Design Hydraulic Modelling Report

Aireys Inlet Stormwater Flood Study

Surf Coast Shire

2 October 2024

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Project Details

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ACKNOWLEDGEMENT OF COUNTRY

The Board and employees of Water Technology acknowledge and respect the Aboriginal and Torres Strait Islander Peoples as the Traditional Custodians of Country throughout Australia. We specifically acknowledge the Traditional Custodians of the land on which our offices reside and where we undertake our work.

We respect the knowledge, skills and lived experiences of Aboriginal and Torres Strait Islander Peoples, who we continue to learn from and collaborate with. We also extend our respect to all First Nations Peoples, their cultures and to their Elders, past and present.

Artwork by Maurice Goolagong 2023. This piece was commissioned by Water Technology and visualises the important connections we have to water, and the cultural significance of journeys taken by traditional custodians of our land to meeting places, where communities connect with each other around waterways.

The symbolism in the artwork includes:

- *Seven circles representing each of the States and Territories in Australia where we do our work*
- *Blue dots between each circle representing the waterways that connect us*
- *The animals that rely on healthy waterways for their home*
- *Black and white dots representing all the different communities that we visit in our work*
- *Hands that are for the people we help on our journey*

EXECUTIVE SUMMARY

This hydraulic assessment report has been prepared to provide Surf Coast Shire with an understanding of the stormwater inundation extents and behaviour within the township of Aireys Inlet under existing conditions for a range of design events.

Validation of the developed hydraulic TUFLOW model was completed using rainfall data from the January 2022 rainfall event and matching the overserved depths/extents from the hydraulic model to those experienced by the community. To match observations to modelled results, adjustments to the hydraulic models initial and continuing losses and Manning's roughness values were made.

Findings from this assessment will be used to evaluate mitigation strategies for the township at key locations identified in the project brief and based on the results from the hydraulic modelling of the design storm events.

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1 INTRODUCTION

Surf Coast Shire engaged Water Technology to complete hydraulic modelling of Aireys Inlet stormwater network to inform potential mitigation strategies as part of the Aireys Inlet and Anglesea Stormwater Drainage and Flood Studies. The overall objective of the study is to strengthen Surf Coast Shire's understanding of flood risk within Aireys Inlet by establishing stormwater inundation mapping while assessing potential flood risk mitigation strategies. Furthermore, the Shire are seeking to undertake and improve the performance of their asset's conveyance and water quality treatment potential.

The outcomes of the Aireys Inlet & Anglesea Stormwater Flood Study are documented in a series of reports detailing each stage of the analysis:

- R01 – Data Review, Background and Return Brief
- **R02 – Stormwater Drainage and Flood Study – This Report**
- R03 – Water Quality Assessment
- R04 – Flood Damages Assessment

This report presents the TUFLOW hydraulic model developed for this project and summarise the methodology adopted, input parameters, verification methods and the design stormwater flood mapping of Aireys Inlet. As this study focuses on the stormwater drainage network of Aireys Inlet, hydrologic and hydraulic modelling of the Painkalac Creek's contributing catchment has not been included in this project.

2 HYDRAULIC MODEL DEVELOPMENT

2.1 Model Overview

A two-dimensional Rain-on-Grid (RoG) hydraulic modelling approached was adopted for this study using Australian Rainfall and Runoff 2019 (ARR19) guidelines and TUFLOW hydraulic flood modelling software. Simulations were completed using TUFLOW Build 2023-03-AE Single Precision with HPC (Highly Parallelised Computations) solution scheme on a GPU solver.

A new hydraulic model was developed using land use, cadastral, topography and aerial imagery datasets to identify varying land uses which were used to determine the hydrologic and hydraulic characteristics of the catchment. The characteristics included surface roughness and initial and continuing infiltration losses. Hydraulic structures within the study area were collated from Surf Coast Shire’s database and information gathered during a site inspection.

A flow chart representing the general model process is shown in Figure 2-1 below.

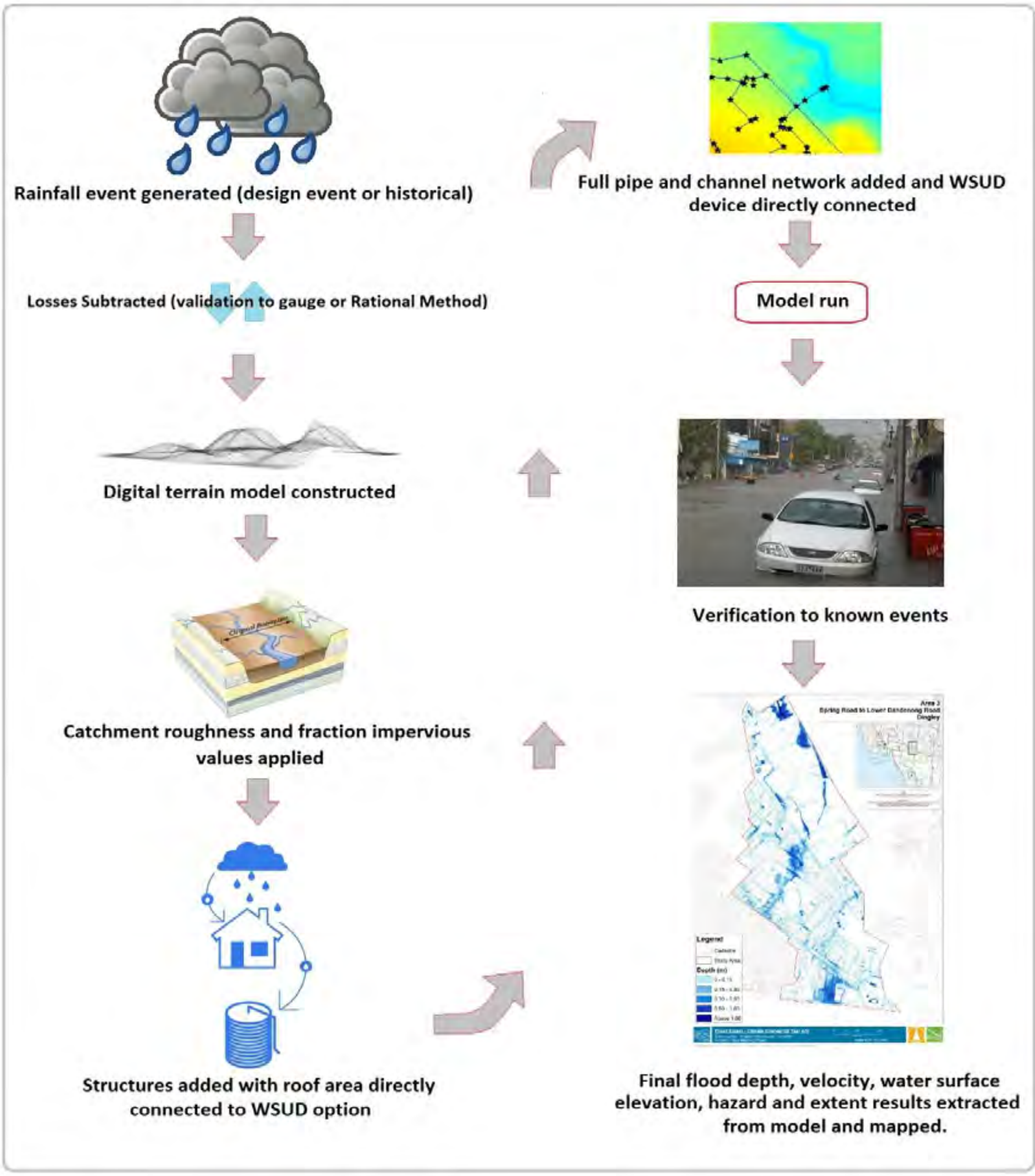


Figure 2-1 Rainfall-on-Grid Modelling Approach

Table 2-1 TUFLOW Model Summary

Terrain	The base terrain for the hydraulic model comprised of LiDAR data obtain from DEECA that was captured on 20 March 2022. This is the latest available dataset for Anglesea. It has a grid cell size of 1-metre with a vertical accuracy of 0.1-metres. LiDAR was supplemented with feature level survey of Fraser Drive, Alice Road and Anderson Street with a 50cm grid cell size. The feature level survey was captured 12 December 2023. ■ LiDAR (2022): cep15_dtv_angesea_2022mar20_dem1 ■ Feature Level Survey: ACAD-2392-FS
Inflow Regime	Rainfall-on-Grid (RoG) (2d_rf) was adopted based on rainfall hyetographs extracted from QGIS ARR2019 Plug-in Tool for design events. Rainfall for historical events was extracted from the Boonah (90187) sub-daily rainfall gauge.

Tailwater Boundary Conditions	Two types of tailwater boundaries were adopted for this study. A water level-flow (HQ) boundary was adopted for most of the model extent where runoff was directed to the ocean, and a water level-time boundary condition was adopted for the outlet of the Painkalac Creek to represent a full berm breach height.
	■ HQ boundaries
	  ■ Outflow 1: 0.02 m/m
	  ■ Outflow 2: 0.007 m/m
	  ■ Outflow 3: 0.001 m/m
	  ■ Outflow 4: 0.001 m/m
	■ HT Boundary
	  ■ Full Berm Breach: 0.6 m AHD

Model Type	TUFLOW HPC
Model Build	2023-03-AE
Hydraulic Roughness	Manning's 'n' values were attributed to different land use or surface types. The adopted manning's 'n' values are described in Table 2-6
Model Cell Size	2-metres
SGS Settings	1-metre Sample Target Distance
Peak Cumulative Mass Error	0.03%
Repeated Timesteps	0
RoG Filtering Parameters	Depth: < 3 cm Puddles: < 200 m^2

2.2 Model Extents and Boundaries

Model Inflows

Design rainfall was applied directly to the 2D domain (2d_rf) using extents derived from Aireys Inlet's stormwater catchments. Due to the size of the stormwater drainage catchments, no rainfall areal reduction factors were applied. Design rainfall hyetographs were extracted from the QGIS plug-in *Extract ARR2019 for TUFLOW* for a range of storm events and temporal patterns (discussed in greater detail in Section 2.6.3

As the aim of this study is to assess Aireys Inlet's stormwater catchments, no inflow hydrographs were applied to the Painkalac Creek where it enters the hydraulic model. Rainfall (2d_rf) was however applied to the Painkalac Creek within the hydraulic model extent.

Mapping of the hydraulic model's Rain-on-Grid (2d_rf) extent is presented in Figure 2-2 below.

Model Outflows

To permit flows to exit the hydraulic model, downstream boundaries (2d_bc) located at waterway/watercourse discharge locations were established. Height vs Flow (HQ) relationship boundary conditions were applied to discharge locations from overland flow paths and watercourses for most of the study area. For the Painkalac Creek, where the full breach berm height was considered, a Height vs Time (HT) relationship boundary conditions was applied.

Mapping of the hydraulic models outflow boundary conditions are presented in Figure 2-2 below.

Height vs Flow boundary conditions were based on the longitudinal slope of the receiving boundary. A summary of the longitudinal slopes applied to each Height vs Flow boundary are presented in Table 2-2 below.

A Heigh vs Time boundary condition was adopted for the Painkalac Creek outlet. The outlet control adopted an elevation consistent with a full breach berm height determined in the 2013 Painkalac Creek Flood Study[1]. The purpose of the Aireys Inlet Stormwater Flood Study is to assess and identify the existing flood risk in the urban catchments and identify areas where stormwater upgrades may be beneficial. For this reason, the full breach berm height was adopted to reduce the influence the Painkalac Creek water levels may have on the stormwater drainage network.

Table 2-2 Height vs Flow Boundary Condition Slopes

Location	Slope (m/m)
Outflow 1	0.02
Outflow 2	0.007
Outflow 3	0.001
Outflow 4	0.001

Table 2-3 Height vs Time Boundary Conditions

Berm Height Scenario	Elevation (m AHD)
Full Breach Height	0.6

[1] T. Jones, G. Taylor, 2013, *Painkalac Creek Flood Study, FPM-2013-1*, Corangamite Catchment Management Authority

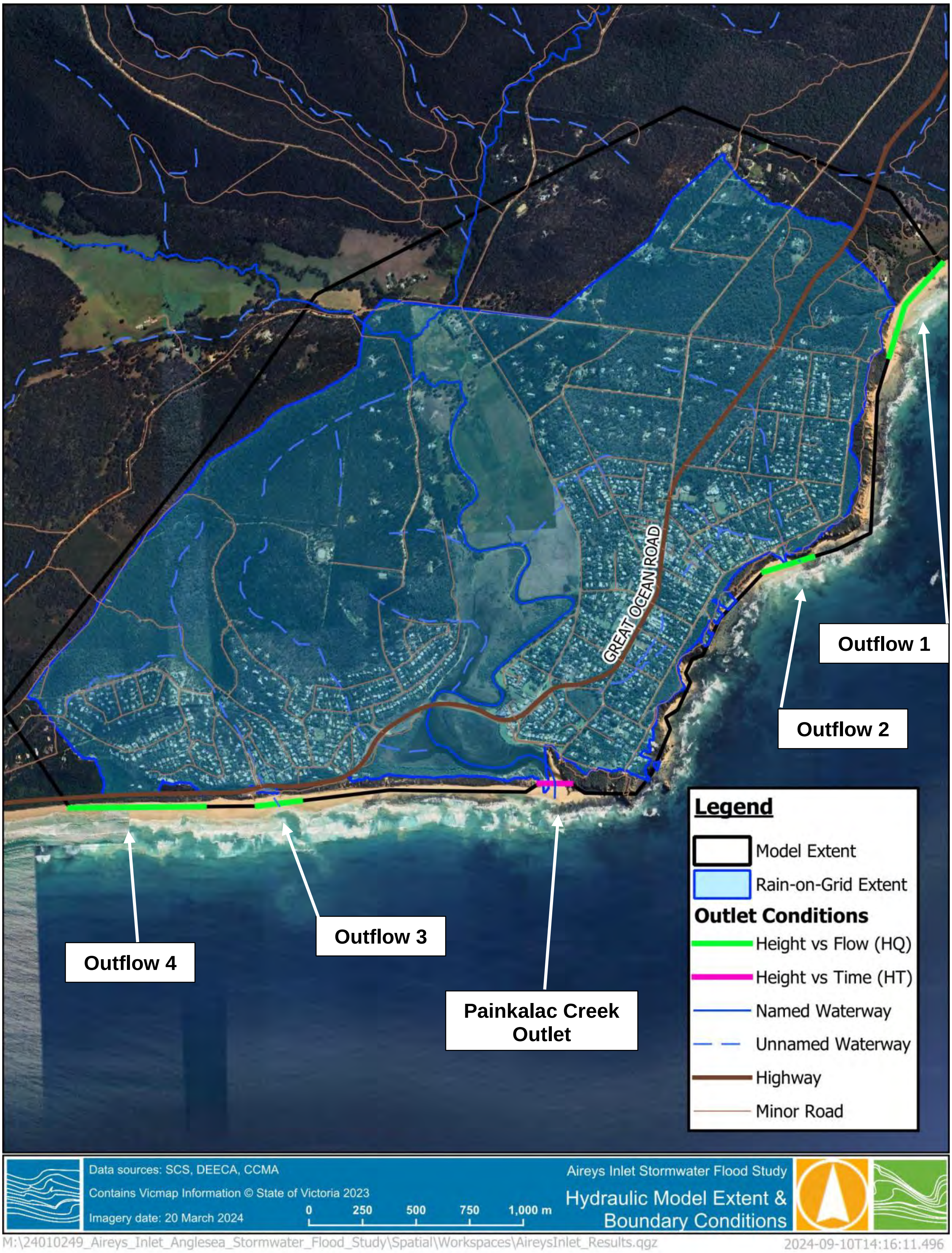


Figure 2-2 Hydraulic Model Extents and Boundaries

2.3 Model Topography

The hydraulic model's topography was based on LiDAR data captured on 20 March 2022, cep15_dtv_anglesea_2022mar20_dem1, which featured a grid cell size of 1-metre and vertical accuracy of ±10cm. Determination of a suitable grid size in the hydraulic model considers the trade-off between accurate representation of low paths and reasonable model run times. Although smaller grid sizes can provide higher resolution mapping, they also significantly increase the model run time and do not guarantee a significant difference in model results. Given the size of the model extent and focus on determining stormwater inundation behaviour, a grid cell size of 2-metres was adopted for the hydraulic model.

A feature level survey for Fraser Drive, Alice Road and Anderson Street was included in the hydraulic model, with a grid cell size of 50 cm, to supplement the LiDAR dataset. A portion of the survey was removed from the dataset along Alice Road as the survey contours provided extended sections of flat spot in road reserve which were not observed during the site inspection. An overview of the feature level survey's digital elevation model (DEM) in the hydraulic model is presented in Figure 2-3 below.

Sub-Grid-Sampling (SGS) was utilized for this study as it has a heavy focus on assessing stormwater performance in open channels and stormwater drainage networks. While the feature level survey has a resolution of 50cm, the LiDAR dataset was the limiting factor to the SGS sample frequency, which was set to 1-metre. An overview of the hydraulic model topography is presented in Figure 2-4 below.

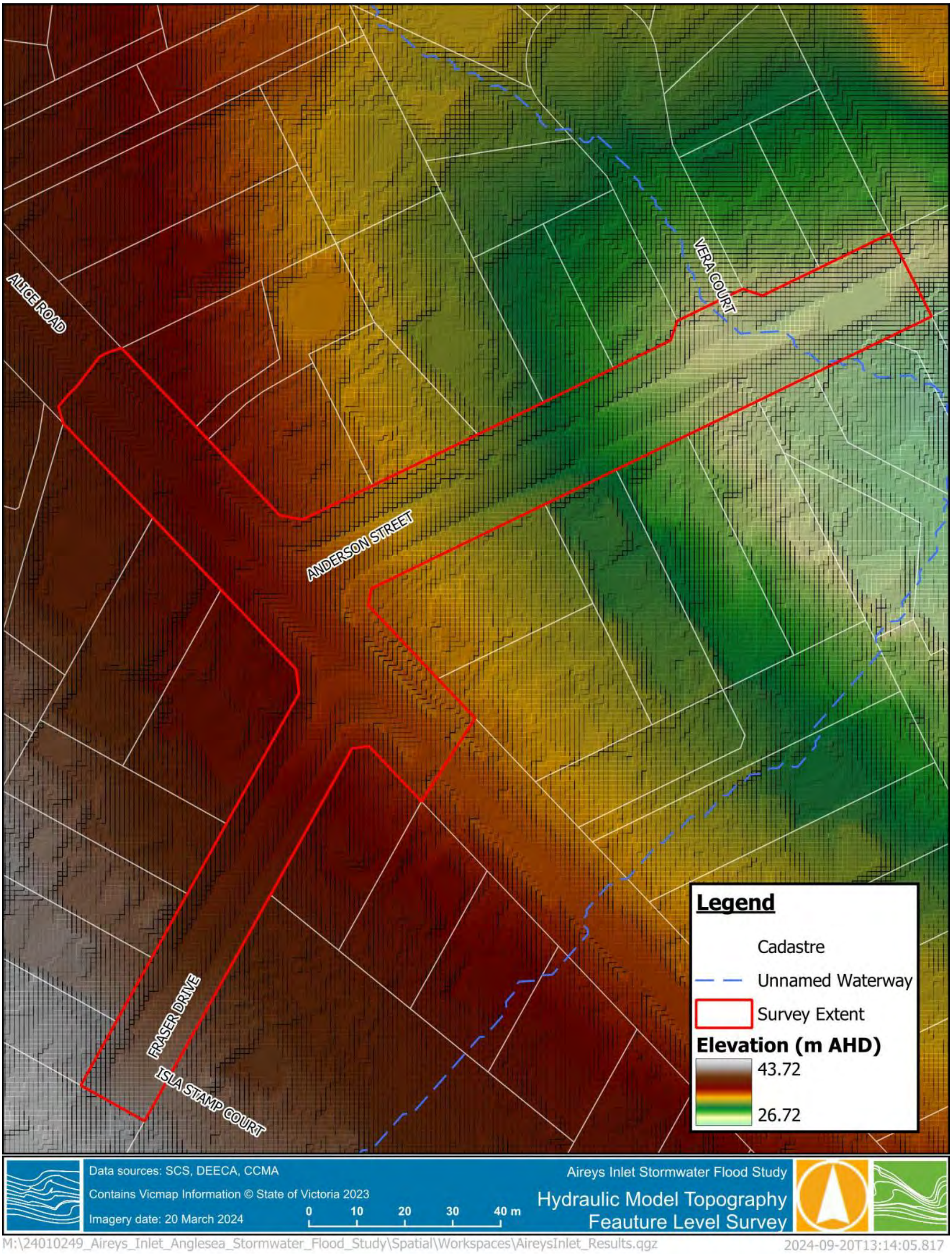


Figure 2-3 Feature Level Survey Digital Elevation Model and Extent

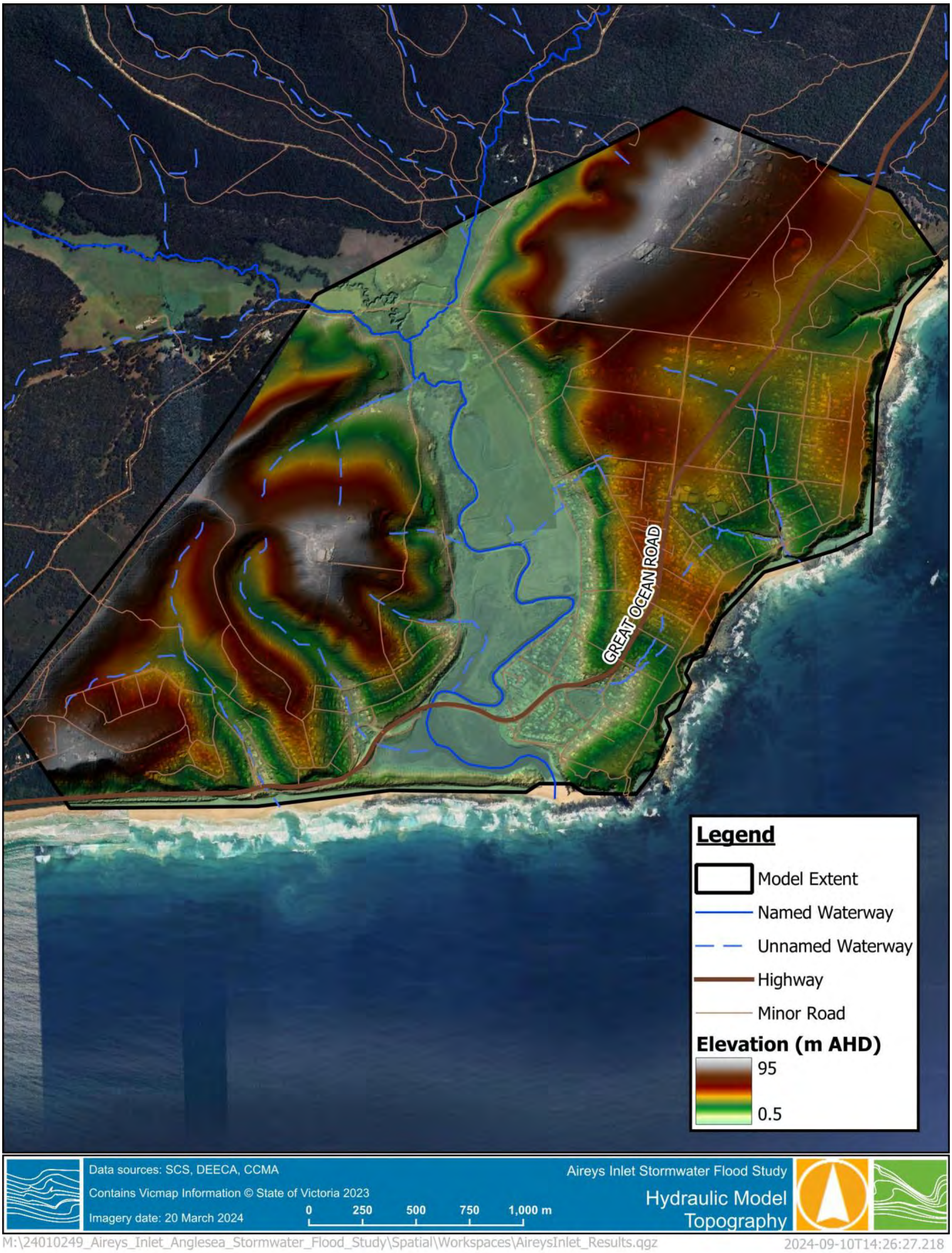


Figure 2-4 Model Topography

2.4 Stormwater Network

The study area included a total of 923 pipes/box culverts and 920 pits. These were represented in the hydraulic model as 1D network (1d_nwk) and connected to the 2D domain by SX/CN Lines. Invert levels were provided in the dataset submitted by the Surf Coast Shire, however, many of the assets invert levels were to local datums (based on the differences in terrain elevation). Without additional survey, the datum of each asset could not be verified as m AHD (Australian Height Datum) or m LHD (Local Height Datum). Therefore, the decision to interpolate invert levels from the LiDAR dataset using size/diameter of the pipe/culvert and depth of the connecting pit was deemed necessary. Adjustments to the interpolated network were then made manual by using the 1D Integrity Tool Plug-in for TUFLOW in QGIS, where each branch was traced and reviewed. An overview of the modelled 1D network for Anglesea, with pipe diameters, is shown in Figure 2-5 below.

The stormwater network adopted *C* (circular) and *R* (rectangular) type features to represent pipes and box culverts, respectively. Roughness was based on the material specified in Surf Coast Shire's dataset. A summary of material roughness's used are described below in Table 2-4. Where no material type was specified, reinforced concrete (0.013) was assumed.

Table 2-4 Pipe/Box Culvert Material Roughness

Material	Roughness (*n*)
Reinforced Concrete	0.013
Stormpro Plastic Pipe	0.010
High Density Polyethylene Pipe	
Polypropylene Pipe	
Polyvinyl Chloride Pipe	

A pedestrian foot bridge is located within the Sandy Gully catchment, in the main flow path of the north branch, between Berthon Street and Hartley Street. The foot bridge was included in the hydraulic model as a two-dimensional layer flow constriction (2d_lfcsh). Photos of the footbridge are shown below in Figure 2-7 and Figure 2-8, and details on the modelled parameters are described in Table 2-5.

Inclusion of the footbridge in the model, and not any other bridges in Aireys Inlet, was due to it being located within the Sandy Gully Catchment. Modelling the footbridge will produce hazard ratings for pedestrian access during storm events and also provide the Shire with an understand of the frequency of inundation. Bridges, such as the Great Ocean Road bridge over the Painkalac Creek was not included as it does not have an impact on the stormwater runoff mechanics in Aireys Inlet.

Table 2-5 Layer Flow Constriction Parameters

Parameter	Value
Sandy Gully Foot Bridge	
Invert Level (m AHD)	17.87
Layer 1 Obvert (m AHD)	18.92
Layer 1 Blockage (%)	5
Layer 1 Flow Constriction	0.045
Layer 2 Depth (m)	0.35
Layer 2 Blockage (%)	100
Layer 3 Depth (m)	0.9
Layer 3 Blockage (%)	33
Layer 3 Flow Constriction	0.28

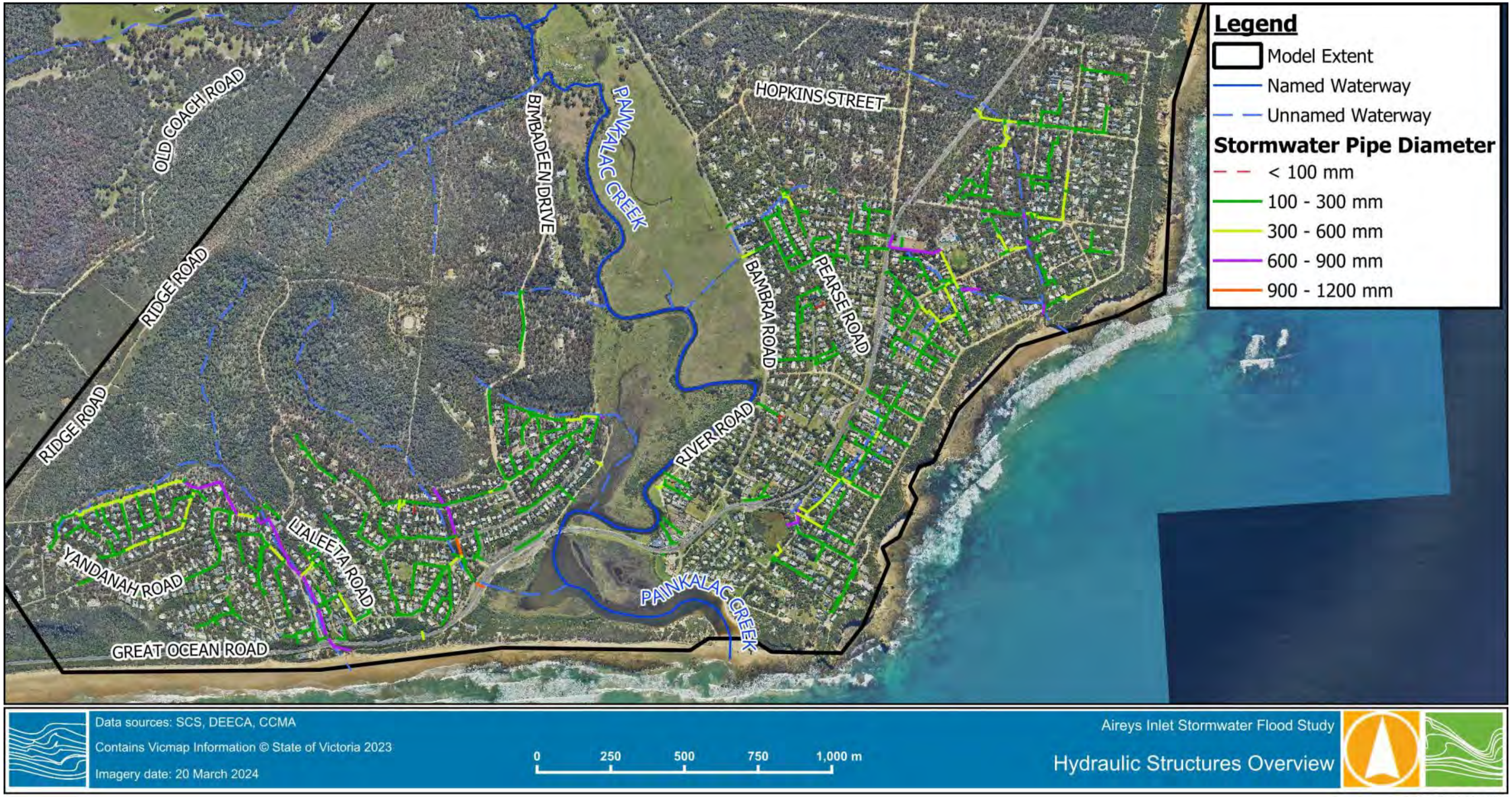


Figure 2-5 Hydraulic Structures – Overview

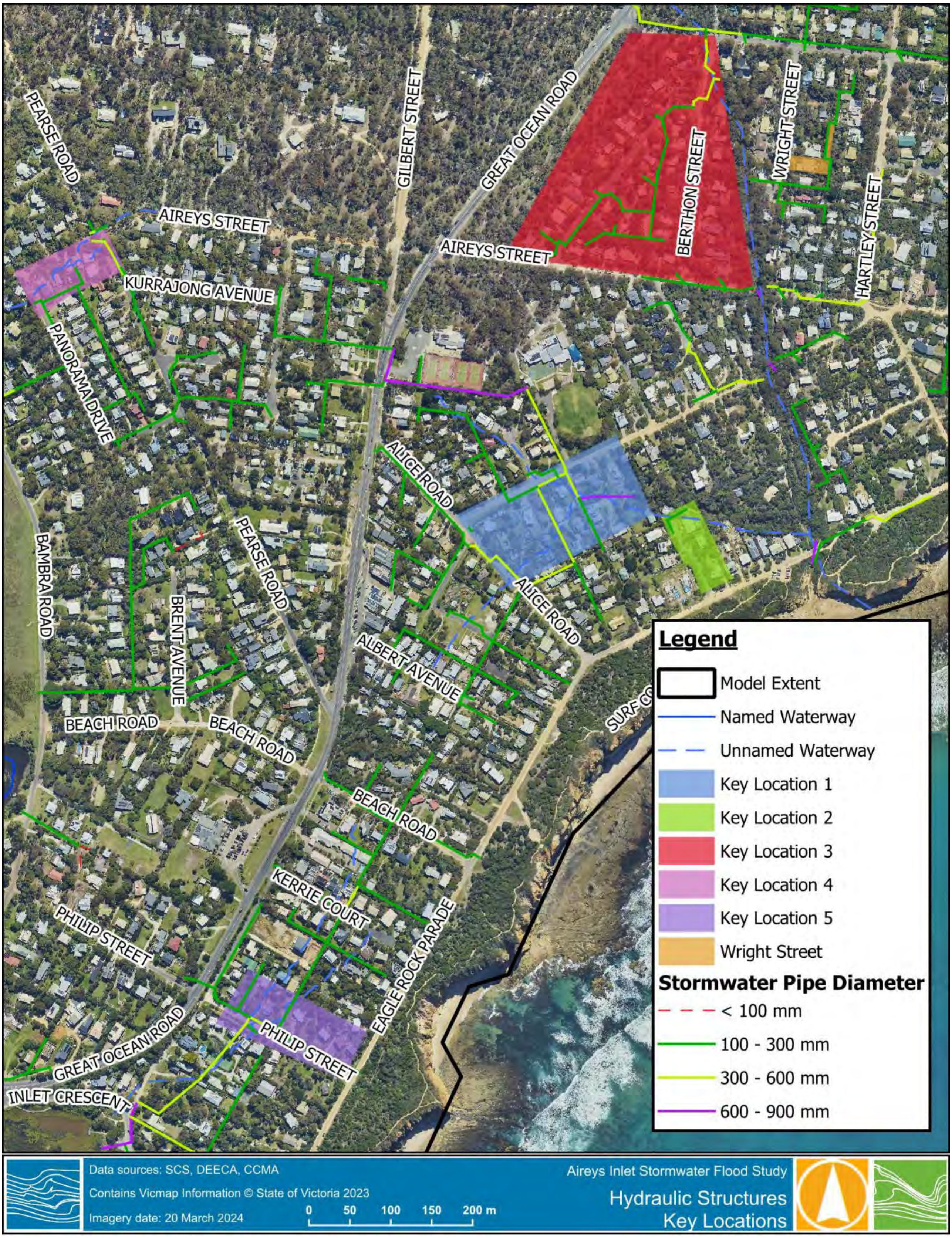


Figure 2-6 Hydraulic Structures – Key Locations

Figure 2-7 Aireys Street Pedestrian Foot Bridge – Facing West

Figure 2-8 Aireys Street Pedestrian Foot Bridge – Facing North

2.5 Surface Roughness

A Manning's (*n*) roughness layer was developed based on aerial imagery and land use layers delineated and assigned zones of appropriate roughness. These are based on industry guidance, Melbourne Water Technical Specifications and the validation from the 2022 rainfall event observations from the Surf Coast Shire. The roughness represents how coarse or smooth to make a cell, and affects the velocity and depth of water travelling across the surface. Flows across a smoother surface (i.e., concrete) travel faster when compared to a rougher surface (i.e., thick grass).

The modelled catchment was dominated by urban areas surrounded by heavily vegetated areas. Road reserves were modelled as one unit, including footpaths, nature strips and median strips (where appropriate). An overview of the adopted roughness values and extents are shown in Table 2-6 and Figure 2-9 below, respectively.

Table 2-6 Manning's Roughness (n) Values Adopted in the Hydraulic Model

Land Type	Manning's Value (n)
Urban residential – building footprints and parcel modelled together	0.45
Rural residential – building footprints and parcel modelled together	0.25
Industrial/commercial or large building sites	0.30
Road reserves - sealed	0.02
Road reserves - unsealed	0.03
Carparks/pavement	0.02
Open spaces – minimal vegetation	0.04
Open spaces – moderate vegetation	0.06
Open spaces – heavy vegetation	0.08
Open water/water bodies	0.02
Railway reserve	0.125
Buildings	0.50

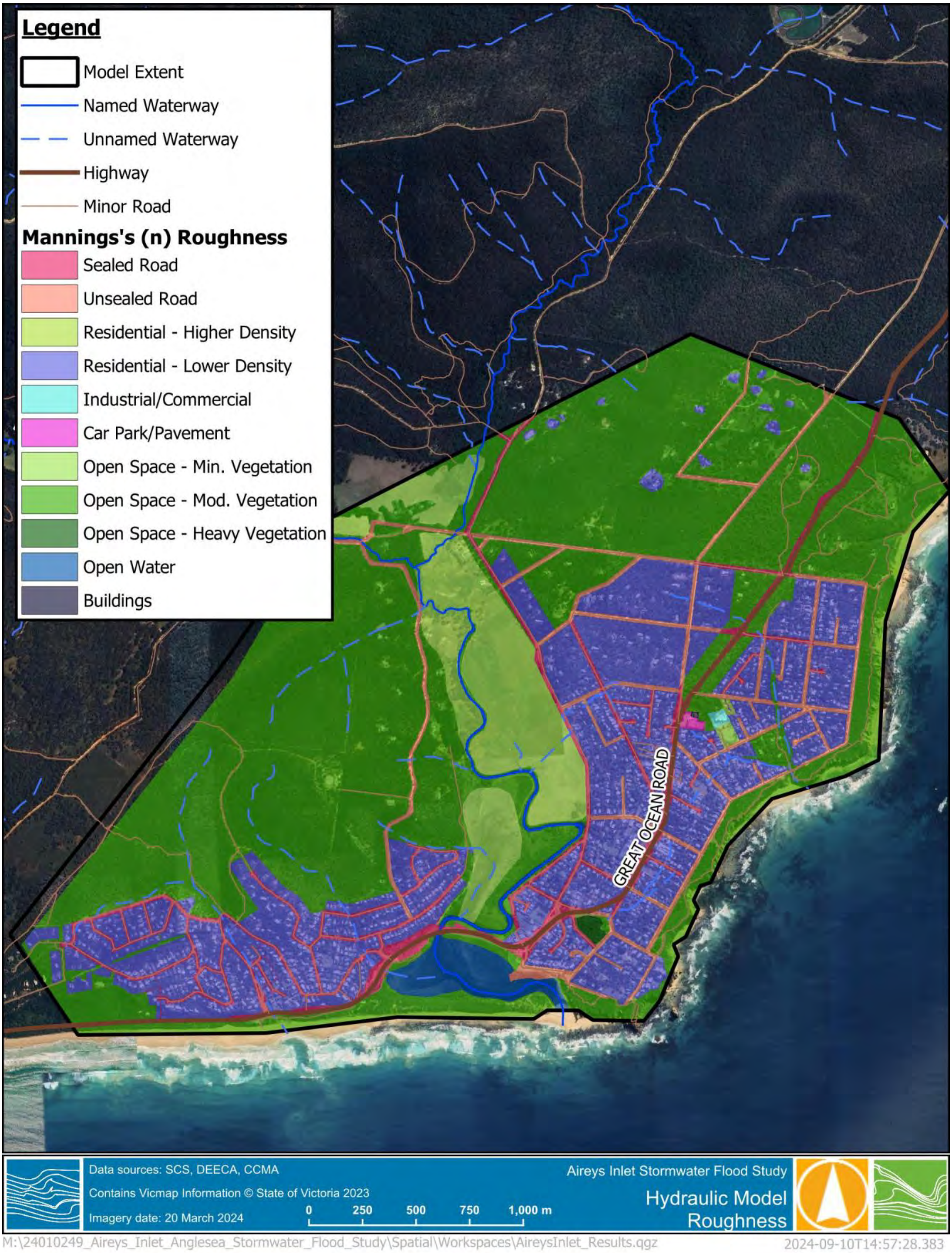


Figure 2-9 Hydraulic Model Roughness

2.6 Rainfall and Losses

The Rainfall-on-Grid (RoG) methodology is extensively used for urban flood mapping. It identifies overland flow paths based on the terrain and drainage network of the modelled area, as illustrated in the flow chart shown in Figure 2-1 above.

Since the commencement of this study, Australian Rainfall and Runoff have released updated guidelines for establishing rainfall depths using the 2016 IFD data. The new guidelines (ARR4.2) state that rainfall data using the 2016 IFD's need to be factored to correlate with the year the study is conducted in (i.e., 2024), or the climate scenario required, to account for rates of change due to projected changes in temperature. The rainfall data used in the Aireys Inlet Stormwater Flood Study has not been factored due to it commencing prior to the release of ARR 4.2.

2.6.1 Losses

Rainfall losses were accounted for in the material roughness layers, where initial loss (IL) and continuing losses (CL) were applied to each land type. A summary of the adopted losses is presented in Table 2-7 below.

Initial and continuing losses were based on values adopted in similar RoG studies and increased slightly to consider the presence of sandy soils on the coast of Victoria. Sensitivity testing of the adopted losses was also undertaken, whereby both initial and continuing losses were halved. The impacts of halving the losses produced changes in water levels of ± 1cm in key locations for this assessment. Therefore, the below losses have been adopted.

Table 2-7 Hydraulic Model Materials Layer Losses

Land Type	Initial Loss (mm)	Continuing Loss (mm/hr)
Urban residential – building footprints and parcel modelled together	5.0	1.0
Rural residential – building footprints and parcel modelled together	10.0	1.5
Industrial/commercial or large building sites	2.5	1.0
Road reserves - sealed	1.0	0.5
Road reserves - unsealed	5.0	1.0
Carparks/pavement	2.0	0.0
Open spaces – minimal vegetation	20.0	2.0
Open spaces – moderate vegetation	20.0	2.0
Open spaces – heavy vegetation	20.0	2.0
Open water/water bodies	0.0	0.0
Railway reserve	10.	3.0
Buildings	1.0	0.0

2.6.2 Historic Rainfall

Stormwater inundation occurred within the study area in late January, early February and mid-October of 2022, when moderate to heavy rainfall was recorded across the region impacting several parts of Aireys Inlet and Anglesea. The Bureau of Meteorology monthly climate summary[2] noted the following:

- State-wide, January rainfall was 91% above the long-term January average, making it the eighth-highest January rainfall total on record, and the highest since 2011.
- A slow-moving high-pressure system over the southern Tasman Sea directed a warm and humid northeasterly airflow over Victoria between the 24th and 28th of January.
- On the 27th and 28th, thunderstorms brought strong winds, heavy rainfall and flash flooding to the western and central parts of the state. Extending to south-eastern and north-eastern parts of the state.
- Thousands of properties across Victoria were left without power between the 26th and 29th of January due to the intense thunderstorm activity. The State Emergency Service received hundreds of requests for help related to these events, mostly flash flooding.

Rainfall data (from the Boonah rainfall gauge) for the January 2022 and October 2022 events are shown in Figure 2-10 and Figure 2-11 below. Sub daily rainfall data for February 2022 was not available at the time this report was being completed. Personal weather stations listed on Wunderground[3] were referenced to confirm the rainfall recorded in Boonah was consistent with what was experienced in Aireys Inlet. Several rainfall stations in Aireys Inlet recorded zero rainfall for the month of January, these records are expected to be false readings. Two gauges in Aireys Inlet recorded totals of 116 mm and 121 mm for the 27th and 28th of January. While approximately 10mm lower than the Boonah rainfall station, these totals confirm the Aireys Inlet was subject to a very similar magnitude storm event to that recorded at Boonah.

Annual Exceedance Probabilities (AEP's) were estimated by comparing the recorded rainfalls to design rainfall intensities from the Bureau of Meteorology's Intensity-Frequency-Duration (IFD) rainfall data for storm durations similar to recorded events. For January 2022, the data indicates the following:

- Rainfall intensities for storm durations 45-minutes to 1-hour had an AEP in the range of 10% to 5%.
- Rainfall intensities for the 1.5-hour storm duration had an AEP of approximately 5% to 2%.
- Rainfall intensities for the 2-hour storm duration had an AEP of approximately 2%.
- Rainfall intensities for the 3-hour storm duration had an AEP in the range of 2% to 1%.
- Rainfall intensities for the 4.5-hour storm duration had an AEP in the range of 1% to 0.2%.
- Rainfall intensities for the 6-hour storm duration had an AEP in the range of 2% to 1%.

[2] Monthly Climate Summary for Victoria, Bureau of Meteorology (2024)
[3] https://www.wunderground.com/wundermap

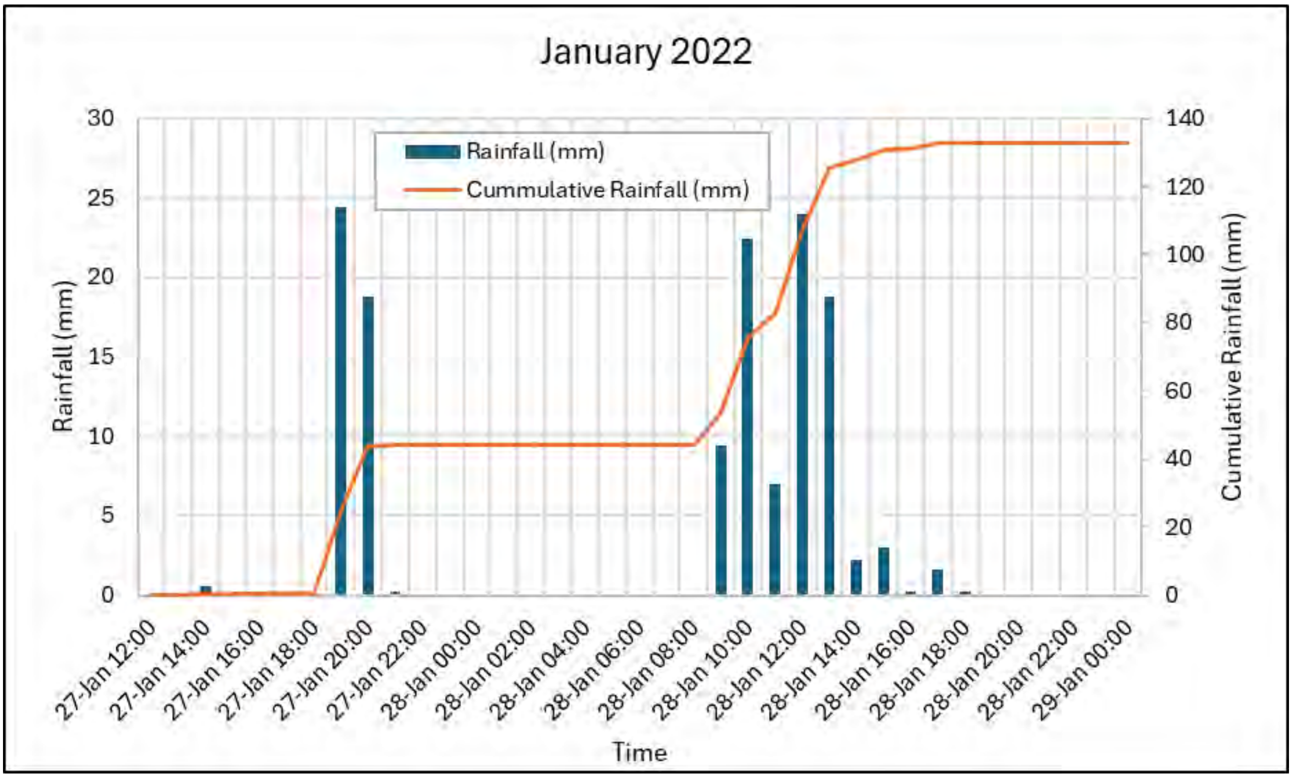


Figure 2-10 January 2022 Storm Event – Boonah (90187) hourly rainfall

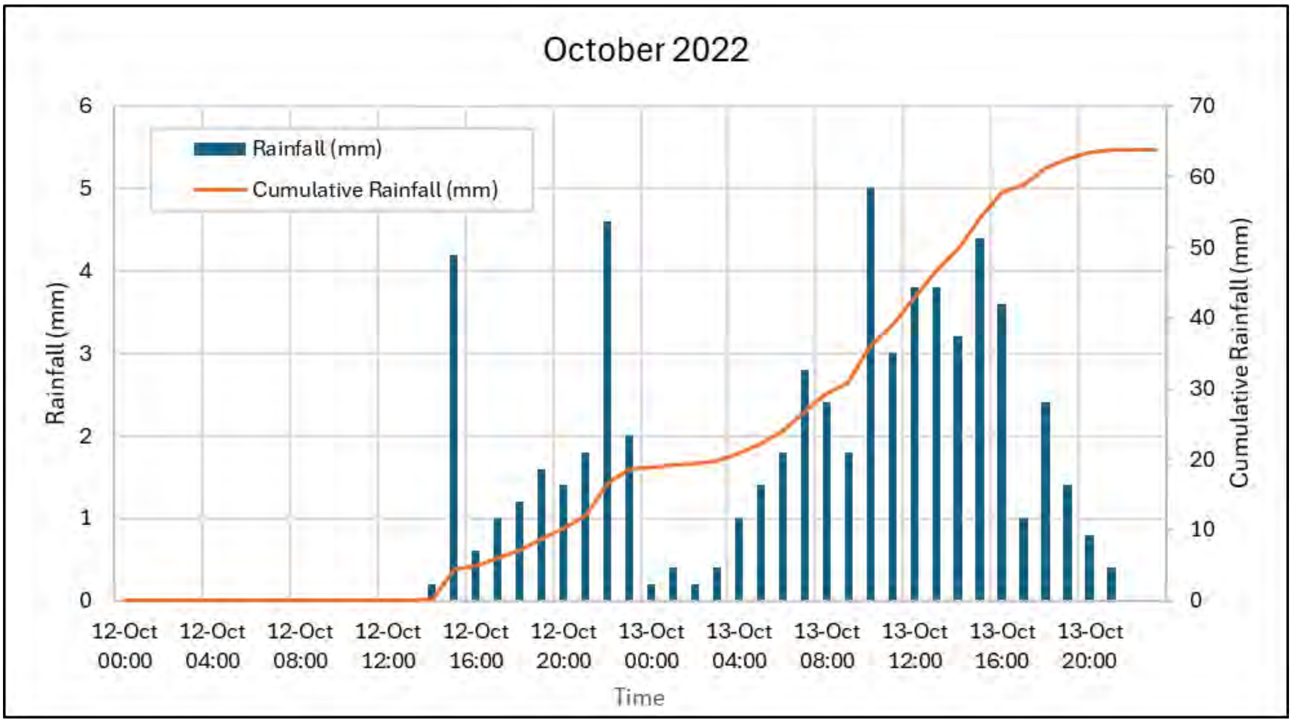


Figure 2-11 October 2022 Storm Event – Boonah (90187) hourly rainfall

2.6.3 Design Rainfall

Critical Duration & Temporal Pattern Assessment

The hydraulic model was run for a range of design events and durations using three ARR2019 temporal patterns that represented front, back and constant loaded storms. The event durations modelled ranged from 30-minutes to 12-hours, a total of 13 durations. A summary of the modelled durations, temporal patterns and corresponding cumulative rainfall is detailed in Table 2-8 below.

Results were processed to select a combination of durations and temporal patterns for each design event, that contributed to the maximum flood event impacting each of the key locations. A summary of the critical duration(s) and temporal pattern(s) for each key location and design event is detailed below in Table 2-9.

Table 2-8 Modelled Durations and Temporal Patterns

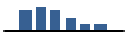
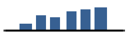
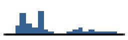
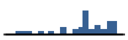
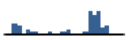
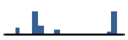
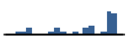
Duration	1% AEP Temporal Pattern	Rainfall Distribution	Cumulative Rainfall (mm)				
			1%	2%	5%	10%	20%
30-min	TP03		26.8	23.3	19.1	16.1	13.3
	TP10						
	TP01						
1-hr	TP02		33.0	28.9	24.0	20.4	17.0
	TP10						
	TP09						
1.5-hr	TP05		37.4	33.0	27.5	23.5	19.6
	TP10						
	TP07						
2-hr	TP02		41.3	36.5	30.5	26.2	21.9
	TP10						
	TP07						
3-hr	TP02		48.6	51.0	42.7	36.7	30.9
	TP10						
	TP08						
4.5-hr	TP04		57.6	51.0	42.7	36.7	30.9
	TP10						
	TP05						
6-hr	TP05		66.2	58.4	48.8	42.0	35.3
	TP01						
	TP09						
9-hr	TP05		81.3	71.6	59.6	51.1	42.9
	TP10						
	TP02						

Table 2-9 Aireys Inlet Key Location Critical Durations and Temporal Patterns

	1%	2%	5%	10%	20%
Key Location 1 – Fraser Drive, Alice Road and Anderson Street					
Critical Event	1-hr, TP10 1.5-hr, TP10 6-hr, TP01	1.5-hr, TP10	2-hr, TP10	2-hr, TP10 9-hr, TP01	3-hr, TP09 6-hr, TP09
Key Location 2 – Kingsley Drive / Sandy Gully					
Critical Event	1-hr, TP10 6-hr, TP01	2-hr, TP10 3-hr, TP10	2-hr, TP10	2-hr, TP10 3-hr, TP09	6-hr, TP09
Key Location 3 – Amoree Crescent, Aireys Street and Berthon Street					
Critical Event	1-hr, TP10 1.5-hr, TP10 6-hr, TP01	3-hr, TP10	3-hr, TP09 6-hr, TP09	3-hr, TP09 9-hr, TP01	6-hr, TP09
Key Location 4 – Pearse Road / Aireys Street					
Critical Event	1-hr, TP10 1.5-hr, TP10	1-hr, TP10 1.5-hr, TP10	2-hr, TP10	2-hr, TP10	3-hr, TP09 6-hr, TP09
Key Location 5 – Philip Street					
Critical Event	1.5-hr, TP10 6-hr, TP01	1.5-hr, TP10 3-hr, TP10	2-hr, TP10	3-hr, TP09	3-hr, TP09 6-hr, TP09
Additional Key Location – Wright Street					
Critical Event	6-hr, TP01	1.5-hr, TP10 2-hr, TP10	2-hr, TP10 3-hr, TP09	3-hr, TP09	6-hr, TP09
Additional Key Location – 140 Bimbadeen Drive					
Critical Event	1-hr, TP10 9-hr, TP05	2-hr, TP10	3-hr, TP09	9-hr, TP01	6-hr, TP09

3 HYDRAULIC MODELLING RESULTS

3.1 Overview

Validation of the hydraulic model was completed by modelling the January 2022 rainfall and observing known impacted areas to compare the accuracy of the hydraulic model based on Surf Coast Shire observations. Following validation, design modelling for the 1%, 2%, 5%, 10% and 20% AEP events was completed, with a focus on the 1% AEP storm event and its impact on each of the key locations identified in the Return Brief Mapping of the results was filtered to remove shallow depths (less than 3 cm) and isolated extents of inundation (less than 200 m^2).

Flood hazard mapping for each of the key locations has also been provided. The mapping is based on ARR2019 and Australian Emergency Management Institute (2014) recommendations. A summary of the vulnerability thresholds classification limits outlined in ARR2019[4] is provided in Table 3-1 below.

Table 3-1 Combined Hazard Curves – Vulnerability Thresholds Classification Limits (Smith et al., 2014)

Hazard Vulnerability Classification	Classification Limit (D and V in combination)	Limiting Still Water Depth (D)	Limiting Velocity (V)
H1	D*V ≤ 0.3	0.3	2.0
H2	D*V ≤ 0.6	0.5	2.0
H3	D*V ≤ 0.6	1.2	2.0
H4	D*V ≤ 1.0	2.0	2.0
H5	D*V ≤ 4.0	4.0	4.0
H6	D*V > 4.0	-	-

3.2 Hydraulic Model Validation

The hydraulic model was validated against observed stormwater inundation experienced during the January 2022 storm event. Rainfall data for the October 2022 event was available, however, the characteristics of this storm event resulted in more riverine inundation than stormwater. Only stormwater inundation from direct rainfall on the catchments was considered, i.e., no inflows to the Painkalac Creek from its upstream catchment were included.

3.2.1 January 2022

Recorded rainfall intensities from the Boonah rainfall station were used to reproduce the storm event that Anglesea experienced in January 2022. The event was simulated with the berm of the Painkalac Creek at its full height (Starting Berm Height).

Validation of the hydraulic model was completed by Surf Coast Shire's firsthand experience of the event and its aftermath. While no surveyed marks or additional photographs from the event are available, at the time of this study, the modelled outputs were compared with the observations made by the Surf Coast Shire's Operations and Maintenance Team and Stormwater Team, who were the Shire's first responders to stormwater inundation/complaints.

Modelled flood depths for the January 2022 event are shown in Figure 3-1 below.

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[4] Smith, G. Cox, R. 2019, *Book 6: Flood Hydraulics – Chapter 7 Safety Design Criteria*,

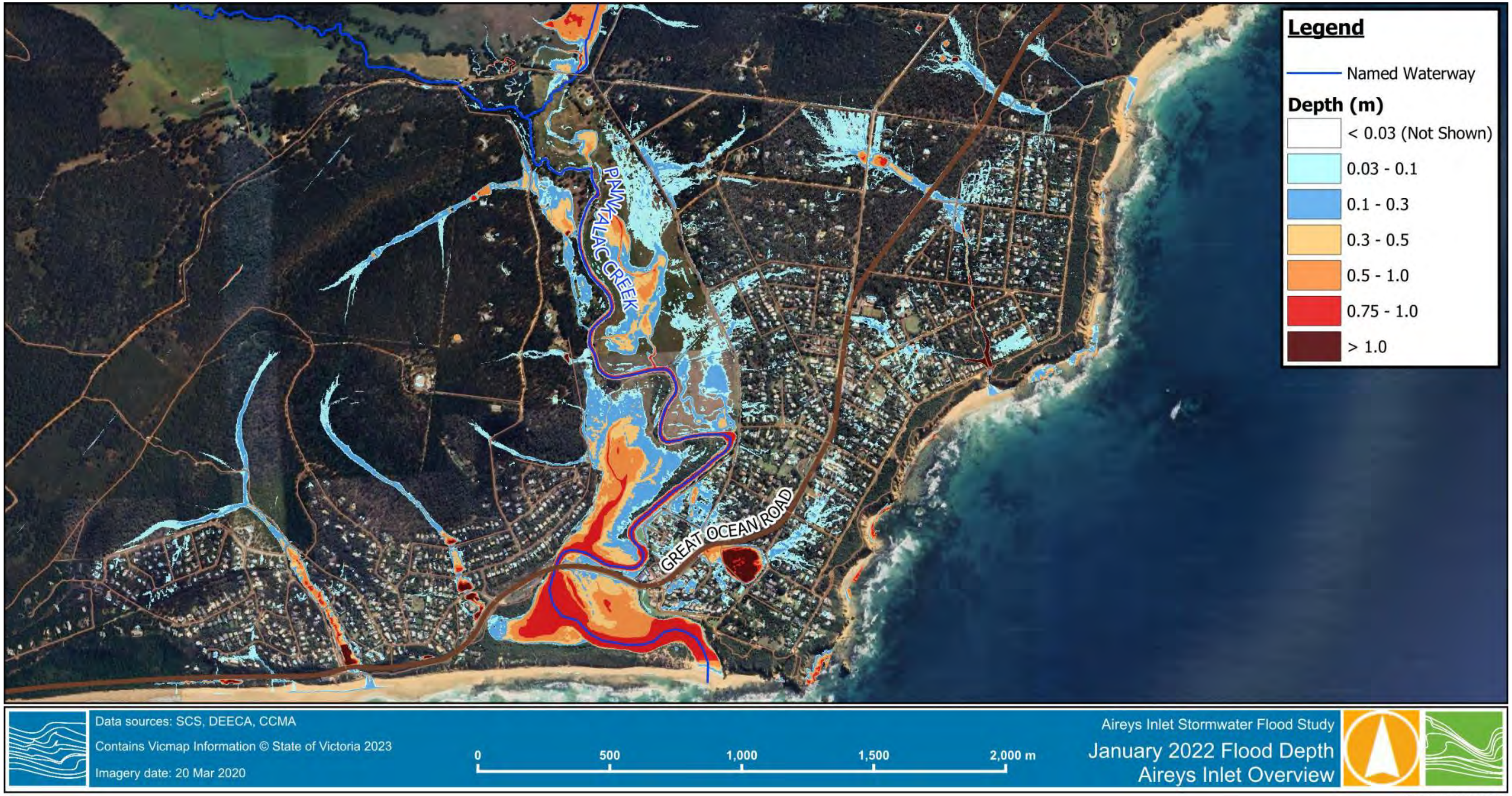

Figure 3-1 January 2022 Modelled Flood Depths – Aireys Inlet Overview

3.3 Flood Mapping Results

Hydraulic modelling of Aireys Inlet including developed/residential areas in the immediate vicinity of the Painkalac Creek and the township of Aireys Inlet has been completed for the range of AEP events. The hydraulic model produced overland flows in known gullies (i.e., Sandy Gully) as well as through established residential areas. These overland flow paths have been named based on their outfall locations and/or location significance. Mapping of the maximum 1% AEP flood depth is illustrated in Figure 3-2 below. For each key location, flood depth, velocity, water level and hazard maps have also been produced.

The results show that to the east of the Painkalac Creek there are four major overland flow paths of relevance to this assessment and include, Painkalac Creek 1, Painkalac Creek 2 and the Sandy Gully (1 and 2). The Sandy Gully 1 and Sandy Gully consist of residential properties, with flows converging immediately upstream of Eagle Rock Parade. At the confluence of Sandy Gully 1 and 2, the size of culvert and height of the Eagle Rock Parade embankment form a retarding basin before the Sandy Gully discharges into ocean. Depths upstream of Eagle Rock Parade reach approximately 5.7 metres. In the upper catchment of Sandy Gully 2, the catchment consists of dense bushland and scattered residential dwellings. Runoff from the upper catchment is retarded by the culvert underneath the Great Ocean Road, where during the 1% AEP event, is overtopped by depths between 0.03 to 0.2 m. Key locations 1, 2, 3 and 4are located within the Sandy Gully catchment and are discussed in further detail in Section 3.3.1 and Section 3.3.2 below.

Painkalac Creek 1 includes the Aireys Street/Pearse Road catchment, where runoff flows through residential properties to the west towards the creek. Depths are generally shallow but fast moving due to the steep nature of the catchment, ranging between 0.03 and 0.1 metres in depth. Key location 5 is situated within the Painkalac Creek 1 catchment. Further analysis into the impacts of stormwater inundation during the 1% AEP event at this location are discussed in Section 3.4 below.

Painkalac Creek 2 includes the Allen Noble Sanctuary, where the main overland flow path to the northeast flows through residential properties and stormwater infrastructure. Discharge from the Allen Noble Sanctuary, during the 1% AEP event spill into the Great Ocean Road road reserve and retarded from flowing north due to the elevation of the highway. The Great Ocean Road embankment results in waters ponding upstream to depths between 0.75 and 1 metre, with three properties experiencing inundation above 0.3 metres deep. Key location 6 is located with Painkalac Creek 2, where there are concerns surrounding the capacity and efficiency of the stormwater drainage network. Discussion on the mechanics and impacts modelled in Key Location 6 are expanded on in Section 3.4.

West of the Painkalac Creek, four major overland flow paths have been identified. Both the Fairhaven Ocean Outfall and Painkalac Creek 4 flow paths originate in bushland before flowing into residential areas. Flood depths in the residential areas are approximately 0.5 to 0.75 metres deep due to hydraulic controls (i.e., roadways). The alignment of the flow path and extent of inundation during the 1% AEP event is primarily located in reserves for the Painkalac Creek 4 flow path; however, the Fairhaven Ocean Outfall flow path is situated directly through residential properties.

The results indicate that the Painkalac Creek 6 is a small overland flow path, compared to Painkalac Creek 4, and does not impact residential properties during the modelled 1% AEP storm event.

Runoff from the Bimbadeen Drive area is generated from an undeveloped catchment, primarily dense bushland, and flows into a series of dams before converging on Bimbadeen Drive. Bimbadeen Drive acts as a retarding basin, attenuating water to the west with depths reaching between 0.3 and 0.5 metres. During the 1% AEP event, Bimbadeen Drive is overtopped by flood depths ranging from 0.1 to 0.3 metres, which results indicating inundation of the farmstead property to the east. Section 3.4 below discuss the impacts of Key Location 7 in further detail.

Flood mapping for the 2%, 5%, 10% and 20% AEP flood depths are presented in Appendix A.

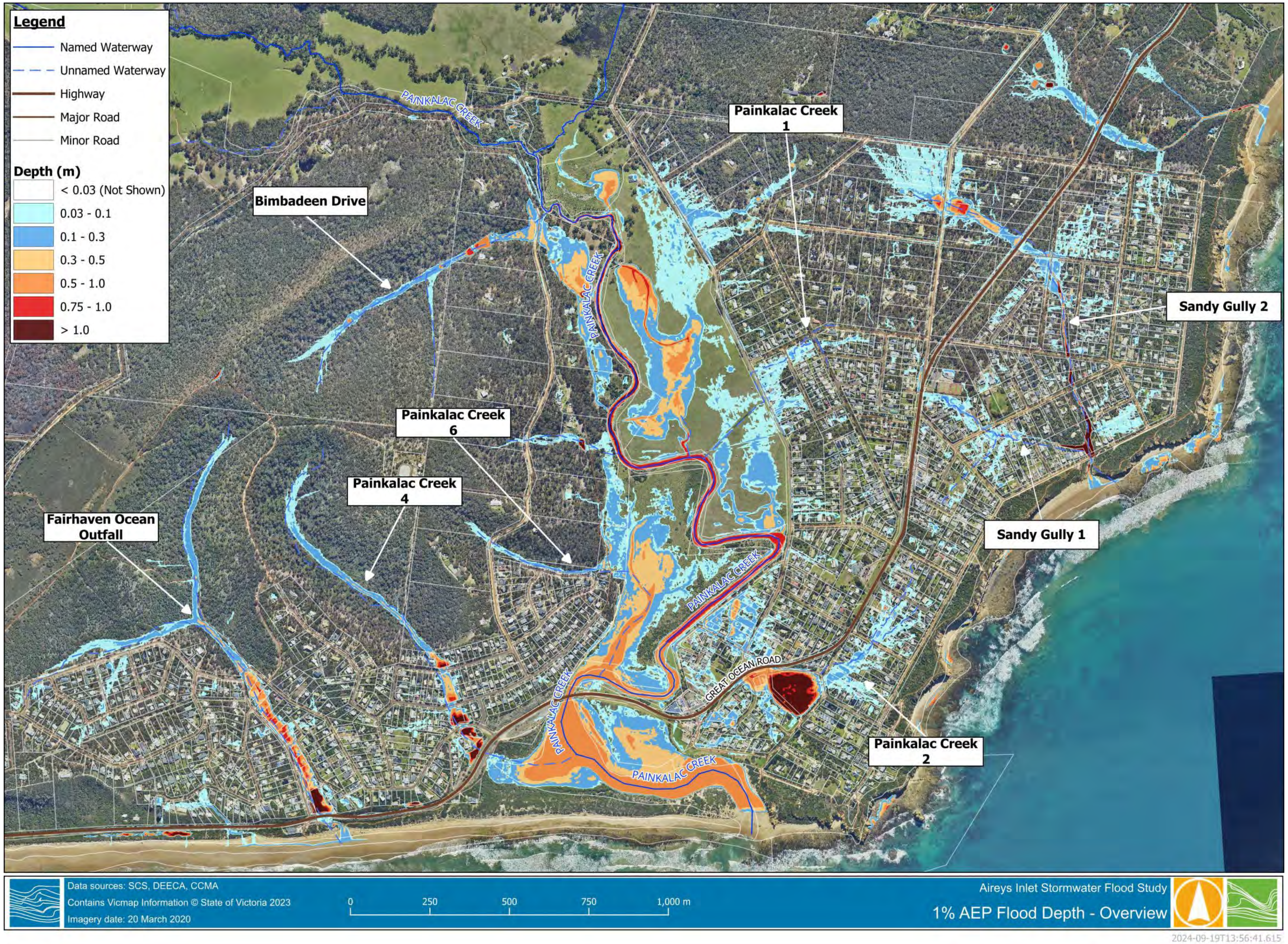

Figure 3-2 1% AEP Flood Depth – Aireys Inlet

3.3.1 Key Location 1 & 2 – Fraser Drive, Anderson Street, Alice Road and Sandy Gully

Key Location 1 – Fraser Drive, Anderson Street and Alice Road

Result of 1% AEP flood mapping indicates that inundation at Key location 1 impacts residential properties from the road reserves of Alice Road and Anderson Street. In addition to this, the runoff from Fraser Drive is shown to contribute to the inundation of properties east of Alice Road due to flow not been captured by the stormwater network.

Filtering of the 1% AEP mapping outputs is based on the flood depth output, more specifically depths less than 3cm and residing puddles less than 200 m^2. Applying this provides a clearer output for visualising overland flow paths, but it can overlook shallower flows. To better understand the mechanics of inundation down Fraser Drive and Alice Road, velocity vectors produced by the hydraulic model have been overlay on high resolution, unfiltered flood depth mapping to fully observe the extent and behaviour of runoff in this area.

Figure 3-3 below shows that there is less than 0.1m of inundation at the north end of Fraser Drive, with flows discharging northeast over Alice Road into the residential properties. The capacity of the 0.3m and 0.375m RCP stormwater pipes at the intersection of Fraser Drive and Alice Road are at 100% capacity during the 1% AEP event. The pits at this intersection do not indicate any surcharge occurs, however inflows are low. Referring to the velocity vectors in Figure 3-3, runoff from Fraser Drive is shown to be directed east, over Alice Road and into the residential properties at . The corresponding velocities of these flows is in the range of 0.4 to 0.5 m/s.

Runoff along Anderson Street, during the 1% AEP storm event is contained within the road reserve from Alice Road to around 6 Anderson Street, where overland flows start to spill to the east into residential properties. The 0.3m stormwater pipe out the front of 2 – 6 Anderson Street is at 100% capacity during the 1% AEP event, with no pits on the southern side of Anderson Street surcharging, however inflows are low.

Spillage from Anderson Street road reserve into residential properties to the south occurs at properties 10-12 and downstream of Vero Court. Two side entry pits are located at the southern end of Vera Court to capture runoff from the road reserve. However, the capacity of the 0.3m stormwater pipe in Vero Court and along the north side of Anderson Street is shown to be at 100% capacity. Runoff that cannot be capture by the network then accumulates on the north side of Anderson Street until it overtops and contributes to the inundation and overland flow path to the south. The 0.3m stormwater network from Vere Court road reserve experiences slight backwaters from the 0.6m diameter network on the southern side of Anderson Street. This results in the stormwater pit in front of 11 Anderson Street surcharging. The depth of inundation overtopping Anderson Street is in the range of 0.05 to 0.3 metres, peak velocities of 0.9 m/s. Flood depths and velocities of this nature are consistent with a H1 hazard classification which is generally safe for vehicles, people and buildings.

Filtered flood depth, velocity, water level and hazard mapping for the 1% AEP storm event is presented in Figure 3-4 to Figure 3-7 below.

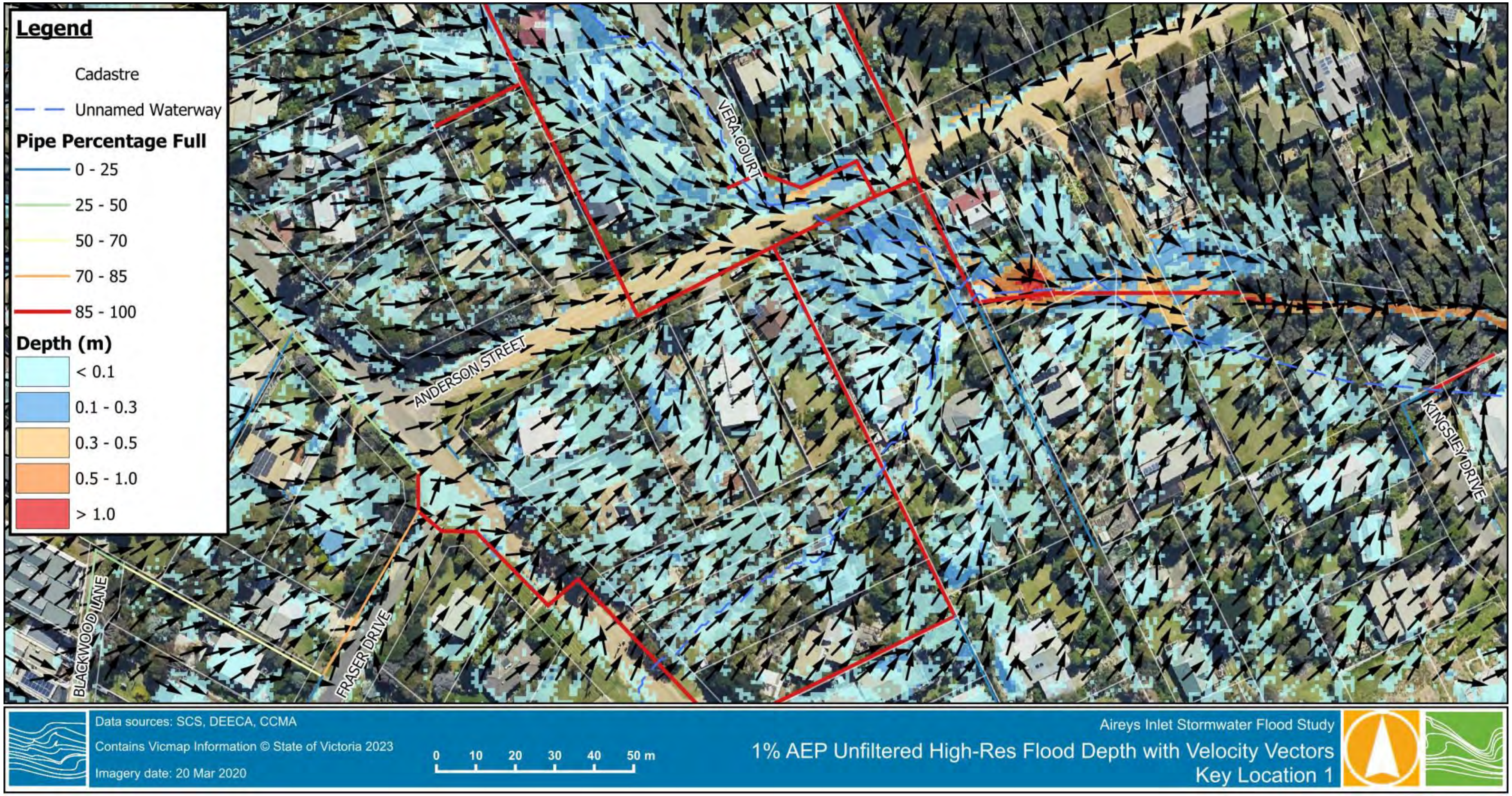

Figure 3-3 1% AEP Flood Depth – Unfiltered High-Res with Velocities Vectors

Key Location 2 – Sandy Gully

The results indicate that flood depths in the Sandy Gully, directly northeast of Kinglsey Drive, are confined to the watercourse by steep banks and a well-defined gully. Flows into the gully are driven by a 750mm pipe that conveys runoff from Anderson Street, Fraser Drive, Isla Stamp Court and the Great Ocean Road.

Velocities at the outlet of the stormwater pipe into the gully have been modelled at approximately 3.4 m/s for the 1% AEP storm event. downstream from the outlet, velocities remain relatively high ranging between 1.0 and 2.5 m/s.

The capacity of the 300mm diameter stormwater network at the northern end of Kinglsey Drive is shown to be at 100% capacity during the 1% AEP storm event. It is important to note that although this network is at capacity, it would not have ever designed to accommodate flows for the 1% AEP event.

Flood mapping for the 1% AEP storm event for Key location 1 and 2 are presented in Figure 3-4 to Figure 3-7 below.

Figure 3-4 1% AEP Flood Depth – Key Location 1

Figure 3-5 1% AEP Flood Velocity – Key Location 1

Figure 3-6 **1% AEP Flood Level – Key Location 1**

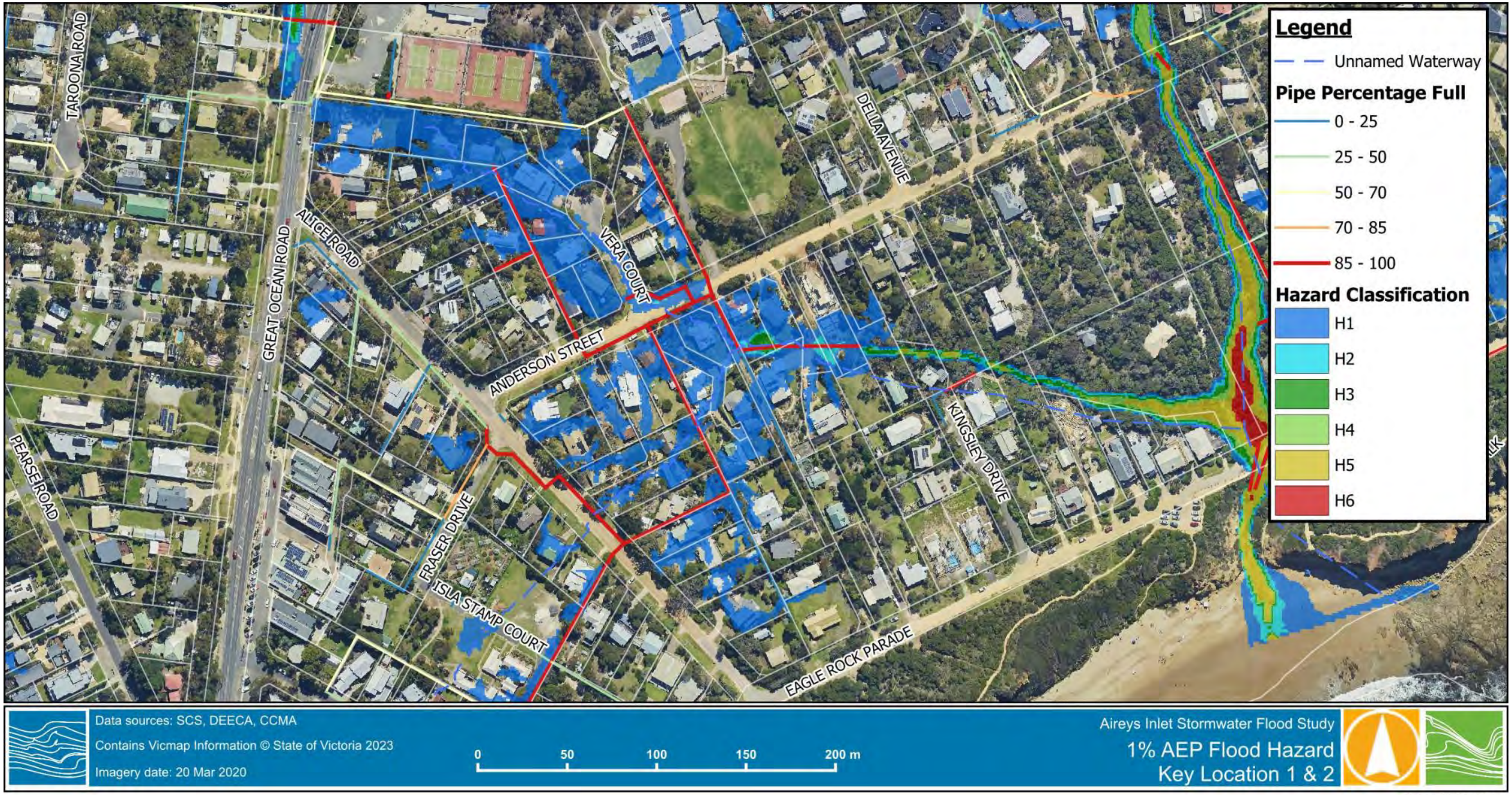

Figure 3-7 1% AEP Flood Hazard – Key Location 1

3.3.2 Key Location 3 – Amaroo Crescent and Berthon Street

Results indicate that inundation at Key Location 3 is driven by a combination of overland flows from the northeast (north of Hopkins Street) and northwest (upstream of the Great Ocean Road). Flooding of Amaroo Crescent is most prominent where it meets Berthon Street, with most of its upper catchment experiencing little inundation during the 1% AEP event.

Flood depths at the intersection of Amaroo Crescent are shown to range between 0.05 to 0.15 m. The main stormwater pipe along Amaroo Crescent is shown to be at 100% capacity for nearly its entire reach. The pipe has a diameter of 225mm starting at Aireys Street until it enters the easement in Haydn Court, where it becomes a 300mm diameter pipe.

Runoff upstream of the Great Ocean Road is conveyed towards Hopkins Street by a 300mm x 600mm reinforced concrete box culvert. During the 1% AEP event, the culverts capacity is exceeded resulting in the Great Ocean Road being overtopped by depths of 0.05 to 0.25 metres. Downstream of the Great Ocean Road, and parallel to Hopkins Street, is the main stormwater pipe which has a diameter of 600mm. This stormwater pipe is at capacity during the 1% AEP storm event. The 600mm stormwater pipe is reduced to a 300mm pipe underneath Hopkins Street and returns to a 600mm in Berthon Street where it then discharges into the Sandy Gully. The restriction in the network capacities results pits north of Hopkins Street surcharging, contributing to overland flows within Hopkins Street and Berthon Street.

Flood velocities within the road reserves of Amaroo Crescent, Berthon Street and Hopkins Street range between 0.8 to 1.9 m/s. The resulting flood hazard rating for the inundated road reserves are predominately H1. Hazard ratings of H2 and above are evident but are located off of the main carriage way.

During the 1% AEP flood event, 12 properties are shown to be inundated by overland flows, not including those located north of Hopkins Road. Of those 12 residential properties, approximately 6 would experience inundation that would affect the main dwelling and its surrounds.

Flood mapping for the 1% AEP depth, velocity, water level and hazard rating are presented in Figure 3-8 to Figure 3-11 below.

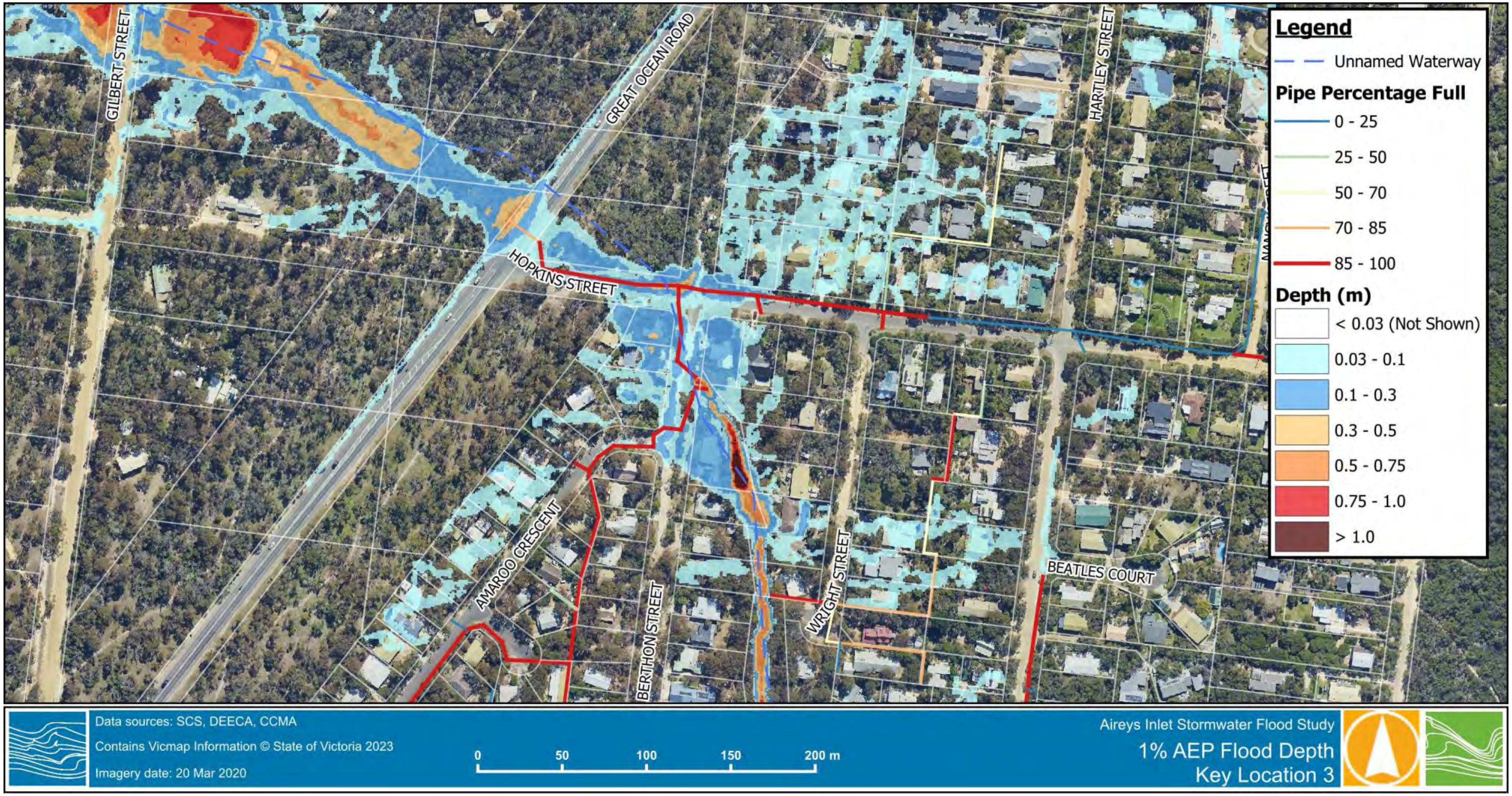

Figure 3-8 1% AEP Flood Depth – Key Location 3

Figure 3-9 1% AEP Flood Velocity – Key Location 3

Figure 3-10 1% AEP Flood Level – Key Location 3

Figure 3-11 1% AEP Flood Hazard – Key Location 3

3.4 Additional Key Locations

Key Location 4 – Pearse Road / Aireys Street

Pearse Road and Aireys Street were flagged as key locations due to reporting of ongoing issues associated with the table drainage performance along Aireys Street and the velocity of waters. Outputs from the design 1% AEP event indicate that flows along Aireys Street are relatively shallow (less than 3cm) and have been subsequently filtered out of the results. However, reference to the unfiltered 1% AEP flood velocity map indicates flow rates between 0.7 and 1.1 m/s along Aireys Street.

Design modelling of the 1% AEP event has however identified an overland flow path through the properties on the southern side of Aireys Street, between Pearse Road and Bambra Road. Depths are shallow and range between 0.03 to 0.11 m. The easement drain at the rear of 49 to 53 Aireys Street is shown to be at 100% capacity, as is with the remaining downstream network. This network appears to be sized to cater for roof runoff as it has a diameter of 225mm in the easements and 300mm further down the network. The behaviour of the overland flows is shallow, less than 0.11 metres, and has a low velocity, less than 0.3 m/s. Values of this scale don't pose a risk to buildings or Shire assets, but it will like result in minor damage to gardens within the properties and may impact water logging under buildings. Based on the ARR 2019 Design Safety Criteria, the identified overland flow path has a hazard rating of H1.

It is noted that the modelling completed for this area is not able to pick up the legal points of discharge for many of these dwelling which may discharge to the roadside swales in Aireys Street. Furthermore, the resolution of the model may under represent the geometry of the drains such that lower flows are shown within them.

A key focal point of Key location 4 was identifying the design velocities in the table drains of Aireys Street. Filtering of the model results is based on the depths and areas of puddles (isolated water bodies), which is then references to clip the remaining outputs. Referring to the raw 1% AEP flood velocity output, it can be observed that velocities in on the shoulders of Aireys are in the range of 0.5 to 1.1 m/s.

Mapping of the 1% AEP design model depths, velocities, water level and hazard are shown in Figure 3-12 to Figure 3-15 below.

Figure 3-12 1% AEP Flood Depth – Key Location 4

Figure 3-13 1% AEP Flood Velocity – Key Location 4

Figure 3-14 1% AEP Flood Level – Key Location 4

Figure 3-15 1% AEP Flood Hazard – Key Location 4

Key Location 5 – Philip Street

Key location 5 refers to the main stormwater pipe that flows into the Allen Noble Sanctuary and collects runoff from properties along Lighthouse Road, Barton Court, Philip Street, Kerrie Court and Beach Road. Desing modelling of the 1% AEP event shows that the stormwater network in this catchment is at 100% capacity. Overland flows are also shown to impact 40 properties through this area. Of those 40 properties, 21 are likely to experienced inundation that would impact the dwelling and surrounds.

Flood depths along the overland flow path are generally less than 0.3 m deep with velocities between 0.3 and 0.15 m/s. Therefore, the associated flood risk of the overland flow path is H1.

Mapping of the 1% AEP design event for depth, velocity, water level and hazard rating are presented in Figure 3-16 to Figure 3-19 below.

Figure 3-16 1% AEP Flood Depth – Key Location 5

Figure 3-17 1% AEP Flood Velocity – Key Location 5

Figure 3-18 1% AEP Flood Level – Key Location 5

Figure 3-19 1% AEP Flood Hazard – Key Location 5

3.4.1 Key Location 6 – 140 Bimbadeen Drive

Key location 6 is located at 140 and 115 Bimbadeen Drive, where concerns of damage to roads/driveways and behaviour of inundation are of primary focus. Hydraulic modelling of the 1% AEP storm event has identified that Bimbadeen Drive and the driveways of 140 and 115 are subject to flooding.

Flood depths for the modelled 1% AEP storm event reach 0.23 m over Bimbadeen Drive and 0.44m on the shoulder. Across the driveways of 140 and 115 Bimbadeen Drive flood depths reach maximums of 0.4 and 0.35 m, respectively.

The velocity of floodwaters during the 1% AEP event peak at approximately 1.5 m/s on the shoulder of Bimbadeen Drive, near the driveway of 115 Bimbadeen Drive. The surround area of inundation all feature flood velocities less than 2 m/s, which is below the vulnerability threshold for limiting velocity.

The associate flood risk for the two driveways and Bimbadeen Drive is classified primarily as H2 and is considered unsafe for small vehicles. This rating is driven by 1% AEP flood depths exceeding 0.3m and less than 0.5 m, with limiting velocities not impacting the rating. There are sections of Bimbadeen Drive that are classified as H1, and a finer resolution hydraulic model would likely increase the extent of H1 rated flood extents. However, driveways for 115 and 140 Bimbadeen Drive are clearly subjected to flood behaviours that exceed the vulnerability thresholds for safe access.

Flood mapping of the 1% AEP depth, velocity, level and hazard rating are present in Figure 3-20 to Figure 3-23 below.

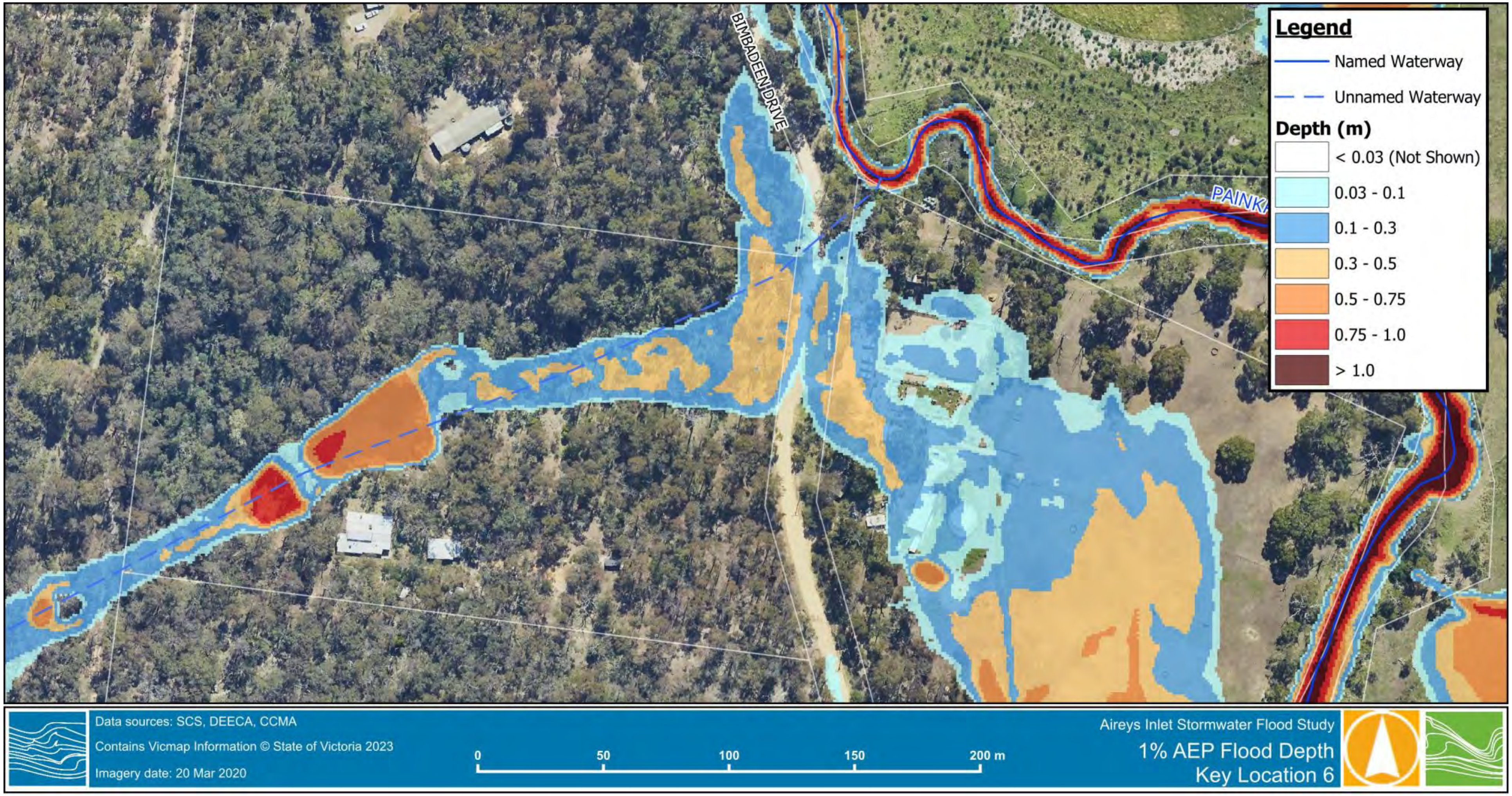

Figure 3-20 1% AEP Flood Depth – Key Location 6

Figure 3-21 1% AEP Flood Velocity – Key Location 6

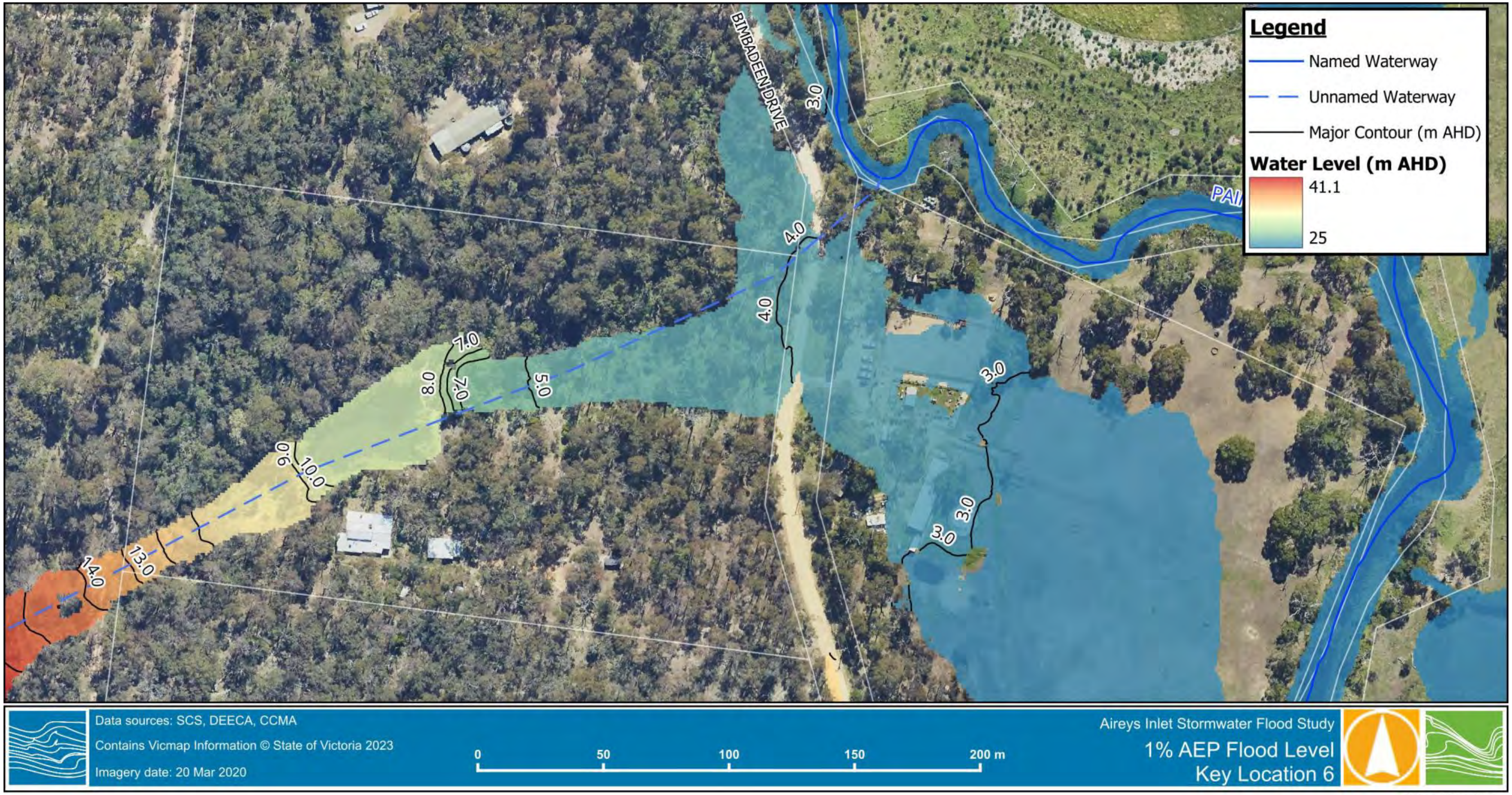

Figure 3-22 1% AEP Flood Level – Key Location 6

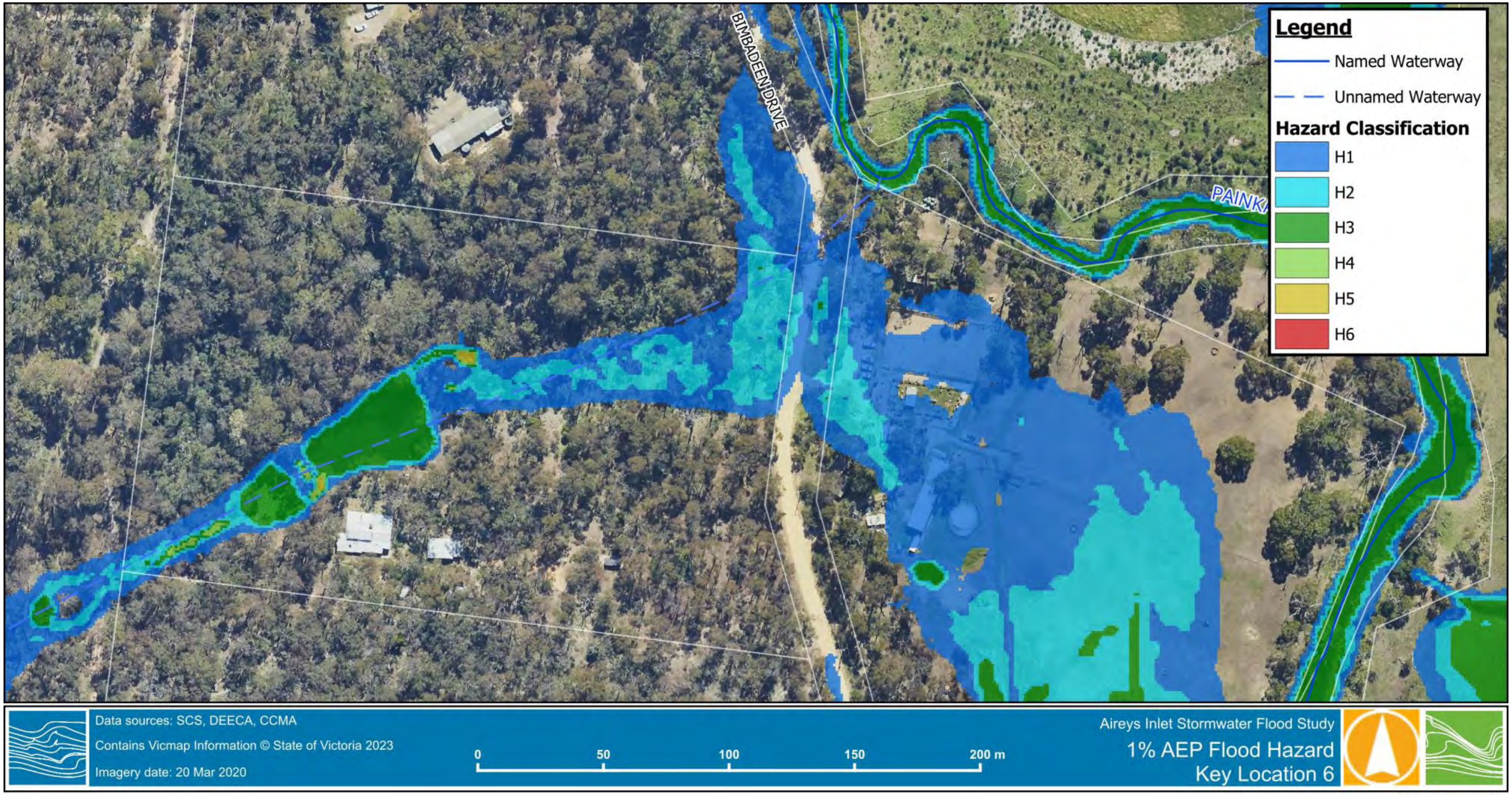

Figure 3-23 1% AEP Flood Hazard – Key Location 6

4 SUMMARY

Design modelling of Aireys Inlet's stormwater catchments consisted of a detailed TUFLOW model, adopting design parameters and rainfall data for a range of storm events. The TUFLOW model adopted a 2-metre grid size and utilized SGS at a 1-metre sampling distance to ensure narrow flow paths were appropriately considered. The hydraulic model can be used to simulate stormwater assessments in both urbanised catchments and overland flow assessments within Aireys Inlet using a rain-on-grid approach.

The hydraulic model simulated the January 2022 storm event based on sub-daily rainfall data from the Boonah rainfall gauge. While sub-daily rainfall data is also available for the October 2022 event, it was not modelled as it produced more riverine flood events. There was limited data on observed damages from this event to validate too. Modelling results of the January 2022 event, were validated against observed damages and inundation extents by Surf Coast Shire's Stormwater Infrastructure Team and Civil and Operations Team. It was found that the hydraulic model provided a good representation of the team's recollections and observations from the January 2022 event.

Hydraulic modelling of design events confirmed inundation of the previously identified key locations during the 1% AEP storm event, it has also identified additional areas where inundation is of concern. These locations include:

- Fraser Drive, Anderson Street and Alice Road – Inundation of Anderson Street is driven by runoff from steep catchments (Vera Court) and runoff attempting to enter a stormwater network that is at capacity. This results in overland flows failing to be captured by pits, and in some instances, pits surcharging. This contributes to the volume of water escaping the Anderson Street road reserve which flows southeast through residential properties. For Alice Road, runoff from Fraser Drive is inefficiently captured and contained within the road reserves. During the 1% AEP event, runoff from Fraser Drive continues across Alice Road and into the residential properties to the east. While the table drains aren't typically sized to convey 1% AEP flows, the road reserve should be designed to minimise runoff into properties should water escape the drains.
- Sandy Gully & Kingsley Drive – Flows at the outlet of the stormwater pipe, located north of Kingsley Drive, discharge at 3.4 m/s during the 1% AEP design event. Velocities of this magnitude can have an impact on the integrity of the banks in the Sandy Gully, resulting in erosion and sediment deposition at Eagle Rock Parade and into the ocean. Additionally, discharge from Kingsley Drive and the residential properties along this section of the Sandy Creek can also contribute to the erosion of the gully banks through the continual and frequent discharge from the properties.
- Amaroo Crescent and Berthon Street – Runoff from the catchment upstream of Hopkins Street and the Great Ocean Road largely contribute to the inundation of residential properties in this key location. With limited capture pits in Hopkins Street and Berton Street, overland flows rely heavily on the shape of the roads and table drains to prevent flows entering/inundation residential properties. Despite the extent of inundation, the associated flood risk is low and considered safe for all vehicle types.
- Pearse Road / Aireys Street – Drainage problems encountered on Aireys Street were not reflected in the hydraulic model as originally intended. The 1-metre resolution of the hydraulic model is too coarse to accurately represent the table drains in Aireys Street. This impacts the level of detail in the output flood depth and velocity maps. This key location would benefit from a more site-specific assessment, which involves undertaking a feature level survey of the road reserve to produce a finer terrain resolution. Using a finer terrain resolution will improve the representation of the table drains, but it cannot guarantee the outcome sought after. Advice on design velocities and preventive erosion measure can be provided based on the current modelling results and numerical assessment of the area.
- Philip Street – Philip Street has been identified as the locality marker for key location 5, as it has the potential to accommodate stormwater drainage capacity upgrades to reduce the volume of runoff from the

road reserve into residential properties. The nature of inundation at this location is frequent, with shallow overland flows modelled during the 20% AEP event. the depths and velocities, while not hazardous to life, are of nuisance to the community and ways to reduce the contributing flows external to the properties is first priority.

- Wright Street – Wright Street was initially identified for its easement drain performance and susceptibility to blockage. While hydraulic modelling of Wright Street does show extents of inundation during the 1% AEP event, this is to be expected. Improvements to the overall performance and resilience to blockages can be assessed on a site basis with recommendations of materials/construction methods and numerical assessments.
- 140 Bimbadeen Drive – Runoff from the catchment upstream of 140 Bimbadeen Drive results in the inundation of the driveways and road reserve. the behaviour of inundation at this location exceeds safety design thresholds to permit safe access/egress for all vehicle types.

Next Steps

Water Technology will coordinate a workshop with the Surf Coast Shire to discuss the outcomes of the design model and strategies suitable to improve flood risk/resilience to impacted areas. These strategies will be tested using the constructed TUFLOW model with their outcome's summarised in a Mitigation Assessment Report.

APPENDIX A
2%, 5%, 10% AND 20% AEP FLOOD DEPTH MAPPING

Figure 4-1 2% AEP Flood Depth Mapping – Aireys Inlet Overview

Figure 4-2 5% AEP Flood Depth Mapping – Aireys Inlet Overview

Figure 4-3 10% AEP Flood Depth Mapping – Aireys Inlet Overview

Figure 4-4 20% AEP Flood Depth Mapping – Aireys Inlet Overview

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