Pulgul Creek Catchment Analysis – Flood Risk



WE18029

Prepared for
Fraser Coast Regional Council

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Cardno

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1 INTRODUCTION

Cardno (Qld) Pty Ltd was commissioned by Fraser Coast Regional Council (FCRC) to prepare a Flood Risk Assessment for Pulgul Creek catchment. The objectives of the analysis were to develop a catchment model to allow for the identification and analysis of a variety of flood risk based components for catchment management, development planning/building, road and infrastructure design and Emergency Management purposes, including to be utilised for the purpose of determining minimum habitable floor levels and defined flood levels under the Fraser Coast Planning Scheme.

The Pulgul Creek catchment is located in the south eastern part of Hervey Bay and includes part of the suburbs of Urangan, Wondunna and Torquay. The catchment has an approximate area of 840 ha. The catchment location and extent is shown on Figure 1.

A number of flood studies have been conducted with the Pulgul Creek catchment:

- Pulgul Creek Catchment Flood Risk Reduction Study (JWP, 2006) – currently adopted catchment analysis which includes modelling of water quantity using RAFTS and TUFLOW.
- Various other studies covering portions of the catchment.

The most recent whole-of-catchment analysis was therefore dated and more recent analyses covered only portions of the catchment. A new whole-of-catchment analysis was required to:

- Confirm the impact of significant changes in land use;
- Confirm the impact of changes in landform as a result of development;
- Incorporate changes to catchment boundaries as a result of road and stormwater network alterations.
- Incorporate updated drainage infrastructure; and
- Employ latest modelling techniques.

Due to the complexities of the flow paths in the study area, and the flat nature of the downstream part of the catchment, a TUFLOW rainfall-on-grid model of the entire catchment was developed. This model ensures that all key flow paths within the catchment are identified and provides detailed flood information at any location within the catchment.

2 AVAILABLE DATA AND CATCHMENT DESCRIPTION

2.1 Available Data

Fraser Coast Regional Council provided the following information for the development of the Assessment:

- Aerial photography – high resolution tiles over the entire catchment
- FCRC GIS exports
  - DCDB
  - Planning zones
  - Stormwater infrastructure (pipes => 150mm dia)
- Digital terrain data (2015 Lidar) – 1km x 1km grids for entire catchment
- FCRC Planning Scheme
- Previous study
  - Pulgul Creek Catchment Flood Risk Reduction Study (JWP, 2006)

2.2 Catchment Description

The Pulgul Creek catchment is located in the south eastern part of Hervey Bay and includes part of the suburbs of Urangan, Wondunna and Torquay. The catchment has an approximate area of 840 ha. The catchment location and extent is shown on Figure 1.

The Pulgul Creek catchment is bounded by Tavistock Street to the west, Boat Harbour Drive in the north, the airport to the south and the Bay to the east. The catchment is predominantly urbanised and includes significant areas identified for future densification. The airport is located along the southern boundary of the catchment, with part of the airport draining to the catchment.

The area downstream of Booral Road is predominantly low lying, with ground levels typically below 2 mAHD, except in the developed parts along Booral Road and the former dumping ground. The remainder of the catchment rises to the west, with ground levels varying from below 0 mAHD at the mouth to 25 mAHD at the highest point, in the north western corner of the catchment. The catchment includes the former dumping ground, which provides an isolated high point, with a peak elevation of approximately 22 mAHD.

3 MODEL METHODOLOGY

3.1 Background

Due to the flat nature of catchment and the complexities of the flow paths, it was considered that the most appropriate catchment model would be a two dimensional model with rainfall applied directly to the grid. A TUFLOW model was therefore developed for the catchment. Applying the rainfall directly to the model allows the topography to determine the direction of the runoff and removes the need for the modeller to define sub-catchment boundaries and to determine an appropriate location for inflows to be applied to the model. In well-defined watercourses, inflow placement does not have a major impact on inundation extents. However, in flat areas, inflow placement can have a significant effect on inundation extents and can provide a false impression of the significance of flow paths.

One dimensional elements (pipes, bridges, pits, grates) were also included in the model. The two dimensional and one dimensional elements are linked, to allow for transfer of flow between the ground and the pipes.

3.2 Model Details

3.2.1 Grid size

A grid size of 4m was adopted for the study. This size provided a balance between achieving an adequate degree of accuracy in the representation of topographic features and providing acceptable run times. This grid size allowed for roadways to be represented by at least two cells. Given the relatively flat nature of the majority of the catchment, a smaller grid size was not considered to provide any appreciable benefits.

3.2.2 Topography

Aerial LiDAR survey data was provided by FCRC for input in the TUFLOW model. The coordinate system of the data was GDA 1994, MGA Zone 56 and was flown in 2015.

It should be noted that the LiDAR data does not pick up invert levels at locations within the study area that are inundated at the time the survey, with the water level at the time of the survey representing the existing “ground” levels. Further, where the vegetation is dense, the LiDAR will not pick up the true ground level. In a limited number of locations, this meant that the topography required modification to incorporate a gully to allow culverts to drain. Each of these locations was confirmed with FCRC prior to modification.

In some areas, the LiDAR shows the ground levels through culverts/bridges as being the true ground level rather than the road level. In these areas, the ground level was modified within TUFLOW to ensure that the waterway area was correctly analysed and road overtopping could be identified. The LiDAR was inconsistent in this respect, with some culverts/bridges not affected. All culverts/bridges were therefore checked to ensure the correct topographic representation.

3.2.3 Inflows

As noted earlier, inflows to the model were applied as rainfall-on-grid. For each event, a temporal pattern of the rainfall depth in each time step is applied to the model. Rainfall depths and temporal patterns were applied in accordance with Australian Rainfall and Runoff.

It is noted that Australian Rainfall and Runoff (ARR) 1987 Intensity – Frequency – Duration (IFD) parameters and temporal patterns were adopted for the assessment. Although ARR2016 had been released at the time of the assessment, several sections remain in draft format and the update has not been widely adopted at the time of writing. Further, ARR2016 requires the analysis of ten temporal patterns for each storm duration to determine the critical event at any location within the catchment. The assessment of this number of events for a catchment of this size was not practical. This issue has not yet been resolved by the ARR team.

The adoption of ARR2016 IFD parameters in association with ARR1987 temporal patterns was considered. However, the Bureau of Meteorology website (from which ARR2016 IFD parameters are extracted) specifically states that the ARR2016 IFD parameters must be used with other ARR2016 parameters. It would therefore be inappropriate to use the ARR2016 rainfall intensities with the ARR1987 temporal patterns.

A comparison of the ARR1987 and ARR2016 IFD parameters was carried out. It is noted that this will not provide an accurate picture of the impact of the ARR changes as any changes in IFD must be considered in conjunction with the changed temporal patterns however it was considered useful to provide a comparison.

Table 3-1 Comparison of ARR 1987 and ARR 2016 Rainfall Depths

Duration (mins)	Rainfall Depth (mm)		Difference (%)
	ARR 1987	ARR 2016	
5	26.0	26.3	+1.2
10	40.0	42.7	+6.8
20	58.0	64.3	+10.9
30	70.5	79.0	+12.1
60	96.5	107.0	+10.9
120	127.6	139.0	+8.9
180	148.8	161.0	+8.2
360	193.8	205.0	+5.8

As shown by this comparison, there are not significant changes in rainfall intensity.

Initial and continuing losses were not applied to the model – that is, an initial and continuing loss of 0 mm and 0 mm/h respectively was applied. The Fraser Coast Planning Scheme recommends no losses for impervious areas. Use of no losses on pervious areas provides a conservative estimate of peak flows – effectively assuming that there has been rainfall prior to the design event occurring. This was considered appropriate due to the predominantly urban nature of the catchment and the fact that there are no areas of the catchment containing significant portions of pervious area.

Storm durations ranging from 25 minutes to 6 hours were analysed for average recurrence intervals of 2 year, 10 year, 50 year and 100 year. Climate change events were also analysed and are discussed further later in this document.

3.2.4 Structures

The local drainage network and culvert/bridge crossings within the study area were included based on the supplied FCRC survey data. Only those pipes with a diameter of 600 mm or greater were included in the model, except where initial modelling indicated that a smaller pipe was required in order to maintain a flowpath or prevent unnecessary ponding. Initial modelling indicated a number of gaps in the data contained in the FCRC GIS database. These gaps were identified by unexpected ponding in the model or missing sections of pipe. Additional information for these areas was provided by FCRC. All pipes and pits included in the model are shown on Figure 2.

Entrance and exit loss coefficients of 0.5 and 1.0 respectively were added to all of the pipes and culverts. A Manning's n value of 0.013 was used for all pipes and culverts.

It was assumed that the majority of pits included a grate with a capacity equivalent to a large lintel. This was to ensure that flooding was controlled by the capacity of the pipe system.

Details for major road crossing structures included in the model are provided in Table 3-2. Locations of each of these structures are shown on Figure 3. A flood risk assessment of these road crossings has been conducted and forms the basis of a separate report.

Table 3-2 Road Crossing Features

Unique Identifier	Road Crossing Location	Structure ID	Structure Type
PC-01	Bideford Street	PIPE024289	4 by 600 mm RCP
PC-02	Exeter Street @ Honiton	P008209 (a,b,c)	2 by 2100 x 1500 mm RCBC
PC-03	Honiton Street	P008209 (a,b,c)	2 by 2100 x 1500 mm RCBC
PC-04	Urangan Street	P009460 (a)	2 by 900 mm RCP
PC-05	Robert Street	PIPE021752	3 by 2100 x 1500 mm RCBC
PC-06	Windermere Road	OFP	OFP
PC-07	Hughes Road	PIPE022427	2 by 1200 x 600 mm RCBC
PC-08	Stringybark Drive	OFP	OFP
PC-09	Garden Drive @Elizabeth Street	OFP	OFP
PC-10	Elizabeth Street	PipeElizaSt	6 by 1800 mm RCP
PC-11	Ladbroke Crescent	OFP	OFP
PC-12	Pulgul Street (South)	PIPE017252	1 by 600 mm RCP
PC-13	Cicada Lane @ Booral Road	PIPE022431	2 by 600 mm RCP
PC-14	Booral Road (North)	PBooralNth	5 by 1800 mm RCP
PC-15	Cicada Lane	PIPE022433	2 by 1200 x 1800 mm RCBC
PC-16	Walkers Road (South)	PIPE024386	7 by 825 mm RCP
		PIPE022414	6 by 300 mm RCP
		PIPE022406	6 by 300 mm RCP
PC-17	Walkers Road @ Silkwood Drive	OFP	OFP
PC-18	Booral Road at IGA	PBooralSth	2 by 1050 mm RCP
PC-19	Island View Drive	PIPE029570	2 by 1125 mm RCP
PC-20	Beck Road	PIPE022331 (a,b)	2 by 1200 mm RCP
PC-21	Emerald Park Way	OFP	OFP
PC-22	Ellengowan Street	PIPE023661	3 by 1200 mm RCP

Note: OFP – Overland Flow path (no structure)

3.2.5 Roughness Coefficients

Manning's n roughness coefficients were determined based on aerial photography, site inspection and land uses and were as detailed in Table 3-3. Manning's values are shown on Figure 4.

Table 3-3 Manning's n Roughness Coefficients

Type	Manning's n
Roads	0.02
Open space (sports fields, parks)	0.035
Medium vegetation	0.08
High vegetation	0.12
Mangroves	0.15
Rural Residential areas	0.06
Low Density Residential areas	0.10
Medium Density Residential areas	0.15
Commercial/Industrial	0.11

It can be noted that Manning's n values have not been applied to a fine scale. The scale adopted is considered appropriate for a catchment wide analysis. Should the modelling be adopted for finer scale analyses, refinement of Manning's n values is recommended.

3.2.6 Boundary Conditions

The downstream limit of the Pulgul Creek model is the Bay. In accordance with the FCRC Planning Scheme, the following tailwater levels were therefore applied:

Table 3-4 Boundary Conditions

Event	Tailwater level requirement	Tailwater level (mAHD)
2 year ARI	MHWS	1.45
10 year ARI	MHWS	1.45
100 year ARI	HAT	2.24
100 year ARI (Climate change at 2050)	HAT + 0.8m	3.04
100 year ARI (Climate change at 2090)	HAT + 0.8m	3.04

3.2.7 Initial Water Levels

The initial water level was set to the tailwater level at all locations.

3.2.8 Time step

A time step of 2 seconds was applied to the model. This is within the recommended range of ½ to ¼ of the grid cell size.

3.2.9 Model Output

The following outputs were produced:

- Water level;
- Depth;
- Unit flow;
- Velocity; and
- Hazard.

3.3 Results and Discussion

The modelling results for the existing case are presented in Appendix A. This appendix includes mapping for flood levels, depths, velocities and hazard. Critical duration mapping is also included.

The mapping provides a clear indication of the overland flow paths throughout the catchment.

3.4 Results Verification

In accordance with best practice, all results of hydrologic modelling should be compared with the results from another method. As the rainfall on grid method was used, the hydrology has been conducted within the hydraulic model. The hydrology is therefore dependent on the quality of the digital elevation model used for the analysis. If the dem is poor, it may result in significant false ponded areas which increases the storage within the catchment and therefore reduces the peak flow. It is therefore particularly important for rainfall on grid models to be verified against another method.

The previous analysis of the catchment was conducted in 2006 by JWP. That analysis used RAFTS for the hydrologic modelling of the catchment. The RAFTS model was verified against the Rational Method. The techniques used to develop and verify the RAFTS model have not changed significantly since 2006. It was therefore considered that the results of this model provided an appropriate set of results for comparison with the current TUFLOW model.

The results of the TUFLOW analysis were compared with those from the 2006 RAFTS analysis at three locations for the 100 year ARI event. This was the only event for which results were available from the 2006 analysis. The results of this comparison are contained in Table 3-5.

Table 3-5 Validation of TUFLOW Model

ARI	Treatment Plant (PO_19)		Urangan Street (PO_17)		Outlet (PO_12)	
	RAFTS	TUFLOW	RAFTS	TUFLOW	RAFTS	TUFLOW
100	47.9	65.7	39.7	43.4	117.8	120.4

It is considered that the TUFLOW and RAFTS results are in good agreement. The results at the outlet are within 2%. The results at the treatment plant and at Urangan Street are higher for TUFLOW than for RAFTS. Given that the results from TUFLOW were not collected at exactly the same location as for RAFTS, due to the extent of inundation at these locations and conflicts with incoming drains, the above listed values are considered to represent a very good match.

3.5 Results Filtering

As the flood modelling has been conducted using rainfall-on-grid, rainfall is applied to every cell. This results in a depth of flooding occurring at every cell in the model. While the rainfall-on-grid (or direct rainfall) method is very useful, particularly for ill-defined catchments, as it allows the topography to determine the direction of flow, rather than the modeller, applying sub-catchment based flows at defined locations, it can result in a lot of 'noise' in the flood mapping. As a result, the Map Cutoff Depth command in TUFLOW is typically used, to prevent mapping from including flooding below the cutoff depth being shown. Note that this command does not affect the calculations. It merely removes those cells from the mapping. Based on experience with direct rainfall models, a value of 0.05 m is typically used for the Map Cutoff Depth.

Despite the use of the Map Cutoff Depth, the flood mapping for the Pulgul Creek catchment contains a significant amount of 'noise' – that is, isolated areas of inundation. These areas are typically caused by the topography – it only takes one cell at a level 100 mm (which is about the accuracy of aerial laser survey) below the surrounding cells to create a puddle. Given that the depth of rainfall for the 120 minute event is 127 mm, then the depth of 'flooding' in this cell could be 127 mm depending on the level of the surrounding cells. Where these ponded areas occur remotely from the overland flow paths, they are clearly not flooding, but are effectively puddles, and should not be included in flood risk mapping. The most appropriate method for filtering these results out of the flood risk mapping therefore needs to be determined.

Research was conducted into the methodology used by other government and local authorities for filtering of flood risk mapping as summarised in Table 3-6. It was found that there was significant variation in methodology and that the method needed to take account of the local conditions.

Table 3-6 Filtering Methodology Examples

Location	Methodology
Little Salt Pan Creek, NSW	Isolated areas of 250 m^2 or less, where the depth was less than 300 mm removed
Melbourne Water*	All points with a depth less than or equal to 50 mm AND a velocity times depth product less than 0.008 are removed.
Geelong	Two step process: Firstly, all flooded cells with depths less than 0.02 m were removed; and any cells where both the depth is less than 0.05 m and the V*D is less than 0.008 were also removed. Then, isolated puddles of less than 100 m^2 were removed from the final flood extents.

*Melbourne Water Flood Mapping Projects - Guidelines and Technical Specifications, November 2012

Similar methodologies to the above examples were applied to the Pulgul Creek results. It was found that none of the above methodologies provided an adequate filter.

Many of the isolated ponded areas in the Pulgul Creek catchment achieved depths of up to 150 mm. However, due to the shallow nature of much of the flow in the catchment, the application of a depth filter greater than 100 mm was found to be inappropriate as it removed genuine flowpaths.

Limiting areas by hazard in addition to depth also provided no benefit as the peak hazard values were often greater than 0.008 (as recommended by Melbourne Water) in the isolated ponded areas.

It was therefore determined that the most appropriate method for the Pulgul Creek catchment was to apply the cutoff depth of 50 mm, as applied in the TUFLOW modelling. Isolated areas of ponding were then removed based on the area of the ponding. A number of areas were trialled to determine the most appropriate area, ensuring that the majority of noise was removed from the model, with no removal of genuine flowpaths. This was the same method applied to the results for the Eli Creek catchment.

In accordance with the recommendations in Table 3-6, isolated areas of 100 m^2, 250 m^2, 500 m^2, 750 m^2 and 1000 m^2 were trialled. None of these areas provided complete removal of isolated ponding. However, the 750 m^2 and 1000 m^2 cases removed some genuine areas of ponding. It is therefore considered that removal of isolated ponded areas up to 500 m^2 is the most appropriate filter. Additional manual removal of ponded areas may then be required. The choice of ponded area was driven by the low density residential area bounded by Boundary Road, Hughes Road, Silkwood Drive and Walkers Road.

4 CLIMATE CHANGE

4.1 Methodology

The climate change analysis was conducted in accordance with Australian Rainfall and Runoff (ARR2016). The ARR2016 chapter on climate change considers not only the impact of climate change on the magnitude of events, but the likely risks of these changes in event magnitude, and the service life of the asset being considered. For example, if the service life of an asset is ten years, then the increase in event magnitude may well be contained within the freeboard of the flood level for the asset. Climate change therefore does not pose a significant risk to the asset.

In order to determine the impact of climate change, the recommended approach is to apply a factor to the rainfall intensity based on climate change projections. This approach is the same as it was prior to ARR2016. ARR2016 provides a formula for determining the factor. The recommended increase in rainfall for the 2050 event is 8% and for the 2090 event (note that although the year 2100 was typically used for climate change projections in the past, ARR2016 does not project to 2100 at this stage) is 15%. Prior to the publication of ARR2016, the factors would have been 10% and 20% respectively (based on the 2010 DERM/DIP/LGAQ report "*Increasing Queensland's resilience to inland flooding in a changing climate: Final report on the Inland Flooding Study*"). The values currently recommended by ARR2016 are therefore not significantly different to those previously recommended and have been adopted for use in this study.

The factors determined using ARR2016 were applied to the existing case 100 year ARI event to determine the Climate Change 2090 flood levels throughout the catchment. In addition, in accordance with Queensland State Policy, the tailwater level was increased by 0.8 metres to account for climate change.

With respect to the selection of an appropriate climate change scenario for application to the flood study, ARR2016 does not make recommendations regarding which projection to use. ARR2016 recommends a risk based approach to determining the appropriate scenario to adopt. Both the planning horizon (or life of the asset if a single element is being assessed) and the risk of failure must be considered. ARR2016 provides a flow chart to assist in determining what should be done. Based on this flowchart, it is recommended that the climate change projection match the planning horizon. Given that the flood study is being used to determine planning levels for the foreseeable future, it is considered that the planning horizon for this study is 50 – 100 years.

The risk of not adopting the climate change scenario in line with the planning horizon, is that development will continue to occur based on the current flood levels. ARR2016 recommends that if the risk of failure of the asset – in this case, flooding of a development – is high should climate change occur, then the climate change scenario should be adopted. All further analysis and reporting has therefore been based on the 100 year ARI event with climate change factors for 2090.

5 CONCLUSIONS

A Flood Risk Assessment has been conducted for the Pulgul Creek catchment. The assessment has involved the use of a rainfall on grid TUFLOW model to identify overland flow paths within the catchment and provide information for development planning/building, road and infrastructure design and Emergency Management purposes, including to be utilised for the purpose of determining minimum habitable floor levels and defined flood levels under the Fraser Coast Planning Scheme.

The assessment has included the analysis of climate change events and the identification of the most appropriate event for future planning.

Pulgul Creek Catchment Analysis – Flood Risk

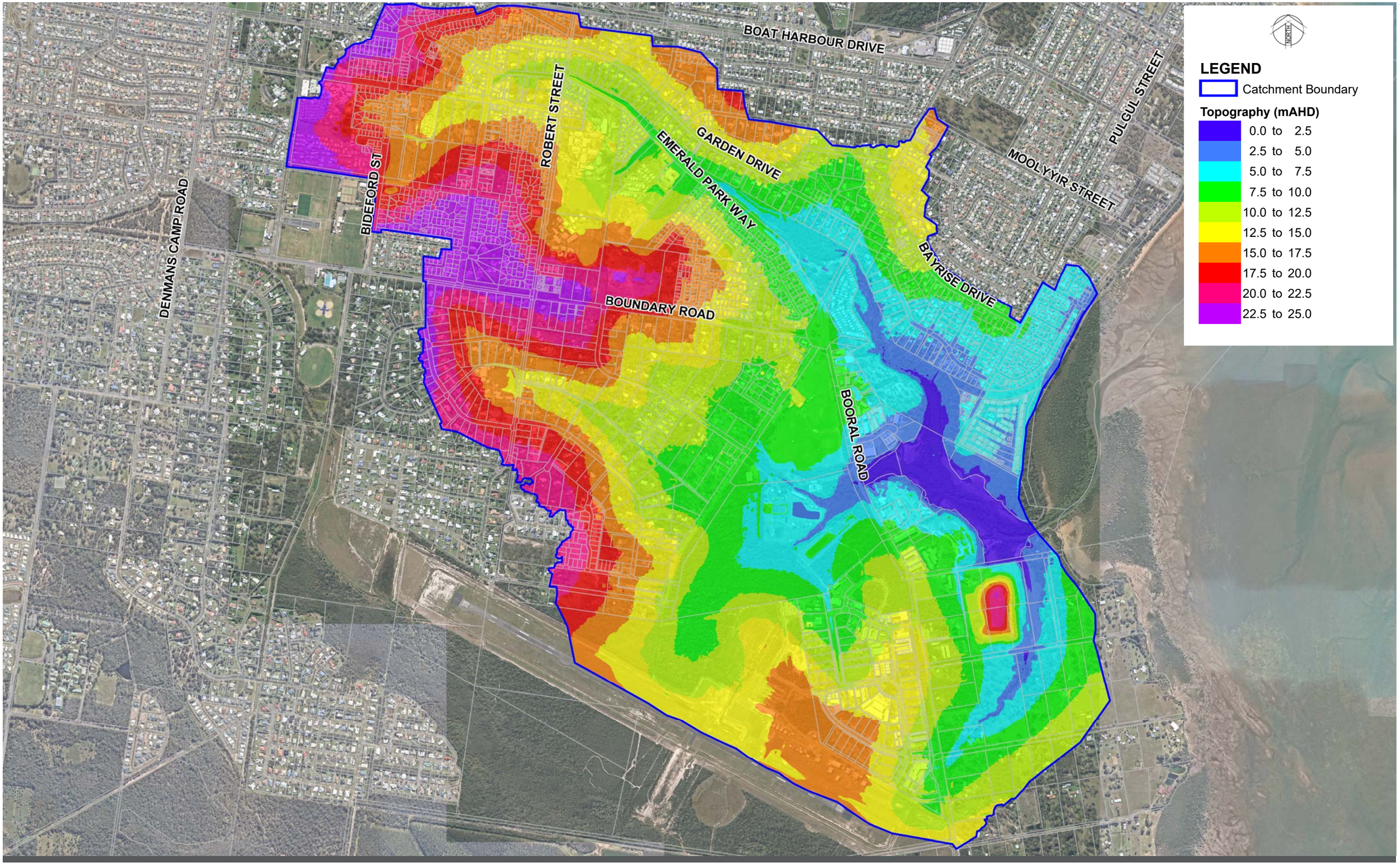
FIGURES

Figure 1 Locality Plan

Figure 2 Modelled Pipe Network

Figure 3 Road Crossing Locations

Figure 4 Manning's n Roughness



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Pulgul Creek Catchment Analysis
Locality Plan

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Figure 1
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Pulgul Creek Catchment Analysis
Modelled Pipe Network

Fraser Coast Regional Council

Figure 2
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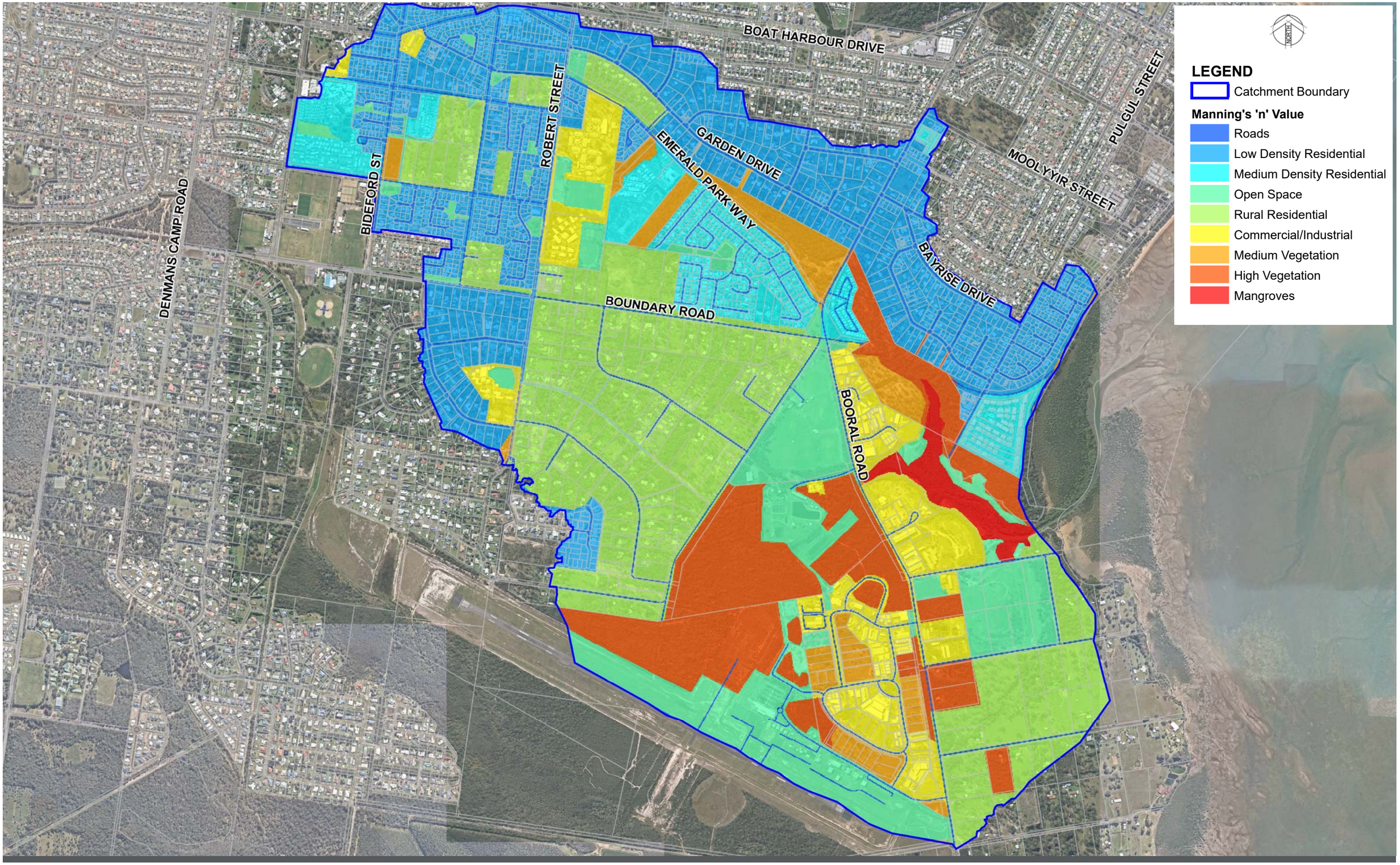
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Pulgul Creek Catchment Analysis
Road Crossing Locations

Fraser Coast Regional Council

Figure 3
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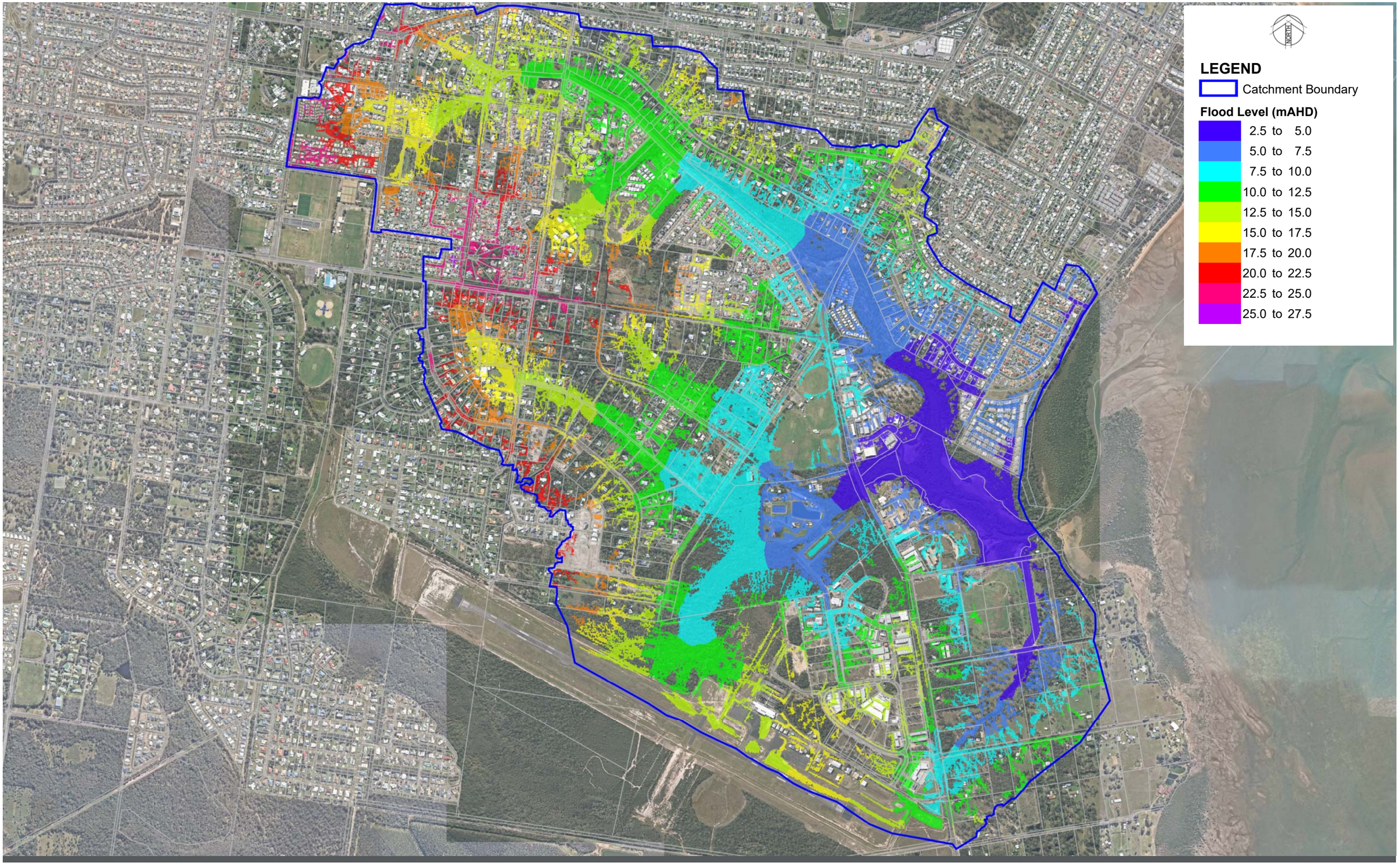
Pulgul Creek Catchment Analysis
Manning's 'n' Roughness
Fraser Coast Regional Council

Figure 4
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Pulgul Creek Catchment Analysis – Flood Risk

APPENDIX A

TUFLOW RESULTS



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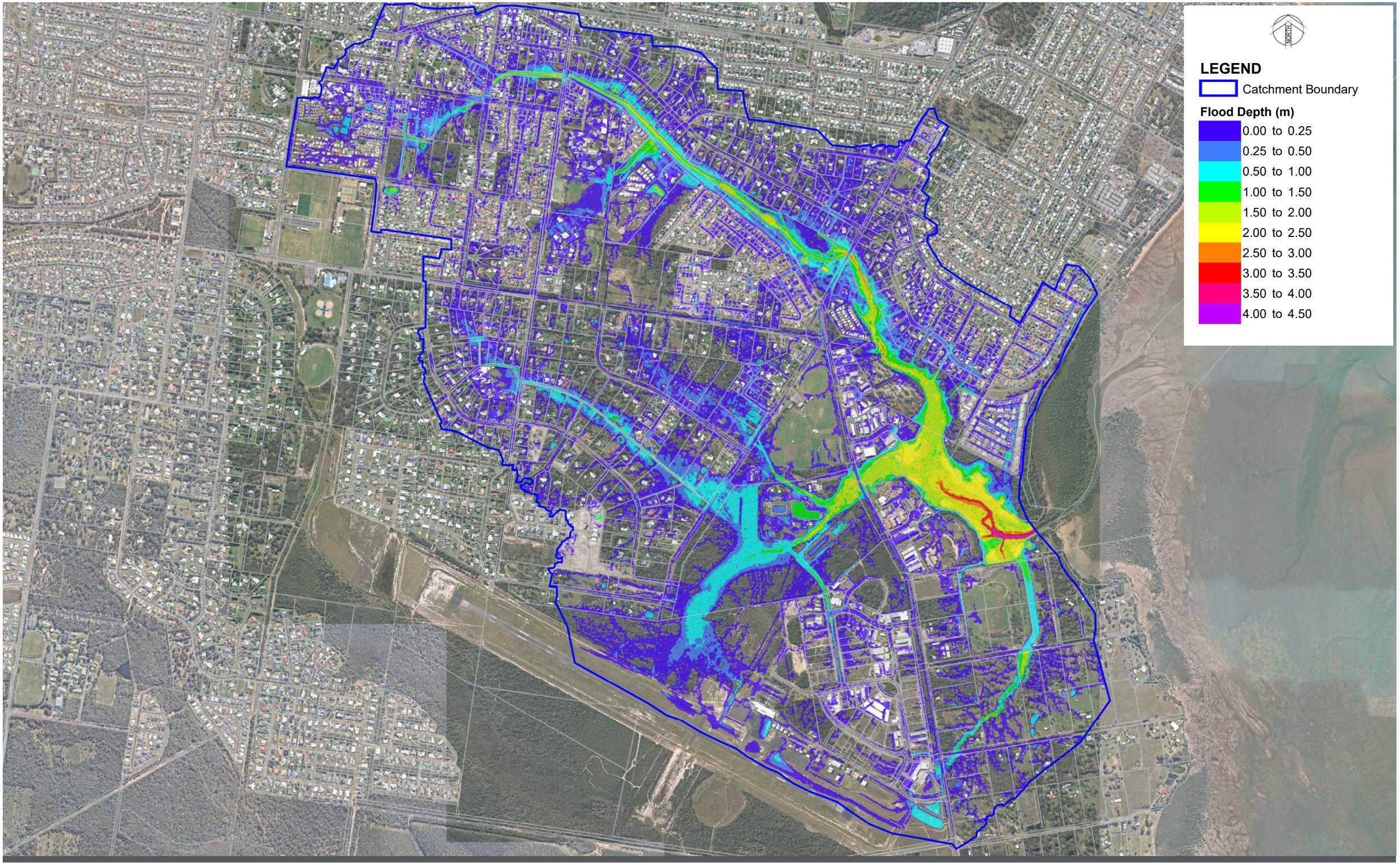
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Scale
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kilometres

Pulgul Creek Catchment Analysis
100 Year ARI (2090 Climate Scenario) - Maximum Flood Level

Fraser Coast Regional Council

Appendix A-1
PC_APPA.wor rev1



FILE: O:\004_JOBS\WE18\29_Pulgul_Crk_Catchment_Analysis\3_Data\2_Analysis\GIS\Figures\Pulgul_Creek
DATE PLOTTED: 14/09/2018 BY: EW

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Date
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Size
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Scale
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kilometres

Pulgul Creek Catchment Analysis
100 Year ARI (2090 Climate Scenario) - Maximum Flood Depth

Fraser Coast Regional Council

Appendix A-2
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FILE: O:\004_JOBS\WE18029_Pulgul_Crk_Catchment_Analysis\3_Data\2_Analysis\GIS\Figures\Pulgul_Creek
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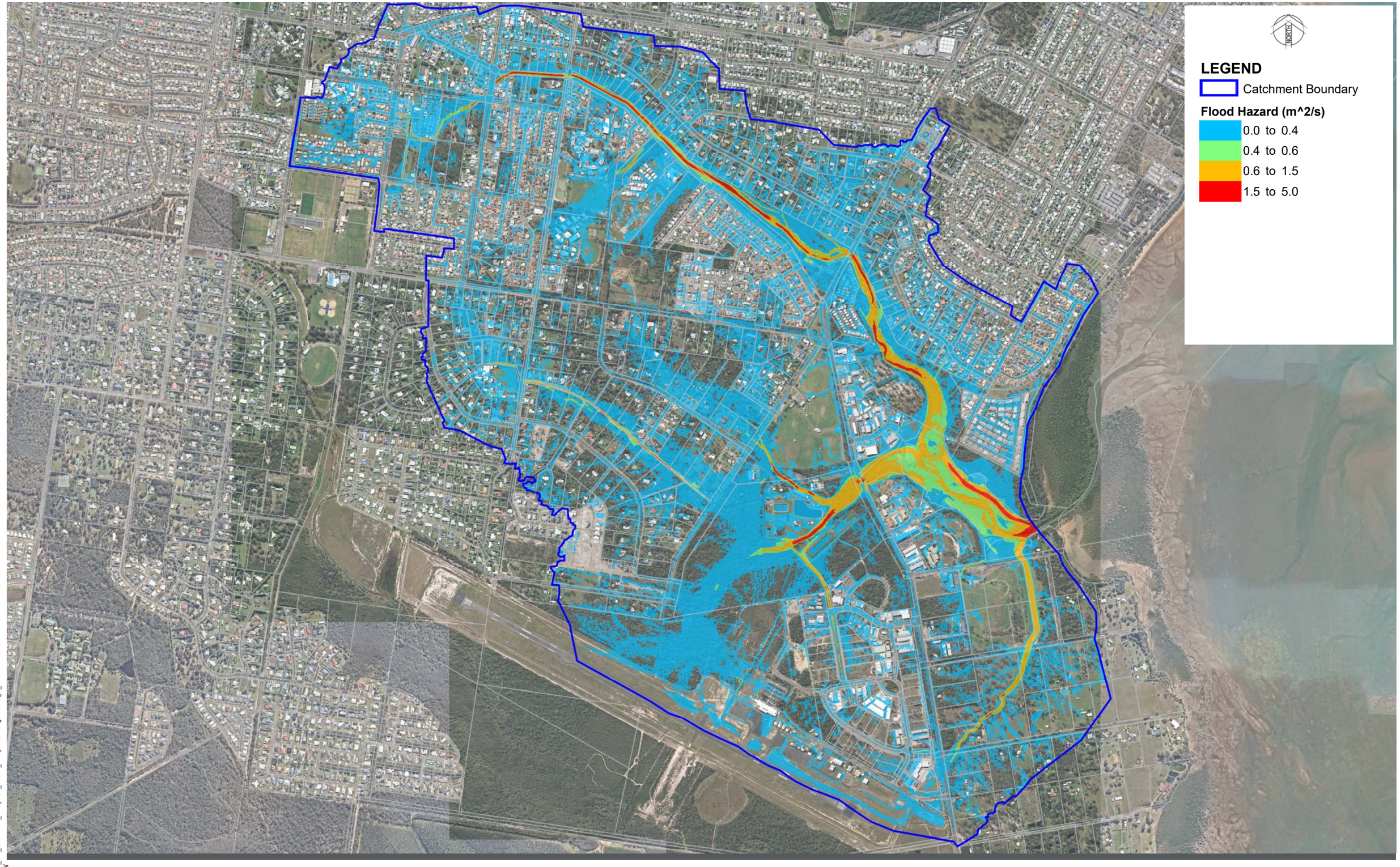
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Pulgul Creek Catchment Analysis
100 Year ARI (2090 Climate Scenario) - Maximum Flood Velocity

Fraser Coast Regional Council

Appendix A-3
PC_APPA.wor rev1



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Pulgul Creek Catchment Analysis
100 Year ARI (2090 Climate Scenario) - Maximum Flood Hazard

Fraser Coast Regional Council

Appendix A-4
PC_APPA.wor rev1

NORTH

LEGEND

Catchment Boundary

Critical Duration (min)

- 15
- 20
- 25
- 30
- 45
- 60
- 90
- 120
- 180

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kilometres

Pulgul Creek Catchment Analysis
100 Year ARI (2090 Climate Scenario) - Critical Duration

Fraser Coast Regional Council

Appendix A-5
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