durations modelled (hr)
2 year	1, 2, 3
5 year	1, 2, 3
50 year	(1), (3), 4.5, 6, 9, (12), 18, (24)
100 year	6, (12)

The *BPFPS* model results for the events shown in brackets were used to extract inflow hydrographs to apply directly as inflow boundary conditions for the Little Bohle River model.
There were a number of events for which Bohle River model results did not exist. To determine the inflows for these events, a scaling factor was determined based on the *BPFPS* model results that were available and the peak flows from the Little Bohle River XP-RAFTS model at the confluence with the Bohle River. This scaling factor was the applied to the 50 year hydrograph of relevant duration, extracted from the *BPFPS* model results.

To determine this scaling parameter, a factor was calculated based on the ratio of event peak flows to 50 year peak flows for each duration. A factor was also determined based on the ratio of 50 year peak flows from the Little Bohle XP-RAFTS model and the scaling factor was chosen as the maximum of these for each event to ensure a conservative estimate of inflows.

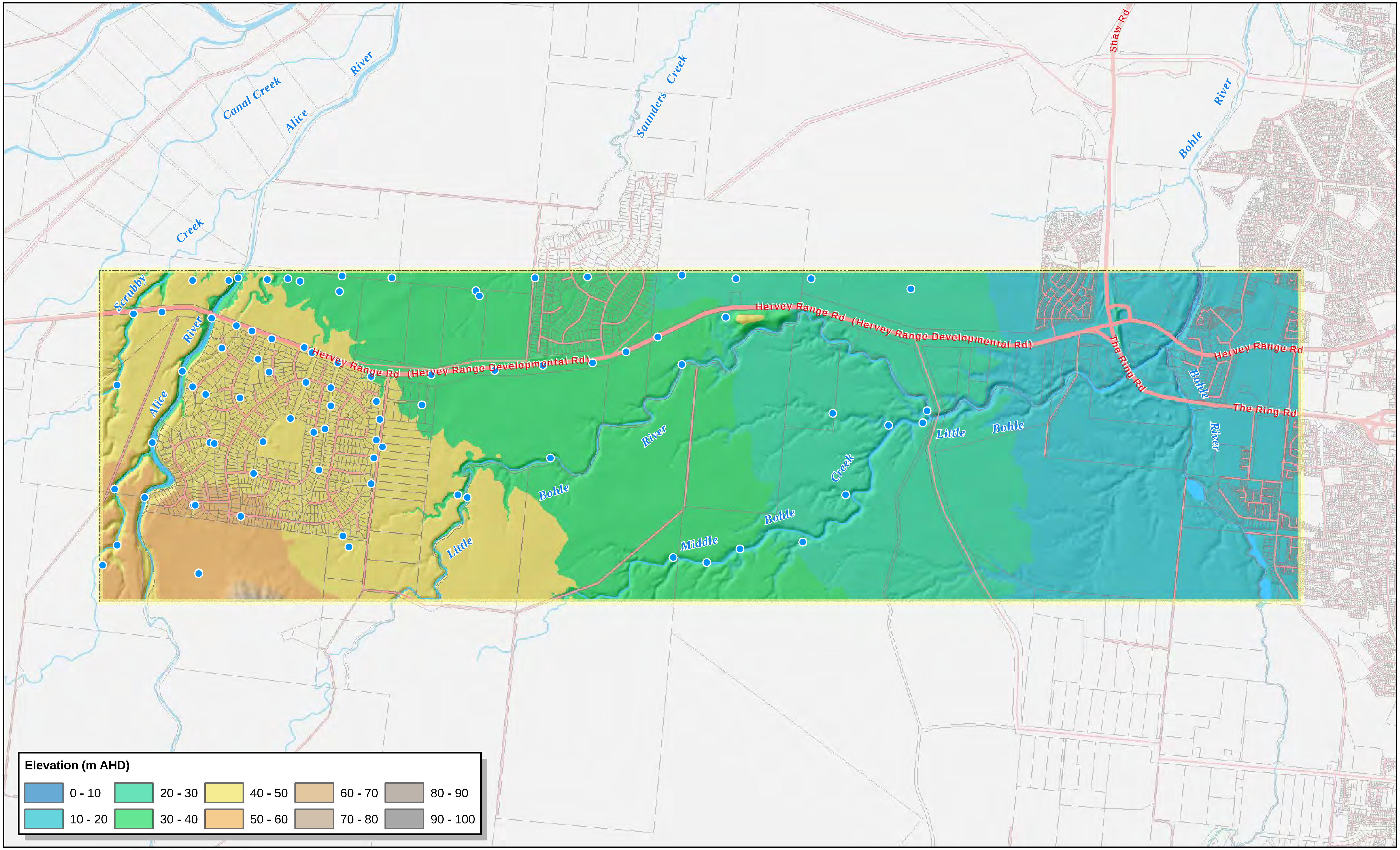
A summary of boundary inflow calculations is detailed in for each event modelled in **Table 26**.

Table 26 Calculation summary for inflow boundaries

Event	Source	Scale Factor – BPFPS Results		Scale Factor – XP-RAFTS Results	Selected Scale Factor
		Scale Factor 1 (Duration)	Scale Factor 2 (Duration)		
2yr 24 hr	Scaled hydrograph	0.37 (1hr)	0.44 (3hr)	0.35	0.44
5yr 24 hr	Scaled hydrograph	0.52 (1hr)	0.64 (3hr)	0.64	0.64
10yr 24hr	Scaled hydrograph	-	-	0.7	0.7
20yr 24 hr	Scaled hydrograph	-	-	0.88	0.88
50yr 1hr	Extracted from BPFPS	-	-	-	-
50yr 3hr	Extracted from BPFPS	-	-	-	-
50yr 12hr	Extracted from BPFPS	-	-	-	-
50yr 24hr	Extracted from BPFPS	-	-	-	-
100yr 1hr	Scaled hydrograph	1.14 (12hr)	-	1.16	1.16
100yr 3hr	Scaled hydrograph	1.14 (12hr)	-	1.16	1.16
100yr 12hr	Extracted from BPFPS	-	-	-	-
100yr 24hr	Scaled hydrograph	1.14 (12hr)	-	1.16	1.16

4.2.6 Inflow Source Points

The local runoff hydrographs for each sub-catchment within the hydrologic model were applied as inflow source points to the hydraulic model. Approximately 85 inflows were applied throughout the model domain. The location of these points is shown in **Figure 15**.



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Legend

- Inflow Points
- Watercourse
- Minor Road
- Property Boundary
- Main Road
- Hydraulic Model Extent

LITTLE BOHLE FLOOD MODEL
MIKEFLOOD Inflow Source Points

Figure 15

4.2.7 Hydraulic Structures

Hydraulic structures within the study area were defined in MIKE11 and coupled into the MIKE21 grid. All major bridges and stormwater culverts along Hervey Range Road, the culvert crossing of the Pinnacle Quarry Road and Granitevale Road and a number of the major culvert crossings within Rupertswood have been modelled using this MIKE 11 network. The details of the structures within the model are shown in **Table 27.**

Table 27 Detail of hydraulic structures modelled in MIKE11

Structure	Configuration	Invert level (m AHD)		Length (m)
		US	DS	
RR_Culv1	6 / 3600 x 3000 RCBC	11.6	11.6	40
RR_Culv2	2 / 3600 x 3000 RCBC	12.6	12.6	40
RPCul_2A	1 / 1200 x 300 RCBC	41.616	41.588	10.8
RPCul_A	19 / 450 x 1200 RCBC	41.546	41.509	12
RP_rdB_ch175	1 / 3000 x 3000 RCBC	40.8	40.7	15.9
RP_rdC_ch411	1 / 3000 x 3000 RCBC	42.64	42.5	14.6
RP_rdA_ch25	4 / 1200 x 300 RCBC	41.606	41.538	13.4
Samhorden_Cul_ch195	8 / 1200 x 600 RCBC	46.84	46.765	11
GrantCst_Cul_ch175	7 / 1350 x RCP	46.24	46.16	12.2
RingRd_Cul_ch43	5 / 1200 x 300 RCBC	50.273	50.213	11
GrantCst_Cul_ch350	1 / 1200 x 300 RCBC	49.078	49.053	11
HR_Cul2B_ch6035	1 / 750 x 375 RCBC	22.25	22.16	9.8
HR_Cul2A_ch5535	2 / 1200 x 300 RCBC	20.48	20.36	9.8
HR_Cul4D	2 / 1200 x 450 RCBC	33.65	33.54	10.8
HR_Cul4C	3 / 1200 x 450 RCBC	31.7	31.66	10.8
HR_Cul4F	6 / 1200 x 450 RCBC	34.66	34.6	12
HR_Cul3B	4 / 1200 x 450 RCBC	30.87	30.79	10.8
HR_Cul5E	4 / 1200 x 450 RCBC	35.29	35.26	10.8
HR_Cul5C	7 / 1200 x 450 RCBC	35.25	35.22	12
HR_Cul7C	2 / 1650 x RCP	39.81	39.72	13.4
HR_Cul7B	4 / 1200 x 450 RCBC	41.24	41.15	11
HR_Cul7A	3 / 1200 x 450 RCBC	41.15	41.06	11
HR_Cul6C	5 / 1200 x 900 RCBC	39.93	39.84	11
HR_Cul6B	4 / 1200 x 900 RCBC	40.23	40.14	11
HR_Cul6A	4 / 1200 x 300 RCBC	39.5	39.44	11
PinnacleQuarries_Bohle	2 / 1500 x RCP	14.9	14.7	10
Granitevale rd culv	5 / 1200 x 600 RCBC	39.18	39.15	10
HR_Culv5D	8 / 1200 x 450 RCBC	37.43	37.34	11
Samhorden A	6 / 1200 x 375 RCBC	43.48	43.43	10
Samhorden B	3 / 1200 x 600 RCBC	44.96	44.93	10
Ring Road_ch859	2 / 1200 x 450 RCBC	46.37	46.29	10
Granitevale Rd Sth	1 / 1200 x 300 RCBC	44.2	44.15	8
Alice River	Bridge			
Hervey Range Road – Inbound bridge	Bridge			
Hervey Range Road – Outbound bridge	Bridge			
Ring Road – Bohle River Bridge	Bridge			
Ring Road – Little Bohle River Bridge	Bridge			

Pre-existing model

There were several culverts and bridge that were not included in the pre-existing model as these structures did not exist pre-2004. The culverts and bridges that were excluded from the pre-existing model are:

- Hervey Range Road – Outbound bridge
- Ring Road – Bohle River Bridge
- Ring Road – Little Bohle River Bridge
- Ring Road_Culv1
- Ring Road_Culv2
- Granitevale rd culv
- Samhorden A culvert
- Samhorden B culvert
- RingRd_Cul_ch43

4.3 Model Calibration and Verification

4.3.1 Calibration

A joint calibration using the XP-RAFTS and MIKEFLOOD model was undertaken for the 1997 event as mentioned in **Section 3.2.5**. The calibration was carried out using flood levels recorded at the Little Bohle River and the Hervey Range Road stream gauges. The pre-existing model was used in this calibration which represents the floodplain conditions during this event and specifically, excludes the Ring Road, culverts, detention basins and outbound Hervey Range Road Bridge.

Initial calibration efforts indicated the conveyance within the Little Bohle River channel was limiting the flow in this watercourse which resulted in higher flood levels upstream. To overcome this problem the minimum LiDAR elevation within the 10m grid cells was selected, rather than the average value, to represent the bed elevation for the grid points of the Little Bohle River channel and other drainage channels throughout the model.

The result of the 1997 event calibration is shown in **Figure 16** and **Figure 17** . This figure shows the model is a relatively good match to the timing and magnitude of the recorded peak flood levels for both the Little Bohle and Hervey Range Road gauges.

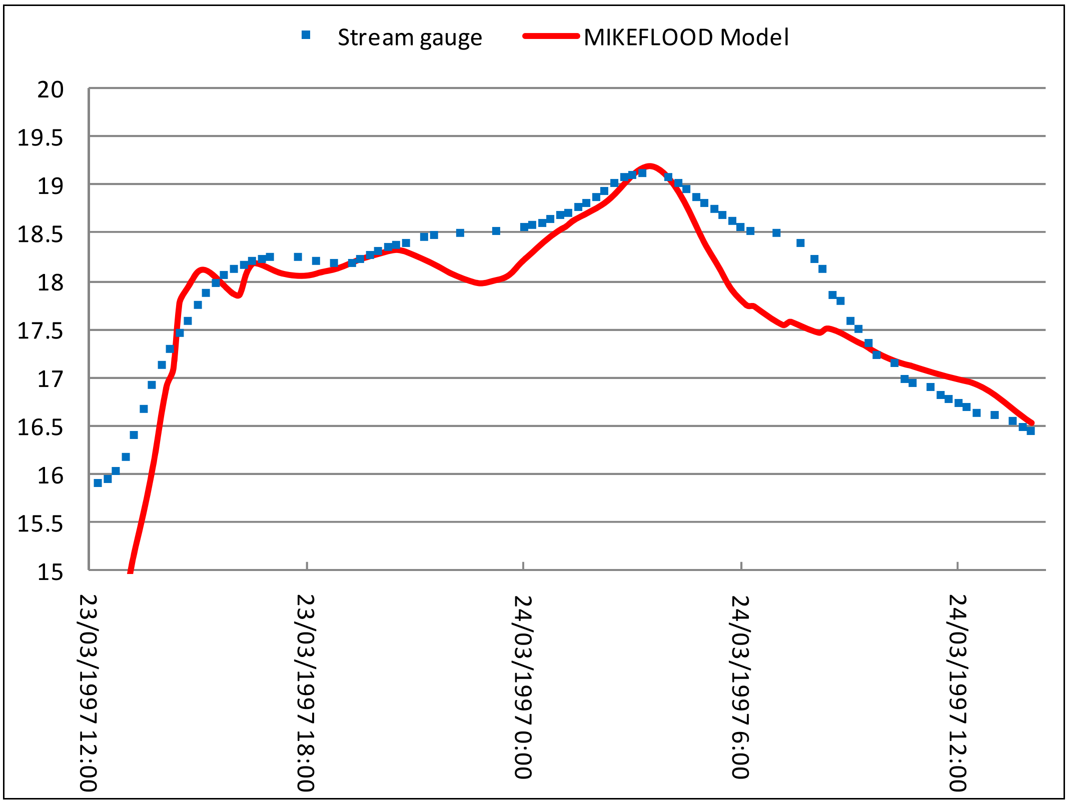


Figure 16 **Calibration results for the 1997 event at the Little Bohle Stream Sauge**

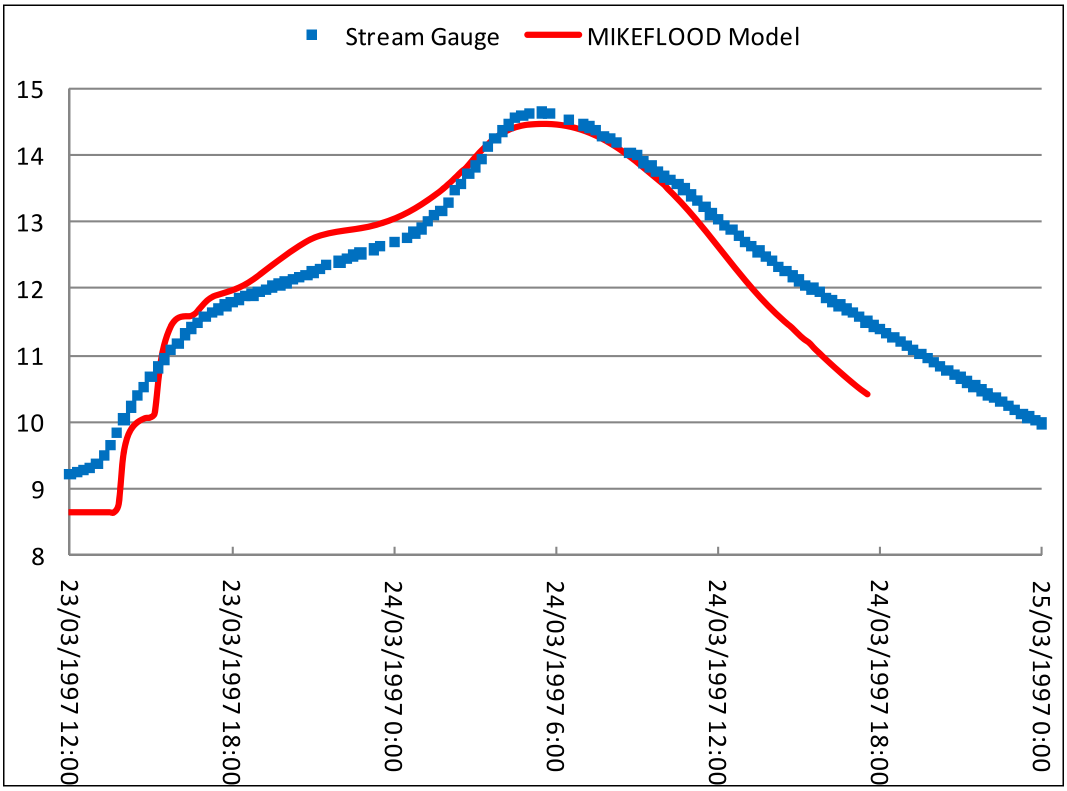


Figure 17 **Calibration results for the 1997 event at the Hervey Range Road Stream Gauge**

4.3.2 Verification

The performance of the XP-RAFTS and MIKEFLOOD models were verified against the stream gauge data recorded during the January 2008 event. The existing model topography including the Ring Road, culverts, detention basins, and the outbound Hervey Range Road Bridge was used for this simulation. Otherwise the model setup and parameters determined during the calibration process remained the same. The results of this verification are shown in **Figure 18** and **Figure 19**. The results show some differences during the drawdown and the increase in the second peak at the Little Bohle River Gauge. The channel roughness was varied to increase the response of the watercourse to improve this match however this worsened the calibration results and the final model parameters is considered the best fit possible. The comparison of flood peaks does show a reasonable match to the timing and magnitude of the peak flood level for both gauges.

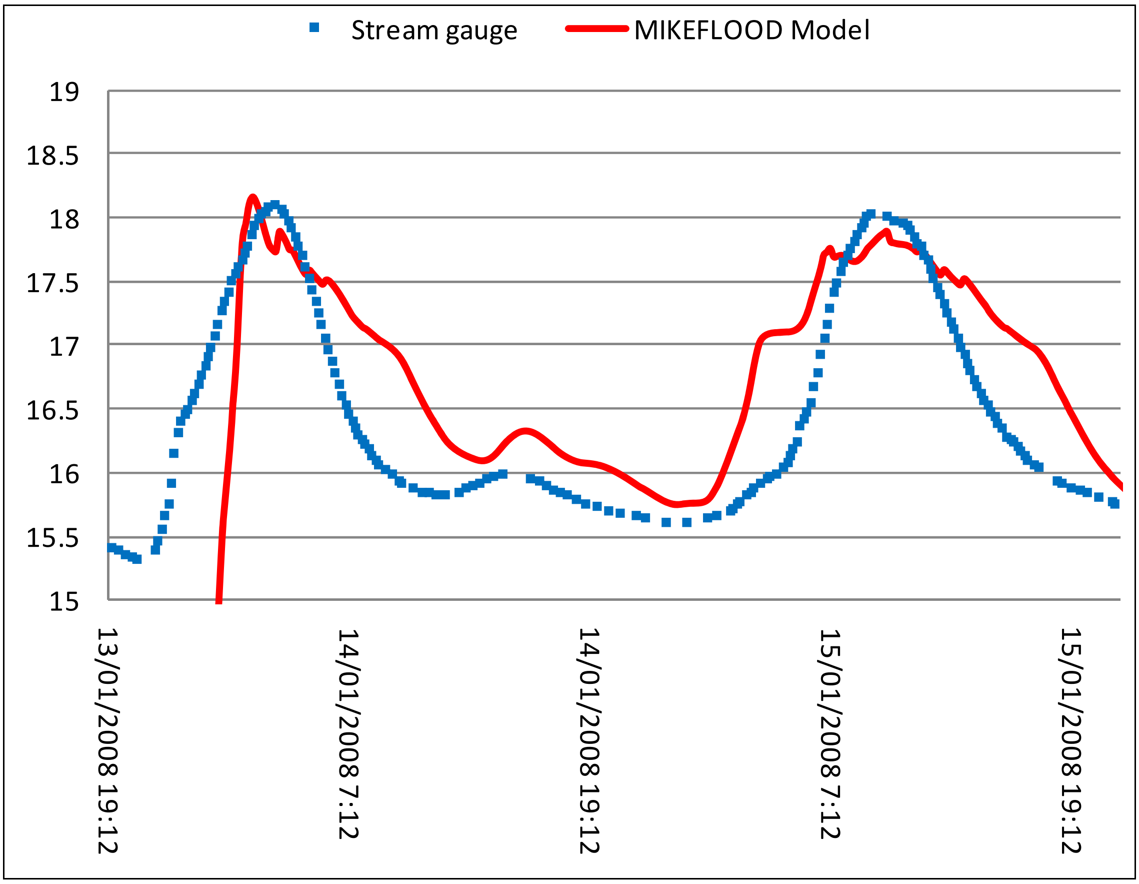


Figure 18 **Verification results for the 2008 event at the Little Bohle Stream gauge**

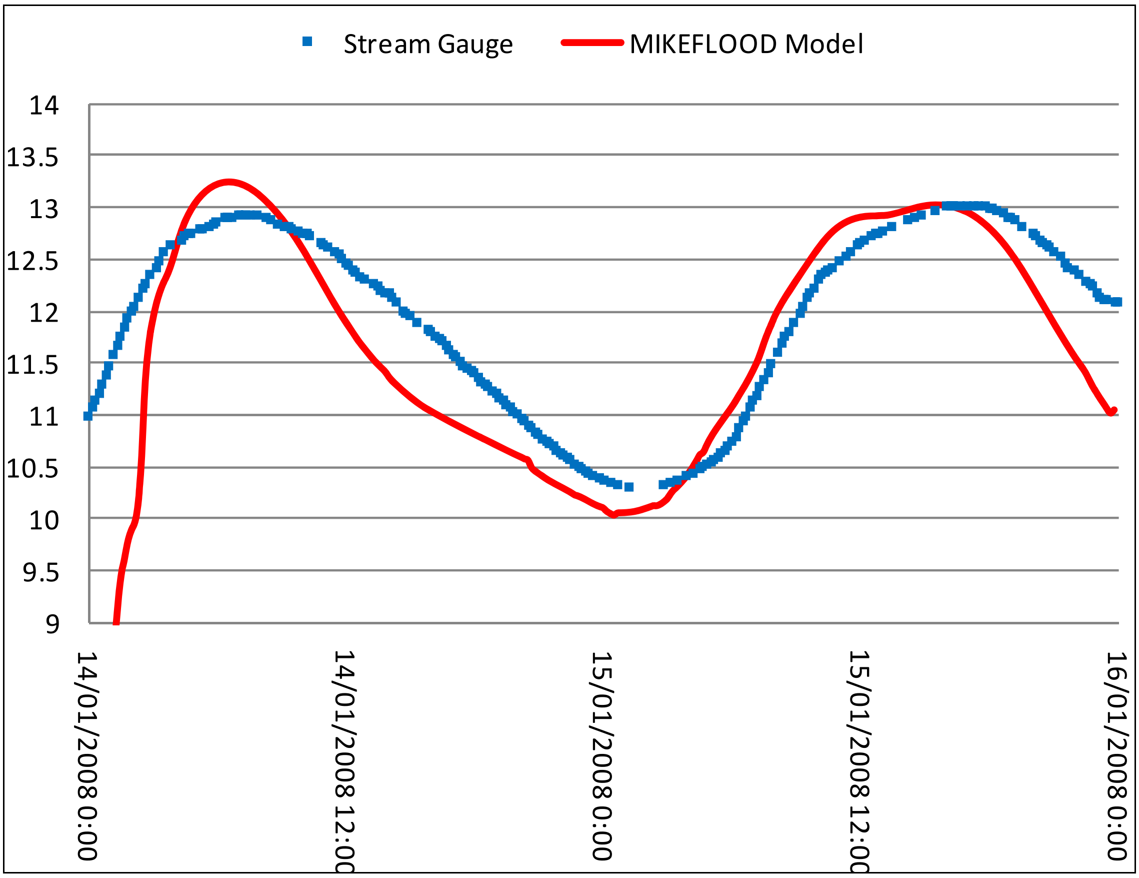
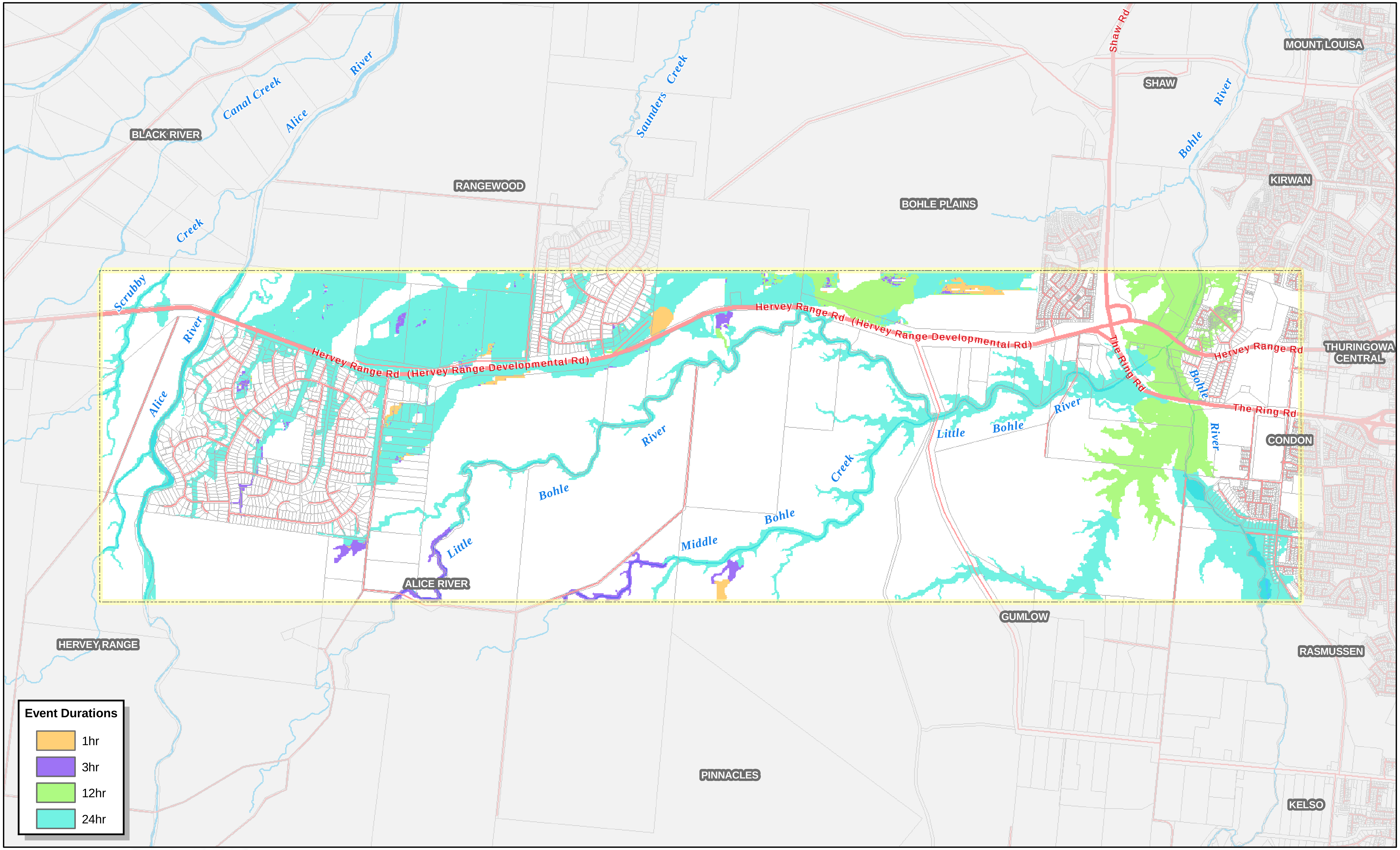


Figure 19 Verification results for the 2008 event at the Hervey Range Road Stream Gauge

4.4 Critical Duration Assessment

The 1, 3, 12 and 24 hour 50 year ARI events were simulated using the existing hydraulic model to determine which storm duration produces maximum flood levels throughout the catchment. The critical duration event had to be modelled for the 2, 5, 10 and 20 year ARI events so this was an important step to identify which event was critical throughout the majority of the model domain.

The results confirm the 24 hour duration event is critical for the majority of the catchment although the 3 hour event does cause higher flood levels at the upper reaches of the watercourses and also some small areas within Rupertswood. This is illustrated by **Figure 20** which shows the critical duration for various areas within the model for the 50 year ARI event.



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Legend

- Minor Road
- Main Road
- Watercourse
- Property Boundary
- Hydraulic Model Extent

LITTLE BOHLE FLOOD MODEL
50 Year ARI Flood Critical Duration

Figure 20

5.0 Base Line Flood Assessment

The existing case MIKE FLOOD model has been used to determine flood levels for the 2, 5, 10, 20, 50 and 100 Year ARI and PMF events. Catchment runoff hydrographs were applied to the MIKE FLOOD model to assess flooding for storms of varying duration.

The MIKE FLOOD model was used to define:

- flood levels;
- water depths;
- flood extents;
- flow velocities; and
- critical duration.

Flood maps showing water depth, flood levels and flow velocities for each design event modelled are shown in **Appendix A**. Long sections of flood levels along the Little Bohle River are shown in **Appendix E.**

5.1 Rupertswood Hydraulic Model Results

The results of the modelling indicate the flood levels and extents within Rupertswood are influenced by drainage features which cannot be accurately represented using the hydraulic model that has been developed for this study. For this reason the flood model results within Rupertswood, including the number of properties affected, should not be relied upon and are considered indicative only.

In order to provide accurate flood level and extent information, it is recommended that the model be refined in this area in the future. Options to refine the model include:

- obtaining survey data for the drainage channels within the Rupertswood area and using this information to represent the drainage channels as one-dimensional elements within the hydraulic model;
- increasing the resolution of the two-dimensional component of the model to ensure all local drainage features can be represented; and
- ensuring all culverts, drains and drainage paths that impact the flows within the development, are represented in the model;

5.2 Flooding impacts

There are rural and rural residential properties located within the study area and this section details the flooding that occurs during the various events that have been modelled. Depths of inundation provide guidance on the potential for overtopping of habitable floor levels.

5.2.1 2 Year ARI Storm Event

The 2 year ARI model results for the critical duration 24 hour event are shown in **Appendix A** in **Figure A1**, **Figure A2** and **Figure A3**. These figures show maximum flood level, depth and velocity.

- Floodwaters are generally contained within the Little Bohle River channel;
- Floodwater overtops Hervey Range Road adjacent to the refuse disposal site. Flood depths over the road are generally less than 50mm;
- 7 rural property boundaries are affected along the Little Bohle River upstream of Pinnacle Quarry Road.
- 15 rural properties are affected along the Little Bohle River downstream of Pinnacle Quarry Road;
- 15 properties are affected by overland flow east of Granitevale Road. Flood depths are less than 0.1m;
- 3 rural properties north of Rupertswood are affected by overland flooding with flood depths up to 0.2m. Flood depths up to 2.5m occur within the watercourse on 1 of these properties;
- 1 rural property north of Rupertswood, bordering Alice River is affected by overland flooding with flood depths up to 0.3m. Flood depths up to 1.6m occur within the watercourses on the property;

- 43 properties within Rupertswood are affected by water depths greater than 0.3m. 42 of these properties are intersected by the drain that runs through the western section of the development and the maximum flood depths occur in this watercourse. The remainder are located adjacent to the main drainage channels within the development.

5.2.2 5 Year ARI Storm Event

The 5 year ARI model results for the critical duration 24 hour event are shown in **Appendix A** in **Figure A4**, **Figure A5** and **Figure A6**. These figures show maximum flood level, depth and velocity.

- Flow from the Little Bohle River is generally contained within the channel and this flow does not contribute to the flow over Hervey Range Road;
- Due to runoff from other areas, floodwater does overtop Hervey range Road at a number of locations:
  - Hervey Range Road crossing of the Bohle River with maximum flood depths up to 0.2m;
  - a 600m section of road adjacent to the refuse disposal site. Flood depths reach a maximum of 100mm over a 20m section of road. Flood depths are generally less than 50mm;
  - near the Granitevale Road intersection for approximately 650m with the maximum flood depth of 40mm east of Granitevale Road and 80mm to the west of the intersection; and
  - near the Ridge Road intersection for 150m with a maximum depth of 40mm.
- 7 rural property boundaries are affected along the Little Bohle River upstream of Pinnacle Quarry Road;
- 15 rural properties are affected along the Little Bohle River downstream of Pinnacle Quarry Road;
- 15 properties are affected by overland flow east of Granitevale Road. Flood depths are less than 0.1m;
- 3 rural properties north of Rupertswood are affected by overland flooding with flood depths up to 0.3m. Flood depths up to 2.8m occur within the watercourse on 1 of these properties;
- 1 rural property north of Rupertswood, bordering Alice River is affected by overland flooding with flood depths up to 0.4m. Flood depths up to 1.7m occur within the watercourses on the property;
- 52 properties within Rupertswood are affected by water depths greater than 0.3m. 45 of these properties are intersected by the drain that runs through the western section of the development and the maximum flood depths generally occur in this watercourse. The remainder are located adjacent to the main drainage channels within the development.

5.2.3 10 Year ARI Storm Event

The 10 year ARI model results for the critical duration 24 hour event are shown in **Appendix A** in **Figure A7**, **Figure A8** and **Figure A9**. These figures show maximum flood level, depth and velocity.

- Flow from the Little Bohle River is generally contained within the channel and this flow does not contribute to the flow over Hervey Range Road;
- Due to runoff from other areas, floodwater does overtop Hervey range Road at a number of locations:
  - Hervey Range Road crossing of the Bohle River with flood depths up to 0.45m;
  - a 600m section of road adjacent to the refuse disposal site. Flood depths reach a maximum of 170mm over a 20m section of road. However the flood depths are generally less than 100mm;
  - near the Granitevale Road intersection for approximately 650m with the maximum flood depth of 40mm east of Granitevale Road and 90mm to the west of the intersection; and
  - near the Ridge Drive intersection for 250m with a maximum depth of 60mm.
  - 800m to the west of the Rupertswood turnoff. 50m of road is inundated with a maximum flood depth of 120mm.
- Flow begins to occur between the Little Bohle and the Bohle River Ring Road detention basins upstream of the Ring Road;
- 7 rural property boundaries are affected along the Little Bohle River upstream of Pinnacle Quarry Road;
- 15 rural properties are affected along the Little Bohle River downstream of Pinnacle Quarry Road;

- 15 properties are affected by overland flow east of Granitevale Road. Flood depths are less than 0.1m;
- 3 rural properties north of Rupertswood are affected by overland flooding with flood depths up to 0.3m. Flood depths up to 2.8m occur within the watercourse on 1 of these properties;
- 1 rural property north of Rupertswood, bordering Alice River is affected by overland flooding with flood depths up to 0.4m. Flood depths up to 1.8m occur within the watercourses on the property;
- 53 properties within Rupertswood are affected by water depths greater than 0.3m. 45 of these properties are intersected by the drain that runs through the western section of the development and the maximum flood depths generally occur in this watercourse. The remainder are located adjacent to the main drainage channels within the development.

5.2.4 20 Year ARI Storm Event

The 20 year ARI model results for the critical duration 24 hour event are shown in **Appendix A** in **Figure A10**, **Figure A11** and **Figure A12**. These figures show maximum flood level, depth and velocity.

- Flow from the Little Bohle River is generally contained within the channel and this flow does not contribute to the flow over Hervey Range Road;
- Due to runoff from other areas, floodwater does overtop Hervey range Road at a number of locations:
    - Hervey Range Road crossing of the Bohle River with flood depths up to 0.8m;
    - a 700m section of road adjacent to the refuse disposal site. Flood depths reach a maximum of 140mm over a 20m section of road. However the flood depths are generally less than 80mm;
    - near the Granitevale Road intersection for approximately 670m with the maximum flood depth of 50mm east of Granitevale Road and 100mm to the west of the intersection; and
    - near the Ridge Drive intersection for 310m with a maximum depth of 90mm.
    - Various sections between the Rupertswood turnoff and Alice River.
- Overflow begins to occur between the Little Bohle and Bohle Rivers along a surcharge path upstream of the Ring Road;
- 7 rural property boundaries are affected along the Little Bohle River upstream of Pinnacle Quarry Road;
- 15 rural properties are affected along the Little Bohle River downstream of Pinnacle Quarry Road. Results indicate existing buildings may be affected on 1 property;
- 15 properties are affected by overland flow east of Granitevale Road with flood depths less than 0.1m;
- 3 rural properties north of Rupertswood are affected by overland flooding with flood depths up to 0.4m. Flood depths up to 2.9m occur within the watercourse on 1 of these properties;
- 1 rural property north of Rupertswood, bordering Alice River is affected by overland flooding with flood depths up to 0.5m. Flood depths up to 1.9m occur within the watercourses on the property;
- 55 properties within Rupertswood are affected by water depths greater than 0.3m. 45 of these properties are intersected by the drain that runs through the western section of the development and the maximum flood depths generally occur in this watercourse. The remainder are located adjacent to the main drainage channels within the development.

5.2.5 50 Year ARI Storm Event

The 50 year ARI model results for the critical 24 hour duration event are shown in **Appendix A** in **Figure A13-A15**. These figures show maximum flood level, depth and velocity for each event.

The maximum flood envelope showing the maximum flood depth for all 50 year ARI duration events is shown in **Figure 21.**

- Flow from the Little Bohle River is generally contained within the channel and this flow does not contribute to the flow over Hervey Range Road;
- Due to runoff from other areas, floodwater does overtop Hervey range Road at a number of locations:
    - Hervey Range Road crossing of the Bohle River with flood depths up to 1.2m;

- a 700m section of road adjacent to the refuse disposal site. Flood depths reach a maximum of 180mm over a 20m section of road. However the flood depths are generally less than 100mm;
- near the Granitevale Road intersection for approximately 670m with the maximum flood depth of 50mm east of Granitevale Road and 120mm to the west of the intersection; and
- near the Ridge Road intersection for 400m with a maximum depth of 100mm.
- various sections between the Rupertswood turnoff and Alice River.

- Significant overflow occurs between the Little Bohle and Bohle Rivers upstream of the Ring Road;
- 7 rural property boundaries are affected along the Little Bohle River upstream of Pinnacle Quarry Road;
- 15 rural properties are affected along the Little Bohle River downstream of Pinnacle Quarry Road. Results indicate existing buildings may be affected on 2 properties;
- 15 properties are affected by overland flow east of Granitevale Road with flood depths up to 0.2m;
- 3 rural properties north of Rupertswood are affected by overland flooding with flood depths up to 0.4m. Flood depths up to 3m occur within the watercourse on 1 of these properties;
- 1 rural property north of Rupertswood, bordering Alice River is affected by overland flooding with flood depths up to 0.6m. Flood depths up to 1.9m occur within the watercourses on the property;
- 59 properties within Rupertswood are affected by water depths greater than 0.3m. 47 of these properties are intersected by the drain that runs through the western section of the development and the maximum flood depths generally occur in this watercourse. The remainder are located adjacent to the main drainage channels within the development.

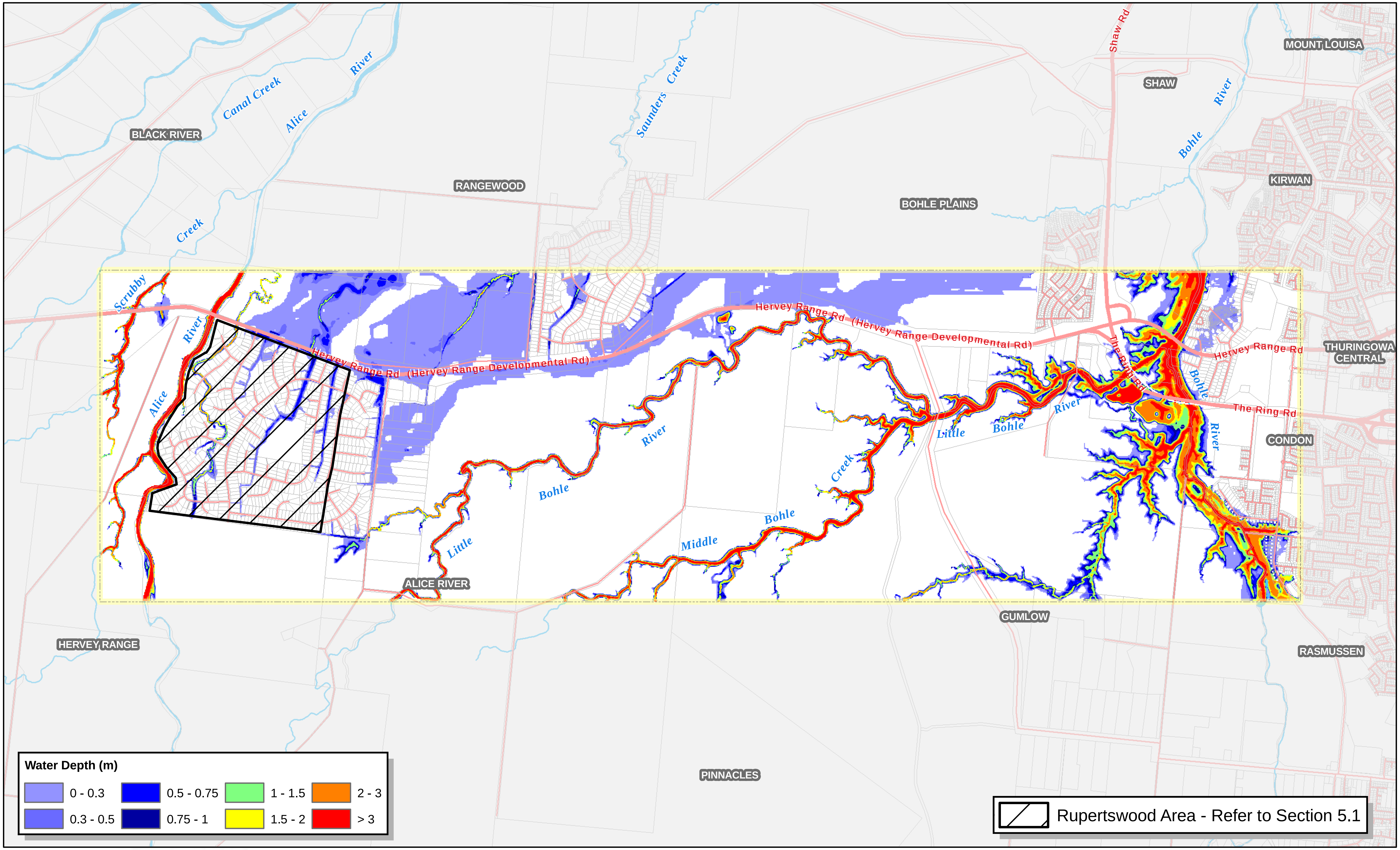
5.2.6 100 Year ARI Storm Event

The 100 year ARI model results for the critical 24 hour duration event are shown in **Appendix A** in **Figure A16-A18**. These figures show maximum flood level, depth and velocity for each event.

The maximum flood envelope showing the maximum flood depth for all 100 year ARI duration events is shown in **Figure 22**.

- Flow from the Little Bohle River is generally contained within the channel and this flow does not contribute to the flow over Hervey Range Road;
- Due to runoff from other areas, floodwater does overtop Hervey range Road at a number of locations:
  - Hervey Range Road crossing of the Bohle River;
  - a 700m section of road adjacent to the refuse disposal site. Flood depths reach a maximum of 200mm over a 20m section of road. However the flood depths are generally less than 110mm;
  - near the Granitevale Road intersection for approximately 670m with the maximum flood depth of50mm east of Granitevale Road and 170mm to the west of the intersection; and
  - near the Rupertswood turn off for a section of road 400m with a maximum depth of 100mm;
  - Various sections between the Rupertswood turnoff and Alice River.
- Significant overflow occurs between the Little Bohle and Bohle Rivers upstream of the Ring Road;
- 7 rural property boundaries are affected along the Little Bohle River upstream of Pinnacle Quarry Road;
- 15 rural properties are affected along the Little Bohle River downstream of Pinnacle Quarry Road. Results indicate existing buildings may be affected on 3 properties;
- 15 properties are affected by overland flow east of Granitevale Road with flood depths up to 0.2m;
- 3 rural properties north of Rupertswood are affected by overland flooding with flood depths up to 0.4m. Flood depths up to 3m occur within the watercourse on 1 of these properties;
- 1 rural property north of Rupertswood, bordering Alice River is affected by overland flooding with flood depths up to 0.6m. Flood depths up to 2.0m occur within the watercourses on the property;

- 63 properties within Rupertswood are affected by water depths greater than 0.3m. 50 of these properties are intersected by the drain that runs through the western section of the development and the maximum flood depths generally occur in this watercourse. The remainder are located adjacent to the main drainage channels within the development.



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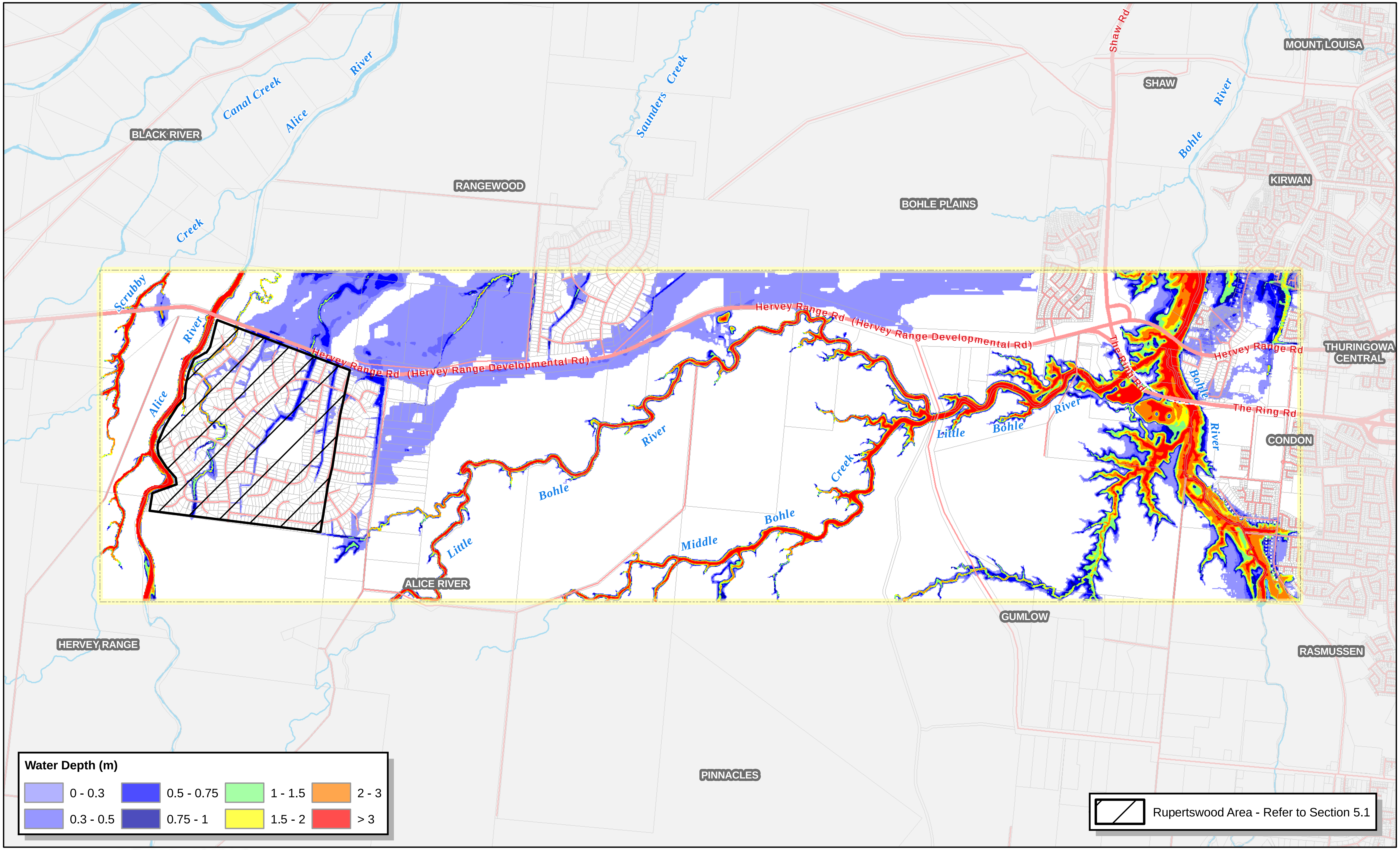
Legend

- Minor Road
- Main Road
- Watercourse
- Property Boundary
- Hydraulic Model Extent

LITTLE BOHLE FLOOD MODEL
50 year ARI Maximmum Flood Envelope

Figure 21



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Legend

- Minor Road
- Main Road
- Watercourse
- Property Boundary
- Hydraulic Model Extent

LITTLE BOHLE FLOOD MODEL
100 year ARI Maximmum Flood Envelope

Figure 22

5.2.7 Flows over Hervey Range Road

The flows over Hervey Range Road and through the culverts, to the north, have been determined in order to provide inputs to future hydraulic models that will be developed as part of the city wide flood constraints project for catchments to the north of the current model extent. The discharge over five sections of the road (including through culverts) has been determined. The sections are identified in **Figure 23** and the discharge through each section is detailed in **Table 28**.

Table 28- Peak Discharge North Through Sections

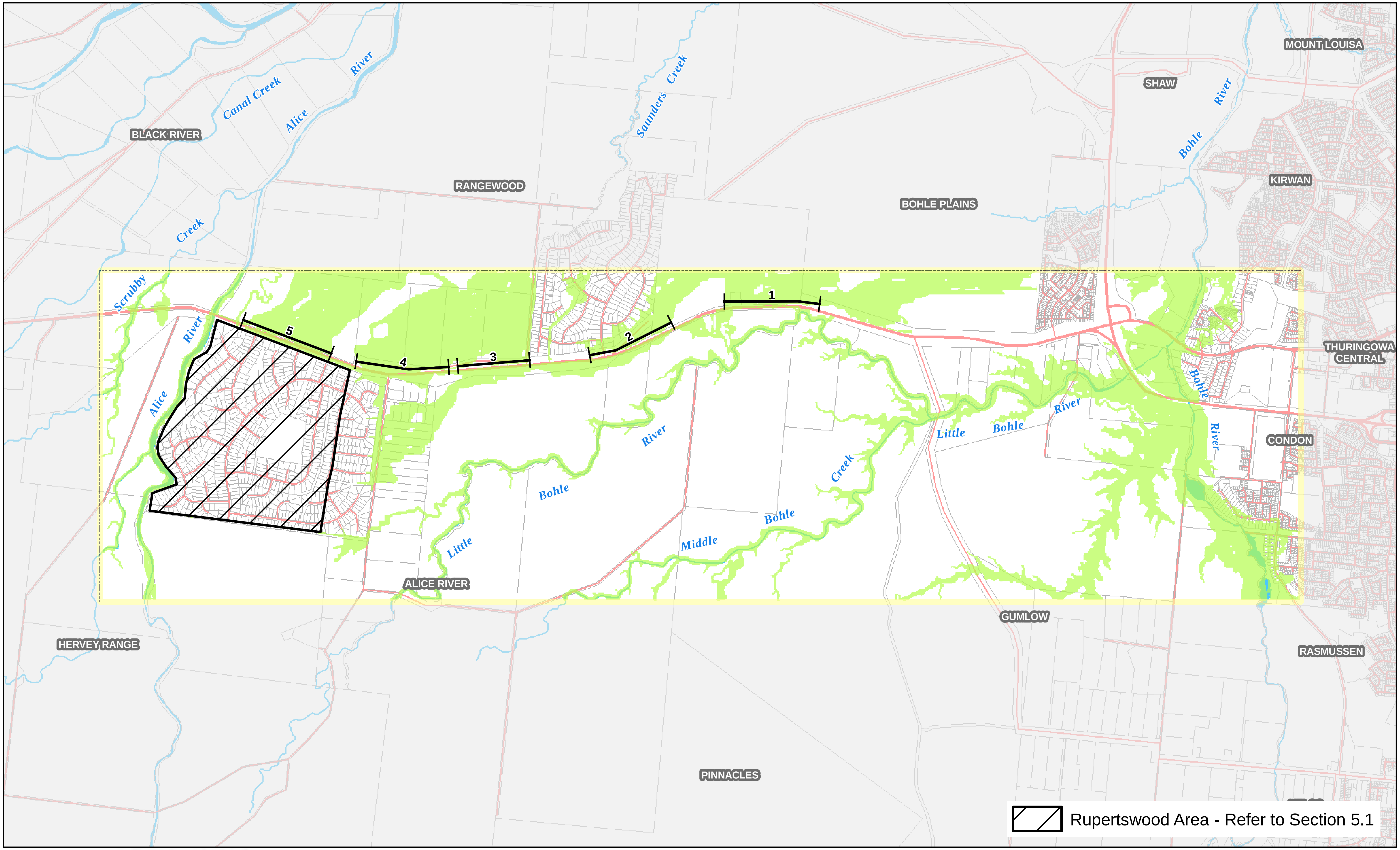
ARI (year)	Section	Peak Discharge (m^3/s)	Overtop Hervey Range Road
2	1	1	Yes
	2	2.5	No
	3	3.5	No
	4	10.5	Yes
	5	16.7	No
5	1	3.8	Yes
	2	4	No
	3	5.5	No
	4	4	Yes
	5	24.9	Yes
10	1	5.2	Yes
	2	4.8	No
	3	6.6	No
	4	22.4	Yes
	5	31.2	Yes
20	1	6.7	Yes
	2	6.2	No
	3	8.2	No
	4	27.7	Yes
	5	39.2	Yes
50	1	7.9	Yes
	2	7.3	No
	3	9.4	No
	4	30.6	Yes
	5	43	Yes
100	1	9.5	Yes
	2	8.5	Yes
	3	11	No
	4	35.8	Yes
	5	49.8	Yes

5.2.8 Probable Maximum Precipitation (PMP) Event

The maximum flood level, depth and velocity for the PMP critical duration 3 hour event is shown in **Appendix A**. **Figures A19**, **A20** and **A21** show the maximum flood level, depth and velocity respectively. The results show:

- The Little Bohle and Middle Bohle floodplains remain separate until just upstream of the junction of the two watercourses;
- the Little Bohle River breaks its banks south of Rangewood and flows north over Hervey Range Road. This flow northward then occurs for the majority of the Little Bohle River downstream to Pinnacle Quarry Road.
- downstream of Pinnacle Quarry Road the Little Bohle River flow does not overtop Hervey Range Road until adjacent to the Ring Road;
- floodwaters from the Middle Bohle overtop the banks and flow overland east to join the Bohle River floodplain;

- overland flow occurs through the lots located to the east of Granitevale Road and this flow continues north east over Hervey Range Road and through Rupertswood;
- significant overland flow also occurs through the properties to the north of Rupertswood; and
- Alice River is generally contained within its banks however floodwater does flow from the drain within Rupertswood into the river, adjacent to Alice Court.



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Legend

- Discharge Sections
- Hydraulic Model Extent
- Property Boundary
- Main Road
- Minor Road
- Watercourse
- Flood Extent

LITTLE BOHLE FLOOD MODEL
Hervey Range Road
Discharge Sections

Figure 23

5.3 Sensitivity Analysis

A sensitivity analysis has been undertaken to determine the sensitivity of the model to various parameters. This analysis used the 24 hour critical duration 50 year ARI event and the parameters analysed include:

- Increasing MIKEFLOOD model roughness by 20%;
- Decreasing MIKEFLOOD model roughness by 20%;
- Adjusting the timing of the Bohle River flood peak to match the flood peak of the Little Bohle; and
- Adjusting the downstream boundary of Alice River

5.3.1 MIKEFLOOD Model Roughness

The results of the sensitivity analysis simulations are shown in **Appendix B. Figure B1** shows the change in flood level due to increasing the model roughness by 20%. The roughness values used to determine the stage discharge boundary conditions remained the same throughout all simulations.

Increasing the model roughness generally increases the flood levels throughout the model with levels generally increasing between 0.1 and 0.25m along the Little Bohle River.

Figure B2 shows the change in flood level when the MIKEFLOOD model roughness is reduced by 20%. The results indicate the flood levels are generally reduced by between 0.5 and 0.1m at the lower reaches of the Little Bohle and between 0.1 and 0.25m further up the Little Bohle.

The model parameters used in this assessment are considered reasonable.

5.3.2 Timing of Flood Peaks

The timing of the flood peaks of the Little Bohle and Bohle River do not occur simultaneously for the 24 hour duration design storm as illustrated in **Figure 24.** This figure shows the timeseries of flood levels for the Bohle and Little Bohle rivers during the 50 year ARI 24 hour event upstream of the junction between the main channels. The solid lines show the Bohle River leads the Little Bohle River flood peak by approximately 1 hour and 45 minutes.

If these flood peaks were to occur simultaneously this will impact the flood levels in both rivers and an analysis was undertaken to determine the impact of the flood peaks coinciding. To carry out this assessment the Bohle River inflow hydrograph timing was adjusted by 1 hour and 45 minutes to ensure these peaks occurred at the same time.

The dotted line in **Figure 24** shows the timeseries of flood levels at the junction of the rivers with the flood peaks coinciding. This figure indicates the maximum flood level within both rivers is increased by 0.28m at this location, when the peaks occur at the same time. **Figure B3** in **Appendix B** shows the change in flood level throughout the model. The results indicate:

- There is an increase in flood levels within the lower reaches of the Bohle River
- The impact decreases with distance upstream and impacts are generally limited to within 1km upstream o the Ring Road.
- The flood levels within the Bohle River are significantly affected and detailed consideration of timing should be undertaken for future Bohle River flood modelling.

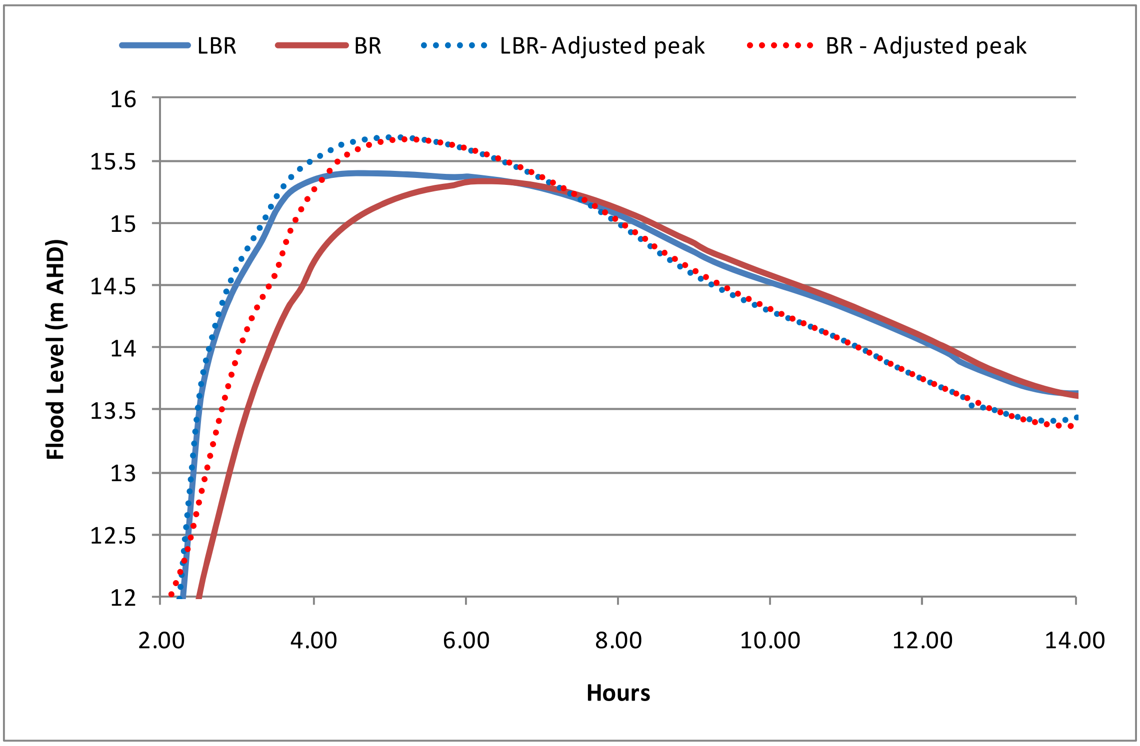


Figure 24 Flood peaks of the Bohle and Little Bohle Rivers

5.3.3 Alice River Tailwater Levels

The downstream boundary of Alice River was specified by a stage discharge relationship which was calculated using the river cross section extracted from the LiDAR data. Mannings equation was then used to determine the discharge for given flood levels. A slope of 2.5% was used to calculate this discharge for the base line runs.

For the sensitivity analysis this slope was decreased to 1% to determine the impact that changing the boundary conditions may have on flood levels. **Figure B4** in **Appendix B** shows the change in flood level due to this change in boundary specification. This figure indicates the flood levels within Alice River are increased downstream of the Alice River bridge however this change in flood level is generally less than 0.05m and does not impact on lots within Rupertswood.

5.4 Future Urbanisation Scenario

The future urbanisation scenario has been developed assuming the catchment to be urbanised in the future with the exception of already developed land, land with a slope above 15% and the Gumlow quadrant. Details of the urbanisation extent are shown in **Figure 11**. The 1, 3, 12 and 24 hour 50 year ARI events were simulated in order to determine the maximum flood envelope.

The maximum flood envelope was determined for the 50 and 100 year ARI events The change in maximum flood level for these two return periods is shown in **Figure 25** and **Figure 26.**

5.4.1 50 year ARI

The 50 year flood levels would be increased in a number of areas if future urbanisation were to occur.

For the Little Bohle River:

- Flood levels would be increased by up to 0.3m at the upper reaches near Rupertswood;
- downstream of Rupertswood the increases in flood levels are generally less than 0.1m until near the confluence with the Middle Bohle;
- downstream from the Middle Bohle Rive confluence flood levels would be increased by up to 0.25m with these increases reducing with distance downstream;

For Alice River:

- Flood levels would be increased by more than 0.5m within Alice River however the River would remain within its banks and overflow into Rupertswood would not significantly increase.

For Rupertswood:

- The flood levels within the drainage channel through the western section of Rupertswood would generally be increased by up to 0.25m with a small section where levels may be increased by up to 0.5m upstream of Grant Crescent.
- Flood levels within the other major drainage channels within Rupertswood would not increase as these catchments are currently fully developed.

5.4.2 100 year ARI

The 100 year flood levels would be increased in a number of areas if future urbanisation were to occur.

For the Little Bohle River:

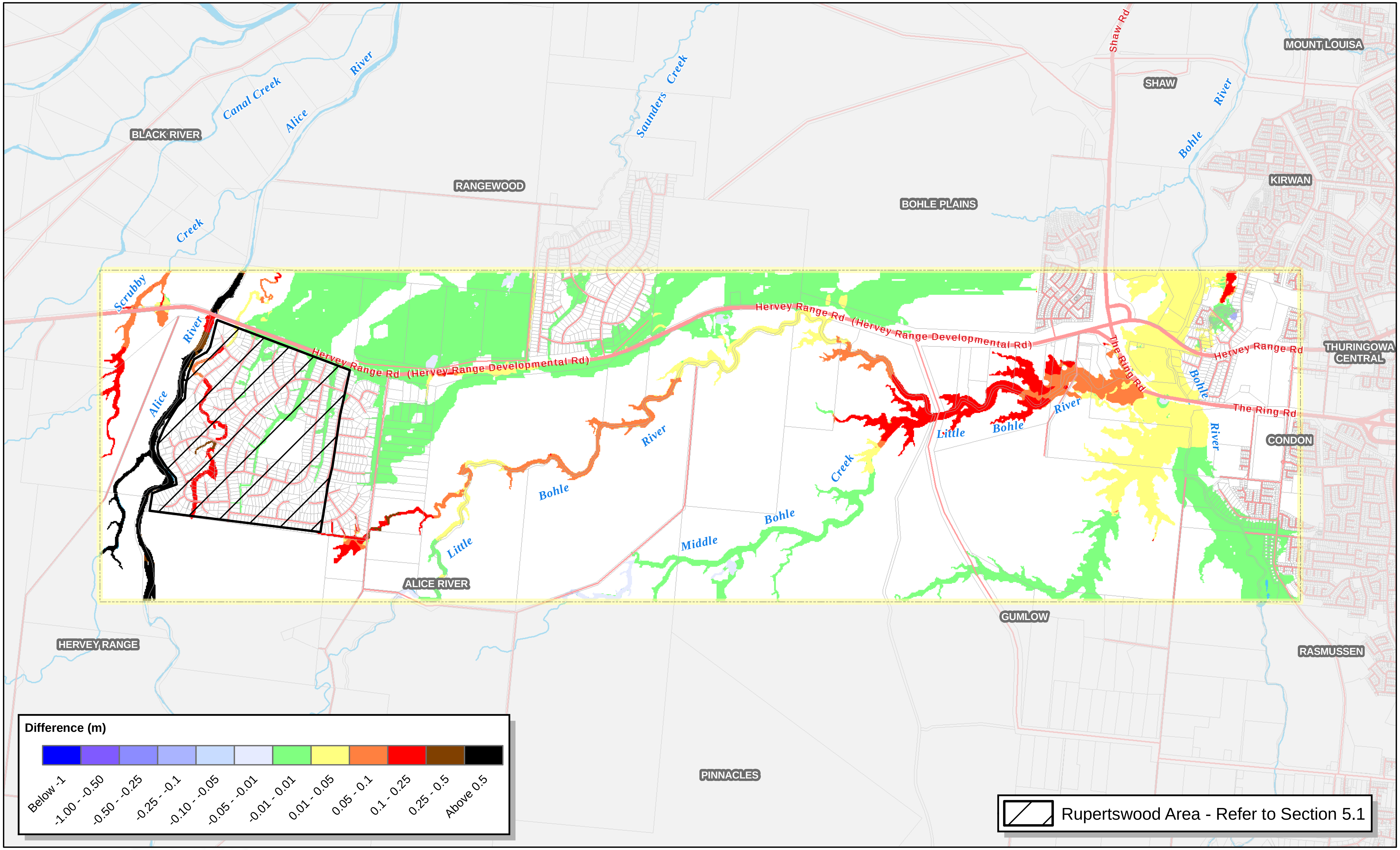
- Flood levels would be increased by up to 0.4m at the upper reaches near Rupertswood;
- downstream of Rupertswood the increases in flood levels are between 0 and 0.1m until near the confluence with the Middle Bohle;
- downstream from the Middle Bohle Rive confluence flood levels would be increased by up to 0.25m with these increases reducing with distance downstream;

For Alice River:

- Flood levels would be increased by more than 0.5m within Alice River however the Rive would remain within it banks and overflow into Rupertswood would not significantly increase.

For Rupertswood:

- The flood levels within the drainage channel through the western section of Rupertswood would generally be increased by up to 0.25m with a small section where levels may be increased by 0.4m.
- Flood levels within the other major drainage channels within Rupertswood would not increase as these catchments are currently fully developed.



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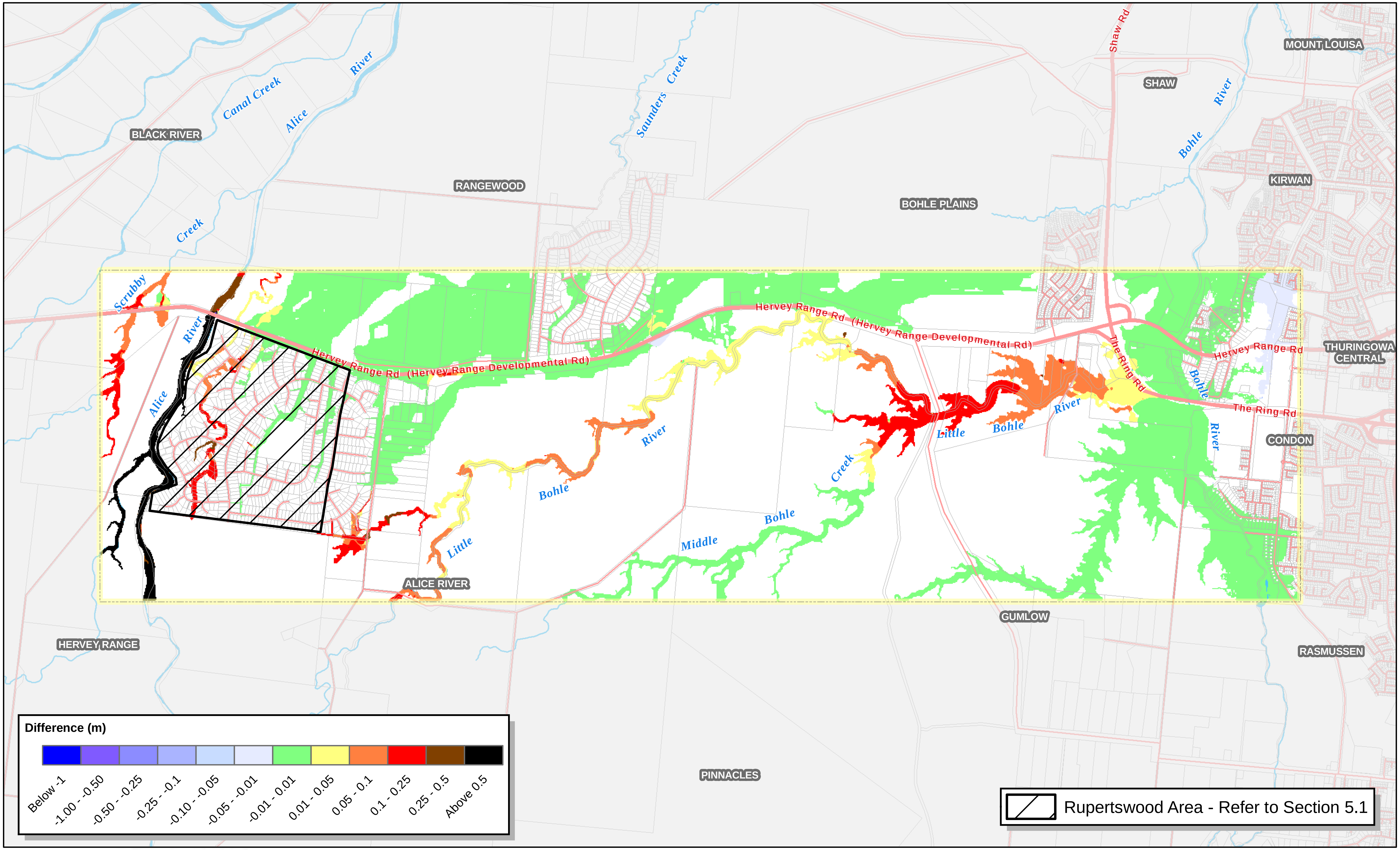
Legend

Minor Road
Main Road
Watercourse
Property Boundary
Hydraulic Model Extent

LITTLE BOHLE FLOOD MODEL
50 year ARI Maximmum Flood Envelope
Impact of Future Catchment Urbanisation

Figure 25



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Legend

- Minor Road
- Main Road
- Watercourse
- Property Boundary
- Hydraulic Model Extent

LITTLE BOHLE FLOOD MODEL
100 year ARI Maximmum Flood Envelope
Impact of Future Catchment Urbanisation

Figure 26

6.0 Granitevale Road Area

Council has requested an assessment of the runoff from the eastern section of Rupertswood including the detention basin that has been constructed in the northeast corner and the Granitevale Road Drain. This forms part of the Saunders Creek catchment that drains this section of the development. Using the MIKEFLOOD model, the aim of this assessment is to quantify the flows through this area for several development scenarios and assess the impact of various drainage configurations on flood levels and flows over Hervey Range and Granitevale Road.

6.1 Overview and Background

The Saunders Creek catchment drains the eastern portion of the Rupertswood Estate. Prior to this area being developed there were no defined creek channels however runoff tended to concentrate at Granitevale Road before flowing eastward over Granitevale Road, while the northern catchment flows tended to concentrate at several locations along Hervey Range Road.

To mitigate the increase in flows due to the Rupertswood development, the Maunsell & McIntyre (MM) reports titled *Rupertswood – Drainage of Eastern Area –Saunders Creek Options (Feb, 19994)* and *Using a Detention Basin Within Rupertswood (May 1994)* recommended a drainage strategy whereby natural flow rates across Hervey Range Road could be maintained by constructing a detention basin within Rupertswood and allowing flows to and across Granitevale Road and Hervey Range Road that were similar to undeveloped flow rates. This report was subsequently adopted by Council.

Following on from this, as the estate moved to detailed design, UDP undertook an assessment *Investigation of the Pre-development and Post-development stormwater flows – Granitevale Road Drain Report (UDP2007)*. This report included detailed design of the Granitevale Road drain and Rupertswood detention basin. This design incorporated a check dam perpendicular to Granitevale Road as per **Drawing HOB007/SK02** to increase water levels within the drain and divert flow over Granitevale Road. The check dam was located at the southern extent of the detention area and is shown in **Appendix D**. The aim of this structure was to ensure the undeveloped flow rates over Granitevale Road were maintained. The elevation of Granitevale Road was not changed.

Subsequently a technical review of the UDP report was undertaken in 2007 by *JWP (Council Reference number S545/25)* which came to a number of conclusions regarding the assessment of the proposed drainage strategy, including the following:

> *The technical analysis of the drainage at the site lacks pertinent detail to demonstrate non-worsening and also the overall representation of the drainage characteristics at the site. A more detailed assessment of the site drainage is therefore warranted especially given the complex nature of the site.*

All previous assessment and design was carried out using empirical methods or steady state one-dimensional models which are insufficient to fully quantify the site drainage effects. The one-dimensional modelling approach can not accurately replicate the flow splits between the various subcatchments and outlet locations and require assumptions which cannot easily be verified using these methods.

Using the hydrologic and hydraulic models developed for this study, assessment of the flow regime during various development stages was undertaken.

As part of a subsequent development of Ken’s Court which runs off Granitevale Road, further changes were made to the drainage in this area:

- The check dam was removed from Granitevale Road drain;
- Granitevale Road has been raised in the previous location of the check dam by up to 320mm; and
- culverts were installed beneath Granitevale Road immediately to the south of the intersection with Hervey Range Road.

Using the models developed for this study, the 50 and 5 year 24 hour critical duration events have been modelled for the following scenarios, to assess these impacts:

- **Pre-existing Undeveloped Scenario -** The pre-existing scenario assumes the eastern portion of Rupertswood is not developed. The topography for this area is based on the 2000 contours.
- **Weir Scenario** - This scenario assumes full development of Rupertswood including the construction of a check dam within Granitevale Road Drain as per UDP’s design drawing **Drawing HOB007/SK02**. The

topography of the site is based on the 2009 LiDAR data which includes the Rupertswood detention basin. The elevation of Granitevale Road remains at the level detailed in the 2000 contours. The culverts that exist immediately south of Hervey Range Road are not included in this scenario; and

- **Existing Scenario** - The developed scenario was based on the changes to the system to accommodate development of Kens Court. This scenario assumes the weir has been removed and Granitevale Road has been raised to the levels detailed in the 2009 contours. Culverts beneath Granitevale Road have been constructed immediately south of the Hervey Range Road intersection. This scenario is based on the 2009 LiDAR which includes the Rupertswood detention basin.

6.2 Pre-existing Undeveloped Scenario

As discussed previously the topography of East Rupertswood in this scenario is based on the 2000 contours provided by TCC and the topography of the area for this scenario is shown in **Figure 27**. The critical duration 50 year 24 hour event has been model which uses the hydrologic inputs determined using the pre-existing XP-RAFTS model detailed in **Section 3.6.** The aim of this scenario was to determine the base line undeveloped flow regime.

Three sub-catchments have been identified which generally correspond to the catchments identified in the previous reports (UDP and MM). The catchment areas are slightly different (see **Section 3.6.2**) however, as the catchments developed for this study were based on more detailed topographic data.

Figure 28 shows the maximum flood depth and velocity vectors for the pre-existing undeveloped case. Discharge hydrographs have been extracted from the hydraulic model to determine the flow from various areas of the undeveloped catchment which are shown in **Figure 28**. The discharges for each section are shown in **Table 29**.