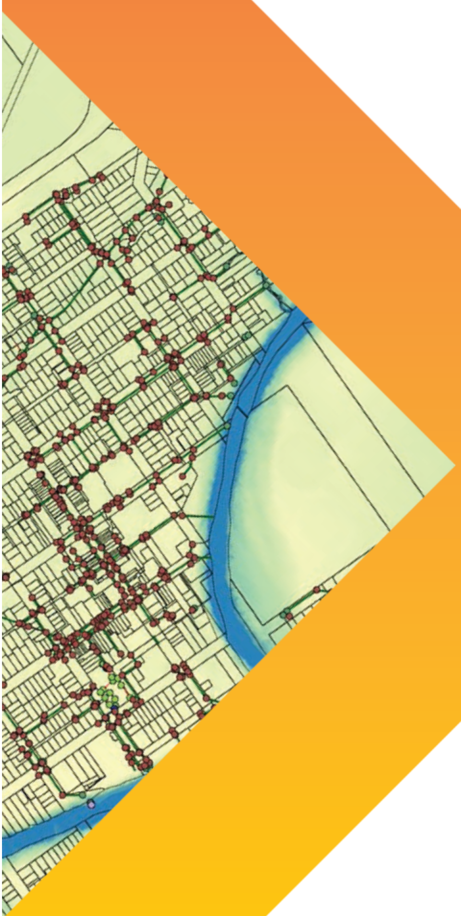
REPORT



103 PATERSON STREET, BYRON BAY, NSW

HYDRAULIC IMPACT ASSESSMENT

Planit Consulting on behalf of the proponent

Our Ref: FW00036

Date: 24 February 2021

Revision 4

Contact us to design the sustainable towns and cities of tomorrow.

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Version Register

Version	Status	Author	Reviewer	Change from Previous Version	Authorised for Release	
					Signature	Date
4	For Issue	DM/TP	AR/VS	Change of retaining wall location. Remove of spoon drain.	D. Mackenzie	24/02/21

Transmission Register

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1. Introduction

Planit Consulting on behalf of the proponent has requested a hydraulic assessment of 103 Paterson Street, Byron Bay (the subject site).

The land area is approximately 3826m^2, with a drainage reserve to the east of the subject site. There is a large upstream catchment that contributes to the eastern drainage reserve (including a piped system and open channel) and will need to be considered in the hydraulic assessment. Site based stormwater falls from Paterson Street to the south east.

The hydraulic assessment will cover both the existing case and developed case scenarios and will determine any potential impacts upon the subject site, neighbouring properties. Guidance will be provided on the hydraulic function affecting the site such as peak heights, localised velocities, extents of inundation and hazard assessment.

The key objectives of this investigation is:

- Understand the 1% AEP (100 year ARI) hydraulic function of the site
- This assessment will identify existing maximum water levels, maximum depths, maximum hazards, maximum velocity and maximum inundation extents for the existing and developed case
- Minimise the potential impacts of the proposed development upon the subject site and neighbouring properties is to be provided.

A detailed 1D/2D modelling has been undertaken to confirm the above objectives.

See Figure 1 below showing the location of the study site.

Figure 1 Subject Site

2. Hydrology

2.1. Methodology

The XP-SWMM runoff-routing model has been used to estimate design flood discharges within the study area. The model represents the sub-catchments as a network of nodes linked to either the 1D pipe drainage network or the 2D Digital Terrain Model (DTM) geometric base. The node is defined by its pervious and impervious areas, fraction impervious and average catchment slope. The net rainfall is routed through the network after appropriate losses (initial and continuing) and roughness factors are applied, resulting in a surface runoff hydrograph for each sub-catchment.

The XP-SWMM model was used to estimate the 100 year ARI design runoff with all hydrologic assessment using Australian Rainfall and Runoff 2019 (ARR2019) methodologies.

A numerical check has been undertaken using the Regional Flood Frequency Estimation model (https://rffe.arr-software.org/) and compared to the XP-SWMM results.

2.2. Hydrologic Model

2.2.1. Configuration

Figure 2 illustrates the extent of the XP-SWMM model. There are 7 sub-catchments (total area is 21.55ha) used to represent the runoff contributing to the study area. These catchments were delineated to accurately represent the inflow location and its impact on the subject site.

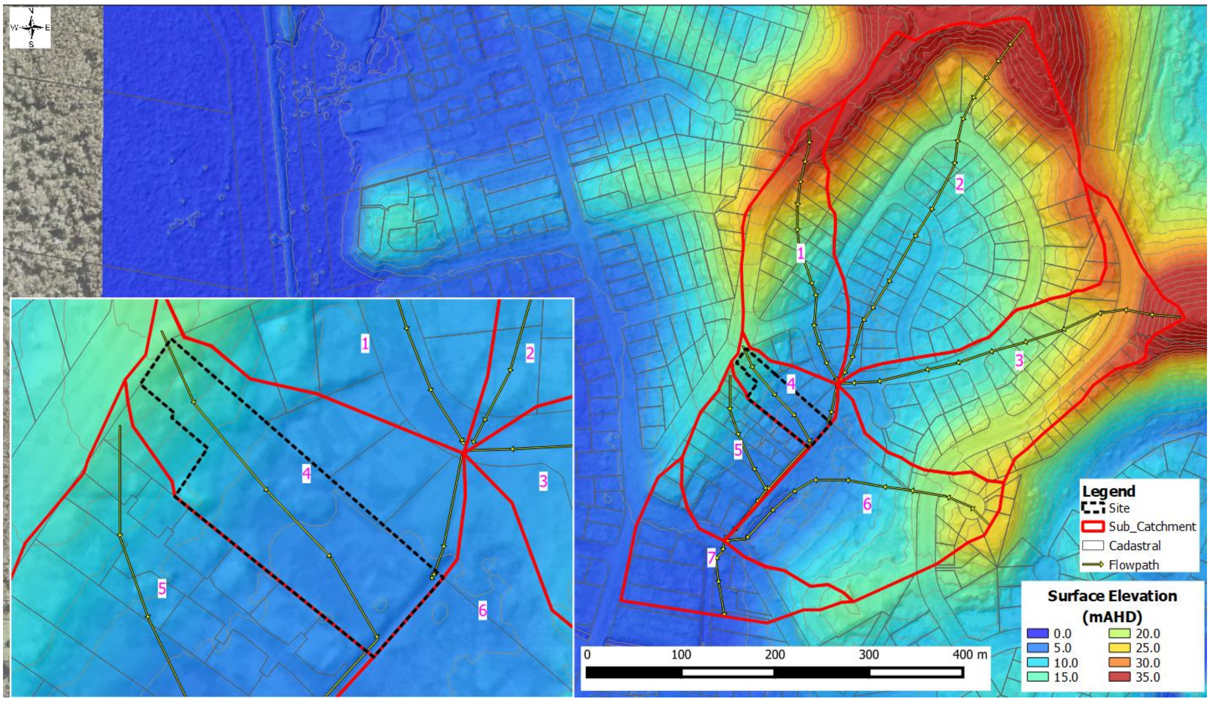


Figure 2 XP-SWMM Model Extents

2.2.2. Hydrologic Routing

Hydrologic modelling has been undertaken using the Laurenson runoff routing method. The Laurenson method requires the catchment to be divided into pervious (undeveloped) and impervious (developed) portions. A fraction impervious of 0% has been applied to the undeveloped portion and 100% to the developed portion.

2.2.3. Manning's Roughness

Manning's roughness (n) values are applied to represent the undeveloped and developed portions of the catchment. XP-SWMM allows a range to be applied to represent the varied degree of roughness that was observed within the catchment.

2.2.4. Rainfall Losses

Initial Loss (IL) and Continuing Losses (CL) were sourced from the Australian Rainfall and Runoff (ARR) Data Hub (*http://data.arr-software.org/*) and were applied to the modelling.

2.2.5. Existing Conditions Parameters

Table 1 summarises the XP-SWMM parameters adopted for the existing catchment conditions. The catchments equal area slope was calculated directly from the Digital Terrain Model for the Catchment.

The total contributing catchment is 21.55 ha. The hydrologic factors adopted have been summarised in Table 1.

Table 1 XP-SWMM Hydrologic Model Parameters

Sub-Catchment	Area (Ha)	Pervious Area (Ha)	Impervious (Ha)	Equal Area Slope (%)
Cat_1	2.283	1.207	1.076	7.52
Cat_2	8.158	4.472	3.685	4.95
Cat_3	4.143	1.973	2.171	6.97
Cat_4	0.670	0.467	0.203	4.44
Cat_5	1.340	0.734	0.607	4.92
Cat_6	3.261	1.398	1.864	5.05
Cat_7	1.692	1.018	0.674	3.69

2.3. ARR 2016 Hydrologic Results

The XP-SWMM ARR Storm Generator allows importation of the ARR Data Hub information, including rainfall global database, infiltration global database, and global storm definitions, into XP-SWMM. Information such as the ARR Data Hub, ARR Temporal Patterns Increments File, and Bureau of Meteorology (BOM) IFD table files are used to produce the Annual Exceedance Probability (AEP) and all of the durations for the given location, which are then analysed in the application.

Ten (10) temporal patterns were assessed per duration for each design event with the results statistically assessed using a box and whisker plot to determine the critical storm duration and temporal pattern for the catchment. The box and whisker plot displays information about the range, median, and quartiles of the results. This plot can easily demonstrate whether a distribution is skewed and whether there are potential outliers in the data set, especially for a large number of observations.

Figure 3 below demonstrates that the highest median storm duration for the 100 year ARI is the 20min storm using the standard temporal pattern 3, and producing a peak discharge of **7.61 m³/s**.

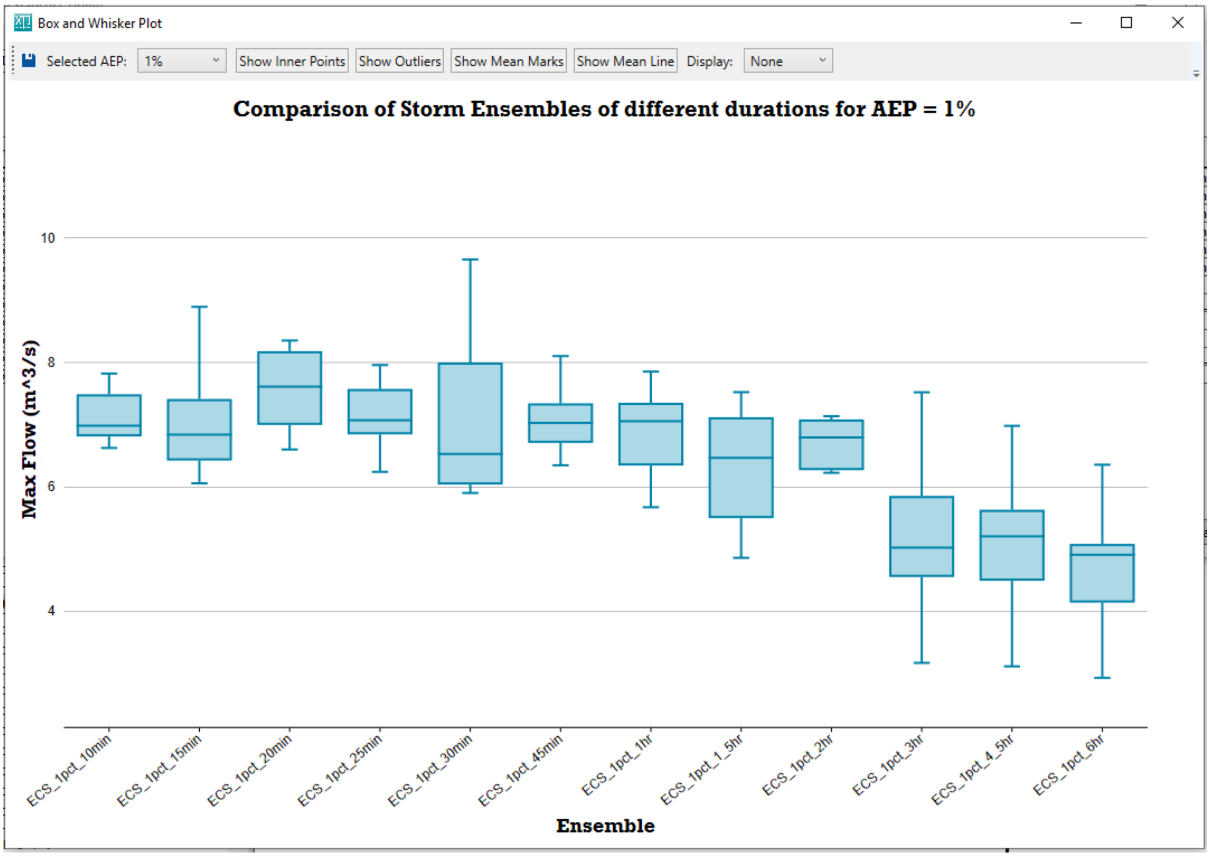


Figure 3 1% AEP Box and whisker plot of Ensemble results

2.4. Flood Frequency Analysis Comparison

ARR Regional Flood Frequency Estimation (RFFE) tool has replaced the rational method as a means to compare XPSWMM's calculation of design discharges for the 100 Year ARI developed conditions at legal points of discharge for the catchment.

The tool requires the geographical coordinates of the catchment centroid and outlet. Based on regional rainfall data at gauged locations near the site the tool produces a statistical estimate of the peak discharge.

The tool has the following limitations:

- The RFFA tool cannot be used for urban catchments, areas where large scale land clearing has occurred or where Dams or other significant Hydraulic controls have significantly affected the natural hydrology (ARR).
- RFFA is not accurate for catchments smaller than 0.5 km^2 or larger than 1000 km^2.
- Catchments that are located more than 300 km from a gauging station used by the tool.

Table 2 and Figure 4 summarises the comparison of the RFFA tool and XP-SWMM peak discharges for the sub-catchment at outlet. Whilst accuracy is reduced for catchments less than 0.5km^2, the RFFE is still a useful tool for checking purposes.

Table 2 XP-SWMM and RFFA Peak Discharge

Event	Regional Estimation Tool			XP_SWMM (ARR2019)
	Discharge (m3/s)	Lower Confidence Limit (5%) (m3/s)	Upper Confidence Limit (95%) (m3/s)	
1% AEP	8.23	2.48	27	7.61

** Based off Medium Ensemble Storm*

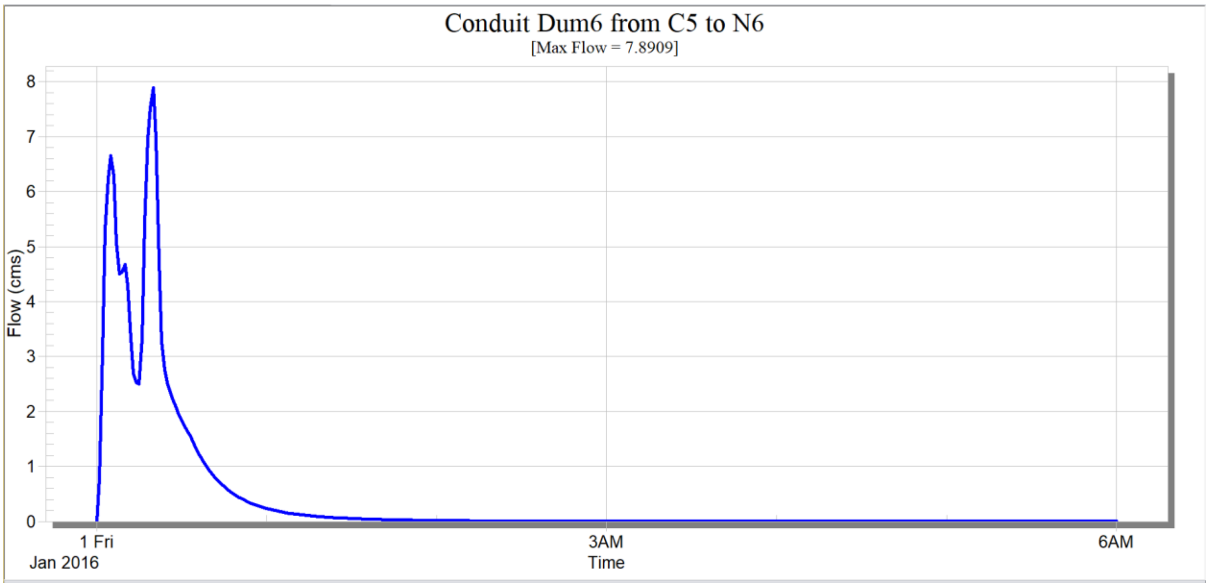


Figure 4 Critical Storm Duration and Temporal Pattern for The Outlet Catchment

3. Overland Flow Hydraulic Assessment

3.1. Objectives

The objective of this hydraulic impact assessment is to demonstrate that the fill pad associated with the proposed development does not significantly increase risk within the floodway or on neighbouring properties.

A 1D/2D TUFLOW has been used for this analysis. The TUFLOW software models the design terrain (i.e., Digital Terrain Model) of the study area as a series of grids (2D cells). This allows flows in excess of channel capacity or pipe network, to break out and continue along the floodway in the 2D domain, as the topography dictates. The hydraulic structures (i.e. the minor culvert network) have been represented as 1D elements (ESTRY) which is dynamically linked to the 2D elements. The TUFLOW model computes the capacity of the 1D element and once exceeded, the surcharged flow is transferred to the 2D model. Flood levels, discharge and velocity can be extracted from the model as functions of time at required locations.

TUFLOW is an industry standard two-dimensional hydraulic analysis model used to estimate flood characteristics such as flood level, velocity, depth and flood hazard and any impacts arising from the proposed development has on the surrounding properties.

3.2. 2D Model Set Up

3.2.1. Model Extent

The model extents for the TUFLOW model are presented in Figure 5. The extents were set at an appropriate distance from the subject site to properly assess the impacts of the proposed development.

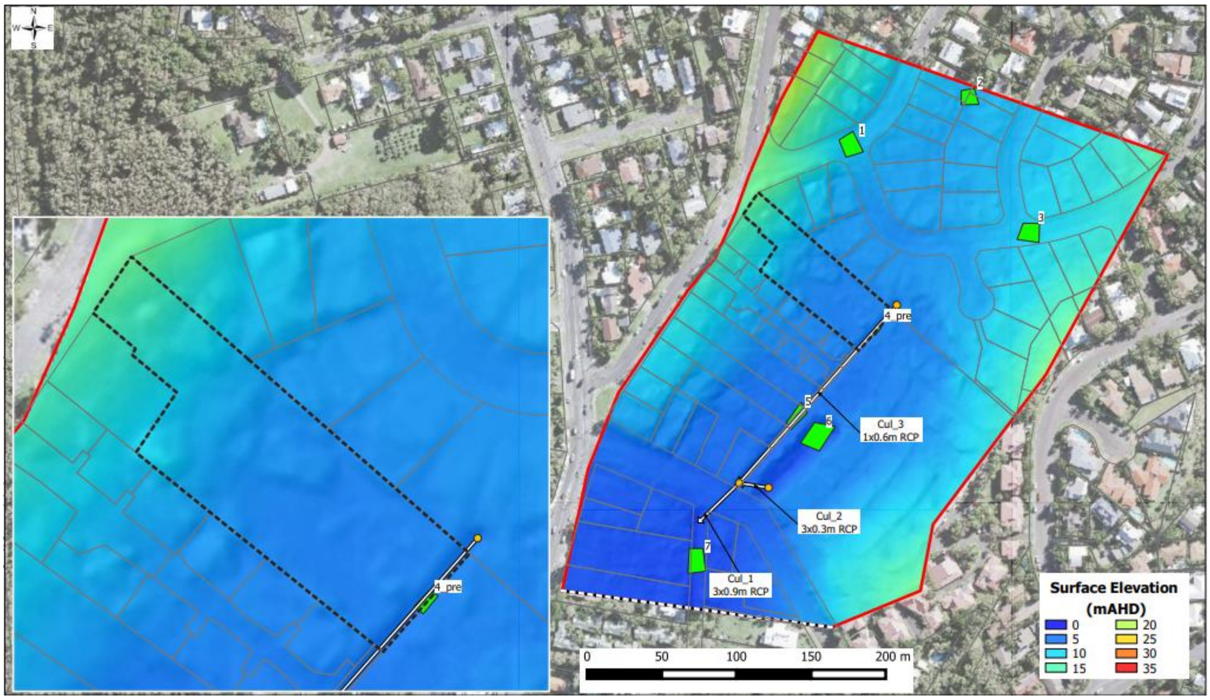


Figure 5 TUFLOW Model Extents

3.2.2. Resolution and Time Step

A grid size of 1m and time step 0.5s were used in the TUFLOW model for all scenarios. The grid size is based on model efficiency and size constraints for the extents of the model.

3.2.3. Topography Pre-Development

Lidar 1m (2010) and survey data around the subject site were used as the base topography for TUFLOW model. The topography used in the pre-development scenario is shown in Figure 6.

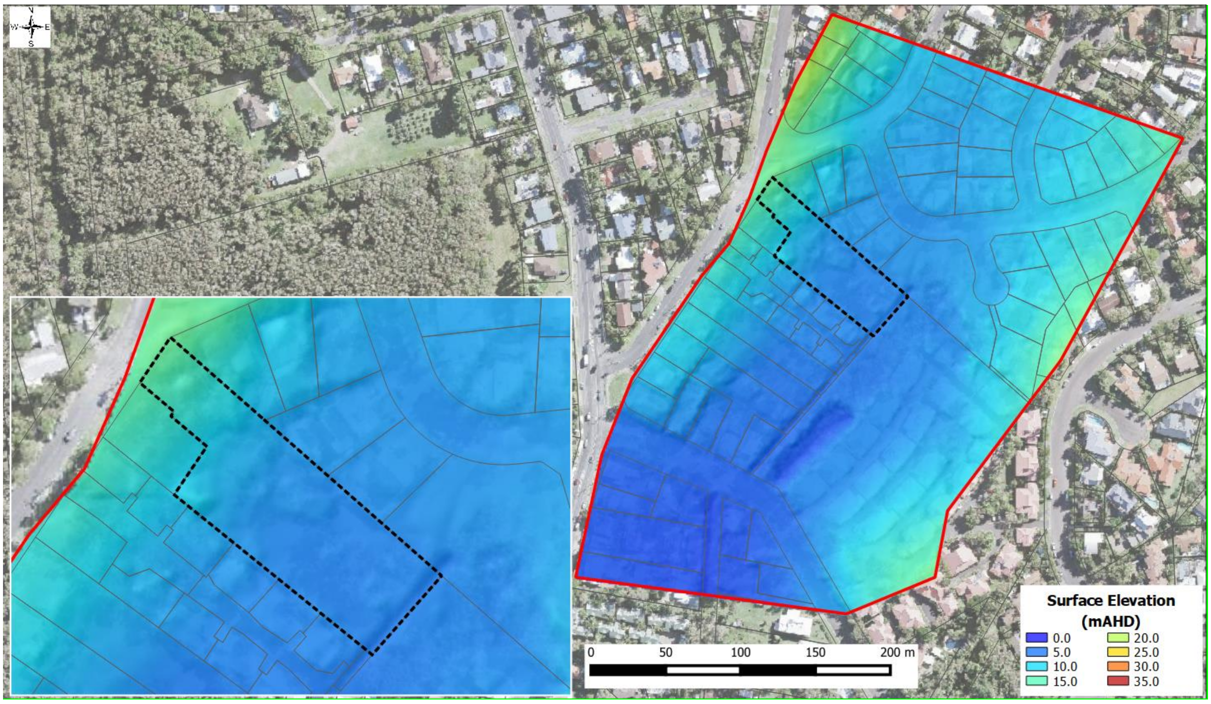


Figure 6 Surface Elevation Data

3.2.4. Topography Post-Development

For the post development scenario, the changes to the topography due to the proposed development are demonstrated in Figure 7.

The level of the proposed fill pad (on site) was raised to be completely flood free in 1% AEP peak water level.

A portion of the site is to be raised on piers or suspended slab. Refer to Civil drawing set for further detail.

A new 16m wide x 0.5m x 1:6 shallow drain is proposed to direct water from Shelly drive to an existing drainage easement to the south. These measures will help alleviate existing nuisance flooding of properties adjoining Shelly drive.

A small increase to the height of the left bank of the existing open channel is proposed to contain water within the drainage easement. Refer Figure 7 below for typical sections.

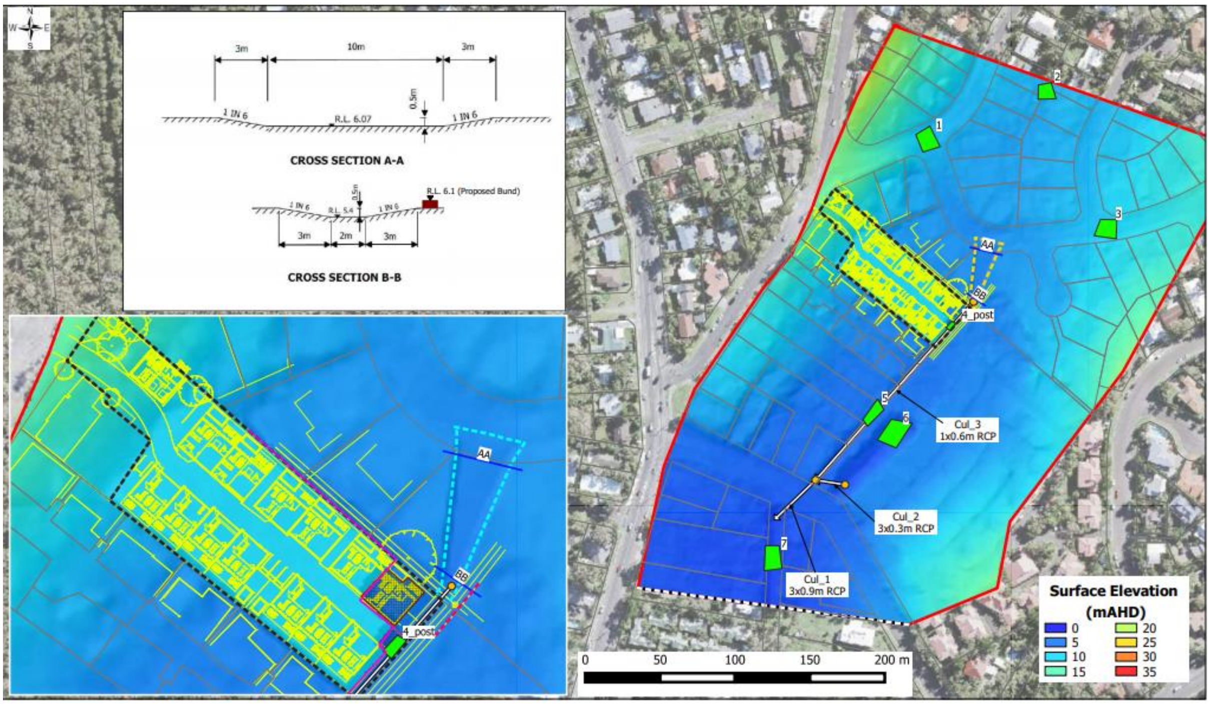


Figure 7 Design Surface Elevation Data

3.2.5. Roughness

Figure 8 and Figure 9 show the roughness adopted in the hydraulic impact assessment model.

Figure 8 Pre Development Roughness Map

Figure 9 Post Development Roughness Map

3.2.6. Inflows

The inflows within the TUFLOW model were extracted directly from XPSWMM Hydrology model (ARR2016). See Figure 5 for inflows location.

3.3. Pre-Development Case

The Pre-Development case includes existing low flow pipes as per Figure 5. The pipe roughness was set at Manning n = 0.014.

1% AEP peak water level, depth, velocity and hazard are shown below in Figure 10, Figure 11 Figure 12 and Figure 13 respectively.

The Flood Planning Level (FPL) shall be as per *Byron Shire Development Control Plan 2014 Chapter C2 Areas Affected by Flood*:

- Habitable dwellings - 6.5m AHD (6.0m AHD + 500mm = 6.5m AHD)
- Non Habitable buildings (carports etc) – 10% AEP + 300mm
  - All internal roads and non-habitable buildings set > 1% AEP.

Figure 10 Pre-Development Maximum Water Level – 1% AEP

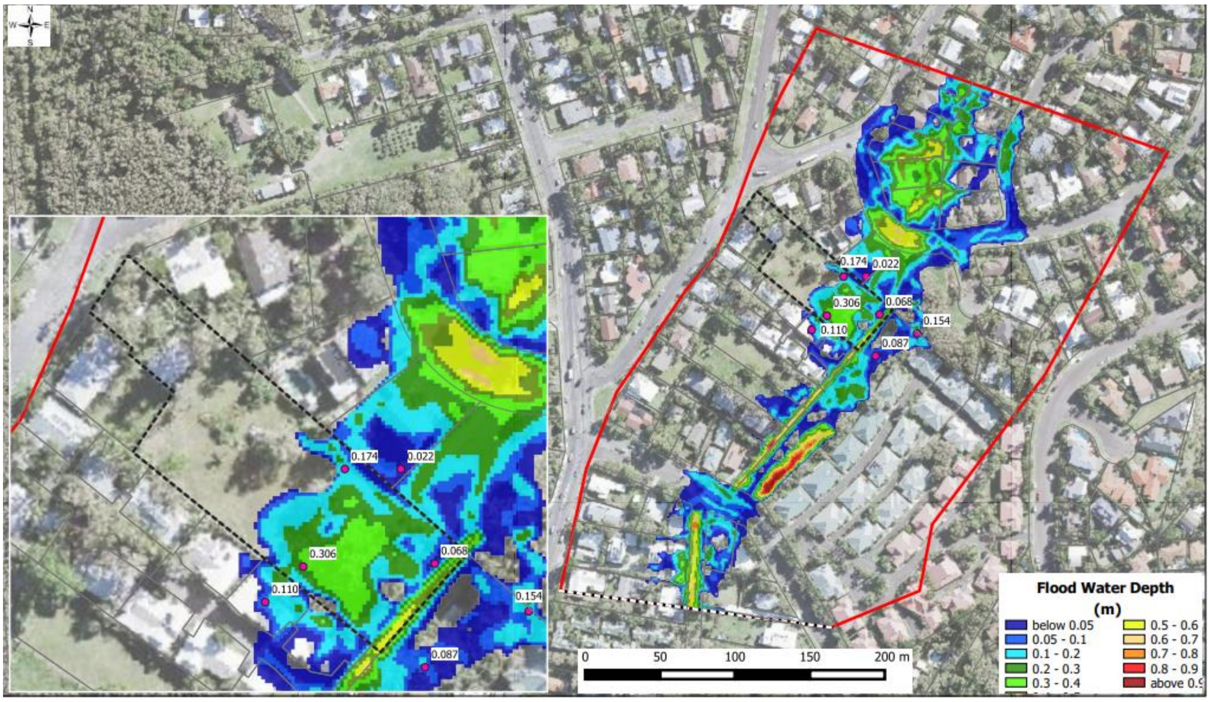


Figure 11 Pre-Development Maximum Depth – 1% AEP

Figure 12 Pre-Development Maximum Velocity – 1% AEP

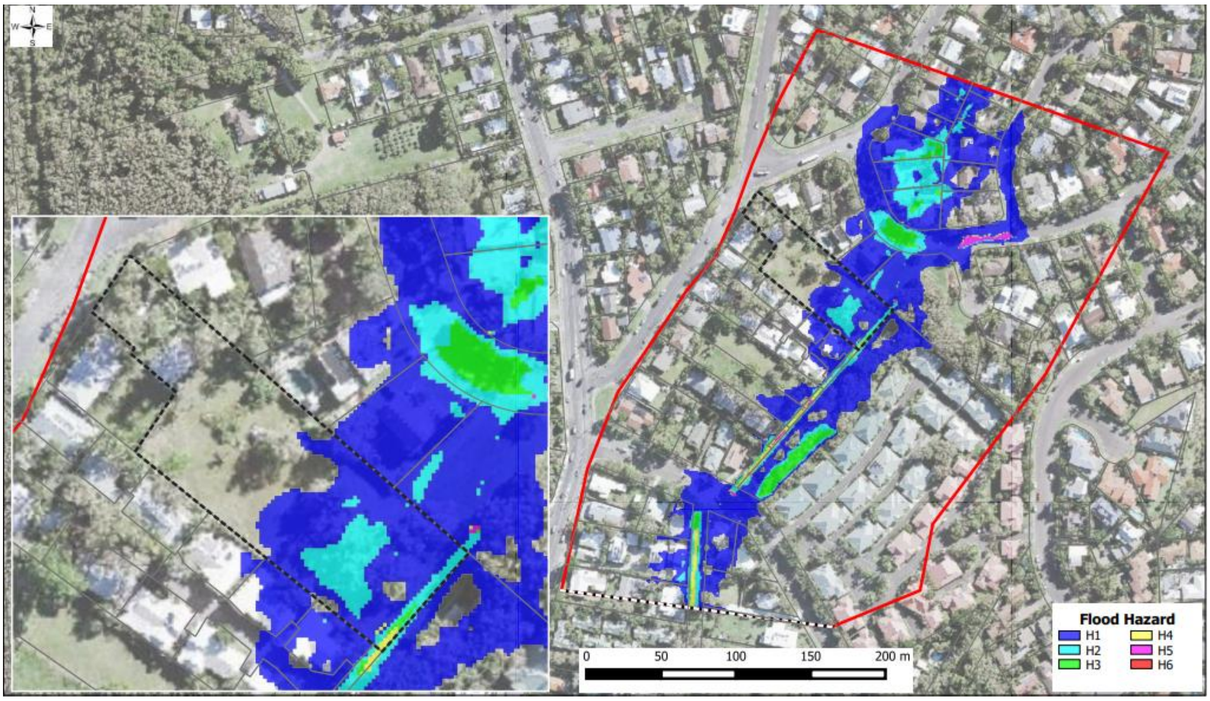


Figure 13 Pre-Development Maximum Hazard – 1% AEP

3.4. Post-Development Case

The modifications in the post-developed case include:

- The filling of proposed pad (within the site) to > 6.5m AHD Flood Planning Level
- A new 16m wide x 0.5m x 1:6 shallow drain is proposed to direct water from Shelly drive to an existing drainage easement to the south

- A portion of the site is to be raised on piers or suspended slab. Refer to Civil drawing set for further detail.
- A small increase to the height of the left bank of the existing open channel is proposed to contain water within the drainage easement.

Figure 14, 15, 16 and 17 below show the maximum water level, depth and velocity, hazard.

Figure 14 Post-Development Maximum Water Level – 1% AEP

Figure 15 Post-Development Maximum Depth – 1% AEP

Figure 16 Post-Development Maximum Velocity – 1% AEP

Figure 17 Post-Development Maximum Hazard – 1% AEP

3.4.1. Impact Assessment

Figure 18 below shows the difference in peak water levels, and Figure 19 below shows the difference in peak water velocity resulting from the proposed development.

The 1% AEP hydraulic assessment has resulted in:

- Generally, the 1% AEP water level afflux is less than 10mm for much of the study area and is considered non-actionable.
- There are some localised increases in maximum water level within subject site, the drainage reserve and a small portion of the park reserve immediately upstream of the drainage reserve of > 120mm
- There are some localised increases in maximum water level immediately downstream of the subject site, within the drainage reserve of 0 - 20mm, and 20 – 40mm.
- There is some localised reduction in maximum water levels of up to -47mm within the drainage reserve.
- Generally, the 1% AEP water velocity afflux is less than 0.1m/s for much of the study area and is considered non-actionable.
- There are some localised areas within the proposed design channel linking Shelly Drive to the drainage easement that has velocity increases of greater than 0.5 m/s
- There are some localised increases in maximum velocity within the drainage reserve of 0.567m/s

Benefits of providing a design channel linking Shelly Drive to the existing drainage reserve include:

- Improvement of existing nuisance flooding of neighbours directly to the north of the subject site. Current legacy flow paths convey water directly through the neighbouring properties to the north and also the subject site

- Formalising an existing conveyance path from the sag pit at Shelly Drive to the existing drainage reserve. Currently stormwater in excess of the minor system overtops the kerb at Shelly Drive as uncontrolled overland flow utilising legacy pathways which currently direct flows through neighbouring properties to the north and also the subject site before reconnecting to the existing drainage reserve
- A similar outcome could not have been achieved by maintaining the informal uncontrolled legacy drainage paths through the neighbouring properties to the north and also the subject site
- Reshaping of the public reserve to the north using low batters and shallow depth will improve visual amenity and usability. Currently the ground levels of the public reserve to the north is uneven in nature and not usable in its current form. Reshaping this area will improve usability.

Figure 18 Water Level Afflux Map – 1% AEP

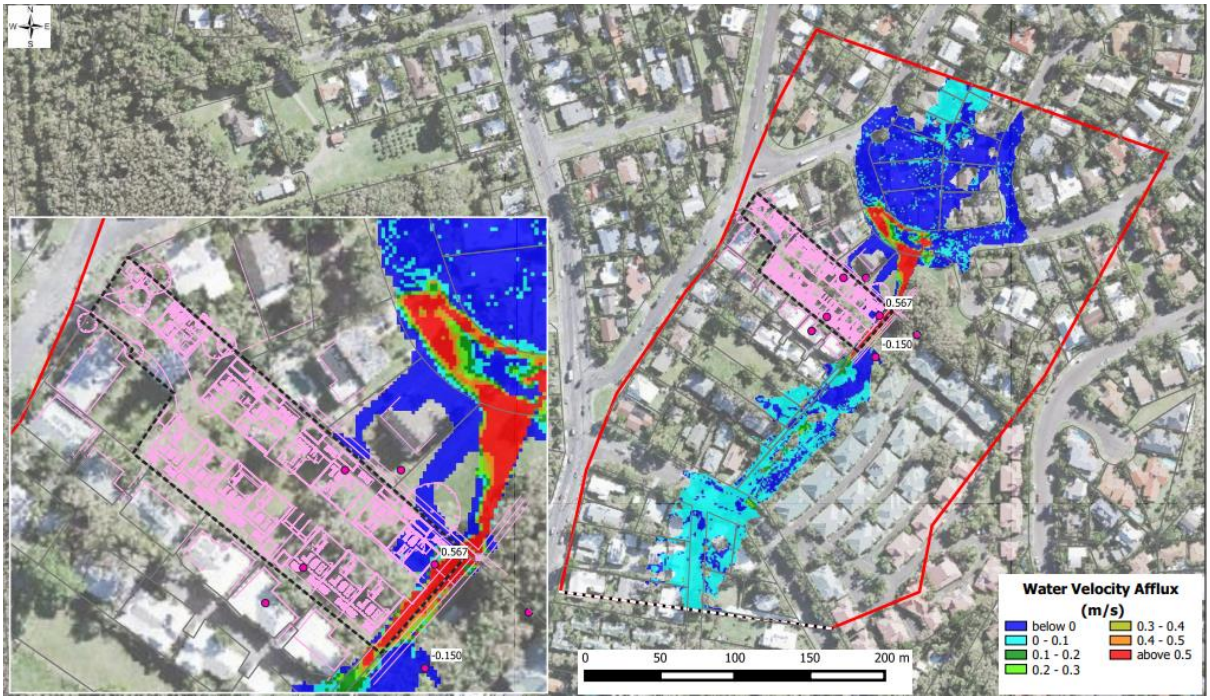


Figure 19 Water Velocity Afflux Map – 1% AEP

4. Summary

Floodworks has completed a hydraulic assessment for the subject site 103 Patterson St Byron Bay. As part of this assessment a dynamic 1D/2D linked TUFLOW flood model was developed for both the existing case and developed case.

A hydrologic assessment of the 1% AEP design flows using XP-SWMM has been completed for the subject site. All hydrologic assessment has been completed to the Australian Rainfall and Runoff 2019 (ARR2019) methodologies, with results comparing well to the Regional Flood Frequency Estimation tool.

The Flood Planning Level (FPL) shall be as per *Byron Shire Development Control Plan 2014 Chapter C2 Areas Affected by Flood*:

- Habitable dwellings – 6.5m AHD (6.0m AHD + 500mm = 6.5m AHD)
- Non-habitable buildings (carports etc) – 10% AEP + 300mm.
    - All internal roads and non-habitable buildings set > 1% AEP.

The 1% AEP hydraulic assessment has resulted in:

- Generally, the 1% AEP water level afflux is less than 10mm for much of the study area and is considered non-actionable.
- There are some localised increases in maximum water level within subject site, the drainage reserve and a small portion of the park reserve immediately upstream of the drainage reserve of > 120mm
- There are some localised increases in maximum water level immediately downstream of the subject site, within the drainage reserve of 0 - 20mm, and 20 – 40mm.
- There is some localised reduction in maximum water levels of up to -47mm within the drainage reserve.
- Generally, the 1% AEP water velocity afflux is less than 0.1m/s for much of the study area and is considered non-actionable.
- There are some localised areas within the proposed design channel linking Shelly Drive to the drainage easement that has velocity increases of greater than 0.5 m/s
- There are some localised increases in maximum velocity within the drainage reserve of 0.567m/s

Benefits of providing a design channel linking Shelly Drive to the existing drainage reserve include:

- Improvement of existing nuisance flooding of neighbours directly to the north of the subject site. Current legacy flow paths convey water directly through the neighbouring properties to the north and also the subject site
- Formalising an existing conveyance path from the sag pit at Shelly Drive to the existing drainage reserve. Currently stormwater in excess of the minor system overtops the kerb at Shelly Drive as uncontrolled overland flow utilising legacy pathways which currently direct flows through neighbouring properties to the north and also the subject site before reconnecting to the existing drainage reserve
- A similar outcome could not have been achieved by maintaining the informal uncontrolled legacy drainage paths through the neighbouring properties to the north and also the subject site

- Reshaping of the public reserve to the north using low batters and shallow depth will improve visual amenity and usability. Currently the ground levels of the public reserve to the north is uneven in nature and not usable in its current form. Reshaping this area will improve usability.

5. References

- BOM (2018) Rainfall IFD Data System
- IPWEA 2013, Queensland Urban Development Manual (QUDM)
- All data (tin, gis data etc) has been sourced from Elevation - Foundation Spatial Data from http://elevation.fsdf.org.au/

Appendix A Results

Appendix B Australian Rainfall & Runoff Data Hub – Results

River Region

Division	South East Coast (NSW)
River Number	2
River Name	Brunswick River

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^b - c\log_{10}Duration\right)Duration^{-d} + eArea^f Duration^g\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i
East Coast North	0.327	0.241	0.448	0.36	0.00096	0.48	-0.21	0.012	-0.0013

Short Duration ARF

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

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

Note: As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. The continuing storm loss information from the ARR Datahub provided below should only be used where relevant under the loss hierarchy (level 5) and where used is to be multiplied by the factor of 0.4.

ID	11934.0
Storm Initial Losses (mm)	27.0
Storm Continuing Losses (mm/h)	2.1

Interim Climate Change Factors

	RCP 4.5	RCP6	RCP 8.5
2030	**0.869 (4.3%)**	0.783 (3.9%)	**0.983 (4.9%)**
2040	**1.057 (5.3%)**	1.014 (5.1%)	**1.349 (6.8%)**
2050	**1.272 (6.4%)**	1.236 (6.2%)	**1.773 (9.0%)**
2060	**1.488 (7.5%)**	1.458 (7.4%)	**2.237 (11.5%)**
2070	**1.676 (8.5%)**	1.691 (8.6%)	**2.722 (14.2%)**
2080	**1.810 (9.2%)**	1.944 (9.9%)	**3.209 (16.9%)**
2090	**1.862 (9.5%)**	2.227 (11.5%)	**3.679 (19.7%)**

Probability Neutral Burst Initial Loss

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	24.2	13.2	12.3	12.0	10.8	7.7
90 (1.5)	25.1	14.7	13.3	12.0	10.2	8.3
120 (2.0)	22.4	13.4	13.0	11.1	10.3	6.1
180 (3.0)	21.9	13.7	12.6	10.2	9.6	5.2
360 (6.0)	19.9	12.8	12.2	10.9	11.1	3.5
720 (12.0)	21.9	15.3	15.0	12.2	13.8	4.5
1080 (18.0)	25.8	19.1	19.6	14.9	16.7	5.4
1440 (24.0)	29.9	21.7	21.4	16.5	14.3	5.9
2160 (36.0)	35.3	26.4	24.8	19.6	17.9	6.2
2880 (48.0)	37.4	27.7	26.6	23.7	23.2	7.0
4320 (72.0)	42.3	32.6	32.1	29.6	27.3	11.7

Baseflow Factors

Downstream	0
Area (km2)	500.181472
Catchment Number	7577
Volume Factor	0.233508
Peak Factor	0.051066

Appendix C Box and Whisker Plots

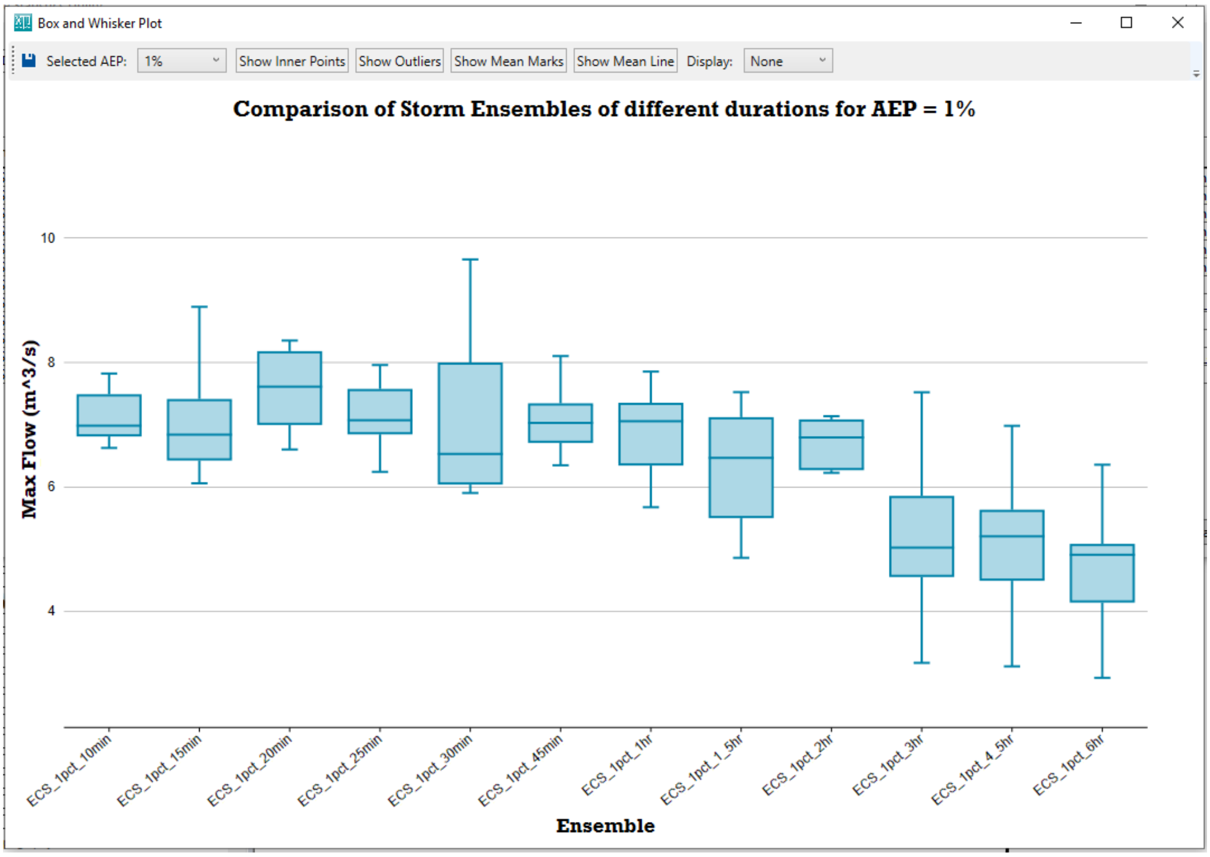
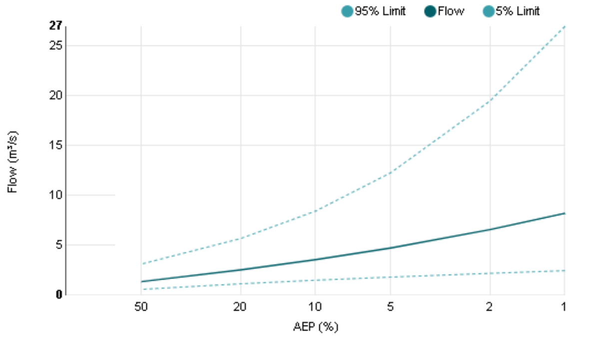


Figure 20 100 Year ARI Box and whisker plot of Ensemble results

Appendix D Regional Flood Frequency Estimation (ARR2016)

Results | Regional Flood Frequency Estimation Model



*The catchment is outside the recommended catchment size of 0.5 to 1,000 km². Results have lower accuracy and may not be directly applicable in practice.

AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	1.38	0.600	3.14
20	2.56	1.16	5.70
10	3.58	1.52	8.46
5	4.75	1.83	12.3
2	6.59	2.21	19.5
1	8.23	2.48	27.0

Input Data

Date/Time	2020-06-16 12:49
Catchment Name	Catchment1
Latitude (Outlet)	-28.65783726
Longitude (Outlet)	153.6170879
Latitude (Centroid)	-28.65502436
Longitude (Centroid)	153.6192878
Catchment Area (km^2)	0.2162*
Distance to Nearest Gauged Catchment (km)	12.81
50% AEP 6 Hour Rainfall Intensity (mm/h)	13.005735
2% AEP 6 Hour Rainfall Intensity (mm/h)	31.279358
Rainfall Intensity Source (User/Auto)	Auto
Region	East Coast
Region Version	RFFE Model 2016 v1
Region Source (User/Auto)	Auto
Shape Factor	0.82
Interpolation Method	Natural Neighbour
Bias Correction Value	-0.246

Statistics

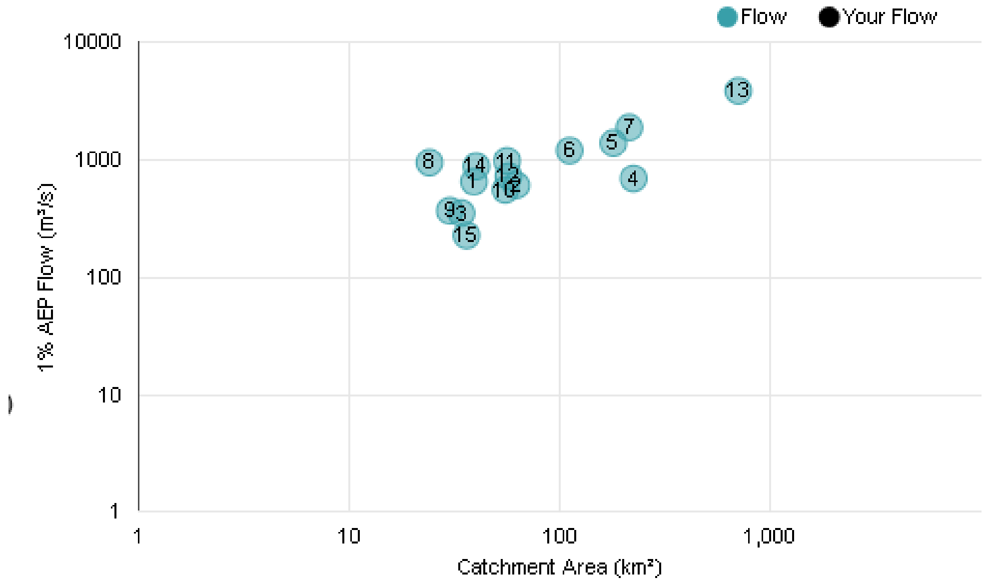
Variable	Value	Standard Dev
Mean	0.162	0.529
Standard Dev	0.642	0.303
Skew	0.074	0.029

Note: These statistics come from the nearest gauged catchment. Details.

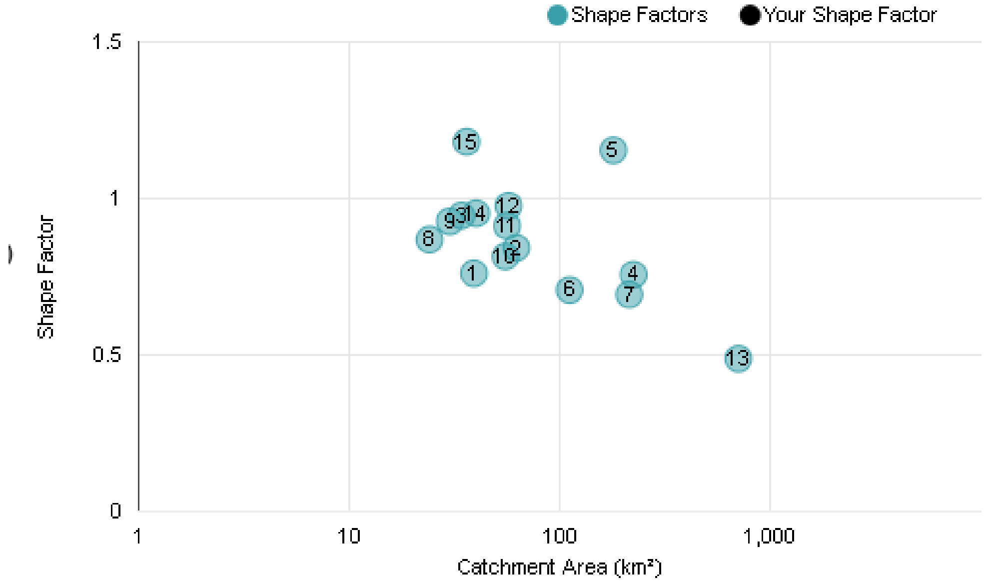
Correlation		
1.000		
-0.330	1.000	
0.170	-0.280	1.000

Note: These statistics are common to each region. Details.

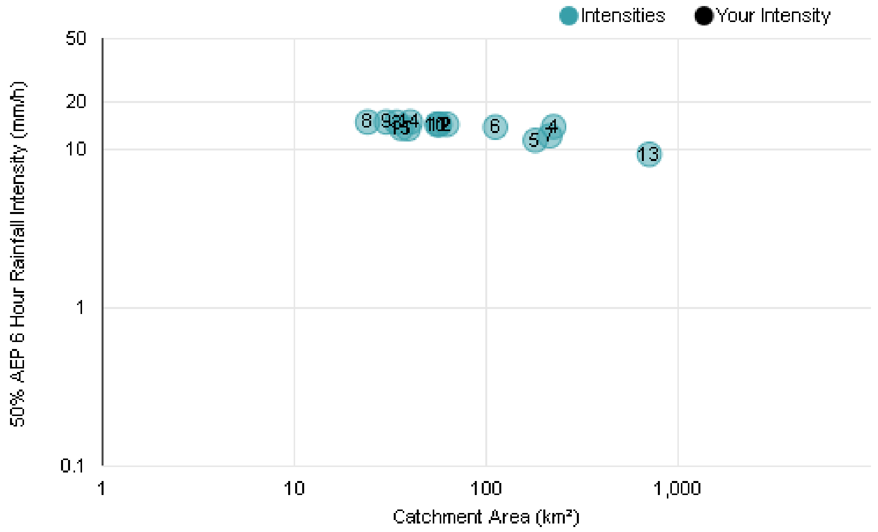
1% AEP Flow vs Catchment Area



Shape Factor vs Catchment Area



Intensity vs Catchment Area



Bias Correction Factor vs Catchment Area