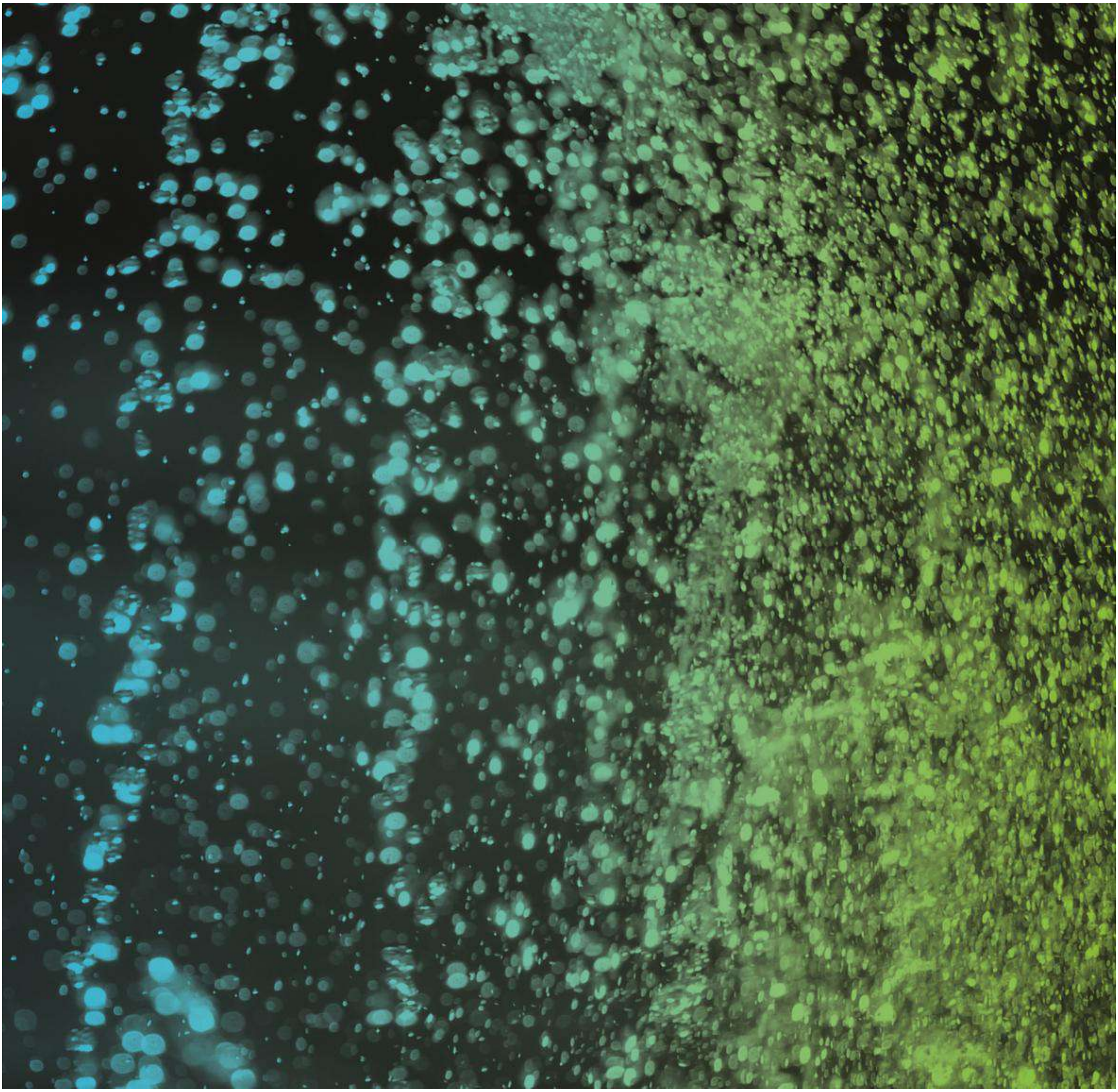
Don River Flood Risk and Mitigation Study

Stage 1 - Flood Risk Assessment



Don River Flood Risk and Mitigation Study

Stage 1 - Flood Risk Assessment

Client: Whitsunday Regional Council

ABN: 63 291 580 128

Prepared by

AECOM Australia Pty Ltd
Level 1, 130 Victoria Parade, PO Box 1049, Rockhampton QLD 4700, Australia
T +61 7 4927 5541 F +61 7 4927 1333 www.aecom.com
ABN 20 093 846 925

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Glossary / Abbreviations

1D	One Dimensional
2D	Two Dimensional
AECOM	AECOM Australia Pty Ltd
AHD	Australian height datum
AEP	Annual Exceedence Probability
AMTD	Adopted Middle Thread Distance
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff
BOM	Bureau of Meteorology
DAF	Decay Amplitude Factor
DNRM	Queensland Department of Natural Resources and Mines
DEM	Digital Elevation Model
DFE	Defined Flood Event
DRCL	Digital Road Crown Levels
DRIT	Don River Improvement Trust
DTM	Digital Terrain Model
DTMR	Queensland Department of Transport and Main Roads
DLG	Department of Local Government
EPW	Extreme Precipitable Water
FM	Flexible Mesh
FFA	Flood Frequency Analysis
GIS	Geographical Information Systems
GTSMR	Generalised Tropical Storm Method
HAT	Highest Astronomical Tide
LAT	Lowest Astronomical Tide
LiDAR	Light Detecting and Ranging
LDMG	Local Disaster Management Group
MAF	Moisture Adjustment Factor
MHWS	Mean High Water Springs
MLWS	Mean Low Water Springs
MIKE FLOOD	1D / 2D hydraulic modelling software
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
POT	Peak Over Threshold
PWSL	Peak Water Surface Level
QR	Queensland Rail
QUDM	Queensland Urban Drainage Manual
RCP	Reinforced concrete pipe
RCBC	Reinforced concrete box culvert
SES	State Emergency Service
SRTM	Shuttle Radar Topography Mission
TAF	Topographic Adjustment Factor
WRC	Whitsunday Regional Council
XP-RAFTS	Rainfall runoff routing (hydrologic) modelling software

Executive Summary

AECOM was commissioned by the Whitsunday Regional Council to assess and quantify the potential flood risk posed by the Don River over a range of annual exceedance probability events and provide mitigation options to help improve future flood resilience of the Bowen community. This study will be delivered in two stages, namely the **Don River Flood Risk Assessment** (this document) and the **Don River Flood Mitigation Assessment**.

The potential of the Don River and its associated tributaries to flood and cause serious economic and social damage, as well as risk to life has been well documented since the settlement of Bowen in 1861. Historic records show the highest recorded flood occurred in 1946, with recent records indicating major flooding occurred in 1970, 1979, 1980, 1988, 1991 and 2008. Almost all major flood events have been the direct result of tropical cyclone movement across the catchment.

The behaviour of regional flooding across the study area is complex due to flow breakouts from the Don River and Euri Creek, hydraulic controls including road and rail crossings of the floodplain, and morphological changes.

The scope of work undertaken in this study included the development of three XP-RAFTS hydrologic models to estimate flood discharge hydrographs and the development of a MIKE FLOOD hydraulic model to estimate flood levels, flood extents, flood velocities and flood hazard. Hydrologic and hydraulic models were calibrated / validated to the January 1980, February 2008 and April 2014 flood events.

In undertaking the hydrologic model calibration a number of uncertainties were noted:

- Pluviograph data is only available at two locations and therefore assumptions must be made on the temporal distribution of the rainfall depths when undertaking calibration.
- There are significant differences between the rating curves at Ida Creek and Reeves gauging stations.
- Mt Dangar and the Bowen Pump Station are BOM flood warning level recorders and have not been accurately rated. There is a very high degree of uncertainty in the discharge data from these gauges due to a lack of quality information.
- Due to the highly dynamic nature of the Don River it is likely that gauging stations are located at sites with unstable cross sections. This may cause a shift in the rating curve causing a systematic but unknown bias during and between flood events.
- The Don River and Euri Creek XP-RAFTS models have been calibrated to three historical events due to a lack of available data. It is suggested that these models be validated to future flood event to confirm the adopted parameters.

Uncertainties were also evident in undertaking the hydraulic model calibration / validation. These included:

- Uncertainties from the hydrologic assessment.
- Lack of detailed topographic information for the 1980 event modelling.
- Lack of detailed bathymetric (river bed) survey for the 1980 event modelling.
- Problems in quantifying the extent of morphological changes that have occurred over time which can significantly alter flood levels due to the importance of the breakouts and distributary characteristics.
- Uncertainty in the accuracy and timing of recorded flood levels.

Broadly speaking, the modelled levels show a reasonable fit with the flood marks for both events and it was clear that the development of the dynamic sediment transport module was important in simulating flood behaviour more accurately in the lower reaches.

Design event modelling was carried out for the 10% AEP, 2% AEP, 1% AEP, 0.2% AEP and the Probable Maximum flood event. The MIKE FLOOD model results were analysed and a series of maps were developed to present the results for each modelled flood event. Maps were produced including:

- Peak water surface levels.
- Peak depths.
- Peak velocities and vector arrows.
- Peak hazard.
- Likelihood of flooding over a 30 year period.

Given the uncertainty in climate change and sea level rise projections, particularly with respect to changes in rainfall intensity, climate change sensitivity has been undertaken as part pf this study. The hydrologic and hydraulic models have been used to assess the impact of climate change that would be expected to occur in year 2100 for the 1% AEP design event.

The following uncertainties also required consideration in respect to sensitivity in the hydraulic model:

- Parameter uncertainty in the hydraulic model (roughness).
- Uncertainty in design flows.
- Uncertainty in respect of downstream boundary conditions.
- Uncertainty related to future changes in breakout characteristics.

In consideration of the results of the sensitivity tests, and minimal data on which to base model calibration, it is recommended that a freeboard of 0.5m be applied to the model results in using them for development control purposes.

Whilst not specifically requested in the Stage 1 scope, several recommendations have also been provided on non-structural flood mitigation measures which could be addressed following completion of this study. Specific information has been provided on Emergency Management Planning, Community Awareness and Development Planning.

A number of other recommendations have been identified throughout the course of this Stage 1 assessment. These additional studies / investigations would reduce uncertainties, provide additional information to Council and provide a better understanding of flooding in the Bowen region. A summary is below:

- Improvements to Stream Gauge Rating Curves.
- Inclusion of regional skewness results in Flood Frequency Analysis when Australian Rainfall and Runoff revision Project 5 is finalised.
- Review of BOM's URBS Model.
- Development of Standards for Modelling Methodologies and Management.

The Don River is deemed to pose a significant existing flood risk for the communities in Merinda, Bowen and Queens Beach due to the relatively short warning time, dynamic nature of the river system, high velocities and flood depths. Isolation of several communities can occur during flood events due to the limited availability for evacuation as a result of the low existing immunity of key transportation links.

There is a need to identify, assess, compare, make recommendations and report on options to improve risk management for the community. This will be undertaken in the Stage 2 Flood Mitigation Assessment Report.

1.0 Introduction

1.1 Study Background and Objectives

In 2013, Whitsunday Regional Council (WRC) received partial funding from the Department of Local Government to carry out a flood risk and mitigation study of the Don River near the township of Bowen. AECOM Australia Pty Ltd (AECOM) was subsequently commissioned by Council to assess and quantify the potential flood risk posed by the Don River over a range of annual exceedance probability (AEP) events and provide mitigation options to help improve future flood resilience of the Bowen community.

The study has been divided into two stages of reporting, namely the **Don River Flood Risk Assessment** (this document) and the **Don River Flood Mitigation Assessment**. The key objectives of the study are:

- The rigorous development of detailed hydrologic and hydraulic modelling tools based on current best practice procedures, capable of adequately simulating the flood characteristics and behaviour of the Don River.
- The assessment of existing flood risk within the lower catchment to inform future emergency planning and floodplain management – particularly through the incorporation of key outputs into Council's updated planning scheme.
- The development of clear and easy to understand flood mapping products for use in future community education and awareness campaigns.
- Selection of priority areas within the lower catchment and the determination of the desired level of flood immunity based on stakeholder agreement.
- Identification of a range of strategic flood mitigation options in agreement with Council and other key external stakeholders based on cost-benefit assessment.

Minimising flood damage through more informed and reliable planning, appropriate mitigation, education, and disaster response is the key to developing more resilient communities which will ultimately result in future growth and prosperity. The overall objective of this study is to minimise loss, disruption and social anxiety; for both existing and future floodplain occupants.

1.2 Bowen and the Don River

The township of Bowen is situated on the eastern bank of the Don River, on the northern side of Port Denison and has an estimated population of 10,300 (2011 census data). The landform over the urban area varies between elevated land of RL 50.0m AHD to the low lying coastal foreshore with levels around 3.0m AHD.

Bowen is the site of diverse horticultural and agricultural industries which underpin the economic stability of the district along with tourism, fishing and mining. The major area for agriculture lies on the Don River floodplain due to the nature of the alluvial soils deposited by the river.

The Don River catchment forms part of the Don River Basin along with the Euri Creek and Sand Gully catchments, and comprise a total area of approximately 1,100km^2. Most of the upper reaches of the catchment has remnant vegetation, with the lower reaches (below 15km AMTD) being extensively cleared for agricultural, residential and urban land purposes. These lower reaches are generally considerably flatter in grade with the river being subject to a number of breakouts.

The potential of the Don River and its associated tributaries to flood and cause serious economic and social damage, as well as risk to life has been well documented since the settlement of Bowen in 1861. Historic records show the highest recorded flood occurred in 1946, with recent records indicating major flooding occurred in 1970, 1979, 1980, 1988, 1991 and 2008. Almost all major flood events have been the direct result of tropical cyclone movement across the catchment.

Despite the number of historical studies carried out for Don River there is still significant uncertainties in the flood behaviour of the Don River and its potential impact on Bowen, Queens Beach and surrounding areas. This is due to the highly dynamic nature of the Don River system, mobility of the mouth and break out locations, complexity of the floodplain, lack of reliable river gauging data and lack of historical data suitable for model calibration purposes.

The Don River has a well-documented history of river channel and mouth mobility. Indeed there were up to ten main river channel / mouth combinations identified. Notable mouth locations include:

- The ancient mouth or ‘old mouth’ – positioned at the current Queen’s Beach locality.
- The ‘1946 Mouth’ – located approximately 10km to the north of the current mouth.
- The current mouth – located directly north of Queen’s Beach.

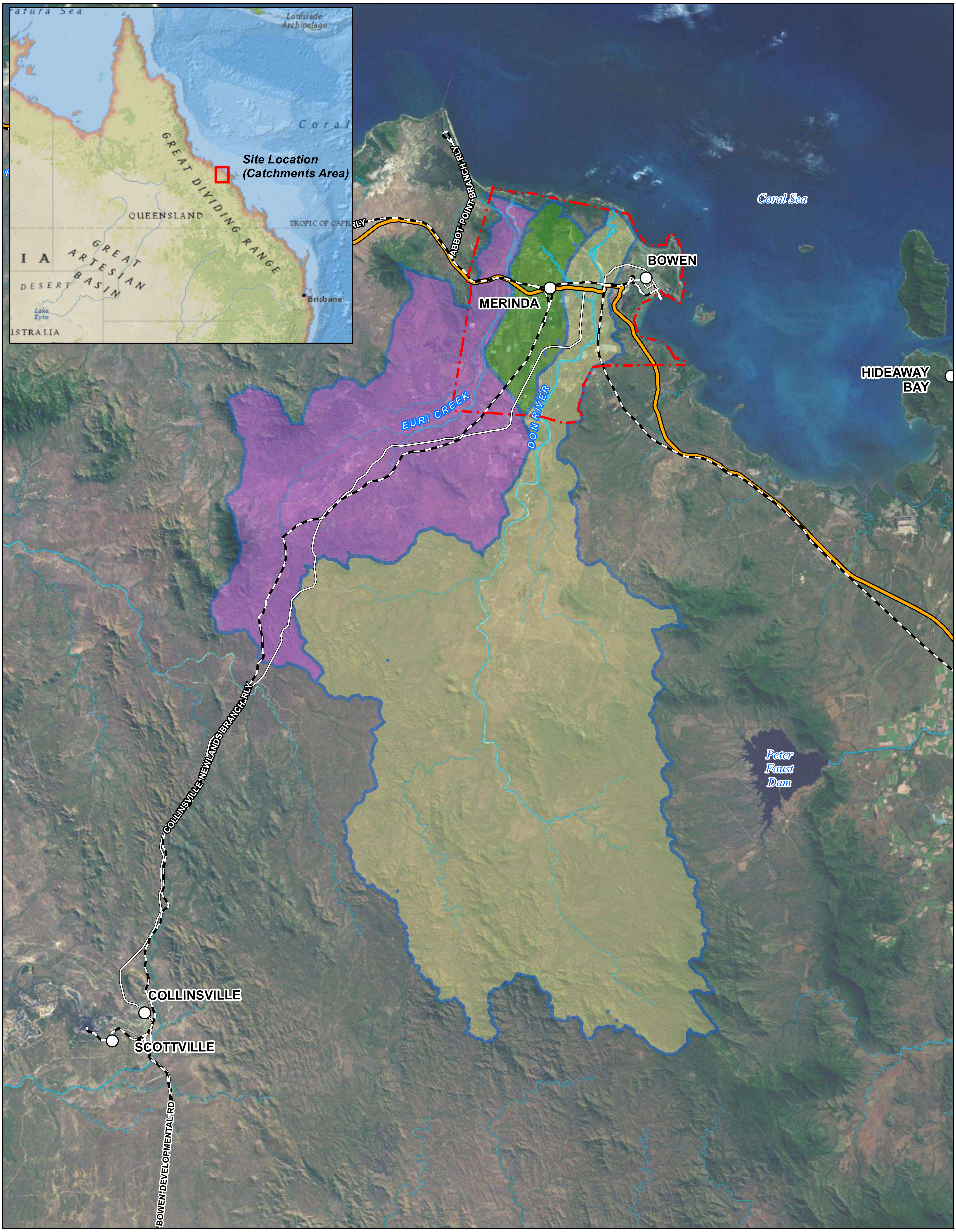
A number of key issues intensify the flood risk associated with the Don River, including:

- Short flood warning lead times of as little as three hours (and up to nine hours), resulting in rapid stream rises and high flow velocities.
- Stream velocities in the lower Don River of up to 4 m/s.
- Extensive sand deposition, particularly at the mouth of the Don River, as a result of upstream erosion.
- Historical and continued vertical and horizontal movement of the river bed.
- The proximity of the current Don River mouth and delta to the suburb of Queen’s Beach.

1.3 Report Structure

This Stage 1 report is structured as follows:

- Section 2.0 describes the characteristics of the Don River, Euri Creek and Sandy Gully catchments, including channel and floodplain characteristics and typical land use within the catchment.
- Section 3.0 describes the data available for the development and calibration of the hydrologic and hydraulic models, including a review of available rating curves.
- Section 4.0 outlines the hydrologic modelling approaches and presents the results of the hydrologic model calibration.
- Section 5.0 outlines the hydraulic modelling approaches and presents the results of the hydrologic model calibration.
- Section 6.0 discusses the sedimentation transport modelling undertaken using the hydrodynamic model.
- Section 7.0 presents the results of the investigation into the effect of climate change on flood discharges and extents in the lower Don River catchment.
- Section 8.0 presents the design flood depths, levels and extents for the study area.
- Section 9.0, 10.0 and 11.0 provides recommendations and advice pertaining to Emergency Management Planning, Community Awareness and Development Planning, respectively.
- Section 12.0 provides a summary of the Flood Risk Assessment and includes additional recommendations for Council’s consideration.
- Section 13.0 is a list of references.



DON RIVER FLOOD STUDY

Locality Plan & Study Area

Figure 1

LEGEND
- Sandy Gully Catchment
- Don River Catchment
- Euri Creek Catchment
- Study Area (Hydraulic Model Area)

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2.0 Catchment Characteristics

2.1 General

The Don River, Euri Creek and Sandy Gully catchments have been identified to be within the study area as each can contribute towards flooding at Bowen and surrounding communities (i.e. Queens Beach and Merinda).

2.2 Sandy Gully

Sandy Gully catchment system is situated between the lower reaches of the Don River and Euri Creek catchments. It conveys ephemeral flows in a northerly direction, through the Bruce Highway and North Coast Rail Line, before discharging to the Coral Sea via swampland and the Don River delta.

The Sandy Gully catchment covers an area of approximately 40km² which is drained via a main channel that is in its natural state for the most part. The main channel is characterised by a sandy bed and medium to densely vegetated banks. The watercourse has been modified in several locations through the construction of both online and offline storages for irrigation purposes.

The catchment is predominantly flat with the levels varying between 35m AHD in the top of the catchment to a level of just under 0m AHD in the creek mouth, over an estimated main stream length of 17km. The majority of the catchment is cleared for farming activities with some uncleared area consisting of open forest. The lower catchment is characterised by flat, tidally affected swamplands.

A number of cross-connections occur between Sandy Gully catchment and the eastern and western catchments (Don River and Euri Creek catchments, respectively). In major events, flows break out from number of locations along Don River and Euri Creek and discharge through Sandy Gully system before discharging to the Coral Sea.

Bruce Highway, North Coast Railway, Collinsville Railway and Merinda Railway Deviation are the major transport infrastructure which cross the Sandy Gully floodplain.

2.3 Euri Creek

Euri Creek is situated to the west of the Don River with a catchment totalling approximately 440km². The headwaters of Euri Creek are located south-west of Bowen in the foothills of Mt Pleasant, Highlanders Bonnet and Mt Aberdeen. The upper sections of the Euri Creek catchment are heavily vegetated, dominated by thick tropical rainforest. The foothills are covered with loose boulders, dense to medium scattered forest and scrub, with alluvial plains adjacent to the main reaches of Euri Creek consisting of sparse scrub and trees with tall grasses or cultivated areas.

Euri Creek is approximately 60km long and splits into two outlets at the confluence with Saltwater Creek. The main Euri Creek outlet to the Coral Sea is located approximately 11km west of the Don River mouth, while the secondary Saltwater Creek outlet joins the Caley Valley Wetlands.

Euri Creek is constrained to the west by the foothills of Mount Roundback, such that during large flood events, overbank discharges tend in an easterly direction towards the Don River.

2.4 Don River

The Don River drains a catchment of about 1,200km² which extends from the Clark Ranges, 70km south of Bowen, to the mouth of Don River, just to the west of Queens Beach. The upper catchment is relatively steep falling 250 metres over 60 Km from its source near Mount Roundhill to Mt Buckley. The river flattens out in the lower reaches (below 15km AMTD), where it drains to the Coral Sea west of Bowen via a delta. Like the Euri Creek catchment, there is cattle grazing in the upper catchment while the lower fertile floodplain is extensively farmed by vegetable and fruit growers.

Don River has formed a delta at its mouth due to higher rates of sand transported and deposited by river compared to the removal capacity of the coastal dynamics. Changes to the sea level, outlet topography, strong northerly longshore currents, dynamic nature of the river channel and river breakouts are other factors which may have contributed to formation of the delta.

2.4.1 Bed Profile

The Don River bed is sandy and highly dynamic because of significant volumes of sediment transport. The lower reaches of the Don River and its banks are generally subject to sand deposition and level increases in the small to medium flood events. In large events however, bed scouring, bank erosion and flow break outs occur in the lower reaches of Don River. Some of the large events have resulted in formation of the new river outlets and channels.

The river bed profile is highly variable in the lower floodplain due to the fluvial nature of the system and therefore breakouts can occur at various locations and are typical during large flood events. Historic reports have documented the various new channels and mouth locations which have previously formed during flood events.

2.4.2 River Mouth

Much of the urban development is situated upon the active delta which is subject to frequent changes in the width and alignment of the main river channel and distributaries. In recent years, the lower Don River area has demonstrated a tendency to outflow over the right bank in the direction of Queen's Beach which is located on what was a previous channel of mouth of the Don River.

Fundamentally, the Don River does not have a stable mouth and the likelihood of new mouth locations is an ongoing risk due to the nature of the delta system and highly mobile river bed. Indeed there have been up to ten main river channel / mouth combinations identified by historical reports dating back to 1980.

A more extensive description of Don River morphology and mouth location is provided in the Don River Flood Investigation (Ullman and Nolan, 1980).

2.4.3 River Breakouts

During large flood events, the Don River overtops its banks at a number of locations resulting in overflows that inundate adjacent floodplain areas. There are ten historically recorded locations of significant breakout flows in the Lower Don River, as listed in Table 1 and Figure 2.

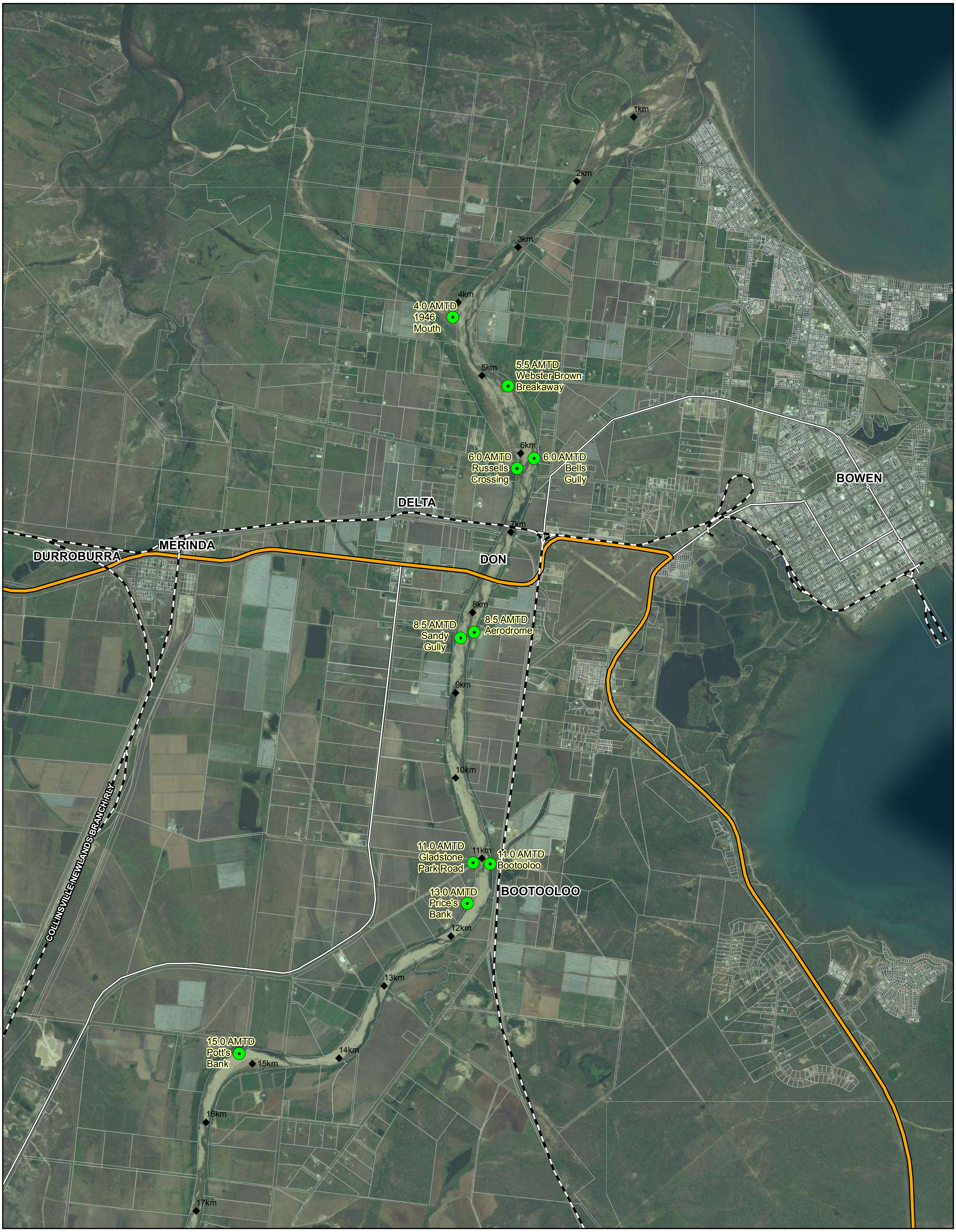
Table 1 **Primary Don River Breakout Locations**

Left Bank (Looking Downstream)		Right bank (Looking Downstream)	
Name	**AMTD (km)**	**Name**	**AMTD (km)**
Pott's Bank	15.0	Bootooloo	11.0
Price's bank	13.0	Aerodrome	8.5
Gladstone Park Road	11.0	Bells Gully	6.0
Sandy Gully	8.5	Webster Brown	5.5
Russell's Crossing	6		
1946 Mouth	4		

*Note that 3km AMTD is the location of the Inverdon Road Bridge.

Historical reports and records suggest that flows are contained within the main channel upstream of Pott's Bank, however there has been speculation of overflows some 32km inland from the mouth in the 1946 flood event. This would suggest a southern most outflow point near the Mt Danger Station. Ullman & Nolan (1993) checked the potential overflow location and noted a thin line of alluvium deposit which gave some credence to the 1946 observation. However, it was also noted that these overflows would be very minor and would not affect the Lower Don River catchment to any great extent.

Breakouts at Bells Gully and Webster Brown occur on the right bank of the river in the lower reach and are adjacent to the heavily populated areas of Bowen and Queens Beach. These breakouts are particularly important for the assessment of existing flood risk associated with this study.



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Coordinate System: GDA 1994 MGA Zone 55

Data sources:
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Catchments, Rivers - QLD Gov© 2012
Roads, Rail - StreetPro 2010

LEGEND
- ◆ AMTD Chainage
- Breakout Location(with AMTD chainage)
- Highways
- Main Road

DON RIVER FLOOD STUDY

Lower Don River Breakout Locations

Figure 2

2.4.4 Flood Warning and Classification System

The Don River flood warning system (ALERT) was completed in 1989 and is operated by WRC and BOM. The BOM Flood Warning Centre issues flood warnings and river height bulletins during potential flood events. In addition to rainfall gauging stations, four river height gauging stations are maintained in the Don River to monitor river levels, and provide flood warnings via telemetry. From the upstream end, these river height stations are located at:

- Ida Creek.
- Mount Dangar.
- Reeves.
- Bowen Pump Station.

Flood warnings at the Bowen Pump Station are classified according to the levels presented in Table 2.

Table 2 Flood Classifications at the Bowen Pump Station

Classification	Gauge Level (m)
Minor	2.5
Moderate	4.0
Major	5.5

2.4.5 Historical Flooding

BOM note that, since settlement in 1861, historical records indicate that major floods occurred in 1869, 1870, 1884, 1910, 1916, 1918, 1928, 1940, 1946 and 1955. The highest recorded flood was in 1946 with rises to 9.70 metres on the flood gauge at Mt Dangar.

The table below summarises the flood history of the Don River catchment - it contains the flood gauge heights of the more significant recent floods. Note that all heights are in metres on the flood gauge.

Table 3 Historical Flood Heights at BOM's River Height Stations (source: BOM, 2011).

River Station	1970 Event	1980 Event	1988 Event	1991 Event	1999 Event	2005 Event	2007 Event	2008 Event	2011 Event
Ida Creek	7.06	8.27	5.29	5.80	-	3.60	5.95	7.90	3.11
Mt Dangar	-	-	-	7.50	5.75	5.50	6.90	9.40	3.45
Reeves	-	10.38	7.62	7.43	5.08	5.11	-	9.16	4.66
Bowen Pump Station	7.25	7.20	5.35	5.55	4.80	4.79	5.29	6.50	4.15

In recent years, major levels were reached in January 1970, February 1979, January 1980, March 1988, February 1991 and February 2008. Figure 3 shows the annual flood peaks at the Bowen Pump Station over this period.

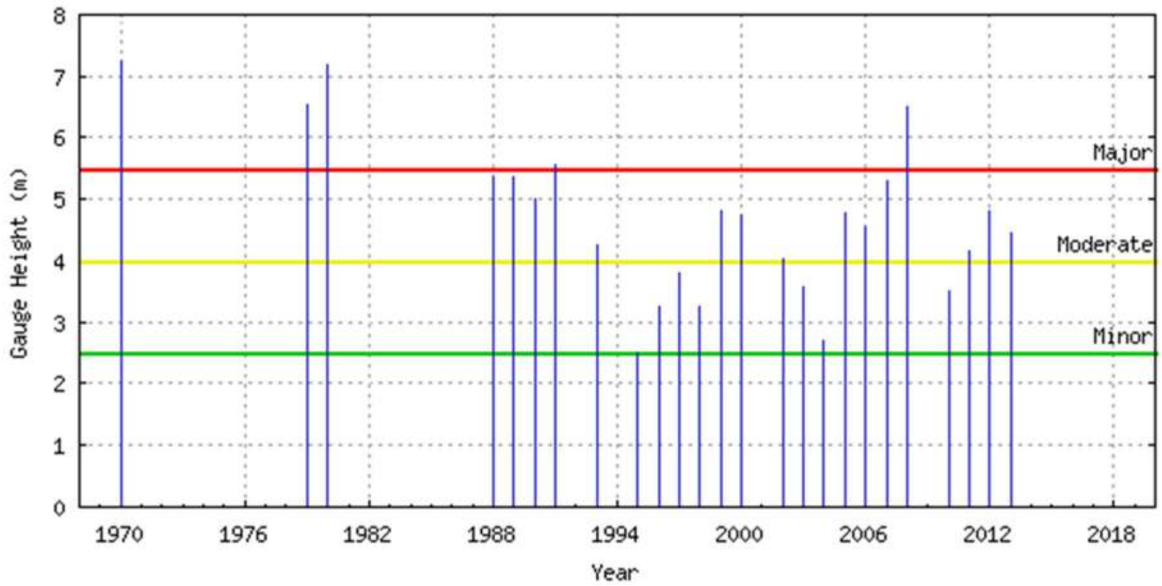


Figure 3 **Annual Flood Peaks at the Bowen Pump Station (source: BOM, 2011)**

2.5 Climate Characteristics

The Don River, Euri Creek and Sandy Gully catchments are situated between latitudes of 19º 56´ and19º 55´ south, about 400 km north of the Tropic of Capricorn. The southern boundary of the catchment is about 70 km from the Pacific Ocean at Bowen. As a result, the catchment experiences a tropical maritime climate.

The climate is dominated by summer rainfalls with heavy falls likely from severe thunderstorms and occasionally from tropical cyclones. Heavy rainfall is most likely to occur between November and April with most of the flood events occurring in the months December to March.

2.6 Rainfall Regime

Bowen has a mean annual rainfall of 900mm – 1000mm. The highest mean monthly rainfall of 225mm occurs in February. The highest and lowest annual rainfall recorded at the Bowen Airport is 2080mm (in 2010) and 370 mm (in 2001) which shows a significant variation in annual rainfall from year to year.

The highest monthly rainfall of 848mm was recorded in December 1990. Highest daily rainfall of 327mm was recorded on 31 December 1991. The following graph shows the distribution of the mean monthly rainfall throughout the year at the Bowen Airport.

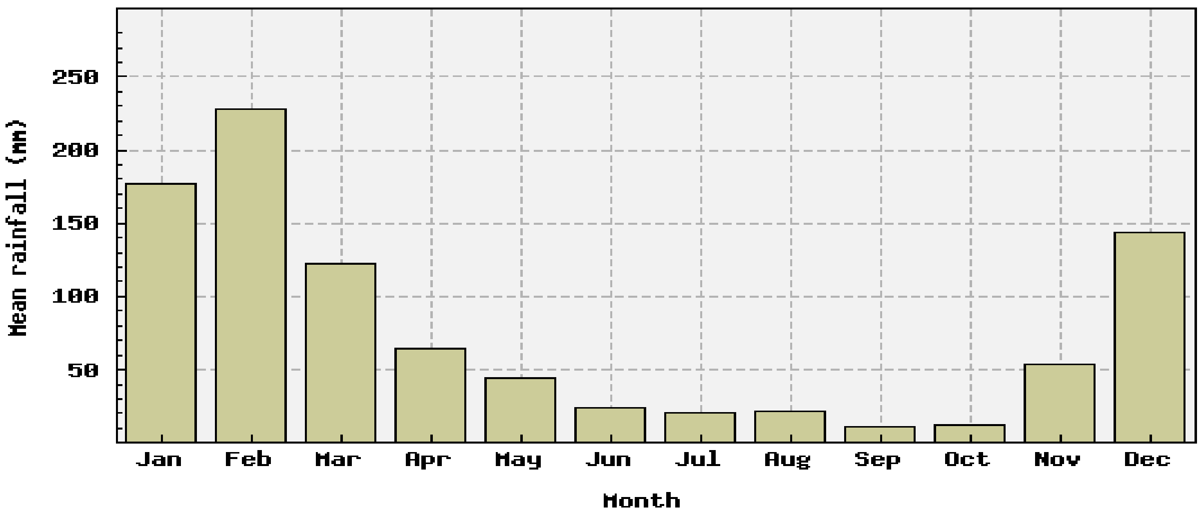


Figure 4 **Mean Monthly Rainfall at the Bowen Airport Rainfall Station**

3.0 Available Data

3.1 General

Available data for the development and calibration of the hydrologic and hydraulic models consisted of:

- Previous reports.
- Recorded rainfall data (daily and pluviograph).
- Recorded water levels at stream gauging stations within the catchment.
- Rating curves to convert recorded water levels to discharges at the stream gauges.
- Tidal data.
- Details of hydraulic structures within the study area (bridges, culverts, etc).
- Don River bed material characteristics.
- Peak recorded water levels for the 1980 and 2008 flood events.

Each of these a described in more detail in the following sections.

3.2 Previous Reports

There are a number of previous studies that have been closely reviewed to help inform various aspects of the flood risk and mitigation assessment. These include:

- Don River Flood Investigation (Prepared by Ullman and Nolan for Water Resource Commission, 1980)
- Don River & Euri Creek Flooding (Water Resource Commission, 1980)
- Don River and Floodplain Hydrology & Hydraulics Study (Ullman & Nolan, 1990)
- Don River Floodplain Upgrading Strategies (Ullman & Nolan for North Queensland Rail and Queensland Department of Transport, 1993)
- Don River Floodplain Management Study (Ullman & Nolan, 1993)
- Queens Beach Flood Study (Ullman & Nolan, 1998)
- Bowen Stormwater Drainage Study (Ullman & Nolan, 2001)
- Don River & Euri Creek Sand Depth Study (Connell Wagner, 2005)
- Abbot Point Flood Study (AECOM, 2008)
- Sandy Gully Flood Study (WBM, 2008)
- Queens Beach Drainage Study, Bells Gully (Cardno Ullman& Nolan, 2010)
- Bowen Strategic Flood Modelling Study-Draft (GHD, 2011)
- Don River Sand Depth Study (Aurecon, 2011)

A brief synopsis of these historical reports, and the relevant information gained from them, is given in the following subsections.

3.2.1 Don River & Euri Creek Flooding Report (Water Resource Commission, 1980)

The Don River & Euri Creek Flooding Report was prepared for Queensland Water Resources Commission following the 1980 flood event. This report provides information on the meteorological system which resulted in the January 1980 rainfall event and the subsequent large flood which occurred in the Don River.

The rainfall data and gauging data available for this event and estimates of the peak discharges and return probability of the event were investigated. The report also provides information on the depth and extent of the flood, mainly using distinct flood marks and anecdotal evidence from landholders which has been subsequently digitised and used in this study.

Discussion was provided on recorded streamflow data during the event in which it was noted that Ida Creek, Warden Bend and the Bowen Pump Station gauges were in operation. The height at Warden Bend was recorded by a landholder at 1.30am but did not record the peak. The flood peak was recorded by the Bowen Pump Station gauge prior to it failing due to a partial bank collapse.

The Ida Creek gauge operated normally up to a height of 7.5 metres but a malfunction of the unit meant that the peaks weren't recorded. Two distinct debris lines were levelled to show flood peaks of 8.0m and 8.28m at the gauge. DNRM have previously used this information to construct the upper range of the 1980 hydrograph at Ida Creek in which a peak discharge of 5,000m^3/s was estimated.

There was no gauging instruments installed on Euri Creek and the only records obtained were peak levels and approximate times of the peak. The Euri Creek peak was reached around the same time as the Don River peak (5am on 7 January 1980).

The report identified the large sediment deposits within the river and adjacent lands that occurred as a result of the 1980 flood event. An estimate of $1.1x10^6m^3$ of sediment was provided. Severe bank erosion and destruction of river bank protection works was noted. Whilst no lives were lost, there was one house and two farm sheds washed away.

3.2.2 Don River Flood Investigation (Ullman & Nolan, 1980)

The Don River Flood Investigation Report was undertaken to investigate Lower Don River flooding and to recommend methods to stabilise the system. It represents arguably one of the most extensive investigations of the Don River and included the following:

- Historical background of Lower Don settlement and development.
- Morphology of the Lower Don River.
- Catchment hydrology.
- Channel flows and hydraulics.
- Sediment transport stream regime.
- Description of previous river works.
- Outline of remedial options.
- Selection of the preferred scheme.
- Discussion on long term considerations.

The report provides valuable information on sediment transport loads and fluvial processes, which is a significant contributor to developing an understanding of the geomorphology and sediment transport processes in the river and delta system.

3.2.3 Don River and Floodplain Hydrology & Hydraulics Study (Ullman & Nolan, 1990)

The Don River and Floodplain Hydrology and Hydraulics Study carried out a hydrological analysis and mathematical river modelling (based on the modelling tools available at the time) and provides an estimate of the magnitude of breakout discharges along the Don River for the flood events of 1970, 1980, 1988 and 1989 events.

The Don River Hydrology and Hydraulics Study provided useful information for the comparison of hydrologic and hydraulic modelling outputs, particularly the Flood Frequency Analysis (FFA) and RORB results.

3.2.4 Don River Floodplain Upgrading Strategies – North Coast Rail Line and Bruce Highway (Appendix A) (Ullman & Nolan 1993)

The Don River Floodplain Upgrading Strategy (Appendix A) report took the results of the previous Don River Floodplain Hydrology and Hydraulics Study and made technical updates, including the estimation of Euri Creek design flood hydrographs and FFA.

3.2.5 Don River Floodplain Management Study (Ullman & Nolan, 1993)

The Don River Floodplain Management Study undertook an extensive hydrological and hydraulic study of Don River and estimated the potential extent and impacts of various AEP flood events in the Don River floodplain. This report has also investigated and proposed a number of mitigation options to protect public infrastructure and farms with information on the implications associated with each mitigation option.

The study area was the Don River and Euri Creek catchments. It was identified that the flood issues in the catchment are limited to the lower reaches of the Don River (up to 17km inland from the river mouth).

The predicted outflow for varying design events was calculated and is shown in Table 4.

Table 4 Predicted Outflows (source: Ullman & Nolan, 1993)

Outflow	AMTD (km)	Outflow Discharge (m^3/s)			
		6.5% AEP ($4,500 m^3/s$)	5% AEPI ($5,000 m^3/s$)	2% AEP ($6,400 m^3/s$)	1% AEP ($7,600 m^3/s$)
Pott's Bank	15.0	564	818	1,681	2,463
Price's Bank	13.0	0	0	28	90
Bootooloo	11.0	77	124	233	332
Gladstone Park Road	11.0	0	5	152	290
Sandy Gully	8.5	275	308	352	374
Aerodrome	8.5	136	217	345	408
Bell's Gully	6.0	92	99	106	109
Russells Crossing	6.0	241	263	288	300
Webster Brown	5.5	1,132	1,161	1,193	1,207
'1946 Mouth'	4.0	1,105	1,113	1,120	1,121
Old Mouth	4.0	888	894	902	906

3.2.6 Queens Beach Flood Study (Ullman & Nolan, 1998)

The Queens Beach Flood Study has attempted to assess the risks to Queens Beach associated with the changes in the flooding regimes as a result of the changes occurring in the Don River estuary. Structural mitigation works were proposed to mitigate the risks as much as possible. This report has provided a brief history of the breakouts which occur in Webster Browns, Bells Creek, 1946 mouth and Old Mouth.

The Queens Beach Flood Study provides useful information for the comparison of hydrologic and hydraulic modelling outputs and a compilation of historical flood levels for use in model calibration. The study suggested mitigation works which was grouped into 'Upstream Works' and 'Downstream Works'. These are outlined below:

- Upstream Works
  - Scheme 1 – Bank protection and embayment works upstream from Webster Brown to Council's Pump Station.
  - Scheme 2 – Bank protection works Webster Brown to the Inverdon Bridge.
- Downstream Works
  - Scheme 1 – Rock revetment works between Queens Beach and Rainbow waterhole.
  - Scheme 2 – Strengthening existing rockwork at the end of Creek and Gloucester Streets, Queens Beach.
  - Scheme 3 – Rock revetment to eastern bank of Rainbow waterhole.

3.2.7 Bowen Stormwater Drainage Study (Ullman & Nolan, 2001)

The Bowen Stormwater Drainage Study has focused on the stormwater drainage of Bowen and Queens Beach. This report has identified the deficiencies in the existing drainage system of Bowen and Queens Beach and provides augmentation options to improve the stormwater drainage system and provide greater local flooding immunity.

3.2.8 Don River & Euri Creek Sand Depth Study (Connell Wagner, 2005)

Following completion of the Bowen Storm Tide Study, Connell Wagner undertook additional investigations regarding the calibration of the MIKE 21 Don River model and to extend the flood modelling to include Euri Creek, located to the north of the Don River. In addition, a study into the aggradation of sand within the Don River channel was undertaken.

A Sediment Study was also undertaken as part of this work which indicated that an average depth of 5 metres of sand material is likely to be mobilised from the bed of the Don River during large flood events. Therefore for calibration purposes this depth of material was removed from the channel bed for the 1980 event to represent the modified river conveyance profile. The report also indicated that ongoing aggradation in the river channel will occur and at least a further metre of material is expected over the next few decades. Therefore for design events the bed level adopted was four metres below that currently in place, allowing for the future metre increase and the five metres moved during flood events.

Based on the analysis undertaken and the mapping produced, a number of potential mitigation measures were identified for consideration by Council, including:

- Planning Controls aimed at limiting development in areas that were considered to be of high risk.
- Setting of minimum floor levels for properties in flood affected areas – including appropriate greenhouse, freeboard and wave setup/run up allowances.
- Further consideration/evaluation of upgrading sections of the Bruce Highway, taking into account duration of inundation and impacts on residents during severe events.
- Extraction of sand from the bed of the Don River.
- Review/Evaluation of current Emergency Management Procedures taking into account the new flood inundation and hazard mapping.

3.2.9 Abbot Point Flood Study (AECOM, 2008)

Abbot Point Flood Study was prepared to identify areas suitable for potential industrial development in Abbot Point district and included a comprehensive study of the Euri Creek catchment.

A XP–RAFTS hydrological model was developed for the local catchments as well as for the Splitters Creek and Euri Creek catchments. Flood hydrographs were generated at key locations for input to the hydraulic model for the 10% AEP, 5% AEP, 2% AEP, 1% AEP and 0.2% AEP flood events.

The MIKE FLOOD hydraulic model was used to simulate flood behaviour for the chosen flood events with different tidal boundary conditions. The model examined the breakout flows and flooding impacts from Euri Creek and Don River. Breakout flows from the Don River were determined from a MIKE21 model previously developed for Bowen Shire Council.

3.2.10 Sandy Gully Flood Study (WBM, 2008)

Preliminary hydraulic design was undertaken by WBM for TMR which focussed on a potential upgrade of the 3.5km stretch of Bruce Highway between Euri Creek and the town of Merinda. The existing highway is part of a 7km stretch of highway with low flood immunity, between the Don River and Euri Creek crossings which have higher immunity from previous upgrades. The highway crosses a number of tributaries of Sandy Gully, with a catchment of approximately 40 km^2 upstream of the highway.

The scope of work included the extension of existing URBS hydrologic models and the development of a TUFLOW hydraulic model of Sandy Gully, Euri Creek and the Don River. Model calibration was based on the 1980 flood event on Euri Creek and the Don River which saw breakouts to Sandy Gully at a number of locations. The calibration process was limited by gaps and poor quality gauge and flood level data available for the event.

WBM noted additional uncertainty in the hydraulic model due to discrepancies identified in the underlying ALS dataset and quantification of bed sand scour in large flood events. The main focus of the hydraulic modelling was to investigate flood impacts on the Bruce Highway within the Sandy Gully floodplain and assess various upgrade options.

The Sandy Gully Flood Study provides useful information on rainfall data, river gauging data and existing road and rail structures. This report also provides information on calibration to 1980 flood event and estimation of the discharges for design flood events.

3.2.11 Queens Beach Drainage Study, Bells Gully (Cardno Ullman &Nolan, 2010)

The Queens Beach Drainage Study looked at the local drainage of Bells Gully and its potential coincidence with Don River outflows. The study provides useful information on the hydraulic capacity of the Bells Gully drainage system, estimated outflow from Don River at Bells Gully and existing structures along the gully. The principal conclusions reached in the study are summarised as follows:

- Bells Gully is subject to outflows from the Don River in extreme events. Previous studies have discussed stopping the outflows from the river and the impact of increased flows to other areas downstream of the Bells Gully overflow.
- Bells Gully is a series of parallel gullies with insufficient capacity to convey the 1% AEP event outflow from the Don River.
- The hydraulic capacity of Bells Gully downstream of Mt Nutt Road reduces from 70 m^3/s to approximately 20 m^3/s at Soldiers Road.
- Upstream of Mt Nutt Road the Don River outflows are directed approximately one-third to the north, one-third to the south and one-third to the east along Bells Gully.
- Downstream of Mt Nutt Road the Don River outflows discharge overbank to the north towards Brighton Road and Wests Lane, and to the south towards Richmond Road.

3.2.12 Don River Sand Depth Study (Aurecon, 2011)

Subsequent to the Don River & Sandy Gully Sand Depth Study in 2005, the Don River Sand Depth Study was undertaken to investigate the effectiveness of sand extraction to mitigate flooding impacts along Don River.

Modelling of various extraction regimes has demonstrated that removal of sand from the river could reduce the severity of flooding in Bowen Township. In particular the removal of sand to form a channel below the railway line could reduce flood levels in most of the urban areas. However the modelling has also shown that if sand is only removed from above the railway line then flood levels could increase. As a result of this study the following recommendations were made:

- Sand extraction should be limited to the area downstream of the rail line.
- A business case should be undertaken to determine if the channel can be constructed. This would be dependent on approval from DERM.
- Additional flood monitoring should be carried out to improve the accuracy of the sediment transport formula developed by Horn et al (1998).
- A standard set of flood monitoring points should be adopted and peak heights recorded at each location.
- Cross-section monitoring points should be established to monitor on-going changes to the bed levels and to determine if extraction regimes are effective in reducing sedimentation of the lower reaches.
- Measures should be investigated to reduce the level of erosion from the upper reaches of the catchment thus reducing the sedimentation of the lower reaches.

3.2.13 Bowen Strategic Flood modelling Study-Draft (GHD, 2011)

GHD was commissioned by the Department of Employment, Economic Development and Innovation (DEEDI) to undertake a Strategic Flood Study for the Don River floodplain in Bowen. The main purpose of the study was to develop an understanding of local and regional riverine flooding constraints and to identify land suitable for future development including provision of accommodation facilities for temporary and permanent workers and community infrastructure.

The scope of work undertaken in the study included the development and refinement of existing hydrologic models to estimate flood flow rates and the development of hydraulic models to estimate flood levels, flood extents, flood velocities and flood hazard. Hydrologic and hydraulic models were developed on both local and regional scales. Flood models of the Don River were calibrated to the January 1980 historical flood event. The calibrated models were used to assess a range of 1% AEP design event flood scenarios.

A set of flood inundation maps were prepared to indicate the flood extent, level, depth and flood hazard across the study area for the January 1980 historical event and a range of design event scenarios. The maps indicated the area of flood free land within the study area and the degree of flood hazard associated with flooded properties.

3.3 Rainfall Data

Historical rainfall data was acquired from the Bureau of Meteorology (BOM) in the form of daily rainfall data and pluviograph data. Data was obtained for rainfall gauging stations which deemed to be relevant for the study area (refer to Figure 5 for location of the rainfall stations).

A list of the rainfall gauging stations, their locations, type of the data and length of the data is provided in Table 5 below. The available rainfall data provides a reasonable coverage of the catchment-wide rainfall events for the recent 2008 event but poor coverage for earlier flood events.

Table 5 Summary of BOM Rainfall Stations used in the Study

Station Number	Site Name	Data Type Available	Start of Record	End of Record	1980 Flood Event	2008 Flood Event	2014 Flood Event
033007	Bowen Post Office	Daily Rainfall	January 1872	August 1987	✗	✗	✗
033094	Bowen Cheetham Salt	Daily Rainfall	November 1960	June 2012	✓	✓	✗
033096	Mount Dangar	Daily Rainfall	May 1961		✓	✓	✓
033097	Moss Vale Station	Daily Rainfall	July 1961	January 2004	✓	✓	✗
033153	Mount Aberdeen	Daily Rainfall	March 1971	February 2002	✓	✓	✗
033257	Bowen Airport	Pluviograph	August 1987	September 2012	✗	✓	✗
033263	Boundary Creek Alert	Daily Rainfall	November 2000		✗	✗	✓
033265	Ida Creek Alert	Daily Rainfall	June 2004		✗	✓	✓
033266	Moss Vale Alert	Daily Rainfall	November 2000		✗	✓	✓
033268	Reeves Alert	Daily Rainfall	November 2000		✗	✓	✓
033269	Roma Peak Alert	Daily Rainfall	November 2000		✗	✓	✓
033270	Upper Don Alert	Daily Rainfall	November 2000		✗	✓	✓
033306	Emu Creek Alert	Daily Rainfall	November 2000		✗	✓	✓
033004	Binbee Station	Pluviograph	November 1932	Unknown	✓	✗	✗
033002	Ayr DPI Research Stn	Pluviograph	April 2011		✗	✗	✓
033013	Collinsville Post Office	Pluviograph	June 1963	September 2010	✓	✓	✗
0332477	Proserpine Airport	Pluviograph	April 2011		✗	✗	✓

The daily rainfall records were analysed along with the available river gauging data to determine the event durations associated with the 1980, 2008 and 2014 flood events. Daily rainfall grid data and pluviograph data were then obtained from BOM for the identified event durations over the entire study area.

Daily rainfall grids are high resolution analyses which are computer generated by BOM using an optimised Barnes successive correction technique that applies a weighted averaging process to the station data. Topographical information is included by the use of rainfall ratio (actual rainfall divided by monthly average) in the analysis process. The output is a spatially varying interpolation of recorded rainfall depths across the catchment which can be coupled with appropriate temporal patterns (derived from pluviograph records) and used to calibrate hydrologic models.

3.4 Stream Gauging Data

Recorded water level data and rating curves for stream gauging stations on Don River and Euri Creek were obtained from BOM and the Department on Natural Resources and Mines (DNRM). Due to availability of stations, equipment malfunctions or other recording problems, recorded water level data was not available at all streamflow monitoring sites for both flood events.

River height data provided by BOM is recorded at the four stations as described in Table 6 below. Refer to Figure 6 for location of the stream gauges.

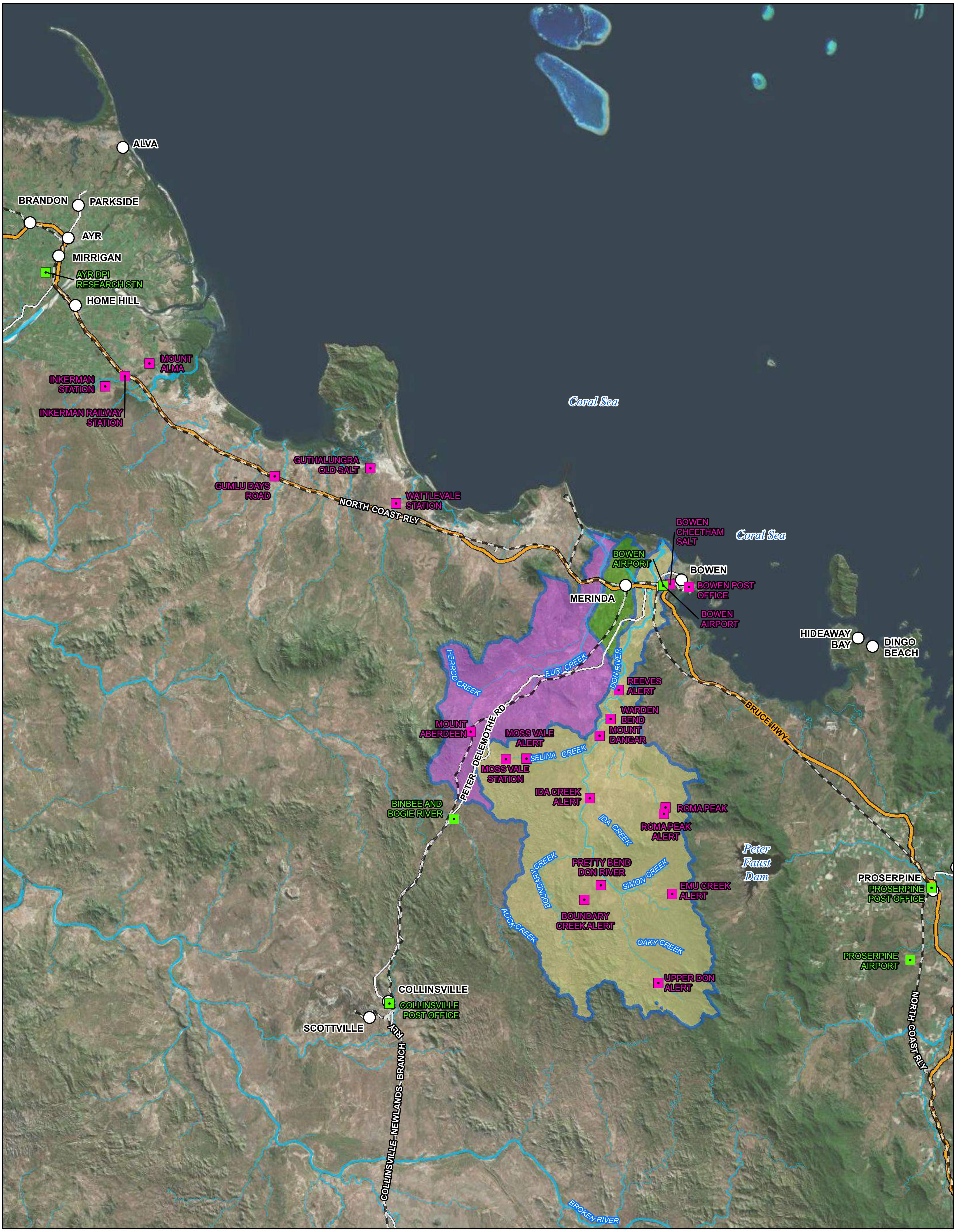
Table 6 Summary of BOM Stream Gauging Stations

Station Number	Station Name	Upstream Catchment Area (km²)	Start of Record	End of Record	1980 Flood Event	2008 Flood Event	2014 Flood Event
033265	Ida Creek at Don River	604	January 1957		✓	✓	✓
033267	Mount Dangar Alert	811	October 1989		×	✓	✓
033268	Reeves at Don River	1,016	May 1990		×	✓	✓
033264	Bowen Pump Station	1,089	January 1970		✓	✓	✓

The river gauging data obtained from DNRM are described in Table 7.

Table 7 Summary of DNRM Stream Gauging Stations

Station Number	Station Name	Upstream Catchment Area (km²)	Start of Record	End of Record	1980 Flood Event	2008 Flood Event	2014 Flood Event
121001A	Ida Creek at Don River	604	March 1957		✓	✓	✓
121003A	Reeves at Don River	1,016	March 1984		×	✓	✓
121002A	Koonandah at Euri Creek	429	November 1998		×	✓	✓



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1:485,000 (when printed at A4)

0 5 10 20
Kilometers

Coordinate System: GDA 1994 MGA Zone 55

LEGEND

- Pluviograph Stations
- Daily Rainfall Stations
- Localities
- Sandy Gully Catchment
- Don River Catchment
- Euri Creek Catchment

Data sources:
Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
Catchments, Rivers - QLD Gov© 2012
Roads, Rail - StreetPro 2010

DON RIVER FLOOD STUDY

Location of Rainfall Stations

Figure 5

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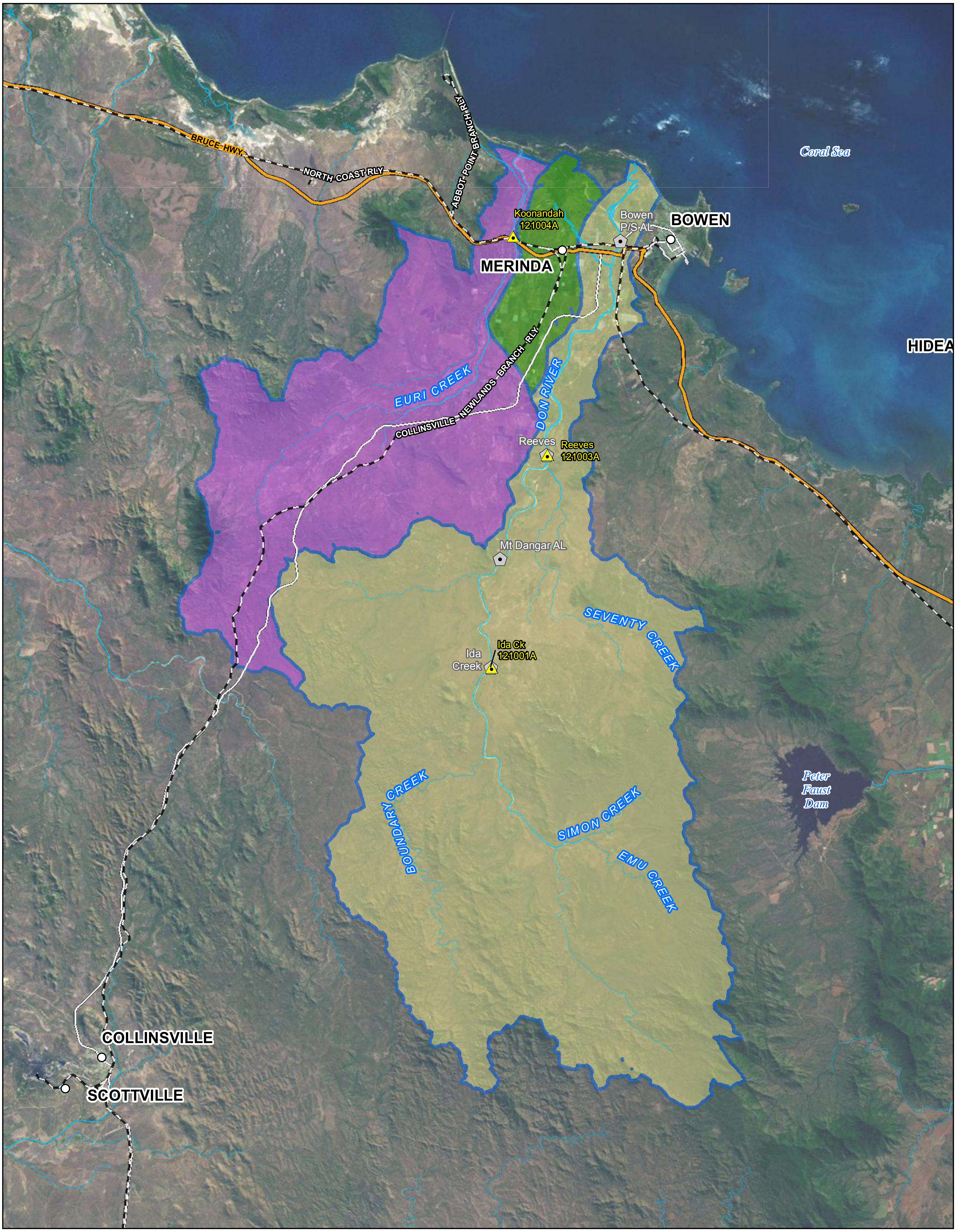

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Kilometers

Coordinate System: GDA 1994 MGA Zone 55

Data sources:
Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
Catchments, Rivers - QLD Gov© 2012
Roads, Rail - StreetPro 2010

LEGEND

- BoM Gauging Stations
- DNRM Gauging Stations
- Localities
- Sandy Gully Catchment
- Don River Catchment
- Euri Creek Catchment

DON RIVER FLOOD STUDY

Location of Stream Gauges

Figure 6

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3.4.1 Rating Curves

BOM did not provide rating curves for their four flood warning gauges when requested by the project team; however rating curves for these gauges were available from data compiled during the 2008 Flood Study for Abbot Point (AECOM, 2008). These rating curves were reviewed along with rating curves provided by DNRM for each of water monitoring gauges.

It is noted that both DNRM and BOM operate the Ida Creek and Revees gauging stations but each adopt significantly different rating curves. A comparison between the BOM and DNRM rating curves at Ida Creek and Reeves are shown below. There are significant differences, particularly at the higher stage which is evidenced by the significant differences in gauged flows for the 1980, 2008 and 2014 flood events.

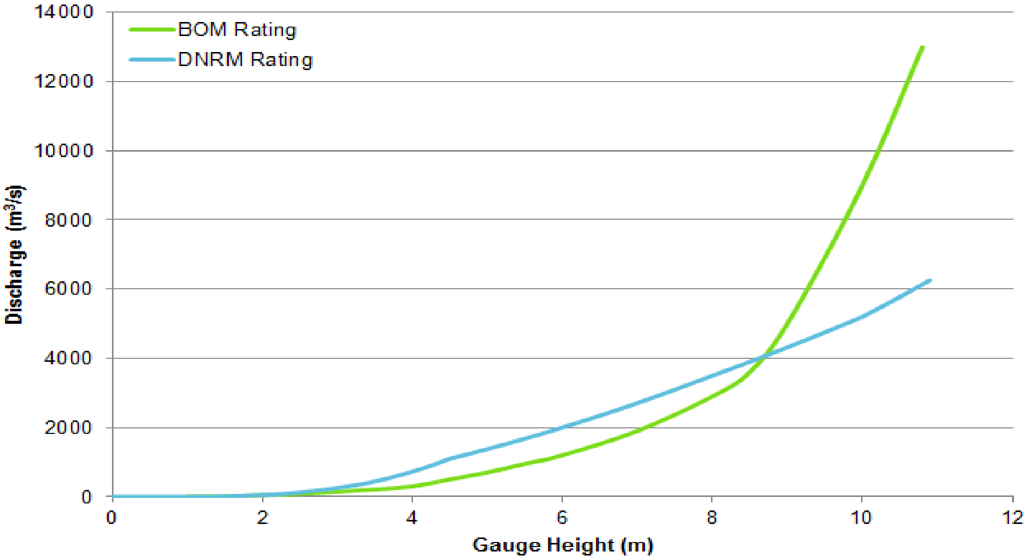


Figure 7 Reeves Gauge Rating Curve Comparison

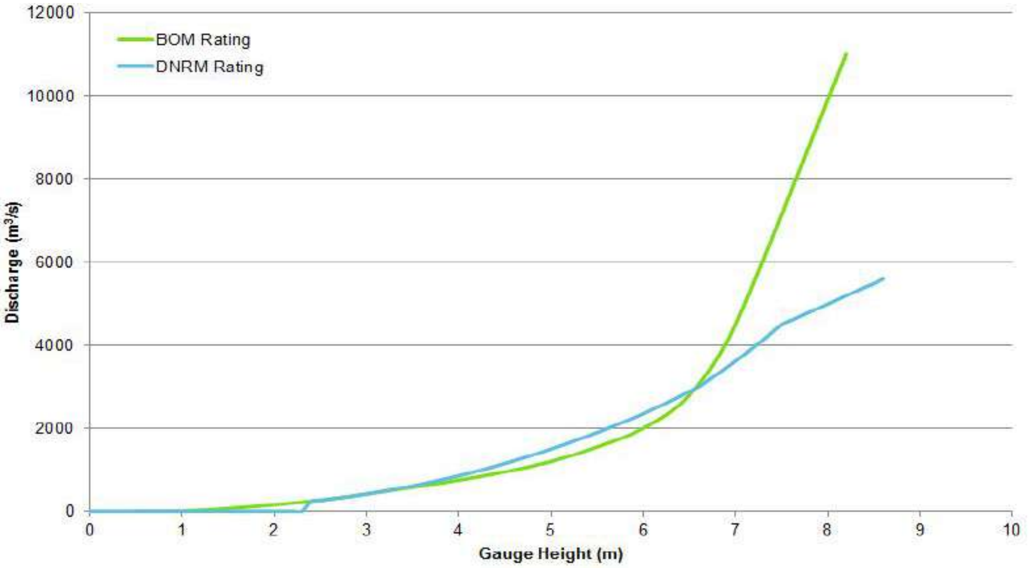


Figure 8 Ida Creek Gauge Rating Curve Comparison

The Ida Creek gauge is located just upstream of the Ida Creek junction. It has a catchment area of approximately 620 km^2, compared with a total Don River catchment of approximately 1,100 km^2. According to the QWRC report on the January 1980 flood event, the recorder malfunctioned for 5 hours at the peak due to an inadequate gas bubble rate. However, two debris lines were deposited which corresponded with eyewitness accounts of two peaks, and data at adjacent stations. This information was used by DNRM to construct the 1980 flood hydrograph.

The DNRM quality information associated with the Ida Creek rating curve suggests that readings above a gauge height of 2.4m (~200m^3/s) are subject to a large degree of uncertainty. Readings below 1.0 m are subject to the uncertainty that is associated with reliable environmental gauging.

There was an inconsistency identified in DNRM's peak discharges at Ida Creek and Reeves for the 2008 flood event. The estimated peak discharge at Ida Creek was found to be greater than the peak discharge at Reeves even though there is over a 400km^2 difference in the upstream catchment areas.

DNRM confirmed that there was a change in the slope of rating curve which did not match with the shape of the cross section or long section. The change in slope occurred at 1,100m^3/s and reduces the rate of rise. Following the adjustment of the rating curve by DNRM they confirmed that the 2008 peak discharge increased from 4,575m^3/s to 6,100m^3/s at Reeves.

It is noted that Mt Dangar, Reeves, Ida Creek and Bowen Pumping Station are all BoM level recorders for flood warning purposes and have not been accurately rated. Mt Dangar in particular has a fully synthetic (modelled) rating. BOM have not provided information relating to the development of their rating curves or any associated quality information to assess the degree of uncertainty in the estimated discharges. Consideration has been given to previous historical reports and data which suggests that the DNRM gauges may have a lesser degree of uncertainty with regard to their ratings.

As a result of the issues associated with the stream gauges and rating curves described above, there is high level of uncertainty surrounding the Don River flow data that is available for calibration of the hydrologic model. This is discussed further in the hydrologic model development chapter of this report.

3.5 Tidal Data

Following the review of the rainfall and stream gauging data and identification of the flood durations in the 1980, 2008 and 2014 events, a list of the tide gauging stations and the period of the required tidal data was submitted to Transport and Main Roads (TMR) – Maritime Branch.

The location and period of the tidal data obtained is described in Table 8 below.

Table 8 Tidal Data provided by TMR

Station ID	Station Name	Data Start date	Data End Date
033001A	Cape Ferguson Storm Surge	15/12/1979	15/01/1980
033007A	Cape Ferguson Storm Surge	01/02/2008	28/02/2008
030003A	Shute Harbour Storm Surge	01/02/2008	28/02/2008
061007A	Bowen Storm Surge	01/02/2008	28/02/2008
030003A	Shute Harbour Storm Surge	12/04/2014	14/04/2014
033007A	Cape Ferguson Storm Surge	12/04/2014	14/04/2014
061007A	Bowen Storm Surge	12/04/2014	14/04/2014

3.6 Topographic Data

3.6.1 Bathymetric Data

Cross section survey of the Don River channel was undertaken by WRC surveyors in 2009 and was provided for the study. This data was compared to the LIDAR which showed reasonably good correlation between the two datasets.

3.6.2 ALS Data

Topographical data was provided by WRC in the form of LIDAR survey. The LiDAR survey from 2009 and 2010 were provided initially until 2013 LiDAR survey became available. Figure 9 shows the extent of the LIDAR data sets made available.

The LIDAR points were used by DNRM to generate a 'bare earth' Digital Elevation Model (DEM) with a grid spacing of 1m. DNRM state that the DEM represents the ground with vertical accuracy of ±0.15 meter on clear, hard surfaces at the 1 sigma confidence level. The absolute horizontal accuracy will be ±0.45 meter at the 1 sigma confidence level.

Two Digital Elevation Models (DEM's) were prepared using the available data sets:

- The 2009 and 2010 LiDAR surveys were combined to produce a DEM for use in the 1980 and 2008 hydraulic model calibration / validation events.
- The 2013 LiDAR survey was used to produce a DEM for use in the 2014 hydraulic model validation event. This DEM was also used for final design event modelling and sensitivity analyses.

In order to improve data size and manageability, both of the LIDAR DEM's were filtered to produce a 5 meter Digital Terrain Model (DTM). The extent of the DTM was then 'trimmed' to match the extent of the hydraulic model.

The 2009 / 2010 LIDAR DTM was combined with the 2009 bathymetric data to create the underlying topographic data used as the ground surface in the hydraulic model. The 2013 LiDAR DTM was not modified as recent bathymetric survey was not available.

The following additional changes were made to each DTM:

- Digital Road Crown Levels (DRCL) for the Bruce Highway was checked against levels from the LIDAR and some minor alterations were made to the DTM to match these levels.
- Queensland Rail (QR) working drawings provided for the North Coast Rail, Collinsville Rail and the Merinda Deviation were reviewed and the rail elevations were compared against the LIDAR DTM. Minor alterations were made to the DTM to match the rail levels provided by QR.

Figure 10 shows a comparison between the DTM's. From the comparison it is clear that the majority of the floodplain is within ± 0.15m difference in elevation. Larger differences were noted in localised areas where development has occurred. Other differences were noted along the Don River channel, 1946 mouth and distributary channel where the 2013 levels are higher than the 2009 / 2010 data as a result of sand transportation and deposition (most likely due to the minor flood events which occurred in March 2011 and January 2013).

3.6.3 SRTM Data

Five metre topographic contours were generated by interpolating the DEM data obtained from the Shuttle Radar Topography Mission (SRTM).

The SRTM was an international research effort that obtained DEM's on a near global scale to generate the most complete high resolution digital topographic database of Earth. The SRTM DEM data used to generate the 5 metre contours was obtained by Space Shuttle Endeavour in February 2000.

These 5 metre contours were used for areas of interest outside of the LIDAR data extent. The contour data was primarily used to delineate sub-catchments for Don River, Euri Creek and Sandy Gully catchments and to determine other sub-catchment characteristics for input into the catchment hydrologic model (i.e. mainstream lengths, sub-catchment slopes and sub-catchment areas).

It should be noted that the contour data was not used to generate surface bathymetry within the hydraulic model as the available LIDAR data represented a more accurate and more recent topographic data set.

3.7 Don River Sediment Characteristics

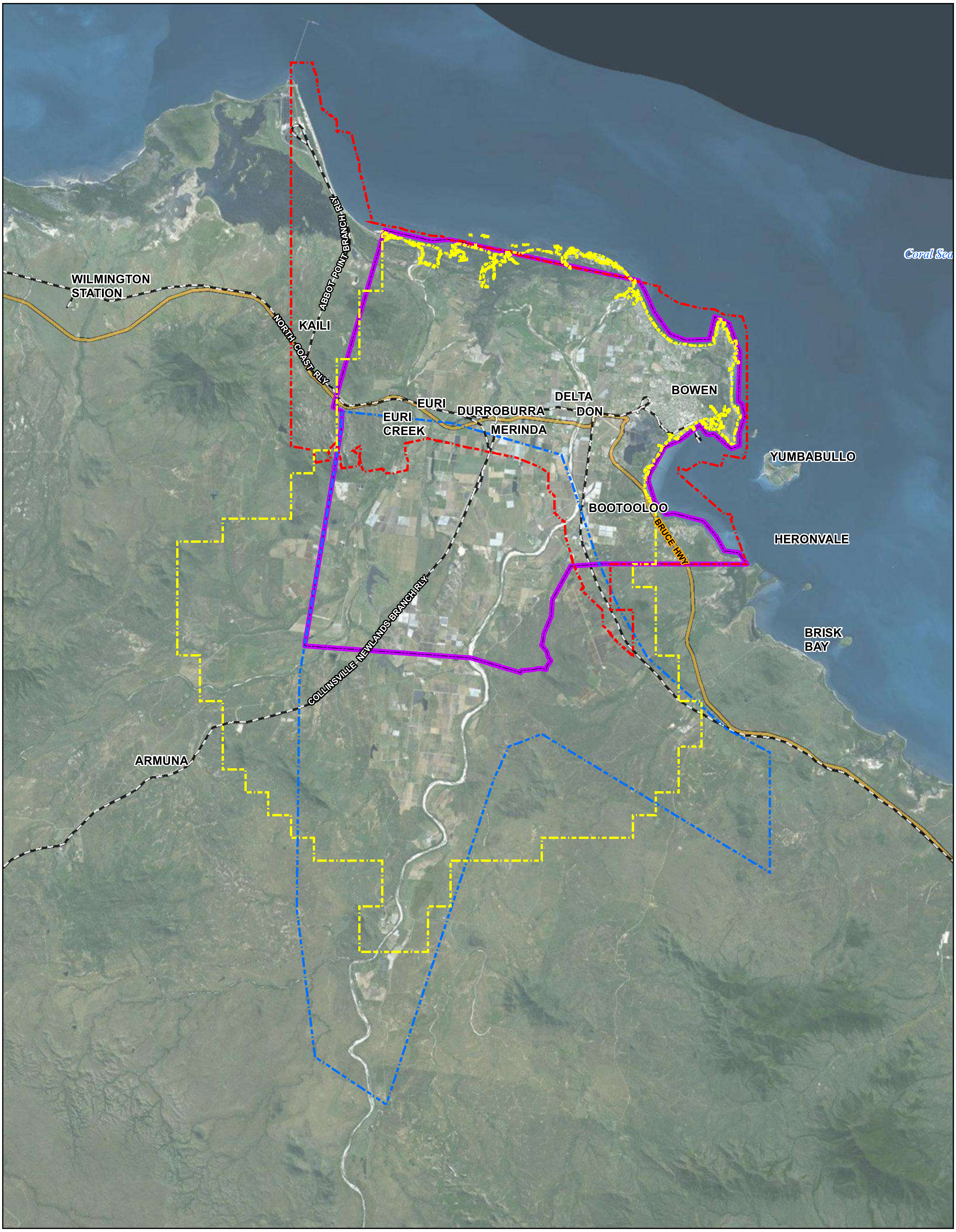
Don River is known to be highly dynamic due to high rates of sediment transport which occurs during flood events. The Sediment Study of the Don River (Hydrobiology Pty Ltd for Connell Wagner) noted the following:

- The Don River bed is aggrading.
- The current rate of catchment sediment erosion is estimated to be approximately 11 times the pre-European value.
- The rate of sediment supplied to the river network appears to be greater than the ability of the river to discharge it to the coast.

- The current sand slug below the Pott's Line (approximately Walsh's Crossing) consists of approximately 8 – 9 million m^3 of high grade quartzo-feldspathic medium to coarse sand.
- Thicknesses of this sand slug range from 0 – 9 m with an average value of 5 – 7 m.
- Approximately 40 – 60% of this may have been deposited in the last 15 years and has added in places up to 3 – 4 m depth of sand.
- Above the Pott's Line there is approximately 1.5 million m^3 of sand as a slug in the channel awaiting downstream transport.

A dynamic sand transport analysis has been incorporated into the two dimensional hydrodynamic model developed for this study. The dynamic sediment transport module simulates bed and bank elevation changes in response to varying hydraulic parameters such as shear stress, stream power, flood depth and flow velocities.

In undertaking the sediment transport modelling, a median bed material size of 0.2mm, sand porosity of 0.4 and relative density of 2.65 was adopted based on geotechnical information collated within the Sediment Study of the Don River Report.



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Kilometers

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Coordinate System: GDA 1994 MGA Zone 55

Data sources:
Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

LEGEND

- Highways
- Railways Lines
- 2009 LiDAR Extent
- 2010 LiDAR Extent
- 2013 LiDar Extent
- Don River Hydraulic Model Extent

DON RIVER FLOOD STUDY

Extent of LiDAR Provided by WRC

Figure 9

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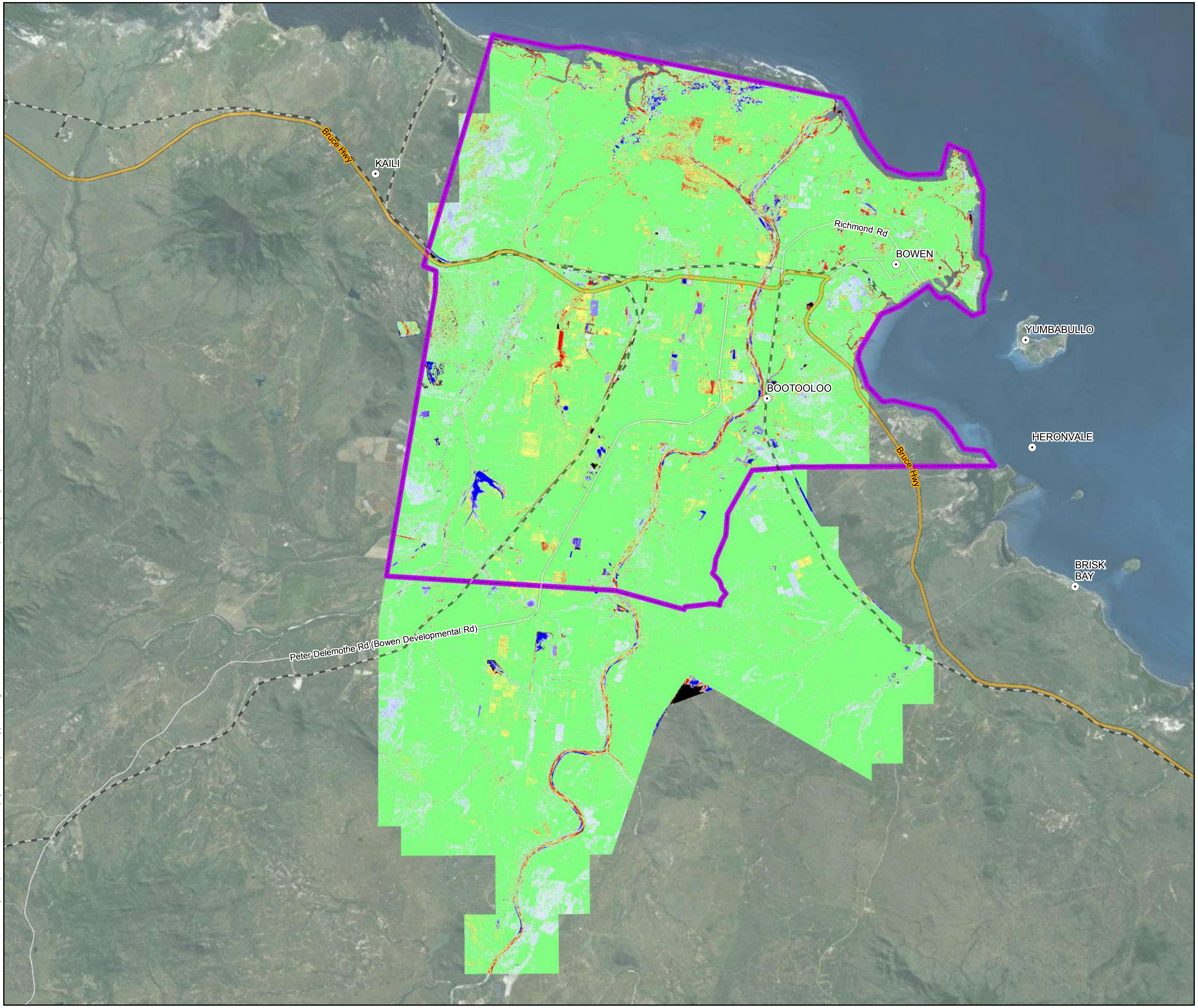

DON RIVER FLOOD STUDY

Comparison Between the 2009 / 2010 LiDAR DEM and the 2013 LiDAR DEM

Figure 10

LEGEND

- Localities
- Highways
- Main Roads
- Railway Lines
- Don River Hydraulic Model Extent

Difference (m)

- > 1.50
- 1.00 - 1.50
- 0.75 - 1.00
- 0.50 - 0.75
- 0.30 - 0.50
- 0.15 - 0.30
- -0.15 - 0.15
- -0.30 - -0.15
- -0.50 - -0.30
- -0.75 - -0.50
- -1.00 - -0.75
- -1.50 - -1.00
- < -1.50

0 0.5 1 2 3 4 5 6
Kilometres

1:120,000 (when printed at A3)

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Coordinate System: GCS GDA 1994

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Lidar - QLD Gov 2013.
Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

3.8 Hydraulic Structures

A comprehensive investigation has been undertaken to identify the hydraulic structures associated with the major road and rail networks within the study area. The following sources were used for identification of the hydraulic structures:

- TMR's working drawings for the Bruce Highway.
- Queensland Rail's drawings and sections for the North Coast Rail Line.
- Aurizon drawings and sections for Collinsville Railway and Merinda Deviation.
- Previous reports.

Approximately 130 sets of culvert crossings and 17 bridges were identified within the hydraulic model extent. However, there were numerous minor structures which were not expected to convey significant flows and were not incorporated into the hydraulic model. Table 9 shows the list of the major structures within the study area which were incorporated into the hydraulic model.

Table 9 Major Hydraulic Structures Incorporated to the Hydraulic Model

Drainage Structure	Configuration	Model Representation
Bruce Highway		
Don River	10/24m span Bridge	2D
Euri Creek	8/25m span Bridge	2D
Sandy Gully Main Branch	2/9.5m span Bridge	2D
Sandy Creek Water Course	5/1.2m × 0.6m RCBC	1D
Euri Culvert (East of Euri Creek)	5/3.0m × 2.8m RCBC	1D
North Coast Railway		
Don River	13/15m span Bridge	2D
Euri Creek	12/15m span Bridge	2D
Sandy Gully	3/11.5m span Bridge	1D
West Merinda	Approx. 40m Bridge	1D
Sandy Creek	4/5.5m and 3/4.3m span Bridge	1D
Bridge No. 257 East of Don River	2/8.22m span Bridge	1D
Branch 141	1/0.6m × 0.6m RCBC	1D
Doughty Creek	4/1.67m RCP	1D
Merinda Rail Deviation		
Sandy Gully	2/25m span Bridge	1D
Sandy Gully East	1/25m span Bridge	1D
Sandy Creek	1/3.65, 2/4.65 and 1/3.65 bridges	1D
MRD 027	5/3m × 2.1m RCBC	1D
MRD 001-1	4/1.35m RCP	1D
Bells Gully		
Jilletts Road	5/1.2m × 0.6m RCBC	1D
Argyle Park Road	5/1.2m × 0.6m RCBC	1D
Soldiers Road	1/0.6m RCP	1D

3.9 Calibration / Verification Data

3.9.1 Rainfall and Streamflow Data

Sections 3.3 and 3.4 describe collation of the rainfall and stream gauging data from BOM and DNRM which was subsequently used for model calibration.

3.9.2 Anecdotal Data

The QWRC report on the January 1980 flood provides a map of flood extents, levels and flowpaths based on reports from landholders, supplemented with information from aerial photography. The data includes surveyed levels taken from landholder observations during / after the flood, surveyor observations during / after the flood, and debris marks.

It was noted that subsequent reports have noted discrepancies in the data – for example, some recorded flood levels were found to be below the ALS ground level, some were located outside the mapped extents, some downstream flood levels were higher than upstream levels etc. Therefore, whilst the QWRC data for the 1980 flood event has been used to guide model verification, it was not taken as definitive.

Fifty-five peak flood heights were obtained on 11 February 2008 and provided by WRC for this study. This was also supplemented by photos and videos compiled by the Don River Improvement Trust (DRIT) and other members of the public.

No peak flood heights were recorded for the April 2014 flood event; however eye witness accounts from the public and staff from the DRIT were compiled by Council and provided to the project team.

3.9.3 Recorded Flood Heights

Recorded flood heights were obtained from BOM at the Bowen Pump Station for the 1980, 2008 and 2014 flood events. These time varying gauge heights were converted to AHD using conversions provided by BOM.

3.10 GIS Data

GIS data provided by WRC included cadastral boundaries, aerial imagery and planning zones. This information was provided in September 2013 and represents the most up to date information at this time.

3.11 Site Inspection

A site inspection was carried out by the project team and WRC staff on 3 September 2013. This site visit was used to record background information on flood behaviour and characteristics in the lower Don River. Photo records were used to review roughness and other hydraulic parameters.

4.0 Hydrologic Assessment

4.1 Overview

In order to estimate flood levels, flood extents and flood hazard across the study area, a hydrologic assessment was undertaken to estimate flood flows and design hydrographs for Don River, Sandy Gully and Euri Creek.

4.2 Adopted Methodology

Hydrological analysis was undertaken to determine the design flood hydrographs for various design events. The general approach taken to define design hydrographs within the study area was to:

- Undertake an at site flood frequency analysis to estimate flood quantiles for the Don River at Ida Creek.
- Develop separate hydrological models of the Don River, Euri Creek and Sandy Gully catchments.
- Calibrate and verify the hydrological models using recorded stream flows arising from known rainfall events (if available).
- Simulate catchment flows for design rainfall events using the calibrated hydrological models.
- Compare the peak design discharges from the Don River hydrologic model with flood flows estimated using flood frequency methods to verify the calibration parameters adopted.

4.3 At Site Flood Frequency Analysis

4.3.1 Overview

Flood peaks are the product of a complex joint probability process involving the interaction of many random variables associated with the rainfall event, antecedent conditions and rainfall-runoff transformation. Peak flood records represent the integrated response of the storm event with the catchment. They provide a direct measure of flood exceedance probabilities. As a result flood frequency analysis is less susceptible to bias, possibly large, that can affect alternative methods based on design rainfall (Kuczera et al., 2003).

FFA is generally based on data extracted from continuous flow records or event-based observations for extreme events. It should be noted that FFA can be conducted using:

- An annual flood series, where the highest flow in each year is selected, whether it is a major flood or not. For N years of record, the annual flood series will consist of N values.
- A partial flood series, where the series consists of all floods with peak discharges above a selected base value, regardless of the number of such floods occurring each year. The number of floods K generally will differ from the number of years of record N, and will be dependent on the base discharge.

The shape of a flood frequency curve reflects the interaction of hydrologic factors for a catchment and the flood response at the specified site that the flood data was available.

FFA was undertaken on the Ida Creek gauge due to the relatively long period of record (55 years). Additional analysis at the Reeves gauge (Don River) and Koonadah gauge (Euri Creek) was not undertaken due to the lack of historical gauge data available. Reeves and Koonadah have gauge data for a period of 29 years and 15 years, respectively.

4.3.2 Data

A peak annual series data set was prepared for the Don River at Ida Creek. Annual peak flows were compared with monthly rainfall totals to validate recorded peaks. Missing flood peaks were noted for 1970, 1972, 1973 and 1974 – however this data was in-filled using information available from historical reports (QWRC, 1980). The peak annual series is depicted in Figure 11.

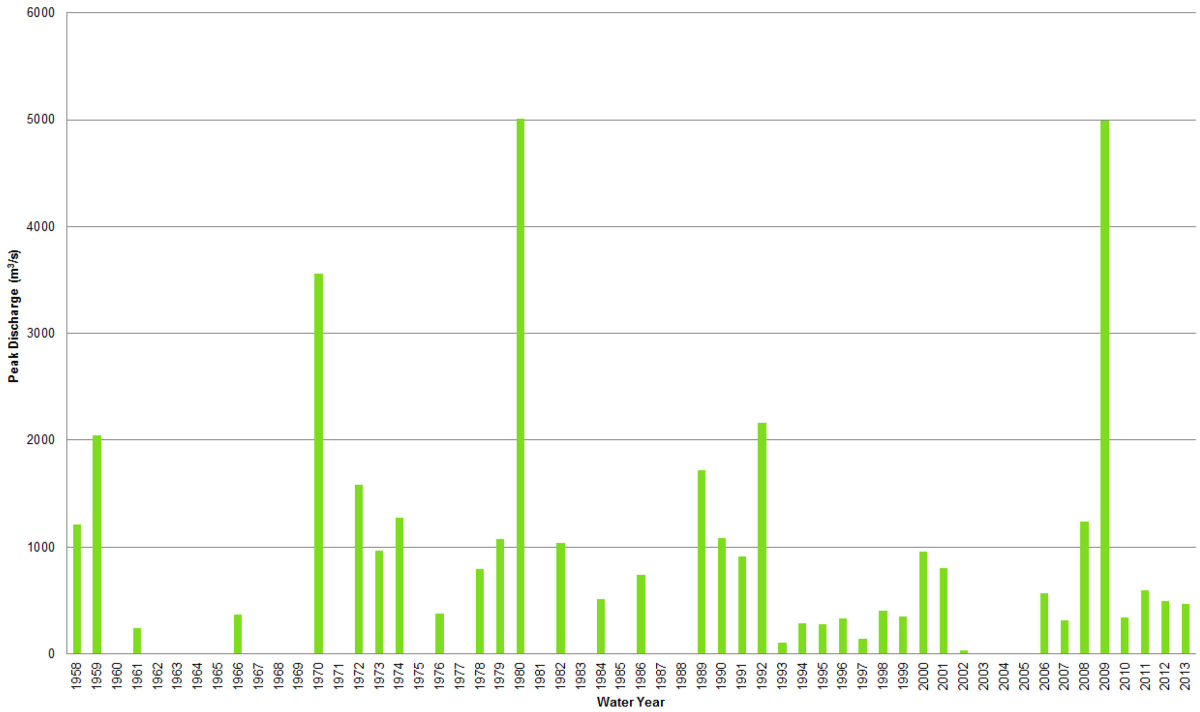


Figure 11 Peak Annual Series for Ida Creek (121001A)

The peak annual series was filtered to remove peak flows lower than 300m^3/s. This was undertaken because the initial overall fit was unduly influenced by the smaller floods. The selected low flow limit was based on review of the fitted distribution and in reference to historical reports where FFA was previously undertaken – notably the Don River Hydrology Report (Ullman & Nolan, 1990).

In undertaking a FFA, it is common that a flood may have occurred before, during or after the period of gauged record, and is known to be the largest flood, or flood of other known rank, over a period longer than that of the gauged record. Such floods can provide valuable information, and should be included in the analysis.

Review of the Don River Flood Investigation Report – Appendix A (Ullman & Nolan, 1980) suggested that at least eight flood events had occurred between 1870 and when records commenced at the Ida Creek gauge in 1957. This information was extremely valuable and was used as censored data when undertaking the assessment using the Bayesian calibration approach discussed in further detail below.

It is important to note that the peak heights for the majority of the data set are well above the limit of the gauging station site to provide a reasonable level of confidence in the calculated flow. Therefore there is a degree of uncertainty with these recorded flows.

4.3.3 Assessment Method

For analytical treatment of flood studies, a probability model must be selected to fit the data. There is no universally accepted flood probability model. Many types of probability distributions have been applied to flood frequency analysis and the appropriateness of these distributions can be tested by examining the fit of each distribution to observed flood data.

For the purposes of this assessment, there were several different probability models used to find the best fit to the peak annual series. These were:

- Generalised Pareto.
- Generalised Extreme Value.
- Gumbel.
- Log Normal.
- Log Pearson Type III.

These probability models were fitted to the data using the Bayesian method on account of its ability to handle gauged and censored data, errors in data and regional information. It should be noted that the new Bayesian calibration approach is being released in the new version of Australian Rainfall and Runoff (ARR).

The Bayesian approach to calibrating flood probability models is numerically complex and has been implemented using the TUFLOW FLIKE extreme value analysis package. The package, originally developed by the University of Newcastle is compliant with the draft update of ARR that is due for release in the near future.

4.3.4 Results

The five probability distributions were initially calibrated to the full data set without any censoring. A comparison between the fit is shown in Figure 12.

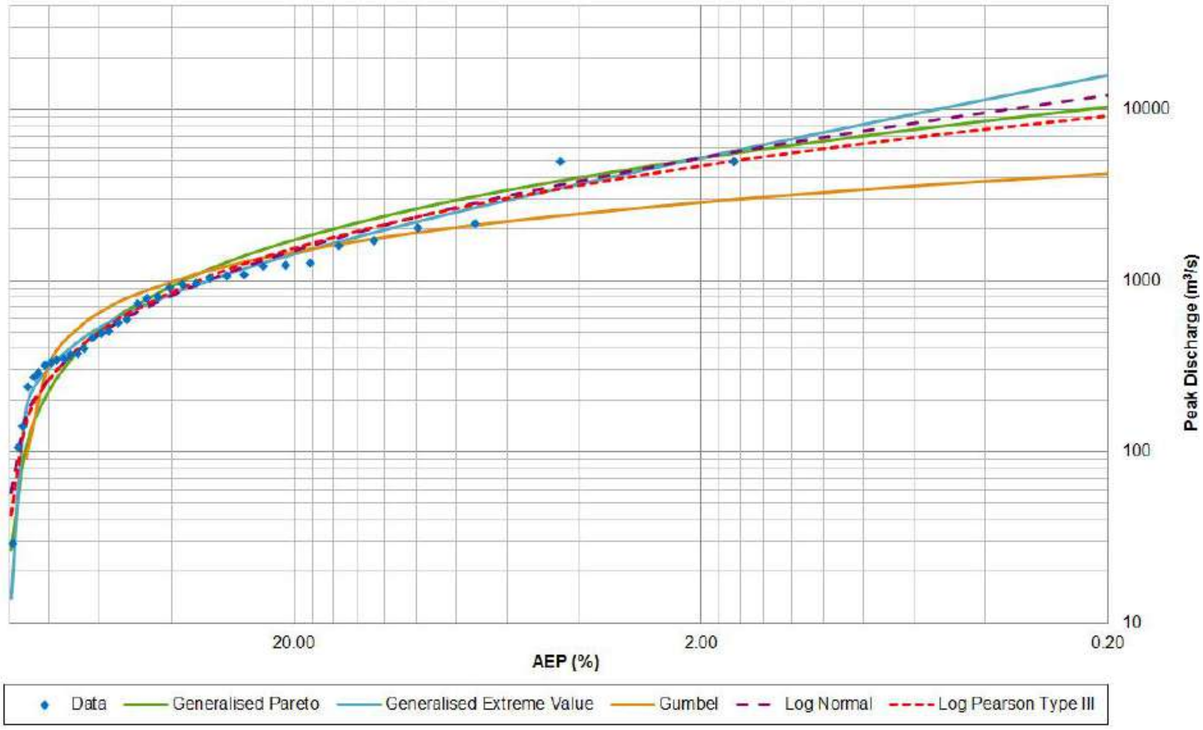


Figure 12 Comparison of Probability Distributions for Uncensored Data Set

The Generalised Pareto, Log Normal and Log Pearson Type III probability distributions generally fitted the data well; however a more detailed assessment of the 5% and 95% confidence limits showed that there was a very high degree of uncertainty – particularly for the upper tail of the distributions. Review of the data clearly suggests that low flow values are unduly influencing the fit and should be censored.

The same five probability distributions were calibrated to the gauged and censored data which included censored historical data based on flood information contained within the Don River Flood Investigation Report. A comparison between the fit is shown in Figure 13.

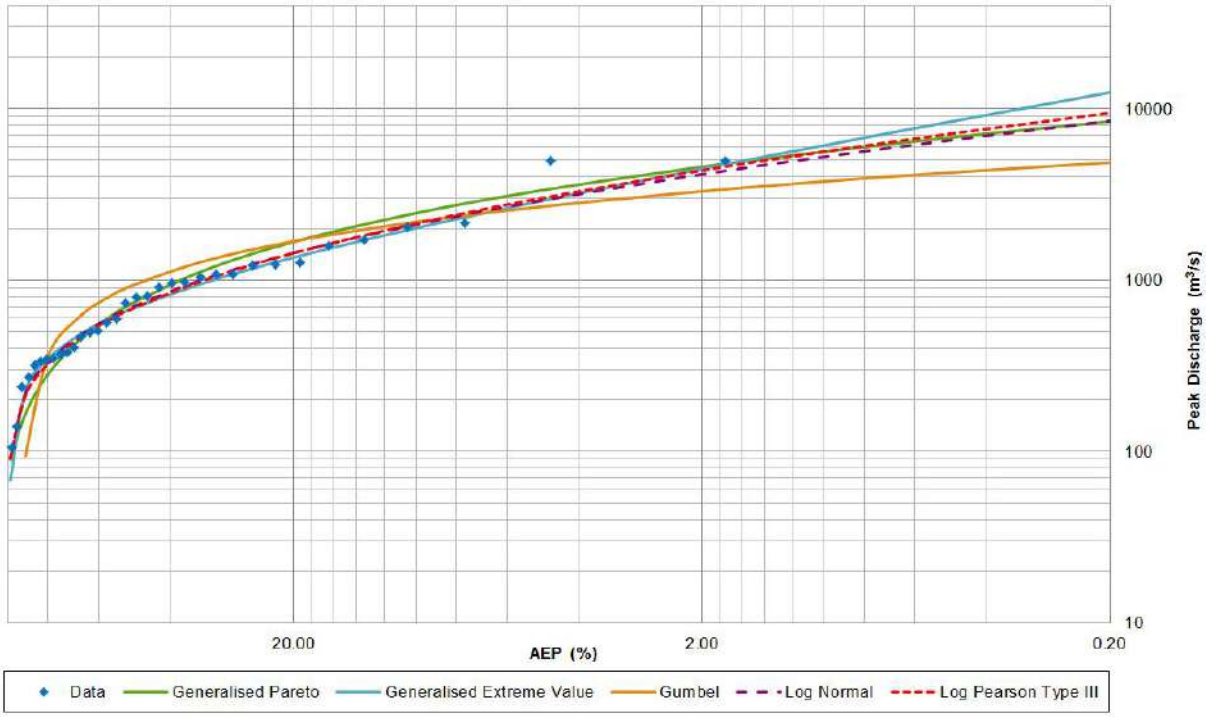


Figure 13 **Comparison of Probability Distributions for Censored Data Set**

The Log Pearson Type III and Log Normal probability distributions both exhibited a good fit to the complete data set. The Log Pearson Type III appears to fit the upper range of the data slightly better than the Log Normal distribution. Whilst the Generalised Pareto also fitted well in the right hand tail, it displayed a poor fit to the data in the left hand tail.

A comparison between the Log Pearson Type III and Log Normal estimated flood flows are shown in Table 10 below.

Table 10 **Comparison of Estimated Flood Quantiles (Log Pearson Type III and Log Normal)**

	Estimated Flood Flow (m^3/s) for AEP's (%)								
	99	50	20	10	5	2	1	0.5	0.2
Log Pearson Type III	92	695	1,444	2,116	2,901	4,138	5,244	6,514	8,470
Log Normal	91	679	1,439	,2144	2,989	4,359	5,618	7,095	9,431

By comparing the results of the two preferred distributions, it is clear that there is only a minor variance between the results of the two distributions at the higher range (e.g. there is a 7% difference in the 1% AEP flood quantile).

Given that the Log Pearson Type III distribution fitted the data in the upper range better and gives slightly more conservative results, it was concluded that the Log Pearson Type III probability distribution be adopted for this assessment.

4.3.5 Adopted Probability Model

Plotted in Figure 14 on a log normal probability plot are the gauged flows, the 1 in Y AEP quantile curve (derived using the posterior mean parameters), the 90% quantile confidence limits and the expected probability curve.

It is noted that this model was fitted without the use of supporting regional information. A regional analysis of skewness is currently being conducted as part of Revision Project 5 for ARR but results are not yet available. It is recommended that regional information be used in future FFA revisions to reduce uncertainty – particularly in the less frequent events.

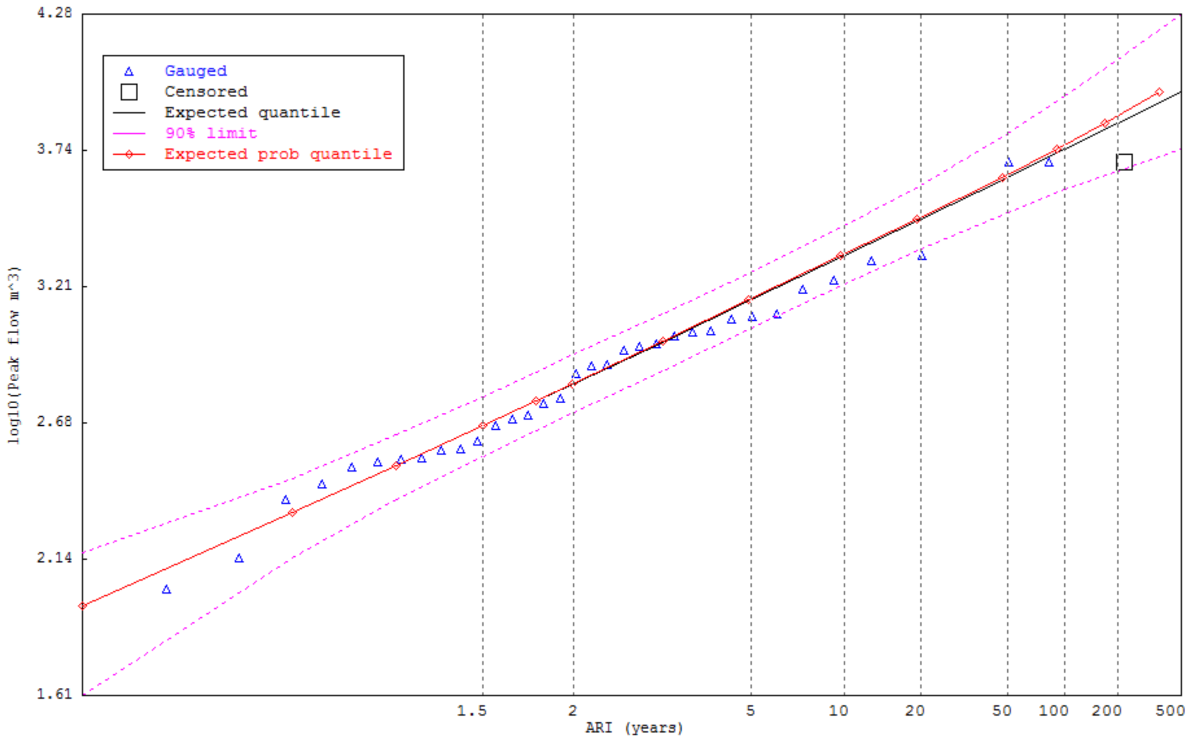


Figure 14 Adopted Log Pearson Type III Distribution

The table of selected 1 in Y AEP flows and their 90% confidence limits are shown in Table 11.

Table 11 Estimated Flood Flows and Confidence Limits for Log Pearson Type III Distribution

AEP (%)	Estimated Flow (m^3/s)	Confidence Limits	
		5% Limit (m^3/s)	95% Limit (m^3/s)
99	91	41	148
50	679	522	879
20	1,439	1,119	1,857
10	2,144	1,656	2,802
5	2,989	2,273	4,052
2	4,359	3,154	6,447
1	5,618	3,885	9,040
0.5	7,095	4,624	12,516
0.2	9,431	5,608	18,952

4.3.6 Extreme Events

Figure 14 shows the extrapolation of the frequency curve beyond the limit of the available data in order to estimate the peak discharges for extreme floods (i.e. the 0.5% and 0.2% AEP events). It must be noted that this extrapolation is subject to a wide error band and is therefore subject to considerable uncertainty.

4.4 Runoff-Routing Modelling

4.4.1 Overview

XP-RAFTS runoff-routing hydrologic models have been developed for Don River, Euri Creek and Sandy Gully catchments to quantify the design discharge hydrographs from these catchments by modelling catchment flows using Laurenson's non-linear routing methods.

XP-RAFTS has been widely used throughout Queensland and is an accepted model to quantify flood flows. The model predicts flows for urban and rural catchments and is well suited to modelling the Don River, Euri Creek and Sandy Gully catchments.

4.4.2 Selection of Calibration Events

The significant flood events presented in Table 3 were evaluated to select the historical events most suitable for model calibration. Event selection was based upon the following characteristics:

- Magnitude of event – calibration to a range of magnitudes is most desirable.
- Time of event – changes in the catchment and on the floodplain over time create changes in flood behaviour. More recent events are generally better for calibration as documentation/information regarding the catchment and floodplain conditions is often more readily available and able to be represented within the hydrologic and hydraulic modelling.
- Availability and completeness of calibration data.

Based upon these characteristics, the 1980, 2008 and 2014 flood events were selected for calibration. Both the 1980 and 2008 events represent significant historical flood events where calibration data is available. The 1980 flood event has generally been used as a calibration event for most historical investigations. No previous investigations have undertaken a calibration to the 2008 flood event.

The 2014 flood event was a moderate flood event which occurred during this study. The event was selected as it represented an event of lesser magnitude which occurred under current floodplain and catchment conditions.

The 1946 and 1970 events also represent major events of interest but there is little to no data available for a meaningful calibration.

Rainfall records for the 1980 event were limited with only two pluviograph rainfall stations available to describe the temporal distribution of the storm burst and only six daily rainfall stations to estimate the spatial distribution. There were three stream gauges operational during the 1980 event within the Don River catchment and none within the Euri Creek catchment, as outlined below:

- Ida Creek (DNRM and BOM)
  - Recorder malfunctioned for five hours at the peak – the peak of the hydrograph was developed by QWRC using debris lines and eyewitness accounts.
- Mt Dangar (BOM)
  - Fully synthetic rating curve with a high degree of uncertainty.
  - Manual heights records taken by landholder until the first peak but did not include the second larger peak.
- Bowen Pump Station (BOM)
  - Both flood peaks were recorded before failure due to partial bank collapse.

Rainfall records were more widespread for the 2008 and 2014 flood events; however there were only two pluviograph stations available to describe the temporal pattern of the storm burst. Fourteen daily rainfall stations were available to estimate the spatial distribution of the rainfall event.

Four stream gauges were operational during the 2008 and 2014 events within the Don River catchment and one within the Euri Creek catchment, as outlined below:

- Ida Creek (DNRM and BOM).
- Mt Dangar (BOM).
- Reeves (DNRM and BOM).
- Bowen Pump Station (BOM).
- Koonandah at Euri Creek (DNRM).

4.4.3 Model Configuration

Don River, Euri Creek and Sandy Gully catchments have been delineated based on 5 metre topographic contours provided by DNRM. The catchment delineation originally carried out by BOM (which has been used as a basis for most of the historical flood studies for Don River area) has been used as a guide to check consistency with BOM hydrological study and subsequent flood studies by other consultants. Figure 15 shows the extent of the Don River, Euri Creek and Sandy Gully catchment and sub-catchment delineation.

Don River

The Don River catchment was subdivided into 53 sub-catchments according to tributary network, catchment topography, land use, location of the river gauging stations and locations where hydrographs were to be applied in the hydraulic model.

The delineation was undertaken with reference to historical delineation in the development of BOM's URBS model for the catchment. The catchment extent, sub-catchment delineation and the total catchment area for Don River catchment compares well with BOM's URBS model.

Each sub-catchment was described in the XP-RAFTS model by specifying:

- Sub-catchment areas (in hectares).
- Average equal area sub-catchment slope (in %).
- Sub-catchment roughness.
- Fraction Impervious.

Individual sub-catchment values for area and slope were defined using 5m SRTM contours for the majority of the sub-catchments. However, 0.5m contours generated from the LIDAR DEM were used for the Sandy Gully due to the relatively flat grades. The roughness and fraction impervious was determined using aerial imagery provided.

Table 12 summarises the parameters adopted for Don River sub-catchments.

Table 12 Don River XP-RAFTS Model Parameters

Catchment ID	Area (ha)	Catchment Slope (%)	Fraction Impervious (%)	Resistance (PERN)
1	3714	4.7	1	0.08
2	1731	3.8	1	0.10
3	6444	1.8	1	0.07
4	2260	1.5	1	0.07
5	708	1.3	1	0.07
6	3202	1.7	1	0.07
7	1273	2.3	1	0.07
8	1383	1.7	1	0.06
9	1807	1.7	1	0.06
10	3112	2.1	1	0.06
11	1499	1.5	1	0.05

Catchment ID	Area (ha)	Catchment Slope (%)	Fraction Impervious (%)	Resistance (PERN)
12	2488	1.4	1	0.05
13	2912	2.1	1	0.08
14	528	5.0	1	0.07
15	1932	2.9	1	0.07
16	1474	5.0	1	0.07
17	2086	1.0	1	0.07
18	1689	4.1	1	0.10
19	4092	1.4	1	0.08
20	3242	4.4	1	0.07
21	1586	3.1	1	0.07
22	3603	2.9	1	0.06
23	3507	2.4	1	0.07
24	2415	2.1	1	0.07
25	1859	5.0	1	0.05
26	2498	1.1	1	0.05
27	1255	0.9	1	0.05
28	2206	1.3	1	0.06
29	1841	0.6	1	0.05
30	3155	0.3	1	0.05
31	2184	1.3	1	0.07
32	1972	0.7	1	0.07
33	2485	0.7	1	0.05
34	2718	0.6	1	0.05
35	415	4.9	1	0.06
36	767	0.5	1	0.06
37	737	1.0	1	0.05
38	3454	0.5	1	0.05
39	2376	0.4	1	0.05
40	1753	0.9	1	0.05
41	3352	0.9	1	0.07
42	2110	1.8	1	0.06
43	1058	0.6	1	0.05
44	2266	1.9	1	0.07
45	1169	0.8	1	0.05
46	1138	1.4	1	0.07
47	1651	1.0	1	0.05
48	3151	0.3	1	0.05

Catchment ID	Area (ha)	Catchment Slope (%)	Fraction Impervious (%)	Resistance (PERN)
51	122.7	0.1	1	0.05
52	1475	0.1	12	0.04
53	740	0.1	1	0.05

Euri Creek

An XP-RAFTS hydrologic model was previously developed by AECOM as part of the Abbot Point Flood Study (Maunsell AECOM, 2008). The model consisted of 22 sub-catchments covering an area of 448 km² and was calibrated to the January 2005 and March 1999 flood events.

The calibrated model has been adopted for this study and checked to ensure catchment delineation and catchment parameters were still applicable. The catchment extent, sub-catchment delineation and the total catchment area for Euri Creek catchment compares well with those of BOM study.

Table 13 summarises the parameters adopted for Euri Creek sub-catchments.

Table 13 Euri Creek XP-RAFTS Model Parameters

Catchment ID	Area (ha)	Catchment Slope (%)	Fraction Impervious (%)	Resistance (PERN)
EC1.10T	3718	2.2	1	0.10
EC1.70L	662	1.9	1	0.04
1MC1.10L	3010	6.0	1	0.08
HC1.10L	3736	6.1	1	0.10
SSC1.10T	2143	3.9	1	0.10
2MC1.10T	3523	1.8	1	0.08
EC1.30L	803	0.6	1	0.08
DMC1.10T	5202	2.2	1	0.08
5MC1.10L	2507	2.0	1	0.08
4MC1.10T	3811	0.8	1	0.08
GC1.20L	1090	0.9	1	0.08
GC1.10T	3183	2.8	1	0.08
SSC1.30L	1822	0.8	1	0.08
DC1.10L	2963	0.2	1	0.08
EC1.50L	1473	3.4	1	0.06
SSC1.20L	1329	0.3	1	0.05
EC1.62T	722	6.3	1	0.05
EC1.61L	724	1.9	1	0.06
EC1.20L	1356	8.8	1	0.10
EC1.15T	1017	2.2	1	0.10

Sandy Gully

The Sandy Gully catchment was subdivided into 8 sub-catchments according to tributary network, catchment topography, land use and locations where hydrographs were to be applied in the hydraulic model.

Table 14 summarises the parameters adopted for Sandy Gully sub-catchments.

Table 14 Sandy Gully XP-RAFTS Model Parameters

Catchment ID	Area (ha)	Catchment Slope (%)	Fraction Impervious (%)	Resistance (PERN)
C1	860	0.4	1	0.05
C2	1490	0.3	1	0.05
C3	1517	0.1	1	0.05
C4	706	0.4	1	0.05
C5	885	0.1	1	0.05
C6	979	0.1	1	0.05
C7	412	0.001	0	0.025
C8	442	0.1	1	0.05

4.4.4 Channel Routing

The Muskingum-Cunge routing method was used to route hydrographs between sub-catchments. This method requires a defined reach length, slope, channel geometry, and roughness to determine appropriate hydrograph routing. Cross sections, link lengths and slopes were determined based on the available topographic data.

4.4.5 Design Rainfall

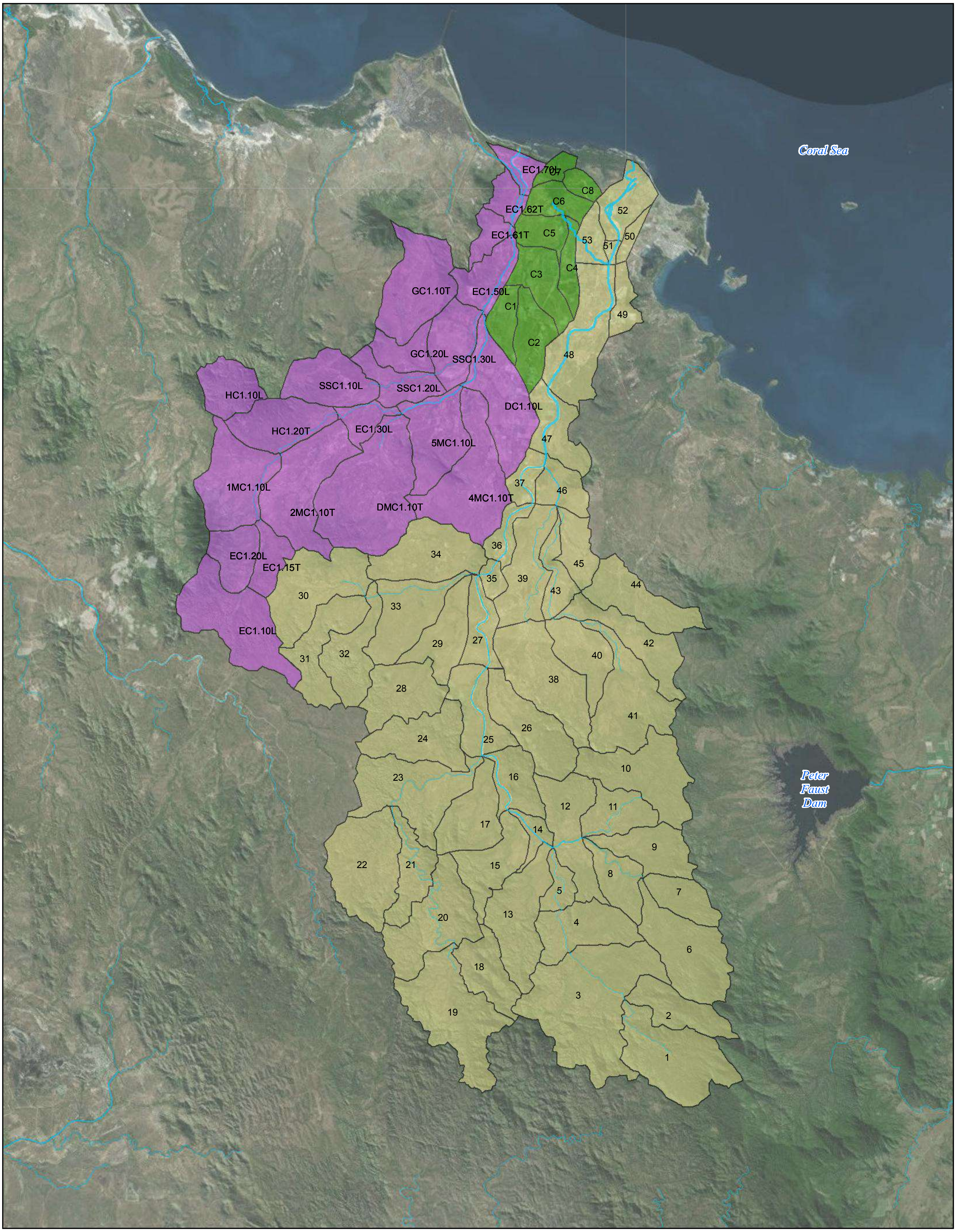
4.4.5.1 Intensity Frequency Duration Rainfall Data

Site specific Intensity Frequency Duration (IFD) data was determined using the design rainfall isopleths from Volume 2 of AR&R, 1987. The IFD input data set obtained for Bowen is shown in Table 15.

Table 15 Adopted IFD Input Parameters

Parameter	Value
1 hour, 2 year intensity (mm/hr)	53.40
12 hour, 2 year intensity (mm/hr)	10.15
72 hour, 2 year intensity (mm/hr)	3.44
1 hour, 50 year intensity (mm/hr)	98.90
12 hour, 50 year intensity (mm/hr)	22.48
72 hour, 50 year intensity (mm/hr)	8.37
Average Regional Skewness	0.10
Geographic Factor, F2	4.01
Geographic Factor, F50	17.58

Standard techniques from ARR were used to determine rainfall intensities up to the 72 hour duration for the 1EY, and 50%, 20%, 10%, 5%, 2%, 1% and 0.2% AEP events. The calculated IFD data is shown in Table 16.



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Coordinate System: GDA 1994 MGA Zone 55

Data sources:
Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

LEGEND
- Sandy Gully Sub Catchment
- Don River Sub Catchment
- Euri Creek Sub Catchment

DON RIVER FLOOD STUDY

Catchment & Sub-Catchment Delineation

Figure 15

Table 16 IFD Design Rainfall Intensities for Bowen (mm/hr)

Duration (hrs)	1EY	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.2% AEP
1	41.4	53.0	67.0	75.0	86.0	101.0	112.0	139.0
2	26.1	33.7	43.4	49.2	57.0	67.0	75.0	95.0
3	19.8	25.6	33.4	38.2	44.4	53.0	59.0	75.0
4.5	15.0	19.5	25.7	29.6	34.6	41.4	46.7	60.0
6	12.3	16.1	21.4	24.7	29.0	34.8	39.4	51.0
9	9.3	12.2	16.5	19.1	22.6	27.3	31.1	40.4
12	7.6	10.1	13.7	16.0	19.0	23.0	26.2	34.3
18	6.1	8.0	11.0	12.9	15.3	18.7	21.3	28.1
24	5.1	6.8	9.4	11.0	13.1	16.1	18.4	24.3
48	3.4	4.5	6.3	7.4	8.9	11.0	12.6	16.9
72	2.6	3.4	4.8	5.8	6.9	8.6	9.9	13.3

New IFD design rainfall depths are now available based on a more extensive database of rainfall records. The new IFD's are part of a larger suite of design flood estimation inputs (temporal patterns, rainfall losses, areal reduction factors, etc) which have not all been released and therefore the new IFD data can only be used to undertake sensitivity analysis for new flood studies (as per Engineers Australia Guidance).

The new IFD design rainfall intensities are shown in Table 17 below.

Table 17 New IFD Design Rainfall Intensities for Bowen (mm/hr)

Duration (hrs)	1EY	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
1	41.5	47.1	63.8	74.4	84.3	96.7	105.7
2	27.2	31.1	43.0	50.7	58.1	67.6	74.6
3	20.9	24.0	33.7	40.2	46.5	54.7	60.8
4.5	15.9	18.4	26.4	31.8	37.1	44.2	49.7
6	13.1	15.2	22.1	26.9	31.6	38.0	43.0
9	9.9	11.6	17.2	21.2	25.1	30.5	34.8
12	8.1	9.6	14.4	17.8	21.3	26.0	29.8
18	6.2	7.4	11.2	13.9	16.7	20.5	23.6
24	5.1	6.1	9.3	11.6	13.9	17.2	19.7
48	3.2	3.8	5.9	7.3	8.8	10.8	12.3
72	2.4	2.9	4.4	5.5	6.6	8.0	9.1

4.4.5.2 Temporal Pattern

Temporal patterns for Zone 3 were adopted for events up to the 0.2% AEP using the standard methodology outlined in ARR (1987).

Temporal patterns for the PMP event were sourced from data provided with the GTSMR guidebook. Patterns from coastal_avm_1000.xls were used as this was the closest applicable data for a catchment area of 1,630 km^2.

4.4.5.3 Areal Reduction Factors

The IFD rainfall values derived in Section 4.4.5.1 are applicable strictly only to one point; however ARR state that they may be taken to represent IFD values over a small area (up to 4 km^2). For larger areas (as is the case for Don River, Euri Creek and Sandy Gully catchments) ARR states that it is not realistic to assume that the same intensity can be maintained over the entire area. Thus some reduction in rainfall depth may be required.

Initially ARFs were applied to the design rainfall in the XP-RAFTS model; however this was removed following model calibration and comparison with the results of the FFA.

4.4.5.4 Probable Maximum Precipitation Event

The PMP has been defined by the World Meteorological Organisation (2009) as 'the greatest depth of precipitation for a given duration, meteorologically possible for a given size storm area at a particular location at a particular time of year'.

The PMP event results in a Probable Maximum Flood (PMF) event. This is a theoretical event which is very unlikely to ever occur within any given catchment. The PMF event is typically used in design of hydraulic structures, such as dams.

Its most common use is in design of dam spillways to minimise the risk over overtopping of a dam and prevent the likelihood of dam failure. Other than this practical use, it is also used to provide an indication of the largest flood extents expected within any given catchment. This data can be used by emergency management agencies in their understanding of and planning for flood events.

The Generalised Tropical Storm Method as revised in 2002 (GTSMR) was applied to derive estimates of PMP. The GTSMR applies to catchments up to 150,000 km^2 in area, for durations of 24 hours and greater. The combined area of Euri Creek, Sandy Gully and Don River catchments is approximately 1,630 km^2, and the critical duration was found to be 24 hours for the 1% AEP design event.

Using the methodology set out in the GTSMR Guidebook the following data for the PMP was determined:

- The coastal GTSMR Method is applicable as the catchment lies on the QLD coast.
- The TAF, Decay Amplitude Factor (DAF), Extreme Perceptible Water (EPW) and Moisture Adjustment Factor (MAF) were calculated as 1.336, 1.0, 94.37 and 0.786 respectively.
- PMP parameters were calculated as shown in Table 17.

Table 18 Adopted PMP Parameters

Duration (hrs)	Rainfall Total (mm)	Rainfall Intensity (mm/hr)
24	1302	54.0
36	1541	42.8
48	1771	36.9
72	2161	30.0

The ARI of the PMP event was calculated as recommended in ARR. Using a catchment area of 1,630 km^2, the PMP event is approximately a 0.0001% AEP event.

4.4.6 Model Calibration Process

Calibration of the Don River XP-RAFTS model was undertaken by applying historical rainfall event data to sub-catchments and comparing the resulting hydrographs to the corresponding gauge records at Ida Creek (121001A) and Reeves (121003A) where available. Hydrographs from BOM's flood warning gauges have not been used as there is considerable uncertainty in their rating curves (as discussed in Section 3.4.1).

The Don River XP-RAFTS model uses and initial and continuing loss model to represent infiltration and storage of runoff in surface depressions. The rainfall applied to each sub-catchment has been based on the daily rainfall values estimated over that sub-catchment and the pluviograph data obtained from one of the pluviograph stations.

The calibration was assessed in terms of both peak discharge and volume of the flows. Three rainfall events for the 1980, 2008 and 2014 flood events have been selected for calibration for Don River hydrologic model. There were five stations with pluviograph data available within or adjacent to the Don River catchment area, depending on the event:

- 033257 (Bowen Airport) – available for the 1980 and 2008 events.
- 033013 (Collinsville Post Office) – available for the 2008 event.
- 033004 (Binbee) – available for the 1980 event.
- 033002 (Ayr DPI Research Stn) – available for the 1980, 2008 and 2014 events.
- 0332477 (Proserpine Airport) – available for the 1980, 2008 and 2014 events.

The Binbee Pluviograph data was not provided by BOM but was sourced from data previously collected for the Abbott Point Flood Study (AECOM, 2008). Bowen Airport is located at the northern end of the Don River catchment. Collinsville Post Office and Proserpine Airport are located outside the Don River catchment to the south. The Ayr rainfall station is located outside the Don River catchment to the north.

The pluviograph data from these stations were analysed in conjunction with daily rainfall records and the river gauging data. A number of XP-RAFTS models were set up and run to investigate which pluviograph station provides a better representation of the temporal pattern of each sub-catchment, thereby resulting in a better calibration.

It is noted that calibration of the Euri Creek model has not been undertaken as this model was previously calibrated in the Abbot Point Flood Study. The rainfall losses determined from the calibration process are provided in Table 19. These parameters were adopted in the Euri Creek XP-RAFTS model.

Table 19 Euri Creek XP-RAFTS Rainfall Losses

Event	Initial Loss (mm)	Continuing Loss (mm)
Calibration Run (January 2005)	20	4
Verification Run (March 1999)	5	3
Design Event Runs	20	4

No separate calibration has been carried out for Sandy Gully as there are no gauging stations located in the catchment. The parameters from the calibrated Don River XP-RAFTS model were applied to Sandy Gully XP-RAFTS model.

4.4.6.1 January 1980 Event

Independent storms were applied to each sub-catchment in the XP-RAFTS model based on rainfall depths obtained from the spatially varying daily rainfall grids and the temporal pattern provided by the Bowen Airport or Binbee rainfall stations. The calibration event commenced at 0900 on 5 January 1980 and continued for 51 hours.

For 1980 event calibration, Binbee appeared to provide a representation of the temporal pattern for the majority of the southern and western sub catchments; however the Bowen Airport temporal pattern was still adopted for sub-catchments in northern and eastern areas of the catchment.

The areal pattern follows a gradient roughly from top to bottom of the catchment in line with the daily rainfall totals recorded, whilst the temporal pattern applied to the sub-catchments abruptly changes between the two pluviograph stations from the more intense Binbee storm burst to the relatively flat Post Office pattern. Whilst this approach does not reflect the January 1980 rainfall event entirely accurately, no additional data has been identified that could improve the representation.

As an example, the rainfall depths that were applied to sub-catchment 1 (one of the southern sub-catchments), sub-catchment 30 (one of the western sub-catchments), sub-catchment 47 (one of the central sub-catchments) and sub-catchment 52 (one of the southern sub-catchments) are shown in Figure 16, Figure 17, Figure 18 and Figure 19 respectively.

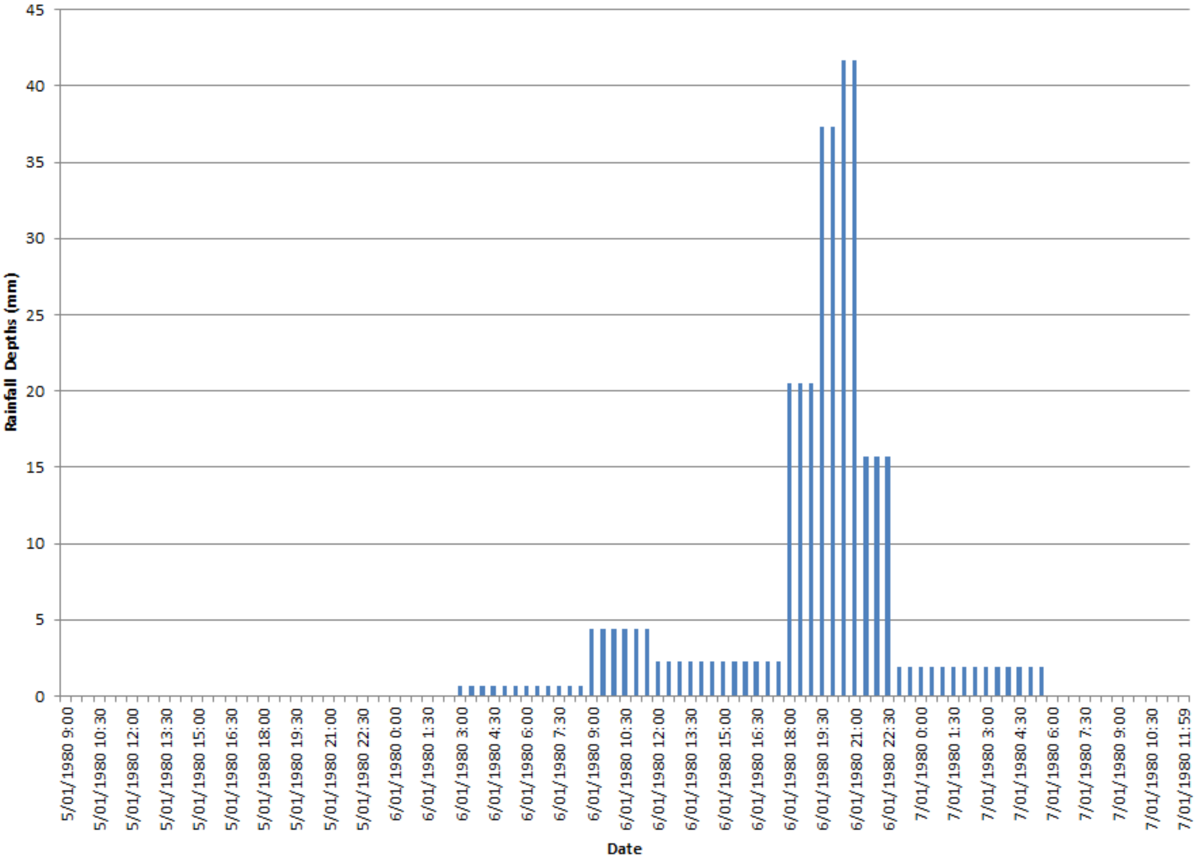


Figure 16 1980 Event Rainfall Hyetograph Applied to Sub-Catchment 1

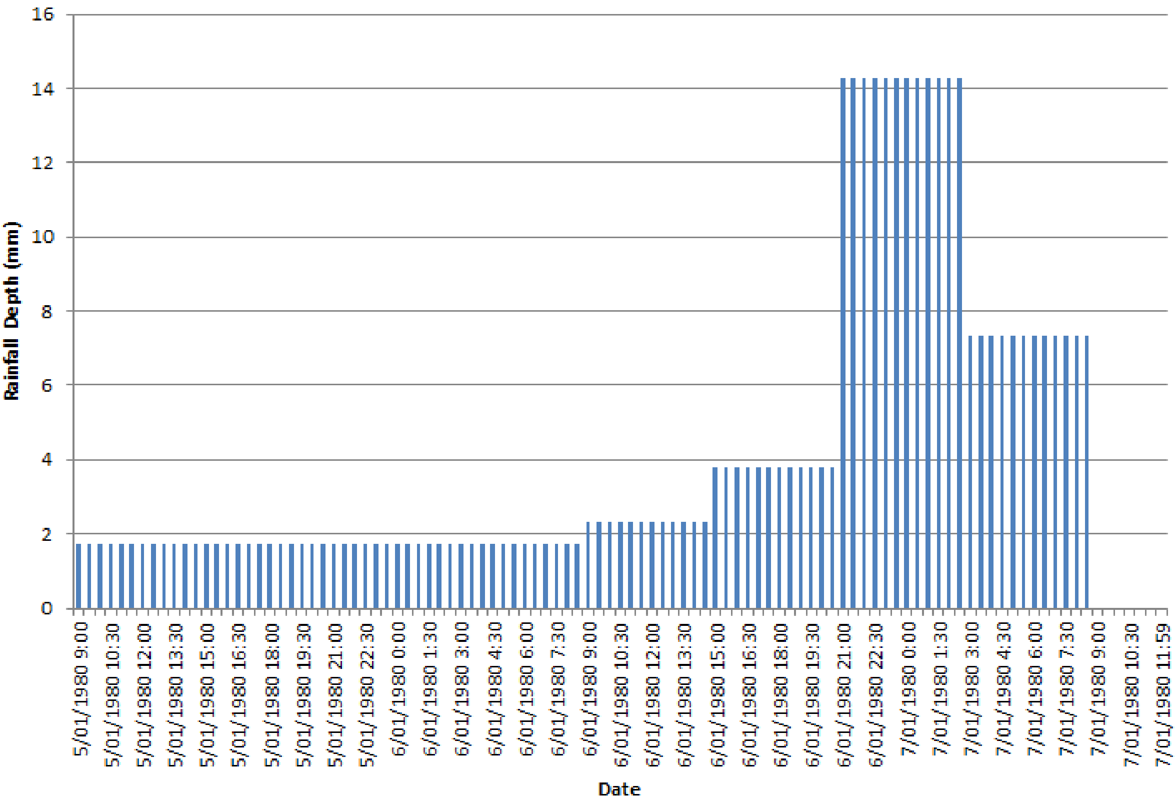


Figure 17 1980 Event Rainfall Hyetograph Applied to Sub-Catchment 30

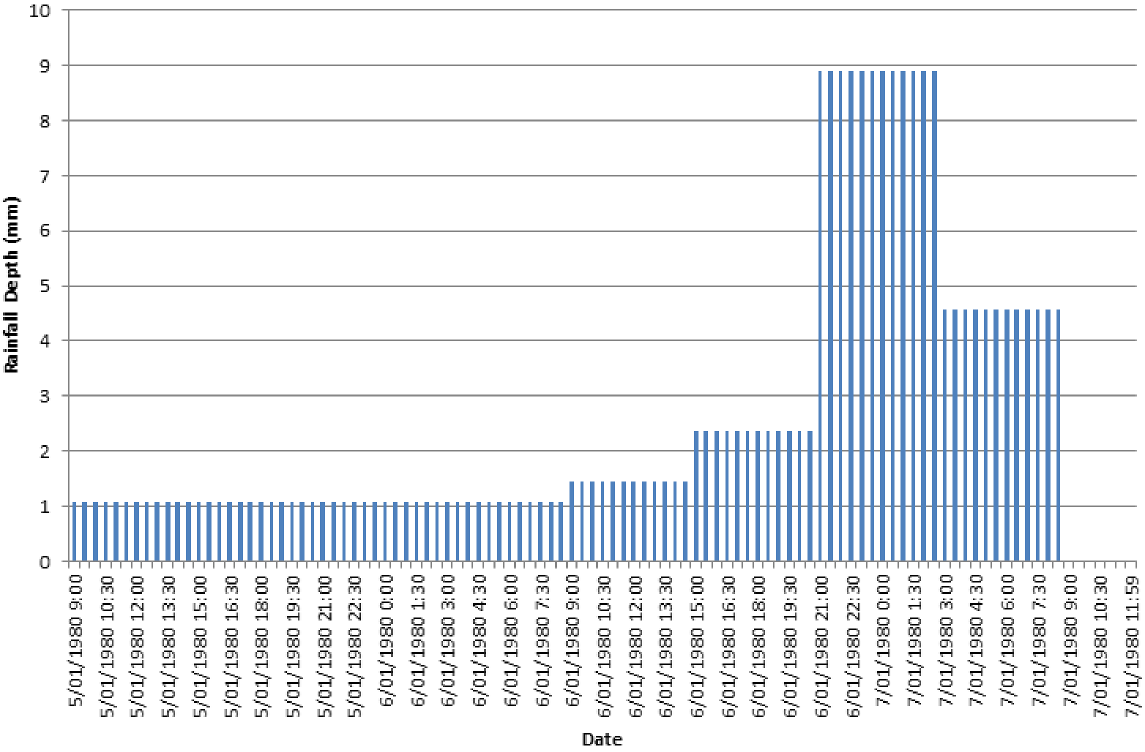


Figure 18 **1980 Event Rainfall Hyetograph Applied to Sub-Catchment 47**

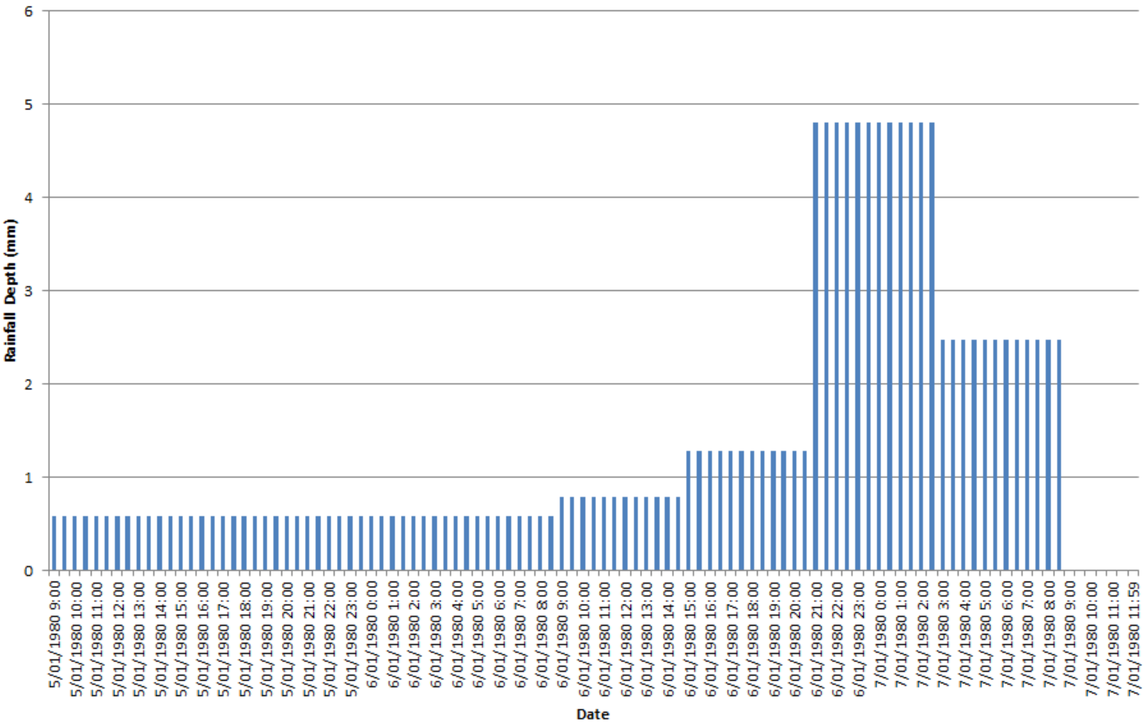


Figure 19 **1980 Event Rainfall Hyetograph Applied to Sub-Catchment 52**

The model was calibrated to the Ida Creek stream gauge. A comparison between the gauged hydrograph and the calibrated model hydrograph is shown in Figure 20.

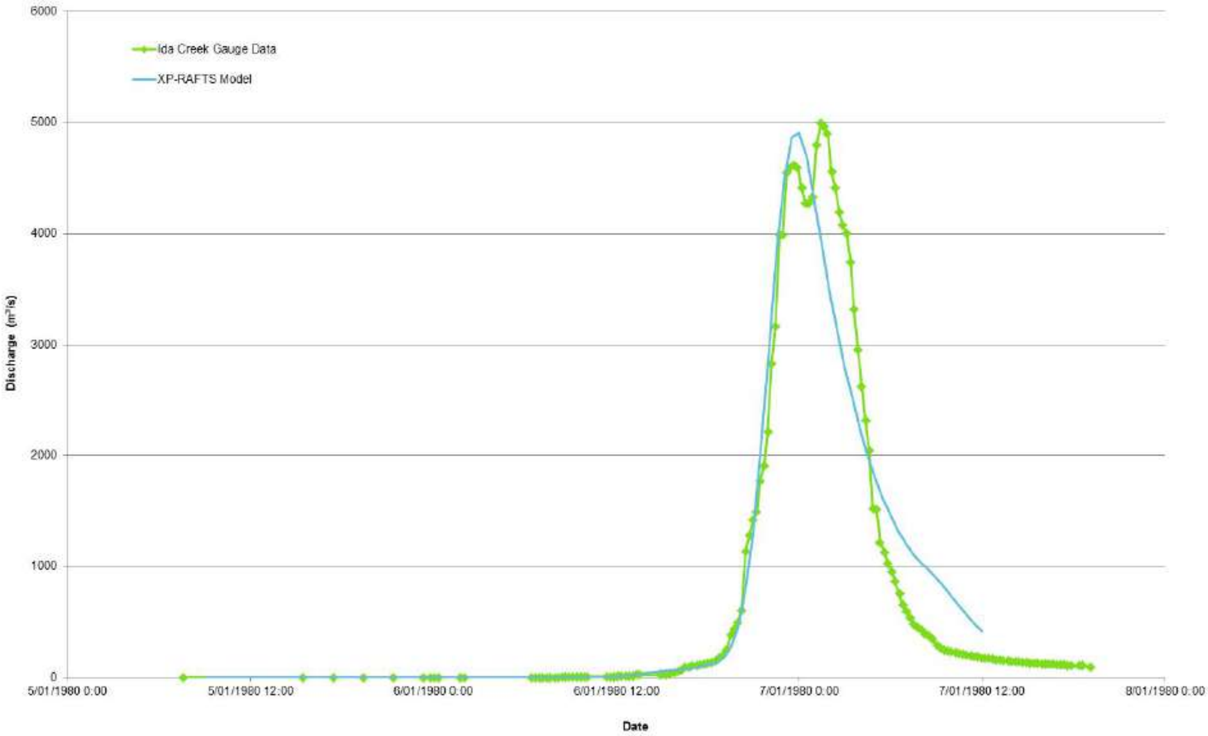


Figure 20 **1980 Event Calibration to Ida Creek Gauge**

A reasonable fit between the recorded data for the 1980 event and the predicted XP-RAFTS hydrograph was achieved at the gauge with the rising and receding limbs reasonably matched. The limited pluviograph information has resulted in only a single modelled peak. The modelled peak discharge was lower than the gauge; however it is within reasonable limits. The modelled runoff volume also matches well with the recoded volume.

The initial and continuing rainfall loss values which achieved the best fit between the model and gauge data are shown in Table 20.

Table 20 **Calibrated Model Loss Values for 1980 event**

Event	Pervious Sub Areas	
	Initial Loss (mm)	Continuing Loss (mm/hr)
Calibration Run (1980 event)	20	4

4.4.6.2 January 2008 Event

Independent storms were applied to each sub-catchment in the XP-RAFTS model based on rainfall depths obtained from the spatially varying daily rainfall grids and the temporal pattern provided by the Bowen Airport or Collinsville rainfall stations. The calibration event commenced at 0900 on 11 February 2008 and continued for 27 hours.

It was noted that neither the temporal pattern from Bowen Airport nor the pattern from Collinsville was applied to all sub-catchments as this did not provide a suitable match with the river gauging data. As a result, a number of different scenarios were developed and run by applying a combination of different temporal patterns to different sub-catchments to determine the most suitable combination of the rainfall data.

As an example, the rainfall depths that were applied to sub-catchment 1 (one of the southern sub-catchments), sub-catchment 30 (one of the western sub-catchments), sub-catchment 47 (one of the central sub-catchments) and sub-catchment 52 (one of the southern sub-catchments) are shown in Figure 21, Figure 22, Figure 23 and Figure 24 respectively.

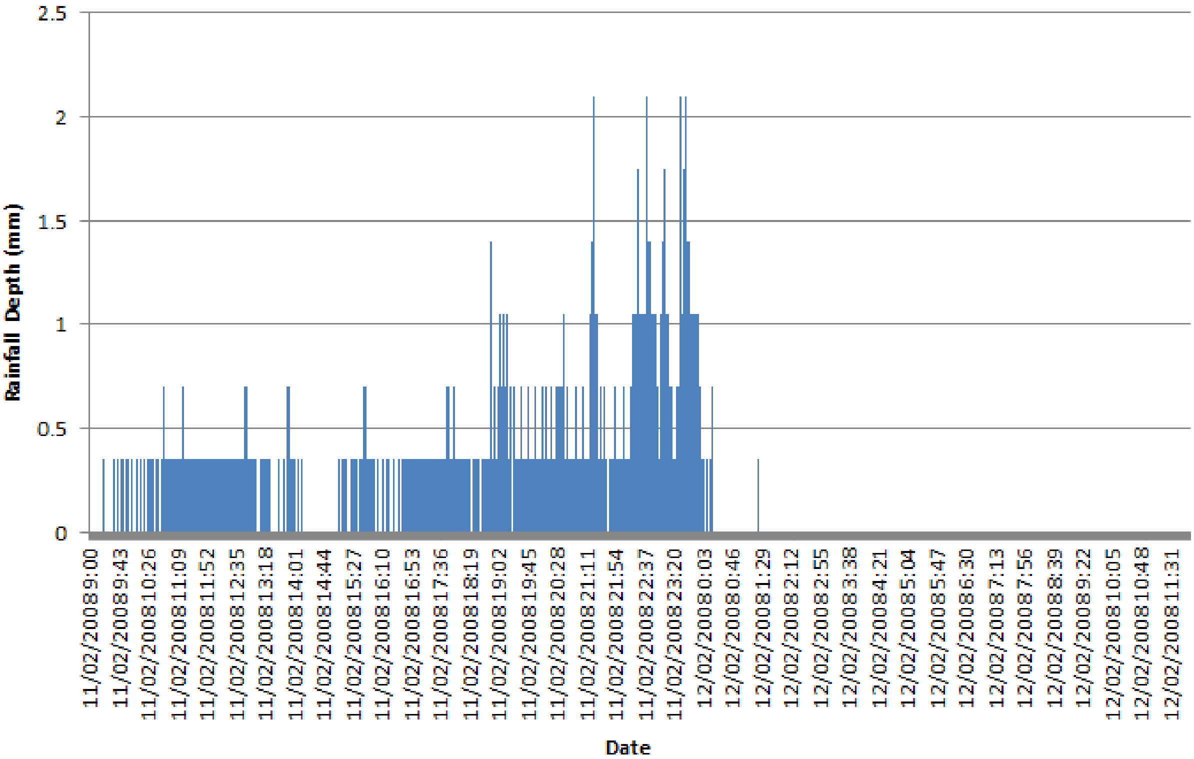


Figure 21 **2008 Event Rainfall Hyetograph Applied to Sub-Catchment 1**

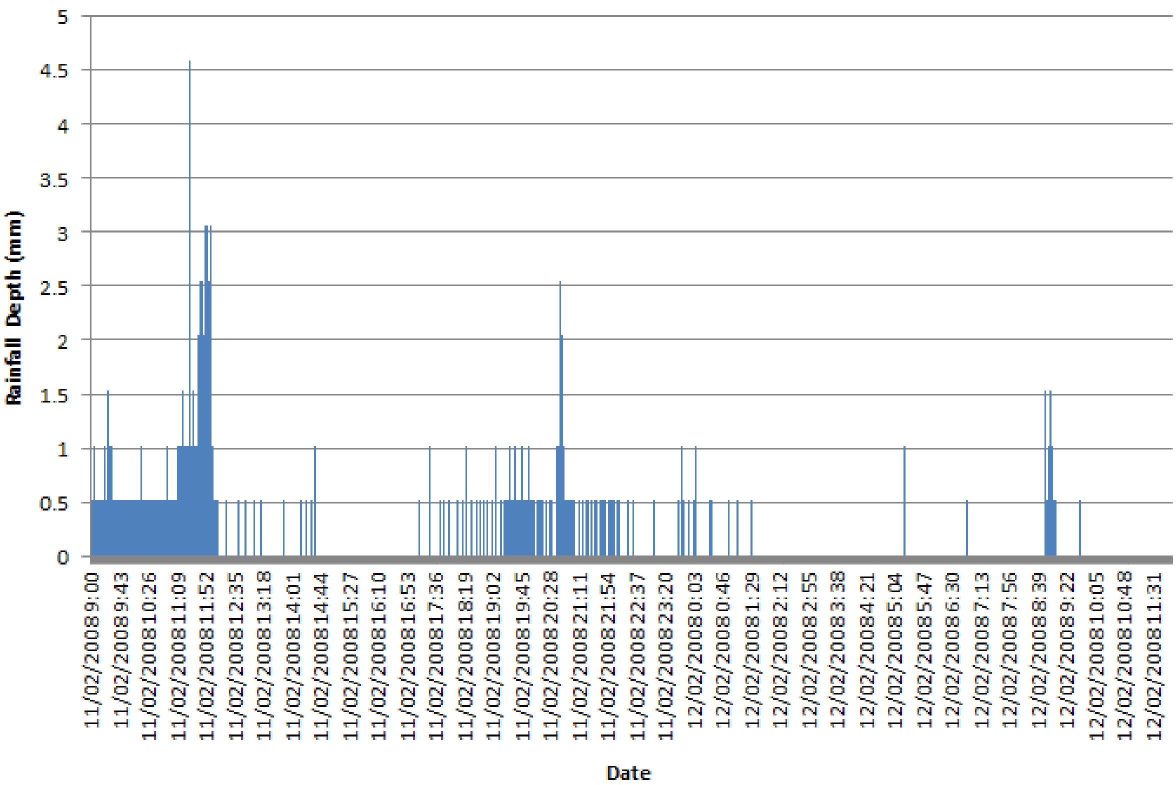


Figure 22 **2008 Event Rainfall Hyetograph Applied to Sub-Catchment 30**

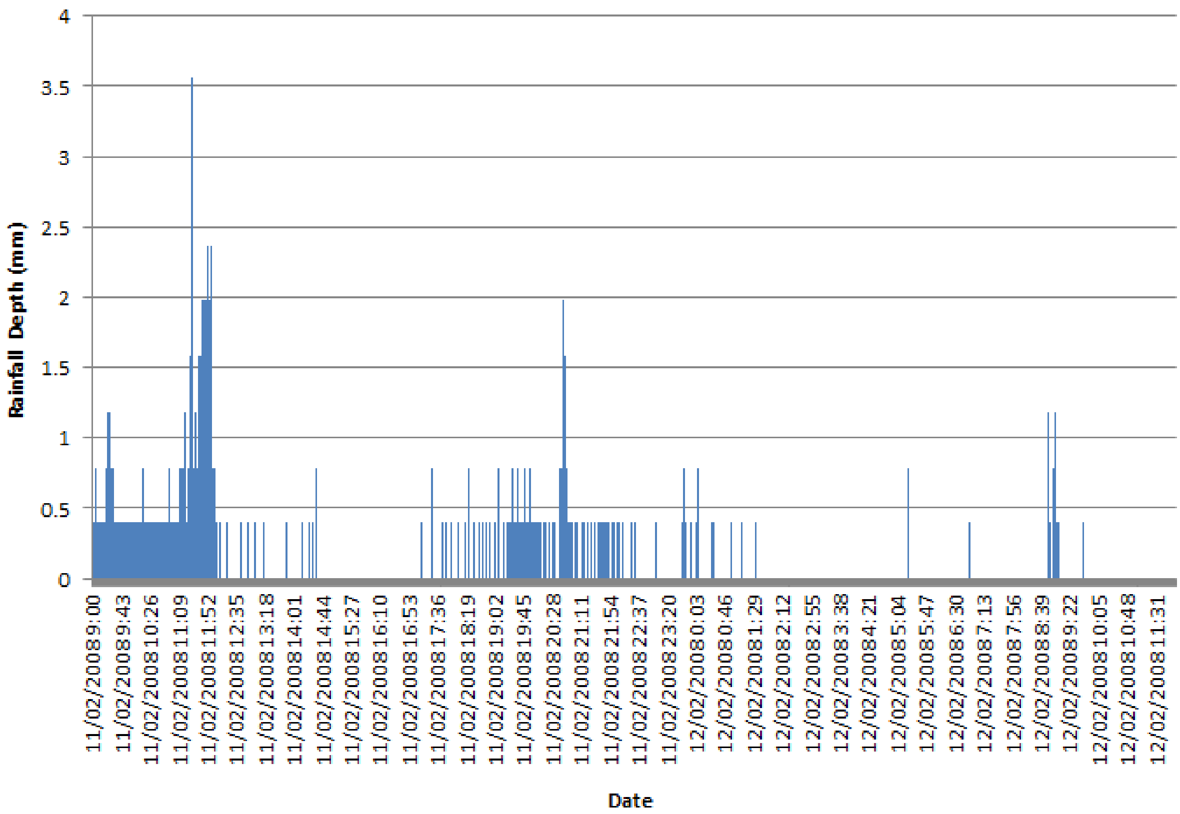


Figure 23 **2008 Event Rainfall Hyetograph Applied to Sub-Catchment 48**

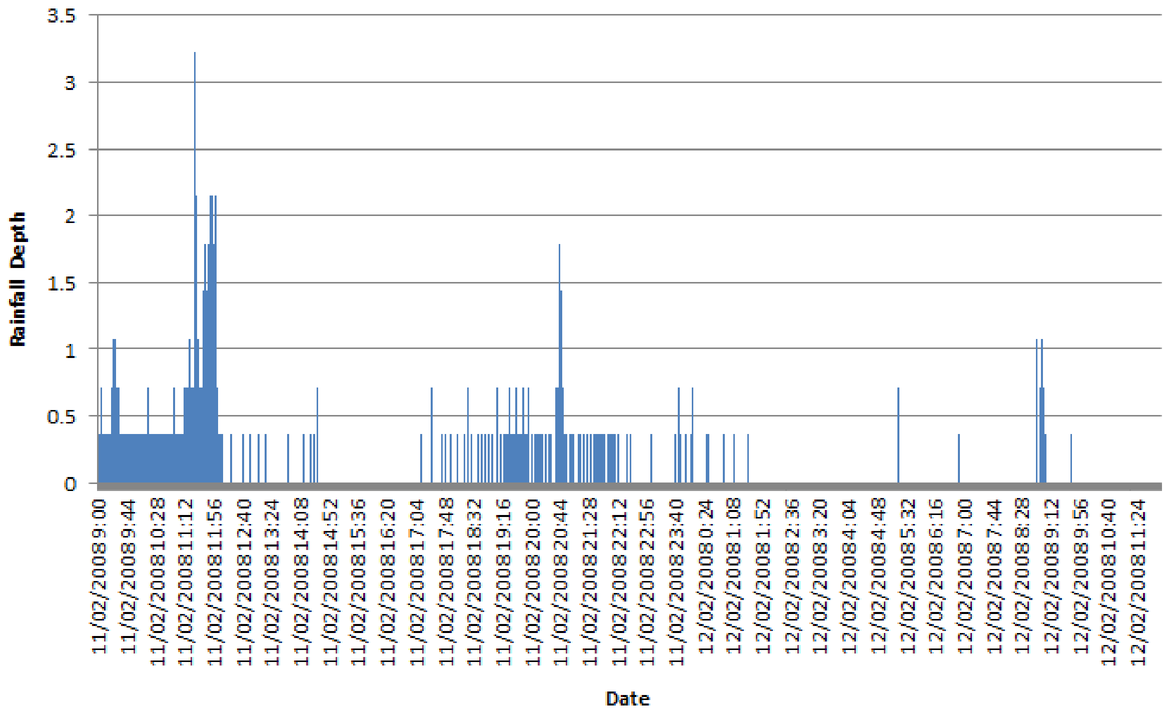


Figure 24 **2008 Event Rainfall Hyetograph Applied to Sub-Catchment 52**

A comparison between the gauged hydrographs and the calibrated model hydrographs are shown in Figure 25 and Figure 26 for Ida Creek and Reeves gauging stations respectively.

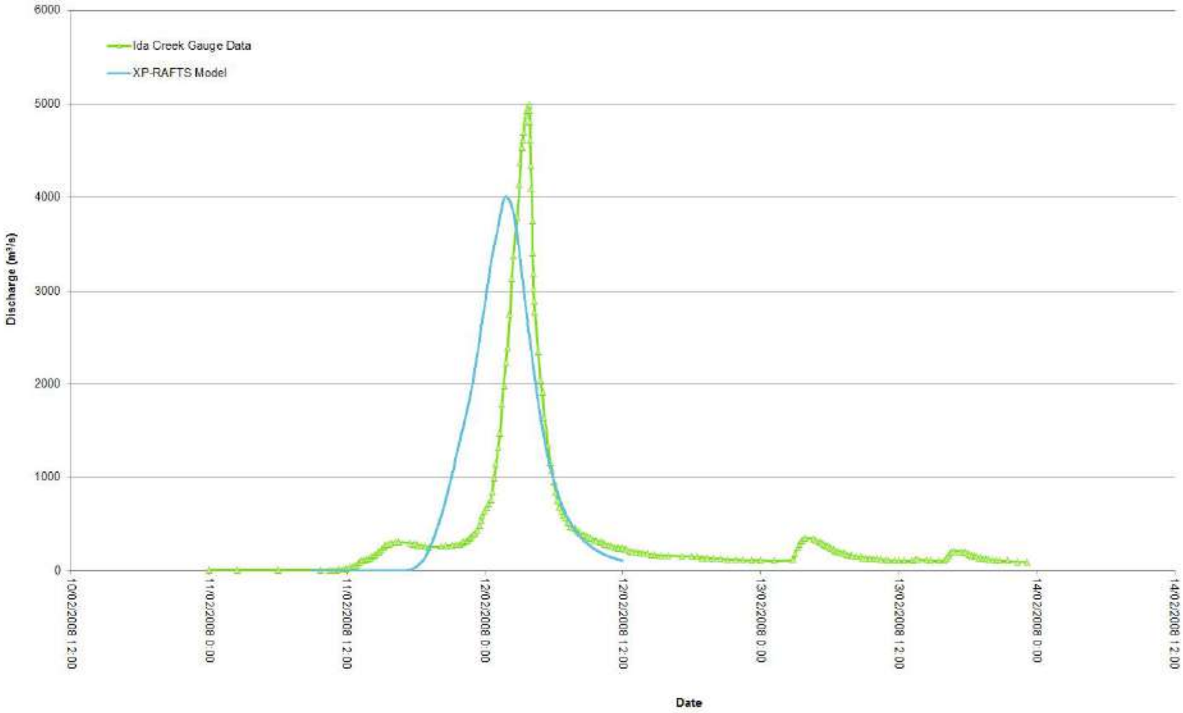


Figure 25 2008 Event Calibration to Ida Creek Gauge

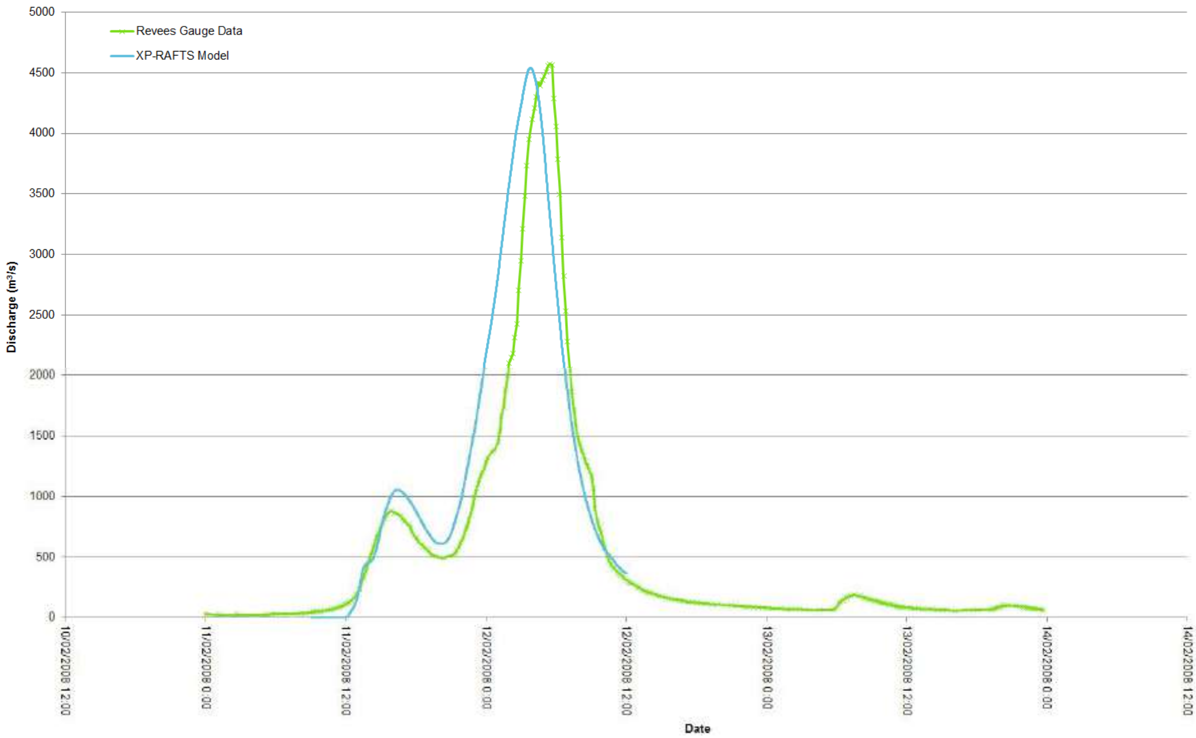


Figure 26 2008 Event Calibration to Reeves Creek Gauge

A reasonable fit between the recorded data for the 2008 event and the predicted XP-RAFTS hydrograph was achieved at the Reeves gauge with the rising and receding limbs well matched. The modelled peak discharge closely matches the recorded peak and the timing of the peak is within acceptable limits. The shift in in peak timing at both gauges is due to the necessity in assigning temporal patterns for either Bowen Airport or Collinsville to individual sub catchments, whereas in reality, there would be a gradual variation in timing.

A poorer fit between the recorded data and the predicted XP-RAFTS hydrograph was achieved at the Ida Creek gauge. Whilst the timing and shape generally matched the recorded data, the modelled peak discharge was below the recorded. Numerous trials were undertaken to improve the fit but was found to impact the fit at the Revees gauge. It is highly likely that the limited pluviograph data did not adequately characterise the peak rainfall burst which occurred in the upper catchment.

The initial and continuing rainfall loss values which achieved the best fit between the model and gauge data are shown in Table 21.

Table 21 Calibrated Model Loss Values for 2008 event

Event	Pervious Sub Areas	
	Initial Loss (mm)	Continuing Loss (mm/hr)
Calibration Run (2008 event)	70	4

4.4.6.3 April 2014 Event

Independent storms were applied to each sub-catchment in the XP-RAFTS model based on rainfall depths obtained from the spatially varying daily rainfall grids and the temporal pattern provided by the Proserpine Airport. The calibration event commenced at 0900 on 12 April 2014 and continued for 42 hours.

The rainfall depths provided by the Proserpine Airport and Ayr DPI Station were compared against daily rainfall totals obtained within the Don River catchment. The comparison showed that the Proserpine Airport pluviograph data better reflected the rainfall depths experienced in the Don River catchment. A comparison between the temporal patterns at each station, as well as the rainfall grids, showed that the storm burst moved in a south westerly direction. The peak storm burst at the Proserpine Airport occurred approximately 7 hours after the peak at the Ayr DPI station. On this basis, the timing of the Proserpine Airport temporal pattern was adjusted by two hours to better reflect the movement of the rainfall as the storm burst travelled across the Don River catchment.

As an example, the rainfall depths that were applied to sub-catchment 1 (one of the southern sub-catchments), sub-catchment 30 (one of the western sub-catchments), sub-catchment 47 (one of the central sub-catchments) and sub-catchment 52 (one of the southern sub-catchments) are shown in Figure 27, Figure 28, Figure 29 and Figure 30 respectively.

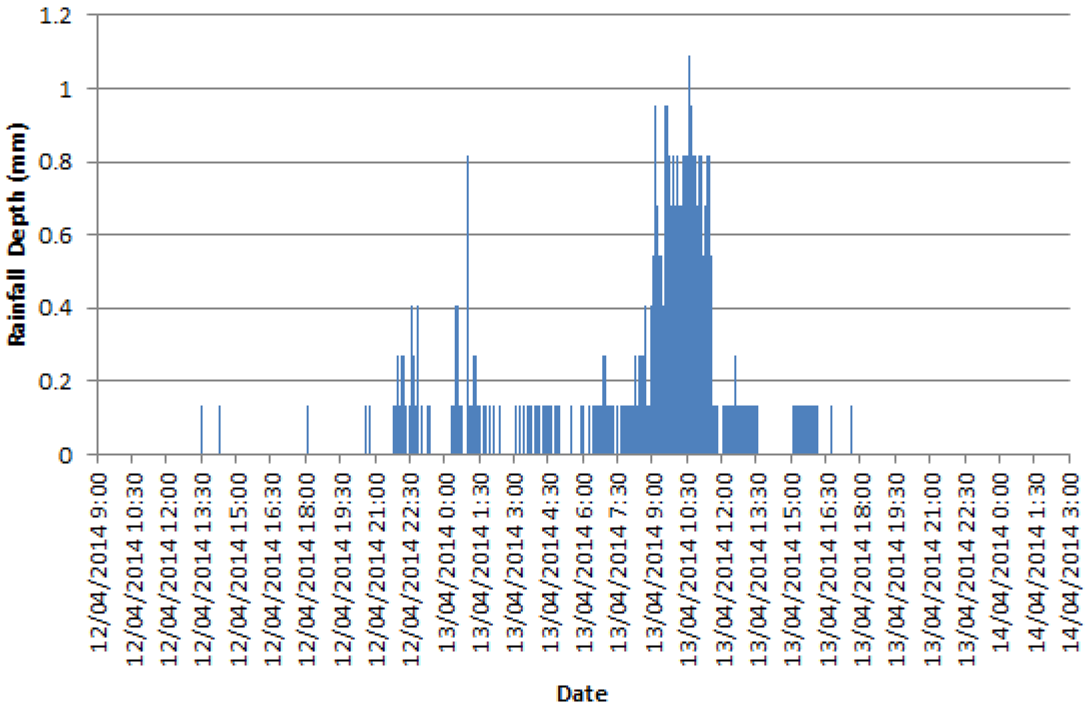


Figure 27 2014 Event Rainfall Hyetograph Applied to Sub-Catchment 1

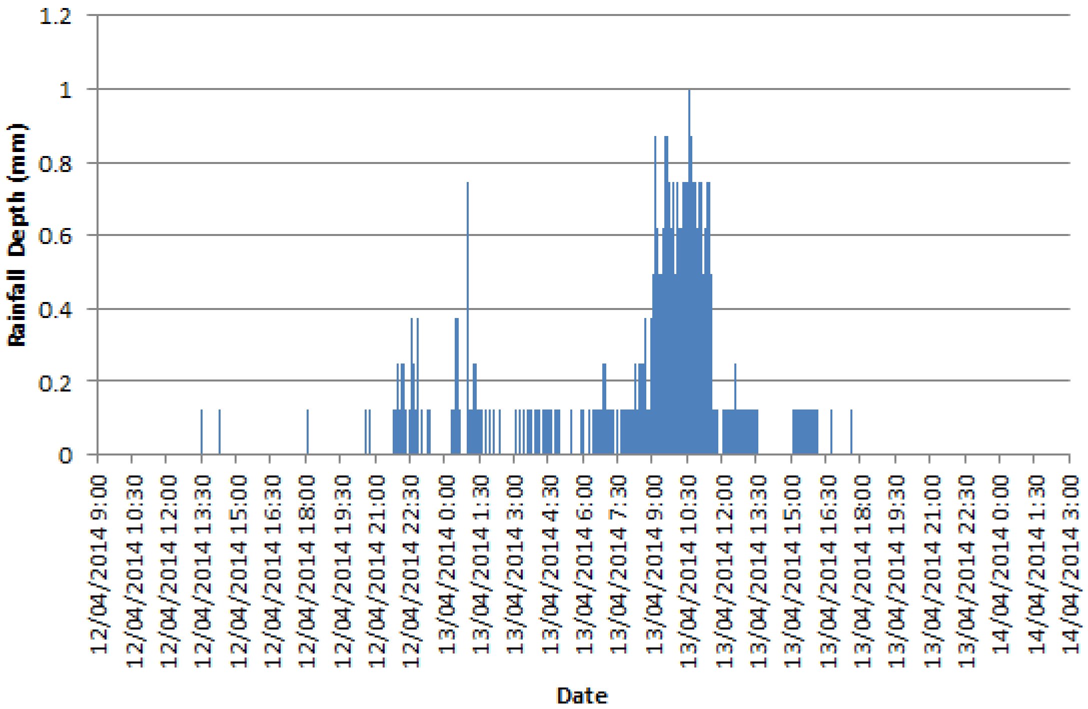


Figure 28 2014 Event Rainfall Hyetograph Applied to Sub-Catchment 30

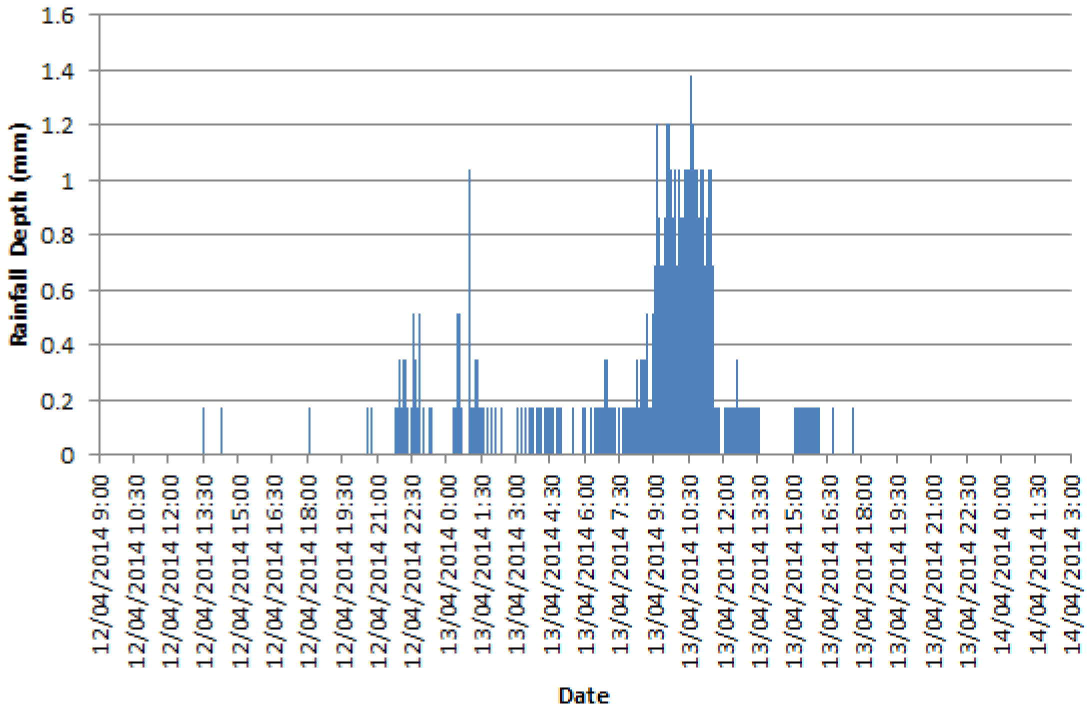


Figure 29 **2014 Event Rainfall Hyetograph Applied to Sub-Catchment 48**

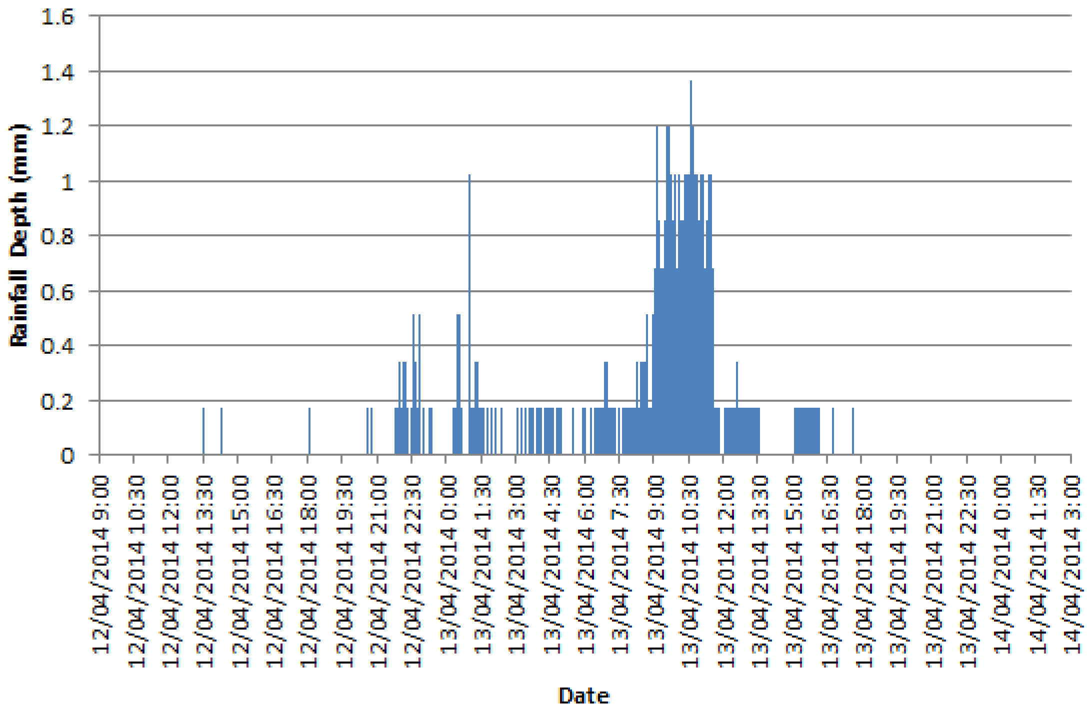


Figure 30 **2014 Event Rainfall Hyetograph Applied to Sub-Catchment 52**

A comparison between the gauged hydrographs and the calibrated model hydrographs are shown in Figure 31 and Figure 32 for Ida Creek and Reeves gauging stations respectively.

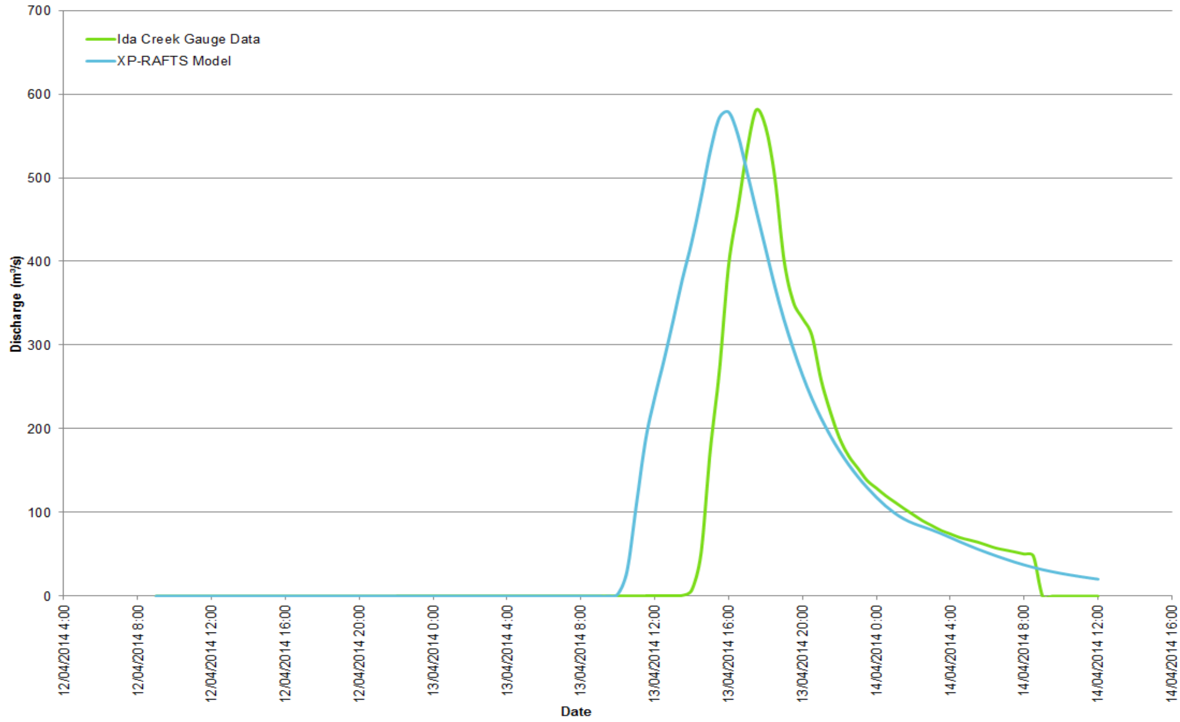


Figure 31 2014 Event Calibration to Ida Creek Gauge

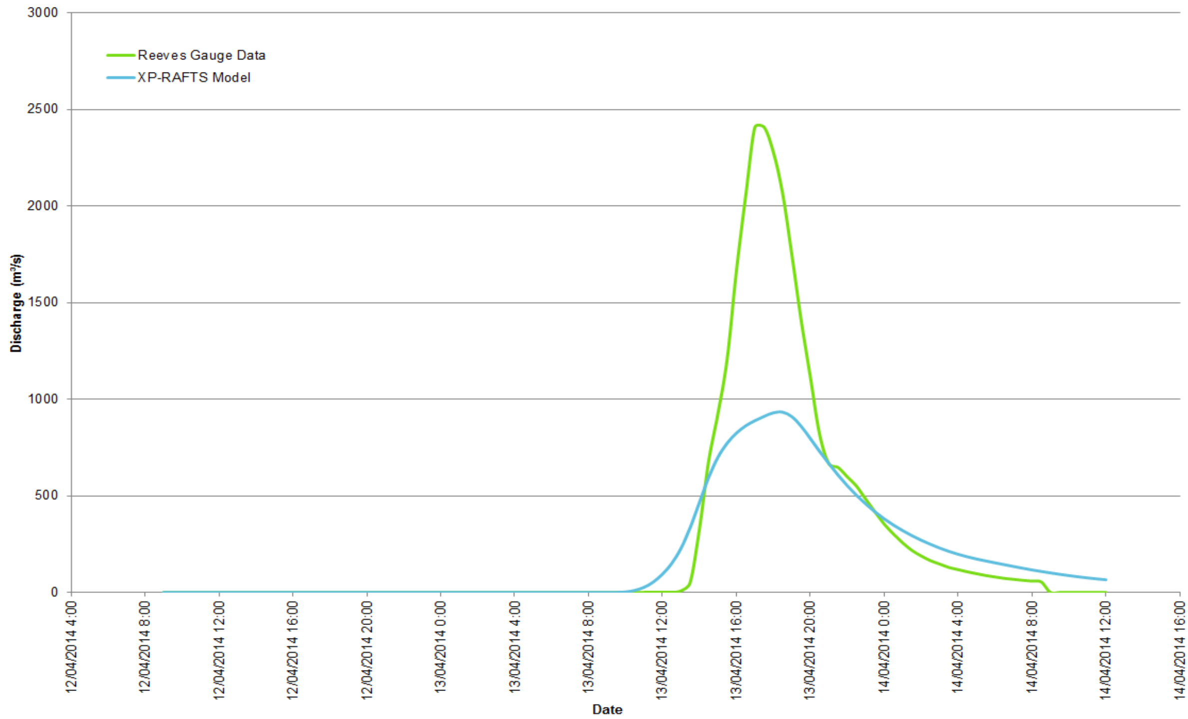


Figure 32 2014 Event Calibration to Reeves Creek Gauge

A reasonable fit between the recorded data for the 2014 event and the predicted XP-RAFTS hydrograph was achieved at the Ida Creek gauge with the peak discharge and receding limb well matched. The rate of rise and fall is reasonably matched, albeit there is a 2-3 hour difference in peak timing which is due to the inherent uncertainty in the storm burst movement in the absence of pluviograph data within the catchment.

A poorer fit between the recorded data and the predicted XP-RAFTS hydrograph was achieved at the Ida Creek gauge. Whilst the timing generally matched the recorded data, the modelled peak discharge was significantly less than recorded. This discrepancy was extensively investigated and in subsequent discussions with BoM staff it was noted that the Reeves gauged data for the 2014 event be treated with caution.

Trials were also conducted by applying inflows to the hydraulic model which matched either the Reeves or Ida Creek records. It was clear that the discharges determined by adopting the Ida Creek gauge data provided a better match to anecdotal records provided by Council and the DRIT.

The initial and continuing rainfall loss values which achieved the best fit between the model and Ida Creek gauge data are shown in Table 21.

Table 22 Calibrated Model Loss Values for 2014 event

Event	Pervious Sub Areas	
	Initial Loss (mm)	Continuing Loss (mm/hr)
Calibration Run (2014 event)	100	4.5

4.4.7 Selection of Rainfall Loss Values for Deign Rainfall Events

Table 23 describes the calibrated loss values for 1980, 2008 and 2014 calibration events.

Table 23 Initial and Continuing Loss Values for 1980, 2008 and 2014 Calibration Runs

Event	Pervious Sub Areas	
	Initial Loss (mm)	Continuing Loss (mm/hr)
1980 Calibration Run	20	4
2008 Calibration Run	70	4
2014 Calibration Run	100	4.5

Analysis of the rainfall and river gauging data for the 1980 and 2014 flood events showed that there was no major rainfall events prior to the rainfall event associated with the floods. This may be the reason why the calibration for the 1980 and 2014 events required higher initial loss values, as the catchment had been generally dry with the soils and vegetation having greater infiltration capacity.

Investigation into the 2008 flood event shows that the rainfall associated with the 2008 flood event was preceded by a number of smaller rainfall events which would have saturated a significant portion of the catchment and is the likely reason for the smaller initial loss suggested by the 2008 calibration run.

It is likely that the majority of the major rainfall events are likely to follow smaller rainfall events. Therefore, an initial loss and continuing loss of 20mm and 4mm is likely to be more suitable for design event runs. This has also been confirmed by comparing peak design discharges from the XP-RAFTS model with the expected quantiles from the FFA work. This comparison is further discussed in Section 4.4.8.

Table 24 Final Rainfall Losses Adopted

Surface Type	Initial Loss (mm)	Continuing Loss (mm/hr)
Pervious	20	4
Impervious	0	0

4.4.8 Comparison between FFA and Runoff-Routing

The XP-RAFTS predicted peak discharges for the design events at the Ida Creek gauge are presented in Table 20 along with the estimated peak discharges determined using the FFA approach at the same location.

Table 25 Comparison between FFA and XP-RAFTS Peak Discharges

AEP (%)	Peak Discharge XP-RAFTS Approach (m^3/s)	Peak Discharge FFA Approach (m^3/s)	% Difference
10	2,275	2,143	6.2
2	4,767	4,359	9.4
1	5,767	5,617	2.7
0.5	6,970	7,094	-1.7
0.2	10,200	9,431	8.2

Figure 33 shows that these peak discharge predictions are very close to the FFA flood quantiles and are all well within the 95% confidence limits of the FFA.

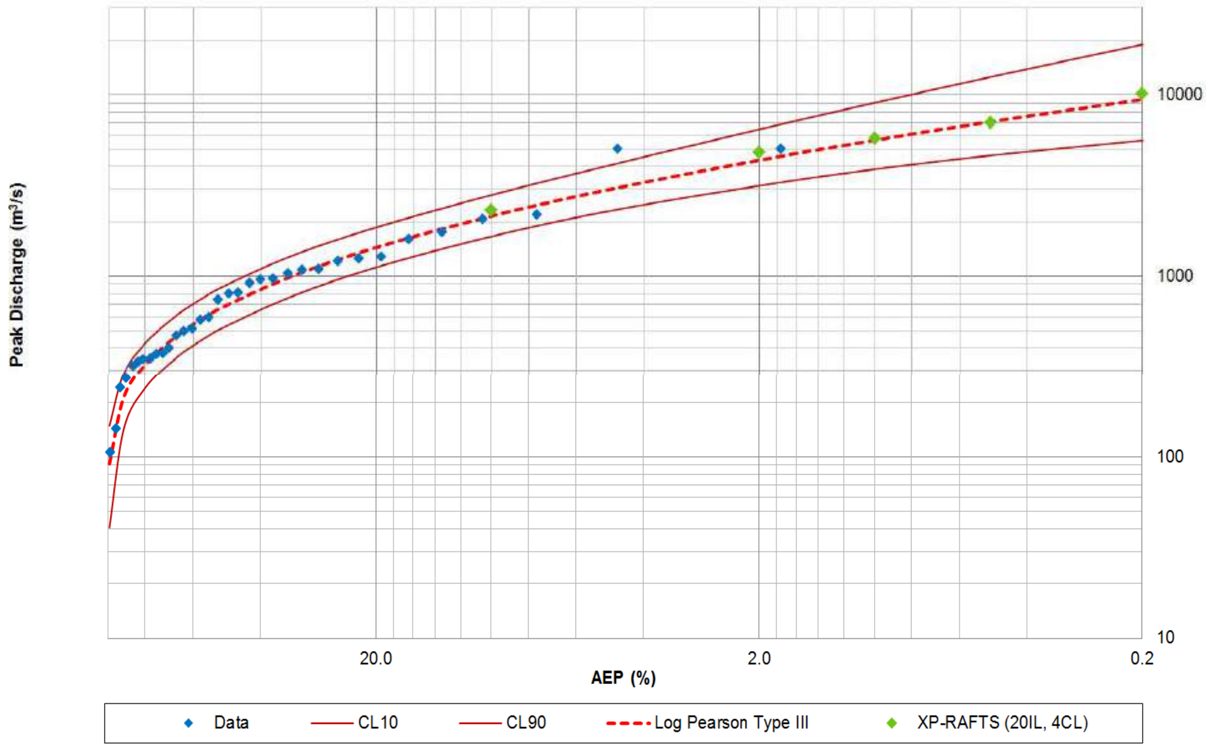


Figure 33 FFA at Ida Creek with XP-RAFTS Peak Discharges

4.5 Discussion

To estimate the design discharge hydrographs for the study, three XP-RAFTS hydrologic models have been developed to estimate design discharge hydrographs. A flood frequency analysis has also been undertaken and compared to hydrologic model results.

Calibration of the hydrologic models was undertaken and the adopted calibration parameters have been further verified using flood frequency analysis results. This has shown a good agreement between the design rainfall approach (runoff-routing) and the FFA approach.

A number of uncertainties are present when undertaking hydrological modelling. The greatest degree of uncertainty for this study is largely due to the following:

- Pluviograph data is generally limited and therefore assumptions must be made on the temporal distribution of the rainfall depths when undertaking calibration.
- There are significant differences between the rating curves at Ida Creek and Reeves gauging stations.
- Mt Dangar and the Bowen Pump Station are BOM flood warning level recorders and have not been accurately rated. There is a very high degree of uncertainty in the discharge data from these gauges due to a lack of quality information.
- Due to the highly dynamic nature of the Don River it is likely that gauging stations are located at sites with unstable cross sections. This may cause a shift in the rating curve causing a systematic but unknown bias.
- The Don River XP-RAFTS model has been calibrated to three historical events due to a lack of available data. It is suggested that this model (and the Euri Creek model) be validated to future flood events to confirm the adopted parameters.

4.6 Adopted Design Discharges

The calibrated hydrologic models were run for the 10%, 2%, 1% and 0.2% AEP as well as PMF event for a range of standard duration storms to determine the critical duration storm event.

The critical durations for Don River, Euri Creek and Sandy Gully catchments are summarized in Table 26.

Table 26 Critical Duration Assessment

AEP	Critical Duration Don River (hours)	Critical Duration Euri Creek (hours)	Critical Duration Sandy Gully (hours)
10%	24	24	18
2%	24	24	18
1%	24	24	18
0.2%	24	24	18
PMF	24	24	24

The 24 hour duration storm was observed to be critical duration event for the Don River and Euri Creek catchments. However, 18 hour duration storm was identified to be the critical storm duration for Sandy Gully which is much smaller in size when compared to the Don River and Euri Creek catchments. For this reason, the 24 hour duration storm event was adopted for the study.

The XP-RAFTS models were used to generate runoff hydrographs for the 10%, 2%, 1% and 0.2% AEP as well as PMF event for the critical duration. These hydrographs were converted to DFS0 files and applied to the MIKEFLOOD hydraulic model as boundary inflow conditions and local source nodes.

4.7 Comparison with Historical Reports

A large number of studies have been undertaken where estimates for historical and design event flow rates for the Don River and Euri Creek have been derived using the following methods:

- Development and analysis of flood rating curves;
- Flood frequency assessment of recorded flood level and flow rate estimates;
- Simple flow estimation based on Manning's Equation and recorded flood height; and
- Development of hydrologic models.

Given that a number flow estimation methods have been used to estimate historical and design event flow rates and that there are limitations and uncertainties associated with each of these methods, a wide range of flow estimates have previously been determined for historical and design event flow rates in the Don River and Euri Creek. A summary of estimated flow rates in the Don River for the 1980, 2008 and the 1% AEP design event is provided in Table 27.

Table 27 Comparison between Don River Peak Discharge Estimates

Study	1980 Event Peak Discharge at Mt Buckley 17km AMTD (m^3/s)	2008 Event Peak Discharge at Mt Buckley 17km AMTD (m^3/s)	1% AEP Peak Discharge at Mt Buckley 17km AMTD (m^3/s)
Don River and Euri Creek Flooding (QWRC, 1980)	6,500	-	-
Bells Gully Investigation Report (Ullman & Nolan, 1986)	6,500	-	10,000
Development Control Plan No. 2 for Don River Flood Plain Planning Study (Bowen Shire Council, 1992)	-	-	9,750
Don River Flood Plain Management Study (Ullman & Nolan, 1993)	6,550	-	7,600
Bowen Shire Storm Tide Study (Connell Wagner, 2004)	10,235	-	7,797
Euri Creek Catchment Flood Study / Don River Sand Depth Study (Connell Wagner, 2006)	10,235	-	8,094
Sandy Gully Flood Study (BMT WBM, 2008)	10,200	-	8,600
Queens Beach Drainage Study – Bells Gully Interim Report (Ullman & Nolan, April 2010)	-	-	-
Don River Sand Study – Don River Catchment Study (Aurecon, 2011)	10,235	-	-
Bowen Strategic Flood Study (GHD, 2011)	10,235	-	8,657
Don River Flood Risk and Mitigation Study (AECOM, 2014)	6,020	4,500	8,485

The comparison indicates:

- There is a highly variable estimate of the 1980 peak discharge. This is due to the selection of either the BOM or DNRM rating curve for Ida Creek.
- Flow estimates for the 1% AEP design event range from 7,600 to 10,000 m^3/s at Mt Buckley (17km AMTD). This compares to AECOM's 1% AEP design flow rate estimate of 8,485 m^3/s at this location.
- The estimated peak design discharge in this study is considered to be appropriate for the purposes of the study given the general consistency with the estimates determined in the three most recent studies.

4.8 Probability of Historical Events

The magnitudes of a number of historical Don River flood events at the Ida Creek gauge have been estimated from the FFA results and are presented in Table 28. The return periods have been calculated using the adopted probability curve which is subject to a degree of uncertainty – therefore these results should be taken as only approximate.

Table 28 Estimated Magnitude of Historical Floods at Ida Creek Gauge

Flood Event	Peak Discharge (m^3/s)	Estimated AEP (ARI)
1970	3,555	3.5% (28 year)
1980	5,005	1.4% (71 year)
1991	2,163	10% (~10 year)
2008	4,989	1.4% (71 year)
2014	942	37% (2 year)

5.0 Hydraulic Model Development and Calibration

5.1 Adopted Methodology

An integrated one-dimensional / two-dimensional numerical hydraulic model has been developed to simulate flood behaviour in the lower reaches of Don River and Euri Creek where break out from the banks and cross-connectivity of the flows can occur.

A MIKE FLOOD hydrodynamic model (DHI, 2014) has been developed which incorporates a MIKE21 Flexible Mesh (two-dimensional model) and a MIKE11 (one dimensional model) to represent hydraulic structures. The 2014 software version has been used which utilises Graphical Processor Units (GPU) to decrease simulation times. The simulation time for the 1% AEP design event is approximately 20 hours.

The MIKE FLOOD model represents hydraulic conditions on a flexible computational mesh by solving the full two-dimensional depth averaged momentum and continuity equations for free surface flow. The flexible mesh uses triangular elements to represent the 2D model domain and this approach allows varying resolution of the computational mesh throughout the model.

5.2 One Dimensional Model Development

The extent of the one-dimensional MIKE11 model components is shown in Figure 34. The one-dimensional model components were used to represent flow through hydraulic structures previously noted in Section 3.8.

Representing these structures in MIKE11 allows a more accurate representation of flow and associated head loss through these components where the structure width is less than the size of the two-dimensional mesh upstream and downstream of the structure. Larger bridges and flood relief culverts have been represented as two dimensional structures.

5.3 Two Dimensional Model Development

5.3.1 Model Extents

Topographic data and historical records were critically analysed to determine the extent of the two-dimensional hydraulic model for this study. The hydraulic model boundaries were dictated by the following:

- The northern boundary of the model is generally defined by the ocean.
- The majority of the eastern boundary is also defined by ocean. The south-eastern boundary was defined by higher ground which is outside the extent of the PMF.
- Mountain range to the west of Euri Creek defined the western boundary of the hydraulic model.
- The southern boundary was selected to ensure that all of the known breaks out point are located within the model domain.

Figure 34 shows the extent of the two dimensional hydraulic model, as well as the locations of the one-dimensional structures and boundaries.

There are three spatially varying model parameters that must be defined for the 2D component of the hydraulic model. These parameters are hydraulic roughness, eddy viscosity and topographic data which are associated with the governing equations of the hydraulic model.

5.3.2 Model Topography

A two-dimensional computational mesh was prepared for the selected model extents. The compiled DTM (as discussed in Section 3.6.2) was applied to the computational mesh to develop the final two-dimensional model topography.

5.3.3 Inflow and Outflow Boundaries

Upstream boundary conditions were specified as time varying discharge hydrographs to represent the flows from catchments upstream of the southern boundary of the hydraulic model.

Discharge hydrographs were applied along the southern and western boundaries of the model as follows:

- Don River inflow hydrograph.
- Euri Creek inflow hydrograph.
- Euri Creek tributary inflow hydrograph.

The discharge hydrographs were determined from the XP-RAFTS hydrological models.

5.3.4 Tidal Boundaries

A static water surface level was applied as downstream boundary condition to represent the sea level for the design event runs. A static level of 1.1 m AHD representing the Mean High Water Springs (MHWS) tide level was adopted.

Sensitivity analysis was also undertaken to investigate the impacts of higher tidal conditions. This was undertaken by applying a static level of 1.97m AHD representing the Highest Astronomical Tide (HAT).

The impacts of future sea level rises have been assessed and details are included in Section 7.0 .

5.3.5 Source Node Inflows

The discharge hydrographs associated with the Don River, Euri Creek and Sandy Gully catchments which were located within the two-dimensional model extent were applied as local source nodes in the model. These discharge hydrographs were extracted from the three XP-RAFTS hydrologic model.

5.3.6 Eddy Viscosity

Eddy Viscosity is associated with the assumptions of sub-mesh scale turbulence. The eddy viscosity parameter describes the degree of turbulence that exists at scales smaller than mesh scale.

The eddy viscosity parameter is critical for describing the simulated transverse distribution of flow velocities in the rivers and creeks and is also important in describing the bifurcation of flows at junctions. The eddy viscosity parameter is generally adopted based on experience from previous modelling studies.

For this study, a constant flux based eddy viscosity of 8.0 was adopted. The viscosity value was based on the model time step and mesh sizes.

5.3.7 Hydraulic Roughness

Hydraulic roughness is an important spatially varying factor that must be defined in the hydraulic model. Hydraulic roughness's associated with bed friction and is represented in MIKE FLOOD as Manning's M. This is the inverse of the most commonly used Manning's n.

The hydraulic roughness generally reflects the types of development and vegetation that exists within the hydraulic model extent. Consequently it is appropriate to develop roughness maps that reflect the land use zoning within the model area.

The roughness distribution adopted for this study was based on aerial topography and land use zoning information provided by WRC. The specific roughness values adopted for each zone are detailed in Table 29.

Table 29 Adopted Roughness Values

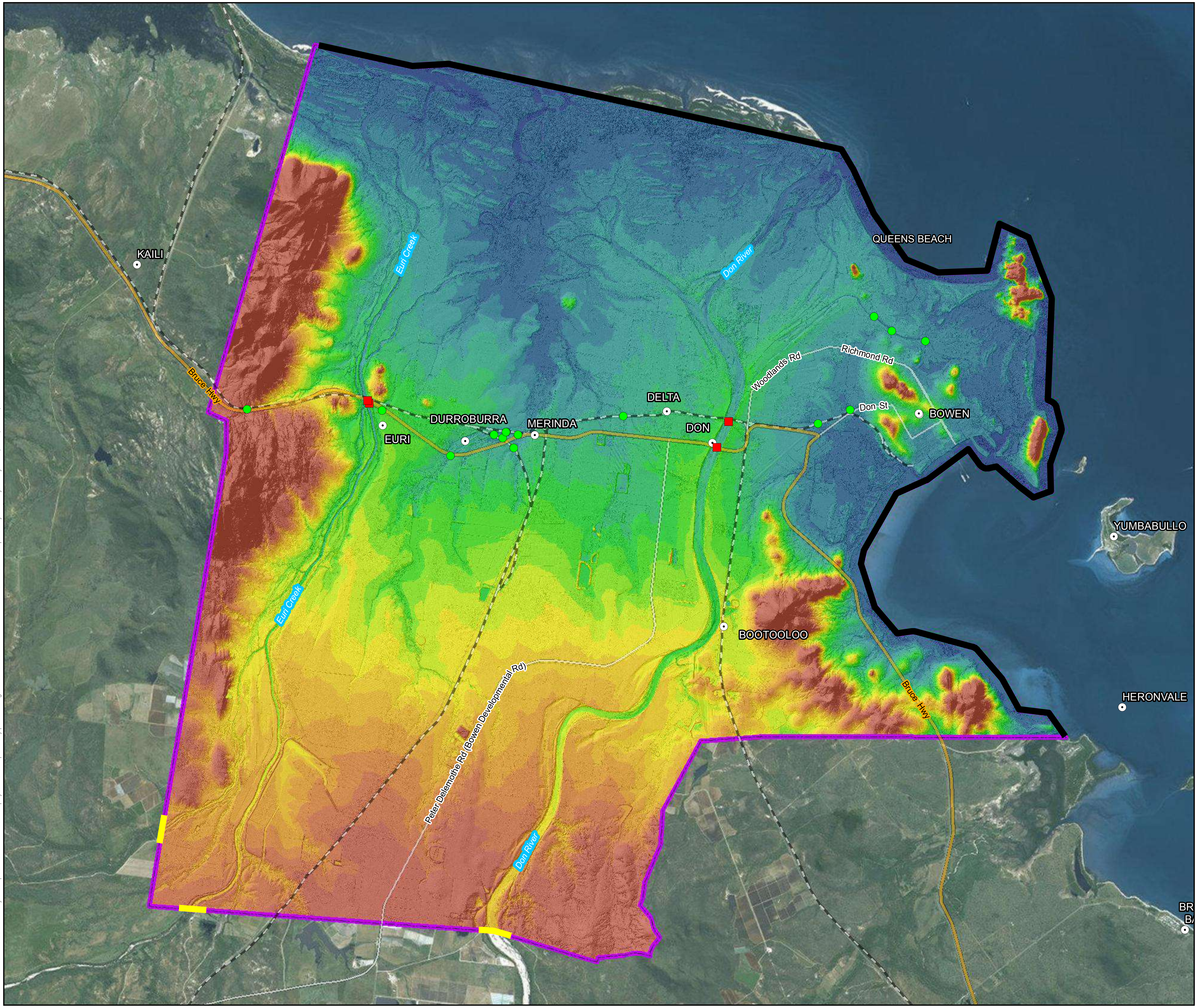
Land Use / Zoning	Manning's 'n'	Manning's M
Urban	0.150	6.66
Mountain and Forest	0.100	10.00
Agriculture/Cleared	0.045	22.22
River and Major Creeks	0.025	40.00
Estuary/Sea	0.020	50.00

The hydraulic roughness within the study are has been schematized as a hydraulic roughness grid, representing varied hydraulic roughness of typical land use element and to be incorporated into the hydraulic model. Figure 35 shows a representation of the roughness map.

DON RIVER FLOOD STUDY

Hydraulic Model Configuration

Figure 34



LEGEND

- Structures- Bridge
- Structures- Hydraulic
- Localities
- Inflow Boundary
- Outflow Boundary
- Highways
- Main Roads
- Railway Lines
- Don River Hydraulic Model Extent

Elevation (m AHD)

- Below 0
- 0-2
- 2- 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16 - 18
- 18 - 20
- 20 - 22
- 22 - 24
- 24 - 26
- 26 - 28
- 28 - 30
- Above 30

0 0.5 1 2 3 4

Kilometres

1:75,000 (when printed at A3)

N

Coordinate System: GDA 1994 MGA Zone 55

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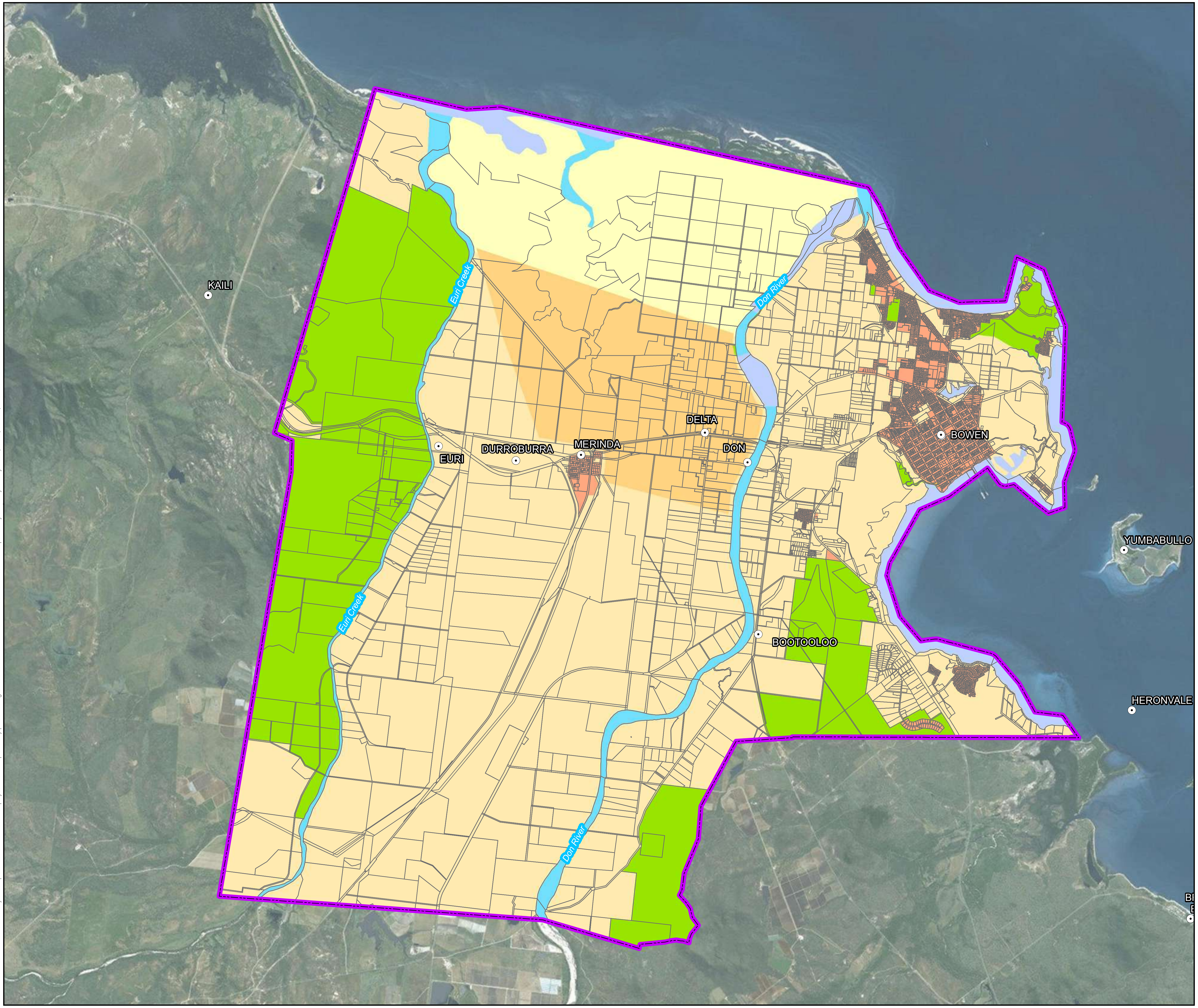
Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

DON RIVER FLOOD STUDY

Adopted Roughness Map

Figure 35



LEGEND

Don River Hydraulic Model Extent

Manning's n

- 0.02
- 0.03
- 0.04
- 0.05
- 0.07
- 0.12
- 0.18

0 0.5 1 2 3 4

Kilometres

1:80,000 (when printed at A3)

Coordinate System: GDA 1994 MGA Zone 55

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5.3.8 Initial Conditions

Initial conditions were applied in the hydraulic model. This typically consisted of a set of adopted 'starting' flood levels in low-lying areas, waterways and storages. At the downstream boundary of the model, initial flood level conditions were set to equal the relevant tail water boundary condition. Initial flood levels in Don River and Euri Creek channel were equivalent to low flow conditions which precede a flood event.

5.3.9 Time Step

The model simulation time step is generally limited by the Courant conditions. The Courant condition is a function of the water depth and the flow velocities at any time step. The Flexible Mesh version of MIKE21 has an adaptive time step, whereby the maximum time step is calculated dynamically during the simulation between specified bounds. The minimum time step was chosen as 0.01 second.

The coupling with MIKE11 components of the model restricts the application of this feature, whereby the maximum time step that can be simulated is governed by the Courant Number at the couple locations. The MIKE FLOOD model was developed with a maximum Courant Number criterion of 0.8. The model simulation results were saved at 10 minute intervals.

5.3.10 Solution Scheme

The simulation time and accuracy of the model computations can be controlled by specifying the order of the numerical schemes which are used in the numerical calculations. For all simulations the higher order solution scheme within MIKE21 was used for both time integration and space discretisation. This is recommended for environments which are dominated by flow rather than diffusion, such as this flooding application.

5.3.11 Flooding and Drying Depths

MIKE21 allows the specification of flooding and drying depths, which control the depths at which elements are included or excluded from the computations. The model simulations were all carried out using:

- Drying depth of 0.01m.
- Flooding depth of 0.05m.
- Wetting depth of 0.10m.

5.4 Model Calibration and Validation

5.4.1 Process Adopted

Calibration and validation of the MIKE FLOOD model was undertaken by simulating historical flood events and comparing the results to observed data. The model was calibrated to the 2008 flood event by varying roughness and eddy viscosity parameters until a good fit to recorded data was achieved. The model was then validated to the 1980 event with no changes to the calibrated model, to verify the accuracy of the model.

The same hydraulic roughness and eddy viscosity parameters determined from calibration / validation to the 2008 and 1980 flood events was adopted in a separate hydraulic model prepared using the 2013 LiDAR provided by Council. This model was validated to the 2014 flood event and also used for subsequent design flood event simulations.

Several different datasets were available to assist with calibration / validation, including time-varying river levels at the Bowen Pump Station and surveyed peak flood levels across the floodplain. In order to achieve calibration, the model was required to replicate the recorded flood data within specified tolerances. For each type of flood record, a different tolerance is specified, reflecting the reliability and accuracy of the historical flood data.

Surveyed peak flood levels are generally based upon flood debris marks or reported flood marks and are of varying levels of accuracy; therefore they are less reliable than recorded gauge levels. Adopted calibration tolerances for this study are as follows:

- Surveyed flood debris marks/peak flood levels ± 0.30m
- Bowen Pump Station Gauge ± 0.15m

5.4.2 Sediment Transport

The dynamic nature of the Don River in response to intense rainfall events has been well documented, with extensive erosion and deposition in the lower reaches of the river observed during and after most significant flood events. Significant discrepancies between modelled and recorded levels have been identified in most historical reports when undertaking calibration. Previous authors have identified the dynamic nature of the river as the cause of poor model calibration and have made large scale changes to model bathymetry in response.

Given the significant uncertainty inherent in previous studies, a two-dimensional MIKE21 sediment transport hydrodynamic model was developed to dynamically simulate channel erosion and deposition in the lower reaches of the Don River with the aim of improving model calibration. Further discussion on the sediment transport assessment can be found in Section 6.0.

It should be noted that the MIKE FLOOD model was run for each calibration event for two different scenarios as described below.

- MIKE21FM without Sediment Transport Module activated.
- MIKE21FM with Sediment Transport Module activated.

This was undertaken to clearly assess the impacts of the dynamic sediment transport module with reference to recorded flood levels.

5.4.3 February 2008 Event Calibration

The 2008 event discharge hydrographs from the XP-RAFTS models were applied to the MIKE FLOOD model. The maximum water surface elevations were extracted from the hydraulic model and compared to recorded peak flood levels provided by WRC.

Peak flood levels were recorded at 54 locations within the lower Don River floodplain. Figure 36 presents the comparison of water levels at these locations without the dynamic sediment transport module used. Figure 37 presents the comparison of water levels with the dynamic sediment transport module used.

The differences between the calculated and recorded flood levels are characterised into bands. Locations where the model predictions are within the tolerance ranges (as presented in Section 5.4.1) are shown as orange, yellow and green points. Locations where the model predictions are outside the tolerance ranges are shown as red and blue points. Locations where there were recorded peak water levels and no predicted water levels are shown as purple points.

From a comparison between the sediment transport scenarios, it is clear that the dynamic sediment transport module provides a better fit to the recorded data, as well as simulating breakout flows that occurred during the 2008 event (evidenced by recorded flood heights) which was not simulated by the static model.

Key outcomes from the calibration using the dynamic sediment transport module are:

- Of the 48 recorded points, 19 of the calculated values are within ±0.3m, an additional 10 values were within ±0.5m, 15 values were outside the tolerances and the inundation extent didn’t reach 4 locations.
- The average difference between calculated and recorded levels is 0.03m.
- The modelled peak water surface elevation at the Bowen Pump Station was 10.64m AHD. There was a reasonable comparison with BOM’s recorded peak level of 11.31m AHD.
- Large differences between modelled and recorded values were noted for the set of recorded points to the north of the ‘1946 mouth’. This was coupled with higher modelled levels through the Webster Brown breakout.
    - It was noted that the hydraulic model topography was based on post-2008 LiDAR survey which may have accounted for higher distributary breakout levels which was the result of sediment deposition in the 2008 flood event.
    - The results of the sediment transport module suggested sand deposition would have occurred at the ‘1946 mouth’. This was also confirmed by comparing aerial imagery pre and post flood event.
    - The hydraulic model topography at the ‘1946 mouth’ was lowered by 0.3m – 0.5m to reflect pre-flood conditions. This resulted in a better fit to the recorded points north of the distributary as well as the points along the Webster Brown flow path.

- The modelled extents appear to match well with the spatial distribution of the recorded flood heights.
- Initial model simulations suggested a minor breakout to Bells Gully which did not occur during the actual event. These simulations were based on an adopted sand diameter of 1.0 mm, with reference to Section 6.4.
    - Breakouts to Bells Gully generally occur due to localised sand deposition in the main river channel in the vicinity of Bells Gully which results in reduced conveyance and subsequent overbank flows.
    - It has been found that modelled outflows to Bells Gully are highly sensitive to the adopted sand diameter in the sediment transport model. A mean sand diameter of 1.5 mm was trialled in the model which showed no breakout to Bells Gully.
    - This is further discussed in Section 6.6.

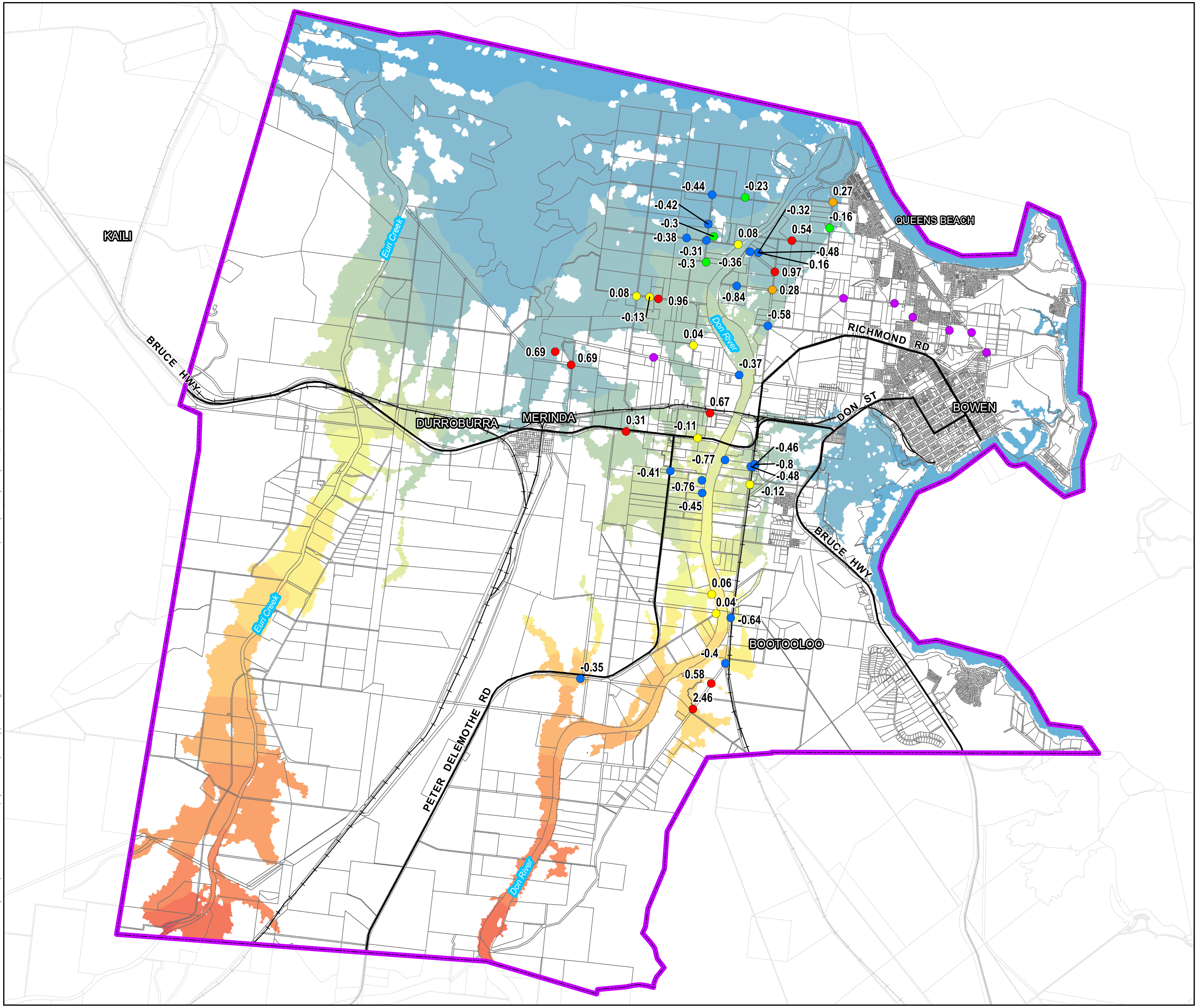
A correlation between the calculated and recorded flood levels at the Bowen Pump Station could not be undertaken as the time series gauge data was not recorded during the peak of the flood event.

Due to the highly dynamic nature of the Don River, it is obvious that a better calibration is achieved when the model topography is based on survey undertaken before the flood event. In this case it was not possible; however a reasonable calibration has still been achieved for the 2008 event.

DON RIVER FLOOD STUDY

2008 Event Calibration (Without Sediment Transport)

Figure 36



0 0.5 1 2 3 4

Kilometres

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Coordinate System: GDA 1994 MGA Zone 55

Water Different Levels, Model - AECOM 2014
Property Boundaries - QLD Gov 2013.

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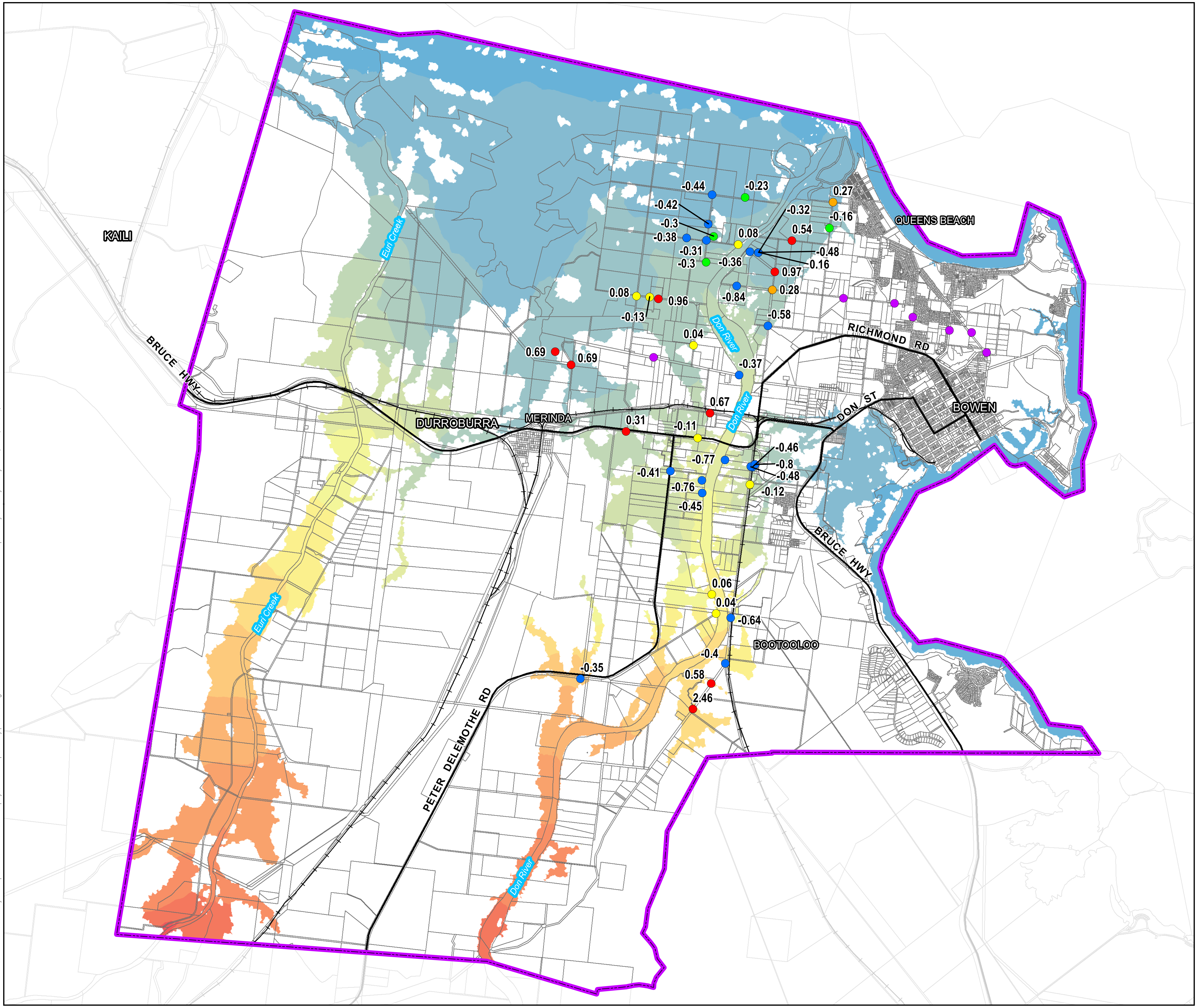

DON RIVER FLOOD STUDY

2008 Event Calibration (With Sediment Transport)

Figure 37

LEGEND

Don River Hydraulic Model Extent

Water Level Difference (m)

Calculated - Record

- > 0.30
- 0.15 to 0.30
- -0.15 to 0.15
- -0.30 to -0.15
- < -0.30
- No Inundation

Levels (m AHD)

- < - 2.0
- 2.1 - 4.0
- 4.1 - 6.0
- 6.1 - 8.0
- 8.1 - 10.0
- 11.1 - 12.0
- 13.1 - 14.0
- 15.1 - 16.0
- 17.1 - 18.0
- 19.1 - 20.0
- 21.1 - 22.0
- 23.1 - 24.0
- 25.1 - 26.0
- 27.1 - 28.0
- 29.1 - 30.0
- > 31.0

0 0.5 1 2 3 4
Kilometres

1:70,000 (when printed at A3)

N

Coordinate System: GDA 1994 MGA Zone 55

Whitsunday Regional Council

AECOM

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Water Different Levels, Model - AECOM 2014
Property Boundaries - QLD Gov 2013.

5.4.4 January 1980 Event Validation

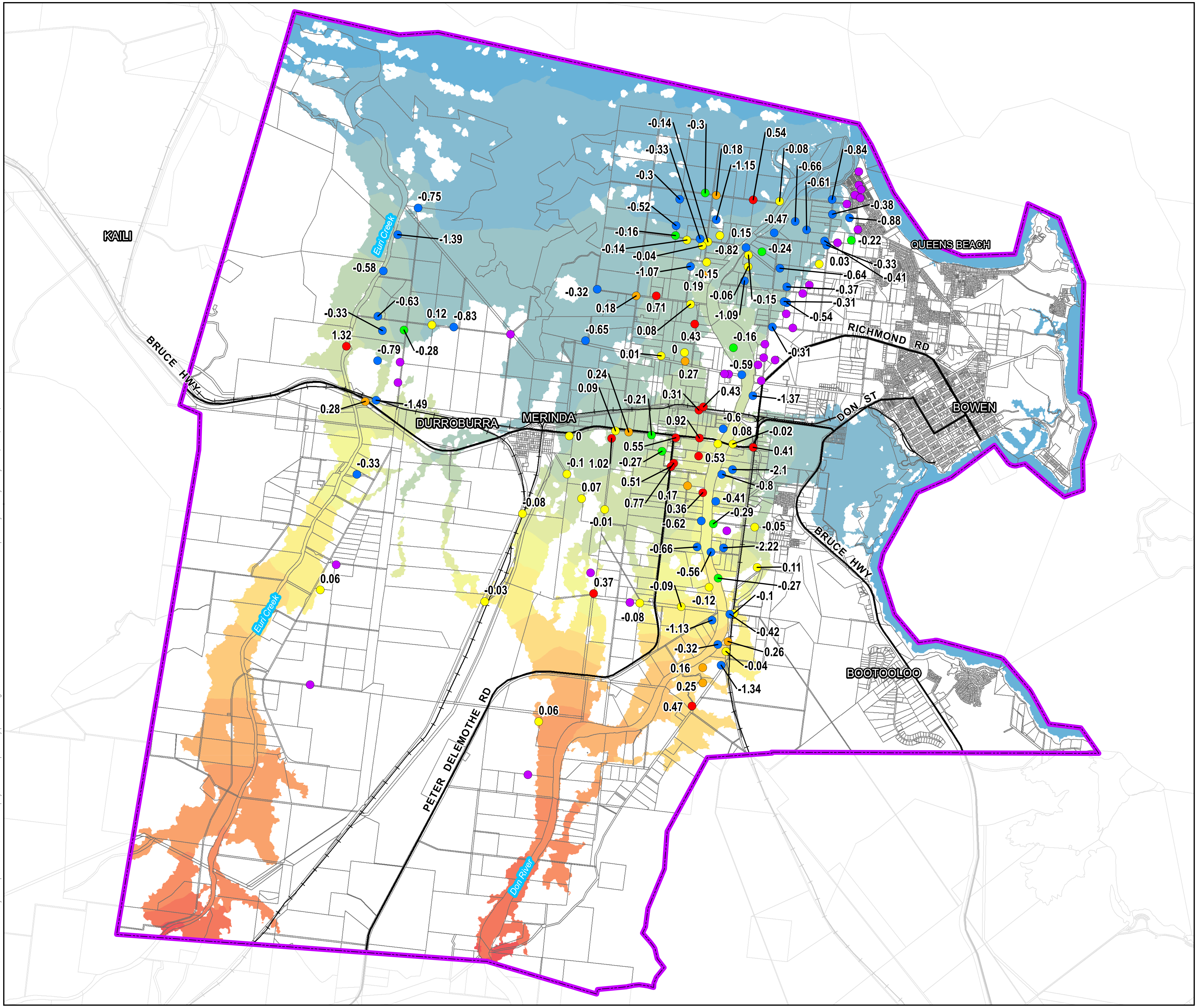
The 1980 event discharge hydrographs from the three XP-RAFTS models were applied to the MIKE FLOOD model. The maximum water surface elevations were extracted from the hydraulic model and compared to recorded peak flood levels provided by WRC.

Peak flood levels were recorded at 139 locations within the lower Don River floodplain. Figure 38 presents the comparison of water levels at these locations without the dynamic sediment transport module used. Figure 39 presents the comparison of water levels with the dynamic sediment transport module used.

From a comparison between the sediment transport scenarios, it is again clear that the dynamic sediment transport module provides a better fit to the recorded data, as well as simulating breakout flows that occurred during the 1980 event (evidenced by recorded flood heights) which was not simulated by the static model.

Key outcomes from the validation using the dynamic sediment transport module are:

- Of the 139 recorded points, 51 of the calculated values are within ±0.3m, an additional 24 values were within ±0.5m, 43 values were outside the tolerances and the inundation extent didn't reach 21 locations.
- The average difference between calculated and recorded levels is -0.26m.
- The modelled peak water surface elevation at the Bowen Pump Station was 11.05m AHD. This compares with BOM's recorded peak level of 7.2m gauge height which is equivalent to 12.01m AHD.
- The modelled extents appear to match well with the spatial distribution of the recorded flood heights with the exception a recorded point near Euri Creek Road East.
- It is noted that several recorded point along the Webster Brown flow path were outside the modelled flood extents.
    - During the 1980 flood event, the Webster Brown protection works failed resulting in an increase in conveyance which wouldn't have otherwise occurred.
    - Lowering the elevation of the Webster Brown breakout in the model showed a better fit to these recorded points.
- Overbank flows were simulated along Bells Gully which matches the historical evidence reviewed during the study. It is noted that a sand diameter of 1.0 mm was adopted in the simulation to represent the Bells Gully flows based on the sensitivities noted in the previous 2008 calibration discussion.
- A number of discrepancies in the recorded levels were identified. For example, some recorded flood levels were found to be below the DEM ground level, some downstream flood levels were higher than upstream levels, etc. Therefore the anecdotal records have been taken as indicative rather than definitive.
- A review of historical aerial imagery and previous reports has highlighted that there has been ongoing geomorphic changes along the lower reaches of the Don River. Therefore the 2009 / 2010 LiDAR adopted in the hydraulic model is only considered to be indicative of the floodplain conditions in 1980.



DON RIVER FLOOD STUDY

1980 Event Validation (Without Sediment Transport)

Figure 38

LEGEND

Don River Hydraulic Model Extent

Water Level Difference (m)

Calculated - Record

- > 0.30
- 0.15 to 0.30
- -0.15 to 0.15
- -0.30 to -0.15
- < -0.30
- No Inundation

Levels (m AHD)

- < - 2.0
- 2.1 - 4.0
- 4.1 - 6.0
- 6.1 - 8.0
- 8.1 - 10.0
- 11.1 - 12.0
- 13.1 - 14.0
- 15.1 - 16.0
- 17.1 - 18.0
- 19.1 - 20.0
- 21.1 - 22.0
- 23.1 - 24.0
- 25.1 - 26.0
- 27.1 - 28.0
- 29.1 - 30.0
- > 31.0

0 0.5 1 2 3 4

Kilometres

1:70,000 (when printed at A3)

N

Coordinate System: GDA 1994 MGA Zone 55

Whitsunday Regional Council

AECOM

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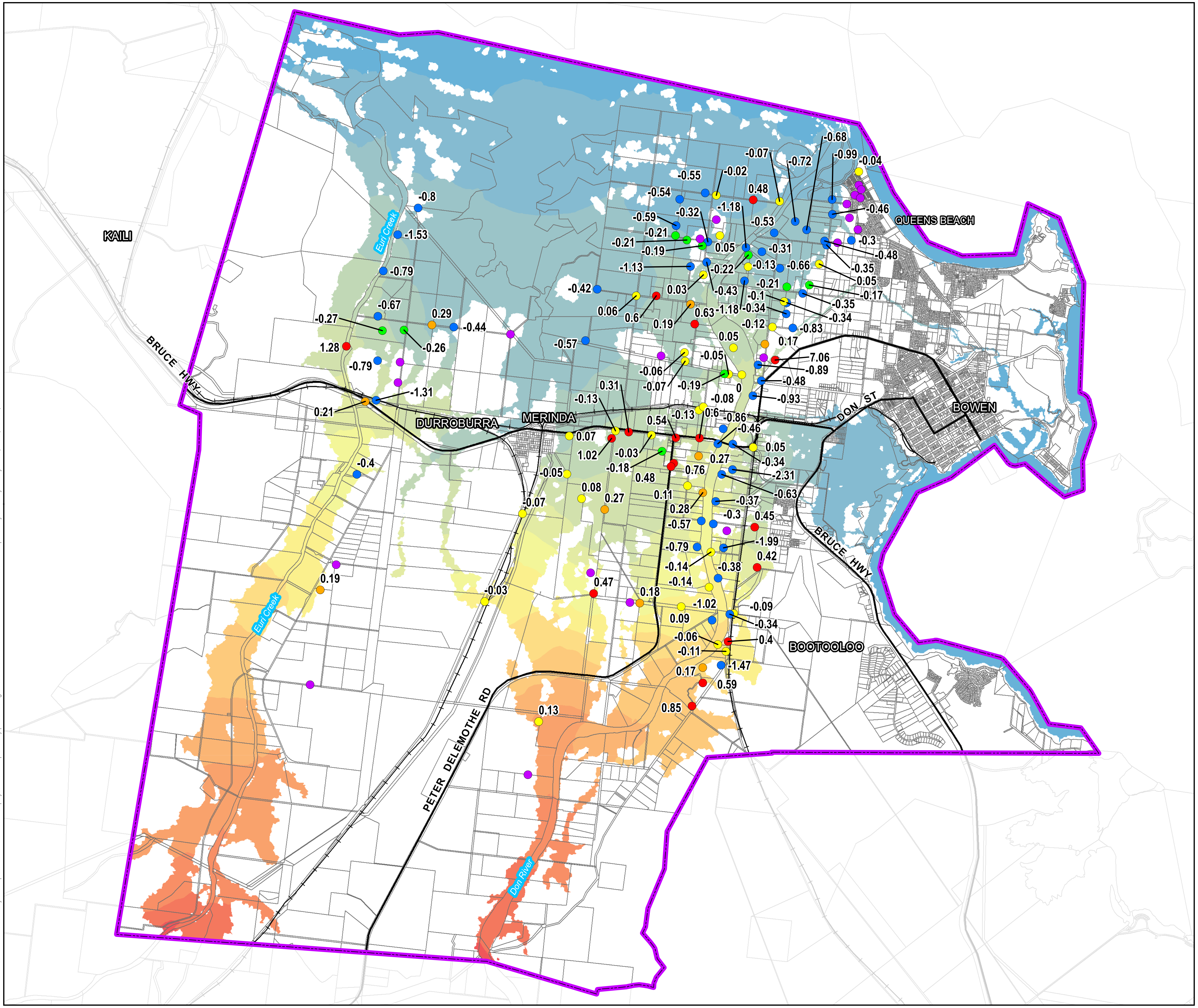
Water Different Levels, Model - AECOM 2014
Property Boundaries - QLD Gov 2013.

DON RIVER FLOOD STUDY

1980 Event Validation (With Sediment Transport)

Figure 39



Water Different Levels, Model - AECOM 2014
Property Boundaries - QLD Gov 2013.

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5.4.5 April 2014 Event Validation

The 2014 event discharge hydrographs from the three XP-RAFTS models were applied to the MIKE FLOOD model. Figure 40 presents the modelled peak water depths with the dynamic sediment transport module used.

No recorded levels were available for this event as flood extents were generally confined to the main river channel, with the exception of several overbank flows which occurred at Millers Lane and near Reibels Road. Anecdotal evidence was collected by Council which was used for the validation. A summary is provided below:

- DRIT / Council noted that a minor breakout occurred downstream of Millers. The modelled peak water surface elevations shows water levels rose to within 0.1m of the bank height but did not break out. This would suggest that slight variation to hydraulic roughness could be undertaken to match this observation.
- Several breakouts were observed to the north of Reibels Road which matches the model outputs. It was also noted that bank failure occurred during the event which is not reflected in the model so there is likely to be some variance.
- Observers noted that river levels were approximately 0.3m below Webster Brown. Modelled water surface compared reasonably well, suggesting that levels reached 0.3m – 0.5m below Webster Brown.

5.4.6 Calibration / Validation Summary

Results indicate that there is reasonable level of agreement between recorded and modelled flood levels and flood extents. Differences between the recorded and modelled flood levels are likely to be due to:

- Uncertainties in the hydrologic assessment.
- Lack of detailed topographic information for the 1980 event modelling.
- Lack of detailed bathymetric (river bed) survey for the 1980 event modelling.
- Problems in quantifying the extent of morphological changes that has occurred over time which can significantly alter flood levels due to the importance of the breakouts and distributary characteristics.
- Uncertainty in the accuracy and timing of recorded flood levels.
- High sensitivity to adopted sediment properties which can affect the outflow characteristics.

Broadly speaking, the modelled levels show a reasonable fit with the flood marks for both events and it is clear that the development of the dynamic sediment transport module is important in simulating flood behaviour more accurately in the lower reaches.

5.5 Discussion

A number of different hydrologic and hydraulic models have previously been used to estimate historical and design event flood extents across the Don River and Euri Creek floodplains. Whilst each of these models are generally considered to be appropriate for their original purpose at the time of assessment, the following observations can be made:

- Earlier studies undertaken by Ullman & Nolan generally adopted QWRC's estimated discharge hydrographs at Ida Creek, whereas more recent studies have adopted BOM's estimated discharge hydrograph.
- No other study has undertaken a calibration to the 2008 and 2014 flood events and therefore significant assumptions have been made on topographic information in 1980.
- Most recent studies adopt BOM's URBS hydrologic model. There are some concerns with the current model as it requires a very high continuing loss rate (8.5mm/hr) to achieve calibration.
- Several recent studies have reported significant difficulties in calibrating hydraulic models to the 1980 event. In some cases the topography of the model has been altered significantly (i.e. river bed levels dropped 5m) to achieve a reasonable level of calibration.
    - It is possible that this difficulty has arisen due to the adoption of discharge hydrographs based on BOM's rating curve which results in high discharge estimates and therefore requires increases in river conveyance capacity to achieve a reasonable level of calibration.

- Dynamic sediment transport modelling has not been undertaken in the past but it has been qualitatively investigated and addressed as best as practicable with regard to objectives of these studies. Findings of this study suggest that the inclusion of a dynamic sediment transport module is important in simulating flood behaviour in the lower reaches of the Don River.

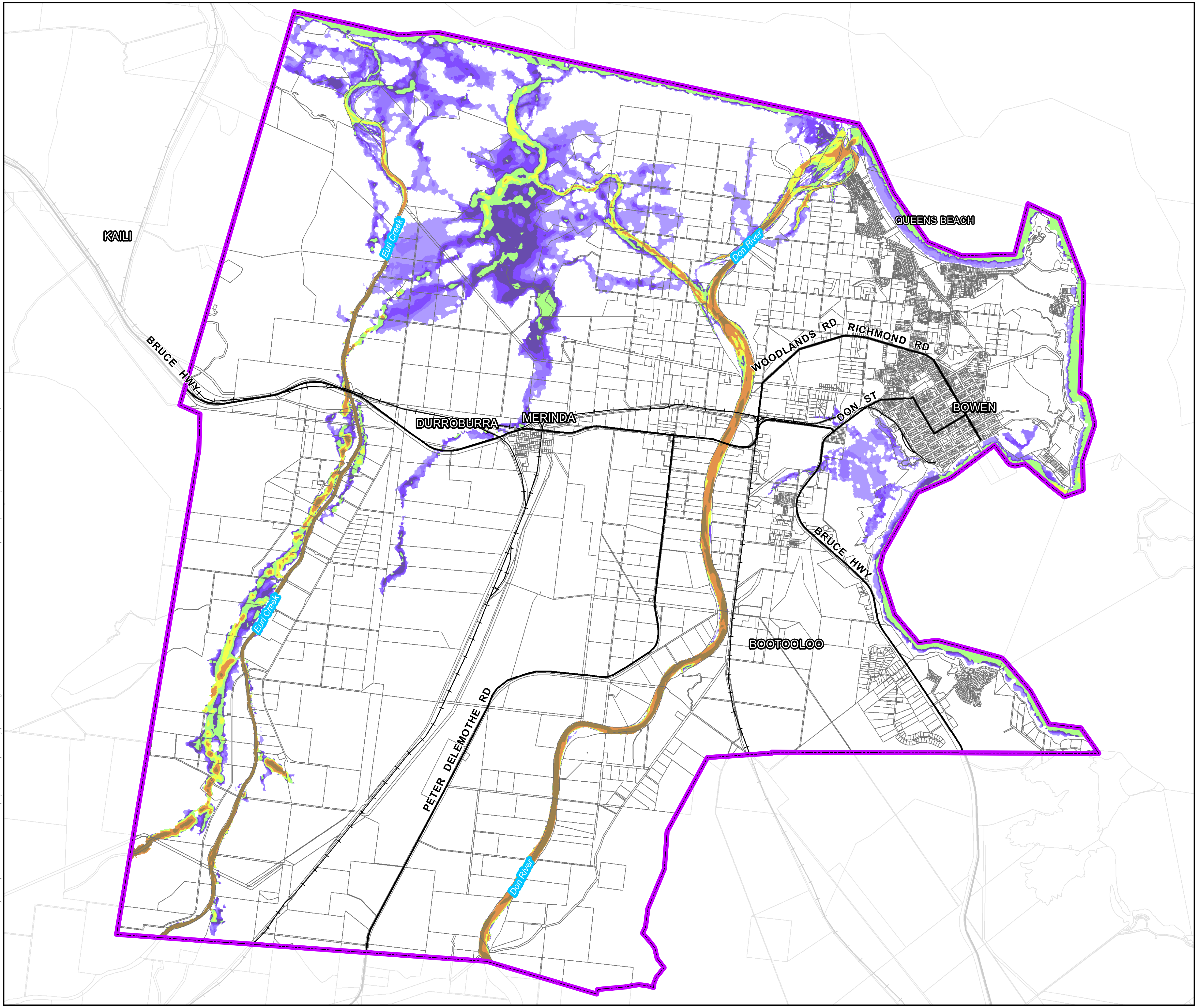
ARR Revision Project 15 outlines several fundamental themes which are also particularly relevant:

- All models are coarse simplifications of very complex processes. No model can therefore be perfect, and no model can represent all of the important processes accurately.
- Model accuracy and reliability will always be limited by the accuracy of the terrain and other input data.
- Model accuracy and reliability will always be limited by the reliability / uncertainty of the inflow data.
- A poorly constructed model can usually be calibrated to the observed data but will perform poorly in events both larger and smaller than the calibration data set.
- No model is ‘correct’ therefore the results require interpretation.
- A model developed for a specific purpose is probably unsuitable for another purpose without modification, adjustment, and recalibration. The responsibility must always remain with the modeller to determine whether the model is suitable for a given problem.

DON RIVER FLOOD STUDY

2014 Event Validation (With Sediment Transport)

Figure 40



LEGEND

Don River Hydraulic Model Extent

Water Depths (m)

- 0 - 0.3
- 0.3 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- > 3

0 0.5 1 2 3 4
Kilometres

1:70,000 (when printed at A3)

N

Coordinate System: GDA 1994 MGA Zone 55

Whitsunday Regional Council

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DCDB - QLD Gov 2013.
Model - AECOM 2014

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6.0 Sediment Transport Assessment

6.1 Background

The Don River is a highly dynamic sand bed river, evident through a number of river mouth migrations during recent times and shifting sand deposition geomorphology. Major flood events also have the capacity to transport a large fraction of the total annual sediment load. It is therefore often, during these flood events, that beds and banks of sand bed rivers adjust, changing the hydraulic characteristics of the system. This is most likely a major cause of the changing breakout locations along the river in recent times.

The sediment transport dynamics of the Don River are complex. Previous studies have been examined to develop an understanding of the geomorphology and sediment transport processes in the river and delta and where possible, identify typical or critical sand bank locations.

Riverbed erosion occurs as a result of increased flow velocity causing an increase in bed shear stress. The erosion rate depends on the force applied by the water and self-weight of the sediment particles. Most stream bank erosion takes place during and right after floods associated with large storm events, with the time scale extending from a couple of hours to a few days, depending on the duration of the flood event.

While overbank flows can take place during a flood, sediment deposition and accumulation on the floodplain will take place over time scales that are much longer (on the order of several years). Deposition of sediment washed out by floods occurs out on the shallow intertidal area immediately offshore and is later reworked on the shoreline by littoral processes causing a build up during winter.

6.2 Catchment Sediment Process

The key aim of the previous Don River Sediment Study was to undertake a sand depth survey to assess sediment transport and storage in the Don River channel. The Executive Summary from the Don River Sediment Study Report prepared by Hydrobiology Pty Ltd for Connell Wagner In September 2005 states:

- The Don River bed is aggrading.
- The current rate of catchment sediment erosion is estimated to be approximately 11 times the pre-European value.
- Sediment delivery ratio (i.e. the proportion of eroded catchment sediment that actually reaches the stream network prior to being re-deposited) is generally high at 55% (i.e. the sediment “conveyor belt” is quite efficient at the start of the process).
- Most eroded sediment is derived from hillslope erosion (86%) compared to gully erosion (11%) and streambank erosion (3%).
- The hillslope erosion value is relatively high compared to Australia-wide values.
- The rate of sediment supplied to the river network appears to be greater than the ability of the river to discharge it to the coast.
- The current sand slug below the Pott’s Line (approximately Walsh’s Crossing) consists of approximately 8 – 9 million m^3 of high grade quartzo-feldspathic medium to coarse sand.
- Thicknesses of this sand slug range from 0 – 9m with an average value of 5 – 7m.
- Approximately 40 – 60% of this may have been deposited in the last 15 years and has added in places up to 3 – 4m depth of sand.
- Above the Pott’s Line there is approximately 1.5 million m^3 of sand as a slug in the channel awaiting downstream transport. This is supplemented by at least as much again awaiting transport to the river channel from adjacent slopes.
- If no flushing of the lower reaches occurs, then movement of additional sand may add approximately another 1m to levels currently found in the lower reaches of the Don River Channel.
- This might be expected to occur over 10’s of years (rather than 100’s) depending on flood frequency.
- Predicted general scour depths for 20-year and 100-year ARI design flow events range between 2m and 11m at various locations in the river system.

The outputs of the study correlate with other historical investigations of the lower Don River, particularly more recent studies which have employed the use of numerical hydraulic models to simulate flood characteristics. These previous studies have generally found calibration to historical flood events to be difficult due to the dynamic nature of the river which is not accounted for in static hydraulic models.

6.3 Approach

The sediment transport module of MIKE21 (MIKE21 ST) applies several empirical methods to predict rates of non-cohesive sediment transport. Using the two-dimensional depth, velocities and bed resistance values from the hydraulic model as inputs, bed load and suspended transport rates of coarse-grained material under the action of currents can be predicted.

The MIKE21FM modelling system is able to link a sand transport module and run it dynamically and simultaneously with the hydraulic model. The hydrodynamic module and dynamic sand transport modules provide continuous feedback to each other.

As the aim of this assessment was to determine changes to the river channel capacity during the short spatial (i.e. local erosion) and temporal scales (i.e. sediment transport event), no consideration was given to the long term channel or floodplain morphology.

6.4 Sediment Properties

The sediment in the lower reaches of the Don River channel is generally made up of non-cohesive sand material. The important properties that govern the hydrodynamics of non-cohesive sediments are particle size, shape and specific gravity (USACE, 1995), of which particle size is the most important in sediment transport modelling.

Particle size analysis has previously been conducted on sediment samples collected from the Don River by Hydrobiology Pty Ltd in 2005. The samples showed that the mean sand diameter ranged between 1.0mm – 1.5mm. A value of 1.0mm has been adopted for this assessment; however it has been shown that a value of 1.5mm resulted in model outputs that better reflected the 2008 flood extents. In selecting a mean diameter of 1.0mm it was noted that this would provide a more conservative assessment of flood risk, particularly along key breakout flow paths such as Bells Gully.

No specific information was available on particle shape and density of the bed material. Previous reports have noted the sands to be dominated by fine to medium quartz and therefore a specific gravity of 2.65 has been adopted. A porosity value of 0.4 was adopted in the sediment transport model.

A non-erodible surface underlying the sandy bed was included in the sediment transport simulation. As such, the calculated sediment transport rates were adjusted in such a way that erosion of the bed below the level of the hard surface will not occur and deposition of sediment on top of the non-erodible surface is allowed. Based on the Don River Sediment Study, a spatially constant non-erodible surface has been set at 5m below the initial bed level.

6.5 Results

Figure 41 shows the two-dimensional results of the 1% AEP sediment transport model – specifically the simulated change in topographic elevations within the hydraulic model domain at the peak of the flood event.

The simulated changes in elevations appear to represent the adjustment of the river longitudinal profile as a result of excess sediment loads transported during the flood event. If the river has too large a load of sediment to be transported, the river will deposit some its sediment load at the point of transportive incompetence. The action of deposition elevates the stream bed at discrete points thus steepening the downstream bed profile thereby increasing the transportive competence of the river. Because the river has excess ability to transport the sediment load, it lowers its longitudinal gradient by scouring a hole. This mechanism is simulated by the sediment transport module, evidenced by the series of depositions and scour holes along the river reach.

Results of the modelling suggests that significant deposition may occur adjacent to Pott's Bank, Sandy Gully and Bells Gully breakouts due a reduction in transporting power and the aggradation which occurs upstream of scour holes. These depositions result in higher proportions of overbank conveyance at these locations which tend to match better with recorded flood heights.

The sediment transport model appears to adequately simulate the river channel scour which occur through the 1.5km section of the river reach through the existing road and rail bridges. High velocities, river constriction and localised effects due to the bridge structures (i.e. piers and abutments) result in high erosive potential which aligns with anecdotal information compiled in previous reports.

The modelling also suggests extensive deposition at the ‘1946 mouth’ which matches historical aerial imagery and anecdotal evidence compiled in previous reports.

Calibration of the sediment transport module could not be undertaken due to a lack of available data. It is suggested that future measurements of bed-load, sediment load and solute load should be made at several gauging stations along the Don River. These observations could be related to stream gauging discharges to assess the accuracy of the high level assessment undertaken in this study.

6.6 Discussion

It is evident that the volume of sand transported along the Don River during high flow events is of a similar magnitude to the current rate of extraction. This is the case until the river meets the delta where multiple upstream distributaries slow the velocity of the flood waters creating an environment for sand deposition. The risk of the changing river morphology in the delta region is thereby increased as the coastal processes cannot function to maintain clear water exit ways.

The assessment suggests that sediment from flood flows is deposited in the lower reaches (that is, below the Bruce Highway crossing) as breakouts in the middle reaches reducing the velocity of flood flows in the main river channel. As most of the sediment is medium to coarse sand it remains in and settles in the river channel rather than being carried in suspension with the overbank flood flows.

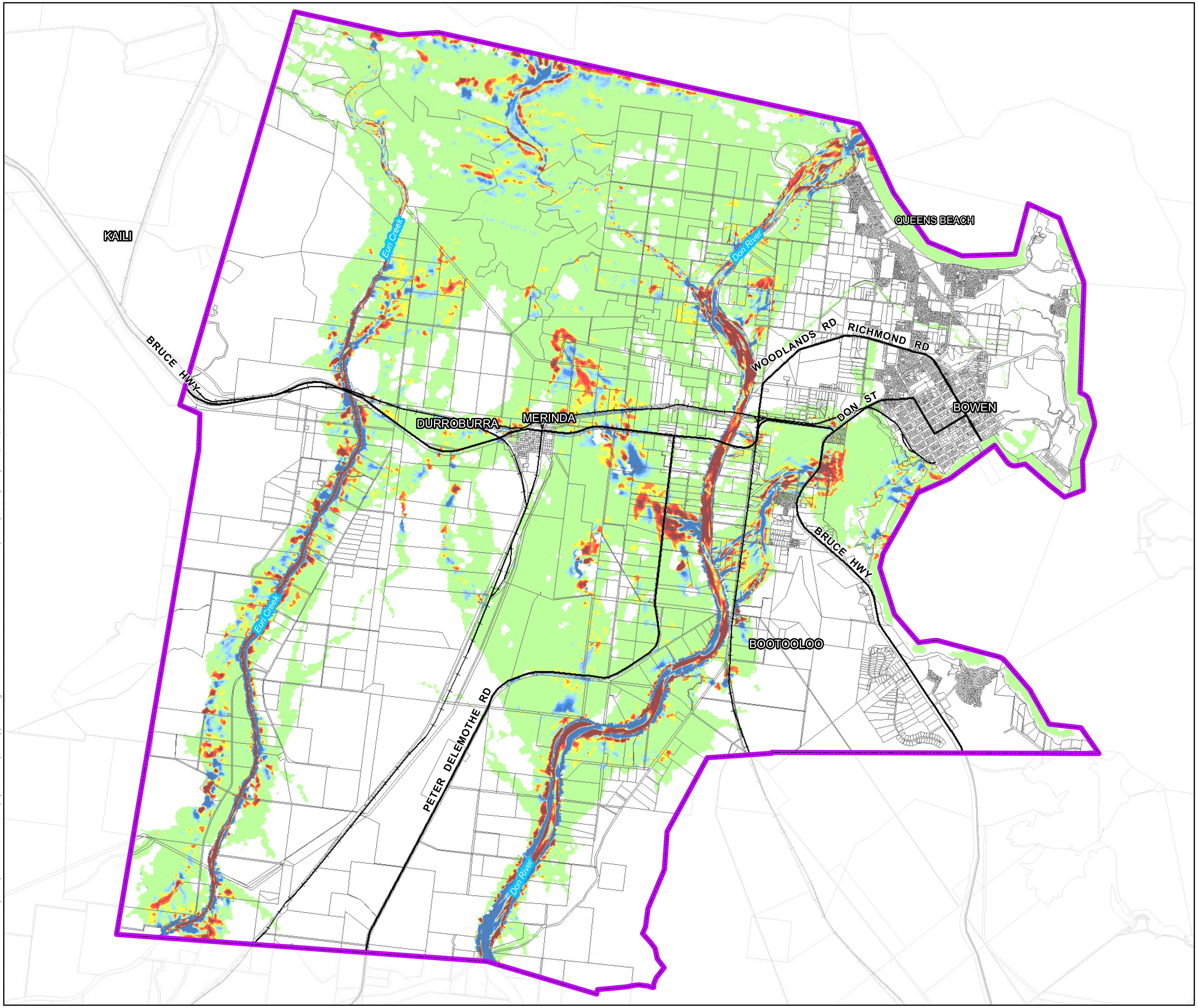
Other historical reports have noted that this process is a ‘positive feedback loop’ as the increased sediment deposited decrease the channel conveyance capacity and therefore increases the proportion of flows directed through breakouts, which in turn increases the sedimentation of the channel.

River morphology is difficult to simulate because of changing flow patterns within the river valley and channel as sediment transport is taking place. Furthermore, the mathematical treatment of sediment erosion and depositional processes is largely empirical since deterministic descriptions of the behaviour have not yet been developed.

DON RIVER FLOOD STUDY

Predicted Two-Dimensional Change in Channel Elevations (1% AEP)

Figure 41



LEGEND

Don River Hydraulic Model Extent

Elevation Change (m)

- < -0.75
- -0.75 - -0.50
- -0.50 - -0.30
- -0.30 - -0.15
- -0.15 – 0.15
- 0.15 – 0.30
- 0.03 – 0.50
- 0.50 – 0.75
- > 0.75

0 0.5 1 2 3 4
Kilometres

1:70,000 (when printed at A3)

N

Coordinate System: GDA 1994 MGA Zone 55

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Model - AECOM 2014

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7.0 Effects of Climate Change

7.1 General

A suite of climate change literature is available, covering global, national and more localised state based climate change discussion and analysis. Whilst much of the literature states that, for Queensland, total annual rainfall is decreasing and rainfall intensity during rainfall events is increasing, there is comparatively little literature recommending actual values to adopt for these changes.

The Queensland Climate Change Strategy (QLD Government, 2007) indicated that cyclone intensity is expected to increase by 2050 with cyclone associated rainfall expected to increase by up to 20-30%. The other recently published document which provides guidance on the adoption of climate change values, and also provides guidance on the use of these scenarios in development planning is the Increasing Queensland's resilience to inland flooding in a changing climate: Final report on the Inland Flooding Study published by DERM, The Department of Infrastructure and Planning (DIP) and the Local Government Association of Queensland (LGAQ) in 2010.

The DERM, DIP and LGAQ Inland Flooding Study (2010) was specifically aimed at providing a benchmark for climate change impacts on inland flood risk. Whilst Bowen is not considered to be an inland area, this document does provide guidance on the adoption of climate change scenarios for development planning. The study recommends a 'climate change factor' be included into flood studies in the form of a 5% increase in rainfall intensity per degree of global warming. For the purposes of applying the climate change factor, the study outlines the following temperature increases and planning horizons:

- 2°Celsius by 2050;
- 3°Celsius by 2070; and
- 4°Celsius by 2100.

These increases in temperature equate to a 10% increase in rainfall intensity by 2050, and 15% increase in rainfall intensity by 2070 and a 20% increase in rainfall intensity by 2100.

In addition to impacts on rainfall, sea level rises are also commonly discussed in climate change literature. The most recent publication that relates to Queensland is the Queensland Coastal Plan (and more specifically the State Planning Policy Coastal Protection). The second document outlines sea level rises that should be considered when planning for development in coastal areas of Queensland. Table 22 details the projected sea level rise up to 2100.

Table 30 Projected Sea Level Rise (SPP 3/11, 2012)

Year of Planning Period	Projected Sea Level Rise (m)
2050	0.3
2060	0.4
2070	0.5
2080	0.6
2090	0.7
2100	0.8

In addition to the Coastal Plan, the Australian Government Department of Climate Change and Energy Efficiency report Climate Change Risks to Australia's Coast – A First Pass National Assessment for Australia (2009) identified that 1.1 m sea level rise by 2100 is a plausible value to adopt. Whilst this document is not a policy document, its recommendations should be considered.

7.2 Adopted Approach

Given the uncertainty in climate change and sea level rise projections, particularly with respect to changes in rainfall intensity, climate change sensitivity has been undertaken as part pf this study. The hydrologic and hydraulic models have been used to assess the impact of climate change that would be expected to occur in 2100 for the 1% AEP design event.

In addition to increased rainfall, climate change has the potential to increase sea levels. A sea level rise of 0.8m is expected by 2100. The MHWS level at the downstream boundary has been increased by 0.8m to 1.9m AHD for the design events.

7.3 Hydrologic Model Results

The XP-RAFTS was run with increased rainfall intensities. The resulting peak discharges for Euri Creek and Don River at the upstream boundary of the hydraulic model are presented in Table 31 and Table 32. Also included in these tables are the existing case peak discharges for each event for comparison.

Table 31 Climate Change Event Peak Discharges for Don River (Year 2100 Scenario)

AEP (%)	Climate Change Scenario (+20%) Peak Discharge (m^3/s)	Existing Case Peak Discharge (m^3/s)
1	9,007	8,486

Table 32 Climate Change Event Peak Discharges for Euri Creek (Year 2100 Scenario)

AEP (%)	Climate Change Scenario (+20%) Peak Discharge (m^3/s)	Existing Case Peak Discharge (m^3/s)
1	2,830	2,152

7.4 Hydraulic Model Results

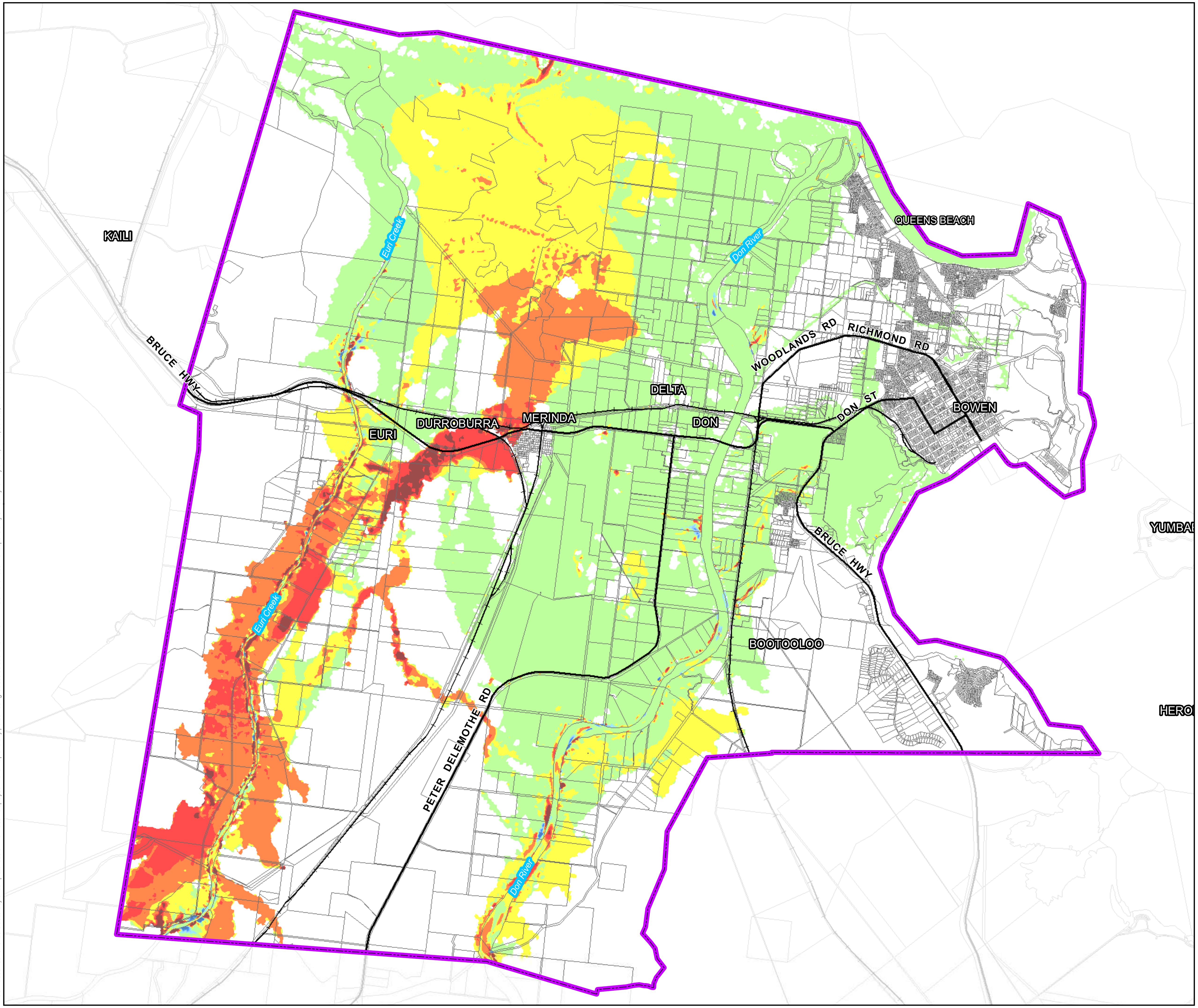
Figure 42 presents the differences between the climate change scenario and the 1% AEP event results. This figure shows that, under a climate change scenario, peak water levels are increased by up to 0.5m along the Euri Creek reach and up to 0.3m along the Don River reach.

Flood extents are also increased in a climate change scenario and several breakouts are expected to convey higher discharges, particularly the Pott's Bank, Price's Bank, Bootooloo and aerodrome overflows.

DON RIVER FLOOD STUDY

Climate Change Scenario Difference Map (1% AEP)

Figure 42



LEGEND

Don River Hydraulic Model Extent

Difference (m)

- < -0.75
- -0.75 - -0.50
- -0.50 - -0.30
- -0.30 - -0.15
- -0.15 – 0.15
- 0.15 – 0.30
- 0.03 – 0.50
- 0.50 – 0.75
- > 0.75

0 0.5 1 2 3 4

Kilometres

1:70,000 (when printed at A3)

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8.0 Design Flood Depths, Levels and Extents

8.1 Overview

The calibrated MIKE FLOOD model described in Section 5.0 was used to estimate the levels, extent and depth of flooding for the 10% AEP, 2% AEP, 1% AEP, 0.2% AEP and PMF events. Design flood hydrographs predicted by the XP-RAFTS model were used as inflows into the MIKE FLOOD model. It is noted that these simulations did not include the effects of Climate Change. Downstream boundary condition was set to MHWS level, as noted in Section 5.3.4.

8.2 Design Flood Depths and Extents

Figure 43 shows the 1% AEP design flood depths and extents for the study area and Figure 44 shows a close-up of the 1% AEP depths and extents around Bowen and Queens Beach.

Design flood depths and extents for the 10% AEP, 2% AEP, 0.2% AEP and PMF events are shown in Appendix A. The following is also of note:

- The 10% AEP design flood is generally contained within the banks of Don River until reaching the Webster Brown and '1946 mouth' for which there is expected to be some overflows through these distributaries. Minor outflow through Bells Gully is also expected to occur in this event.
- Euri Creek has limited main channel conveyance capacity and is expected to have some overbank flows in the 10% AEP flood event. Much of these flows are limited to the left overbank (looking downstream), however there is some overflows from the right bank downstream of the Bruce Highway.
- For the 2% AEP design flood:
  - Overflows are expected at all primary Don River breakout locations. This results in cross connectivity of flows between Euri Creek, Don River and Sandy Gully systems.
  - Numerous rural properties are expected to be inundated due to overflows from the left bank.
  - All major transportation links in the area are inundated (Bruce Highway, North Coast rail line, Merinda Deviation, Collinsville rail line and the aerodrome). This results in communities at Merinda, Queens Beach and Bowen becoming isolated.
  - There is expected to be some overflows conveyed by Bells Gully, however this is limited. Further analysis of the model outputs suggests that the quantity of sediment deposition adjacent to Bells Gully can have significant impacts on predicted overflow. This is discussed further in Section 8.7.4.2.
- For the 1% AEP design flood:
  - Significant overflows are expected at all of the primary breakout locations. Pott's Bank, Price's Bank, Webster Brown and the '1946 mouth' are expected to convey significant discharges.
  - Numerous rural properties are expected to be inundated due to overflows from the left bank.
  - Substantial inundation depths are expected in the lower floodplain and all transportation links are expected to be severely impacted.
  - Current topography information and sediment transport modelling suggests limited flows will be conveyed by Bells Gully. This is highly sensitive to the flood characteristics, particularly event duration which can result in greater sediment deposition and increases in overflows in Bells Gully.
- For the 0.2% AEP design flood:
  - Significant inundation occurs throughout the lower floodplain between Euri Creek and Don River as a result of significant overflows at a number of locations along the western banks of Don River.
  - The results for 0.2% AEP shows that majority of flows in excess of 1% AEP and up to 0.2% AEP will be conveyed through Bootooloo on the eastern bank and a number of break outs on the western bank.
  - Additional properties at Merinda are expected to be inundated in comparison with the 1% AEP event, particularly on Houlder Street and Matthews Street.

- For the PMF flood:
  - Most of the lower reaches of the Don River and Euri Creek floodplain are expected to be significantly inundated as a result of a PMF flood in the Don River and Euri Creek.
  - The majority of the transport networks (road and rail) within the study area are expected to be substantially inundated as a result of a PMF flood event.
  - Merinda is expected to become completely submerged as a result of the PMF event.
  - Significant inundation of the area to the south of Bowen is expected as a result of PMF as a result of overflows from Bootooloo.

8.3 Design Flood Elevations

Figure 45 shows the 1% AEP design flood elevations for the study area and Figure 46 shows a close-up of the 1% AEP flood elevations around Bowen and Queens Beach. Design flood elevations for the 10% AEP, 2% AEP, 0.2% AEP and PMF events are shown in Appendix B.

8.4 Design Flood Velocities

Figure 47 shows the 1% AEP design flood velocities for the study area and Figure 48 shows a close-up of the 1% AEP flood velocities around Bowen and Queens Beach. Flow direction arrows are also shown and are scaled to represent the magnitude of the velocity (i.e. larger arrows means faster velocity).

Design flood velocities for the 10% AEP, 2% AEP, 0.2% AEP and PMF events are shown in Appendix C.

8.5 Flood Hazard Mapping

Flood hazard categorisation provides a better understanding of the variation of flood behaviour and hazard across the floodplain and between different events. The degree of hazard varies across a floodplain in response to the following factors:

- Flow depth
- Flow velocity
- Rate of flood level rise (including warning times)
- Duration of inundation.

The State Planning Policy Guideline 1/03 (Sec A2.30) provides the following flood hazard definitions:

- Low – there are no significant evacuation problems. If necessary, children and elderly people could wade to safety with little difficulty; maximum flood depths and velocities along evacuation routes are low: evacuation distances are short. Evacuation is possible by a sedan-type motor vehicle, even a small vehicle. There is ample time for flood forecasting, flood warning, and evacuation routes remain trafficable for at least twice as long as the time required for evacuation.
- Medium – fit adults can wade to safety, but children and the elderly may have difficulty; evacuation routes are longer; maximum flood depths and velocities are greater. Evacuation by sedan-type vehicles is possible in the early stages of flooding, after which 4WD vehicles or trucks are required. Evacuation routes remain trafficable for at least 1.5 times as long as the necessary evacuation time.
- High – fit adults have difficulty in wading to safety; wading evacuation routes are longer again; maximum flood depths and velocities are greater (up to 1.0 m and 1.5 metres per second respectively). Motor vehicle evacuation is possible only by 4WD vehicles or trucks and only in the early stages of flooding. Boats or helicopters may be required. Evacuation routes remain trafficable only up to the maximum evacuation time.
- Extreme – boats or helicopters are required for evacuation; wading is not an option because of the rate of rise and depth and velocity of floodwaters. Maximum flood depths and velocities are over 1.0 m and over 1.5 m/s respectively.’

For the purposes of this study, flood hazard maps have been generated according to SCARM guidelines using both flood depth and flood velocity outputs to determine flood hazard. No assessment of evacuation times were incorporated in this assessment.

A flood hazard map has been prepared for the 1% AEP flood event and is shown in Figure 49. Additional mapping information has also been provided to WRC in GIS format to produce flood hazard maps for other AEP events as required.

8.6 Likelihood of Flooding

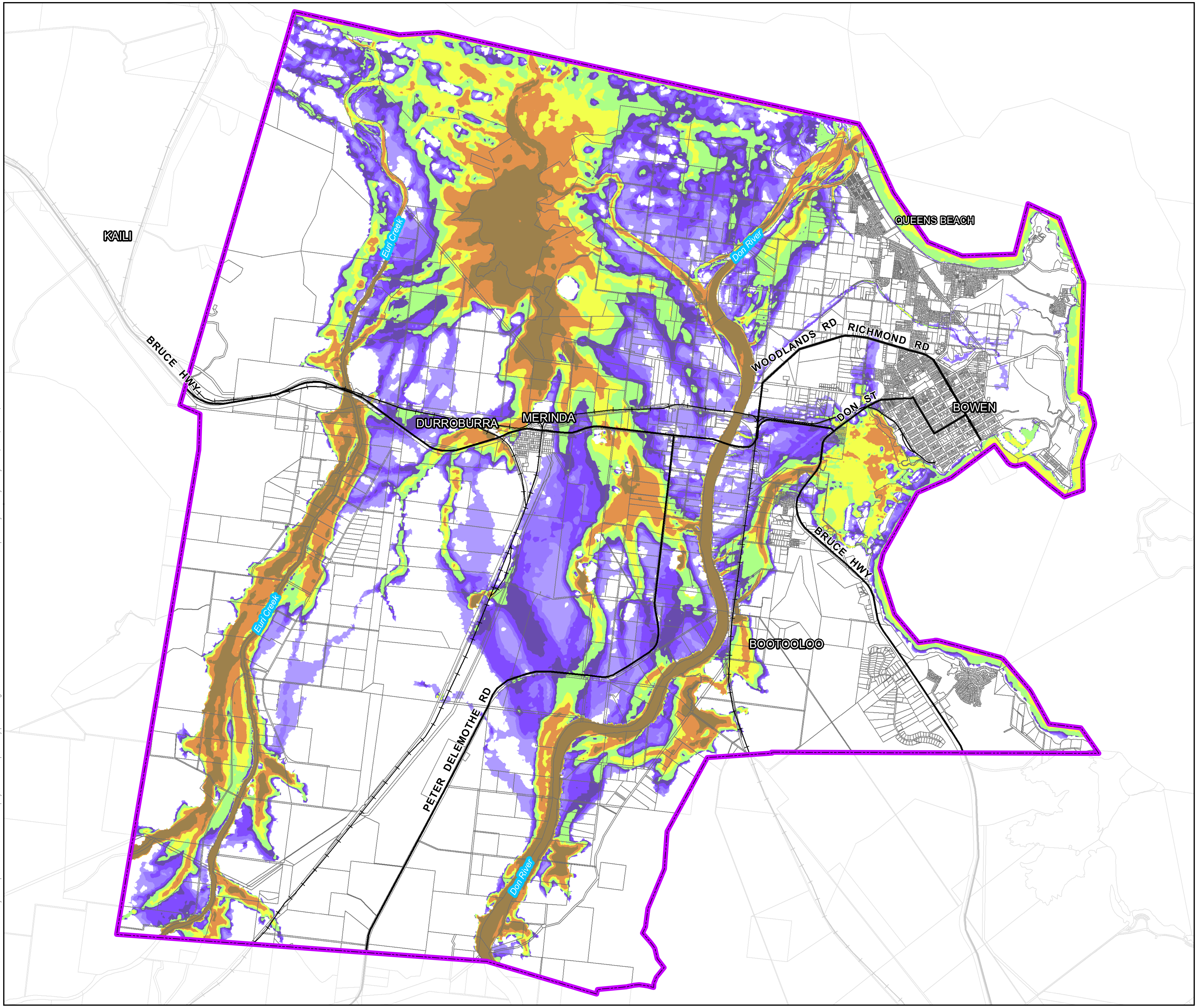
Conveying the likelihood or chance of flooding, independent of flood depth or velocity, over a defined time period has been found to be a simple way to communicate flood risk.

A ‘percent chance’ map has been produced based on modelled AEP water surfaces to show the chance of flooding over a 30 year period, aligning with typical home mortgage periods (refer to Figure 50).

DON RIVER FLOOD STUDY

1% AEP Design Flood Depths and Extents

Figure 43



LEGEND

Don River Hydraulic Model Extent

Water Depths (m)

- 0 - 0.3
- 0.3 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- > 3

0 0.5 1 2 3 4

Kilometres

1:70,000 (when printed at A3)

N

Coordinate System: GDA 1994 MGA Zone 55

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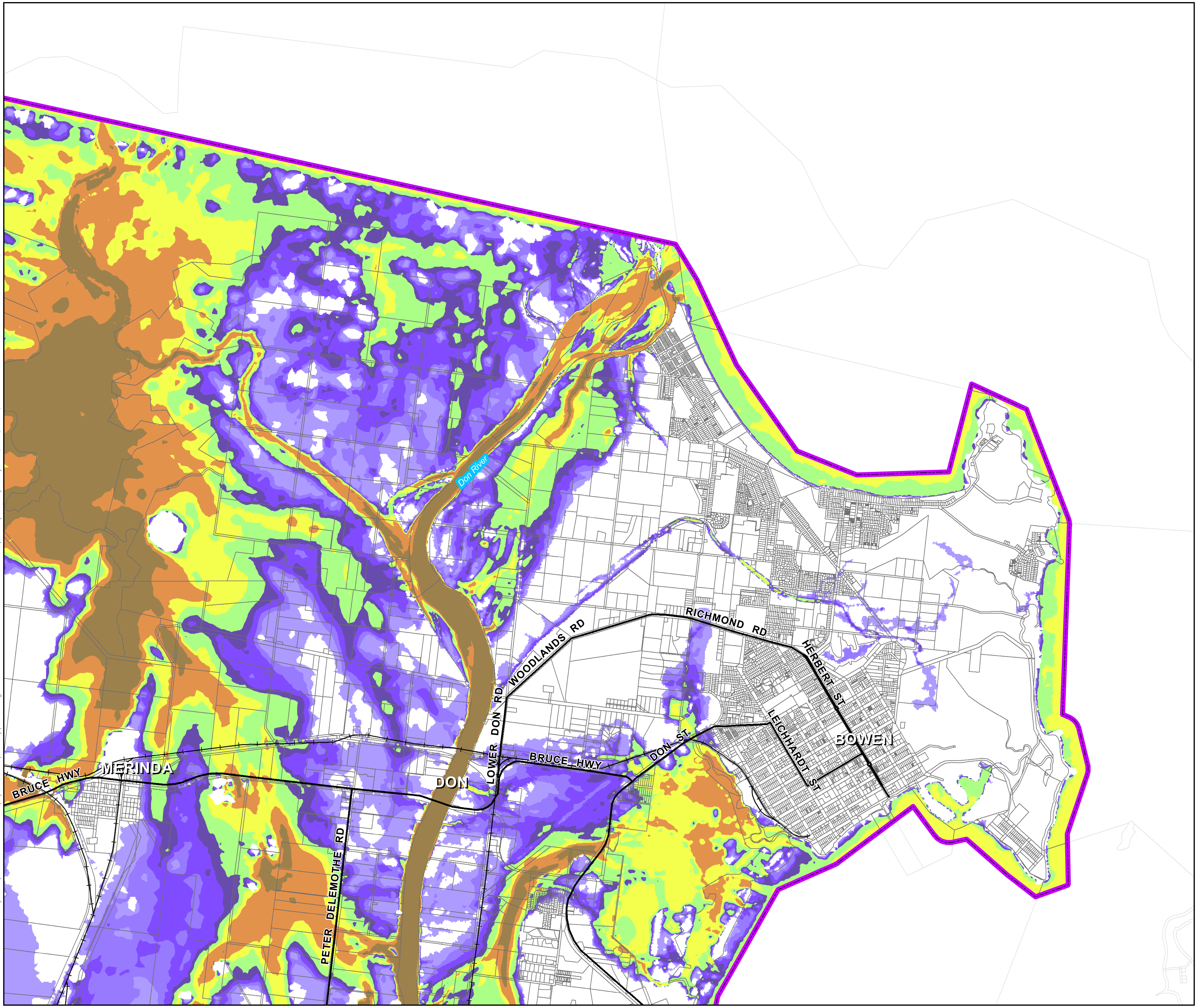


DON RIVER FLOOD STUDY

1% AEP Design Flood Depths and Extents (zoomed)

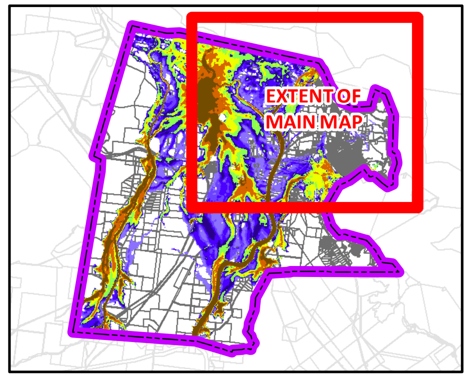
Figure 44

LEGEND

Don River Hydraulic Model Extent

Water Depths (m)

- 0 - 0.3
- 0.3 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- > 3



0 0.5 1 2

Kilometres

1:40,000 (when printed at A3)

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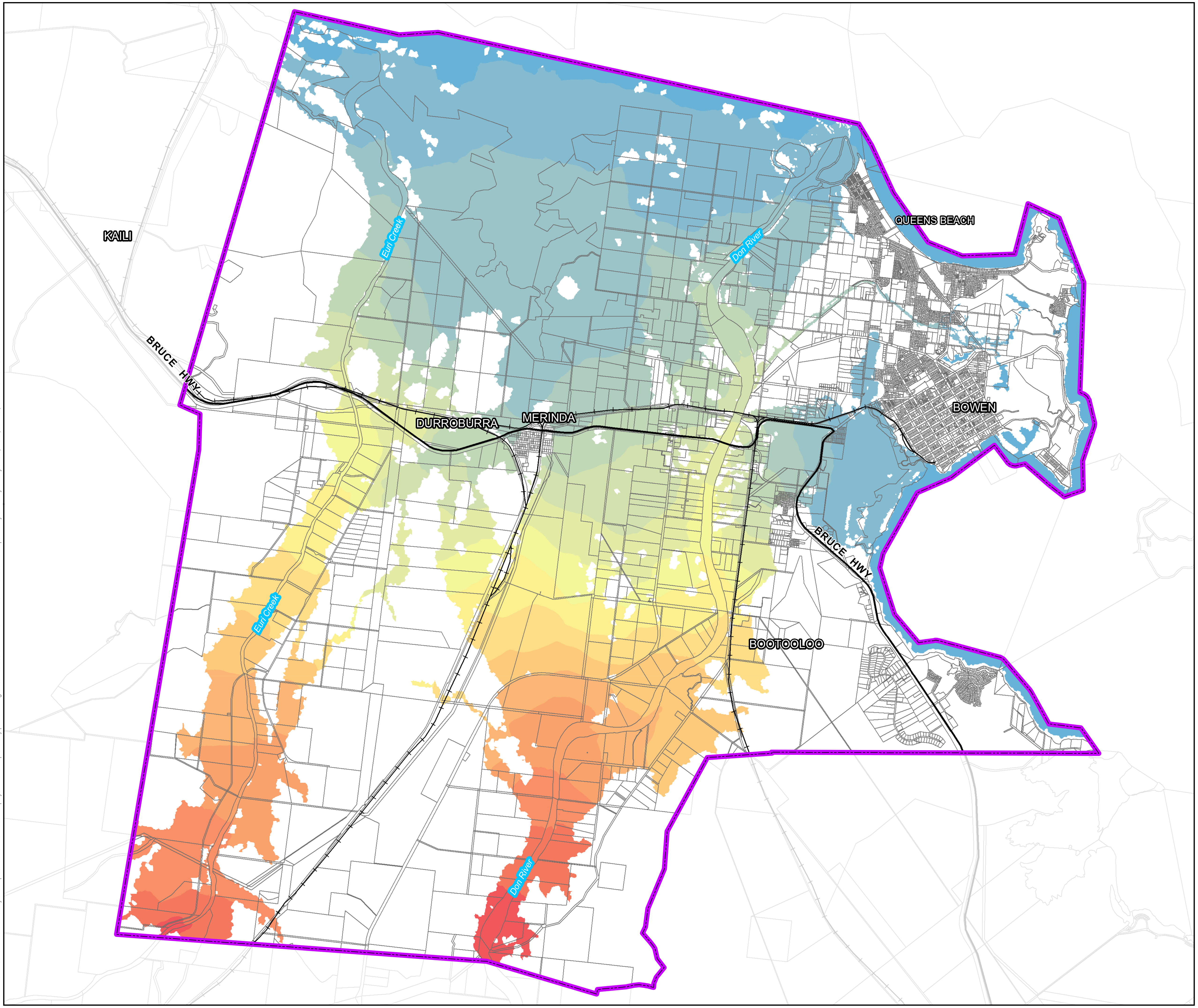
DON RIVER FLOOD STUDY

1% AEP Design Flood Elevations

Figure 45



LEGEND

Don River Hydraulic Model Extent

Levels (m AHD)

- < - 2.0
- 2.1 - 4.0
- 4.1 - 6.0
- 6.1 - 8.0
- 8.1 - 10.0
- 11.1 - 12.0
- 13.1 - 14.0
- 15.1 - 16.0
- 17.1 - 18.0
- 19.1 - 20.0
- 21.1 - 22.0
- 23.1 - 24.0
- 25.1 - 26.0
- 27.1 - 28.0
- 29.1 - 30.0
- > 31.0

0 0.5 1 2 3 4

Kilometres

1:70,000 (when printed at A3)

N

Coordinate System: GDA 1994 MGA Zone 55

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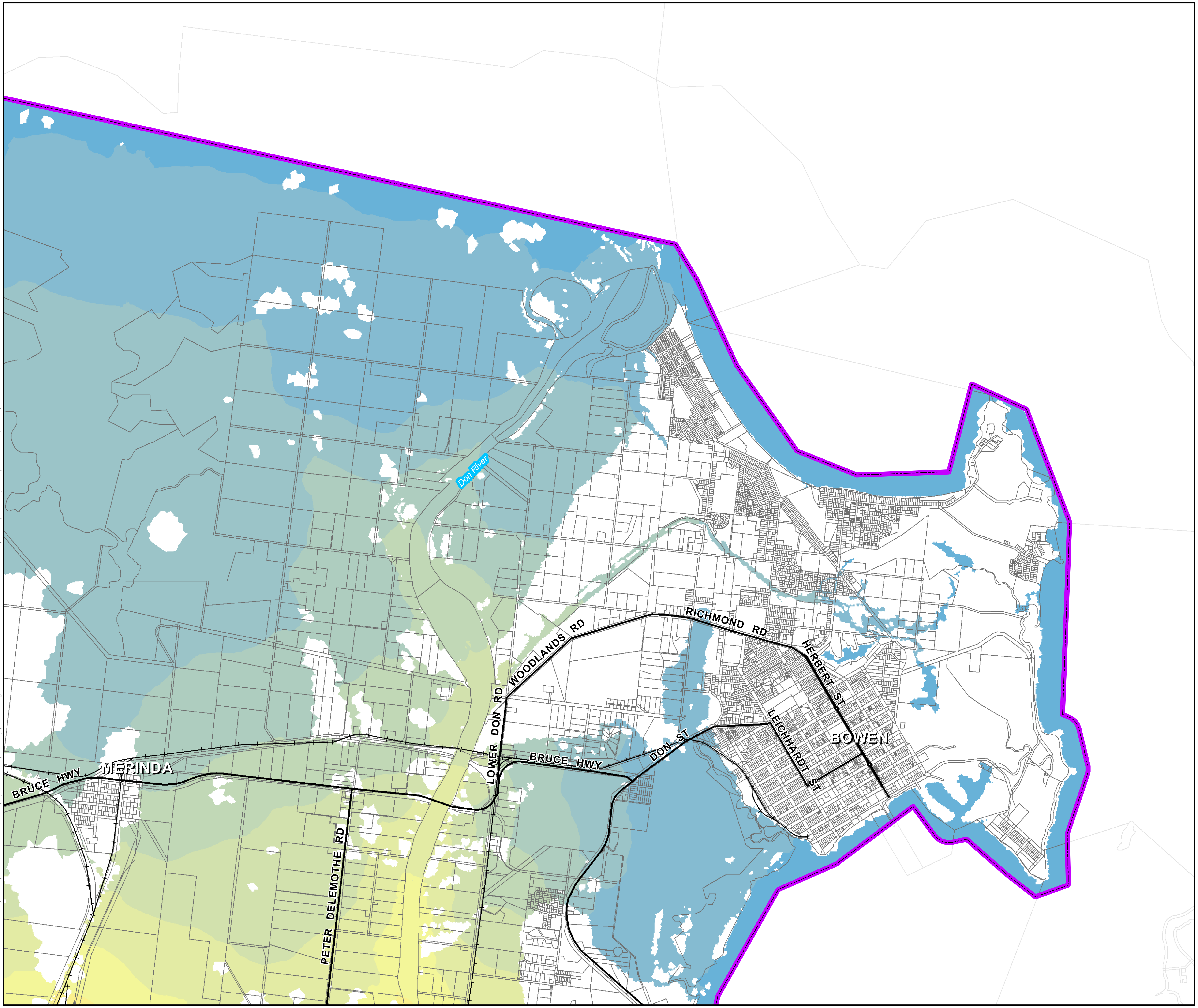
DON RIVER FLOOD STUDY

1% AEP Design Flood Elevations (zoomed)

Figure 46

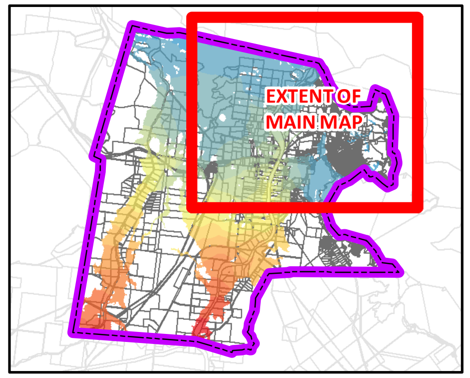


LEGEND

- Don River Hydraulic Model Extent

Levels (m AHD)

- < - 2.0
- 2.1 - 4.0
- 4.1 - 6.0
- 6.1 - 8.0
- 8.1 - 10.0
- 11.1 - 12.0
- 13.1 - 14.0
- 15.1 - 16.0
- 17.1 - 18.0
- 19.1 - 20.0
- 21.1 - 22.0
- 23.1 - 24.0
- 25.1 - 26.0
- 27.1 - 28.0
- 29.1 - 30.0
- > 31.0



0 0.5 1 2
Kilometres

1:40,000 (when printed at A3)

Coordinate System: GDA 1994 MGA Zone 55

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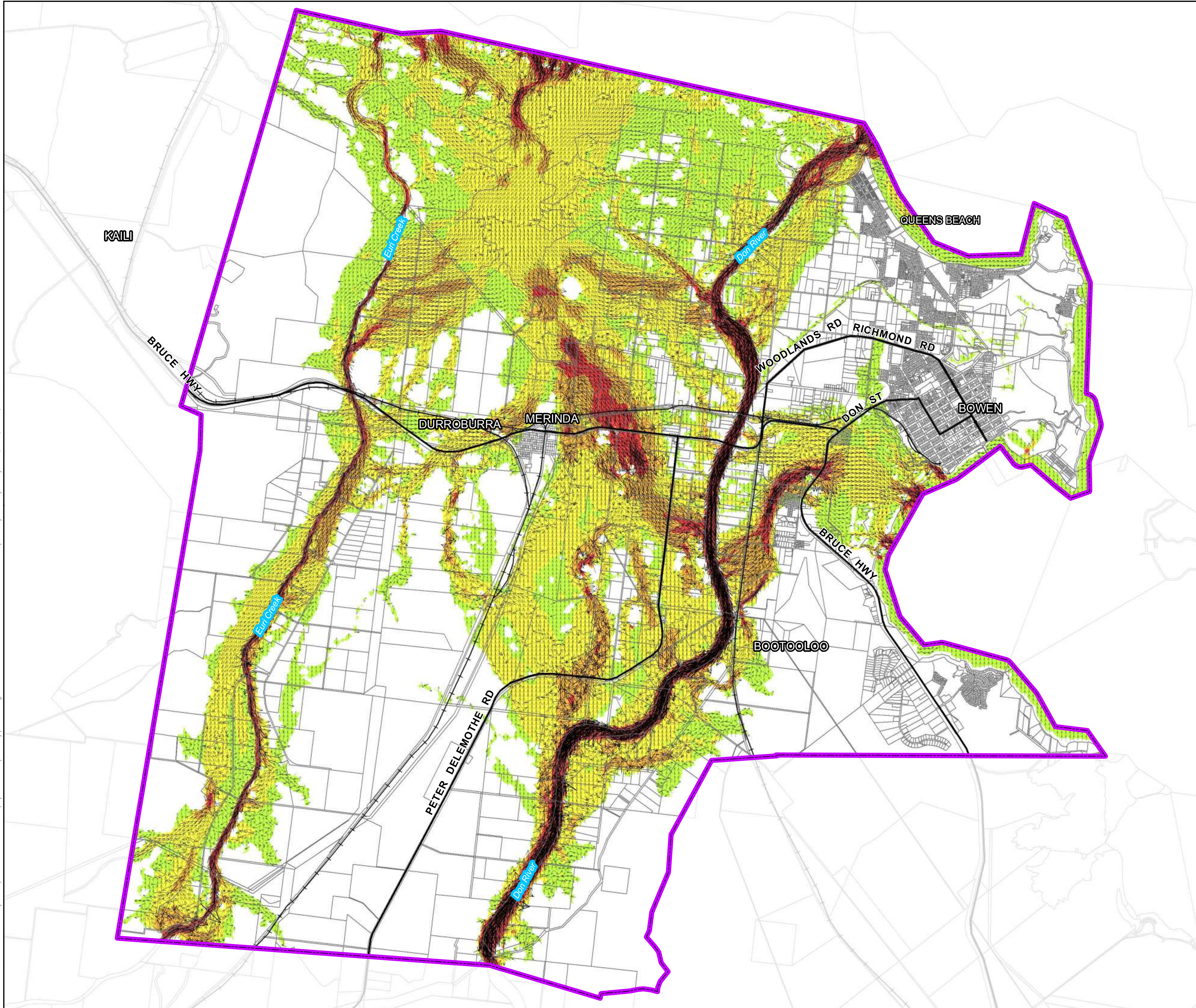

DON RIVER FLOOD STUDY

1% AEP Design Flood Velocities

Figure 47

LEGEND

Don River Hydraulic Model Extent

Velocity Vectors (m/s)

- 0.00 - 0.50
- 0.50 - 1.00
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

Velocity (m/s)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5

0 0.5 1 2 3 4

Kilometres

1:70,000 (when printed at A3)

Coordinate System: GDA 1994 MGA Zone 55

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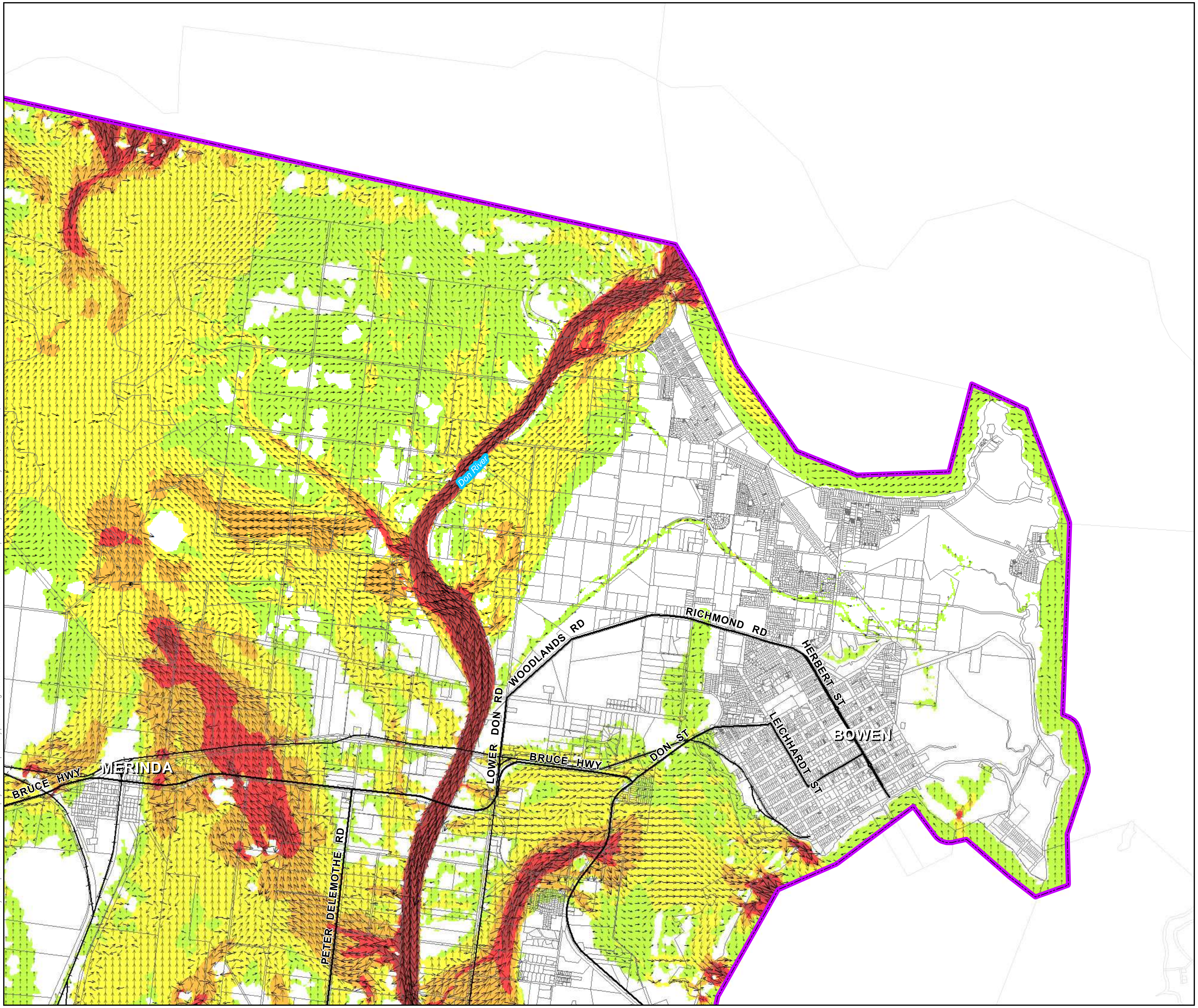
Model - AECOM 2014



DON RIVER FLOOD STUDY

1% AEP Design
Flood Velocities (zoomed)

Figure 48

LEGEND

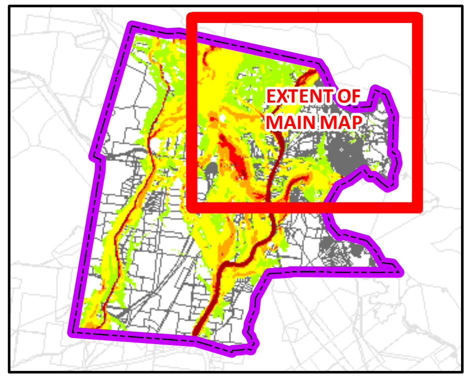
Don River Hydraulic Model Extent

Velocity Vectors (m/s)

- 0.00 - 0.50
- 0.50 - 1.00
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

Velocity (m/s)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5



0 0.5 1 2
Kilometres

1:40,000 (when printed at A3)

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Coordinate System: GDA 1994 MGA Zone 55

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Model - AECOM 2014

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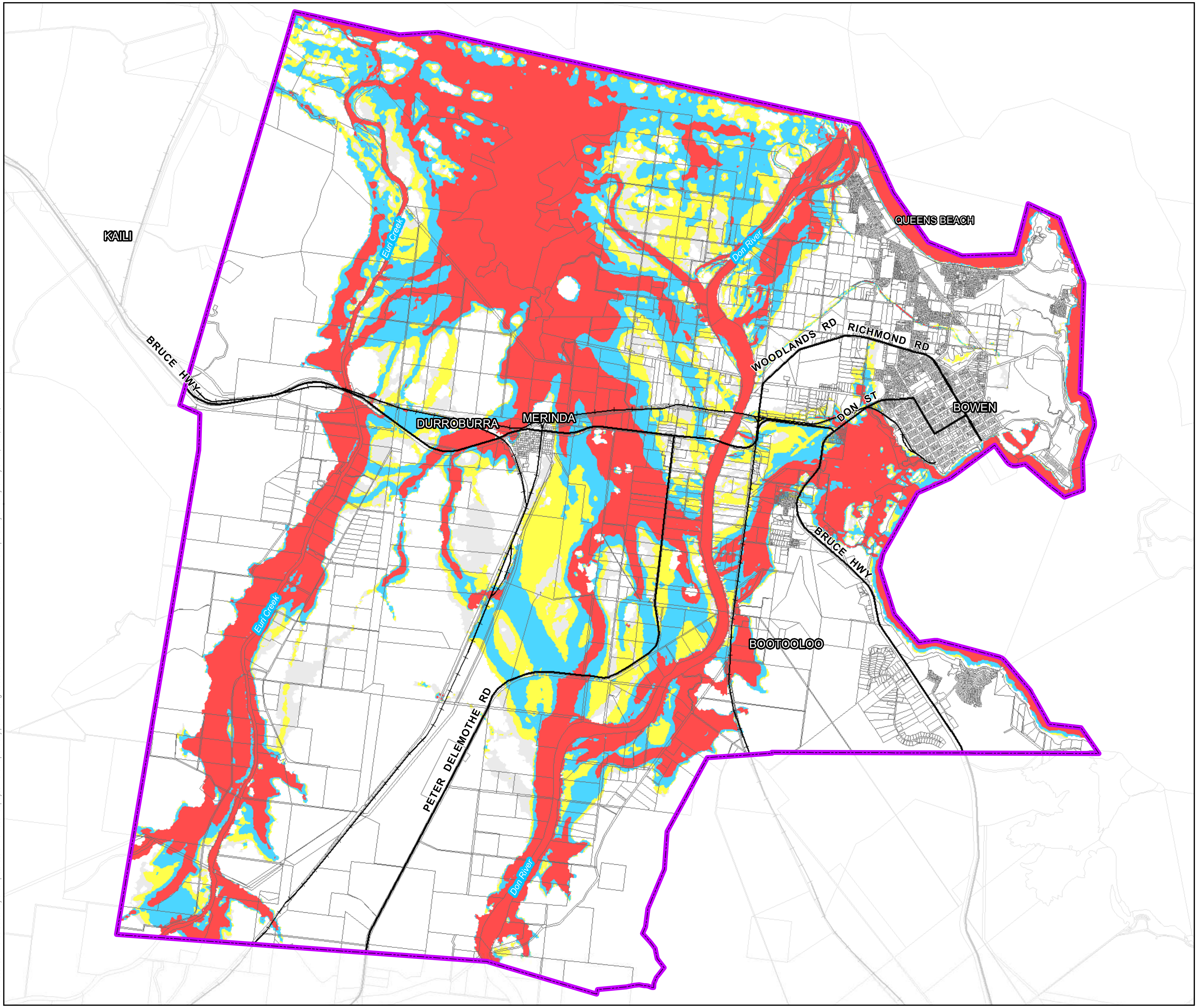
DON RIVER FLOOD STUDY

1% AEP Flood Hazard Map

Figure 49



LEGEND

Don River Hydraulic Model Extent

Hazard

- < 1
- 1.1 - 2
- 2.1 - 3
- > 3

0 0.5 1 2 3 4
Kilometres

1:70,000 (when printed at A3)

Coordinate System: GDA 1994 MGA Zone 55

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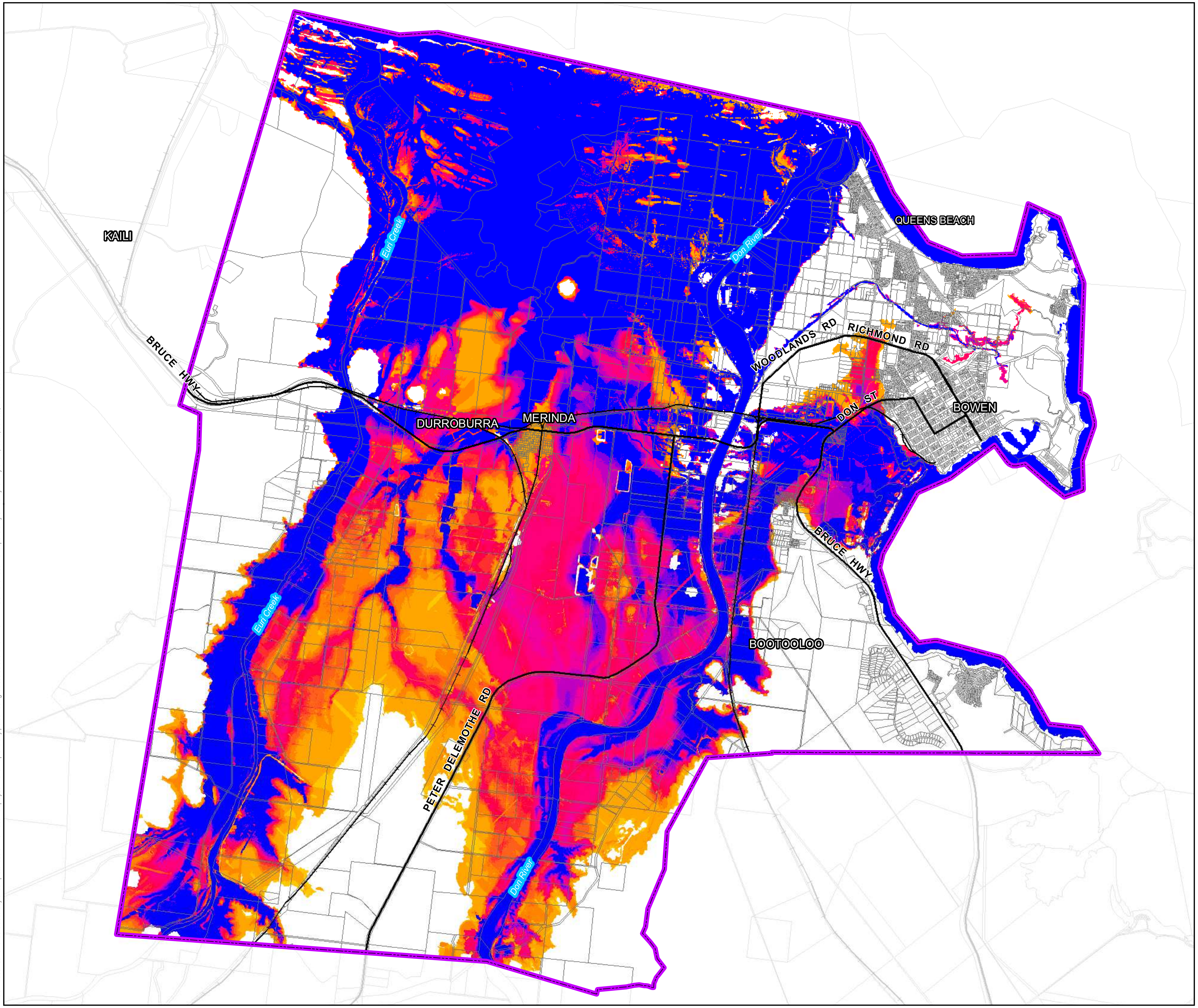
DON RIVER FLOOD STUDY

Likelihood of Flooding Over 30 Years

Figure 50



LEGEND

Don River Hydraulic Model Extent

30 Year % Chance of Flooding

- 0.3 - 0.5
- 0.5 - 5.0
- 5.0 - 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- 50 - 60
- 60 - 70
- 70 - 80
- 80 - 90
- 90 - 95.6

0 0.5 1 2 3 4
Kilometres

1:70,000 (when printed at A3)

Coordinate System: GDA 1994 MGA Zone 55

DCDB - QLD Gov 2013.
Model - AECOM 2014

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8.7 Sensitivity and Uncertainty in Design Flood Outputs

The following uncertainties required consideration in respect to sensitivity in the hydraulic model:

- Parameter uncertainty in the hydraulic model (roughness).
- Uncertainty in design flows.
- Uncertainty in respect of downstream boundary conditions.
- Uncertainty related to future changes in breakout characteristics.
- Formation of standing waves in the lower reach of the Don River.

8.7.1 Hydraulic Roughness

In determining an appropriate freeboard allowance to account for possible errors in the model roughness and other parameters, sensitivity runs with roughness values 25% higher were undertaken. This sensitivity testing was undertaken only for the 1% AEP event. The predicted difference in flood height due to a 25% increase in roughness is shown in Figure 51.

Reference to Figure 51 shows that this scenario results in an increase in peak flood levels, particularly in the lower reaches of Don River and Euri Creek. The maximum differences were up to 1.0m upstream of Pott's Bank but this reduces downstream (generally less than 0.3m difference).

8.7.2 Uncertainty in Design Flows

The hydrologic assessment undertaken for this study has included FFA and runoff routing approaches to ensure a robust means of estimating design discharge hydrographs. Several issues have been identified and discussed in Section 4.5, in which it was noted that there is still some uncertainty inherent in the hydrologic assessment.

The impact on flood level estimation was evaluated by running the 1% AEP model with inflow hydrographs increased by 25% to account for uncertainty in the estimate. The variation resulting from the increased discharge hydrographs is shown in Figure 52.

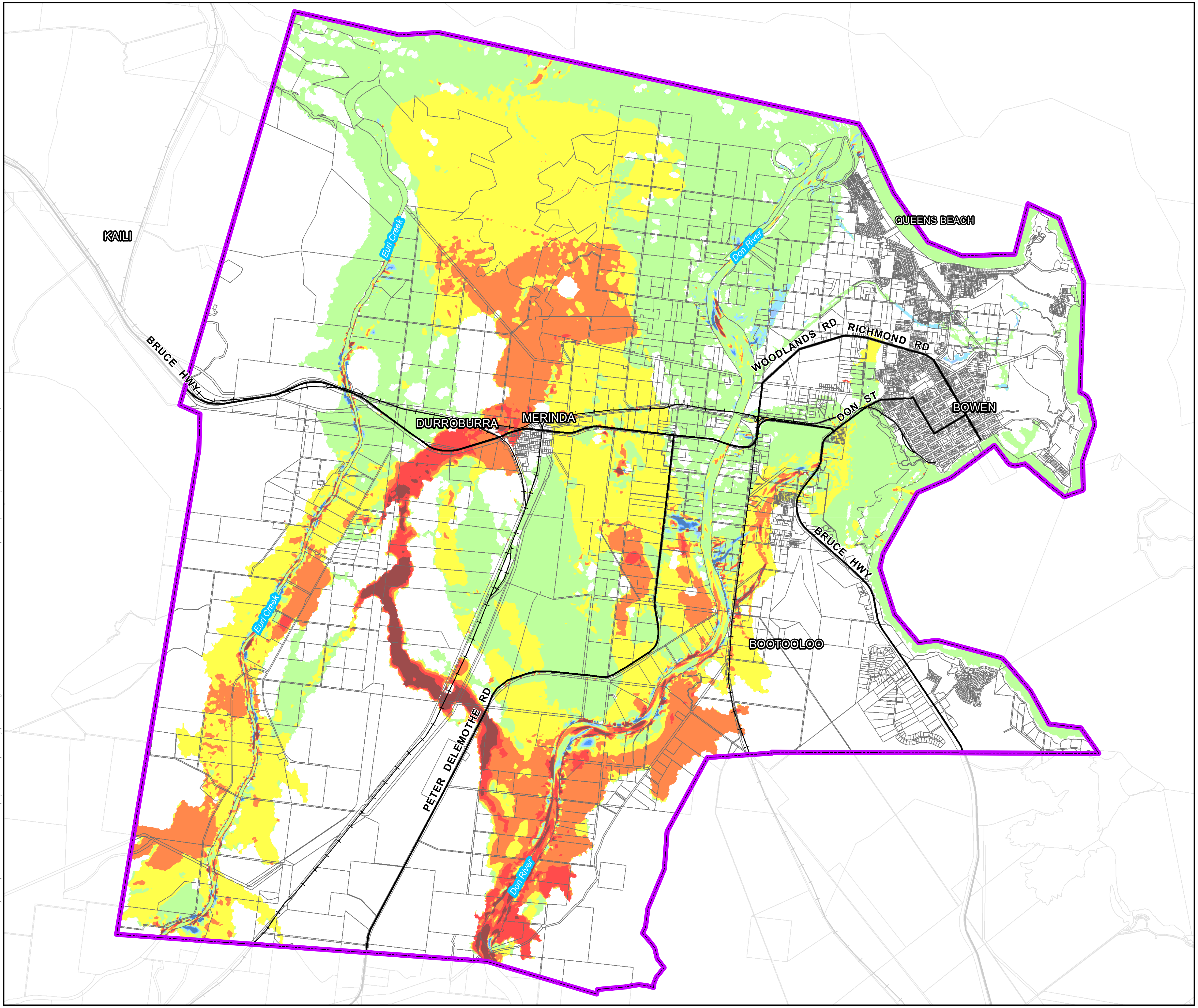
The results show that increased design discharges will be conveyed primarily by the upstream breakouts (Pott's Bank, Price's Bank and Bootooloo). Design flood levels are expected to increase through Sandy Gully by more than 0.75m. Levels in the delta region are expected to increase by up to 0.15m. The levels in the lower reaches of Don River are expected to increase by more than 0.75m which appears to be as result the hydraulic grade imposed by the Sandy Gully system.

8.7.3 Downstream Boundary Condition

Sensitivity to the downstream boundary condition was modelled by running the 1% AEP event with a higher boundary level equivalent to the HAT level of 1.97m AHD. The variation resulting from the increased boundary level is shown in Figure 53.

In a practical sense, the extent of inundation (or flood footprint) is more important than the difference in flood levels. If this difference is significant between various boundary conditions then careful consideration must be made. On the other hand, if the difference in flood footprint is only marginal, then there is no need to consider this in great detail as the outcome is not sensitive to boundary conditions assumptions.

In this case, the latter situation occurs and the flooded area was found to not be significantly impacted by the boundary level adopted.



DON RIVER FLOOD STUDY

Differences Due to Increased Roughness

Figure 51

LEGEND

Don River Hydraulic Model Extent

Difference (m)

- < -0.75
- -0.75 - -0.50
- -0.50 - -0.30
- -0.30 - -0.15
- -0.15 – 0.15
- 0.15 – 0.30
- 0.03 – 0.50
- 0.50 – 0.75
- > 0.75

0 0.5 1 2 3 4

Kilometres

1:70,000 (when printed at A3)

Coordinate System: GDA 1994 MGA Zone 55

Whitsunday Regional Council

AECOM

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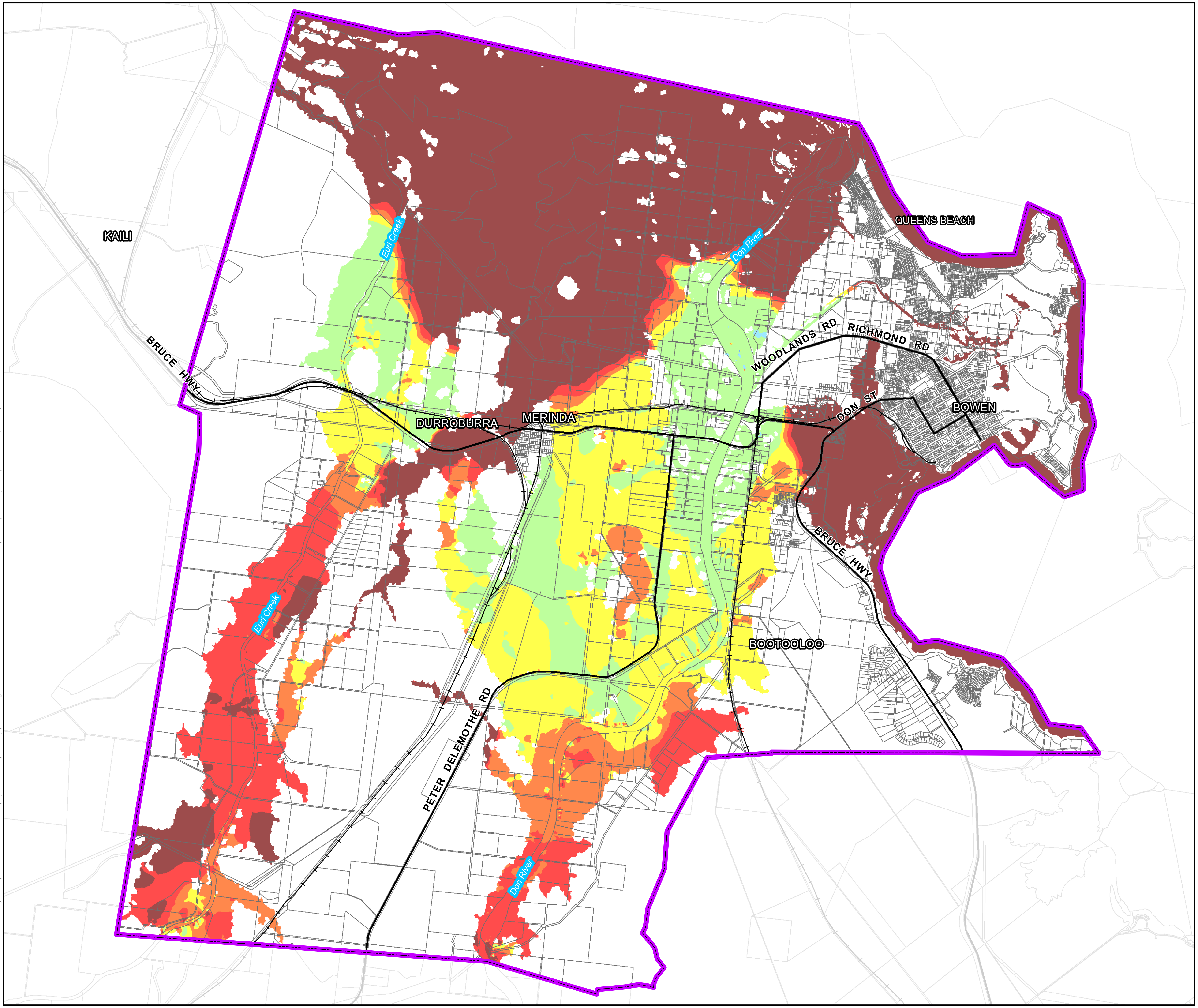
Model - AECOM 2014

User: smithc5 | Date Saved: 19/08/2014 | FileName: J:\MMPL\60306443\4. Tech Work Area\4.99 GIS\60306433_WIS_088.mxd



DON RIVER FLOOD STUDY

Differences Due to Increased Inflow-Sensitivity

Figure 52

LEGEND

Don River Hydraulic Model Extent

Difference (m)

- < -0.75
- -0.75 - -0.50
- -0.50 - -0.30
- -0.30 - -0.15
- -0.15 – 0.15
- 0.15 – 0.30
- 0.03 – 0.50
- 0.50 – 0.75
- > 0.75

0 0.5 1 2 3 4
Kilometres

1:70,000 (when printed at A3)

Coordinate System: GDA 1994 MGA Zone 55

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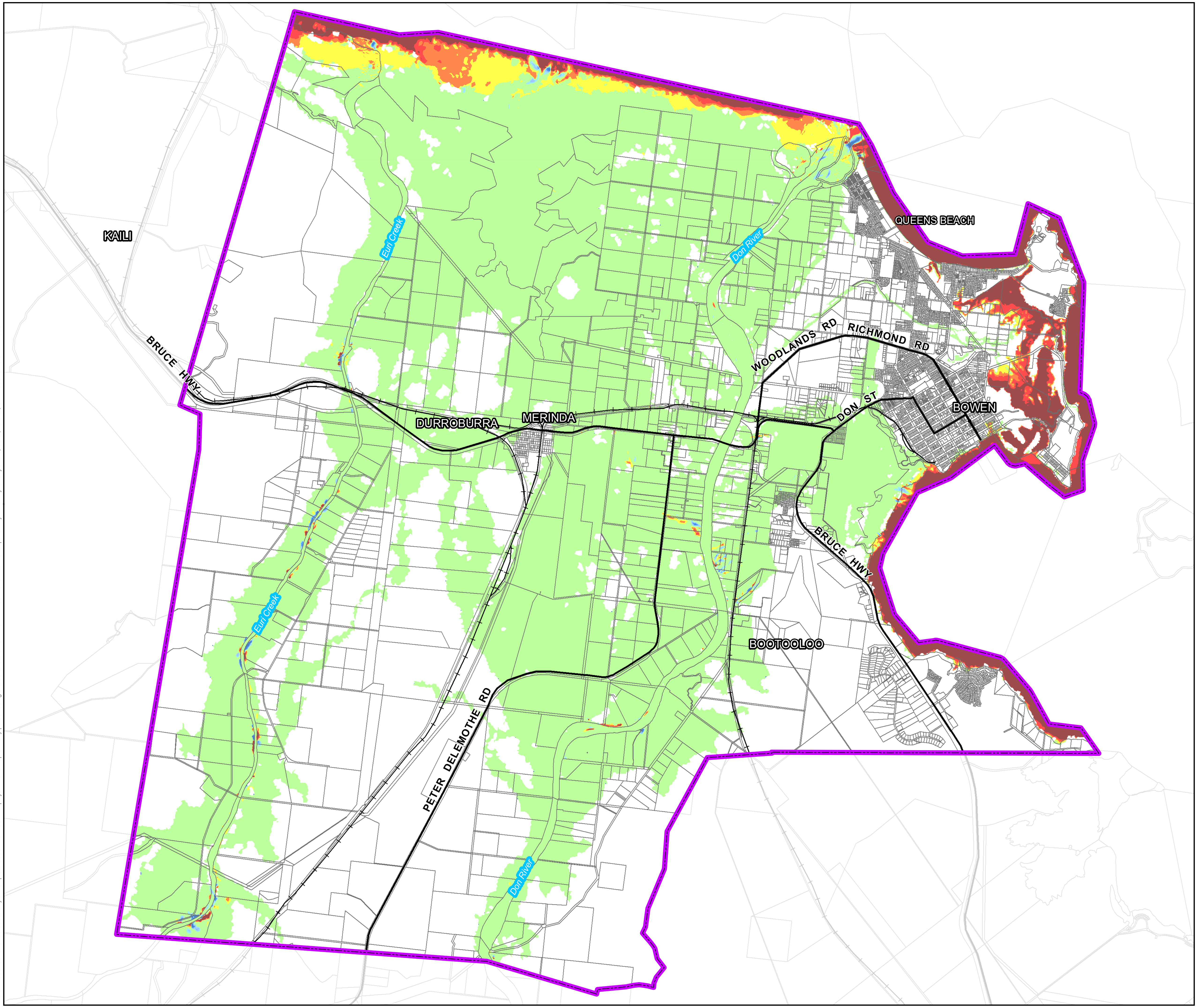
Model - AECOM 2014



DON RIVER FLOOD STUDY

Differences Due to Higher Downstream Boundary Level

Figure 53

LEGEND

Don River Hydraulic Model Extent

Difference (m)

- < -0.75
- -0.75 - -0.50
- -0.50 - -0.30
- -0.30 - -0.15
- -0.15 – 0.15
- 0.15 – 0.30
- 0.03 – 0.50
- 0.50 – 0.75
- > 0.75

0 0.5 1 2 3 4
Kilometres

1:70,000 (when printed at A3)

Coordinate System: GDA 1994 MGA Zone 55

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8.7.4 River Bank Outflow Characteristics

There is no doubt that the Don River system is highly dynamic, evidenced by the number of minor and major breakouts which occur along the banks of the lower Don River in moderate and major flood events. River breakouts in some locations can directly threaten Merinda, Queens Beach, Bowen and the farming communities. Webster Brown, Bells Gully, Sandy Gully and Boottooloo are known break out points along the eastern and western banks of Don River which have potential to flood these areas.

Webster Brown, Bells Gully and the '1946 mouth' are still considered to be the highest risk breakout points in terms of future flood risk management for Bowen and Queens Beach. Any potential erosion of the bank adjacent to Webster Brown and significant deposition in the river channel adjacent to Bells Gully may potentially increase the conveyance through these flow paths and subsequently increase flood risk. Continual deposition and aggradation of the '1946 mouth' distributary could also have severe impacts as this results in a greater proportion of flows through Webster Brown.

This study, and others undertaken in the past, has reiterated the significant uncertainty associated with the geomorphology of Don River and the dynamic characteristics of the river bed and banks. Therefore, carrying out sensitivity analysis is necessary to investigate the impacts of the changes in the characteristics of several major breakout points – especially those which could have an effect on existing floodplain occupants.

The following sensitivity analyses have been developed and run by altering breakout heights at the location of the breakout points. These sensitivities were run for the 1% AEP design event and compared to initial results in order to assess the severity of future changes to breakout characteristics.

8.7.4.1 1946 Mouth

The present mouth of the Don River is located immediately west of the Queens Beach township and is referred to in previous reports as the 'Old Mouth'. Whilst the Old Mouth is an important flood channel, it ranks behind Webster Brown and the '1946 mouth' as a major flood distributor.

Historical aerial imagery shows ongoing sediment deposition at the 1946 mouth which is confirmed by eye witness accounts summarised in previous reports. Of particular concern is the propensity for ongoing sediment deposition which would reduce overflow conveyance and impact flood risk for the Queens Beach community.

In order to assess the relative impacts of ongoing sediment deposition at the 1946 mouth, the elevation of the breakout was raised by 0.5m. This increase in elevation due to deposition is possible in the short term. Figure 54 shows the predicted difference in 1% AEP flood levels as a result of this change. It suggests that 0.5m of localised aggradation of the 1946 mouth would not increase flood levels by more than 0.15m in the 1% AEP event. Further analysis of more widespread changes to the 1946 mouth will be investigated in the Stage 2 Report.

8.7.4.2 Bells Gully

There is evidence that Bells Gully has experienced major outflows from the Don River in the past – particularly in the 1970 and 1980 flood events. Modelling undertaken during this study has shown

To assess the relative change in conveyance characteristics, the baseline model was altered to increase the river channel elevation by 1.0m in the vicinity of Bells Gully. This could conceivably occur in future flood events and accounts for the high sensitivity found in the sediment diameter adopted in the modelling.

The predicted differences in flood levels are shown in Figure 55. It suggests that localised changes to main channel deposition adjacent to Bells Gully can have a significant effect on the resulting overbank flow. Water surface levels are seen to increase by 0.15m – 1.0m

8.7.4.3 Potts Bank

The initial MIKE FLOOD runs for variety of design events indicates that Don River overflows at Potts Bank in higher flood events. It is possible that the breakout characteristics at Potts Bank could have impacts on the breakout discharge and consequently the flows in the Don River.

In this sensitivity analysis the model bathymetry was edited to raise the bank level by approximately 0.5m to reduce the conveyance capacity of Potts Bank and assess the impact on downstream flood levels as a result. The predicted differences in flood levels are shown in Figure 56.

8.7.4.4 Webster Brown

There is historical evidence that the Webster Brown overflow has operated at least fourteen times in the past 90 years with the latest discharge occurring in 2008.

A major outflow occurred in 1980 when large sections of bank protection works in the Webster Brown reach of the river were destroyed. Modelling has indicated that high velocities, in excess of 3.0m/s can be experienced along this flow path. The discharge flows directly from the Webster Brown bank towards the Rainbow Waterhole to re-join the Don River 'Old Mouth'.

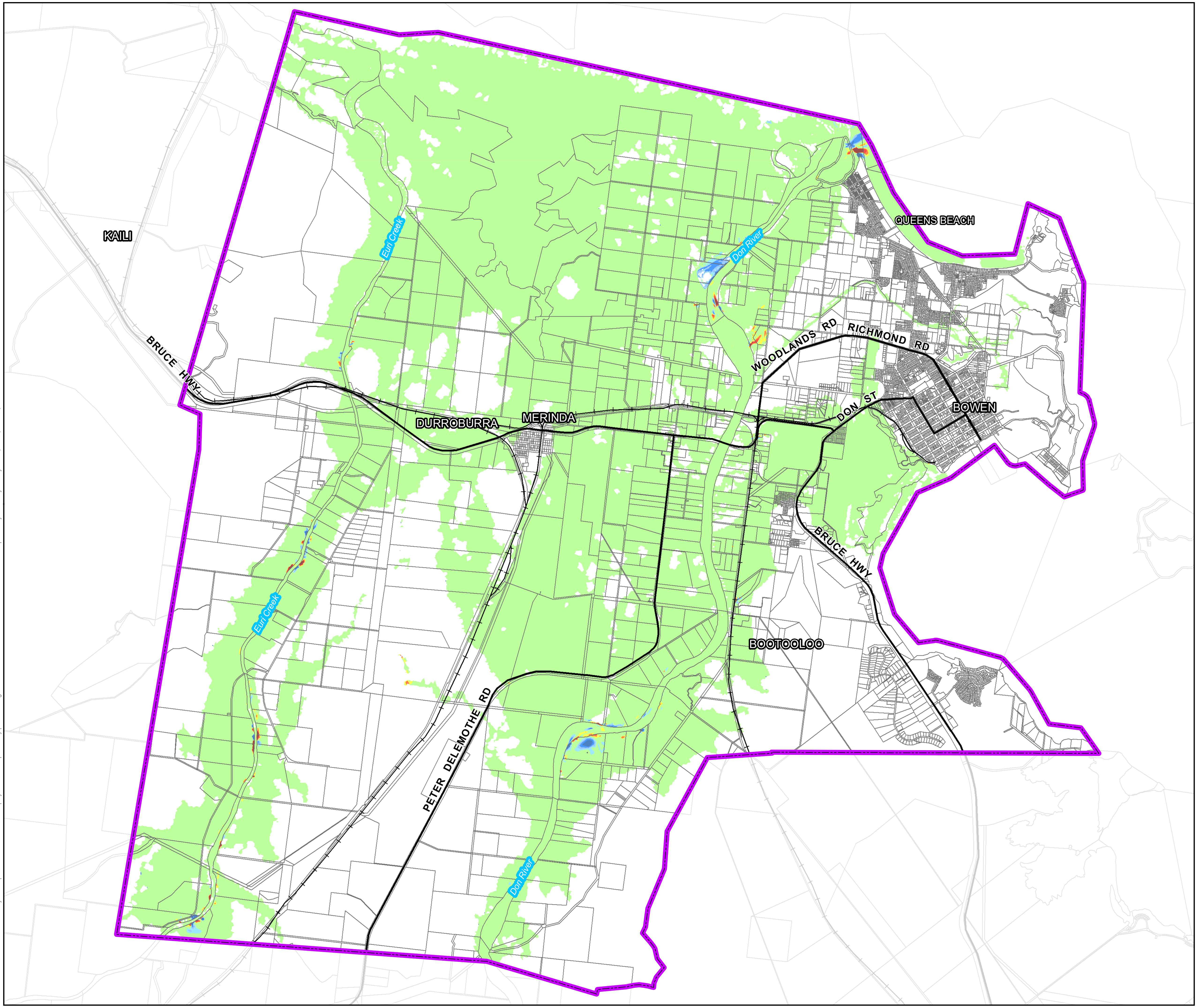
There is extensive evidence of the ongoing issues with the stability of the Webster Brown bank consolidated in previous reports. Of particular concern is the possibility of bank failure during a flood event which results in significant discharges being directed towards the Queens Beach community.

A sensitivity analysis has been carried out by lowering the Webster Brown bank elevation to simulate the potential damage to protection works and subsequent erosion of this bank in a future flood event. The predicted differences in flood levels are shown in Figure 57.

DON RIVER FLOOD STUDY

1% AEP Difference in Flood Depths for 1946 Mouth Sensitivity

Figure 54



LEGEND

Don River Hydraulic Model Extent

Difference (m)

- < -0.75
- -0.75 - -0.50
- -0.50 - -0.30
- -0.30 - -0.15
- -0.15 – 0.15
- 0.15 – 0.30
- 0.03 – 0.50
- 0.50 – 0.75
- > 0.75

0 0.5 1 2 3 4
Kilometres

1:70,000 (when printed at A3)

N

Coordinate System: GDA 1994 MGA Zone 55

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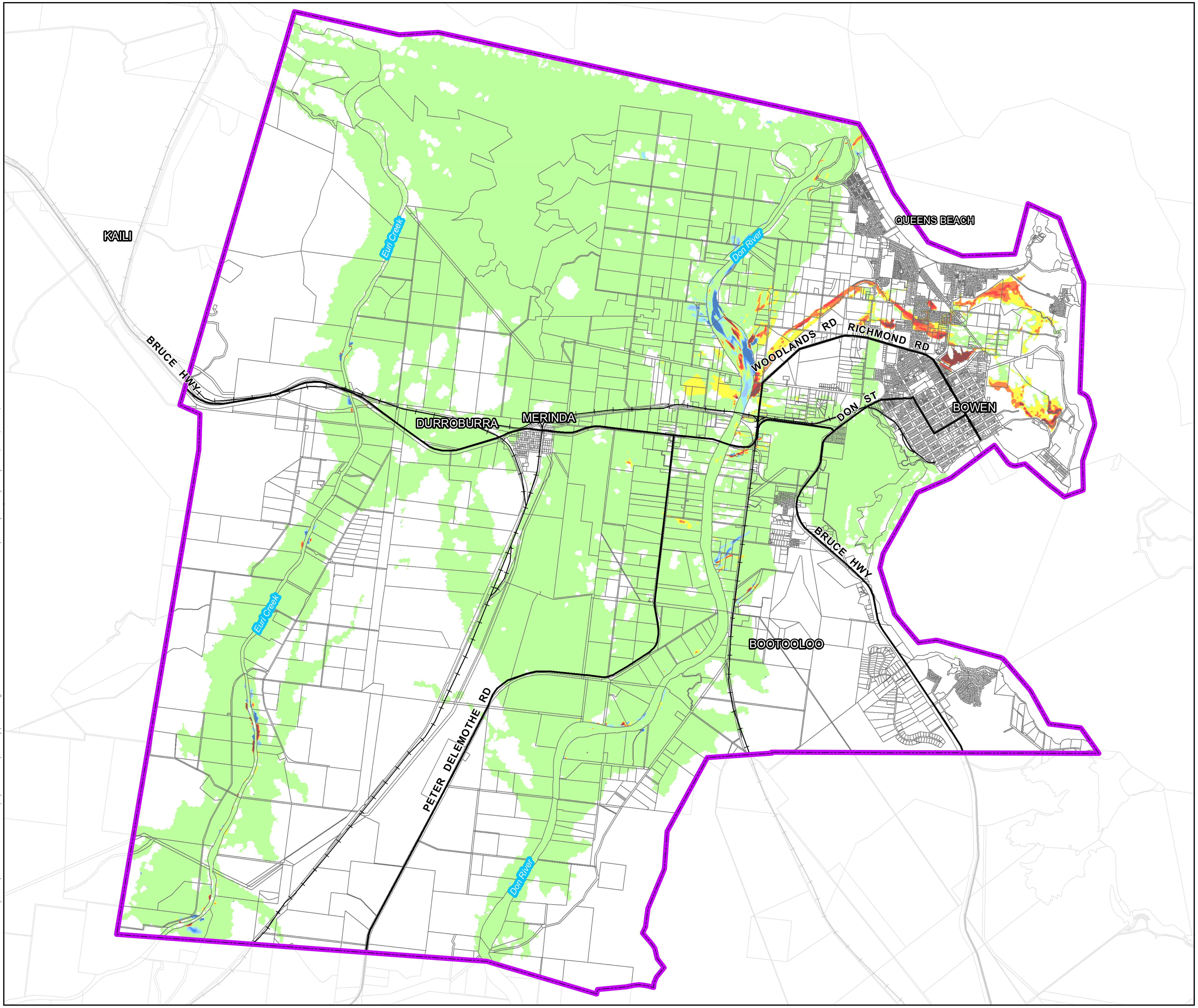
DON RIVER FLOOD STUDY

1% AEP Difference in Flood Depths for Bells Gully Sensitivity

Figure 55



0 0.5 1 2 3 4
Kilometres

1:70,000 (when printed at A3)

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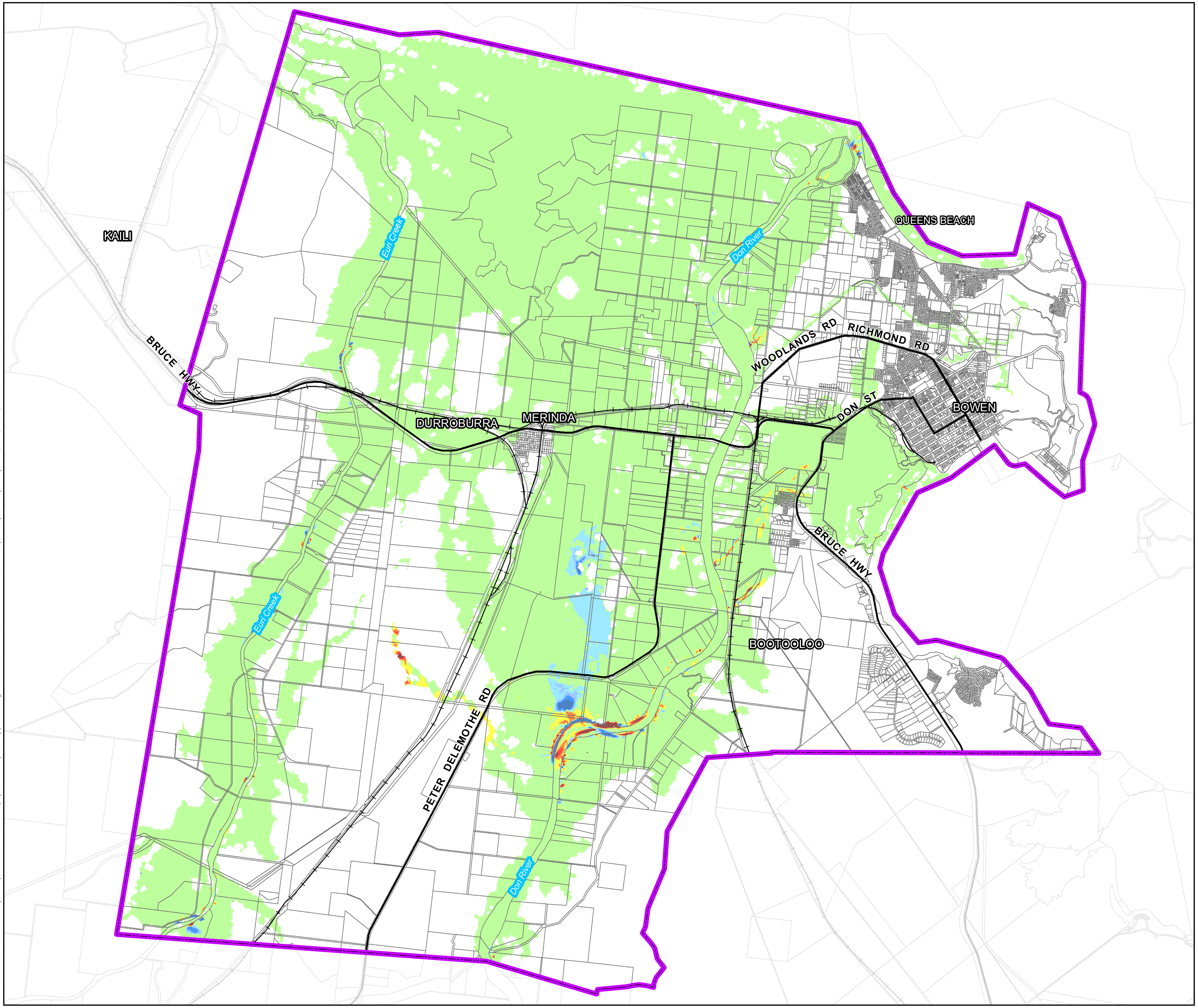
DON RIVER FLOOD STUDY

1% AEP Difference in Flood Depths for Potts Farm Sensitivity

Figure 56



LEGEND

Don River Hydraulic Model Extent

Difference (m)

- < -0.75
- -0.75 - -0.50
- -0.50 - -0.30
- -0.30 - -0.15
- -0.15 – 0.15
- 0.15 – 0.30
- 0.03 – 0.50
- 0.50 – 0.75
- > 0.75

0 0.5 1 2 3 4

Kilometres

1:70,000 (when printed at A3)

N

Coordinate System: GDA 1994 MGA Zone 55

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Model - AECOM 2014

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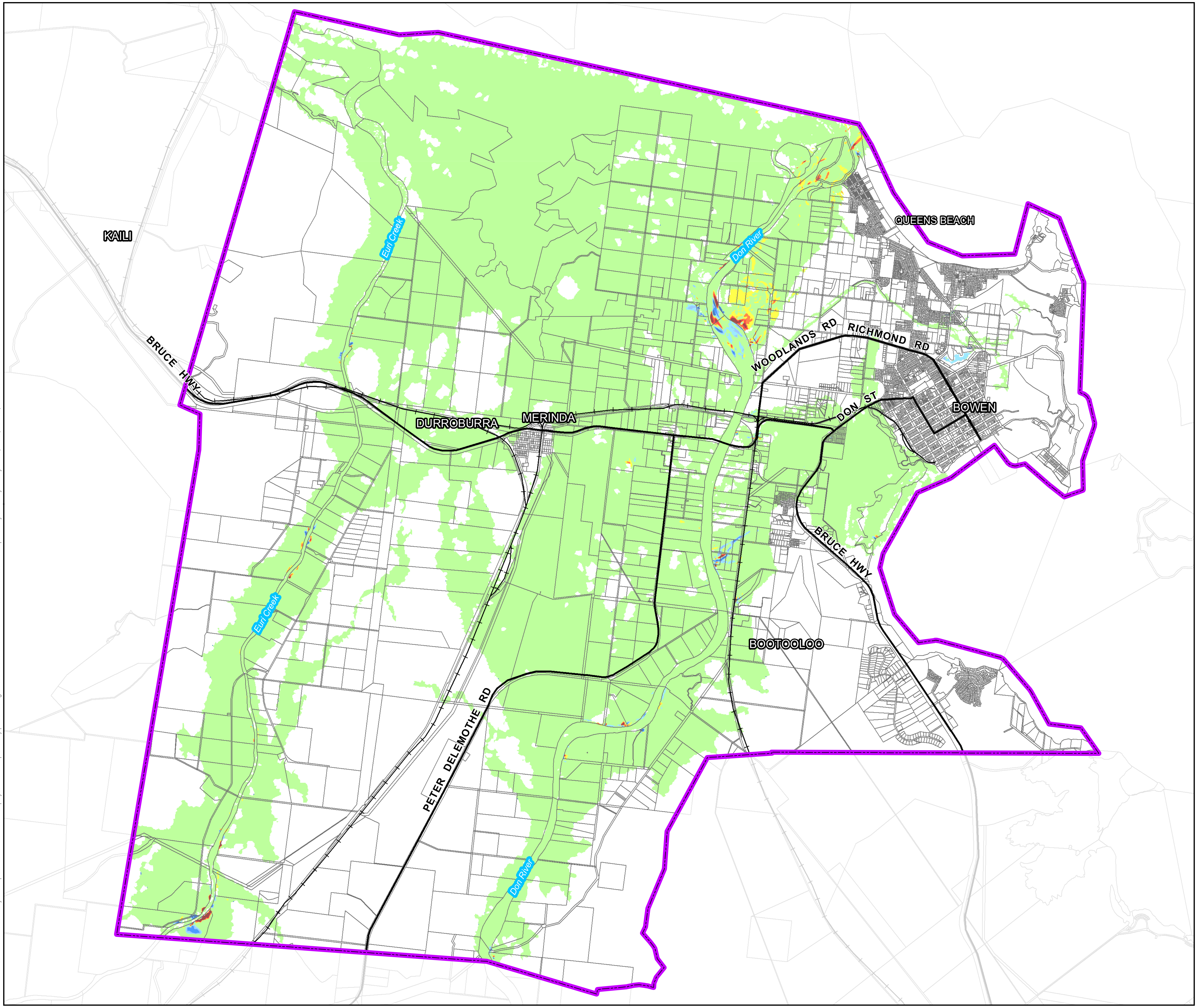
DON RIVER FLOOD STUDY

1% AEP Difference in Flood Depths for Webster Brown Sensitivity

Figure 57



LEGEND

Don River Hydraulic Model Extent

Difference (m)

- < -0.75
- -0.75 - -0.50
- -0.50 - -0.30
- -0.30 - -0.15
- -0.15 – 0.15
- 0.15 – 0.30
- 0.03 – 0.50
- 0.50 – 0.75
- > 0.75

0 0.5 1 2 3 4

Kilometres

1:70,000 (when printed at A3)

Coordinate System: GDA 1994 MGA Zone 55

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8.7.5 Don River Standing Waves

A review of photographs and videos compiled during the study has shown evidence of standing waves forming along the lower reaches of the Don River. Standing waves during the 2008 flood event are shown below.

Figure 58 Standing Wave during the 2008 Flood Event

Figure 59 Standing Wave during the 2008 Flood Event (Russel's Crossing)

In upper-regime flow, the river bed may have a plane surface or it may have long, smooth sand formations in phase with the surface waves (Leopold and others, 1964; Karim, 1995). These surface waves are known as standing waves or antidunes (refer to Figure 60).

Standing waves are typically found in fluvial environments in shallow areas with a high flow rate. Unlike ripples and dunes in lower flow regime, they are generally symmetric and migrate counter to the flow direction. The standing waves can evolve rapidly, growing in amplitude as they migrate against the current. As the size of the waves grow, the water-surface slope on the upstream side of the waves becomes steeper, and they may eventually collapse.

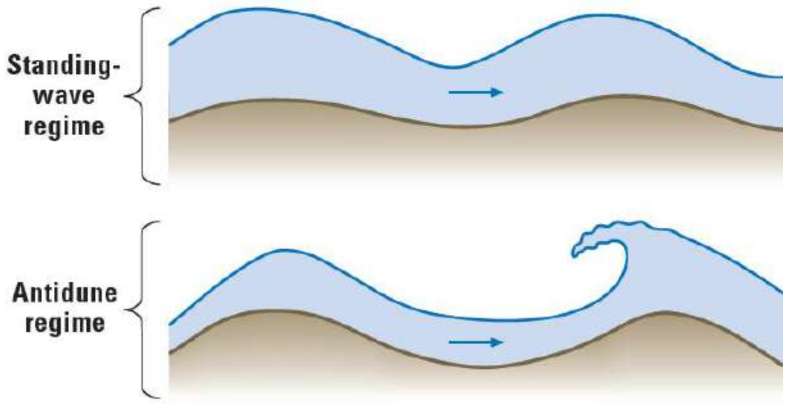

Figure 60 Depiction of Upper Regime Flow in Alluvial Streams and Rivers (source: USGS, 2007)

Photos and videos compiled during the 2008 flood event suggest the formation of standing waves along the lower reaches of the Don River. Hydrodynamic modelling does not account for these localised effects and therefore flood heights along the river channel may be higher than the modelled outputs.

8.8 Freeboard Provision

Freeboard is added to flood levels to provide reasonable certainty of achieving the desired level of service from setting a general standard or Define Flood Event (DFE) for planning controls. The freeboard has been estimated in consideration of the following factors:

- Uncertainty in the estimate of flood levels.
  - Uncertainties with upstream gauge rating curves, the highly dynamic nature of the river system and the limited number of calibration / validation events suggests a degree of uncertainty in the estimated flood levels.
- Local factors that can result in differences in water levels across the floodplain. These factors can often not be determined in flood modelling (i.e. standing waves along the lower reaches of the Don River).
- Wave action is not considered in hydraulic models. Models assume flat surfaces and do not replicate the undulations in surface levels occurring in flood events.
  - Waves can result from local factors, wind from meteorological events, movement of boats and vehicles through flooded areas, and coastal processes.
  - Open coastal waterways with broad, deep entrances can also allow a high degree of coastal wave penetration.
- The cumulative effect of subsequent infill development of existing zoned land.
- Where the future climate has the potential to significantly increase risk.

In effect, freeboard acts as a factor of safety. However, it should not be considered as giving additional protection beyond the DFE to which it is applied

In consideration of the results of the sensitivity tests, and minimal data on which to base model calibration, it is recommended that Council consider a freeboard of 0.5m to be applied to the model results in using them for development control purposes.

9.0 Emergency Management Planning

9.1 Overview

WRC's Local Disaster Management Group (LDMG) is responsible for coordinating local planning and response for flood events. A lack of available data can be a limiting factor for a LDMG's ability to plan for the event and to communicate the expected impacts to local residents / media.

It is for this reason that it is recommended that Council officers hold workshops with key members of the LDMG and emergency service personnel following the finalisation of this study to disseminate design event modelling outputs. This will enable the LDMG to review the outputs and request any additional information which would be of most use during a flood emergency.

The following sections provide information on several key items which should be developed to support emergency management planning.

9.2 Flood Emergency Plan

It is common for emergency management agencies to develop or amend their Flood Emergency Plan following the completion of a Flood Risk Study. This is a detailed document containing an agreed set of roles, responsibilities, functions, actions and management arrangements to deal with flood events of all sizes.

The primary aim of a flood emergency plan is to reduce hazard during an actual flood. Essential issues addressed in the plan are flood forecasting, flood warning, location of vulnerable people/communities and evacuation and initial recovery. A local flood emergency plan forms an essential component of a floodplain management plan and requires close liaison between emergency management staff.

Typically, a flood emergency plan has several trigger points that result in the activation and implementation of the plan as the actual flood event develops. The flood emergency plan should include activities to protect and reinstate essential infrastructure services required during clean-up and in the recovery phase.

9.3 Assessment of Critical Infrastructure

A list of critical infrastructure and the Bowen Pump Station gauge level at which it is likely to be inundated could be prepared. This could include infrastructure such as:

- Emergency services facilities (e.g. ambulance, police, fire, hospital).
- Significant facilities for evacuation (e.g. child care, education, retirement, nursing care).
- Key water and sewerage infrastructure.
- Roads / bridges.

9.4 Decision Support Tool

A decision support tool for emergency management procedures can assist the LDMG to identify the major decisions to be made during a flood event and during an evacuation.

This tool acts as a trigger for the LDMG to identify which decisions are required depending upon the expected magnitude of the flood event.

9.5 Flood Warnings

Pre-written flood warnings can be prepared. This allows for these warnings to be readily available for dissemination to the media during a flood event.

9.6 Evacuation Route Assessment

Using the inundation maps presented in this report, the persons likely to be affected by floods should be identified and their ability to manage their well-being during floods assessed. Evacuation routes should be assessed for susceptibility to flooding.

The assessment should include the development of evacuation messages containing the main evacuation routes, description of safe havens and a description on how to behave during an evacuation. This message should be differentiated according to the situation of the inhabitants regarding risk, evacuation routes and safe areas and shelter place. Vulnerable parts of the community should also be identified when assessing evacuation routes (i.e. hospitals, nursing homes, schools, etc) to ensure consideration is made for evacuation timings and special requirements.

10.0 Community Awareness

10.1 Overview

It is critical that the flood-prone communities of Bowen, Queens Beach and Merinda be made aware – and remain aware – of their role in the overall floodplain management strategy for the region, including defence of their communities and the evacuation of themselves. Sustaining an appropriate level of flood awareness involves continuous effort by Council and the emergency services but can significantly increase the community's resilience to future flood events.

Irrespective of flood warnings, there can be widespread variation in flood awareness in a community which can result in a high degree of variation in flood damages. Within the Bowen area, the recent flood events have greatly raised the awareness of the community. However, as time passes, this awareness will reduce.

Council can enhance flood awareness through, for example, regular public education programs via newspaper, videos, pamphlets, meetings and other media outlets. Community awareness brochures have been widely adopted and many followed the successful implementation of NSW SES's 'Flood Safe' brochures. These brochures can include material specific to the local region and provide the following information:

- What floods are and the history on flooding in Bowen
- Flood behaviour in Bowen
- Flood warnings
- What to do before, during and after a flood
- Preparation of a household emergency plan

It is recommended that Council develop a communications plan to explain existing flood risk to the Bowen community following finalisation of this Stage 1 Report. Additional consultation is also recommended upon finalising the Stage 2 Report.

11.0 Development Planning

11.1 Overview

Appropriate development and building controls can significantly reduce flood hazard and the amount of damage to flood prone properties when a flood greater than the DFE occurs. The level of protection provided by the Planning Scheme should be a consequence of an analysis of the risks and consequences of flooding and the opportunities provided by sustainable land uses.

An underlying factor of community vulnerability is the degree of exposure to flooding. Where people have chosen to live is their own decision however, they may not be aware of the flood risk and hazard to which they are exposed. Planning schemes are a key element to prevent increasing the number of people, business and assets exposed to flooding from events less than the design flood event. It is therefore fundamental that future development is guided so that people and their property have limited exposure to flood hazard.

Several broad recommendations have been provided below for further discussions with Council's Planning and Development officers:

- Council needs to have regard to the cumulative impacts of developments, i.e. the consideration of the impacts of a development in combination with other developments.
- A key component of land use planning is the adoption of a DFE. This has traditionally been adopted as the 1% AEP flood however there is considerable evidence that rainfall intensity will increase during current planning horizons.
    - In application, a DFE being the 1% AEP flood with an allowance for the adverse impacts of climate change as represented by an increase in design rainfall intensities (of 20% being a 5% per degree Celsius rise in mean global temperature of 4°C to the year 2100) is recommended.
- In consideration of the results of the sensitivity tests, and minimal data on which to base model calibration, it is recommended that a freeboard of 0.5m be applied to the model results in using them for development control purposes (refer to Section 8.8).
- In consideration of the results of sensitivity tests and additional modelling, it is suggested that development controls be put in place along Bells Gully which accounts for the high sensitivity in outflows due to sand deposition in the main river channel.
- A comprehensive suite of measures against which to assess developments is recommended that not only includes the direct impact of development, but also the indirect impacts regarding flood warning and evacuation.
- Relevant Council staff should be appropriately trained in assessing flood study reports with respect to the development control measures selected.

12.0 Summary

12.1 Conclusion

This study has been divided into two stages of investigation and reporting, namely the **Don River Flood Risk Assessment** (this document) and the **Don River Flood Mitigation Assessment.**

This Stage 1 flood risk assessment of the Don River, including Euri Creek and Sandy Gully, has been undertaken to determine the existing flood risk posed by flooding throughout the study area to assist WRC in land use planning, development assessment, community awareness and emergency management. The results of this report will also be used to assess potential mitigation measures as part of the Stage 2 investigation.

Thee XP-RAFTS runoff-routing hydrologic models were developed for the Don River, Euri Creek and Sandy Gully catchments and a MIKE FLOOD flexible mesh two dimensional hydraulic model was developed for the lower reaches of the Don River, including Euri Creek and Sandy Gully channels and floodplain. The XP-RAFTS and MIKE FLOOD models were calibrated and verified against recorded stream flows within the Don River catchment for historical flood events.

Design flood discharges, flood levels, flood extents and flood velocities were determined for a range of events from the 10% AEP to the PMF event. The study also included an assessment of the impact of climate change based on recommendations from the Queensland Government.

The Don River poses a significant flood risk for the communities in Merinda, Bowen and Queens Beach due to the relatively short warning time, dynamic nature of the river system, high velocities and flood depths and the isolation of several communities due to the limited availability for evacuation as a result of the low existing immunity of key transportation links.

There is a need to identify, assess, compare, make recommendations and report on options to improve risk management for the community. This will be undertaken in the Stage 2 Flood Mitigation Assessment Report.

12.2 Recommendations

A number of recommendations have been identified throughout the course of this Stage 1 assessment. These additional studies / investigations would reduce uncertainties, provide additional information to Council and provide a better understanding of flooding in the Bowen region.

12.2.1 Improvements to Stream Gauge Rating Curves

Much of the differences between previous investigations can be attributed to the choice of rating curve and ultimately the estimated discharge hydrographs adopted at the Ida Creek and Revees gauging stations. Both DNRM and BOM utilise these gauges but use significantly different rating curves.

It is recommended that officers from WRC, DNRM and BOM meet to discuss the disparities in rating curves and undertake additional investigations to ensure there is common rating curve applied to these gauges.

12.2.2 Review of BOM’s URBS Model

The Don River URBS model was developed by BoM for flood forecasting purposes and has been calibrated to a number of historical storm events ranging in size and duration. It is understood that there has been some concerns raised with the current URBS model due to the high continuing loss rate required to achieve calibration (8.5mm/hr) and the uncertainty of the current rating curve used for the Bowen Pump Station gauge.

It is recommended that BOM review the URBS model whilst undertaking investigations into their rating curves, as discussed above. It is possible that the current rating curve is overestimating discharges and therefore a high continuing loss is required to achieve an appropriate level of calibration.

12.2.3 Standards for Modelling Methodologies and Management

It is recommended that Council adopt a standard for modelling methodologies and model management, particularly given the number of models Council now possess.

Well defined standards can:

- Allow Council to be confident that their modelling and model results are consistent across the region and therefore easily comparable from catchment to catchment.

- Allow Council to better manage their files within their own systems.
- Ensure that original versions of models are protected.
- Can be more easily refined as more recent data becomes available rather than building a new model.

12.2.4 Development of a Communications Plan

It is recommended that Council develop a communications plan to explain existing flood risk to the Bowen community. Additional consultation is also recommended upon finalising the flood mitigation options.

12.2.5 Review of Emergency Management Planning

It is recommended that Council officers hold workshops with key members of the LDMG and emergency service personnel to disseminate design event modelling outputs. Other key items related to the improvement of the emergency management planning should also be developed where possible.

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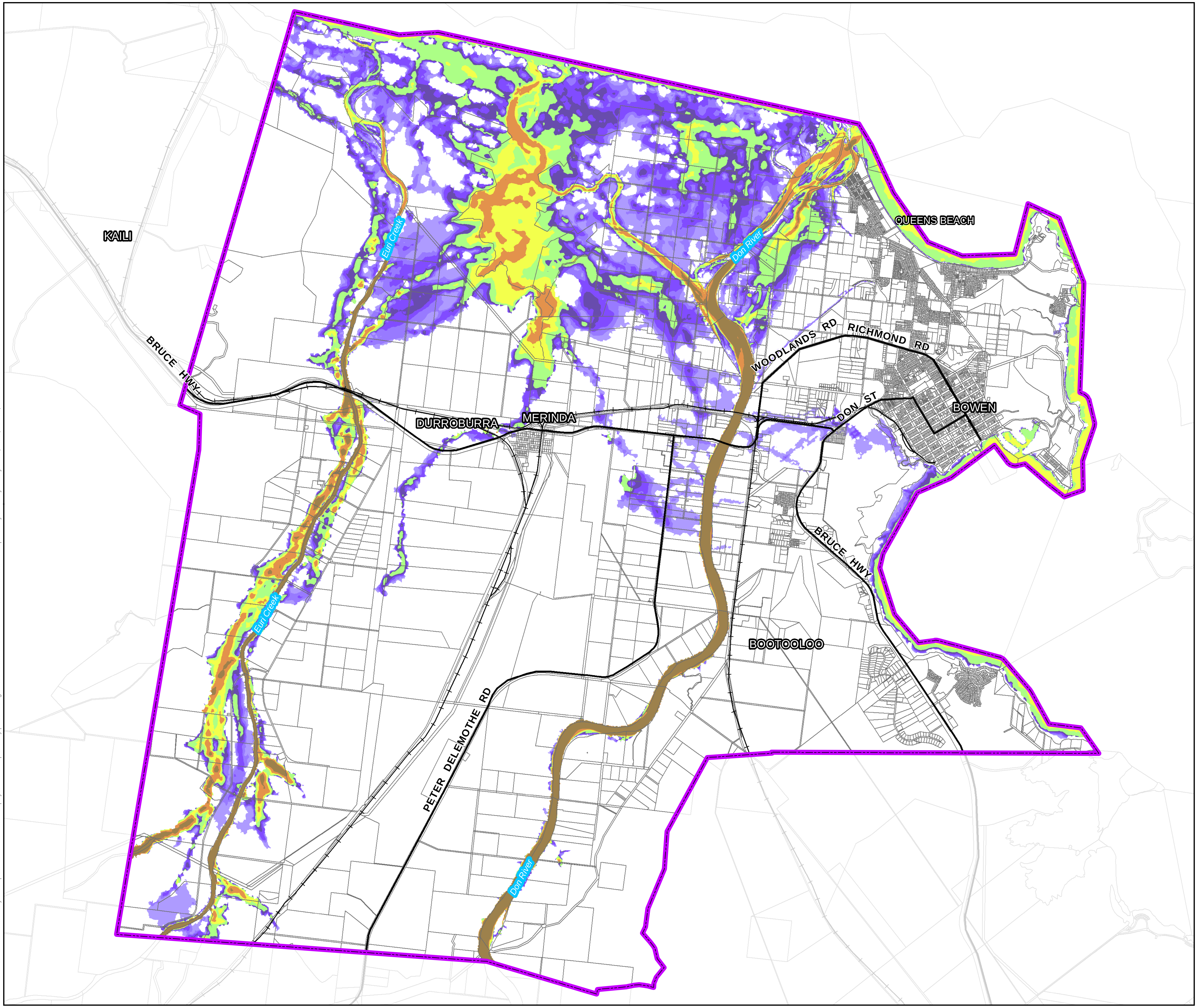
Appendix A

Design Flood Depths and Extents Maps

DON RIVER FLOOD STUDY

Peak Flood Depths
10% AEP Basecase

Appendix A



LEGEND

Don River Hydraulic Model Extent

Water Depths (m)

- 0 - 0.3
- 0.3 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- > 3

0 0.5 1 2 3 4
Kilometres

1:70,000 (when printed at A3)

Coordinate System: GDA 1994 MGA Zone 55

Whitsunday Regional Council

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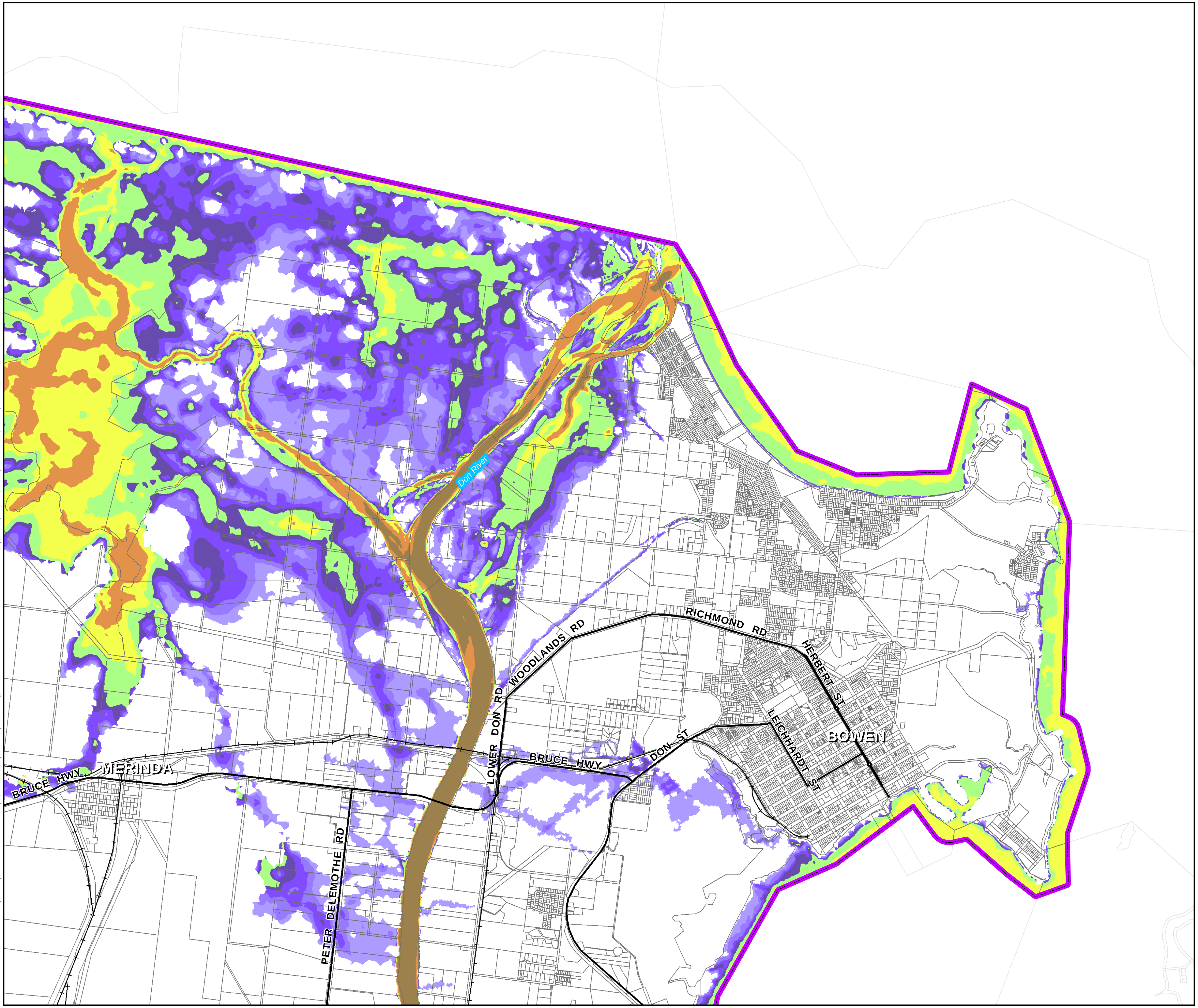
Model - AECOM 2014



DON RIVER FLOOD STUDY

Peak Flood Depths
10% AEP Basecase

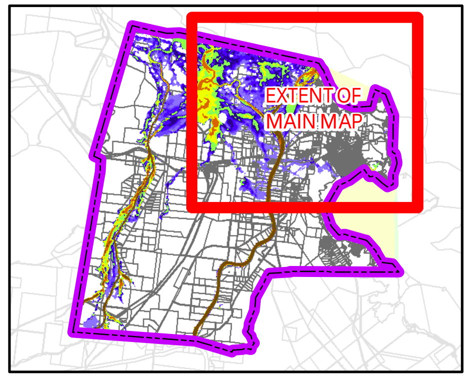
Appendix A

LEGEND

Don River Hydraulic Model Extent

Water Depths (m)

- 0 - 0.3
- 0.3 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- > 3



0 0.5 1 2

Kilometres

1:40,000 (when printed at A3)

1

Coordinate System: GDA 1994 MGA Zone 55

DCDB - QLD Gov 2013.
Model - AECOM 2014

Whitsunday Regional Council

AECOM

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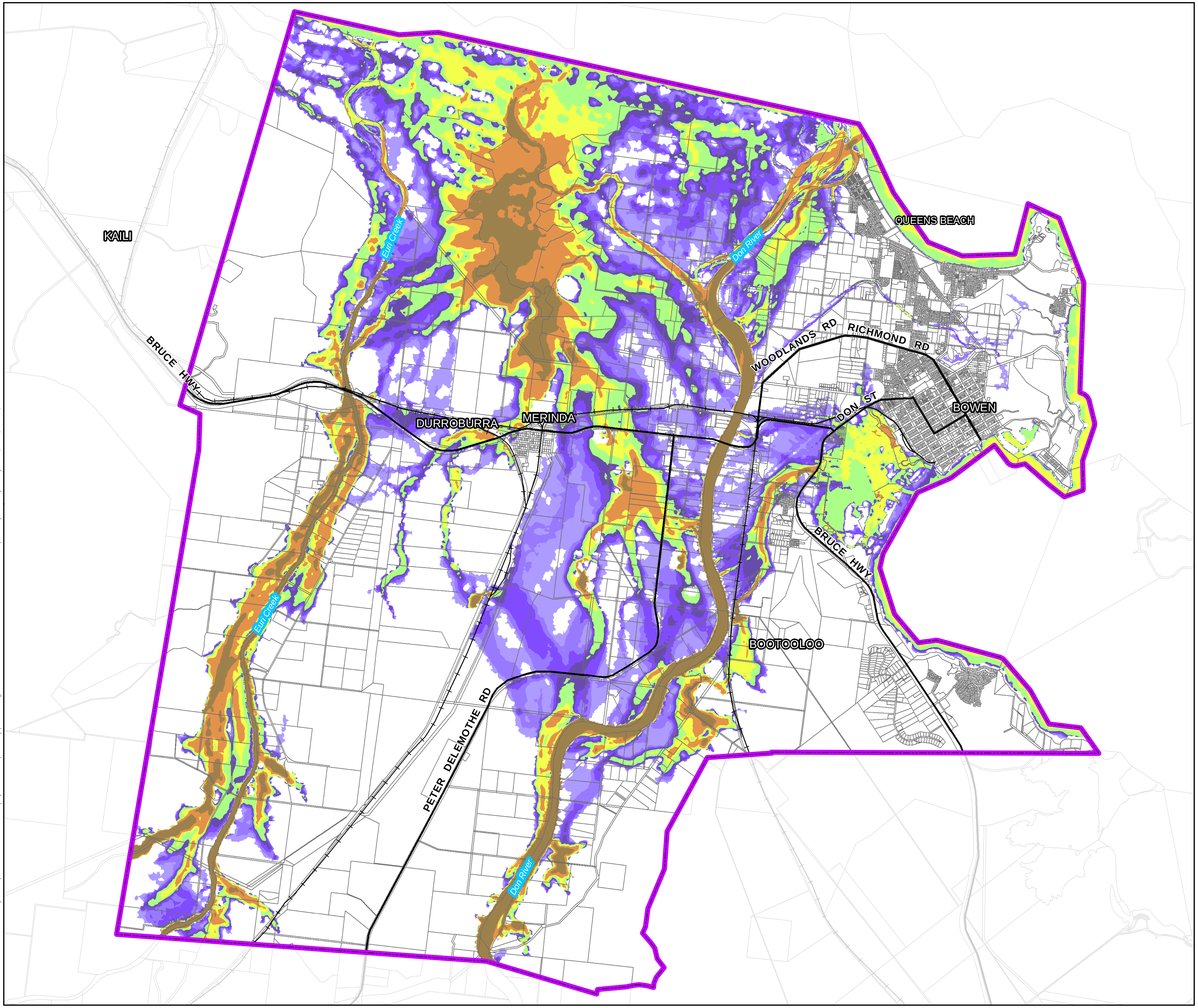
DON RIVER FLOOD STUDY

Peak Flood Depths
2% AEP Basecase

Appendix A



LEGEND

Don River Hydraulic Model Extent

Water Depths (m)

- 0 - 0.3
- 0.3 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- > 3

0 0.5 1 2 3 4
Kilometres

1:70,000 (when printed at A3)

Coordinate System: GDA 1994 MGA Zone 55

Whitsunday Regional Council

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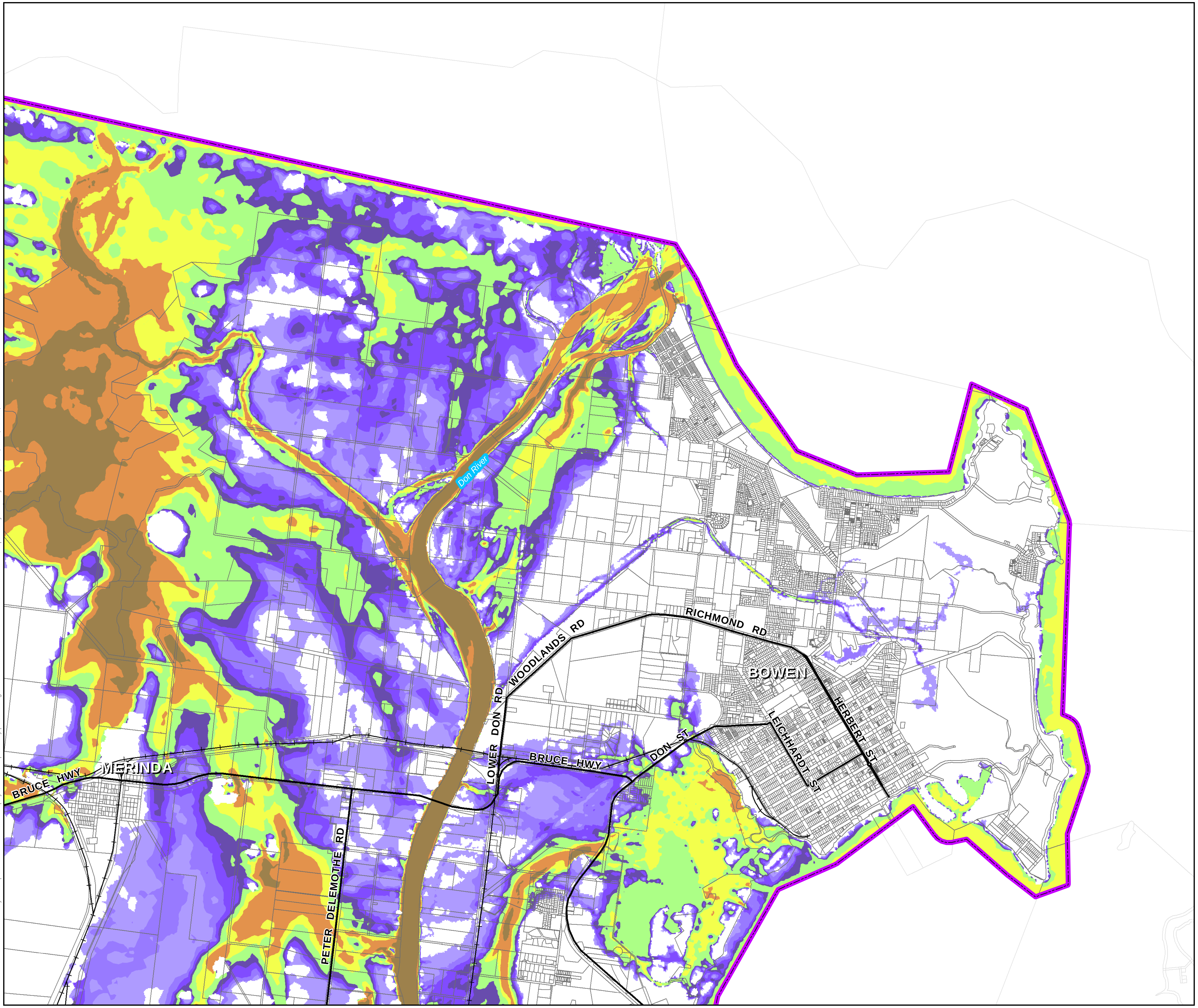
DCDB - QLD Gov 2013.
Model - AECOM 2014



DON RIVER FLOOD STUDY

Peak Flood Depths
2% AEP Basecase

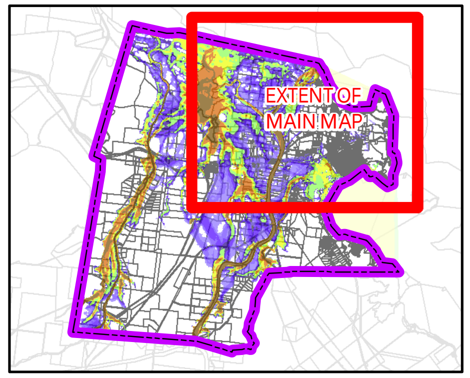
Appendix A

LEGEND

- Don River Hydraulic Model Extent

Water Depths (m)

- 0 - 0.3
- 0.3 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- > 3



0 0.5 1 2
Kilometres

1:40,000 (when printed at A3)

1

Coordinate System: GDA 1994 MGA Zone 55

Whitsunday Regional Council

AECOM

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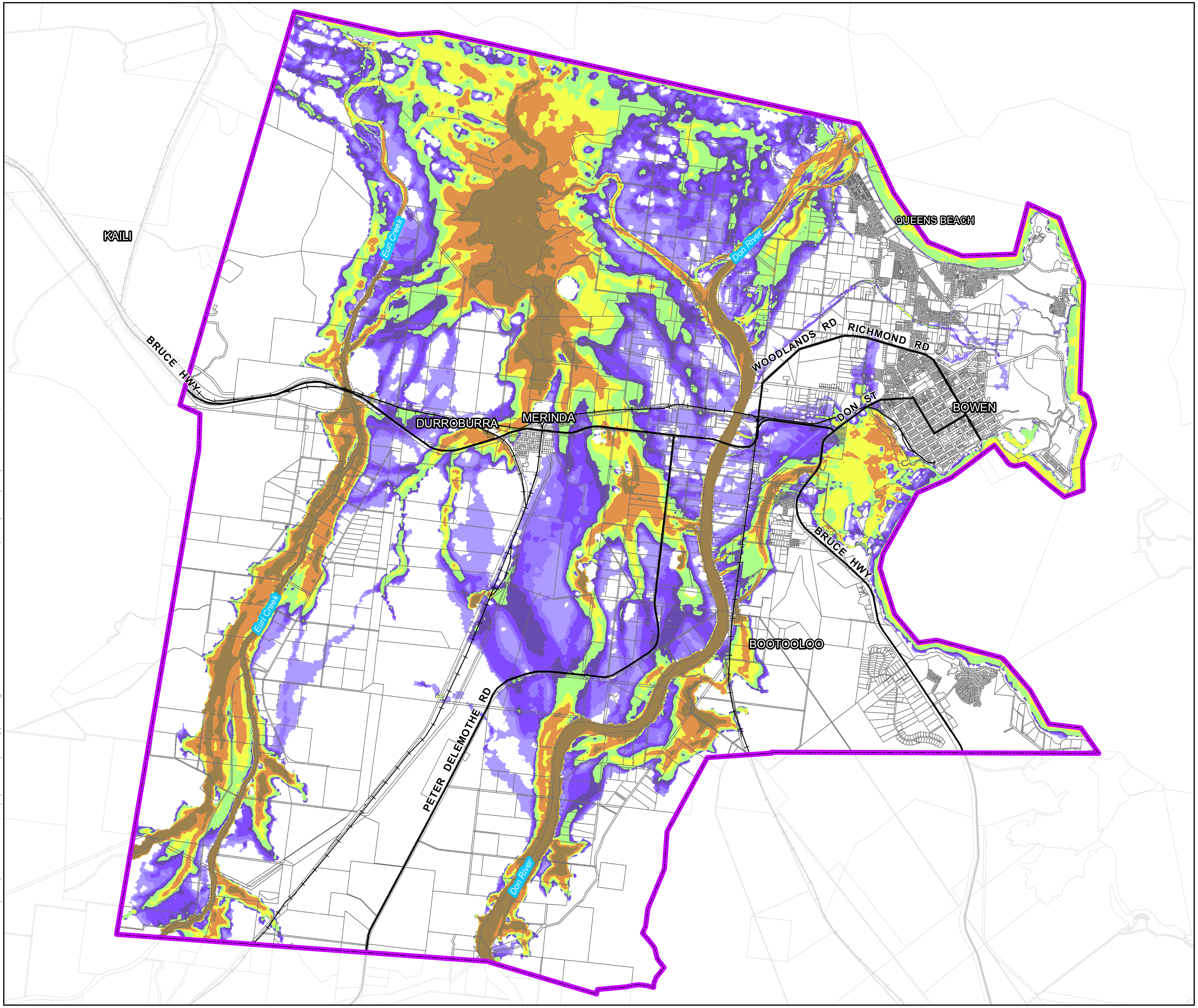
DCDB - QLD Gov 2013.
Model - AECOM 2014



DON RIVER FLOOD STUDY

1% AEP Design

Flood Depths and Extents

Appendix A

0 0.5 1 2 3 4

Kilometres

1:70,000 (when printed at A3)

N

Coordinate System: GDA 1994 MGA Zone 55

Whitsunday Regional Council

AECOM

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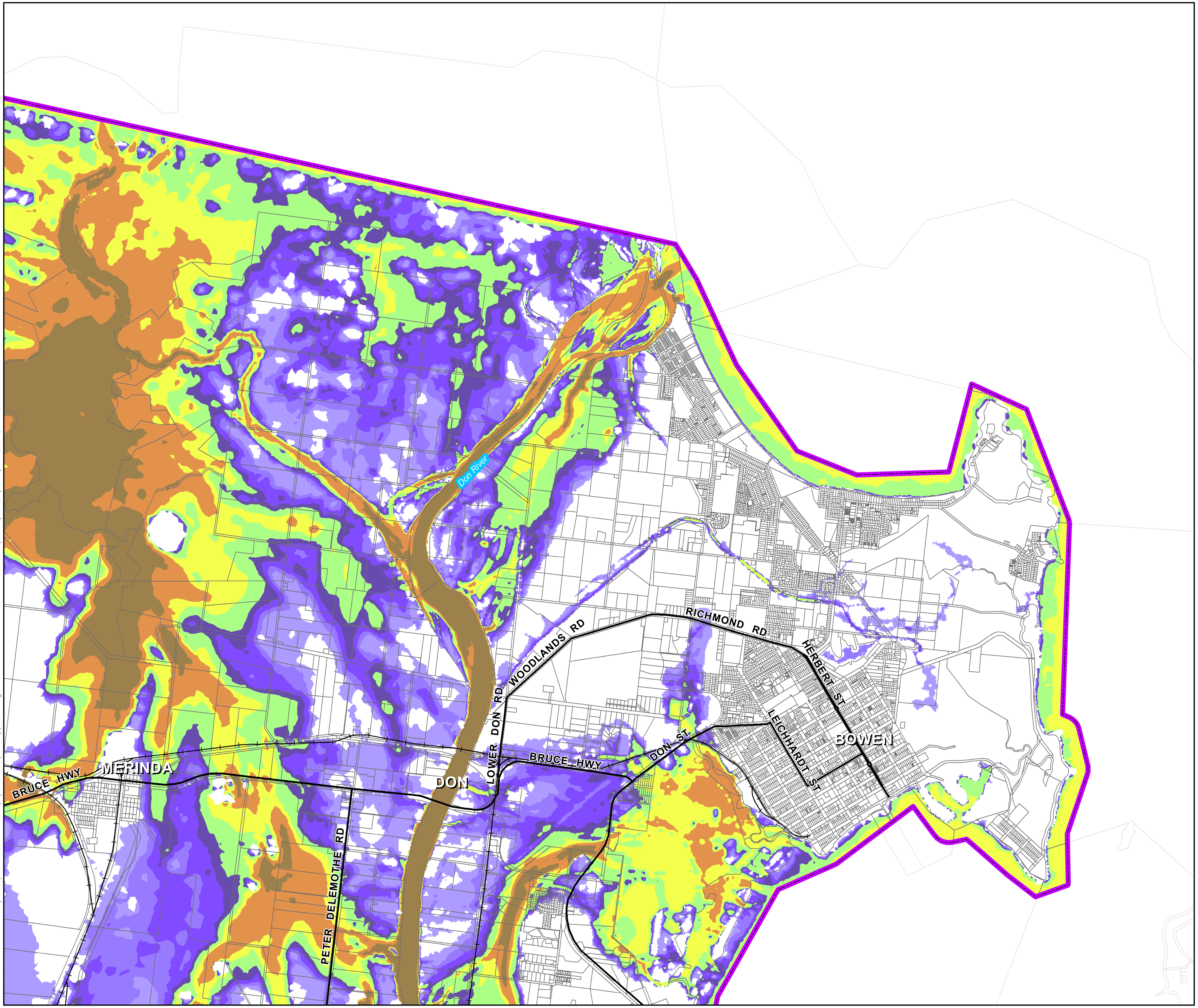
DCDB - QLD Gov 2013.
Model - AECOM 2014



DON RIVER FLOOD STUDY

1% AEP Design

Flood Depths and Extents (zoomed)

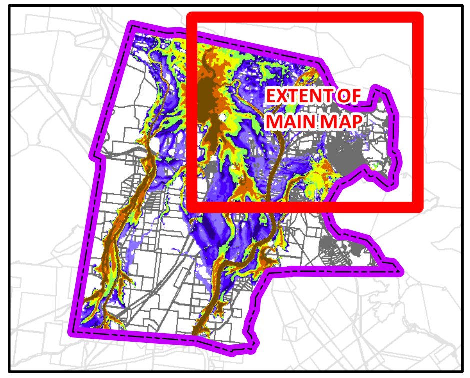
Appendix A

LEGEND

Don River Hydraulic Model Extent

Water Depths (m)

- 0 - 0.3
- 0.3 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- > 3



0 0.5 1 2
Kilometres

1:40,000 (when printed at A3)

N

Coordinate System: GDA 1994 MGA Zone 55

Whitsunday Regional Council

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DCDB - QLD Gov 2013.
Model - AECOM 2014

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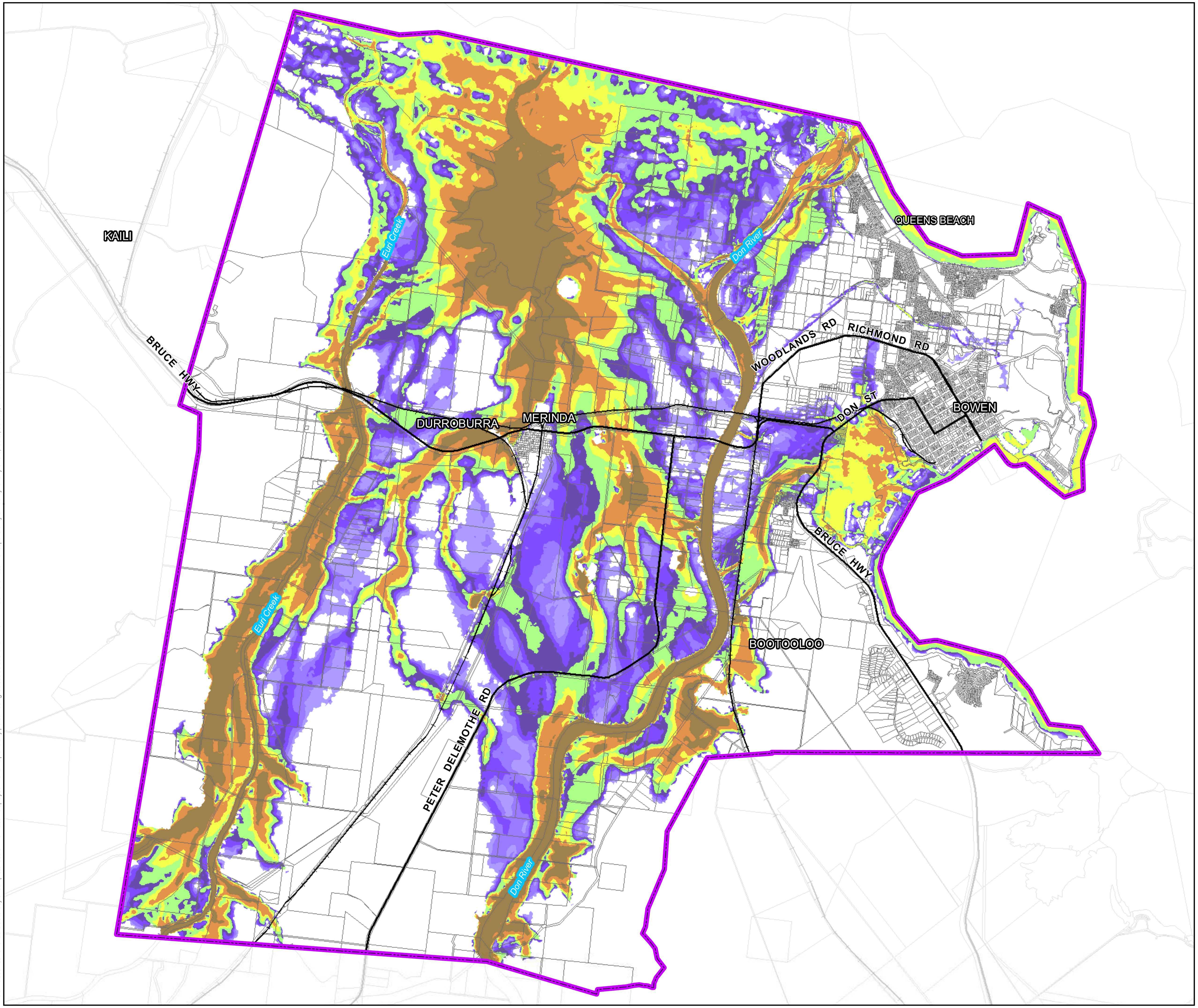
DON RIVER FLOOD STUDY

Peak Flood Depths
0.2% AEP Basecase

Appendix A



0 0.5 1 2 3 4

Kilometres

1:70,000 (when printed at A3)

N

Coordinate System: GDA 1994 MGA Zone 55

DCDB - QLD Gov 2013.
Model - AECOM 2014

AECOM

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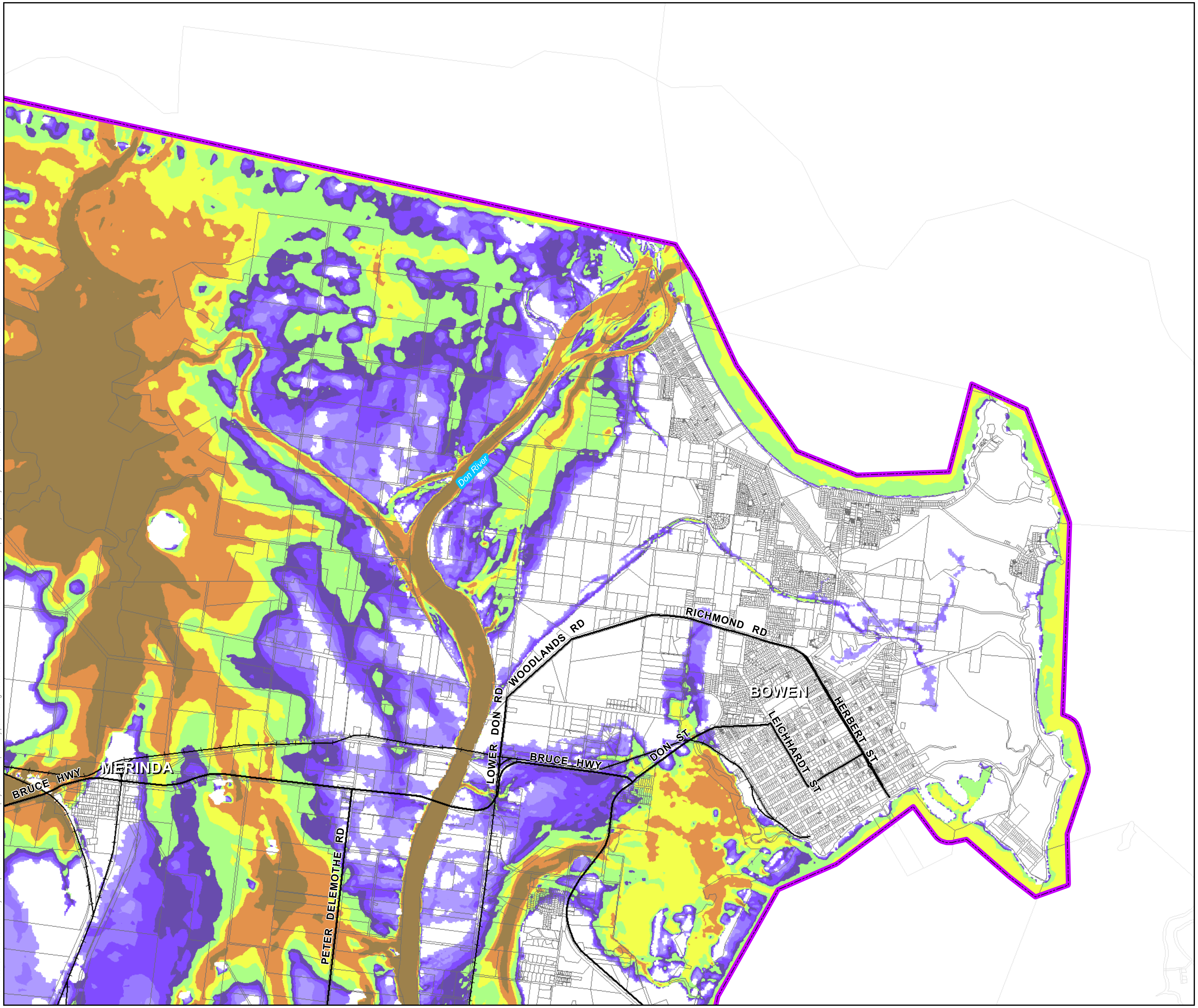


DON RIVER FLOOD STUDY

Peak Flood Depths
0.2% AEP Basecase (zoomed)

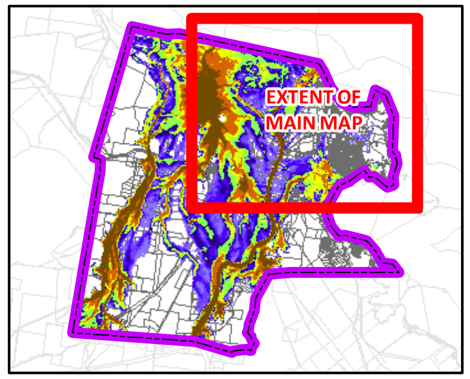
Appendix A

LEGEND

Don River Hydraulic Model Extent

Water Depths (m)

- 0 - 0.3
- 0.3 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- > 3



0 0.5 1 2
Kilometres

1:40,000 (when printed at A3)

Coordinate System: GDA 1994 MGA Zone 55

DCDB - QLD Gov 2013.
Model - AECOM 2014

AECOM
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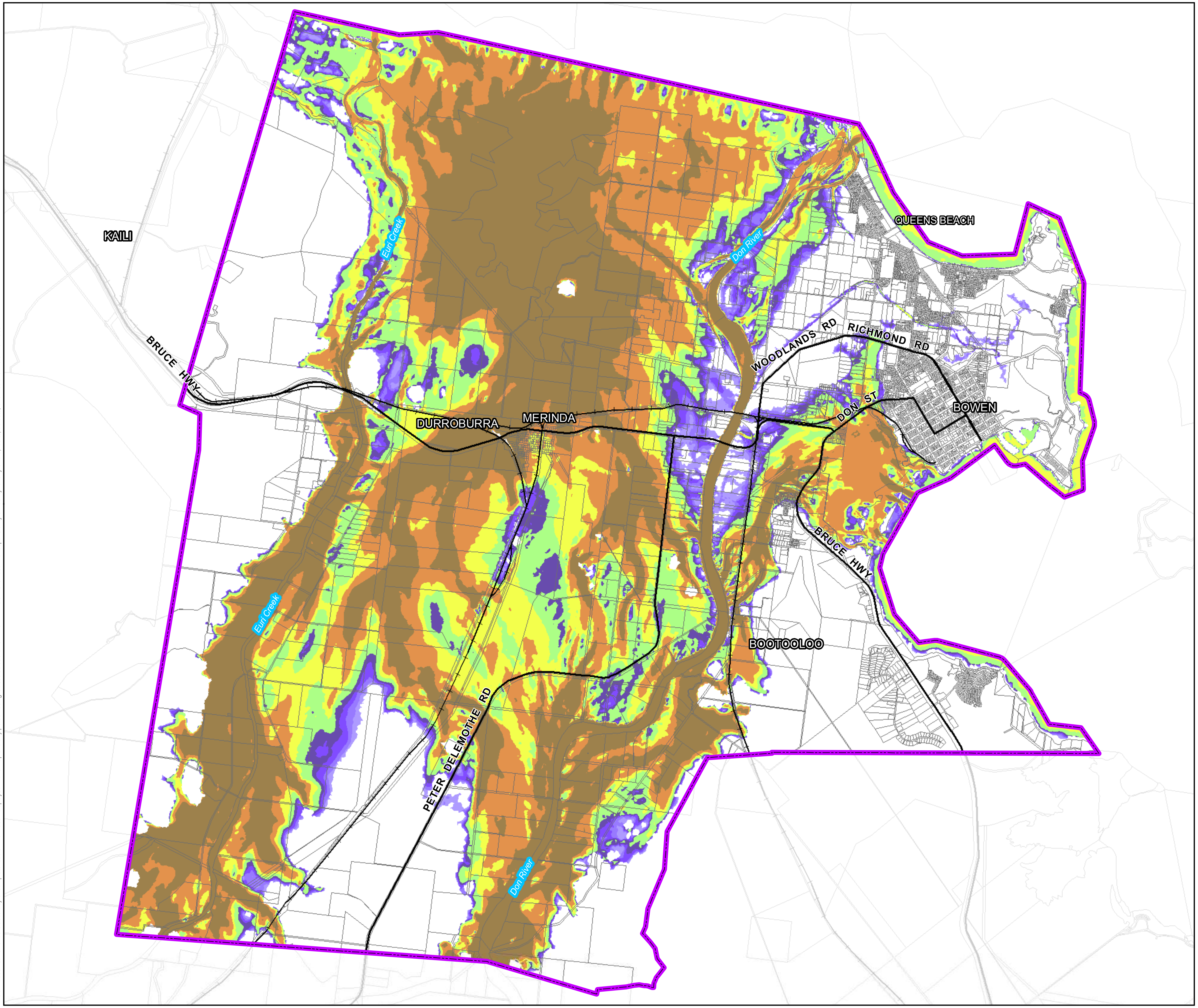

DON RIVER FLOOD STUDY

Peak Flood Depths
PMF

Appendix A

LEGEND

Don River Hydraulic Model Extent

Water Depths (m)

- 0 - 0.3
- 0.3 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- > 3

0 0.5 1 2 3 4
Kilometres

1:70,000 (when printed at A3)

N

Coordinate System: GDA 1994 MGA Zone 55

DCDB - QLD Gov 2013.
Model - AECOM 2014

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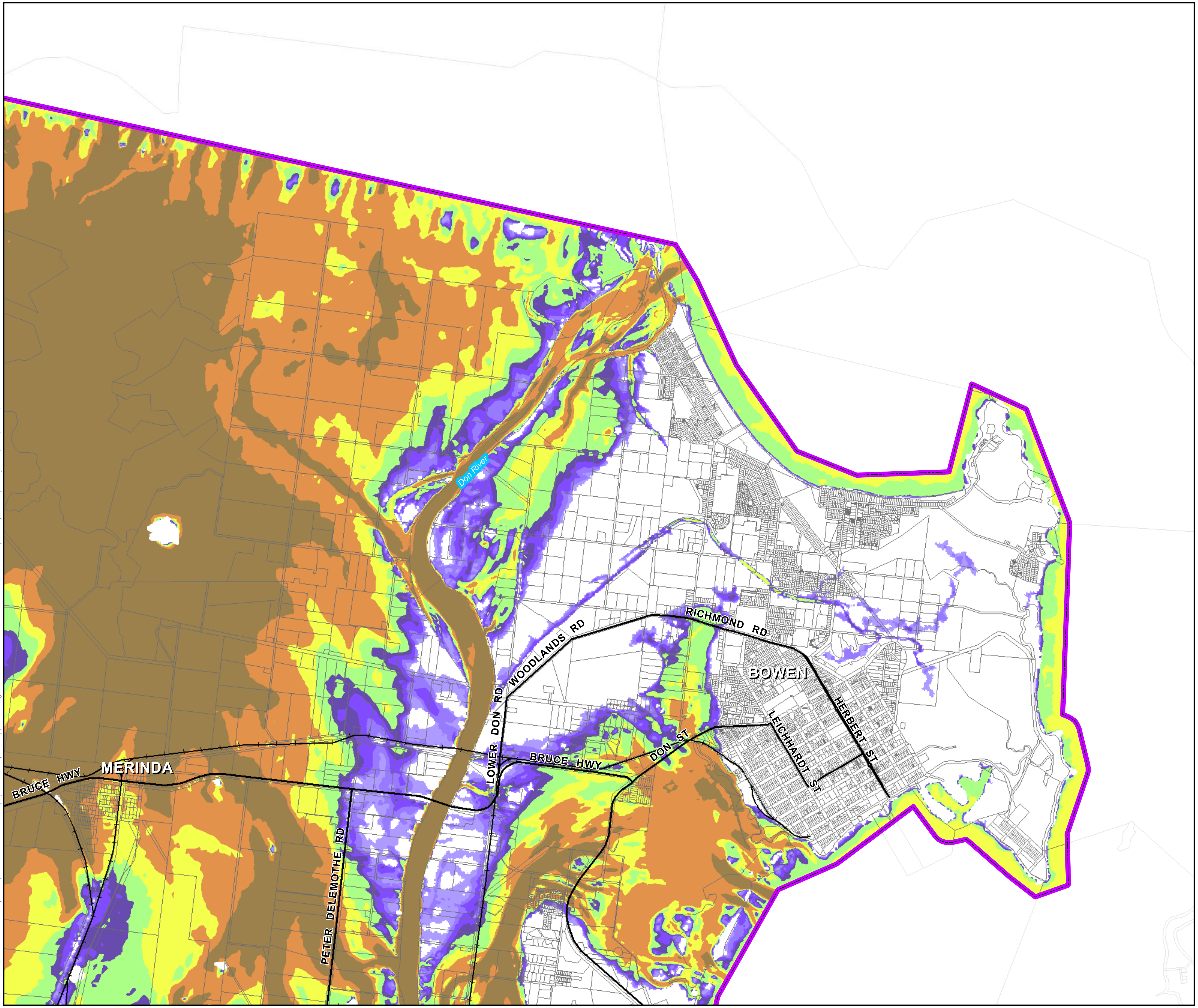
DON RIVER FLOOD STUDY

Peak Flood Depths
PMF (zoomed)

Appendix A

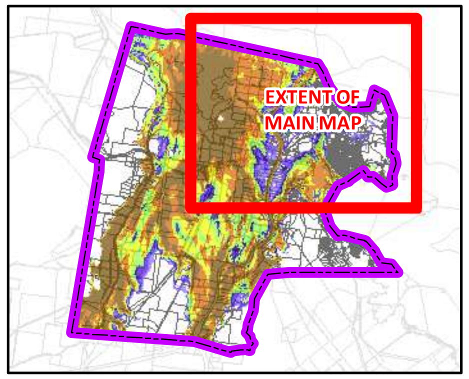


LEGEND

Don River Hydraulic Model Extent

Water Depths (m)

- 0 - 0.3
- 0.3 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- > 3



0 0.5 1 2
Kilometres

1:40,000 (when printed at A3)

N

Coordinate System: GDA 1994 MGA Zone 55

DCDB - QLD Gov 2013.
Model - AECOM 2014

AECOM
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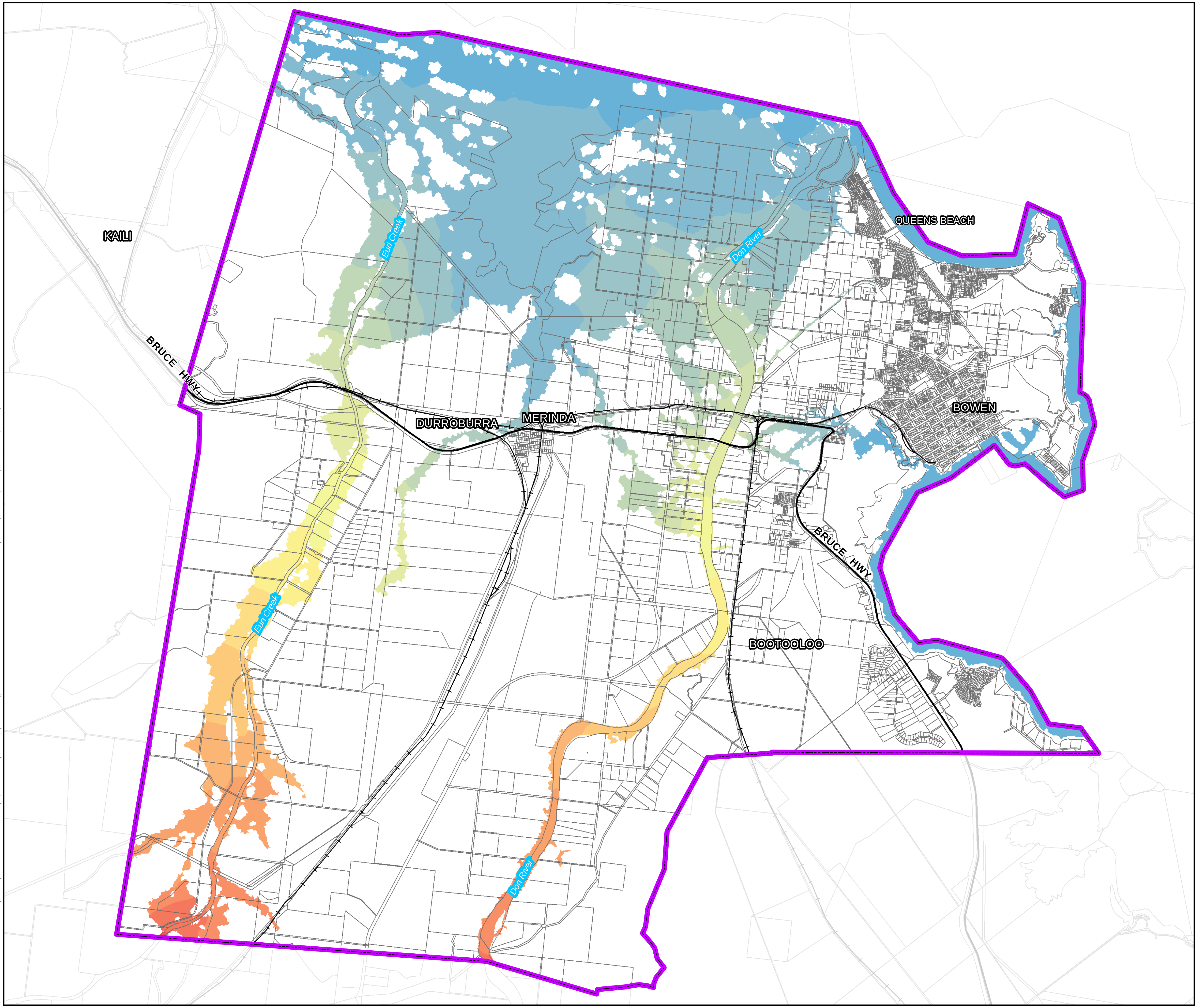
Appendix B

Design Flood Elevation Maps

DON RIVER FLOOD STUDY

Peak Water Surface Elevation
10% AEP Basecase

Appendix B



LEGEND

Don River Hydraulic Model Extent

Levels (m AHD)

- < - 2.0
- 2.1 - 4.0
- 4.1 - 6.0
- 6.1 - 8.0
- 8.1 - 10.0
- 11.1 - 12.0
- 13.1 - 14.0
- 15.1 - 16.0
- 17.1 - 18.0
- 19.1 - 20.0
- 21.1 - 22.0
- 23.1 - 24.0
- 25.1 - 26.0
- 27.1 - 28.0
- 29.1 - 30.0
- > 31.0

0 0.5 1 2 3 4
Kilometres

1:70,000 (when printed at A3)

Coordinate System: GDA 1994 MGA Zone 55

DCDB - QLD Gov 2013.
Model - AECOM 2014

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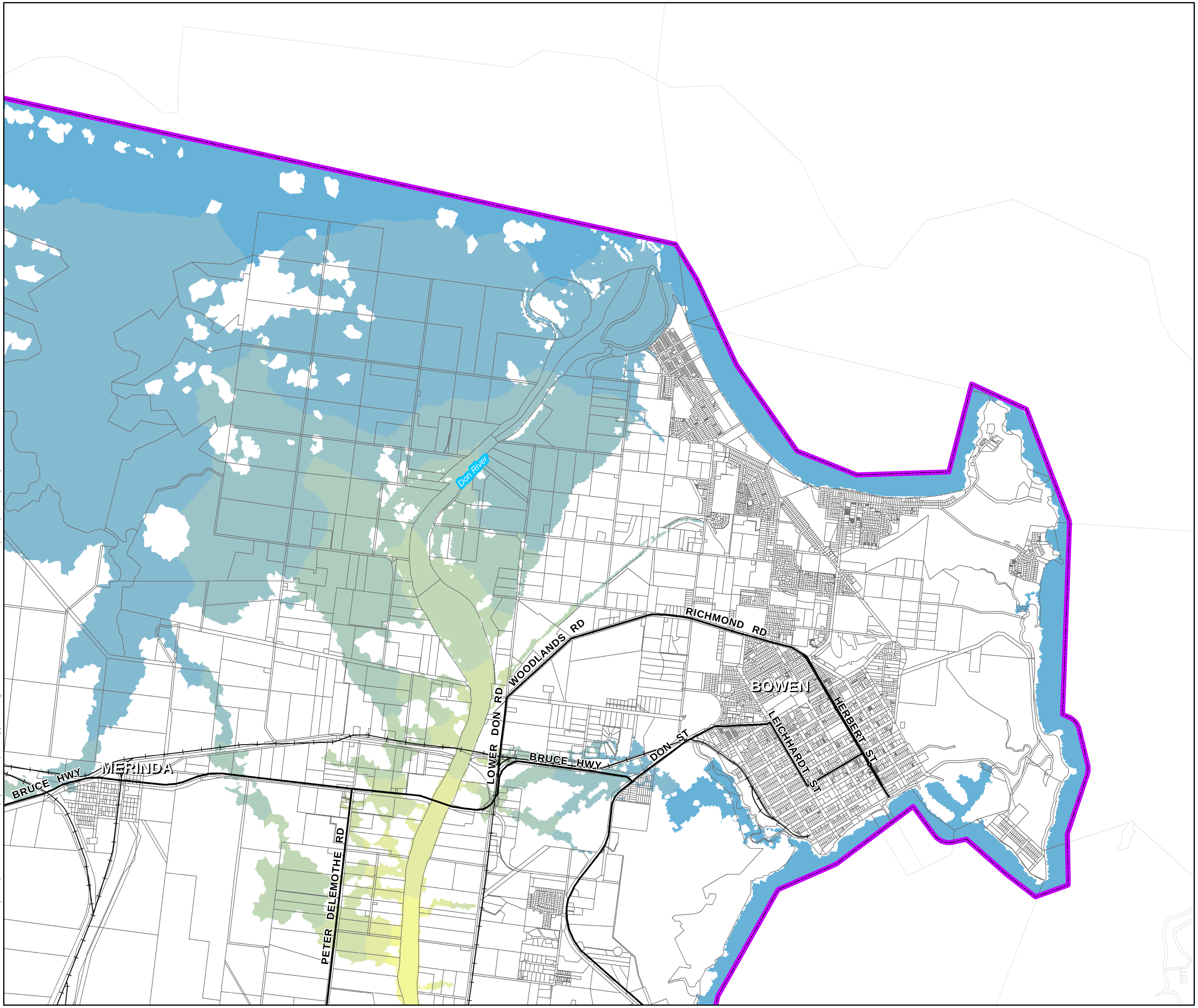


DON RIVER FLOOD STUDY

Peak Water Surface Elevation
10% AEP Basecase

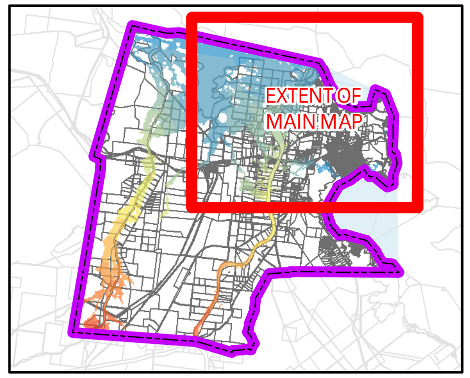
Appendix B

LEGEND

Don River Hydraulic Model Extent

Levels (m AHD)

- < - 2.0
- 2.1 - 4.0
- 4.1 - 6.0
- 6.1 - 8.0
- 8.1 - 10.0
- 11.1 - 12.0
- 13.1 - 14.0
- 15.1 - 16.0
- 17.1 - 18.0
- 19.1 - 20.0
- 21.1 - 22.0
- 23.1 - 24.0
- 25.1 - 26.0
- 27.1 - 28.0
- 29.1 - 30.0
- > 31.0



0 0.5 1 2
Kilometres

1

1:40,000 (when printed at A3)

Coordinate System: GDA 1994 MGA Zone 55

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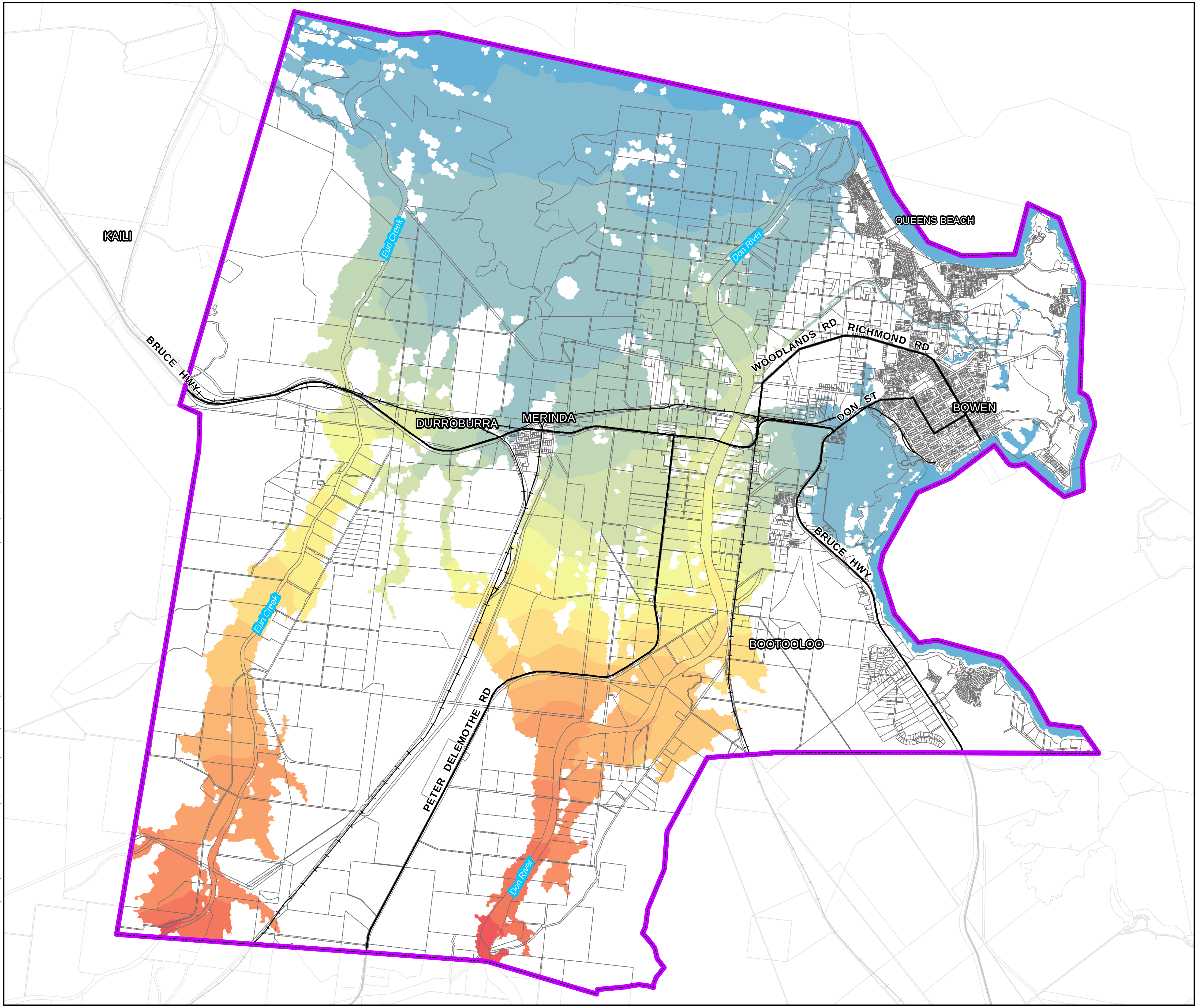
DCDB - QLD Gov 2013.
Model - AECOM 2014



DON RIVER FLOOD STUDY

Peak Water Surface Elevation
2% AEP Basecase

Appendix B

LEGEND

Don River Hydraulic Model Extent

Levels (m AHD)

- < - 2.0
- 2.1 - 4.0
- 4.1 - 6.0
- 6.1 - 8.0
- 8.1 - 10.0
- 11.1 - 12.0
- 13.1 - 14.0
- 15.1 - 16.0
- 17.1 - 18.0
- 19.1 - 20.0
- 21.1 - 22.0
- 23.1 - 24.0
- 25.1 - 26.0
- 27.1 - 28.0
- 29.1 - 30.0
- > 31.0

0 0.5 1 2 3 4
Kilometres

1:70,000 (when printed at A3)

Coordinate System: GDA 1994 MGA Zone 55

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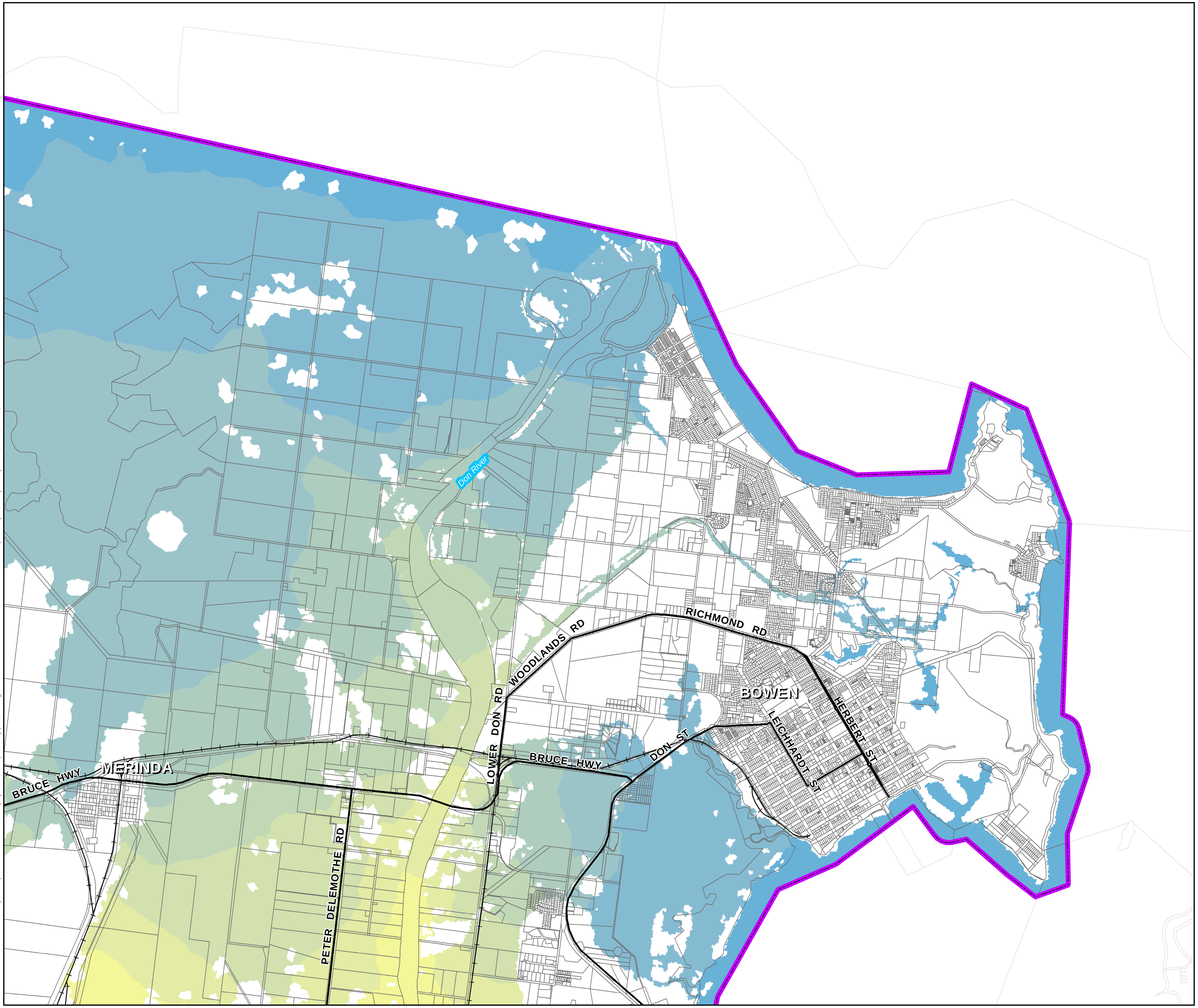
DCDB - QLD Gov 2013.
Model - AECOM 2014



DON RIVER FLOOD STUDY

Peak Water Surface Elevation
2% AEP Basecase

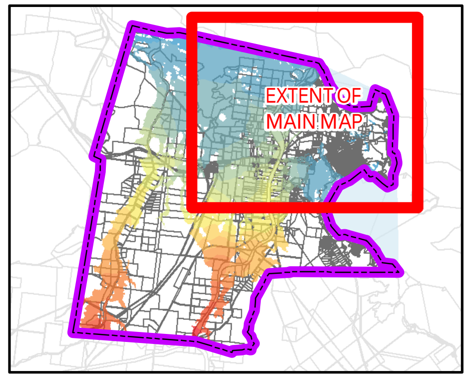
Appendix B

LEGEND

Don River Hydraulic Model Extent

Levels (m AHD)

- < - 2.0
- 2.1 - 4.0
- 4.1 - 6.0
- 6.1 - 8.0
- 8.1 - 10.0
- 11.1 - 12.0
- 13.1 - 14.0
- 15.1 - 16.0
- 17.1 - 18.0
- 19.1 - 20.0
- 21.1 - 22.0
- 23.1 - 24.0
- 25.1 - 26.0
- 27.1 - 28.0
- 29.1 - 30.0
- > 31.0



0 0.5 1 2
Kilometres

1:40,000 (when printed at A3)

1

Coordinate System: GDA 1994 MGA Zone 55

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DCDB - QLD Gov 2013.
Model - AECOM 2014

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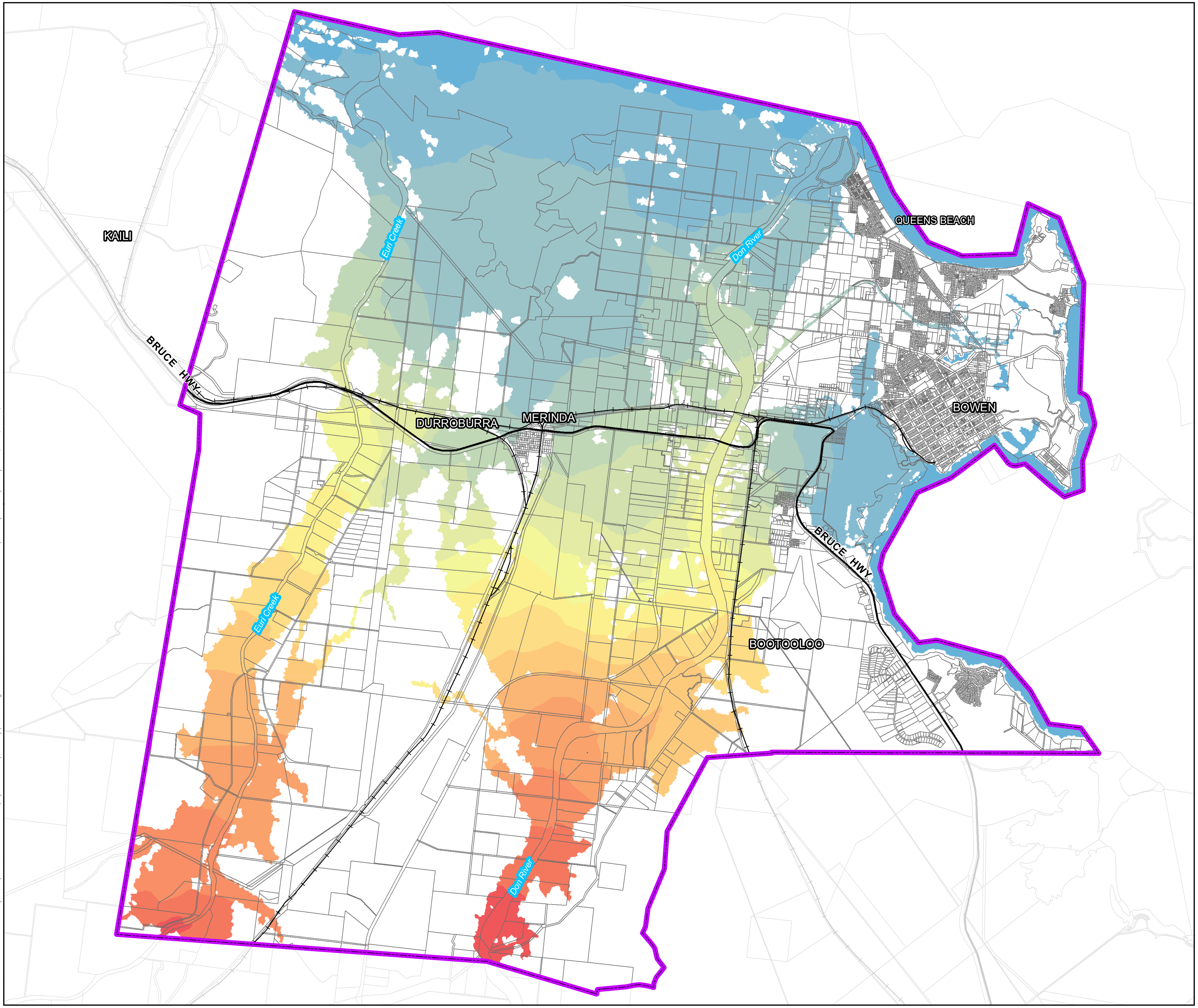
DON RIVER FLOOD STUDY 1% AEP Design Flood Elevations

Appendix B



LEGEND

Don River Hydraulic Model Extent

Levels (m AHD)

- < - 2.0
- 2.1 - 4.0
- 4.1 - 6.0
- 6.1 - 8.0
- 8.1 - 10.0
- 11.1 - 12.0
- 13.1 - 14.0
- 15.1 - 16.0
- 17.1 - 18.0
- 19.1 - 20.0
- 21.1 - 22.0
- 23.1 - 24.0
- 25.1 - 26.0
- 27.1 - 28.0
- 29.1 - 30.0
- > 31.0

0 0.5 1 2 3 4

Kilometres

1:70,000 (when printed at A3)

N

Coordinate System: GDA 1994 MGA Zone 55

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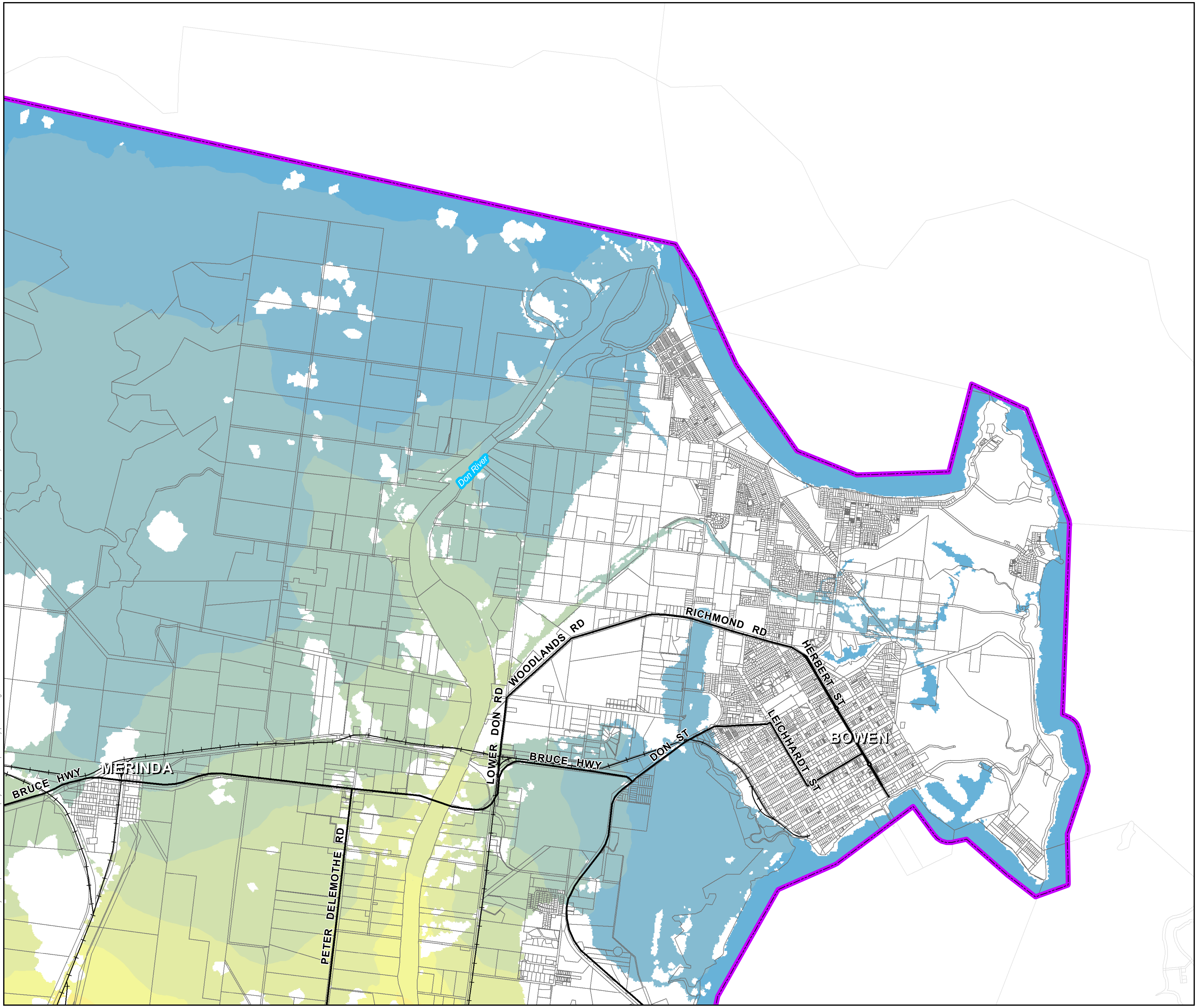
Model - AECOM 2014



DON RIVER FLOOD STUDY

1% AEP Design

Flood Elevations (zoomed)

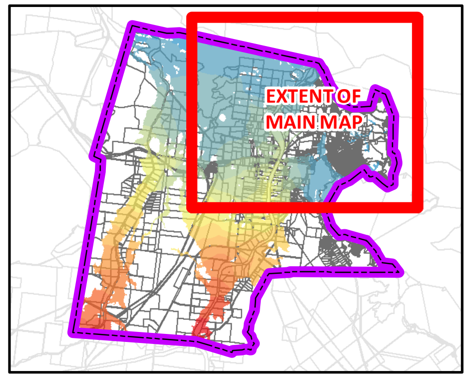
Appendix B

LEGEND

Don River Hydraulic Model Extent

Levels (m AHD)

- < - 2.0
- 2.1 - 4.0
- 4.1 - 6.0
- 6.1 - 8.0
- 8.1 - 10.0
- 11.1 - 12.0
- 13.1 - 14.0
- 15.1 - 16.0
- 17.1 - 18.0
- 19.1 - 20.0
- 21.1 - 22.0
- 23.1 - 24.0
- 25.1 - 26.0
- 27.1 - 28.0
- 29.1 - 30.0
- > 31.0



0 0.5 1 2

Kilometres

1:40,000 (when printed at A3)

N

Coordinate System: GDA 1994 MGA Zone 55

Whitsunday Regional Council

AECOM

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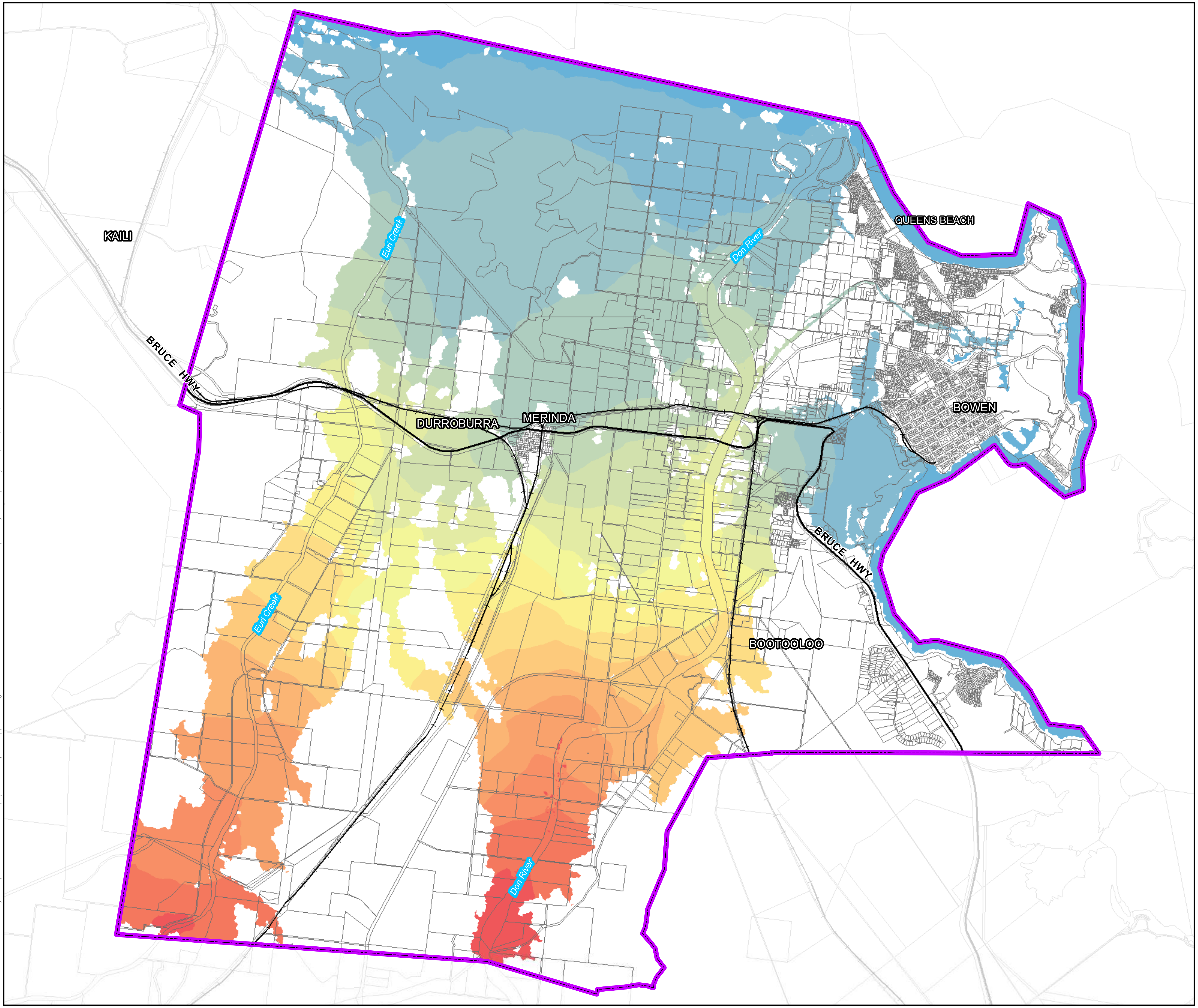
DCDB - QLD Gov 2013.
Model - AECOM 2014

DON RIVER FLOOD STUDY

Peak Water Surface Levels
0.2% AEP Basecase

Appendix B



LEGEND

Don River Hydraulic Model Extent

Levels (m AHD)

- < - 2.0
- 2.1 - 4.0
- 4.1 - 6.0
- 6.1 - 8.0
- 8.1 - 10.0
- 11.1 - 12.0
- 13.1 - 14.0
- 15.1 - 16.0
- 17.1 - 18.0
- 19.1 - 20.0
- 21.1 - 22.0
- 23.1 - 24.0
- 25.1 - 26.0
- 27.1 - 28.0
- 29.1 - 30.0
- > 31.0

0 0.5 1 2 3 4

Kilometres

1:70,000 (when printed at A3)

Coordinate System: GDA 1994 MGA Zone 55

DCDB - QLD Gov 2013.
Model - AECOM 2014

AECOM

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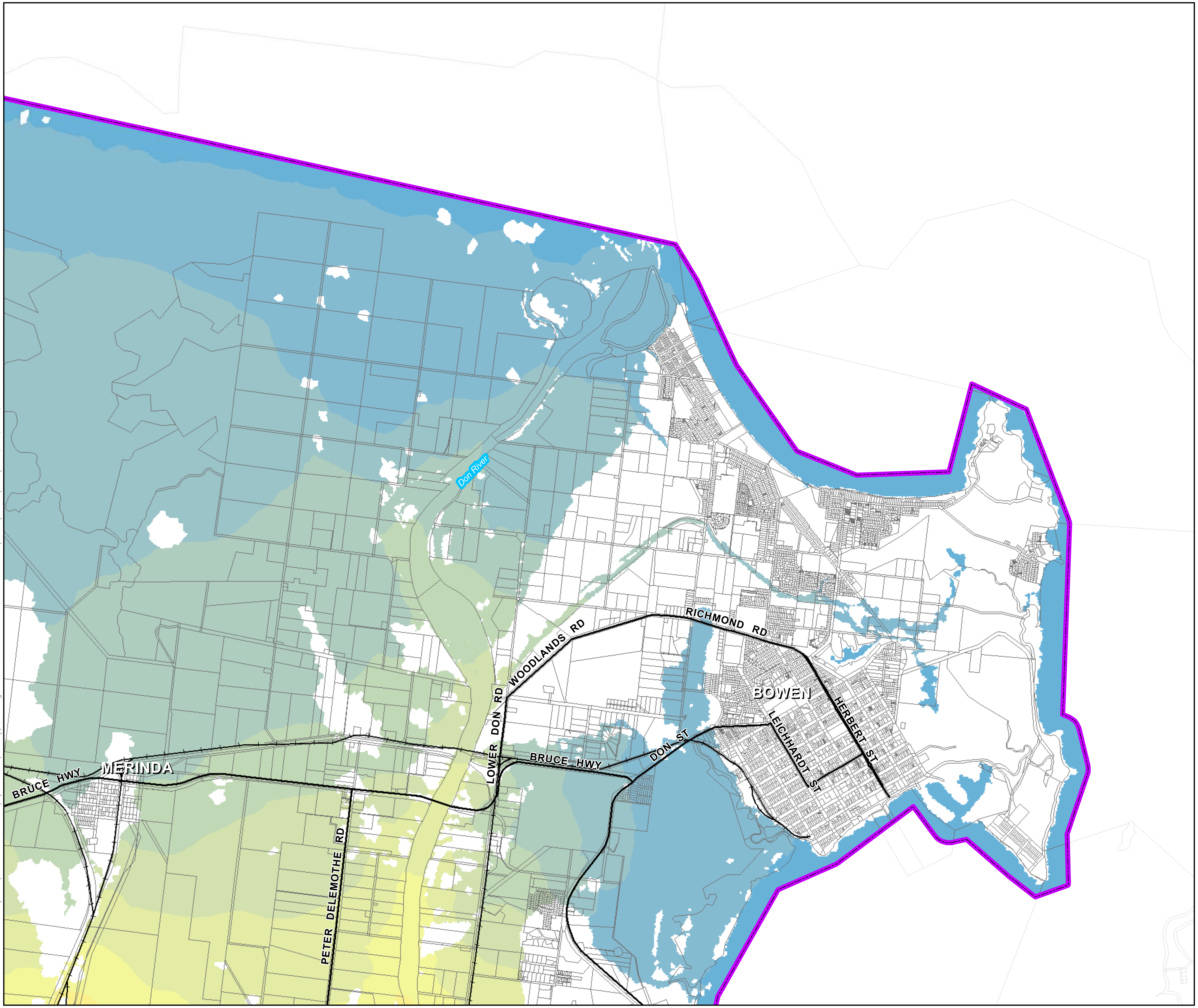
DON RIVER FLOOD STUDY

Peak Water Surface Elevation 0.2% AEP Basecase (zoomed)

Appendix B

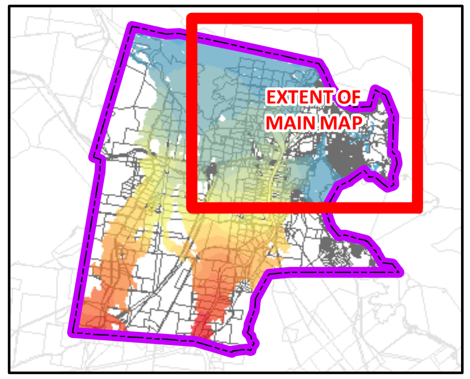


LEGEND

Don River Hydraulic Model Extent

Levels (m AHD)

- < - 2.0
- 2.1 - 4.0
- 4.1 - 6.0
- 6.1 - 8.0
- 8.1 - 10.0
- 11.1 - 12.0
- 13.1 - 14.0
- 15.1 - 16.0
- 17.1 - 18.0
- 19.1 - 20.0
- 21.1 - 22.0
- 23.1 - 24.0
- 25.1 - 26.0
- 27.1 - 28.0
- 29.1 - 30.0
- > 31.0



0 0.5 1 2

Kilometres

1:40,000 (when printed at A3)

N

Coordinate System: GDA 1994 MGA Zone 55

DCDB - QLD Gov 2013.
Model - AECOM 2014

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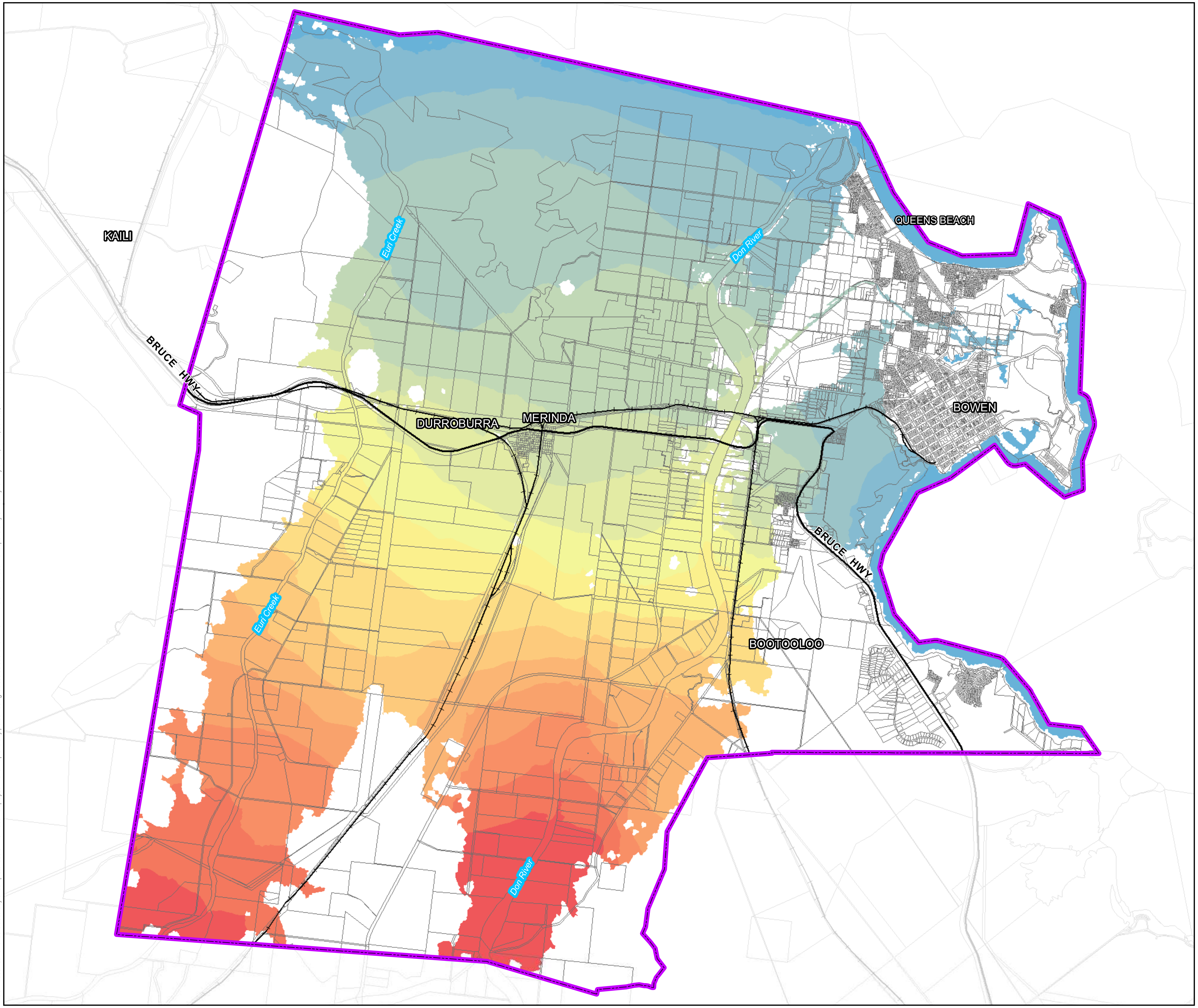
DON RIVER FLOOD STUDY

Peak Water Surface Levels PMF

Appendix B



LEGEND

Don River Hydraulic Model Extent

Levels (m AHD)

- < - 2.0
- 2.1 - 4.0
- 4.1 - 6.0
- 6.1 - 8.0
- 8.1 - 10.0
- 11.1 - 12.0
- 13.1 - 14.0
- 15.1 - 16.0
- 17.1 - 18.0
- 19.1 - 20.0
- 21.1 - 22.0
- 23.1 - 24.0
- 25.1 - 26.0
- 27.1 - 28.0
- 29.1 - 30.0
- > 31.0

0 0.5 1 2 3 4

Kilometres

1:70,000 (when printed at A3)

N

Coordinate System: GDA 1994 MGA Zone 55

DCDB - QLD Gov 2013.
Model - AECOM 2014

AECOM

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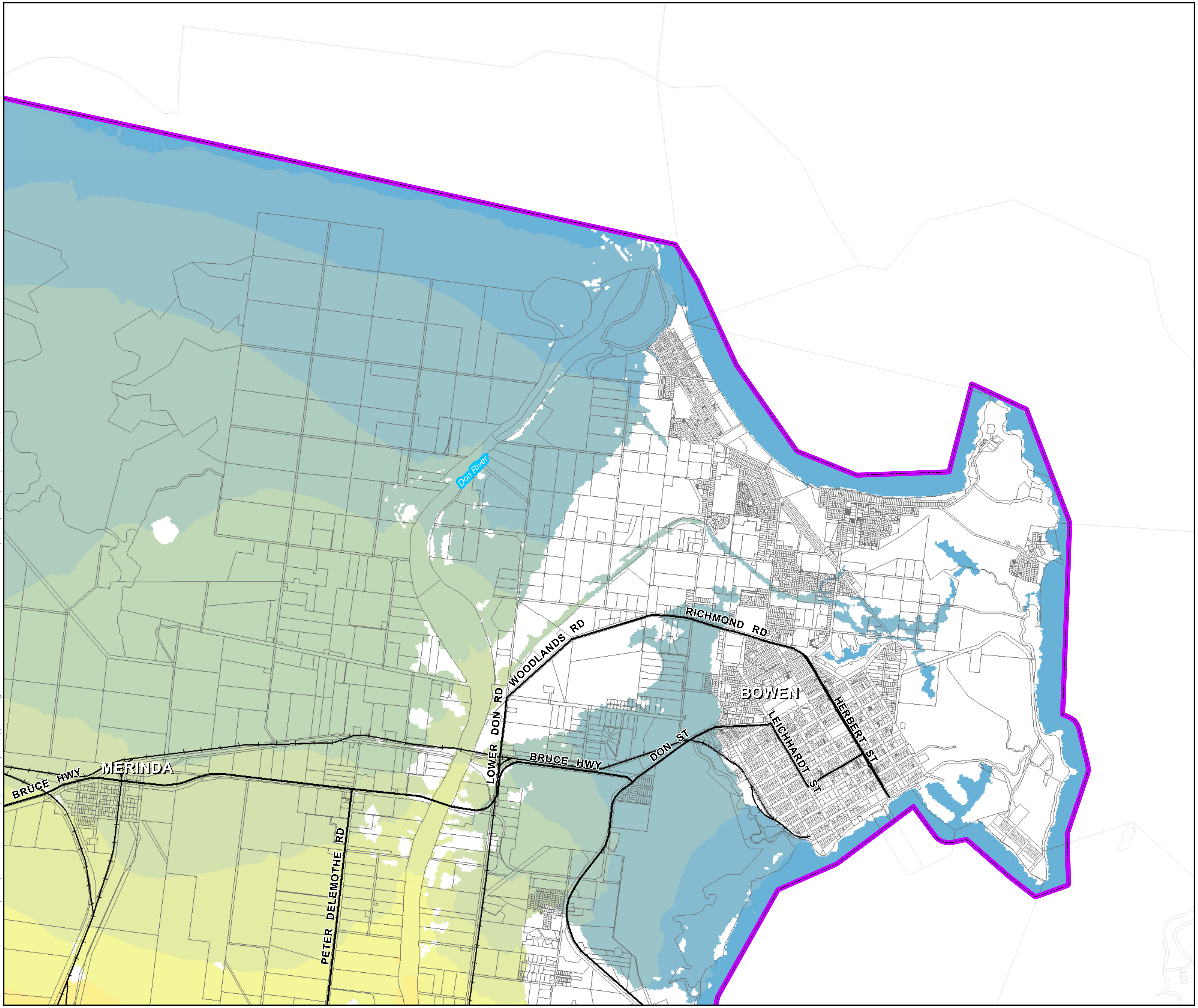


DON RIVER FLOOD STUDY

Peak Water Surface Levels
PMF (zoomed)

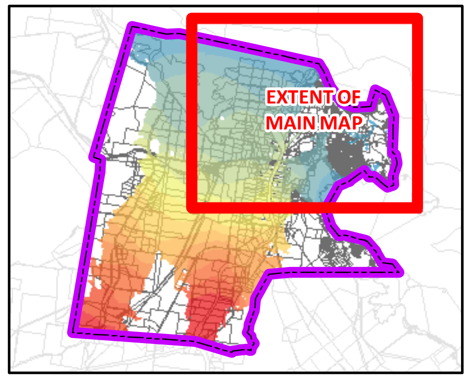
Appendix B

LEGEND

Don River Hydraulic Model Extent

Levels (m AHD)

- < - 2.0
- 2.1 - 4.0
- 4.1 - 6.0
- 6.1 - 8.0
- 8.1 - 10.0
- 11.1 - 12.0
- 13.1 - 14.0
- 15.1 - 16.0
- 17.1 - 18.0
- 19.1 - 20.0
- 21.1 - 22.0
- 23.1 - 24.0
- 25.1 - 26.0
- 27.1 - 28.0
- 29.1 - 30.0
- > 31.0



0 0.5 1 2
Kilometres

1:40,000 (when printed at A3)

Coordinate System: GDA 1994 MGA Zone 55

DCDB - QLD Gov 2013.
Model - AECOM 2014

AECOM
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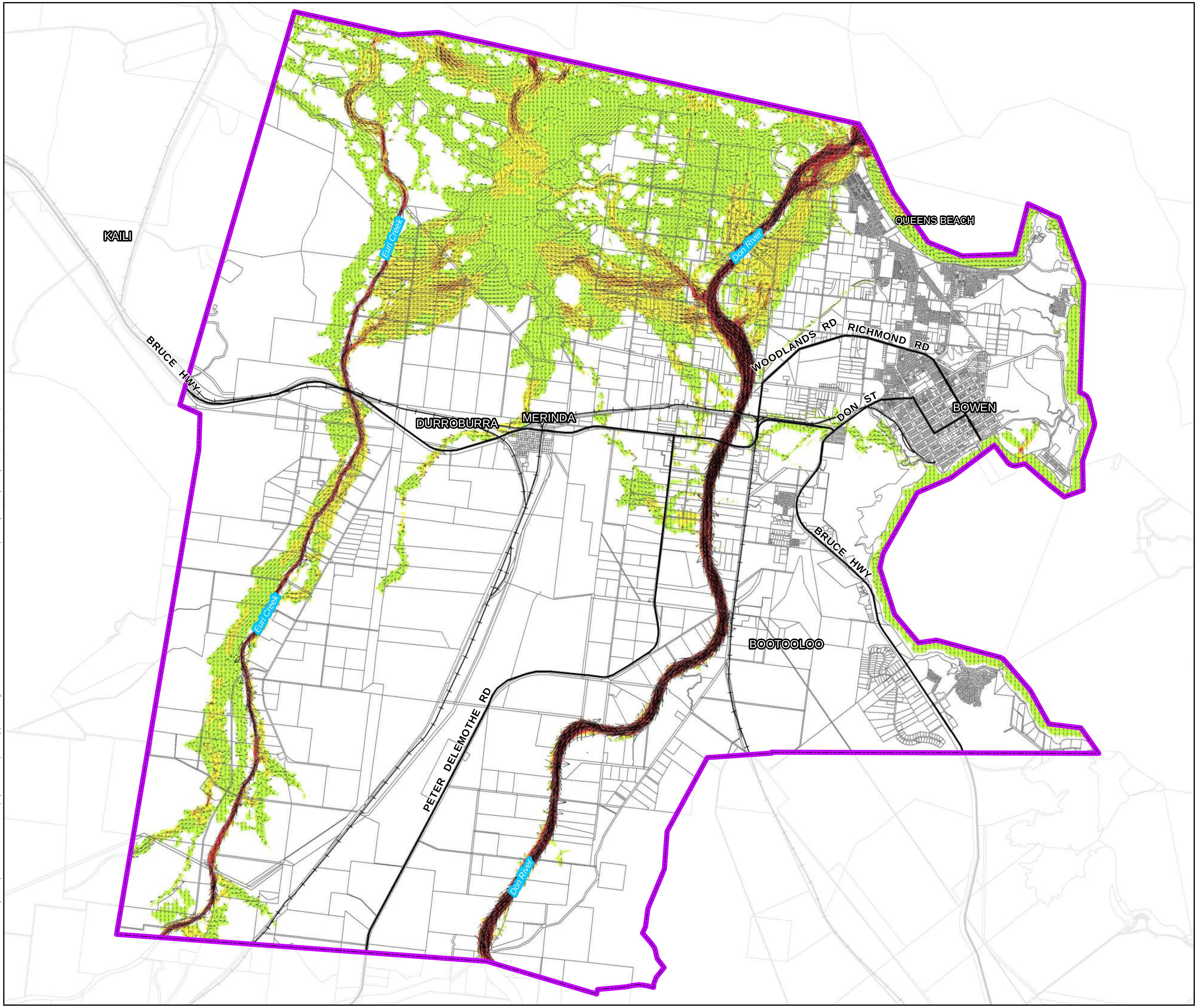
Appendix C

Design Flood Velocity Maps



DON RIVER FLOOD STUDY

Peak Velocity
10% AEP Basecase

Appendix C

LEGEND

Don River Hydraulic Model Extent

Velocity Vectors (m/s)
- 0.00 - 0.50
- 0.50 - 1.00
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

Velocity (m/s)
- 0.0 - 0.5
- 0.5 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5

0 0.5 1 2 3 4
Kilometres

1:70,000 (when printed at A3)

Coordinate System: GDA 1994 MGA Zone 55

Whitsunday Regional Council

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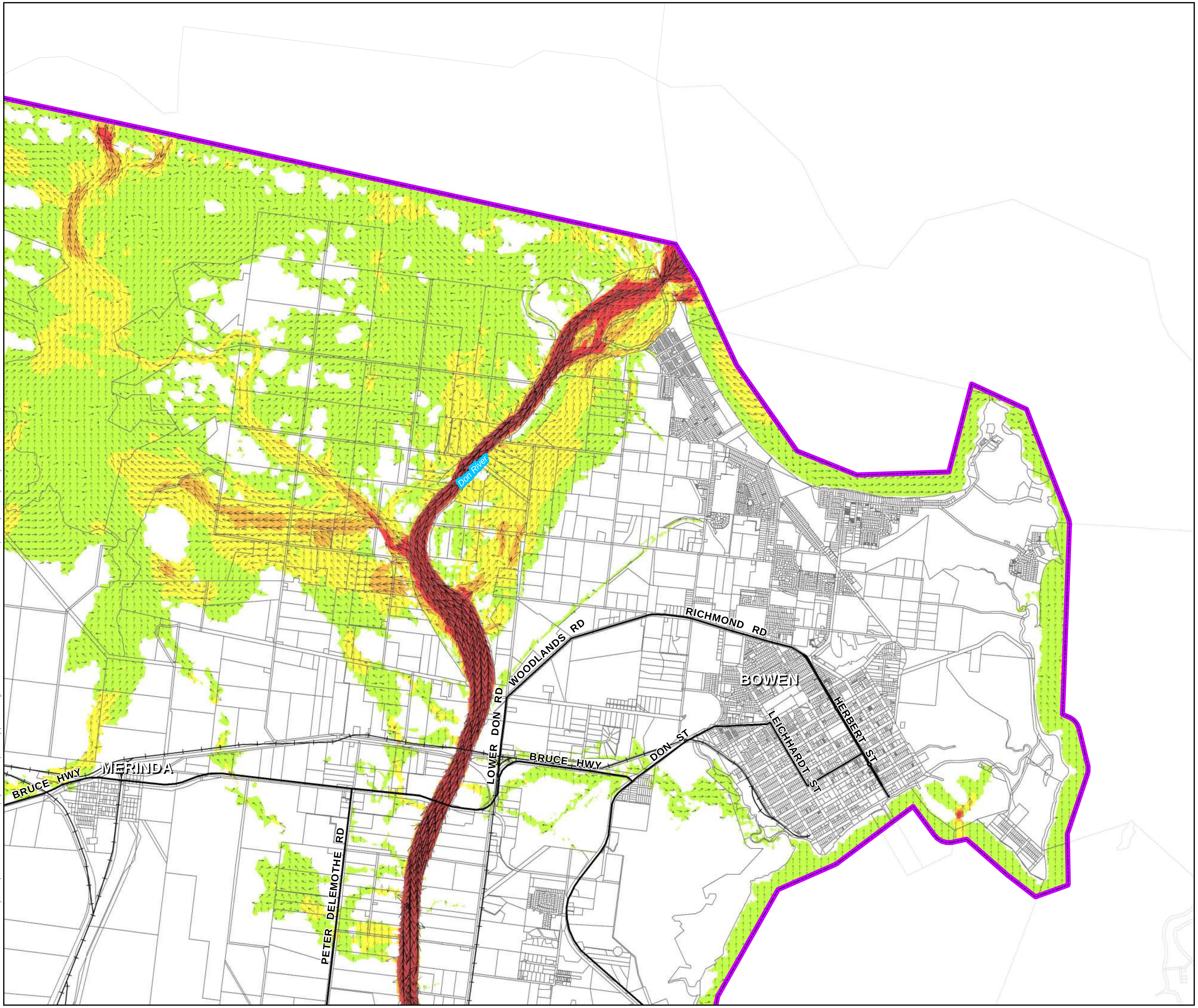
DON RIVER FLOOD STUDY

Peak Velocity
10% AEP Basecase

Appendix C



LEGEND

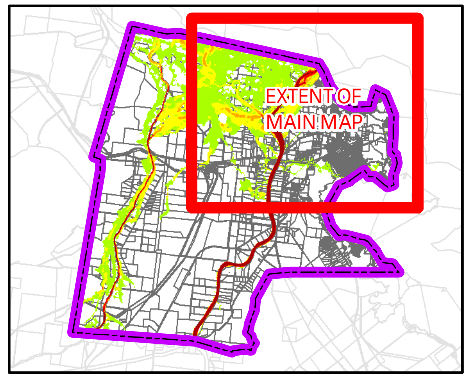
Don River Hydraulic Model Extent

Velocity Vectors (m/s)

- 0.00 - 0.50
- 0.50 - 1.00
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

Velocity (m/s)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5



0 0.5 1 2
Kilometres

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Coordinate System: GDA 1994 MGA Zone 55

Whitsunday Regional Council

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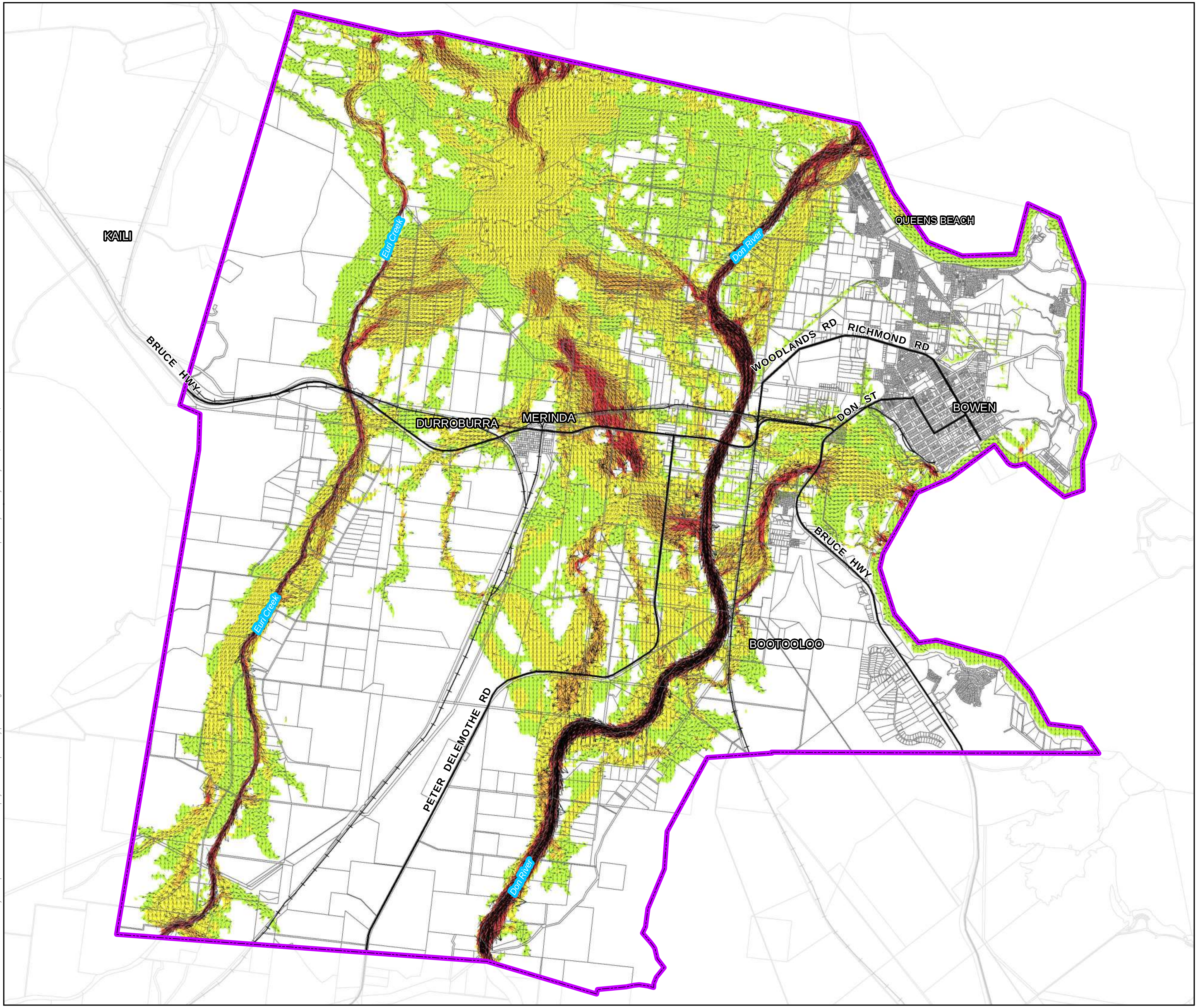

DON RIVER FLOOD STUDY

Peak Velocity
2% AEP Basecase

Appendix C

LEGEND

Don River Hydraulic Model Extent

Velocity Vectors (m/s)

- 0.00 - 0.50
- 0.50 - 1.00
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

Velocity (m/s)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5

0 0.5 1 2 3 4

Kilometres

1:70,000 (when printed at A3)

Coordinate System: GDA 1994 MGA Zone 55

Whitsunday Regional Council

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Model - AECOM 2014

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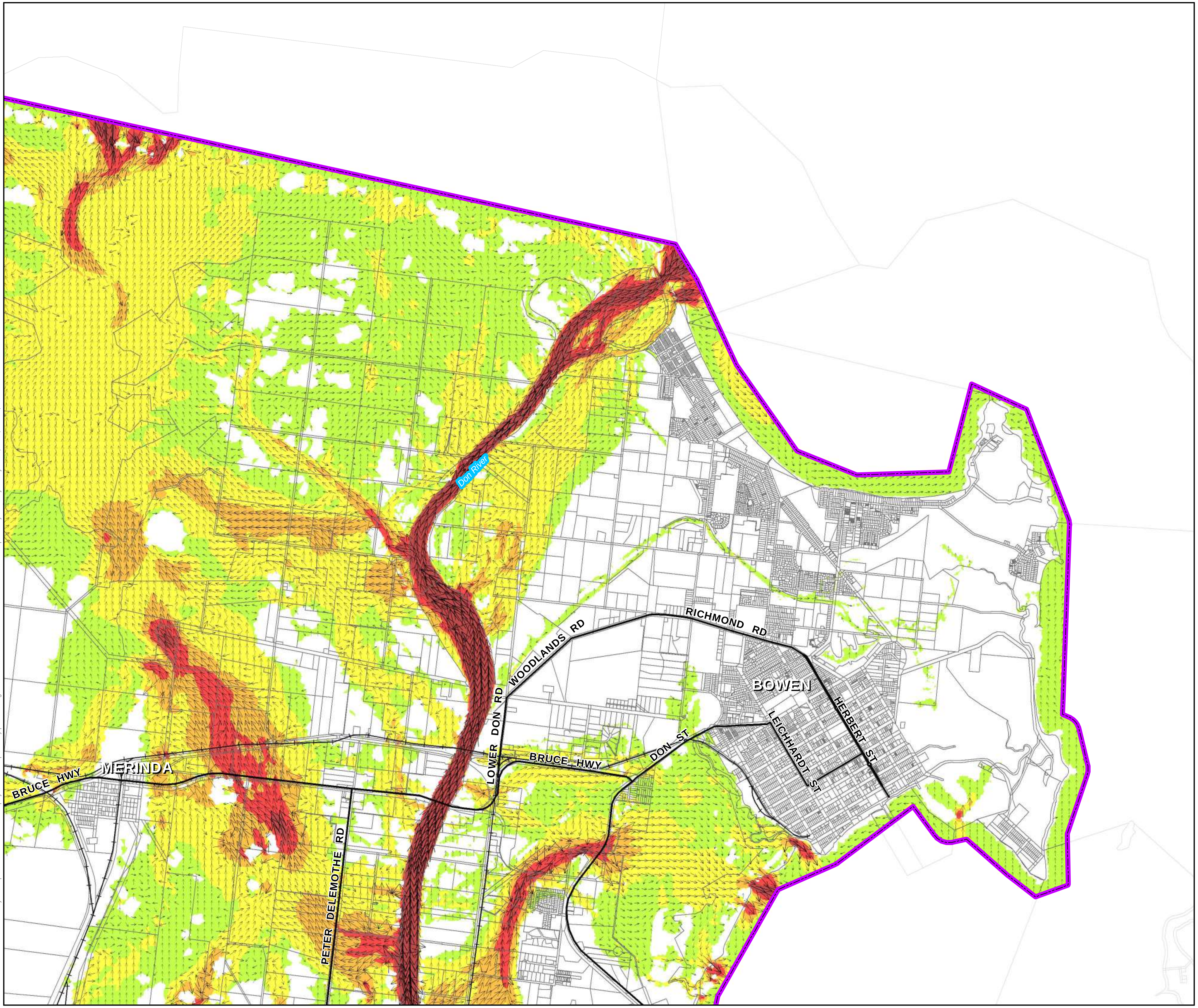


DON RIVER FLOOD STUDY

Peak Velocity
2% AEP Basecase

Appendix C

LEGEND

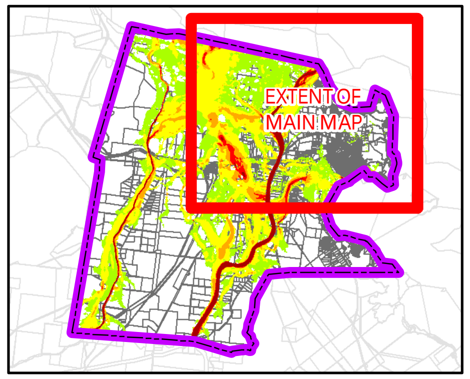
Don River Hydraulic Model Extent

Velocity Vectors (m/s)

- 0.00 - 0.50
- 0.50 - 1.00
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

Velocity (m/s)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5



0 0.5 1 2

Kilometres

1:40,000 (when printed at A3)

1

Coordinate System: GDA 1994 MGA Zone 55

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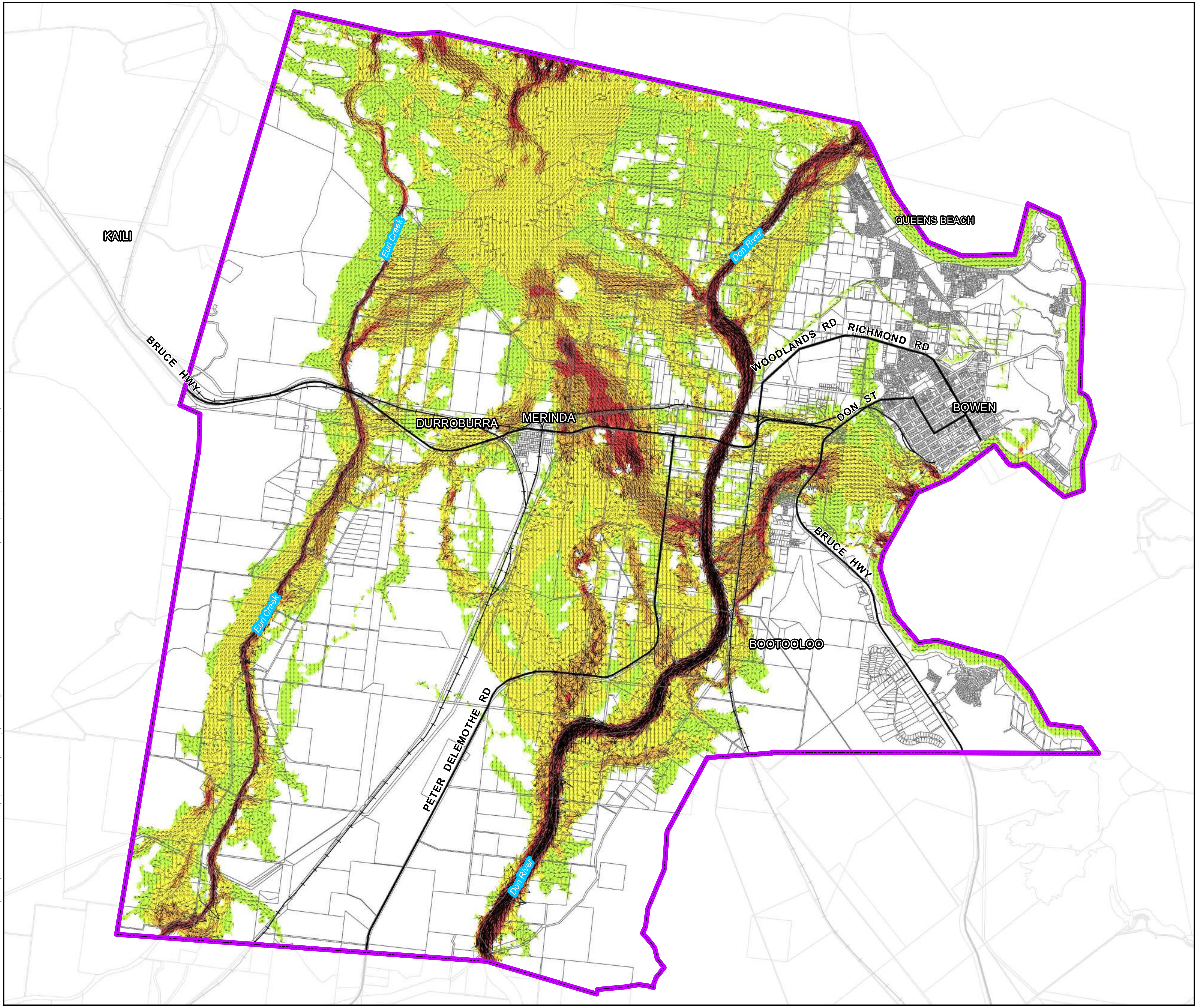
DON RIVER FLOOD STUDY

1% AEP Design

Flood Velocities

Appendix C



LEGEND

Don River Hydraulic Model Extent

Velocity Vectors (m/s)

- 0.00 - 0.50
- 0.50 - 1.00
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

Velocity (m/s)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5

0 0.5 1 2 3 4

Kilometres

1:70,000 (when printed at A3)

Coordinate System: GDA 1994 MGA Zone 55

Whitsunday Regional Council

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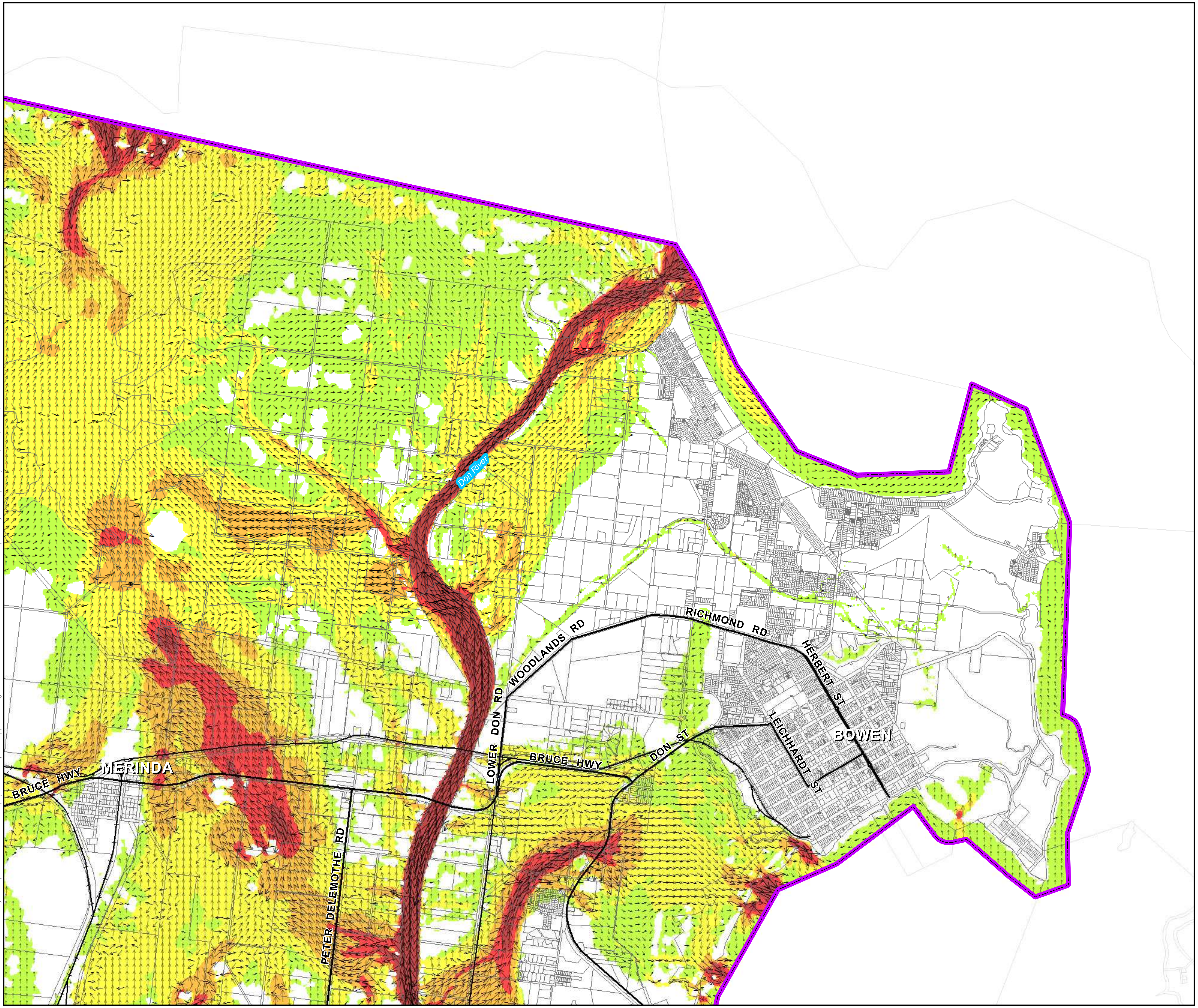


DON RIVER FLOOD STUDY

1% AEP Design Flood Velocities (zoomed)

Appendix C

LEGEND

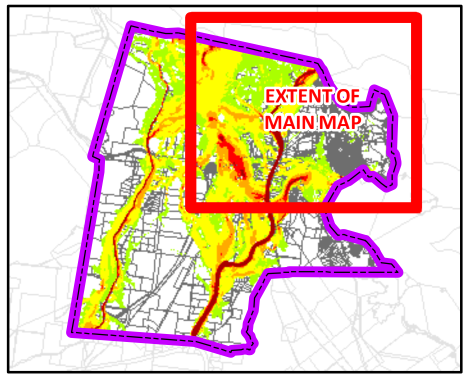
Don River Hydraulic Model Extent

Velocity Vectors (m/s)

- 0.00 - 0.50
- 0.50 - 1.00
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

Velocity (m/s)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5



0 0.5 1 2

Kilometres

1:40,000 (when printed at A3)

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Coordinate System: GDA 1994 MGA Zone 55

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Model - AECOM 2014

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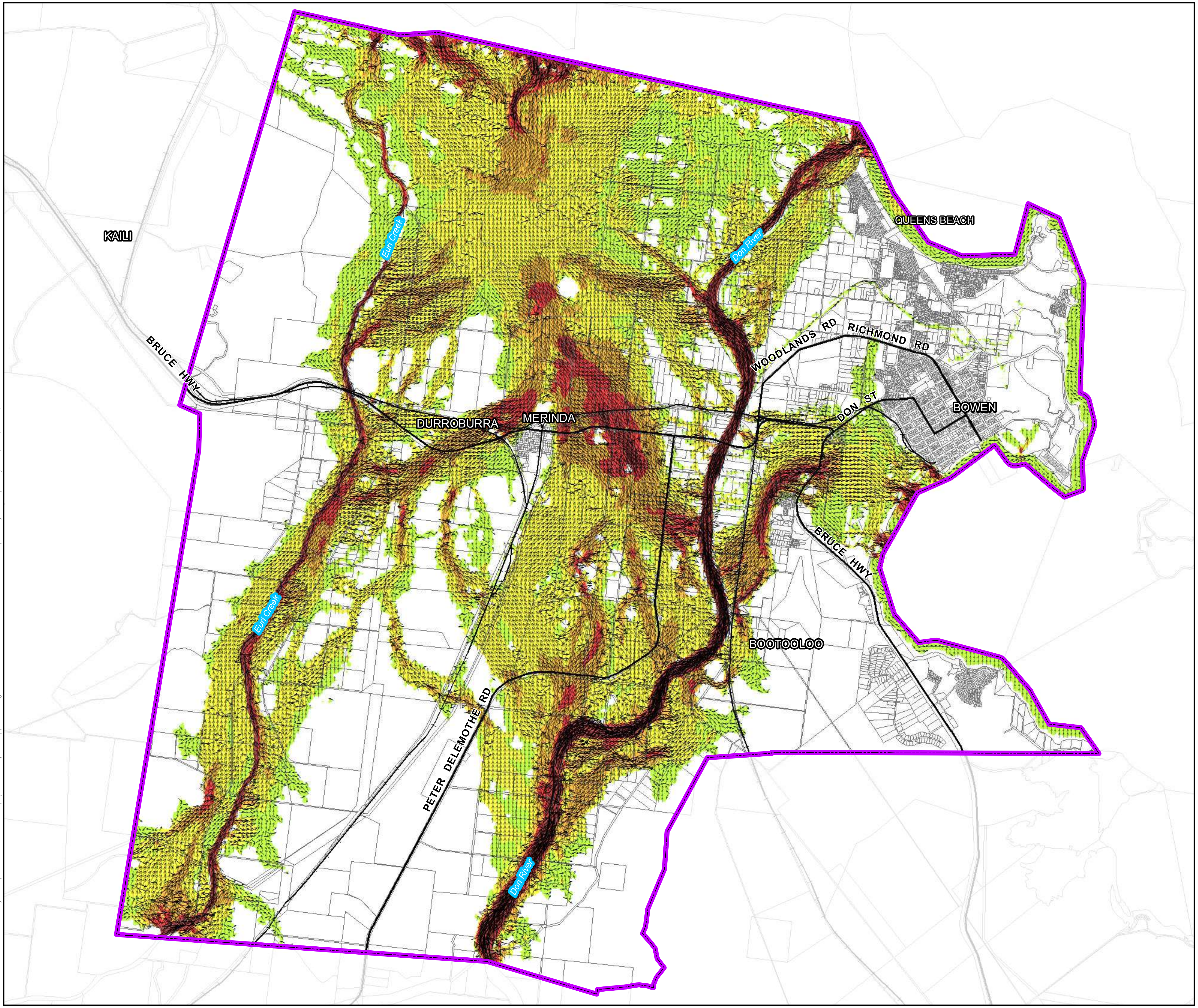

DON RIVER FLOOD STUDY

Peak Velocity
0.2% AEP Basecase

Appendix C

LEGEND

Don River Hydraulic Model Extent

Velocity Vectors (m/s)
- 0.00 - 0.50
- 0.50 - 1.00
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

Velocity (m/s)
- 0.0 - 0.5
- 0.5 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5

0 0.5 1 2 3 4
Kilometres

1:70,000 (when printed at A3)

Coordinate System: GDA 1994 MGA Zone 55

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Model - AECOM 2014

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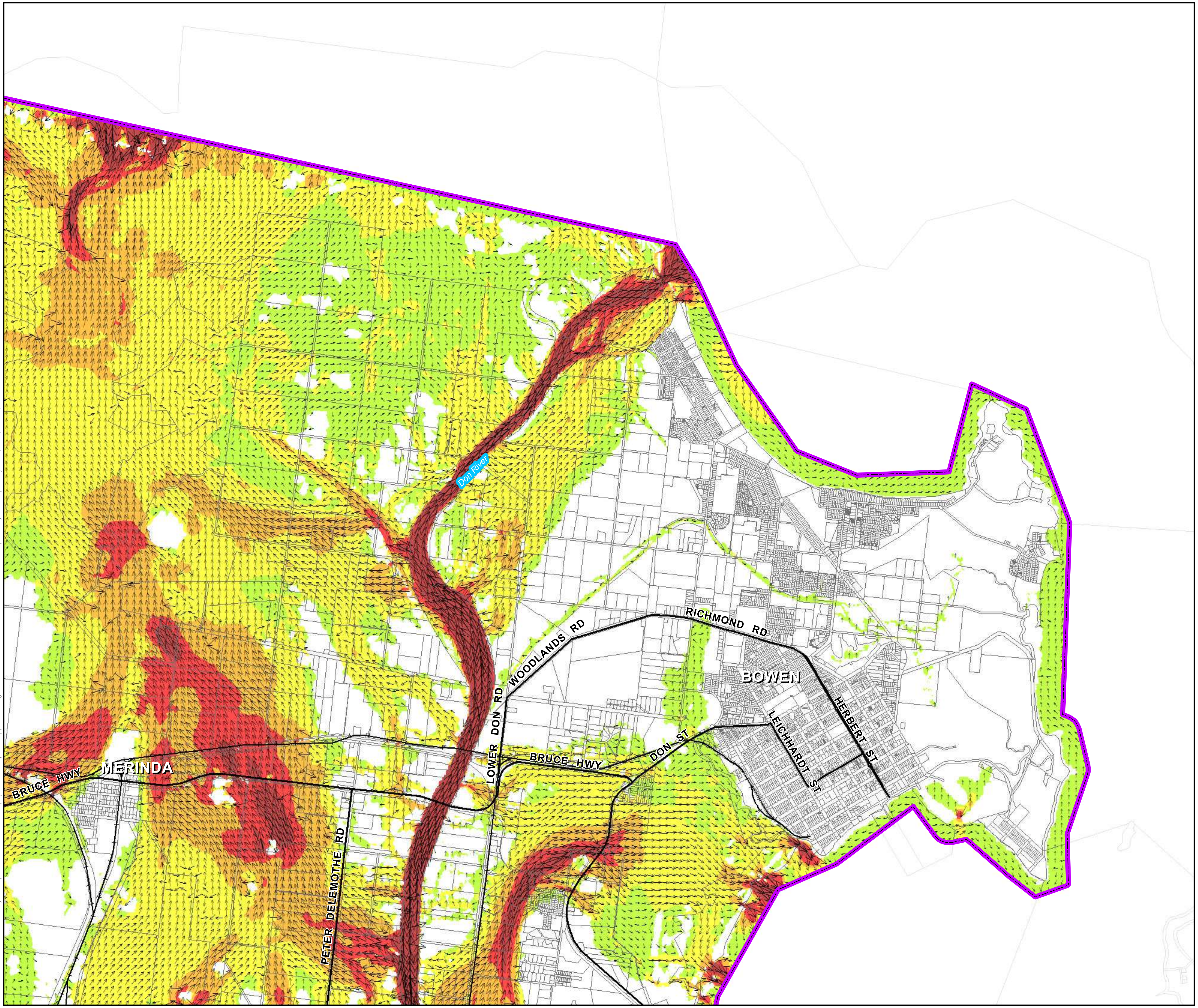


DON RIVER FLOOD STUDY

Peak Velocity
0.2% AEP Basecase (zoomed)

Appendix C

LEGEND

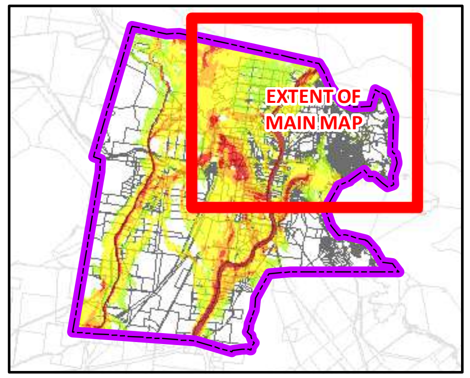
Don River Hydraulic Model Extent

Velocity Vectors (m/s)

- 0.00 - 0.50
- 0.50 - 1.00
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

Velocity (m/s)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5



0 0.5 1 2

Kilometres

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Coordinate System: GDA 1994 MGA Zone 55

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Model - AECOM 2014

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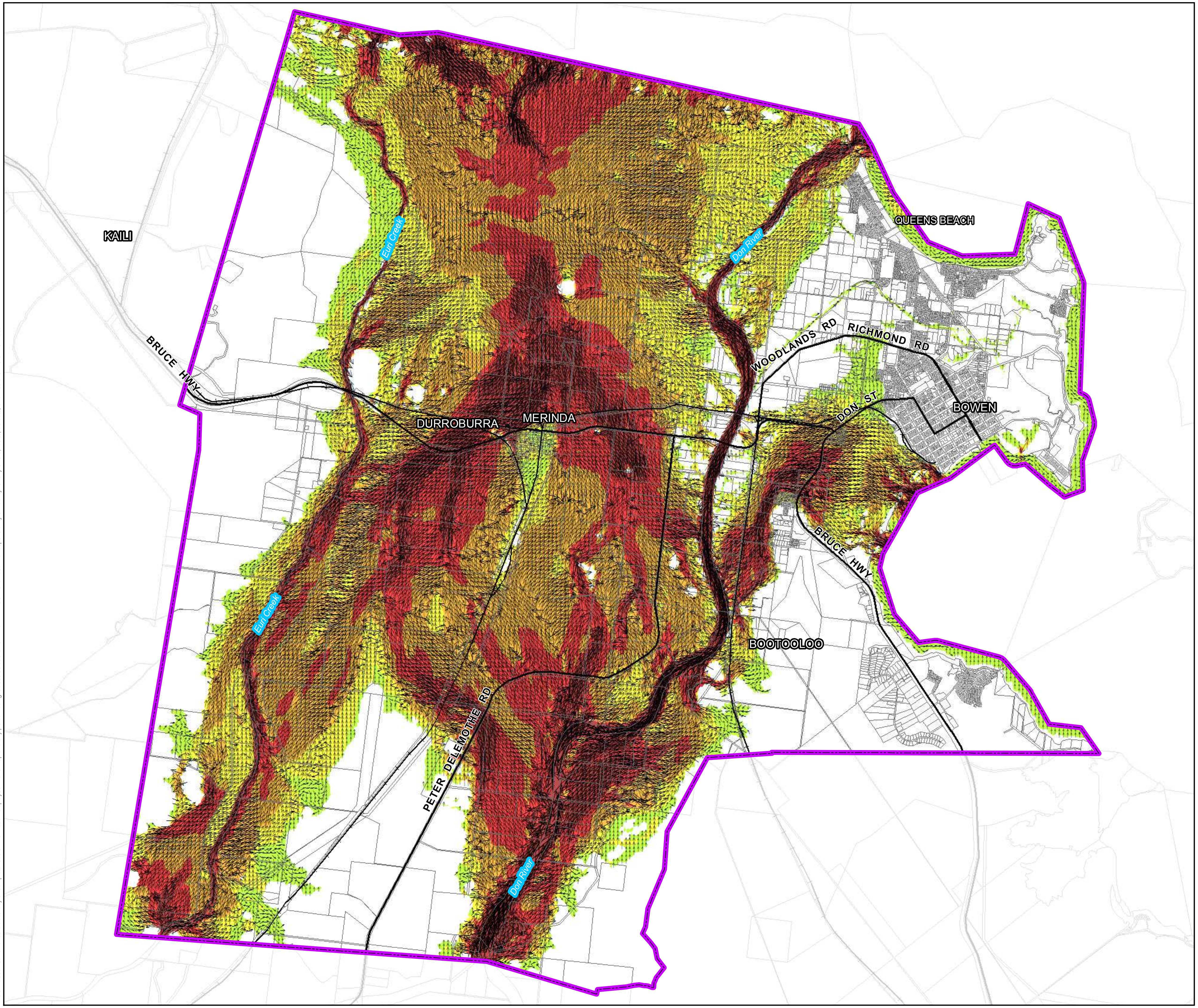

DON RIVER FLOOD STUDY

Peak Velocity
PMF

Appendix C

LEGEND

Don River Hydraulic Model Extent

Velocity Vectors (m/s)

- 0.00 - 0.50
- 0.50 - 1.00
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

Velocity (m/s)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5

0 0.5 1 2 3 4
Kilometres

1:70,000 (when printed at A3)

Coordinate System: GDA 1994 MGA Zone 55

DCDB - QLD Gov 2013.
Model - AECOM 2014

AECOM
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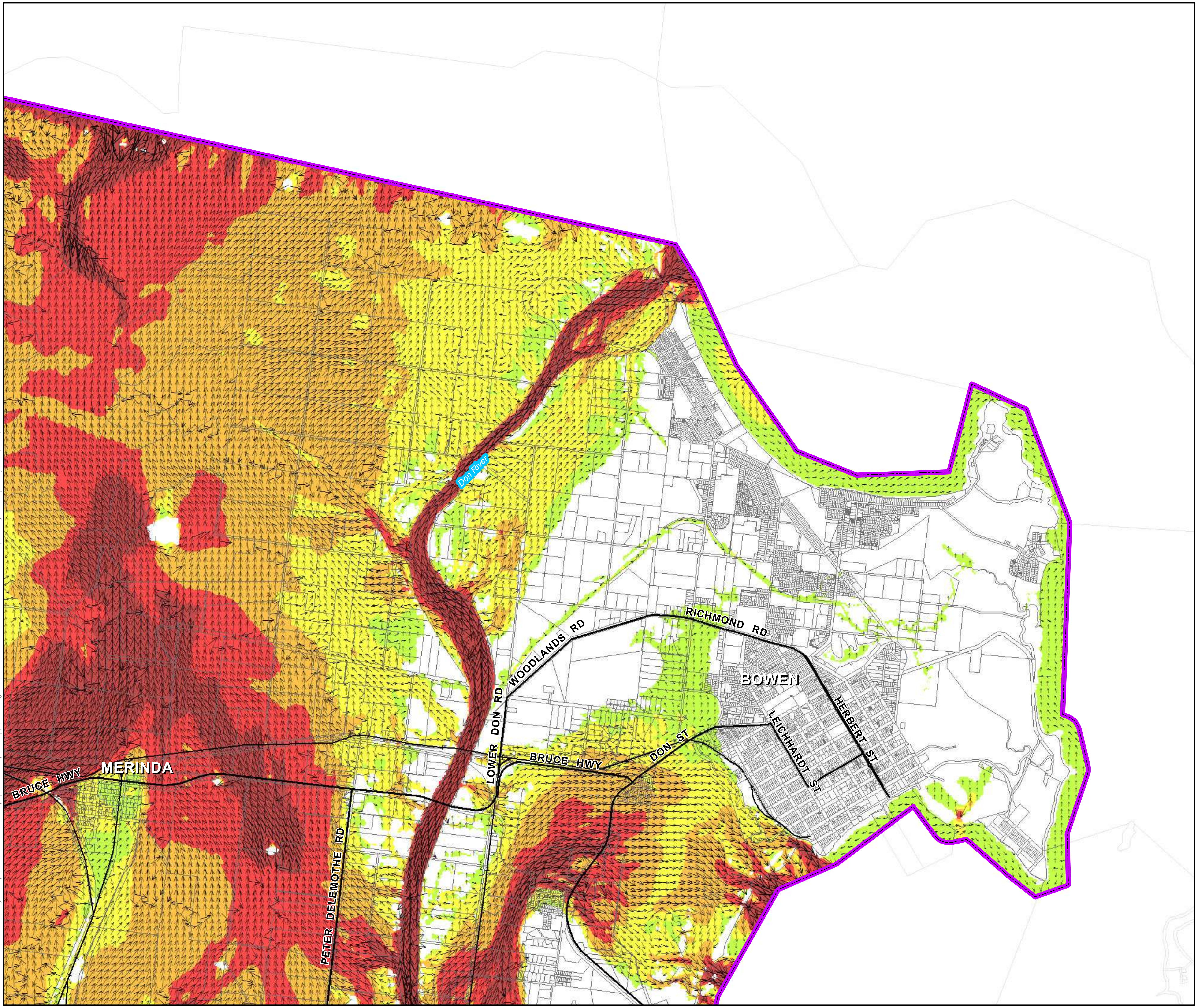
DON RIVER FLOOD STUDY

Peak Velocity
PMF (zoomed)

Appendix C



LEGEND

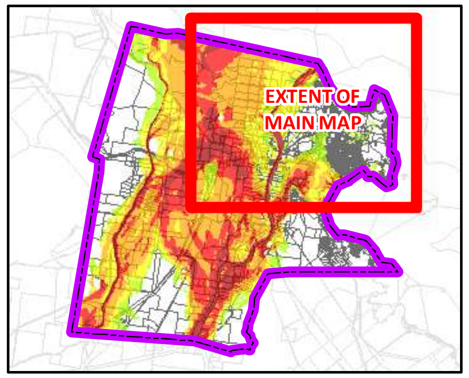
Don River Hydraulic Model Extent

Velocity Vectors (m/s)

- 0.00 - 0.50
- 0.50 - 1.00
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

Velocity (m/s)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5



0 0.5 1 2

Kilometres

1:40,000 (when printed at A3)

N

Coordinate System: GDA 1994 MGA Zone 55

DCDB - QLD Gov 2013.
Model - AECOM 2014

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