Memo

Project	Greater Avalon Employment Precinct – Drainage and Flood Strategy
Subject	Deliverable 4 – Existing Conditions Flood Modelling Report
Distribution	Nathan Guttmann, Victorian Planning Authority
Date	31 May 2024
From	Alluvium – GAEP Project team (Caroline Carvalho, Alex Shen, Dylan Brand, Tim Ferguson)

1 Introduction

Alluvium has been engaged by the Victorian Planning Authority (VPA) to prepare a Drainage and Flood Strategy for the proposed future development area known as the Greater Avalon Employment Precinct (GAEP). The objectives of this GAEP study are to undertake a drainage and flood assessment for the proposed growth areas and determine **existing and future** drainage and flooding issues and/or constraints affecting the site and surrounds.

This memo report represents the summary of the existing conditions flood assessment of the GAEP study**.** It provides a summary of the hydrologic (RORB) and hydraulic (TUFLOW) modelling results, parameters, assumptions and outputs. The report:

- summarises the key data, models and reports that have been provided for:
    - The Western treatment Plant (WTP) waterway mapping project (BMT WBM)
    - The Lara flood study flood modelling project (Water Technology)
- provides commentary on the hydrologic and hydraulic model outputs, and the importance of this information in influencing our approach to the GAEP Drainage and Flood Strategy.

The outputs of the existing conditions modelling will:

- Confirm existing base case flood conditions
- Determine potential future flooding impacts under climate change
- Assess impacts across a range of rainfall events (scenarios) including a combination of a 1.1m sea level rise with a 1% AEP flood event with tidal effects / storm surge considerations.

2 Site Overview

The GAEP consists of approximately **1587 ha** proposed for future industrial development of areas surrounding the existing Avalon Airport. The precinct is generally bounded by Princes Freeway to the north, Western Road to the east, Port Phillip Bay to the south and Avalon Road to the west.

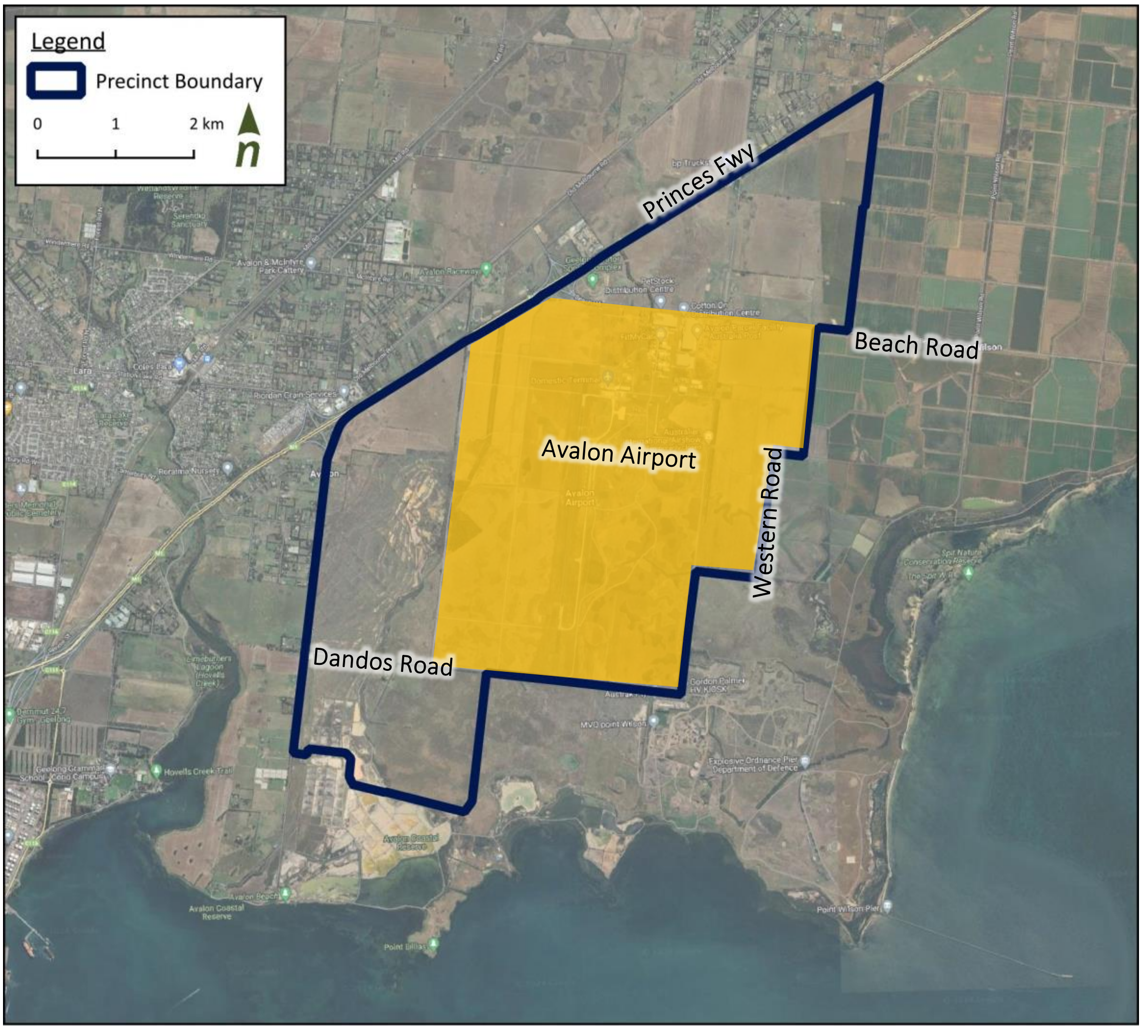

Figure 1. *Project study area full extent (Avalon Airport shown in orange)*

2.1 Location context

The proposed GAEP is located approximately 16 kms north-west of Geelong and contains a large portion of open grassland and vegetated areas, with significant open waterbodies throughout. The GAEP will consist of future proposed industrial land use zones surrounding the Avalon Airport, which is expected to expand in the coming years.

The characteristics of the study area consists of former saltpan works along the western portion of the site, which is characterised by a number of shallow depressions where water would accumulate, evaporate, and deposit salt. The Avalon airport is currently operational, with future development of the site expected. The remainder of the site is primarily used for agricultural purposes.

The GAEP boundary is located only a few kms from the Port Phillip Bay (to the south), which will be the ultimate outfall from the site. The coastal region of Port Phillip Bay is characterised by large open waterbodies and wetlands along low-lying areas. The area includes two key conservation areas, the Avalon Coastal Reserve, and the Spit Nature Conservation Reserve.

The coastal reserves consist of highly sensitive ephemeral wetland areas, which support significant bird migration from overseas, in particular migratory birds from China, Japan and South Korea which use the area for roosting. Migratory birds from New Zealand are also known to frequent the reserve area. The wetlands are considered high value natural assets and are protected under the Ramsar Convention, that is, an international treaty marking the wetlands for protection and/or enhancement. An overview of key characteristics of the GAEP study area is shown in Figure 2.

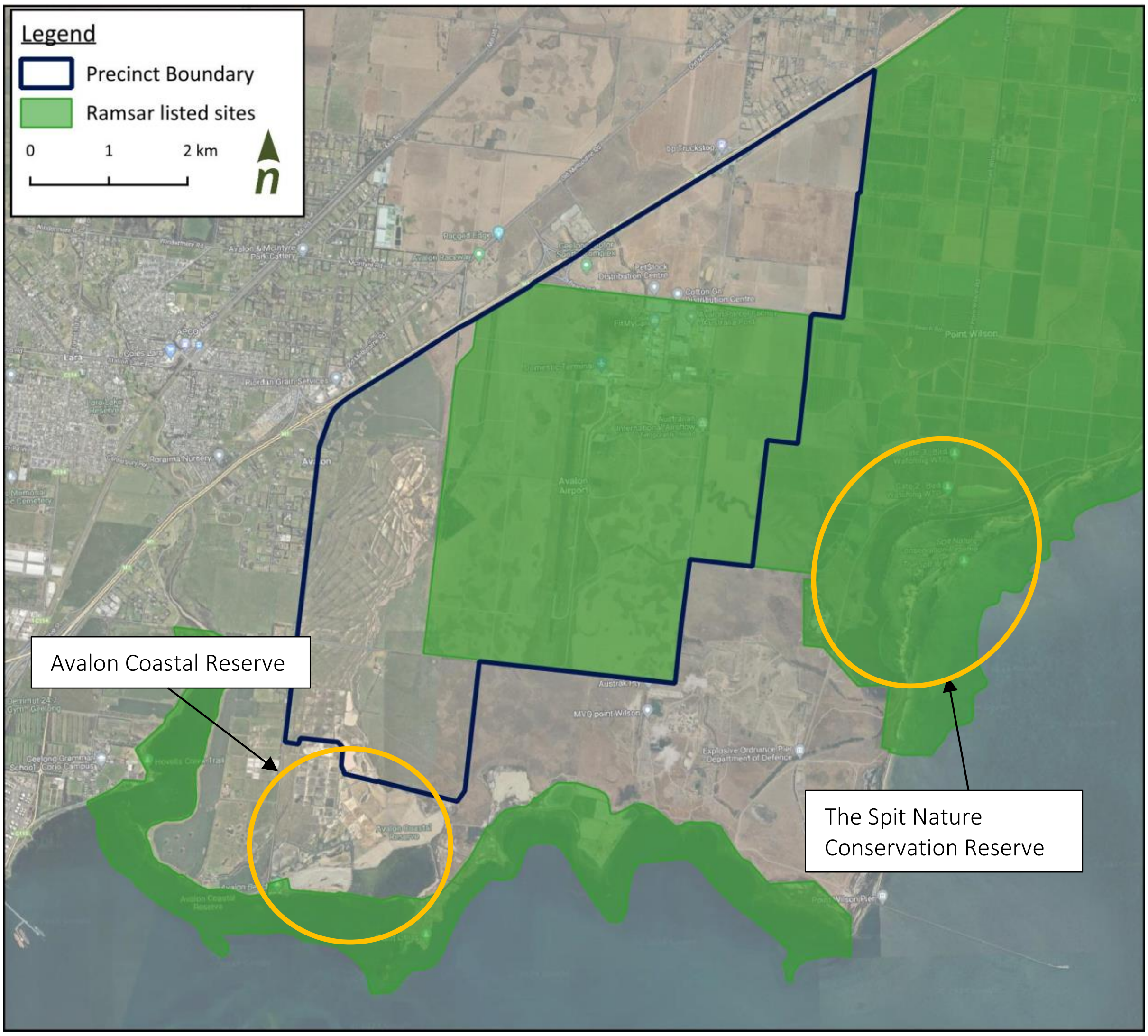

Figure 2. *Key characteristics within the GAEP*

The GAEP outfalls in two distinct directions, south through the Avalon Coastal Reserve, and south-east through the WTP and into The Spit Nature Conservation Reserve.

3 Background data

The GAEP is divided into two major catchments, the western catchment (which is managed by Corangamite CMA) and the eastern catchment (which is managed by Melbourne Water). An overview of the CMA boundaries is shown in Figure 3 below.

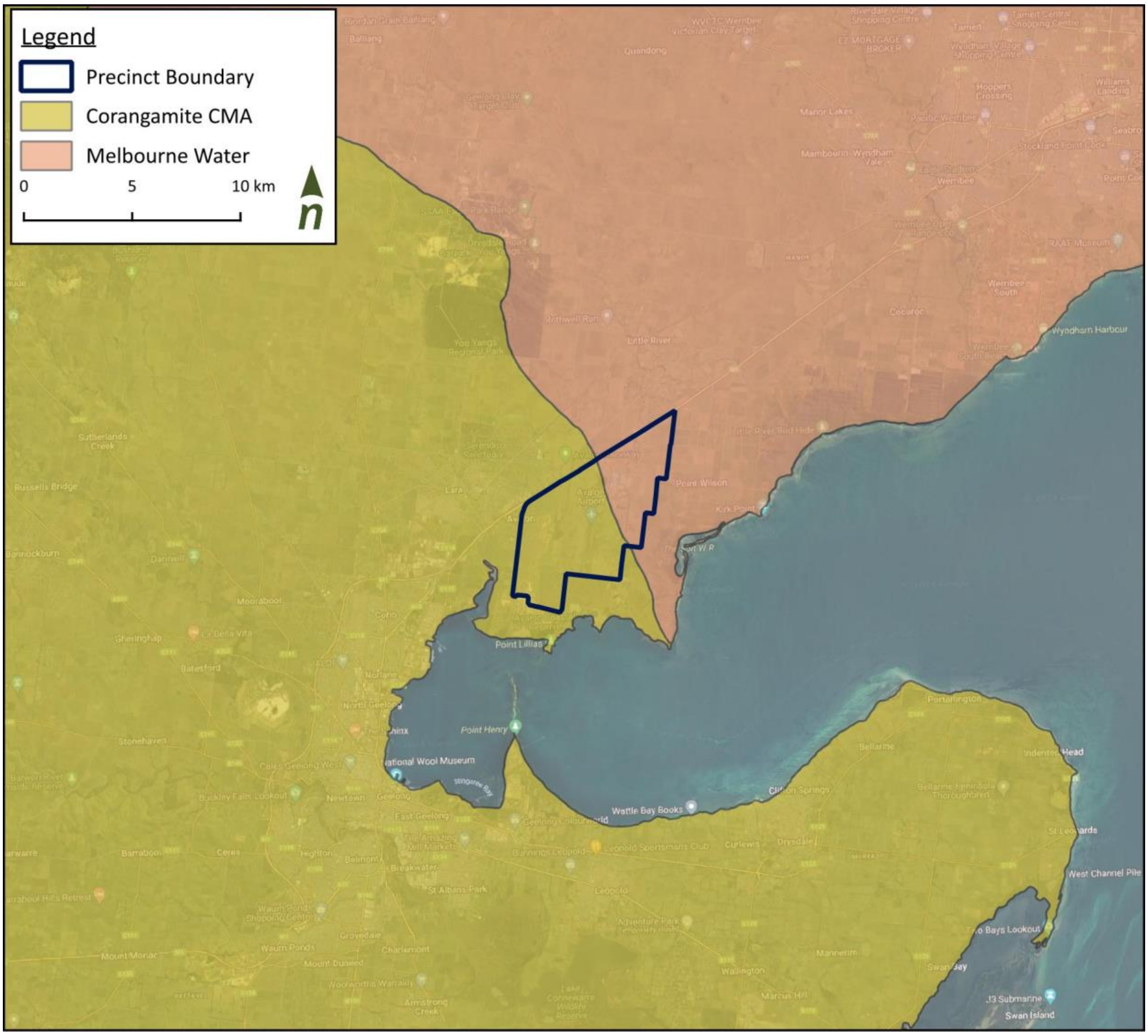

Figure 3. CMA boundaries within the GAEP

Hydrologic (RORB) and hydraulic (TUFLOW) models have been provided for the western and eastern catchments, including the associated reports produced as part of each model. The models are covered in the following approved studies:

- The Lara flood study (Water Technology), which covers the western catchment (i.e. Corangamite CMA catchment).
- The Western Treatment Plant waterway mapping project (BMT WBM), which covers the eastern catchment (i.e. Melbourne Water catchment).

A summary of each of the obtained hydrologic (RORB) and hydraulic (TUFLOW) models is provided below, further details of the RORB and TUFLOW modelling inputs and parameters are provided in Sections 4 & 5.

3.1 WTP flood modelling project (Melbourne Water catchment)

The WTP flood modelling projects covers the eastern portion of the GAEP. Figure 4 below indicates the total extents of the RORB and TUFLOW models within the GAEP study area.

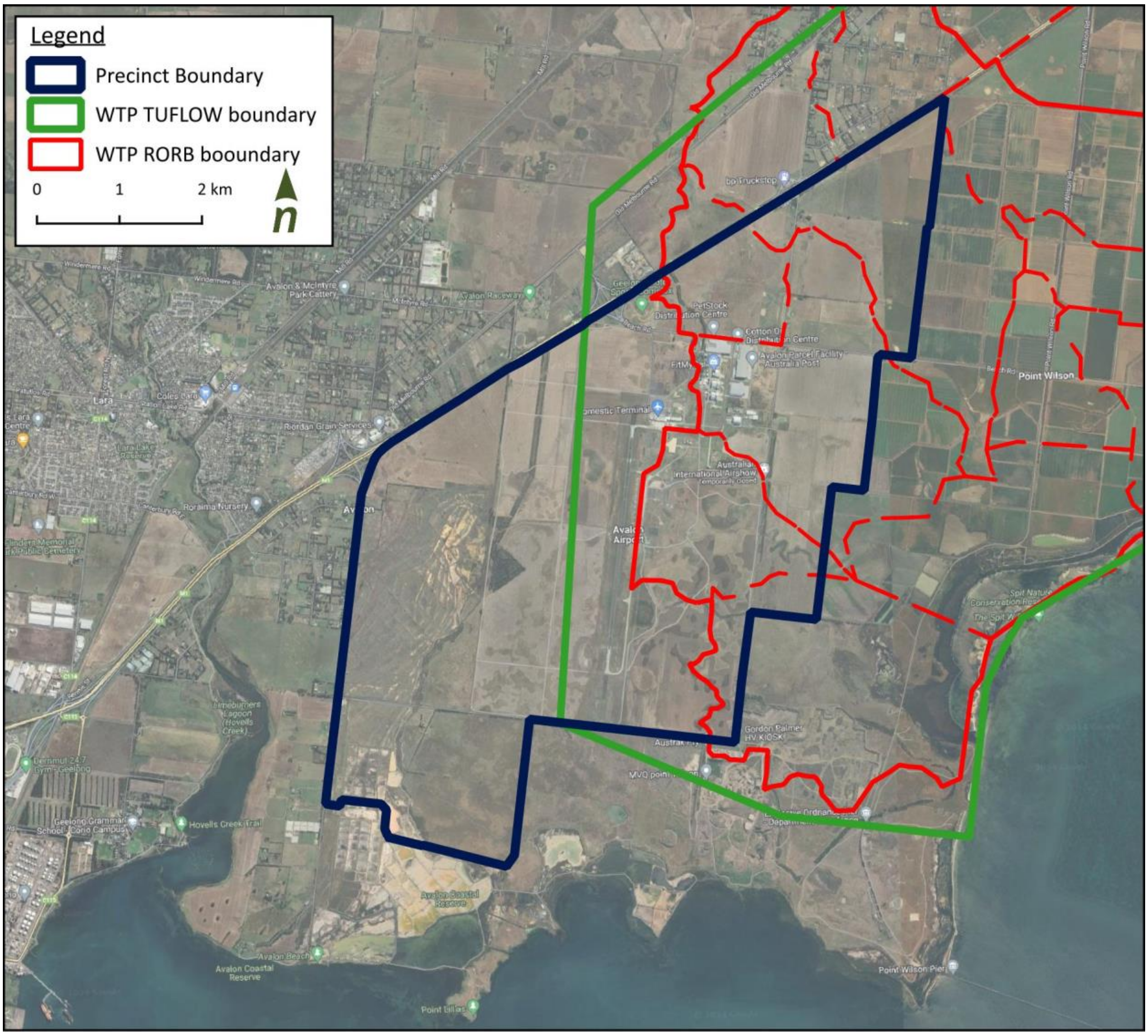

Figure 4. *WTP model extents within the GAEP*

The RORB and TUFLOW models produced as part of the WTP flood mapping project have been approved by Melbourne Water as part of their flood mapping of the WTP, and have been provided to Alluvium for use.

Hydrologic RORB model

The purpose of the RORB modelling undertaken as part of the WTP modelling was to route and extract sub-area hydrographs to use as input boundary conditions for the TUFLOW model. The modelling was undertaken using existing RORB models that were provided by Melbourne Water to BMT WBM for the following catchments:

- Little River
- Cherry Creek
- Trib of Cherry Creek
- Werribee River
- Western Treatment Plant model (developed by BMT WBM to provide internal rainfall boundaries for the flood mapping).

As stated in the BMT WBM report, sufficient stream gauging data is not available within the study catchments to support a model calibration. As a result, the models were calibrated against the Regional Flood Frequency Estimates (RFFE). The model parameters are further discussed in Section 4.2.

An overview of the contributing catchments is shown in Figure 5 below.

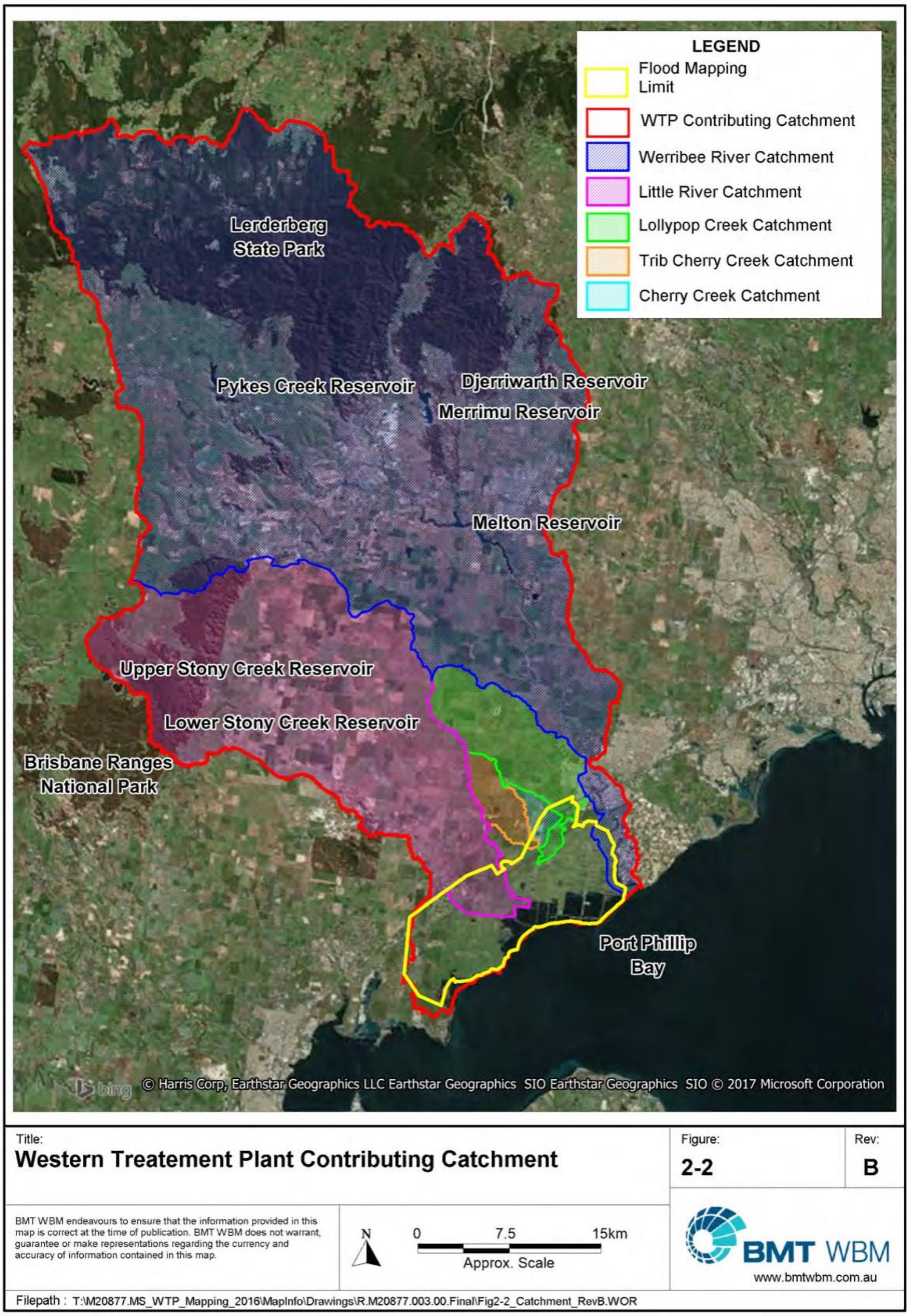

Figure 5. *WTP contributing catchments and study area (source: BMT WBM, 2017)*

Hydraulic TUFLOW model

A TUFLOW model was generated for the WTP project, the model covers an area of approximately 171.7 km^2. The TUFLOW model was generated and run for the 20%, 10%, 5%, 2%, and 1% Annual Exceedance Probability (AEP) events, as well as the Probable Maximum Flood (PMF).

Sensitivity testing of a range of modelling approaches with respect to sea level rise and climate change were also undertaken. The following scenarios were tested:

- Scenario A – base conditions (i.e. no sea level rise or climate change rainfall intensity factoring)
- Scenario B – consideration of sea level rise
- Scenario C – consideration of sea level rise and increased rainfall intensity
- Scenario D – consideration of increased rainfall intensity.

The TUFLOW model was run for the following peak duration and temporal patterns (Table 1).

Table 1. Critical events and durations

AEP	Hydrologic model	Hydraulic model
20%	48 hour (Temporal Pattern 4)	48 hour (Temporal Pattern 7)
10%	48 hour (Temporal Pattern 1)	48 hour (Temporal Pattern 7)
5%	48 hour (Temporal Pattern 1)	12 hour (Temporal Pattern 4) 24 hour (Temporal Pattern 1) 48 hour (Temporal Pattern 3)
2%	48 hour (Temporal Pattern 4)	24 hour (Temporal Pattern 1) 48 hour (Temporal Pattern 2) 72 hour (Temporal Pattern 4)
1%	48 hour (Temporal Pattern 4)	24 hour (Temporal Pattern 3) 48 hour (Temporal Pattern 2)
PMF	24 hour	4 hour 24 hour

3.2 Lara flood study flood modelling project (Corangamite CMA catchment)

The Lara flood model covers the western portion of the GAEP. Figure 3 below indicates the total extents of the RORB and TUFLOW models within the GAEP.

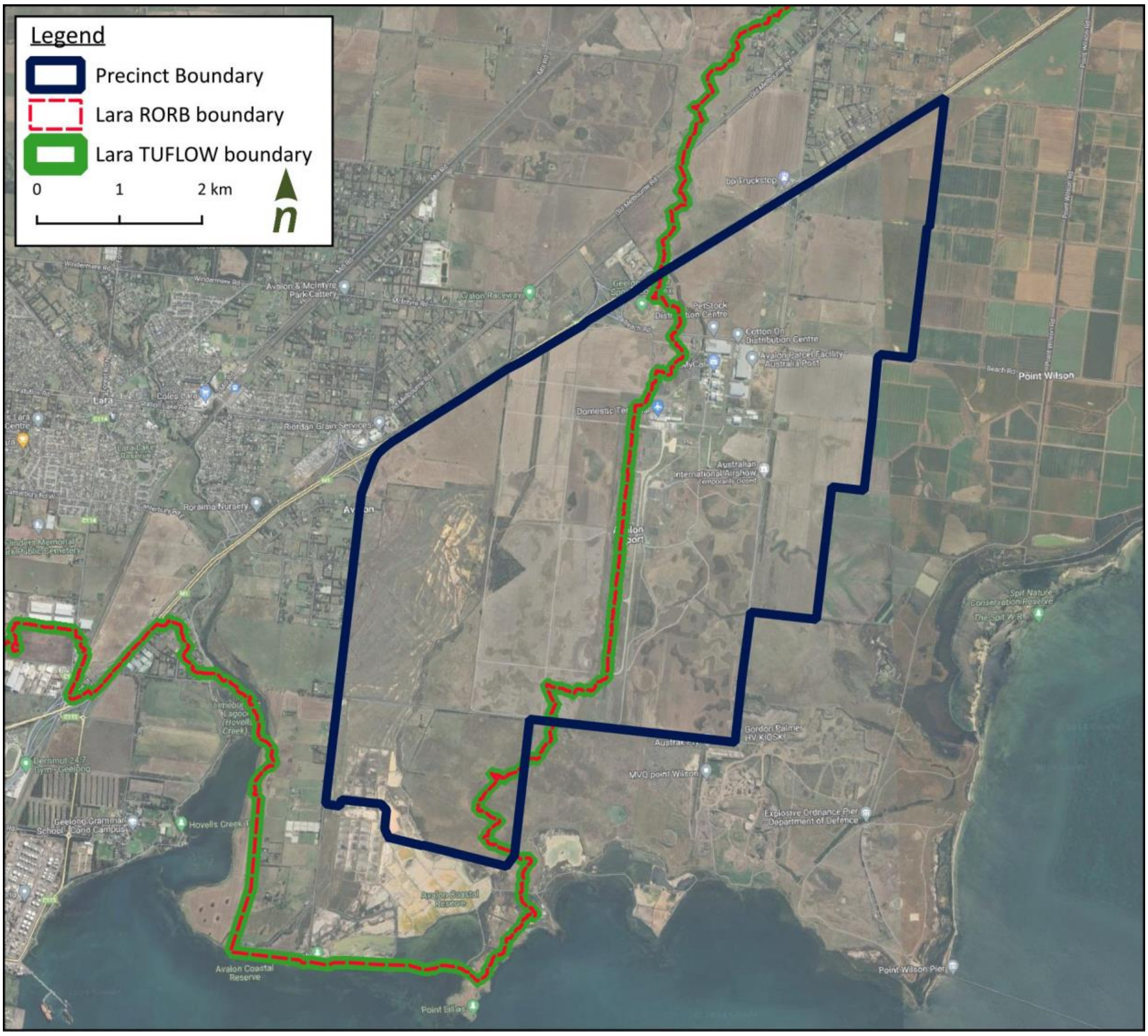

Figure 6. *Lara model extents within the GAEP*

Hydrologic RORB model

The flood study for the Lara township investigated two major catchments that outfall through the township of Lara – the Avalon Catchment (to the east) and the Lara / Hovells Creek Catchment (to the north) as shown in Figure 7. A RORB model was developed for the Lara/Hovells Creek and the Avalon Catchments by Water Technology.

Water Technology indicated that there is limited streamflow data available for the Hovells Creek Catchment, and limited data available for Avalon. There was some historic rainfall data sources that provided a basis for calibration. A summary of the historical data is provided in Table 2 below.

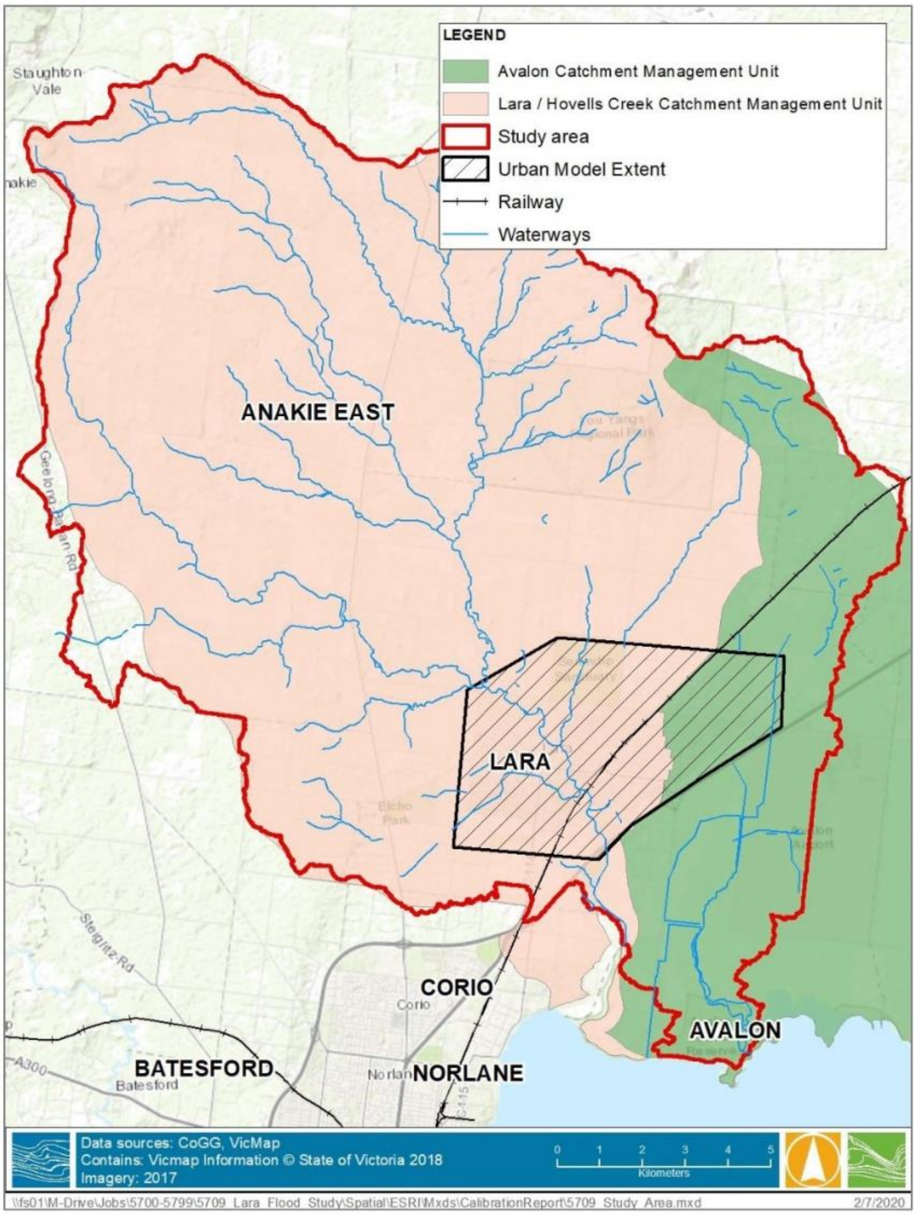

Figure 7. *Lara township (internal/external) contributing catchments (source: Water Technology, 2020)*

Table 2. Existing calibration event data sources

Event	Data Available	Flinders Av. Gauge Height (m AHD)	Hovells Creek Flow Estimates (m^3/s)	Reliability of Calibration Data
February 1973	Flood extent, aerial photography, anecdotal evidence, surveyed flood heights	8.74	350	Moderate
December 1988	Aerial photography, anecdotal evidence, surveyed flood heights	9.10	500	Moderate
February 2005	Anecdotal flood heights	7.64	Unknown	Low
April 2017	Water level data (Flinders Ave & Rennie St)	6.84	20	High

Hydraulic TUFLOW model

A TUFLOW model was developed by Water Technology for the Lara flood study. The TUFLOW model used input hydrographs from the RORB modelling undertaken. The hydraulic modelling reflected the current conditions of the catchment (at the time of the project, i.e. March 2020). The extent of the TUFLOW model is provided in Figure 6 below.

The TUFLOW model was run for a range of sensitivity tests, including:

- 10% and 1% AEP with climate change scenarios
- 10% and 1% AEP with blockage scenarios, in line with ARR 2016
- 10% and 1% AEP with increased channel roughness
- 10% and 1% AEP with sea level rise and storm surge scenarios

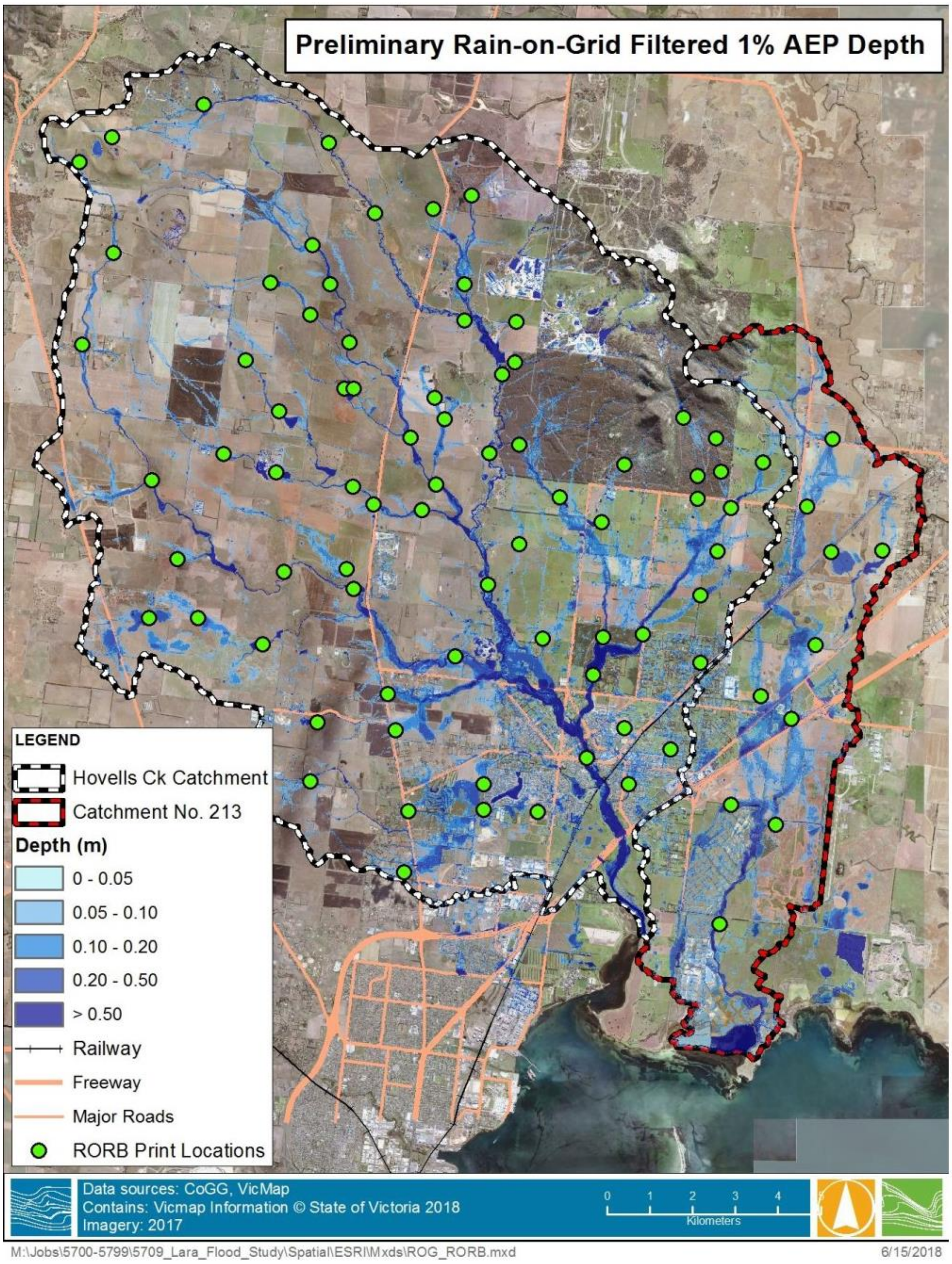

Figure 8. *Lara TUFLOW model extents (source: Water Technology, 2020)*

4 Hydrology

The hydrologic analysis of the GAEP was undertaken to determine the existing peak runoff flow rate (m^3/s) for various flood events throughout the catchment. The hydrologic analysis is used to inform the existing peak flow rates flowing into and out of the catchment. The peak flow rates at the points of interest were determined for further use in the flood modelling.

4.1 Hydrologic modelling

The hydrologic analysis was undertaken using RORB (v6.31), which is a runoff-routing software designed to simulate attenuation and time of concentrations to produce flood estimates at specified catchment locations.

As previously discussed, RORB models were provided for the eastern and western catchments, the models were checked, validated and run to determine:

- Existing peak flows
- Flood hydrographs for the existing peak flows

The RORB models were built by delineating the major catchments into sub-areas based on topography. The major catchments include the undeveloped areas proposed for future residential use and the existing residential areas.

4.2 Input parameters

In line with the Australian Rainfall & Runoff (2019), calibration of the hydrologic model (i.e. RORB model) is required in order to determine the estimation of rainfall intensities for a specific site. Given there are two models across two major catchments (i.e. eastern and western), two different calibration methods were adopted as part of the approved modelling. The calibration methods are summarised below.

WTP flood modelling (BMT WBM) – eastern catchment

As stated in the BMT WBM report, sufficient stream gauging data is not available within the study catchments to support a model calibration. As a result, the models were calibrated against the Regional Flood Frequency Estimates (RFFE). As a result, the kc parameter was calibrated using RFFE and sensitivity tested against the previous modelling undertaken. a summary of the RORB model parameters adopted are summarised below (Table 3).

Table 3. Summary of RORB model parameter – WTP flood mapping (source: BMT WBM)

Parameter		Value
Routing parameter kc	Werribee River –	72.60
	Little River –	40.00
	Lollypop Creek –	23.70
	Cherry Creek –	3.00
	Trib of Cherry Creek –	7.50
	WTP Local Catchment –	10.50
m		0.80
Initial Loss (mm)		20.00
Continuing Loss (mm/hr)		1.90

The flows determined were compared against the RFFE flow rates. A summary of the RORB flows and the RFFE flows is shown in Table 4 below.

Table 4. Results of model calibration (source: BMT WBM)

Catchment	kc	1% AEP RFFE flow (m^3/s)	1% AEP RORB flow (m^3/s)
Werribee River	72.60	812	800
Little River	40.00	353	344
Lollypop Creek	23.70	103	102
Cherry Creek	3.00	18.0	18.1
Trib of Cherry Creek	7.50	36.6	34.4
WTP Local Catchment	10.50	1,200	1,212

Lara flood study flood modelling project (Water Technology) – Western Catchment

Water Technology indicated that the modelling was calibrated to the Flinders Avenue and Rennie Street stream gauges for the 2017 flood event, to flood extents, aerial imagery and anecdotal evidence for all remaining events. A summary of the adopted RORB modelling parameters adopted are provided below (Table 5).

Table 5. Summary of RORB model parameter – WTP flood mapping (source: Water Technology)

Parameter	Value	
Routing parameter kc	Flinders Avenue –	15.00
	North Lara –	2.00
	Elcho Drain –	8.00
	Rennie Street –	15.00
	Avalon –	13.64
	Catchment outlet –	6.42
m		0.80
Initial Loss (mm)		15.00
Continuing Loss (mm/hr)		1.50

The Lara Flood Study RORB model was calibrated by adjusting the kc parameters to match flows to the hydraulic model at interstation locations. The flows were adjusted to calibrate flows to match closer to the gauged and surveyed flood levels within the catchment. An overview of the modelled and recorded flood levels at Hovells Creek are provided below (Figure 9). Further details on the calibration methods are provided in the Water technology Lara flood study reporting.

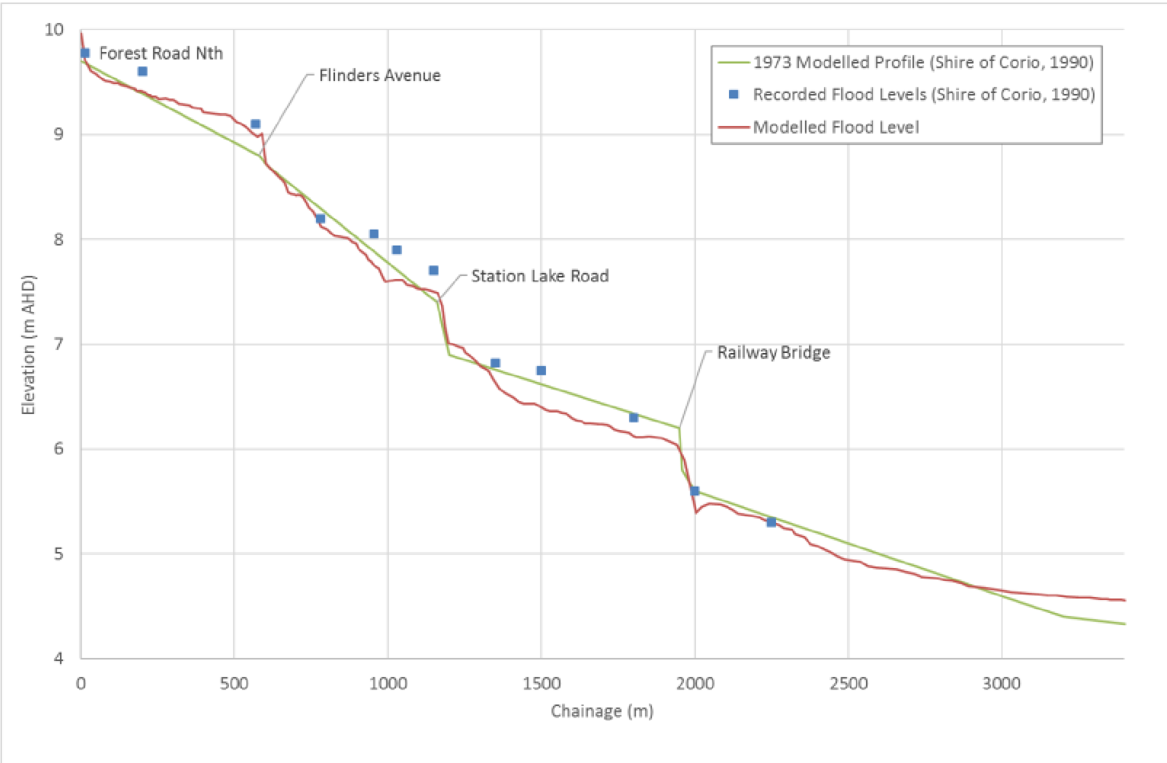

Figure 9. *Modelled and recorded flood levels of Hovells Creek (source: Water Technology)*

4.3 Catchment modelling

The aim of the RORB modelling is to establish critical peak flows flowing into and out of the GAEP, in particular the points of interest used as the inputs into the flood modelling and where future locations of proposed stormwater management assets are located.

The RORB model setup for the existing conditions modelling is provided in Figure 10.

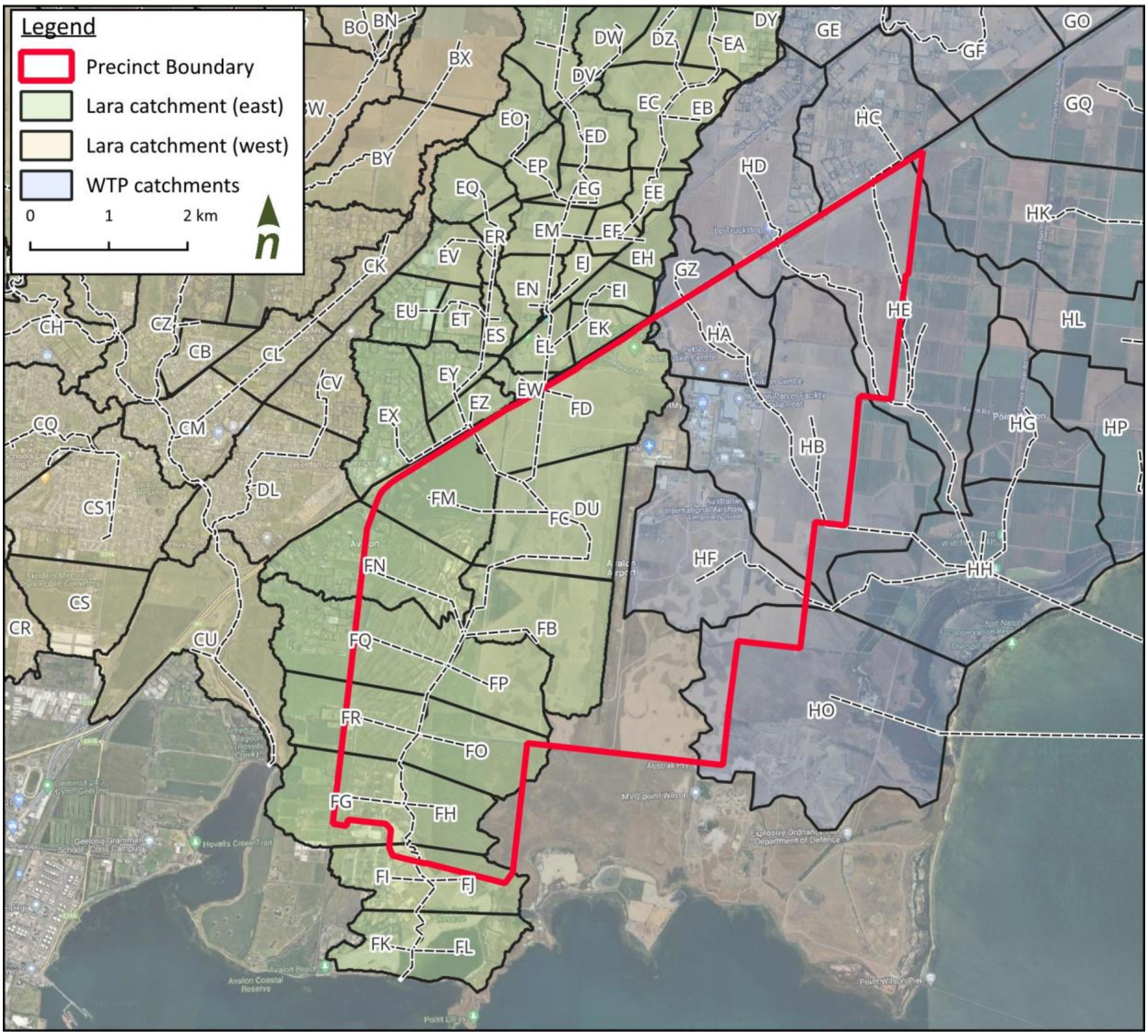

Figure 10. *RORB model catchments for the GAEP*

The RORB model has been run for the 1%, 1% (with Climate change), 2%, 5%, 10% and 20% AEP events. A number of flow outputs were determined at key locations within the growth areas as identified in Figure 11 below. Details of these peak flow rates are provided in Table 6.

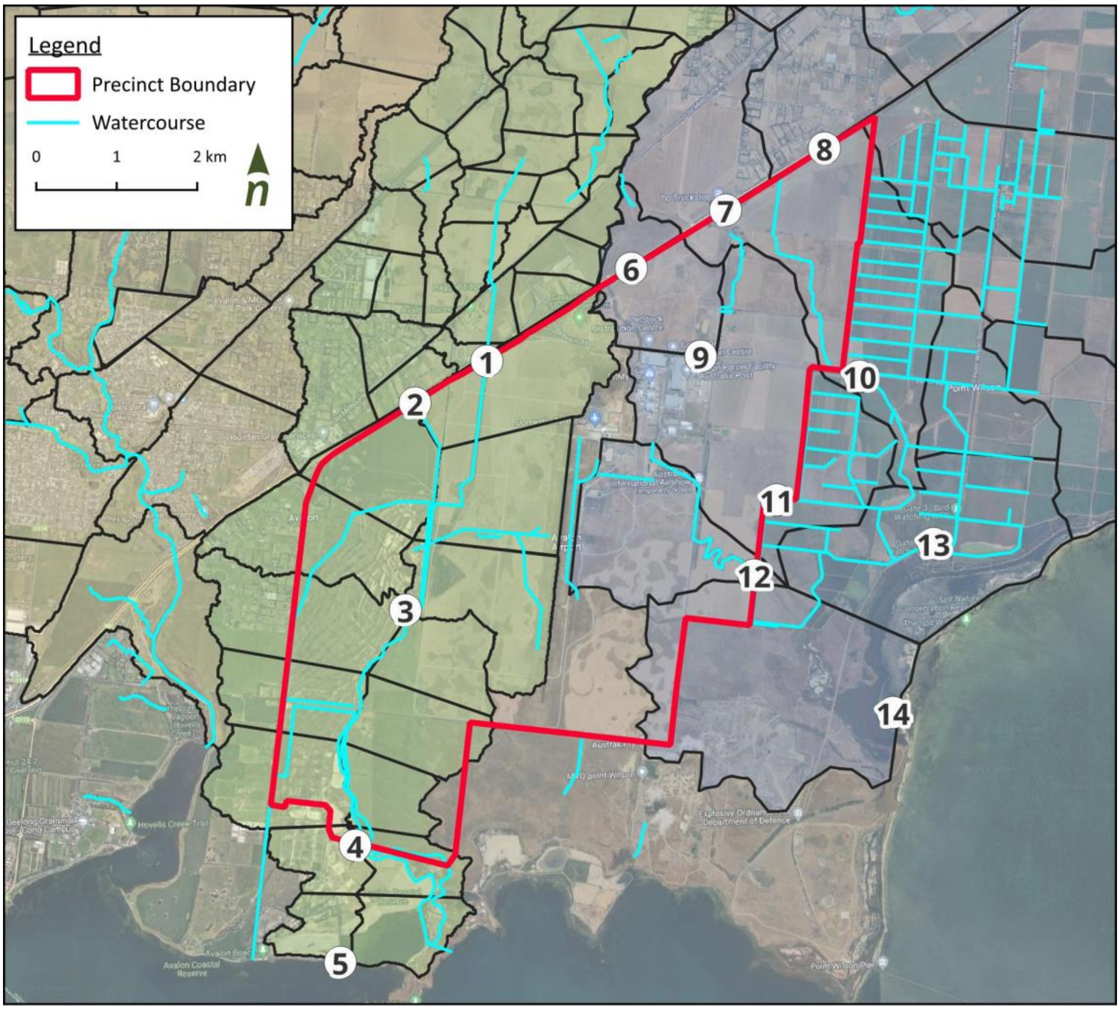

Figure 11. *Location of key flow rates within the GAEP*

Table 6. RORB modelling results for major catchments of GAEP under existing conditions

Flow location	1%AEP with CC (m^3/s)	1%AEP (m^3/s)	2%AEP (m^3/s)	5%AEP (m^3/s)	10%AEP (m^3/s)	20%AEP (m^3/s)
1	6.20	5.13	4.47	3.20	2.74	2.39
2	3.75	3.04	2.63	2.11	1.82	1.59
3	33.87	27.56	23.34	16.45	12.91	9.45
4	48.24	37.74	32.38	24.73	19.56	13.89
5	50.79	40.37	33.50	25.42	19.86	14.17
6	1.65	1.34	1.18	0.90	0.71	0.53
7	8.83	7.34	6.40	4.88	3.18	2.62
8	6.75	5.56	4.78	3.20	2.34	1.87
9	5.72	4.69	4.04	3.05	2.08	1.65
10	24.93	20.09	16.86	11.41	8.80	6.10
11	23.45	19.33	16.64	12.46	8.17	6.53

Flow location	1%AEP with CC (m^3/s)	1%AEP (m^3/s)	2%AEP (m^3/s)	5%AEP (m^3/s)	10%AEP (m^3/s)	20%AEP (m^3/s)
12	6.83	5.51	4.64	3.25	2.56	1.88
13	54.05	43.00	36.22	25.03	18.61	11.26
14	18.17	15.23	13.30	9.99	8.23	7.21

5 Hydraulic modelling

A 1D/2D hydraulic model was created for the Lara Flood Study and the Western Treatment Plant flood mapping as previously discussed. The model was run using TUFLOW version 2020-10-AF. The TUFLOW model is used to estimate peak flood levels, flood extents, flows and velocities for a range of storm events and durations. The model was run using HPC (heavily Parallelised Compute). The TUFLOW model was computed for the existing conditions scenario.

The TUFLOW model is based on the following data:

- LiDAR information used to generate a Digital Elevation Model (DEM),
- Inflow boundary conditions to produce runoff within the model, hydrographs were generated from the RORB models in section 4,
- Surface roughness values based on the existing site conditions,
- 1D network data for pipes, pits & culvert crossings,
- Downstream 1D & 2D boundary conditions where required.

The following summarises the key inputs and limitations of the TUFLOW models.

Summary of applied models

The provided flood studies were reviewed and deemed appropriate for application for initial flood planning for the site. The hydrologic models and outputs provided were not changed due to the detailed calibration undertaken in the development of the flood studies.

The hydraulic models were manipulated and run for selected relevant scenarios and storm events to capture expected critical flood conditions across the study site. A summary of modelled scenarios and events run for each model are provided in Table 7 below.

Table 7. GAEP combination model scenarios

Parameter	WTP flood model	Lara flood model
Storm AEP	10% AEP, 1% AEP, 1% AEP climate change	10% AEP, 1% AEP, 1% AEP climate change
Storm durations	15m, 30m, 1h, 2h, 3h, 6h, 12h, 24h, 48h, 72h	2hr 6hr 9hr 12hr 18h 48hr CC: 12hr and 18hr
Temporal patterns	All 10 ensemble patterns	Previously determined critical temporal patterns for each duration
Existing scenario assumptions	Conservative Manning’s assumption of n=0.12 adopted for maize fields (Scenario M2)	Post 1990 levee conditions (Scenario EX)

Parameter	WTP flood model	Lara flood model
Climate change scenario assumptions	Increased rainfall intensity and sea level rise (Scenario CC02)	Increased rainfall intensity and sea level rise (Scenario SLR and RCP8.5 2090 rainfall)

Limitations of applied models

Due to the positioning of the GAEP over the boundary of both catchments and the application of two independent models to assess flooding, the below limitations of the modelling are noted:

- The topography across the airport creates a valley which is excluded from both models, resulting in an area of around 340ha of the GAEP catchment that is not included in the flood modelling (Figure 12).
- The GAEP sits across the boundaries of both models, at the top of their respective catchments where the accuracy of flood results tend to be more limited.

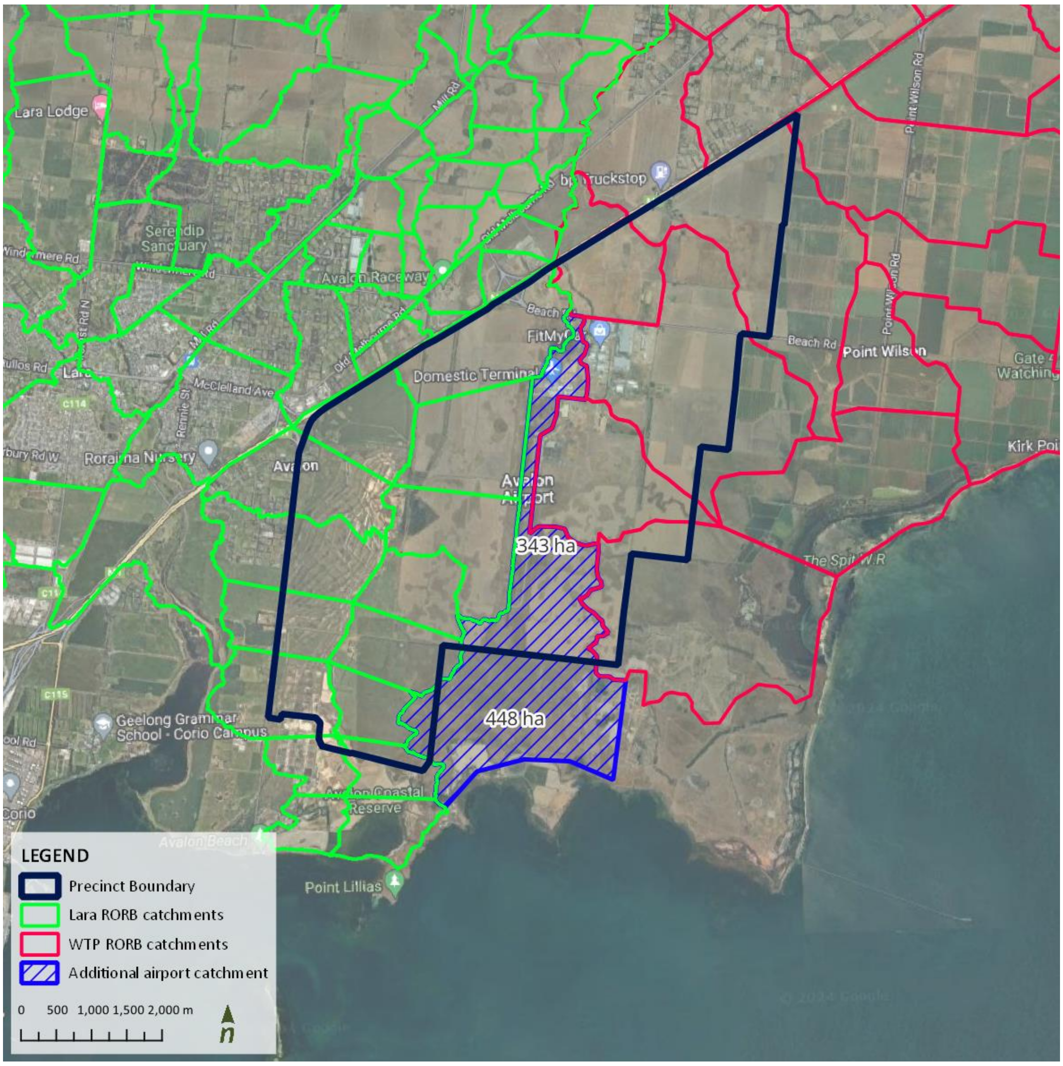

Figure 12. *GAEP catchment that is not covered by existing flood studies*

Note, whilst the additional catchment has not been included in either flood model, the catchment is expected to outfall in a southerly direction, based on discussions with the Avalon Airport.

5.1 Model Development

Model Extent

Two separate models exist across the GAEP study area, the WTP flood mapping TUFLOW model to the east and the Lara Flood study to the east. The WTP flood mapping model extends from Avalon to the west, Werribee South to the east, Princes Highway to the north and Port Phillip Bay to the south. The WTP flood mapping model covers an area of approximately 171.7 km^2. The Lara flood study extends across the total catchment boundary and covers a total area of approximately 292.4 km^2. An overview of the two model extents is provided in Figure 12.

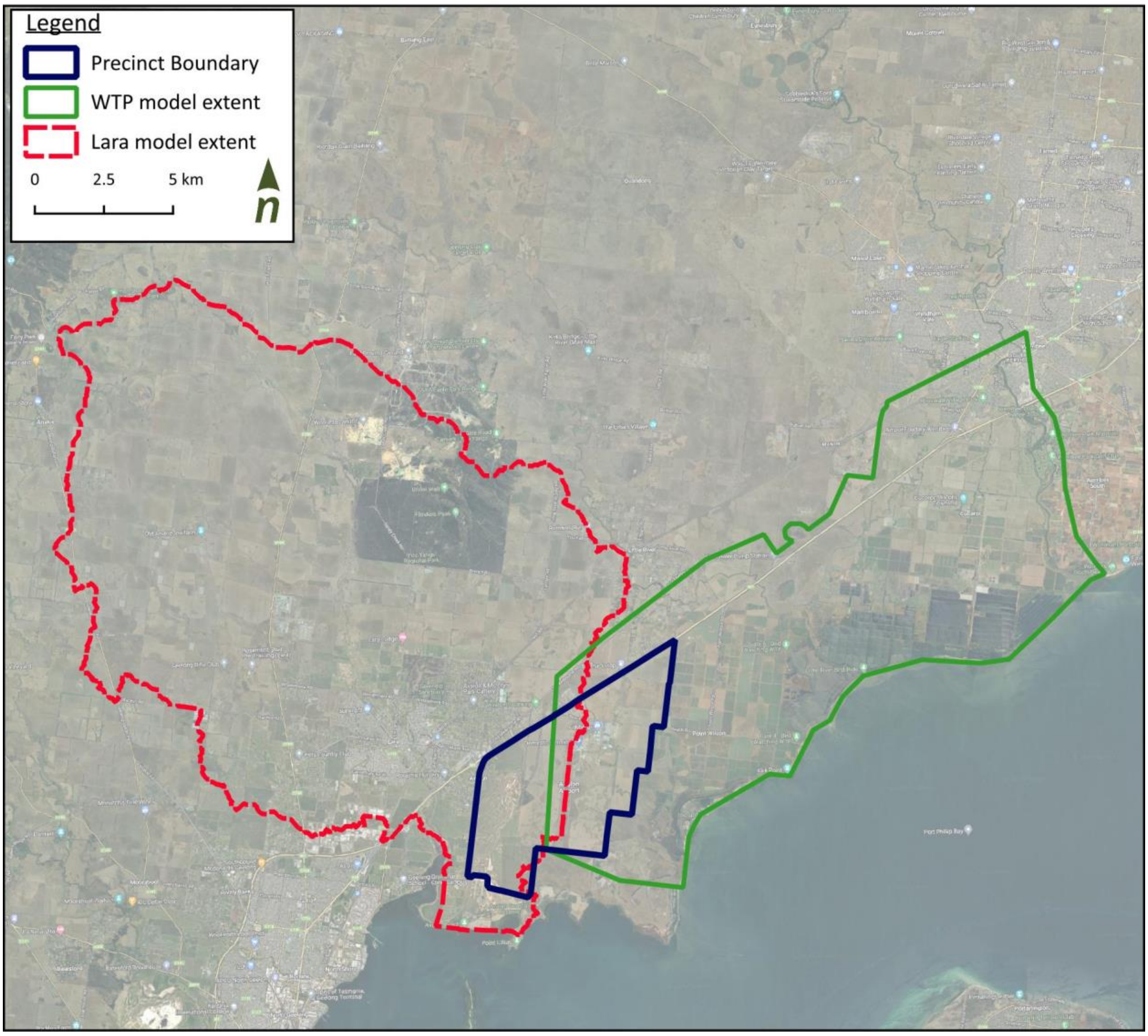

Figure 13. *GAEP TUFLOW model extents*

Topography

The DEM used for the TUFLOW model was created using a combination of LiDAR and 10m statewide digital terrain data (where gaps in LiDAR data exists). The LiDAR tiles were provided for both the Lara flood model and the WTP flood model. A summary of the LiDAR data sets used are provided below (Table 8).

Table 8. Summary of LiDAR data

Data set	Resolution	Year captured
Lara flood model		
“mosaic_all-lidar-photogrammetry_revised_dem1m_mga55.asc”	1m	-
WTP flood model		
“DTM_10m_e_MGA55.txt”	10m	-
“DEM_WTP_25JUL_2_0m.flt”	2m	-
“DEM_TIN_2017_1MDEM_FIRST-RETURN_converted.flt”	1m	2017
“DEM_TIN_2008WTP1MDTM_converted.flt”	1m	2008
“DEM_TIN_2009WTP1MDTM_converted.flt”	1m	2009
“DEM_TIN_2017_1MDEM_GROUND_converted.flt”	1m	2017

The Lara flood model and the WTP flood model were run using a 4m grid size and a 10m grid size respectively.

Boundary Conditions

Boundary conditions were determined at the upstream and downstream areas of the TUFLOW model. A number of QT (flow vs time) boundary conditions were defined at the upstream end of the model extents, where runoff enters the models along major overland flow paths. Within the model extents, 2D source areas were used to apply rainfall directly to the model surface, the source areas are represented by subcatchments directly exported from the RORB model. Rainfall excess hydrographs were exported from the RORB model and apply to the source areas.

The downstream boundary conditions consisted of 2D HQ (Head vs flow) conditions, where overland flow exits the model extents, to prevent pooling at the downstream boundary of the model.

An overview of the boundary conditions applied to the Lara flood model and the WTP flood model are provided in Figures 14 & 15 respectively.

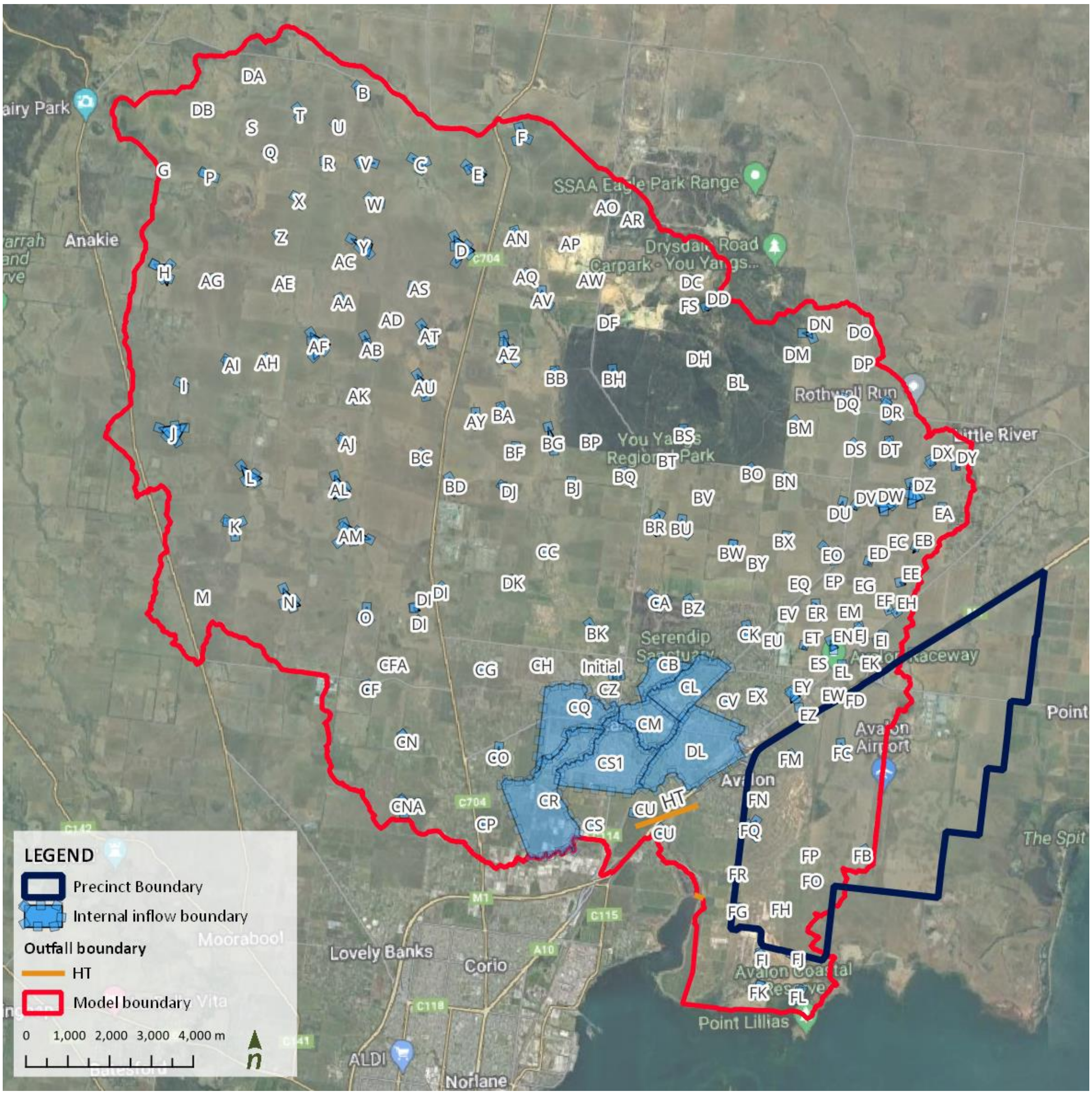

Figure 14. *Lara flood model TUFLOW boundary conditions*

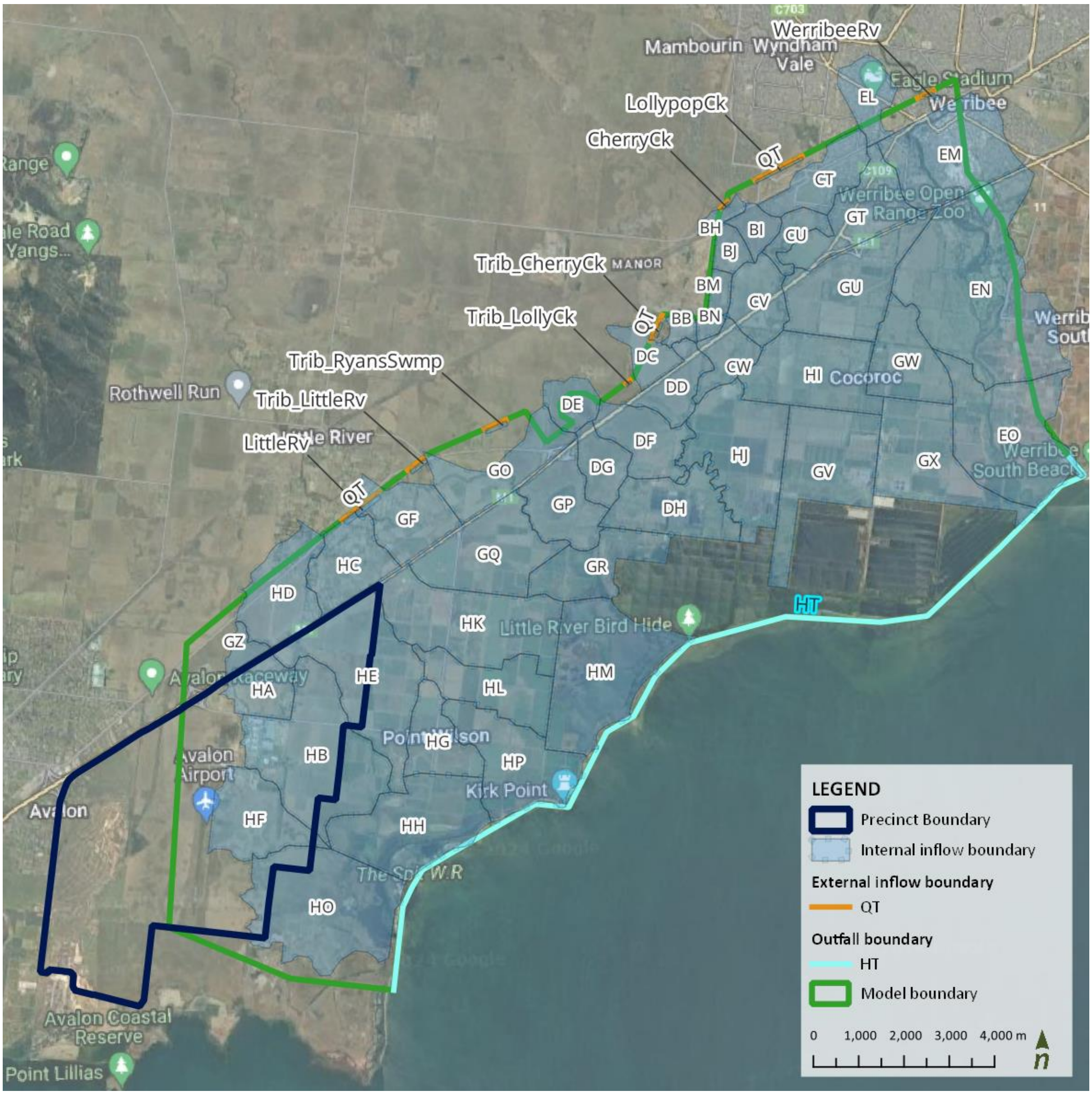

Figure 15. *WTP flood model TUFLOW boundary conditions*

Surface Roughness

Land use types were defined based on the existing site conditions. The land use types were determined in order to reflect the appropriate Manning's 'n' roughness value within the Lara flood model and the WTP flood model. A summary of the Manning's roughness values applied in each model are summarised in Table 9 below.

Table 9. Material roughness

Material Type	Lara flood model (Mannings' n)	WTP flood model (Mannings' n)
Pasture & some tall trees	0.06	0.055
Residential	0.2	0.20
Industrial	0.3	-
Carpark	0.05	0.025
Cemetery	0.15	-

Material Type	Lara flood model (Mannings' n)	WTP flood model (Mannings' n)
Large grassed areas	0.035	0.03
Paved road	0.02	0.025
Unpaved road	0.03	0.025
Ponds and other water bodies	0.03	0.02
Railway	0.045	-
Rural residential	0.1	-
Dense bushed	0.1	-
Creek with vegetation	0.1	0.12
Vegetated waterway	0.07	0.07
Roof	0.02	-
Clean straight stream	-	0.035
Open space	-	0.05
Irrigation channels	-	0.04

5.2 Model Results

Both hydraulic models were run using the available hydrology information to provide a combined overview of expected flood conditions though the region. This involved creating maximum flood maps to report on the critical flood extent for the entire modelled area. The combined 10%, 1% and 1% AEP climate change flood depth and velocity results are presented in Figure 16 through to Figure 21.

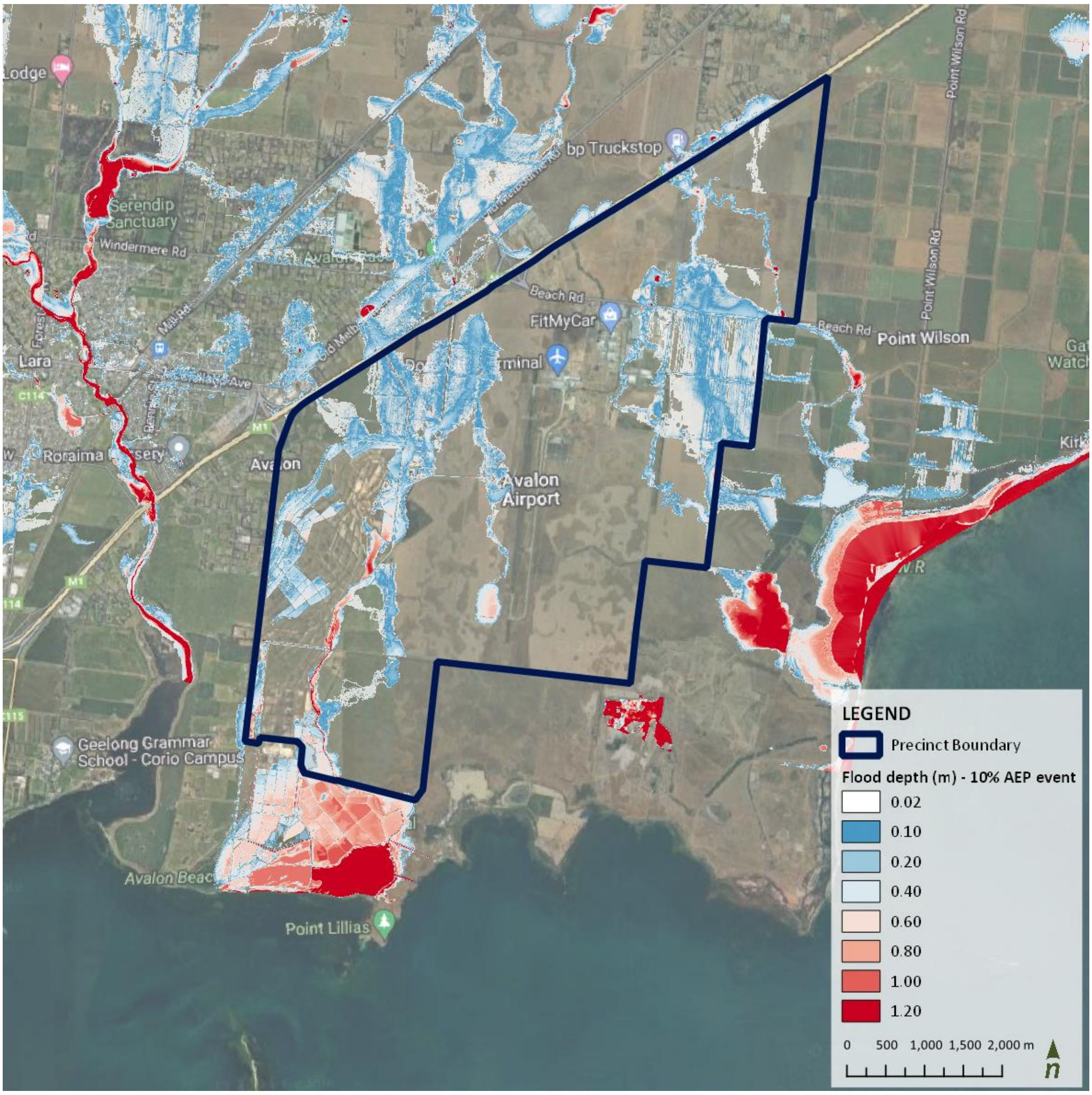

Figure 16. *Combined maximum flood depth results for the 10% AEP flood event*

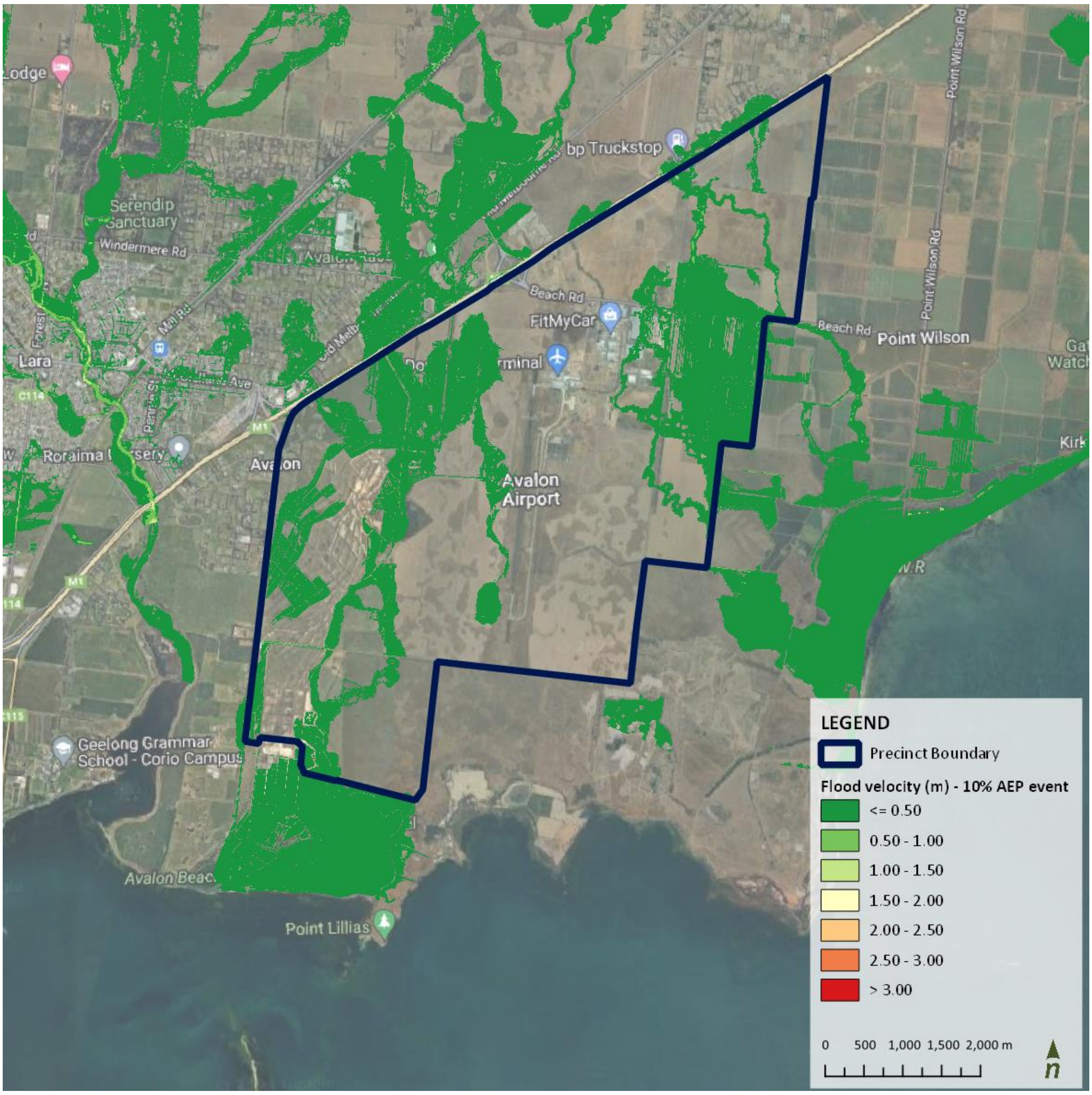

Figure 17. *Combined maximum flood velocity results for the 10% AEP flood event*

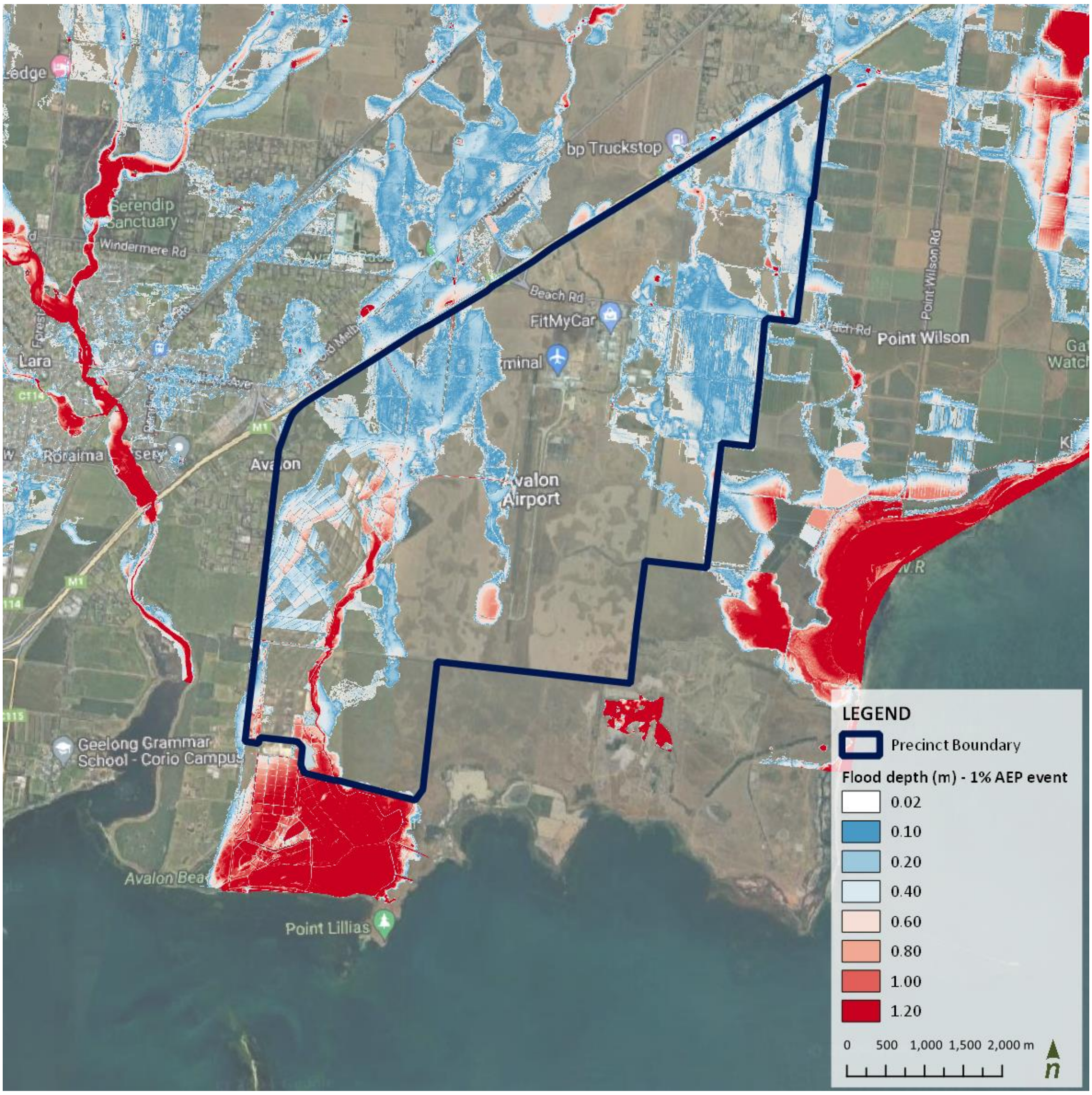

Figure 18. *Combined maximum flood depth results for the 1% AEP flood event*

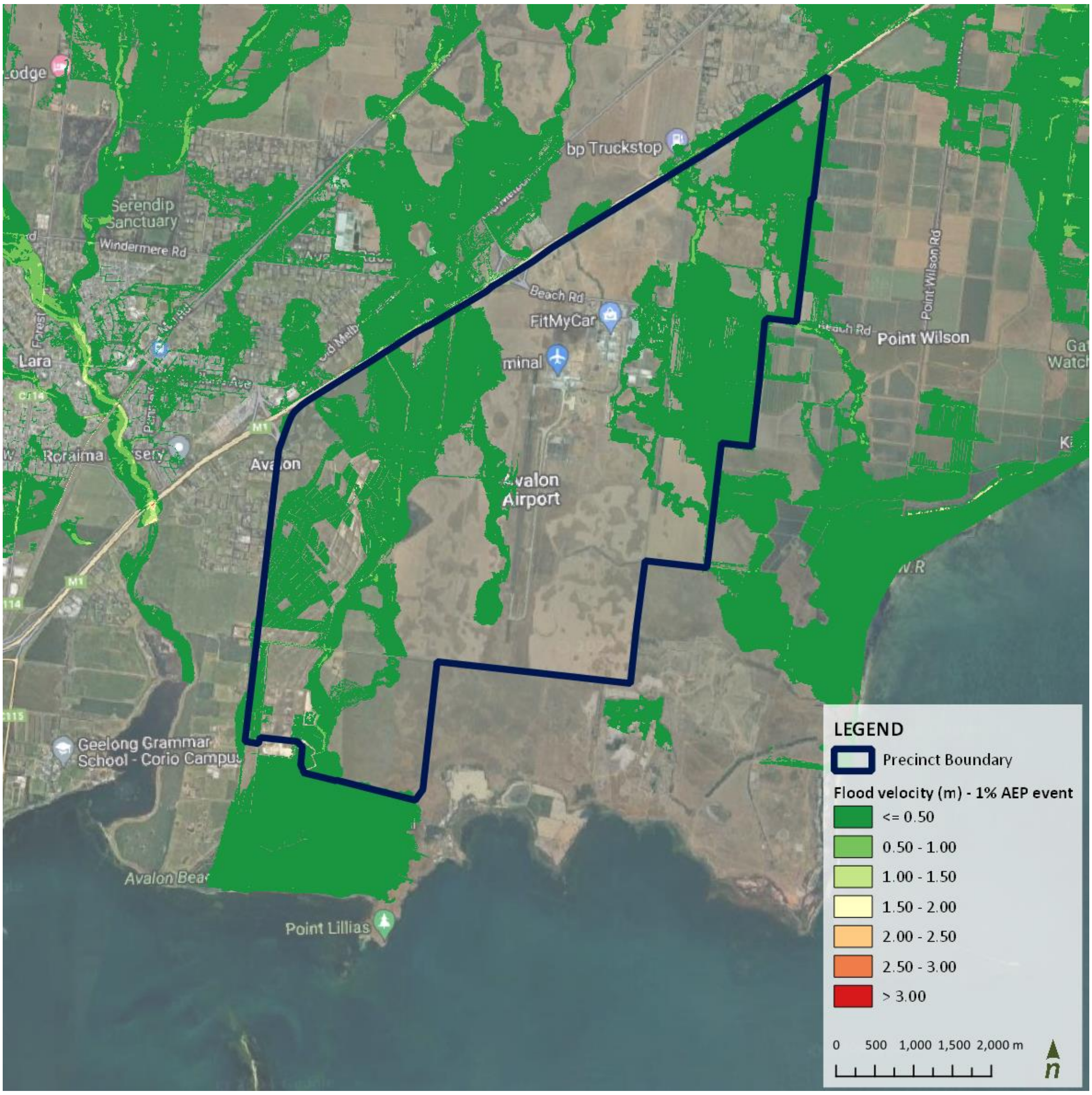

Figure 19. *Combined maximum flood velocity results for the 1% AEP flood event*

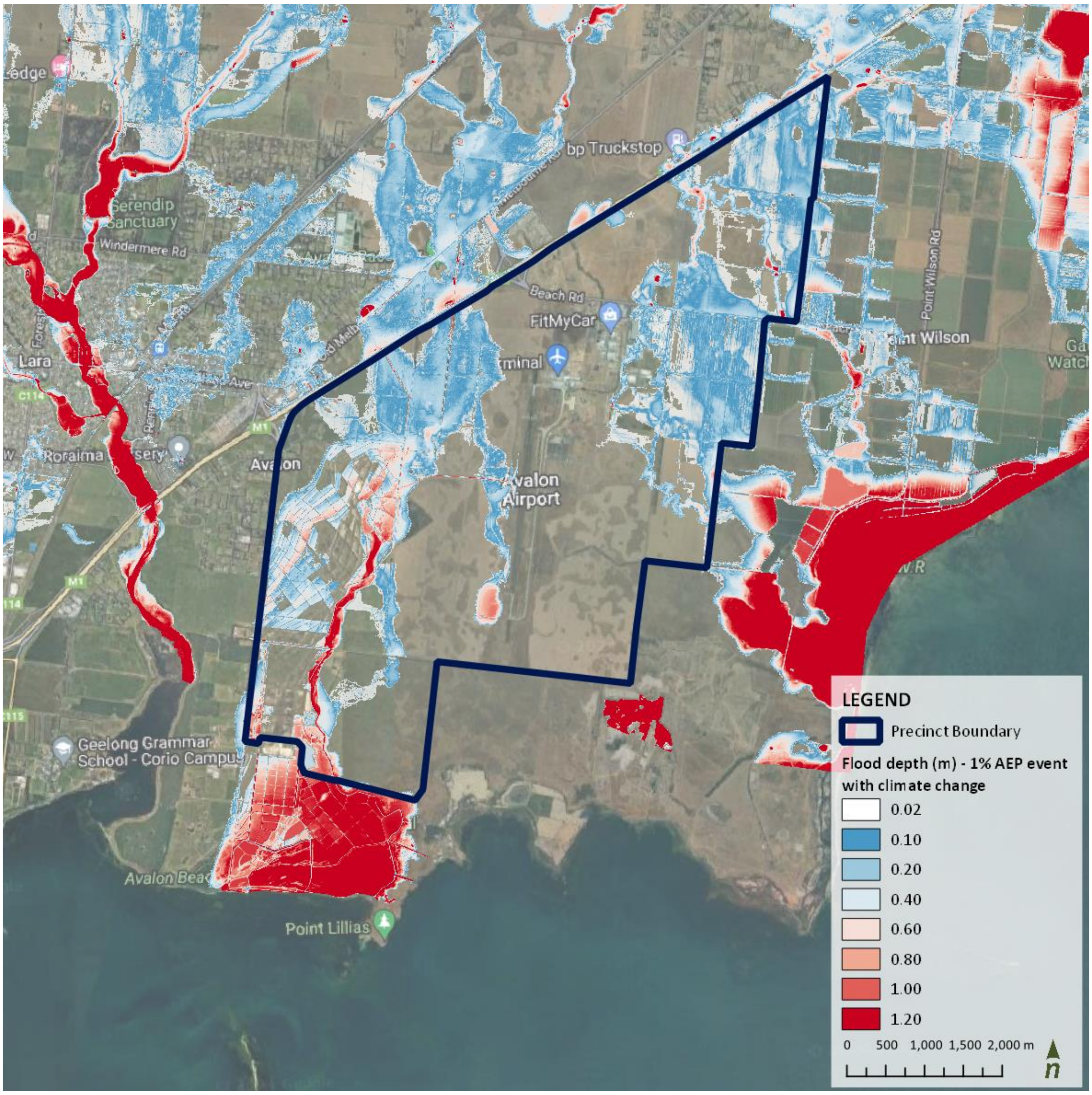

Figure 20. *Combined maximum flood depth results for the 1% AEP flood event with climate change (intensity & sea level rise)*

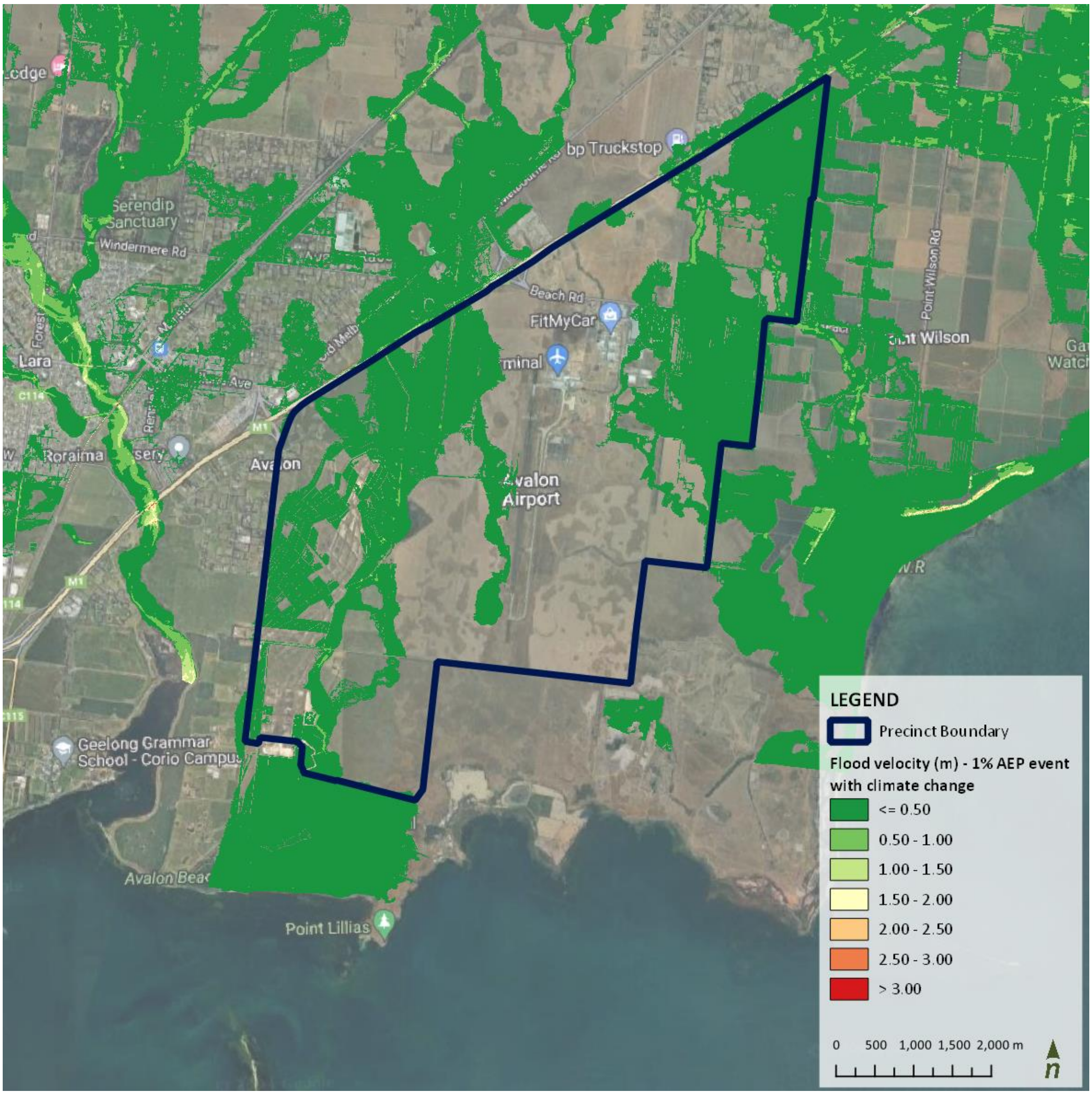

Figure 21. *Combined maximum flood velocity results for the 1% AEP flood event with climate change (intensity & sea level rise)*

5.3 Results discussion

The results from the existing conditions flood modelling assessment indicate that there is significant runoff outfalling through the GAEP from the upstream external catchments in the 10% AEP, 1% AEP and 1% AEP with climate change results. External catchments are generally conveyed through existing drains downstream of the Princes Freeway before overtopping and sheet flowing through the GAEP (Figure 22).

Runoff from the GAEP outfalls via the two major existing waterways/ drains along the western and eastern areas. The waterways outfall into the Avalon Coastal Reserve (west) and into the Spit Nature Reserve via the WTP (east). Significant inundation occurs along the Coastal Reserves, due to the direct connection to Port Phillip Bay. The results show that the Coastal Reserves creates a high tailwater back through the GAEP (Figure 23).

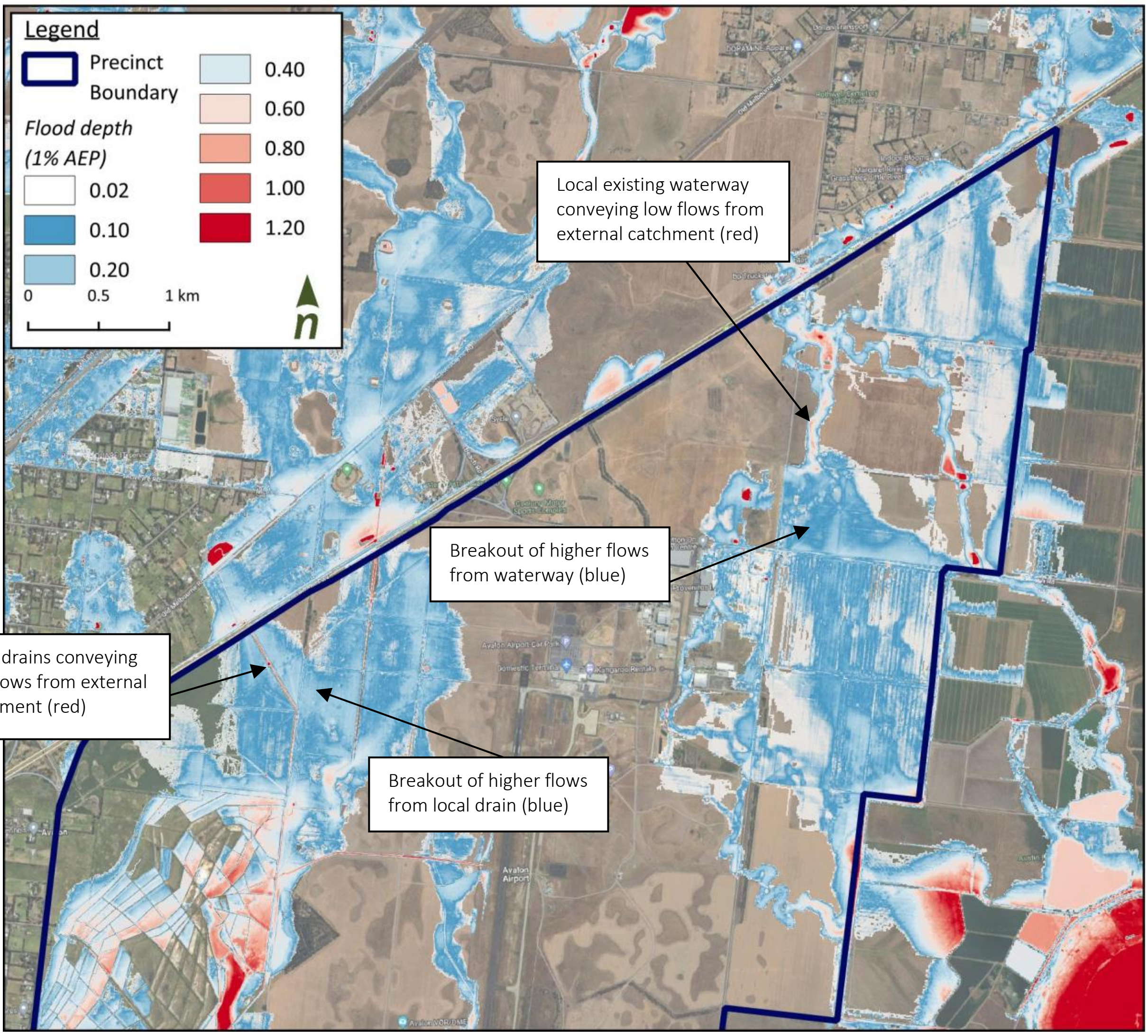

Figure 22. *External catchments Conveyed through the GAEP*

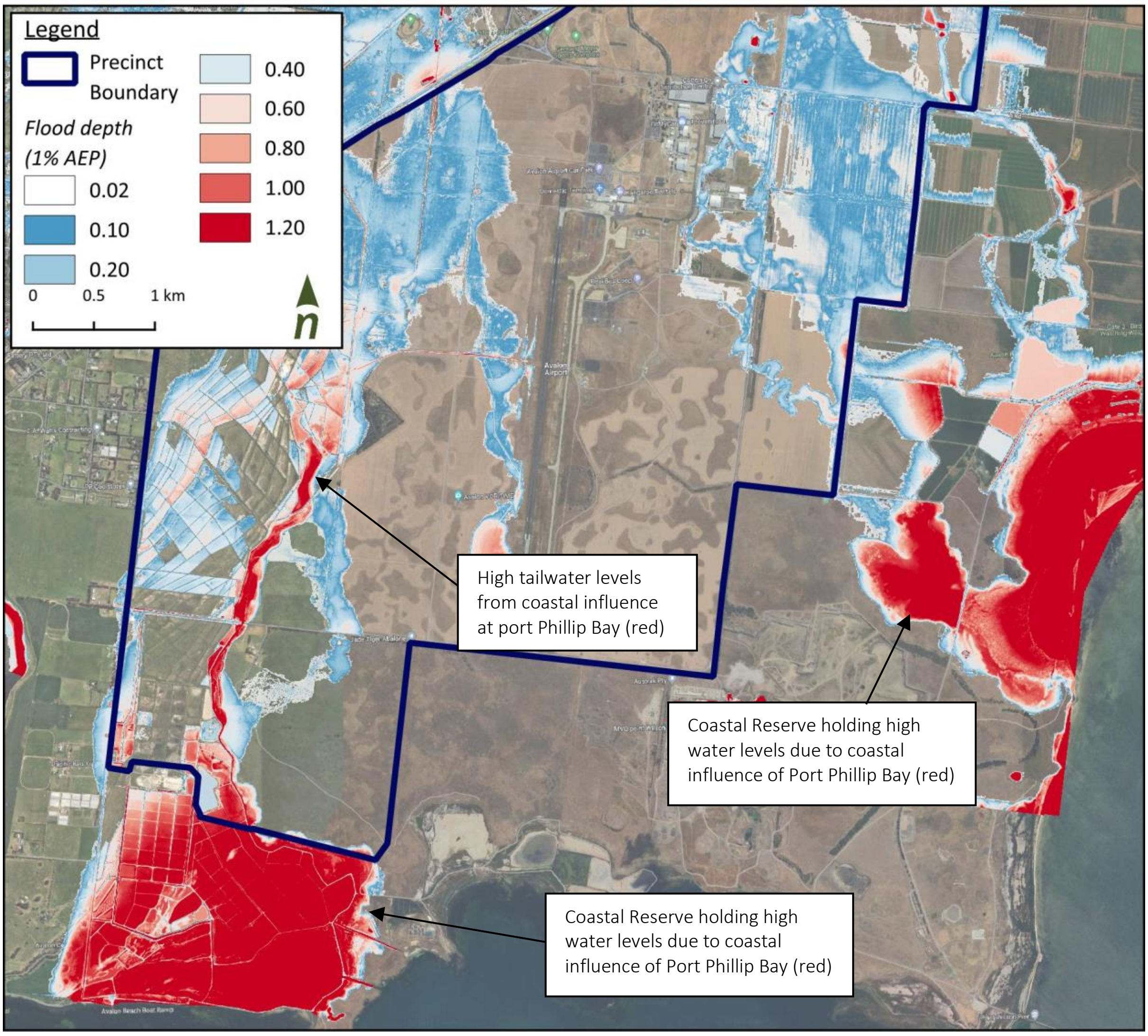

Figure 23. *Tailwater impacts on the GAEP*

6 Summary

The flood modelling assessment of the Greater Avalon Employment Precinct has been undertaken to inform existing flood behaviours for the proposed development area. This modelling combines two existing flood studies that overlap the site for concept level identification of risk areas, major flow path alignment and future asset location.

The outputs of this modelling will help inform the proposed stormwater quality and quantity management of the site and inform strategic locations for retarding basins & constructed wetlands, as well as any future constructed waterways that will be required.