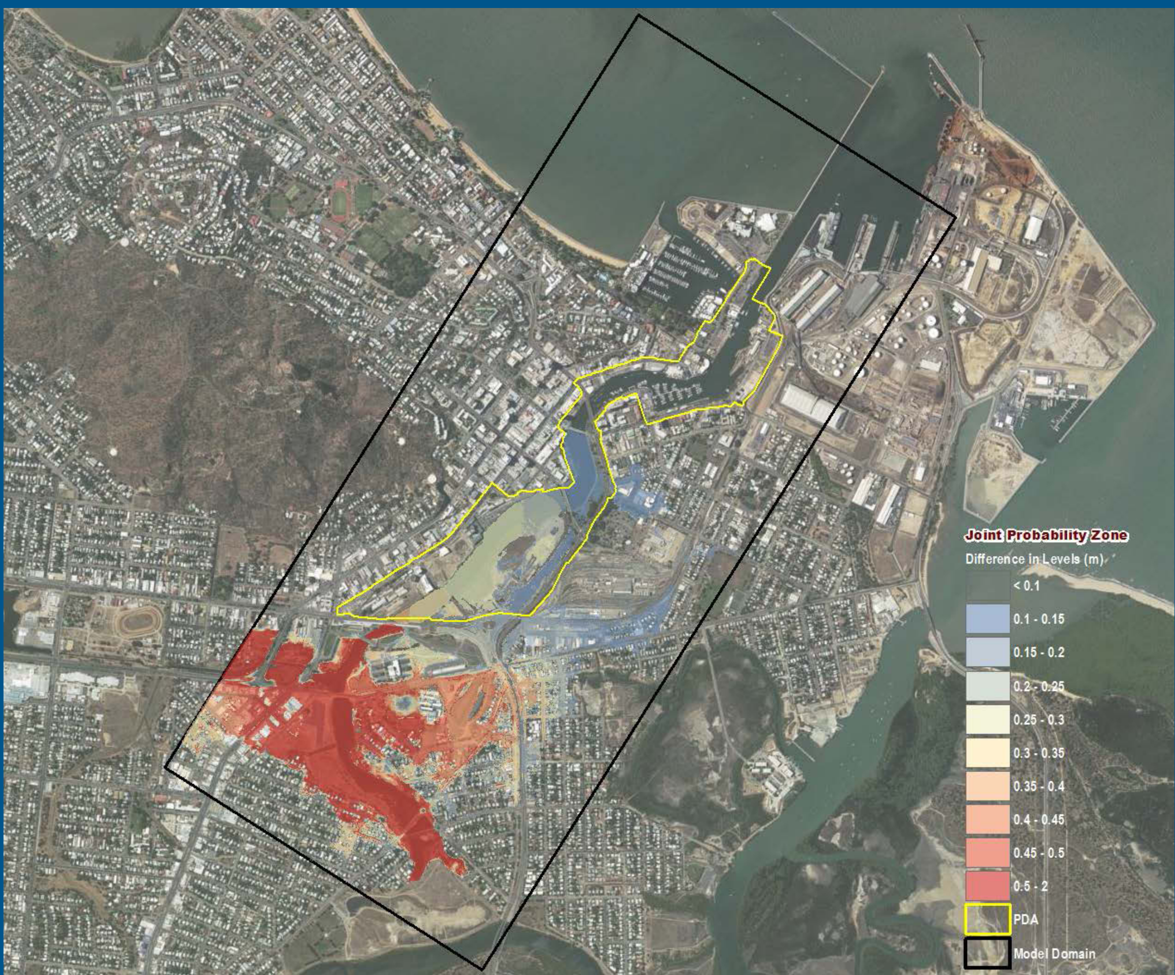
Townsville

TOWNSVILLE CITY COUNCIL

# CBD HYDRAULIC MODEL

MAY 2016




103 WALKER STREET, TOWNSVILLE QLD 4810 • PO BOX 1268, TOWNSVILLE QLD  4817

# Quality Information

### Prepared for:

Information

### Prepared by:

Manjur Murshed Zahid Ahmed

Document CBD Hydraulic Model

DW ID

Date

### Revision History

| Revision | Revision Date | Details | Authorised | |
|---|---|---|---|---|
| | | | Name/Position | Signature |
| A | 17/05/2016 | Draft for Review | Wesley Bailey Stormwater Drainage Planning Engineer | |
| B | 30/05/2016 | Final for Approval | Wesley Bailey Stormwater Drainage Planning Engineer | |

Townsville City Council
ABN 44 741 992 072
103 Walker Street
Townsville QLD 4810
PO BOX 1268
Townsville QLD 4810

Telephone: 4727 9000
Facsimile: 4727 9050
Email: enquiries@townsville.qld.gov.au

# Table of Contents


**Executive Summary** .......... **v**

**Glossary** .......... **vi**

**1.0 Introduction** .......... **1**

1.1 Overview .......... 1
1.2 Study Area .......... 1
1.3 Scope of Works .......... 3
1.4 Study Approach .......... 5

**2.0 Available Data** .......... **6**

2.1 Topographic and Bathymetric Data .......... 6
2.2 Structure Information .......... 6
2.3 Cyclone Yasi 2011 .......... 9
2.4 Aerial Photography .......... 9
2.5 Previous Flooding Reports .......... 9

**3.0 Hydrological Assessment** .......... **10**

3.1 Catchment Overview .......... 10
3.2 Hydrological Modelling Software .......... 11
3.3 Design Rainfall .......... 13
3.4 Rainfall Loss Values .......... 14
3.5 Hydrologic Results .......... 14

**4.0 Hydraulic Assessment** .......... **15**

4.1 Hydraulic Model Overview .......... 15
4.2 MIKE FLOOD .......... 15
4.3 Model Setup .......... 15
4.4 Model Calibration .......... 23
4.5 Model Verification .......... 30
4.6 Design Flood Assessment .......... 32

**5.0 Model Results** .......... **34**

5.1 Baseline Flooding Results .......... 34
5.2 Hydraulic Grade Line .......... 34
5.3 Flow Distributions .......... 38
5.4 Joint Probability of Coastal and Riverine Flooding .......... 40

**6.0 Summary and Conclusions** .......... **42**

**7.0 References** .......... **43**

**Appendix A – Sub-Catchments of CBD** .......... **A**

**Appendix B – Culvert and Bridge Details** .......... **B**

**Appendix C – Underground Drainage Details** .......... **C**

**Appendix D – Flood Maps** .......... **D**

**Appendix E – Hydraulic Gradelines**......................................................................E

**Appendix F – Peak Surface Flow Results** .................................................................F

# Executive Summary

This study has developed a detailed hydraulic model for Ross Creek and Central Business District (CBD) area of Townsville based on recent data. This hydraulic model is a three-way coupled MIKE FLOOD Model representing two-dimensional topography, one-dimensional structures and trunk underground drainage network.

This hydraulic model has the capability to run different storm scenarios in combination with storm tide and to determine the hydraulic design parameters for the new structures to be built under the implementation strategy of the Waterfront PDA.

Ross Creek is an urban tidal waterway. It extends about 5 km from close to the Ross River through the CBD of Townsville to Cleveland Bay and drains much of the urban area of Townsville. The hydraulic model is based on a 4 meter topographic rectangular grid and it covers an area of 8.9 km2 (4.6 kmX1.94 km).  This model has incorporated the latest floor level survey data captured between September 2014 and March 2015 and utilised existing hydrologic and hydraulic models to generate boundaries and source data. Aerial photography captured in 2015 has been used for assigning fraction pervious/impervious and hydraulic roughness in the Hydraulic Model.

The hydraulic model has been calibrated with the cyclone Yasi (2011) and the extreme storm event of January 1998. It has been verified with the head losses by comparing the MIKE FLOOD model results with the HEC-RAS model results. For this verification, the HEC-RAS models for all of the bridges were developed separately by representing the structure in detail level using HEC-RAS modelling software.

The simulation results of 100 Year ARI flood event for a range of storm durations from 1 hour to 72 hours show that the critical storm durations at the CBD area is 1 hour and in Ross Creek is 12 hours except at its mouth where critical duration is 1 hour.

Flood maps generated based on the model results have been used to quantify the floodplain hydraulic response with hydraulic grade lines and flow distributions. All of the hydraulic grade lines show head losses across the bridges. The maximum head losses have been found in Abandoned Railway Bridge 1 and 2. Flow distribution results show that peak flow through Woolcock Canal is 109 m3/s and flows at different sections of Ross Creek varies from 115 $m^3$/s (at upstream section) to 132 $m^3$/s (at downstream section) in 100 Year ARI flood event.

The hydraulic model has been applied to develop a joint probability zone for 1% AEP flood and storm tide events in Ross Creek area, where the magnitude of flooding is dependent on both coastal flooding and riverine (fluvial) flooding. The difference between the complete independence (the peak water level of the 1% AEP flood event or the 1% AEP storm tide level) and complete dependence (the peak water level from 1% AEP flood coincidence with 1% AEP storm tide level) results were evaluated with areas identified where the difference is above 0.1m identified as the *joint probability zone*. The present model does not cover sufficiently far enough upstream to identify the upstream extent of the join probability zone. The maximum difference between complete independence and complete dependence scenarios is in the order of 0.5 m to 0.7m is found at the upstream of Railway Bridge.

# Glossary

| | |
|---|---|
| AEP | Annual Exceedance Proability |
| AHD | Australian Height Datum |
| ARI | Average Recurrence Interval |
| AR&R | Australian Rainfall and Runoff |
| BoM | Bureau of Meteorology |
| CBD | Central Business District |
| CL | Continuous Loss of Rainfall in impervious/pervious layer |
| DEM | Digital Elevation Model |
| DERM | Department of Environment and Resource Management |
| DTMR | Department of Transport and Main Roads |
| GTSMR | Generalised Tropical Storm Method Revised – Methodology for estimating the PMP |
| HEC-RAS | 1D hydraulic modelling software |
| Hydraulic model | A model used for assessing flood levels and velocities from inflows and topography |
| Hydrologic model | A model used for assessing catchment outflows from rainfall and catchment conditions |
| IFD | Intensity–Frequency-Duration |
| IL | Initial Loss of Rainfall in impervious/pervious layer |
| LiDAR | Light Detection and Ranging (Aerial Laser Survey) |
| MHWS | Mean High Water Springs – the average height of the high waters of spring tides |
| MIKE11 | Fully dynamic 1D hydraulic model |
| MIKE21 | Fully dynamic 2D hydraulic model |
| MIKE FLOOD | Coupled 2D/1D hydraulic model combining MIKE11 and MIKE21 |
| PDA | Priority Development Area |

| | |
|---|---|
| PMF | Probable Maximum Flood |
| PMP | Probable Maximum Precipitation |
| RCBC | Reinforced Concrete Box Culvert |
| RCPC | Reinforced Concrete Pipe Culvert |
| TCC | Townsville City Council |
| TC Yasi | Tropical Cyclone Yasi |
| XP-RAFTS | An urban and rural runoff-routing hydrologic model |

# 1.0 Introduction

## 1.1 Overview

This study has developed a detailed hydraulic model for Ross Creek and Townsville Central Business District (CBD) area in order to support the land use and infrastructure planning of the Townsville City Waterfront Priority Development Area (PDA).

The Townsville City Waterfront PDA Development Scheme was adopted by the State Government on 23 October 2015. This project marked a major milestone in the future planning of Townsville's CBD with a clear focus on stimulating economic growth in the city heart.

The implementation strategy of the Waterfront PDA comprises major public works, parks and public realm and movement networks in waterfront promenade. This implementation strategy includes construction of waterfront promenade and public realm, pedestrian and cycle bridges, redevelopment of North Rail Yards site and associated infrastructure upgrades etc. through master planning process.

Considering the location of the Waterfront PDA, it is very important to have a hydraulic model, which has the capability to run the different storm scenarios in combination with storm tide and to determine the hydraulic design parameters for the new structures to be built under the implementation strategy of the Waterfront PDA.

## 1.2 Study Area

The study area, shown in **Figure 1-1**, covers Ross Creek and its surrounding area which includes the Waterfront PDA. The Ross Creek extends about 5 km from close to the Ross River through the CBD of Townsville to Cleveland Bay and drains much of the urban area of Townsville. In the study area, the magnitude of flooding is dependent of on both coastal flooding and riverine (fluvial) flooding. The water level at the lower reach of the study area varies due to the influence of tides and storm surges associated with cyclones and severe weather systems in the region. The water level at the upper reach of the study area is influenced by the tide and the stormwater runoff from the Ross Creek catchment. As this region is affected by two or more extremes is referred to as the joint probability zone, and the task of flood risk estimation in this zone is complicated due to the dependence of extreme events. In this study, a two-dimensional hydraulic model has been developed in order to estimate the flood levels in this joint-probability zone.

Ross Creek is an urban tidal waterway, which is a focal point for tourism, recreation and culture and commerce. Both sides of Ross Creek are highly urbanised: CBD is located on the left bank and residential and industrial areas on the right bank. The main tributary of Ross Creek is Woolcock Canal, which is controlled by Tide Gates near the confluence. There are seven bridges along Ross Creek within the study area.

Historically, Ross Creek was anabranch of the Ross River, forming Ross Island, consisting of Railway Estate and South Townsville. In the 1970s it was disconnected from Ross River by construction of Bicentennial Park.

Ross Creek drains the suburbs of:

- Cranbrook;
- Aitkenvale;
- Heatley (parts of);
- Vincent (parts of);
- Gulliver;
- Mundingburra;
- Mysterton;
- Pimlico;
- Currajong;
- Garbutt (parts of);
- West End (parts of);
- Hyde Park;
- Hermit Park;
- Railway Estate (parts of);
- Townsville City; and
- South Townsville (parts of).

The Woolcock Canal drains much of the upper catchment to Ross Creek. Only portions of Hermit Park, Railway Estate, West End, South Townsville and Townsville City drain directly to Ross Creek.

The tidal regime of Ross Creek is interrupted by a series of roads and causeways, which divide the creek into four basins:

Basin 1 - Cleveland Bay to Boundary Street causeway;
Basin 2 - Boundary Street causeway to Queens Road causeway;
Basin 3 - Queens Road causeway to Sandy Crossing causeway; and
Basin 4 - Sandy Crossing causeway to Bicentennial Park.

All basins are connected through a series of culverts.

## 1.3 Scope of Works

The scope of works for this study includes:

- reviewing of previous engineering reports and data;
- compilation and analysis of relevant data including rainfall, construction drawings, topographic survey and hydrographic survey;
- identification of a suitable approach for hydrologic and hydraulic modelling;
- development of hydraulic model capable of simulating different storm scenarios in combination with storm tide and to determine the hydraulic design parameters for the new structures to be built under the implementation strategy of the Waterfront PDA;
- calibration of the model with the cyclone induced storm tide levels (i.e. Cyclone Yasi, 2011) and the historical flood event of January 1998 (i.e. 500 Year ARI storm event);
- verification of the model with the head-losses across the seven existing bridges in Ross Creek;
- generation of the base-line flooding for design storms; and
- determination of the joint probability zone of Ross Creek .


# CBD HYDRAULIC MODEL Study Area

## Figure 1-1

## LEGEND

- PDA
- ModelDomain
- Suburbs

City of Townsville

SCALE: 1:20,000 @A3

300 150 0 300 600 Metres



Produced by:
STRATEGIC PLANNING
Planning and Development

DATE: dd/mm/yyyy

DATE PRINTED: 28/04/2016

DRAWN BY: ZZA

DIGITAL FILE: Figure1_StudyArea.mxd

## 1.4 Study Approach

The hydraulic model for CBD and Ross Creek PDA has been developed in a rectangular grid model with high grid resolution (4mX4m) in order to understand inundation from flooding and storm tide events in the CBD area as well as to assist the planning and design of PDA.

This hydraulic model is a three-way coupled MIKE Flood Model representing two-dimensional floodplain topography, one-dimensional structures and trunk underground drainage. This model has been calibrated to two representative historical events: Cyclone Yasi and January 1998 flood event.

The model has been verified with the head losses across the seven bridges within Ross Creek computed in HEC-RAS models.

The existing hydrological model has been used to represent the flood flows from the upper catchment draining into the study area. The “Rain on Grid” approach has been used to represent a majority of the local rain within the bounds of the hydraulic model.

The model has been applied to develop a joint probability zone for Ross Creek, where the magnitude of flooding is dependent on both coastal flooding and riverine (fluvial) flooding.

# 2.0 Available Data

## 2.1 Topographic and Bathymetric Data

An accurate representation of topography and bathymetry is a key to any hydrologic and hydraulic investigation. In this study, topographic and bathymetric data collected from different sources have been used for appropriate representation of topography and bathymetry of the study area. The main datasets and sources used in this study are as follows:

***Topographic data***

- LiDAR data having 1m resolution (captured around September/October 2009) obtained from a joint government agency project, with;
- Crest level data of roads obtained from Townsville City Council (TCC) database; and
- Floor level survey data (captured between September 2014 and March 2015) obtained from TCC database.

***Bathymetric Data***

- Underwater survey data of Ross Creek obtained from TCC database:
  - Ross Creek down to Inner Harbour; and
  - Inner Harbour to sea (Oct-Nov 2009);
- E Atlas JCU bathymetry gbr100

**Figure 2-1** shows the extent of the topographic and bathymetric datasets.

## 2.2 Structure Information

Hydraulic structures such as culverts and bridges are critical to flooding hydraulics and accurate representation is important in hydraulic modelling. In this study information on hydraulic structures have been collected from the following sources:

- Townsville City Council Database;
- Existing Ross Creek Flood Model; and
- Field investigation.

There are seven bridges in Ross Creek and four major culverts in Woolcock Canal.
The bridges are:

1. Denham Bridge/ George Roberts Bridge;
2. Victoria Bridge;
3. Lowths Bridge;

4. Abandoned Railway Bridge 1;
5. Abandoned Railway Bridge 2;
6. Railway Bridge; and
7. V8 Race Bridge.

The information on bridges & culverts and sub-surface drainage network used for model development are presented in **Appendix-B** and **Appendix-C** respectively. In MIKE FLOOD model, the Bridges and culverts were implemented through MIKE 11 modelling software and the sub-surface drainage network including manholes, inlets and outlets through MIKE URBAN.

# CBD HYDRAULIC MODEL Data

**Figure 2-1**

## LEGEND

ModelDomain

Harbour to Sea

RossCreek to Harbour

Road

**Buildings**

**LiDAR**

N

City of Townsville

SCALE: 1:20,000 @A3

300 150 0 300 600 Metres



Produced by:
STRATEGIC PLANNING
Planning and Development

DATE: dd/mm/yyyy

DATE PRINTED: 28/04/2016

DRAWN BY: ZZA

DIGITAL FILE: Figure2-1_Data.mxd

## 2.3 Cyclone Yasi 2011

Category 5 Tropical Cyclone Yasi (TC Yasi) made landfall during a falling tide on 3 February 2011 with the eye passing over the Mission Beach Region. As TC Yasi made landfall, a minimum central pressure of 929 hPa was recorded at Clump Point storm tide gauge (maintained by Department of Science, Information Technology and Innovation), with an estimated maximum wind gust of 285 km/h offshore. TC Yasi was 500 kilometres wide with an eye of 30 kilometres diameter and a recorded maximum sustained wind speed of 185 km/h, resulting in significantly damaging winds between Innisfail and Townsville.

The peak storm tide recorded at Cardwell was 4.504 m AHD (i.e. 6.36 m LAT) at 01:20 AEST and at Townsville was 2.634 m AHD at 08:20 AEST on 3 February 2011.

In this study, the storm tide data of TC Cyclone Yasi was obtained from the website of ‘Queensland Government data’ (https://data.qld.gov.au/dataset/townsville-tide-gauge-archived-interval-recordings).

## 2.4 Aerial Photography

Townsville City Council’s aerial photography captured in 2015 has been used for image classification in order to assign fraction pervious/impervious and hydraulic roughness in the Hydraulic Model.

## 2.5 Previous Flooding Reports

***Ross Creek Flood Study – Base Line Flooding Assessment (TCC, May 2013)***

Ross Creek Flood Study– Base Line Flooding Assessment completed in 2013 as a component of TCC under City Wide Flood Constraints Project. That study developed a detailed Hydraulic Model in a 10-m grid resolution for quantifying the flood risk on portions of the Townsville Floodplain that drains to Ross Creek. It covered all of the catchments of Ross Creek. The study developed MIKE FLOOD coupled two-dimensional/one-dimensional hydraulic model.

The present study has developed 4-meter grid resolution MIKE FLOOD coupled two-dimensional/one-dimensional hydraulic model covering only Ross Creek and its surrounding area including CBD. The open boundary inflows of this model have been obtained from the existing Ross Creek model results. The present study has also utilised the existing hydrologic model developed under Ross Creek Flood Study for generating catchment/sub-catchment flows.

# 3.0 Hydrological Assessment

## 3.1 Catchment Overview

The Ross Creek catchment is a highly urbanised catchment, draining much of the urban area of Townsville. With the exception of the southern slopes of Castle Hill, the Ross Creek catchment is very flat. The area of the Ross Creek catchment is approximately 26.1 $km^2$. There is high density commercial within the Central Business District (CBD). The creek drains to the Inner Harbour of the Port of Townsville.

The two primary tributaries for the catchment are the Mindham Park System and the Lakes System, which both drain into Woolcock Canal and ultimately Ross Creek.

The suburb of Cranbrook drains through Aitkenvale and into the Mindham Park System. The Mindham Park system also drains Mundingburra, parts of Gulliver, Mysterton, parts of Pimlico, Hermit Park and parts of Hyde Park.

The suburbs of Currajong, parts of Garbutt, parts of West End, parts of Gulliver, parts of Pimlico and parts of Hyde Park all generally drain directly to the Lakes.

Downstream of the confluence of Woolcock Canal and Ross Creek, portions of the suburbs of West End, Railway Estate and South Townsville drain to the Creek directly.

## 3.2 Hydrological Modelling Software

***XP-RAFTS***

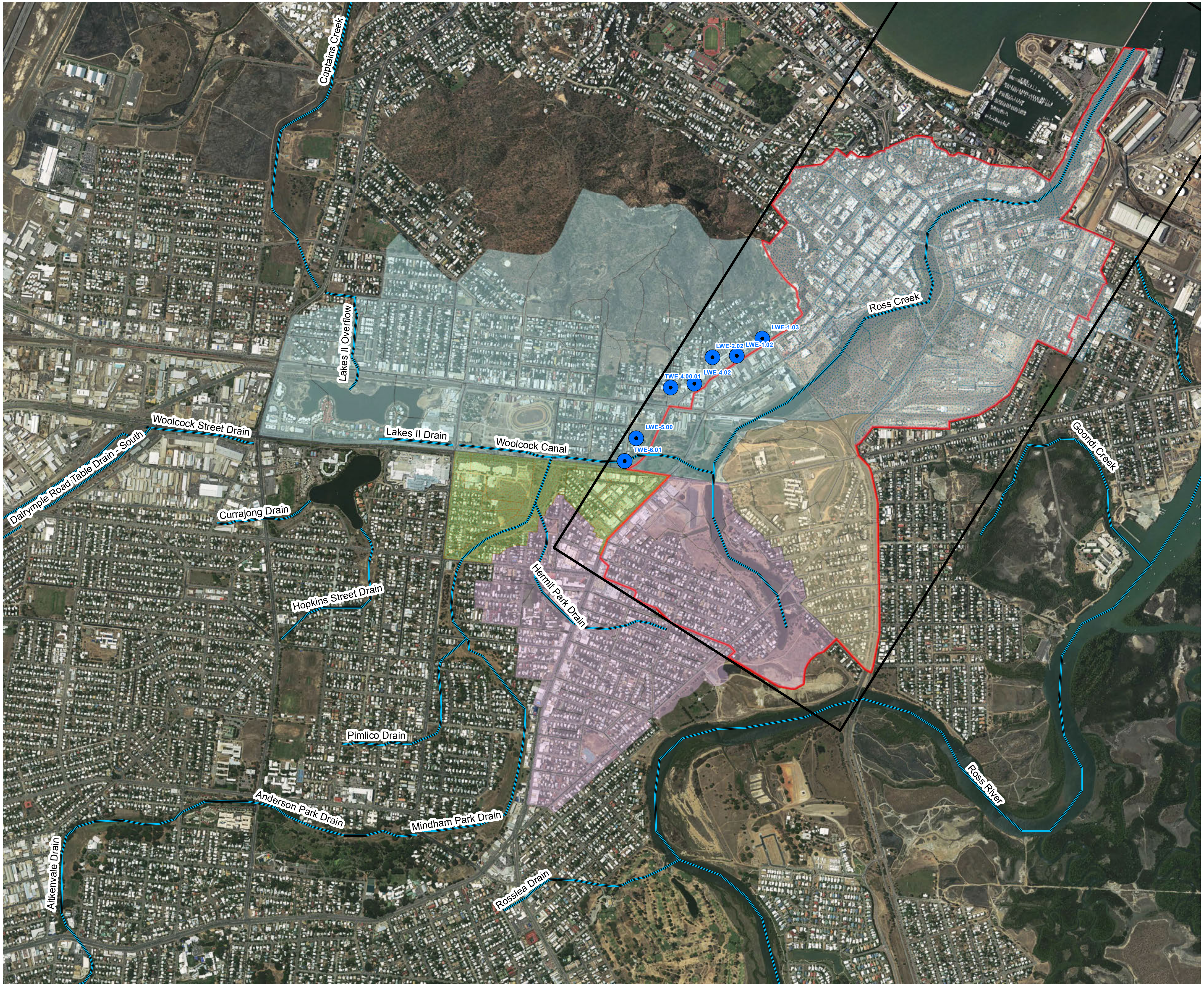
The hydrologic modelling software XP-RAFTS calculates catchment flows from rainfall based on Laurenson's non-linear routing method. The model is able to predict flows for catchments containing both urban and rural land uses accounting for surface roughness, catchment slope, soil infiltration and depression storage losses. It is well suited to the study area due to the need for detailed sub-catchment definition and representation of both rural and urban areas combined.

The existing XP-RAFTS model developed/applied in Ross Creek Flood Study has been used to generate flows at the source points in the hydraulic model. A detailed description on the sub-catchment parameters can be found in the Ross Creek Flood Study report.

***"Rain on Grid" Approach***

The "Rain on Grid" approach has been used in this study. It involves directly applying rainfall excess to the two-dimensional grid of the MIKE Hydraulic Model. Rainfall excess is the rainfall less initial and continuing losses associated with surface depression storage and infiltration.

**Figure 3-1** shows an overview of a part of Ross Creek sub-catchments around the area of interest, the tributaries of Ross Creek and the source points applied in the model. The source points represent the sub-catchments' flow of the south-eastern part of Castle Hill under West End suburb outside the rain-on-grid. A detailed description of parameters of the highlighted sub-catchments is provided in **Appendix A**.




**CBD**
**FLOOD STUDY**
**Sub-catchments**

**Figure 3-1**

## LEGEND

- ModelDomain
- Applied Sources
- Drains/Tributaries
- West End
- City
- Hyde Park
- Harmit Park
- Harmit Park
- Railway Estate
- CBD_RainOnGrid

N

City of Townsville

SCALE: 1:20,000 @A3

300 150 0 300 600 Metres




Produced by:
STRATEGIC PLANNING
Planning and Development

DATE: dd/mm/yyyy
DATE PRINTED: 27/04/2016
DRAWN BY: ZZA
DIGITAL FILE: Figure3-1_Sub-catchments.mxd

## 3.3 Design Rainfall

The design rainfall for Ross Creek catchment was developed under Ross Creek Flood Study from the Intensity Frequency Duration (IFD) methods outlined in Australian Rainfall and Runoff (1998) using catchment specific IFD input parameters. The IFD input parameters, adopted in this study, have been provided in **Table 3-1**. The resulting IFD rainfall intensities for the study area are provided in **Table 3-2**.

**Table 3-1 CBD IFD Input Data**

| Parameter | Value |
|---|---|
| Latitude | 19.322 Deg S |
| Longitude | 146.765 Deg E |
| 2 Year, 1 Hour Intensity | 53.82 mm/h |
| 2 Year, 12 Hour Intensity | 11.92 mm/h |
| 2 Year, 72 Hour Intensity | 3.87 mm/h |
| 50 Year, 1 Hour Intensity | 110.12 mm/h |
| 50 Year, 12 Hour Intensity | 24.8 mm/h |
| 50 Year, 72 Hour Intensity | 9.48 mm/h |
| Skewness (G) | 0.05 |
| Geographical Factor (F2) | 3.93 |
| Geographical Factor (F50) | 17.08 |

**Table 3-2 CBD IFD Rainfall Data**

| Storm Duration | Rainfall Intensity (mm/h) for Given ARI | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1Y | 2Y | 5Y | 10Y | 20Y | 50Y | 100Y | 200Y | 500Y |
| **5 min** | 115.47 | 149.70 | 195.51 | 222.87 | 258.76 | 306.49 | 343.23 | 381.04 | 432.56 |
| **6 min** | 109.14 | 141.51 | 184.87 | 210.78 | 244.75 | 289.94 | 324.73 | 360.53 | 409.33 |
| **10 min** | 91.54 | 118.73 | 155.26 | 177.10 | 205.74 | 243.84 | 273.19 | 303.40 | 344.58 |
| **15 min** | 78.22 | 101.49 | 132.83 | 151.59 | 176.16 | 208.87 | 234.08 | 260.03 | 295.42 |
| **20 min** | 69.33 | 89.98 | 117.84 | 134.53 | 156.38 | 185.48 | 207.91 | 231.00 | 262.51 |
| **30 min** | 57.81 | 75.05 | 98.39 | 112.38 | 130.69 | 155.09 | 173.90 | 193.28 | 219.72 |
| **45 min** | 47.64 | 61.87 | 81.19 | 92.79 | 107.96 | 128.18 | 143.78 | 159.85 | 181.79 |
| **1 hour** | 41.28 | 53.64 | 70.44 | 80.54 | 93.74 | 111.34 | 124.92 | 138.91 | 158.02 |
| **1.5 hour** | 32.48 | 42.21 | 55.50 | 63.49 | 73.93 | 87.85 | 98.61 | 109.69 | 124.83 |
| **2 hour** | 27.30 | 35.49 | 46.69 | 53.44 | 62.25 | 74.01 | 83.08 | 92.45 | 105.24 |
| **3 hour** | 21.31 | 27.71 | 36.51 | 41.80 | 48.72 | 57.95 | 65.09 | 72.45 | 82.51 |
| **4.5 hour** | 16.61 | 21.62 | 28.51 | 32.66 | 38.09 | 45.33 | 50.93 | 56.71 | 64.61 |
| **6 hour** | 13.93 | 18.13 | 23.92 | 27.42 | 31.99 | 38.09 | 42.80 | 47.67 | 54.33 |
| **9 hour** | 10.87 | 14.15 | 18.70 | 21.45 | 25.03 | 29.82 | 33.53 | 37.35 | 42.59 |
| **12 hour** | 9.12 | 11.88 | 15.71 | 18.03 | 21.04 | 25.08 | 28.20 | 31.43 | 35.85 |
| **18 hour** | 7.14 | 9.35 | 12.54 | 14.50 | 17.04 | 20.45 | 23.11 | 25.87 | 29.66 |
| **24 hour** | 5.99 | 7.87 | 10.67 | 12.41 | 14.64 | 17.66 | 20.03 | 22.49 | 25.88 |
| **30 hour** | 5.21 | 6.87 | 9.39 | 10.96 | 12.99 | 15.73 | 17.88 | 20.13 | 23.24 |
| **36 hour** | 4.64 | 6.14 | 8.44 | 9.89 | 11.75 | 14.28 | 16.27 | 18.36 | 21.24 |
| **48 hour** | 3.84 | 5.10 | 7.09 | 8.36 | 9.98 | 12.19 | 13.95 | 15.79 | 18.35 |
| **72 hour** | 2.89 | 3.85 | 5.45 | 6.48 | 7.80 | 9.61 | 11.05 | 12.57 | 14.70 |

***Probable Maximum Precipitation***
Estimates of the Probable Maximum Precipitation (PMP) have been made for a range of storm durations. The Generalised Short Duration Method (GSDM) has been used for storm events up to 6 hours, while the Generalised Tropical Storm Method - Revised (GTSMR) has been used for storm events longer than 24 hours.

## 3.4 Rainfall Loss Values

Rainfall loss values for the design events have been adopted from the Ross Creek Flood Study. It was determined based on the model calibration. A summary of the loss values is as follows:

- Impervious – 1 mm IL and 0 mm CL;
- Pervious – 25 mm IL and 2.5 mm CL.

## 3.5 Hydrologic Results

Although the rainfall within the bounds of the hydraulic model has been represented with the “Rain on Grid”, the local/ total sub-catchment flows from the portion of West End catchments have been generated using the existing XP-RAFTS model and incorporated in the MIKE Hydraulic Model as sources. The hydrologic model results at these sources are presented in **Table 3-3**.

**Table 3-3 XP-RAFTS Design Flood Flows**

| Suburb | Sub-catchment/ Source ID | Peak Flood Flows (m3/s) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2Y | 5Y | 10Y | 20Y | 50Y | 100Y | 200Y | 500Y | PMF |
| West End | LWE-1.02 | 1.9 | 3.4 | 4.3 | 5.5 | 6.9 | 8.0 | 9.0 | 10.3 | 25.4 |
| | LWE-1.03 | 2.0 | 3.5 | 4.4 | 5.5 | 6.9 | 8.0 | 8.9 | 10.2 | 25.6 |
| | LWE-2.02 | 0.8 | 1.1 | 1.3 | 1.6 | 1.9 | 2.1 | 2.4 | 2.8 | 5.2 |
| | LWE-4.02 | 1.7 | 2.4 | 2.8 | 3.4 | 4.1 | 4.7 | 5.3 | 6.2 | 12.4 |
| | LWE-5.00 | 0.4 | 0.7 | 0.9 | 1.2 | 1.5 | 1.8 | 2.1 | 2.5 | 6.6 |
| | TWE-4.00.01 | 1.4 | 2.6 | 3.2 | 4.1 | 4.9 | 5.7 | 6.4 | 7.4 | 18.3 |
| | TWE-6.01 | 1.7 | 3.2 | 4.0 | 5.2 | 6.7 | 7.9 | 9.1 | 10.7 | 25.3 |

# 4.0 Hydraulic Assessment

## 4.1 Hydraulic Model Overview

In this study, a two-dimensional hydraulic model has been developed using MIKE FLOOD modelling system. It has been calibrated with the cyclone Yasi, 2011 and verified with the head-losses across the bridges in Ross Creek. So, that it can be applied for determining the hydraulic design parameters for new structures to be built under the Waterfront PDA implementation strategy and for estimating the flood levels in the joint-probability zone of Ross Creek area.

## 4.2 MIKE FLOOD

MIKE FLOOD is a dynamically linked 3-way hydraulic modelling package, which couples the 1D river hydraulics model, MIKE11 and the 1D sub-surface drainage model, MIKE URBAN with the 2D hydrodynamic model in MIKE21. MIKE FLOOD can be used to simulate:

- coincident river and storm surge flooding in coastal areas;
- the detailed flooding patterns on floodplains in terms of flow velocities and water levels;
- water exchange between channels, canals, sub-surface drainage and adjacent floodplains, ponds, reservoirs, etc.; and
- flood waves in channels and on flood plains associated with a dam failure.

The hydrodynamic model in the MIKE 21 Flow Model (MIKE 21 HD) simulates unsteady two-dimensional flows in one layer (vertically homogeneous) fluids using the conservation of mass and momentum equations. The momentum equation includes bottom shear stress, wind shear stress, barometric pressure gradients, Coriolis force, momentum dispersion, sources and sinks, evaporation, flooding and drying and wave radiation stresses. It also adequately represents the complex 2D hydraulics of the floodplain. The MIKE11 1D component of the MIKE Hydraulic Model has been used to provide a more accurate representation of the hydraulics of structures such as bridges and culverts. The MIKE URBAN 1D component of the MIKE Hydraulic Model has been used to represent sub-surface drainage that has the potential to impact on flood levels. Sub-surface drainage generally larger than or equal to the equivalent waterway area of 900 mm diameter pipe has been considered to have the potential to impact on flood levels.

## 4.3 Model Setup

***Topographic Grid***
The MIKE Hydraulic Model developed for Ross Creek and CBD area is based on a 4 meter topographic rectangular grid and it covers an area of 8.9 km$^2$ (4.6 kmX1.94 km). The model set-up is shown in **Figure 4-1**. The topographic grid for the flood plains of

Ross Creek is based on the LiDAR data of 2009 and it has been updated with the floor level and road/street level data. The bathymetry of the Ross Creek is based on underwater survey data obtained from the TCC database.

***Boundary Conditions***

There are nine open boundaries in the CBD Hydraulic Model, where inflow time-series have been assigned at the western boundaries and Mean High Water Spring (MHWS) water level (i.e. 1.254 m AHD) has been applied at the downstream boundaries at Cleveland Bay for the design flood events. The time-series inflow boundaries were extracted from the existing result files of Ross Creek Flood Study for all of the design events. The locations of the model boundaries are shown in the **Figure 4-1**.

***Rain on Grid***

The application of rainfall excess directly to the MIKE FLOOD 2D grid is limited to flat portions of the study area to ensure model stability. The extent of the “Rain on Grid” area is shown in the **Figure 4-1**. The rainfall excess has been applied in the MIKE FLOOD 2D grid with a spatial distribution representing the impervious areas within study area. The impervious areas have been identified from a detailed review of aerial photography and zoning information. The spatial distribution of impervious areas is shown in **Figure 4-2**.

In this study the rainfall loss values determined in the Ross Creek Flood Study have been applied. These are:

- initial loss - 25mm; and
- continuing loss 2.5 mm/h.

The design rainfall applied using “Rain on Grid” is provided in **Section 3.3**.

***Source Points***

Inflows from the surrounding sub-catchments outside “Rain on Grid” area and not considered in inflow boundaries have been included in MIKE Flood Model as sources (shown in **Figure 4-1**). The existing XP-RAFTS model has been run for different design storms in order to obtain the flows at different source points.

# CBD HYDRAULIC MODEL
## Model Set-up

**Figure 4-1**

## LEGEND

- MU Manholes
- MU Pipes
- M11 Bridge/Culvert
- M21_RainOnGrid
- M21 Sources
- M21 Boundaries
- ModelDomain

N

City of Townsville

SCALE: 1:20,000 @A3

300 150 0 300 600 Metres



Produced by:
STRATEGIC PLANNING
Planning and Development

DATE: dd/mm/yyyy

DATE PRINTED: 28/04/2016

DRAWN BY: ZZA

DIGITAL FILE: Figure4-1_ModelSetup.mxd

# CBD HYDRAULIC MODEL Fraction Impervious

**Figure 4-2**

## LEGEND

**Pervious/Impervious**

- Impervious
- Pervious
- *Model Domain*

N

City of Townsville

SCALE: 1:15,000 @A3

200 100 0 200 400 Metres




Produced by:
STRATEGIC PLANNING
Planning and Development

DATE: dd/mm/yyyy

DATE PRINTED: 28/04/2016

DRAWN BY: ZZA

DIGITAL FILE: Figure4-2_FractionImpervious.mxd

### *Hydraulic Structures*

All of the hydraulic structures built on Ross Creek and Woolcock Canal have been represented as one-dimensional elements in the model by either:

- representing the structure as an implicit coupled structure;
- representing the structure as an explicit coupled structure; or
- representing the structure within a 1-dimensional branch that was laterally coupled immediately upstream and downstream of the structure.

The main hydraulic structures represented in the model include:

- Denham Bridge;
- Victoria Bridge;
- Lowths Bridge (represented as culvert);
- Railway Abandoned Bridge 1;
- Railway Abandoned Bridge 2;
- Railway Bridge;
- V8 Race Bridge;
- Two culverts in Woolcock Canal on Charters Towers Road having tide gates;
- Two culverts in Woolcock Canal on Stuart Street;
- One culvert at Boundary Street; and
- One culvert at Queens Road.

The tide gates are kept open during storm event to allow the runoff water to drain through the culverts. During cyclonic event these tide gates are kept closed to stop the storm tide travelling inland through the culverts.

Details of the culverts and bridges represented within the CBD Hydraulic Model are provided in **Appendix B**.

### *Underground Drainage*

Components of the underground drainage network that have potential to impact on surface flood levels have been represented using the MIKE URBAN component of the MIKE Flood Model. Following an assessment of the conveyance within a typical street cross-section, with typical grades experienced in Townsville, it was identified that underground drainage with a cross-sectional area equal to a 900mm diameter pipe or greater was able to impact flood levels within the street cross-section by 10mm or greater. Generally only sections of the underground drainage, where the pipe cross-sectional area is greater than the equivalent of a 900mm pipe have been represented.

**Figure 4-1** shows the general layout of the underground drainage network represented in the MIKE Hydraulic Model. Recently completed drainage works of Stanley Street have been incorporated in the underground drainage network. Few outlets of the underground drainage network are controlled by Tideflex. The Tideflex valves are implemented by incorporating “head-loss vs flow” relationship for the relevant diameter pipe. Details of the underground drainage network and Tideflex represented in the MIKE Flood Model are provided in **Appendix C**. Information to specify levels and dimensions of the network have been sourced from the existing Council’s corporate GIS database and Ross Creek Flood Model and field investigation.

### *Hydraulic Roughness*

In this study recent aerial photography (2015), floor level data (surveyed in 2015), land-use data, and site assessment have been analysed and represented in the model as hydraulic roughness. The hydraulic roughness within the model is specified as Manning's 'M' values, which is reciprocal of Manning's 'n'. All of the 'M' values have been determined based on the past studies and literature review and finalised during the model calibration process. The roughness distribution map adopted within the MIKE21 component of the MIKE Flood Model are shown in **Figure 4-3**. The specific roughness values adopted for different land-use are detailed in Table 4.1.

**Table 4-1 Adopted Roughness Values in MIKE 21 Model**

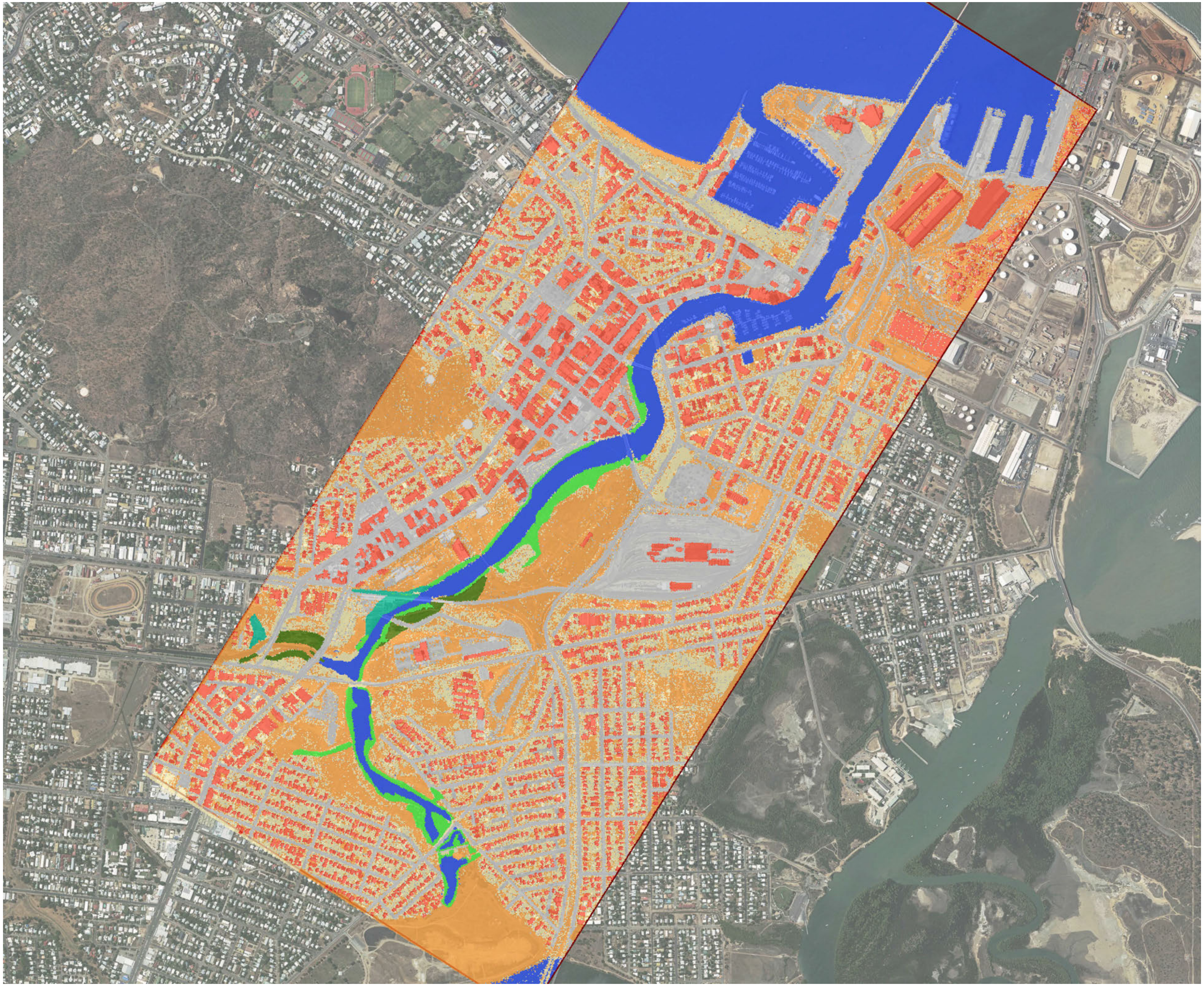
| *Land-use* | *Roughness* | |
|---|---|---|
| | *Manning's 'M'* | *Manning's 'n'* |
| Buildings (data obtained from floor level survey, 2015) | 3.3 | 0.300 |
| Roads and carparks in CBD area, Railway Yard in Railway Estate, Developed area at the Port of Townsville and Roads. | 50.0 | 0.020 |
| Flood plains having cleared land with tree stumps (no sprouts) | 33.0 | 0.030 |
| Garden, Backyards and Green Fields with trees | 25.0 | 0.040 |
| Ross Creek, Marina and Cleveland Bay | 40.0 | 0.025 |
| Woolcock Canal | 33.0 | 0.030 |
| Mangrove trees along the banks of Ross Creek | 12.5 | 0.080 |
| Floodplains having green fields with mangrove trees | 14.0 | 0.071 |

The Manning's 'M' value for Buildings is based on the investigation carried out under Australian Rainfall and Runoff, Revision Project 15: Two Dimensional Simulations in Urban Areas- Representation of Buildings in 2D Numerical Hydraulic Models, February 2012.

Higher roughness (i.e. 'M'= 10) is considered on the left hand side of the Railway bridge and at the flow path of one of the sources defined in the model (i.e. LWE-5.00) in order to stabilise the overland flow coming to Ross Creek and Woolcock Canal respectively.

### *Eddy Viscosity*

The eddy viscosity parameter describes the degree of turbulence that exists at scales smaller than the model grid scale of 4m. Turbulence on the horizontal plan with a scale larger than 4m can be represented by flows in the model from one grid cell to the next. In this study eddy viscosity has been considered 2 for floodplain, 2.1 for Ross Creek and Cleveland Bay and 4 for Woolcock Canal during model calibration process.



# CBD HYDRAULIC MODEL MIKE 21 Roughness

**Figure 4-3**

## LEGEND

**Mannings 'M'**

- 3.33
- 10
- 12.5
- 14
- 25
- 33
- 40
- 50

N

City of Townsville

SCALE: 1:15,000 @A3

200 100 0 200 400 Metres



Produced by:
STRATEGIC PLANNING
Planning and Development

DATE: dd/mm/yyyy

DATE PRINTED: 1/06/2016

DRAWN BY: ZZA

DIGITAL FILE: Figure4-3_Roughness.mxd

### *Flow Couples*

Several types of coupling can be used to simultaneously represent 2D floodplain flows (based on MIKE 21 model) with, 1D channel flows (based on MIKE 11 model) and 1D pipe flows (based on MIKE URBAN model) and also for transferring flow between models. The following is a general description of the couple types adopted within the MIKE Hydraulic Model setup:

- *Standard Couple* – representing flow transfer between MIKE21 and MIKE11 where one or more MIKE21 cells are linked to the end of a MIKE11 branch (either upstream or downstream end). This type of couple is useful for connecting a detailed MIKE21 grid into a broader MIKE 11 network, or to connect an internal MIKE11 branch/structure (with an extent of more than a grid cell) inside the MIKE 21 grid.
- *Lateral Couple* – representing flow transfer between MIKE21 and MIKE11 where a string of MIKE21 cells are laterally linked to MIKE11 for either a section of a branch or an entire branch. This type of couple is useful for simulating overflow from a channel onto a flood plain.
- *Structure Couple* – representing flow transfer between MIKE21 and MIKE11 where a structure is represented in MIKE11. The structure couple takes the flow terms from a structure in MIKE11 and inserts them directly into the momentum equations of MIKE21.
- *Zero Flow Couple* – prevent flow through a series of MIKE21 cells. These zero flow couples have been used in conjunction with standard couples, when the standard couples are used for structure branches. These couples ensure all flow travels through the MIKE11 branch.
- *River / Urban Couple* – representing flow transfer between MIKE11 and MIKE URBAN where a chainage in MIKE11 and a Node in MIKE URBAN are linked. This kind of couple is used for representing outlets from the underground drainage network. Flow can travel both ways through this couple depending on the head difference in MIKE11 and MIKE URBAN.
- *Urban Outlet Couple* – representing flow transfer between MIKE21 and MIKE URBAN where a MIKE21 cell and a Node in MIKE URBAN are linked. This kind of couple is used for representing outlets from the underground drainage network. Flow can travel both ways through this couple depending on the head difference in MIKE21 and MIKE URBAN.
- *Urban Inlet Couple* – representing flow transfer between MIKE21 and MIKE URBAN where a MIKE21 cell and a Node in MIKE URBAN are linked. This kind of couple is used for representing inlets to the underground drainage network. Flow can travel both ways through this couple depending on the head difference in MIKE21 and MIKE URBAN.

The MIKE Hydraulic Model has a total 312 couples comprising:

- 22 standard couples;
- 4 structure couples;
- 10 zero flow couples; and
- 276 urban inlet/Manhole/outlet couples.

## 4.4 Model Calibration

The MIKE Flood Model of CBD has been calibrated to two representative historical events on the following basis:

- **Cyclone Yasi** – was a category 5 Tropical Cyclone Yasi. The recorded peak storm tide at Townsville was 2.634 m AHD, which is higher than 100 Year ARI (or 1% Annual Exceedance Probability) storm tide level (i.e. 2.6 m AHD); and
- **January 1998** – was a large flood event resulting from rainfall directly on the local catchment and a large peak water level data set was obtained.

Specific details of the calibration for each event are provided in the sections below.

***Cyclone Yasi***

A brief description on cyclone Yasi has been provided at Section 2.3. The CBD Hydraulic Model was run for 12 hours from 7:00 PM, 2 Feb 2011 to 7:00 PM, 3 Feb 2011 to include the cyclone induced storm surge and compared the model result with the measured storm tide levels obtained from the TCC database. **Figure 4-4** shows the comparison locations in red board pins, where two observations are in Ross Creek and rest are on the land.

For this simulation, the storm tide data at Townsville harbour and Rooney’s Bridge were obtained from the website of “Queensland Government Data” and TARDIS respectively. The storm tide data of Townsville harbour was applied at the downstream boundaries and Rooney’s Bridge data at the eastern boundaries by adjusting levels. In case of downstream boundaries the storm tide level was increased by 0.2m and at eastern boundaries the level was decreased by 0.36 m based on the sensitivity analysis.

In the model run, it was assumed that all of the tidal gates in Woolcock canal were closed during cyclone Yasi. There is a culvert in the boundary street causeway. It was also assumed that the culvert was blocked by 33% during cyclone.

No rain was applied in the model as there was no significant rain in Ross Creek catchment during the cyclone period. Intensity-Frequency-Duration (IFD) Chart of rainfall in TARDIS shows that the rainfall intensities (mm/h) are less than or equal to 1 Year ARI at Castle Hill, Mysterton, South Townsville, Townsville Airport and Aplin Weir rainfall gauge stations and less than 2 Year ARI at Rooney’s Bridge and Kirwan rainfall gauge stations (between 6 to 24 hours durations). **Figure 4-5** shows the IFD chart of rainfall at Kirwan rainfall gauge station during the period of cyclone Yasi.

**Figure 4-6** shows the storm tide comparison results in Ross Creek for a location adjacent to tide gates in Woolcock Canal and another location near the Queens Road causeway. In the figures the continuous lines represent simulated storm tide levels and the dashed lines represent surveyed peak storm tide levels. The comparison result in **Figure 4-6** shows very good agreement at the tide gate location, where simulated and measured storm tide levels are almost same, i.e. 2.75 m AHD. Near the Queens Road, the simulated level is found to be 2.14 m AHD, which is about 0.12m lower than the observed level (i.e. 2.254 m AHD).


**CBD HYDRAULIC MODEL**

**Cyclone Yasi 2011**
**Comparison Locations**
**Figure 4-4**

**LEGEND**

Comparison Point
Model Domain
M21 Boundaries

SCALE: 1:10,000 @A3

150 75 0 150 300 Metres

DISCLAIMER

The information shown on this map has been produced from the Townsville City Council's digital database. There is no warranty implied or expressed regarding the accuracy or completeness of the data. The data has been compiled for information and convenience only, and it is the responsibility of the user to verify all information before placing reliance on it. For accurate service locations please contact the Customer Services Centre on 1300 878 001.
This is not a legal document and is published for information and convenience only. The Townsville City Council takes no responsibility for any errors or omissions herein or for any acts that may occur due to its use.

Produced by:
STRATEGIC PLANNING
Planning and Development

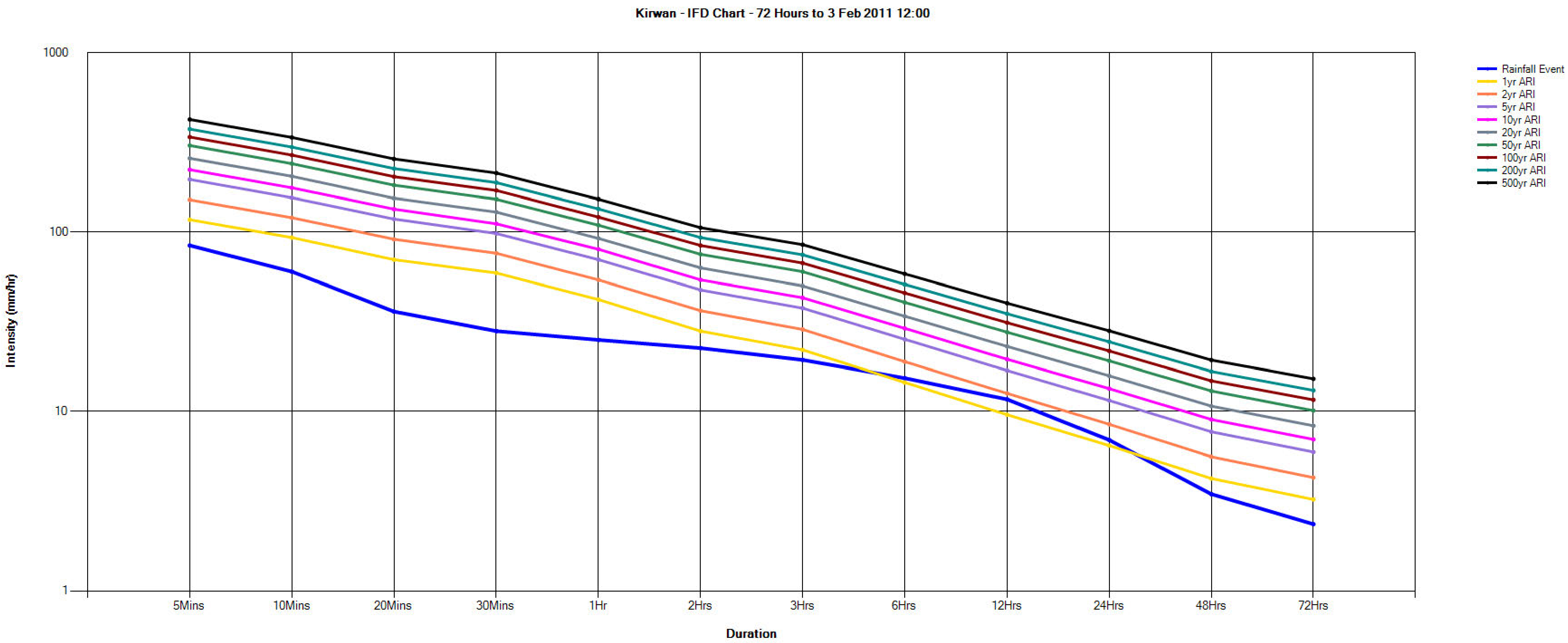
DATE: dd/mm/yyyy

DATE PRINTED: 28/04/2016

DRAWN BY: ZZA

DIGITAL FILE: Figure4-4_Cali_Yasi2011.mxd

**Figure 4-5**: IFD chart of rainfall at Kirwan during cyclone Yasi

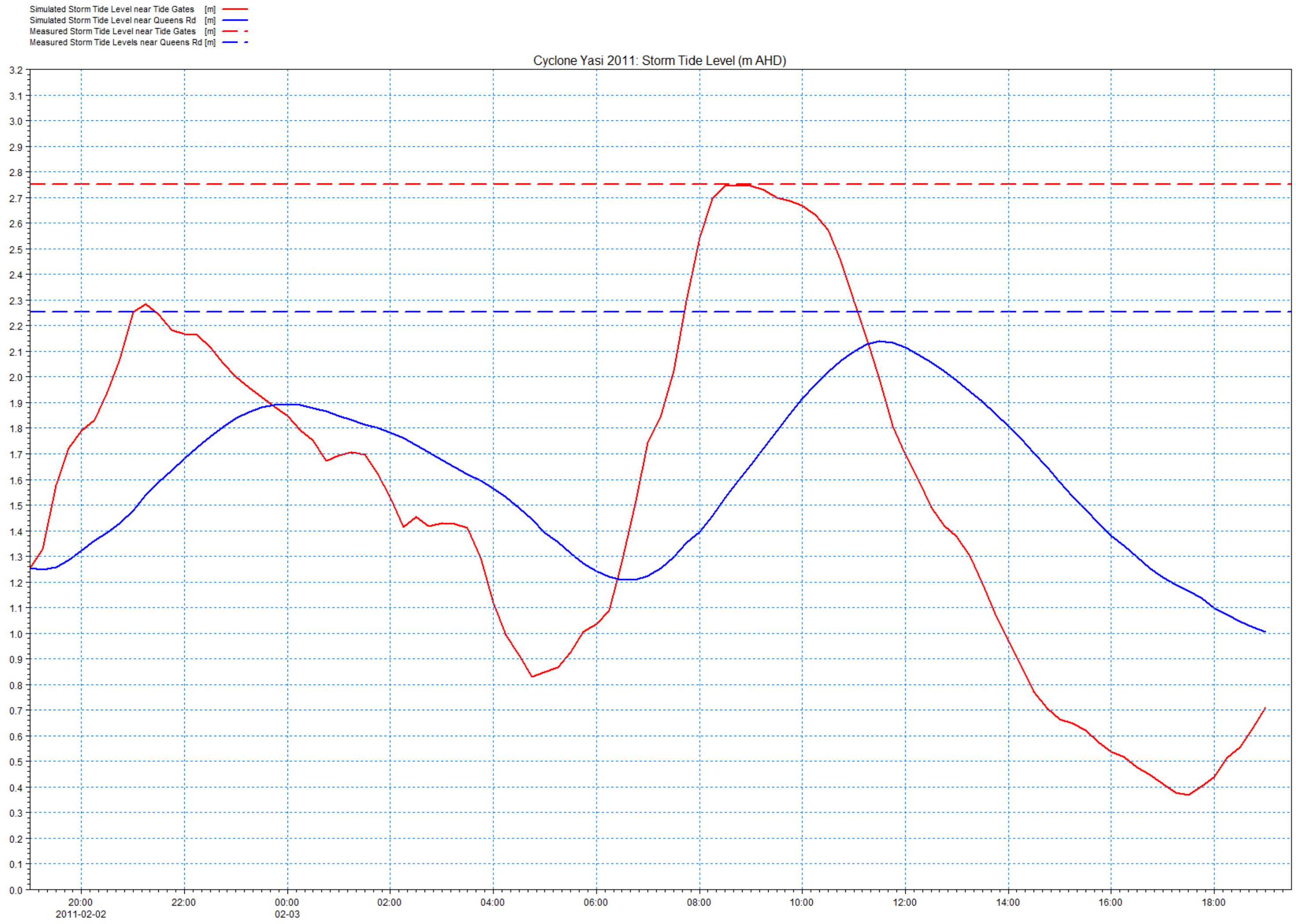


For other locations, the comparison results between the simulated and observed storm tide levels are presented in **Table 4-1**.

**Table 4-1**: Comparison between Simulated and Observed Storm Tide Levels

| *Serial Number* | *Location* | *Observed Storm Tide Level (m AHD)* | *Simulated Storm Tide Level (m AHD)* | *Difference (mm)* |
|---|---|---|---|---|
| *1* | Adjacent to Tide gates | 2.75 | *2.75* | 1 |
| *2* | Near Queens Road | 2.25 | *2.14* | 116 |
| *3* | Tully Street | 2.82 | 2.81 | 7 |
| *4* | Seventh Street | 2.77 | 2.79 | -21 |
| *5* | Perkins Street West | 2.76 | 2.75 | 10 |
| *6* | Twelfth Avenue | 2.80 | 2.75 | 58 |
| *7* | Boundary Street | 2.80 | 2.76 | 33 |

**Figure 4-6:** Comparison of storm tide levels in Ross Creek



### *January 1998*

The January 1998 event was a large rainfall event that occurred between 5pm on the 10th of January 1998 and 8am on the 11th of January 1998. Approximately 510 mm of rain was recorded at the Townsville Airport Gauge during that period. The 1998 storm event was estimated as a 500 Year ARI storm event particularly for durations beyond 6 hours (Ross Creek Flood Study, 2013). A spatial distribution of flood levels surveyed by Townsville City Council in the immediate aftermath of the event was used to calibrate the model.

As the existing Ross Creek model was calibrated to January 1998 storm event, same Thiessens polygons based on the daily rainfall gauges, rainfall distribution and rainfall losses have been used for the calibration of this model. Following rainfall losses have been adopted for this event:

**Table 4-2:** January 1998 Rainfall Losses

| Loss Type | Pervious | Impervious |
|---|---|---|
| Initial | 25 mm | 1mm |
| Continuing | 2.5 mm/h | 0mm/h |

For the calibration, the model has been run for 15 hours during the peak period of the event (5:00 PM, 10/1/1998 to 8:00 AM 11/1/1998) and the model results have been compared with the surveyed data. **Figure 4-7** shows the difference between the observed and the simulated flood levels. Here, positive and negative values indicate higher and lower observed flood levels from the simulated levels respectively.

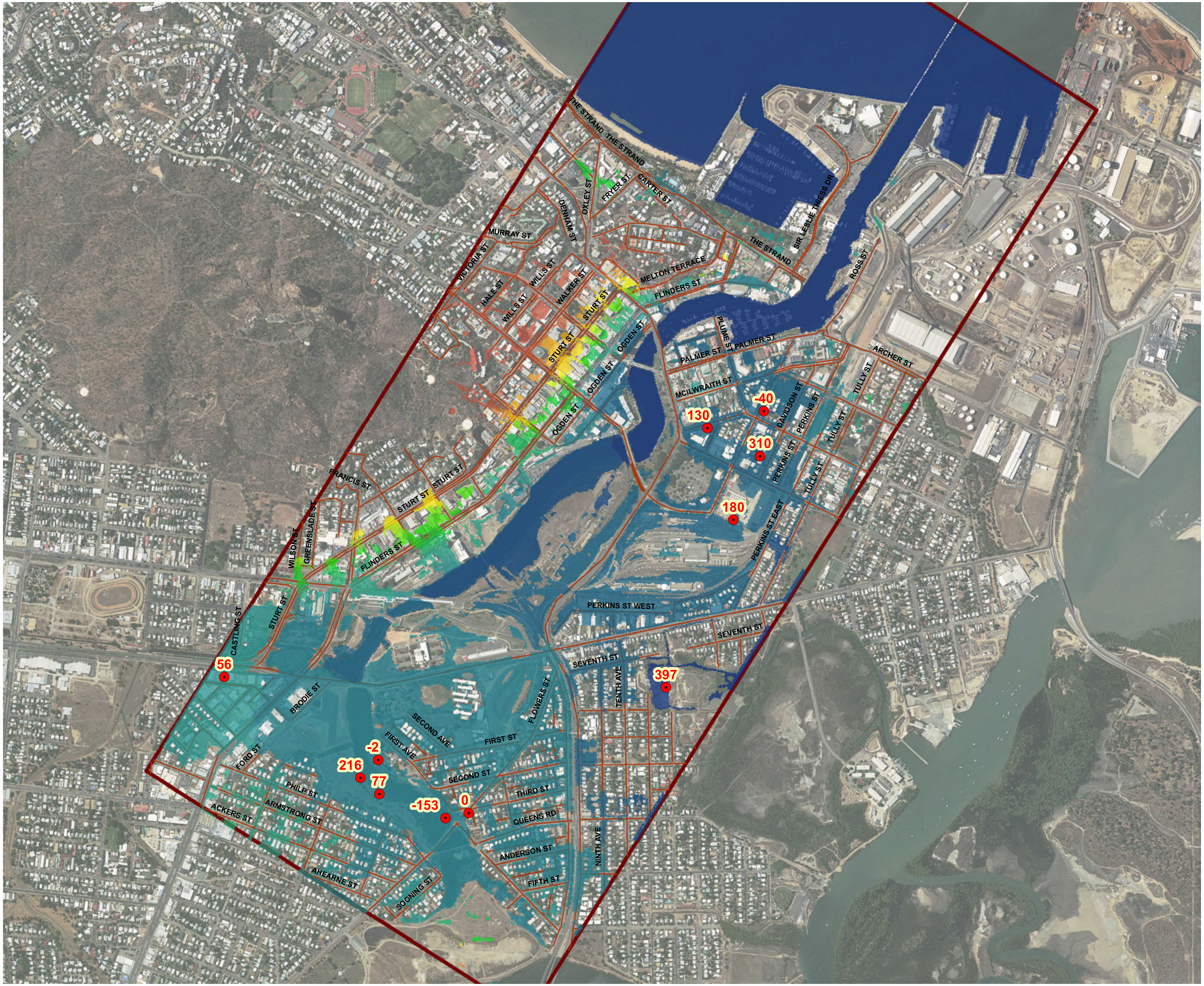
The comparison results show that the flood levels determined from the model are generally within ±0.22 m of the surveyed flood levels where less development took place since 1998, except at two locations: Davidson Street (+0.31m) and Seventh Street (+0.4m).

It is worthwhile to mention that the model bathymetry is based on 2009 data. At few locations (i.e. Dean Street Car Park, First Street, Fifth Street, Barlow Street, Clarendon Street, Charters Tower Road, Regent Street, and Summerfield Street) the observed flood levels could not be compared due to the change in topography from 1998 condition.

The model results show good agreement (i.e. within ± 0.1 m) at Second Avenue, Morehead Street, Castling Street and First Avenue.

During calibration following parameters have been considered:

- Manning's 'n' = 0.08 for Mangrove Trees; and
- Eddy, E= 2.0 on land, E= 2.1 in Ross Creek and E= 4 in Woolcock Canal.




# CBD HYDRAULIC MODEL

**Model Calibration**
**(Storm Event Jan 1998)**
**Figure 4-7**

## LEGEND

**Comparison POINTS**

- Difference in Levels (mm)
- TCC_Road_Clipped

N

City of Townsville

SCALE: 1:0 @A3

150 75 0 150 300 Metres




Produced by:
STRATEGIC PLANNING
Planning and Development
DATE: dd/mm/yyyy
DATE PRINTED: 1/06/2016
DRAWN BY: ZZA
DIGITAL FILE: Figure4-7_Cali_Jan1998.mxd

## 4.5 Model Verification

The CBD Hydraulic Model mainly focusses on Ross Creek and its surrounding area including PDA. There are seven bridges within the 3.5 km reach of Ross Creek, which are causing head losses (i.e. drop in water level across the bridge).

This model has been verified with the head losses by comparing the MIKE FLOOD model results with the HEC-RAS model results. For this verification, the HEC-RAS models for all of the bridges were developed separately by representing the structure in detail level using HEC-RAS modelling software.

HEC-RAS is one-dimensional software and its steady flow component is capable of modelling subcritical, supercritical, and mixed flow regime water surface profiles. The basic computational procedure is based on the solution of the one-dimensional energy equation. Energy losses are evaluated by friction and contraction/expansion. The momentum equation is utilised in situation where water surface profile is rapidly varied. These situation include mixed flow regime calculations (i.e. hydraulic jumps), hydraulics of bridges, and evaluating profiles at river confluences.

From the MIKE FLOOD model run, head-losses have been computed across the bridges for the 18-hour duration 100 Year ARI (i.e. 1% AEP) flood event and presented in the table below. The flows and downstream tailwater levels at all of the bridges were extracted from the MIKE FLOOD model results and then applied to the HEC-RAS models as boundary conditions. **Table 4-3** shows the head-losses comparison between the MIKE FLOOD and HEC-RAS model results across the bridges in Ross Creek.

The comparison of results shows that the head-loss differences between the MIKE FLOOD model and the HEC-RAS model at Victoria Bridge, Abandoned Railway Bridge-1, Railway Bridge and V8-Race Bridge are within +/- 5mm. The maximum difference is found to be 18 mm at Abandoned Railway Bridge-2, where the MIKE FLOOD Model produces higher head-loss than the HEC-RAS model. The head-loss differences at Denham Bridge and Lowths Bridge are 14 mm and 11 mm respectively. Even 18mm difference in head loss is considered reasonable. It is worthwhile to mention that MIKE 21 hydrodynamic module gives accurate solution by representing the convective and cross-momentum terms in its Momentum equation.

**Table 4-3**: Comparison of head-losses across the bridges of Ross Creek

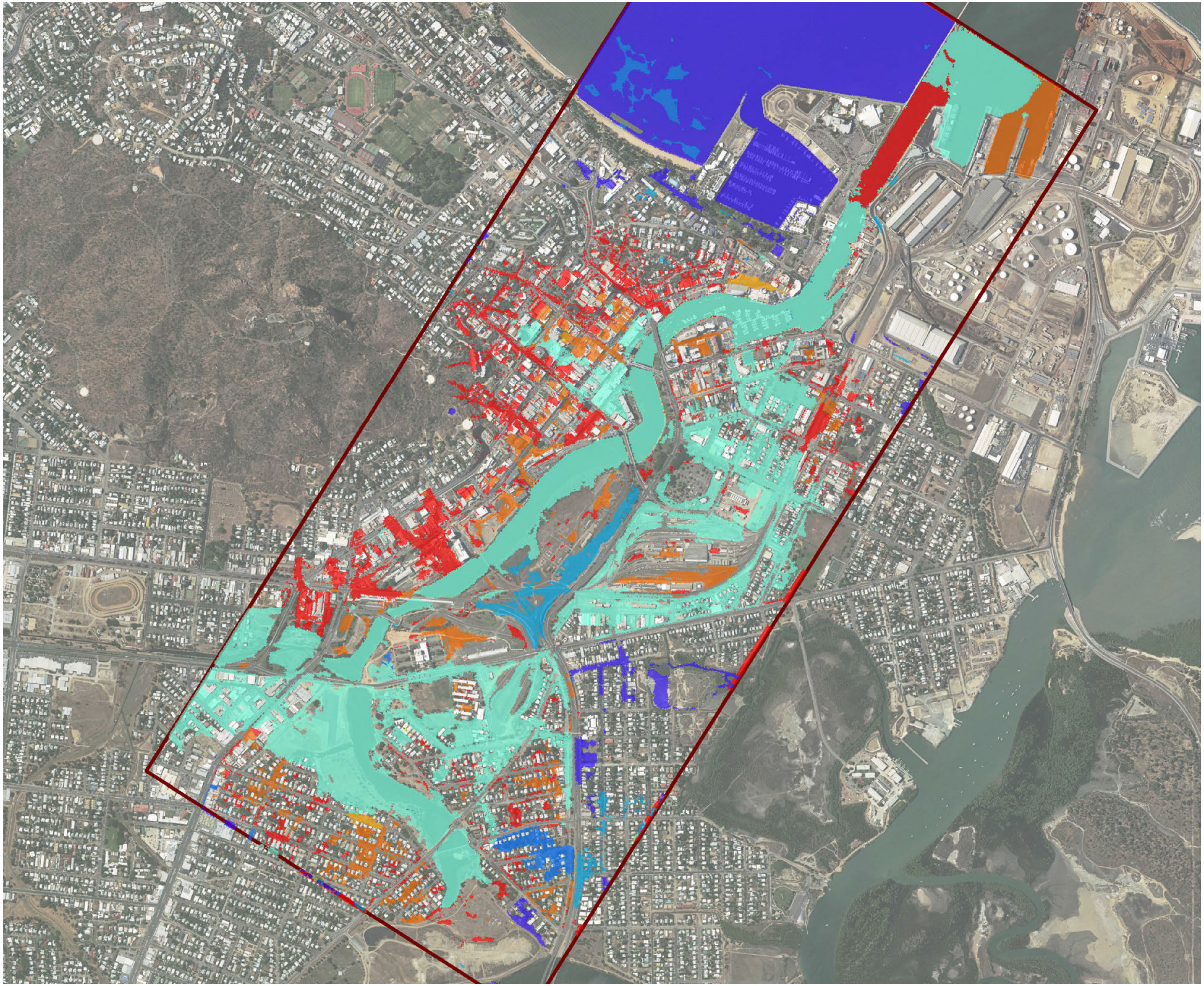
| Bridges | | MIKE FLOOD Model Result of 18-hour duration 1% AEP flood event | | | | HEC-RAS Model Result of 18-hour duration 1% AEP flood event | | | **Differences (mm)** |
|---|---|---|---|---|---|---|---|---|---|
| Name | SKEW (°) | Q | WL (next to coupled cells) | | | Bridge | | | |
| | | m3/s | u/s | d/s | **Head losses (m)** | u/s | d/s | **Head losses (m)** | |
| Denham Bridge | *31* | **118** | 1.48 | 1.44 | **0.034** | 1.48 | 1.46 | **0.020** | **14** |
| Victoria Bridge | | **116.5** | 1.52 | 1.49 | **0.030** | 1.53 | 1.50 | **0.030** | **0** |
| Lowths Bridge | | **116** | 1.61 | 1.57 | **0.041** | 1.60 | 1.57 | **0.030** | **11** |
| Abandoned Railway Bridge-1 | *45* | **116** | 1.71 | 1.62 | **0.082** | 1.69 | 1.61 | **0.080** | **2** |
| Abandoned Railway Bridge-2 | | **113** | 1.87 | 1.79 | **0.078** | 1.85 | 1.79 | **0.060** | **18** |
| Railway Bridge | *45* | **111** | 2.11 | 2.09 | **0.016** | 1.95 | 1.93 | **0.020** | **-4** |
| V8-Race Bridge | | **111** | 2.29 | 2.26 | **0.030** | 2.26 | 2.23 | **0.030** | **0** |

## 4.6 Design Flood Assessment

Following verification of the hydraulic model, the model was used to simulate design flood events, by ensuring the underground network represent 2015 conditions.

Initially the 100 Year ARI was run for a range of storm durations from 1 hour to 72 hours in order to establish critical storm durations across the Ross Creek and its surrounding area. **Figure 4-8** shows the critical flood durations for 100 Year ARI flood event. The figure shows that the critical storm durations at the CBD area is 1 hour and in Ross Creek is 12 hours except at its mouth where critical duration is 1 hour.

For the remainder of the design events up to the 500 Year ARI, 1 hour, 12 hours and 18 hours storm durations have been simulated. For Probable Maximum Flood (PMF) only the 2 hours, 24 hours and 72 hours duration events have been simulated.



# CBD HYDRAULIC MODEL

## Critical Storm Duration
## (100 Year ARI)
## Figure 4-8

## LEGEND

**Critical Storm Duration (hour)**

- 1 h
- 1.5 h
- 2 h
- 3 h
- 6 h
- 12 h
- 18 h
- 24 h
- 72 h
- Model Domain

N

City of Townsville

SCALE: 1:15,000 @A3

150 75 0 150 300
Metres



Produced by:
STRATEGIC PLANNING
Planning and Development
DATE: dd/mm/yyyy
DATE PRINTED: 30/05/2016
DRAWN BY: ZZA
DIGITAL FILE: Figure4-8_CriticalFloodDuration.mxd

# 5.0 Model Results

## 5.1 Baseline Flooding Results

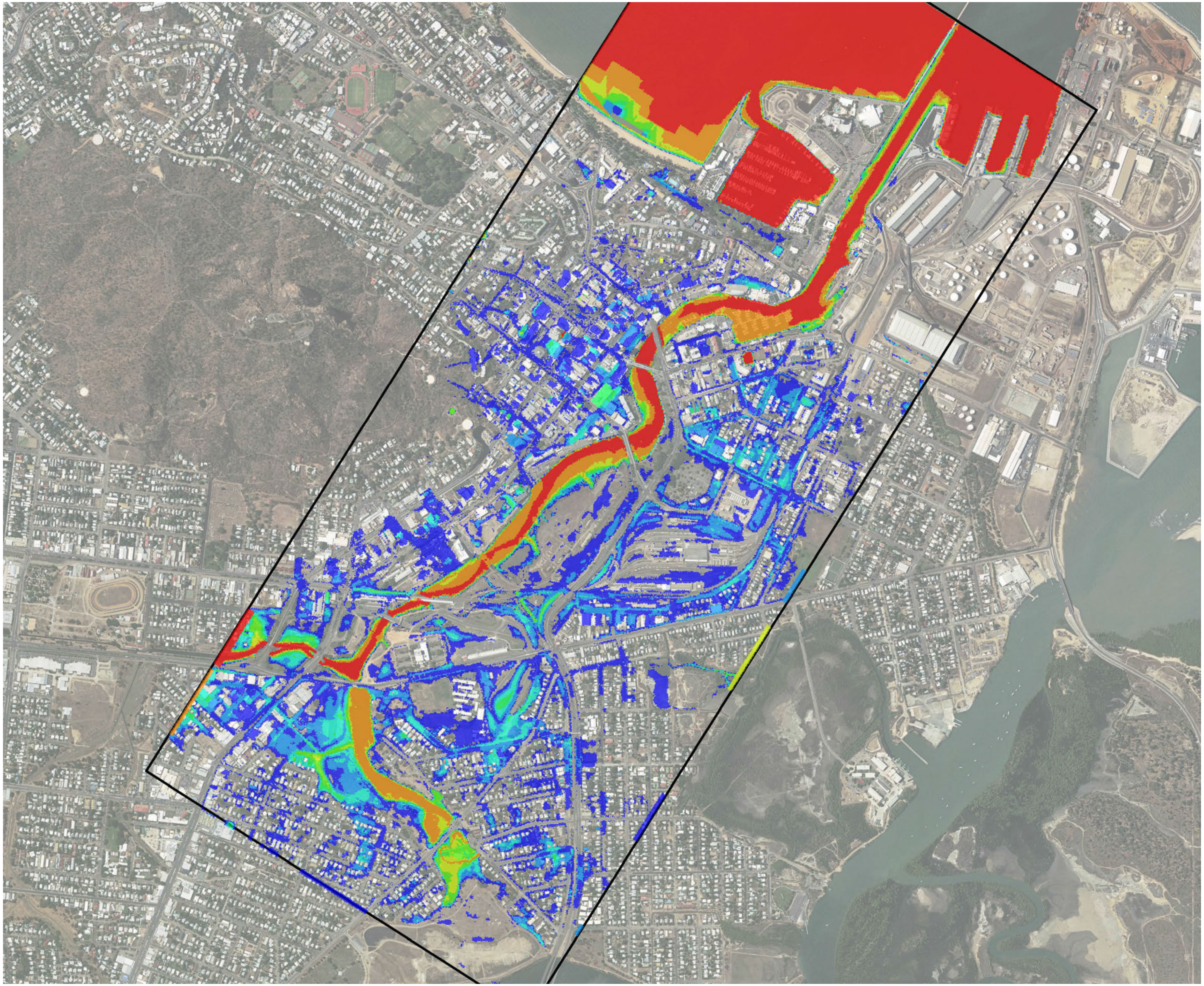
The base-line flood maps for the design flood events have been generated for the following flood events:

- 2 Year ARI;
- 5 Year ARI;
- 10 Year ARI;
- 20 Year ARI;
- 50 Year ARI;
- 100 Year ARI;
- 200 Year ARI;
- 500 Year ARI; and
- Probable Maximum Flood.

**Figure 5-1** shows the flood depth map of 100 Year ARI flood event. The flood maps of water depths, flood levels, flow velocities and critical storm durations for all of the ARIs have been provided in **Appendix D**. For all storm frequencies the flood map results are based on the critical flood envelope from all storm durations. Given the "Rain on Grid" approach has all cells within the model wet areas with depths of less than 0.1m or velocity less than 0.8 m/s have not been shown as inundated.

## 5.2 Hydraulic Grade Line

Ross Creek has seven bridges within its 3.5 km reach from Boundary Street Causeway to Townsville Port. **Figure 5-2** shows the location of Hydraulic Gradeline. The hydraulic grade lines extracted from the model results for design flood events are presented in **Figure 5-3**. All of the hydraulic grade lines show head losses across the bridges. The maximum head losses have been found in Abandoned Railway Bridge 1 and 2.



# CBD Hydraulic Model Flood Depth Map (100 Year ARI)

**Figure 5-1**

## LEGEND

**Water Depth (m)**

- 0.01 - 0.3
- 0.3 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- 3 - 25
- ModelDomain

N

City of Townsville

SCALE: 1:15,000 @A3

150 75 0 150 300 Metres

DISCLAIMER

The information shown on this map has been produced from the Townsville City Council's digital database. There is no warranty implied or expressed regarding the accuracy or completeness of the data. The data has been compiled for information and convenience only, and it is the responsibility of the user to verify all information before placing reliance on it. For accurate service locations please contact the Customer Services Centre on 1300 878 001.

This is not a legal document and is published for information and convenience only. The Townsville City Council takes no responsibility for any errors or omissions herein or for any acts that may occur due to its use.

Produced by:
STRATEGIC PLANNING
Planning and Development

DATE: dd/mm/yyyy

DATE PRINTED: 30/05/2016

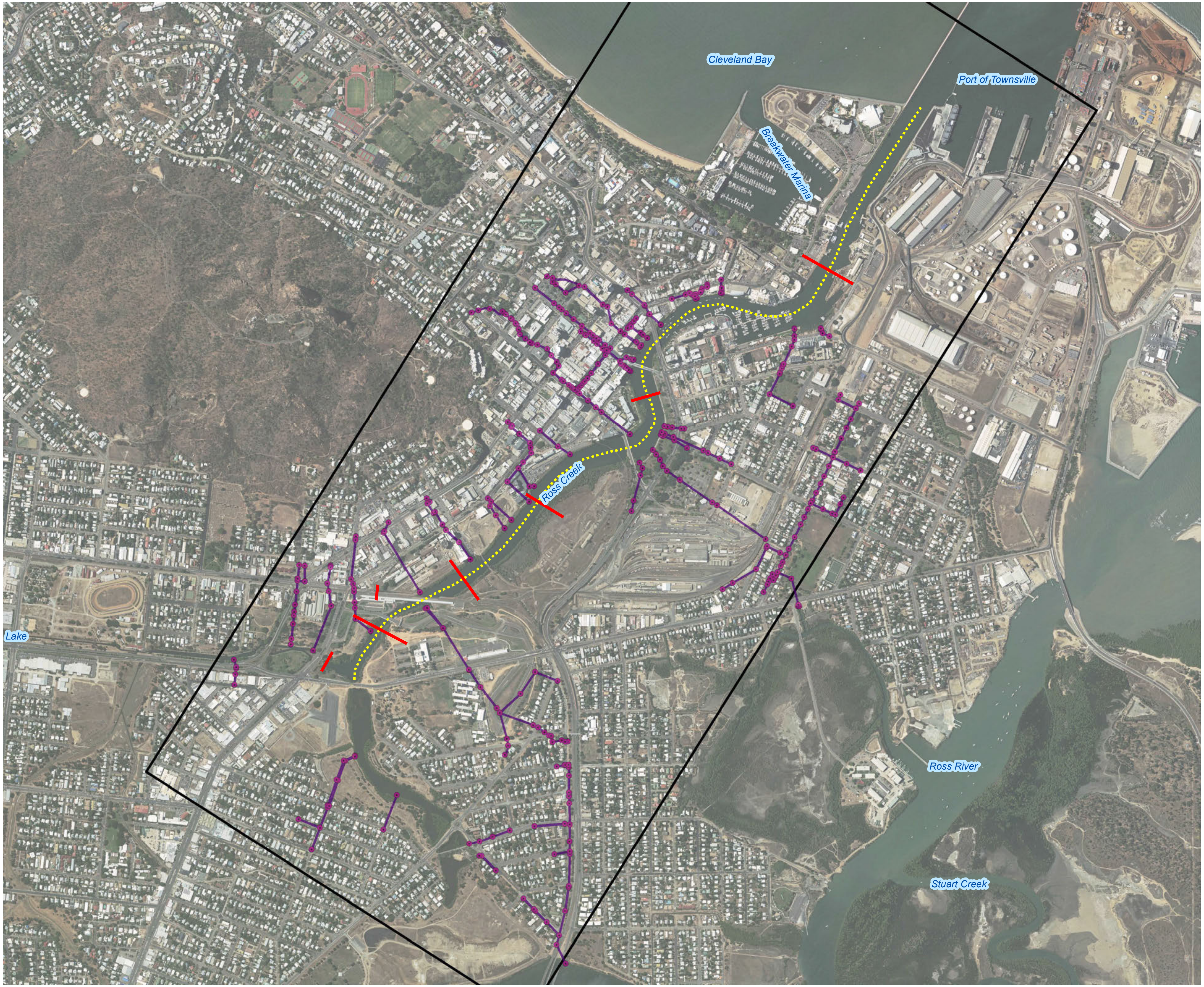
DRAWN BY: ZZA

DIGITAL FILE: Figure5-1_FloodMap_100yARI.mxd

# CBD Hydraulic Model

## HGL and Flow Locations

### Figure 5-2




## LEGEND

- Location of Flow
- Hydraulic Grade Line
- MIKE Urban Nodes
- MIKE Urban Links
- ModelDomain

N

City of Townsville

SCALE: 1:15,000 @A3

200 100 0 200 400 Metres

DISCLAIMER

The information shown on this map has been produced from the Townsville City Council's digital database. There is no warranty implied or expressed regarding the accuracy or completeness of the data. The data has been compiled for information and convenience only, and it is the responsibility of the user to verify all information before placing reliance on it. For accurate service locations please contact the Customer Services Centre on 1300 878 001.

This is not a legal document and is published for information and convenience only. The Townsville City Council takes no responsibility for any errors or omissions herein or for any acts that may occur due to its use.

Produced by:
STRATEGIC PLANNING
Planning and Development

DATE: dd/mm/yyyy

DATE PRINTED: 25/05/2016

DRAWN BY: ZZA

DIGITAL FILE: Figure5-2_KeyFeatures.mxd

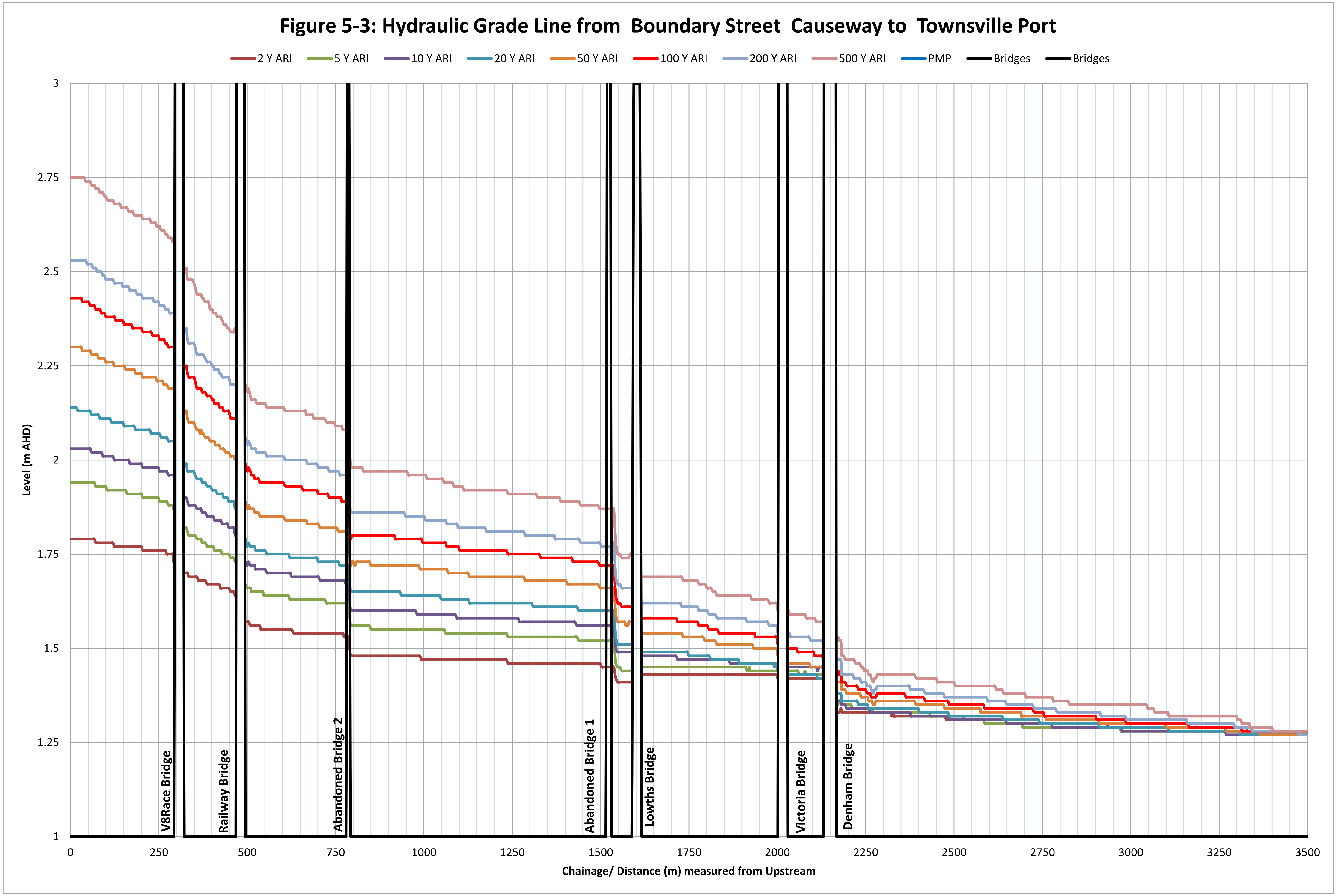


Figure 5-3: Hydraulic Grade Line from Boundary Street Causeway to Townsville Port
2 Y ARI
5 Y ARI
10 Y ARI
20 Y ARI
50 Y ARI
100 Y ARI
200 Y ARI
500 Y ARI
PMP
Bridges
Bridges
Level (m AHD)
3
2.75
2.5
2.25
2
1.75
1.5
1.25
1
V8Race Bridge
Railway Bridge
Abandoned Bridge 2
Abandoned Bridge 1
Lowths Bridge
Victoria Bridge
Denham Bridge
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
3250
3500
Chainage/ Distance (m) measured from Upstream

## 5.3 Flow Distributions

The flows at Woolcock Canal, different sections of Ross Creek and an open drain in CBD area have been calculated from the CBD model results. The flow locations are shown in **Figure 5-2**.

The Woolcock Canal, a main tributary of Ross Creek, has a peak flow of 109 $m^3/s$ in 100 Year ARI flood event. The peak flow at different sections of Ross Creek varies from 115 $m^3/s$ to 132 $m^3/s$ in 100 Year ARI flood event.

At the same locations, the model results of Ross Creek Flood Study (2013) have been compared. It shows higher peak flows with respect to the CBD model results for the same condition (i.e. 100 Year ARI and 12 hours storm duration). The peak flows at the Ross Creek flood model varies by about 9% at the upstream and 14% at the downstream of Ross Creek with respect to the CBD hydraulic model.

The main reasons for these variations may be due to the incorporation of floor level survey data and its higher roughness in CBD model and the consideration of recent aerial photography (captured in 2015) to assign fraction pervious/impervious and hydraulic roughness in CBD model.

The peak flows for the design flood events at different locations of Ross Creek have been extracted from the CBD hydraulic model results and provided in **Table 5-3**. Note that the peak flows provided here are the maximum of the peak flows for all duration storm events for the given ARIs. The peak flows in all storm durations for all ARIs have been presented in **Appendix-F**.

**Table 5-3: Peak Flow Distribution Results**

| Serial No. | Flow Sections/ Locations: Description | MIKE 21 Grids: From | MIKE 21 Grids: To | Peak Flow ($m^3/s$) for different ARIs: 2 Y | 5 Y | 10 Y | 20 Y | 50 Y | 100 Y | 200 Y | 500 Y | PMF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Woolcock Canal | (195, 382) | (219, 382) | **40.6** | **54.1** | **62.2** | **74.1** | **92.0** | **109.2** | **119.4** | **124.1** | **124.3** |
| | (Critical Durations) | | | 18h | 18h | 18h | 12h | 12h | 12h | 12h | 12h | 72h |
| 2 | Ross Creek- U/S of V8-Race Bridge | (268, 321) | (263, 385) | **42.4** | **56.9** | **65.7** | **77.7** | **96.2** | **114.9** | **131.2** | **157.0** | **250.2** |
| | (Critical Durations) | | | 18h | 18h | 18h | 12h | 12h | 12h | 12h | 12h | 2h |
| 3 | Ross Creek- in between Railway Bridge and Abandoned Railway Bridge-2 | (348, 281) | (368, 330) | **43.3** | **58.3** | **67.6** | **80.4** | **99.3** | **117.6** | **134.5** | **161.0** | **265.0** |
| | (Critical Durations) | | | 18h | 18h | 18h | 18h | 12h | 12h | 12h | 12h | 2h |
| 4 | Ross Creek- in between two abandoned bridges | (471, 251) | (471, 298) | **43.5** | **59.2** | **68.6** | **81.7** | **101.1** | **119.2** | **136.6** | **163.8** | **417.2** |
| | (Critical Durations) | | | 18h | 18h | 18h | 12h | 12h | 12h | 12h | 12h | 24h |
| 5 | Ross Creek- in between Lowths Bridge and Victoria Bridge | (640, 233) | (616, 254) | **45.3** | **62.5** | **73.5** | **86.3** | **105.8** | **122.9** | **153.0** | **169.9** | **494.5** |
| | (Critical Durations) | | | 18h | 18h | 18h | 18h | 12h | 18h | 12h | 12h | 24h |
| 6 | Ross Creek- D/S of Denham Bridge | (847, 121) | (845, 183) | **49.9** | **67.8** | **80.0** | **95.3** | **113.9** | **131.8** | **153.0** | **231.5** | **643.4** |
| | (Critical Durations) | | | 18h | 18h | 18h | 18h | 18h | 12h | 12h | 1h | 24h |
| 7 | Open Drain on the left hand side of Railway Bridge | (291, 372) | (307, 380) | **1.2** | **2.1** | **2.5** | **3.1** | **3.7** | **4.2** | **4.7** | **5.3** | **13.6** |
| | (Critical Durations) | | | 1h | 1h | 1h | 1h | 1h | 1h | 1h | 1h | 24h |

## 5.4 Joint Probability of Coastal and Riverine Flooding

The Ross Creek estuary has a joint probability zone, where the magnitude of flooding is dependent on both coastal flooding and riverine (fluvial) flooding. The joint probability zone has been assessed based on the guidelines mentioned in the report on “Review of Australian Rainfall and Runoff 2016, TCC” (Ref. 10/).

The extent of the joint probability zone have been determined by simulating the riverine flooding for 1% AEP flood event (which provides a complete independence levels) and the riverine flooding in combination with storm tide having same probability (which provides a complete dependence levels).

The pre-screening test was performed for the 1% AEP events under present day conditions. The CBD hydraulic model was run to determine to theoretical bounds of inundation levels as follows:

- Complete independence – the peak water level of the 1% AEP flood event (12 hours storm duration) or the 1% AEP storm tide level (2.6 m AHD); and
- Complete dependence - the peak water level from 1% AEP flood coincidence with 1% AEP storm tide level.

The difference between the complete independence and complete dependence results were evaluated with areas identified where the difference is above 0.1m identified as the *joint probability zone*. **Figure 5-4** shows the joint probability zone, which is located upstream of Victoria Bridge to the upstream bounds of the model. The joint probability zone would not extend indefinitely up the catchment however the present model does not cover sufficiently far enough upstream to identify the upstream extent of the join probability zone. The maximum difference between complete independence and complete dependence scenarios is in the order of 0.5 m to 0.7m is found at the upstream of Railway Bridge.

# CBD HYDRAULIC MODEL

## Joint Probability Zone

## Figure 5-4

## LEGEND

**Difference in Levels (m)**

- < 0.1
- 0.1 - 0.15
- 0.15 - 0.2
- 0.2 - 0.25
- 0.25 - 0.3
- 0.3 - 0.35
- 0.35 - 0.4
- 0.4 - 0.45
- 0.45 - 0.5
- 0.5 - 2
- PDA
- Model Domain

N

City of Townsville

SCALE: 1:15,000 @A3

150 75 0 150 300 Metres

DISCLAIMER



Produced by:
STRATEGIC PLANNING
Planning and Development

DATE: dd/mm/yyyy

DATE PRINTED: 30/05/2016

DRAWN BY: ZZA

DIGITAL FILE: Figure5-4_100y12h_StormTide_JointProba

# 6.0 Summary and Conclusions

This study has developed a detailed hydraulic model for Ross Creek and Central Business District (CBD) area of Townsville based on recent data. This hydraulic model is a three-way coupled MIKE FLOOD Model representing two-dimensional topography, one-dimensional structures and trunk underground drainage network.

This hydraulic model has the capability to run different storm scenarios in combination with storm tide and to determine the hydraulic design parameters for the new structures to be built under the implementation strategy of the Waterfront PDA.

Ross Creek is an urban tidal waterway. It extends about 5 km from close to the Ross River through the CBD of Townsville to Cleveland Bay and drains much of the urban area of Townsville. The hydraulic model is based on a 4 meter topographic rectangular grid and it covers an area of 8.9 km2 (4.6 kmX1.94 km). This model has incorporated the latest floor level survey data captured between September 2014 and March 2015 and utilised existing hydrologic and hydraulic models to generate boundaries and source data. Aerial photography captured in 2015 has been used for assigning fraction pervious/impervious and hydraulic roughness in the Hydraulic Model.

The hydraulic model has been calibrated with the cyclone Yasi (2011) and the extreme storm event of January 1998. It has been verified with the head losses by comparing the MIKE FLOOD model results with the HEC-RAS model results. For this verification, the HEC-RAS models for all of the bridges were developed separately by representing the structure in detail level using HEC-RAS modelling software.

The simulation results of 100 Year ARI flood event for a range of storm durations from 1 hour to 72 hours show that the critical storm durations at the CBD area is 1 hour and in Ross Creek is 12 hours except at its mouth where critical duration is 1 hour.

Flood maps generated based on the model results have been used to quantify the floodplain hydraulic response with hydraulic grade lines and flow distributions. All of the hydraulic grade lines show head losses across the bridges. The maximum head losses have been found in Abandoned Railway Bridge 1 and 2.

Flow distribution results show that peak flow through Woolcock Canal is 109 m3/s and flows at different sections of Ross Creek varies from 115 $m^3/s$ (at upstream section) to 132 $m^3/s$ (at downstream section) in 100 Year ARI flood event.

The hydraulic model has been applied to develop a joint probability zone for 1% AEP flood and storm tide events in Ross Creek area, where the magnitude of flooding is dependent on both coastal flooding and riverine (fluvial) flooding. The difference between the complete independence (the peak water level of the 1% AEP flood event or the 1% AEP storm tide level) and complete dependence (the peak water level from 1% AEP flood coincidence with 1% AEP storm tide level) results were evaluated with areas identified where the difference is above 0.1m identified as the *joint probability zone*. The present model does not cover sufficiently far enough upstream to identify the upstream extent of the join probability zone. The maximum difference between complete independence and complete dependence scenarios is in the order of 0.5 m to 0.7m is found at the upstream of Railway Bridge.

# 7.0 References

1/ Bureau of Meteorology, (2003) *Guidebook to the Estimation of Probable Maximum Precipitation: Generalised Tropical Storm Method,* Report prepared by hydrometeorological advisory service and Re-issued in September 2005

2/ Department of Science, Information Technology, Innovation and the Arts, (2012) Tropical Cyclone Yasi 2011- Post Cyclone Coastal Field Investigation, November 2012

3/ DHI Software, (2012) *MIKE FLOOD 1D-2D Modelling User Manual,* for MIKE FLOOD 2012

4/ Engineers Australia, (1998) *Australian Rainfall and Runoff – Volume 1*

5/ Engineers Australia, (1987) *Australian Rainfall and Runoff – Volume 2*

6/ Engineers Australia, (2012) Australian Rainfall and Runoff, Revision Project 15: Two Dimensional Simulations in Urban Areas- Representation of Buildings in 2D Numerical Hydraulic Models, February 2012

7/ HEC-RAS, (2008) River Analysis System, Hydraulic Reference Manual, Version 4.0, US Army Corps of Engineers, March 2008

8/ James Cook University, (2011) Tropical Cyclone Yasi Structual Damage to Building, Cyclone Testing Station (CTS) Technical Report No 57, April 2011

*9/* Townsville City Council (2013) *Ross Creek Flood Study - Base-line Flooding Assessment, Volumes 1 and 2*

*10/* Townsville City Council (2016) *Townsville Floodplain Management Strategy – Review of Australian Rainfall and Runoff, March 2016*

11/ XP-SOFTWARE, (2009*) XP-RAFTS Urban & Rural Runoff Routing Software – Reference Manual* for XP RAFTS 2009