



Design Hydraulic Modelling Report

Anglesea Stormwater Flood Study

Surf Coast Shire

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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 Anglesea 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 observed 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 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 Anglesea's 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 Anglesea 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 Anglesea. As this study focuses on the stormwater drainage network of Anglesea, hydrologic and hydraulic modelling of the Anglesea River's contributing catchment has not been included in this project. Consideration for the impact of the Anglesea River on stormwater outlets has however been considered by assessing varying berm heights and corresponding river levels.



2 HYDRAULIC MODEL DEVELOPMENT

2.1 Model Overview

A two-dimensional Rain-on-Grid (RoG) hydraulic modelling approach 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.

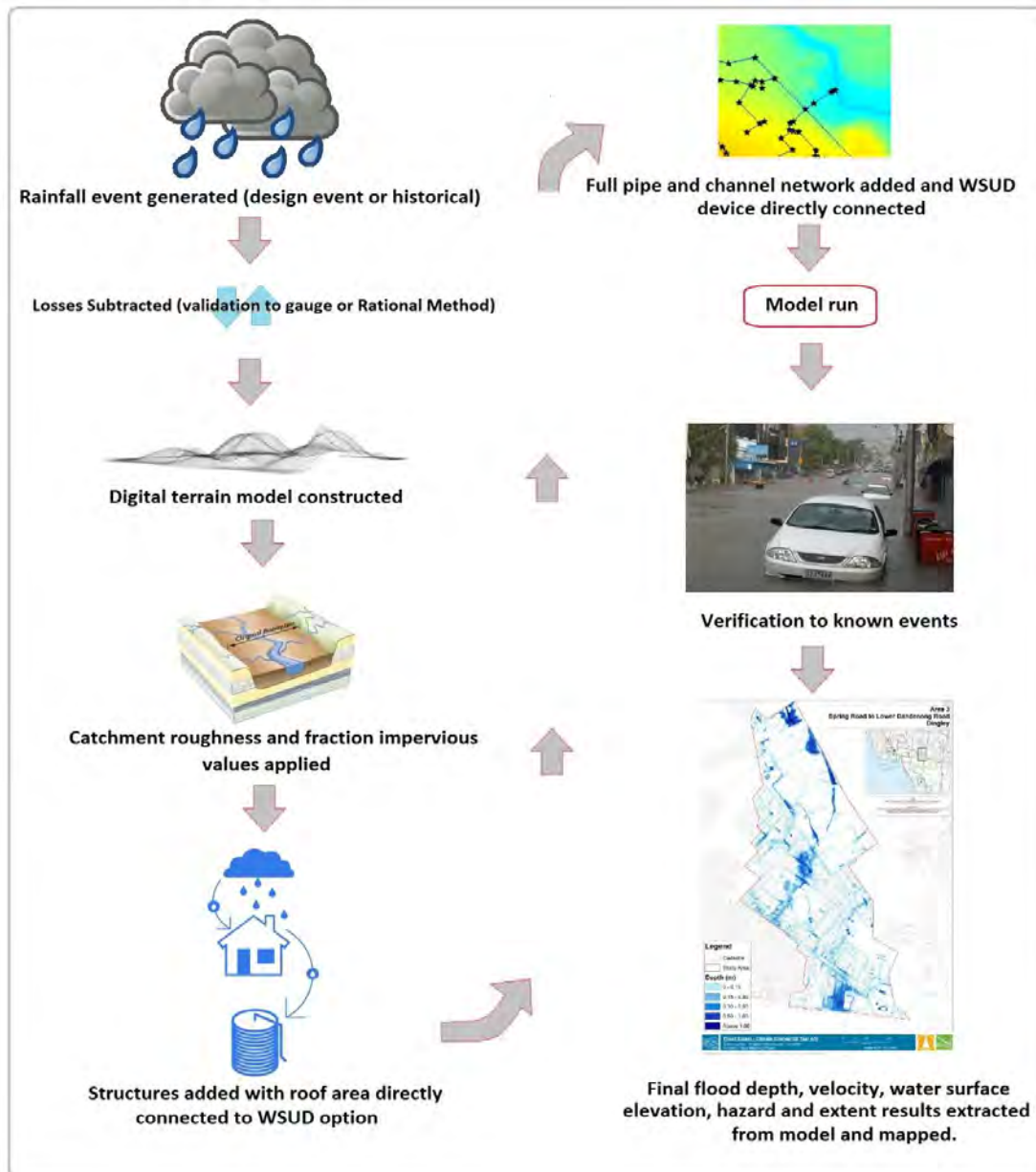


Figure 2-1 Rainfall-on-Grid Modelling Approach



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. Bathymetry survey of the Anglesea River with a resolution of 1-metre was adopted for the waterway. ■ LiDAR (2022): cep15_dtv_anglesea_2022mar20_dem1 ■ Bathymetry Survey (2000) of Anglesea River: anglesea_bathy_1m
Inflow Regime	Rainfall-on-Grid (RoG) (2d_rf) was adopted based on rainfall hyetograph 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. A water level-time boundary condition was adopted for the outlet of the Anglesea River to represent varying berm height scenarios. ■ HQ boundaries ■ Outflow 1: 0.004 m/m ■ Outflow 2: 0.001 m/m ■ Outflow 3: 0.015 m/m ■ Outflow 4: 0.01 m/m ■ Outflow 5: 0.05 m/m ■ HT Boundary ■ Full Berm Breach: 0.8 m AHD ■ Starting Berm Height: 2.0 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 2-5.
Model Cell Size	2-metres
SGS Settings	1-metre Sample Target Distance
Peak Cumulative Mass Error	0.08%
Repeated Timesteps	0
RoG Filtering Parameters	Depth: < 3 cm Puddles: < 200 m²



2.2 Model Extents and Boundaries

Model Inflows

Design rainfall was applied directly to the 2D domain (2d_rf) using extents derived from Anglesea'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). As the aim of this study is to assess Anglesea's stormwater catchments, no inflow hydrographs were applied to the Anglesea River where it enters the hydraulic model. Rainfall (2d_rf) was however applied to the Anglesea River within the hydraulic model extent. An initial water level was also applied to the Anglesea River, with an elevation of 1.21 m AHD.

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 Anglesea River, where varying berm heights were 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. The Height vs Time boundary conditions, representing varying heights of the berm at the outlet of the Anglesea River, was based on modelling parameters used in the 2013 Anglesea River Flood Study¹. For this study, two berm height scenarios were assessed: Starting Berm Height and Full Breach Height. The values adopted for each scenario were the design base case values adopted in 2013¹ study. For both scenarios, the height was set for the entire duration of the model run. By applying these values for the entire storm duration, it represents stormwater flooding events prior to and following the Anglesea River berm breaching.

Table 2-2 Height vs Flow Boundary Condition Slopes

Location	Slope (m/m)
Outflow 1	0.004
Outflow 2	0.001
Outflow 3	0.015
Outflow 4	0.01
Outflow 5	0.05

Table 2-3 Height vs Time Boundary Conditions

Berm Height Scenario	Elevation (m AHD)
Starting Berm Height	2.0
Full Breach Height	0.8

¹ T. Jones, G. Taylor, 2013, *Anglesea River Flood Study, FP-2013-2*, Corangamite Catchment Management Authority

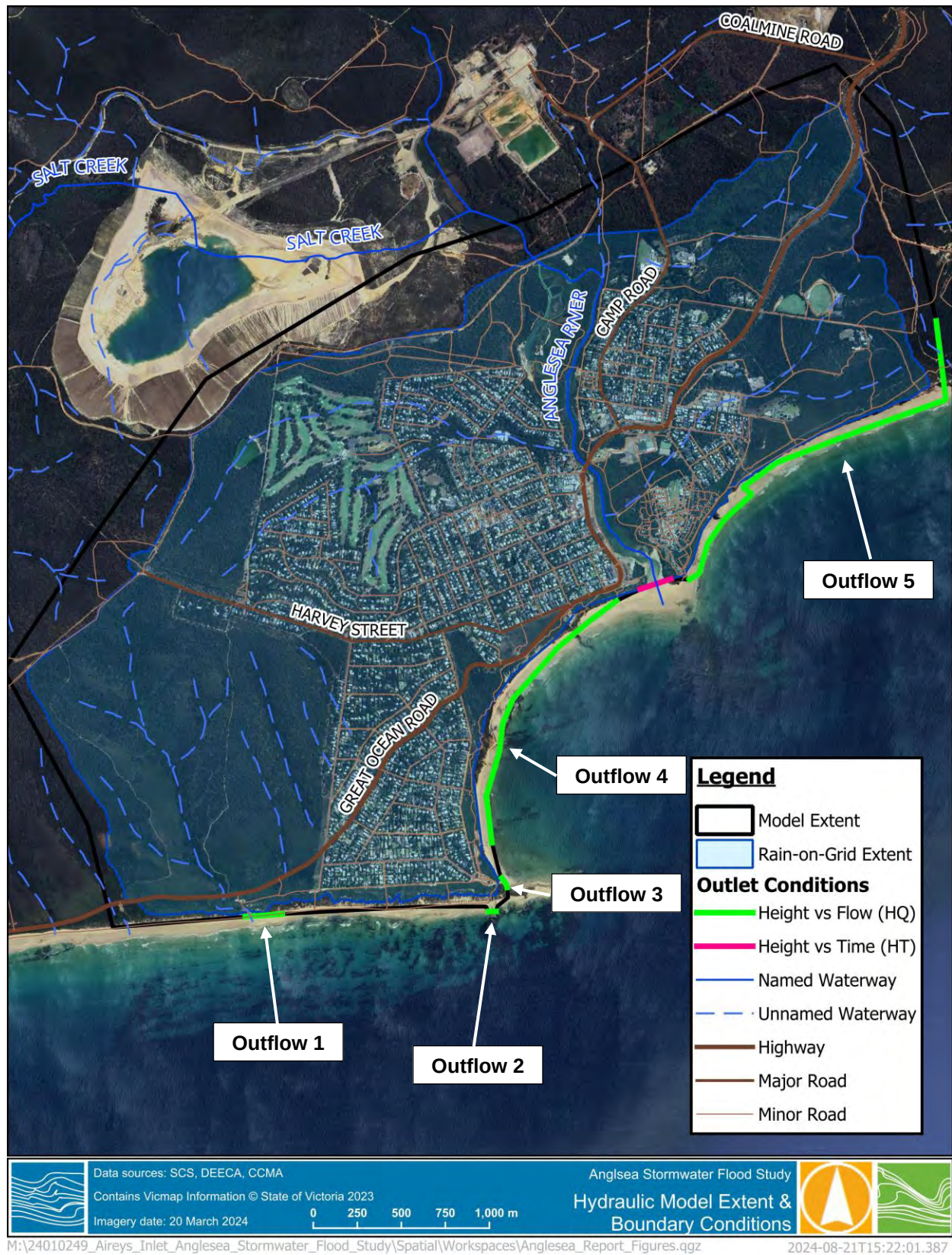


Figure 2-2 Hydraulic Model Extents and Boundaries



2.3 Model Topography

The hydraulic model's topography for the stormwater catchments was based on LiDAR data captured on 20 March 2022, which featured a grid cell size of 1-metre and vertical accuracy of $\pm 10\text{cm}$. Bathymetry for the Anglesea River, with a resolution of 1-metre, was also available and captured around the year 2000. While the bathymetry is approximately 24-years old and not a key focus point of this study, it does provide an additional layer of detail in the hydraulic model. Controls impose on the outlets of the stormwater networks will be driven by water levels in the Anglesea River, not its bed levels.

Determination of a suitable grid size in the hydraulic model considers the trade-off between accurate representation of flow 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 the accuracy of 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.

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. The utilisation of SGS allows for the capacity of open drains/road reserves/narrow flow paths to be represented in the hydraulic model on a finer resolution. This allows for a better representation of overland flows that interact with inflows/outflows of the stormwater network. The input LiDAR was a limiting factor to the SGS sample frequency, which was set to 1-metre.

Some post processing of the LiDAR data was completed to remove an unnatural low point in the dataset, likely a result of processing of the raw dataset when buildings/roofs were removed. Removal of the low point was completed by using a 2d_zsh polygon that interpolated the extents of the polygon to 'smooth' the low point. The total area 'smoothed' was approximately 225 m². A comparison between the raw LiDAR and 'smoothed' terrain is shown in Figure 2-4 below.

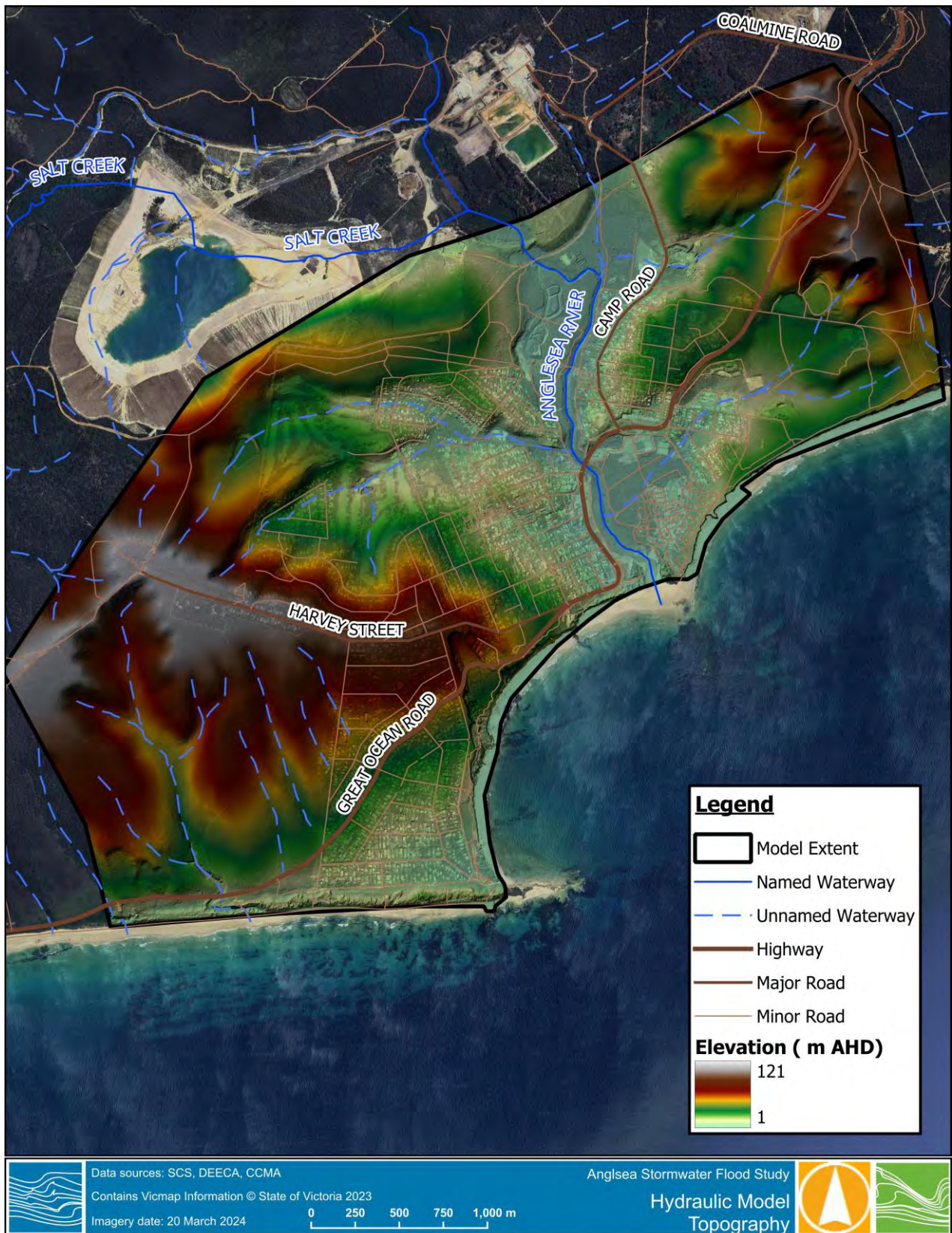


Figure 2-3 Model Topography

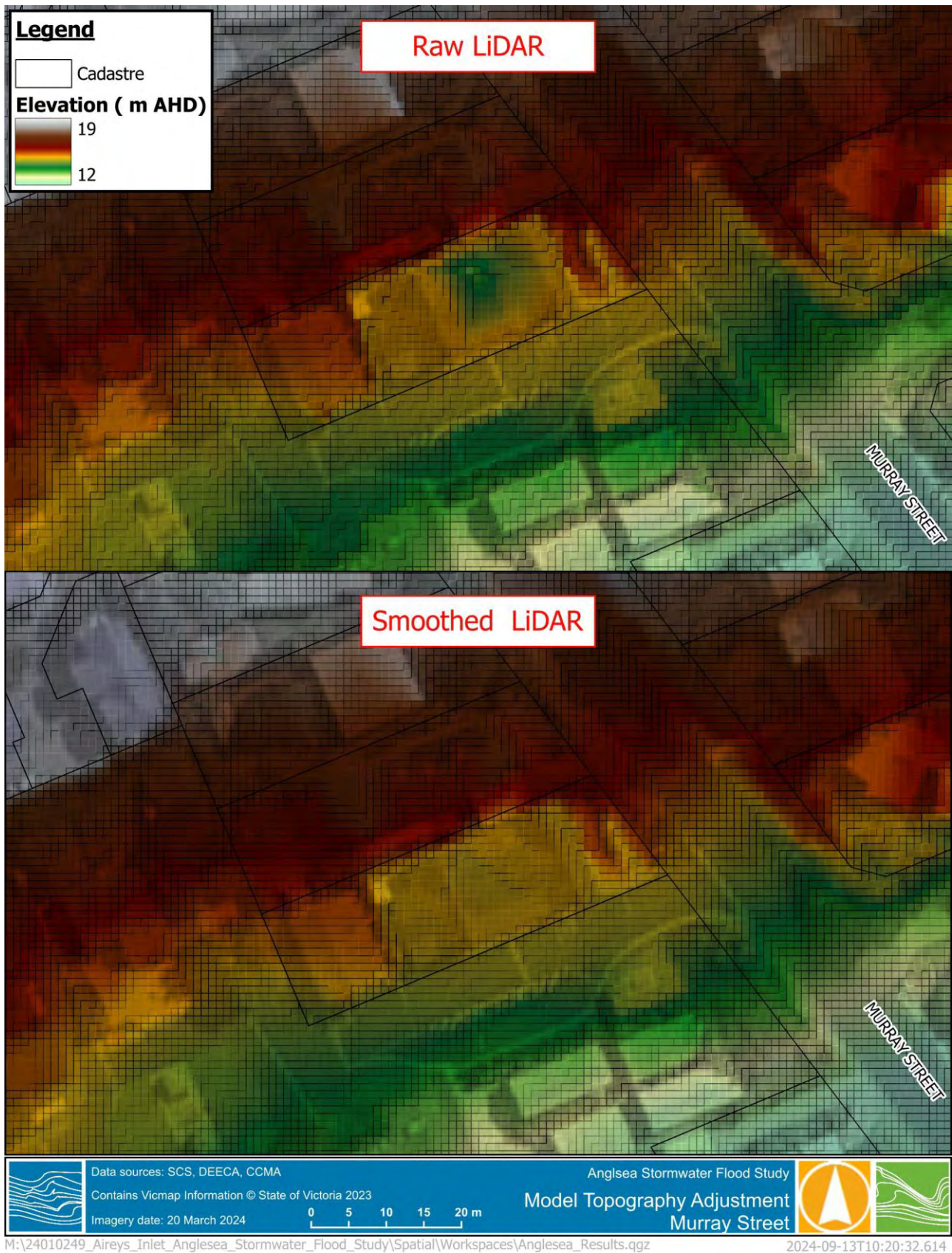


Figure 2-4 Model Topography Adjustment – Murray Street



2.4 Stormwater Network

The study area included a total of 1579 pipes/box culverts and 1567 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. 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 (<i>n</i>)
Reinforced Concrete	0.013
Stormpro Plastic Pipe	0.010
High Density Polyethylene Pipe	
Polypropylene Pipe	
Polyvinyl Chloride Pipe	

McMillan Street

the stormwater pipe under McMillan Street discharges into the Anglesea River, where its outlet is submerged. The concern is that the constraint on the outlet is impacting the overall performance of the McMillan Street stormwater network, which collects runoff from Charles Street, George Street, Jackson Street, Murray Street and Parker Street. Currently, the stormwater pipe in McMillan Street, between Murray Street and the Great Ocean Road, is a 1.05m reinforced concrete pipe (RCP). Mapping of McMillan Street stormwater network is shown below in Figure 2-6.

Anglesea Retirement Village

The internal stormwater network of the Anglesea Retirement Village was not included in the hydraulic model for two reasons. The first being it is not an asset of the Surf Coast Shire, and secondly, the network is typically sized for 5% AEP storm events and to address on-site runoff and does not consider more significant events including the 1%. A 1.125m RCP is located immediately to the south of the retirement village and is designed to convey flows from Weir Street (and upstream) to the Anglesea River. Mapping of the Anglesea Retirement Village stormwater network is shown in Figure 2-7 below.

Golf Course Overland Flow Paths

There are two main discharge points from the Anglesea Golf Course, the southern one being adjacent to Carrawe Court and the northern is located opposite 34-36 Golf Links Road. The southern discharge location is fed into a 0.975m concrete pipe that goes under Carrawe Court and the Paringa Nature Reserve. The discharge location from the northern overland flow path, adjacent to 34-36 Golf Links Road, is controlled by a detention basins with riser pits as outlet controls. A 0.75m pipe conveys flows form the basin to the east and



merges with the southern outlet pipe north of Paringa Crescent. Mapping of the Golf Course and downstream area stormwater network is shown in Figure 2-7 below.

Butterworth Crescent

Stormwater drainage for Butterworth Crescent includes a 0.3m concrete pipe at its upstream end, which covey's stormwater captured from Noble Street to the south. Runoff from the road reserve of Butterworth Crescent from Murray Street is captured by the 0.3m diameter pipe adjacent to 7 Butterworth Crescent. The pipe size increases from a 0.3m to 0.375m approximately after 93 m, adjacent to 15 Butterworth Crescent, before feeding into the easement drain behind 23-31 Butterworth Crescent. An overview of the stormwater network at Butterworth Crescent is shown below in Figure 2-8.

Larencia Way

The stormwater network within Larencia Way is a 0.375m diameter pipes that flow towards the main pipe in Camp Road. The receiving stormwater pipe in Camp Road is sized at a 1.2m, which is considerably large due to the low number of inflow pipes. It is assumed that the 1.2m pipe was used by a school that was located where Larencia Way now reside, and may have been used for stormwater detention. Mapping of the stormwater network around Lawrencia Way is shown below in Figure 2-9.

Charlse Street

Stormwater pipes along Charles Street is limited as it mostly consists of table drains and culverts (typically 0.3m) underneath driveways. Runoff from Charlse Street is directed towards a 0.3m pipe that flows northeast through easements and forms part of the upper catchment of McMillan Street. Mapping of the stormwater network within Charlse Street and downstream is shown in Figure 2-10 below.

Anglesea Business Park

Stormwater mapping of the Anglesea Business Park shows it drains to the south, along Saltwater Place, with typical pipe sizes through the business park being approximately 0.3m and 0.375m in diameter, with some easement drains sized at 0.225m in diameter. Mapping of the Anglesea Business Park stormwater network, and downstream, is shown in Figure 2-11 below.



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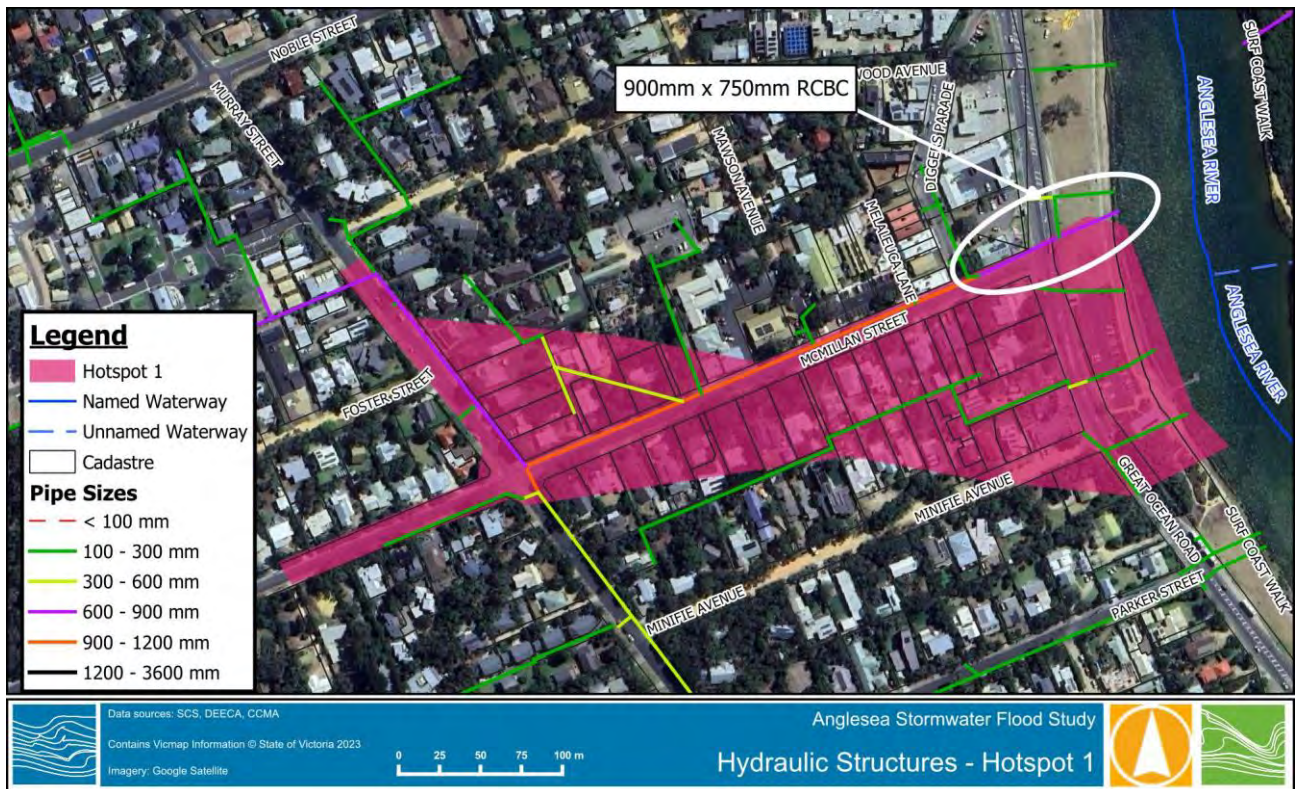


Figure 2-6 Hydraulic Structures – Key Location 1

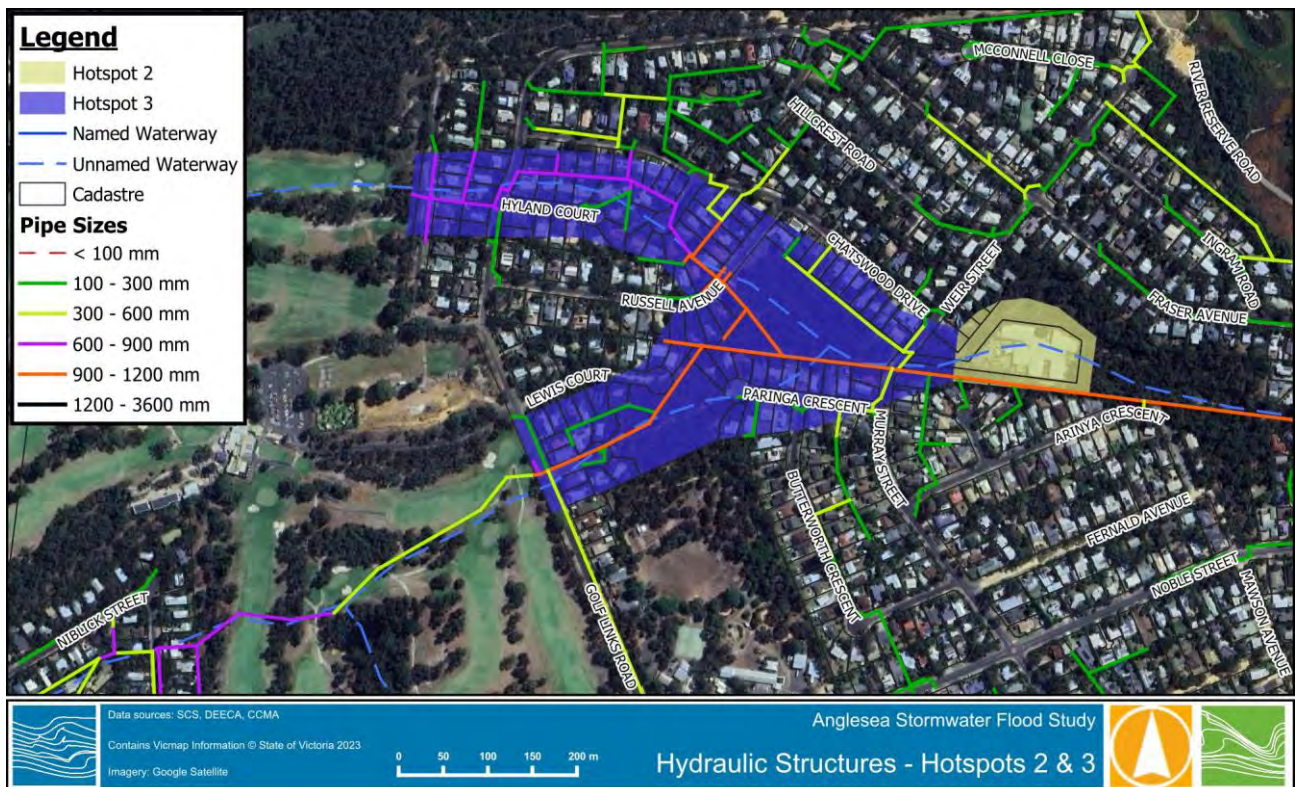


Figure 2-7 Hydraulic Structures – Key Locations 2 and 3

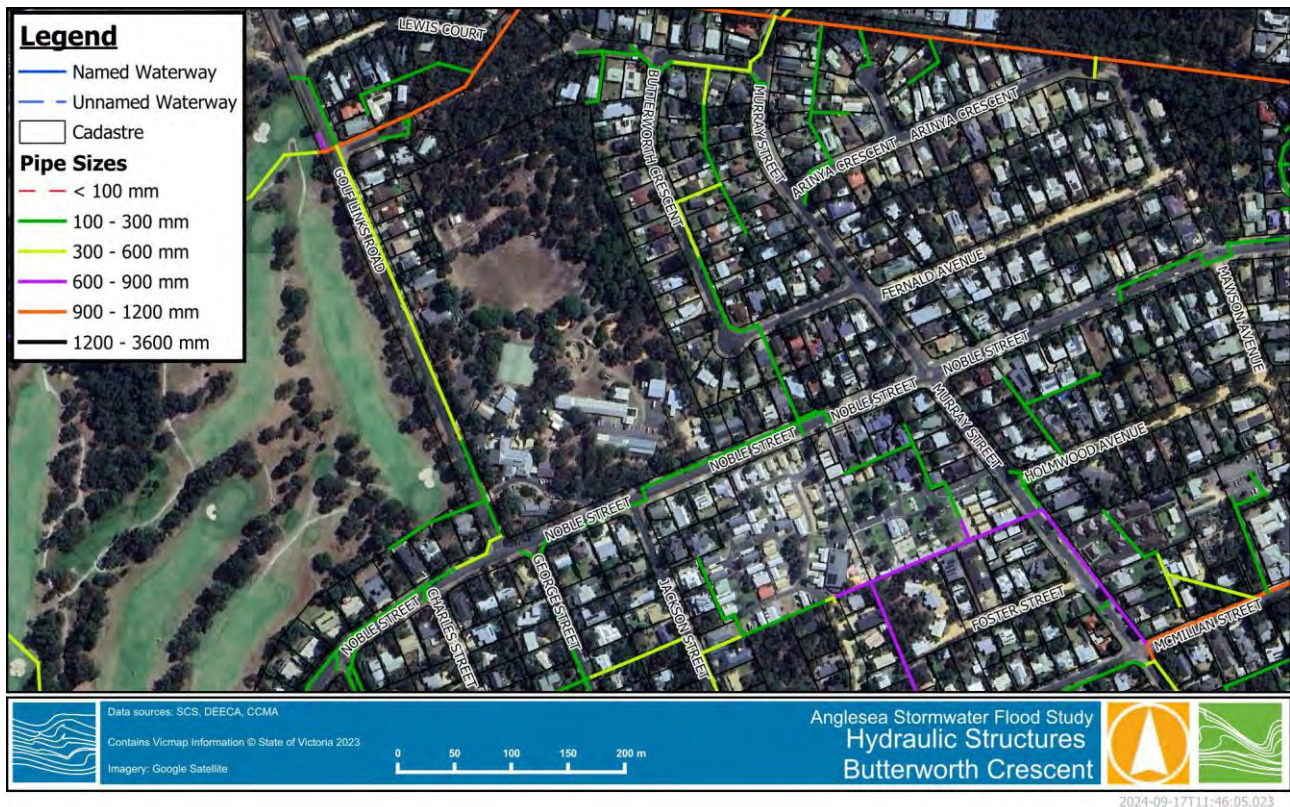


Figure 2-8 Hydraulic Structures – Butterworth Crescent

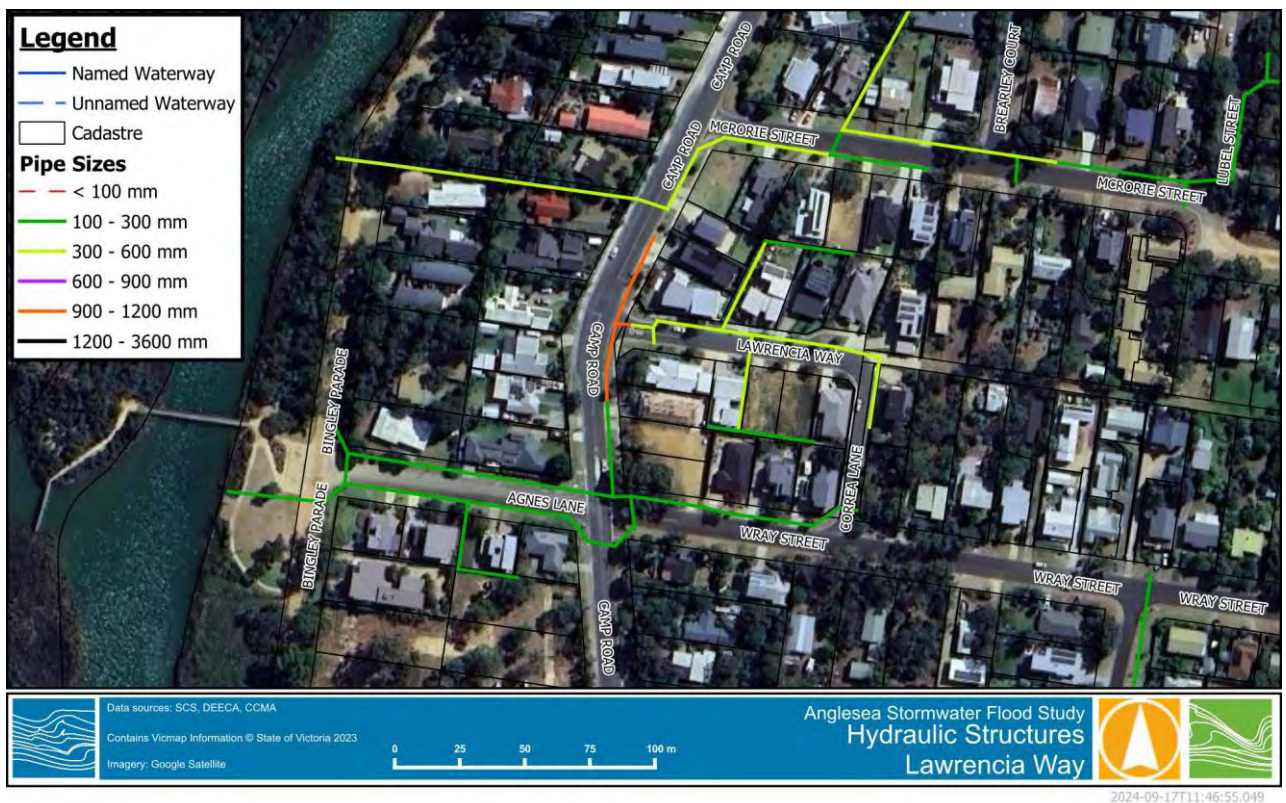


Figure 2-9 Hydraulic Structures – Lawencia Way

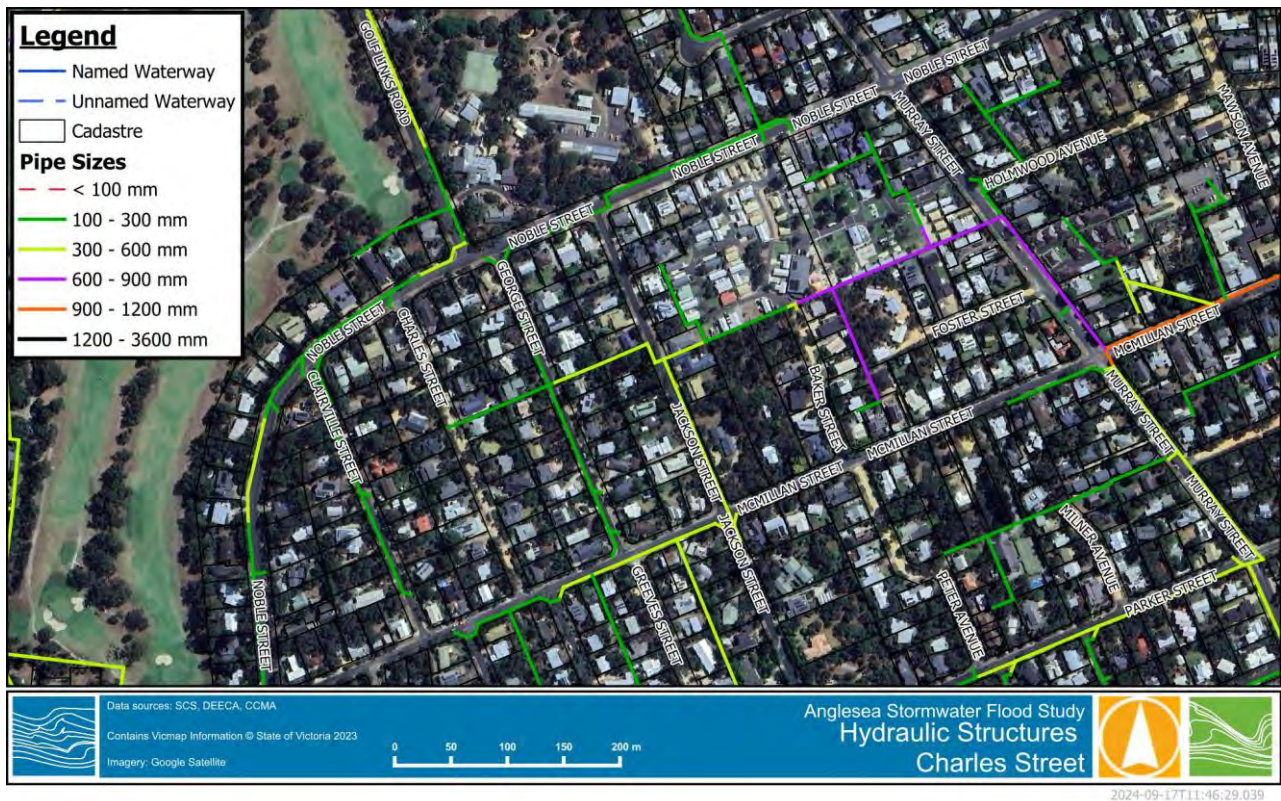


Figure 2-10 Hydraulic Structures – Charles Street

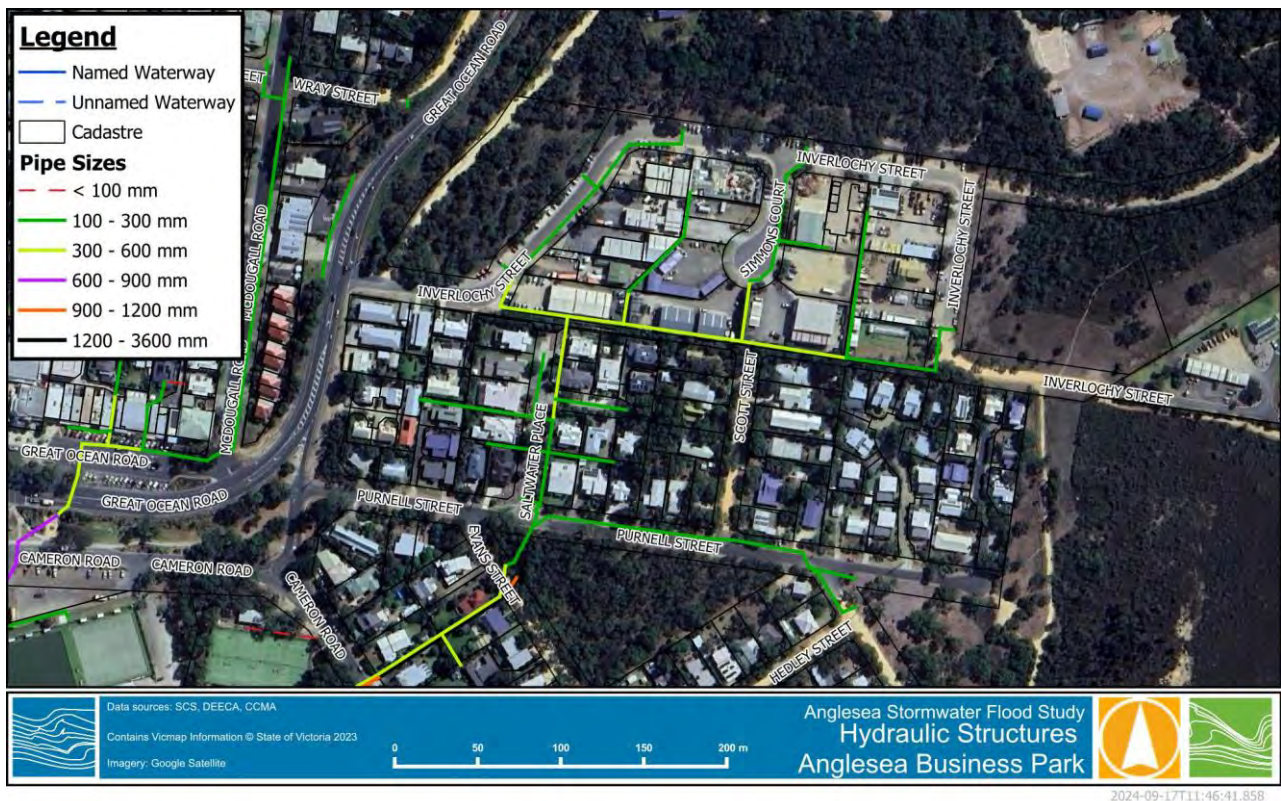


Figure 2-11 Hydraulic Structures – Anglesea Business Park



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 2-5 and Figure 2-12 below.

Table 2-5 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

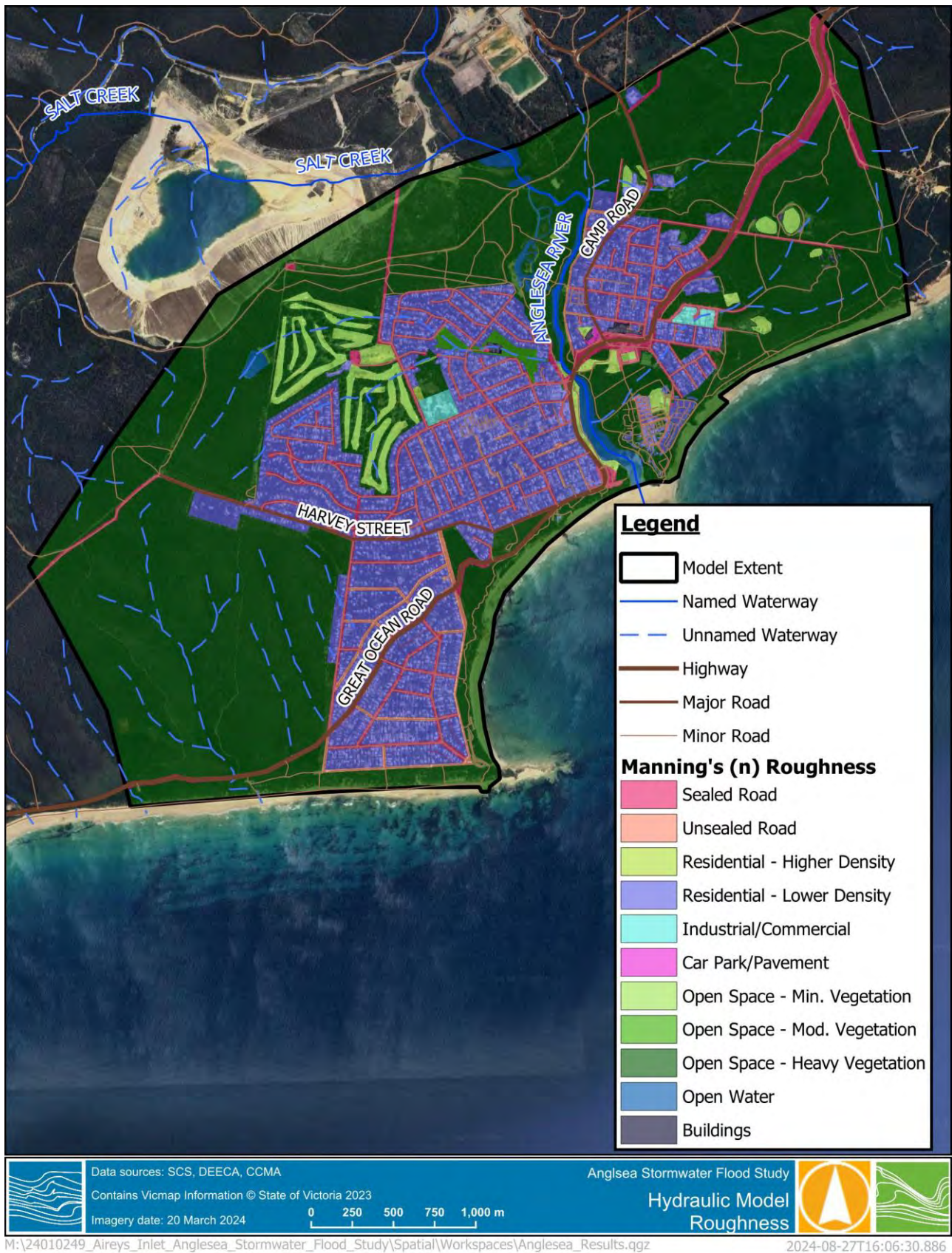


Figure 2-12 Hydraulic Model Roughness



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 Anglesea 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 attached to each land type. A summary of the adopted losses is presented in Table 2-6 below.

Initial and continuing losses were based on values adopted in similar RoG studies and increased slightly to consider the presence of more 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 $\pm 1\text{cm}$ in key locations for this assessment. Therefore, the below losses have been adopted.

Table 2-6 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 summary² 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 station for the January 2022 and October 2022 events are shown in Figure 2-13 and Figure 2-14 below. Rainfall during February 2022 at the Boonah rainfall station was low, with the month total only reaching approximately 7 mm. 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)

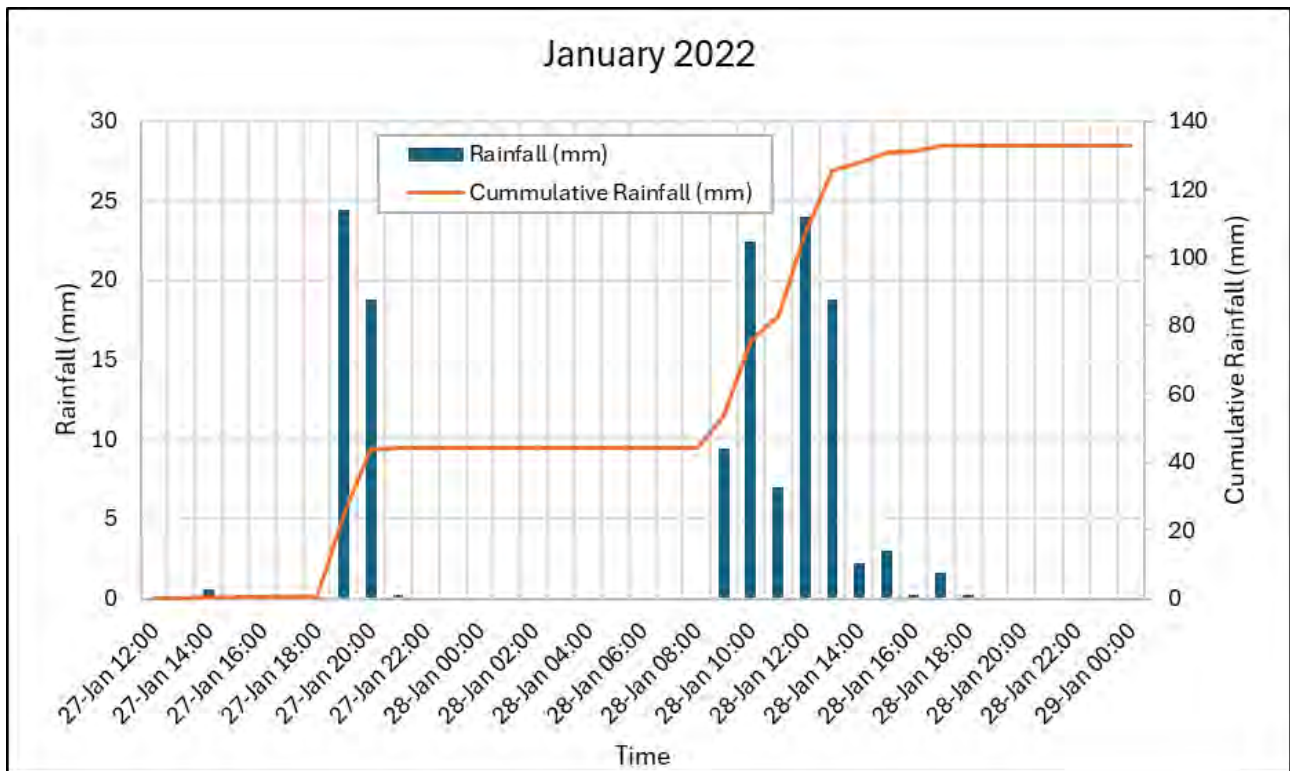


Figure 2-13 January 2022 Storm Event – Boonah (90187) hourly rainfall

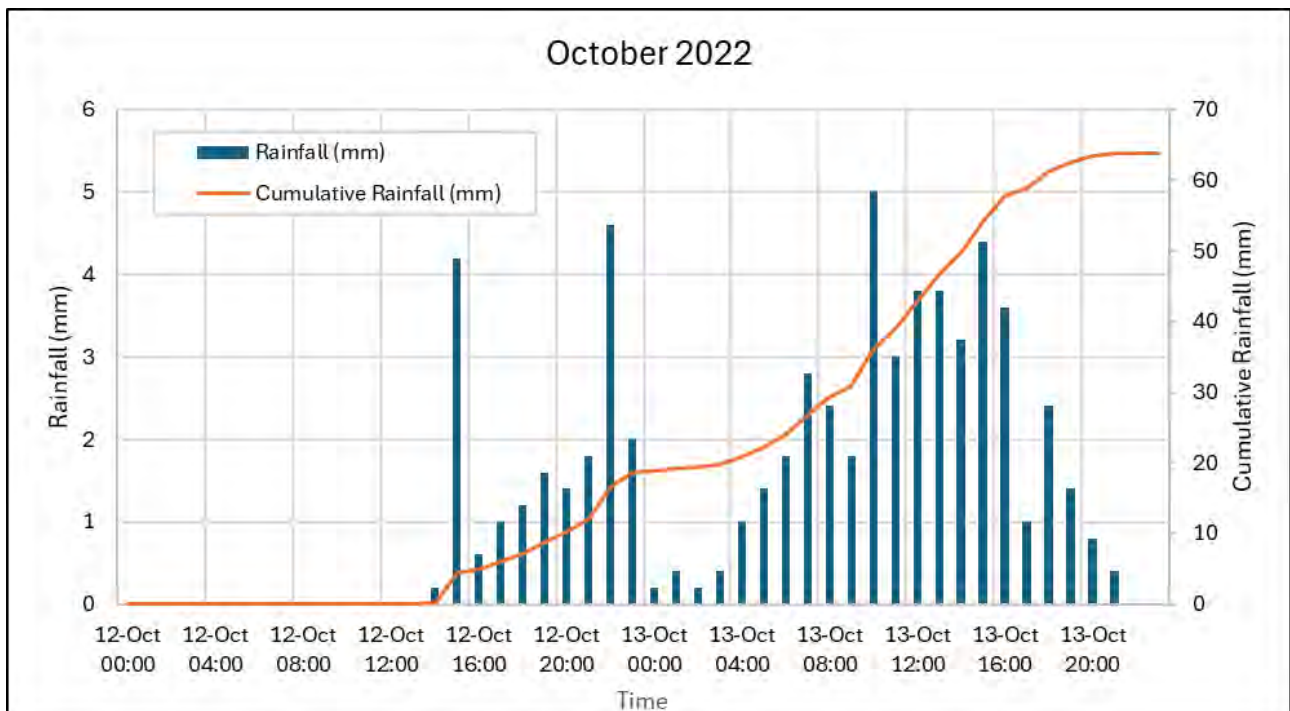


Figure 2-14 October 2022 Storm Event – Boonah (90187) hourly rainfall



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 2-7 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 2-8.



Table 2-7 Modelled Durations and Temporal Patterns

Duration	1% AEP		Cumulative Rainfall (mm)				
	Temporal Pattern	Rainfall Distribution	1%	2%	5%	10%	20%
30-min	TP03		27.5	23.3	19.5	16.4	13.5
	TP10						
	TP01						
1-hr	TP02		33.8	28.9	24.5	20.8	17.1
	TP10						
	TP09						
1.5-hr	TP05		38.1	33.0	27.9	23.8	19.7
	TP10						
	TP07						
2-hr	TP02		41.7	36.5	30.8	26.3	21.9
	TP10						
	TP07						
3-hr	TP02		56.2	51.0	41.7	36.0	30.3
	TP10						
	TP08						
4.5-hr	TP04		56.2	51.0	41.7	36.0	30.3
	TP10						
	TP05						
6-hr	TP05		63.6	58.4	47.1	40.6	34.3
	TP01						
	TP09						
9-hr	TP05		76.6	71.6	56.3	48.6	41.1
	TP10						
	TP02						



Table 2-8 Anglesea Key Location Critical Durations and Temporal Patterns

	1%	2%	5%	10%	20%
Key Location 1 – McMillan Street					
Critical Event	6-hr, TP01	2-hr, TP10 3-hr, TP10	2-hr, TP10 3-hr, TP09 4.5-hr, TP09	3-hr, TP09 9-hr, TP01	3-hr, TP09 6-hr, TP09
Key Location 2 – Anglesea Retirement Village					
Critical Event	6-hr, TP01	3-hr, TP10	3-hr, TP09	9-hr, TP01	6-hr, TP09
Key Location 3 – Overland Flow Paths at Anglesea Golf Course					
Critical Event	1.5-hr, TP10 6-hr, TP01 9-hr, TP05	1.5-hr, TP10 2-hr, TP10 3-hr, TP10	2-hr, TP10 3-hr, TP09 6-hr, TP09	2-hr, TP10 3-hr, TP09 9-hr, TP01	3-hr, TP09 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 Brief³. Mapping of the results was filtered to remove shallow depths (less than 3 cm) and isolated extents of inundation (less than 200 m²).

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 ARR2019⁴ 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	$D \cdot V \leq 0.3$	0.3	2.0
H2	$D \cdot V \leq 0.6$	0.5	2.0
H3	$D \cdot V \leq 0.6$	1.2	2.0
H4	$D \cdot V \leq 1.0$	2.0	2.0
H5	$D \cdot V \leq 4.0$	4.0	4.0
H6	$D \cdot V > 4.0$	-	-

³ Water Technology, 2024, *Return Brief – Aireys Inlet and Anglesea Stormwater Drainage Flood Study*, Surf Coast Shire

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



3.2 Hydraulic Model Validation

The hydraulic model was validated against overserved stormwater inundation experienced in 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 Anglesea River from the upstream catchment were included. For this reason, only the January 2022 storm event was validated.

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 Anglesea River at its full height (Starting Berm Height).

Validation of the hydraulic model was completed by Water Technology using photographs provided by the Surf Coast Shire that captured inundated areas after the event. The area with the most reliable time of capture and location was the carpark of the Anglesea Retirement Village. While no surveyed marks or additional photographs for the event are available, the model results were compared with the observations made by the Surf Coast Shire's Operations and Maintenance Team and Stormwater Team, who were the shires first responders to stormwater inundation/concerns at this location.

Modelled flood depths for the January 2022 event are shown in Figure 3-1 below, with a photograph of the inundated carpark of the Anglesea Retirement Village shown in Figure 3-2 below.



Figure 3-1 January 2022 Modelled Flood Depths – Anglesea Retirement Village



Figure 3-2 Photograph of Anglesea Retirement Village Carpark on 28 January 2022



3.3 Anglesea River Sensitivity Testing

Modelling of the two berm heights identified that, while the Anglesea River does control the discharge efficiency of the McMillan Street drainage network, the level in the river only affects inundation in the immediate area of the Great Ocean Road by approximately 2.4 cm, as shown in Figure 3-3 below.

Further up the catchment of McMillan Street, the water level difference mapping indicates no changes in levels around stormwater pits (i.e., surcharging). With the sensitivity testing of levels in the Anglesea River impacting the stormwater drainage network showing minimal changes in water levels along the Great Ocean Road (less than 2.5 cm) and no changes in water levels in the upper catchment (within the tolerance of ± 1 cm), presentation of the Starting Berm Height scenario was considered appropriate for this report. While levels are slightly lower in the Full Breach scenario, it is considered more conservative and representative of the daily berm condition of the Anglesea River.



Figure 3-3 1% AEP Flood Level Difference – Starting Berm Height vs Full Breach Berm



3.4 Flood Mapping Results

Hydraulic modelling of Anglesea covered all the developed/residential areas in the immediate vicinity of the Anglesea River and included a range of AEP events from the 1% to the 20%. The hydraulic model established major flow paths through known areas of frequent inundation as well as areas previously established within limited knowledge on flood risk. The overland flow paths are referred to by their known names or their outfall locations. Mapping of the maximum 1% AEP flood depth is illustrated in Figure 3-4 below. For each key location, detailed flood depth, velocity, level and hazard mapping has been produced in the following sections.

Results of the 1% AEP storm event identify the overland flow paths associated with each major catchment in Anglesea. Five of six catchments flow direction into the Anglesea River, appropriately named Anglesea River 1 to 5. To the south of Anglesea, the Point Roadknight catchment discharges to the southeast into ocean.

Anglesea River 1 captures McMillan Street, Murray Street and Charles Street, referred to as Key Location 1 for McMillan Street. Flood depth mapping of the 1% AEP design event shows that runoff commences just east of Charles Street and north of Harvey Street all flows down to McMillan Street, before discharging into the Anglesea River. The catchment is predominantly developed with residential properties with scattered commercial properties throughout in its upper catchment. Along the river front, land use in the catchment is primarily commercial.

Anglesea River 2 includes Key Locations 2 and 3, the Anglesea Retirement Village and the Anglesea Golf Course, respectively. Flood depth mapping shows that the upper catchment consists of four contributing flow paths that flow into the Anglesea Golf Course at two locations. The Golf Course then discharges the runoff at two locations where they converge immediately west of the Anglesea Retirement Village. From this point onward, overland flows are confined in a gully and discharge into the Anglesea River.

Anglesea River 3 catchment is located on the east side of the Anglesea River and features considerably less development along the river than catchments 1 and 2. This catchment has been identified due to the modelled flood depths overserved through the Anglesea Business Park.

Anglesea River 4 is located at the northern end of the hydraulic model and displays a wide extent of stormwater inundation during the 1% AEP event. The catchment includes the Lawrencina Way key location which show minimal impacts to flooding during the modelled event.

Anglesea River 5 is located north of Anglesea River 4 and consists of runoff from residential dwellings into the Anglesea River. Modelled flood depths during the 1% AEP event for this catchment indicate the properties and road reserves are not greatly affected. Levels within the Anglesea River floodplain does appear to inundate River Reserve Road, however riverine inundation has not been assessed fully in this report.

Outside of the main study area of the Anglesea Stormwater Flood Study, the hydraulic model has identified several overland flow paths to the south, that primarily discharge at Point Roadknight. Hydraulic structures for this catchment have been included in the hydraulic model, however, this area was not visited during the site inspection. The extent of inundation is widespread through the residential area with depths averaging 0.15 m through residential properties. This area would benefit from a more in-depth drainage investigation on the back of this assessment.

Further analysis and mapping on each of the Key Locations are presented in the sections below.



Figure 3-4 1% AEP Flood Depth – Anglesea Overview



3.4.1 Key Location 1 – McMillan Street

McMillan Street connects onto the Great Ocean Road, near the mouth of the Anglesea River, and includes drainage that discharges directly into the Anglesea River.

Flood depth mapping for the 1% AEP event has identified that rainfall runoff activates overland flow paths through numerous properties on Murray Street and McMillan Street, with depths ranging between 0.2 to 0.75 m. A low point in Murray Street, between Foster Street and McMillan Street shows depths of approximately 0.2 m that overtop the nature strip and flow into the properties to the northeast.

On McMillan Street, east of Murray Street, overland flows in the road reserve are shallow (less than 0.1 m) but present velocities up to 1.7 m/s. Overland flows in the road reserve appear to overtop the kerb and channel, and nature strip, before flowing into the properties at 4 to 16 McMillan Street. Overland flows then continue east towards the Great Ocean Road.

Both the flood depth and velocity maps include details on the drainage networks capacity during the critical storm event, shown as a percentage. For McMillan Street, the main drain is 100% full for the 1% AEP critical storm event, along with many of the upstream main drains that connect into it.

Mapping of the 1% AEP flood depth, velocity, level, hazard and pipe capacities for the McMillan Street area are presented in Figure 3-5 to Figure 3-8 below.

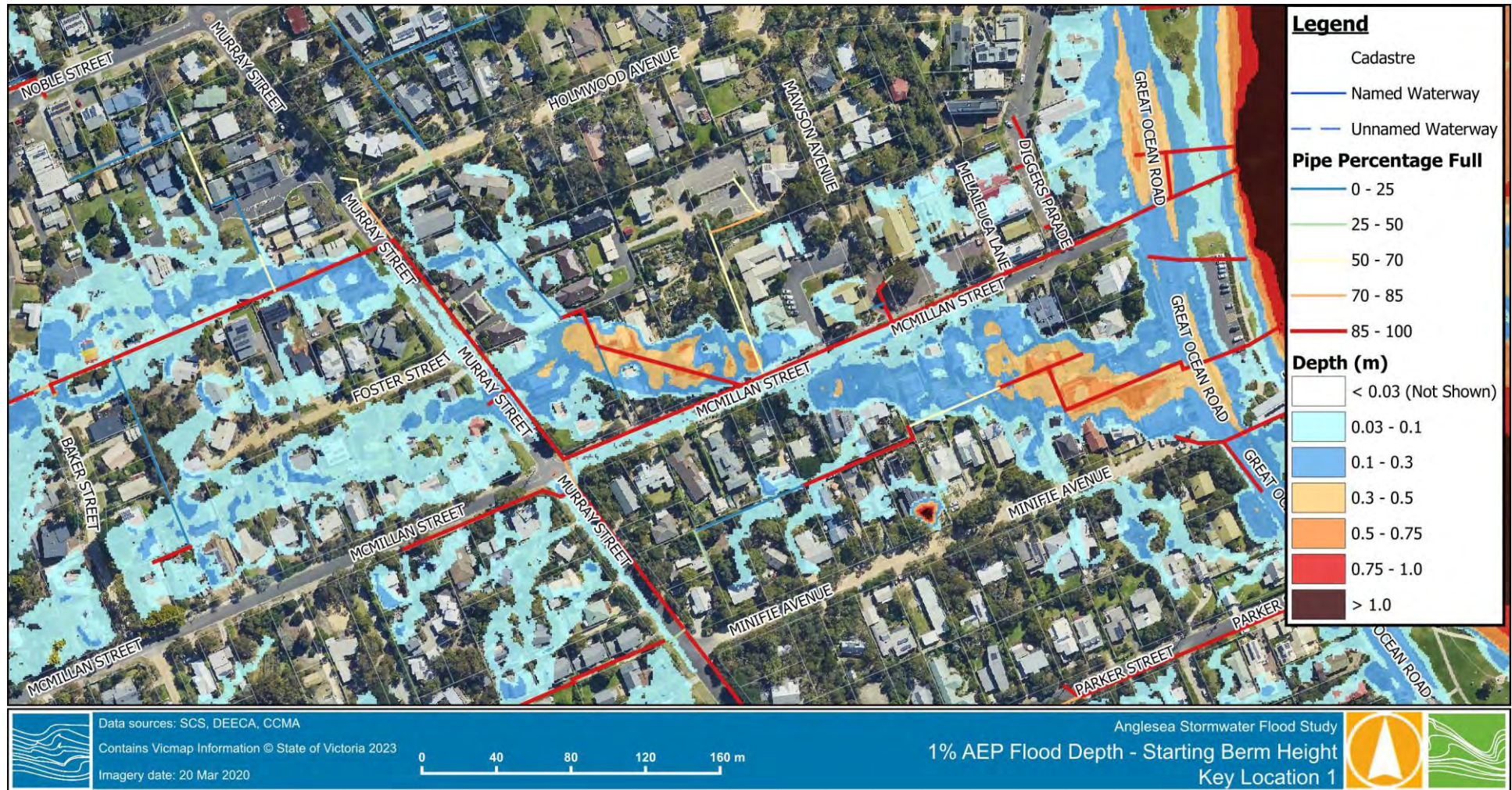


Figure 3-5 1% AEP Flood Depth – Key Location 1



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



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



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



3.4.2 Key Location 2 – Anglesea Retirement Village

The Anglesea Retirement Village (known as Calvary Cordelia Grove) is located within a valley that experiences significant inundation. This site was used to assist in validating the hydraulic model to the January 2022 storm event. Hydraulic modelling of the site and its catchment has confirmed the retirement village is located within an overland flow path that discharges to the Anglesea River.

Flood depths within the site exceed 1m during the 1% AEP storm event, with depths greatest in the carpark and north of the building. Based on the results, overland flows that enter the site are directed around the main building, north then west, before reconverging with the main overland flow path. Outputs from the hydraulic model's drainage network shows that the drainage infrastructure within the catchment of the Retirement Village is at capacity (85% to 100% full).

Modelled water levels through the site range from 5.25 m AHD, at the property road boundary (driveway), to 4.00 m AHD at the east end of the building. Water levels within the building are estimated to be 4.75 m AHD.

The flood risk associated with the 1% AEP event has been identified with flood velocity and hazard mapping. Velocities along the driveway are shown to exceed 2.0 m/s, which exceeds safety design thresholds for safe access/egress. The resulting flood hazard classification for the access point at the Anglesea Retirement Village is H5, which is considered unsafe for vehicles and people⁵.

Mapping of the 1% AEP flood depth, velocities, water level, hazard and pipe percentage full is presented below in Figure 3-9 to Figure 3-12.

⁵ Smith, G., and Cox, R. (Editors), 2019, Book 6: Flood Hydraulics, Chapter 7 – Safety Design Criteria Flood Hydraulics, © Commonwealth of Australia (Geoscience Australia), 2019

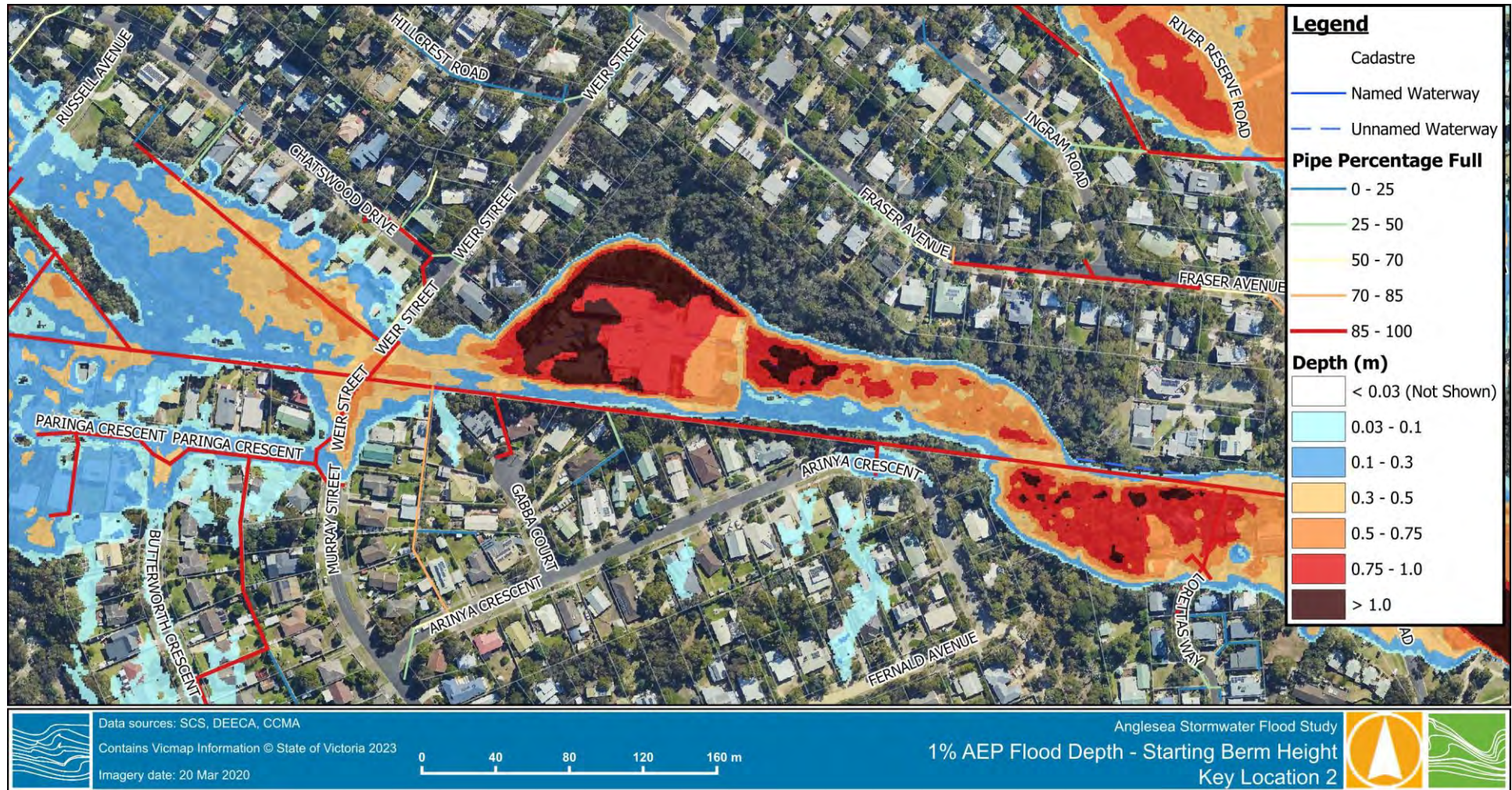


Figure 3-9 1% AEP Flood Depth – Key Location 2



Figure 3-10 1% AEP Flood Velocity – Key Location 2



Figure 3-11 1% AEP Flood Level – Key Location 2



Figure 3-12 1% AEP Flood Hazard – Key Location 2



3.4.3 Key Location 3 – Overland Flow Paths at Anglesea Golf Course

Overland flow paths in the Anglesea Golf Course are detained by a constructed embankment where they meet Golf Links Road, on the east side of the course. Although a degree of retardation occurs, properties and roadways downstream of the golf course are significantly inundated due to the stormwater drainage network exceeding its capacity. This shown by the pipe underneath Carrawe Crescent being at 100% capacity and the stormwater pit adjacent to 34-36 Golf Links Road surcharging.

Hydraulic modelling of the catchment has identified that overland flows through Carrawe Court and Paringa Crescent range between 0.2 to 0.5 m in depth during the 1% AEP critical storm event. The northern overland flow path from the golf course is retarded by an earthen embankment with a crest height of approximately 15.75 m AHD at its lowest point. Water levels at this location are approximately equal to the embankment height during the 1% AEP event, meaning inundation downstream is driven by runoff generated from rainfall directly to the area and water surcharging from the drainage pits downstream of the embankment.

Flood velocities during the 1% AEP critical event crossing Golf Links Road, Carrawe Court and Paringa Crescent range from 1.4 m/s to 2.5 m/s, with the highest velocities in Carrawe Court. Velocities of this magnitude are consistent with a flood hazard classification of H5, which is considered unsafe for vehicles and people⁵. Flood hazard classifications in Paringa Crescent are H2 (unsafe for small vehicles), with pockets of H3 (unsafe for vehicles, children and the elderly) ratings.

Mapping of the 1% AEP critical storm event depth, velocity, level, hazard and pipe capacity are shown in Figure 3-13 to Figure 3-16 below.

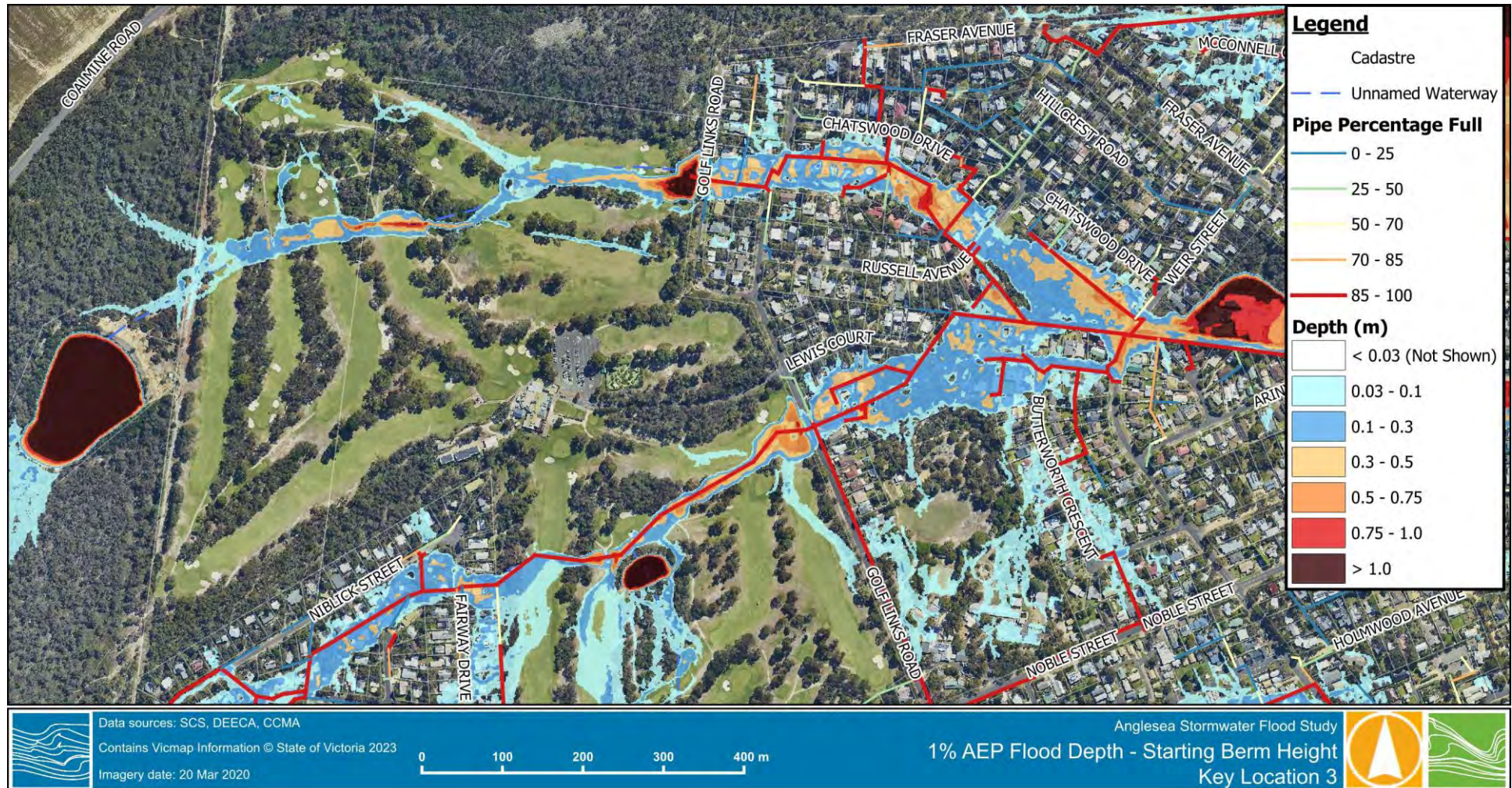


Figure 3-13 1% AEP Flood Depth – Key Location 3

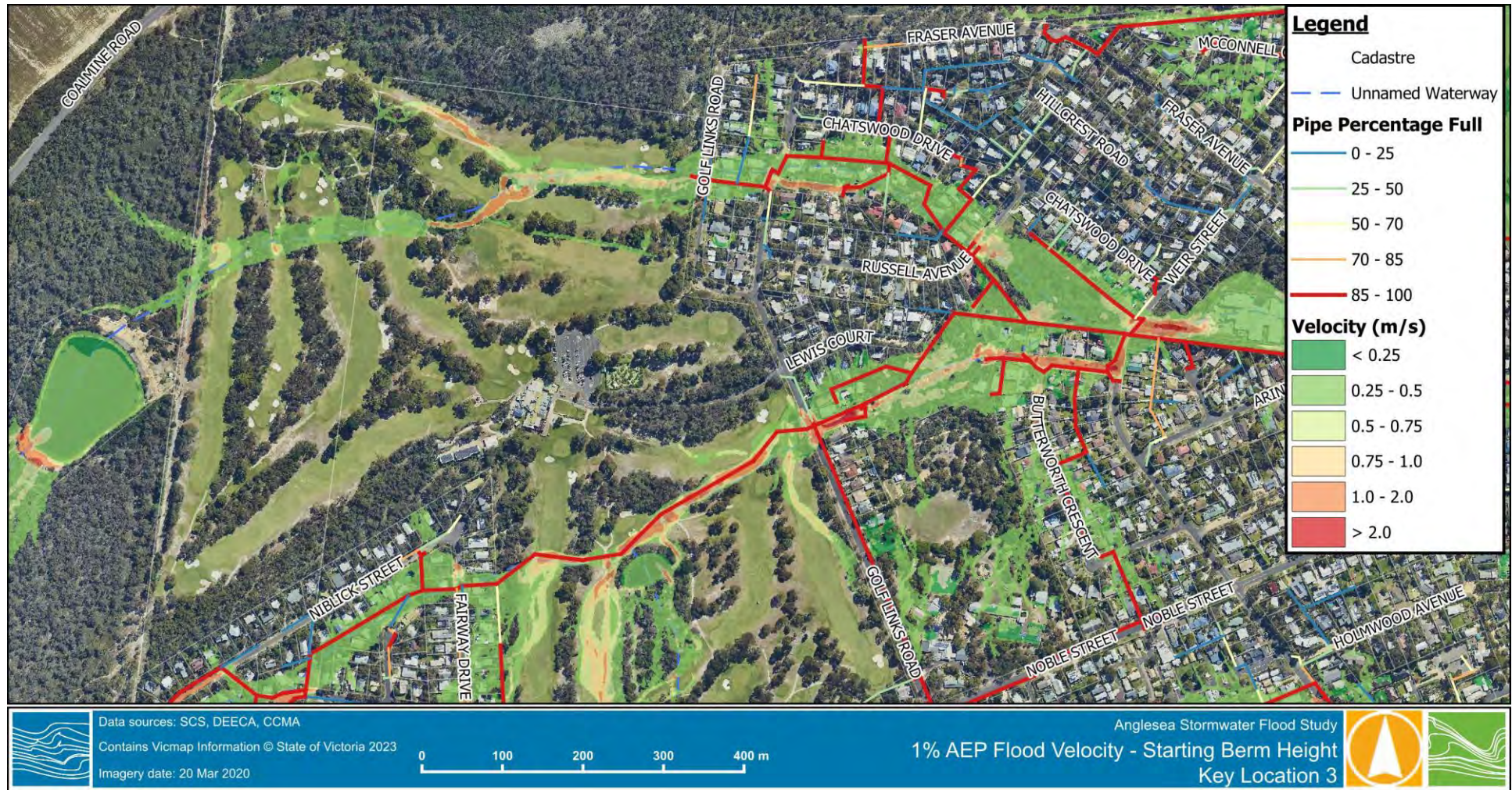


Figure 3-14 1% AEP Flood Velocity – Key Location 3

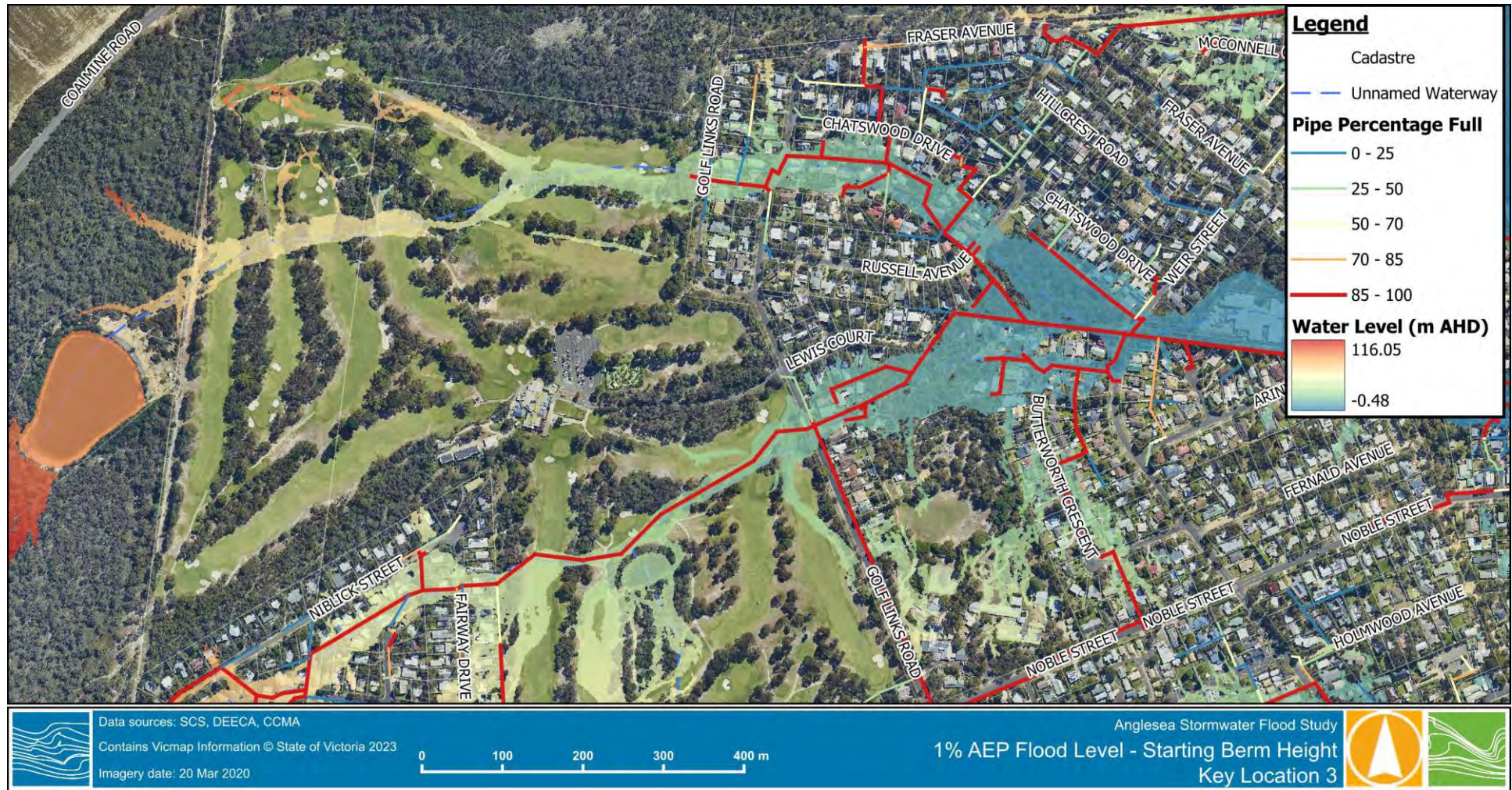


Figure 3-15 1% AEP Flood Level – Key Location 3

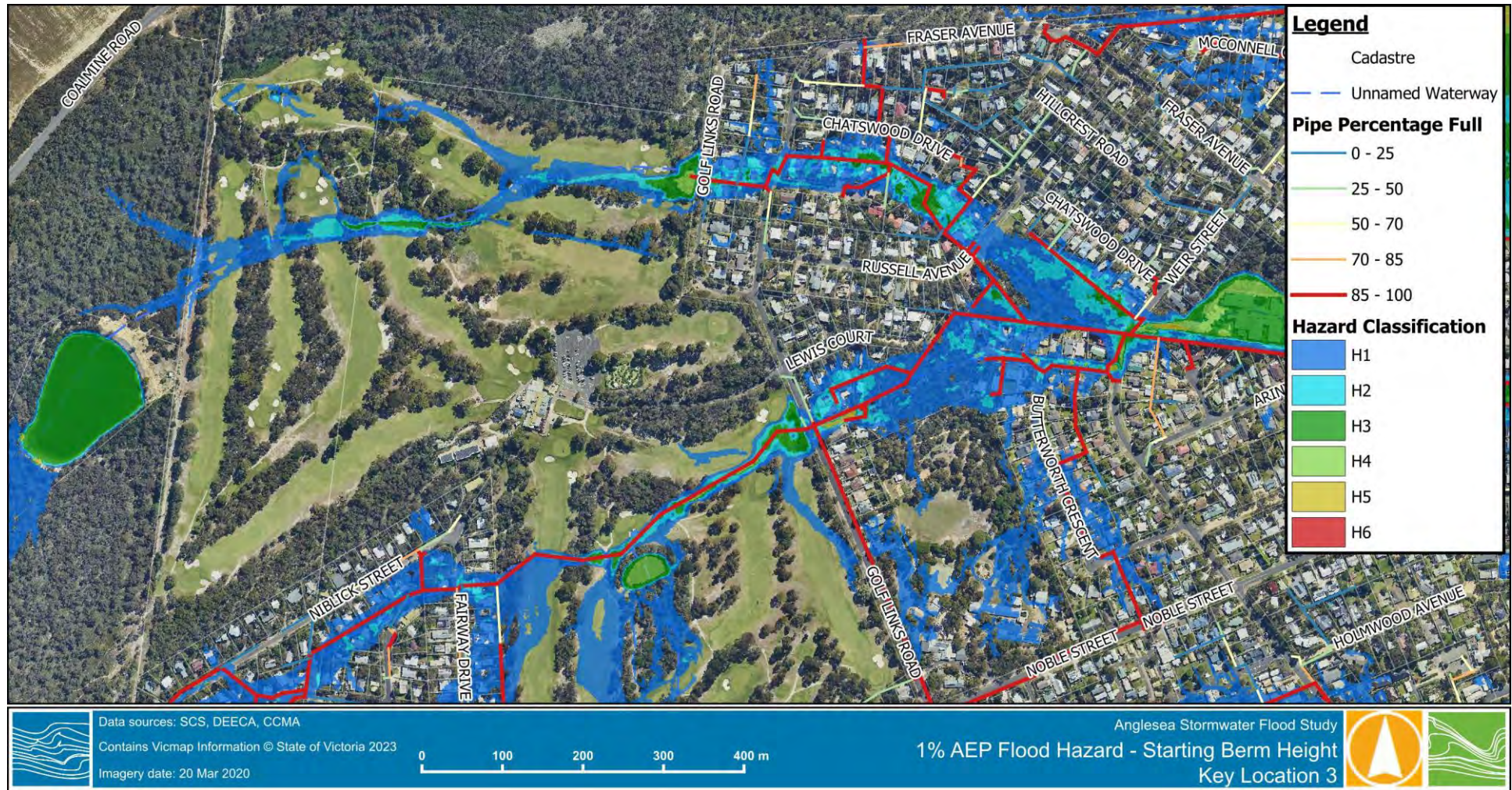


Figure 3-16 1% AEP Flood Hazard – Key Location 3



3.5 Additional Key Locations

Additional locations of concern were identified during the site inspection for this project, as well as during the review stage of the hydraulic model outputs. These additional locations were not initially considered at the start of this project, however, they have been identified as Key Locations that are to be considered for mitigation strategies when possible. An overview of the results at each of the additional locations is provided below.

Key Location 4 – Butterworth Crescent

The stormwater network drainage at the southern end of Butterworth Crescent is shown to surcharge from a pit adjacent to 12 Butterworth Crescent, contributing to runoff ponding out the front of 7 Butterworth Crescent. Ponding in the road reserve, adjacent to 7 Butterworth Crescent is due to the stormwater network being at capacity and the surround terrain not directing overland flows down along the road reserve. This results in runoff accumulating, rising and eventually entering 7 Butterworth Crescent from the road reserve and flowing north. Flood depth mapping and pipe capacities for the 1% AEP critical event are shown in Figure 3-17 below.

Key Location 5 – Lawrencina Way

Hydraulic modelling of Lawrencina Way has produced outputs that differ from Surf Coast Shire recollections and discuss had during the site inspection. This is likely due to the steep and fast draining nature of the roadway the modelled pits capturing runoff from the road more effectively than what would occur in reality. High resolution modelling outputs, indicate that depths at the bottom of Lawrencina Way, where it converges with Camp Road, are approximately 5 cm deep. There is no indication from the high-resolution outputs that flows overtop the crest of Camp Road and flow west. High resolution mapping of the 1% AEP critical event is shown in Figure 3-18 below.

Key Location 6 – Charles Street

Hydraulic modelling outputs differ from Surf Coast Shires description of past events, with minimal overland flows shown in the flood depth mapping for the 1% AEP critical event. The capacity of the stormwater pipe in the easement of 16 Charles Street is approximately 30% full. Downstream of the network though, at George Street, the capacity of the stormwater pipe climbs to 100% full.

The difference in observed flows along Charles Street and modelled extents is likely due to the table drains in the road reserve not being as well defined in the model terrain, thus allowing runoff to disperse more and be captured by open channels and directed towards the pipe inlets. Mapping of Charles Street and its terrain are shown in Figure 3-20 for reference.

Key Location 7 – Anglesea Business Park

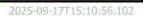
The Anglesea Business Park is constructed over a drainage path, and during the 1% AEP event overland flows from the northeast inundate the park to depths of 0.2 to 0.45 m. Depths of this magnitude will result in the inundation of all parcels within the business park, as well as residential properties to the south. Mapping of the 1% AEP flood depth and pipe capacities is presented in Figure 3-21 below.



Figure 3-17 Key Location 4 – Butterworth Crescent



Figure 3-18 Hotpot Location 5 – Larencia Way



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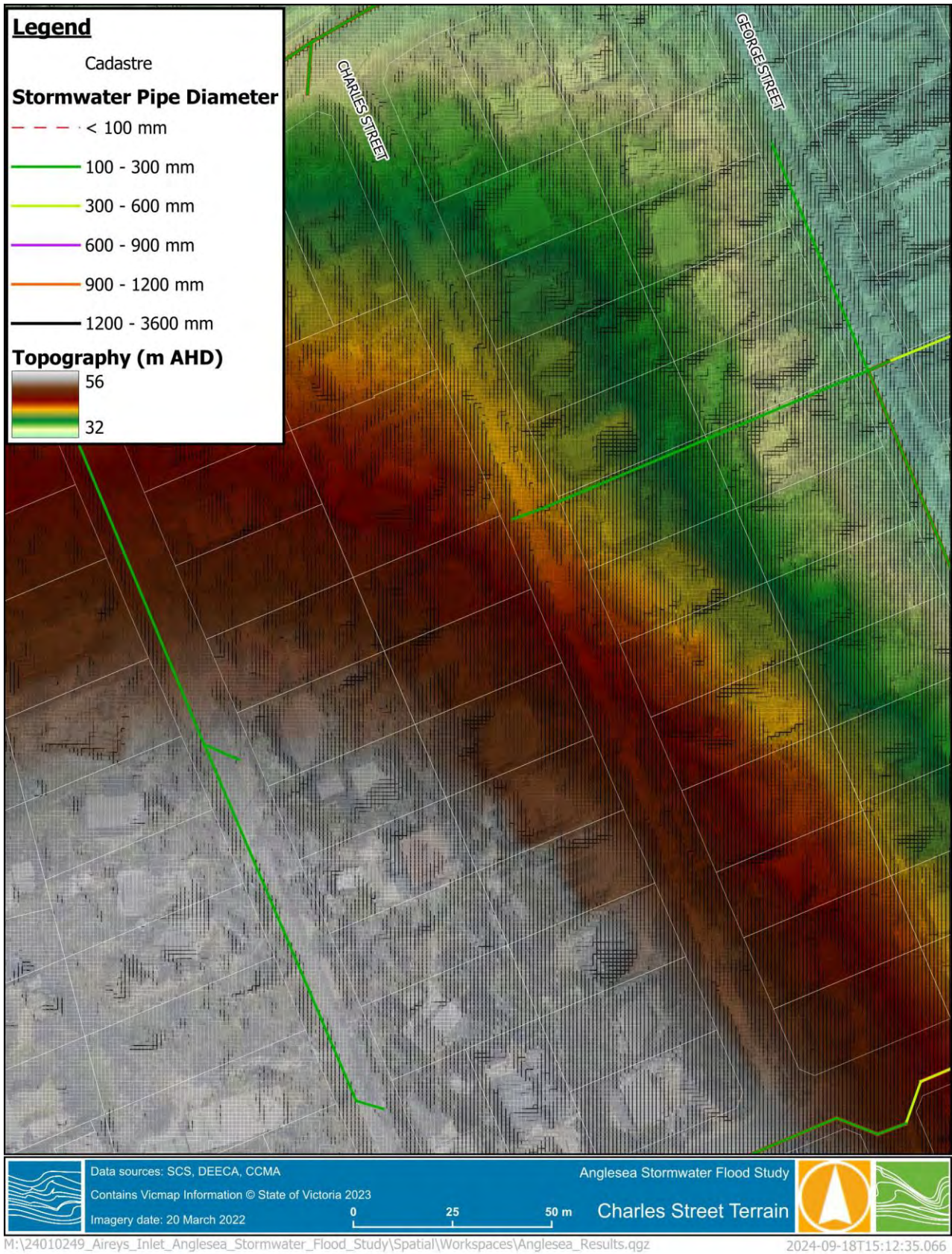


Figure 3-20 Charles Street Topography

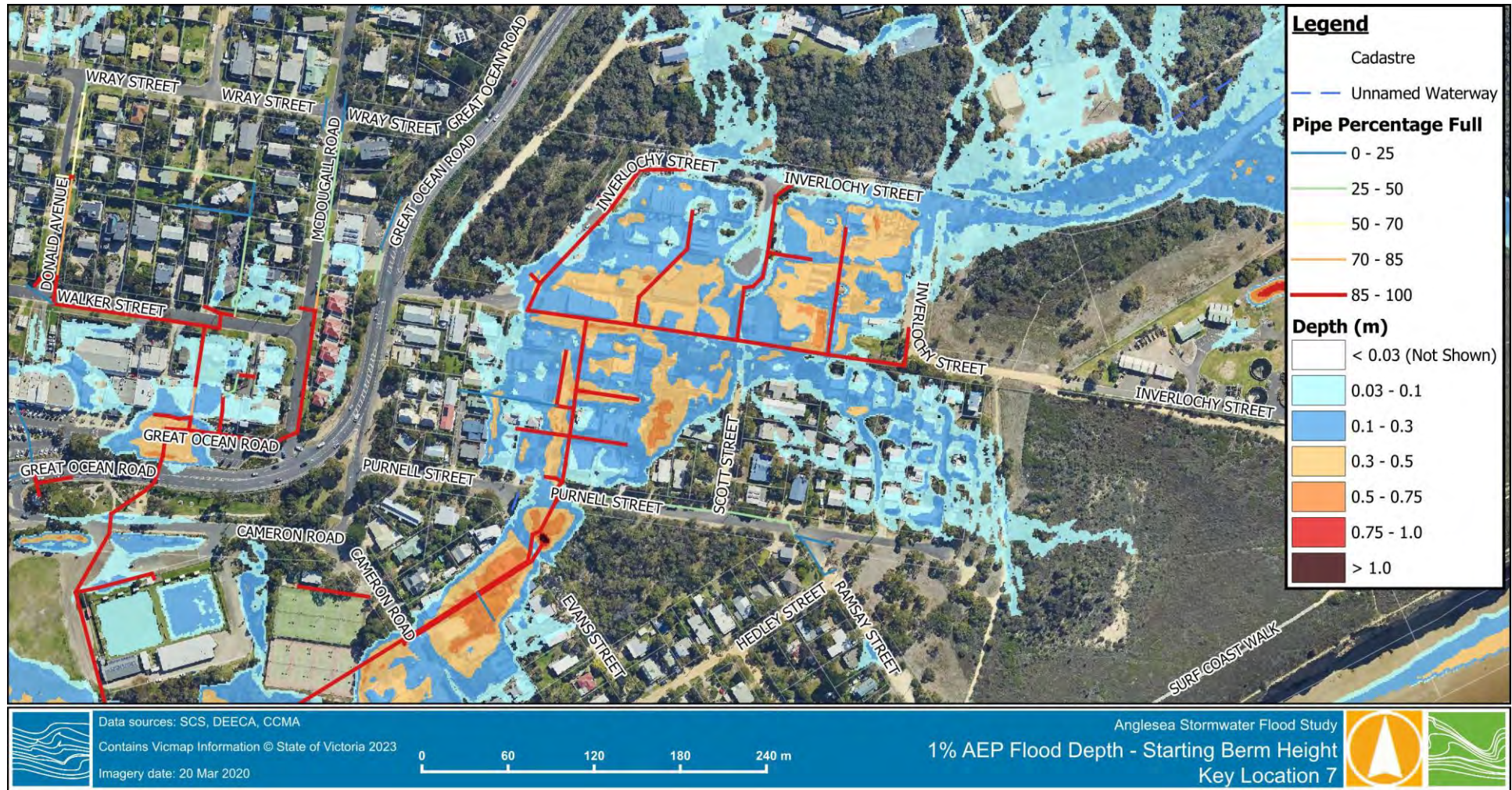


Figure 3-21 Key Location 7 – Anglesea Business Park



4 SUMMARY

Design modelling of Anglesea's stormwater catchments consisted of a detailed TUFLOW model, adopting design parameters and historical 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 Anglesea 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 also limited data on observed damages from this event to validate too. Modelling results of the January 2022 event, however, 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 teams recollections and observations from the January 2022 event.

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

- McMillan Street – Overland flows are not being confined to the road reserve during the 1% AEP storm event. While levels in the Anglesea River do impact the downstream water level in the system, it doesn't have much of an impact on water levels further up into the catchment (i.e., it does not cause pits upstream to surcharge more).
- Anglesea Retirement Village (Calvary Cordelia Grove) – The retirement centre is located in an overland flow path during the 1% AEP storm event and experiences inundation of up to 1-metre. Flows down the retirement villages driveway are in excess of design safety thresholds, posing risk to vehicles and people alike during a flood event.
- Anglesea Golf Club – Runoff from the golf course results in overland flow paths along Carrawe Court and Paringa Crescent between depths of 0.1 to 0.5 m. This results in numerous properties being inundated during the 1% AEP event. Runoff from the north of the golf course is retarded by an embankment, which contributes to surcharging pits downstream result in the inundation of residential properties.
- Butterworth Crescent – The drainage network at the southern end of Butterworth Crescent is at capacity and runoff from the road reserve cannot enter the stormwater network. This results in runoff accumulating, rising and eventually inundating properties to the north.
- Anglesea Business Park – Majority of the business park is inundated during the 1% AEP storm event to depths between 0.1 to 0.5 m. The absence of formal inlet for external flows appears to contribute to the extent of overland flows in the business park.

Two key locations discussed with Surf Coast Shire during the site inspection yielded results that differed from past observations. It is likely that further adjustment to the hydraulic model is required to improve the accuracy of the model in these areas, however, based on the current outputs the following has been identified.

- Lawrencia Way – The steep catchment of Lawrencia Way conveys runoff to the base of the hill very quickly, often overshooting pit entries and resulting in the inundation of the Larencia Way and Camp Road intersection and properties to the west. The size of the stormwater pipe in Camp Road, at the intersection of Lawrencia Way is large, and confirmation on the assets' diameter and blockages of the smaller pipes is recommended to confirm the accuracy of the stormwater network in the hydraulic model.
- Charles Street – Modelled runoff and inundation in Charles Street during the 1% AEP event hasn't shown the impacts described by Surf Coast Shire, with inundation from the road reserve appearing minimal, based on the filtered flood map outputs.



Next Steps

Water Technology will organise a workshop with the Surf Coast Shire to discuss the outcomes of the design model and strategies suitable mitigation strategies to improve flood risk/resilience to the identified key locations. These strategies will be testing using the constructed TUFLOW model with their outcome's summaries in a Mitigation Assessment Report.





APPENDIX A

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





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



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



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



Figure 4-4 20% AEP Flood Depth Mapping – Anglesea Overview

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