City Wide Flood Constraints Project
Townsville City Council
24-Jun-2014

Black River Flood Study

Base-line Flooding Assessment

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Base-line Flooding Assessment

Client: Townsville City Council

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Executive Summary

AECOM Australia Pty Ltd (AECOM) was engaged by Townsville City Council (TCC) to carry out the *Black River Flood Study* to determine the existing flood characteristics of the Black River catchment as part of the *TCC City Wide Flood Constraints Project*.

The focus area for this study is the Black River catchment, approximately 20 km west of Townsville City. The Saunders Creek and Stony Creek catchments were also included to facilitate the representation of flows between catchments during extreme flood events.

The *Black River Flood Study* builds on a number of previous flood assessments carried out in the area of interest. Coarse scale hydrologic and hydraulic models developed by AECOM have been updated to reflect recent changes within the floodplain and refined to enable the assessment of a wider range of flood events. The models were also re-calibrated to match measured data from historical flood events.

XP-RAFTS hydrological models of the Black River, Saunders Creek and Stony Creek catchments previously developed by AECOM as part of the *Deeragun Flood Study* formed a basis for this study. The Black River hydrologic model was updated and refined to take into account changes in the land use, river conditions and development of land within the catchment. This model was then calibrated to the January 1998 and February 2008 Black River flood events.

A MIKE FLOOD hydraulic model was developed to represent the existing Black River catchment conditions. The model consisted of a 10 m grid MIKE 21 overland flow model dynamically linked to several one-dimensional (MIKE 11) branches representing the major structures throughout the floodplain.

The model topography was developed from a range of datasets for the study area, which included hydrographic survey of the lower reaches of the Black River, as well as the latest available LiDAR topographic survey data (2012).

The Rain-on-Grid method was applied across the majority of the sub-catchments within the hydraulic model extent to represent local runoff at a 10 m grid scale. Upstream river inflows to the hydraulic model were obtained from the XP-RAFTS hydrological models and a Mean High Water Springs tidal elevation was applied downstream where the river discharges into Halifax Bay.

The MIKE FLOOD model was calibrated to measured levels from the Black River at Bruce Highway stream gauge data for the January 1998 flood event. Calibration results show good agreement with the recorded data in terms of both peak flood levels and timing. Model parameters adopted for surface roughness were in line with those used in other studies undertaken as part of the *City Wide Flood Constraints Project* in the area.

From an assessment of the several storm durations modelled for the 100-year Average Recurrence Interval (ARI) flood event, it was concluded that 9 and 24 hour durations are the critical storm durations for the area of interest and these durations were therefore adopted for the assessment of all other ARI flood events.

Two-dimensional mapping of the model outputs included water surface elevations, water depth and flow velocity envelopes for each of the design flood events. These maps are provided in Appendix A.

Table EX-1 provides a summary of the existing flooding constraints for the Black River study area. This table includes indicative rainfalls for the design events to allow a broad comparison with real flood events.

The majority of the flow was found to be contained within the main Black River channel for events up to the 20-year ARI. A relatively minor break out occurs near the Bruce Highway and the North Coast Rail line into the unnamed tributary parallel to the main channel during the 50-year ARI event, with more flow breaking out of the main channel during higher ARI events. During the Probable Maximum Flood (PMF), it was predicted that a significant breakout would occur from the Black River into Low Creek from approximately 1 km downstream of the Alick Creek confluence.

Various residential developments within the Black River, Jensen, Deeragun and Mount Low suburbs are in very close proximity to the Black River and its tributaries. Flood impacts on the actual buildings were not assessed as part of this study. Water velocity was predicted to be generally low across flat residential areas but could be as high as 1.5 m/s in the steeper localities such as Bushland Beach for events up to the 100-year ARI flood event.

In general, local roads within the study area have a low flood immunity with localised ponding and overtopping widely observed. The main roads and highways across the area are, however, predicted to have a much higher level of flood immunity.

It is recommended that opportunities to mitigate flood risk across the affected areas are evaluated as part of an overall floodplain management strategy. For major arterial roads, possible ways to increase the flood immunity should be investigated to ensure a safe escape path for the local residents during significant flood events.

Table EX-1 Flooding Assessment Summary for Black River Flood Study

Event	Indicative Rainfall	Indicative Peak Gauge Height	Description
2-year ARI	55 mm in 1 hour 73 mm in 2 hours 87 mm in 3 hours 103 mm in 4.5 hours 115 mm in 6 hours 136 mm in 9 hours 154 mm in 12 hours 178 mm in 18 hours 198 mm in 24 hours 249 mm in 48 hours 276 mm in 72 hours	10.6 m AHD	- The majority of flows in Black River are within the main channel with localised sections of the Black River experiencing velocities greater than 2 m/s. - Some minor ponding noticed in low lying locations across the study area.
5-year ARI	70 mm in 1 hour 95 mm in 2 hours 113 mm in 3 hours 134 mm in 4.5 hours 151 mm in 6 hours 180 mm in 9 hours 203 mm in 12 hours 239 mm in 18 hours 269 mm in 24 hours 348 mm in 48 hours 393 mm in 72 hours	11.5 m AHD	- The majority of flows in Black River are within the main channel with a large section downstream of the Alice River confluence experiencing velocities greater than 2 m/s. - Some ponding noticed in low lying locations across the study area. - Various rural residential lots across Jensen and Black River affected by flooding.
10-year ARI	80 mm in 1 hour 108 mm in 2 hours 129 mm in 3 hours 153 mm in 4.5 hours 173 mm in 6 hours 206 mm in 9 hours 233 mm in 12 hours 277 mm in 18 hours 312 mm in 24 hours 410 mm in 48 hours 469 mm in 72 hours	12.1 m AHD	- The majority of flows in Black River are within the main channel with most of the section downstream of the Alice River confluence having velocity greater than 2 m/s. - Increase in number of locations affected by ponding across the study area. - Various rural residential lots across Jensen and Black River affected by flooding. - Some urban residential lots across Mount Low and Bushland Beach likely to be affected by flooding albeit to a shallow depth (under 0.3 m)
20-year ARI	92 mm in 1 hour 126 mm in 2 hours 149 mm in 3 hours 178 mm in 4.5 hours 201 mm in 6 hours 239 mm in 9 hours 272 mm in 12 hours 325 mm in 18 hours 369 mm in 24 hours 490 mm in 48 hours 565 mm in 72 hours	13.0 m AHD	- The majority of flows in Black River are within the main channel with most of the section downstream of the Alice River confluence having velocity greater than 2 m/s. - Further flooding across rural residential lots in the Black River and Jensen suburbs. - Increase in the extent of flooding across urban residential lots in the suburbs of Mount Low and Bushland Beach. Flood depth remains relatively shallow (0.3 m).
50-year ARI	108 mm in 1 hour 148 mm in 2 hours 177 mm in 3 hours 211 mm in 4.5 hours 239 mm in 6 hours 285 mm in 9 hours	14.0 m AHD	- The majority of flows in Black River are within the main channel, with a minor break out near the Bruce Highway into the unnamed tributary parallel to the main channel. Most of the Black River main channel experiences velocities

Event	Indicative Rainfall	Indicative Peak Gauge Height	Description
	324 mm in 12 hours 390 mm in 18 hours 445 mm in 24 hours 600 mm in 48 hours 698 mm in 72 hours		greater than 2 m/s. - Further flooding across rural residential lots in the Black River and Jensen suburbs. - Increase in the extent of flooding across urban residential lots in the suburbs of Mount Low and Bushland Beach. Flood depth remains relatively shallow (0.3 m).
100-year ARI	121 mm in 1 hour 166 mm in 2 hours 198 mm in 3 hours 234 mm in 4.5 hours 268 mm in 6 hours 320 mm in 9 hours 364 mm in 12 hours 441 mm in 18 hours 505 mm in 24 hours 687 mm in 48 hours 804 mm in 72 hours	14.6 m AHD	- The majority of flows in Black River are within the main channel, with a break out near the Bruce Highway into the unnamed tributary parallel to the main channel. Most of the Black River main channel experiences velocities greater than 2 m/s. - Extensive flooding across rural residential lots in the Black River and Jensen suburbs. - Significant extent of flooding across urban residential lots in the suburbs of Mount Low and Bushland Beach. Flood depth remains relatively shallow (0.3 m).
500-year ARI	157 mm in 1 hour 216 mm in 2 hours 258 mm in 3 hours 297 mm in 4.5 hours 348 mm in 6 hours 419 mm in 9 hours 480 mm in 12 hours 592 mm in 18 hours 686 mm in 24 hours 955 mm in 48 hours 1138 mm in 72 hours	15.8 m AHD	- The flows are mainly within the Black River main channel with some overflowing into the floodplain. Significant channel break out near the Bruce Highway and the railway line into the unnamed tributary parallel to the main channel. The entire section of Black River main channel experiences velocities greater than 2 m/s. - Extensive flooding across rural residential lots in the Black River and Jensen suburbs with some locations experienced depths of up to 0.5 m. - Significant extent of flooding across urban residential lots in the suburbs of Mount Low and Bushland Beach with localised areas experiencing up to 0.5 m of flooding.
PMF	290 mm in 1 hour 410 mm in 2 hours 501 mm in 3 hours 590 mm in 4.5 hours 648 mm in 6 hours 810 mm in 9 hours 960 mm in 12 hours 1278 mm in 18 hours 1584 mm in 24 hours 2242 mm in 48 hours 2794 mm in 72 hours	18.3 m AHD	- Significant break out from the Black River into the Low Creek and Alick Creek. - Overflow from Stony Creek into the Black River catchment. - Extensive flooding across most of the study area. Water Depths in excess of 0.3 m can be expected across the majority of the flooded areas.

1.0 Introduction

1.1 Overview

AECOM Australia Pty Ltd (AECOM) was engaged by Townsville City Council (TCC) to develop refined base-case hydrologic and hydraulic flood models for the Black River area as part of the *City Wide Flood Constraints Project*.

The *TCC City Wide Flood Constraints Project* seeks to develop flood models to:

- define flood levels for most urban properties
- identify strategies for trunk stormwater and flood mitigation infrastructure for future capital investment
- provide a means of evaluating the impacts of future flood mitigation and development projects
- assess escape routes and flooding along major arterial roads to assist in disaster management processes.

The current study supercedes the previous *Bohle Plains Flood Planning Report, Appendix A Black River Flood Modelling* (AECOM, 2010) and augments overlapping studies undertaken as part of the *TCC City Wide Flood Constraints Project* by providing detailed hydrologic and hydraulic models for the Black River catchment.

1.2 Study Area

The study area is shown in Figure 1-1. For the purposes of this study, the area of interest was identified as all areas within the hydraulic model extent that contribute to the Black River catchment.

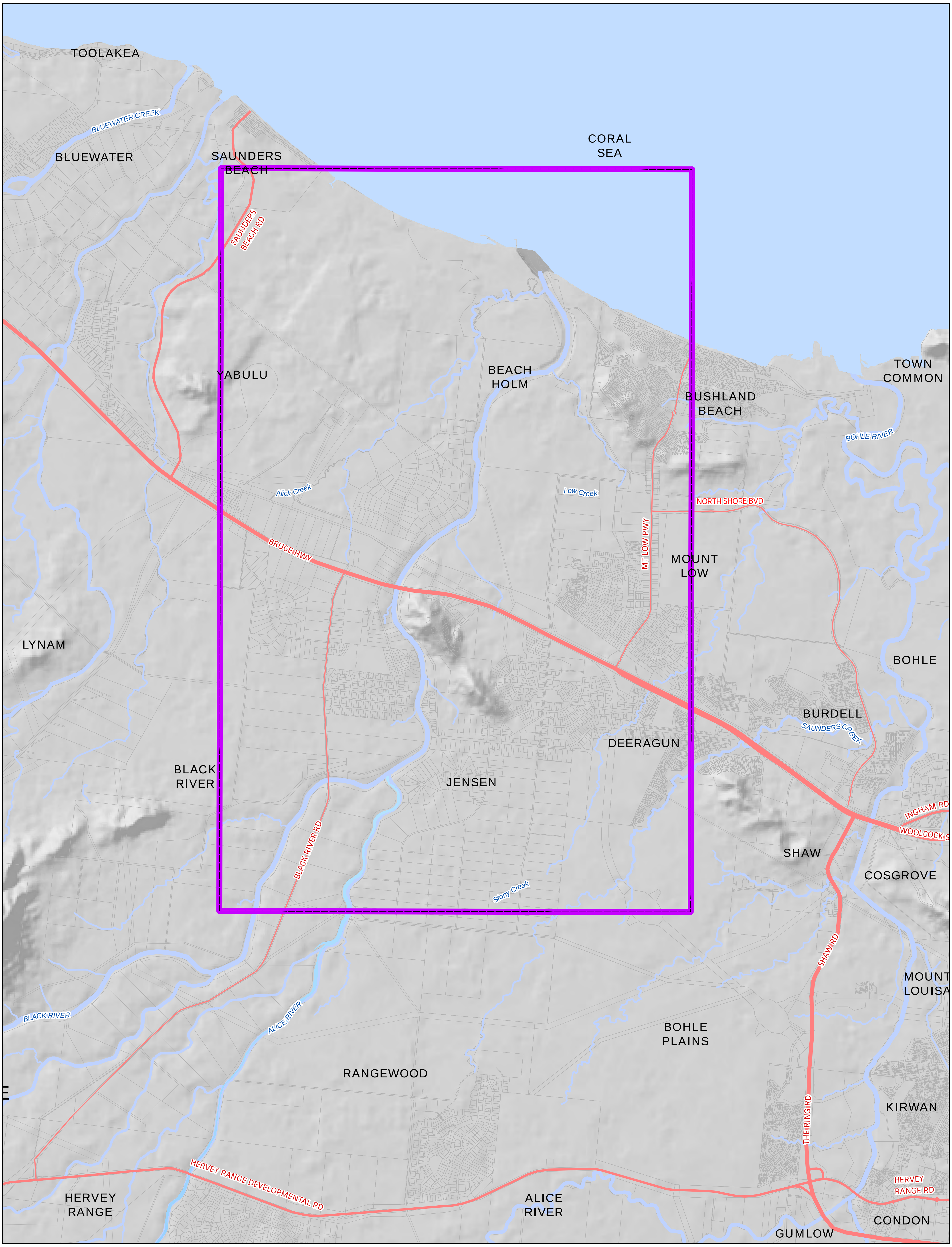
Major watercourses across the study area include the Black River and its tributaries (i.e. Low Creek, Alick Creek and Alice River). Additionally, Saunders Creek and Stony Creek flows were included to represent break out flows affecting the area of interest during extreme events.

Major road links across the study area include the Bruce Highway, Black River Road and Mount Low Parkway. Existing residential developments within the study area include the suburbs of Black River, Jensen, Beach Holm, and Mount Low, as well as portions of Bushland Beach, Yabulu and Deeragun.

1.3 Scope of Works

The scope of works for the *Black River Flood Study* included:

- collate and review of available data including previous models relevant to the study
- assess of the study area to confirm catchment parameters as well as gain an understanding of hydraulic controls and flow pathways
- review, update and calibrate relevant XP-RAFTS hydrologic models where significant changes in land-use have occurred and to account for changes in the new LiDAR
- derive inflow hydrographs for the hydraulic model for the 2, 5, 10, 20, 50, 100, 200, 500 and 2000-year ARI storm events and the Probable Maximum Flood (PMF) event from the hydrologic models. Runoff resulting from the Probable Maximum Precipitation (PMP) storm is referred to as the PMF event
- derive two-dimensional inflow hydrographs to represent localised runoff within the hydraulic model extent for the application of the Rain-on-Grid method
- develop MIKE FLOOD hydraulic models within the study area to determine:
    - base-case flood extents, velocity and depth of flow for the 2, 5, 10, 20, 50, 100, 200, 500 and 2000-year ARI storm events and PMP storm runoff
    - two critical durations and peak flood envelope for the 100-year ARI storm events under the Base-Case scenario (developed from the highest water surface elevation from the 3, 4.5, 6, 9, 12, 18, 24 and 48 h storm durations).



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0 0.5 1 2 km

Coordinate System: WGS 1984 Web Mercator Auxiliary Sphere

Base Data:
DCDB © 2013 (Queensland Govt)
Roads © 2013 (StreetPro Pitney Bowes)

Highways	Property Boundary
Main Roads	Hydraulic Model Extent
Watercourses	

BLACK RIVER FLOOD STUDY

Locality Plan

Figure 1-1

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1.4 Study Approach

This study builds on a number of previous flood studies in the vicinity. Where needed, existing hydrologic and hydraulic models have been updated, refined and re-calibrated in accordance with the *Preparation of Flood Studies and Reports - Guidelines* (2010) developed by TCC, to account for significant changes.

The hydraulic model developed includes the representation of culverts, bridges and pipes with a cross sectional area equivalent or greater than that of a 900 mm diameter pipe. An exception to this rule is made when the combination of smaller culverts at a particular location is deemed to contribute significantly to the overall conveyance within the area. .

Upstream inflow boundary conditions for the hydraulic model were obtained from the XP-RAFTS hydrologic models. Downstream boundary conditions included rating curves derived for major creeks, fixed Mean Water High Springs (MHWS) for the ocean boundary. A combination of XP-RAFTS local source points and Rain-on-Grid net precipitation was adopted to represent runoff.

1.5 Spatial Data

TCC provided the following data for the study:

- topography data in the form of 0.25 m contour intervals based on 2004 LiDAR survey
- topography data in the form of contours and XYZ tiles at 1 metre (m) spacing based on 2009 LiDAR survey
- topography data in the form of contours and XYZ tiles at 1 m spacing based on 2012 LiDAR survey
- hydrographic survey data for the Black River main channel extending approximately 2.4 km upstream from the ocean mouth
- aerial photography flown in 2011 with pixel sizes of 0.125 m (to help identify development that has taken place since the 2009 LiDAR was flown)
- aerial photography flown in 2009 with pixel sizes of 0.125 m
- hydraulic structure information for various bridges and culverts identified within the extents of the model
- stormwater network database within the modelling extents (received on February 2013)
- digital cadastral database containing property boundaries (received in February 2013)
- Althaus Creek MIKE 11 model network files (received in February 2013).

The bathymetry of Halifax Bay outside of the hydrographic survey extent was obtained from the *GBR - Project 3DGBR: High-resolution Topography for the Great Barrier Reef and Coral Sea* by James Cook University (JCU, May 2013).

1.6 Previous Reports

There are a number of previous flood / drainage assessments completed by AECOM and others within and around the study area. A summary of the most relevant previous studies referenced throughout this report is provided below.

- **Black River Geomorphological and Stabilisation Study (Maunsell McIntyre, 2002)**

The Black River Geomorphological and Stabilisation Study assessed the impacts of sand and water extraction on the geomorphology of Black River. The report also provided recommendations for rehabilitating the Black River channel and restricting development adjacent to the banks of the river on the basis of risk from erosion and flooding.

- **Lower Black River Flood Assessment (Maunsell, 2007)**

The Lower Black River Flooding Assessment established baseline flood levels and flows within the Lower Black River for the 50 year ARI flood event. An XP-RAFTS hydrological model was developed for the Black River catchment. These flows were input into a MIKE-FLOOD hydraulic model extending from approximately 2.5 km upstream of the Bruce Highway to the mouth of the Black River.

- **Bohle Plains Flood Planning Report (AECOM, April 2010)**

The *Bohle Plains Flood Planning Report* (*BPFPR*) consolidated all modelling studies completed in the Bohle Plains area since the *Bohle River Floodplain Management Study (2002)*. The assessment included hydrologic and hydraulic modelling of the Bohle River, Saunders Creek, Stony Creek and Black River catchments for the 50-year ARI storm event.

- **Deeragun Flood Study (AECOM, July 2012)**

The *Deeragun Flood Study (DFS)* assessed base case flooding for the Deeragun area based on previously developed and calibrated models as part of the *City Wide Flood Constraints Project*. Hydrology models for the Black River, Bohle River 2, Bohle River 3, Saunders Creek and Stony Creek catchments were updated using TCC's LiDAR topography flown in 2009. A MIKE FLOOD hydraulic model was built based on the LiDAR topography with major culverts and large open channel drains within existing developments included in the model using the 1D MIKE 11 and MIKE URBAN elements. This hydraulic model was verified to the February 2008 storm event. The hydraulic model developed for this study overlaps the area of interest for the Black River Flood Study

- **Althaus Creek Flood Study (TCC, 2013)**

Completed as part of the *City Wide Flood Constraints Project*, the *Althaus Creek Flood Study* assessed the baseline flood levels and flows within the Althaus Creek area. The hydraulic model developed for this study overlaps the area of interest for the Black River Flood Study. The Rain-on-Grid approach was utilised within the hydraulic model extent and XP-RAFTS was used to determine the flows from the catchments upstream of Althaus Creek.

- **Lower Bohle / Stony Creek Flood Study (AECOM, 2014)**

Completed as part of the *City Wide Flood Constraints Project*, the *Lower Bohle / Stony Creek Flood Study* assessed the baseline flood levels and flows within the lower reaches of the Bohle River and Stony Creek area. The hydraulic model developed for this study overlaps the area of interest for the Black River Flood Study. The Rain-on-Grid approach was utilised within the hydraulic model extent and XP-RAFTS was used to determine the flows from the upstream catchments.

2.0 Hydrology Assessment

2.1 Overview

2.1.1 Catchment Description

The Black River catchment rises approximately 540 m above sea level in the Hervey's and Paluma Ranges approximately 28 km from the mouth of the Black River and has a total area of approximately 295 km^2. The river crosses Black River Road, the Bruce Highway and the North Coast Railway before discharging into Halifax Bay approximately 6 km downstream of the highway.

The upper reaches of the catchment are broadly fan-shaped and constitute a significant portion of the total catchment area (Figure 2-1). At its head in the Hervey's and Paluma Ranges the catchment is steep and undeveloped. The lower reaches of the catchment are a more elongated shape and, with the exception of Mount Kulburn, are generally much flatter and comprise of open grassland and bushland with some rural residential development.

The main watercourses of the Black River catchment are the Black River and its tributary the Alice River, as well many smaller named and unnamed creeks and tributaries. Significant creeks in the Lower Black River catchment include Low Creek and Alick Creek (Figure 1-1).

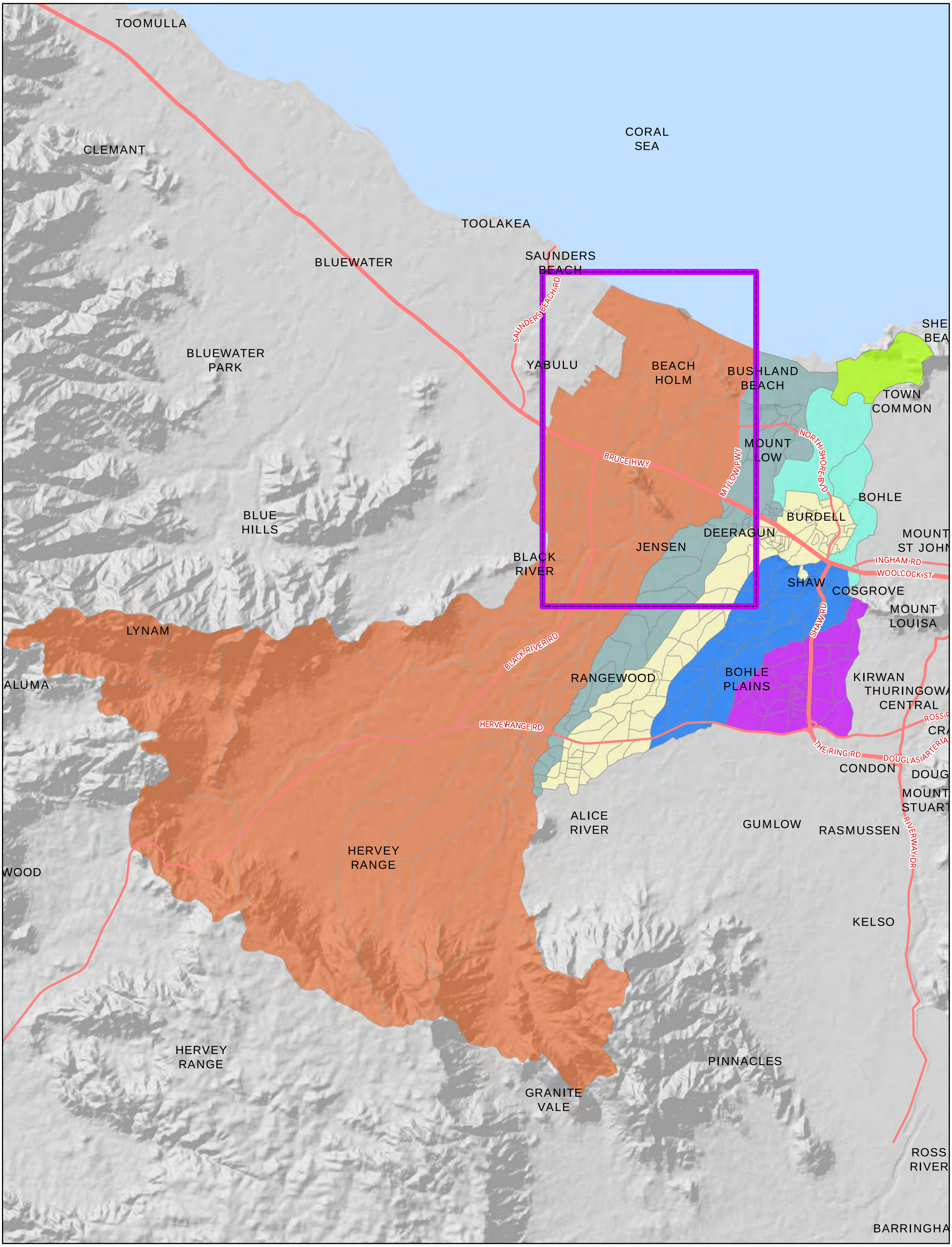
2.1.2 Assessment Approach

Two methods were used to represent rainfall-runoff within the hydraulic model developed for this study. These were:

- the rainfall-runoff hydrological modelling approach (XP-RAFTS) which was generally applied across rural as well as steep sub-catchments; and
- the rain-on-grid method which was used across the more urban and relatively flat catchments.

Standard techniques from the Institute of Engineers, Australia "Australian Rainfall and Runoff" (AR&R) guide were used to determine design rainfall intensities for the storms to be assessed.

The derivation of the design rainfall intensities and the application of the two runoff modelling methods is further described in the subsequent sections of this report.



Hydraulic Model Extent	Bohle River 3 Catchment
Black River Catchment	Bohle River 4 Catchment
Bohle River 1 Catchment	Saunders Creek Catchment
Bohle River 2 Catchment	Stony Creek Catchment

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0 0.75 1.5 3 km

Coordinate System: GDA 1994 MGA Zone 55

Base Data:
DCDB © 2013 (Queensland Govt)
Roads © 2013 (StreetPro Pitney Bowes)

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Location and Extents of Model Catchments
Figure 2-1

2.2 Design Rainfall

2.2.1 Up to 100-year ARI

Intensity Frequency Duration (IFD) input parameters specific for the study area were determined from Volume 2 of the *Australian Rainfall and Runoff* report (AR&R, 1987). The values are summarised in Table 2-1.

Standard techniques from AR&R were used to determine rainfall intensities for the durations assessed and for ARIs up to the 100-year event. The design rainfall intensities developed correlate with those established in the *BPFPR* for the Black River catchment while the same IFD parameters from the *Deeragun Flood Study* were used for Stony Creek and Saunders Creek Catchments.

Table 2-1 IFD Input Parameters

Parameter	Black River	Stony and Saunders Creeks
2 year ARI, 1 hour duration (mm/h)	54.8	55.0
2 year ARI, 12 hour duration (mm/h)	12.8	13.0
2 year ARI, 72 hour duration (mm/h)	3.9	4.0
50 year ARI, 1 hour duration (mm/h)	107.0	105.0
50 year ARI, 12 hour duration (mm/h)	26.7	27.5
50 year ARI, 72 hour duration (mm/h)	9.6	9.5
G	0.05	0.05
F2	3.92	3.93
F50	17.01	17.00
Zone	3	3

2.2.2 Extreme Events (500-year ARI and Probable Maximum Precipitation)

The Generalised Short Duration Method (GSDM) and the Generalised Tropical Storm Method (GTSM) were used to estimate the Probable Maximum Precipitation (PMP) for this study. PMP rainfall calculations were completed with catchments grouped as follows:

- Black River
- Bohle River 1, Bohle River 2 and Bohle River 3 as well as Saunders and Stony Creek

The sub-catchments were grouped to represent major tributaries within the catchment being assessed and to identify the one combination likely to generate the greatest rainfall for the PMP event across the wider catchment. This approach was based on the generally accepted premise that it is highly unlikely that PMP rainfall would fall across more than one of the main tributaries (all sub-catchments grouped) at the same time.

Three different methods can be used to estimate the rainfall intensity for the 500-year event:

- CRC Forge
- extrapolation from ARR
- interpolation between ARR and PMP rainfall depth derived from GSDM and GTSM.

To ensure conservatism, the rainfall intensities adopted for the 500-year ARI event were the highest value from the three different methodologies. This was taken as the interpolation between ARR and PMP rainfall depth derived from GSDM and GTSM. The critical durations adopted were 9 and 24 h. This was based on the 100-year ARI hydraulic modelling critical duration assessment. The rainfall intensity for the 500-year and PMP events assessed in this study are summarised in Table 2-2.

Table 2-2 Extreme Rainfall Events Intensity (mm/h)

Critical Duration (h)	Black River		Combined Bohle River 1, Bohle River 2 and Bohle River 3, Saunders Creek and Stony Creek	
	500-year ARI	PMP	500-year ARI	PMP
1	157	290	154	350
2	108	205	106	245
3	86	167	87	193
4.5	68.5	131	72	152.5
6	58	108	60	127
9	46.6	90	48.5	98
12	40	80	41.6	84
18	32.9	71	33.6	70
24	28.6	66	29	63
36	23.2	54	23.2	52
48	19.9	46.7	19.7	45.3
72	15.8	38.8	15.4	38

2.3 Runoff Routing Method

The XP-RAFTS runoff routing models used for the Black River Flood Study were developed as part of the previously completed *Deeragun Flood Study.* These hydrological models cover the Black River, Saunders Creek and Stony Creek catchments. The location and extent of modelled catchments in relation to the study area is shown in Figure 2-1.

The Black River XP-RAFTS model was updated, refined and re-calibrated to take into account changes in land use, river conditions and new developments.

No changes to the Saunders Creek and Stony Creek XP-RAFTS models were made as the main area of interest was the Black River Catchment. Additionally, both Saunders and Stony Creek XP-RAFTS models were updated recently (2012).

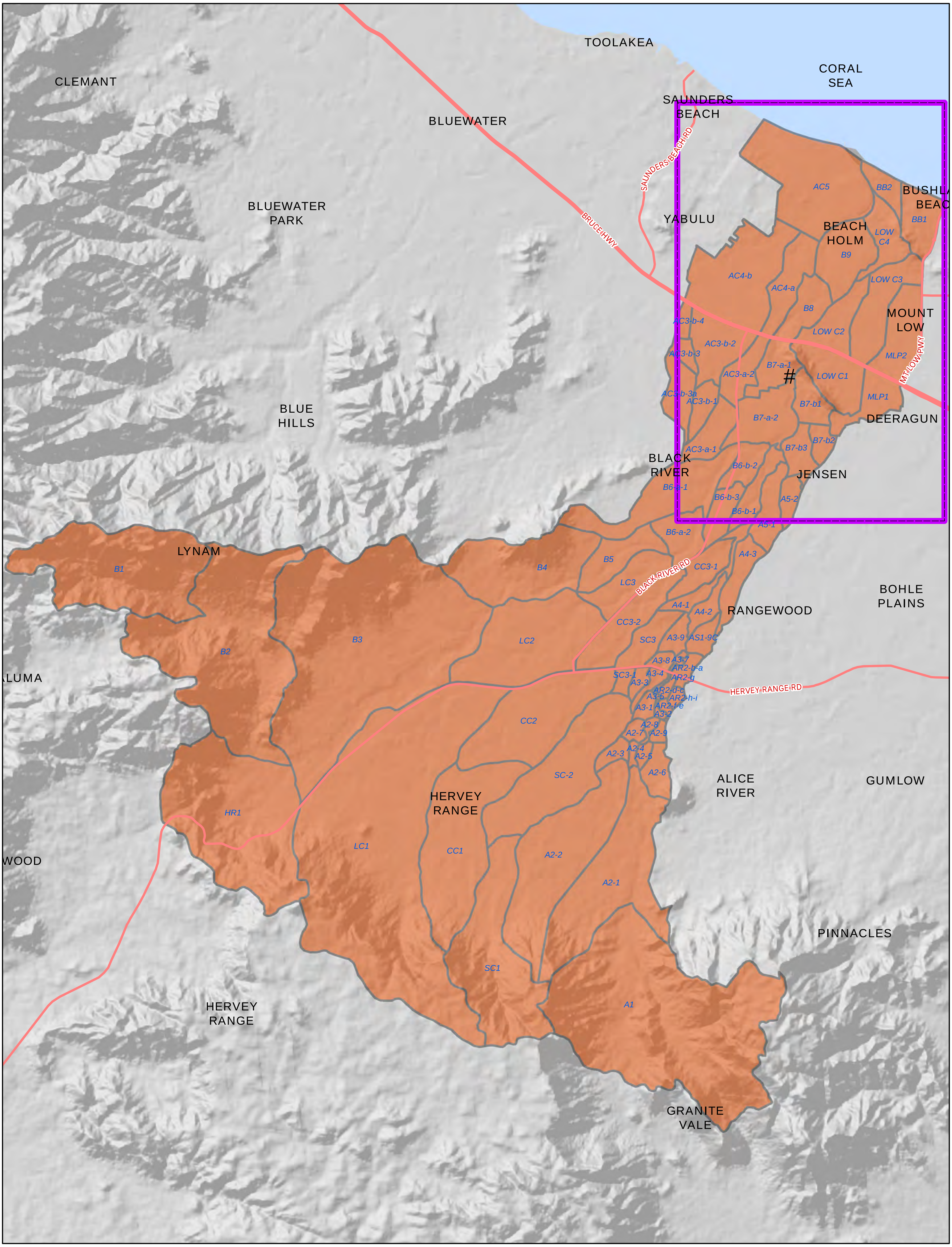
2.3.1 Sub-Catchment Delineation

Catchment delineation as shown in Figure 2-2 was updated based on the following:

- latest topographic data available
- location of the Black River stream gauge
- extent of the hydraulic model to maximise Rain-on-Grid application.

2.3.2 Sub-Catchment Parameters

The XP-RAFTS model was updated to incorporate revised sub-catchment slope, area, roughness and impervious fraction. Additionally, channel routing links properties such as channel slope, geometry and length were reviewed to ensure they were appropriate for the purposes of the study. A summary of the updated sub-catchment parameters is included in Table B1, Appendix B.



#	Black River Stream Gauge
	Hydraulic Model Extent
	Black River Catchment

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0 0.75 1.5 3 km

Coordinate System: GDA 1994 MGA Zone 55

Base Data:
DCDB © 2013 (Queensland Govt)
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Black River Catchment

Figure 2-2

2.4 Hydrologic Model Calibration

The calibration of the XP-RAFTS hydrologic model for Black River was revisited in light of the updates made to the model. The recalibration of the hydrologic model was carried out against the January 1998 storm event.

2.4.1 Flood Frequency Analysis

Flood Frequency Analysis (FFA) was undertaken for the annual peak discharge recorded for the Black River Bruce Highway stream gauge (117002A). The 39 years of peak discharge record length from 1974 to 2012 were reduced to 32 years by excluding low peak discharges (i.e. under 100 m^3/s) to avoid statistical bias towards lower ARI events. The following distribution methods were used to fit the dataset:

- Log Pearson Type III
- Gumbel Extreme Value
- Logarithmic Equation
- Weibull Distribution.

It was found that the Log-Pearson III technique provides the best fit for the higher ARI events. The results for the Log-Pearson III with 95 % confidence level intervals are shown in Figure 2-3. The peak discharge recorded at the Black River Bruce Highway Stream gauge for the January 1998 event was 2236 m^3/s. This was estimated to be around the 100-year ARI according to Figure 2-3.

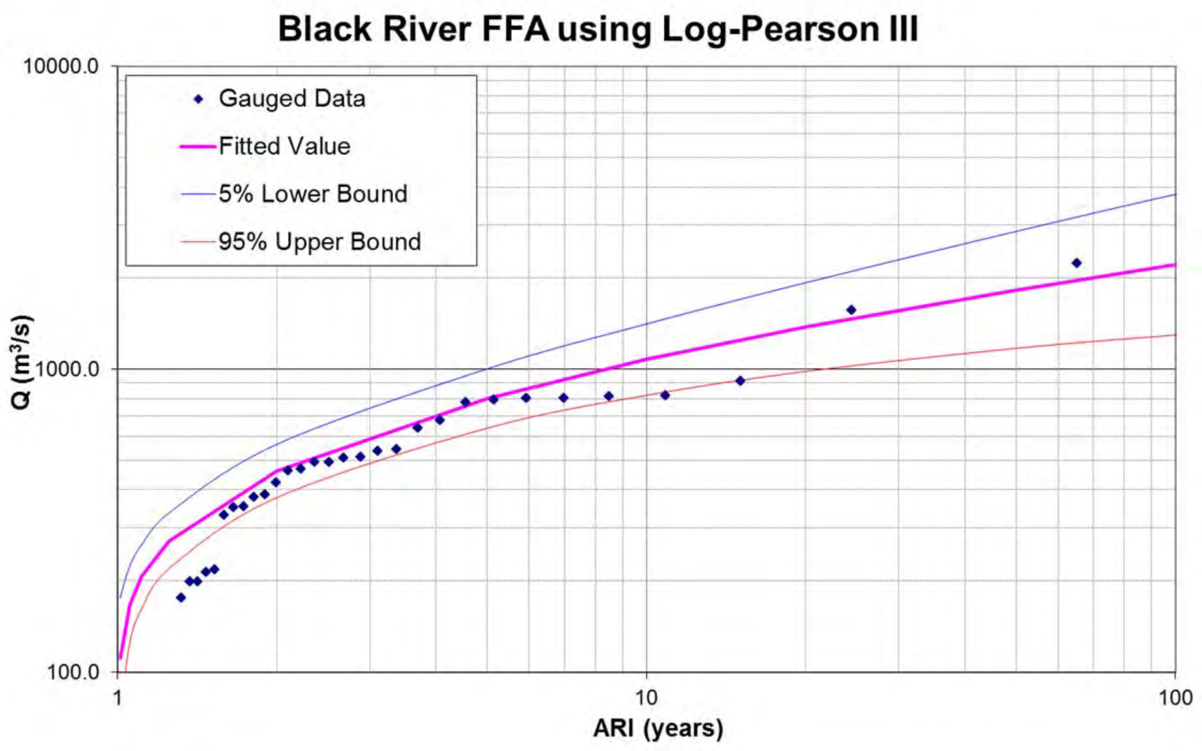


Figure 2-3 Black River FFA using Log-Pearson III

2.4.1.1 Intensity Frequency Duration (IFD) Analysis

A comparison of the following IFD relationships for the January 1998 event is shown in Figure 2-4.

- Yabulu Refinery daily rainfall (032050) and temporal pattern from pluviograph data from the Bluewater gauge (11703A)
- Yabulu daily rainfall (032157) and temporal pattern from pluviograph data from the Bluewater gauge (11703A)
- Pluviograph data from the Bluewater gauge (11703A).

From Figure 2-4, the following conclusions can be reached:

- for any rainfall duration, the January 1998 rainfall event was greater than 5-year ARI
- for the 24 h rainfall duration, the January 1998 rainfall event represented rainfall between 10-year and 100-year ARI, depending on the gauge. This implies that the rainfall intensity was not uniform spatially.

It is important to point out that there were no rainfall gauges installed in the upper reaches of Black River during the 1998 event. This has now been addressed, however, with the installation of the Upper Black River Alert (532045).

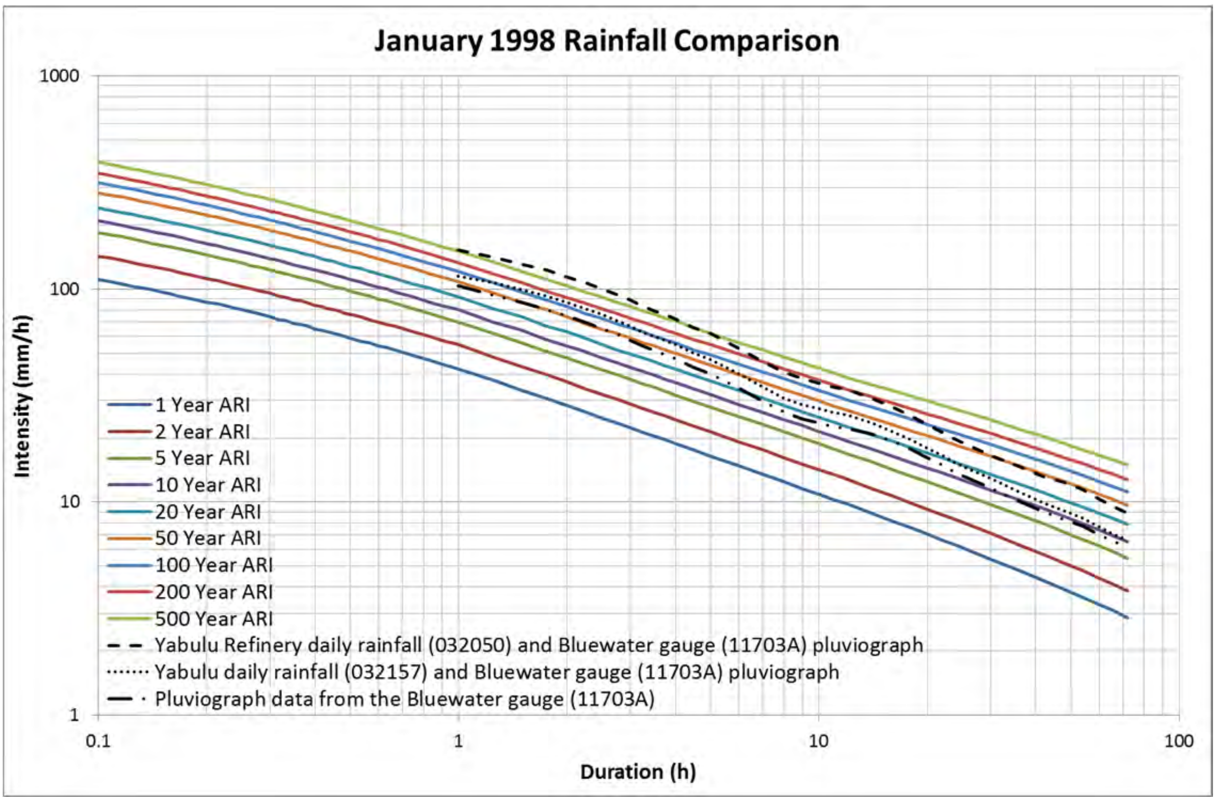


Figure 2-4 January 1998 Rainfall and Black River IFD comparison

2.4.1.2 Re-Calibration

A range of rainfall patterns as described in Section 2.4.1.1 was used to recalibrate the updated XP-RAFTS model. It was found that rainfall pluviograph data from the Bluewater gauge (11703A) applied uniformly across the catchment with a pervious initial loss of 70 mm enabled replication of the flow recorded at the gauging station during the January 1998 event. A continuous loss of 2.5 mm/h, as adopted in the previous Black River model in *BPFPR,* was used. The discharge comparison between the gauge flow and XP-RAFTS, shown in Figure 2-5, indicates a good fit in terms of peak values and shape.

The following initial loss values were used in past studies:

- *BPFPR:* 30 mm for all events
- *Lower Black River Flood Assessment:* 30 mm for events with ARIs of 50-year or higher and 95 mm for events with ARIs lower than 50-year.

The high initial loss values adopted can be justified as follows:

- the initial loss value is within the range of 0-140 mm for Eastern Queensland as recommended by *Australian Rainfall and Runoff* (1998)
- coarse sandy soils present within the lower reaches
- significant vegetation cover at the upper reaches of the Black River catchment.

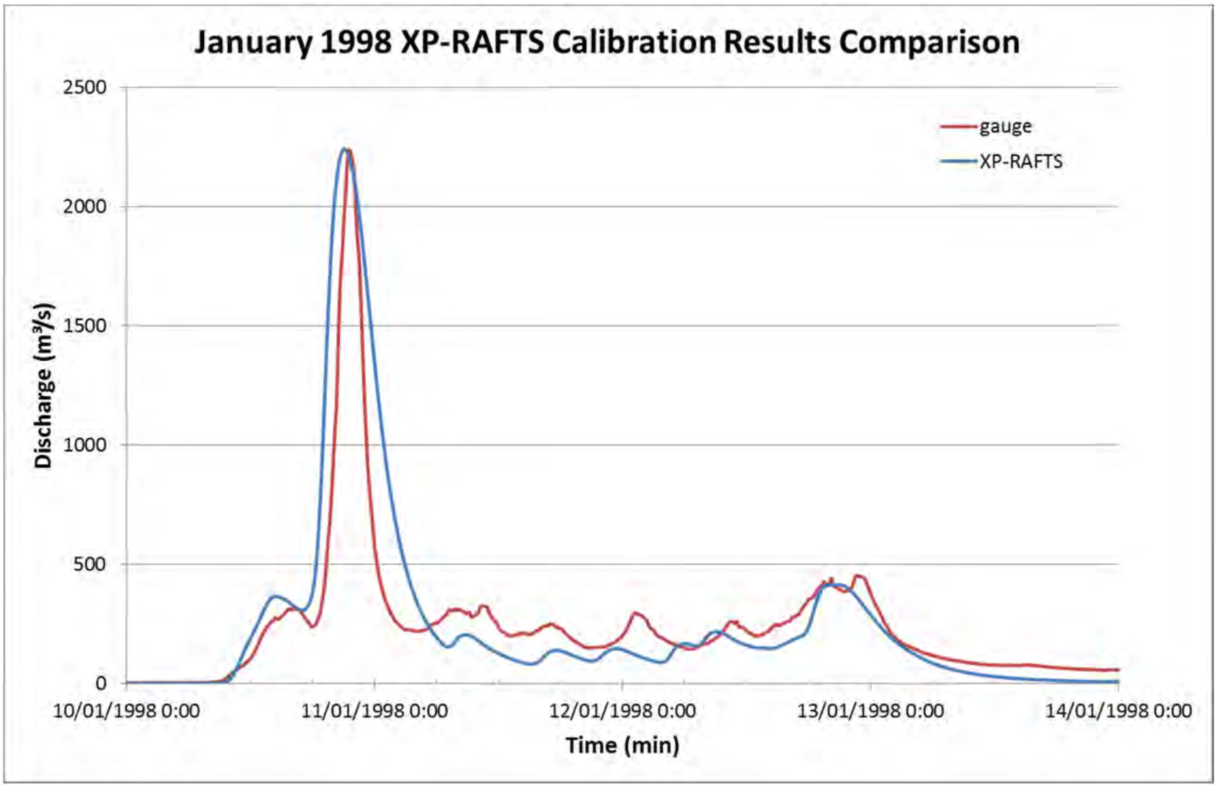


Figure 2-5 January 1998 XP-RAFTS results

2.4.2 Comparison between Design Storms and FFA

A number of design rainfall events ranging between 2-year and 100-year ARI were analysed for durations between 1 h and 72 h. The design peak flow values at the Black River Bruce Highway Stream gauge (117002A) were compared with the FFA flows and summarised in Figure 2-6. It was found that the design storm flows are within the 95% confidence level intervals for all ARIs except for the 2-year ARI event. This is consistent with the findings in Section 2.4.1 which indicate that Log-Pearson III technique provides a better fit for higher ARI events.

For lower ARIs, comparison shows that the differences are much greater which suggests that higher initial and continuing loss values are required for these more frequent events. However, these design flows were found to be higher which indicate conservatism of the XP-RAFTS model in generating the design flows. From previous studies for the area, the stream flows for lower ARIs are predicted to be contained within the banks of the river channel and therefore it is not deemed crucial to develop another set of XP-RAFTS parameters for the lower ARI events.

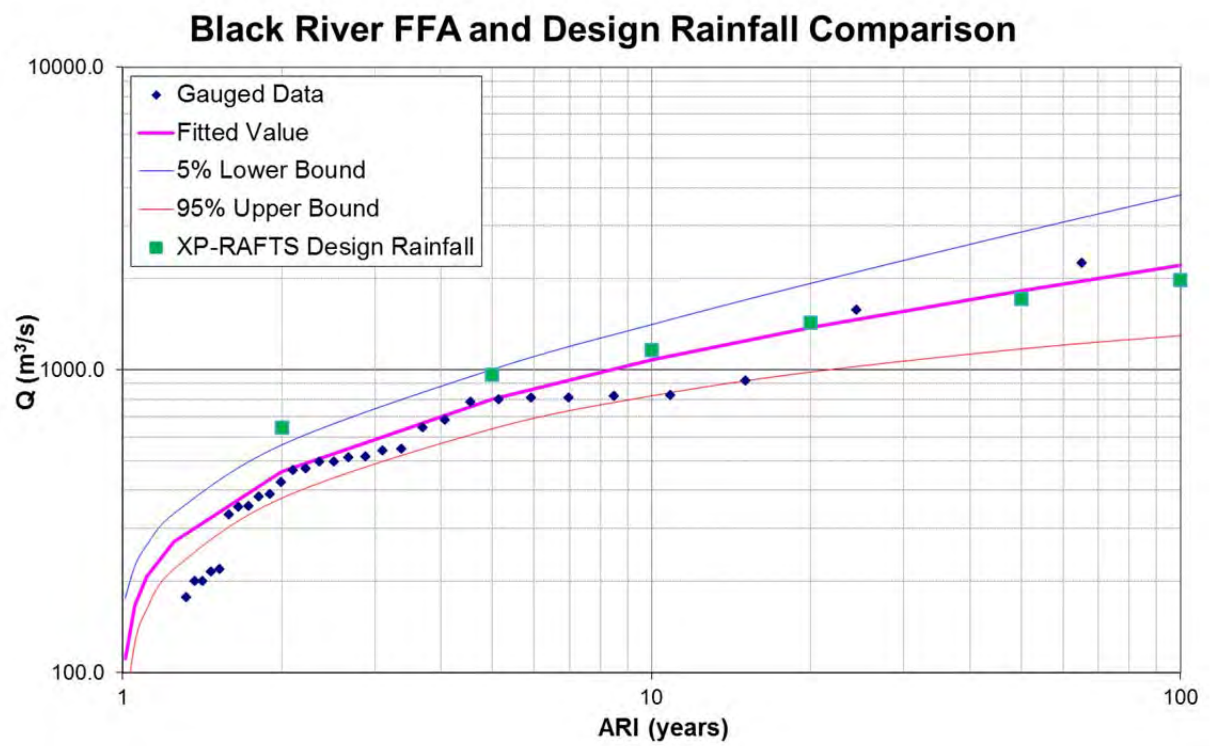


Figure 2-6 Comparison between Design Storms and FFA

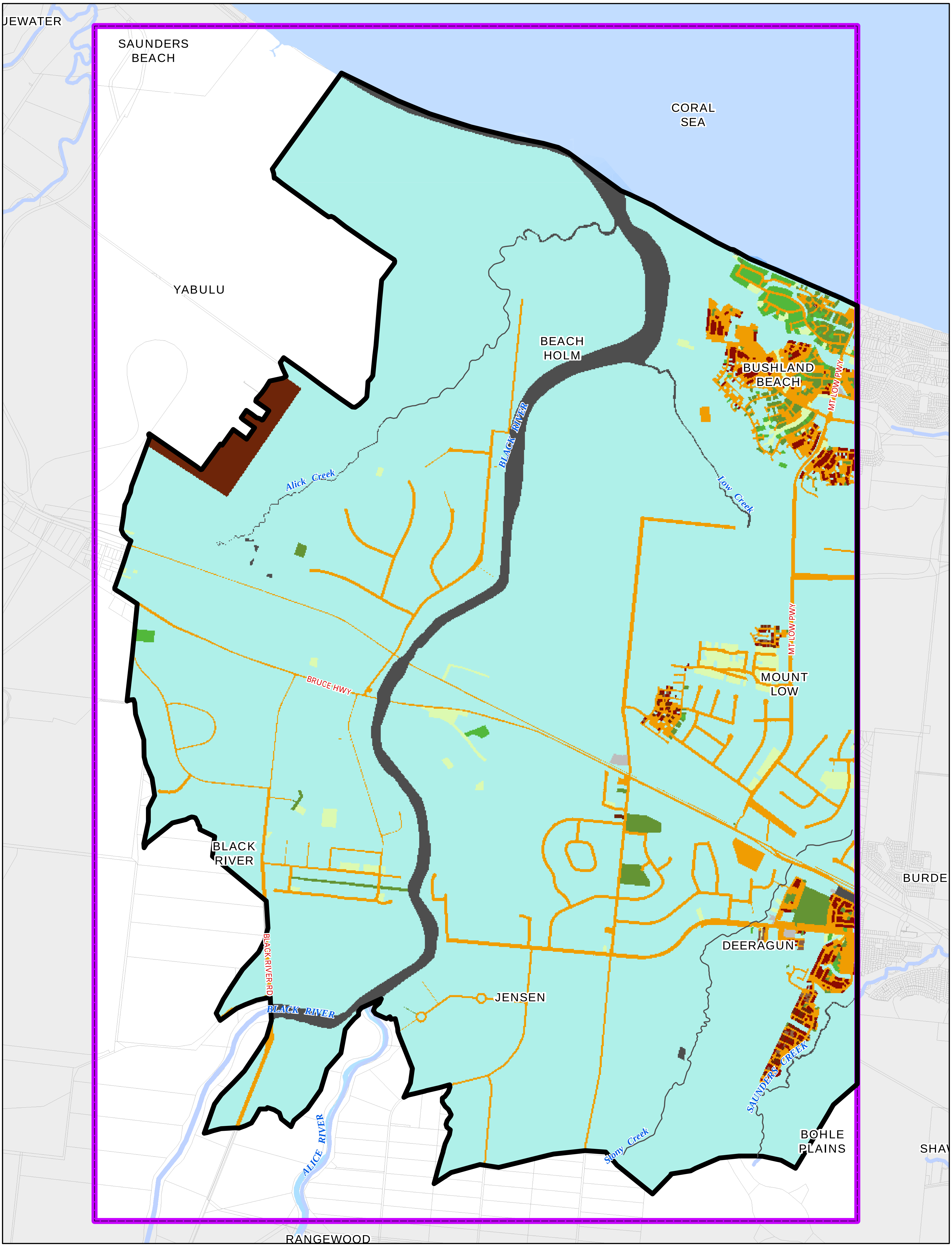
2.5 Rain-on-Grid Method – Local Runoff

Rain-on-Grid is a method for applying rainfall to a hydraulic model. It involves applying the rainfall directly on the two-dimensional grid. This method is particularly advantageous in ungauged urban areas adjacent to large flat floodplains and was considered suitable for the lower reaches of the Black River catchment.

Two-dimensional rainfall excess time series for each ARI and duration were created to represent the local net precipitation for the study area. This rainfall excess is calculated by applying initial and continuing losses to the design rainfall for two extreme scenarios (i.e. pervious and impervious). Initial and continuing loss values represent infiltration and storage of runoff in surface depressions. Initial and continuous loss values of 70 mm / 2.5 mm/h and 0 mm / 1 mm/h were applied to the pervious and impervious areas respectively. These loss values were obtained from the re-calibrated XP-RAFTS model.

For design events between the 2 and 500-year ARI, temporal patterns were applied based on AR&R Volume 2. For the PMF event with a storm duration greater than 6 h, duration specific temporal patterns were applied based on the Generalised Tropical Storm Method.

An imperviousness map for the base case scenario was created using TCC's property boundary dataset and high resolution aerial imagery (in Figure 2-7). The property boundary dataset contains suitable descriptors that allow the separation between vacant land, residential dwellings, parks, commercial and industrial land, etc. To determine the imperviousness percentage for residential dwellings, an average house size to land parcel ratio was used. For all other parcels, an imperviousness fraction was applied based on typical values for the type of land in the area.



Impervious Fraction (%)		
0 - 10% Impervious	30 - 40% Impervious	70 - 80% Impervious
10 - 20% Impervious	40 - 50% Impervious	80 - 90% Impervious
20 - 30% Impervious	50 - 60% Impervious	90 - 100% Impervious
	60 - 70% Impervious	Rain-on-Grid Extent

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0 0.25 0.5 1 km

Coordinate System: GDA 1994 MGA Zone 55

Base Data:
DCDB © 2013 (Queensland Govt)
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BLACK RIVER FLOOD STUDY

Imperviousness Map

Figure 2-7

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3.0 Hydraulic Modelling

3.1 Overview

MIKE FLOOD was used as the platform to construct a hydraulic model to assess the flooding under the base case scenario across the Black River area. The extent of the Black River model in relation to previous studies in the surrounding area is shown in Figure 3-1.

3.2 MIKE FLOOD Hydraulic Model

MIKE FLOOD is a numerical hydraulic model developed by the Danish Hydraulic Institute (DHI). The model dynamically couples the one-dimensional MIKE 11 elements (culverts, bridges and open channels) hydraulics with the two-dimensional surface water hydraulic model MIKE 21. Outputs from MIKE FLOOD include GIS compatible maps of flood extents, water depth, water level, flow and velocities.

3.2.1 MIKE 11

MIKE 11 is a software package used for one-dimensional simulation of flows, water quality and sediment transport in estuaries, rivers, irrigation systems, channels and other water bodies. The model is typically used to assess one-dimensional flows through structures such as weirs, bridges and culverts. It also enables simulation of complex river systems where one-dimensional flow predominates.

3.2.2 MIKE 21

MIKE 21 is a software package used for two-dimensional simulation of flow distribution based on water and ground levels at each time step of a model run. The two-dimensional model provides a more accurate determination of the extent, magnitude and direction of the flood flows than MIKE 11, without the need to pre-determine the flow path.

3.3 Model Development

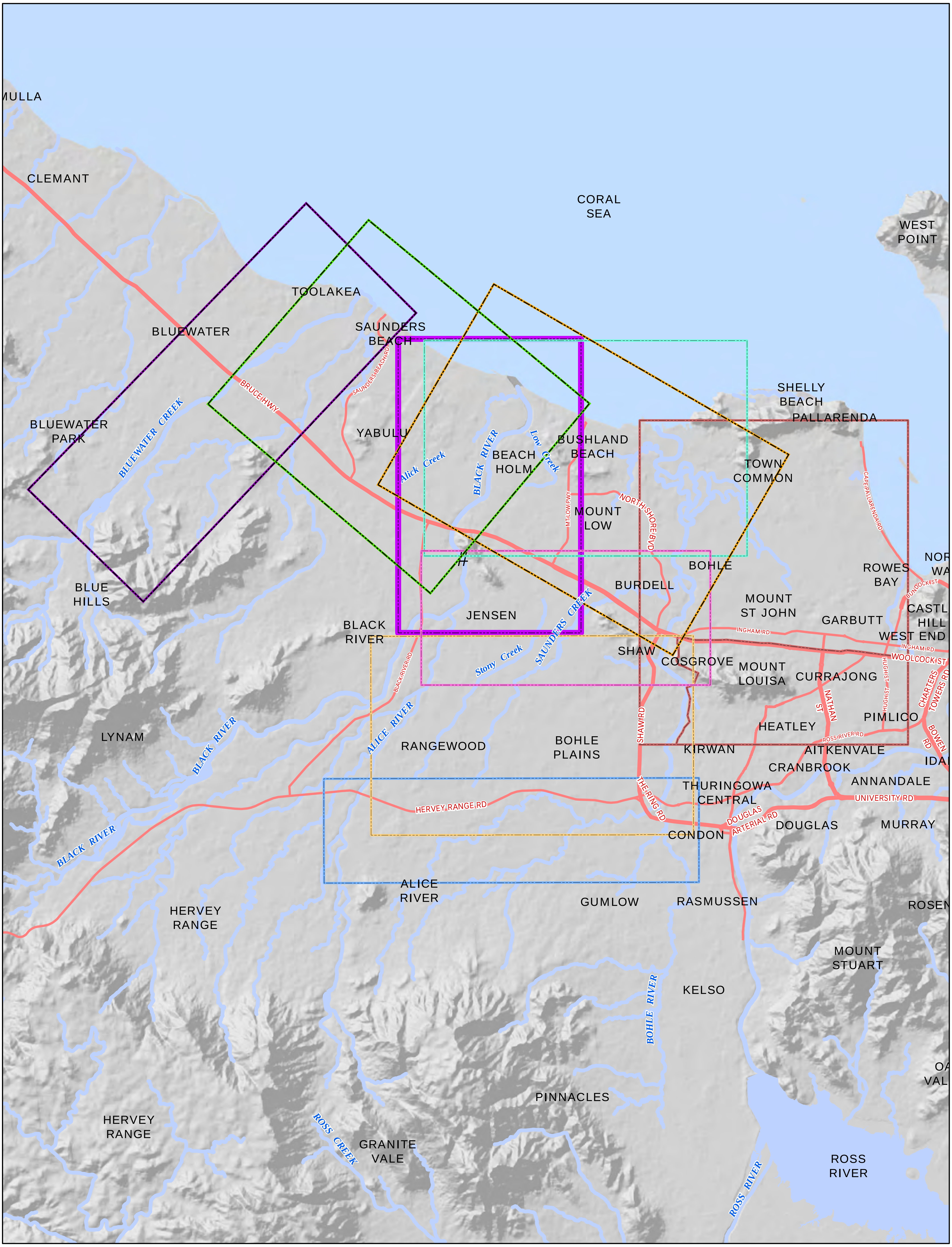
The Black River hydraulic model was constructed using as-built plans, TCC stormwater network database, and information from existing MIKE FLOOD hydraulic models, survey data and site visit measurements. Previous overlapping models, shown in Figure 3-1, provided relevant information for the construction of the current Black River model.

3.3.1 Model Grid

A 10 m by 10 m Cartesian grid was developed to represent the topography of the hydraulic model surface elevation. The grid was based on the following data:

- 2004 Contour (Provided by TCC)
- 2009 LiDAR (Provided by TCC)
- 2012 LiDAR (Provided by TCC)
- hydrographic survey data for the downstream section of the Black River (Provided by TCC)
- JCU *GBR - Project 3DGBR: High-resolution Topography for the Great Barrier Reef and Coral Sea* for the ocean.

The model consists of approximately 987,000 cells with each cell representing the average elevation over each cell area (10 m x 10 m). Most stream inverts representing the minimum cell values for the major watercourses within the study extents were stamped into the MIKE 21 grid to ensure continuity of the creek bed in the model grid. The maximum grid values were used for cells over roads and flood levees that act as major flood control mechanisms within the study area. The data sources used for the development of the model grid and the areas where they were applied are shown in Figure 3-2.



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0 0.75 1.5 3 km

Coordinate System: GDA 1994 MGA Zone 55

Legend	
# Black River Stream Gauge	Althaus/Deep Creek Model Extent (2013)
Louisa Creek Model Extent (2012)	Black River Model Extent (Current Study)
	Bluewater Creek Model Extent (2013)
	Deeragun Model Extent (2012)
	Little Bohle River Model Extent (2011)
	Lower Bohle Model Extent (2012)
	Lower Bohle Model Extent (2014)
	Upper Bohle Plains Model Extent (2011)

Base Data:
DCDB © 2013 (Queensland Govt)
Roads © 2013 (StreetPro Pitney Bowes)

BLACK RIVER FLOOD STUDY

Model Extents

Figure 3-1

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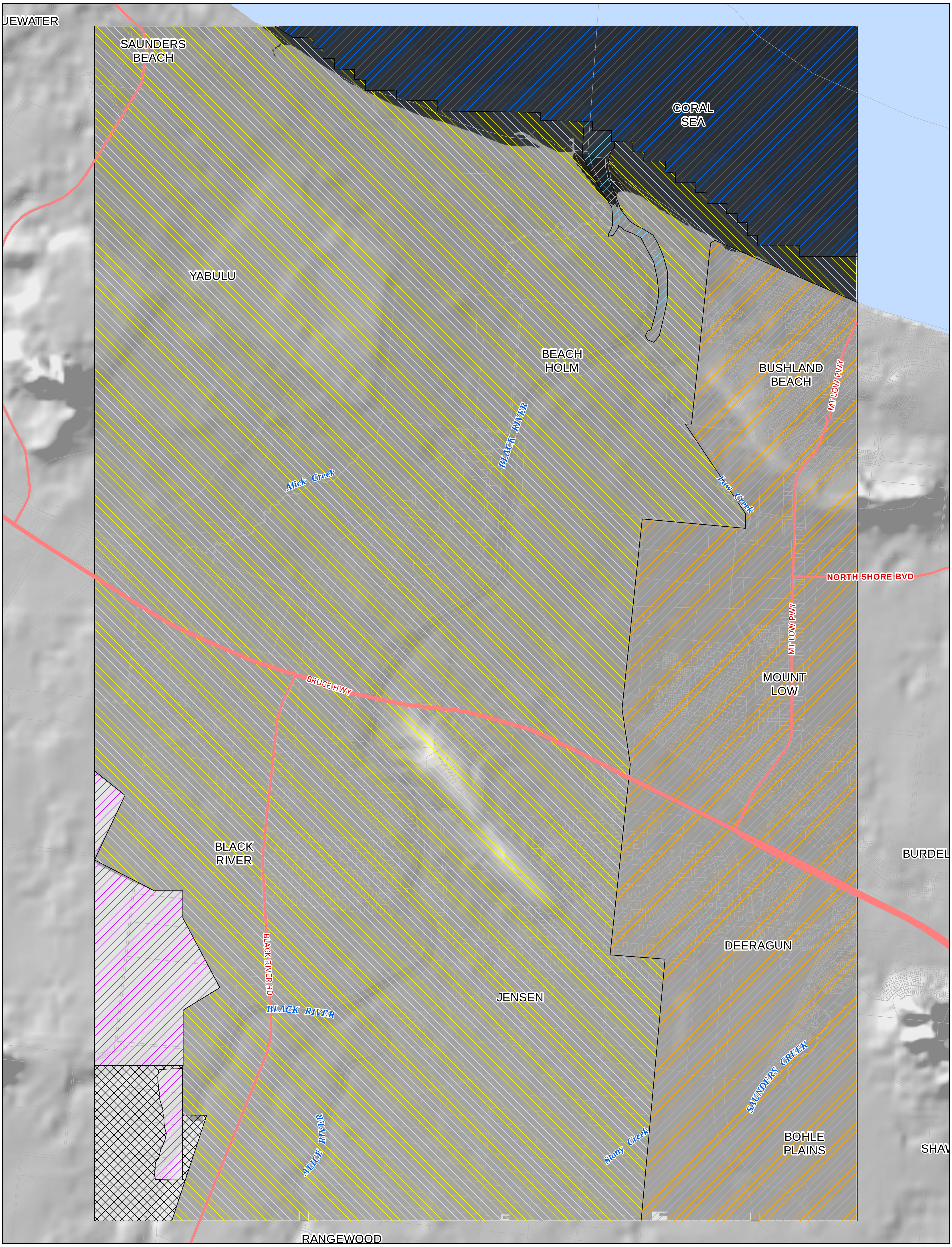

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0 0.25 0.5 1 km

Coordinate System: GDA 1994 MGA Zone 55

2004 Contour	Hydrographic Survey
2009 LiDAR	JCU GBR
2012 LiDAR	No Data

Base Data:
DCDB © 2013 (Queensland Govt)
Roads © 2013 (StreetPro Pitney Bowes)

BLACK RIVER FLOOD STUDY

Black River Model Grid
Data Source - Application Extent
Figure 3-2

3.3.2 Hydraulic Structures

Hydraulic structures within the study area were represented using MIKE 11 elements that were coupled into the 2D MIKE 21 grid. Major bridges and culverts along all roadways were represented in MIKE 11 as shown in Figure 3-3. Note that only structures with a cross-sectional area equivalent or in excess of that of a 900 mm diameter pipe were included in the model, except in areas like the Bruce Highway where a combination of smaller culvert structures carries major flow which may have an impact to the overall flooding across the area. Details of the structures modelled using MIKE 11 are summarised in Table 3-1 for culverts and Table 3-2 for bridges.

Table 3-1 Details of culverts modelled using MIKE11

Map Reference	Culvert Reference	Configuration	Invert level (m AHD)		Length (m)
			Upstream	Downstream	
1	0561K	4/750RCP	3.47	3.46	16.20
2	Alick_Trib1Hwy	4/3000x1500RCBC	13.42	13.38	20.40
3	Alick_Trib1McKinnon	2/1200RCP	14.92	14.85	14.16
4	Alick_Trib2Hwy	3/1200RCP	13.70	13.40	14.80
5	Alick_Trib3aMcKinnon	4/1200x300RCBC	17.54	17.44	10.90
6	Alick_Trib3aMoree	4/1200x450RCBC	15.56	15.51	12.90
7	Alick_Trib3bBRRoad	2/1800x1200RCBC	12.37	12.25	10.98
8	Alick_Trib3bMcKinnon	3/1050RCP	15.84	15.54	11.10
9	Alick_Trib4Percheron	2/1200x600RCBC	9.68	9.50	13.20
10	Alick_Trib5Clydesdale	2/1200RCP	3.87	3.77	12.20
11	AlickCk_BRRoad	2/1800x1200RCBC	16.79	16.71	10.98
12	AlickCk_Percheron	1/1800RCP	7.45	7.36	12.41
13	ArabianPl_Culv	3/1200x300RCBC	8.28	8.00	9.60
14	BH 14A	9/1200x750RCBC	11.52	11.41	20.00
15	BH 14A1	4/450RCP	11.69	11.52	17.00
16	BH MLPU_02	4/1650RCP	10.18	9.97	37.85
17	BH MLPU_03	1/525RCP	11.73	11.14	39.04
18	BH MLPU_04	3/375RCP	11.66	11.58	18.59
19	BH MLPU_05	2/750RCP	11.90	11.84	32.94
20	BH MLPU_06	3/525RCP	12.28	12.07	21.96
21	BH MLPU_07	1/375RCP	12.29	12.11	17.69
22	BH MLPU_08	1/600x300RCBC	12.50	12.41	22.68
23	BH MLPU_09	1/600x300RCBC	12.46	12.35	22.71
24	BH MLPU_10	1/375RCP	12.10	11.89	19.86
25	BH_2C	4/600x300RCBC	11.50	11.37	12.20
26	BH_2D	11/1200x600RCBC	11.50	11.37	12.20
27	BH_2E	4/600x300RCBC	11.50	11.37	12.20
28	BH_2F	4/600x300RCBC	11.75	11.40	12.20
29	BH_2G	4/600x300RCBC	11.75	11.45	12.20
30	BH_2H	1/1200x450RCBC	12.25	12.00	11.70
31	BH_2I	1/375RCP	11.94	11.78	14.70
32	BH_3A	2/1200x450RCBC	12.25	12.00	11.00
33	BH_3B	2/1200x450RCBC	12.50	12.25	11.00
34	BH_3C	2/1200x450RCBC	13.00	12.87	13.40
35	BH_3D	1/1200x450RCBC	13.25	13.05	16.30
36	BH_3E	2/450RCP	15.22	14.90	14.00

Map Reference	Culvert Reference	Configuration	Invert level (m AHD)		Length (m)
			Upstream	Downstream	
37	BH_3F	2/750RCP	17.00	16.75	14.00
38	BH_TMR_16400	1/375RCP	12.11	12.10	17.70
39	Black_Trib2Church	1/1200RCP	13.91	13.09	14.25
40	Black_Trib3Church	2/750RCP	15.10	15.04	13.42
41	Black_Trib4Church	2/1200x300RCBC	16.63	16.57	10.98
42	Black_Trib5Church	2/1050RCP	16.15	16.10	10.98
43	Black_Trib6Church	5/750RCP	16.26	16.17	12.42
44	BlackR_Trib1Church	1/2100x2100RCBC	10.76	10.75	8.00
45	BlackviewAv	2/900x450RCBC	18.51	18.47	13.42
46	BonnettRd1	6/1200x900RCBC	7.40	7.00	24.00
47	BonnettRd2	8/1200x300RCBC	10.08	9.97	24.00
48	Bruce Highway 1	3/1680RCP	12.50	12.47	17.30
49	Bruce Highway 3	5/1500RCP	12.10	12.00	18.00
50	Bruce Highway 4	8/2100x2100RCBC	11.85	11.65	16.00
51	Bruce Highway 5	2/1524RCP	12.60	12.40	16.00
52	CouttsDr	6/900x600RCBC	2.20	2.16	9.76
53	DarlingRd1	7/1200x450RCBC	13.88	13.78	10.90
54	Holstein_Culv1	2/1200x300RCBC	9.96	9.75	9.60
55	JensenRd1	1/1500RCP	12.39	12.32	12.20
56	KregorSt	4/750RCP	9.01	8.94	17.29
57	MacquarieSt	4/750x300RCBC	16.97	16.89	10.98
58	MarinaDr	4/1200x600RCBC	2.97	2.88	15.86
59	MLP_1B	1/1200x375RCBC	10.41	10.36	16.80
60	MLP_6A	1/900RCP	9.71	9.40	27.30
61	MLP_7A	5/825RCP	7.72	7.66	13.50
62	MLP_7B	1/900RCP	6.03	5.96	14.80
63	QR_1356.97	8/1200x1200RCBC	9.58	9.57	9.00
64	QR_1358.17	2/1200x600RCBC	11.22	11.21	7.30
65	QR_1358.23	6/1200x600RCBC	11.52	11.51	7.20
66	QR_1358.25	3/1200x600RCBC	11.14	11.23	7.38
67	QR_1358.30	2/1200x600RCBC	11.31	11.28	7.28
68	QR_1358.39	1/1200x600RCBC	11.39	11.39	7.31
69	QR_1358.91	1/1200x600RCBC	12.21	12.20	7.20
70	QR_1359.05	1/900x600RCBC	12.15	12.14	7.20
71	QR_1359.16	1/1200x600RCBC	12.33	12.28	7.20
72	QR_1359.18	1/1200x600RCBC	12.12	12.11	7.20
73	QR_1359.25	1/900x450RCBC	12.23	12.20	7.20
74	QR_1359.33	1/900x450RCBC	12.01	12.00	7.20
75	QR_1359.52	1/900x450RCBC	11.86	11.81	7.20
76	QR_1359.63	1/900x450RCBC	11.60	11.60	7.20
77	QR_1359.71	1/1200x450RCBC	11.61	11.59	7.20
78	QR_1359.82	1/1200x450RCBC	11.61	11.60	7.20
79	QR_1359.85	1/900x450RCBC	11.53	11.52	7.20

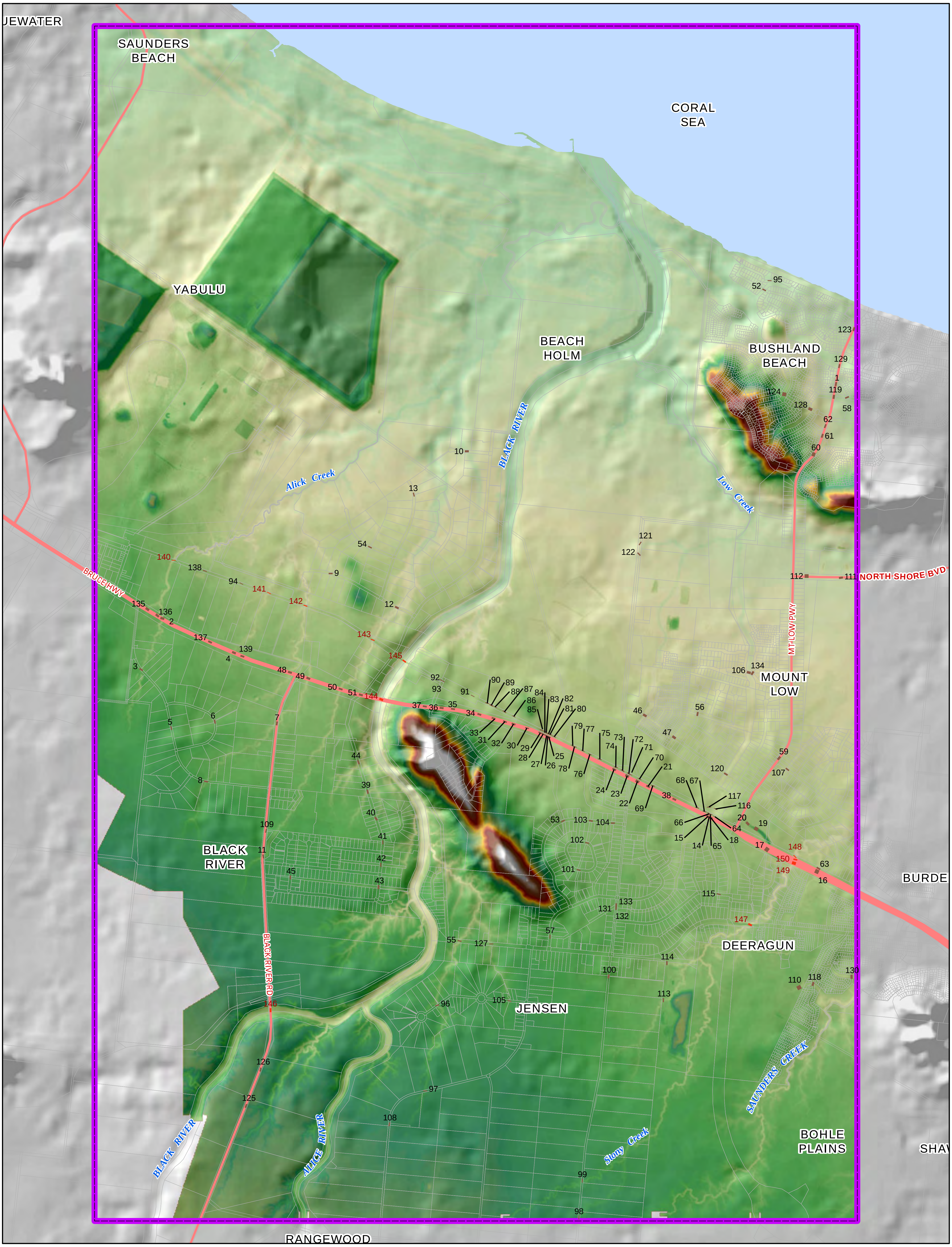
Map Reference	Culvert Reference	Configuration	Invert level (m AHD)		Length (m)
			Upstream	Downstream	
80	QR_1360.04	2/1200x600RCBC	11.14	11.12	7.20
81	QR_1360.09	3/1200x600RCBC	11.05	11.04	7.20
82	QR_1360.12	1/1200x900RCBC	10.98	10.97	7.20
83	QR_1360.14	1/900x600RCBC	11.23	11.22	7.20
84	QR_1360.16	1/1200x900RCBC	10.90	10.85	7.20
85	QR_1360.19	2/1200x600RCBC	11.06	11.05	7.20
86	QR_1360.52	2/900x600RCBC	11.78	11.77	7.20
87	QR_1360.62	2/900x600RCBC	11.44	11.43	7.20
88	QR_1360.75	1/1200x600RCBC	11.50	11.47	7.20
89	QR_1360.79	2/1200x600RCBC	11.38	11.36	7.20
90	QR_1360.82	1/1200x600RCBC	11.39	11.39	7.20
91	QR_1360.99	1/900x450RCBC	11.73	11.72	7.20
92	QR_1361.34	1/1200x450RCBC	12.33	12.32	7.20
93	QR_1361.36	1/1200x600RCBC	12.38	12.37	7.20
94	QR_1363.67	1/900x600RCBC	11.65	11.63	7.20
95	RumbulaCt	2/750x600RCBC	2.40	2.35	9.76
96	SiteVisit01	2/2600x2400RCBC	14.90	14.80	11.00
97	SiteVisit02	2/2100x2100RCBC	19.16	19.14	6.10
98	SiteVisit03	2/220x140RCBC	18.70	18.64	5.70
99	SiteVisit04	3/2100x2100RCBC	18.15	18.15	6.10
100	SiteVisit05	2/1200x450RCBC	16.48	16.41	11.60
101	SiteVisit06	6/1200x300RCBC	15.18	15.18	11.10
102	SiteVisit07	7/1200x300RCBC	11.30	11.22	11.90
103	SiteVisit08	6/1200x900RCBC	13.65	13.57	10.80
104	SiteVisit09	10/1200x450RCBC	13.41	13.35	9.70
105	SiteVisit10	2/450RCP	17.03	16.94	7.00
106	SiteVisit11	9/1200x1200RCBC	6.49	6.37	14.40
107	SiteVisit12	4/1200x600RCBC	9.54	9.35	10.20
108	SiteVisit13	1/1200x450RCBC	22.22	22.10	9.40
109	SiteVisit14	3/1200x450RCBC	17.90	17.83	9.50
110	SomertonSt	2/2100x900RCBC	11.82	11.76	39.40
111	STC_NSB_11A	2/1500x1200RCBC	4.34	4.33	19.00
112	STC_NSB_11B	8/2400x900RCBC	4.50	4.40	34.50
113	Stony_1	1/2400x900RCBC	13.56	13.51	9.70
114	Stony_2	1/2400x900RCBC	12.82	12.67	13.30
115	Stony_3	5/1200x450RCBC	13.76	13.74	9.87
116	Stony_4	2/475RCP	11.36	11.33	6.30
117	Stony_5	2/475RCP	11.36	11.34	6.30
118	Summerland Dve	2/900x800RCBC	13.43	12.73	20.00
119	TCC_868-871	4/1050RCP	3.52	3.50	18.80
120	TCCSurvey_1	7/1820x1220RCBC	9.60	9.49	12.29
121	TCCSurvey_10_1	1/610x320RCBC	6.35	6.27	8.48
122	TCCSurvey_10_2	1/610x320RCBC	5.59	5.52	10.82

Map Reference	Culvert Reference	Configuration	Invert level (m AHD)		Length (m)
			Upstream	Downstream	
123	TCCSurvey_2	2/740RCP	2.82	2.62	18.50
124	TCCSurvey_3	2/1400RCP	13.18	12.75	36.81
125	TCCSurvey_4	1/1220RCP	22.61	22.51	14.85
126	TCCSurvey_5	1/900RCP	22.44	22.38	14.21
127	TCCSurvey_6	3/1215x920RCBC	13.84	13.76	9.93
128	TCCSurvey_7	5/1400RCP	8.01	7.71	27.09
129	TCCSurvey_8	5/575RCP	3.78	3.68	16.15
130	Valerie Ln	3/800RCP	11.05	10.59	23.00
131	VealesRd1a	4/1200x300RCBC	15.66	15.61	10.98
132	VealesRd1b	1/600x225RCBC	15.66	15.61	10.98
133	VealesRd2	3/1200x300RCBC	15.66	15.61	10.98
134	WongableCt	2/900x450RCBC	7.60	7.47	19.95
135	Yab1_Hwy	1/900RCP	14.00	13.70	9.76
136	Yab2_Hwy	1/900RCP	14.55	14.53	9.76
137	Yab3_Hwy	2/450RCP	14.96	14.92	9.76
138	Yab3_Rail	1/900x600RCBC	13.06	13.04	7.20
139	Yab5_Hwy	3/675RCP	13.91	13.88	9.76

Note: *RCP – Reinforced concrete pipe*
RCBC – Reinforced concrete box culvert

Table 3-2 Details of bridges modelled using MIKE11 in the Middle Bohle Model

Map Reference	Bridge Reference	Bridge Deck Soffit (Bottom) (m AHD)	Bridge Deck Level (Top) (m AHD)
140	Alick_Trib1Rail	13.70	14.10
141	Alick_Trib2Rail	11.06	11.50
142	Alick_Trib3Rail	11.24	11.78
143	AlickCk_Rail	12.69	13.23
144	BlackR_Hwy	13.72	14.92
145	BlackR_Rail	11.80	13.60
146	BlackRiver	19.37	20.85
147	Gaeney Lane	14.75	15.25
148	QR Stony	10.95	12.15
149	Stony Hwy Nbound	12.49	13.49
150	Stony Hwy Sbound	11.65	12.45



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Coordinate System: GDA 1994 MGA Zone 55

Bridge
Culvert

Base Data:
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Roads © 2013 (StreetPro Pitney Bowes)

BLACK RIVER FLOOD STUDY

Hydraulic Structures

Figure 3-3

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3.3.3 Boundary Conditions and local source points

Inflow hydrographs at the upstream boundaries were taken from discharge hydrographs from the Black River, Stony Creek and Saunders Creek XP-RAFTS models.

An ocean downstream boundary was applied as a fixed water level of 1.254 m AHD which represents the mean high water spring (MHWS) tide for the Townsville area as obtained from the Queensland Tide Tables (2011).

At the minor depressions east of the hydraulic model extent, water was discharged out of the model through the use of infinite sinks. The use of the infinite sink in the hydraulic model can be justified as follows:

- For the section between Bruce Highway and the ocean, discharge flowing out of the hydraulic model is mainly controlled by Mount Low Parkway which indirectly acts as a levee.
- The remaining section is within the Saunders and Stony Creek catchments which are not the focus of the current study.

Downstream of the main Saunders and Stony Creek MIKE 21 grid, 1D MIKE 11 channels were used to extend the waterways further downstream and reduce the sensitivity to downstream boundary conditions within the MIKE 21 grid. Discharge rating curves calculated from the normal flow depth at the last cross section of these channels were used as boundary conditions at the downstream end of these MIKE 11 channels.

Local source points were also applied across the hydraulic model to represent local run-off in catchments for which the Rain-on-Grid method was not applied or at any minor tributaries entering into the model extent.

The locations and type of boundary conditions as well as the local source points used in the hydraulic model can be seen in Figure 3-4.

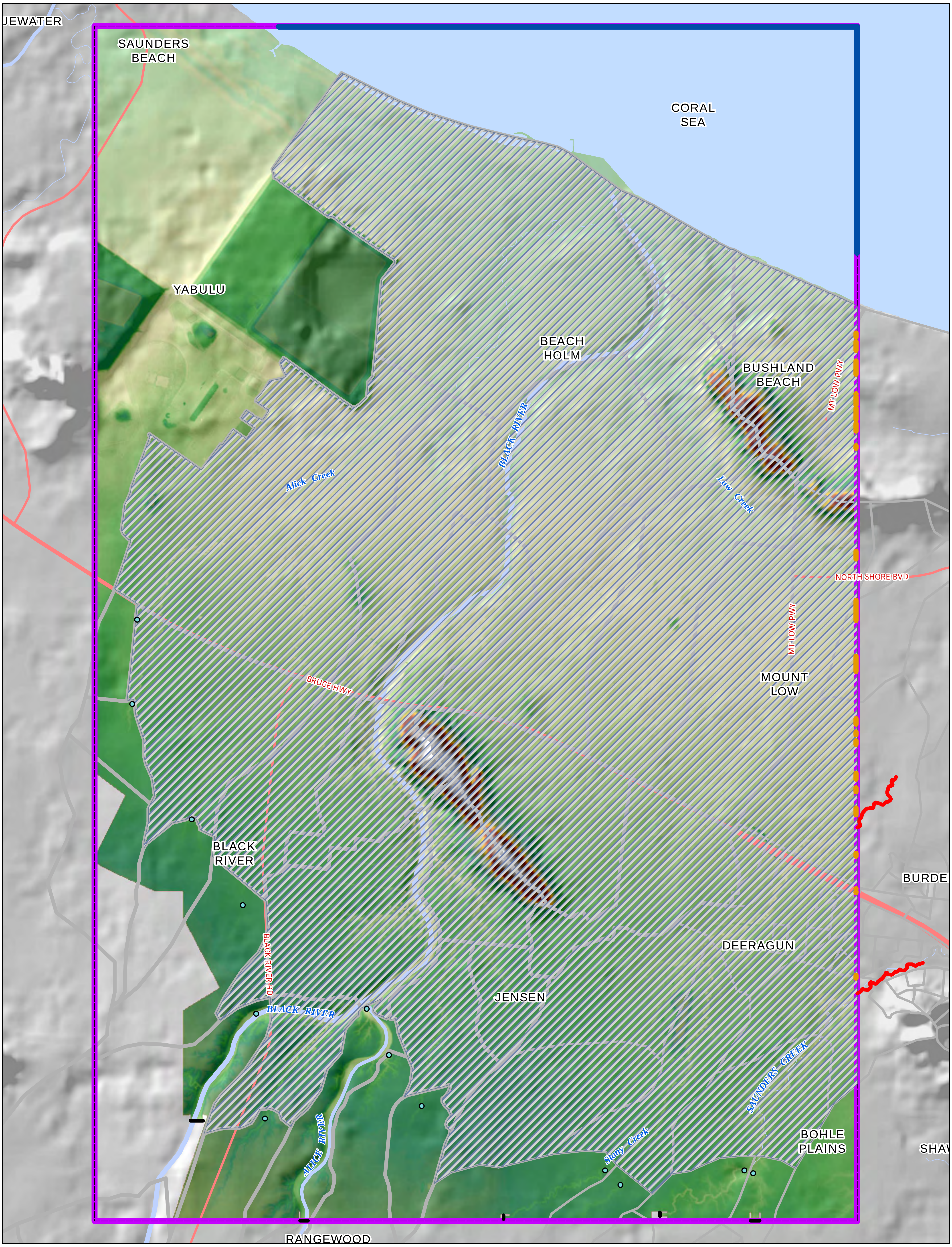
3.3.4 Roughness

Hydraulic roughness (Manning's n value) is a measure of the resistance to flow and is primarily dependent on land use. Values selected for each land use are provided in Table 3-3 and a roughness map is shown in Figure 3-5.

These values are mainly consistent with previous flood study reports undertaken as part of the *City Wide Flood Constraints Project* in the Bohle Flood Plains area. The only exception is the Black River main channel where a lower roughness was adopted mainly due to the clean sandy riverbed observed during the site visit and confirmed through the 1998 calibration.

Table 3-3 Hydraulic Roughness Values

Land Use	Manning's n Value
Bush Land	0.07
River Channel (All others)	0.03
River Channel (Black River)	0.02
Riparian Zone	0.08
Drainage Easements	0.02
Roads/Rail	0.025
Open Space/Sandy area	0.05
Urban Areas	0.06
Rural Residential	0.055
Ocean/ Ponds	0.011
Farmland	0.035



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Mike 11 Channels
Infinite Sinks
Source Points
Ocean Boundary
Open Inflow Boundary
Rain-on-Grid Extent

BLACK RIVER FLOOD STUDY

Model Boundary Conditions

Figure 3-4

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Mannings N		
0.011	0.030	0.060
0.020	0.035	0.070
0.025	0.050	0.080
	0.055	

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BLACK RIVER FLOOD STUDY

Roughness Map

Figure 3-5

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3.4 Model Calibration

The MIKE FLOOD model was calibrated to stream gauge data for the flood event of 10th – 11th January 1998. Stream gauge data was obtained for the Black River Gauge (117002A) near the Bruce Highway.

3.4.1 Model Calibration against the January 1998 Event

Flow hydrographs from the calibrated XP-RAFTS model were applied to the MIKE FLOOD model. For the Rain-on-Grid area, rainfall pluviograph data from the Bluewater gauge (11703A), as adopted in the XP-RAFTS model calibration, was used. Initial and continuous loss values of 70 mm / 2.5 mm/h and 0 mm / 1 mm/h were applied to the pervious and impervious areas respectively. This generated a two-dimensional rainfall excess time series with a 15 minutes time step that represents the local net precipitation on the catchment during the 1998 storm event.

The comparison of modelled and gauged flood levels at the Black River Gauge is shown in Figure 3-6.The comparison shows good agreement in terms of peak flood levels and timing between the recorded levels and those predicted by the MIKE FLOOD model. It was therefore concluded that the calibration of the MIKE FLOOD confirms its suitability for determining design flood levels for the Black River area.

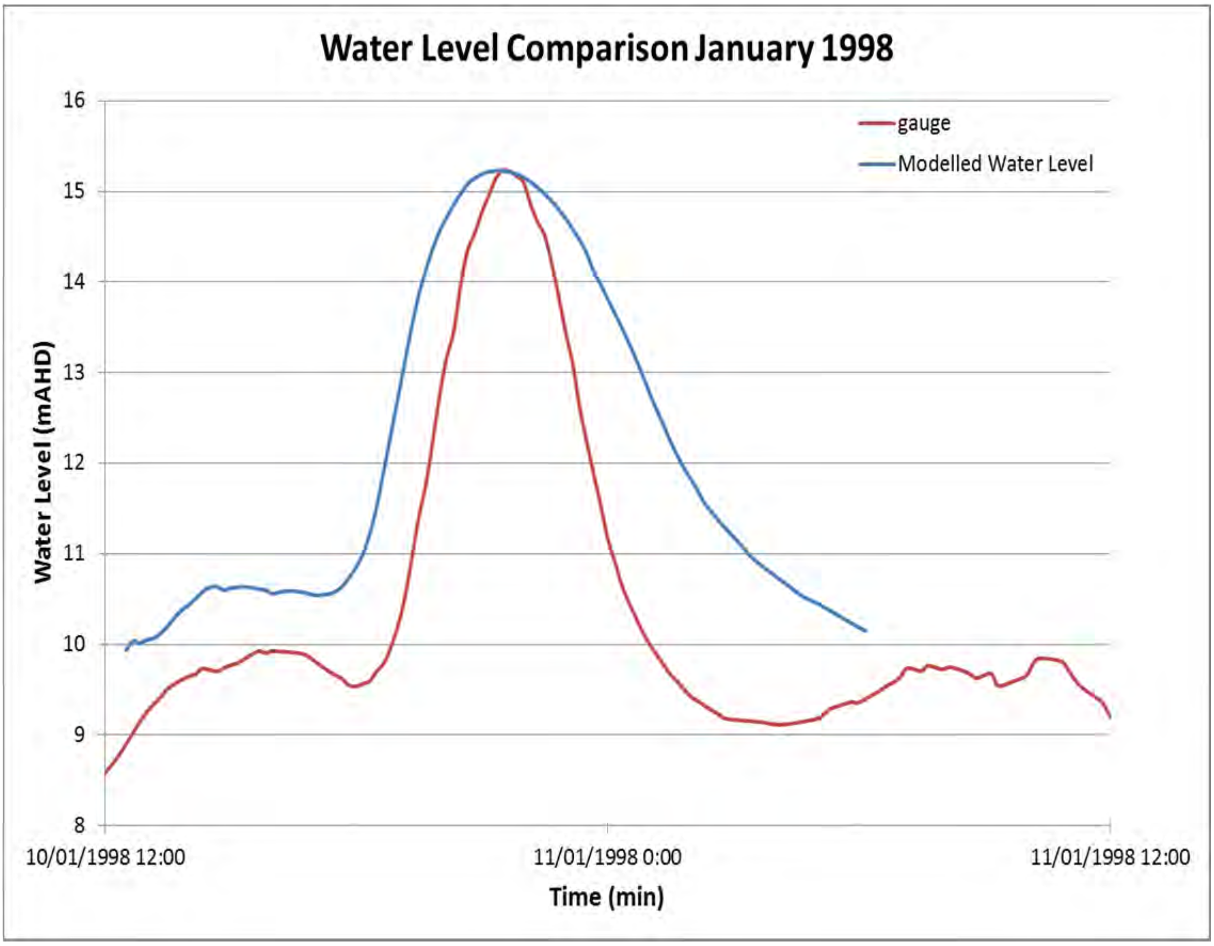
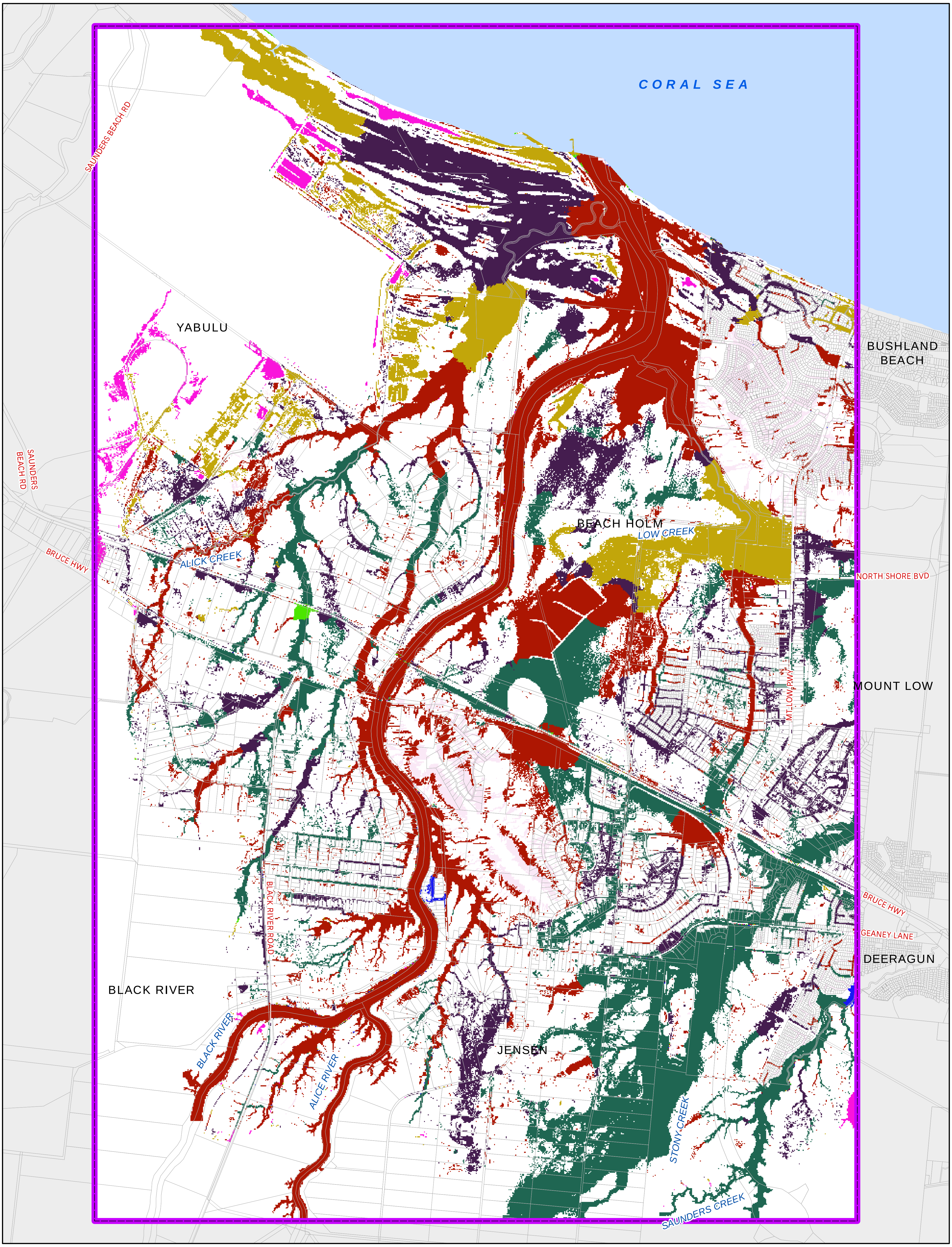


Figure 3-6 MIKE FLOOD Model Calibration – January 1998 Flood Event

3.5 Design Flood Critical Duration Assessment

The critical duration and maximum flood envelopes for the 2, 5, 10, 20, 50-year ARI and the Probable Maximum Flood (PMF) events, were assessed and established by simulating the 100-year ARI 3, 4.5, 6, 9, 12, 18, 24 and 48 h storm durations. Figure 3-7 shows the 100-year ARI critical durations for various areas within the hydraulic model extent.

The critical durations adopted and used to generate peak flood envelopes for the remaining ARIs were 9 and 24 h.



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Critical Duration

3 h, 4.5 h, 6 h, 9 h, 12 h, 18 h, 24 h, 48 h

BLACK RIVER FLOOD STUDY

100 Year ARI
Critical Duration Assessment
Figure 3-7

4.0 Design Flood Assessment

It is important to note that this study provides a high level assessment of the likely flooding that could be experienced within the model extent and it is therefore not intended to represent flooding at an individual property level. Further refinement of the model to account for site-specific features is required for this purpose.

With the Rain-on-Grid methodology adopted for this study and not all culverts included in the hydraulic model, localised flooding within the study area is common. As this project seeks to assess the major flow paths within the study area, this localised flooding may not represent the true localised drainage condition but can be used as a guide to identify potential inundation issues.

4.1 Flooding across the Study Area

Base case flood maps for design ARI storms are provided in Appendix A. The maps show maximum water depth, water surface level and flow velocity magnitude for the following storms:

- 2-year ARI
- 5-year ARI
- 10-year ARI
- 20-year ARI
- 50-year ARI
- 100-year ARI
- 500-year ARI
- Probable Maximum Flood.

For mapping purposes the criteria adopted involves:

- including water depths greater than or equal to 0.1 m; or
- including water velocities greater than or equal to 0.3 m/s.

Therefore, only areas predicted to experience water depths lower than 0.1 m and water velocities lower than 0.3 m/s are shown as free from flooding in the mapping undertaken. This is in line with TCC's Flood Hazard Mapping Criteria.

To facilitate reading of flood modelling results, the majority of labels have been left out of the flood maps. The key areas mentioned in the assessment included in this section are shown in the locality map (see Figure 1-1) and therefore it is recommended that this is used as a reference when reviewing the flood maps.

Description of flooding for the various design events assessed is provided in Table 4-1. The assessment focused on identifying out of bank flow, channel break out and high velocities within channels for each ARI.

Table 4-1 Flooding Assessment Summary for the Black River Main Channel

Event	Description	Map Reference
2-year ARI	- The majority of flows in Black River are within the main channel with localised sections of the Black River experiencing velocities greater than 2 m/s. - Some minor ponding noticed in low lying locations across the study area.	A1, A9, A17
5-year ARI	- The majority of flows in Black River are within the main channel with a large section downstream of the Alice River confluence experiencing velocities greater than 2 m/s. - Some ponding noticed in low lying locations across the study area. - Various rural residential lots across Jensen and Black River affected by flooding.	A2, A10, A18
10-year ARI	- The majority of flows in Black River are within the main channel with most of the section downstream of the Alice River confluence having velocity greater than 2 m/s. - Increase in number of locations affected by ponding across the study area.	A3, A11, A19

Event	Description	Map Reference
	- Various rural residential lots across Jensen and Black River affected by flooding. - Some urban residential lots across Mount Low and Bushland Beach likely to be affected by flooding albeit to a shallow depth (under 0.3 m)	
20-year ARI	- The majority of flows in Black River are within the main channel with most of the section downstream of the Alice River confluence having velocity greater than 2 m/s. - Further flooding across rural residential lots in the Black River and Jensen suburbs. - Increase in the extent of flooding across urban residential lots in the suburbs of Mount Low and Bushland Beach. Flood depth remains relatively shallow (0.3 m).	A4, A12, A20
50-year ARI	- The majority of flows in Black River are within the main channel, with a minor break out near the Bruce Highway into the unnamed tributary parallel to the main channel. Most of the Black River main channel experiences velocities greater than 2 m/s. - Further flooding across rural residential lots in the Black River and Jensen suburbs. - Increase in the extent of flooding across urban residential lots in the suburbs of Mount Low and Bushland Beach. Flood depth remains relatively shallow (0.3 m).	A5, A13, A21
100-year ARI	- The majority of flows in Black River are within the main channel, with a break out near the Bruce Highway into the unnamed tributary parallel to the main channel. Most of the Black River main channel experiences velocities greater than 2 m/s. - Extensive flooding across rural residential lots in the Black River and Jensen suburbs. - Significant extent of flooding across urban residential lots in the suburbs of Mount Low and Bushland Beach. Flood depth remains relatively shallow (0.3 m).	A6, A14, A22
500-year ARI	- The flows are mainly within the Black River main channel with some overflowing into the floodplain. Significant channel break out near the Bruce Highway and the railway line into the unnamed tributary parallel to the main channel. The entire section of Black River main channel experiences velocities greater than 2 m/s. - Extensive flooding across rural residential lots in the Black River and Jensen suburbs with some locations experienced depths of up to 0.5 m. - Significant extent of flooding across urban residential lots in the suburbs of Mount Low and Bushland Beach with localised areas experiencing up to 0.5 m of flooding.	A7, A15, A23
PMF	- Significant break out from the Black River into the Low Creek and Alick Creek. - Overflow from Stony Creek into the Black River catchment. - Extensive flooding across most of the study area. Water Depths in excess of 0.3 m can be expected across the majority of the flooded areas.	A8, A16, A24

There are various unnamed tributaries, as well as Low Creek and Alick Creek that serve as secondary drainage paths for the localised sub-catchments on both sides of the Black River main channel. Various residential developments of the Black River, Jensen, Deeragun and Mount Low suburbs have been built in very close proximity to these tributaries and therefore inundation to some properties is likely even during low ARI events. Overall, a large number of the properties, consisting mostly of rural residential, are impacted even during low ARI events but it is unknown whether the actual houses are directly affected.

In general, local roads have low level of immunity and localised ponding and overtopping is widely observed especially where the road crosses the local drainage easement or Creek tributaries. In terms of flooding extent, the flow is generally contained within minor tributaries and drainage easements for the 2-year ARI storm, and the flood extent increases gradually until the PMF event where widespread flooding is expected.

Velocity is generally low across flat areas but can be as high as 1.5 m/s in steeper parts of the catchment such as Bushland Beach for events up to the 100-year ARI. During the PMF event, velocity above 2 m/s can be expected at the unnamed tributary that cuts across the Black River rural residential area downstream of the railway line. This could potentially cause significant scour on this unnamed tributary channel.

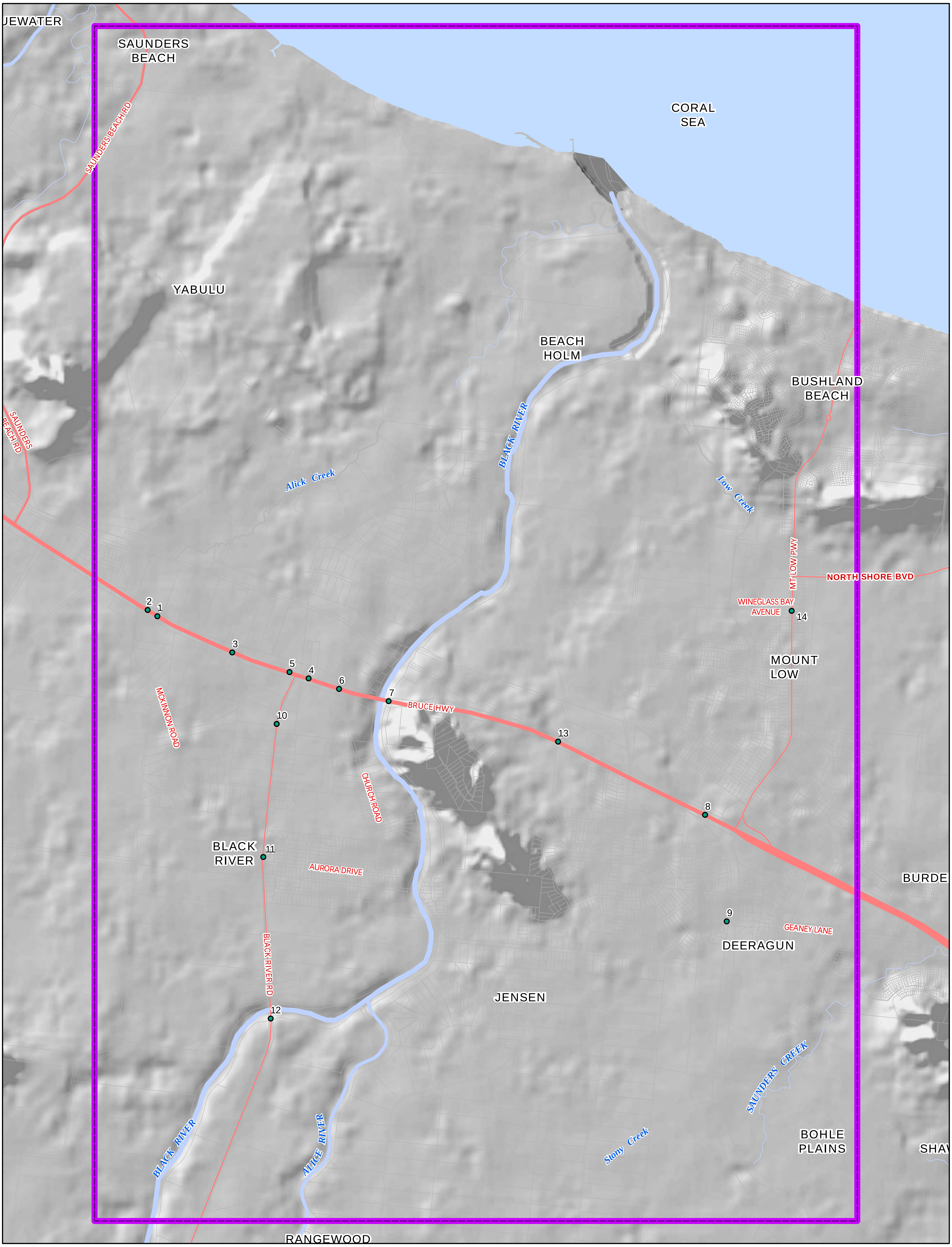
4.2 Major Arterial Roads

An indication of the estimated level of flooding for different flood events over important roadways within the area of interest is provided in Table 4-2. The location of the road crossings assessed is included in Figure 4-1.

Table 4-2 Water Depth over main roads at selected waterway crossings (m)

Location	Description	Event (Year ARI)							PMF
		2	5	10	20	50	100	500	
1	Bruce Highway at Alick Creek	-	-	-	-	-	-	0.1	0.4
2	Bruce Highway at Alick Creek overflow	-	-	-	0.1	0.1	0.1	0.2	0.3
3	Bruce Highway at Unnamed Tributary of Alick Creek	-	-	-	-	-	-	-	0.1
4	Bruce Highway at Unnamed Tributary of Alick Creek, East of Black River Road intersection	-	-	-	-	-	-	-	0.2
5	Bruce Highway at Unnamed Tributary of Alick Creek, West of Black River Road intersection	-	-	-	-	-	-	-	0.1
6	Bruce Highway at Unnamed Tributary of Alick Creek, West of Church Road intersection	-	-	-	-	-	-	-	1.3
7	Bruce Highway at the Black River Bridge	-	-	-	-	-	-	0.2	2.5
8	Bruce Highway adjacent to Michael Hooper Park	-	-	-	-	-	-	0.2	0.5
9	Geaney Lane near Stony Creek Crossing	-	-	-	-	-	0.2	0.5	1
10	Black River Road between McKinnon Road and the Bruce Highway	-	0.2	0.4	0.5	0.7	0.7	0.9	1.7
11	Black River Road North of the Aurora Drive intersection	-	-	0.1	0.1	0.2	0.3	0.5	0.7
12	Black River Road at the Black River Bridge	-	-	-	-	-	-	0.3	2.6
13	Bruce Highway at headwaters of Low Creek, East of the Black River Bridge	-	-	-	0.2	0.2	0.3	0.4	0.6
14	Mount Low Parkway Road at the intersection of Wineglass Bay Avenue	-	-	-	-	-	0.1	0.1	0.5

Note: It must be noted that for the purposes of the above table only water depths in excess of 0.1 m have been considered. This is due to the fact that rainfall is directly applied across the vast majority of the model extent and therefore water depths lower than this threshold can be attributed to the use of the rain-on-grid method rather than actual flooding.



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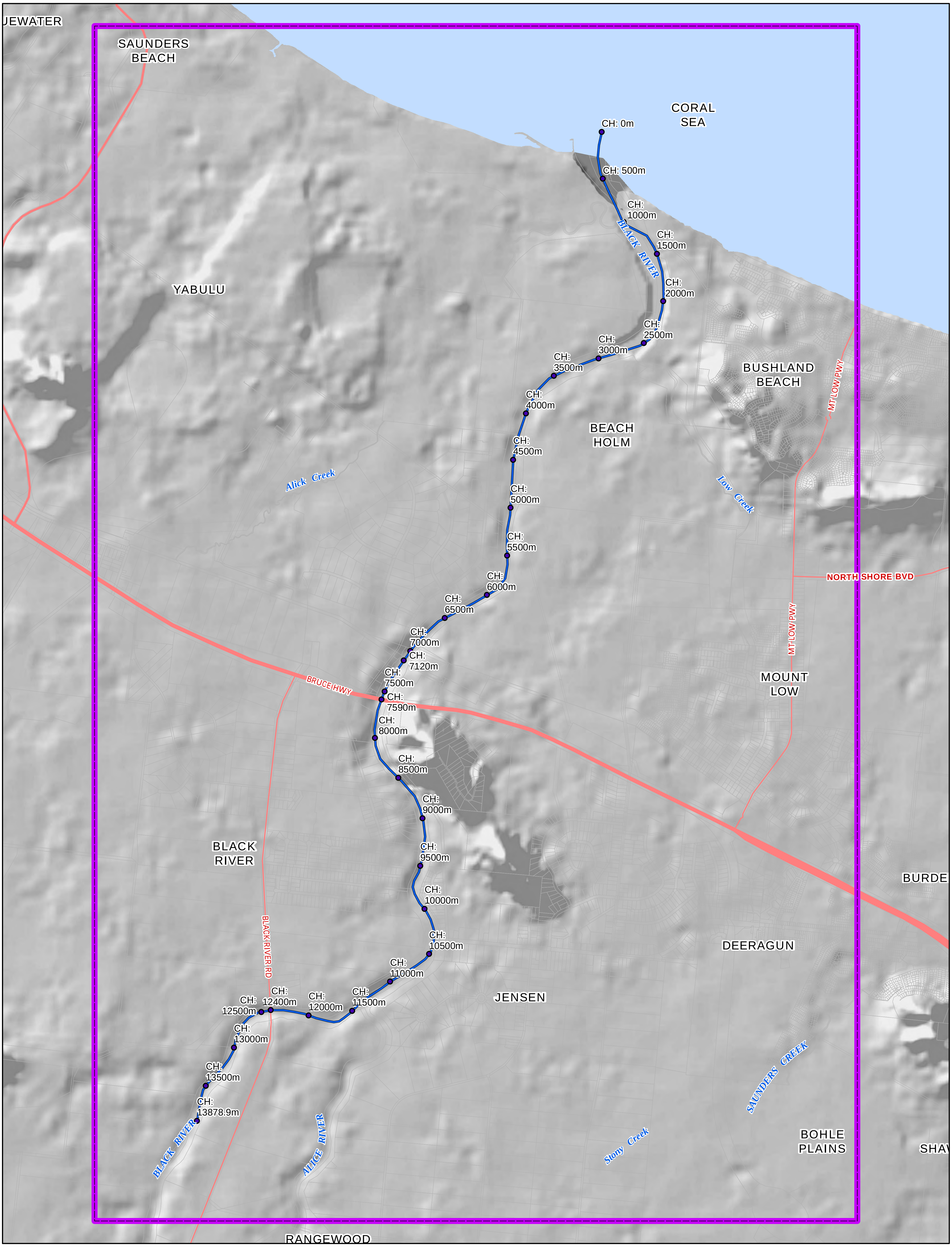
● Location of Waterway Crossings Assessed

BLACK RIVER FLOOD STUDY

Location of Flooding Affecting Major Arterial Roads
Figure 4-1

4.3 Hydraulic Grade Line

Results of the flood modelling have been used to derive hydraulic grade lines for the Black River. Long-sections showing these hydraulic grade lines are shown in Appendix C. Locations of the chainages are shown in Figure 4-2.



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- Chainage
- Black River Main Channel

BLACK RIVER FLOOD STUDY

Longitudinal Profile
Plan View
Figure 4-2

5.0 Conclusions and Recommendations

5.1 Conclusions

The following conclusions are drawn from this study:

- The XP-RAFTS and the MIKE FLOOD model developed for the Black River Flood Study were calibrated against the January 1998 storm event. Calibration results indicate a good fit in terms of peak values and timing of peak. Therefore, the models are suitable to assess the base case flooding behaviour within the Black River catchment.
- The Black River XP-RAFTS model was updated and refined to take into account changes in land use, river conditions and new developments.
- FFA of the annual peak discharge recorded at the Black River Bruce Highway stream gauge (117002A) using the Log-Pearson III technique estimated that the January 1998 storm represents a 100 Year ARI event.
- Design rainfall IFD comparison with the January 1998 rainfall data from Yabulu Refinery (032050), Yabulu (032157) and Bluewater (11703A) rainfall gauge indicated that the rainfall intensity for this event represent between 10 and 100-year ARI for 24 h duration. This implies that the rainfall intensity was not uniform spatially.
- The Rain-on-Grid method was used across the majority of the sub-catchments assessed with the more traditional source points method applied to represent local runoff across the rest of the model extent.
- The model parameters adopted for roughness are in line with those used in other studies undertaken as part of the City Wide Flood Constraints Project in the area.
- Due to the known highly dynamic nature of the Black River channel bed, it is recommended that hydrographic survey is carried out following a large flood event and the results used, in conjunction with the latest LiDAR for the area to update the hydraulic model.
- The critical durations adopted for all ARI events were 9 h and 24 h.
- The majority of the flow was found to be contained within the Black River main channel for events up to the 20-year ARI. A minor breakout occurred near the Bruce Highway and the Railway into the unnamed tributary parallel to the main channel during the 50-year ARI event; with more flow breaking out of the channel as the storm ARI increases.
- During the PMF storm event, significant break outs from the Black River into Low Creek and Alick Creek were evident.
- Various residential developments across the Black River, Jensen, Deeragun and Mount Low suburbs are built in close proximity to the Black River tributaries which causes inundation to some properties. Impacts on the actual buildings were not assessed as part of this study.
- In general, local roads have a low level of flood immunity with localised ponding and overtopping widely observed. On the other hand, major roads across the area are predicted to have much higher flood immunity.
- Velocity is generally low in flat residential areas, but may be as high as 1.5 m/s in steeper areas such as Bushland Beach for events up to the 100-year ARI.

5.2 Recommendations

The following recommendations are made as part of this study:

- The models should be revisited when revised LiDAR data is available in order to provide a more up-to-date representation of the topography across the study area.
- Undertake further local refinement of the model if a site specific assessment of flood risk is needed.
- Undertake a hydrographic survey of the Black River channel following a large storm event to understand the changes in ground levels resulting from the highly dynamic nature of the Black River channel.
- Explore opportunities or options to mitigate flood risk across the affected areas through the implementation of strategic large scale measures. This could include the use of flood mitigation measures at strategic locations and should be explored as part of an overall floodplain management strategy.

6.0 References

The following publications were used as references during the production of this study:

- AECOM (2012), "Deeragun Flood Study"
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- Institution of Engineers Australia (2011) "*Rainfall-on-Grid Modelling - a Decade of Practice"*
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- Maunsell McIntyeare Pty Ltd (2007) "*Lower Black river Flood Assessment*"
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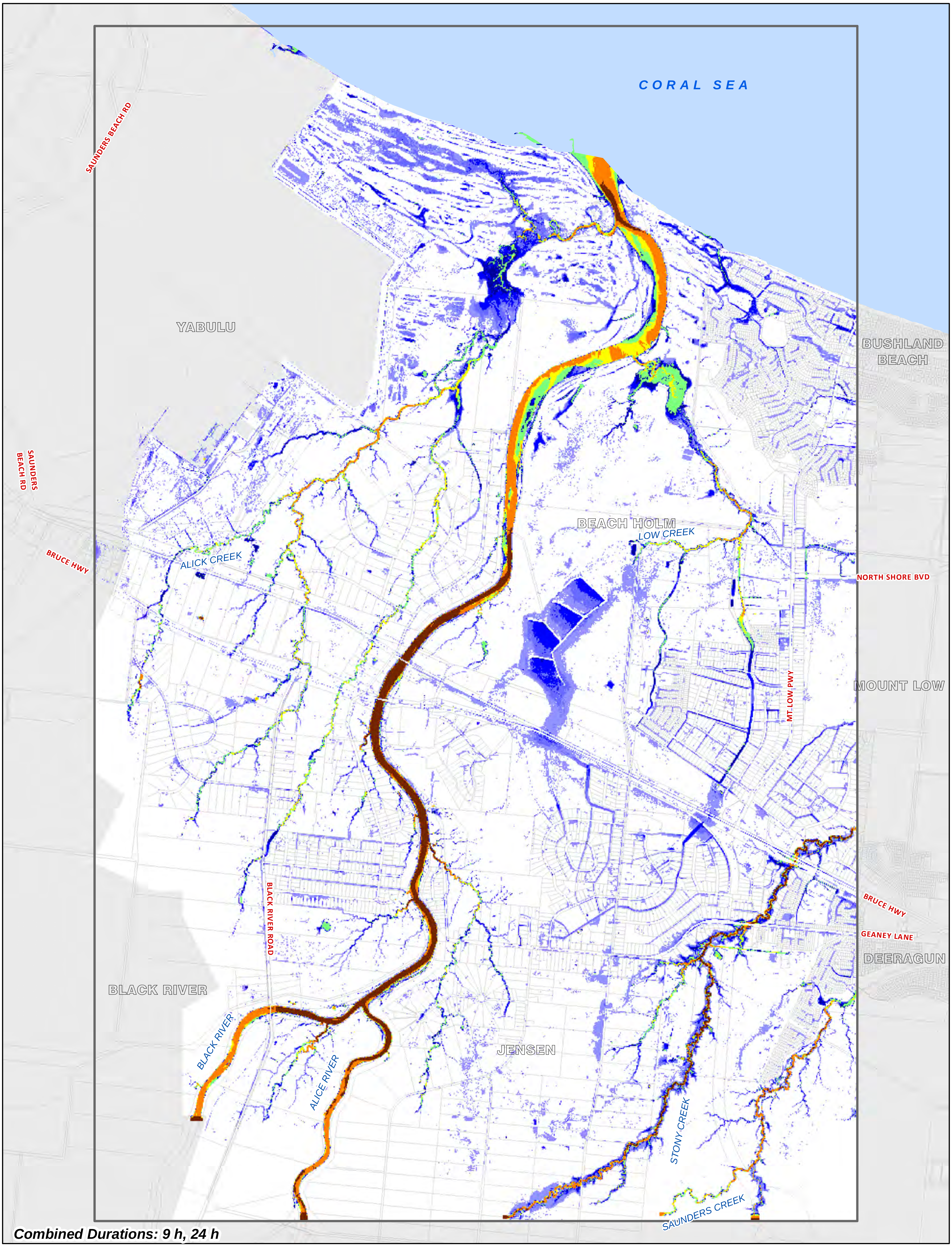
- WP Software (1994) "*RAFTS-XP User's Manual"*

Appendix A

Flood Maps



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Water Depths (m)

0.00 - 0.30
0.30 - 0.50
0.50 - 0.75
0.75 - 1.00
1.00 - 1.50
1.50 - 2.00
2.00 - 3.00
> 3.00

BLACK RIVER FLOOD STUDY

Maximum Water Depths
2 Year ARI
Base Case
Appendix A1

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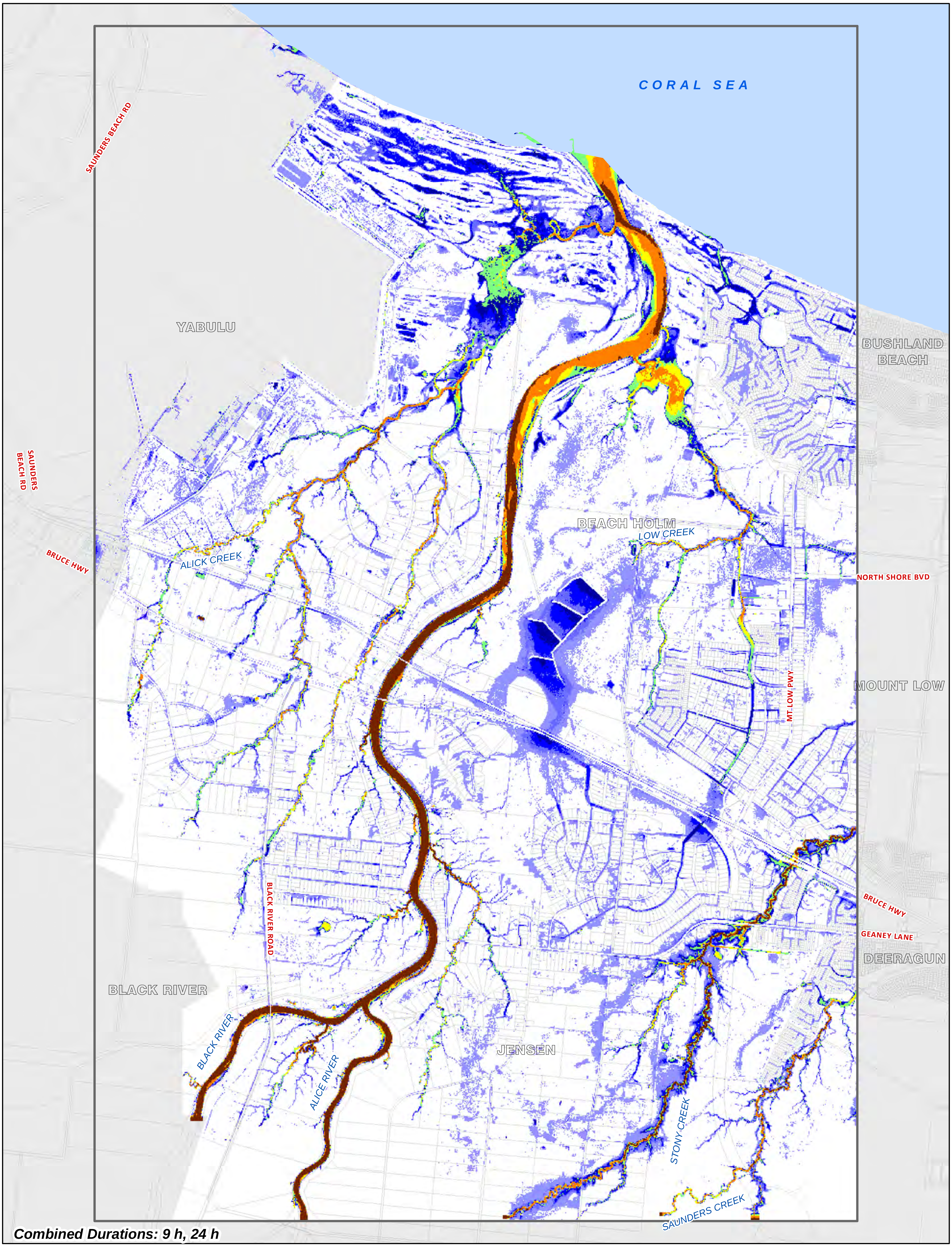

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N

Coordinate System: GDA 1994 MGA Zone 55

Base Data:
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Roads © 2013 (StreetPro Pitney Bowes)

Water Depths (m)

0.00 - 0.30
0.30 - 0.50
0.50 - 0.75
0.75 - 1.00
1.00 - 1.50
1.50 - 2.00
2.00 - 3.00
> 3.00

BLACK RIVER FLOOD STUDY

Maximum Water Depths
5 Year ARI
Base Case
Appendix A2