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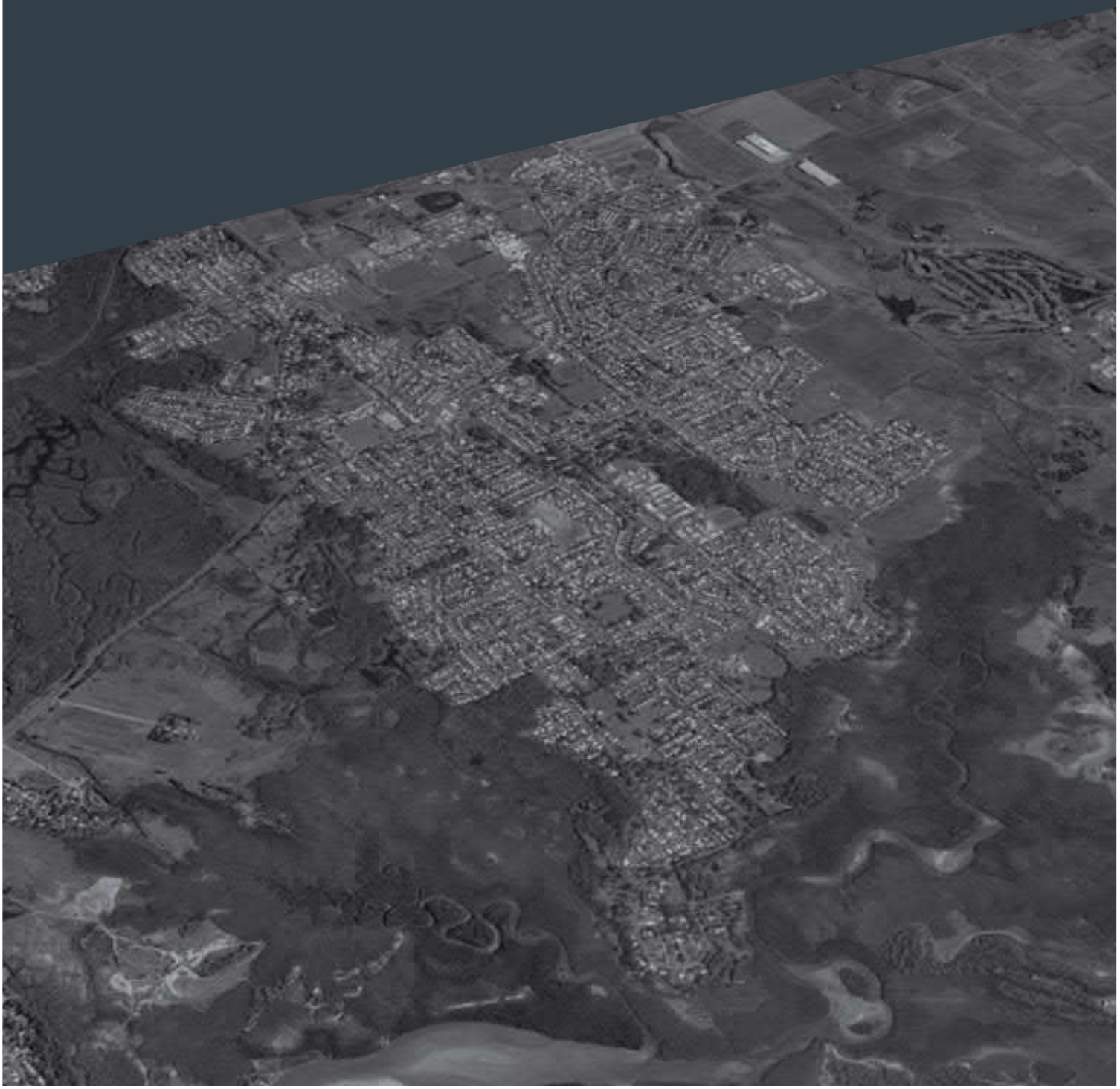
Andergrove Beaconsfield Drainage Study

Volume 1 Report



Andergrove Beaconsfield Drainage Study

Volume 1 Report

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17-Aug-2020

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Quality Information

Document	Andergrove Beaconsfield Drainage Study
	60630744
Ref	p:\606x\60630744 - 840 mrc agrove bfield d'age st\500_deliverables\501_dreport\m015-20 andergrove beaconsfield drainage study volume 1.docx
Date	17-Aug-2020
Prepared by	Trevor Corney / Hayden Brigg
Reviewed by	Sally Williams

Revision History

Rev	Revision Date	Details	Authorised	
			Name/Position	Signature
1.0	17-Aug-2020	Final for Client Issue	Trevor Corney Principal Project Manager	

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Executive Summary

AECOM Australia Pty Ltd (AECOM) has been commissioned by Mackay Regional Council (Council) to undertake the Andergrove and Beaconsfield drainage and mitigations options study. The study aims to provide recommendations for future works for increased flood resilience within the area.

The study involved developing a 2D hydraulic model to understand local flood behaviour and assess potential options to reduce existing and future flood risk for the community. The purpose of the study and mitigation options assessment is to inform Council's flood hazard mapping, capital works planning, budgetary processes, residual risk and also to assist Council in emergency management planning activities.

The development of the local catchment drainage study and stormwater trunk infrastructure assessment will ultimately provide council with the ability to:

- Determine existing flood level and associated flood hazard for the purpose of setting minimum habitable floor levels and flood hazard mapping suitable for incorporation into Mackay Region Planning Scheme (MRPS) overlays; and
- Investigate and determine appropriate trunk stormwater infrastructure required for the study area for the purpose of catering for the ultimate catchment development conditions in accordance with MRPS.

The Andergrove Beaconsfield Drainage Study Report has been split into 2 volumes:

- Volume 1 → Study methodology, results, findings and recommendations.
- Volume 2 → A3 flood results mapping associated with the Volume 1 report.

Existing Case Model Development

Hydrology

In order to estimate peak flood levels, flood extents and flood risk across the study area, a hydrologic assessment was undertaken to estimate flood flows resulting from the local catchment design rainfall events.

Hydrologic models were developed over the McCreadys Creek catchment. These models have been developed primarily using CatchmentSIM, XP-RAFTS and Storm Injector software. Peak flows from the hydrologic models were applied to the TUFLOW hydraulic model as external boundary inflows. The hydrologic models were also used to inform the critical duration and temporal pattern selection for the hydraulic modelling.

Standard techniques from AR&R were used to determine rainfall intensities from the 30 minute duration to the 6 duration for the 1EY (exceedance per year), 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP events.

The probable maximum flood (PMF) rainfall intensities were determined using the coastal Generalised Short-Duration Method (GSDM), which is applicable for small coastal catchments with short critical durations.

Hydraulic Model Development

An integrated one-dimensional (1D) / two-dimensional (2D) numerical hydraulic model was developed for the study. The model solves the depth averaged two-dimensional momentum and continuity equations for free-surface flow.

Hydrologic model and rain on grid boundary inflows were applied to the hydraulic model in combination with tidal boundary conditions.

The rain on grid method involves the application of rainfall directly to the two dimensional model domain. The rainfall depth in a particular timestep is applied to each individual hydraulic model grid cell, and the two dimensional model calculates the runoff from this particular cell.

The hydraulic model was unable to be calibrated due to a lack of recorded rainfall events and peak flood heights over the study area. Rather a model check was undertaken to the February 2008 rainfall event using recorded rainfall from the Gooseponds Alert (south of the study area) and a number of surveyed flood heights over the western portion of the study area

The comparison with the 2008 rain event shows reasonable correlation with the Holts Road east being the slight outlier. The miss-correlation at Holts Road east can be attributed to development in this area post the 2008 event. The model check indicates that the McCreadys Creek flow regime for the 2008 event is a reasonable correlation.

The modelled results were reviewed by council officers and there was general agreement that the flood footprints up to and including the 1% AEP event are a reasonable representation of the collective anecdotal information on current flood behaviour within the study area.

Baseline Modelling

The baseline TUFLOW model was simulated to map and report the peak flood depth, extents and velocities for the 1 EY, 50% AEP, 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP design events as well as the PMF. The observed results for each of these scenarios were tabulated and mapped within the Volume 1 and Volume 2 reports respectively.

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.
- Flow depth multiplied by flow velocity (DV).

The flood hazard for each design event was determined in accordance with AR&R 2019 Guidelines and included as part of this study. No assessment of evacuation times or duration of inundation was incorporated in this assessment.

The baseline assessment found that:

- There are six pipes with a discharge elevation below MWHS elevation of 2.35 mAHD.
- There are 86 pipes with discharge elevations below HAT elevation of 3.64 mAHD.
- Council may wish to undertake an audit of the stormwater infrastructure where culvert discharge elevations are below the normal tidal range of HAT and MHWS to understand the if the culvert is of the appropriate condition to withstand tidal influences and also to understand if a backflow prevention device is required to reduce tidal inundation upstream of the pipe outlet.
- In general terms the urban footprint hydraulic behaviour as simulated in the TUFLOW model follows the generalised minor/major flow capacity, whereby the pit and pipe system cater for the more frequent events (the so called nuisance flows) with the roads and dedicated drainage paths catering for the rarer events up to and including the 1% AEP event.
- However, there are a number of areas where there is substantial road inundation in the 50%AEP event. These areas included: Coles Road, Farquhar Street, Avocado Court, Barnfield Drive, Renae Street, Rhapis Court, Tropical Avenue & Newton Street.
- Council may wish to undertake an audit of all urban positive flow paths to understand if each individual flow paths is operating as intended and possibly to undertake works to provided positive flow paths. These works may include earthworks to lower ground profiles and provision of “grade or level savers” (perhaps concrete paths) to ensure long term grade maintenance.

Flood Mitigation Options Development

Non-Structural Mitigation Options

A number of non-structural flood mitigation measures were outlined for Council's consideration. These were broadly broken into the following areas:

- Community awareness.
- Land use planning and development control.
- Emergency management planning.

Structural Mitigation Options

Due to the flat topography and grade of land within Andergrove and Beaconsfield, there is only limited opportunities to improve the capacity of the underground network for the majority of the study area. The urbanised area has a reasonably a well-developed drainage network. In discussion with council, a number of areas were selected for assessment of structural mitigation options.

These included:

- Future Lot development
- Surveyed Discharge Locations.
- Coles Road
- Cabbage Tree Road open drain
- Farquhar Street and Avocado Court.

Mitigation Options Assessment

A mitigated case model was simulated as part of the study, this scenario included:

- Future Lot development – no works required except for Cabbage tree Road drain area
- Surveyed Discharge Locations – no works required.
- Coles Road – no works required.
- Cabbage Tree Road open drain – planning study - update the 2000 Master Plan with indicative development lot layouts and earthworks profiles.
- Farquhar Street and Avocado Court:
  - Add additional 900 RCP to Avocado Court.
  - Make changes to the north south pit and pipe systems to allow for pie/pit surcharging to the adjacent drain.
  - Construct Farquhar Street stormwater system.
  - Improve overland flow for Avocado Court cul-de-sac to western drain.

Indicative structural mitigation construction costs (base year 2020) for structural mitigation options are summarised in Table 1. The project costs exclude Goods and Service Tax (GST) and have a number of limitations as explained within this report.

Table 1 Indicative Structural Mitigation Costs

Location	Indicative Cost
Farquhar Street and Avocado Court	$ 1,790,000
Cabbage Tree Road Drain	$ 1,700,000
TOTAL	**$ 3,490,000**

A tangible flood damages assessment was undertaken for the Basecase and Developed Case, to provide an estimate of the existing financial burden borne by the community due to flood damages, and to quantify the financial benefit which may be realised by the implementation of the mitigation works.

A cost benefit assessment was undertaken to understand the net economic costs and tangible benefits associated with the mitigation options proposed. The cost benefit analysis below provides guidance on the net tangible impact of the proposed mitigated case against the existing conditions.

The assessment assumed a minimum stormwater asset life of 50 years and hence an assessment period of 50 years. No discount rate was applied. The results are shown in Table 2.

Table 2 Project Cost Benefit Ratios

Mitigation Option	Cost	Reduction in AAD	BCR
Farquhar Street and Avocado Court Drainage Upgrade & Cabbage Tree Road Drain	$ 3,490,000	$ 153,590 per year	2.20

Key Study Findings

There are a number of key findings of this study, including:

- East and west access to the study area is compromised in events larger than a 5% AEP design event. Alternative access to the study area is south along Norris Road and Glenpark Street.
- Over floor flooding is predicted within the study area with the majority around Farquhar Street.
- Tidal impacts are minimal up to the 1% AEP baseline design storm.
- The baseline scenario was corroborated to the few levels along McCreadys Creek for the 2008 event.
- The baseline scenario and the mitigated scenario did not include consideration of the ultimate planning scheme development to the west of Mackay Bucasia Road.
- The study area critical storm duration in both the Baseline and Mitigated scenarios:
  - Ranging from 30 minutes hour to 6 hours across the across the study area and the range of design AEP.
- The Baseline sensitivity analysis shows:
  - A 20% increase and decrease in roughness showed minimal change to urban drainage patterns with the study area.
  - A 20% increase in rainfall intensity and 0.8m increase in tidal levels, as a result of climate change by 2100, results in significant widespread additional flooding in the Aspley Creek area and some adjacent lots.
- Structural mitigation options provide some benefit in reducing flood extents and depths in Farquhar Street and Avocado Court.

It is recommended that this study be used as a basis for further investigations, setting development elevations and assisting in emergency management planning.

1.0 Introduction

1.1 Project Background

AECOM Australia Pty Ltd (AECOM) has been commissioned by Mackay Regional Council (Council) to undertake the Andergrove and Beaconsfield drainage and mitigations options study to provide recommendations for future works for increased flood resilience within the area. The study involved developing a 2D hydraulic model to understand local flood behaviour and assess potential options to reduce existing and future flood risk for the community. The purpose of the study and mitigation assessment is to inform Council's flood hazard mapping, capital works planning, budgetary processes, residual risk and also assist Council in emergency management planning purposes.

The development of the local catchment drainage study and stormwater trunk infrastructure assessment will ultimately provide council with the ability to:

- Determine existing flood level and associated hazards for the purposes of minimum floor levels and flood hazard mapping suitable for incorporation into Mackay Region Planning Scheme (MRPS) overlays; and
- Investigate and determine appropriate trunk stormwater infrastructure required for the study area for the purposes of catering for the ultimate catchment development in accordance with MRPS.

The Andergrove Beaconsfield Drainage Study, bordered by the state-controlled Mackay-Bucasia Road to the west, is encompassed by diverse land-use outlets including low-density residential, sport, recreation and commercial centres and facilities. To potentially reduce future flood risk, Council is seeking to understand flood behaviour occurring through Andergrove and Beaconsfield. Of particular interest is the nuisance flooding within low-lying areas of the study area across Holts Road, Zamia Court and Farquhar Street. Mitigation works to reduce flooding within the area have been proposed for assessment. A flood damage analysis and cost benefit analysis have been used to compare potential mitigation options for this area.

1.2 Study Objectives

The project objectives for the Andergrove Beaconsfield drainage study included the following:

- Develop 'best practice' hydrologic and hydraulic models capable of appropriately simulating the existing local catchment characteristics for the base case model, assessing existing flood risk within the Andergrove Beaconsfield area.
- Develop flood hazard overlays for inclusion in planning scheme (1% and 0.2% AEP levels + climate change factor).
- Development of structural and non-structural flood mitigation options, to improve resilience within the Andergrove Beaconsfield area.
- Develop a clear and achievable flood mitigation recommendations in consultation with Council staff, to reduce direct and indirect losses associated with future flooding.
- Prepare a preliminary cost/benefit of possible mitigation options.
- Minimise flood damage through more informed and reliable planning, appropriate mitigation, education, and disaster response.
- Minimise loss, disruption and social anxiety, for both existing and future floodplain occupants, helping develop a more resilient community.
- Provide more certainty of flood impacts within the broader community, changing community understanding and expectations to enable a more resilient community.

1.3 Notes on Flood Frequency

The frequency of flood events is generally referred to in terms of their Annual Exceedance Probability (AEP) or Average Recurrence Interval (ARI). For example, for a flood magnitude having 5% AEP, there is a 5% probability that there will be floods of equal or greater magnitude each year. As another example, for a flood having 5 year ARI, there will be floods of equal or greater magnitude of once in 5 years on average.

The correspondence between the two systems is shown in Table 3 below.

Table 3 Flood Frequency Classification

Annual Exceedance Probability (AEP) %	Average Recurrence Interval (ARI) Years
1EY	1
50	1.44
39	2
20	4.48
18	5
10	10
5	20
2	50
1	100
0.5	200
0.2	500

In this report, the AEP terminology has been adopted to describe the frequency of flooding.

1.4 Limitations and Exclusions

The following limitations and exclusions apply to the Andergrove Beaconsfield Drainage Study:

- Design flood events have been assessed using a max-max method across a range of storm durations, this process was applied for each design flood event.
- Aerial survey data (in the form of LiDAR) used to develop the topography for the hydraulic model has a vertical accuracy of ± 0.15 m on clear, hard surfaces and a horizontal accuracy of ± 0.45 m (described in Section 3.3).
- There were significant gaps in the surveyed underground drainage network information. Assumptions have been made where necessary to fill these. Other datasets, including design drawings and sketch plans provided by Council have been used wherever possible.
- The hydraulic model results have been compared to recorded flood heights following the rainfall event occurring in February 2008. Of note is that the pipes and culverts are based on 2020 current data and some of the culverts (Holts Road east in particular) were not installed in 2008. Due to significant development across the catchment since the last major recorded flood event, a true model calibration process was unable to be undertaken.
- The hydrologic and hydraulic modelling undertaken as part of the study have been based on methods and data outlined in Australian Rainfall and Runoff (AR&R) 2019 Guidelines, adopted as per Council's request. The updated 2016 rainfall intensities (BOM) have been used for hydrologic aspects of the study.
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- Where information has been supplied by the Client or other external sources, the information has been assumed correct and accurate unless stated otherwise. No responsibility is accepted by AECOM for incorrect or inaccurate information supplied by others.
- Council's Terrestrial LiDAR was provided with floor level data in the form of heights above ground levels. These levels were left unchanged unless noted in Appendix B.

Australian Rainfall and Runoff (AR&R) 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.
- Recognition that no two flood events behave in exactly the same manner.
- Design floods are a best estimate of an "average" flood for their probability of occurrence.

1.4.1 Interpretation of Results

The interpretation of results and other presentations in this report requires an appreciation of the limitations in accuracy, as noted above.

Unless otherwise stated, presentations in this report are based on peak values of water surface level, flow, depth and velocity. Using flood levels as an example, the peak level does not occur everywhere at the same time and, therefore, the values presented are based on taking the maximum value which occurred at each computational point in the model during the entire flood.

Hence, a presentation of peak levels does not represent an instantaneous point in time, but rather an envelope of the maximum values that occurred at each computational point over the duration of the flood event.

1.5 Report Structure

The Andergrove Beaconsfield Drainage Study Report has been split into 2 volumes:

- Volume 1 → Study methodology, results, findings and recommendations.
- Volume 2 → A3 GIS results mapping associated with the Volume 1 report.

The structure of this Volume 1 report is as follows:

- Section 2.0 describes the characteristics of the local catchments including typical land use and rainfall characteristics.
- Section 3.0 describes the data available for the development of the hydrologic and hydraulic models.
- Section 4.0 outlines the hydrologic modelling approach.
- Section 5.0 outlines the hydraulic modelling approach.
- Section 6.0 presents the baseline design flood depths, levels and extents for the study area.
- Section 7.0 presents the results of the investigation with the effects of climate change on discharges and modelled flood extents.
- Section 8.0 summarises the floodplain management principles.
- Section 9.0 provides recommendations and non-structural mitigation measures.
- Section 10.0 provides a summary of the preliminary structural mitigation options.
- Section 11.0 outlines the anticipated building impacts and results of the flood damages assessment
- Section 12.0 identifies the sequencing of mitigation options and the cost benefit ratios of associated options.
- Section 13.0 provides a constructability summary of proposed mitigation options
- Section 14.0 summarises the conclusions and recommendations.
- Section 15.0 provides a list of references utilised for the study.

2.0 Study Area and Key Characteristics

2.1 Study Area

The Andergrove and Beaconsfield Drainage study provided by Mackay Regional Council consists of the area bounded by McCreadys Creek by the north, east by Keeleys Road and south-west by Mackay-Bucasia and Golf Links road (refer Figure 3).

The study area is approximately 14 km^2 and comprises of a mix of medium to low-density residential land use on predominately council controlled roads, the landuse incorporates schools, light commercial (mainly ribbon strip shops), sport, recreation, throughout the suburban precincts.

2.2 Catchment History

The Andergrove area in 1970 was mainly rural pursuits such as cane farming and market gardening with the main access roads being Bedford Road, Andergrove, Oak Street and Maple Drive. Refer Figure 1 for 1976 aerial imagery of the area.

The Beaconsfield area in 1970 was predominately cane farming with some ribbon development along the then Mackay Bucasia Road (now Beaconsfield Road) and Eaglemount Road Refer Figure 1 for the 1976 aerial imagery.

Urbanisation of the two suburbs commenced in the early 1980's. Refer to Figure 2 from 1986 aerial imagery.

Today the two suburbs are pronominally dormitory suburbs for the main economic activity south of the Pioneer River (refer Figure 3 for the latest aerial imagery). The two suburbs host four schools, spots fields and low density commercial activity – ribbon shopping centres, nurseries and the like.

Figure 1 1976 Aerial Imagery of Andergrove / Beaconsfield (QLD Gov)

Figure 2 1986 Aerial Imagery of Andergrove / Beaconsfield (QLD Gov)

The suburb of Andergrove is the area generally to the east of Pitmann Street. The area is predominately flat with elevations ranging from 9 mAHD to 5 mAHD (refer Figure 3). The general slopes are from south to north and from east to west. The upper soil profiles to the east of Bedford Road are generally more sandy in nature whereas the upper soil profiles to the west of Bedford Road are more clayey in nature.

The suburb of Beaconsfield is the area between the Mackay Bucasia Road and Pitmann Street. The area is dominated by the hill on which Creese Street is located with a peak elevation of 29 mAHD and sloping down to 6 to 9 mAHD.

Land use are predominately low density residential, with community facilities (schools, emergency services), open space and some local centre (commercial activities such as shops).

Minimum development elevations across Andergrove and Beaconsfield are set within the current planning scheme at 5.5 mAHD

2.3 Climate Characteristics

The study area is located on a latitude of 21º South, about 250 km north of the Tropic of Capricorn. As a result, the catchment experiences a tropical coastal 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 of December to March.

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Legend

- Major Contour (2m Interval)
- Minor Contour (1m Interval)
- Roads
- Study Area (TUFLOW Model Extent)
- State Controlled Road Network

MACKAY REGIONAL COUNCIL

Andergrove Beaconsfield Drainage Study

Study Area and Topography

03

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2.3.1 Rainfall Regime

Mackay has a mean rainfall of 1550mm – 1600mm. The highest monthly rainfall of 320mm occurs throughout February. The highest and lowest annual rainfall totals recorded at the Mackay Meteorological Station were 2944mm (in 2010) and 794mm (in 1987) which shows a significant variation in annual rainfall from year to year.

The highest monthly rainfall of 1158mm was recorded in December 1990. The highest daily rainfall of 660mm was recorded on 15 February 2008. Figure 4 shows the distribution of the mean and median monthly rainfall throughout the previous year at the Mackay Meteorological Station (approximately 5km southeast of the study area).

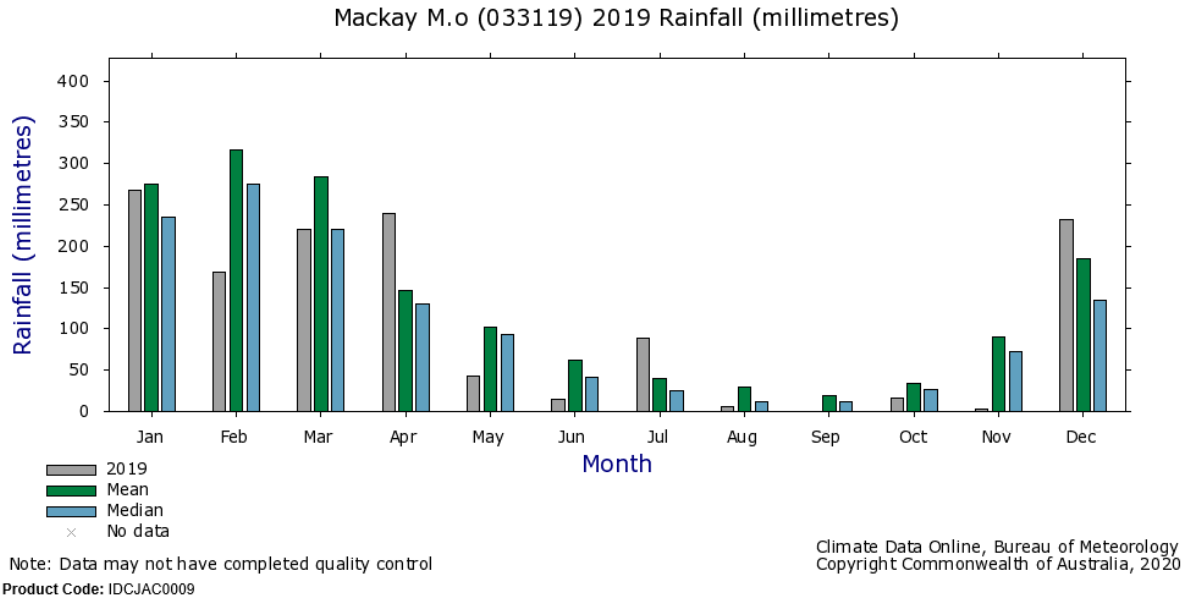


Figure 4 Mackay Meteorological Office Rainfall Statistics (BoM, 2019)

2.4 Tidal & Riverine Influences

The Mackay coastal region is characterised by a sandy coastline of 40km from Bakers Creek to the south and Shoal Point to the north. A considerable variation in water levels and water flows cause a large tidal range, exceeding 6 metres. The area of study is adjacent to the coastline and at the closest approximately 1 kilometre from the coastline. Direct tidal influences are the McCready creek estuary to the north of Andergrove and Beaconsfield and Apsley Creek to the east of Andergrove (refer Figure 3). Both of these tidal areas influence discharge from urban stormwater infrastructure especially during periods of higher tide elevations Figure 5 shows the extent of the Pioneer River influences within the study area.

Tidal levels from the 2020 Queensland Semidiurnal Tidal Planes Tables are:

- Mean High Water Springs (MHWS) - 2.349 mAHD
- Highest Astronomical Tide (HAT) – 3.639 mAHD.

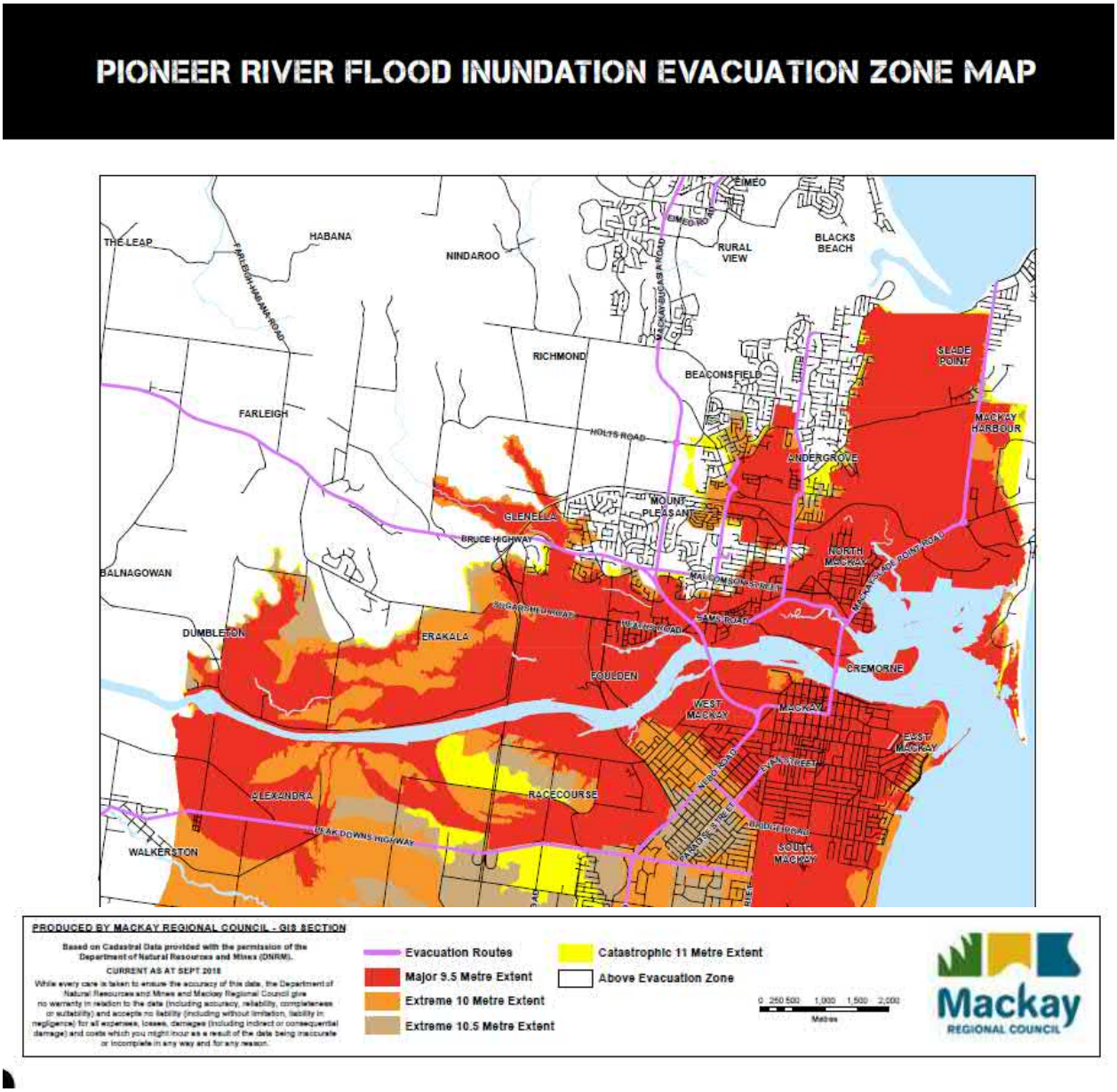


Figure 5 Pioneer River Flood Influences

3.0 Available Data

3.1 General

Available data for the development of baseline flood modelling for the catchment consisted of:

- Previous studies
- 2015 LiDAR topographical data
- 2019 July aerial imagery
- Council terrestrial LiDAR.
- Areas of development since the 2015 LiDAR data capture
- Stormwater infrastructure network database
- Details of hydraulic structures within the study area
- Tidal data
- Historical rainfall data for the 2008 flood event
- Historical flood records for the 2008 flood event
- Planning Scheme Guidelines
- GIS Data.

Detailed information relating to each dataset is provided in the subsequent sections.

3.2 Previous Reports

The following previous reports were referenced as part of the Andergrove Beaconsfield Drainage Study.

3.2.1 Andergrove Beaconsfield Neighbourhood Drainage Study (Ullman & Nolan 1983)

This report was targeted at producing a rational master stormwater drainage plan which allowed for the then existing and future residential allotments to be drained. The report nominated road layouts and stormwater drainage infrastructure and reserves. The majority development footprints and stormwater reserves within Andergrove and Beaconsfield is based are on the master planning within this report.

3.2.2 Glenella-Beaconsfield Trunk Stormwater Drainage Study (Ullman and Nolan Consulting, 1998)

This report was targeted at providing an overall strategy for the future development of the major stormwater channel which extends from Pioneer Street to downstream of Golf Links Road. In particular the report then addressed capacity of the existing truck drainage system and spatial requirements of the then future stormwater drainage reserves. The study used WBNM to assess catchment hydrology and HEC-RAS to assess stream hydraulics. Value of this report to the current study is that this study laid the ground works of allocating truck drainage paths and reserves which in part are still active in 2020.

3.2.3 Addendum-Glenella-Beaconsfield Trunk Stormwater Study (Ullman and Nolan Consulting, 2000)

This report addressed the then requirement to provide a 5% AEP culvert immunity for Holts Road east. This report is superseded by later studies.

3.2.4 McCreadys Creek Stormwater Drainage Study (KBR, 2006)

This report encompassed the whole of the McCready creek catchment that reported the mouth of McCready Creek. The study assessed the flood behaviour of the then existing conditions and provided recommendations for works within nominated priority subcatchments.

This report used RAFTS for the catchment assessment and HEC-RAS for the assessment of flood behaviour. For McCreadys Creek south this report has been superseded by the McCreadys Creek South Stormwater Trunk Infrastructure (WRM, 2015).

3.2.5 Central Andergrove Drainage – Capacity of Existing Trunk Drainage System (Cardno, 2012)

This report was targeted at reviewing the local catchment discharges and hydraulically model the existing stormwater network along Oak Street to Keeleys Road to understand the various flow regimes, peak water surface elevations and flow velocities. The study used WBNM to assess catchment hydrology and XP-UDD one dimensional hydraulic model to assess stormwater infrastructure behaviour. Value of this report to the current study is that this study is within the study area and will provide a measure of corroboration to this studies outcome.

3.2.6 McCreadys Creek South Stormwater Trunk Infrastructure Study (WRM, 2015)

This report was targeted at the Richmond development area to the west of the Mackay Bucasia Road an undertakes stormwater infrastructure planning for a then 5 year planning scenario and the ultimate development conditions. Value to this project is the base line case flows within McCreadys Creek south and the validation of the hydraulic performance to the 2008 rainfall event. Of note that the validated model includes the2012 culverts under Holts Road East. This study used RAFTS for the catchment hydrology and TUFLOW for the floodplain hydraulics.

3.3 Topographical Data

The topographical information used for the Andergrove / Beaconsfield local catchment hydraulic model was provided by Council in the form of LiDAR survey, which was undertaken in by the Department of Natural Resources and Mines (DNRM) between the 5th and 20th of August, 2015.

The LiDAR points were used to generate a base Digital Elevation Model (DEM) with a grid spacing of 1m. It is stated in the LiDAR metadata that the Horizontal Spatial Accuracy is estimated to be ±0.45m and the Vertical Spatial Accuracy is estimated to be ±0.15m, on clear open ground.

3.4 Aerial Photography

Aerial photography of Andergrove, Beaconsfield and surrounding region was supplied by Council. The dataset was supplied as a single mosaic image which covers the extents of the study area. The imagery was captured in July 2019 at a resolution of 10cm intervals.

3.5 Terrestrial LiDAR

Mackay Regional Council has captured property information through the attainment of Mobile Laser Scanning (MLS) point cloud LiDAR used to develop the Council Terrestrial LiDAR dataset. The data was captured throughout the entire Mackay Region in 2017.

The point cloud data has been translated into multiple GIS points, these points contain property information and levels such as: building purpose, floor type, construction material, garage level, edge of building level, patio level, habitable floor level, bottom of window level and eave height.

For the purposes of the tangible flood damages assessment, the building purpose, floor type and habitable floor level information was used to help classify property and assess inundation above floor level. The point information contained within the Terrestrial LiDAR dataset was joined to Council's cadastral database as part of the assessment, this made it easier to attach multiple fields to a singular building footprint for each lot.

3.6 Existing Stormwater Drainage Infrastructure

Drainage asset information was supplied by Council in the form of an ArcGIS Shapefile containing location and size for pit and pipe assets. Surveyed pit & pipe invert levels were also provided in the data files. A gap analysis of the database revealed some sections where pipe inverts and pit inlet dimensions were missing. Where stormwater infrastructure data was absent, details were estimated using the following assumptions:

- All upstream invert levels are at a higher elevation than downstream invert levels.
- Congruent pipe slopes between known inverts.
- No fall across pit structures.
- Minimum depth of cover of 600mm, where practicable.
- Upstream pipe diameter matched downstream pipe diameter.

Pits were categorised based on the layer types provided in the Shapefile and a supporting AutoCAD drawing provided by Council. In cases were pit data was missing or incomplete, Google Street View was used to correctly attribute the pit type. Council provided pit inlet and outlet elevations in a spreadsheet.

3.7 Hydraulic Structures

Identification of hydraulic structures associated with the major road and rail networks within the study area was completed using a combination of Council's stormwater infrastructure network database and site-specific visits. Major hydraulic structures networks are shown in Figure 6 which identity culverts that are greater than 900mm wide.

3.8 GIS Data

GIS data provided by Council included cadastral boundaries, road lines, railway lines, sewer mains, reticulated water mains, aerial imagery and planning zones. This information was provided in April 2020.

3.9 Tidal Data

Historic tidal data used in the February 2008 model validation eas obtained from open data made available by Maritime Safety Queensland. Historical records are available for the inclusive period of 1996-2020 at Mackay Outer Harbour.

For design events and sensitivities (without tidal influences or storm surge), tailwater levels used during this investigation were based on the MHWS level at Mackay Outer Harbour (2.35m AHD). The MHWS level was sourced from the 2020 QLD Semidiurnal Tidal Planes Tables.

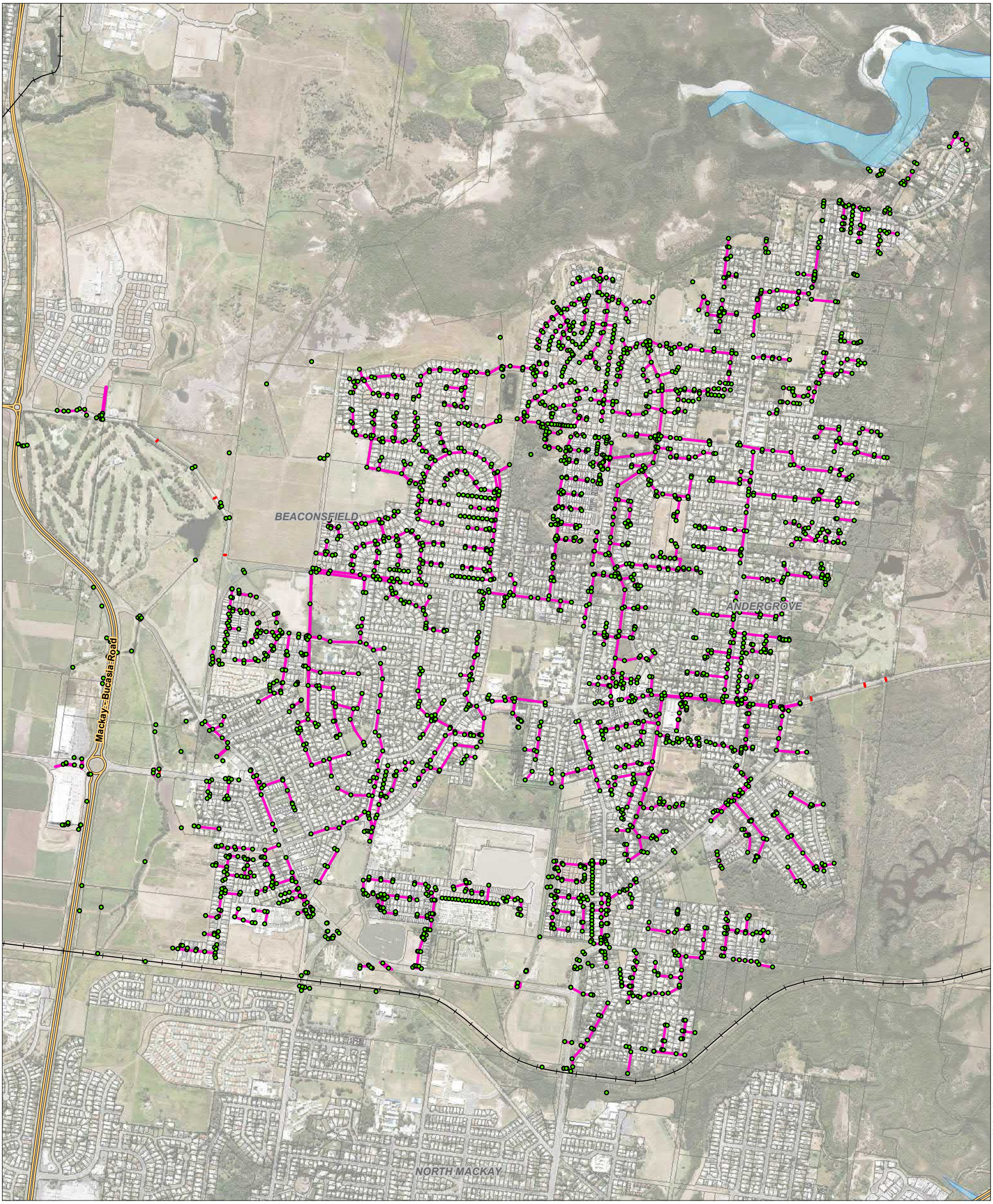
3.10 Historical Rainfall Data

Historic rainfall records for the 2008 Flood event were obtained from the Gooseponds Alert Station (533061) located approximately 4.5km southwest of the study area.

In an active phase of the monsoon trough, a low, originating in the Gulf of Carpentaria, traced a path southeast across southern Cape York Peninsula to intensify over land to the near west of Proserpine. The system brought with it localised severe winds to Airlie Beach and heavy rainfall to areas between Townsville and Rockhampton.

The low quickly moved out to sea allowing a strong high-pressure ridge to develop along the Queensland coast south of the monsoon trough. This brought about stable conditions to most parts of the state except the far north, where the monsoon trough remained active and about the Central Coast on the leading edge of the strengthening ridge. Conditions in Mackay deteriorated early on the 15th of February producing phenomenally intense rainfalls in the area and severe flash flooding (BoM 2008).

Figure 7 shows the recorded rainfall total at the Gooseponds Alert Station (533061) for the 2008 event.



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Legend

- Stormwater Node
- Stormwater Pipe
- Culvert
- Railway
- State Controlled Road Network
- Cadastre
- Watercourse Line
- Watercourse Area

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Andergrove Beaconsfield Drainage Study

MRC Suppluied Stormwater Drainage Infrastructure & Hydraulic Structures

06

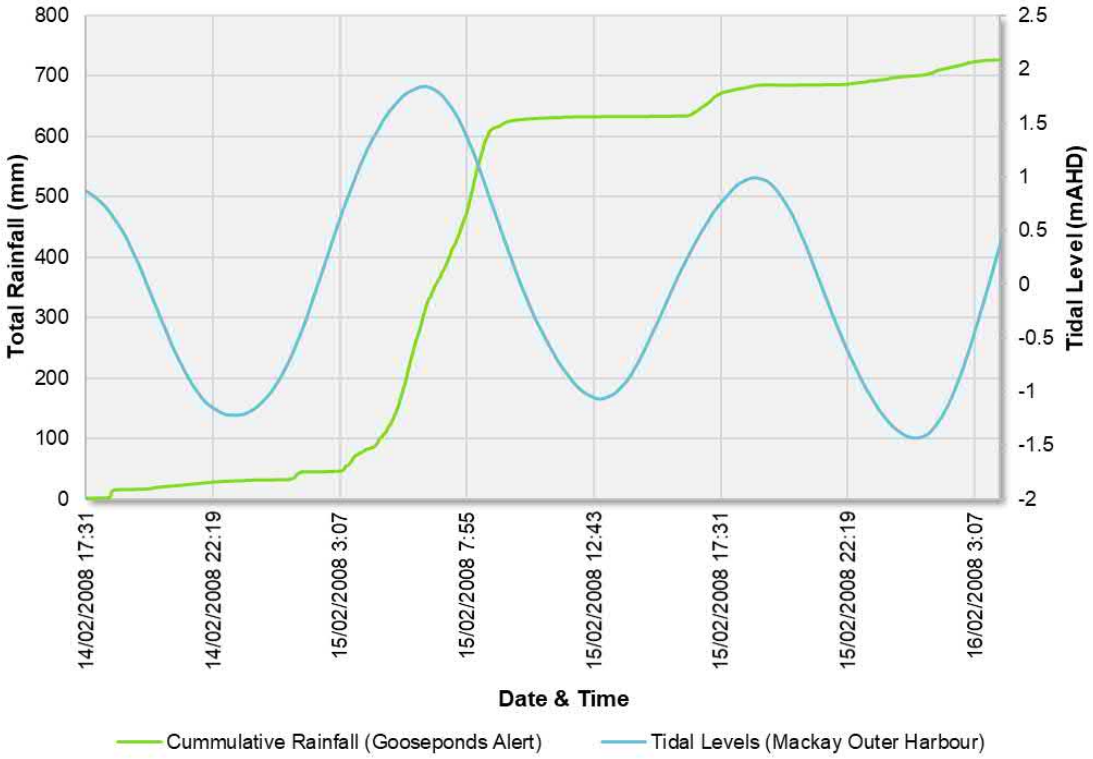

Figure 7 2008 Event Recorded Rainfall Depth

3.11 Historical Flood Records

Historical flood levels were recorded at key points across the Andergrove Beaconsfield Catchment by Council for the February 2008 rainfall event. These points and levels were provided by Council and used to assist in the validation of the baseline model, however due to substantial development in the catchment since 2008 and lack of recorded rainfall within the study boundary, a true model calibration process was unable to be undertaken.

The recorded flood height points provided are shown spatially in Figure 8.

Figure 8 2008 Event Recorded Flood Heights

3.12 Planning Scheme – Design Criteria

The planning scheme outlines the following desired standard of service for the stormwater network (sourced from the Mackay Regional Planning Scheme (2017) v3.0):

1. Collect and convey stormwater flows for both major and minor flood events from existing and future land use in a manner that protects life and does not cause nuisance or inundation of habitable rooms.
2. Design the stormwater network to comply with council's adopted standards identified in the planning scheme, which generally accord with the Queensland Urban Drainage Manual.
3. Design road crossing structures to provide an appropriate level of flood immunity in accordance with Council's adopted standards identified in the planning scheme.
4. Meet water quality objectives for receiving waters at all times, and comply with environmental permits, licences, management plans and performance standards.

The engineering design guidelines (stormwater drainage design) outline the following design criteria for the minor system:

a. Open Space – 1 Exceedance Per Year.
b. Residential – 18.13% Annual Exceedance Probability (Former 5 Year ARI).
c. Commercial – 18.13% Annual Exceedance Probability (Former 5 Year ARI).
d. Industrial – 18.13% Annual Exceedance Probability (Former 5 Year ARI).
e. Rural Residential – 18.13% Annual Exceedance Probability (Former 5 Year ARI).
f. Central Business – 7.5% Annual Exceedance Probability (Former 15 Year ARI).

3.13 Planning Scheme Guidelines

The following design standards have been outlined in the Mackay Region Planning Scheme Policy – Stormwater Drainage Design (Version 1.0, 2020):

The objectives of stormwater drainage design are as follows:

a. Provide a drainage system that will collect and convey stormwater from a catchment to its receiving waters with minimal nuisance, danger or damage and at a financial and environmental cost that is acceptable to the community as a whole.

b. Limit flooding of public and private property, both within the catchment and downstream, to acceptable levels; and

c. Provide convenience and safety for pedestrians and traffic in frequent stormwater flows by controlling those flows within prescribed velocity/depth limits.

For new developments, the engineer shall design a stormwater drainage system in accordance with the “major/minor” system concept in accordance with Queensland Urban Design Manual (QUDM). That is, the “major” system shall provide safe, well-defined overland flow paths for rare and extreme storm runoff events while the “minor” system shall be capable of carrying and controlling flows from frequent runoff events.

For redevelopment areas, the on-site drainage system is to be designed in such a way that the estimated peak flow rate from the site for the design Average Exceedance Probability of the receiving minor system is no greater than which would be expected from the existing development. Further, it is not to be concentrated in such a way as to cause nuisance to downstream properties.

The drainage study will act as a master plan for determining the drainage system and contributions for the development. The cost of the drainage plan shall be credited against drainage contributions required.

The design of the stormwater drainage system for any development shall be such that it caters for:

a. That upstream drainage / properties are not adversely affected.

b. That the downstream drainage system is capable of adequately catering for the discharge of the modified flow produced as a result of the development.

c. It is consistent with any relevant drainage study or catchment and waterway management plan, and;

d. Is based on the premise of peak load reduction by the use of suitable detention or infiltration methods.

If the downstream system is not capable of carrying the modified discharge, the engineer shall indicate the measure proposed to ensure the downstream system is capable of carrying the modified discharge. This will involve negotiation with adjoining landowners to produce easements over downstream drainage paths from the development site to the legal point of discharge.

Alternatively, where a development will result in increased runoff, the stormwater drainage system may include on-site measures such as detention basins to ensure that the peak discharge from the development area is restricted to a level no greater than that discharging prior to the development.

All works proposed within creeks and natural watercourse must have the approval of all relevant authorities prior to commencing the work and evidence of such approvals shall be provided with the design submission.

4.0 Hydrologic Assessment

4.1 Overview

In order to estimate peak flood levels, flood extents and flood risk across the study area, a hydrologic assessment was undertaken to estimate flood flows resulting from the local catchment design rainfall events.

4.2 Adopted Methodology

Australian Rainfall and Runoff (AR&R) is a national guideline document, data and software suite that can be used for the estimation of design flood characteristics in Australia. AR&R is pivotal to the safety and sustainability of Australian infrastructure, communities and the environment. It is an important component in the provision of reliable and robust estimates of flood risk. Consistent use of AR&R ensures that development does not occur in high risk areas and that infrastructure is appropriately designed.

The new release of the AR&R guidelines presented several changes to the previous 'best practice' modelling advice. Key changes that are relevant to the modelling of the study area are listed below:

- Updates to design rainfall Intensity Frequency Duration (IFD) values based on the inclusion of nearly 30 years additional rainfall data since the estimation of the AR&R 1987 IFDs.
- Changes to design hydrograph simulation approaches including the addition of the ensemble event approach where the magnitude of the design flood is estimated from the weighted average of a group (or ensemble) of design hydrographs. By using a set of design rainfall patterns to produce the estimates rather than a single pattern of variability, a reasonably unbiased estimate of the design flood is produced.
- Updates to catchment initial/continuing loss values based on regionalisation methods as well as the incorporation of pre-burst rainfall to simulate rainfall before the beginning of the design storm.
- Updates to Areal Reduction Factors (ARF) and the calculation process based on a more regionalised approach. ARFs convert the design point rainfall depth into a rainfall depth over the entire catchment.
- Climate change factors and calculations have also been updated based on the current industry best practise and knowledge.

4.3 Hydrologic Modelling

Hydrologic models were developed over the McCreadys Creek catchment as shown in Figure 9. These models have been developed primarily using CatchmentSIM, XP-RAFTS and Storm Injector software. Peak flows from the hydrologic models were applied to the TUFLOW hydraulic model (refer Section 5.0) as external boundary inflows.

The hydrologic models were also used to inform the critical duration & temporal pattern selection for the rain on grid modelling (Refer Section 4.4).The hydrologic assessment methodology follows that recommended in the 2019 revision of the AR&R guidelines and is outlined in the following sections.

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Legend

- Streamlines
- XP-RAFTS Nodal Link
- Hydrologic Model Extent
- Hydrologic Model Subcatchments
- Railway
- State Controlled Road Network
- Watercourse Area

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0 0.55 1.1 km

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Andergrove Beaconsfield Drainage Study

Hydrologic Model Extent and Subcatchment Delineation

09

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4.3.1 CatchmentSIM

CatchmentSIM was utilised for analysis of terrain based on LiDAR data (refer Section 2.3) to delineate the McCreadys Creek catchment into smaller sub-catchments for runoff routing calculations. Individual sub-catchment values for area and slope parameters were defined using the provided LiDAR data (refer Section 3.3). The catchment delineation of sub-catchments within the study area is shown in Figure 9.

4.3.2 XP-RAFTS

Hydrological modelling was undertaken to determine the design flood hydrographs for simulation through a two-dimensional hydraulic model (refer Section 4.0). XP-RAFTS software was used to model the rainfall-runoff processes of the McCreadys Creek catchment.

XP-RAFTS software is an event type rainfall-runoff hydrological model that calculates catchment flows based on rainfall data for application to flood simulation. Within the hydrological model, catchments are represented by nodes that are inter-connected by links. Each node in the model represents the characteristics of a sub-catchment and each link represents flow path routing between sub-catchments.

The model parameters required for each catchment are:

- Sub-catchment area.
- Sub-catchment slope.
- Sub-catchment surface roughness, and;
- Sub-catchment fraction impervious.

Routing lag times between sub-catchments were calculated using the Stream Velocity Method (QUDM, 2017) based on the use of an ‘assumed’ average stream velocity to determine a nominal ‘time of concentration’, that compensates for the flow attenuation effects of floodplain storage.

The average subcatchment slope was used to determine the stream velocity for each subcatchment as per the relationship presented in Table 4. The catchment slope is a measure of the average slope of the full drainage catchment, not the stream bed, thus it is not the same as stream slope or ‘equal area slope’. This is consistent with the methodology outlined in QUDM.

Table 4 Modified Stream Velocity Method (QUDM, 2017)

Catchment Description		Travel Velocity (m/s)
Flat country (0 to 1.5% average catchment surface slope)		0.3
Rolling country (1.5 to 4% average catchment surface slope)		0.7
Hilly country (4 to 8% average catchment surface slope)	Significant floodplain storage exists along most of the waterway.	0.9
	Natural floodplain storage is limited by adjacent hill slopes, or the natural floodplain storage has been reduced by urbanisation and/or land filling.	1.5
	The waterway has experienced significant channelization that has removed most of the floodplain storage relevant to the flood event being studied.	2.0

The XP-RAFTS model network is shown in Figure 9. Impervious fraction parameters were determined based on land use classification automated through GIS machine learning (ML) principles.

Appendix C summarises the parameters applied to the nodes in XP-RAFTS to define sub-catchments.

4.3.3 Storm Injector

The ensemble temporal patterns from the AR&R Data Hub for the Wet Tropics region were simulated through the XP-RAFTS hydrologic model mentioned above. Storm Injector software serves as the interface between the existing hydrologic models and AR&R Data Hub, allowing for efficient employment of range of magnitude-duration-temporal pattern combinations. The Storm Injector software platform was also used to prepare hydrologic outputs for presentation, as well as inflow files for the TUFLOW hydraulic model.

Once the hydrological models were simulated for all ensemble temporal patterns, the design event hydrograph for each catchment was selected though statistical analysis of the results. AR&R does not provide definitive guidance regarding rationale behind selecting the representative design event hydrograph from an ensemble of storms. Based on current industry trend, the design hydrograph for this project was selected as the result of the temporal pattern that delivers a peak flow rate that is **closest to the mean flow rate with a bias of 2 to those exceeding the mean** from the critical duration flood. The critical duration is determined based on the ensemble of storms with the highest mean flow from all storm durations across the durations for the given storm probability.

Figure 8 shows a flow chart visualisation of the process described above, detailing how the design flow hydrograph was selected through the ensemble approach. The design flow hydrograph for each event at key sites was then prepared for input into the TUFLOW hydraulic model following completion of formal checking and verification processes.

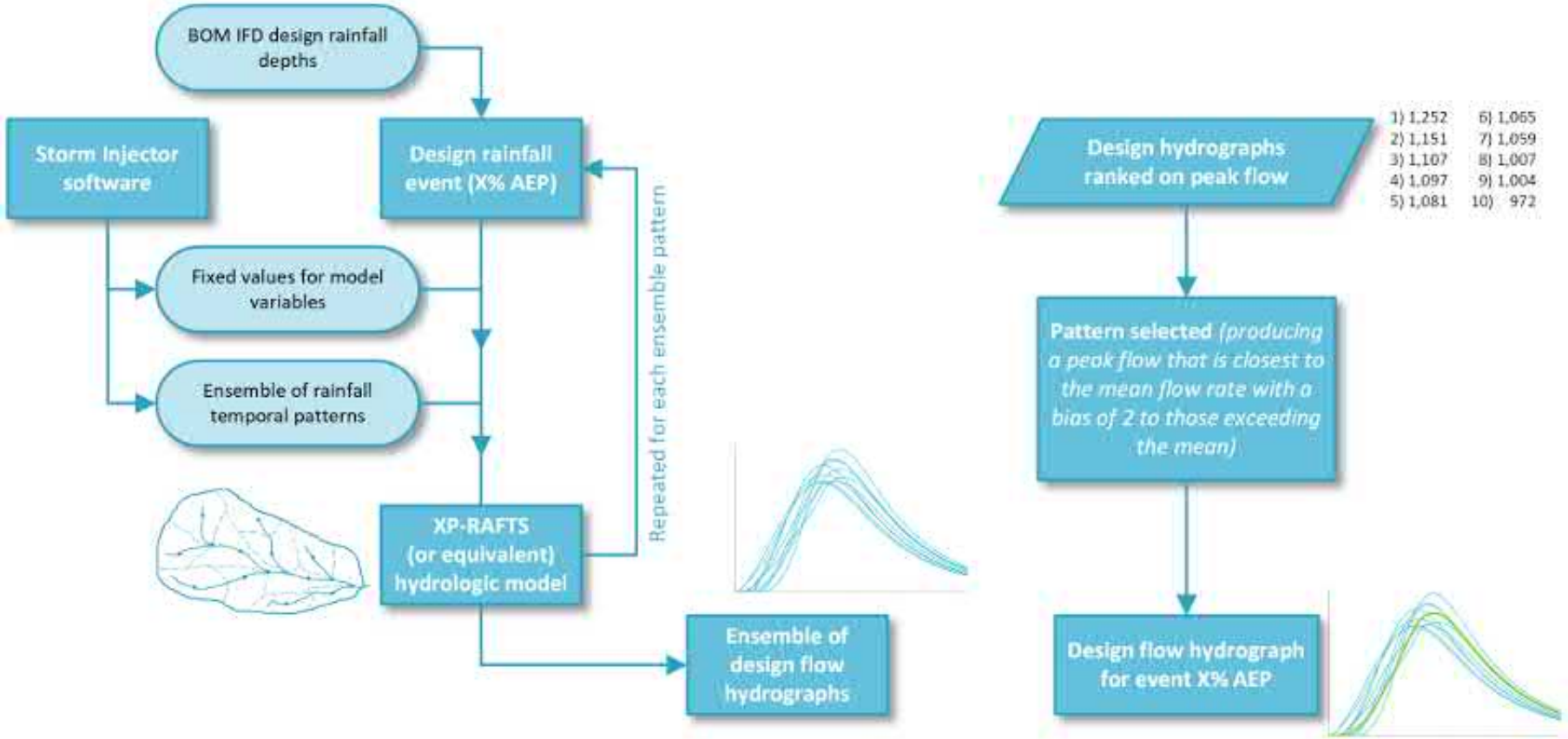


Figure 10 Ensemble Approach to Design Flow Hydrograph Selection

4.4 Direct Rainfall Approach

In traditional hydrologic modelling, the hydrological model converts the rainfall within a sub-catchment into a peak flow hydrograph. This flow hydrograph is then applied to the hydraulic model, which estimates flood behaviour across the study area.

In the direct rainfall approach, the hydrological model is either partially or completely removed from the process. The hydrological routing is undertaken in the two dimensional hydraulic model domain, rather than in a lumped hydrological package.

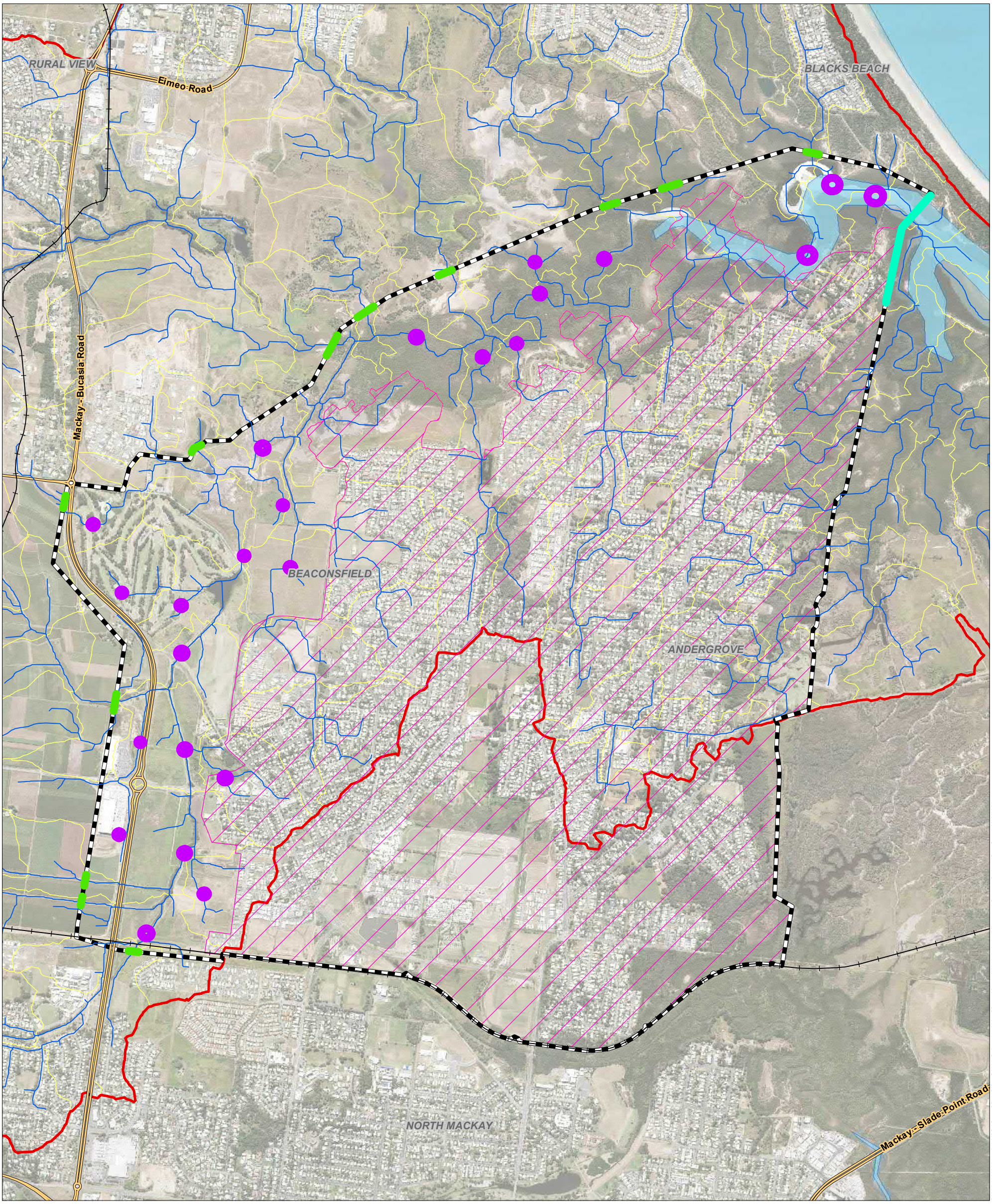
The direct rainfall method involves the application of rainfall directly to the two dimensional model domain. The rainfall depth in a particular timestep is applied to each individual hydraulic model grid cell, and the two dimensional model calculates the runoff from this particular cell.

AR&R Revision Project 15 notes the following advantages of direct rainfall modelling:

- Use of the direct rainfall approach can negate the need to develop and calibrate a separate hydrological model, thus reducing overall model setup time.
- Assumptions on catchment outlet locations are not required. When a traditional hydrological model is utilised, an assumption is required on where the application of catchment outflows are made to the hydraulic model.
- Assumptions on catchment delineation are not required. Flow movement is determined by 2D model topography and hydraulic principles, rather than on the sub catchment discretisation, which is sometimes based on best judgement and can be difficult to define in flat terrains.
- Cross catchment flow is facilitated in the model. In flat catchments, flow can cross a catchment boundary during higher rainfall events. This can be difficult to represent in a traditional hydrological model.
- Overland flow is incorporated directly. Overland flow models in traditional hydrological packages require a significant number of small sub-catchments, to provide sufficient flow information to be applied to a hydraulic model.

There are also several disadvantages associated with the use of the direct rainfall approach:

- Direct rainfall is a new technique, with limited calibration or verification to gauged data.
- The rain-on-grid approach can potentially increase hydraulic model run times.
- Requires digital terrain information. Depending on the accuracy of the results required, there may be a need for extensive survey data, such as aerial survey data.
- Insufficient resolution of smaller flow paths may impact upon timing. Routing of the rainfall applied over the 2D model domain occurs according to the representation of the flow paths by the 2D model.
- The shallow flows generated in the direct rainfall approach may be outside the typical range where Manning's 'n' roughness parameters are utilised.



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Legend

- Tidal Boundary
- External Hydrological Inflows (Total Upstream Catchment)
- Internal Hydrological Inflows (Local Catchment)
- Streamlines
- Hydrologic Model Extent
- Hydrologic Model Subcatchments
- Railway
- Rain on Grid Extent
- TUFLOW Model Extent
- State Controlled Road Network
- Watercourse Area

AECOM

N

0 0.3 0.6 km

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Andergrove Beaconsfield Drainage Study

Hydrologic Inflow Locations and Rain on Grid Modelling Extent

11

4.5 Hydrologic Parameters

The following sections outline the hydrologic parameters that were applied to both the hydrologic models and the rain on grid modelling extent.

4.5.1 Intensity Frequency Duration (IFD) Parameters

Site specific Intensity Frequency Duration (IFD) data was determined using the design rainfall database from the Bureau of Meteorology (BoM) as per advice within the AR&R guidelines.

The design rainfall IFD input data was obtained at the nearest grid cell to the centroid of each sub-catchment. The 2016 IFD values were sourced April 2020. The design rainfall was extracted from the centroid of the overall Andergrove / Beaconsfield catchments (21.09°S / 149.18°E) is shown in Table 5.

Table 5 IFD Design Rainfall Depth (mm) (BoM, 2020)

Duration	Design Rainfall Depth (mm)						
	1EY	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
30 min	32.6	36.5	48.2	55.9	63.3	72.7	79.8
45 min	39.3	44.1	58.7	68.3	77.6	89.4	98.3
1 hour	44.5	50.0	67.0	78.3	89.2	103	114
1.5 hour	52.4	59.2	80.4	94.5	108	126	139
2 hour	58.5	66.5	91.2	108	124	144	160
3 hour	68.2	78.1	109	130	150	176	196
4.5 hour	79.4	91.7	130	156	181	215	241
6 hour	88.5	103	148	178	208	249	280
9 hour	103	121	177	215	254	306	347
12 hour	115	135	200	246	291	355	405
18 hour	134	158	238	295	353	436	503
24 hour	149	177	268	335	404	504	585

4.5.2 Ensemble Temporal Patterns

The 2019 revision of the AR&R guidelines introduced an ensemble approach to design flood peak flow estimation which aims to provide a more robust assessment than traditional methods (refer Section 4.2). The ensemble approach requires hydrological simulation of 10 separate temporal patterns for each combination of storm duration and probability, rather than the single temporal pattern approach from AR&R 1987.

A common difference between the old and new temporal patterns is how rainfall is distributed across a storm event. Generally, over two thirds of each storm's rainfall falls in the first half of the previous AR&R 1987 temporal patterns. Temporal patterns for AR&R 2019 have been determined based on updated analysis with a range of rainfall distributions, however rainfall is more often consistent throughout each storm duration compared with AR&R 1987 temporal patterns.

Figure 12 illustrates the distribution of new temporal patterns against the AR&R 1987 temporal pattern for a 9-hour storm.

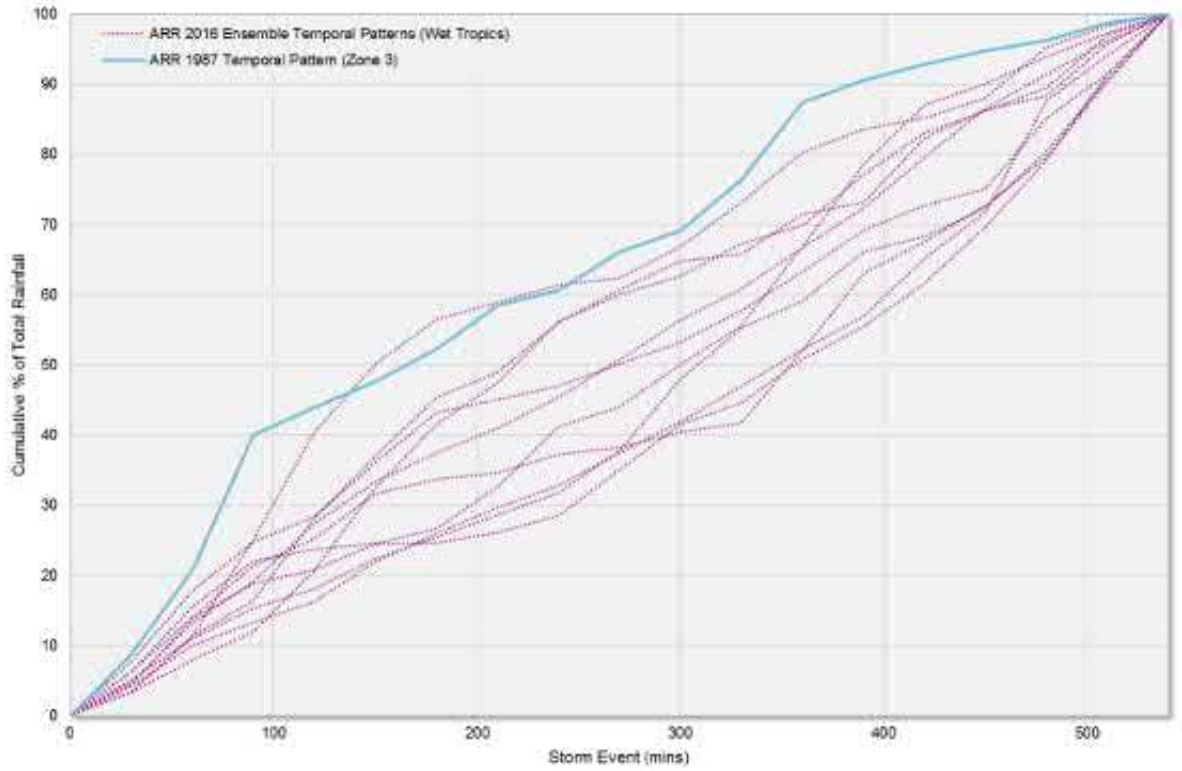


Figure 12 Comparison of Temporal Patterns – 1% AEP 9 Hour Storm

4.5.3 Areal Reduction Factors (ARF)

As the Andergrove / Beaconsfield catchments cover a large area, design rainfall intensities at a point are not representative of the areal average rainfall intensity across the catchments. The ratio between the design values of areal average rainfall and point rainfall, computed for the same duration and (AEP, is called the Areal Reduction Factor (ARF). This allows for the fact that larger catchments are less likely than smaller catchments to experience high intensity storms simultaneously over the whole of the catchment area.

ARF values were calculated as per the AR&R 2019 guidelines. As the critical duration was found to be between 30 minutes and 6 hours (refer Section 4.5.6) which is within the short duration storms range (less than or equal to 12 hours), the ARF was determined using the short duration equation below.

$$ARF = \min\left\{1, \left[1 - 0.287(Area^{0.265} - 0.439\log_{10}(Duration)).Duration^{-0.36} + 2.26\times10^{-3}\times Area^{0.226}.Duration^{0.125}(0.3+\log_{10}(AEP)) + 0.0141\times Area^{0.213}\times10^{-0.021}\frac{(Duration-180)^2}{1440}(0.3+\log_{10}(AEP))\right]\right\}$$

Where Area is in km^2, Duration is in minutes and AEP is a fraction (between 0.5 and 0.0005).

The results of the calculation of ARF factors applied to the Andergrove / Beaconsfield hydrologic model are displayed in Table 6.

Table 6 Design Storm Areal Reduction Factors

Storm Duration	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
30 min	0.8357	0.827	0.8203	0.8137	0.8049	0.7983
45 min	0.8637	0.8539	0.8464	0.839	0.8292	0.8218
1 hour	0.8807	0.8698	0.8617	0.8535	0.8426	0.8344
1.50 hour	0.9013	0.8885	0.8789	0.8692	0.8564	0.8468
2 hours	0.9138	0.8994	0.8885	0.8776	0.8632	0.8523
3 hours	0.9289	0.9129	0.9009	0.8888	0.8728	0.8608
4.50 hours	0.9415	0.9282	0.9182	0.9081	0.8948	0.8848
6 hours	0.9492	0.9409	0.9346	0.9283	0.92	0.9137
9 hours	0.9584	0.9538	0.9503	0.9468	0.9422	0.9387
12 hours	0.964	0.9593	0.9558	0.9523	0.9477	0.9442

4.5.4 Embedded Bursts

Embedded bursts occur when the rainfall accumulated over a subset (the “burst”) of a storm’s temporal pattern has a depth (mm) that exceeds the IFD value for the burst’s duration for the same AEP. Consideration of ARFs (which vary by duration) also exacerbates problems with embedded bursts since ARFs tend to be lower (more reduction) for shorter durations which reduces the amount of rainfall that can occur in embedded bursts and, as such, increases the amount and severity of embedded bursts.

AR&R states that consideration should be given to filtering out (or excluding) embedded bursts of lower AEP by re-distributing rainfalls of high intensity to other time increments proportionally to their magnitudes. Embedded bursts smoothing was applied for all bursts that exceeded 2% of specified IFD depth value (mm).

4.5.5 Design Event Rainfall Losses

XP-RAFTS & TUFLOW rain on grid modelling calculates a design rainfall excess time series for each storm probability (AEP) and duration to represent the local net precipitation for the study area. This rainfall excess was calculated by applying initial and continuing losses to the design rainfall to represent infiltration and storage of runoff in surface depressions.

The AR&R data hub provides a mean initial loss for the Andergrove / Beaconsfield catchments (from the North East Coast region) of 37.0 mm and a continuing loss of 4.8 mm/hr.

This is to be considered in conjunction with the preburst depth, which AR&R provides values for various percentiles of occurrence. For this project the median preburst depth has been adopted.

Where the initial storm loss exceeds the preburst depth, the difference is taken as the initial burst loss parameter. Where the preburst depth exceeds the initial loss the excess preburst rainfall was reduced to 0mm.

The median preburst depths for the study area are shown in Table 7.

The continuing loss value for each sub-catchment was set to 2.5 mm/hr. This was consistent with previous modelling undertaken in the Mackay Region. The AR&R data hub suggested a continuing loss value in excess of 4 mm/hr, this was deemed inappropriate based on previous models developed within the region and did not align with calibrated losses from bounding studies.

The initial / continuing loss values were applied to impervious areas in both the hydrologic model and hydraulic model within the rain on grid extent.

Table 7 Median Preburst Depths – ARR Data Hub

Storm Duration (hrs)	Design Event (AEP) Median Preburst Depth (mm)					
	50%	20%	10%	5%	2%	1%
1	9	10.6	11.7	12.7	41	62.3
1.5	16.2	28	35.8	43.3	50.4	55.6
2	23.8	30.3	34.6	38.7	51.2	60.5
3	23.8	34	40.8	47.4	61.1	71.4
6	23.2	42.6	55.4	67.6	93.1	112.2
12	28.4	52.5	68.5	83.8	100.9	113.7
18	17.9	39.3	53.5	67.1	61.8	57.9
24	10.7	35.2	51.4	67	74.9	80.8
36	2.1	28.6	46.1	62.8	75.4	84.8

4.5.6 Critical Duration Assessment

A critical duration assessment was undertaken reviewing the results of the hydrologic modelling for each AEP event. This assessment was undertaken using methodologies outlined in the AR&R 2019 guidelines. A box and whisker plot was produced at each sub-catchment to assess the statistical variation of the ensemble peak flows for each event.

The critical duration storm for the study area was assessed at several key locations within the catchment, by simulating the 10 Wet Tropics ensemble temporal patterns through the XP-RAFTS hydrological model (refer Section 4.3.2) for a variety of durations. These durations range from the 15 minute to the 36 hour storm duration.

The results of the critical duration assessment for the 1% AEP event at Golf Links Road (Sub-catchment 76) are presented in Figure 13. At this location, the 6 hour storm returned the highest mean peak flow rate for the ensemble assessment. Full results from the critical duration assessment for the 1% and 10% AEP events at key locations are included in Appendix E.

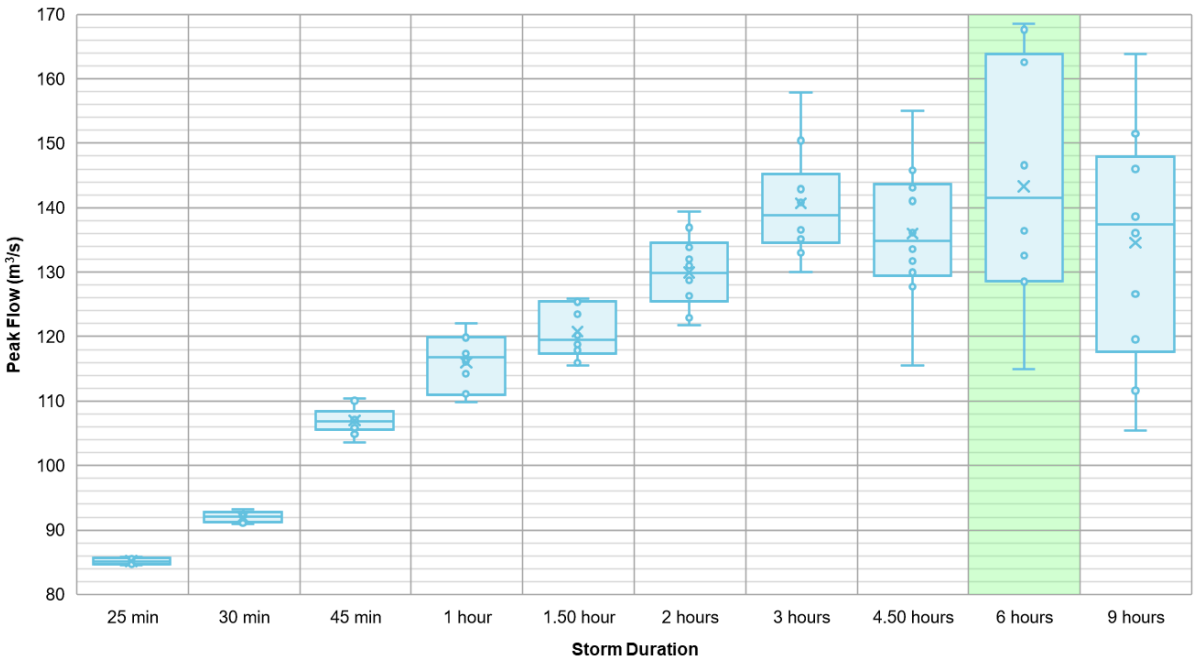


Figure 13 1% AEP Critical Duration Box Plot at Golf Links Road (Subcatchment 76)

4.5.7 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 of overtopping of a dam and minimise the likelihood of dam failure.

Other than this practical use, it is used to provide an indication of the largest flood extents expected within any given catchment and also forms the upper bound within flood damages assessments. PMF behaviours can be used by emergency management agencies in their understanding of and planning for flood events.

The Generalised Short-Duration Method (GSDM), as revised in 2003, was applied to derive estimates of PMP for short duration storms. The GSDM applies to catchments up to 1,000 km2 in area and durations up to 6 hours, which makes the method applicable to the Andergrove Beaconsfield Study which has a catchment area of approximately 36.5 km^2 and a critical duration of 6 hours or less (refer Section 4.5.6).

Using the methodology set out in the GSDM Guidebook (BoM, 2003), the following data for the PMP was determined:

- The coastal GSDM Method is applicable as the catchment lies on the Queensland coast.
- The Roughness (R), Elevation Adjustment Factor (EAF) and Moisture Adjustment Factor (MAF) were calculated as 1.0, 1.0 and 0.90 respectively.
- PMP parameters were calculated as shown in Table 8.

Table 8 Adopted PMP Rainfall Depths & Immunity

Duration (hrs)	Rainfall Total (mm)	Rainfall Intensity (mm/hr)
0.5	272.9	545.8
1	412.2	412.2
2	528.2	264.1
3	592.0	197.3
6	754.0	125.7

The AEP of the PMP event was calculated as recommended in AR&R (Pilgrim, et al, 1987). For a catchment area of 36.5 km^2, the PMP event is approximately a 1 in 10,000,000 AEP event.

5.0 Hydraulic Modelling

5.1 Overview

An integrated one-dimensional (1D) / two-dimensional (2D) hydraulic model was developed to simulate flood behaviour within the study area. TUFLOW software (version 2020-01-AB) was used for all model simulations. This is consistent with other drainage studies undertaken for MRC.

5.2 Hydraulic Model Parameters

This section of the report documents the development of the hydraulic model used to simulate piped drainage and overland flows within the catchment. A TUFLOW hydraulic model was produced with parameters as shown in Table 9.

Table 9 TUFLOW Model Parameters

Parameter	Andergrove / Beaconsfield TUFLOW Hydraulic Model
Completion Date	June 2020
AEP's Assessed	1EY, 50%, 20%, 10%, 5%, 2%, 1%, 0.2%, 0.5% AEP & PMF
Hydrologic Modelling	Direct rainfall on 2D grid
IFD Input Parameters	AR&R 2016, Refer Section XXX
Hydraulic Model Software	TUFLOW Version 2020-01-AB-iSP-w64
Grid Size	3 m (with sub-grid sampling)
DEM (year captured)	LiDAR (2015)
Roughness	Spatially varying and depth varying standard values (Refer to Appendix A)
Eddy Viscosity	Smagorinsky
Model Calibration	No model calibration undertaken due to major developments in the catchment since the previous (2008) flood event and lack of recorded rainfall within the study area. Comparison to 2008 Rainfall event.
Downstream Model Boundary	Height varying discharge based on catchment slope at overland outflow locations. A static tidal boundary (HT) using the level for Mean High Water Springs (MHWS) was used for the model boundary at McCreadys Creek discharging to Slade Bay.
Timesteps	HPC mode uses a varying time step for the 2d domain with a specified minimum time step of 0.8 seconds. 0.5 seconds was adopted for the 1D network.
Wetting and Drying Depths	Cell centre 0.0002 m
Sensitivity Testing (refer Section 6.9)	Manning's Roughness ± 20% Climate Change to year 2100 (1% and 0.2% flood models only) Highest Astronomical Tide (HAT) Boundary Storm Surge Tidal Boundary

5.3 Model Setup

A visual representation of the model setup including the code, boundaries, 1D network and hydraulic roughness delineation are included in Figure 14 to supplement the detailed setup notes provided in Appendix A.

5.3.1 Modelling Cross Drainage Structures

The pit and pipe data provided by Council was reviewed for completeness and data quality. With changes made where required (refer Section 3.6).

Modelling parameters associated with the 1D network were consistent with the recommended energy loss values in the TUFLOW reference manual. Manning's roughness coefficient values which were applied to the cross drainage infrastructure were consistent with aged concrete (0.013).

The same assumptions were applied to existing case and developed case models.

5.3.2 2D Modelling Roughness

Within the model extent, land use was delineated using machine learning (ML) techniques within a GIS interface to rapidly classify landuse using the latest imagery. This process was leveraged of training a computational model to inform manual assignment of landuse classes and distributions.

By applying this process to automatically classify land use from the latest aerial imagery, the accuracy and precision of the spatial distribution of hydraulic roughness values is increased substantially when compared to previous roughness digitisation methods. The machine learning process is also easily repeatable and will provided consistency to hydraulic modelling in future studies.

The hydraulic roughness distribution (resampled to a 3m grid) that was applied to the TUFLOW model is displayed in Figure 15. Details on the Manning's roughness values applied to each category is available in Appendix A.

5.4 Critical Duration Assessment

The critical storm duration for the study area was assessed by simulating the 30 minute, 45 minute, 1 hour, 1.5 hour, 2 hour, 3 hour, 4.5 hour, 6 hour, 9 hour and 12 hour duration storms for the range of AEP events using the selected 'mean' temporal pattern derived from the RAFTS model for each individual AEP event and simulated in the baseline hydraulic model.

Figure 16 shows the 1% AEP critical duration map for the selected temporal patterns using ARR 2019 methodology. Table 10 nominates the durations that were selected as critical for each AEP. The results of each of these durations were combined to present a maximum results raster, representative of the critical duration at all locations within the model extent.

Table 10 Critical Duration Storms for Each Event

Duration	1EY	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
30 min						✓	✓
45 min						✓	✓
1 hour						✓	✓
1.5 hour			✓	✓	✓	✓	✓
2 hours	✓	✓	✓				✓
3 hours	✓	✓	✓			✓	✓
4.5 hours	✓	✓	✓				
6 hours	✓	✓		✓	✓	✓	✓
9 hours	✓			✓	✓		
12 hours	✓	✓					

5.5 Rainfall Simulation

The model adopted the following process to simulate design storm events:

- Over the urbanised footprint of the localities of Andergrove and Beaconsfield direct rainfall was applied.
- Over the non-urbanised areas of the study area which is essentially the catchment and watercourse of McCreadys Creek inflow hydrographs where adopted either as boundary inflow hydrographs or local catchment inflow hydrographs.

Figure 11 in Section 4.0 shows the spatial footprint of the rain on grid simulation.

5.6 Model Confirmation

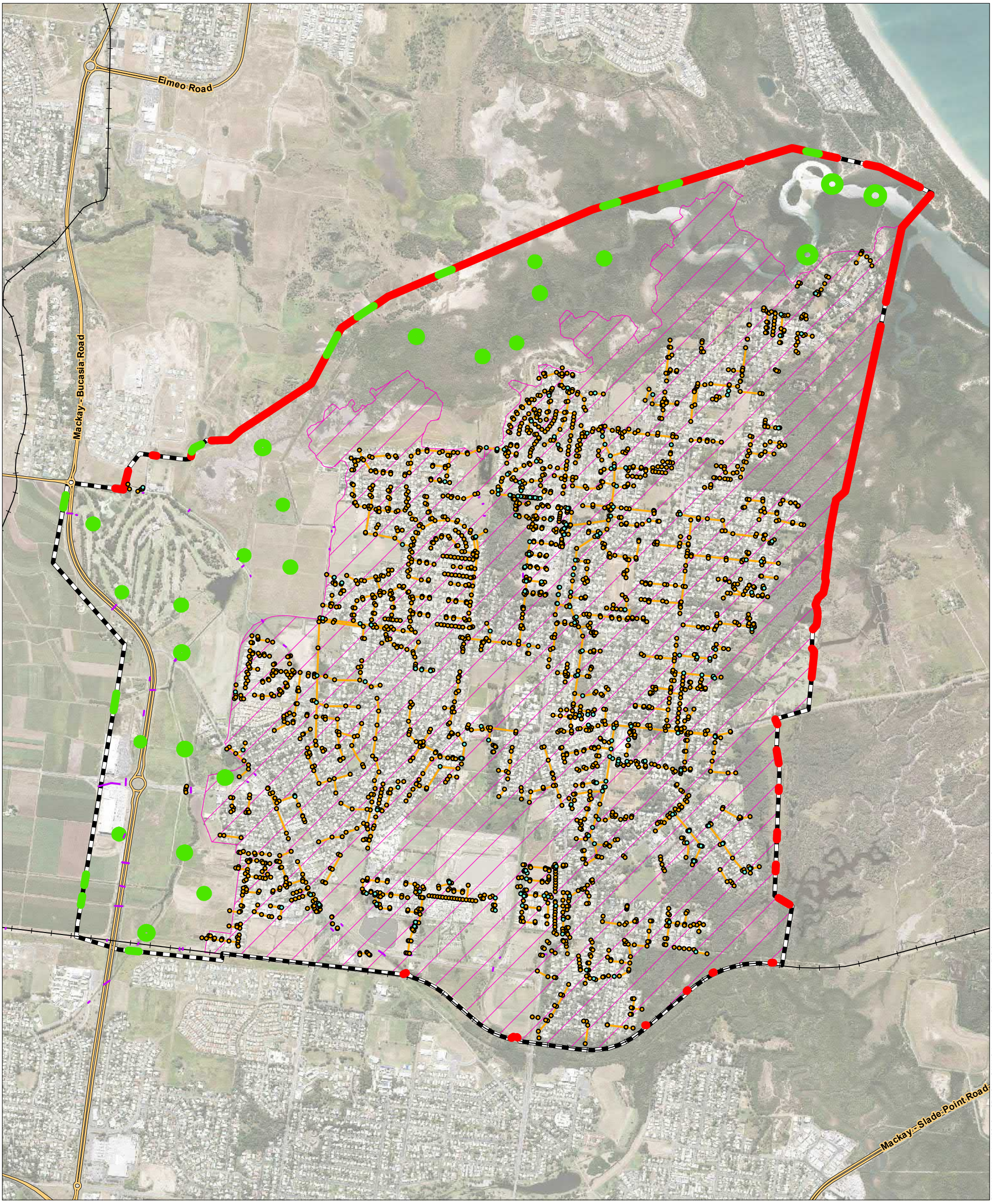
Table 11 shows the 2008 event record elevations, the WRM 2015 report PWSE elevations and the PWSE derived from this study.

Table 11 Model Conformation to 2008 Event

Location	Lidar Ground Elevation (mAHD)	2008 PWSE (mAHD)	WRM 2015 2008 PWSE	PWSE – 2008 event
Mackay Bucasia Road	7.13	7.24	7.36	7.27
Holts Road East	6.00	5.86	6.21	6.17
Beaconsfield Road	4.84	5.30	5.35	5.25
Golf Links Road	4.80	4.86	-	4.88

The comparison with the 2008 rain event and the WRM 2015 report shows reasonable correlation with the Holts Road east being the slight outlier. As discussion previously both the WRM report and this study include the Holts Road east culverts constructed in 2008. The correlation at Holts Road east is of academic interest only and indicates the McCreadys Creek flow regime for the 2008 event is a reasonable correlation.

The 2008 event data only has information for the western portion of the study area. The modelled results were reviewed by council offices and there was general agreement the flood footprints up to and including the 1% AEP event is a reasonable representation of the collective anecdotal information on flood behaviour within the study area.



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Legend

- Manhole
- Pit
- Pipe
- Culvert
- Outflow Boundary
- Hydrological Inflow Boundary
- Railway
- Rain on Grid Extent
- TUFLOW Model Extent
- State Controlled Road Network

AECOM

N

0 0.3 0.6 km

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Andergrove Beaconsfield Drainage Study

TUFLOW Hydraulic Model Setup

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Legend

- TUFLOW Model Extent
- Open Space
- Light Vegetation
- Medium Vegetation
- Heavy Vegetation
- Sugar Cane
- Roads / Concrete
- Waterbodies
- Buildings

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Andergrove Beaconsfield Drainage Study

Hydraulic Roughness Delineation

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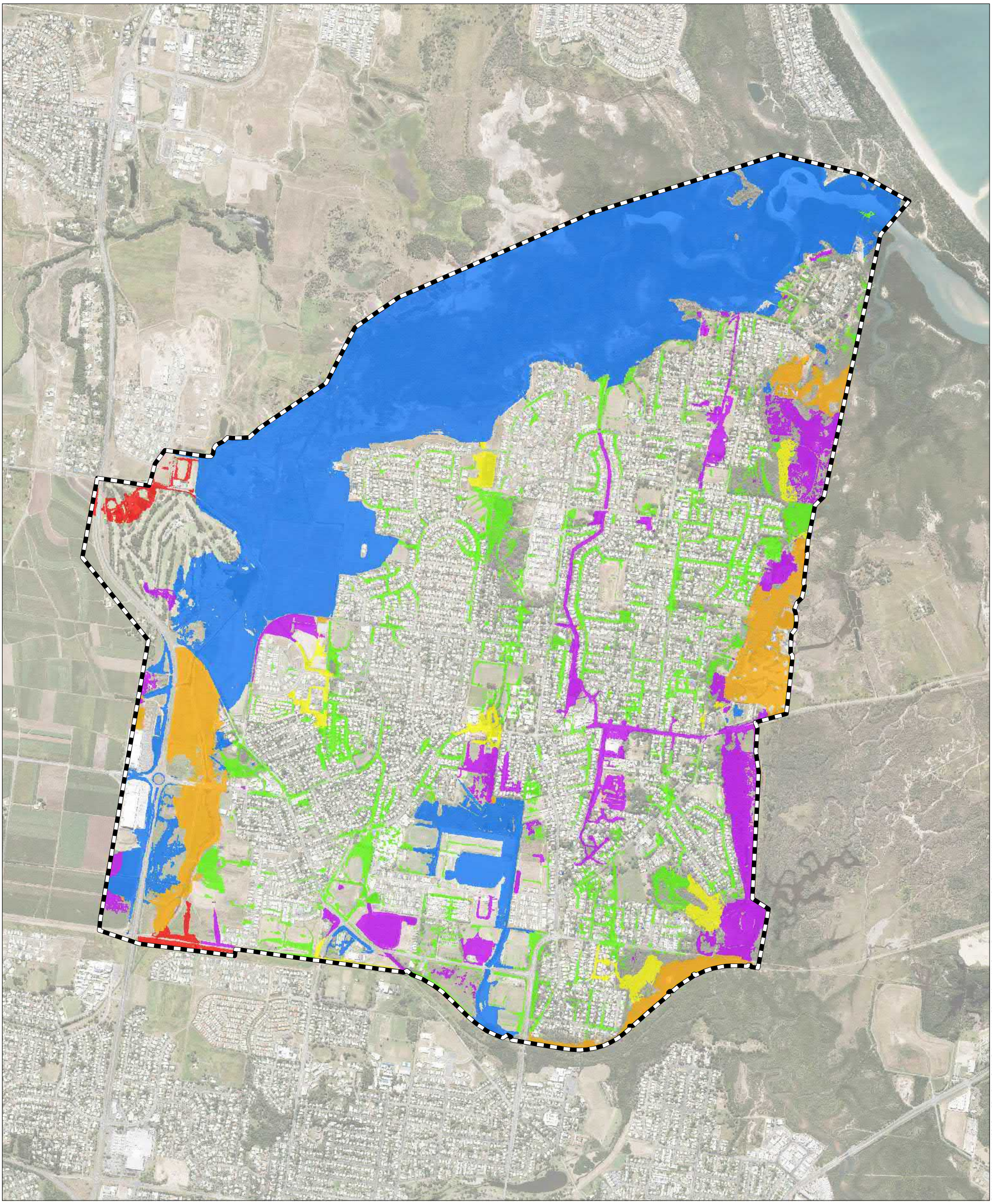

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Legend

- TUFLOW Model Extent
- 30min Storm
- 45min Storm
- 1hr Storm
- 1.5hr Storm
- 2hr Storm
- 3hr Storm
- 6hr Storm

AECOM

N

0 0.3 0.6 km

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Andergrove Beaconsfield Drainage Study

1% AEP Critical

Duration Map

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6.0 Baseline Hydraulic Results

6.1 Overview

Direct rainfall modelling uses a process whereby rainfall is applied to every model cell. Mapping of these results in their raw form would show that the entire model extent was flooded. For this reason, areas where the flow depth is less than 0.1m were removed from the mapping, as is standard practice. Note that these depths are not excluded in the computational scheme. Furthermore, areas where the flood extent was less than 36m^2 (4 grid cells), were removed from the result mapping for the modelling undertaken. Both these processes are in accordance with guidance from AR&R.

GIS results mapping includes peak flood elevations, depths and velocities and can be found in the Andergrove Beaconsfield Drainage Study – Volume 2 Report.

6.2 Baseline Peak Flood Depths, Extents and Velocities

Maps 01 to 30 within the Volume 2 Report show the flood depth, extents and velocities for the 1 EY, 50% AEP, 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and PMF Baseline events respectively. The observed results for each of these scenarios are described further in the following sections.

6.3 Baseline Peak Water Surface Levels

Appendix G provides a summary of the baseline peak water surface levels at key interest points for the 1EY, 50% AEP, 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP events as well as the 1% AEP event with climate change to 2100 (refer Section 7.0).

GIS results maps of the baseline peak water surface levels across the entire model extent and are available in the Andergrove Beaconsfield Drainage Study – Volume 2 Report (Maps 21-30).

6.4 Baseline Peak Discharges

Appendix G provides a summary of the baseline peak discharges at key interest points for the 50% AEP, 20% and 1% AEP events.

6.5 Baseline Velocity

Appendix G provides a summary of the baseline velocities at key interest points for the 1EY, 50% AEP, 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP events.

GIS results maps of the baseline velocities across the entire model extent and intersection site are available in the Andergrove Beaconsfield Drainage Study – Volume 2 Report (Maps 11-20).

6.6 Baseline Flood Hazard

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.
- Flow depth multiplied by flow velocity (DV).

No assessment of evacuation times or duration of inundation was incorporated in this assessment.

Maps 31 to Map 40 within the Volume 2 report show the Baseline Flood Hazard for the velocities for the 1 EY, 50% AEP, 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and PMF Baseline events respectively. Definitions of the associated flood hazard categories are also included in the Volume 2 report.

6.7 Baseline Trunk Network Capacity

A summary of the Baseline trunk network capacity identifying the capacity of the network within Study Extent during the design storm for 39%, 18% and 1% AEP as provided in Table 12 with the capacity related to pipe diameter displayed in Table 13.

Table 12 Baseline 1D Pipe Network Capacity

ARI Event	Total Length (m)	Pipe Capacity		
		39% AEP	18% AEP	1% AEP
Baseline 1D network	69960	55%	79%	97%

Table 13 1D Pipe Network Capacity by Diameter

Nominal Pipe Dimension (mm)	Length greater in area than (m)	Pipe Capacity (for pipes with an area greater than listed)		
		39% AEP	18% AEP	1% AEP
375	65426	54%	78%	96%
450	47231	56%	80%	97%
525	37442	57%	80%	96%
600	30854	57%	79%	96%
675	23570	56%	77%	95%
750	19218	56%	77%	95%
828	11933	53%	73%	94%
900	11532	52%	73%	94%
1050	8684	50%	71%	93%
1200	5892	47%	71%	92%
1350	3762	41%	71%	88%
1500	2441	35%	64%	82%
1800	1547	34%	53%	82%

Pipe capacity is assessed by TUFLOW. It is to be noted that the baseline model has no backflow prevention devises on any of the drainage infrastructure. This was due to lack of information provided at the commencement of the study.

6.7.1 Possible Tidal impacts pipes

Appendix G lists pipes with the urban footprint of the study area that are:

- Pipes with discharge elevations below MWHS elevation of 2.35 mAHD. There are six pipes listed in this table.
- Pipes with discharge elevations below HAT elevation of 3.64 mAHD. There are 86 pipes listed in this table.

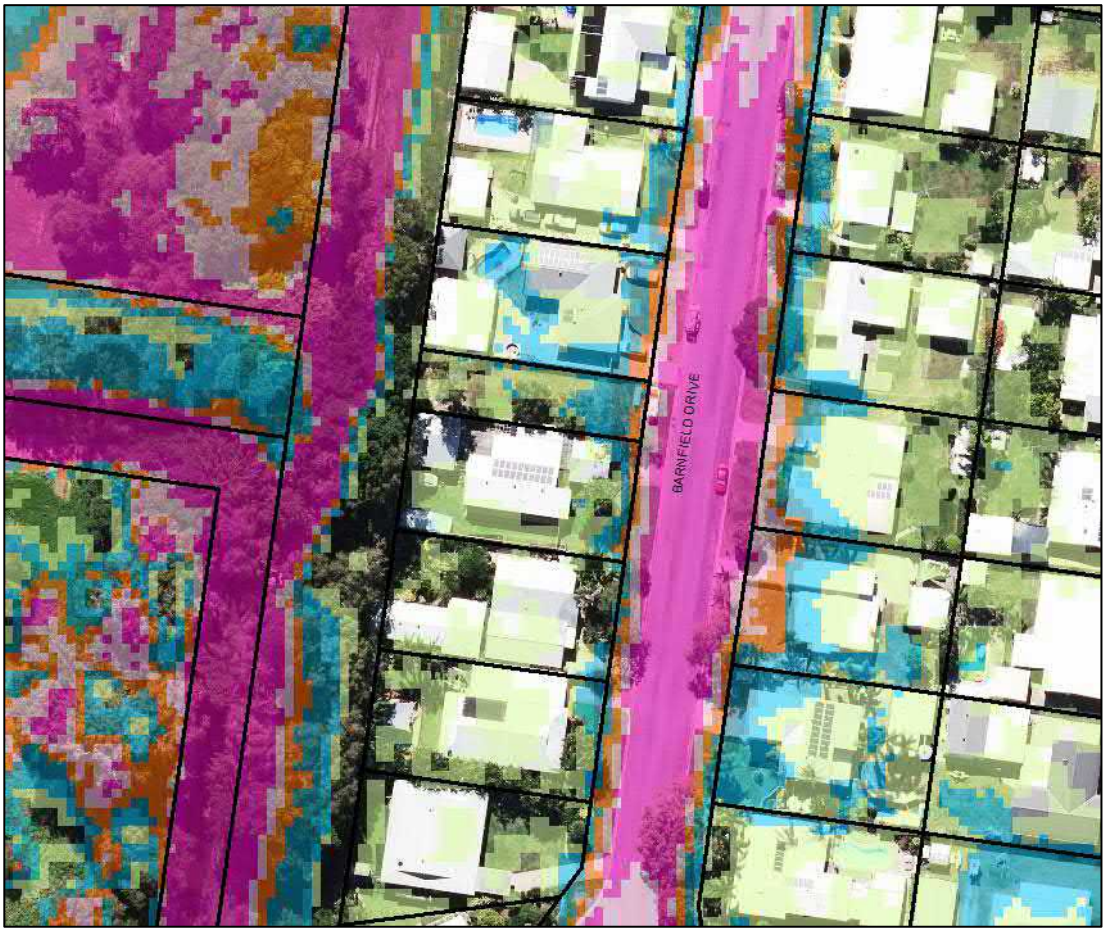
Council may wish to undertake an audit of the stormwater infrastructure where culvert discharge elevations are below the normal tidal range of HAT and MHWS to understand the if the culvert is of the appropriate condition to withstand tidal influences and also to understand if a backflow prevention device is required to reduce tidal inundation upstream of the pipe outlet.

6.7.2 Positive Discharge Paths

Barnfield Drive in the 1% AEP event is flooded up to approximately 0.75m depth. The flooded area is adjacent to the drainage path. However, in the 1% AEP event the drainage path is not engaged due to the reserve being approximately 0.5m higher than the top of the existing kerb and channel. While in the current circumstances only 1 house experiences over floor flooding (18mm in a 1% AEP event)hence the main issues being one of access and safety.

Council may wish to undertake an audit of all urban positive flow paths to understand if each individual flow paths is operating as intended and possibly to undertake works to provided positive flow paths. These works may include earthworks to lower ground profiles and provision of “grade or level savers” (perhaps concrete paths) to ensure long term grade maintenance.

Figure 17 Barnfield Drive with 1% AEP flood footprint



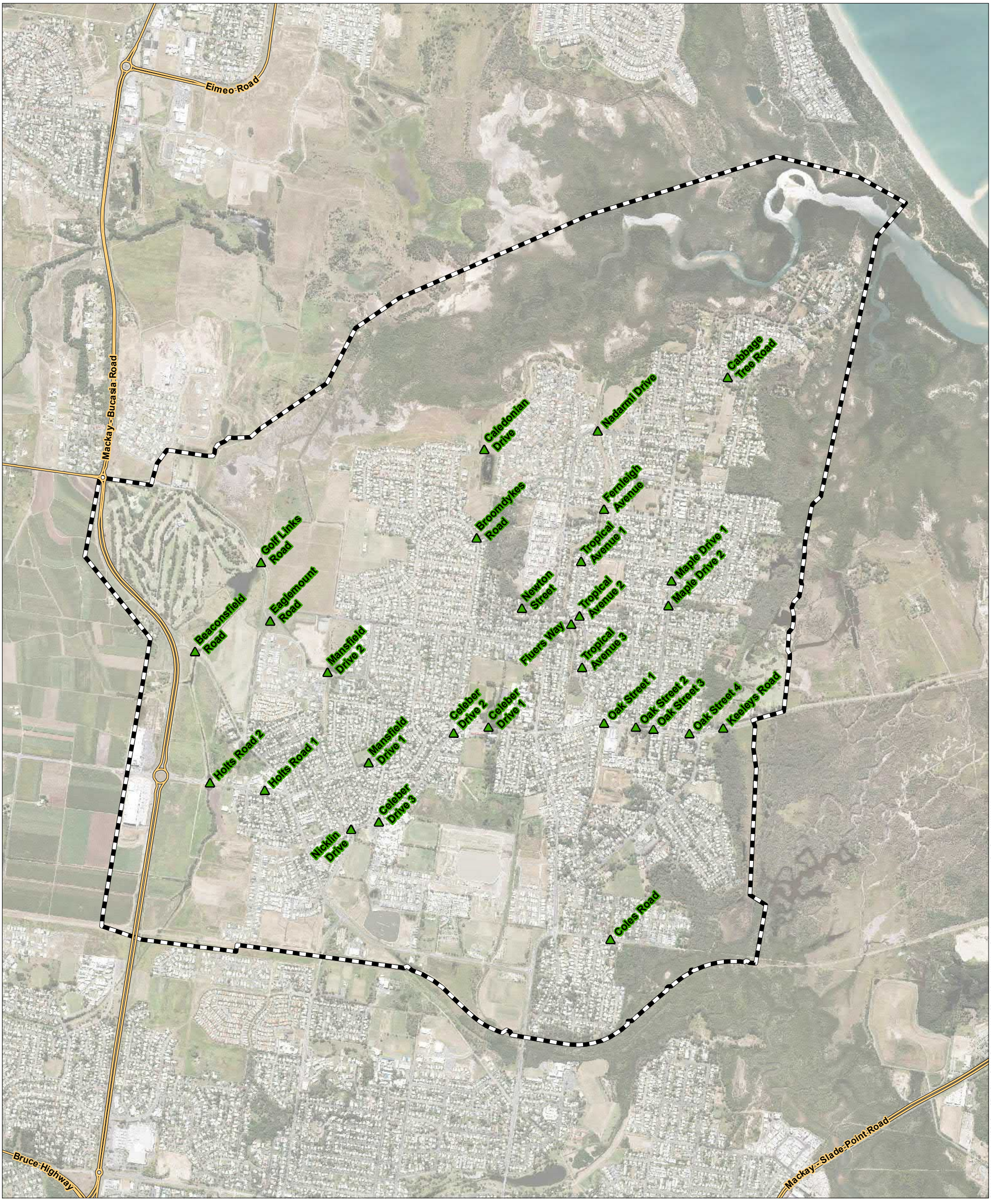
6.8 Baseline Impacts and Egress to Study Area

The baseline hydraulic simulation has identified several major roads within the study area that are flooded in various AEP's.

These are listed in the table below. These points are shown spatially in Figure 18.

Table 14 Baseline Major Road Peak Flood Depths

Road	1EY Peak Depth (m)	50% AEP Peak Depth (m)	20% AEP Peak Depth (m)	10% AEP Peak Depth (m)	5% AEP Peak Depth (m)	2% AEP Peak Depth (m)	1% AEP Peak Depth (m)
Beaconsfield Road			0.12	0.15	0.17	0.20	0.22
Broomdykes Road				0.25	0.29	0.37	0.42
Cabbage Tree Road							
Caledonian Drive							0.11
Celeber Drive 1			0.43	0.50	0.58	0.62	0.66
Celeber Drive 2				0.10	0.12	0.14	0.18
Celeber Drive 3					0.10	0.18	0.23
Coles Road	0.32	0.37	0.46	0.48	0.51	0.54	0.57
Eaglemount Road							
Fernleigh Avenue							
Fluers Way					0.16	0.24	0.31
Golf Links Road	0.23	0.28	0.49	0.60	0.70	0.81	0.89
Holts Road 1					0.10	0.13	0.18
Holts Road 2							0.14
Keeleys Road					0.10	0.13	0.18
Mansfield Drive 1			0.12	0.16	0.17	0.19	0.21
Mansfield Drive 2					0.12	0.16	0.19
Maple Drive 1						0.11	0.13
Maple Drive 2						0.10	0.12
Nadarmi Drive							
Newton Street	0.15	0.18	0.27	0.37	0.42	0.51	0.56
Nicklin Drive						0.10	0.12
Oak Street 1			0.12	0.26	0.37	0.48	0.58
Oak Street 2					0.21	0.32	0.42
Oak Street 3						0.18	0.26
Oak Street 4							0.25
Tropical Avenue 1				0.16	0.20	0.26	0.31
Tropical Avenue 2	0.13	0.15	0.20	0.23	0.25	0.30	0.34
Tropical Avenue 3			0.10	0.14	0.15	0.19	0.21



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AECOM

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0 0.3 0.6 km

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Legend

- Road Assessment Location
- TUFLOW Model Extent
- State Controlled Road Network

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Andergrove Beaconsfield Drainage Study

Major Road
Assessment Locations

Of note is the number of high order roads that are inundated in a 1EY event – 4 of the 29 locations. Newton Street when inundated, does not have an alternative egress option for flooded in residents.

In general terms the urban footprint hydraulic behaviour as simulated in the TUFLOW model follows the generalised minor/major flow capacity, whereby the pit and pipe system cater for the more frequent events (the so called nuisance flows) with the roads and dedicated drainage paths catering for the rarer events up to and including the 1% AEP event.

This is evidenced in the land development areas that have occurred since the Queensland Urban Drainage Manual (QUDM) become in 1992 the guiding document is the area of urban drainage.

However, there are a number of areas where there is substantial road inundation in the 50%AEP event. These areas are discussed below:

- Coles Road is inundated at the road crown by approximately 0.3m in the 50% AEP event. The location is within a sag in the road grade and has no overland flow path to cater for flows that are excess to the pit and pipe capacity. In low order events the residents to the east of Coles Road flooding may have an alternate access by means of Annmore and Hartog Street. In the 1% AEP event residents to the east of the flooding in Coles Road have no alterative access
- Farquhar Street and Avocado Court are inundated at the road in the 50% AEP event by 0.26m and 0.30 metres respectively. The inundation in the more frequent events is caused by:
    - Farquhar Street by low capacity discharge pipe network and low capacity overland flow path through RP738772/264.
    - Avocado Court – cul-de-sac is impacted in the first instance by backwater impacts from Farquhar Street. The cul-de-sac is approximately 0.5m below the road crown of the adjacent Farquhar Street. Both street stormwater systems are connected to a single 1050 RCP.
    - Avocado Court – intersection with Illawara Court is impacted by low capacity discharge pipe network and overland flow path through RP741474/46. 2/900 RCP in Illawara Court discharge into 1/900 with the excess capacity stored in the street before finding its way across the adjacent reserve.
- Barnfield Drive by low capacity discharge pipe network and low capacity overland flow path through RP742237/65. The depths within Barnfield Drive are 0.30m and 0.7m for the 50% and 1% AEP event respectively.
- Renae Street and Rhapis Court by low capacity discharge pipe network and low capacity overland flow path through their respective overland flow paths.
- Tropical Avenue - low capacity discharge pipe network and low capacity overland flow path.
- Newton Street- adequate capacity discharge pipe network and low capacity overland flow path. The depths within Newton Street are 0.20m and 0.6m for the 50% and 1% AEP event respectively. Residents to the west of the inundation have now alternative evacuation route if Newton Street.

In the 1% AEP event major access roads to Andergrove and Beaconsfield are flooded as follows:

- Keeleys Road
- Holts Road East
- Beaconsfield Road
- Golf Links Road.

In high order events access to Beaconsfield and Andergrove is only available by means of Norris Road and Glenpark Street.

6.9 Sensitivity Analysis

6.9.1 Hydraulic Roughness

As the roughness values applied to the hydraulic model were based of previous studies and recommendations from AR&R, two sensitivities were run to simulate both a 20% increase and decrease to the roughness values adopted for the study. These results were used to check if differences in the Manning's 'n' values would have significant effects on stormwater runoff across the study area.

The sensitivity modelling was undertaken for the 1% AEP events, in the baseline. The GIS results maps of the hydraulic roughness sensitivity are available in the Volume 2.

In summary, the mapping shows that the results are sensitive to the hydraulic roughness change over the drains within the study area. The maximum increase in PWSE across the entire study extent is 84mm.

6.9.2 Tidal Boundary Condition

Sensitivity model simulations were undertaken with varying tidal conditions to assess the impacts on the McCready Catchment. The boundary condition sensitivity runs completed included (results have been mapped in the Volume 2 Report):

- Highest Astronomical Tide (HAT)
- 1% AEP Storm Surge Tide
- 1% AEP Storm Surge Tide with Climate Change to 2100

For the modelled scenarios, a constant value was set as the tidal boundary. The tidal boundaries for each model scenario are summarised in Table 15

Table 15 Tidal Boundary Summary

Model Scenario	Tidal Boundary
Mean High Water Springs (MHWS)	Constant WSE of 2.35m AHD
Projected MHWS with climate change (Section 7.0)	Constant WSE of 3.15m AHD
Highest Astronomical Tide (HAT)	Constant WSE of 3.64m AHD
1% AEP Storm Surge Tide	Constant WSE of 4.403m AHD
1% AEP Storm Surge Tide with Climate Change to 2100	Constant WSE of 5.39m AHD

In summary, the results mapping shows that as the tidal range increases through to an elevation of 5.39 MAHD access to Andergrove and Beaconsfield are restricted to Norris Road and Glenpark Street.

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. This document provides 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
- 4°Celsius by 2100.

These increases in temperature equate to a 10% increase in rainfall intensity by 2050, a 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 16 details the projected sea level rise up to 2100.

Table 16 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 with respect to changes in rainfall intensity, climate change sensitivities have been undertaken as part of this study. The hydraulic model has been used to assess the impact of climate change that would be expected to occur in 2100 and beyond for the 1% AEP and 0.2% AEP Baseline events.

Therefore a 20% (to 2100) increase in rainfall intensity was applied for the 1% and 0.2% AEP Baseline events to incorporate effects of climate change into the study.

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 3.15m AHD for the design event incorporating climate change effects.

7.3 Climate Change Hydraulic Model Results

Map 47 within the Volume 2 report presents the difference between the climate change scenario and the 1% AEP Baseline event results. This figure shows that, under a climate change scenario:

- Peak water surface levels are expected to increase by an approximate average of 0.05m through the majority of the study area.
- All drains and previously mentioned flooded streets and storage areas have an increase in PWSE on approximately 0.15m
- Portions of McCreadys Creek near the estuary mouth show an increase in PWSE up to 0.45m due to the combined influence of tidal and runoff.

8.0 Floodplain Management Principles

8.1 Framework

This study aligns to current best practice guidelines, including the Australia Disaster Resilience Handbook Collection, Handbook 7 – Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia (Commonwealth of Australia, 2017).

For a government agency with primary responsibility for managing flood risk in their area, the flood risk management framework provides a basis to improve management of flood risk for their community.

The purpose of the framework is to assist Flood Management Agencies (FMA), like Council, to:

- Understand roles and responsibilities related to flood risk management.
- Identify and engage with relevant stakeholders and agencies.
- Identify and understand relevant legislation, policies, regulations and guidelines.
- Identify vulnerable and high risk areas of the community.
- Collate the best available information and use it appropriately.
- Identify knowledge gaps and risks, to inform the decision making process related to these issues.
- Develop plans to improve knowledge and manage flood risk, including implementation guidance.
- Make informed development decisions related to flood prone areas.
- Conduct community and stakeholder engagement related to flood risk and management.

A well formulated floodplain management plan enables informed communities, flood risk managers, land-use planners and emergency managers to make sound floodplain management decisions. The full range of potential flood risk treatment options must be carefully considered, in relation to the specific flood risk associated with the area, to ensure suitability and resilience.

Figure 10.1 (reproduced as Figure 19 below) of Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia (Commonwealth of Australia, 2017), illustrates the current best practice floodplain management process.

Figure 19 demonstrates how this report fits within the overall process.

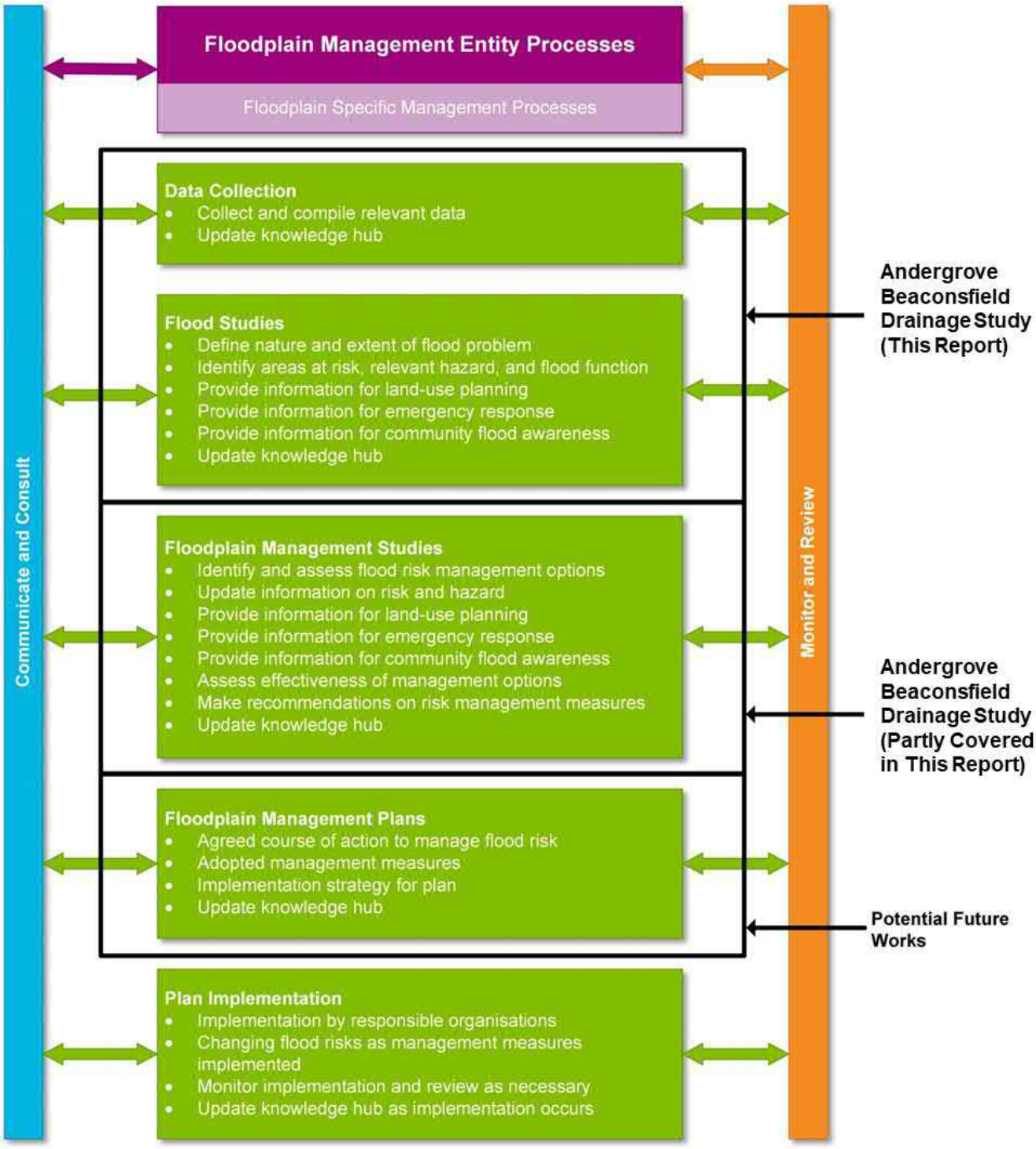


Figure 19 Floodplain Specific Management Process
Reproduction of Figure 10.1 from Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia (Commonwealth of Australia, 2017).

8.2 Floodplain Mitigation Measures

Floodplain management measures can be broadly grouped into Non Structural and Structural options, as follows:

- Non Structural (refer Section 9.0.)
  - Community awareness.
  - Land use planning and development control.
  - Emergency management planning.
- Structural (refer Section 10.0)
  - Property buyback.
  - Levees (both permanent and temporary).
  - Detention basins.
  - Improved conveyance through channel works and culverts.
  - Development planning – Raising of dwellings.
  - Development planning – Flood proofing of dwellings.
  - Backflow prevention devices.
  - Diversion channels.

Non-structural flood mitigation measures relate to the management of current, potential and residual flood risks, whereas structural measures targets the partial or complete elimination of flood risk. Whilst sound floodplain management is preferably achieved through land use and development planning this is not always feasible where development has already occurred within the floodplain.

Where development has occurred within flood prone areas, a reduction in flood risk can be achieved through the application of structural measures.

9.0 Non-Structural Flood Mitigation Measures

9.1 Overview

A summary of non-structural flood mitigation measures are outlined below for Council's consideration.

9.2 Community Awareness

It is critical that community living in the flood-prone areas of Andergrove & Beaconsfield be made aware – and remains aware – of their role in the overall floodplain management strategy for the region, including defence of their communities and their personal evacuation. Sustaining an appropriate level of flood awareness involves continuous effort by Council and the emergency services which 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 study area, more recent flood events (i.e. 2008 event) have raised flood awareness in 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 of flooding in Mackay.
- Flood behaviour in North Mackay
- 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 Andergrove & Beaconsfield communities using outputs from this report. This should be incorporated into Council's current Coastal and Inland Flood Hazards Adaption Study (CIFHAS) community awareness campaign.

9.3 Land Use Planning Development Control

Through suitable land use planning, the likelihood and consequence of flooding can be managed by guiding appropriate future development, removing existing inappropriate development and selecting land use zoning which is flood compatible. Sound land use planning goes hand in hand with sound development planning.

Appropriate development and building controls can significantly reduce flood risk and the amount of damage to flood prone properties when a flood 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 Defined Flood Event (DFE). It is therefore fundamental that future development is guided so that people and their property have limited exposure to flood hazard and/or the development uses flood resilient building material and practices and adopts/accepts a flood impact philosophy of shelter in place.

Several broad recommendations are provided below for further consideration by Council's Planning and Development officers:

- This study has assessed existing flood risk for local catchment events only. Storm surge and Pioneer River flood events should be considered in conjunction with the results of this study, when undertaking development planning and assessments.
- Council should consider the cumulative impacts of developments, i.e. the consideration of the impacts of a development in combination with other developments.
- 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 0.3m be applied to the model results from this report, when using them for development control purposes.
- A comprehensive suite of development assessment measures are 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.

The aim of land use planning and development control is to:

- Not unnecessarily sterilising land on the floodplain.
- Manage future development.
- Be ecologically, socially and culturally sustainable.
- Provide a balanced and integrated mix of management measures.
- Obtain best value.
- Provide direction for implementation.
- Promote community awareness, seek and take into account public comment.
- Meet legislative requirements and act in good faith.

There are a range of methods that can also be considered for future development and or future planning scheme controls. Methods include:

- Internal Council Policy to guide development assessments including draft conditions for stormwater flooding prevention and control.
- Preparing a more stringent *Flood Hazard Overlay Code*, using the flood maps prepared for this study.
- Planning maps easily accessible by the public to find out if Council has planning controls for flooding on the subject property.
- Ensuring in development control provisions that any portion of a structure below flood planning levels will be built from materials that minimise potential damage due to inundation and impact from flood velocities.

Planning scheme controls can also provide Performance Criteria & Acceptable Solutions that seek to achieve the following objectives:

- Habitable floor areas for residential developments to be above the defined flood event plus freeboard.
- Commercial buildings all habitable flooring to be above the ground floor for multi-story buildings.
- Increase housing density that makes use of prefabricated or tilt up concrete panels.
- Basement carparks prohibited in areas where the 1% (or lower) AEP event extends above to top of existing kerb and channel flood areas.
- Major electrical equipment (switchboard, lift controls, etc.) for the buildings to be above the defined flood event.

- Major plumbing and house drainage equipment (switchboard, pump controls, etc.) for the buildings to be above the defined flood event.
- Maximum site discharge to be no greater than 39% AEP - to be triggered by development application.
- Avoid filling to minimise cumulative impacts on flood plains.
- Maximise use of non-stud frame dwellings to reduce contents damage.
- Place electrical outlets approximately 1m minimum above floor height.
- Build all external wall and load bearing internal walls below the DFE plus freeboard of masonry construction e.g. double brick, concrete block, concrete panel rather than brick veneer or framed walls.
- Use timber framed walls with sheet cladding only for non-load-bearing internal partitions.
- Building foundations to be flood impact and inundation resilient.
- For structural purposes use materials that are dimensional stable and not weakened by immersion.
- Use of water resistant bracing materials – e.g. steel straps, fibre cement or waterproof plywood sheets.
- Ignore bracing contribution from plasterboard wall lining.
- Use medium of heavy-duty side fixed brick ties.
- Use insulation with minimal absorption that dries- e.g. polystyrene panels.
- Ensure adequate ventilation to cavities.
- Staircases should be designed to facilitate the relocation of contents from the ground floor to the upper floor.

9.3.1 Habitable Floor Level

Council currently set habitable floor levels based on the highest of (MRC Planning Scheme):

a. 300mm above the DFE; or

b. 300mm above the DSTE relevant to the subject site; or

c. the minimum floor level, as follows:

   i. Mackay urban area – RL 5.4m AHD; or

   ii. Midge Point – RL 5.0m AHD; or

   iii. Seaforth, Haliday Bay, Ball Bay, Louisa Creek, Half Tide Beach, Salonika Beach, Grasstree Beach, Sarina Beach, Freshwater Point and Armstrong Beach – RL 5.3m AHD; or

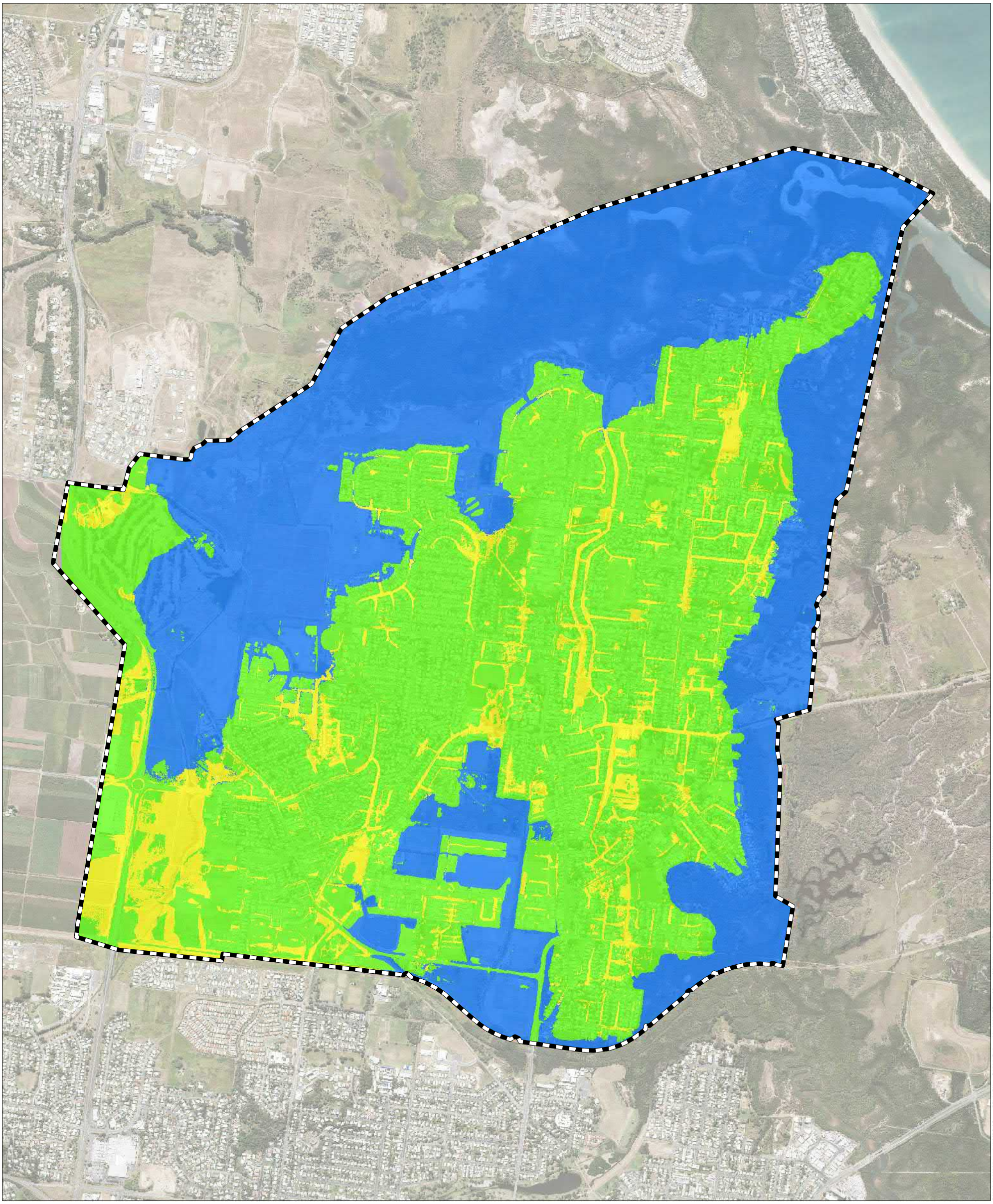
d. in addition to (c) above, an additional 600mm is provided for higher wave effects and run up in the foreshore area (the foreshore area shall be taken as extending inland for a minimum of 100 metres from the higher of toe of the frontal dune or Highest astronomical tide): or

e. (e) 225mm above natural ground level; or

f. (f) 300mm above the greater of top of the kerb level or the crown of the adjacent bitumen road.

It may be the case however that higher flood levels may be experienced during a 1% AEP Local Catchment event including Climate Change to 2100 and 0.3m freeboard, rather than the events listed above.

Figure 20 shows which criteria results in the highest level across the study area, which should be used to set minimum habitable floor levels. It is to be noted that the condition of 300mm above kerb / crown of the road could not be shown on this figure as detailed kerb / crown levels for the entire catchment were not available.



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Legend

- TUFLOW Model Extent
- Minimum Level of 5.4mAHD
- 1% AEP Storm Tide with Climate Change to 2100 + 0.3m Freeboard
- 1% AEP Baseline Local Catchment Event including Climate Change to 2100 + 0.3m Freeboard
- 225mm Above Natural Surface Level

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0 0.3 0.6 km

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Andergrove Beaconsfield Drainage Study

Minimum Floor Level Requirements

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It can be seen that the 1% AEP Storm Surge event with Climate Change to 2100 and 0.3m freeboard is predicted to produce higher flood levels across a lots adjacent to Aspley Creek particularly Renae Court, Kimberley Court and McGuire Street.

9.4 Emergency Management Planning

Council'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.

9.4.1 Flood Emergency Plan

It is recommended that Council further develop or amend their existing Flood Emergency Plan (FEP) following the completion of this study. The FEP should be 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 the FEP 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 FEP forms an essential component of a floodplain management plan and requires close liaison between emergency management staff.

Typically, a FEP 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.

9.4.2 Assessment of Critical Infrastructure

A list of critical infrastructure, and the corresponding gauge levels at which it is likely to be inundated, should 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 evacuation routes.
- Key water and sewerage infrastructure.
- Roads / bridges.
- Airport facilities.

Of particular note is the location of the Emergency Services on Holts Road East. As discussed above Holts Road east crossing of McCreadys Creek South becomes inundated in a 5% AEP event.

9.5 Summary of Non-Structural Mitigation Measures

A summary of non-structural flood mitigation measures is shown in Table 17, with a brief discussion on the various types of mitigation measures also provided.

Table 17 Mitigation Options Summary

Measure	Mitigation Option	Description	Advantages / Disadvantages
Community awareness	Community and Stakeholder consultation	Engagement throughout the floodplain management process, to inform the community on flood risk and develop flood resilience within the community.	Advantages - Creates a flood resilient community. - Gives the community a sense of 'buy in' related to flood risk. - Allows for informed debate regarding flood mitigation strategies. Disadvantages - May result in negative community feelings towards flood prone areas. - Flood risk remains.
Land use planning	Zoning	Appropriate land use zoning to guide future development away from flood prone areas. Re-zoning of existing developments within flood prone areas, to flood compatible land uses (e.g. parks and open spaces).	Advantages - Eliminates future development in areas affected by flooding. - Reduces flood risk. Disadvantages - Re-zoning of existing developed areas may take time to have an effect on flood risk, as existing residents may not move on for some time. - May reduce land values, particularly on the flood fringe areas.
	Buyback / Purchase	Voluntary or forced purchase of existing buildings within high hazard flood areas, to eliminate the flood risk.	Advantages - Eliminates flood risk. - Links with re-zoning. Disadvantages - Costly. - May cause distress if residents resist the purchase. - Could take a long time, particularly if there is isolated resistance within a larger group of buybacks.

Measure	Mitigation Option	Description	Advantages / Disadvantages
Development planning and building controls	Planning Scheme	An overarching plan for the city / region to guide areas of development outside flood prone areas.	Advantages - Provides a clear picture of areas where development should not take place, due to flood risk. Disadvantages - Could sterilise areas on the flood fringe.
	Minimum floor levels	Habitable floor levels are set based on a minimum height (freeboard) above the defined flood event.	Advantages - Provides a level of flood resilience, up to the Defined Flood Elevation (DFE). Disadvantages - Residual risk remains for flooding in events larger the DFE. - There may be issues with flood free access / egress to buildings.
	Raising of dwellings	Lifting of the habitable floor level of an existing dwelling, based on a minimum height (freeboard) above the defined flood event.	Advantages - Provides a level of flood resilience, up to the DFE. - May prove to be cost effective, when compared to other building controls. Disadvantages - Not possible for all types of buildings. - Residual risk remains for flooding in events larger the DFE. - There may remain issues with flood free access to the building.
	Flood proofing of dwellings	Improving the flood resistance of a building to inundation and velocities, through the use of appropriate materials. This is done by retrofitting to existing buildings or designing into new buildings.	Advantages - Structural damage is reduced during flooding. Disadvantages - Other detrimental effects of flooding remain, including access, clean up, etc.
	Raising of services – electrical and plumbing	Improved flood resilience of building to loss of services if major electrical equipment (lifts and switchboards) and major plumbing items (pumps) are above the DFE	Advantages - Loss of service is reduced during flooding. Disadvantages Other detrimental effects of flooding remain, including access, clean up, etc.

Measure	Mitigation Option	Description	Advantages / Disadvantages
Emergency management planning	Response planning	Planning associated with managing flood forecasting, flood preparedness, emergency response and flood recovery.	Advantages - Provides clear details on the responsibilities and actions to be taken prior to, during and after a flood event. - Identifies areas that require improvement, in relation to flood response. Disadvantages - Flood risk remains.
	Forecasting and warning	Relates to the prediction of flood severity, flood extent and flood timing for a specific area, and the methods by which affected persons are informed.	Advantages - Provides advanced warning of a flood event, which allows for flood preparedness and flood response. Disadvantages - Flood risk remains.
	Flood preparedness	Refers to the awareness of affected parties (community and agency alike) of what they need to do prior to the arrival of a flood. This will include items such as agency staff training and individual resident's actions taken to prevent loss.	Advantages - Reduces incidental flood damage. - Reduces social impacts. - Allows for effective flood response. Disadvantages - Flood risk remains.
	Flood Response	Refers to the response by agencies and individuals affected by the flood, to reduce the hazard. This could include road closures, evacuations and rescue.	Advantages - May reduce the consequences of flooding. Disadvantages - Flood risk remains.
	Recovery	Once flood waters recede, the recovery process includes clean-up, services restoration, financial assistance and other activities to ensure safe access is available to flood affected areas.	Advantages - Good planning will accelerate the recovery process. - Clearly defines the roles and responsibilities related to flood recovery. Disadvantages - Flood risk remains.

Measure	Mitigation Option	Description	Advantages / Disadvantages
Structural	Temporary barriers and gates	A temporary physical barrier, which is installed prior to the arrival of flood waters. Examples include sandbags and demountable barriers.	Similar to permanent levees, except: Advantages - Less impact on visual amenity, due to the temporary nature. - Smaller footprint, depending on type of temporary levee. - Ability to maintain access between the leveed and non-leveed area during non-flood times. Disadvantages - Additional storage requirements. - Additional training requirements, related to transport, installation, cleaning, removal and packing of the temporary levee. - More susceptible to damage due to impact.
	Detention and retention basins	An area of low ground that provides temporary storage (detention) or permanent storage (retention) of flood waters.	Advantages - Provides an attenuation of flood peaks downstream of the basin. - Can fulfil other uses such as sporting fields. Disadvantages - Significant land area required. - Does not remove risk of flooding.
	Improved conveyance through channel works or culvert augmentation and structure upgrades	Increasing flood water conveyance through drainage and. Improved hydraulic performance of structures such as culverts by increasing culvert numbers or size. This is particularly affective for structures which experience high head loss.	Advantages - Reduces flood levels, by providing additional conveyance through channels and/or structures. - Channel works can be very cost effective. Disadvantages - Potential increases to downstream flood levels. - Structure upgrades can be expensive, particularly when increasing bridge spans. - Potential downstream environmental impacts.

Measure	Mitigation Option	Description	Advantages / Disadvantages
Structural	Backflow prevention devices	Installation of backflow prevention device (BPDs) to prevent flood waters from backing up through stormwater and sewerage systems.	Advantages - Cost effective. - Dependent on topography, can protect large areas from back up flooding. Disadvantages - Limited in application to areas that experience flooding due to back up through the stormwater or sewerage network. - Requires a stringent maintenance program, to ensure BPDs operate correctly. - Required additional infrastructure to cope with local catchment coincidental flooding (i.e. when BPDs are closed and the stormwater system is non-operational).
	Diversion channels	Redirection of a portion of the flood waters away from a high hazard area, via a diversion channel. These are commonly associated with levee systems.	Advantages - Effective in reducing flood levels, particularly when used in conjunction with levees. Disadvantages - Directs floodwaters to an alternative location. - Restricted by topography and land availability.

10.0 Structural Mitigation Options

10.1 Overview

Due to the flat topography and grade of land within Andergrove and Beaconsfield, there is only limited opportunities to improve the capacity of the underground network for a majority of the study area. The urbanised area has a reasonably a well-developed drainage network.

In discussion with council a number of areas have been selected for assessment of structural mitigation options.These are:

- Future Lot development
- Surveyed Discharge Locations.
- Coles Road
- Cabbage Tree Road open drain
- Farquhar Street and Avocado Court.

Each area is discussed in detail in the sections below.

10.2 Future Development

Council has nominated a number of lots that may be developed and is seeking to understand what additional flow pressures may be imposed on the existing drainage infrastructure.

To simulate the impacts of such development the following changes were made to the mitigation scenario model.

- Inclusion in the mitigation scenario of a number of lots that are earmarked for potential development. These lots have been represented in the baseline mode as having small impervious areas and roughness factors representing isolated hard surfaces. In discussions with Council the lots have been included into the mitigation scenario as follows:
    - Decrease in rainfall losses cognisant of the impervious fraction for proposed development type (medium density, district centre and low density residential.
    - Change in roughness factors cognisant of the proposed future development land-use type (medium density, district centre and low density residential
    - Baseline lot topography was not altered.

Sequencing or staging of any or all developments was not included into the simulation. The mitigation scenario assumed that all nominated lots are fully operation with respect to their individual planning zone.

The proposed development lots principal discharge locations are listed in Table 18.

Table 18 Proposed Development Lots

Lot	Planning Zone	Discharge Location
2 RP711214	Medium Density Residential	Southwards to Coles Road Drain
3 RP747912	Medium Density Residential	Southwards to Coles Road Drain
18 RP884942	Medium Density Residential	Westwards to Oak Street Drain
20 SP189773	Medium Density Residential and District Centre	Northwards to Oak Street
1 RP717896	Low Density Residential	Eastwards to Cabbage Tree Road Drain
1 RP720365	Low Density Residential	Eastwards to Cabbage Tree Road Drain
2 RP 730787	Low Density Residential	Centrally to Cabbage Tree Road Drain
12 SP271085	Low Density Residential	Westwards to Cabbage Tree Road Drain
2 RP712589	Low Density Residential	Eastwards to Cabbage Tree Road Drain
21 SP212071	Low Density Residential	Centrally to Cabbage Tree Road Drain

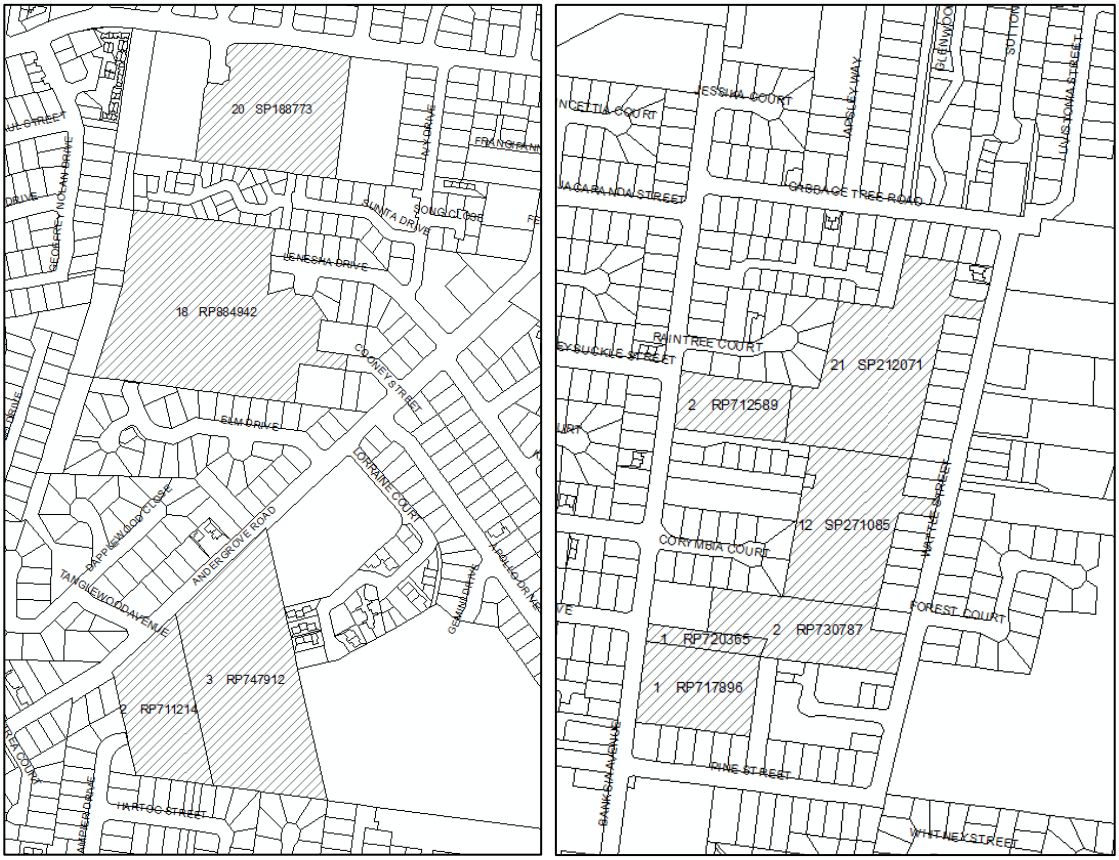

Figure 21 Proposed Development Lots

For the change in development impervious fraction (to simulate future development) an approximate 10% increase in peak flows for the 1% AEP event was assumed. It is to be noted that when the development footprints are better known and modelled the expected outcome is likely to be an increase in flows over and above the increase noted in this mitigation scenario. This is particularly so in the Cabbage Tree Road areas where there is currently substantially storage within the lots nominated for future development.

Of note, and discussed below, Lots 2 RP711214 and 3 RP 747912 at the time of development may require some attenuation of the developed case runoff as there is no “spare” capacity within the Coles Road Drainage Infrastructure.

10.3 Surveyed Discharge Locations

As part of the mitigation scenario, a review of the aerial imagery and LiDAR representation of narrow discharge drains was undertaken. A significant number of the surveyed discharge locations were not well represented in the LiDAR. Cognisant of the cost of ground survey, culverts discharging to Aspley Creek (which in general terms has a heavy tree canopy) were considered for some modifications.

There are two broad methods to potentially enhance discharge ability within the simulation:

- Alter the Lidar by overlay generated drain profiles or the like
- Extending the culvert end point to a location where the LiDAR is at or below the outlet elevation.

The second method was chosen for ease of operation and transparency. It is to be noted that this assessment does not trigger any construction activity nor clearing of vegetation. The assessment is essentially to provide for improved hydraulic simulation.

The outcome is a small reduction is PWSE elevations of approximately 20mm.

10.4 Coles Road

The existing open drain commences in a rural with lot with frontage along Andergrove Road. The drain flows south across Hartog Street and Coles Road with the eventual discharge into Aspley Creek area by means of 2/900 RCP. The crossing on is with a low section of Coles Road that does not have a high flow discharge path. The catchment area reporting to Coles Road is approximately 13 hectares. Table 19 shows the peak flows along the existing drain

Table 19 Peak Flows Around Coles Road

Location	Reference	Baseline 50% AEP flow (m^3/s)	Baseline 20% AEP flow (m^3/s)	Baseline 1% AEP flow (m^3/s)
PO_77	Upstream of Hartog Street	0.5	0.9	2.5
PO_76	Hartog Street	0.0	0.1	1.6
PO_34	Downstream of Hartog Street	0.7	1.3	3.3
PO_35	Upstream of Coles Road	1.2	2.3	5.3
PO_36	Coles Road	0.8 (0.37m deep)	2.1 (0.47m deep)	5.7 (0.56m deep)

In the high order events (larger than a 20% AEP event), residents to the east of the existing drain will be isolated as both Coles Road and Hartog Street are inundated. It is to be noted that the damages assessment shown no over floor flooding associated with the existing drainage path. Thus, the structural mitigation option become one of provide safe access to a trapped island area. With no over floor flooding it is expected that a cost benefit assessment will return a zero or negative outcome.

As there are limited opportunities within the existing easement to widen and provide a positive drainage path the preferred option is as follows:

- 2/900 RCP from the existing drain just upstream of Coles Road extending east along Coles Road and then south as 2/1050RCP along an existing road reserve to discharge near to the outlet of the existing 2/900 RCP.

The construction of the proposed pipe network will require the following:

- Construction of 2/900 RCP along the southern traffic lane of Coles Road through a crest of approximately 0.5m.
- Crossing a 375mm diameter AC sewer rising main
- Crossing a 300mm diameter AC sewer rising main.

The hydraulic simulation shows there is a benefit in terms of access to the eastern residential lots with the mitigated case showing no road inundation up to the 2% AEP event and reduced depths of inundation thereafter to the 1% AEP. The details are shown in Appendix H. The baseline case shows that Coles Road is flooded in the very frequent events. However, the significant cost and difficulties in crossing the major gravity and pressure sewers mains are likely to be prohibitive factor in this mitigation options. Refer to the MiMaps detail Figure 22.

No further details have been undertaken on this option.

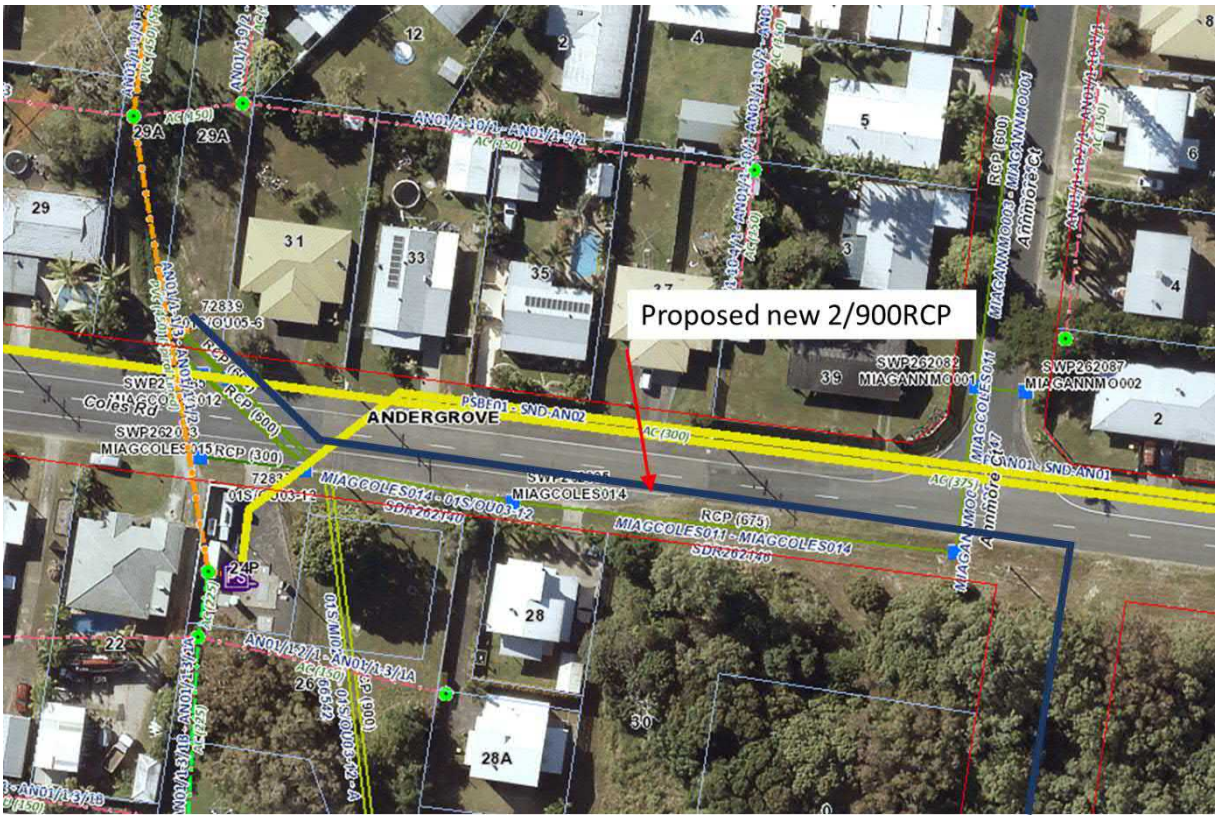

Figure 22 MiMaps Infrastructure and Conceptualised Proposed Drainage Culverts

If the propose development discussed in Section 10.2 is to proceed then the current flood circumstance at Coles Road and Hartog Street flooding is likely to worsen. Future development of the two lots with Andergrove frontage may need to include detention of developed flows so as to not pressure the existing capacity of drainage infrastructure.

Perhaps at some future time when these sections of sewer infrastructure are to be scheduled for significant maintenance, then consideration may be given to including stormwater infrastructure needs into the scenario.

10.5 Cabbage Tree Road Open Drain

This mitigation is based on Council's 2000 report – Master Drainage Plan McCreadys One Andergrove. Some of the then mooted drainage infrastructure has been constructed. These are:

- 1200 mm diameter pipe from about 20 metres upstream of Cabbage Tree Road north for 160 metres. The works included junctions pit and drainage channel over the culvert.
- Cabbage tree Road has 6/1200x750 RCBC to cater for the surface drainage.

Refer to the report drawings (A1-4565 and A1-4566) in Appendix H. The infrastructure included into the mitigation model is from point 1 to point midpoint of points 10 and 11 (approximately chainage 620).

Results of this scenario are tabulated in Appendix H and are shown in the Volume 2 Report. The proposed development that reports to the Cabbage Tree Road drain has been simulated in as discussed in Section 10.2. In particular, reference is made to the significant storage within in the proposed development area.

The mitigation outcomes from this assessment are likely to be on the low side of what maybe the final developed catchment and associated drain responses.

Figure 23 Cabbage Tree Road Proposed Infrastructure Scenario Showing 1% AEP Depth Above 0.15m

While it is understood that the proposed drainage infrastructure may be considered as a trunk system the nature of the sequenced or staged development may alter the concept as shown in the report. It is noted the development of these lots may require drain crossing.

Each drain crossing may alter the flood behaviour and thus require additional /different trunk drainage infrastructure. The 2000 report estimate was $805,000. Indictive cost estimate (circa 2020) is $1,700,000 excluding site/drain earthworks.

Consideration should be made to update the 2000 report and undertake conceptual earthworks design to inform the trunk drainage infrastructure.

10.6 Farquhar Street and Avocado Court

The baseline assessment identified that Farquhar Street, Avocado Court and Waratah Street are impacted by street inundation in the more frequent design storm events. Avocado Court has the highest incidence of over floor flooding within the study area.

The underlying issue is one of topography with Avocado Court generally 0.4m lower than Farquhar Street on the west and Waratah Street on the east. The baseline assessment demonstrated that:

- Farquhar Street has no identified high flow overland flow path. Excess street capacity flows east across lots toward Avocado Court and Waratah Street. The existing discharge pipe cross a lot without the benefit of an easement.
- Avocado Court stormwater network is directly connected to the Farquhar Court and Waratah Street systems. With Avocado Court being lower of the two adjacent streets in all design storms the existing pits within Avocado Court backflow as the PWSE in the directly connected adjacent street are higher. Thus, Avocado Court is an urban street detention basin. Avocado Court has a high flow overland flow path which due to the ground elevations only operates at high order events.
- Waratah Street does not have an identified high flow discharge path. The existing stormwater network has a particular problem in that the final link to the outlet is a 900 RCP whereas the next upstream link is 2/900 RCP. The excess capacity is discharged in Avocado Court.
- The capacity of the drain parallel to Monterrico Circuit is such that in the 1% AEP event the drain PWSE “holds” excess capacity with the adjacent street systems.

Figure 24 shows the existing pipe network with the 50% AEP flood depths.

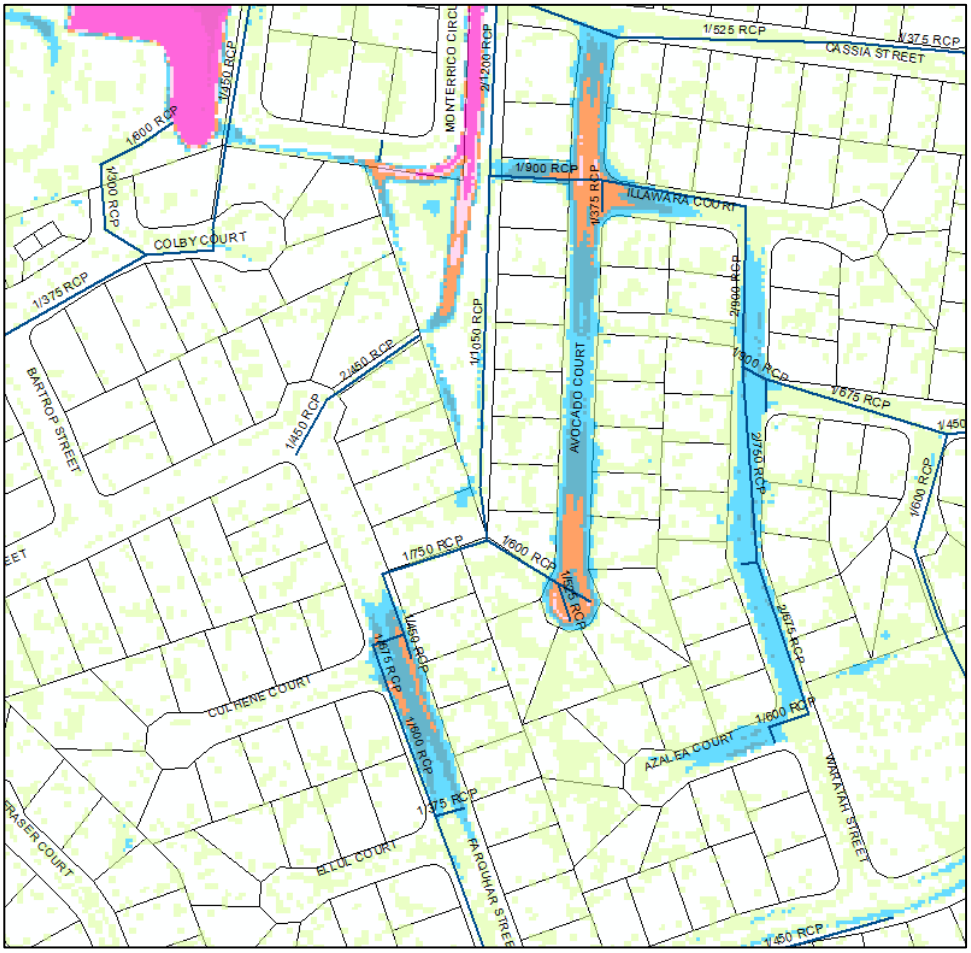

Figure 24 Farquhar, Avocado and Waratah Stormwater Infrastructure with 50% AEP Depths

10.6.1 Options to Improve Conveyance and Reduce Risk

Options to improve conveyance and reduce risk are listed below:

1. Provide overland flow paths for Waratah Street and Avocado Court. This option considers regrading both streets such that the hydraulic grade is from South to North and then west along Illawarra Court and the regraded high flow overland path. Essentially this will require lowering some sections of both streets by approximately 0.2 to 0.3m. Unfortunately, such a lowering of road levels impacts on the existing stormwater and water infrastructure by reducing cover and thus increasing risk to these assets. Additionally, the downstream drain capacity in a 1% AEP may cause backwater impacts within the newly regraded streets.
2. Duplicating the existing 900 RCP from Illawarra Court across Avocado Court west to the drain.
3. Disconnecting the Farquhar Street stormwater system from the Avocado Court system by a new pipe north to the reserve in Harris Street.
4. Improve the capacity of the overland flow path form the Avocado Court cul-de-sac west to the existing drain.
5. Allow for the existing junctions long the north south drain near Monterrico Circuit to surcharge into the adjacent drain to allow for lower hydraulic gradients within the existing pit and pipe system.

The mitigation scenario for Avocado, Farquhar and Waratah included items 2 to 5 inclusive from the above list.

10.6.2 Results

Farquhar Street improved pit captures rates leading to a reduction in PWSE.

Avocado Court – cul-de-sac pit surcharges in the baseline 50% AEP event of approximately 40L/s to the mitigated scenario with pit captures of 40L/s – from flooding the cul-de-sac in the baseline case to positive drainage in the mitigated scenario.

Avocado Court – intersection pit surcharges in the baseline 50% AEP event of approximately 140L/s to the mitigated scenario with pit surcharge of 40L/s – a reduction of street flooding.

The mitigated scenario provided a reduction in the 1% AEP event in Farquhar Street of 70mm, Waratah Street of 20mm and Avocado Court of a maximum of 80mm (cul-de-sac)

Table 20 Pre and Post structural mitigation PWSE

LOCATION	Lidar Elevation (mAHD)	M03 50% AEP PWSE (mAHD)	M03 20% AEP PWSE (mAHD)	M03 1% AEP PWSE (mAHD)	Baseline 50% AEP PWSE (mAHD)	Baseline 20% AEP PWSE (mAHD)	Baseline 1% AEP PWSE (mAHD)
Avocado Court (intsn)	5.36		5.38	5.58	5.41	5.47	5.62
Avocado Court (mid)	5.10	5.32	5.38	5.58	5.41	5.47	5.63
Avocado Court (culdesac)	5.15	5.32	5.38	5.62	5.43	5.50	5.70
Farquhar Street	5.54	5.55	5.56	5.91	5.78	5.89	5.98
Waratah Street	5.445	5.53	5.62	5.77	5.60	5.67	5.79

Refer to Volume2 for the mitigation scenario mapping.

Refer to Appendix H for details of the proposed new stormwater infrastructure.

11.0 Building Impacts and Flood Damages Assessment

11.1 Overview

The predicted baseline flood levels were used to undertake a building impact assessment and FDA, including calculation of the Average Annual Damages (AAD) for the catchment.

Flood damages, or the anticipated cost to residents, businesses and infrastructure due to flooding, have been estimated using a standardised approach adopted throughout Australia. The approach estimates the tangible impacts flooding has on people, property, and infrastructure, such as flooding of a building and/or contents, the lost opportunity value associated with wages and revenue and flooding of transport and utility networks. These tangible impacts are estimated based on the depth, likelihood of flooding and type of building. Intangible impacts, such as emotional stress and inconvenience, were not quantified due to their non-tangible nature.

A building's estimated depth of flooding and whether it is a residential single story, multi-story or raised building or a non-residential building, determines the total estimated flood damage for that building. The direct flood damage is determined based on depth-damage curves, which relate building type, building area and flood depth to the damage associated with the structure and content. Indirect damages associated with lost opportunity value, i.e. wages and revenue and the cost of temporary relocation, are then estimated as an additional percentage for residential and non-residential buildings.

The combined direct and indirect damages then represent the total damage to the building. Infrastructure damages, i.e. water treatment plants and utility and transport networks, are then estimated as a percentage of the total residential and non-residential damage combined.

Full details of the methodology applied during this study have been included in Appendix B.

11.2 Baseline Building Impacts and Flood Damages

Table 21 provides a summary of the number of residential and commercial buildings anticipated to be inundated above floor level for various flood events within the Andergrove / Beaconsfield catchment. These results are also shown graphically in Figure 25 through Figure 27.

Note that the indicated number of buildings is for entire buildings. Residential multi-unit buildings may contain multiple dwellings per building. Also, large commercial/industrial buildings may include multiple businesses.

Table 21 Baseline Building Impacts

AEP (%)	Number of Impacted Residential Buildings	Number of Impacted Commercial Buildings	Total Impacted Buildings
1EY	162	3	165
50%	172	3	175
20%	190	4	194
10%	216	4	220
5%	226	7	233
2%	252	7	259
1%	266	9	275
0.5%	287	10	297
0.2%	343	12	355

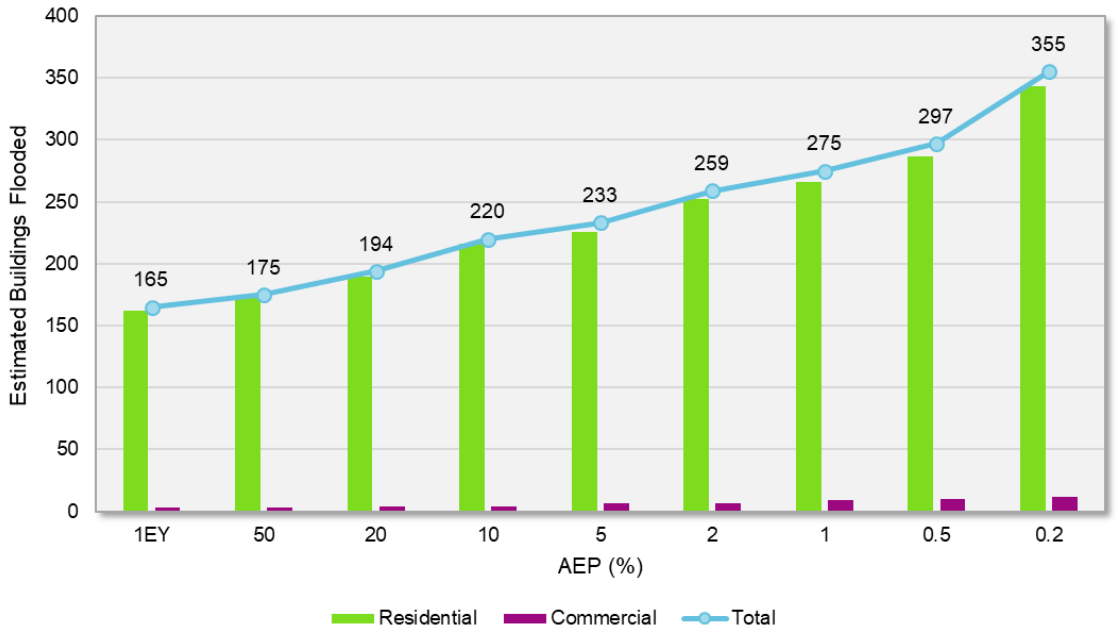

Figure 25 Plot of Estimated Baseline Building Impacts

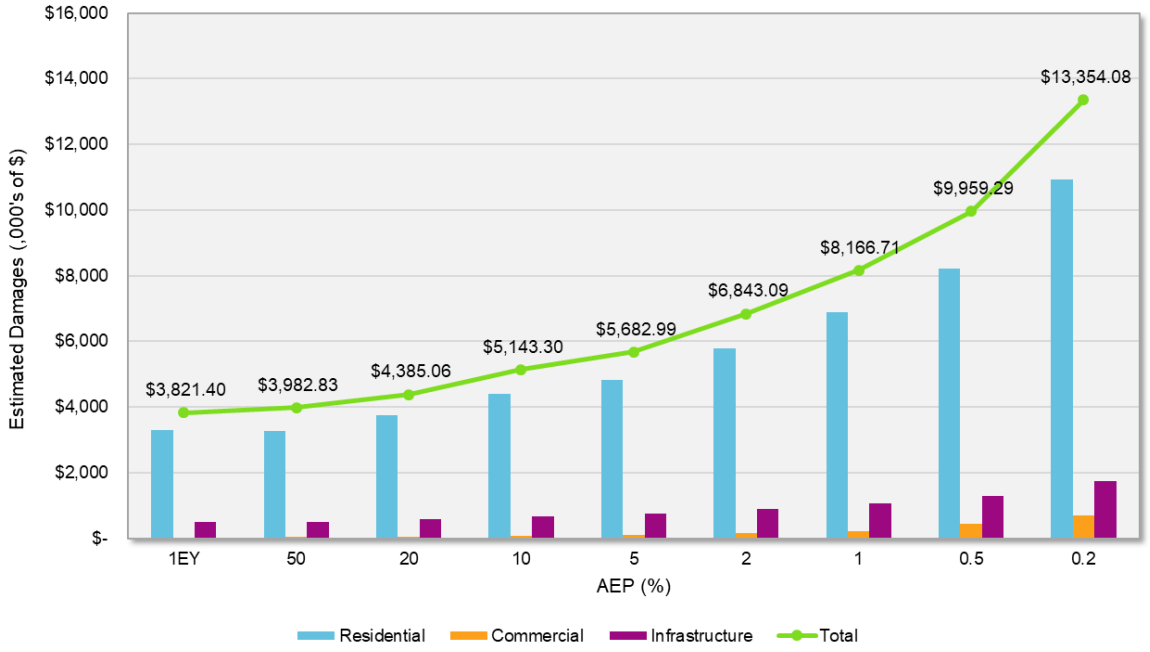

Figure 26 Plot of Estimated Baseline Damages Cost

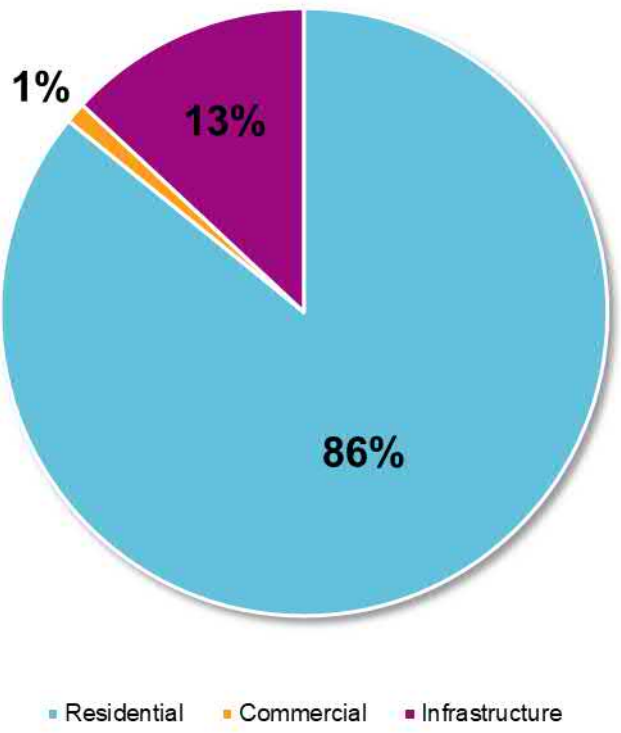

Figure 27 Percentage Breakdown of Baseline Damages

11.3 Mitigated Scenario Impacts and Flood Damages

A high-level estimate of the predicted above floor flooding property impacts has also been conducted for the Mitigated Case.

Table 22 provides a summary of the number of residential and commercial buildings anticipated to be inundated above floor level for various flood events within the Andergrove / Beaconsfield catchment for the mitigated case. These results are also shown graphically in Figure 28 and Figure 30. The anticipated benefits compared back to the baseline assessment are presented in Figure 29 and Figure 31.

Table 22 Mitigated Case Building Impacts

AEP (%)	Number of Impacted Residential Buildings	Number of Impacted Commercial Buildings	Total Impacted Buildings
1EY	161	3	164
50%	170	3	173
20%	185	4	189
10%	210	4	214
5%	216	6	222
2%	240	6	246
1%	254	8	262
0.5%	276	9	285
0.2%	333	11	344

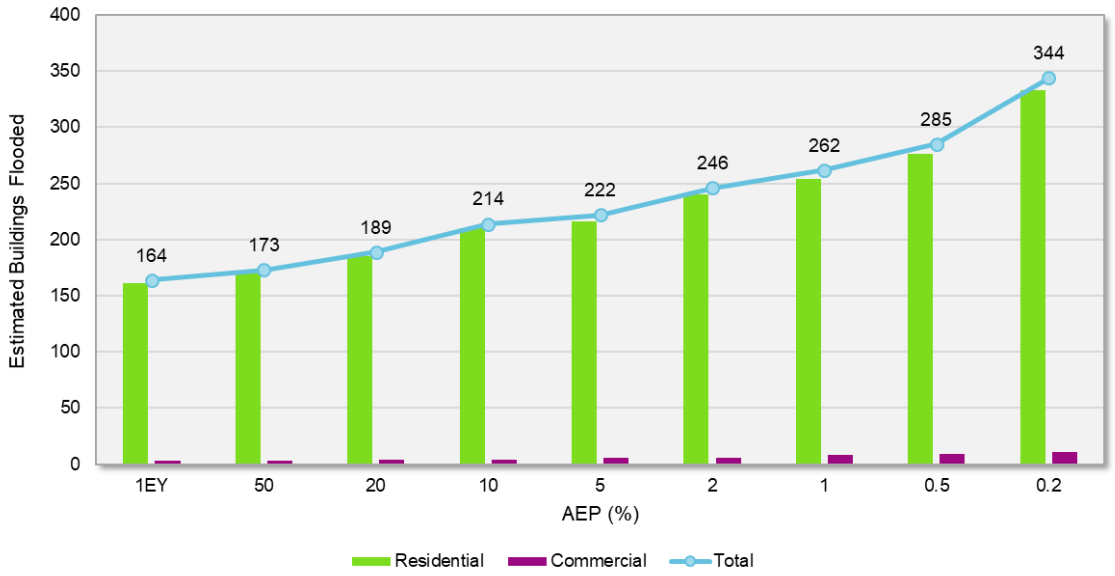

Figure 28 Plot of Estimated Mitigated Case Building Impacts

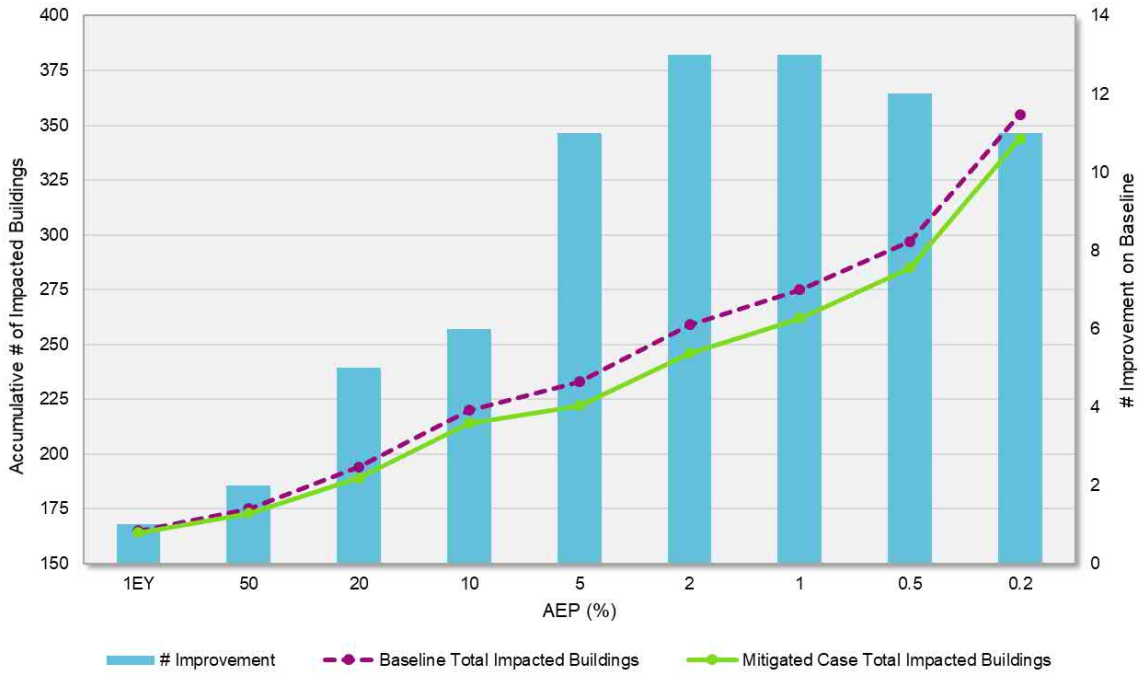

Figure 29 Plot of Improvement on Building Impacts in Mitigated Case

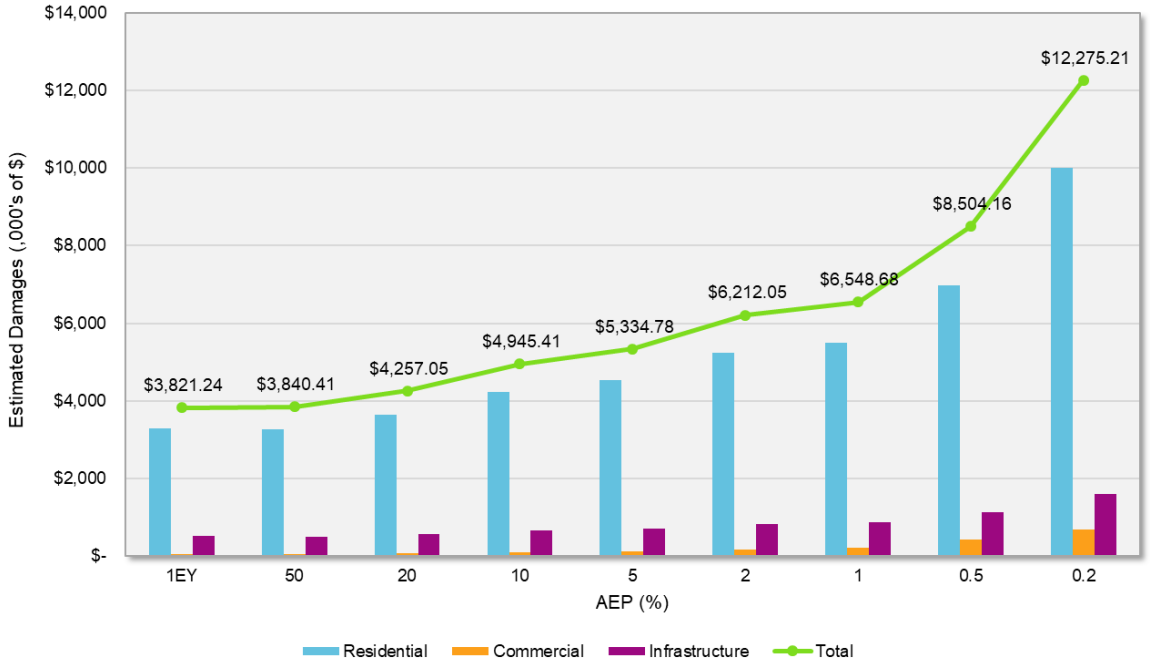

Figure 30 Plot of Estimated Mitigated Case Damages Cost

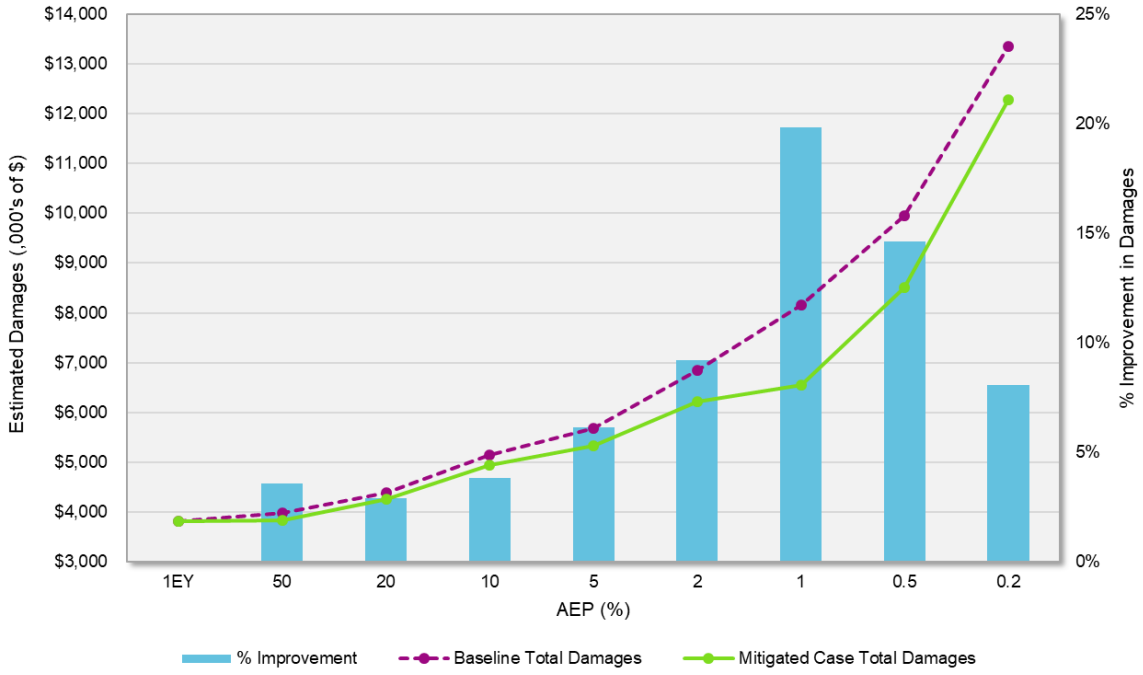

Figure 31 Plot of Improvement on Damages Cost in Mitigated Case

12.0 Implementation of Mitigation Options

12.1 Structural Mitigation Costs

Indicative structural mitigation construction costs (base year 2020) for structural mitigation options are summarised in Table 23. Cost estimates are available in Appendix H.

Table 23 Indicative Structural Mitigation Costs

Location	Indicative Cost
Farquhar Street and Avocado Court	$ 1,790,000
Cabbage Tree Road Drain	$ 1,700,000
TOTAL	**$ 3,490,000**

The above project costs exclude Goods and Service Tax (GST).

The indicated project costs are for trunk drainage works only. The costs include a contingency of 25% of the direct costs for unforeseen works. This allowance is considered appropriate given the preliminary nature of the investigation. No allowance has been made in the project costs for any maintenance or repair costs associated with the existing drainage infrastructure. All new culverts are assumed to be non-aggressive environment culverts.

Earthworks volumes have been estimated using the topographical data from the 2015 LiDAR survey.

The volumes of earthworks are subject to final survey and detailed design. No detailed services infrastructure investigation has been undertaken for this study. In preparing the project costs, known service infrastructure has been identified and nominal allowances have been made for its location, protection and realignment (if required).

No subsurface investigations have been undertaken for this study. No allowance has been made for unsuitable ground conditions or for the remediation and management of potential acid sulfate soils.

The project costs do not include any allowances for government agency costs, community consultation costs and community awareness costs. No allowance has been made for acquisition of drainage reserves or easements.

Indicative project costs for each individual section are based on separate standalone construction time frames. Project savings may accrue if sections are constructed within the same time frames.

12.2 Cost Benefit Ratio

The cost benefit ratio will only be assessed for the Farquhar Street and Avocado Court as well as the Cabbage Tree Road Drain proposed mitigation scenarios, mentioned in Table 23.

An assessment was undertaken to understand the net economic costs and tangible benefits associated with the mitigation options proposed. The cost benefit analysis below provides guidance on the net tangible impact of the proposed mitigated case against the existing conditions.

The assessment assumed a minimum stormwater asset life of 50 years and hence an assessment period of 50 years. No discount rate was applied. The results are shown in Table 24.

Table 24 Project Cost Benefit Ratios

Mitigation Option	Cost	Reduction in AAD	BCR
Farquhar Street and Avocado Court Drainage Upgrade & Cabbage Tree Road Drain	$ 3,490,000	$ 153,590 per year	2.20

12.3 Sequencing of Options

Sequencing of mitigations may be as follows:

- Future Lot development – no works required except for Cabbage tree Road drain area
- Surveyed Discharge Locations – no works required.
- Coles Road – no works required.
- Cabbage Tree Road open drain – planning study - update the 2000 Master Plan with indicative development lot layouts and earthworks profiles.
- Farquhar Street and Avocado Court:
    - Add additional 900 RCP to Avocado Court.
    - Make changes to the north south pit and pipe systems to allow for pie/pit surcharging to the adjacent drain.
    - Construct Farquhar Street stormwater system.
    - Improve overland flow for Avocado Court cul-de-sac to western drain.

13.0 Constructability

13.1 Constructability Assessment

Only the Farquhar/Avocado systems are assessed for constructability. The proposed stormwater drainage system has in part been concept designed by Council with the proposed redirection of the system outlet being an outcome of the baseline study.

The constructability assessment has assumed the Council concept design has undergone a form a constructability due diligence. Only the culverts forming part of the redirection of the outlet will be discussed in terms of constructability.

The elemental parts of the construction are:

- 2/900 RCP north along Farquhar Street to Harris Street cul-de-sac:
  - This section traverses a slight rise within the road profile and will require a trench depth of approximately 2 metres over a length of approximately 80 metres. Construction within the road pavement is considered more appropriate to reduce the impact on water, power and communication services
- An existing 150 AC gravity main:
  - Approximately mid-way on this section will intersect the 2/900 RCP about 0.4 above the pipe invert. This interaction will require a stormwater chamber to allow an enveloped sewer pie to traverse the new stormwater alignment.
- At the Harris Street cul-de-sac:
  - The proposed 2/900 RCP alignment is within the existing 4.8m wide reserve to outlet in the rear drain. There are existing water and communications services with the road verve of the reserve. The existing 2/450 RCP will need to be removed. A 150 AC gravity sewer crosses the pipe alignment near the outlet location. It is anticipated that the new construction will adopt the existing stormwater pipe elevation and thus have approximately 300mm cover over the sewer main. The standard trench width for 2/900 RCP's is 3.2m. The easement is 4.8m wide. Trench depth is approximately 1.4m deep. There are a number of alternatives to reduce the anticipated trench widths as follows:
    - Reduce the distance between barrels to (say 300mm) and use flowable fill.
    - Use 2/900 CSP with approximately 100mm between the barrels with flowable fill for the bedding/backfill. This option may reduce the culvert handling issues in a confined space as the CSP are considerably lighter.

14.0 Conclusion

14.1 Summary

There are a number of key findings of this study, including:

- Previous studies undertaken within the study area and the McCreadys creek system. Of particular interest is the Oak Street Study, the Cabbage Tree Street Master plan and the McCreadys Creek South study. From this there was general corroboration with the aforementioned report outcomes.
- East and west access to the study area is compromised in events larger than a 5% AEP design event. Alternative access to the study area is south along Norris Road and Glenpark Street.
- Over floor flooding is predicted within the study area with the majority around Farquhar Street.
- Tidal impacts are minimal up to the 1% AEP baseline design storm.
- The baseline scenario was corroborated to the few levels along McCreadys Creek for the 2008 event.
- The baseline scenario and the mitigated scenario did not include consideration of the ultimate planning scheme development to the west of Mackay Bucasia Road.
- The study area critical storm duration in both the Baseline and Mitigated scenarios:
  - Ranging from 30 minutes hour to 6 hours across the across the study area and the range of design AEP.
- The baseline sensitivity analysis shows:
  - A 20% increase and decrease in roughness showed minimal change to urban drainage patterns with the study area.
  - A 20% increase in rainfall intensity and 0.8m increase in tidal levels, as a result of climate change by 2100, results in significant widespread additional flooding in the Aspley Creek area and some adjacent lots.
- Structural mitigation options provide some benefit in reducing flood extents and depths in Farquhar Street and Avocado Court.

14.2 Recommendation

It is recommended that this study be used as a basis for further investigations, setting development elevations and assisting in emergency management planning.

15.0 References

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Appendix A

TUFLOW Hydraulic Model Parameters

Appendix A TUFLOW Hydraulic Model Parameters

Model Setup Parameters

The grid cell size selected for the model was 8m.

The minimum time step for the 2D model domain was set to 0.8 seconds, as the TUFLOW HPC Solver utilises an adaptive time step and resultantly can wind down the time step to ensure model stability. The corresponding 1D time step was set at 0.5 seconds. These time steps are within the feasible time step range given the grid cell size.

The wetting and drying depth represents the depth of water on a cell which is the criteria for whether the cell is “wet” or “dry”. Direct rainfall modelling applies rainfall to each cell in small increments, so the wetting and drying values must also be very small or the intermediate calculations will not take place satisfactorily. The wetting and drying depth has been set to the default of 0.0002m for the centre of a cell. The “Cell Side Wet/Dry Depth” command is no longer used as of the 2008 version release.

Model Topography

Base model topography was derived from LiDAR survey flown in 2015 and supplied by MRC. The data was supplied as a 1m resolution Digital Elevation Model (DEM).

Due to limitations surrounding large-scale hydraulic modelling, the adopted grid cell size (3m) may not always adopt the peak level of road and rail features such as crown levels, culvert headwalls and small table drains. Given the hydraulic significance of these particular features within urban catchment flow paths, manual topography modifications were made in required areas using TUFLOW Z-Shape files that enforce set topography.

Hydraulic Roughness

The specified hydraulic roughness reflects the different types of development and ground cover that exists within the hydraulic model extent. The roughness categories adopted for the model were based on the latest aerial imagery and land use zoning information.

Within the model extent, land use was delineated using machine learning (ML) techniques within a GIS interface to rapidly classify landuse using the latest imagery. This process was leveraged of training a computational model to inform manual assignment of landuse classes and distributions.

By applying this process to automatically classify land use from the latest aerial imagery, the accuracy and precision of the spatial distribution of hydraulic roughness values is increased substantially when compared to previous roughness digitisation methods. The machine learning process is also easily repeatable and will provided consistency to hydraulic modelling in future studies.

Variable Manning’s ‘n’ values based on depth can be utilised within TUFLOW. Manning’s ‘n’ 1 is applied for all flow depths up to depth 1, between depths 1 and 2 the Manning’s ‘n’ utilised by TUFLOW is interpolated between Manning’s ‘n’ 1 and 2 and for all depths greater than depth 2 Manning’s ‘n’ 2 is applied. In the instance of road reserve and open water a single roughness has been applied.

Specific roughness values for each category as applied in the model are outlined in Table A1

Table A1 Hydraulic Model Roughness Parameters

Material Description	Manning's 'n'			
	Depth 1 (m)	Manning's 'n' 1	Depth 2 (m)	Manning's 'n' 2
Open Space	0.10	0.035	0.30	0.030
Light Vegetation	0.10	0.060	0.30	0.045
Medium Vegetation	0.10	0.075	0.30	0.050
Heavy Vegetation	0.10	0.090	0.30	0.060
Sugar Cane	0.10	0.180	0.30	0.135
Roads / Concrete	0.020			
Waterbodies	0.030			
Buildings	0.500			

The spatial variation of hydraulic roughness within the TUFLOW model is shown in Figure 15.

Boundary Conditions

Peak flows from the hydrologic models were applied to the TUFLOW hydraulic model as external boundary inflows from the bounding McCreadys Creek catchment (refer Figure 11). Flows were applied as a varying flow over time (QT) boundaries.

The downstream model boundary was modelled as a height over time varying (HT) boundary based on Mean High Water Springs (MHWS) tidal levels for the area. A static water surface level of 2.35mAHD was applied as the downstream boundary condition for consistency with other Council studies with tidal downstream boundaries.

Appendix B

Tangible Flood Damages Assessment Methodology

Appendix B Tangible Flood Damages Assessment Methodology

1.0 Introduction

As part of the Andergrove Beaconsfield Study, a flood damages assessment has been conducted to help quantify the financial burden borne by the community due to the local catchment flood damages. The flood damages assessment will also assist in assessing the potential economic benefits of the proposed mitigation options, in providing flood mitigation for the study area during local catchment flood events.

This flood damages assessment considers the financial impacts of flooding, comprising the costs associated with direct damages to property and infrastructure, and indirect costs associated with the disruptive impacts of flooding. This document presents the methodology used to assess flood damages, and the resulting estimates.

2.0 Estimating Flood Damages

2.1 Overview

Flooding can result in significant financial and social impacts on a community. A breakdown of the various types of flood damages is displayed in Figure B1. As intangible flood damages are difficult to quantify as a monetary value, they have not been included in this flood damages assessment. Therefore, reference to flood damages within this report refers to tangible flood damages only.

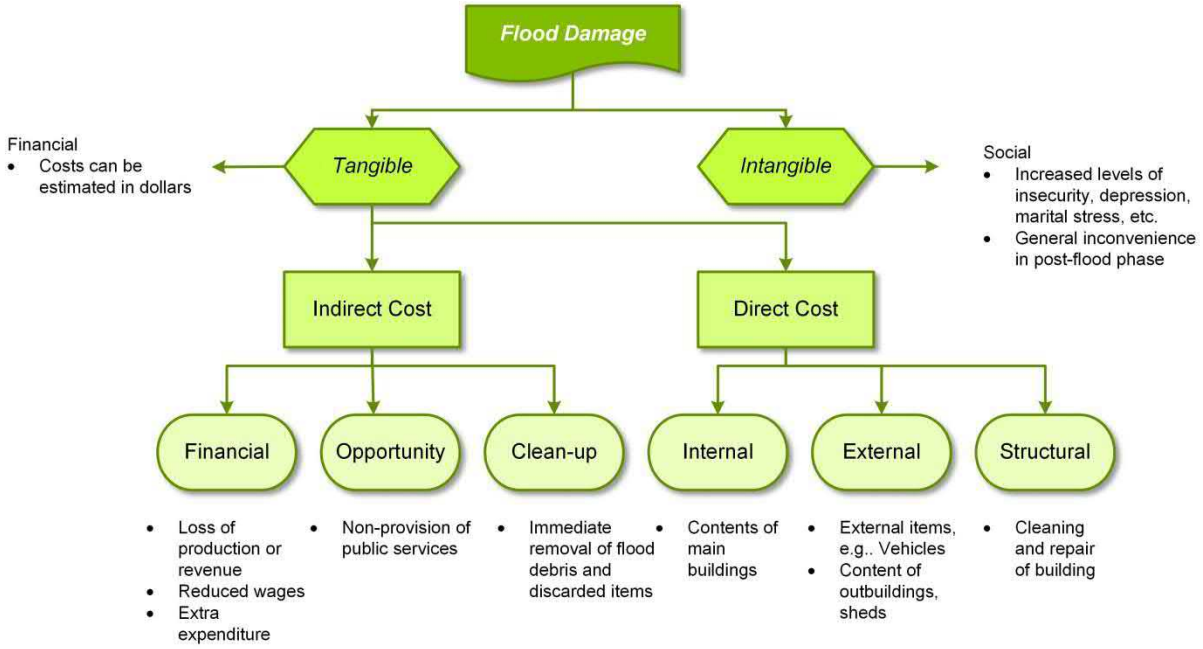

Figure B1 Breakdown of Flood Damage Categories (DNRM, 2002)

Tangible flood damages, or the anticipated cost to residents, businesses and local government infrastructure due to flooding, have been estimated using a standardised approach adopted throughout Australia.

The approach estimates the tangible impacts flooding has on people, property, and infrastructure, such as flooding of a building and contents, the lost opportunity value associated with wages and revenue and flooding of transport and utility networks. These tangible impacts are estimated based on the depth, likelihood of flooding and type of building/infrastructure.

A building's estimated depth of flooding and its classification (single storey, high-set, double storey or units), determines the total estimated flood damage for that building. The direct flood damage is determined based on stage-damage curves, which relate building type, building area and flood depth to the monetary loss associated with the structure and contents damage.

Indirect damages associated with lost opportunity value, i.e. wages and revenue and the cost of temporary relocation, are then estimated as an additional percentage for residential and non-residential buildings. The combined direct and indirect damages then represent the total damage to the building. For this assessment, infrastructure damages, such as water treatment plants and utility and transport networks, are then estimated as a percentage of the total residential and non-residential damage combined.

3.0 General Methodology

Flood damages have been estimated through the application of stage-damage curves. These curves provide damage costs as a function of water depth and are used to estimate direct flood damages for individual buildings based on the peak flood depth that the building experiences during a flood event. Indirect damages and infrastructure damage have been estimated as a percentage of the direct damage.

The assessment has been undertaken using the results of hydraulic modelling of the Andergrove and Beaconsfield Catchments for the Andergrove Beaconsfield Drainage Study. Details of the hydraulic modelling are discussed in the Andergrove Beaconsfield Drainage Study Report – Volume 1 and Volume 2 (AECOM, 2020).

3.1 Council 2018 Stage-Damage Curves

Mackay Regional Council (Council) engaged WRM Water & Environment as part of the Mackay Floodplain Management Plan (2018) to undertake a review of flood stage-damage curves and develop curves specific to properties within the Mackay Region. This investigation was intended to provide the most accurate and up to date curves for use in flood damages assessments across the Mackay Region. The Council 2018 Stage-Damage Curves were provided by Council for application to the South Mackay Bakers Creek Stormwater Trunk Infrastructure Study and have been developed using the following methodology (WRM, 2018):

"Flood stage-damage curves (flood damage curves) relate the depth of flooding at a property to the cost of flood damage. The underlying data in the existing flood stage-damage curves in Australia is generally quite dated. Therefore, a new property damage survey was undertaken to derive locally representative stage-damage curves for the predominant residential and commercial property types identified in Mackay. The survey was conducted by an experienced valuer (from VASA valuers) visiting and physically inspecting the selected properties and estimating potential internal, external and structural damages at different depths of flooding using the valuation survey method. The survey also captured general property information on size, style, age, construction material, ownership, etc.

The Mackay damage survey was conducted on 26 properties, 20 of which were residential and 6 of which were commercial properties. The properties for survey were selected from volunteers across Mackay. Comprehensive property damage assessment forms were designed and used to capture the specific data required for the derivation of stage-damage curves for the surveyed property types.

The data collected for Mackay properties was supplemented with an additional 96 property surveys (66 residential properties and 30 commercial properties) that were conducted by WRM and VASA for the Brisbane River Strategic Floodplain Management Plan (BRSFMP) in May and June 2017. The methodology for the BRSFMP property survey was consistent with Mackay property survey.

It was found that the shape and magnitude of the stage-damage curves developed from the Mackay residential data was consistent with the Brisbane data and therefore a combined dataset was considered suitable. There was some differences in the magnitude of the commercial stage-damage curves, however this was overcome by adopting value classes one class lower for the regional (Mackay) commercial properties when compared to the Brisbane commercial properties for higher value class enterprises.

The flood stage-damage curves are suitable for flood damage estimation on a regional scale and are not appropriate for estimation of flood damages on an individual property basis."

3.2 Alternative Approaches

Several other approaches for estimating residential flood damages and stage-damage curves have been applied in Australia, including those by the Victorian Natural Resources and Environment, Risk Frontiers, WRM (for Sunshine Coast Regional Council) and O2 Environmental (for Ipswich City Council). While these approaches follow the same general approach as the Council Stage-Damage Curves as outlined in Section 3.1, they use different estimates for stage-damage curves or consider damage types differently. A summary of literature relevant to these approaches is provided below. These provide detail on these alternative approaches.

- Department of Infrastructure, Planning and Natural Resources (DIPNR) (2004) "Floodplain Management Guideline No 4 Residential Flood Damage Calculation", Department of Infrastructure, Planning and Natural Resources, New South Wales Government, February 2004.
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The Queensland Department of Natural Resources and Mines (DNRM) recommends the use of the ANUFLOOD stage-damage curves for estimating potential flood damages; however there is a consensus that ANUFLOOD underestimates damage values for residential properties. For instance, DIPNR (2004) states:

> *"The Victorian Natural Resources and Environment, Rapid Assessment Method (RAM) for Floodplain Management, May 2000, indicates that ANUFLOOD estimates needed to be increased by 60% to be in the vicinity of Water Studies damages surveys. Even with this adjustment ANUFLOOD estimates are still well below those of Risk Frontiers."*

A review of residential stage-damage curves was undertaken as part of the Mackay CBD Drainage Study (AECOM, 2015). This review compares flood damages estimated using the ANUFLOOD stage-damage curves against two of the Australian methods mentioned above and one approach used in the USA, and demonstrates the variation in estimates of flood damages between different approaches. Based on this review, the WRM stage-damage curves and O2 Environmental stage-damage curves based on rebuilding costs were adopted for estimating residential direct damages, to be presented as bounds of potential flood damages.

3.3 Actual and Potential Damages

The stage-damage curves used during this study provide estimates of the potential flood damages which would occur during a flood event if no actions were taken to reduce the amount of damage. During actual flood events, residents will usually take measures to reduce the amount of damage incurred, such as moving possessions to higher ground.

The reduction in flood damages resulting from such preventative measures is dependent on the warning time available during a flood, the experience of the community in preparing for flooding and whether or not it is possible to move possessions to safety.

Residents of Andergrove & Beaconsfield typically have very little notice prior to a local catchment flood event, as critical durations for the study area are short (in the order of 2 to 3 hours Therefore the stage-damage curves were not adjusted using the ratios of actual to potential (A/P) flood damages recommended in DNRM (2002). An actual to potential damages ratio of 1 has been applied to all the damage curves.

4.0 Building Digitisation and Classification

4.1 Building Footprint Digitisation

Building footprints were digitized using machine learning techniques and classified LAS data derived from the LiDAR capture. Building footprints are used to determine whether a building is flooded, and to estimate the size of the building required for building classification. The following limitations to building footprints should be noted:

- Footprints were digitized based on roof outlines, which may not correspond to the actual building footprint when there is a complex roof shape and given the overhang of eaves. It is unlikely this will significantly impact flood damage estimates, since the variation in area and extent is typically minimal.
- Trees obscure some buildings, requiring an assumption of the likely extent and shape of the building. Again, it is unlikely this will significantly impact damages since rarely do trees prevent reasonable assessment of the building shape and extent in this catchment area.
- Multiple tenancy complexes, e.g. units, shopping centres, strip malls, and warehouses, were digitized as multiple buildings where delineation between individual ownership could be identified from the cadastral boundaries. If a group of buildings could not be digitized separately based on the aerial image, this could skew localized estimates of damages; for instance, a shopping centre digitized as a single building where only the first business was flooded, would produce flood damages for the entire building.
- In cases where shared tenancies could not be separated by the cadastral boundaries, flood damages will be estimated based on the mean surveyed habitable floor level or assumed depth above ground elevation around the entire building footprint. This will tend to estimate flood damages only when the majority of the buildings is actually flooded, regardless of whether they were digitized individually or as a group.

The area of the building footprint was used for classifying buildings into different size classes. For large commercial buildings, the stage-damage curves give damages in units of $\$/m^2$, therefore building areas were used directly in the damage calculations.

4.2 Classification

To assign classes to buildings, the building footprints were intersected with property information from Council's Terrestrial LiDAR database for residential properties (refer Section 5.0) and the land use planning scheme layer for commercial properties. It is to be noted that commercial property classification includes commercial, industrial and public buildings.

4.2.1 Residential Building Classification

Residential buildings were further classified based on size, foundation type and storey height to align with the building categories presented in Section 6.1. Building classification was based on the floor type classification from the Council Terrestrial LiDAR database (refer Section 5.0) as well as the area of the digitised building footprints.

4.2.2 Commercial Building Classification

Commercial buildings were further classified based on size and value of the building contents to align with the classes presented in Table B1. Building classification was based on the area of the building footprints, and the property description field of the Council land use dataset.

5.0 Terrestrial LiDAR Data

Mackay Regional Council has recently captured property information through the attainment of Mobile Laser Scanning (MLS) point cloud LiDAR used to develop the Council Terrestrial LiDAR dataset.

The point cloud data has been translated into multiple GIS points as shown in Figure B2, these points contain property information and levels such as: building purpose, floor type, construction material, garage level, edge of building level, patio level, habitable floor level, bottom of window level and eave height.

For the purposes of the tangible flood damages assessment, the building purpose, floor type and habitable floor level information was used to help classify property and assess inundation above floor level.

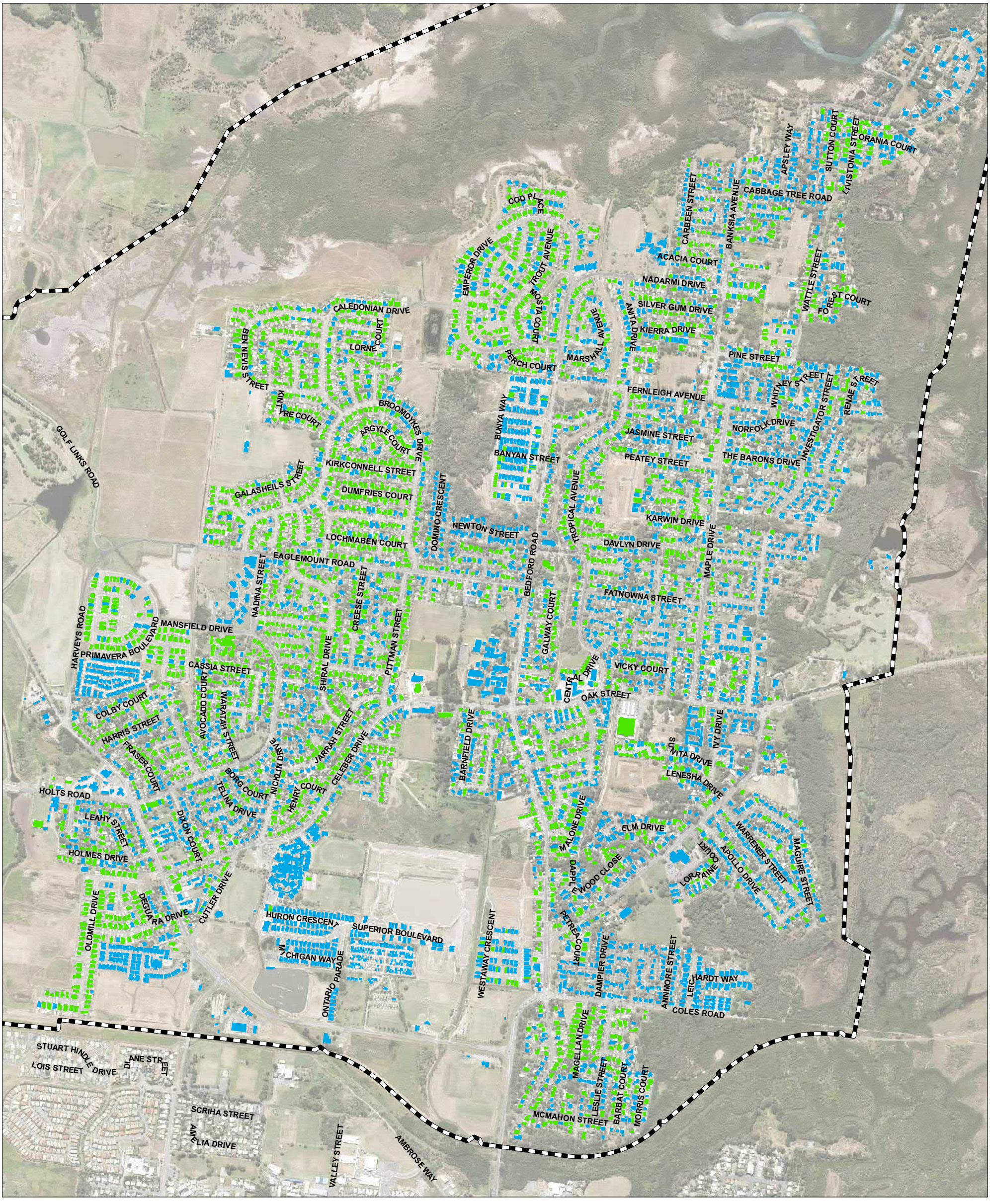
Figure B2 Visualisation of the Council Terrestrial LiDAR Database

The point information contained within the Terrestrial LiDAR dataset (as shown in Figure B2) was joined to Council's cadastral database as part of the assessment, this made it easier to attach multiple fields to a singular building footprint for each lot.

Some properties are missing floor level information, other building attributes or have negative floor information, in this case, a desktop assessment using street imagery was undertaken to assume the classification and habitable floor level of each residence.

This was based upon visible features such as slab height or number of steps into a dwelling. A minimum height above ground level of 10mm was specified by Council for all categories, where the height was less than 10mm. Buildings were assumed to have a minimum habitable floor level of 10mm above ground level.

The ground level at each building was estimated based on the 1m LiDAR DEM provided for the project. Ground levels were assigned to the building footprints based on the average elevation of the DEM immediately surrounding the building extents.



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AECOM

N

0 0.2 0.4 km

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Legend

Floor Level Source

- LiDAR Interpolated Floor Level
- MRC Terrestrial LiDAR Floor Level
- Railway
- TUFLOW Model Extent

MACKAY REGIONAL COUNCIL

Andergrove Beaconsfield Drainage Study

Building Impacts Floor Level Data Source

B-3

6.0 Damage Categories

The tangible damages assessment requires buildings to be categorised in to three building types so that the relevant damages can be applied to the property. These categories are:

- Fully Detached Residential
- Multi-Unit Residential
- Commercial.

Fully detached residential properties are defined as standalone houses with one residential dwelling per allotment whilst multi-unit dwellings are made up of multiple buildings per allotment whether they are combined or smaller individual residences. Commercial properties are assigned a Damage Class based on Council defined land use.

Properties were categorised based on the 'Building Purpose' field of Council's Terrestrial LiDAR database (refer Section 11.5). Multi-unit properties were cross checked using the address fields of the Council cadastral database where the 'Unit' code was not equal to 0 (i.e. address formatted as Unit/Number Street Name).

6.1 Residential Categories

Properties identified as residential (fully detached or multi-unit) were then categorised based on the 'Floor Type' field of Council's Terrestrial LiDAR database (refer Section 5.0). The 6 residential property sub-categories are as follows:

- Fully Detached Residential:
  - Fully detached, lowset, single storey, slab-on-ground (FDSS-SOG)
  - Fully detached, lowset, single storey, stumps (FDSS-Stumps)
  - Fully detached, highset (FDHS)
  - Fully detached, double storey (FDDS).
- Multi-Unit Residential:
  - Semi/non-detached (multi-unit) single storey (MUSS)
  - Semi/non-detached (multi-unit) double storey (MUDS).

As noted in Section 5.0, Council provided information on the floor type and height above ground. A minimum habitable floor level of 10mm above ground level was proposed by Council for all categories, where the height above ground level was less than 10mm. Buildings lacking data regarding what type of floor they have were assumed to be on slabs.

6.2 Commercial Categories

Commercial buildings were categorised into the ANUFLOOD commercial classes based on the property description field of the Council land use dataset. The ANUFLOOD damage value classes for commercial buildings are shown in Figure B4.

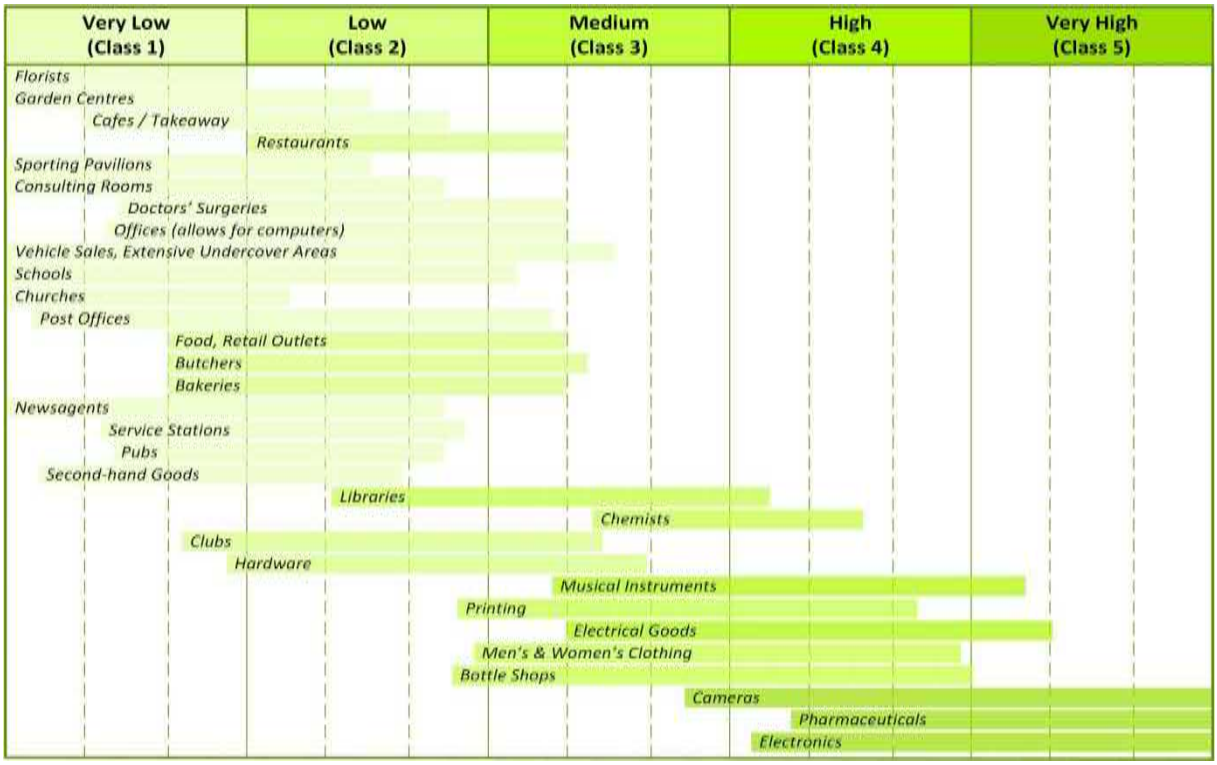


Figure B4 ANUFLOOD Commercial Damage Value Classes (DNRM, 2002)

Where the property description code did not correspond directly to an ANUFLOOD damage value class, a reasonable value class was assigned. Table B1 shows the value class assigned to each property description code in the Council land use dataset.

Table B1 Assignment of Commercial Damage Class Curves Based on Council Land Use Dataset

Council Land Use	Class	Council Land Use	Class	Council Land Use	Class
Animals Special	3	Horses	1	Service Station	2
Builders Yards/Contractors Yard	3	Hospitals/Nursing Homes	2	Shop Single	3
Car Park	2	Hotel/Tavern	2	Shops 2 to 6	3
Car Yards etc.	2	Iceworks	2	Shops Main Retail	3
Caravan Parks	2	Irrigation Small Corps	2	Shops over 6	3
Cattle Breeding/Fattening	2	Library	3	Shops Secondary Retail	3
Child Care Centre	1	Licenced Clubs	2	Showgrounds etc.	2
Churches/Halls	1	Light Industry	3	Sports Clubs	2
Clubs Non-Business	2	Motel	2	Theatre/Cinema	3
Council Owned	2	Nurseries	2	Transformers	3
Defence Forces	4	Offices	2	Transport Terminal	3
Drive Shopping Centre	3	Oil Depot	3	Tropical Fruits	1
Fire/Ambulance	3	Parks & Gardens	1	Uni/Schools etc.	2
Funeral Parlours	1	Reservoirs etc.	3	Vineyards	2
General Industry	3	Restaurant	2	Warehouses etc.	3
Guesthouse	2	Retail Warehouse & Showroom	2	Service Station	2
		School	2	Shop Single	3

6.3 Building Footprint Size

Furthermore to the category, a building footprint size is also required to attribute each property to the correct stage-damage curve for their size. As the building footprints have been digitised as part of the damages assessment (refer Section 4.1) using GIS software the footprint size can be automatically calculated. From this size, the building can then be classified as a small, medium or large type property based on the following criteria:

- Fully Detached and Multi-Unit Residential Properties:
  - Small (< 140m2)
  - Medium (140 to 210m2)
  - Large (> 210m2).
- Commercial Properties:
  - Small (< 186m2)
  - Medium (186 to 650m2)
  - Large (> 650m2).

7.0 Consumer Price Index Adjustment

All stage-damage curves were adjusted to present day dollars based on Consumer Price Index (CPI) ratios. Current CPI values were taken from the most recent statistics available from the Australian Bureau of Statistics (ABS) dated March 2020.

The Council commercial damage curves were adjusted using the CPI for All Groups, as to the ratio of structure to contents damages is unknown. The external, contents and structural components of the Council damage curves were adjusted separately using their relevant CPI. The Council curves were developed using the June 2017 CPI's. Table B2 shows the CPI adjustment ratios for the Council stage-damage curves.

Table B2 Council Stage-Damage Curves CPI Adjustment Summary (Mar 2020 $)

Damage Curve	Relevant CPI Group	Reference	Ref. CPI	Current CPI	CPI Ratio
MRC Commercial	All Groups	June, 2017	111.0	116.2	4.68%
MRC External - Motor Vehicle	Maintenance and repair of motor vehicle	June, 2017	107.4	112.8	5.03%
MRC External - Other Damage	Tools and Equipment for house and garden	June, 2017	116.5	118.2	1.46%
MRC Contents	All Groups	June, 2017	111.0	116.2	4.68%
MRC Structural	Maintenance and repair of dwelling	June, 2017	107.8	114.3	6.03%

Historically, the WRM & O2 Environmental curves have been used for residential tangible flood damages assessments in the Mackay Region, with ANUFLOOD curves utilised for commercial damages. To provide a comparison between the Council 2018 stage-damage curves and the historical curves, the WRM, O2 Environmental and ANUFLOOD curves have also been adjusted to March 2020 dollars.

The commercial ANUFLOOD damage curves were adjusted using the CPI for All Groups, as the allotment of ANUFLOOD damages to structure damages and contents damages is unknown. The external and structural components of the WRM & O2 Environmental damages were adjusted separately using the relevant CPI's. Table B3 presents an overview of the historical curve CPI adjustments.

Table B3 Historical Stage-Damage Curves CPI Adjustment Summary (Mar 2020 $)

Damage Curve	Relevant CPI Group	Reference	Ref. CPI	Current CPI	CPI Ratio
ANUFLOOD Commercial	All Groups	March, 2002	74.2	116.2	56.60%
O2 External - Motor Vehicle	Maintenance and repair of motor vehicle	March, 2006	82.8	112.8	36.23%
O2 External - Other Damage	Tools and Equipment for house and garden	March, 2006	92.0	118.2	28.48%
O2 Contents	All Groups	March, 2012	99.9	116.2	16.32%
O2 Structural	Maintenance and repair of dwelling	March, 2012	99.5	114.3	14.87%
WRM External - Motor Vehicle	Maintenance and repair of motor vehicle	March, 2006	82.8	112.8	36.23%
WRM External - Other Damage	Tools and Equipment for house and garden	March, 2006	92.0	118.2	28.48%
WRM Contents	All Groups	March, 2006	83.0	116.2	40.00%
WRM Structural	Maintenance and repair of dwelling	March, 2006	88.4	114.3	29.30%

8.0 Damage Curves

8.1 Residential Damage Curves

Residential damages were estimated using the Council 2018 stage-damage curves and have been based on rebuilding costs associated with flooding.

Damage calculations were carried out separately for the external, contents and structural damage components and combined to give total damages. This allowed a range of raised building heights to be easily assessed, with external damages increasing with water over ground depth, and contents and structural damages increasing with water over floor depth. Raised floor levels were identified using Council's Terrestrial LiDAR database as per Section 5.0.

8.1.1 Fully Detached Residential Damages

Fully detached residential damages were estimated using the Council 2018 stage-damage curves and have been based on rebuilding costs associated with flooding.

Damage calculations were carried out separately for the external, contents and structural damage components and combined to give total damages. This allowed a range of raised building heights to be easily assessed, with external damages increasing with over ground depth, and contents and structural damages increasing with over floor depth. Raised floor levels were identified using Council's Terrestrial LiDAR database.

All damage values have been adjusted to March 2020 Dollars, which corresponds to the most recent Consumer Price Index (CPI) values available. No adjustment of Stage-Damage curves to represent actual / potential flood damages was undertaken.

Figure B5 shows the decision processes made as part of the fully detached residential building classification prior to applying the relevant stage-damage curve. The 12 classifications as shown in the flow chart have individual stage-damage curves that have been graphed in Figure B6 through Figure B9.

Individual curves are given for external, contents and structural damages, however these graphs present stage damage curves representing total flood damages (sum of external, contents and structural damages). The historical WRM and O2 Environmental curves (CPI adjusted to March 2020 dollars) have also been graphed for comparison.

Indirect fully detached residential damages were assumed to be 15% of the total direct residential damages (DNRM, 2002).

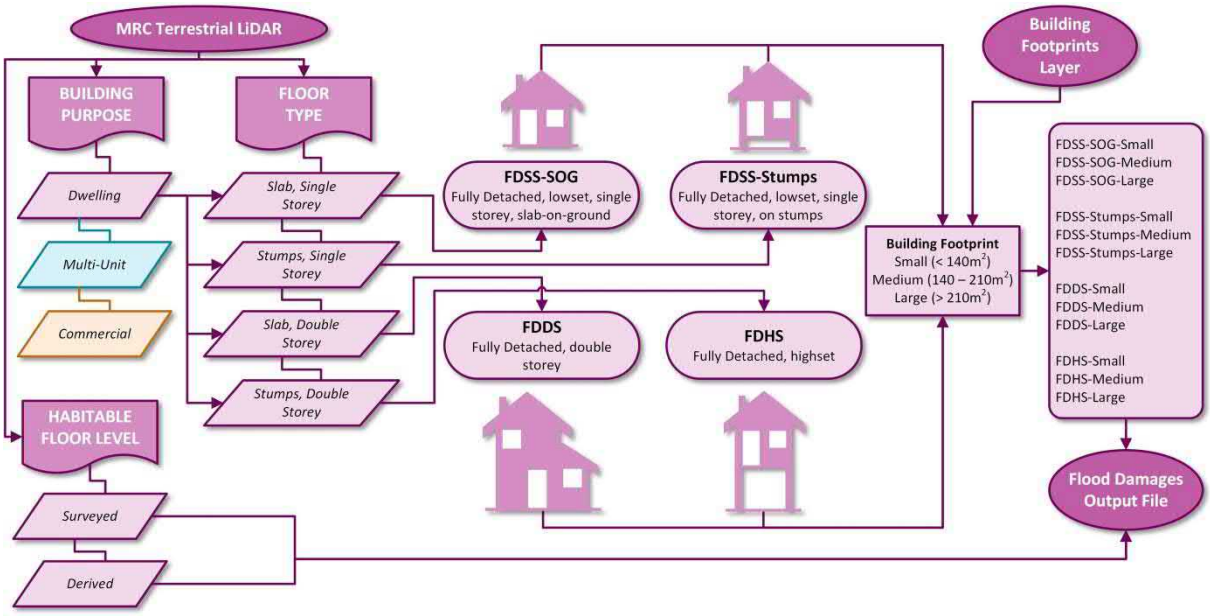


Figure B5 Fully Detached Residential Building Classification Flowchart

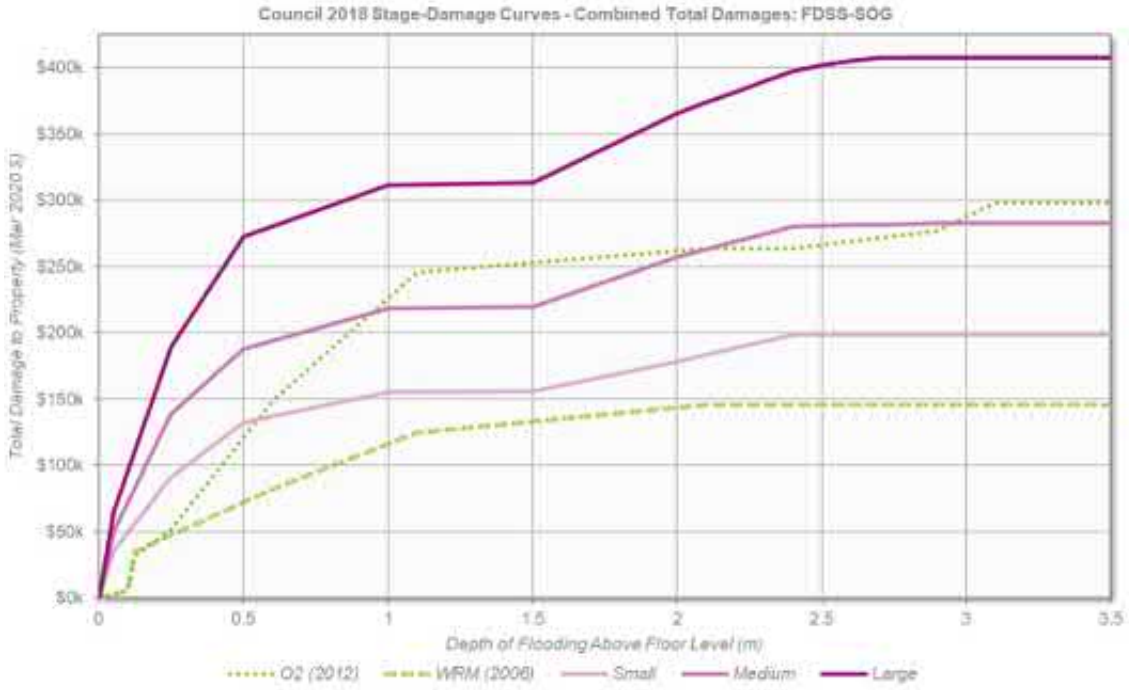


Figure B6 Combined Stage-Damage Curves: FDSS-SOG

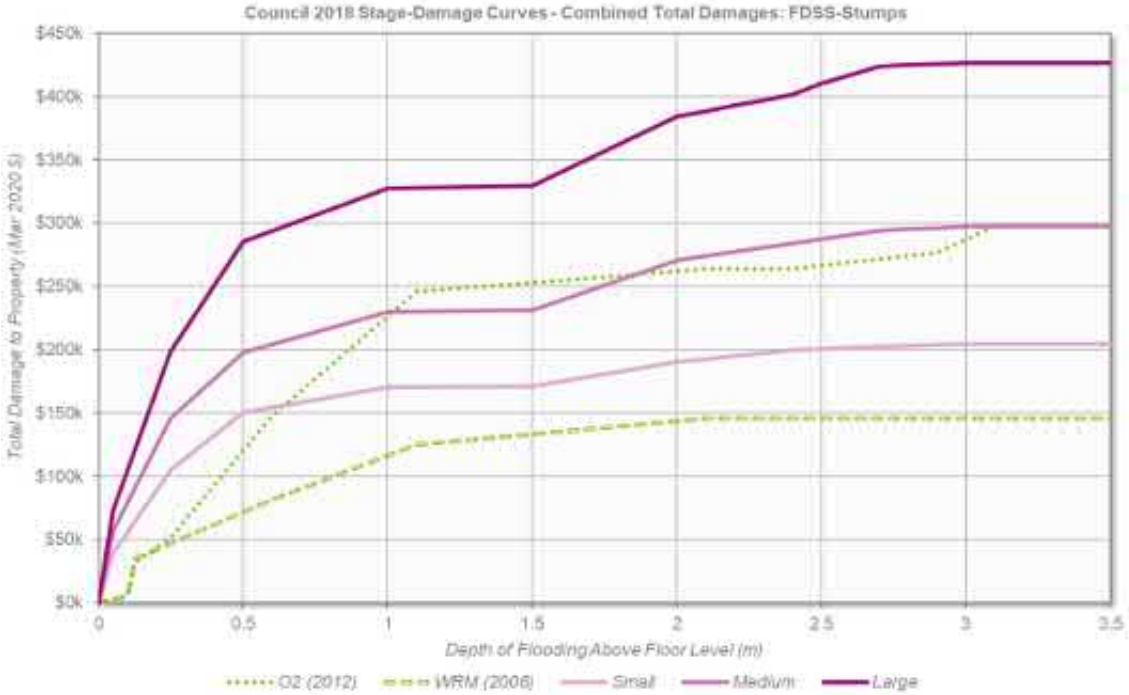


Figure B7 Combined Stage-Damage Curves: FDSS-Stumps

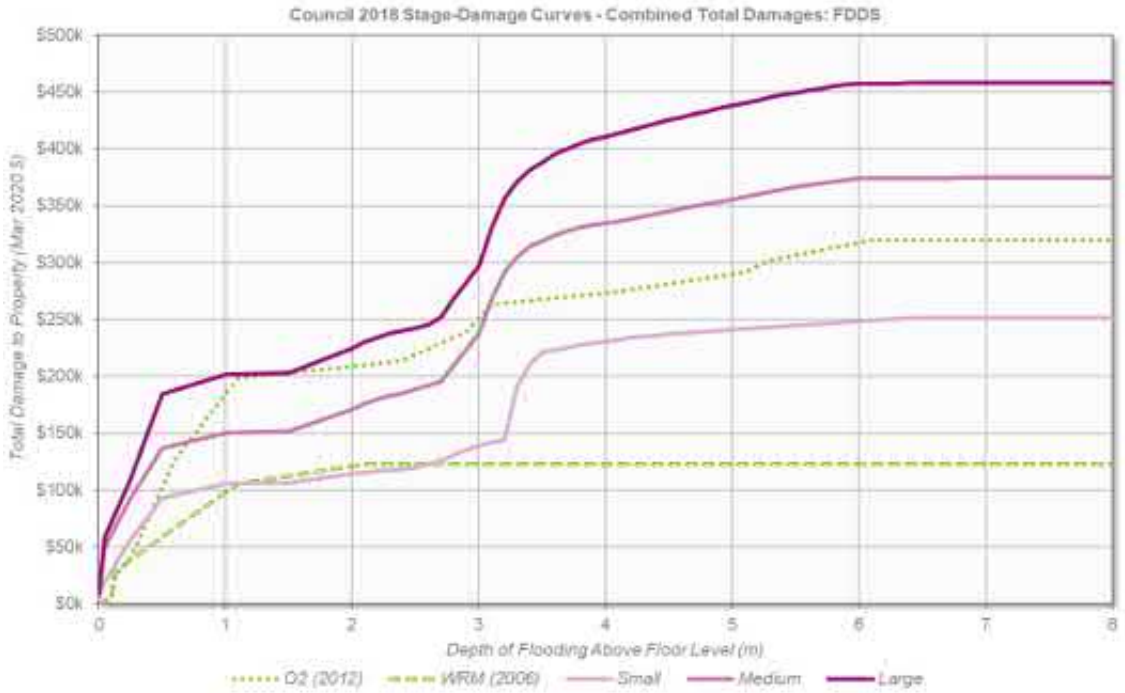


Figure B8 Combined Stage-Damage Curves: FDDS

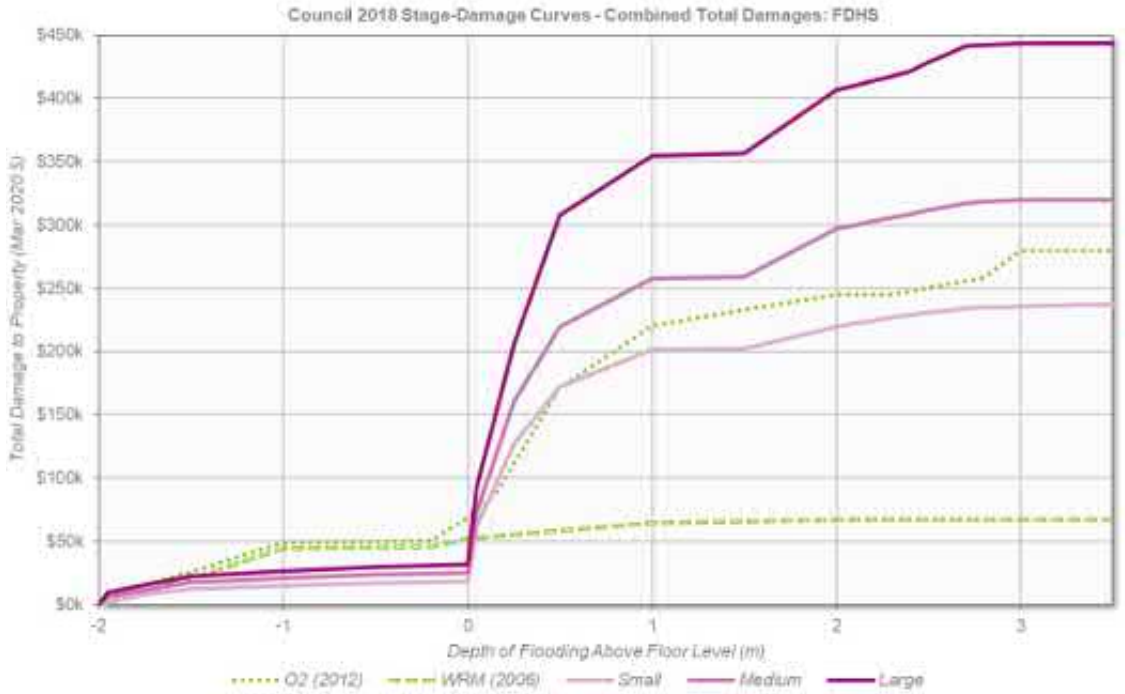


Figure B9 Combined Stage-Damage Curves: FDHS

8.1.2 Multi-Unity Residential Damages

Multi-unit residential damages were estimated using the Council 2018 stage-damage curves and have been based on rebuilding costs associated with flooding.

Damage calculations were carried out separately for the external, contents and structural damage components and combined to give total damages. This allowed a range of raised building heights to be easily assessed, with external damages increasing with over ground depth, and contents and structural damages increasing with over floor depth. Raised floor levels were identified using Council's Terrestrial LiDAR database.

All damage values have been adjusted to March 2020 Dollars, which corresponds to the most recent Consumer Price Index (CPI) values available. No adjustment of Stage-Damage curves to represent actual / potential flood damages was undertaken.

Figure B10 shows the decision processes made as part of the multi-unit residential building classification prior to applying the relevant stage-damage curve. The 6 classifications as shown in the flow chart have individual stage-damage curves that have been graphed in Figure B11 and Figure B12. Individual curves are given for external, contents and structural damages, however these graphs present stage damage curves representing total flood damages (sum of external, contents and structural damages). The historical WRM and O2 Environmental curves (CPI adjusted to March 2020 dollars) have also been graphed for comparison.

Indirect multi-unit residential damages were assumed to be 15% of the total direct residential damages (DNRM, 2002).

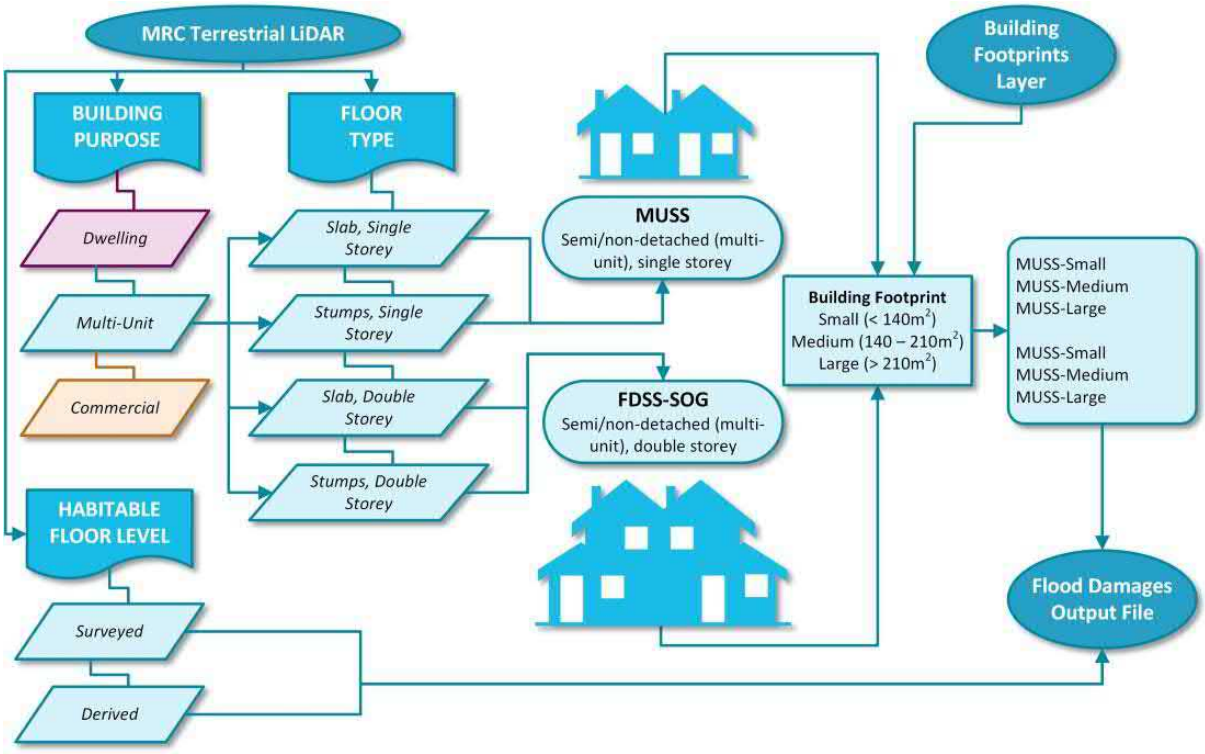


Figure B10 Multi-Unit Residential Building Classification Flowchart

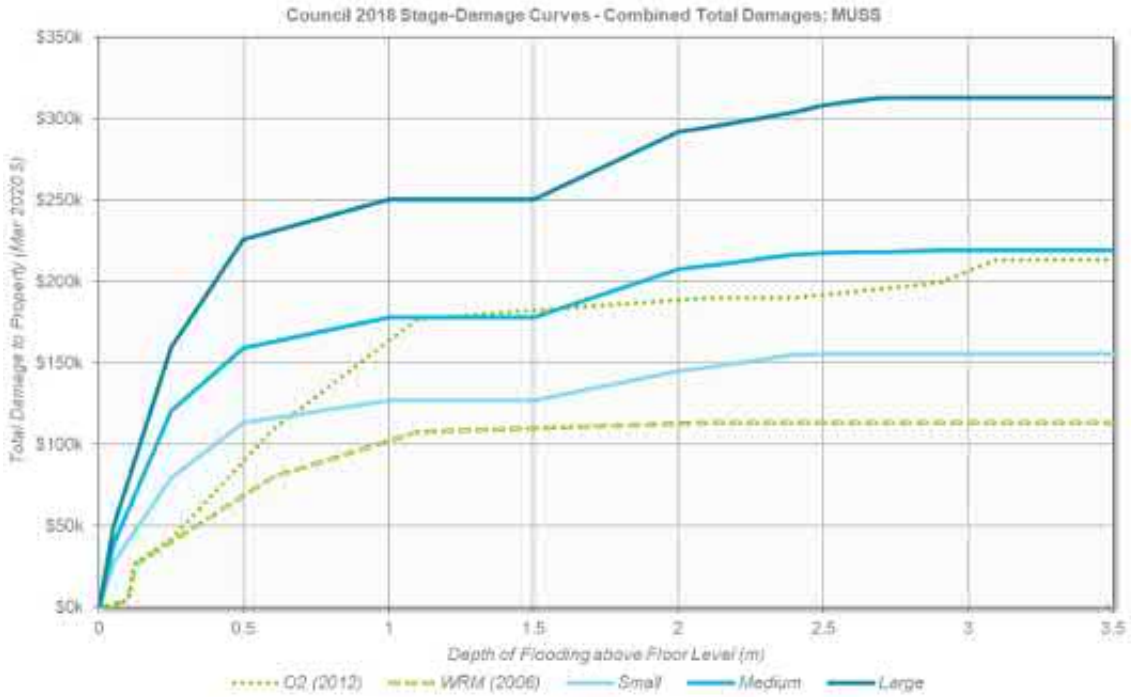


Figure B11 Combined Stage-Damage Curves: MUSS

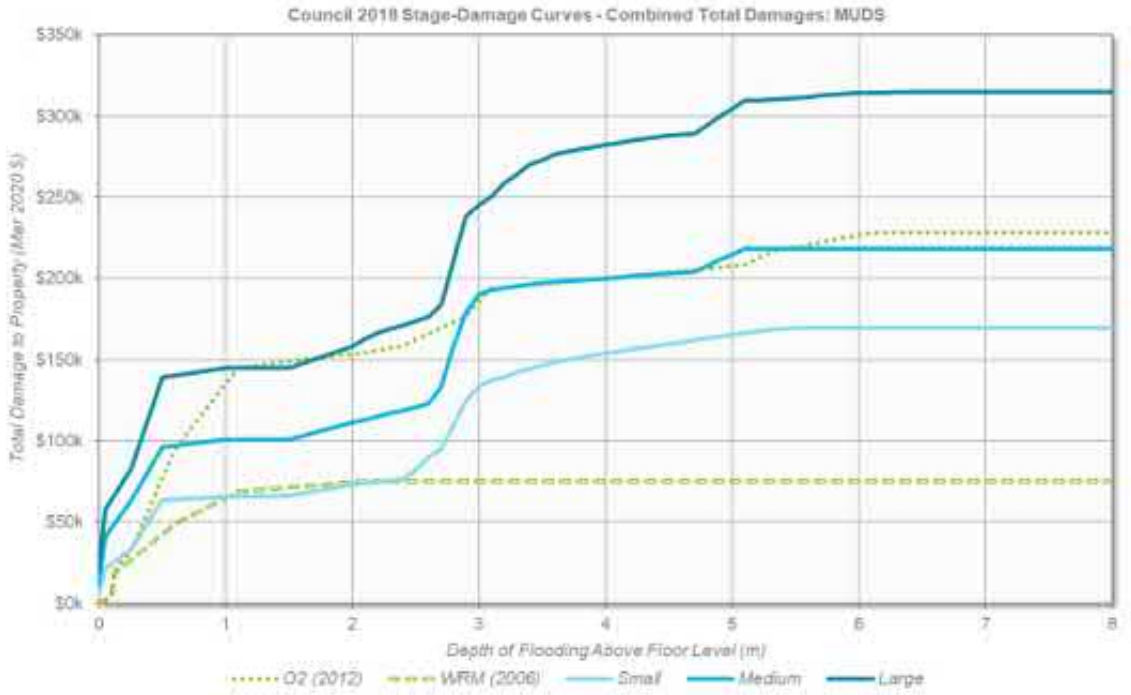


Figure B12 Combined Stage-Damage Curves: MUDS

8.2 Commercial Damage Curves

Commercial damages were estimated using the Council 2018 stage-damage curves. These curves represent present day adjusted ANUFLOOD commercial stage-damage curves and estimate rebuilding costs associated with flooding inflicted on commercial property.

Commercial buildings were assigned a value class based on their use. Details on commercial building classification are presented in Table B1. It should be noted that large-classed building damages were estimated using area directly (i.e. the large-class building damage curves are in units of $/m2 vs. $). Raised floor levels were applied using the surveyed floor level from the Council's Terrestrial LiDAR dataset. Estimated damages were assumed to remain constant after a depth over floor of 4m, corresponding to the maximum damage value provided in the ANUFLOOD literature.

All damage values have been adjusted to March 2020 Dollars, which corresponds to the most recent Consumer Price Index (CPI) values available. No adjustment of Stage-Damage curves to represent actual / potential flood damages was undertaken.

Figure B13 shows the decision processes made as part of the multi-unit residential building classification prior to applying the relevant stage-damage curve. The 15 classifications as shown in the flow chart have individual stage-damage curves that have been graphed in Figure B14 through Figure B16. The historical ANUFLOOD curves (CPI adjusted to March 2020 dollars) have also been graphed for comparison.

Indirect damages for commercial buildings were assumed to be 55% of the direct damages. This number is significantly higher than the indirect damage value for residential buildings due to the assumed loss of business revenue, according to the ANUFLOOD literature. It should be noted that this applies to all buildings classified as commercial, which includes community assets such as park facilities, schools, etc. which may not actually recognize business–related revenue.

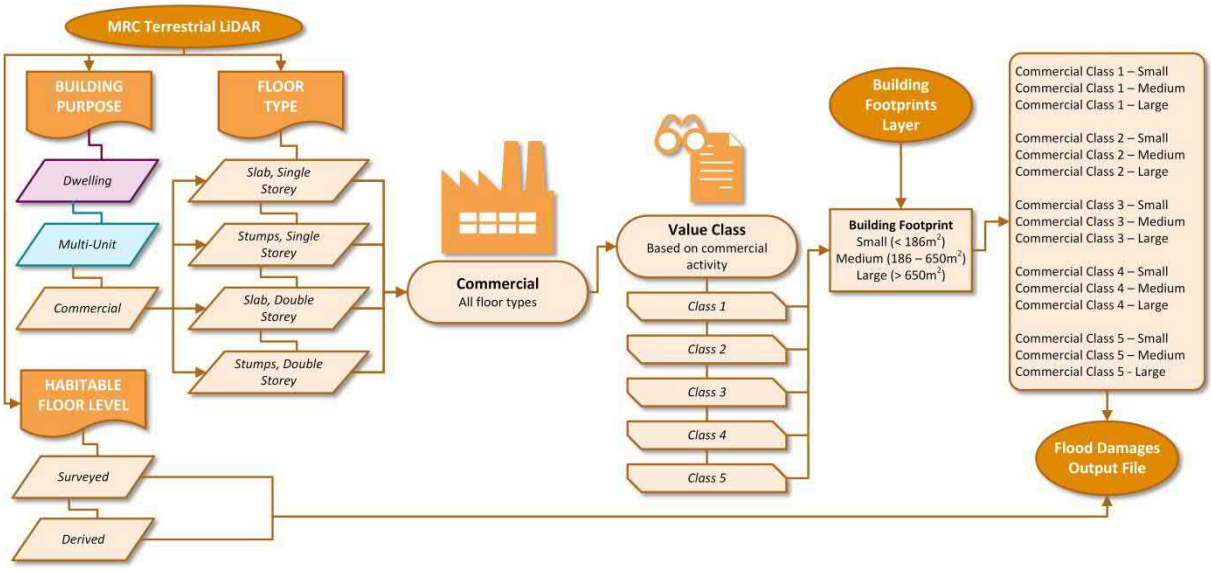


Figure B13 Commercial Building Classification Flowchart

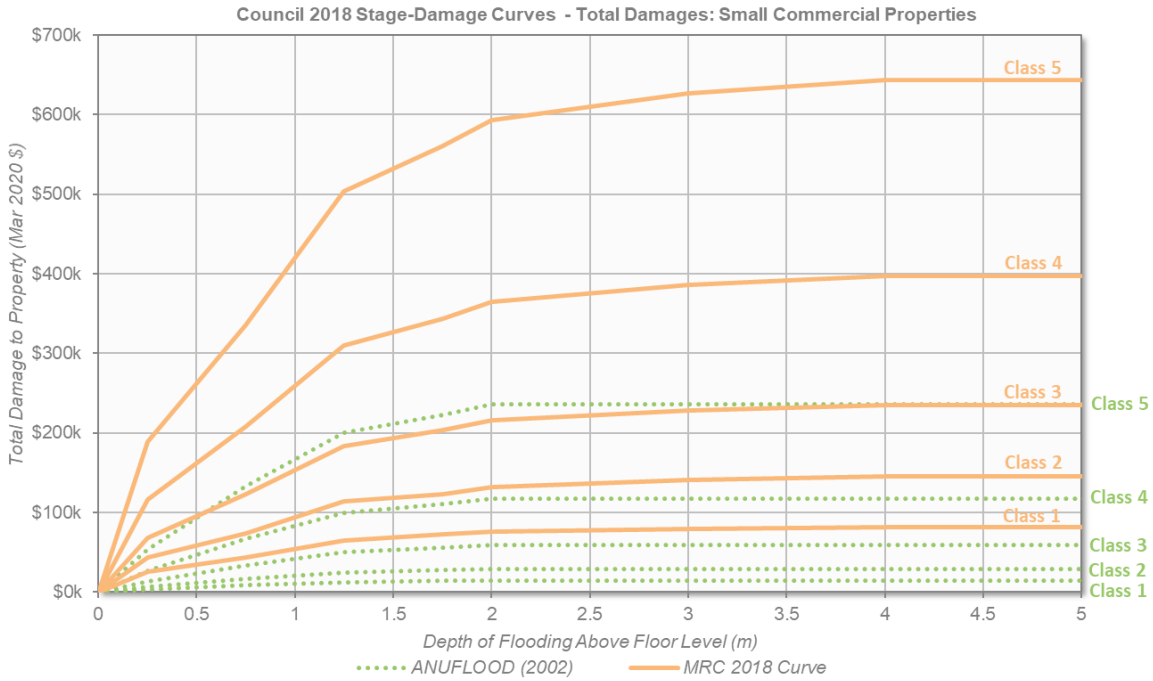


Figure B14 Total Stage-Damage Curve: Small Commercial

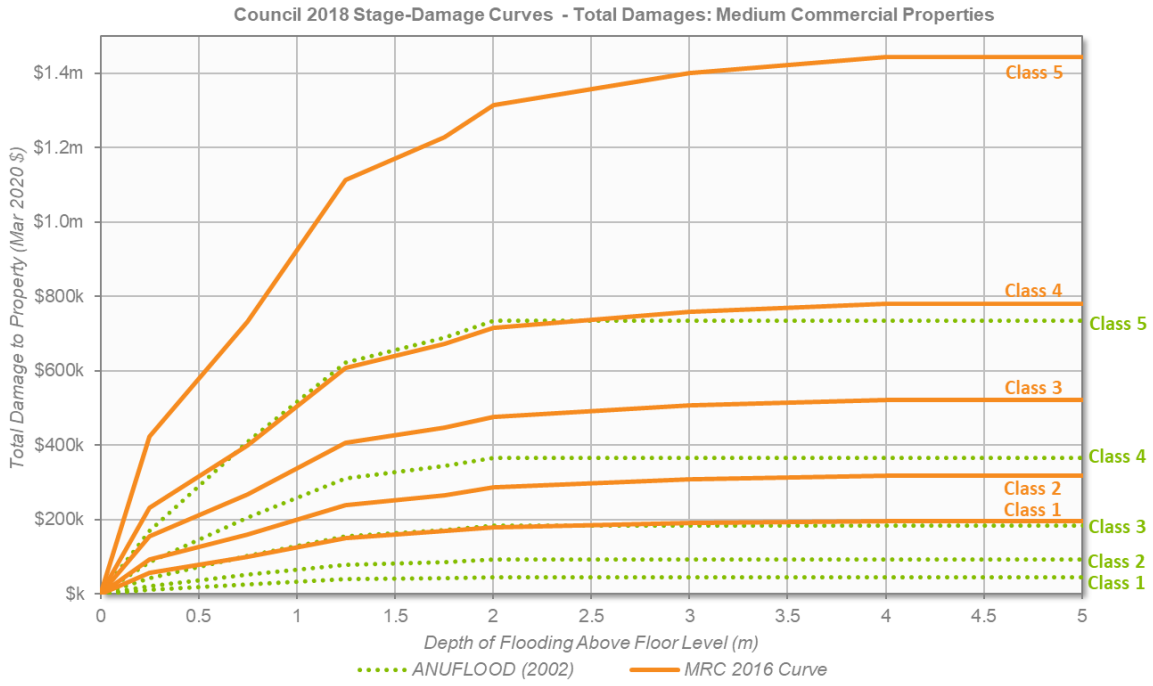


Figure B15 Total Stage-Damage Curve: Medium Commercial

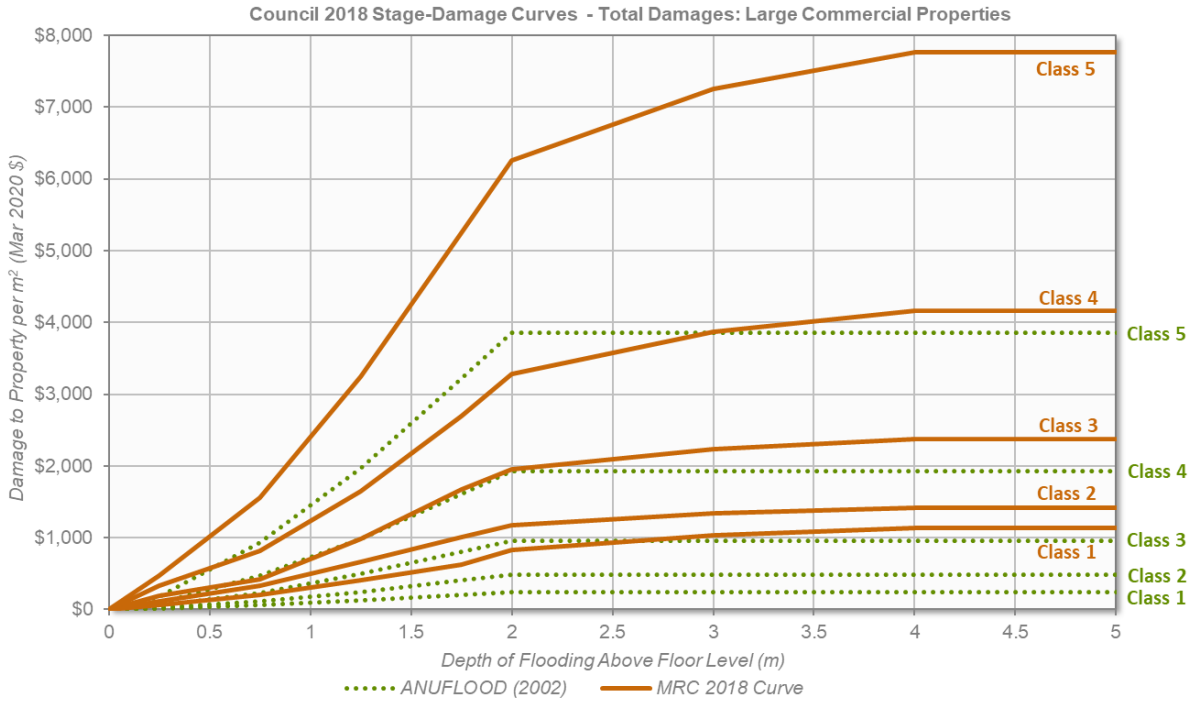


Figure B16 Total Stage-Damage Curve: Large Commercial

9.0 Infrastructure Damages

Costs associated with damage to infrastructure such as roads, water and wastewater facilities, and utilities have been estimated as 15% of the total direct residential and commercial flood damages. This is consistent with the recommendations of the Office of Environment and Heritage (OEH).

10.0 Average Annual Damages (AAD)

While the methodology above and in Appendix B provides an estimate of potential damages during specific flood events, understanding what damages may be expected on an annual basis is often an easier way to relate risk to residents and businesses.

As such, the above damages were converted to Average Annual Damages (AAD) based on the likelihood of the flood event and the total estimated damage during that event. The AAD is determined by taking the estimated damage for each AEP event and multiplying it by the likelihood of the event. The process is repeated and AAD values are summed for the total AAD.

For instance, the AAD for a 10% AEP event is based on the estimated $8.02M damages and 10% or 0.01 likelihood, corresponding to an AAD of $802,000. As a result, low-likelihood events such as the PMF have minor influence due to their low probability of occurrence.

AAD is a measure of the average tangible flood damages experienced each year and is calculated as the area under the Probability Damages Curve. Therefore, accurate estimates of AAD require consideration of flood events ranging from the smallest flood that causes damage, up to the PMF.

For this study, flood events ranging from the 39% AEP (2 year ARI) event up to the PMF have been considered.

Appendix C

XP-RAFTS Model Configuration

Appendix C XP-RAFTS Model Configuration

Table C1 XP-RAFTS Node Parameters

RAFTS ID	Total Area (ha)	Catchment Manning's 'n' (n value)	Percentage Impervious (%)	Catchment Slope (%)
1	0.90	0.037	0.00	1.80
2	20.62	0.057	3.85	1.00
3	20.60	0.044	0.68	1.19
4	26.09	0.039	31.67	1.40
5	20.20	0.037	26.39	1.00
6	21.11	0.039	14.58	1.73
7	20.04	0.036	44.33	1.00
8	24.45	0.040	32.56	1.60
9	22.59	0.049	0.99	1.97
10	20.03	0.042	28.21	2.28
11	20.03	0.046	17.39	1.00
12	20.70	0.040	5.84	1.26
13	20.01	0.039	11.07	1.00
14	26.98	0.041	34.11	1.51
15	23.14	0.037	33.44	1.09
16	20.04	0.041	38.87	1.06
17	28.31	0.043	36.26	1.28
18	30.82	0.042	31.62	1.00
19	20.03	0.039	37.65	1.00
20	22.79	0.037	42.21	1.13
21	20.03	0.041	26.69	1.00
22	20.10	0.058	1.85	1.09
23	16.62	0.043	20.52	1.00
24	27.75	0.057	8.90	1.00
25	21.65	0.038	13.27	1.00
26	28.17	0.043	7.25	1.00
27	27.61	0.059	8.28	1.00
28	20.21	0.063	2.63	1.00
29	20.10	0.037	20.64	1.00
30	20.04	0.070	0.32	1.00
31	36.77	0.063	1.79	1.00
32	20.15	0.041	30.55	1.00
33	29.24	0.061	12.52	1.00
34	23.92	0.043	29.41	1.00
35	20.10	0.053	4.08	1.83

RAFTS ID	Total Area (ha)	Catchment Manning's 'n' (n value)	Percentage Impervious (%)	Catchment Slope (%)
36	20.26	0.069	1.20	1.18
37	21.16	0.039	36.42	1.00
38	21.98	0.042	36.77	1.00
39	22.28	0.070	0.00	1.08
40	26.80	0.066	2.24	1.25
41	30.50	0.068	7.60	1.00
42	19.53	0.045	3.87	1.00
43	22.71	0.051	1.86	2.79
44	20.05	0.076	0.00	1.00
45	17.92	0.048	6.54	1.00
46	20.01	0.041	37.46	1.00
47	20.26	0.065	2.59	1.38
48	20.01	0.040	1.63	1.00
49	20.17	0.064	0.06	1.71
50	24.44	0.077	0.18	1.10
51	31.07	0.041	31.19	1.00
52	24.23	0.040	23.09	1.00
53	21.04	0.040	9.80	1.00
54	26.31	0.042	0.56	1.00
55	20.04	0.074	0.00	1.64
56	20.25	0.040	41.47	1.58
57	20.08	0.045	4.34	1.05
58	21.33	0.045	1.68	1.00
59	20.12	0.075	0.16	2.18
60	26.06	0.040	33.94	1.00
61	28.15	0.043	15.73	1.00
62	28.44	0.054	2.21	1.83
63	12.16	0.048	6.21	1.00
64	20.71	0.049	0.25	1.00
65	21.25	0.042	4.43	1.00
66	24.83	0.068	1.73	1.97
67	20.86	0.040	38.82	1.00
68	23.46	0.041	32.73	1.00
69	20.08	0.044	0.32	1.00
70	31.03	0.038	26.79	1.00
71	25.39	0.047	24.12	1.00
72	20.64	0.075	1.67	1.85
73	20.10	0.046	1.82	1.00

RAFTS ID	Total Area (ha)	Catchment Manning's 'n' (n value)	Percentage Impervious (%)	Catchment Slope (%)
74	25.77	0.052	17.01	1.44
75	29.51	0.053	0.00	1.00
76	20.26	0.041	2.81	1.00
77	21.71	0.045	3.18	1.00
78	20.19	0.051	0.00	1.07
79	8.95	0.042	15.58	1.00
80	11.78	0.040	0.00	1.00
81	24.29	0.041	23.87	1.00
82	20.53	0.064	3.21	2.60
83	23.01	0.040	34.20	2.22
84	20.06	0.039	30.08	1.00
85	20.71	0.049	0.12	1.00
86	31.42	0.039	3.75	1.00
87	26.59	0.048	1.81	1.00
88	26.31	0.041	8.98	1.00
89	20.58	0.052	0.00	1.00
90	27.00	0.040	4.74	1.84
91	22.59	0.052	4.08	2.63
92	20.04	0.042	1.31	1.53
93	20.08	0.039	33.22	1.00
94	23.12	0.053	6.95	1.00
95	20.48	0.062	2.78	3.92
96	29.20	0.066	0.28	2.10
97	35.13	0.065	2.75	1.87
98	24.23	0.042	6.52	1.24
99	21.16	0.057	0.00	1.00
100	26.22	0.048	0.05	1.15
101	22.94	0.051	0.64	1.00
102	20.22	0.040	0.57	1.00
103	20.02	0.047	1.31	1.00
104	6.56	0.047	2.83	1.51
105	36.31	0.043	0.05	1.00
106	20.39	0.045	0.00	1.00
107	20.42	0.049	0.00	1.00
108	20.33	0.046	3.12	1.00
109	20.30	0.038	4.22	1.24
110	20.28	0.046	0.00	1.00
111	23.49	0.055	0.38	1.12

RAFTS ID	Total Area (ha)	Catchment Manning's 'n' (n value)	Percentage Impervious (%)	Catchment Slope (%)
112	12.43	0.050	5.87	1.00
113	20.61	0.037	0.28	1.00
114	20.35	0.054	1.60	2.61
115	29.40	0.053	0.28	1.00
116	20.17	0.044	4.44	2.44
117	20.44	0.053	2.07	2.63
118	21.61	0.040	10.63	2.55
119	20.02	0.046	0.00	1.00
120	30.00	0.048	11.61	1.40
121	20.03	0.056	0.16	6.65
122	20.90	0.045	0.28	1.00
123	20.06	0.047	7.88	3.45
124	20.21	0.041	9.21	1.99
125	23.10	0.051	5.18	1.00
126	20.01	0.041	0.03	1.00
127	23.18	0.051	1.55	1.00
128	20.01	0.043	17.52	1.80
129	20.34	0.047	0.91	1.27
130	20.61	0.051	0.56	1.30
131	21.59	0.043	26.92	1.55
132	21.54	0.052	1.99	1.10
133	35.54	0.047	10.41	1.00
134	20.31	0.056	0.00	1.00
135	20.73	0.053	0.00	1.00
136	20.49	0.045	1.37	4.03
137	20.03	0.050	0.13	1.00
138	21.94	0.049	0.00	1.00
139	24.40	0.052	0.97	1.01
140	20.62	0.041	11.17	1.19
141	21.84	0.044	1.58	3.11
142	23.72	0.054	0.13	1.00
143	20.29	0.039	39.48	2.50
144	23.25	0.047	0.99	1.00
145	21.36	0.040	2.58	1.00
146	20.50	0.042	22.01	1.00
147	20.02	0.041	36.51	1.00
148	20.52	0.040	0.00	1.00
149	22.69	0.044	15.85	4.29

RAFTS ID	Total Area (ha)	Catchment Manning's 'n' (n value)	Percentage Impervious (%)	Catchment Slope (%)
150	26.09	0.042	0.10	1.00
151	22.39	0.038	22.21	1.03
152	20.03	0.056	0.77	1.00
153	26.52	0.042	15.25	1.00
154	20.02	0.038	24.52	1.00
155	22.84	0.041	34.92	3.01
156	21.52	0.041	5.59	1.54
157	11.28	0.043	25.94	1.00
158	17.73	0.042	30.00	1.00
159	17.11	0.044	25.54	1.00
160	11.55	0.044	23.77	1.00
161	7.97	0.041	31.94	1.20
162	15.58	0.050	20.30	1.00
163	9.77	0.051	12.65	1.00
164	8.37	0.041	33.64	1.00
165	14.49	0.038	41.92	1.13
166	14.98	0.045	7.77	1.01
167	18.20	0.040	8.76	1.00
168	6.91	0.040	15.94	1.00
169	17.70	0.066	0.87	1.00
170	11.10	0.036	19.61	1.00

Appendix D

ARR Data Hub Parameters

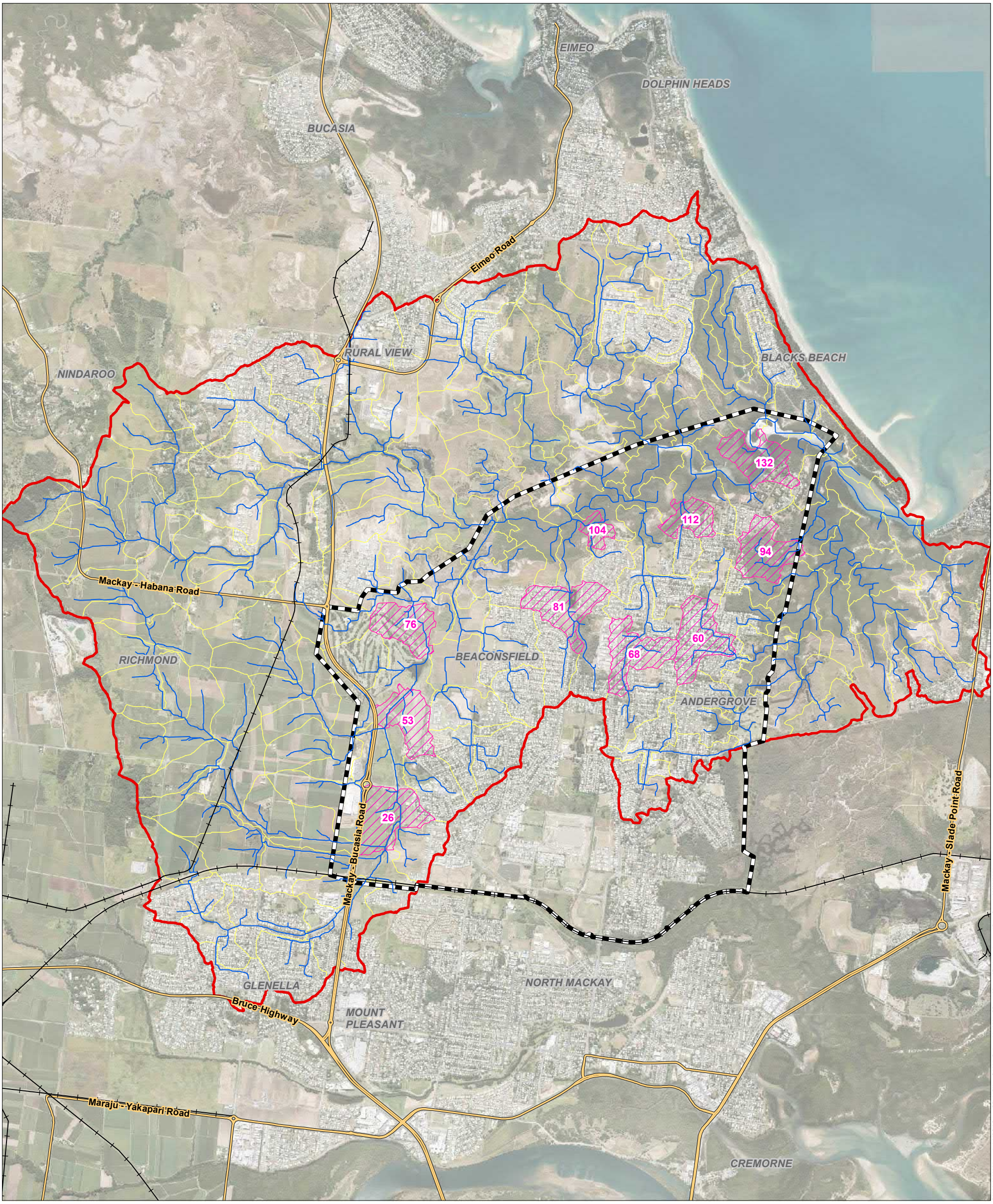
Appendix D ARR Data Hub Parameters

Table 25 ARR Data Hub Parameters

Parameter	Value
Latitude	-21.0822
Longitude	149.1697
Storm Initial Losses (mm)	67
Storm Continuing Losses (mm/h)	4.8
River Region - Division	North East Coast
River Region - Number	24
River Region	O'Connell River
Point Temporal Pattern Code	WT
Point Temporal Pattern Label	Wet Tropics
Areal Temporal Pattern Code	WT
Areal Temporal Pattern Label	Wet Tropics
Time Accessed	01 June 2020 02:21PM
Version	2016_v1
Storm Loss ID	27972

Appendix E

XP-RAFTS Critical Duration Box Plots



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Legend

- Streamlines
- Hydrologic Model Extent
- Subject Subcatchments
- Hydrologic Model Subcatchments
- TUFLOW Model Extent
- Railway
- State Controlled Road Network

AECOM

N

0 0.55 1.1 km

Source: © The State of Queensland, 2017. Includes material © Planet Labs Netherlands B.V. 2017, reproduced under licence from Planet and Geoplex, all rights reserved. Landsat data available from the U.S. Geological Survey. Data acquired under the Spatial Imagery Subscription Plan (SISP) and QSat initiative.

MACKAY REGIONAL COUNCIL

Andergrove Beaconsfield Drainage Study

Critical Duration
Box Plot Extraction
Locations

E1

P:\60x\60530744 - 840 MRC ABGrove BField D'Age SI\500_Deliverables\501_Report\Figures\E1_box_plotsmxd Date Saved: 29/07/2020

Appendix E XP-RAFTS Critical Duration Box Plots

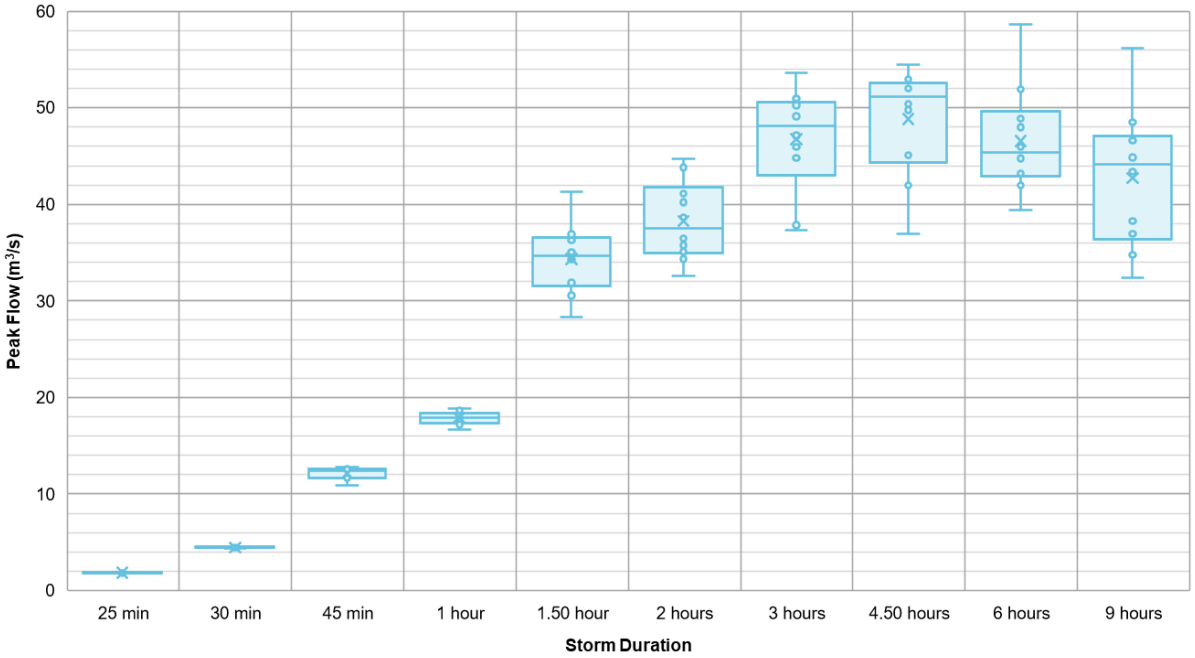


Figure E1 20% AEP Critical Duration Box Plot – Subcatchment 26

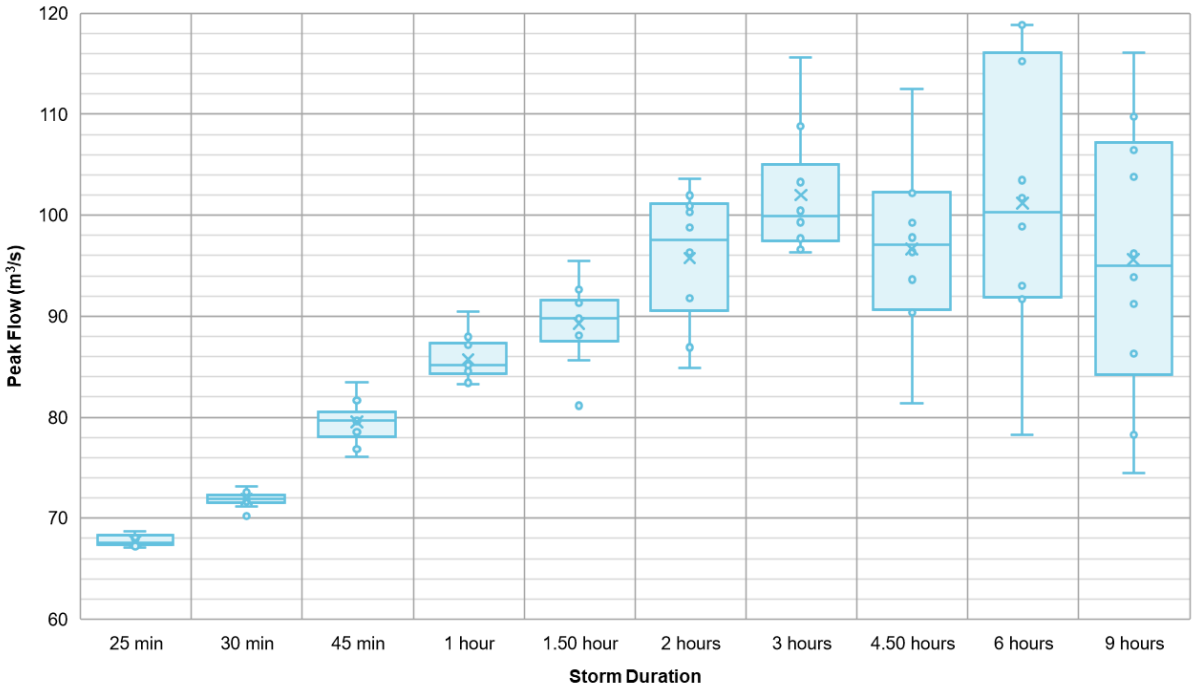


Figure E2 1% AEP Critical Duration Box Plot – Subcatchment 26

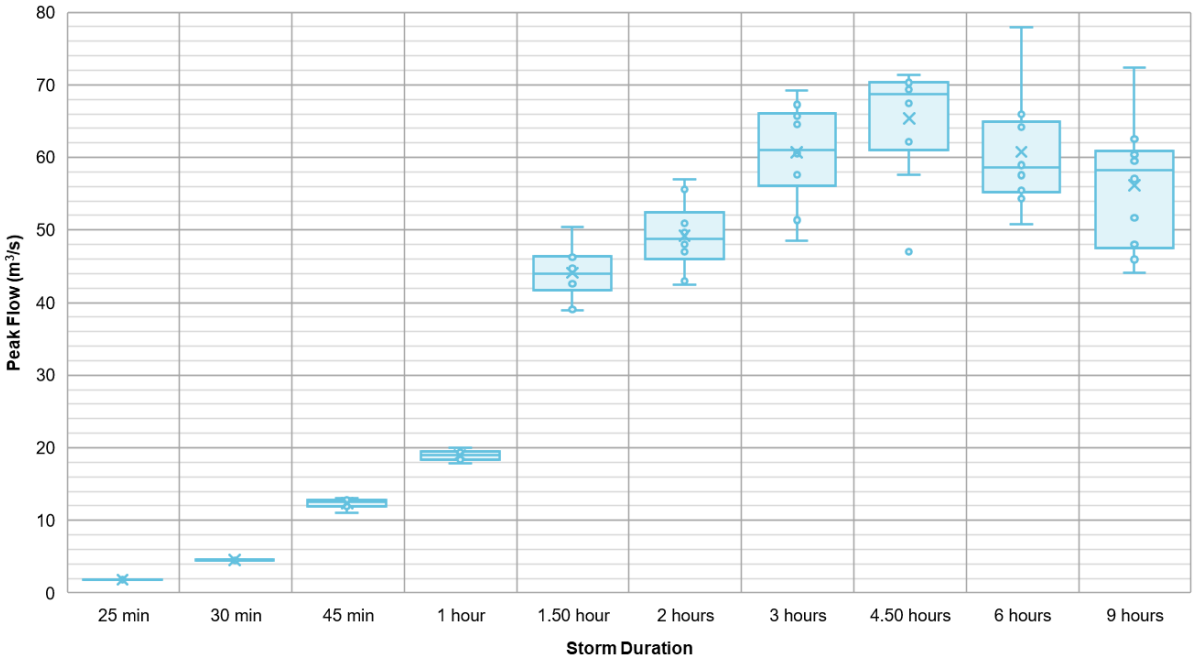
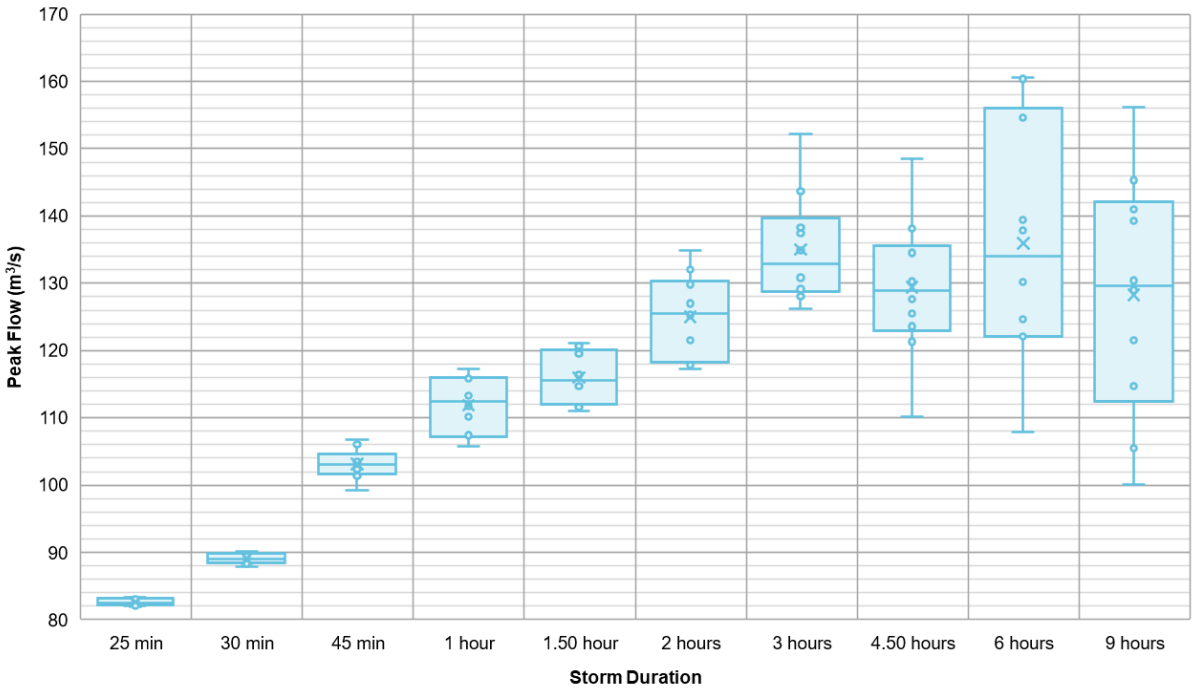


Figure E3 20% AEP Critical Duration Box Plot – Subcatchment 53



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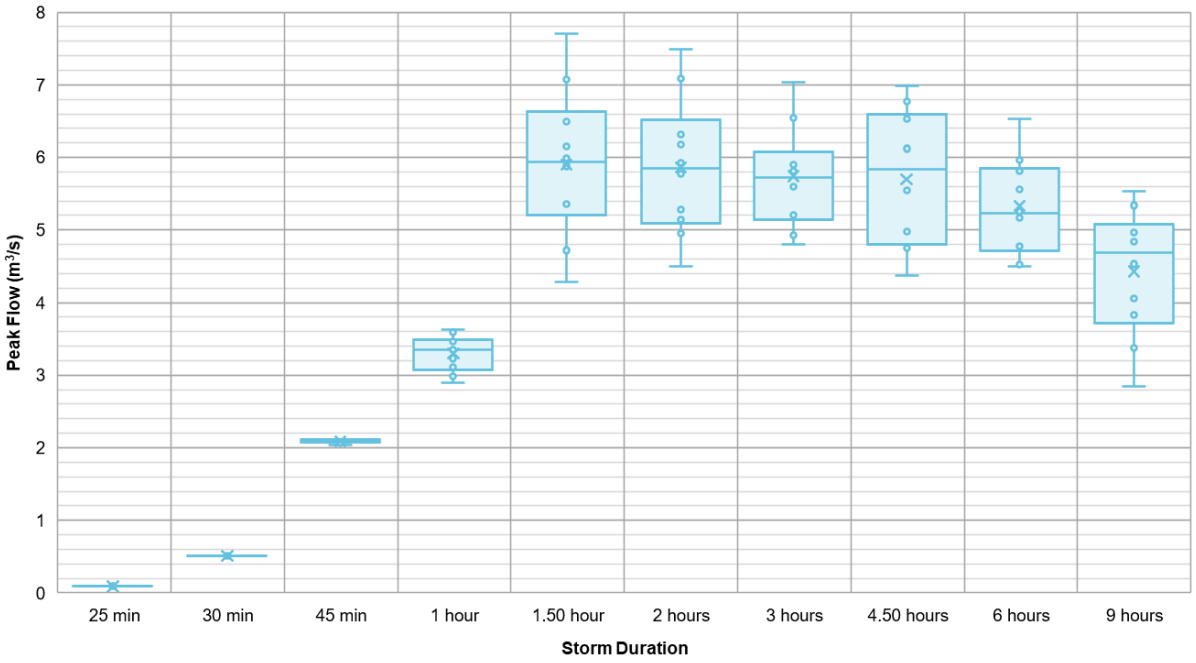
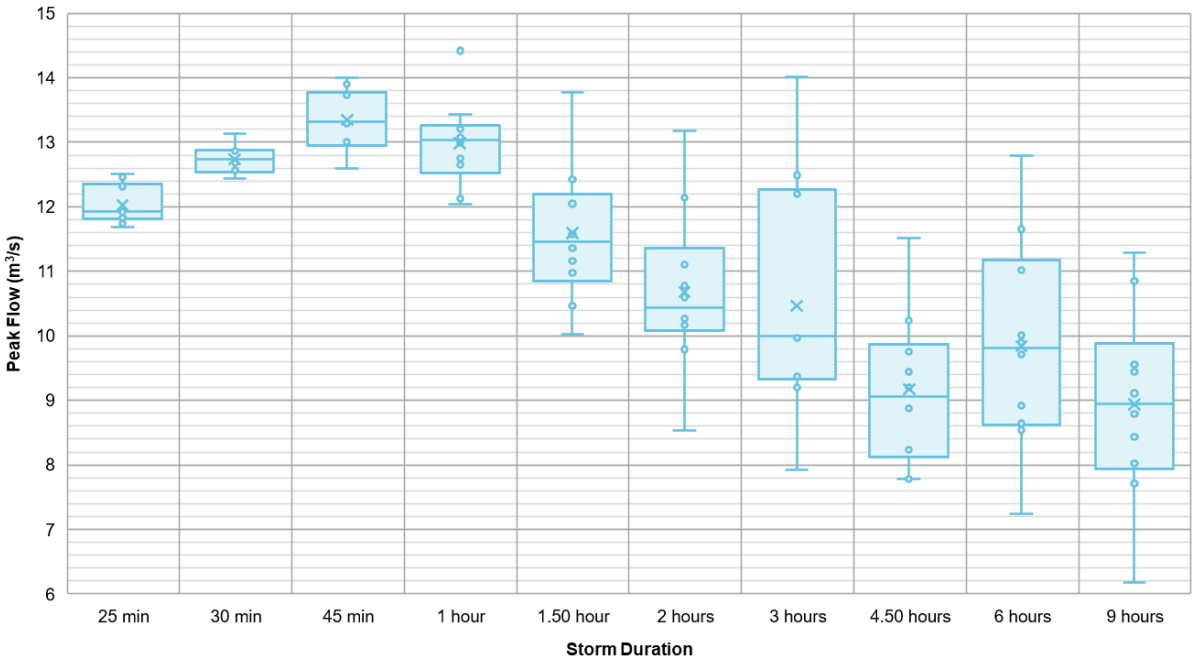


Figure E5 20% AEP Critical Duration Box Plot – Subcatchment 60



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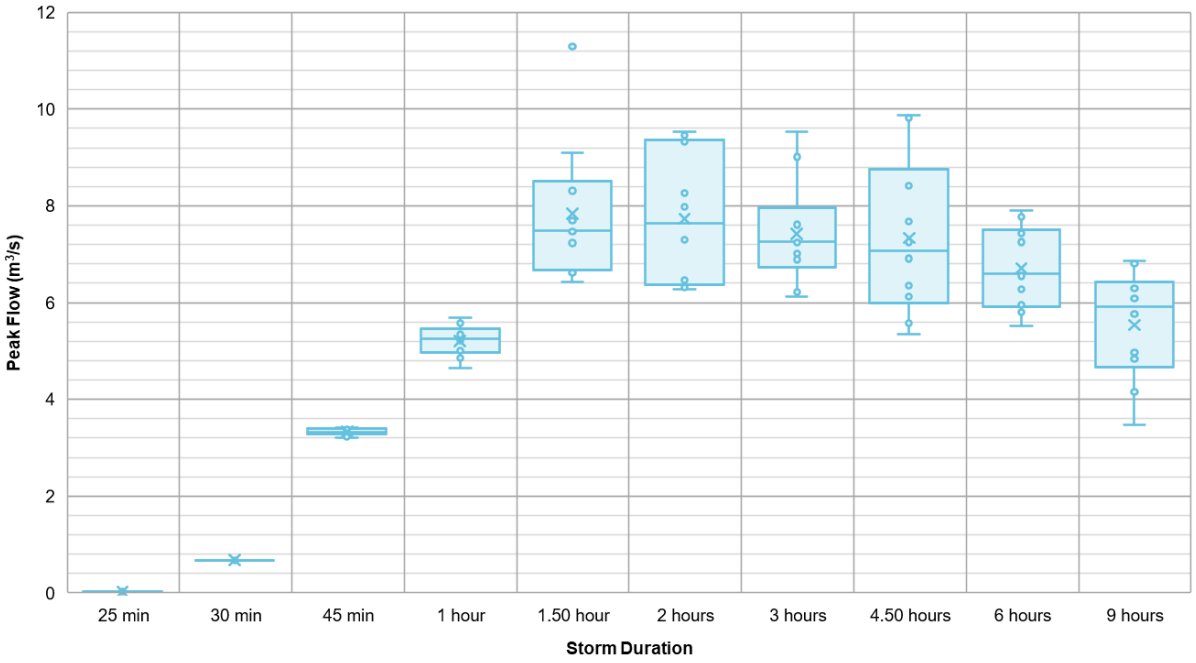
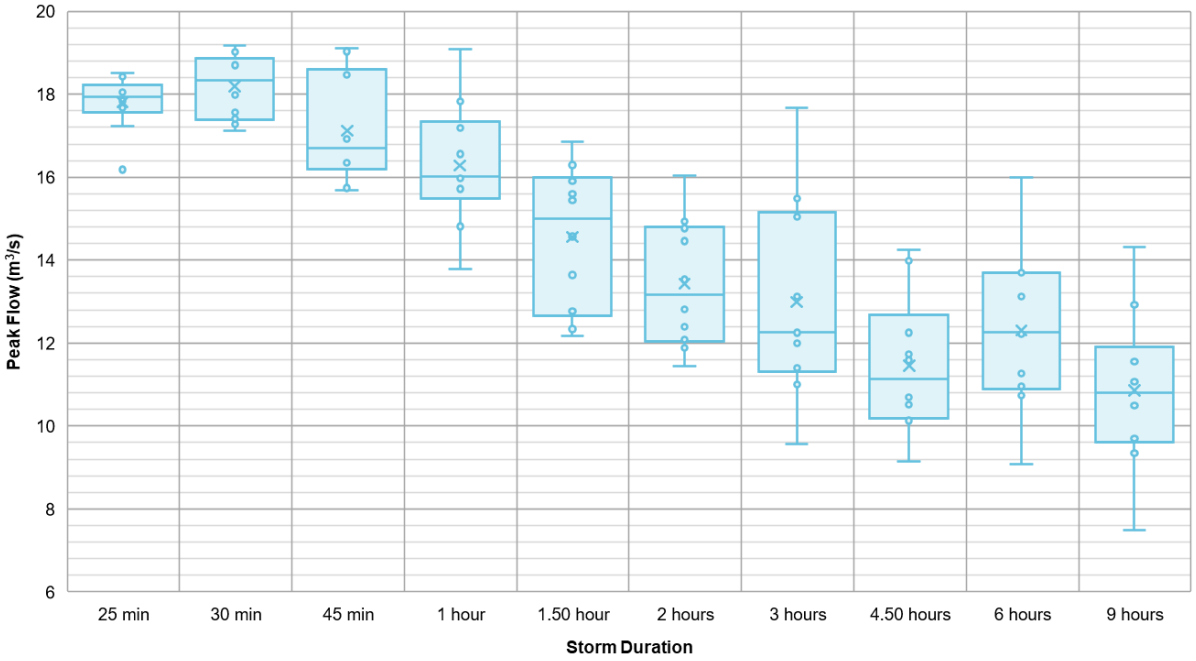


Figure E7 20% AEP Critical Duration Box Plot – Subcatchment 68



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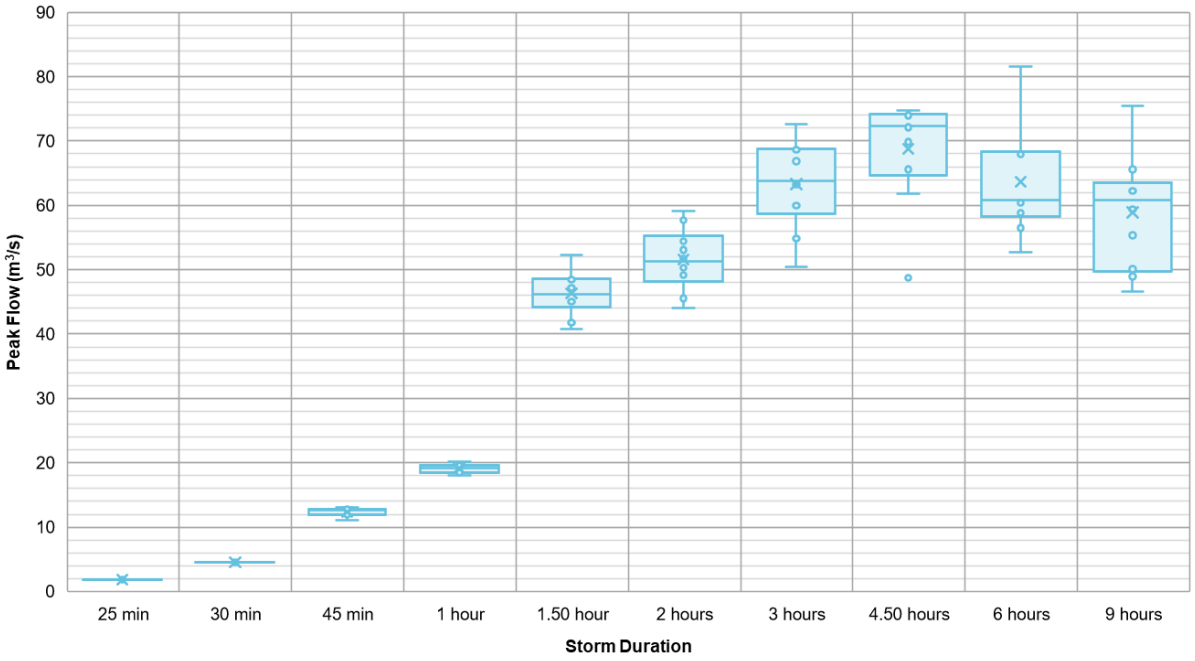

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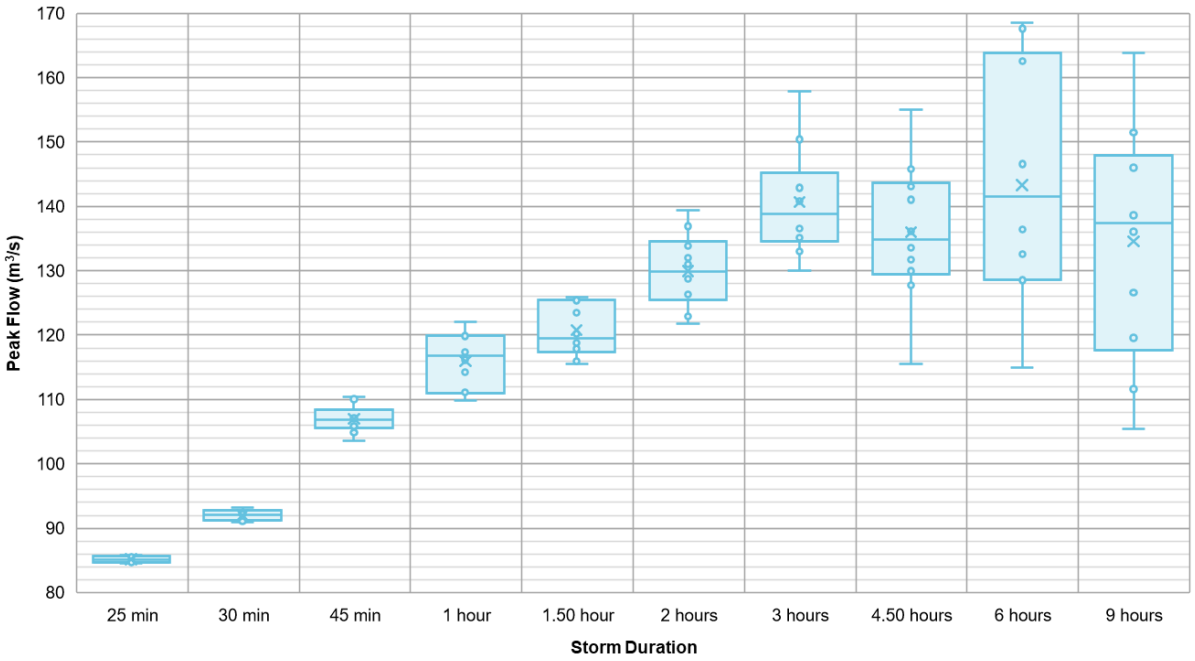

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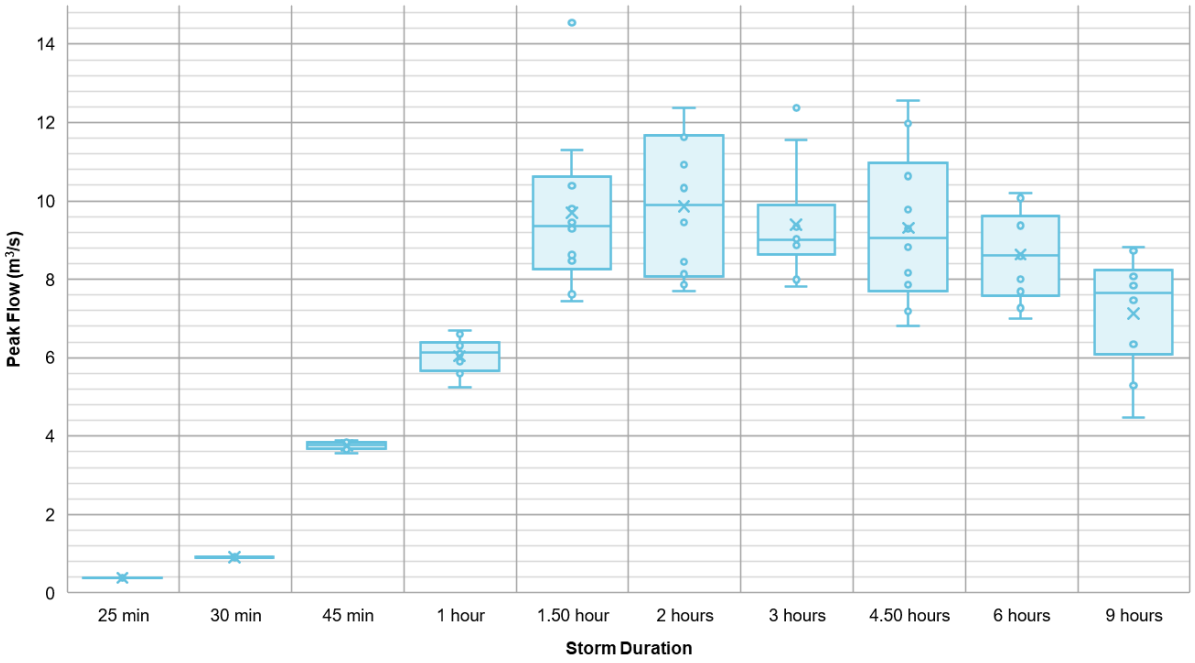

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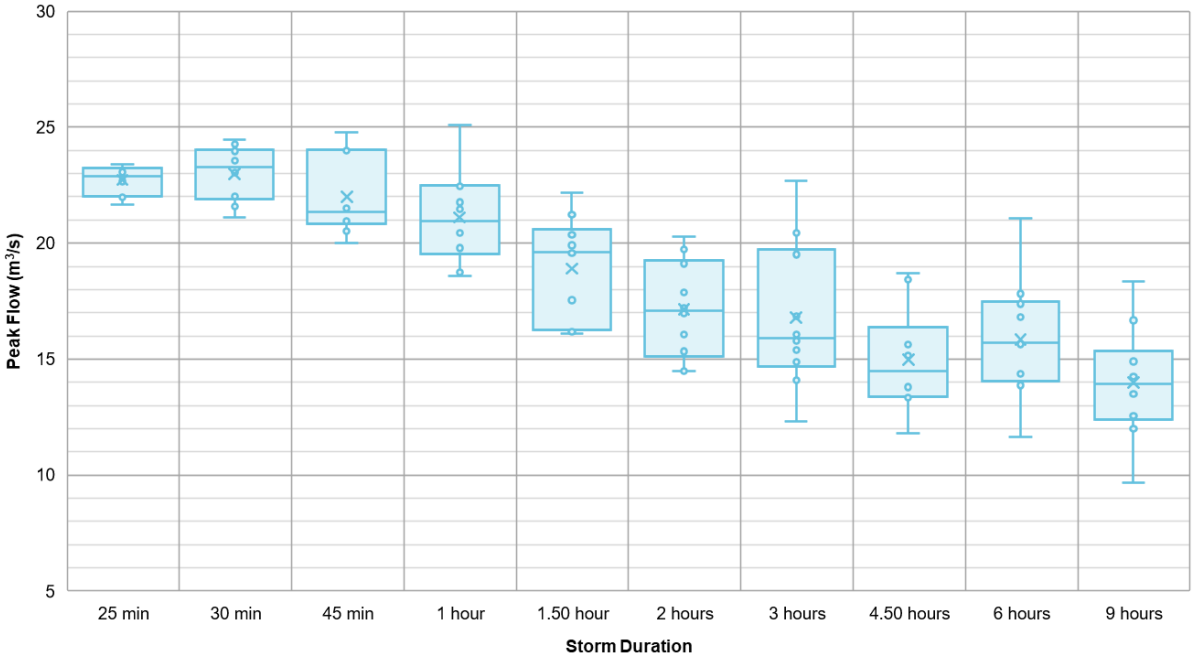

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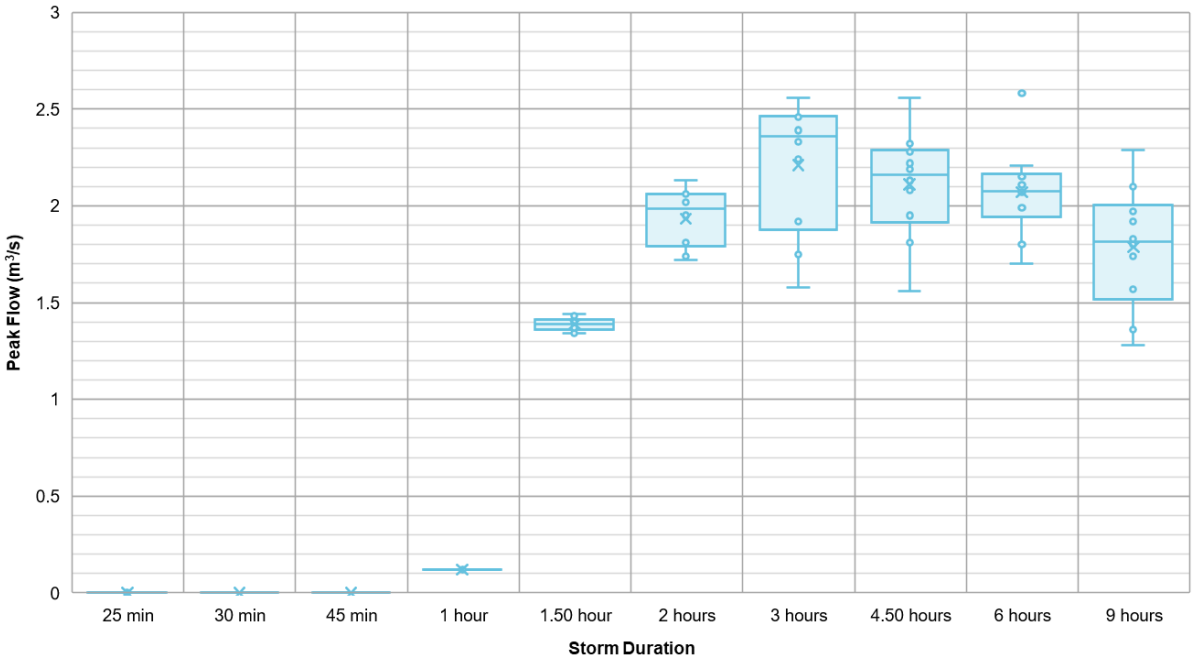

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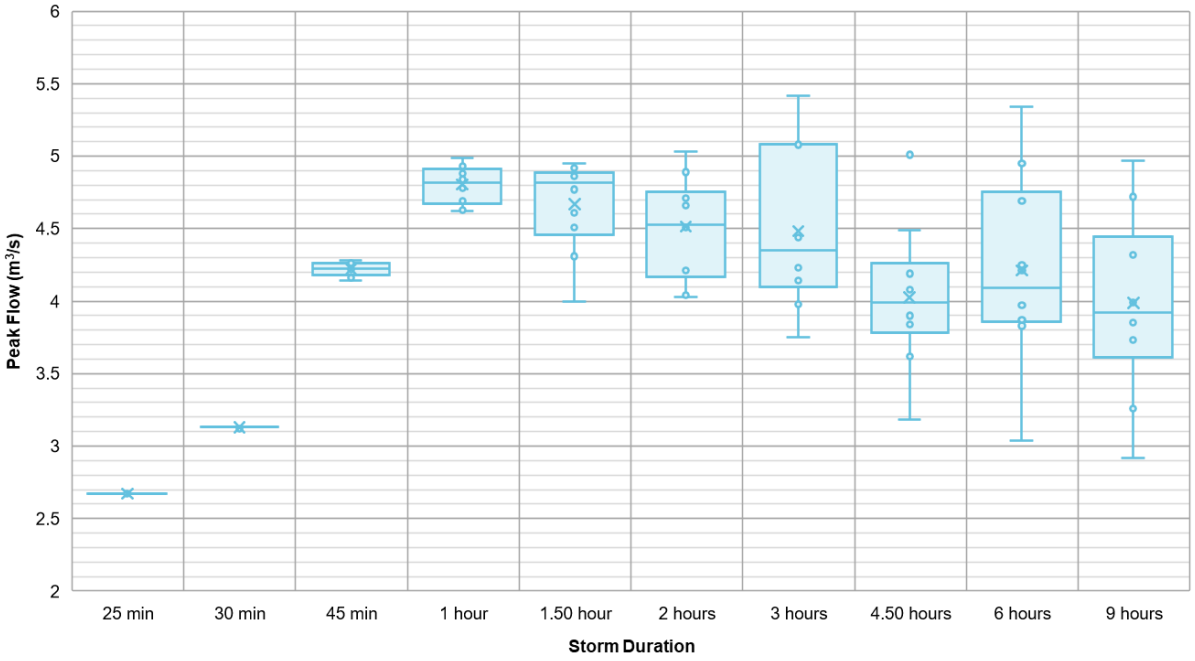

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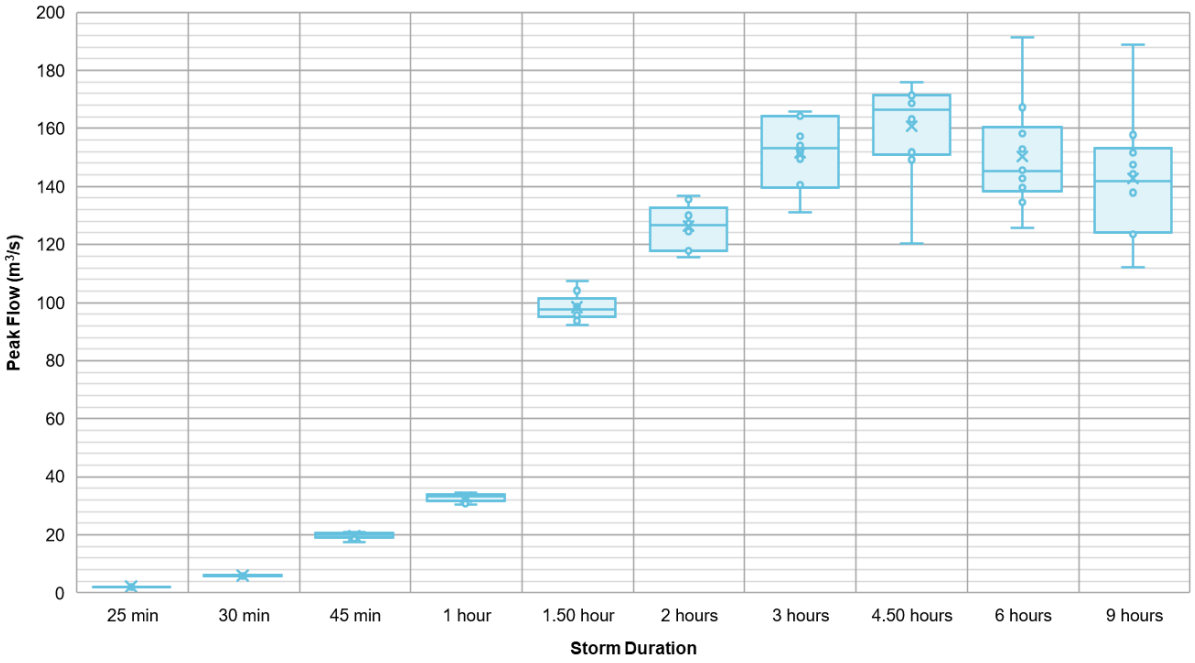

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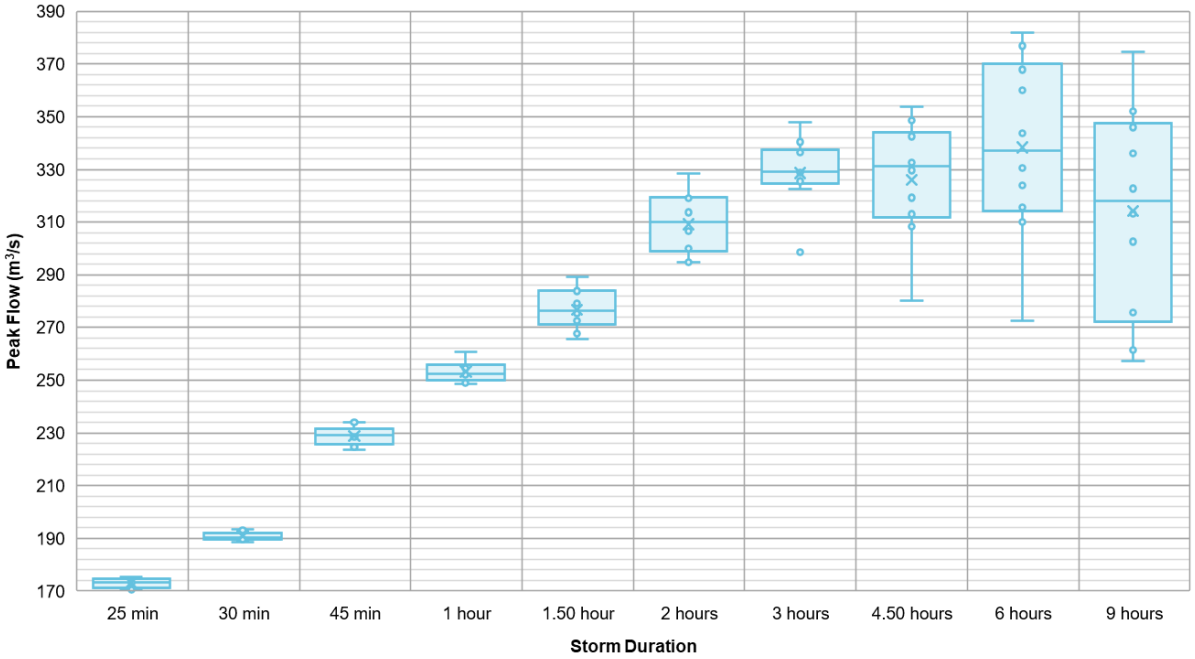

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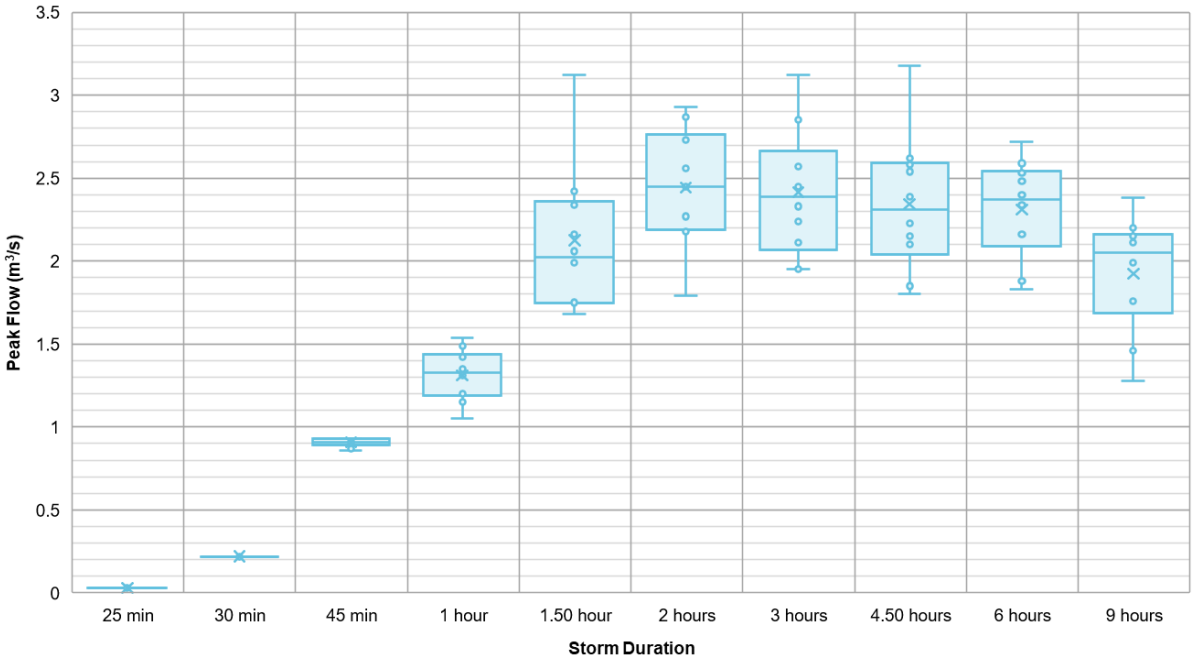

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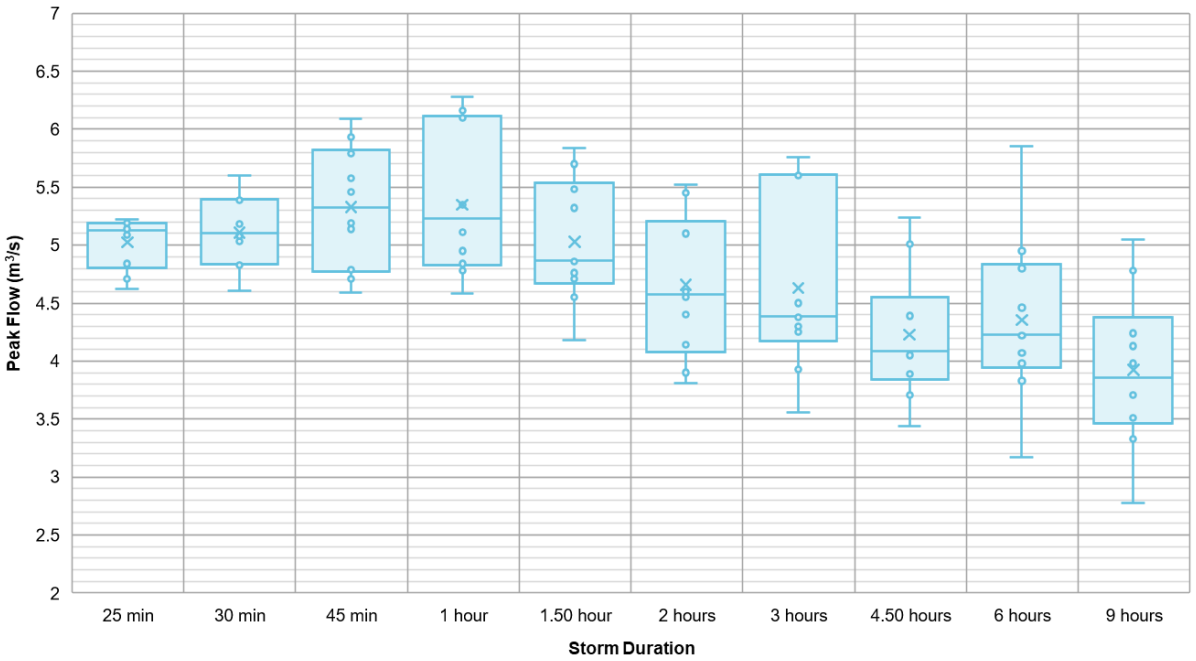

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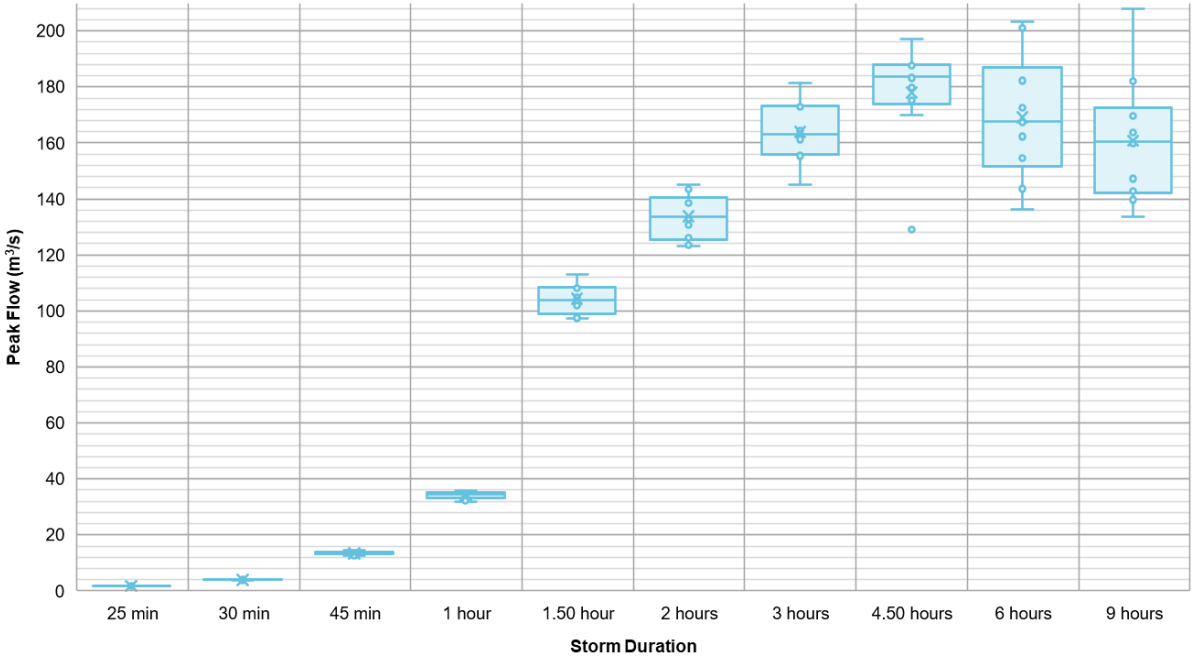


Figure E19 20% AEP Critical Duration Box Plot – Subcatchment 132

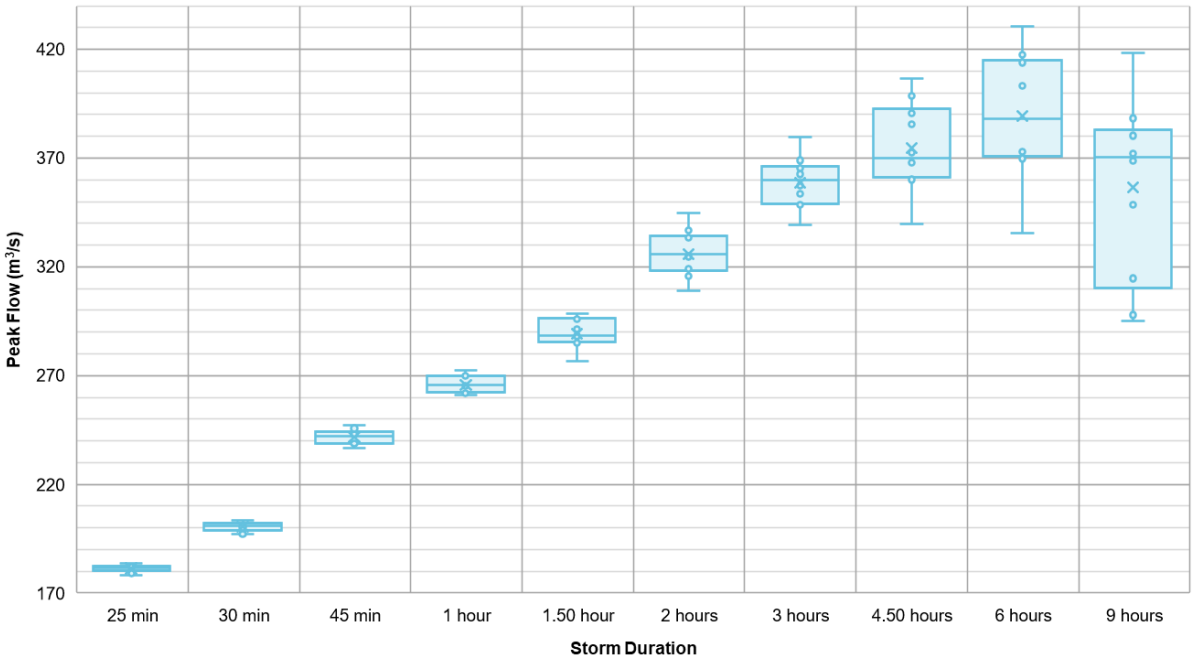
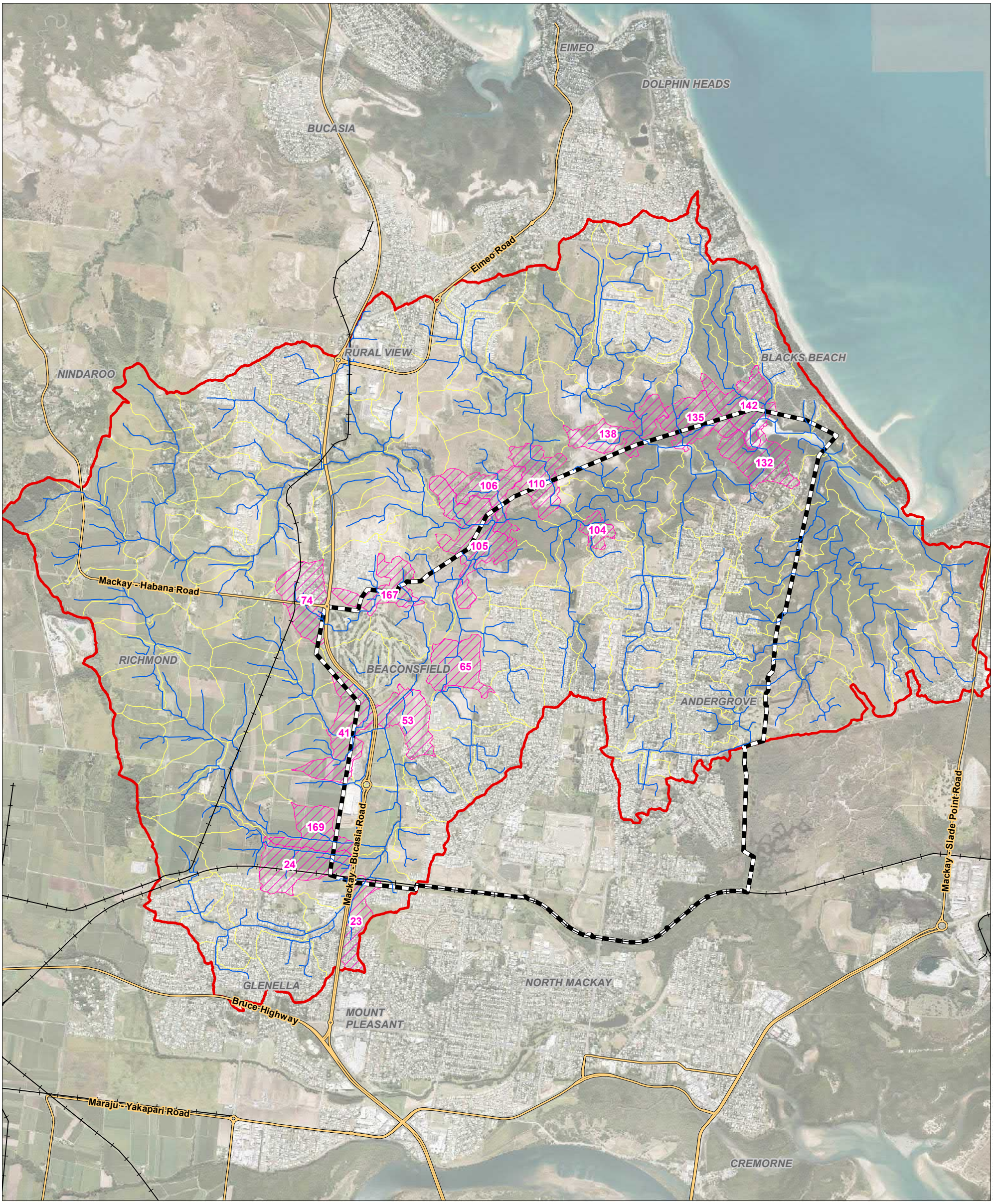


Figure E20 1% AEP Critical Duration Box Plot – Subcatchment 132

Appendix F

XP-RAFTS Ensemble Hydrographs



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Legend

- Streamlines
- Hydrologic Model Extent
- Subject Subcatchments
- Hydrologic Model Subcatchments
- TUFLOW Model Extent
- Railway
- State Controlled Road Network

AECOM

N

0 0.55 1.1 km

Source: © The State of Queensland, 2017. Includes material © Planet Labs Netherlands B.V. 2017, reproduced under licence from Planet and Geoplex, all rights reserved. Landsat data available from the U.S. Geological Survey. Data acquired under the Spatial Imagery Subscription Plan (SISP) and QSat initiative.

MACKAY REGIONAL COUNCIL

Andergrove Beaconsfield Drainage Study

Ensemble Temporal Pattern
Hydrograph Extraction
Locations

F1

P:\60\x\60530744 - 840 MRC AGrove BField D'Age 3\1500_Deliverables\501_DReport\Figures\F1_ensemble.mxd Date Saved: 28/07/2020

Appendix F XP-RAFTS Ensemble Hydrographs

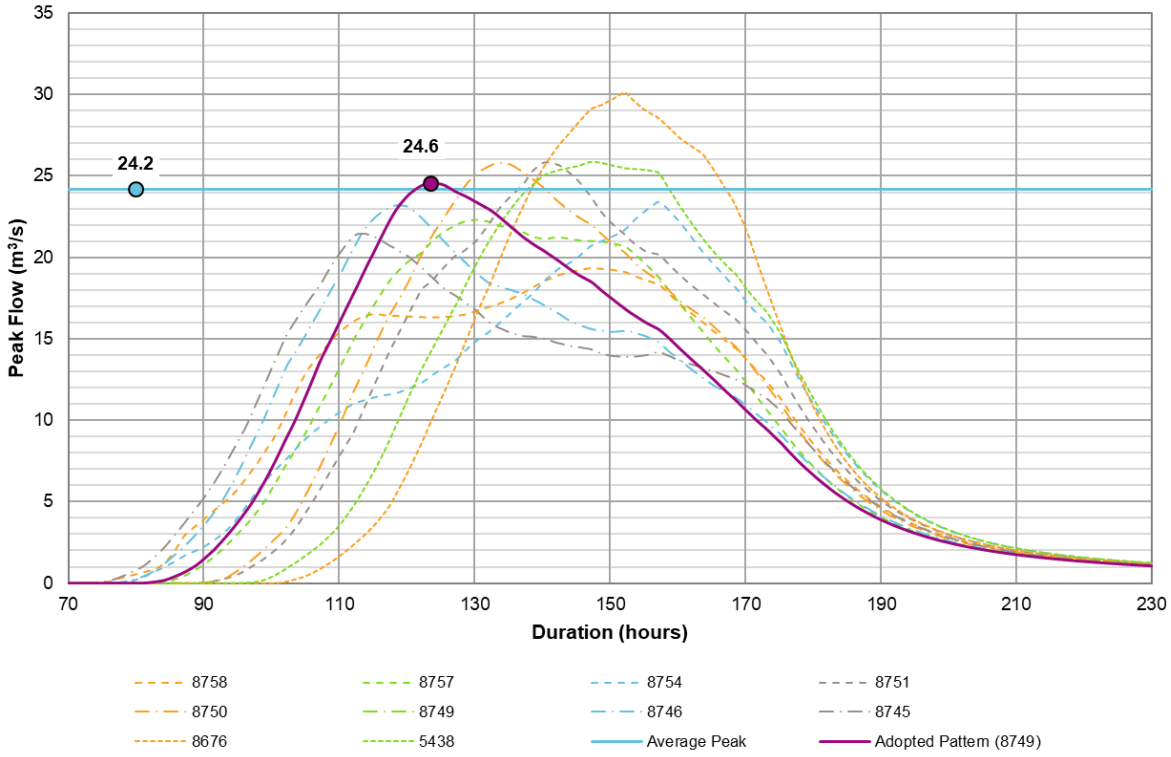
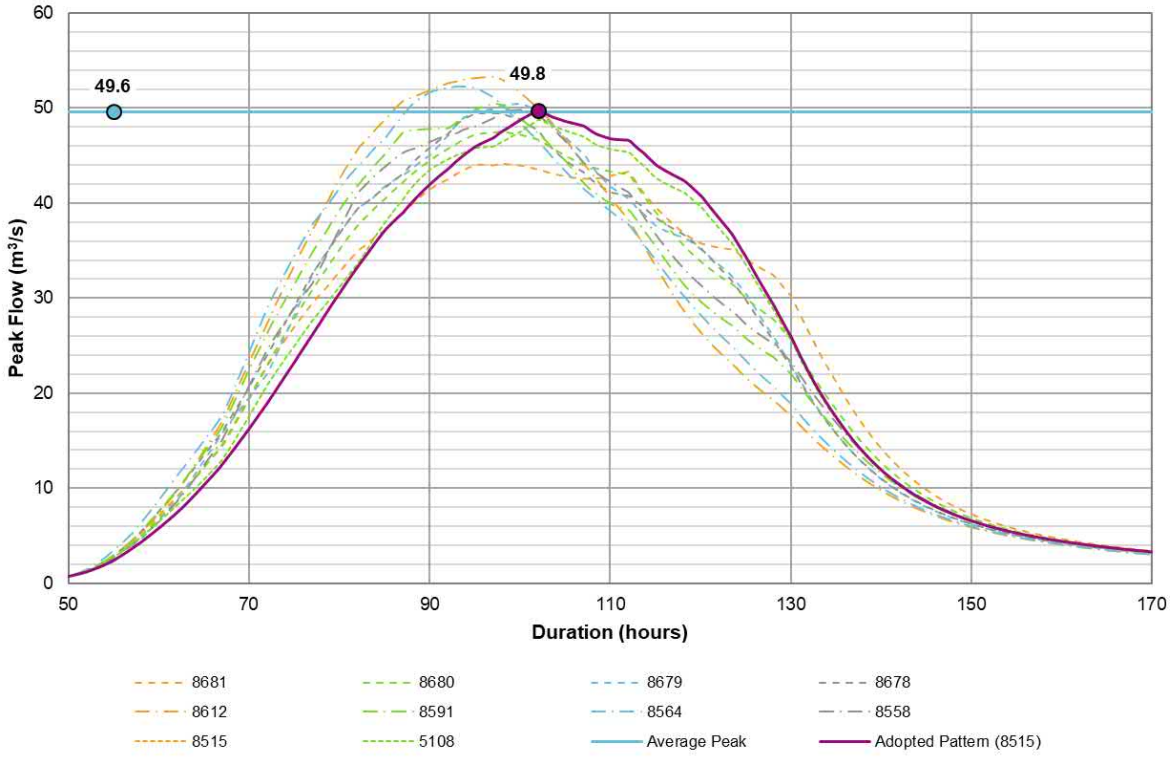


Figure F1 20% AEP Ensemble Hydrographs Plot – Subcatchment 23



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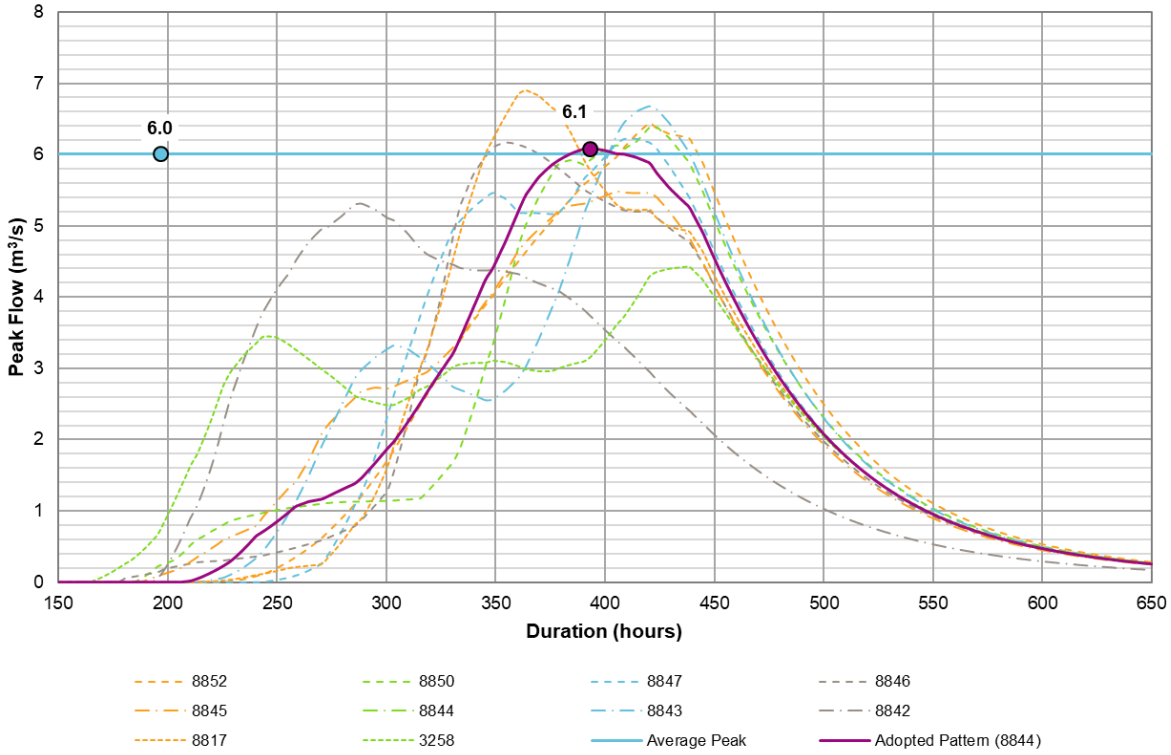
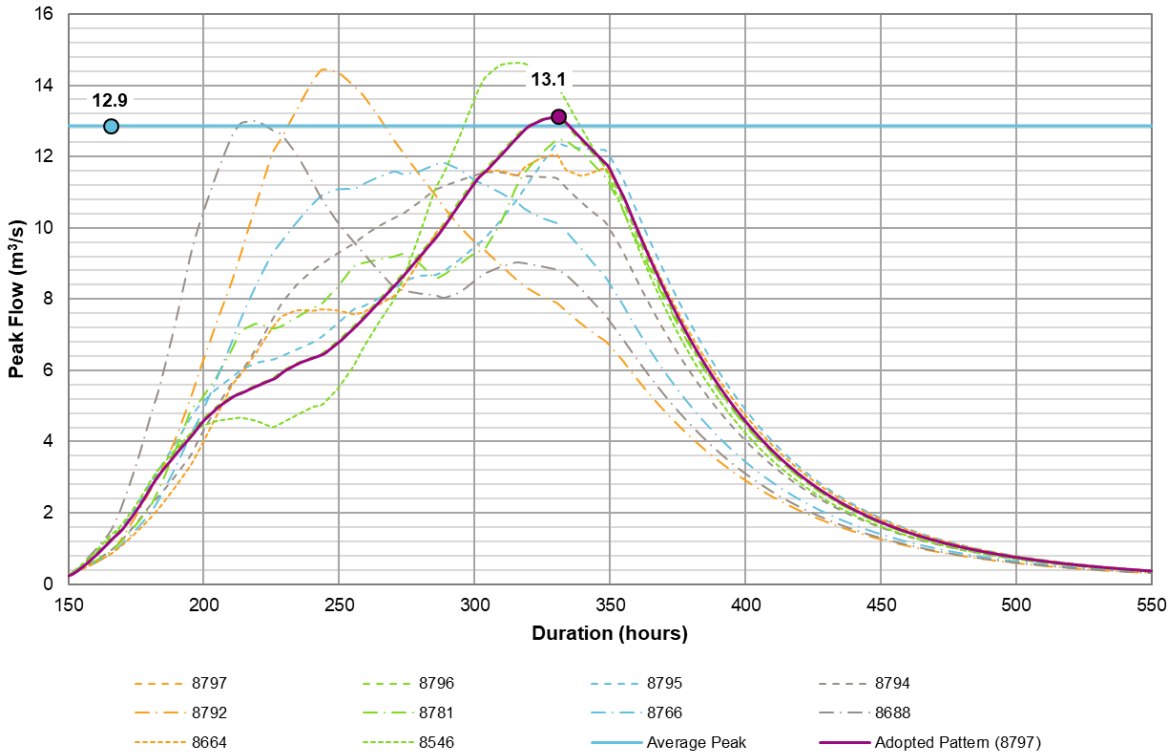


Figure F3 20% AEP Ensemble Hydrographs Plot – Subcatchment 24



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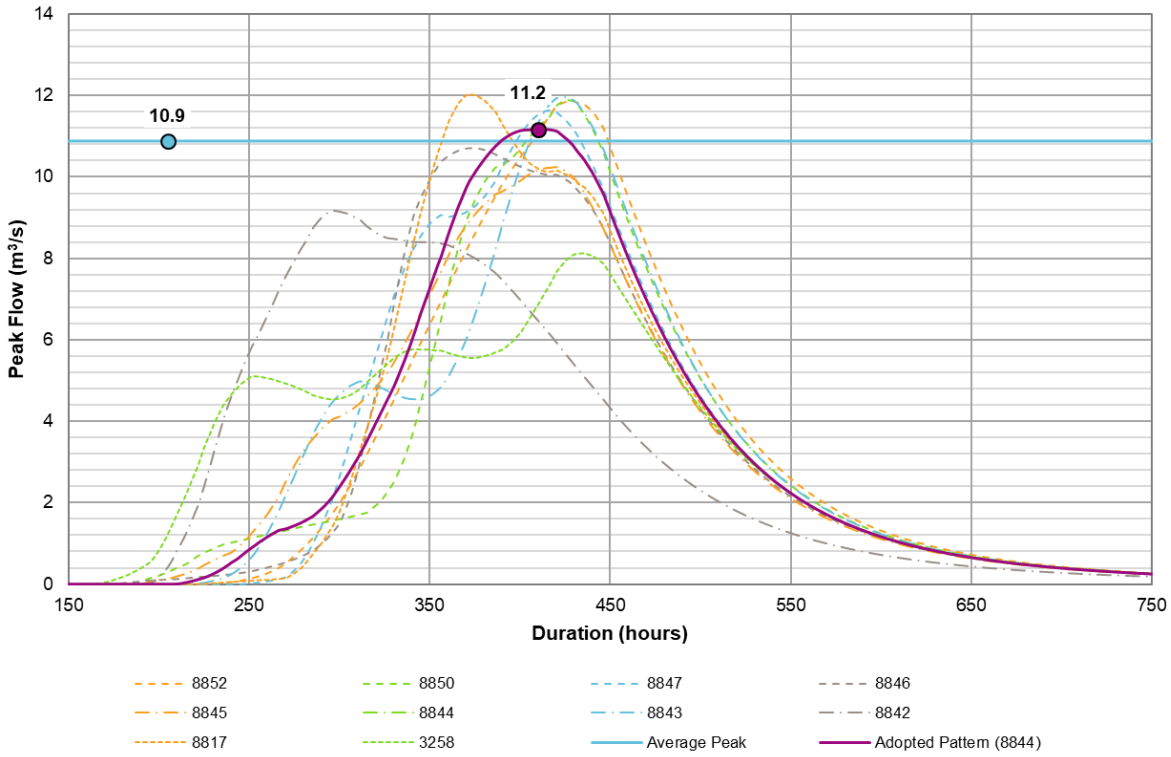

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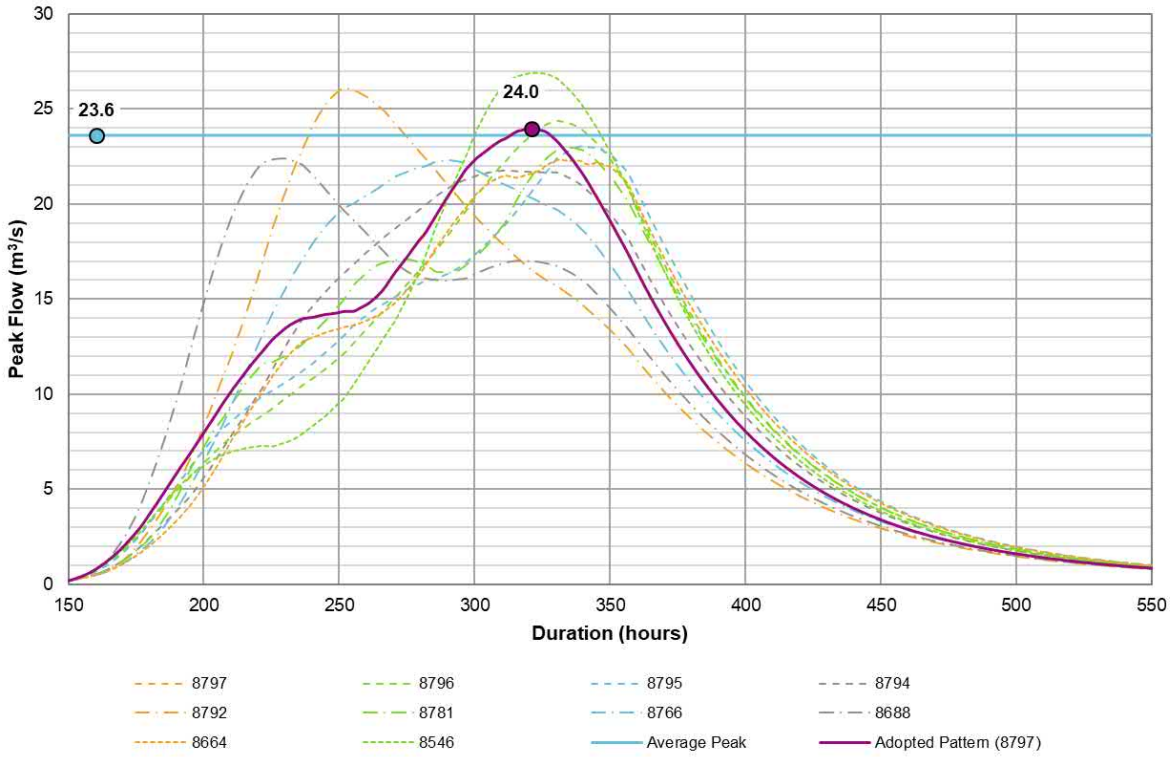

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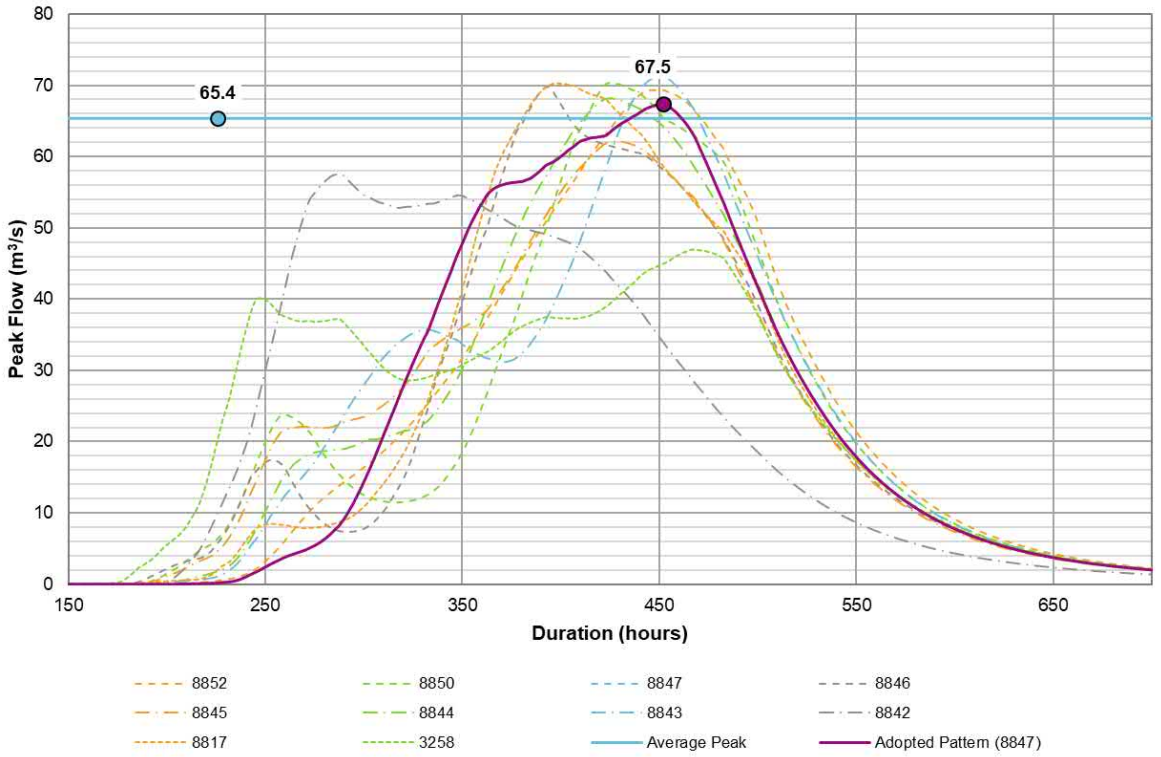

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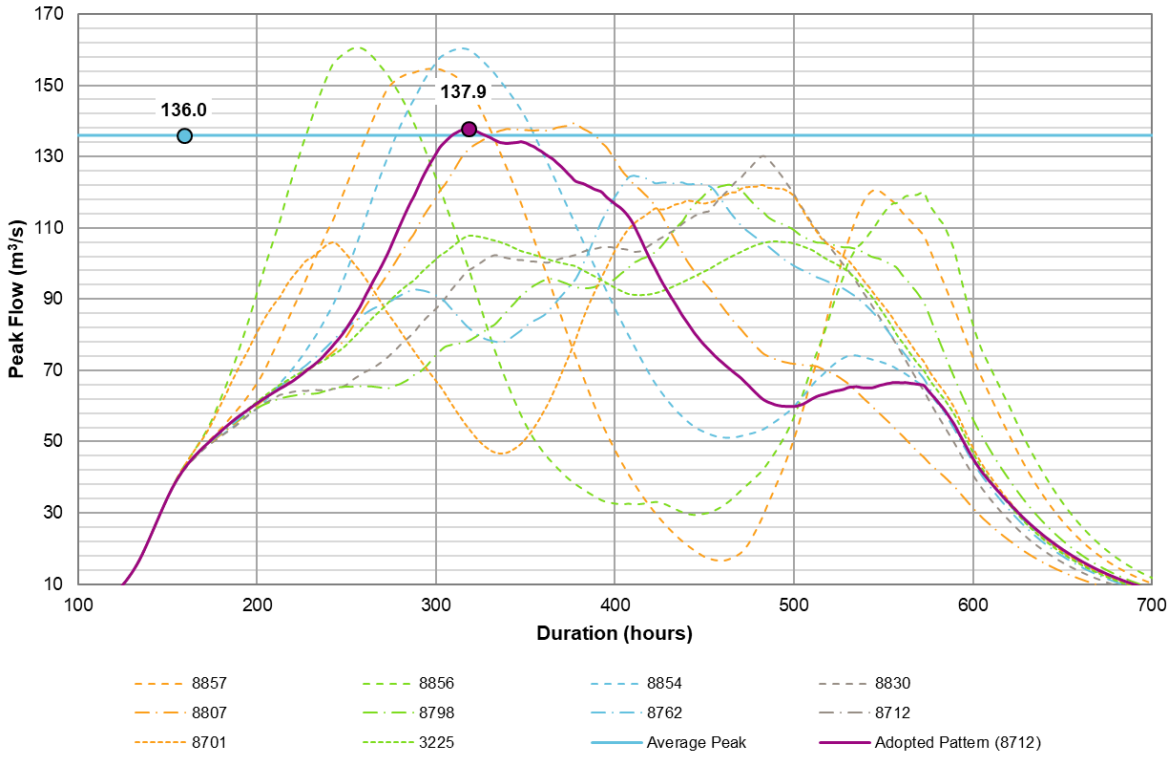
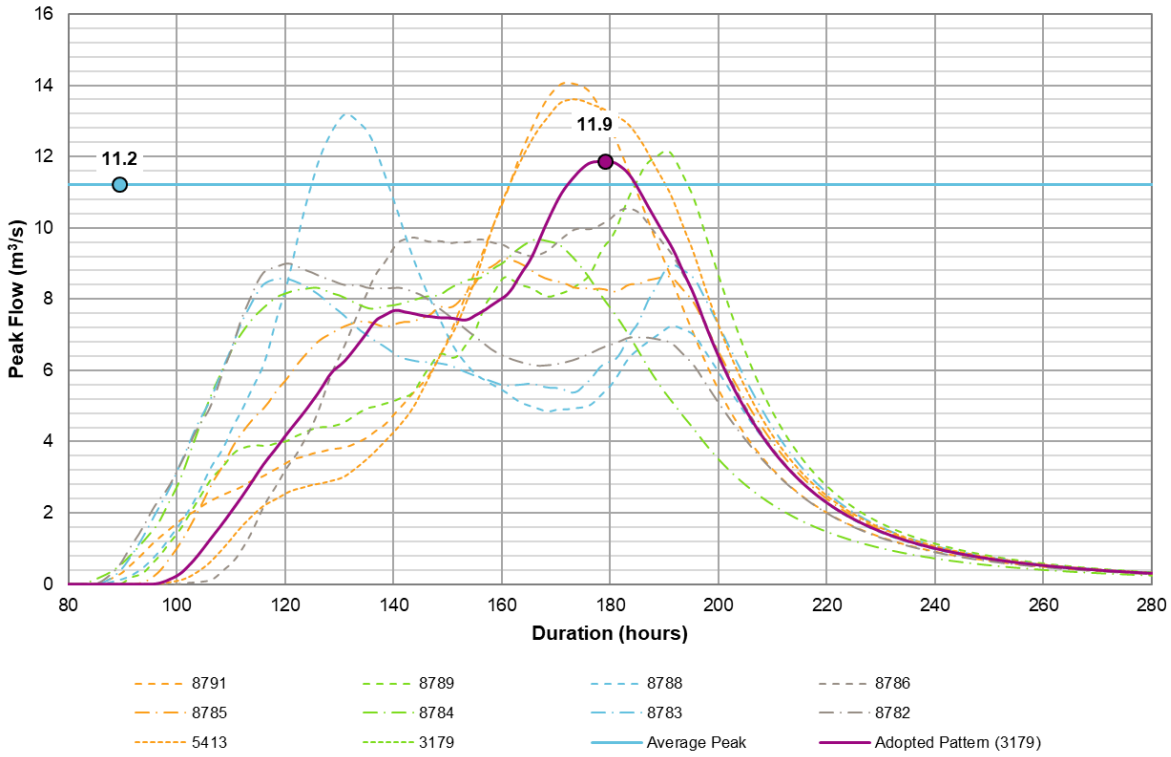


Figure F8 1% AEP Ensemble Hydrographs Plot – Subcatchment 53



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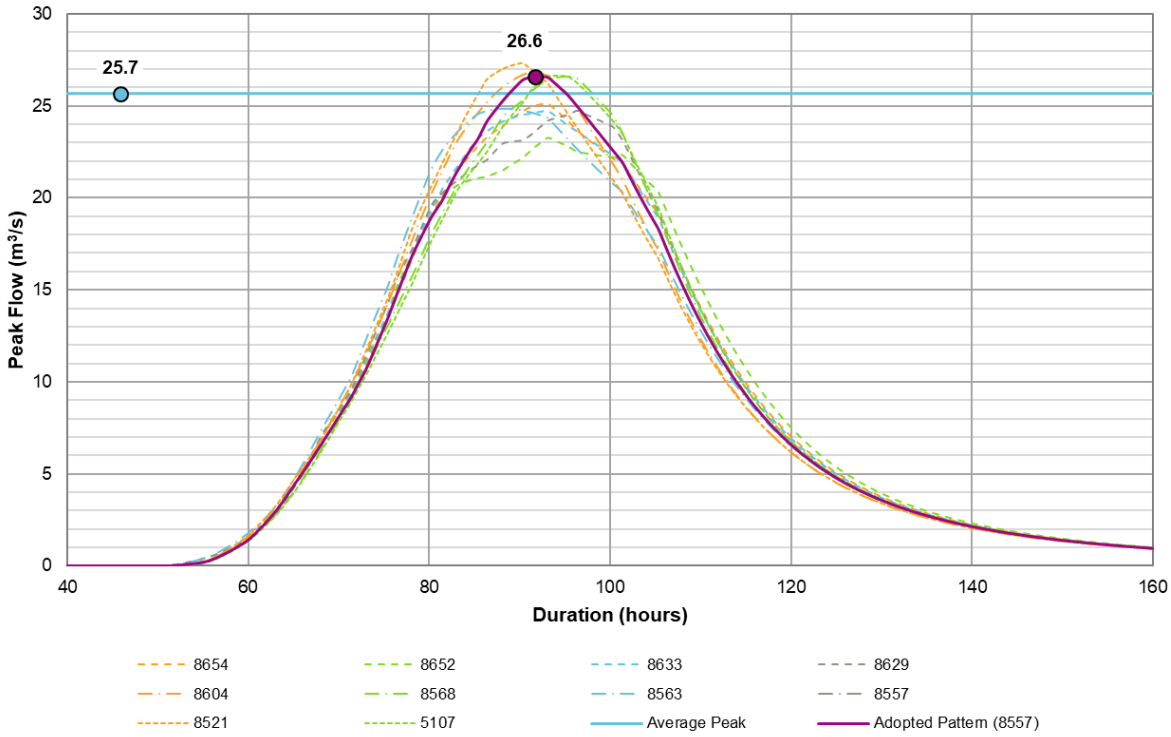


Figure F10 1% AEP Ensemble Hydrographs Plot – Subcatchment 65

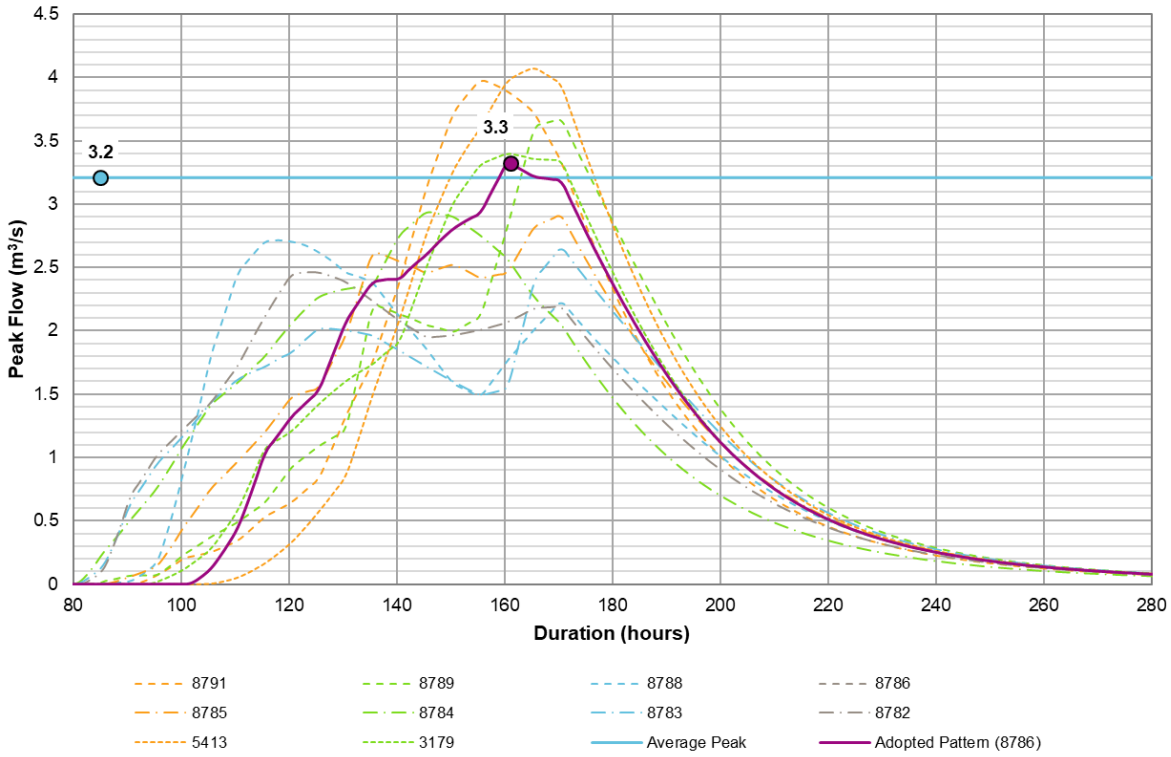
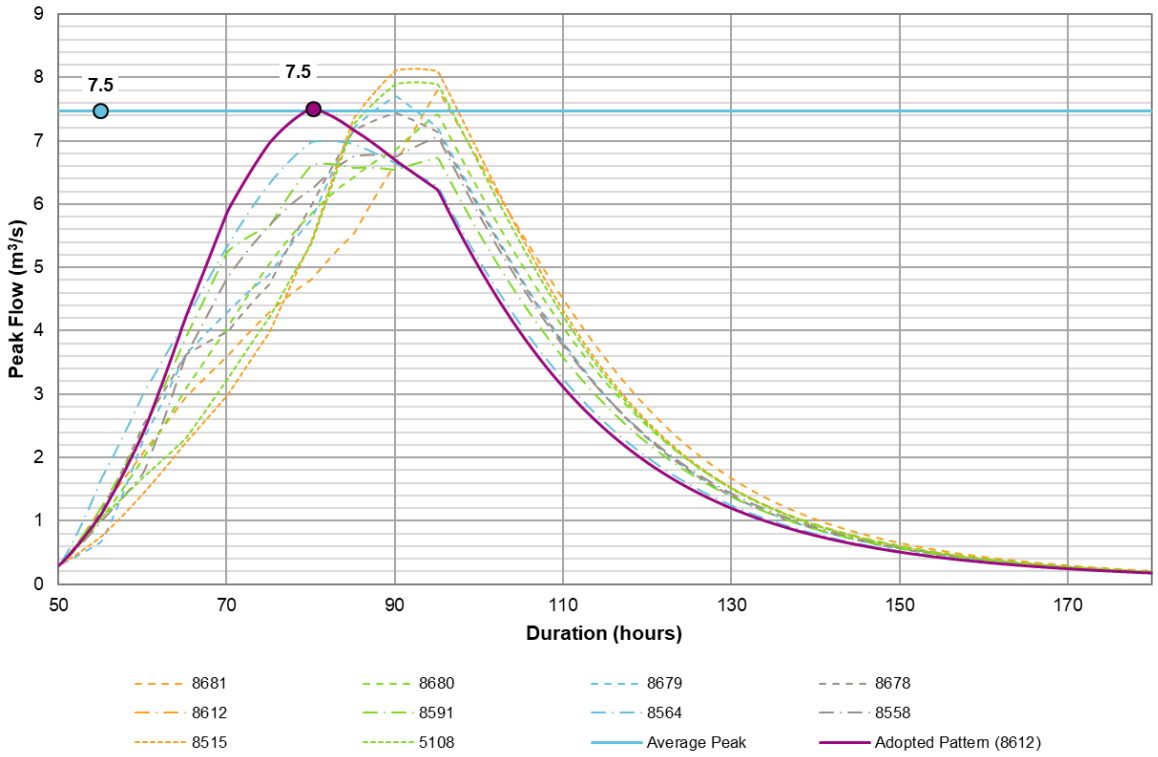


Figure F11 20% AEP Ensemble Hydrographs Plot – Subcatchment 74



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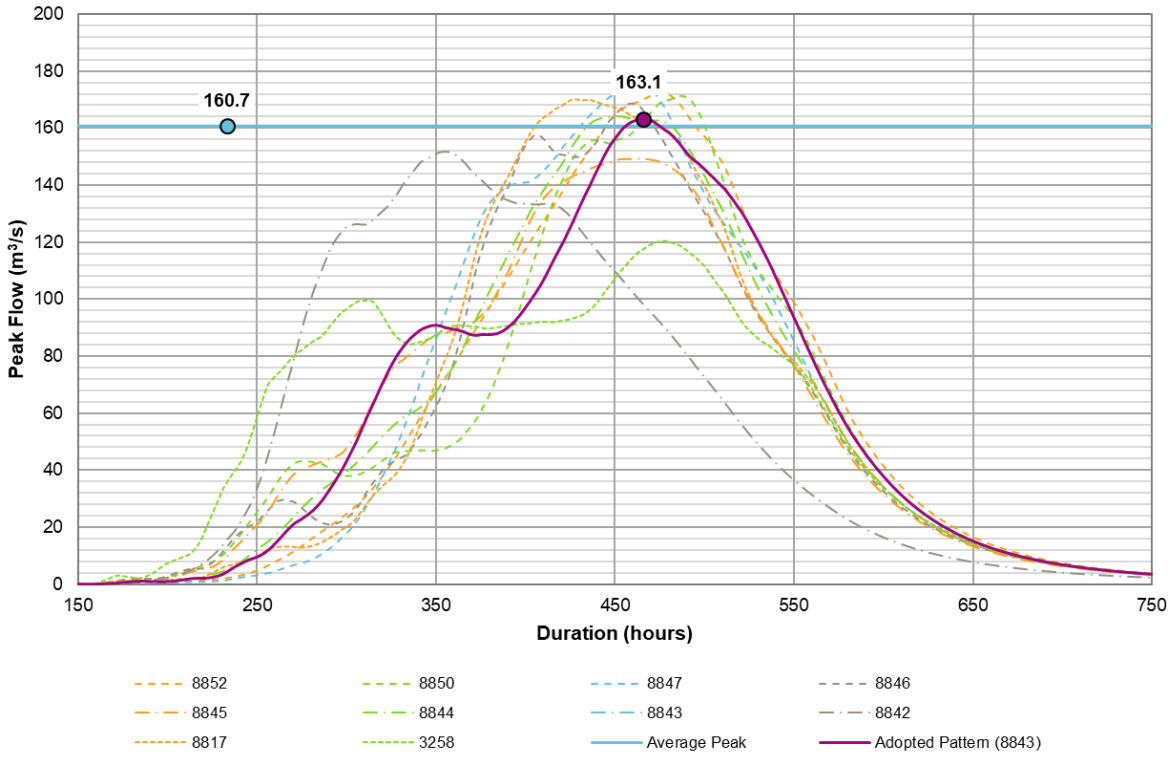
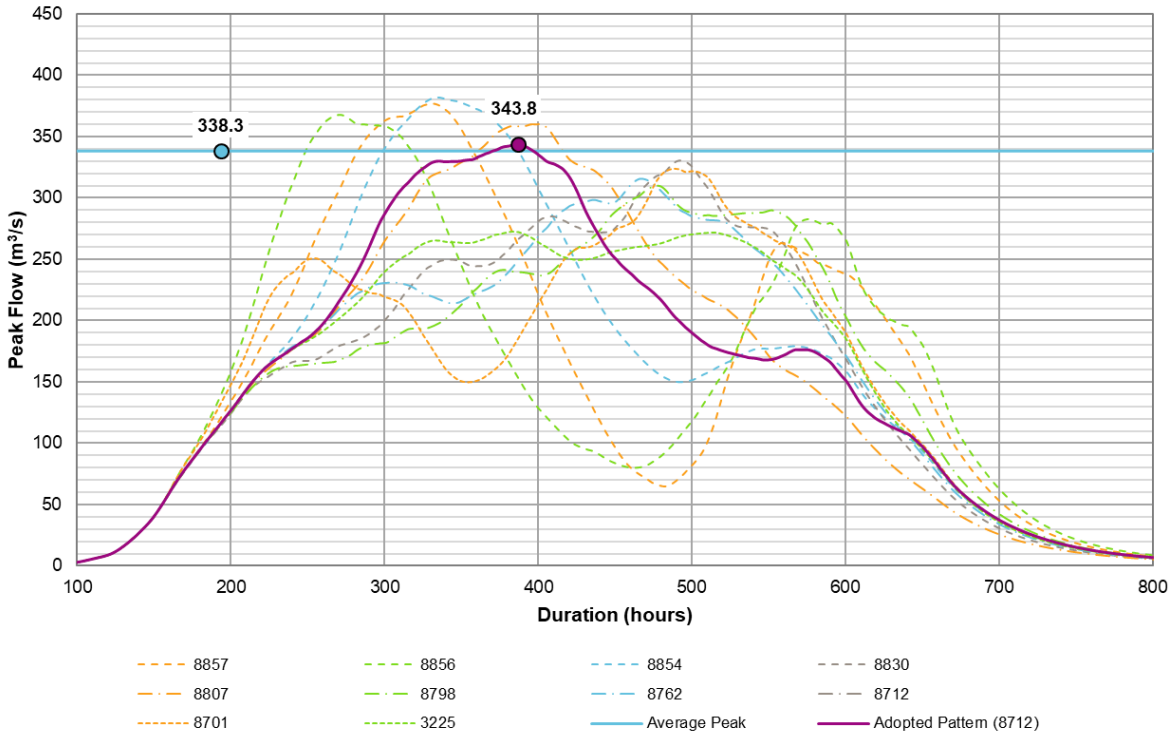


Figure F13 20% AEP Ensemble Hydrographs Plot – Subcatchment 104



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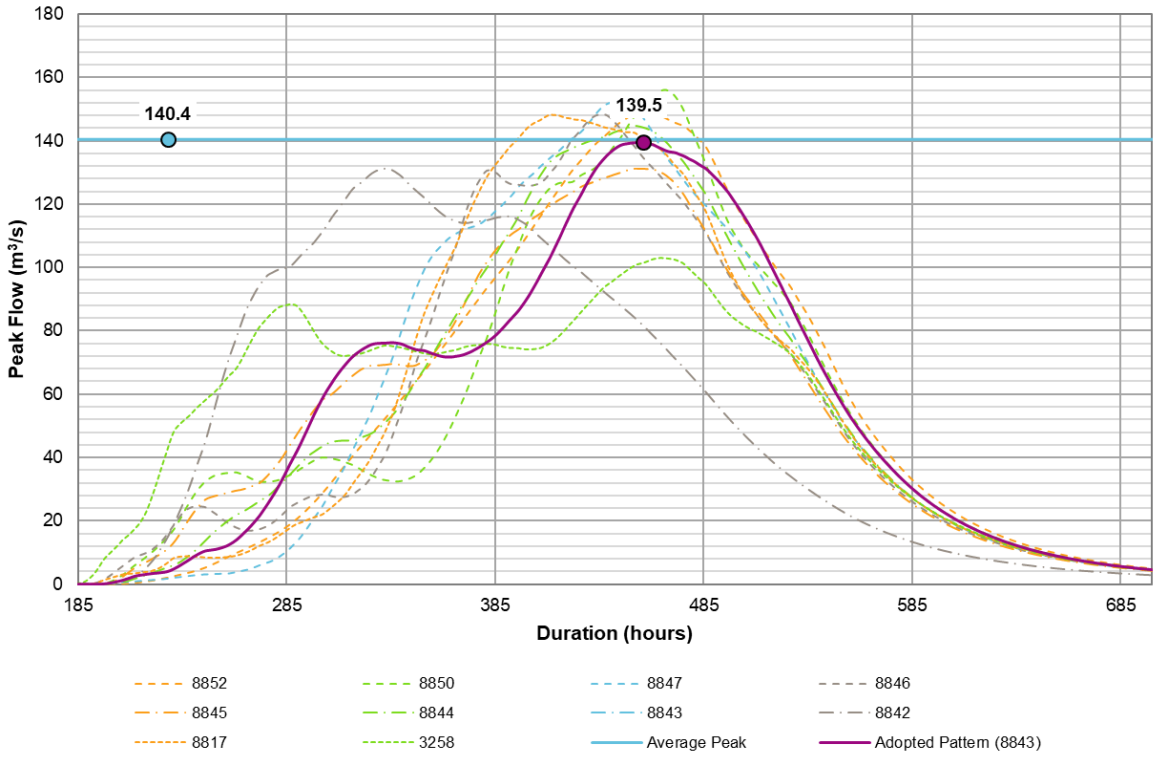

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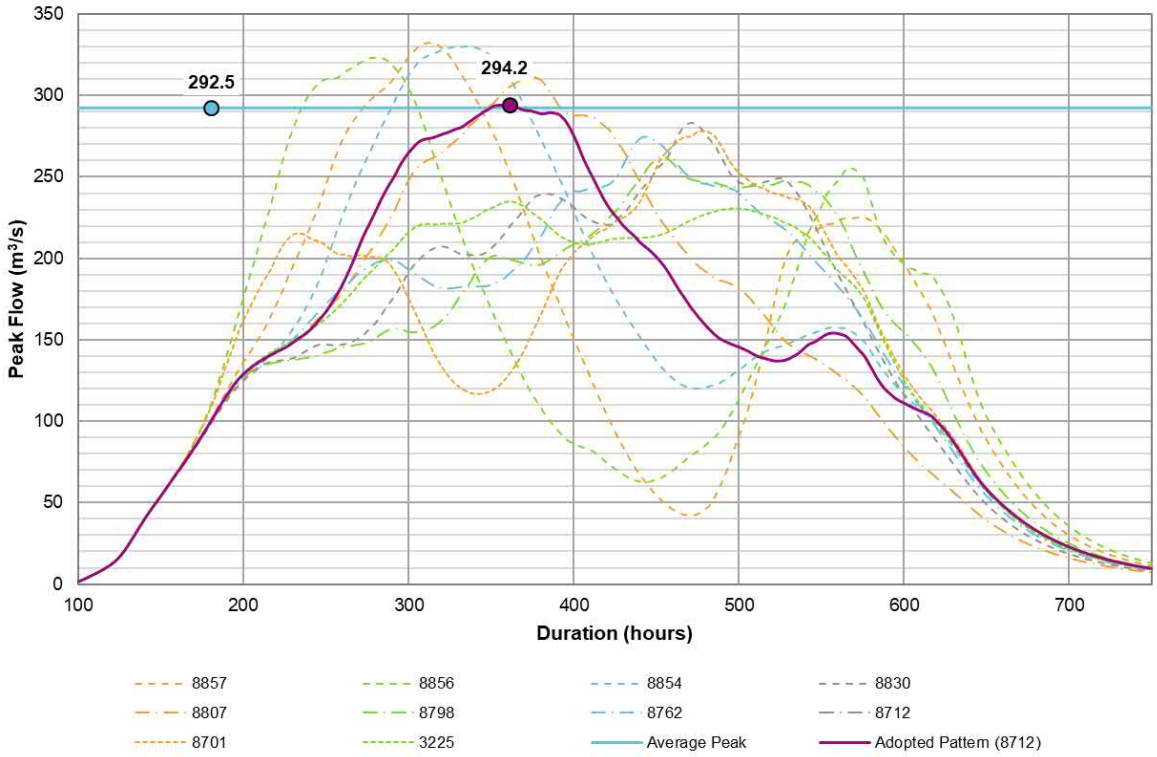

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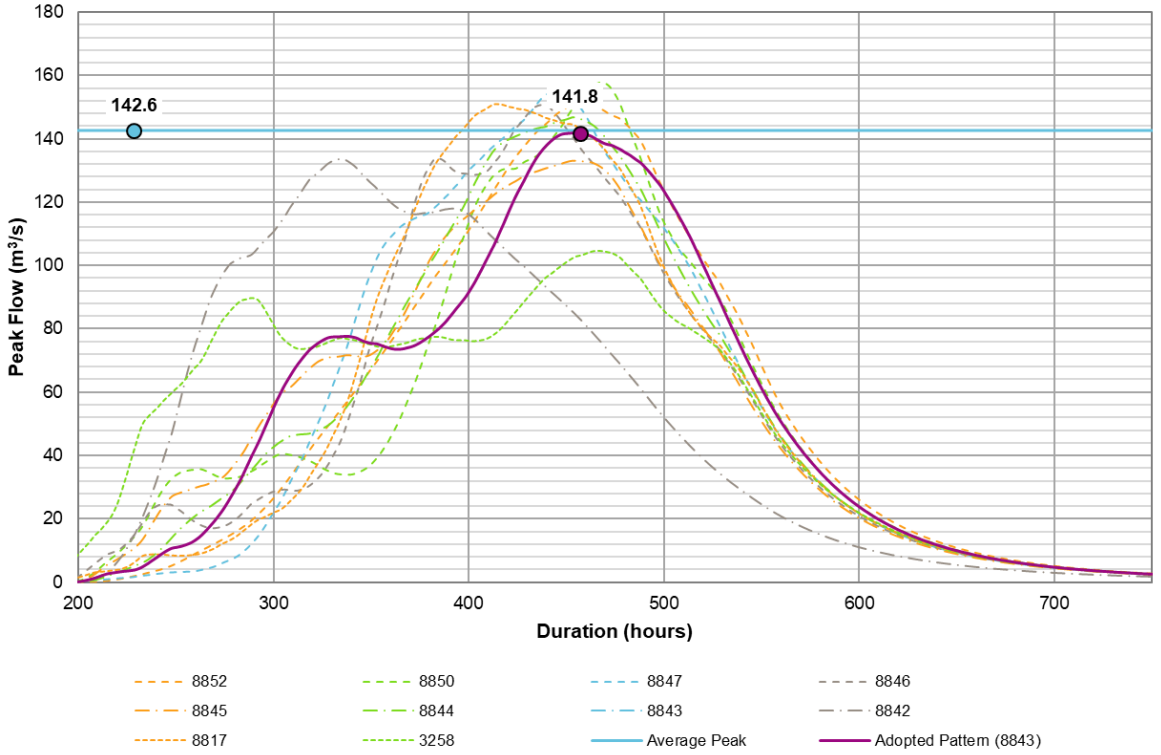

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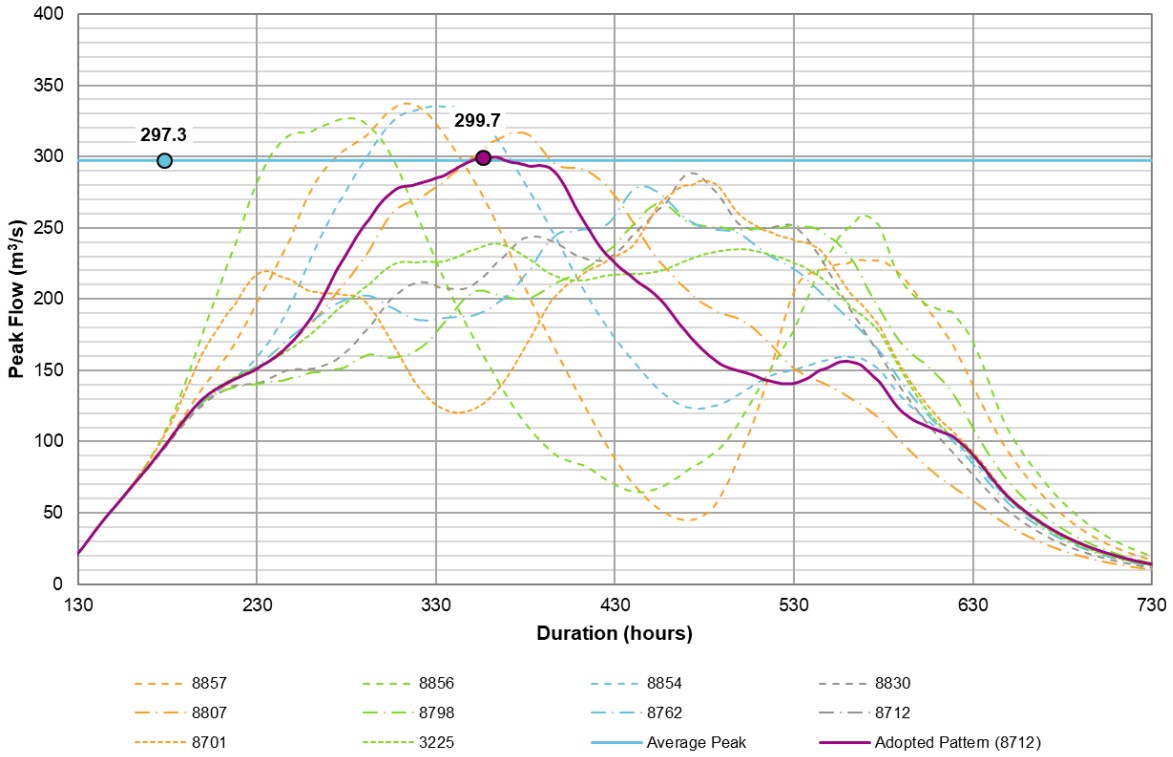


Figure F18 1% AEP Ensemble Hydrographs Plot – Subcatchment 106

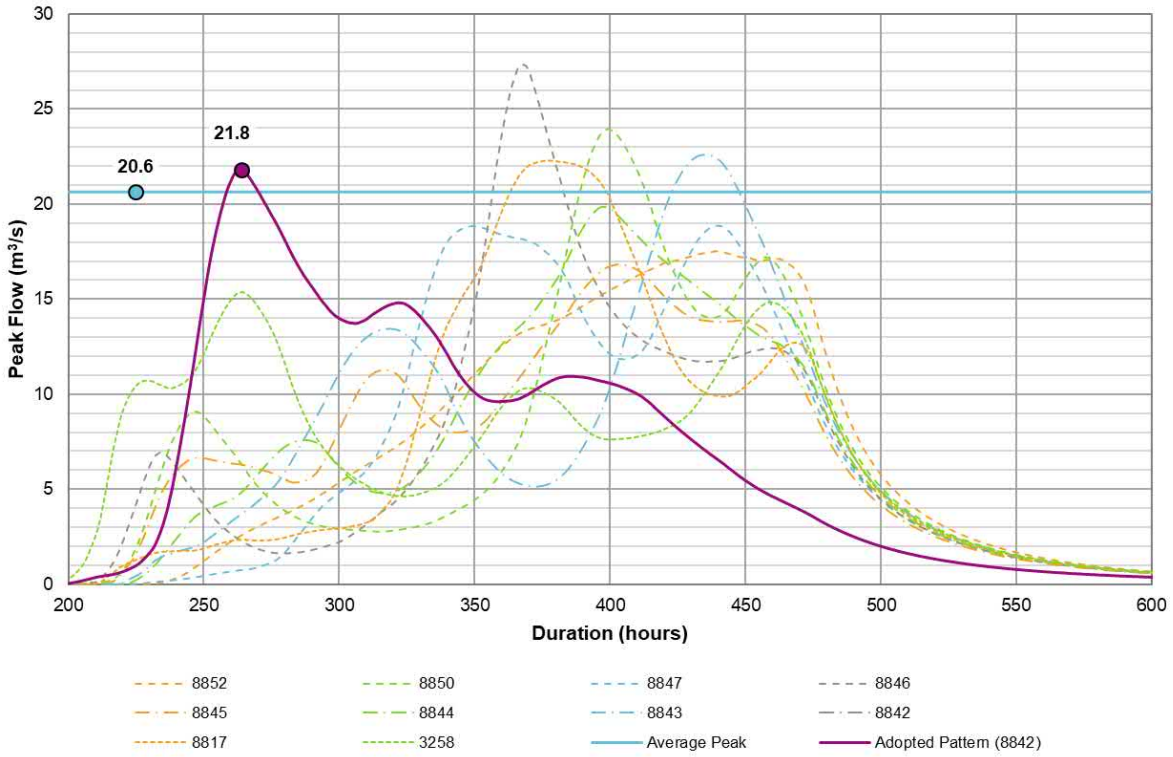
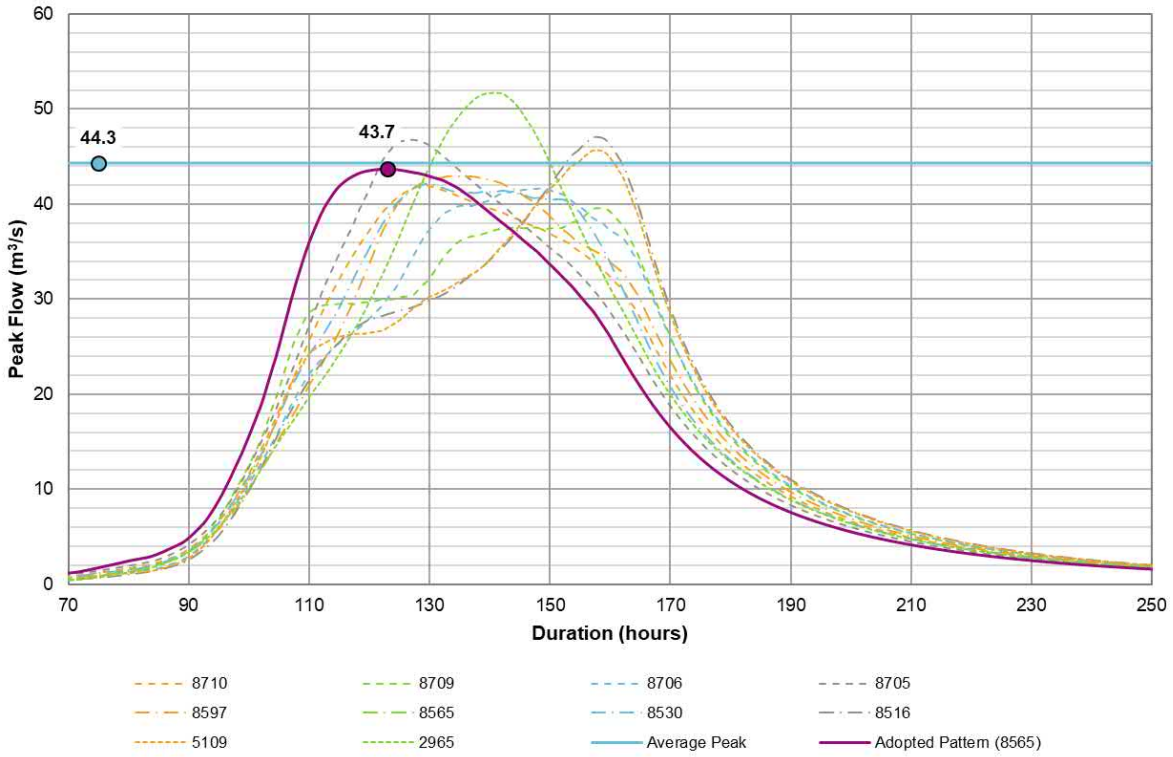


Figure F19 20% AEP Ensemble Hydrographs Plot – Subcatchment 110



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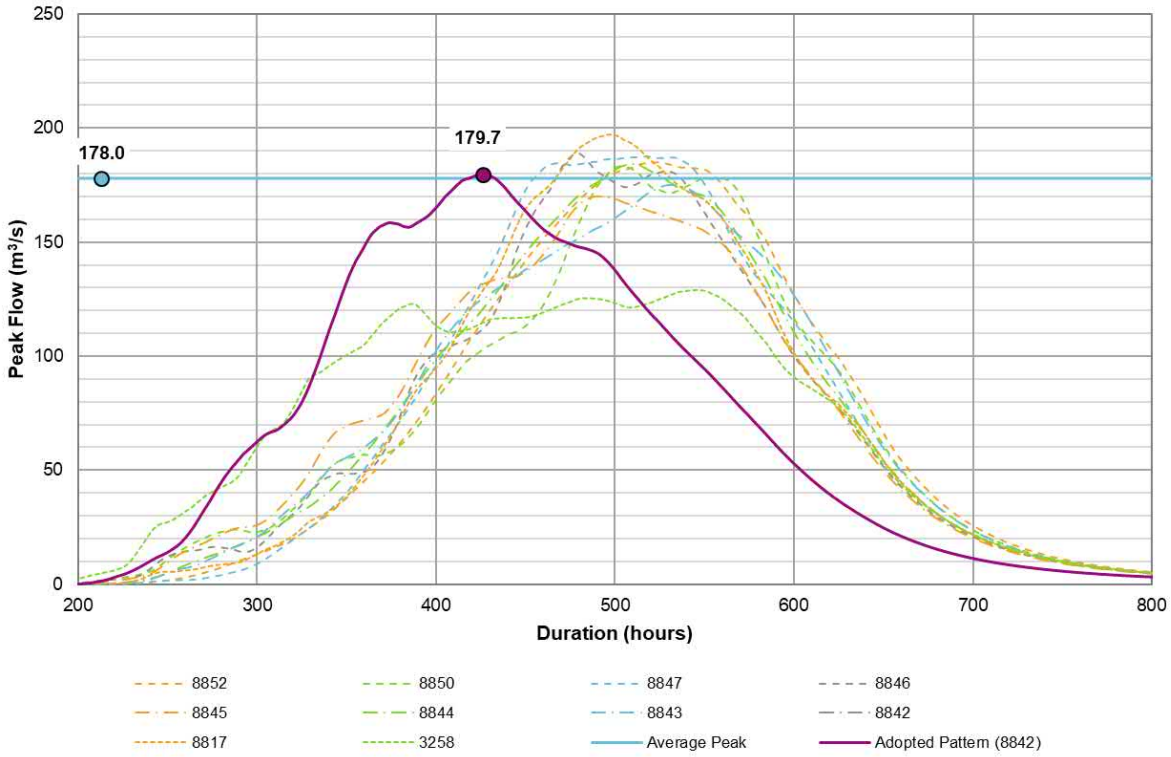

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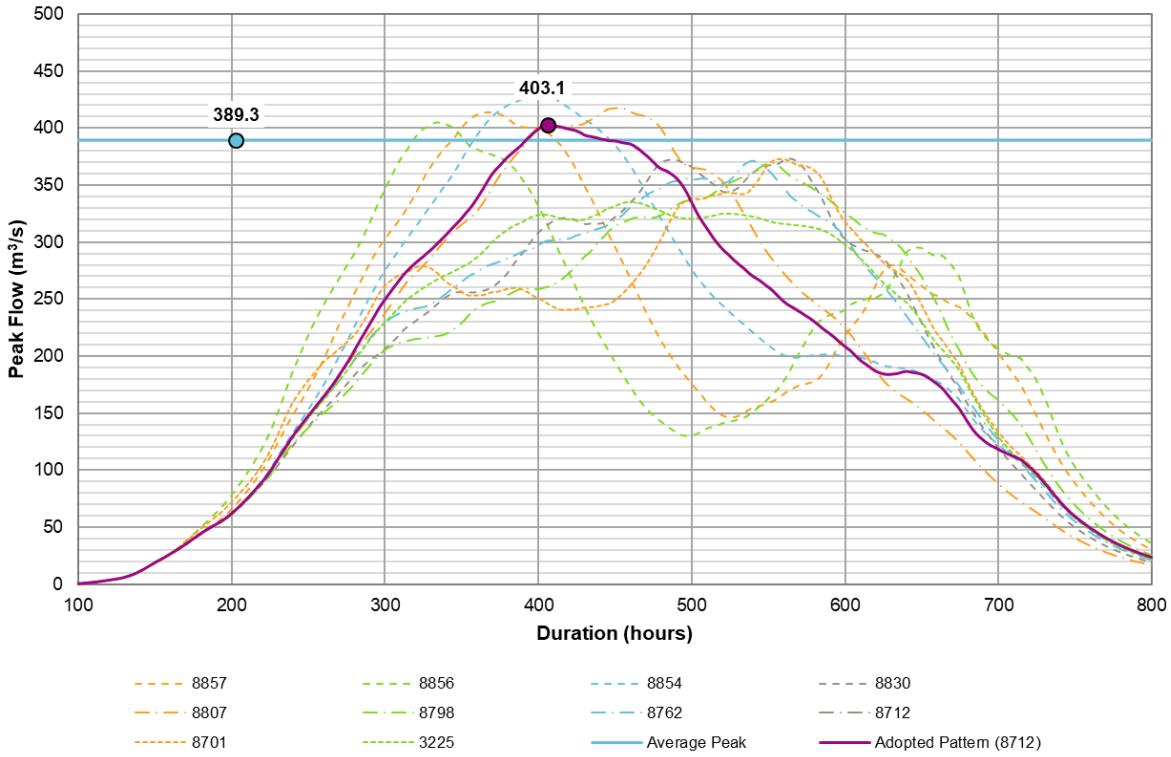

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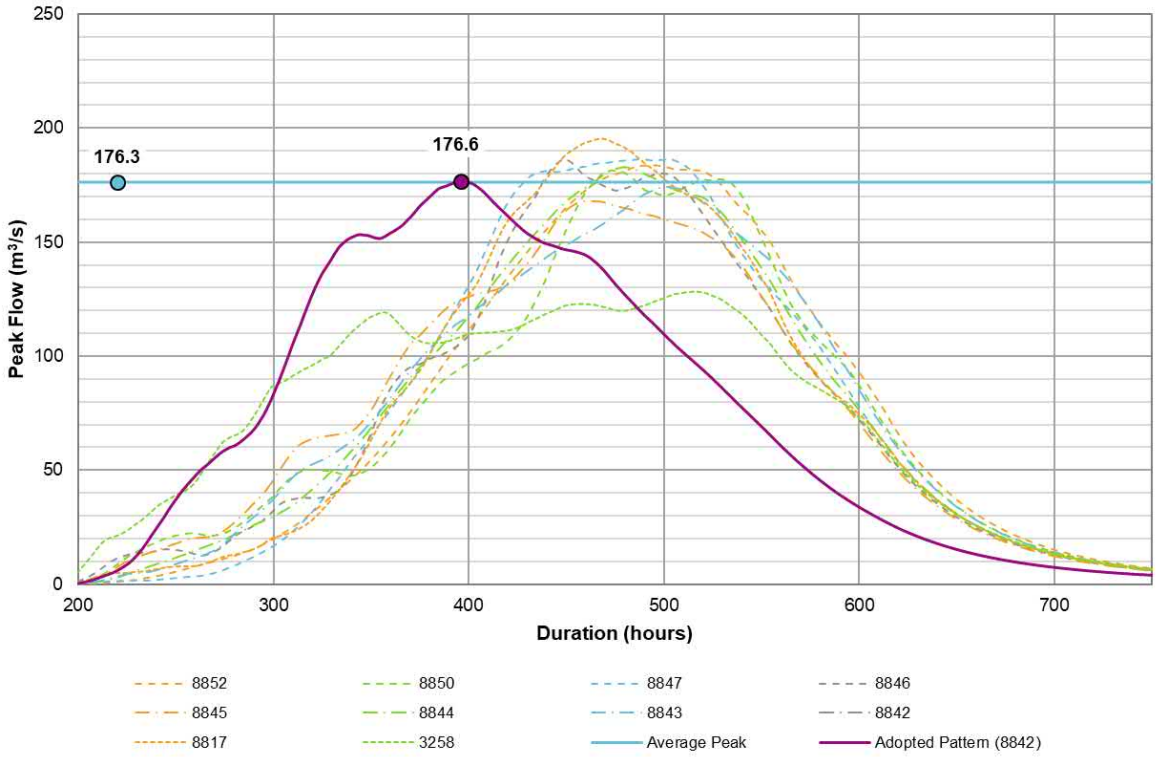

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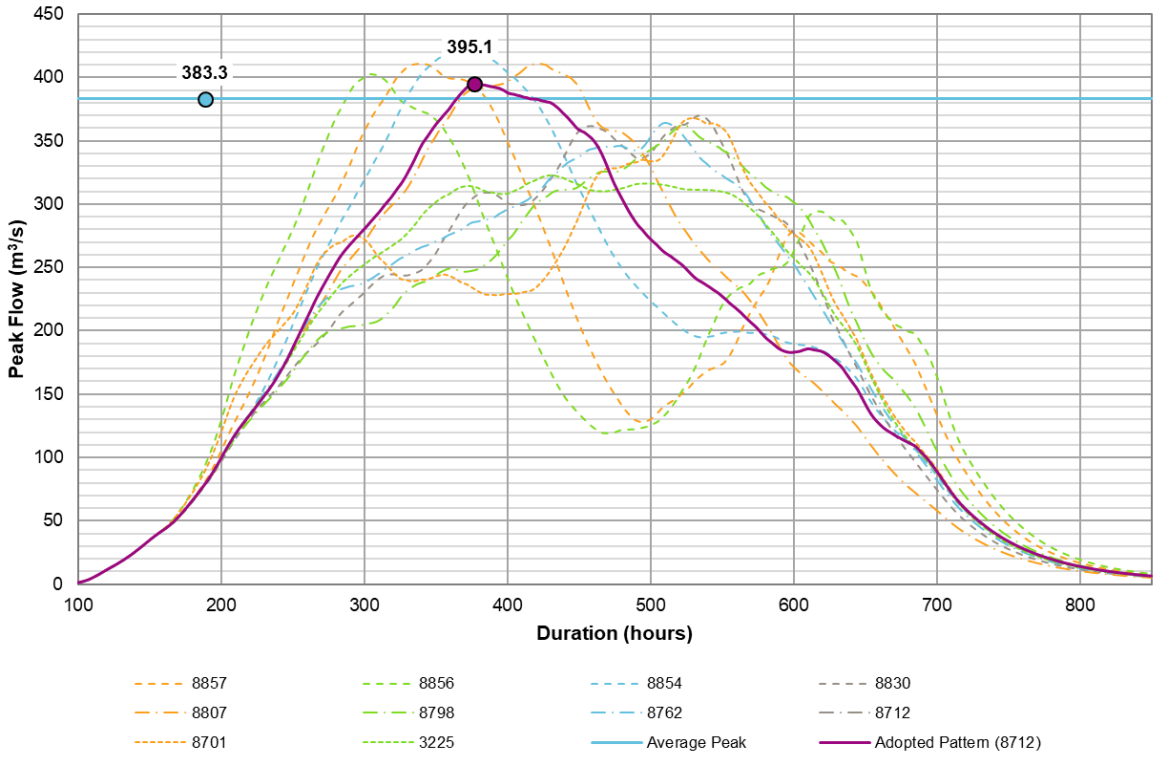

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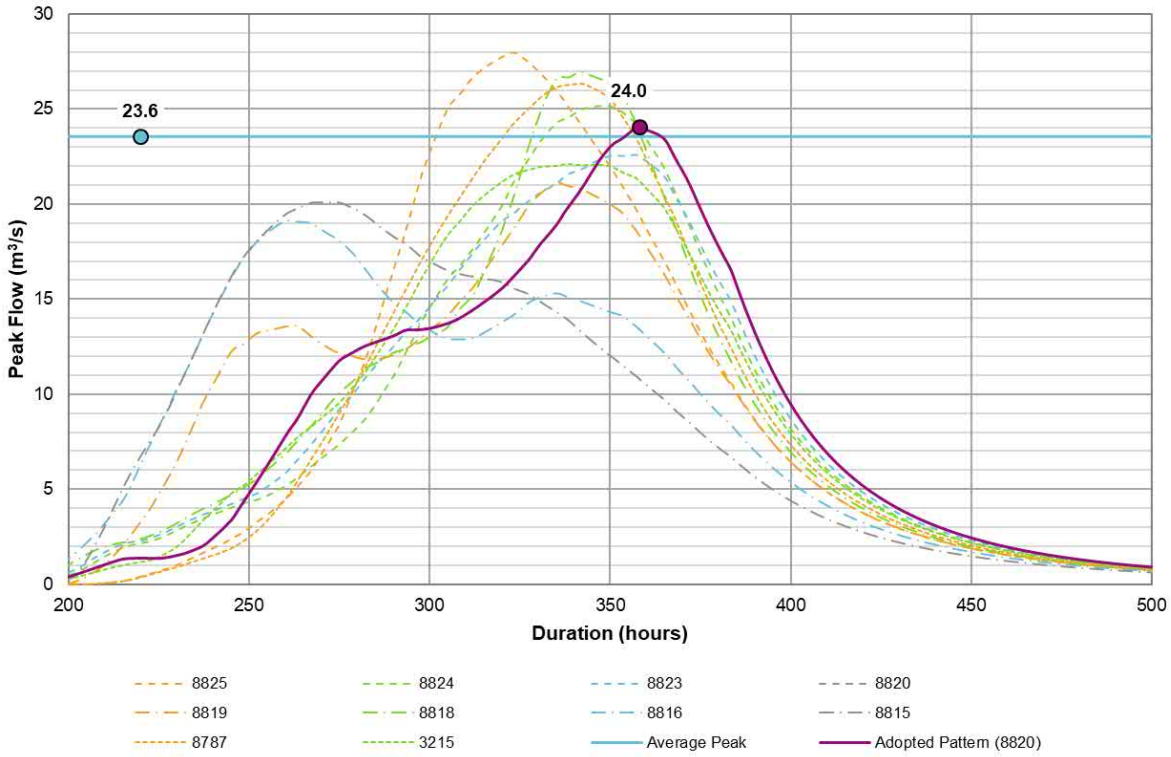

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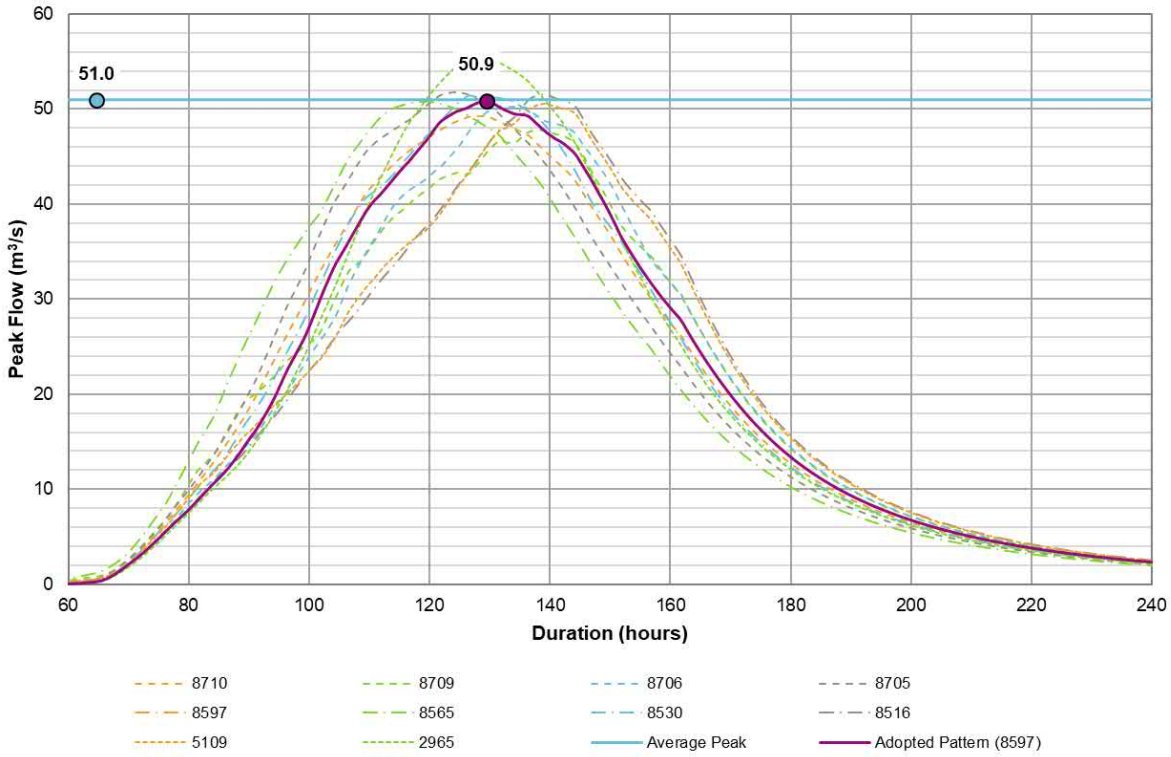

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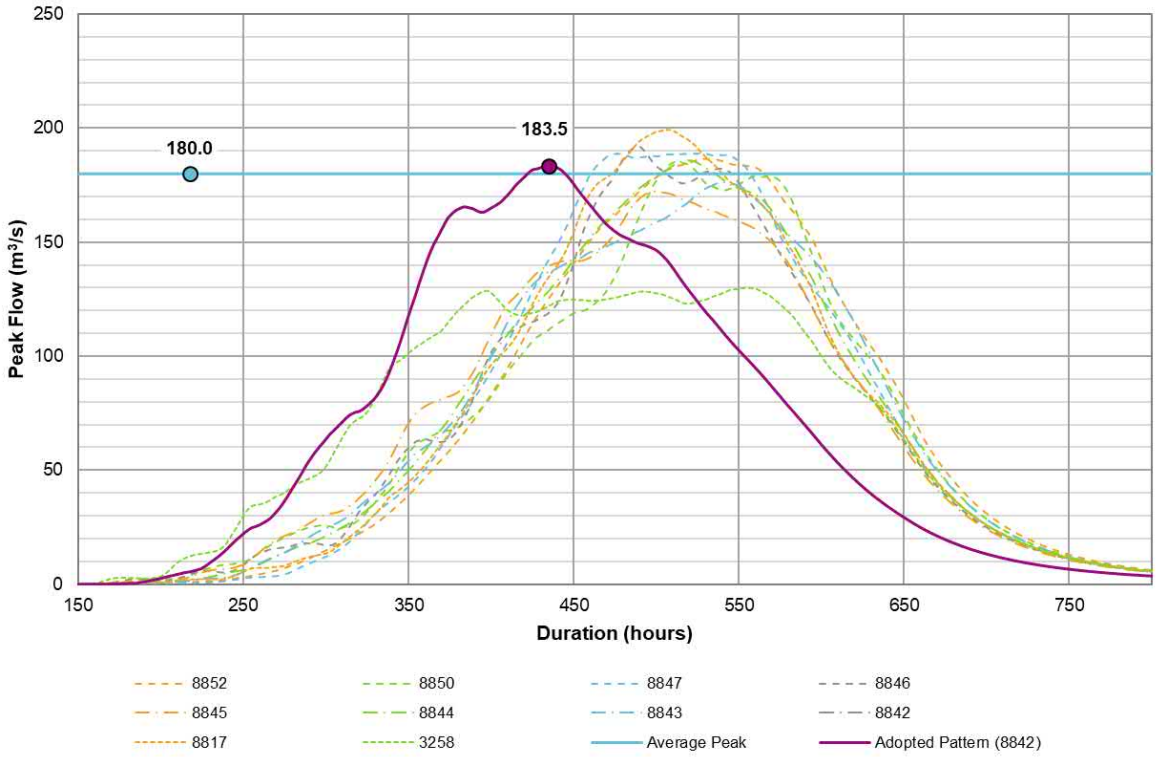


Figure F27 20% AEP Ensemble Hydrographs Plot – Subcatchment 142

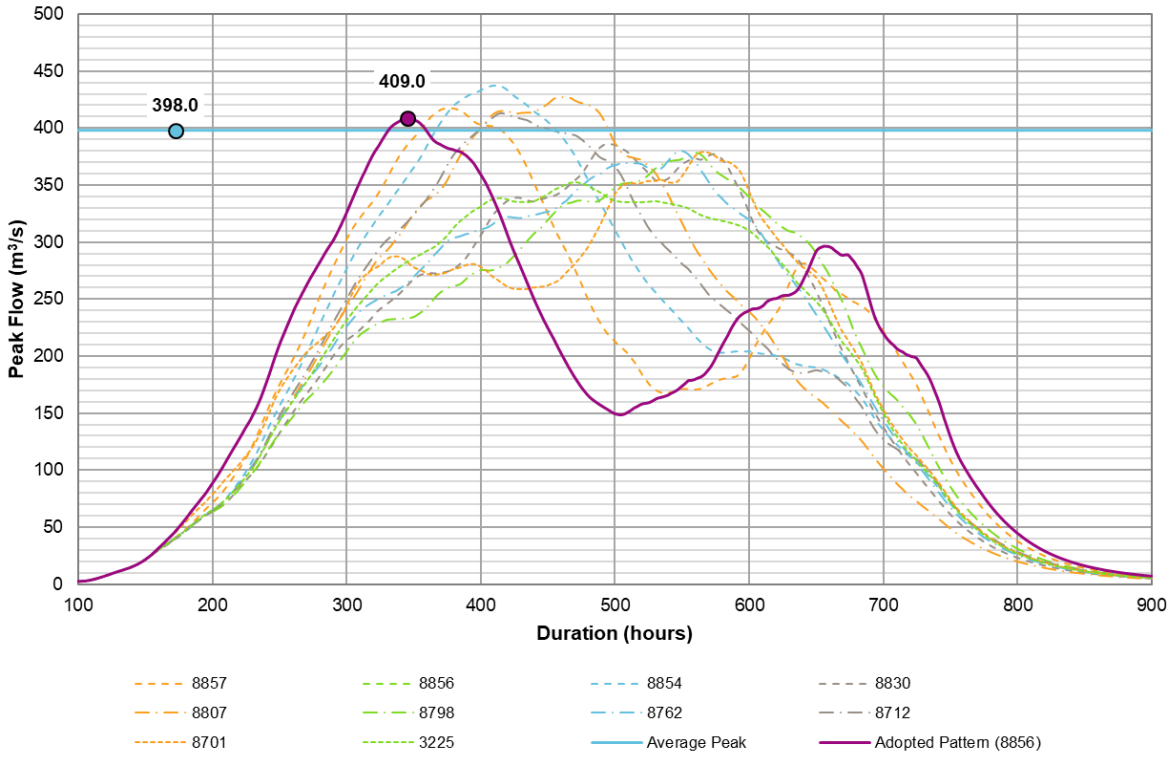


Figure F28 1% AEP Ensemble Hydrographs Plot – Subcatchment 142

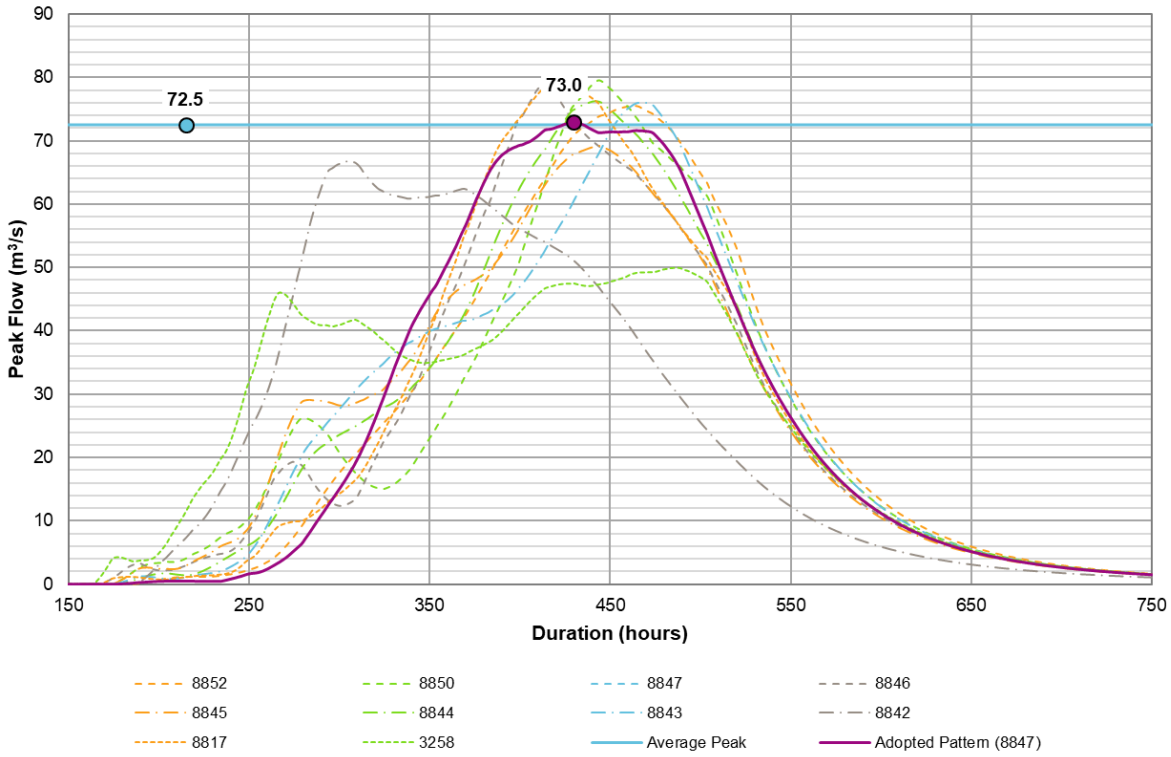


Figure F29 20% AEP Ensemble Hydrographs Plot – Subcatchment 167

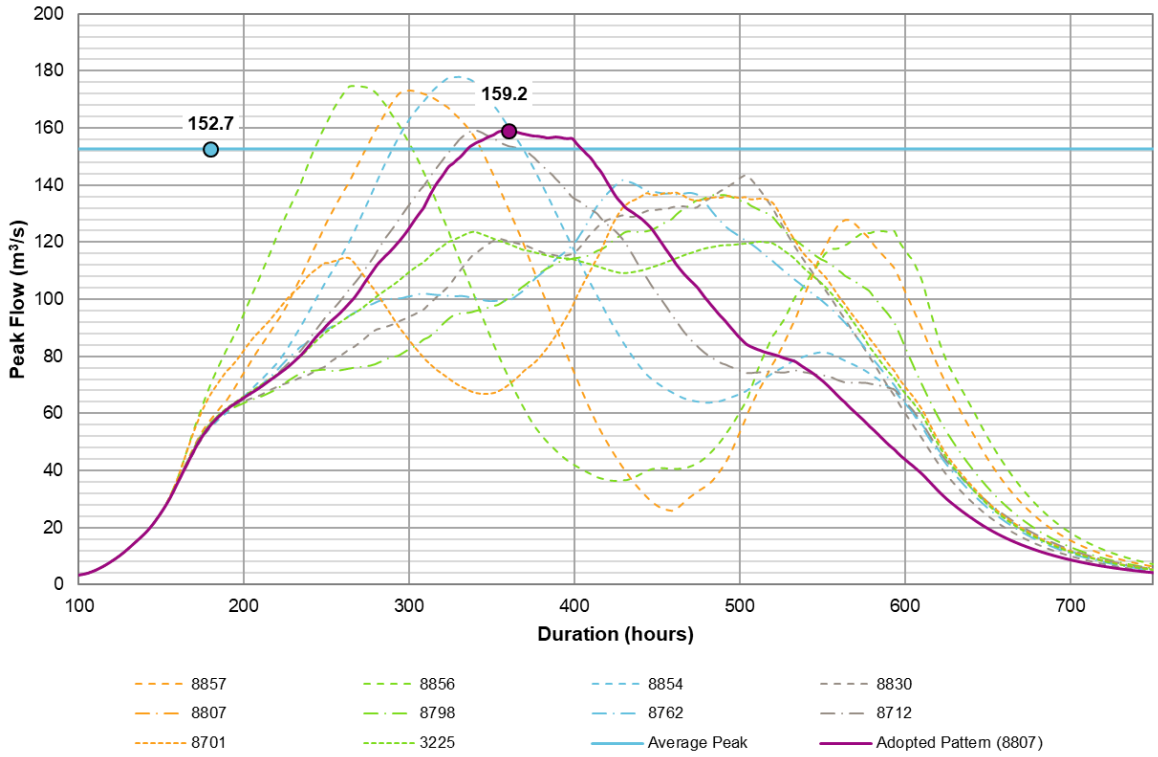


Figure F30 1% AEP Ensemble Hydrographs Plot – Subcatchment 167

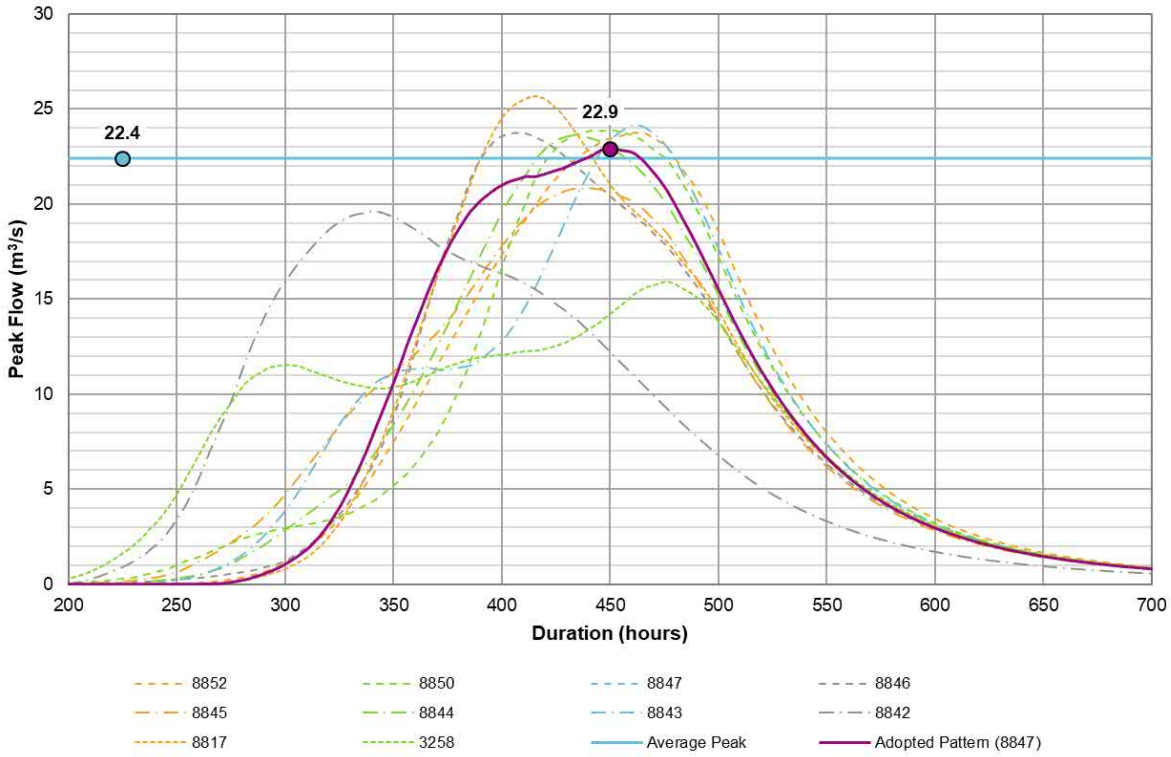


Figure F31 20% AEP Ensemble Hydrographs Plot – Subcatchment 169

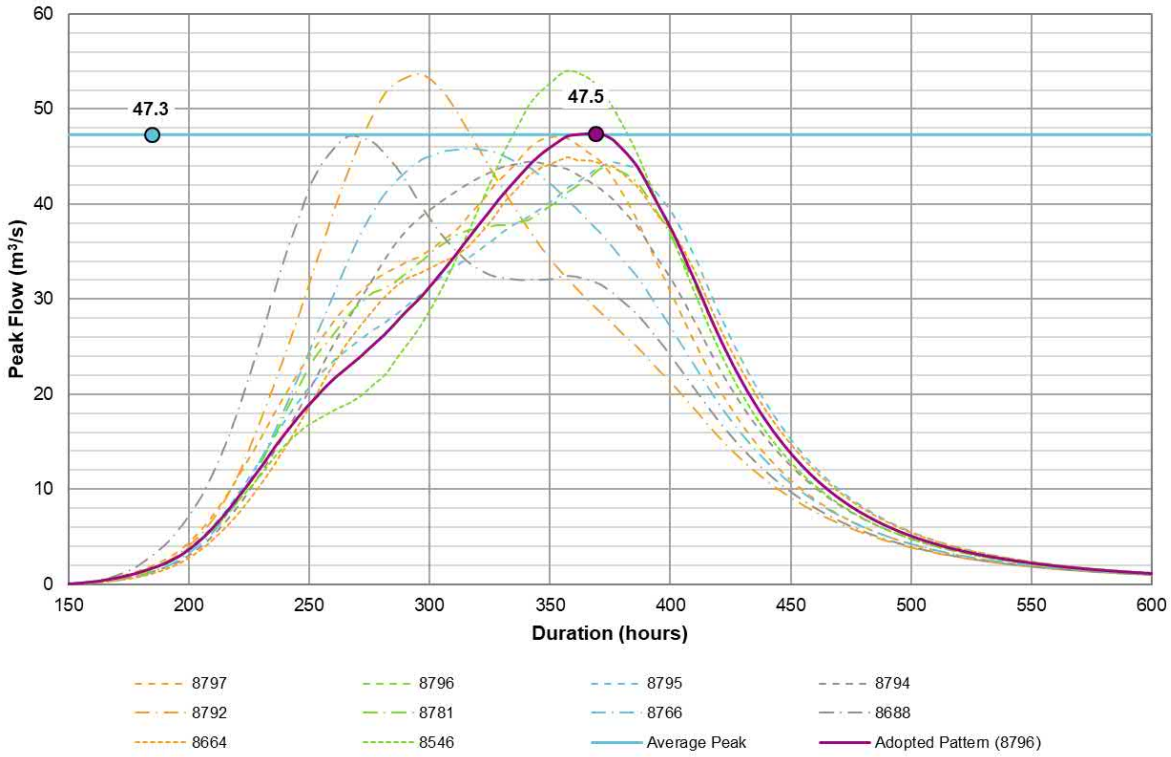
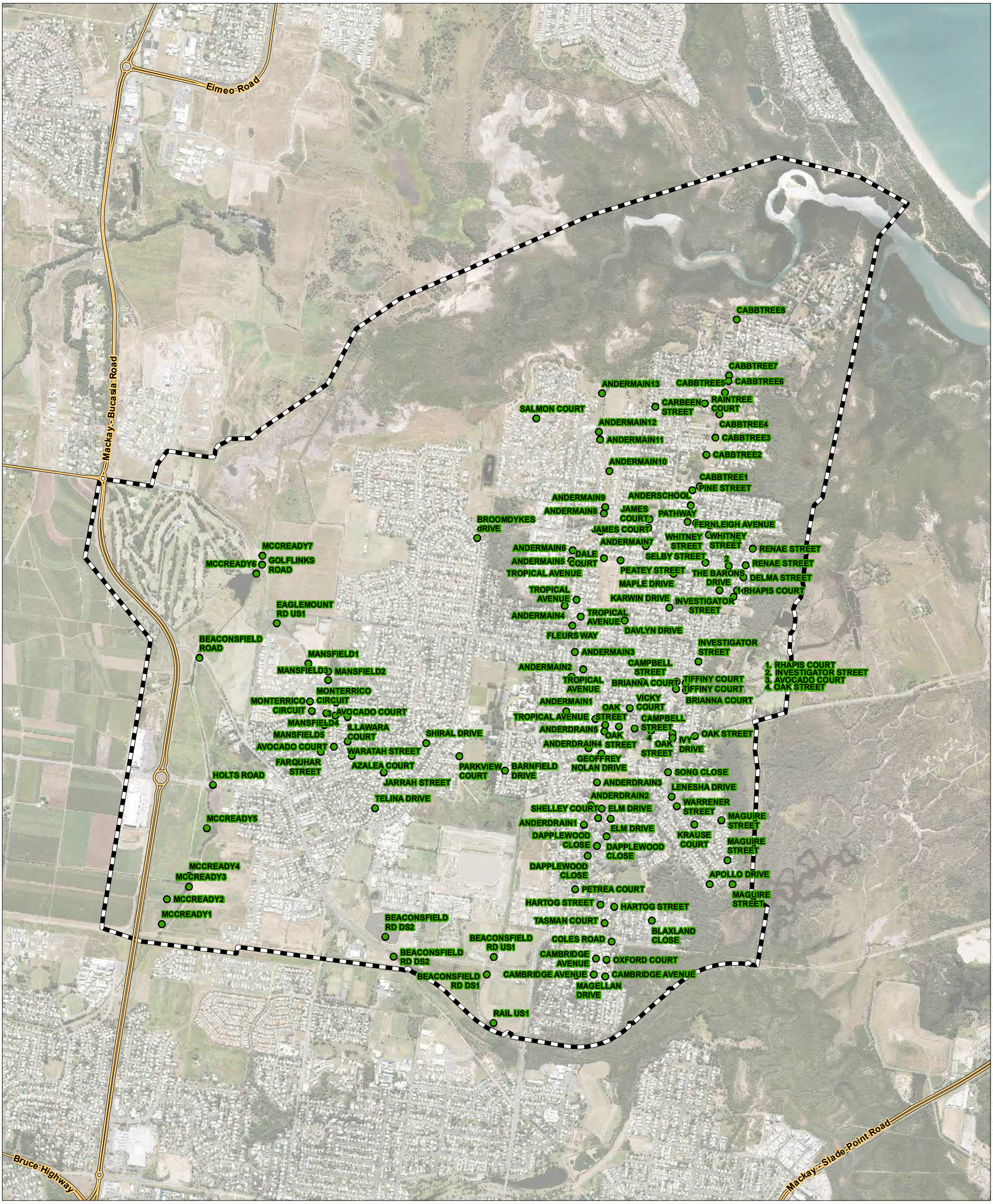


Figure F32 1% AEP Ensemble Hydrographs Plot – Subcatchment 169

Appendix G

Baseline Model Outputs



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AECOM

N

0 0.3 0.6 km

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Legend

- ABDS_POI_SpatialJoin_v4
- TUFLOW Model Extent
- State Controlled Road Network

MACKAY REGIONAL COUNCIL

Andergrove Beaconsfield Drainage Study

Plot Output
Height & Velocity
Locations

G1

P:\60636106\07744 - Bdb MRC AGrove BField D'Age 3\500_Deliverables\501_DReport\Figures\G1_PO_pointsmxd Date Saved: 28/07/2020

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AECOM

N

0 0.3 0.6 km

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Legend

- Plot Output Location
- TUFLOW Model Extent
- State Controlled Road Network

MACKAY REGIONAL COUNCIL

Andergrove Beaconsfield Drainage Study

Plot Output
Flow Reporting
Locations

G2

P:\60630744 - 840 MRC AGrove BField D'Age 31500_Deliverables\501_DR\epsMaps\632_PO_lines.mxd Date Saved: 28/07/2020

Eimeo Road
Mackay - Bucasia Road
Golf Links Road
Eaglemount Road
Beaconsfield Road
Mansfield Drive 2
Holts Road 2
Holts Road 1
Mansfield Drive 1
Nicklin Drive
Celeber Drive 3
Celeber Drive 2
Celeber Drive 1
Broomdykes Road
Caledonian Drive
Nadarmi Drive
Cabbage Tree Road
Fernleigh Avenue
Tropical Avenue 1
Newton Street
Tropical Avenue 2
Fluers Way
Tropical Avenue 3
Maple Drive 1
Maple Drive 2
Oak Street 1
Oak Street 2
Oak Street 3
Oak Street 4
Keeleys Road
Coles Road
Bruce Highway
Mackay - Slade Point Road

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AECOM

N

0 0.3 0.6 km

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Legend

- Road Assessment Location
- TUFLOW Model Extent
- State Controlled Road Network

MACKAY REGIONAL COUNCIL

Andergrove Beaconsfield Drainage Study

Major Road
Assessment Locations

G3

P:\60630744 - 640 Mkt AGrove BField D\Apr SI\500_Deliverables\501_DRepor\Figures\G3_Major_Road_Assessment_Locations.mxd Date Saved: 29/07/2020

Appendix G Baseline Model Outputs

Table G1 Baseline Locational Peak Water Surface Elevations (Refer Figure G1)

Location	Lidar Elevation (mAHD)	Baseline 63.2% AEP PWSE (mAHD)	Baseline 50% AEP PWSE (mAHD)	Baseline 20% AEP PWSE (mAHD)	Baseline 10% AEP PWSE (mAHD)	Baseline 5% AEP PWSE (mAHD)	Baseline 2% AEP PWSE (mAHD)	Baseline 1% AEP PWSE (mAHD)	Baseline 1% AEP with CC (mAHD)	Increase to CC for 1% AEP event
Anderdrain1	7.41				7.45	7.52	7.59	7.67	7.73	0.07
Anderdrain2	7.08		7.08	7.21	7.31	7.41	7.51	7.60	7.70	0.10
Anderdrain3	6.97	7.06	7.09	7.19	7.30	7.40	7.50	7.59	7.69	0.10
Anderdrain4	6.63	7.05	7.07	7.14	7.26	7.37	7.48	7.58	7.68	0.11
Anderdrain5	6.66	7.05	7.07	7.12	7.23	7.35	7.45	7.55	7.66	0.11
Andermain1	7.30	7.60	7.63	7.73	7.81	7.91	8.00	8.06	8.15	0.09
Andermain10	5.86	6.27	6.33	6.45	6.49	6.53	6.58	6.62	6.69	0.08
Andermain11	4.25	4.57	4.64	4.80	4.90	5.02	5.13	5.26	5.44	0.18
Andermain12	5.17	5.28	5.28	5.29	5.32	5.34	5.36	5.38	5.42	0.04
Andermain13	3.21	3.87	3.94	4.07	4.13	4.17	4.21	4.23	4.28	0.04
Andermain2	6.58	7.51	7.56	7.72	7.81	7.91	8.00	8.06	8.16	0.10
Andermain3	6.91	7.45	7.52	7.71	7.80	7.90	7.99	8.06	8.16	0.10
Andermain4	6.59	7.22	7.33	7.55	7.64	7.75	7.85	7.94	8.06	0.13
Andermain5	6.45	7.07	7.18	7.41	7.51	7.62	7.71	7.82	7.97	0.15
Andermain6	6.26	7.02	7.14	7.37	7.46	7.56	7.67	7.78	7.93	0.15
Andermain7	6.35	6.89	7.01	7.24	7.33	7.43	7.55	7.67	7.83	0.16
Andermain8	5.93	6.75	6.86	7.10	7.19	7.32	7.46	7.59	7.76	0.18
Andermain9	5.90	6.68	6.76	6.91	6.96	7.02	7.08	7.12	7.22	0.10
Anderschool	8.18		8.20	8.27	8.32	8.34	8.39	8.42	8.46	0.04
Apollo Drive	4.55	4.73	4.74	4.76	4.78	4.79	4.80	4.82	4.84	0.01

Location	Lidar Elevation (mAHD)	Baseline 63.2% AEP PWSE (mAHD)	Baseline 50% AEP PWSE (mAHD)	Baseline 20% AEP PWSE (mAHD)	Baseline 10% AEP PWSE (mAHD)	Baseline 5% AEP PWSE (mAHD)	Baseline 2% AEP PWSE (mAHD)	Baseline 1% AEP PWSE (mAHD)	Baseline 1% AEP with CC (mAHD)	Increase to CC for 1% AEP event
Avocado Court	5.36	5.38	5.41	5.47	5.51	5.54	5.59	5.62	5.66	0.04
Avocado Court	5.10	5.38	5.41	5.47	5.52	5.54	5.60	5.63	5.67	0.04
Avocado Court	5.15	5.40	5.43	5.50	5.55	5.59	5.66	5.70	5.75	0.05
Azalea Court	5.57		5.61	5.69	5.73	5.76	5.80	5.84	5.87	0.04
Barnfield Drive	5.75	6.00	6.03	6.10	6.17	6.26	6.34	6.40	6.44	0.04
Beaconsfield Rd Ds1	2.76	3.51	3.59	3.75	3.93	4.03	4.09	4.17	4.30	0.13
Beaconsfield Rd Ds2	3.47	4.01	4.06	4.28	4.38	4.48	4.61	4.75	4.97	0.22
Beaconsfield Rd Ds2	3.18	3.79	3.84	4.09	4.21	4.29	4.39	4.49	4.66	0.17
Beaconsfield Rd Us1	3.15	3.61	3.69	3.85	4.06	4.18	4.26	4.42	4.66	0.24
Beaconsfield Road	4.41			4.45	4.49	4.52	4.55	4.57	4.61	0.04
Blaxland Close	5.69	5.75	5.76	5.78	5.79	5.81	5.95	6.06	6.12	0.06
Brianna Court	6.93	6.94	6.95	7.17	7.28	7.32	7.35	7.37	7.39	0.02
Brianna Court	6.85	6.87	6.90	7.17	7.28	7.32	7.35	7.37	7.39	0.02
Broomdykes Drive	5.16	5.16	5.17	5.27	5.42	5.46	5.54	5.59	5.64	0.06
Cabbtree1	8.10			8.12	8.15	8.20	8.22	8.28	8.34	0.06
Cabbtree2	7.43	7.89	7.94	8.05	8.10	8.15	8.19	8.25	8.32	0.07
Cabbtree3	7.41	7.87	7.92	8.05	8.10	8.15	8.19	8.25	8.32	0.07
Cabbtree4	7.52	7.83	7.88	8.00	8.04	8.09	8.14	8.22	8.30	0.08
Cabbtree5	7.30	7.75	7.80	7.93	7.98	8.03	8.07	8.15	8.24	0.09
Cabbtree6	7.19	7.41	7.44	7.57	7.65	7.72	7.76	7.89	8.01	0.12

Location	Lidar Elevation (mAHD)	Baseline 63.2% AEP PWSE (mAHD)	Baseline 50% AEP PWSE (mAHD)	Baseline 20% AEP PWSE (mAHD)	Baseline 10% AEP PWSE (mAHD)	Baseline 5% AEP PWSE (mAHD)	Baseline 2% AEP PWSE (mAHD)	Baseline 1% AEP PWSE (mAHD)	Baseline 1% AEP with CC (mAHD)	Increase to CC for 1% AEP event
Cabbtree7	7.01	7.36	7.41	7.57	7.65	7.71	7.75	7.85	7.94	0.09
Cabbtree8	2.88	3.56	3.64	3.86	4.00	4.13	4.22	4.36	4.40	0.04
Cambridge Avenue	6.51			6.57	6.68	6.73	6.78	6.83	6.93	0.09
Cambridge Avenue	6.12				6.23	6.39	6.62	6.76	6.91	0.15
Cambridge Avenue	6.47				6.48	6.50	6.62	6.77	6.92	0.15
Campbell Street	8.37	8.37	8.38	8.39	8.42	8.44	8.46	8.49	8.52	0.03
Campbell Street	7.11				7.13	7.23	7.34	7.43	7.55	0.11
Carbeen Street	6.17				6.20	6.26	6.40	6.48	6.56	0.07
Coles Road	6.66	6.91	6.97	7.05	7.08	7.10	7.13	7.17	7.21	0.05
Dale Court	8.73			8.74	8.82	8.85	8.89	8.95	9.00	0.05
Dapplewood Close	7.53			7.53	7.61	7.68	7.73	7.77	7.83	0.05
Dapplewood Close	7.45			7.53	7.61	7.68	7.73	7.77	7.83	0.05
Dapplewood Close	7.40	7.50	7.50	7.60	7.65	7.70	7.74	7.77	7.83	0.05
Davlyn Drive	8.45	8.50	8.52	8.58	8.63	8.66	8.71	8.76	8.81	0.06
Delma Street	5.26			5.31	5.38	5.42	5.49	5.53	5.58	0.05
Eaglemount Rd Us1	3.23	3.66	3.75	4.10	4.24	4.31	4.35	4.37	4.40	0.03
Elm Drive	7.23			7.34	7.46	7.57	7.64	7.71	7.76	0.05
Elm Drive	7.21	7.25	7.26	7.34	7.46	7.57	7.64	7.71	7.76	0.05
Farquhar Street	5.54	5.70	5.78	5.89	5.92	5.94	5.96	5.98	6.02	0.03
Fernleigh Avenue	8.13				8.16	8.18	8.24	8.27	8.33	0.05
Fleurs Way	7.61	7.75	7.76	7.79	7.81	7.89	7.97	8.04	8.15	0.10

Location	Lidar Elevation (mAHD)	Baseline 63.2% AEP PWSE (mAHD)	Baseline 50% AEP PWSE (mAHD)	Baseline 20% AEP PWSE (mAHD)	Baseline 10% AEP PWSE (mAHD)	Baseline 5% AEP PWSE (mAHD)	Baseline 2% AEP PWSE (mAHD)	Baseline 1% AEP PWSE (mAHD)	Baseline 1% AEP with CC (mAHD)	Increase to CC for 1% AEP event
Geoffrey Nolan Drive	7.40			7.42	7.52	7.59	7.65	7.71	7.77	0.07
Golflinks Road	3.21	3.38	3.43	3.63	3.72	3.81	3.92	4.00	4.12	0.12
Hartog Street	7.06	7.19	7.20	7.25	7.29	7.33	7.36	7.39	7.42	0.04
Hartog Street	7.29	7.30	7.32	7.36	7.37	7.39	7.41	7.43	7.46	0.03
Holts Road	4.73				5.38	5.56	5.64	5.70	5.76	0.06
Illawara Court	5.54		5.56	5.60	5.63	5.65	5.69	5.71	5.74	0.03
Investigator Street	6.95	6.96	6.97	7.00	7.02	7.04	7.08	7.10	7.12	0.03
Investigator Street	6.51		6.53	6.58	6.61	6.63	6.66	6.69	6.73	0.05
Investigator Street	5.97	6.00	6.03	6.15	6.21	6.24	6.28	6.31	6.35	0.04
Investigator Street	6.45				6.47	6.49	6.51	6.54	6.56	0.02
Ivy Drive	6.54		6.55	6.56	6.59	6.62	6.72	6.84	6.99	0.15
James Court	10.02				10.09	10.17	10.34	10.42	10.48	0.06
James Court	10.04				10.09	10.17	10.34	10.42	10.48	0.06
Jarrah Street	6.65				6.68	6.70	6.72	6.75	6.77	0.02
Karwin Drive	8.38						8.42	8.44	8.47	0.03
Krause Court	6.59	6.61	6.62	6.69	6.80	6.84	6.85	6.86	6.89	0.02
Lenesha Drive	7.23	7.26	7.35	7.47	7.50	7.52	7.53	7.55	7.56	0.02
Magellan Drive	6.66	6.73	6.73	6.76	6.88	6.92	7.00	7.06	7.12	0.06
Maguire Street	4.99			5.02	5.12	5.17	5.20	5.22	5.25	0.03
Maguire Street	4.57	4.72	4.74	4.77	4.81	4.85	4.91	4.94	4.97	0.03
Maguire Street	4.83					4.84	4.89	4.92	4.94	0.02
Mansfield1	3.72	4.23	4.31	4.52	4.61	4.72	4.81	4.89	4.99	0.10

Location	Lidar Elevation (mAHD)	Baseline 63.2% AEP PWSE (mAHD)	Baseline 50% AEP PWSE (mAHD)	Baseline 20% AEP PWSE (mAHD)	Baseline 10% AEP PWSE (mAHD)	Baseline 5% AEP PWSE (mAHD)	Baseline 2% AEP PWSE (mAHD)	Baseline 1% AEP PWSE (mAHD)	Baseline 1% AEP with CC (mAHD)	Increase to CC for 1% AEP event
Mansfield2	3.68	4.49	4.57	4.77	4.86	4.97	5.08	5.17	5.30	0.13
Mansfield3	3.73	4.52	4.63	4.93	5.07	5.16	5.25	5.31	5.41	0.10
Mansfield4	4.18	4.60	4.69	4.99	5.13	5.22	5.32	5.40	5.52	0.12
Mansfield5	4.37	4.62	4.71	5.00	5.13	5.22	5.32	5.40	5.52	0.12
Maple Drive	8.23				8.26	8.28	8.31	8.33	8.36	0.03
Mccready1	6.25			6.61	6.80	6.97	7.06	7.12	7.21	0.09
Mccready2	7.10							7.10	7.18	0.08
Mccready3	4.77	5.15	5.23	5.62	5.78	5.96	6.10	6.20	6.36	0.16
Mccready4	5.90							5.91	6.02	0.11
Mccready5	5.12			5.29	5.45	5.60	5.70	5.78	5.90	0.11
Mccready6	2.15	3.66	3.72	3.85	3.89	3.94	4.02	4.08	4.19	0.11
Mccready7	1.88	3.36	3.42	3.61	3.71	3.80	3.92	4.00	4.12	0.12
Monterrico Circuit	4.94	5.03	5.03	5.10	5.13	5.21	5.32	5.39	5.52	0.12
Monterrico Circuit	5.04	5.05	5.05	5.07	5.13	5.22	5.32	5.40	5.52	0.12
Oak Street	6.99			7.09	7.22	7.34	7.45	7.55	7.66	0.11
Oak Street	7.12				7.21	7.32	7.43	7.53	7.64	0.11
Oak Street	7.02						7.11	7.19	7.28	0.09
Oak Street	6.62						6.70	6.81	6.97	0.15
Oak Street	6.43					6.44	6.53	6.68	6.79	0.11
Oxford Court	6.25			6.57	6.67	6.73	6.78	6.83	6.92	0.09
Parkview Court	5.96			5.98	6.01	6.01	6.03	6.05	6.07	0.02
Pathway	7.95			8.00	8.05	8.09	8.15	8.20	8.27	0.07

Location	Lidar Elevation (mAHD)	Baseline 63.2% AEP PWSE (mAHD)	Baseline 50% AEP PWSE (mAHD)	Baseline 20% AEP PWSE (mAHD)	Baseline 10% AEP PWSE (mAHD)	Baseline 5% AEP PWSE (mAHD)	Baseline 2% AEP PWSE (mAHD)	Baseline 1% AEP PWSE (mAHD)	Baseline 1% AEP with CC (mAHD)	Increase to CC for 1% AEP event
Peatey Street	9.08	9.11	9.12	9.14	9.18	9.20	9.24	9.30	9.33	0.04
Petrea Court	7.47	7.76	7.78	7.80	7.81	7.82	7.84	7.85	7.87	0.02
Pine Street	8.52						8.54	8.56	8.58	0.02
Rail Us1	3.19		3.23	3.36	3.49	3.58	3.66	3.84	4.14	0.30
Raintree Court	8.32			8.38	8.45	8.52	8.55	8.58	8.60	0.02
Renae Street	5.24	5.30	5.32	5.36	5.41	5.46	5.52	5.55	5.57	0.03
Renae Street	5.06	5.29	5.31	5.36	5.41	5.46	5.52	5.55	5.59	0.04
Rhapis Court	5.25	5.48	5.49	5.52	5.53	5.54	5.57	5.59	5.63	0.04
Rhapis Court	5.42		5.43	5.45	5.47	5.47	5.51	5.54	5.58	0.04
Rhapis Court	5.22	5.48	5.50	5.52	5.53	5.54	5.57	5.59	5.62	0.03
Salmon Court	5.93	6.46	6.48	6.50	6.54	6.55	6.58	6.61	6.63	0.02
Selby Street	10.43			10.43	10.52	10.56	10.64	10.70	10.74	0.04
Shelley Court	7.30			7.35	7.46	7.57	7.64	7.71	7.76	0.05
Shiral Drive	7.81				7.98	8.04	8.14	8.20	8.23	0.04
Song Close	7.17				7.21	7.24	7.27	7.29	7.33	0.03
Tasman Court	7.12	7.17	7.21	7.25	7.27	7.28	7.30	7.31	7.34	0.03
Telina Drive	6.20	6.20	6.21	6.23	6.27	6.29	6.32	6.36	6.38	0.02
The Barons Drive	7.08	7.09	7.10	7.15	7.19	7.22	7.27	7.29	7.33	0.04
Tiffiny Court	7.06	7.08	7.08	7.18	7.29	7.33	7.36	7.38	7.41	0.03
Tiffiny Court	6.97	7.01	7.05	7.18	7.28	7.33	7.36	7.38	7.41	0.03
Tropical Avenue	8.11	8.12	8.13	8.16	8.24	8.28	8.33	8.38	8.43	0.05
Tropical Avenue	8.06	8.18	8.21	8.26	8.29	8.31	8.36	8.40	8.45	0.05

Location	Lidar Elevation (mAHD)	Baseline 63.2% AEP PWSE (mAHD)	Baseline 50% AEP PWSE (mAHD)	Baseline 20% AEP PWSE (mAHD)	Baseline 10% AEP PWSE (mAHD)	Baseline 5% AEP PWSE (mAHD)	Baseline 2% AEP PWSE (mAHD)	Baseline 1% AEP PWSE (mAHD)	Baseline 1% AEP with CC (mAHD)	Increase to CC for 1% AEP event
Tropical Avenue	8.03	8.18	8.21	8.26	8.29	8.31	8.36	8.39	8.44	0.05
Tropical Avenue	7.98	8.00	8.03	8.07	8.11	8.13	8.16	8.19	8.21	0.03
Tropical Avenue	7.01			7.13	7.23	7.34	7.45	7.55	7.67	0.12
Vicky Court	7.977				8.01	8.04	8.09	8.11	8.15	0.03
Waratah Street	5.445	5.56	5.60	5.67	5.71	5.72	5.76	5.79	5.82	0.03
Warrener Street	7.239				7.27	7.29	7.31	7.33	7.37	0.04
Whitney Street	7.75	7.76	7.78	7.82	7.88	7.91	7.97	8.01	8.07	0.05
Whitney Street	7.594		7.60	7.64	7.71	7.75	7.83	7.87	7.94	0.06

Table G2 Baseline Locational Depth Averaged Velocities (Refer Figure G1)

Location	Baseline 63.2% AEP Velocity (m/s)	Baseline 50% AEP Velocity (m/s)	Baseline 20% AEP Velocity (m/s)	Baseline 10% AEP Velocity (m/s)	Baseline 5% AEP Velocity (m/s)	Baseline 2% AEP Velocity (m/s)	Baseline 1% AEP Velocity (m/s)
Anderdrain1				0.2	0.2	0.2	0.2
Anderdrain2		0.1	0.1	0.1	0.2	0.2	0.2
Anderdrain3	0.09	0.1	0.2	0.3	0.4	0.4	0.4
Anderdrain4	0.05	0.1	0.1	0.1	0.2	0.2	0.2
Anderdrain5	0.03	0.0	0.1	0.2	0.2	0.2	0.2
Andermain1	0.25	0.3	0.3	0.3	0.3	0.3	0.4
Andermain10	1.02	1.1	1.3	1.4	1.4	1.5	1.6
Andermain11	1.09	1.2	1.5	1.6	1.6	1.7	1.7
Andermain12				0.2	0.3	0.4	0.5
Andermain13	0.78	0.9	1.1	1.2	1.3	1.4	1.5
Andermain2	0.08	0.1	0.1	0.1	0.1	0.1	0.1
Andermain3	0.28	0.3	0.3	0.3	0.3	0.3	0.3
Andermain4	0.46	0.5	0.6	0.6	0.6	0.6	0.6
Andermain5	0.37	0.4	0.5	0.6	0.6	0.6	0.6
Andermain6	0.35	0.4	0.5	0.5	0.6	0.6	0.6
Andermain7	0.42	0.5	0.6	0.6	0.7	0.7	0.7
Andermain8	0.49	0.6	0.7	0.7	0.7	0.7	0.7
Andermain9	0.70	0.8	0.9	0.9	0.9	1.0	1.0
Anderschool		0.1	0.1	0.2	0.2	0.2	0.2
Apollo Drive	0.05	0.1	0.1	0.2	0.2	0.2	0.3
Avocado Court	0.05	0.1	0.2	0.3	0.3	0.3	0.4
Avocado Court	0.15	0.2	0.2	0.3	0.3	0.4	0.4

Location	Baseline 63.2% AEP Velocity (m/s)	Baseline 50% AEP Velocity (m/s)	Baseline 20% AEP Velocity (m/s)	Baseline 10% AEP Velocity (m/s)	Baseline 5% AEP Velocity (m/s)	Baseline 2% AEP Velocity (m/s)	Baseline 1% AEP Velocity (m/s)
Avocado Court	0.03	0.0	0.1	0.1	0.1	0.2	0.2
Azalea Court		0.1	0.2	0.3	0.3	0.4	0.4
Barnfield Drive	0.06	0.1	0.1	0.1	0.1	0.2	0.2
Beaconsfield Rd Ds1	0.25	0.3	0.4	0.5	0.5	0.6	0.7
Beaconsfield Rd Ds2	0.02	0.0	0.0	0.1	0.1	0.1	0.1
Beaconsfield Rd Ds2	0.34	0.4	0.5	0.5	0.6	0.6	0.6
Beaconsfield Rd Us1	0.47	0.5	0.6	0.7	0.7	0.7	0.8
Beaconsfield Road			1.0	1.1	1.2	1.3	1.4
Blaxland Close	0.19	0.2	0.3	0.3	0.3	0.3	0.3
Brianna Court	0.11	0.1	0.1	0.1	0.1	0.2	0.2
Brianna Court	0.21	0.2	0.2	0.2	0.2	0.2	0.3
Broomdykes Drive	0.09	0.1	0.2	0.2	0.3	0.4	0.5
Cabbtree1			0.1	0.1	0.1	0.1	0.1
Cabbtree2	0.22	0.2	0.3	0.4	0.4	0.4	0.4
Cabbtree3	0.19	0.2	0.2	0.2	0.2	0.2	0.2
Cabbtree4	0.17	0.2	0.3	0.3	0.3	0.3	0.3
Cabbtree5	0.44	0.4	0.5	0.5	0.5	0.6	0.6
Cabbtree6	0.85	1.0	1.1	1.1	1.1	1.1	1.1
Cabbtree7	0.42	0.5	0.6	0.6	0.6	0.7	0.7
Cabbtree8	0.50	0.6	0.6	0.6	0.6	0.6	0.6
Cambridge Avenue			0.3	0.3	0.4	0.4	0.4
Cambridge Avenue				0.1	0.2	0.2	0.3
Cambridge Avenue						0.3	0.4

Location	Baseline 63.2% AEP Velocity (m/s)	Baseline 50% AEP Velocity (m/s)	Baseline 20% AEP Velocity (m/s)	Baseline 10% AEP Velocity (m/s)	Baseline 5% AEP Velocity (m/s)	Baseline 2% AEP Velocity (m/s)	Baseline 1% AEP Velocity (m/s)
Campbell Street	0.21	0.2	0.3	0.4	0.4	0.5	0.5
Campbell Street				0.6	0.8	0.9	1.0
Carbeen Street				0.1	0.1	0.2	0.2
Coles Road	0.18	0.2	0.2	0.2	0.2	0.2	0.3
Dale Court			0.4	0.6	0.7	0.7	0.8
Dapplewood Close			0.0	0.0	0.0	0.0	0.0
Dapplewood Close			0.0	0.0	0.0	0.1	0.1
Dapplewood Close	0.08	0.1	0.1	0.2	0.2	0.2	0.2
Davlyn Drive	0.09	0.1	0.1	0.2	0.2	0.2	0.2
Delma Street			0.4	0.5	0.5	0.6	0.6
Eaglemount Rd Us1	0.13	0.1	0.2	0.2	0.2	0.3	0.3
Elm Drive			0.0	0.1	0.1	0.1	0.1
Elm Drive	0.19	0.2	0.3	0.3	0.3	0.3	0.3
Farquhar Street	0.11	0.1	0.1	0.1	0.1	0.1	0.2
Fernleigh Avenue				0.1	0.1	0.2	0.1
Fleurs Way	0.12	0.2	0.3	0.4	0.5	0.6	0.7
Geoffrey Nolan Drive			0.1	0.2	0.3	0.4	0.3
Golflinks Road	1.20	1.3	1.4	1.4	1.5	1.5	1.5
Hartog Street	0.06	0.1	0.1	0.2	0.2	0.2	0.3
Hartog Street	0.24	0.3	0.4	0.4	0.4	0.5	0.5
Holts Road					0.8	1.0	1.2
Illawara Court		0.4	0.4	0.5	0.5	0.7	0.6
Investigator Street	0.44	0.5	0.7	1.0	1.1	1.4	1.5

Location	Baseline 63.2% AEP Velocity (m/s)	Baseline 50% AEP Velocity (m/s)	Baseline 20% AEP Velocity (m/s)	Baseline 10% AEP Velocity (m/s)	Baseline 5% AEP Velocity (m/s)	Baseline 2% AEP Velocity (m/s)	Baseline 1% AEP Velocity (m/s)
Investigator Street			0.4	0.5	0.5	0.7	0.8
Investigator Street	0.06	0.1	0.1	0.1	0.1	0.1	0.1
Investigator Street				0.3	0.3	0.4	0.5
Ivy Drive		0.1	0.2	0.3	0.5	0.6	0.6
James Court				0.0	0.1	0.1	0.1
James Court				0.1	0.1	0.1	0.1
Jarrah Street				0.8	0.8	0.9	0.9
Karwin Drive						0.2	0.2
Krause Court	0.09	0.1	0.1	0.1	0.1	0.1	0.1
Lenesha Drive	0.32	0.3	0.3	0.3	0.3	0.3	0.3
Magellan Drive	0.08	0.1	0.1	0.1	0.1	0.1	0.1
Maguire Street			0.2	0.3	0.3	0.3	0.3
Maguire Street	0.09	0.1	0.1	0.2	0.2	0.2	0.2
Maguire Street					0.0	0.1	0.2
Mansfield1	0.35	0.4	0.5	0.5	0.6	0.6	0.7
Mansfield2	0.27	0.3	0.3	0.4	0.5	0.5	0.5
Mansfield3	0.32	0.3	0.4	0.4	0.5	0.5	0.6
Mansfield4	0.55	0.5	0.6	0.6	0.6	0.6	0.6
Mansfield5	0.29	0.3	0.3	0.3	0.3	0.4	0.4
Maple Drive				0.3	0.3	0.4	0.4
Mccready1							
Mccready2							0.9
Mccready3	0.30	0.3	0.5	0.6	0.6	0.7	0.7

Location	Baseline 63.2% AEP Velocity (m/s)	Baseline 50% AEP Velocity (m/s)	Baseline 20% AEP Velocity (m/s)	Baseline 10% AEP Velocity (m/s)	Baseline 5% AEP Velocity (m/s)	Baseline 2% AEP Velocity (m/s)	Baseline 1% AEP Velocity (m/s)
Mccready4							1.0
Mccready5			0.6	0.6	0.7	0.8	0.9
Mccready6	0.32	0.4	0.4	0.5	0.5	0.5	0.5
Mccready7	0.64	0.7	0.8	0.8	0.9	0.9	0.9
Monterrico Circuit	0.05	0.1	0.2	0.3	0.3	0.4	0.3
Monterrico Circuit	0.08	0.1	0.1	0.2	0.2	0.3	0.3
Oak Street			0.3	0.3	0.3	0.4	0.5
Oak Street				0.2	0.3	0.4	0.4
Oak Street						0.7	0.9
Oak Street						1.2	1.4
Oak Street					0.3	0.5	0.7
Oxford Court			0.1	0.1	0.1	0.2	0.2
Parkview Court			0.1	0.2	0.2	0.3	0.4
Pathway			0.4	0.5	0.5	0.5	0.6
Peatey Street	0.22	0.3	0.3	0.4	0.5	0.6	0.5
Petrea Court	0.03	0.0	0.1	0.1	0.1	0.1	0.1
Pine Street						0.4	0.5
Rail Us1		0.3	0.4	0.5	0.6	0.6	0.6
Raintree Court			0.0	0.0	0.0	0.0	0.0
Renae Street	0.04	0.0	0.1	0.1	0.1	0.1	0.1
Renae Street	0.12	0.1	0.1	0.2	0.2	0.2	0.2
Rhapis Court	0.03	0.0	0.1	0.1	0.1	0.1	0.1
Rhapis Court		0.2	0.2	0.3	0.3	0.3	0.4

Location	Baseline 63.2% AEP Velocity (m/s)	Baseline 50% AEP Velocity (m/s)	Baseline 20% AEP Velocity (m/s)	Baseline 10% AEP Velocity (m/s)	Baseline 5% AEP Velocity (m/s)	Baseline 2% AEP Velocity (m/s)	Baseline 1% AEP Velocity (m/s)
Rhapis Court	0.06	0.1	0.1	0.1	0.1	0.1	0.1
Salmon Court	0.04	0.0	0.1	0.1	0.1	0.1	0.1
Selby Street			0.2	0.2	0.2	0.1	0.1
Shelley Court			0.3	0.4	0.4	0.5	0.4
Shiral Drive				0.2	0.2	0.2	0.2
Song Close				0.3	0.3	0.3	0.3
Tasman Court	0.18	0.2	0.2	0.3	0.3	0.4	0.4
Telina Drive	0.47	0.5	0.6	0.6	0.7	0.7	0.7
The Barons Drive			0.6	0.9	1.0	1.2	1.3
Tiffiny Court	0.09	0.1	0.0	0.1	0.1	0.1	0.1
Tiffiny Court	0.13	0.2	0.2	0.2	0.2	0.3	0.3
Tropical Avenue				0.3	0.3	0.3	0.4
Tropical Avenue	0.05	0.1	0.1	0.1	0.1	0.1	0.1
Tropical Avenue	0.07	0.1	0.1	0.1	0.1	0.2	0.2
Tropical Avenue	0.07	0.1	0.1	0.2	0.2	0.2	0.3
Tropical Avenue			0.2	0.2	0.3	0.3	0.4
Vicky Court				0.2	0.1	0.1	0.2
Waratah Street	0.04	0.1	0.2	0.3	0.3	0.4	0.4
Warrener Street				0.3	0.3	0.4	0.5
Whitney Street	0.26	0.3	0.4	0.5	0.5	0.5	0.6
Whitney Street		0.1	0.1	0.2	0.2	0.3	0.3

Table G3 Baseline Locational Peak Flows (Refer Figure G2)

Drain Name	Location	Reference	Baseline 50% AEP flow (m3/s)	Baseline 20% AEP flow (m3/s)	Baseline 1% AEP flow (m3/s)
Coles Road	PO_77		0.5	0.9	2.5
	PO_76	Hartog Street	0.0	0.1	1.6
	PO_34		0.7	1.3	3.3
	PO_35		1.2	2.3	5.3
	PO_36	Coles Road	0.8	2.1	5.7
Oak street	PO_25		0.1	0.3	1.9
	PO_26		0.1	0.5	3.4
	PO_27		0.2	0.6	4.3
	PO_28	Oak Street	0.1	0.9	3.0
	PO_29	Oak Street	0.0	0.5	6.0
	PO_30	Oak Street	0.0	0.2	6.8
	PO_31	Oak Street	0.1	0.2	6.8
	PO_32	Oak Street	0.0	0.0	3.5
Tropical Avenue Park - Nardarmi Drive	DrainUS	Tropical Avenue park	0.9	1.3	2.1
	PO_24	Fleurs Way upstream	1.1	1.8	3.3
	PO_23	Fleurs Way downstream	1.6	2.7	5.7
	PO_22		1.6	2.9	5.9
	PO_21		2.1	3.8	8.4
	PO_20	Fernleigh Avenue upstream	3.4	5.9	11.1
	PO_19		4.5	7.2	12.6
	PO_18	Nadarmi Drive upstream	3.8	7.3	14.6
	PO_17		6.8	11.4	21.2
	DrainDS		6.9	11.4	20.6

Drain Name	Location	Reference	Baseline 50% AEP flow (m3/s)	Baseline 20% AEP flow (m3/s)	Baseline 1% AEP flow (m3/s)
Newton Street - Caledonian Drive	PO_61		0.2	0.6	2.2
	PO_13	Newton Street upstream	1.1	1.5	2.8
	PO_14	Newton Street downstream	0.0	0.1	1.6
	PO_15		0.0	0.1	1.7
	Po_12		1.8	2.7	6.1
	PO_11		3.8	6.4	15.0
	PO_8	Caledonian Drive	0.0	0.0	0.2
McCreadys Creek	PO_47	Downstream of Mackay Bucasia Road	3.4	6.1	14.8
	PO_48	Downstream of Mackay Bucasia Road	0.0	0.9	9.5
	PO_49		20.9	34.9	61.8
	PO_1		26.2	47.5	93.5
	PO_2	Holts Road	0.0	0.0	33.6
	PO_3		26.2	47.4	89.9
	PO_56		23.0	40.2	78.7
	PO_4	Beaconsfield Road	7.2	21.3	51.2
	PO_56		23.0	40.2	78.7
	PO_5	Golf Links Road	31.3	47.7	75.3
Cabbage Tree Road	PO_63		0.3	0.4	1.0
	PO_64		0.5	0.9	1.8
	PO_65		0.9	1.4	2.9
	PO_66		1.4	2.2	3.9
	PO_67		0.2	0.8	2.4
	PO_68		1.7	2.8	5.1
	PO_69		1.8	2.9	5.3

Table G4 Baseline Major Road Reference Immunity (Refer Figure G3)

Street	Baseline 1EY Depths (m)	Baseline 50% AEP Depths (m)	Baseline 20% AEP Depths (m)	Baseline 10% AEP Depths (m)	Baseline 5% AEP Depths (m)	Baseline 2% AEP Depths (m)	Baseline 1% AEP Depths (m)
Beaconsfield Road		0.03	0.12	0.15	0.17	0.20	0.22
Broomdykes Road			0.06	0.25	0.29	0.37	0.42
Cabbage Tree Road				0.00	0.00	0.00	0.00
Caledonian Drive	0.04	0.05	0.05	0.06	0.06	0.09	0.11
Celeber Drive 1	0.03	0.04	0.43	0.50	0.58	0.62	0.66
Celeber Drive 2		0.02	0.06	0.10	0.12	0.14	0.18
Celeber Drive 3				0.03	0.10	0.18	0.23
Coles Road	0.32	0.37	0.46	0.48	0.51	0.54	0.57
Eaglemount Road							
Fernleigh Avenue							
Fluers Way	0.02	0.03	0.06	0.07	0.16	0.24	0.31
Golf Links Road	0.23	0.28	0.49	0.60	0.70	0.81	0.89
Holts Road 1			0.03	0.08	0.10	0.13	0.18
Holts Road 2					0.02	0.09	0.14
Keeleys Road		0.01	0.04	0.07	0.10	0.13	0.18
Mansfield Drive 1		0.02	0.12	0.16	0.17	0.19	0.21
Mansfield Drive 2	0.02	0.02	0.03	0.07	0.12	0.16	0.19
Maple Drive 1			0.03	0.06	0.08	0.11	0.13
Maple Drive 2				0.04	0.06	0.10	0.12
Nadarmi Drive				0.00	0.01	0.04	0.08
Newton Street	0.15	0.18	0.27	0.37	0.42	0.51	0.56
Nicklin Drive	0.02	0.02	0.04	0.07	0.08	0.10	0.12

Street	Baseline 1EY Depths (m)	Baseline 50% AEP Depths (m)	Baseline 20% AEP Depths (m)	Baseline 10% AEP Depths (m)	Baseline 5% AEP Depths (m)	Baseline 2% AEP Depths (m)	Baseline 1% AEP Depths (m)
Oak Street 1			0.12	0.26	0.37	0.48	0.58
Oak Street 2			0.01	0.08	0.21	0.32	0.42
Oak Street 3					0.07	0.18	0.26
Oak Street 4						0.09	0.25
Tropical Avenue 1	0.03	0.05	0.08	0.16	0.20	0.26	0.31
Tropical Avenue 2	0.13	0.15	0.20	0.23	0.25	0.30	0.34
Tropical Avenue 3	0.03	0.05	0.10	0.14	0.15	0.19	0.21

Table G5 Pipes with Outlet Elevations Below MHWS (2.35mAHD)

ID	Culvert Details	Street/Location	U/S Invert	D/S Invert
106694	675 CC	Apsley Way	2.773	2.163
146485	1200 CC	3/RP811171	2.654	2.180
62286	2/675 CC	Apsley Way	2.978	2.219
63238	600 CC	Carbeen Street Park	3.370	2.332
70728	900 CC	Maguire Street	2.902	2.330
85874	525 CC	7/RP869350	2.050	2.050
96804	3/525 CC	7/RP869350	2.600	2.050

Table G6 Pipes with Outlet Elevations Below HAT (3.64mAHD)

ID	Culvert Details	Street	U/S Invert	D/S Invert
105548	2/900 CC	EMPEROR DRIVE	3.270	2.579
105954	2/1200 CC	318/SP178804	3.091	2.500
106694	675 CC	APSLEY WAY	2.773	2.163
127042	750 CC	TRAMONTANA PARK	3.188	3.144
139452	900 CC	100/SP168452	3.444	3.405
146485	1200 CC	3/RP811171	2.654	2.180
149224	11/1200x600 RC	187/CI3946	3.150	3.120
364055	1200 CC	23/RP734612	4.596	3.097
364067	375 CC	23/RP734612	3.900	3.545
390047	375 CC	22/RP734613	2.680	2.435
396566	375 CC	902/SP252787	3.673	3.527
396575	375 CC	902/SP252787	3.535	3.452
396577	450 CC	MONTERRICO CIRCUIT	3.870	3.590
396581	600 CC	MONTERRICO CIRCUIT	3.670	3.599
397886	3/825 CC	MONTERRICO CIRCUIT	3.579	3.500
397891	2/1050 CC	37/SP249168	3.454	3.012
397894	2/825 CC	902/SP252787	3.230	3.030
62286	2/675 CC	APSLEY WAY	2.978	2.219
62288	2/1200 CC	APSLEY WAY	2.770	2.670
62488	12/1200 CC	BEACONSFIELD ROAD EAST	3.100	3.000
62497	7/1200 CC	BEACONSFIELD ROAD EAST	3.580	3.200

ID	Culvert Details	Street	U/S Invert	D/S Invert
63238	600 CC	CARBEEN STREET PARK	3.370	2.332
63801	450 CC	EAGLEMOUNT ROAD	3.120	2.927
64361	750 CC	GILLHAMS PARK	3.424	3.350
65053	750 CC	38/RP734647	4.300	3.400
65381	750 CC	KIMBERLEY STREET	3.221	3.200
66263	2/900 CC	12/RP892821	3.100	3.075
66277	600 CC	900/RP858183	3.247	3.100
66364	675 CC	57/RP741469	3.450	3.440
70040	1050 CC	BEDFORD ROAD	3.800	2.450
70076	2/525 CC	CULLODEN PLACE	3.750	2.700
70080	2/1050 CC	12/RP892821	2.792	2.479
70117	3/900 CC	900/RP858183	3.300	2.410
70122	1050 CC	12/RP892821	3.200	3.075
70149	1050 CC	BEN NEVIS STREET	3.388	2.787
70600	750 CC	34/RP814160	4.287	3.350
70726	450 CC	4/RP732846	3.143	3.063
70728	900 CC	MAGUIRE STREET	2.902	2.330
71184	825 CC	MAGUIRE STREET	3.215	3.050
71242	3/1200x1550 RC	ANDERGROVE ROAD	3.645	3.452
71359	930 CC	RENAE STREET	3.410	3.390
71365	375 CC	ZAMIA COURT	3.447	2.850
71403	900 CC	NADARMI DRIVE	4.034	2.550

ID	Culvert Details	Street	U/S Invert	D/S Invert
71476	900 CC	EAGLEMOUNT ROAD	3.566	2.977
71477	375 CC	ROAD	2.992	2.897
79927	525 CC	CAMERON STREET	3.483	3.450
85665	900 CC	908/SP100960	3.563	3.421
85667	750 CC	1/SP249155	3.280	3.221
85874	525 CC	7/RP869350	2.050	2.050
86071	4/2400x1200 RC	CALEDONIAN DRIVE	3.100	2.900
96804	3/525 CC	7/RP869350	2.600	2.050
A10249	375 CC	HOLTS ROAD	3.631	3.521
A10250	375 CC	803/SP249178	3.540	3.430
A13735	600 CC	800/SP249350	3.751	3.588
A13974	750 CC	800/SP249350	3.400	3.356
A14637	2/600 CC	902/SP252787	3.400	3.040
A16796	525 CC	902/SP252787	3.360	2.550
A16801	525 CC	902/SP252787	3.390	2.850
A17132	2400 CC	901/SP252741	3.250	3.240
A4200	1350 CC	901/SP252741	3.450	3.250
A4236	750 CC	73/SP252741	3.750	2.648
A4453	1050 CC	902/SP252787	3.277	3.270
A5514	825 CC	800/SP249350	4.040	3.096
A5530	600 CC	800/SP249350	3.708	3.462
A5546	825 CC	800/SP249350	3.296	3.260

ID	Culvert Details	Street	U/S Invert	D/S Invert
A5563	825 CC	800/SP249350	3.557	3.500
Brmdyk	3/1200x300 RC		3.280	3.160
Brmdyk2	300 CC		3.750	3.550
Eagle1	8/600 CC	EAGLEMOUNT ROAD	3.000	2.950
Eagle2	3100x1500 RC	902/SP252787	4.500	2.880
MIRA_FLOR	3/2700x1200 RC		3.300	3.200
SDR261445	1200x1550 RC	KEELEYS ROAD	4.150	3.500
SDR262106	1200 CC	MCMAHON STREET	3.776	3.635
SDR262110	450 CC	MCMAHON STREET	5.378	2.639
SDR262120	675 CC	ROAD	3.202	2.997
SDR262121	2/675 CC	GLENPARK STREET	3.556	3.173
SDR262277	450 CC	901/SP252741	3.380	3.300
SDR262282	450 CC	901/SP252741	3.380	3.300
SDR262481	900 CC	12/SP111341	3.390	3.350
SDR263497	450 CC	12/RP892821	2.900	2.700
SDR263500	2/450 CC	12/RP892821	2.960	2.800
SDR263503	2400x1200 RC	CALEDONIAN DRIVE	3.480	2.900
SDR263504	2400x1200 RC	CALEDONIAN DRIVE	3.030	2.900
SDR264663	3/1200x900 RC	801/SP249168	3.600	3.500
SDR357337	1350 CC	902/SP252787	3.000	2.920
Soccer	4/1200x400 RC		2.700	2.300

Appendix H

Mitigated Options Summary

Appendix H Mitigated Options Summary

Table H1 Legend for Mitigated Options Summary

Legend	
	Results **higher** than relative baseline results
	Results **lower** than relative baseline results

Table H2 Mitigated Scenario Locational Peak Water Surface Elevations (Refer Figure G1)

Location	Lidar Elevation (mAHD)	M03 63.2% AEP PWSE (mAHD)	M03 50% AEP PWSE (mAHD)	M03 20% AEP PWSE (mAHD)	M03 10% AEP PWSE (mAHD)	M03 5% AEP PWSE (mAHD)	M03 2% AEP PWSE (mAHD)	M03 1% AEP PWSE (mAHD)
Anderdrain1	7.41				7.47	7.54	7.61	7.67
Anderdrain2	7.08		7.08	7.25	7.34	7.44	7.53	7.61
Anderdrain3	6.97	7.10	7.11	7.24	7.33	7.43	7.52	7.60
Anderdrain4	6.63	7.08	7.09	7.18	7.29	7.40	7.50	7.58
Anderdrain5	6.66	7.07	7.08	7.15	7.27	7.37	7.47	7.56
Andermain1	7.30	7.60	7.62	7.73	7.81	7.91	8.00	8.06
Andermain10	5.86	6.27	6.33	6.45	6.48	6.53	6.58	6.61
Andermain11	4.25	4.57	4.64	4.81	4.90	5.01	5.11	5.24
Andermain12	5.17	5.25	5.26	5.26	5.29	5.31	5.34	5.38
Andermain13	3.21	3.87	3.94	4.07	4.13	4.17	4.21	4.23
Andermain2	6.58	7.50	7.56	7.72	7.81	7.91	8.00	8.06
Andermain3	6.91	7.45	7.52	7.71	7.80	7.90	7.99	8.06
Andermain4	6.59	7.22	7.33	7.55	7.64	7.74	7.84	7.94
Andermain5	6.45	7.06	7.18	7.41	7.50	7.61	7.71	7.82
Andermain6	6.26	7.02	7.14	7.36	7.45	7.56	7.66	7.78
Andermain7	6.35	6.90	7.01	7.24	7.32	7.43	7.55	7.67
Andermain8	5.93	6.76	6.87	7.10	7.18	7.31	7.45	7.59
Andermain9	5.90	6.68	6.76	6.91	6.96	7.01	7.07	7.12
Anderschool	8.18			8.20	8.27	8.30	8.36	8.40
Apollo Drive	4.55	4.60	4.60	4.61	4.68	4.72	4.76	4.79
Avocado Court	5.36			5.38	5.42	5.45	5.52	5.58
Avocado Court	5.10	5.30	5.32	5.38	5.42	5.45	5.52	5.58

Location	Lidar Elevation (mAHD)	M03 63.2% AEP PWSE (mAHD)	M03 50% AEP PWSE (mAHD)	M03 20% AEP PWSE (mAHD)	M03 10% AEP PWSE (mAHD)	M03 5% AEP PWSE (mAHD)	M03 2% AEP PWSE (mAHD)	M03 1% AEP PWSE (mAHD)
Avocado Court	5.15	5.30	5.32	5.38	5.42	5.46	5.55	5.62
Azalea Court	5.57			5.63	5.69	5.72	5.78	5.82
Barnfield Drive	5.75	6.00	6.03	6.10	6.16	6.26	6.34	6.39
Beaconsfield Rd Ds1	2.76	3.51	3.59	3.77	3.94	4.03	4.09	4.18
Beaconsfield Rd Ds2	3.47	4.01	4.07	4.29	4.39	4.49	4.61	4.75
Beaconsfield Rd Ds2	3.18	3.79	3.85	4.09	4.21	4.30	4.40	4.50
Beaconsfield Rd Us1	3.15	3.61	3.69	3.87	4.06	4.18	4.27	4.43
Beaconsfield Road	4.41			4.45	4.49	4.52	4.55	4.57
Blaxland Close	5.69	5.72	5.73	5.74	5.75	5.80	5.96	6.06
Brianna Court	6.93	6.94	6.94	7.17	7.28	7.32	7.35	7.37
Brianna Court	6.85		6.86	7.17	7.28	7.32	7.35	7.37
Broomdykes Drive	5.16			5.18	5.40	5.45	5.53	5.58
Cabbtree1	8.10				8.15	8.19	8.23	8.27
Cabbtree2	7.43	7.82	7.90	8.00	8.06	8.11	8.17	8.22
Cabbtree3	7.41	7.81	7.88	7.99	8.06	8.11	8.16	8.22
Cabbtree4	7.52	7.77	7.84	7.94	8.00	8.05	8.11	8.18
Cabbtree5	7.30	7.65	7.73	7.85	7.92	7.97	8.02	8.10
Cabbtree6	7.19	7.28	7.33	7.44	7.55	7.62	7.70	7.79
Cabbtree7	7.01	7.24	7.30	7.43	7.56	7.63	7.70	7.78
Cabbtree8	2.88	3.61	3.73	3.92	4.11	4.23	4.36	4.39
Cambridge Avenue	6.51							6.60
Cambridge Avenue	6.12					6.23	6.48	6.62
Cambridge Avenue	6.47				6.47	6.49	6.52	6.62
Campbell Street	8.37	8.37	8.38	8.39	8.42	8.44	8.46	8.49
Campbell Street	7.11				7.16	7.26	7.35	7.44
Carbeen Street	6.17					6.21	6.37	6.47
Coles Road	6.66					6.70	6.94	7.04
Dale Court	8.73				8.83	8.85	8.90	8.95
Dapplewood Close	7.53			7.54	7.62	7.69	7.74	7.77
Dapplewood Close	7.45			7.54	7.62	7.69	7.73	7.77
Dapplewood Close	7.40	7.40	7.43	7.60	7.65	7.70	7.74	7.78

Location	Lidar Elevation (mAHD)	M03 63.2% AEP PWSE (mAHD)	M03 50% AEP PWSE (mAHD)	M03 20% AEP PWSE (mAHD)	M03 10% AEP PWSE (mAHD)	M03 5% AEP PWSE (mAHD)	M03 2% AEP PWSE (mAHD)	M03 1% AEP PWSE (mAHD)
Davlyn Drive	8.45	8.48	8.52	8.57	8.63	8.66	8.71	8.76
Delma Street	5.26			5.26	5.34	5.40	5.48	5.52
Eaglemount Rd Us1	3.23	3.68	3.79	4.11	4.24	4.31	4.35	4.37
Elm Drive	7.23			7.36	7.47	7.59	7.65	7.71
Elm Drive	7.21	7.22	7.22	7.36	7.47	7.59	7.65	7.71
Farquhar Street	5.54	5.55	5.55	5.56	5.62	5.71	5.86	5.91
Fernleigh Avenue	8.13				8.14	8.17	8.22	8.26
Fleurs Way	7.61	7.74	7.75	7.79	7.80	7.89	7.97	8.04
Geoffrey Nolan Drive	7.40			7.40	7.52	7.58	7.65	7.70
Golflinks Road	3.21	3.38	3.43	3.63	3.72	3.81	3.92	4.00
Hartog Street	7.06	7.13	7.14	7.20	7.23	7.27	7.34	7.38
Hartog Street	7.29	7.30	7.32	7.36	7.37	7.38	7.41	7.43
Holts Road	4.73				5.38	5.56	5.64	5.70
Illawara Court	5.54	5.56	5.56	5.57	5.60	5.62	5.66	5.69
Investigator Street	6.95			6.99	7.02	7.04	7.07	7.09
Investigator Street	6.51		6.52	6.57	6.61	6.63	6.66	6.69
Investigator Street	5.97	5.98	5.98	6.13	6.20	6.23	6.28	6.31
Investigator Street	6.45				6.47	6.48	6.51	6.53
Ivy Drive	6.54			6.54	6.56	6.58	6.64	6.77
James Court	10.02				10.03	10.14	10.35	10.42
James Court	10.04					10.14	10.35	10.42
Jarrah Street	6.65				6.67	6.69	6.71	6.74
Karwin Drive	8.38						8.41	8.43
Krause Court	6.59	6.60	6.61	6.73	6.82	6.85	6.86	6.87
Lenesha Drive	7.23	7.24	7.35	7.48	7.51	7.52	7.54	7.55
Magellan Drive	6.66				6.85	6.90	6.99	7.05
Maguire Street	4.99				5.07	5.16	5.20	5.22
Maguire Street	4.57	4.72	4.73	4.75	4.79	4.82	4.89	4.94
Maguire Street	4.83						4.88	4.92
Mansfield1	3.72	4.28	4.36	4.53	4.62	4.72	4.81	4.89
Mansfield2	3.68	4.53	4.62	4.77	4.87	4.96	5.06	5.16

Location	Lidar Elevation (mAHD)	M03 63.2% AEP PWSE (mAHD)	M03 50% AEP PWSE (mAHD)	M03 20% AEP PWSE (mAHD)	M03 10% AEP PWSE (mAHD)	M03 5% AEP PWSE (mAHD)	M03 2% AEP PWSE (mAHD)	M03 1% AEP PWSE (mAHD)
Mansfield3	3.73	4.57	4.68	4.90	5.04	5.12	5.21	5.29
Mansfield4	4.18	4.63	4.73	4.95	5.08	5.17	5.27	5.36
Mansfield5	4.37	4.67	4.76	4.95	5.09	5.17	5.27	5.36
Maple Drive	8.23				8.25	8.27	8.31	8.33
Mccready1	6.25			6.61	6.80	6.97	7.06	7.12
Mccready2	6.00		6.10	6.61	6.80	6.96	7.05	7.10
Mccready3	4.77	5.15	5.23	5.62	5.78	5.96	6.10	6.20
Mccready4	5.90							5.91
Mccready5	5.12			5.29	5.45	5.60	5.70	5.78
Mccready6	2.15	3.66	3.72	3.85	3.89	3.94	4.02	4.08
Mccready7	1.88	3.36	3.42	3.61	3.71	3.80	3.92	4.00
Monterrico Circuit	4.94	4.95	4.96	4.97	4.98	5.09	5.26	5.35
Monterrico Circuit	5.04	5.05	5.05	5.06	5.09	5.16	5.27	5.36
Oak Street	6.99			7.13	7.25	7.36	7.46	7.55
Oak Street	7.12				7.24	7.34	7.44	7.53
Oak Street	7.02						7.11	7.18
Oak Street	6.62						6.63	6.75
Oak Street	6.43							6.56
Oxford Court	6.25					6.30	6.42	6.59
Parkview Court	5.96			5.98	6.00	6.01	6.02	6.05
Pathway	7.95			7.98	8.04	8.07	8.13	8.18
Peatey Street	9.08			9.12	9.19	9.21	9.24	9.29
Petrea Court	7.47	7.76	7.78	7.80	7.81	7.82	7.84	7.85
Pine Street	8.52						8.52	8.55
Rail Us1	3.19		3.23	3.37	3.50	3.59	3.67	3.85
Raintree Court	8.32			8.40	8.47	8.53	8.56	8.58
Renae Street	5.24	5.27	5.30	5.34	5.38	5.43	5.51	5.54
Renae Street	5.06	5.21	5.24	5.31	5.37	5.42	5.50	5.54
Rhapis Court	5.25	5.48	5.49	5.51	5.53	5.54	5.57	5.59
Rhapis Court	5.42		5.42	5.45	5.46	5.47	5.50	5.53
Rhapis Court	5.22	5.48	5.50	5.52	5.53	5.54	5.57	5.59

Location	Lidar Elevation (mAHD)	M03 63.2% AEP PWSE (mAHD)	M03 50% AEP PWSE (mAHD)	M03 20% AEP PWSE (mAHD)	M03 10% AEP PWSE (mAHD)	M03 5% AEP PWSE (mAHD)	M03 2% AEP PWSE (mAHD)	M03 1% AEP PWSE (mAHD)
Salmon Court	5.93	6.46	6.48	6.50	6.54	6.55	6.58	6.61
Selby Street	10.43				10.48	10.52	10.60	10.68
Shelley Court	7.30			7.37	7.47	7.59	7.65	7.71
Shiral Drive	7.81				7.96	8.03	8.13	8.20
Song Close	7.17				7.20	7.23	7.27	7.29
Tasman Court	7.12		7.12	7.21	7.25	7.26	7.29	7.30
Telina Drive	6.20				6.24	6.26	6.30	6.35
The Barons Drive	7.08		7.09	7.14	7.19	7.22	7.27	7.29
Tiffiny Court	7.06	7.08	7.08	7.18	7.29	7.33	7.36	7.38
Tiffiny Court	6.97	6.99	7.04	7.18	7.28	7.33	7.36	7.38
Tropical Avenue	8.11		8.12	8.15	8.23	8.27	8.33	8.38
Tropical Avenue	8.06	8.18	8.21	8.26	8.29	8.31	8.36	8.40
Tropical Avenue	8.03	8.18	8.21	8.26	8.29	8.31	8.36	8.39
Tropical Avenue	7.98	8.00	8.02	8.07	8.11	8.13	8.16	8.18
Tropical Avenue	7.01		7.01	7.14	7.26	7.37	7.47	7.55
Vicky Court	7.977				8.01	8.04	8.08	8.11
Waratah Street	5.445	5.48	5.53	5.62	5.67	5.70	5.74	5.77
Warrener Street	7.239				7.27	7.29	7.32	7.34
Whitney Street	7.75		7.77	7.81	7.87	7.90	7.95	8.00
Whitney Street	7.594			7.63	7.71	7.74	7.81	7.86

Table H3 Mitigated Scenario Locational Depth Averaged Velocities (Refer Figure G1)

Location	Baseline 63.2% AEP Velocity (m/s)	Baseline 50% AEP Velocity (m/s)	Baseline 20% AEP Velocity (m/s)	Baseline 10% AEP Velocity (m/s)	Baseline 5% AEP Velocity (m/s)	Baseline 2% AEP Velocity (m/s)	Baseline 1% AEP Velocity (m/s)
Anderdrain1				0.2	0.2	0.2	0.2
Anderdrain2		0.1	0.1	0.2	0.2	0.2	0.2
Anderdrain3	0.16	0.2	0.2	0.3	0.3	0.4	0.4
Anderdrain4	0.07	0.1	0.1	0.2	0.2	0.2	0.2
Anderdrain5	0.05	0.1	0.2	0.2	0.2	0.3	0.3
Andermain1	0.24	0.3	0.3	0.3	0.3	0.4	0.4
Andermain10	1.03	1.1	1.3	1.4	1.4	1.5	1.6
Andermain11	1.08	1.2	1.5	1.6	1.6	1.7	1.7
Andermain12					0.3	0.4	0.5
Andermain13	0.79	0.9	1.1	1.2	1.3	1.4	1.5
Andermain2	0.08	0.1	0.1	0.1	0.1	0.1	0.1
Andermain3	0.27	0.3	0.3	0.3	0.3	0.3	0.3
Andermain4	0.46	0.5	0.6	0.6	0.6	0.6	0.6
Andermain5	0.35	0.4	0.5	0.6	0.6	0.6	0.6
Andermain6	0.35	0.4	0.5	0.5	0.6	0.6	0.6
Andermain7	0.42	0.5	0.6	0.6	0.7	0.7	0.7
Andermain8	0.49	0.6	0.7	0.7	0.7	0.7	0.7
Andermain9	0.70	0.8	0.9	0.9	0.9	1.0	1.0
Anderschool			0.1	0.1	0.1	0.2	0.2
Apollo Drive	0.04	0.1	0.1	0.2	0.2	0.3	0.2
Avocado Court			0.1	0.1	0.2	0.3	0.3
Avocado Court	0.04	0.0	0.1	0.2	0.2	0.3	0.3
Avocado Court	0.02	0.0	0.1	0.1	0.1	0.1	0.1
Azalea Court			0.1	0.2	0.3	0.3	0.4
Barnfield Drive	0.06	0.1	0.1	0.1	0.1	0.2	0.2
Beaconsfield Rd Ds1	0.25	0.3	0.4	0.5	0.5	0.6	0.7
Beaconsfield Rd Ds2	0.02	0.0	0.0	0.1	0.1	0.1	0.1
Beaconsfield Rd Ds2	0.34	0.4	0.5	0.5	0.6	0.6	0.6
Beaconsfield Rd Us1	0.47	0.5	0.6	0.7	0.7	0.7	0.7
Beaconsfield Road			1.0	1.1	1.2	1.3	1.4

Location	Baseline 63.2% AEP Velocity (m/s)	Baseline 50% AEP Velocity (m/s)	Baseline 20% AEP Velocity (m/s)	Baseline 10% AEP Velocity (m/s)	Baseline 5% AEP Velocity (m/s)	Baseline 2% AEP Velocity (m/s)	Baseline 1% AEP Velocity (m/s)
Blaxland Close		0.2	0.3	0.3	0.2	0.3	0.3
Brianna Court	0.10	0.1	0.2	0.2	0.2	0.2	0.2
Brianna Court		0.2	0.3	0.2	0.3	0.3	0.3
Broomdykes Drive			0.3	0.3	0.3	0.4	0.5
Cabbtree1				0.1	0.1	0.1	0.1
Cabbtree2	0.16	0.2	0.3	0.4	0.3	0.4	0.4
Cabbtree3	0.25	0.2	0.3	0.3	0.3	0.3	0.3
Cabbtree4		0.3	0.3	0.4	0.4	0.4	0.4
Cabbtree5	0.36	0.4	0.5	0.5	0.5	0.6	0.6
Cabbtree6	0.66	0.8	1.0	1.1	1.1	1.1	1.1
Cabbtree7	0.27	0.4	0.5	0.5	0.6	0.6	0.7
Cabbtree8	0.55	0.6	0.6	0.6	0.6	0.6	0.7
Cambridge Avenue							0.2
Cambridge Avenue					0.1	0.2	0.3
Cambridge Avenue						0.3	0.4
Campbell Street	0.21	0.2	0.3	0.4	0.4	0.5	0.5
Campbell Street				0.7	0.9	0.9	1.0
Carbeen Street					0.2	0.2	0.2
Coles Road					0.0	0.2	0.3
Dale Court				0.6	0.7	0.7	0.8
Dapplewood Close			0.0	0.0	0.0	0.0	0.0
Dapplewood Close			0.0	0.0	0.0	0.1	0.1
Dapplewood Close			0.2	0.2	0.2	0.3	0.3
Davlyn Drive	0.05	0.1	0.1	0.2	0.2	0.2	0.2
Delma Street			0.4	0.5	0.5	0.6	0.6
Eaglemount Rd Us1	0.13	0.1	0.2	0.2	0.2	0.3	0.2
Elm Drive			0.0	0.0	0.1	0.1	0.1
Elm Drive	0.13	0.1	0.2	0.2	0.2	0.3	0.3
Farquhar Street	0.06	0.1	0.1	0.4	0.4	0.4	0.4
Fernleigh Avenue					0.1	0.2	0.1
Fleurs Way	0.10	0.1	0.3	0.4	0.5	0.6	0.7

Location	Baseline 63.2% AEP Velocity (m/s)	Baseline 50% AEP Velocity (m/s)	Baseline 20% AEP Velocity (m/s)	Baseline 10% AEP Velocity (m/s)	Baseline 5% AEP Velocity (m/s)	Baseline 2% AEP Velocity (m/s)	Baseline 1% AEP Velocity (m/s)
Geoffrey Nolan Drive			0.0	0.2	0.2	0.3	0.3
Golflinks Road	1.20	1.3	1.4	1.4	1.5	1.5	1.5
Hartog Street	0.12	0.1	0.2	0.2	0.2	0.3	0.3
Hartog Street	0.25	0.3	0.4	0.4	0.4	0.5	0.5
Holts Road					0.8	1.0	1.2
Illawara Court	0.39	0.4	0.5	0.5	0.6	0.7	0.7
Investigator Street			0.7	1.0	1.1	1.4	1.5
Investigator Street			0.4	0.5	0.5	0.7	0.8
Investigator Street			0.1	0.1	0.1	0.1	0.1
Investigator Street				0.2	0.3	0.4	0.5
Ivy Drive			0.1	0.1	0.2	0.5	0.7
James Court				0.1	0.0	0.0	0.1
James Court					0.1	0.1	0.1
Jarrah Street				0.7	0.8	0.9	0.9
Karwin Drive						0.2	0.2
Krause Court	0.09	0.1	0.1	0.1	0.1	0.1	0.13
Lenesha Drive	0.22	0.3	0.3	0.3	0.3	0.3	0.3
Magellan Drive				0.2	0.2	0.2	0.2
Maguire Street				0.5	0.5	0.5	0.5
Maguire Street	0.10	0.1	0.2	0.2	0.2	0.2	0.3
Maguire Street						0.1	0.2
Mansfield1	0.38	0.4	0.5	0.5	0.6	0.6	0.7
Mansfield2	0.31	0.3	0.4	0.4	0.4	0.4	0.5
Mansfield3	0.33	0.3	0.4	0.4	0.4	0.5	0.5
Mansfield4	0.57	0.5	0.6	0.5	0.6	0.6	0.7
Mansfield5	0.52	0.5	0.6	0.6	0.6	0.7	0.7
Maple Drive				0.4	0.4	0.4	0.4
Mccready1							
Mccready2							0.9
Mccready3	0.30	0.3	0.5	0.6	0.6	0.7	0.7
Mccready4							1.0

Location	Baseline 63.2% AEP Velocity (m/s)	Baseline 50% AEP Velocity (m/s)	Baseline 20% AEP Velocity (m/s)	Baseline 10% AEP Velocity (m/s)	Baseline 5% AEP Velocity (m/s)	Baseline 2% AEP Velocity (m/s)	Baseline 1% AEP Velocity (m/s)
Mccready5			0.6	0.6	0.7	0.8	0.9
Mccready6	0.32	0.4	0.4	0.5	0.5	0.5	0.5
Mccready7	0.64	0.7	0.8	0.8	0.9	0.9	0.9
Monterrico Circuit	0.19	0.2	0.2	0.3	0.2	0.2	0.3
Monterrico Circuit	0.07	0.1	0.1	0.1	0.2	0.3	0.4
Oak Street			0.4	0.4	0.4	0.5	0.5
Oak Street				0.3	0.4	0.4	0.5
Oak Street						0.8	0.9
Oak Street						0.9	1.4
Oak Street							0.6
Oxford Court					0.1	0.1	0.1
Parkview Court			0.1	0.2	0.2	0.3	0.4
Pathway			0.4	0.4	0.5	0.5	0.6
Peatey Street			0.3	0.5	0.5	0.6	0.5
Petrea Court	0.03	0.0	0.0	0.1	0.1	0.1	0.1
Pine Street						0.5	0.5
Rail Us1		0.3	0.5	0.5	0.6	0.6	0.6
Raintree Court			0.0	0.0	0.0	0.0	0.0
Renae Street	0.03	0.1	0.1	0.1	0.1	0.1	0.1
Renae Street	0.19	0.2	0.2	0.2	0.2	0.3	0.2
Rhapis Court	0.02	0.0	0.1	0.1	0.1	0.1	0.1
Rhapis Court		0.2	0.2	0.3	0.3	0.3	0.4
Rhapis Court	0.04	0.0	0.0	0.0	0.0	0.1	0.1
Salmon Court	0.04	0.0	0.0	0.1	0.1	0.1	0.1
Selby Street				0.1	0.1	0.1	0.1
Shelley Court			0.3	0.4	0.4	0.5	0.4
Shiral Drive				0.1	0.2	0.2	0.2
Song Close				0.3	0.4	0.4	0.4
Tasman Court		0.2	0.2	0.3	0.3	0.4	0.4
Telina Drive				0.6	0.6	0.7	0.7
The Barons Drive			0.6	0.8	1.0	1.2	1.3

Location	Baseline 63.2% AEP Velocity (m/s)	Baseline 50% AEP Velocity (m/s)	Baseline 20% AEP Velocity (m/s)	Baseline 10% AEP Velocity (m/s)	Baseline 5% AEP Velocity (m/s)	Baseline 2% AEP Velocity (m/s)	Baseline 1% AEP Velocity (m/s)
Tiffiny Court	0.09	0.1	0.0	0.1	0.1	0.1	0.1
Tiffiny Court	0.16	0.2	0.2	0.2	0.2	0.3	0.3
Tropical Avenue				0.3	0.3	0.4	0.5
Tropical Avenue	0.04	0.1	0.1	0.1	0.1	0.1	0.1
Tropical Avenue	0.08	0.1	0.1	0.1	0.1	0.2	0.2
Tropical Avenue	0.07	0.1	0.1	0.2	0.2	0.2	0.3
Tropical Avenue			0.2	0.2	0.2	0.3	0.4
Vicky Court				0.2	0.1	0.2	0.2
Waratah Street	0.08	0.0	0.1	0.2	0.2	0.3	0.4
Warrener Street				0.3	0.4	0.4	0.5
Whitney Street		0.3	0.3	0.4	0.5	0.5	0.6
Whitney Street			0.1	0.1	0.17	0.3	0.3

Table H4 Mitigated Scenario Locational Peak Flows (Refer Figure G2)

Drain Name	Location	Reference	Baseline 50% AEP flow (m3/s)	M03 50% AEP flow (m3/s)	Baseline 20% AEP flow (m3/s)	M03 20% AEP flow (m3/s)	Baseline 1% AEP flow (m3/s)	M03 1% AEP flow (m3/s)
Coles Road	PO_77		0.5	0.7	0.9	1.1	2.5	2.6
	PO_76	Hartog Street	0.0	0.0	0.1	0.0	1.6	1.4
	PO_34		0.7	1.0	1.3	1.5	3.3	3.4
	PO_35		1.2	1.6	2.3	2.4	5.3	5.4
	PO_36	Coles Road	0.8	0.0	2.1	0.0	5.7	1.9
Oak street	PO_25		0.1	0.0	0.3	0.4	1.9	1.8
	PO_26		0.1	0.2	0.5	0.9	3.4	3.5
	PO_27		0.2	0.3	0.6	0.9	4.3	4.5
	PO_28	Oak Street	0.1	0.1	0.9	0.8	3.0	3.0
	PO_29	Oak Street	0.0	0.0	0.5	0.8	6.0	6.2
	PO_30	Oak Street	0.0	0.0	0.2	0.4	6.8	7.0
	PO_31	Oak Street	0.1	0.1	0.2	0.2	6.8	6.8
	PO_32	Oak Street	0.0	0.0	0.0	0.0	3.5	1.7
Tropical Avenue Park - Nardarmi Drive	DrainUS	Tropical Avenue park	0.9	0.9	1.3	1.3	2.1	2.1
	PO_24	Fleurs Way upstream	1.1	1.1	1.8	1.8	3.3	3.3
	PO_23	Fleurs Way downstream	1.6	1.6	2.7	2.7	5.7	5.7
	PO_22		1.6	1.6	2.9	2.9	5.9	5.9
	PO_21		2.1	2.1	3.8	3.8	8.4	8.4
	PO_20	Fernleigh Avenue upstream	3.4	3.4	5.9	5.9	11.1	11.1
	PO_19		4.5	4.5	7.2	7.2	12.6	12.6
	PO_18	Nadarmi Drive upstream	3.8	3.8	7.3	7.3	14.6	14.6
	PO_17		6.8	6.8	11.4	11.4	21.2	21.2
	DrainDS		6.9	6.9	11.4	11.4	20.6	20.6

Drain Name	Location	Reference	Baseline 50% AEP flow (m3/s)	M03 50% AEP flow (m3/s)	Baseline 20% AEP flow (m3/s)	M03 20% AEP flow (m3/s)	Baseline 1% AEP flow (m3/s)	M03 1% AEP flow (m3/s)
Newton Street - Caledonian Drive	PO_61		0.2	0.3	0.6	0.6	2.2	2.2
	PO_13	Newton Street upstream	1.1	1.1	1.5	1.4	2.8	2.8
	PO_14	Newton Street downstream	0.0	0.0	0.1	0.3	1.6	1.9
	PO_15		0.0	0.1	0.1	0.3	1.7	2.0
	Po_12		1.8	1.8	2.7	2.6	6.1	6.0
	PO_11		3.8	3.5	6.4	6.2	15.0	14.5
	PO_8	Caledonian Drive	0.0	0.0	0.0	0.0	0.2	0.2
McCreadys Creek	PO_47	Downstream of Mackay Bucasia Road	3.4	3.4	6.1	6.1	14.8	14.8
	PO_48	Downstream of Mackay Bucasia Road	0.0	0.0	0.9	0.9	9.5	9.5
	PO_49		20.9	20.9	34.9	34.9	61.8	61.8
	PO_1		26.2	26.2	47.5	47.5	93.5	93.5
	PO_2	Holts Road	0.0	0.0	0.0	0.0	33.6	33.6
	PO_3		26.2	26.2	47.4	47.4	89.9	89.9
	PO_56		23.0	23.0	40.2	40.2	78.7	78.7
	PO_4	Beaconsfield Road	7.2	7.2	21.3	21.3	51.2	51.2
	PO_56		23.0	23.0	40.2	40.2	78.7	78.7
	PO_5	Golf Links Road	31.3	31.3	47.7	47.7	75.3	75.3
Cabbage Tree Road	PO_63		0.3	0.3	0.4	0.5	1.0	1.1
	PO_64		0.5	0.5	0.9	0.8	1.8	1.7
	PO_65		0.9	1.0	1.4	1.4	2.9	3.1
	PO_66		1.4	1.5	2.2	2.2	3.9	4.0
	PO_67		0.2	0.1	0.8	0.4	2.4	2.0
	PO_68		1.7	2.2	2.8	3.1	5.1	5.7
	PO_69		1.8	2.3	2.9	3.2	5.3	5.9