West Gippsland
Catchment Management Authority

WGCMA Floodplain Mapping Program

Floodplain Mapping for Hedley

2024

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1 INTRODUCTION

1.1 PURPOSE

The project seeks to improve flood information for the study area where there is currently a knowledge gap as identified by the West Gippsland CMA Regional Floodplain Management Strategy (2018-2027). The purpose of conducting floodplain mapping for the Hedley catchment is to predict the potential hazards and consequences of a flood event and estimate flood depths, velocity and extent. The information presented in this report has been compiled for use by West Gippsland Catchment Management Authority (WGCMA) for statuary planning, community education/preparedness, flood risk for insurance purposes and emergency management purposes.

1.2 OBJECTIVE

The primary objective of the Flood Study is to conduct a desktop study of the catchment to identify the model requirements and key features which can then be used to develop a suitably robust hydrologic and hydraulic modelling system. The objectives of the floodplain mapping project as stated by the WGCMA are:

- Estimate the design flow peaks and hydrographs using RORB for the 0.5%, 1%, 2%, 5%, 10% and 20% Annual Exceedance Probability (AEP)
- Develop a TUFLOW hydraulic model(s) and simulate the 0.5%, 1%, 2%, 5%, 10% and 20% AEP flood events
- Generate a map showing the flood extent of an 0.5%, 1%, 2%, 5%, 10% and 20% Annual Exceedance Probability (AEP), showing depths, velocity and water surface elevation

1.3 CATCHMENT DESCRIPTION

The Hedley catchment is located 199 km east of Melbourne (Figure 1). The township of Hedley forms part of the Corner Inlet area of the West Gippsland Catchment Authority region and is part of the South Gippsland Shire Council area. The upper and mid catchment is underlain by predominantly sandstone becoming alluvial throughout the lower reaches of the study area. The point of highest elevation is 292 m AHD along the northern boundary of the catchment, while the point of lowest elevation is approximately 0m AHD at the southern boundary, where Nine-Mile Creek flows into Middle Ground Channel within the Corner Inlet waterway.

Most of the catchment has been cleared for a range agricultural land uses particularly grazing and cropping. With a current population of 108 (Census, 2021) Hedley has lightly developed rural infrastructure including roads, housing, a church, hall and fire station. There is limited underground stormwater drainage in and around the town and as such, stormwater is primarily conveyed through open drainage channels adjacent to the roadways and discharging into the creeks. The main watercourse through the area is Nine-mile creek, water is conveyed through natural channels up to approximately 3.5km past the South Gippsland Highway where the course has been extensively modified and diverted into a straightened channelised system.

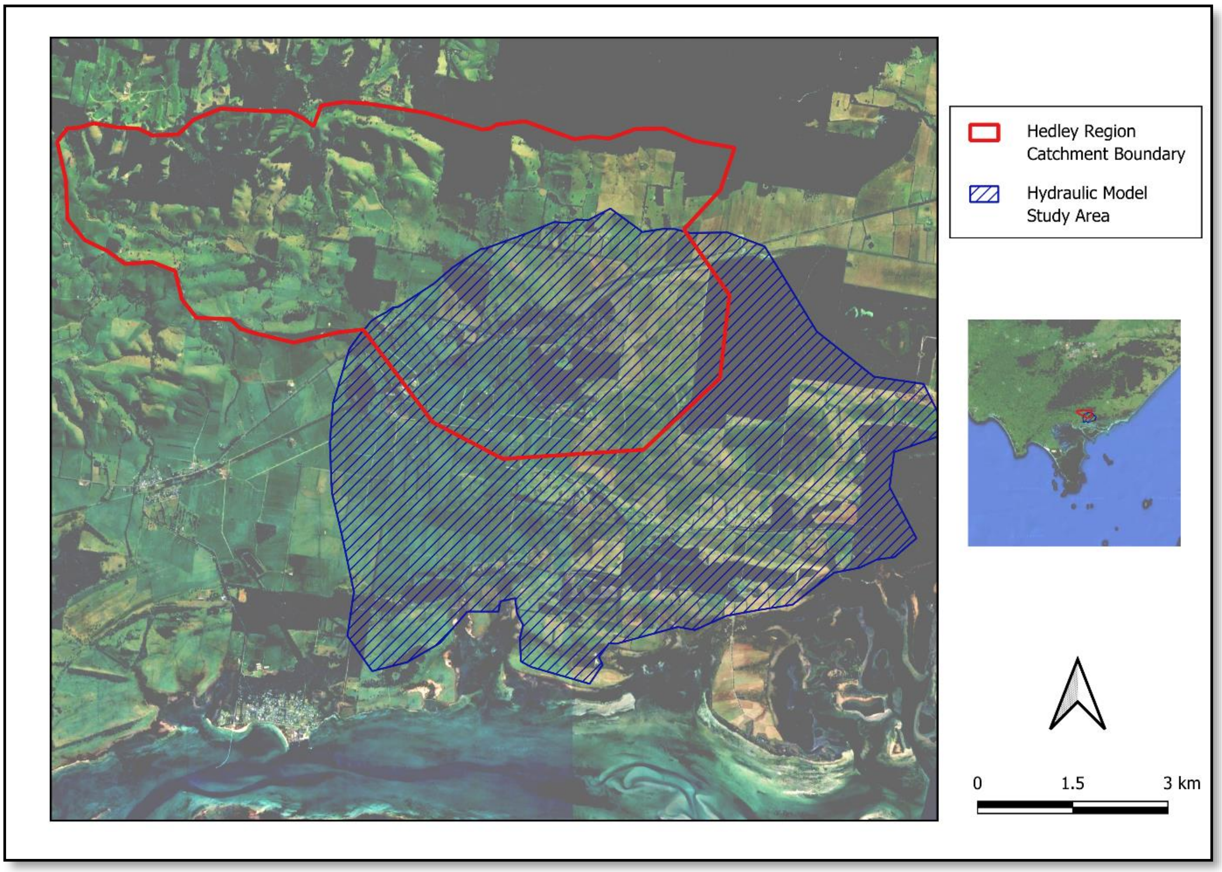


Figure 1-1 Hedley region Catchment

1.4 FLOOD HISTORY

There have been several contemporary and historical storm events that are known to have caused flooding in the Hedley township, though detailed information within the catchment is scarce. The most recent significant event occurring on the 26th of December 2023. No rainfall gauges are currently active in the catchment however, 145 mm of rainfall was recorded at Mount Best-Upper Toora station gauge 12.5km away (BOM, 2024). As a result of the storm there were multiple flooding events throughout the region. Evidence sourced from newspapers in the Trove database suggest that flooding events occurred around or near the area in March 1930, December 1934 and July 2011.

Jun 1930 - There have been heavy rains over the district with 210 points falling at Hedley (The Age, Wednesday 4th June 1930, pg11)

July 2011 - Parts of Welshpool, Hedley, Toora and Port Franklin were inundated and the South Gippsland Highway was cut in several places, including Hedley and Alberton. The old general store at Hedley was hit particularly hard (The Mirror News, 27th July 2011).

Figure 1-2 Aerial photograph of Nine Mile (Drain) Hedley - July 2016

2 HYDROLOGY

2.1 DESCRIPTION OF HYDROLOGIC MODELLING APPROACHES ADOPTED

The aim of the hydrological modelling is to calculate runoff at locations throughout the study area to apply the TUFLOW hydraulic model. When determining the hydrological response of the study area, there are several factors that need to be considered. These include catchment characteristics, design rainfalls and model parameters determined through model calibration.

Catchment and sub-catchment areas together with other physical catchment characteristics were determined from topographic information. Once the physical characteristics of a catchment have been determined and design rainfall calculated it is necessary to determine the hydrological model parameters. These parameters can be determined through standard relationships or, more commonly, through calibration. The approach to calibration is dependent on the available data. If there is sufficient data available, the hydrological model should be calibrated to this data. As a minimum this would require streamflow data at one location. However, there was no streamflow data available within the study area.

2.2 STREAMFLOW AND RAINFALL GAUGE REVIEW

Rainfall Gauge Data

There are currently no rain gauges in the Hedley/Nine Mile Creek catchment therefore the absence of historical rainfall data, specifically continuous rainfall observations represent a significant data gap. A more network of continuous and daily read gauges exists in the broader region, which can be used to provide insight into rainfall behaviour during historical flood events. The rain gauges in the vicinity of Nine Mile Creek are listed in Table 1

Table 1 Available weather station data record including operation period, types and distance from Hedley.

Distance (km)	Station Number	Station Name	Operational Dates	Type
7.75	085107	Alberton West (Kallara)	1905-1915	Daily
8.93	085070	Port Albert	1872-1976	Daily
9.53	085003	Alberton Post Office	1901-1984	Daily
10.38	085120	Hedley (Vivaleigh)	1899-1917	Daily
18.6	085151	Yarram Airport	2010 - current	Continuous
36.53	085301	Corner Inlet (Yanakie)	2013 - current	Continuous

Stream Flow Gauge Data

There are currently no stream gauges in the Hedley/Nine Mile Creek catchment therefore the absence of historical stream flow data, specifically continuous observations represent a significant data gap.

2.3 REGIONAL FLOOD FREQUENCY ESTIMATION

Flood frequency estimation was provided by the ARR Regional Flood Frequency Estimation Model tool. The RFFE Model 2015 is based on the concept of regionalisation where data from gauged catchments are utilised to make flood quantile estimates at ungauged locations. Flood quantiles are estimated using a regional log Pearson Type 3 (LP3) distribution where the location, scale and shape parameters are estimated based on prediction equations. In the ARR RFFE model, the model coefficients have been embedded in an application software (known as RFFE Model 2015), which enables the user to obtain design flood estimates relatively easily using simple input data such as latitude, longitude and catchment area of the ungauged catchment of interest.

Table 2 Design flows based on ARR Regional Flood Frequency Estimation Model tool

AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	15.8	7.61	32.6
20	30.1	15.1	59.9
10	42.6	21.2	86.1
5	56.8	27.7	117
2	79.0	37.1	170
1	98.6	44.8	218

2.4 RORB HYDROLOGIC MODEL

RORB is the standard hydrology model used by the West Gippsland Catchment Management Authority (WGCMA). RORB is a general runoff and streamflow routing program used to calculate flood hydrographs from rainfall and other channel inputs. In RORB the catchment is represented by network of sub-areas and reaches, rainfall is applied at the centroid of each sub-area and runoff is calculated by subtracting losses. The rainfall excess from each sub-catchment is then routed from the centroid of that sub-catchment, along the main reach, to the next downstream node where the runoff hydrograph is combined with (a) runoff hydrographs from other tributaries and/or (b) rainfall excess hyetograph from the sub-catchment of the downstream node reach. The combined runoff hydrograph is then routed downstream to the next node until the outlet is reached.

Model Schematisation

The delineation of the catchment and sub-catchment the model was done using QGIS and LiDAR available to WGCMA. The model was then constructed from within RORB using the Graphical Editor available in the software and information was input directly into the program (Figure 2-1).

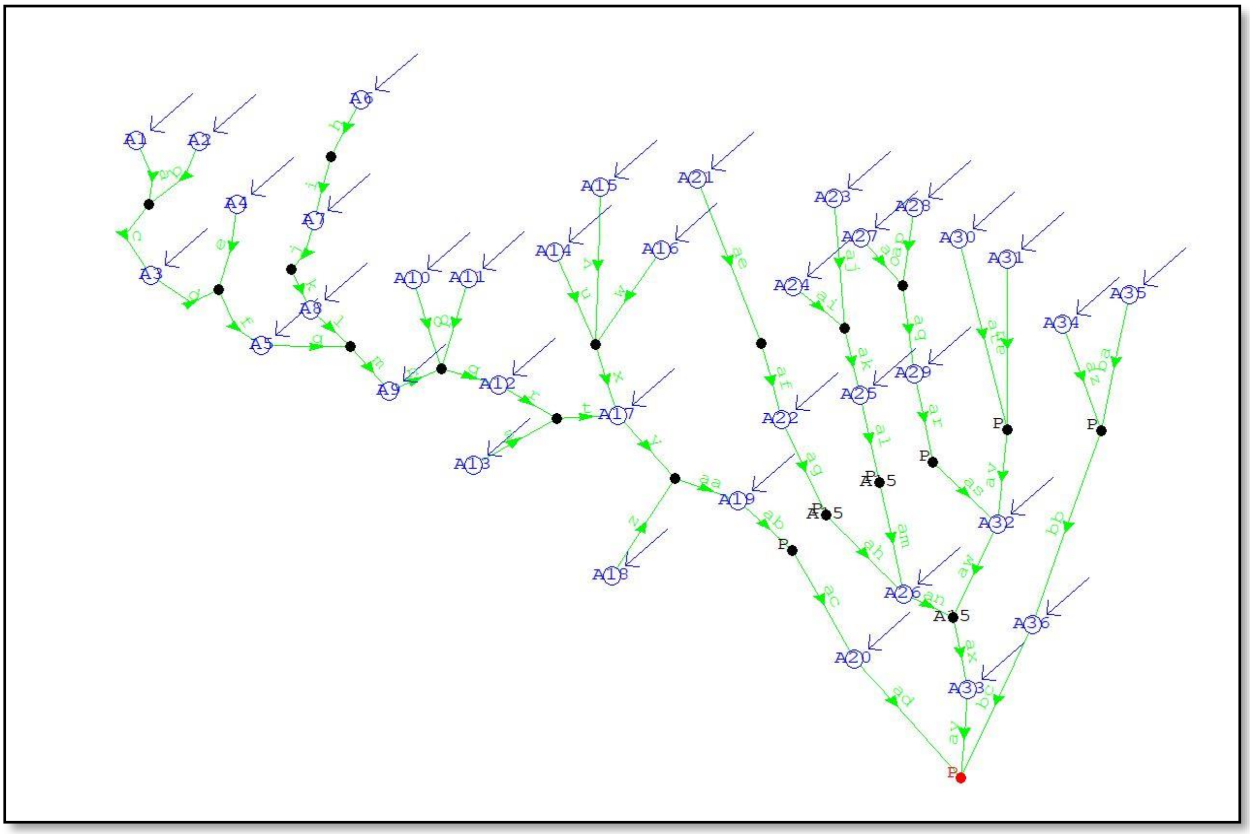


Figure 2-1 Representation of Hedley catchment in RORB graphical editor

Catchment and sub-catchment Delineation

The hydrologic catchment area covered a region of 40.359 km^2. This area was defined by the topographical ridges that form the upper bounds of the watershed area. The development of the sub-catchments was based on the stream network and the drainage characteristics of the catchment. Where possible similarity in sub-catchment area and shape was sought after. A total of 36 sub-catchments were delineated across the total hydrologic catchment area which fits within the 5-20 sub-areas recommended in the RORB manual. The catchment and sub-catchment extents are shown in Figure 2-2.

Channel and waterflow pathways were based on sub-catchment centroids and drainage characteristics. Much of the flow within the catchment is via natural unlined channels. Therefore, Reach Type 1 was adopted with a Fi value of 0.0 which is the default RORB setting.

Due to the width and topographic layout six print nodes were deemed necessary to achieve a more accurate outflow, thereby enabling the Hydraulic model to be positioned higher in the floodplain. The RORB model outlet was positioned around 3.5 to 5km from each print node at a convergence point determined by using the GRASS *r.drain* tool in QGIS (r.drain is a least cost path tool that traces a flow through an elevation model or cost surface on a raster map). Subsequent models were run based on this outlet.

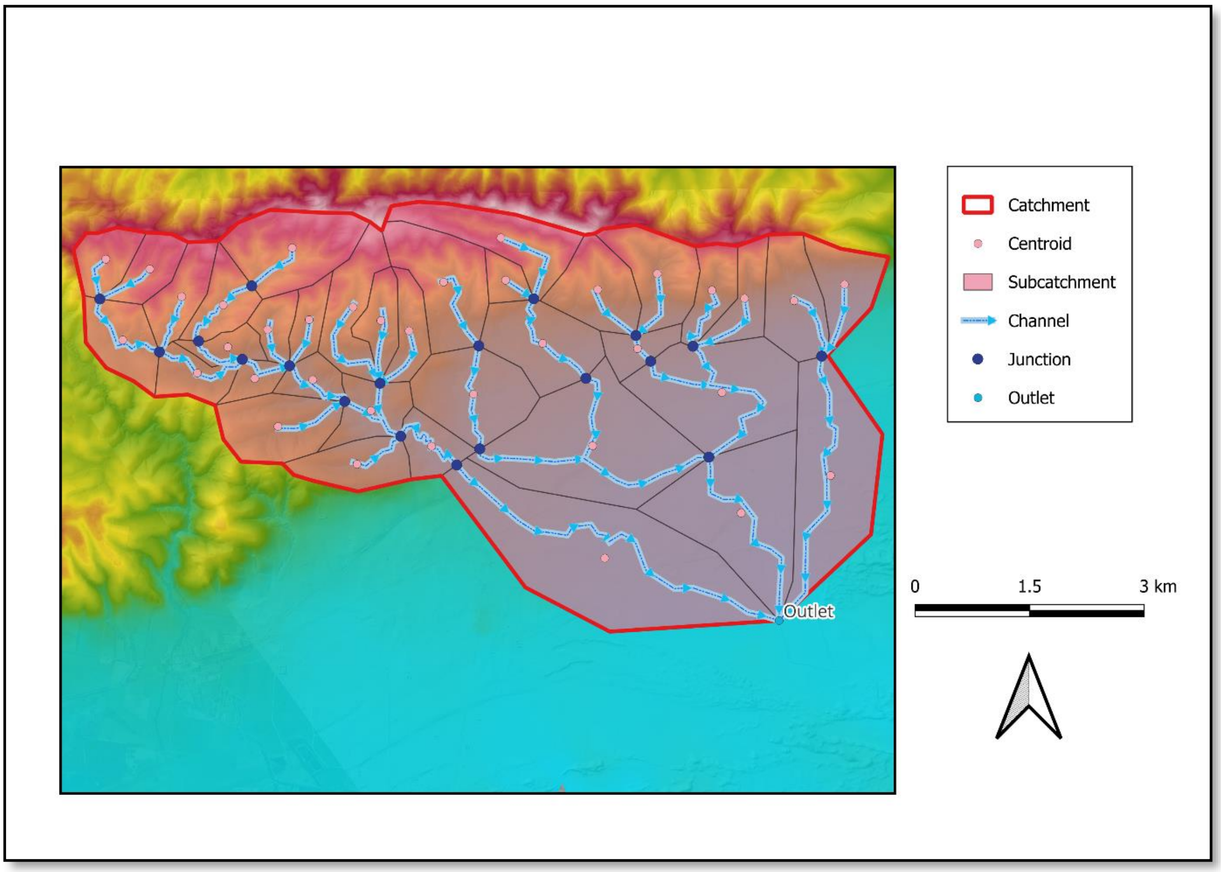
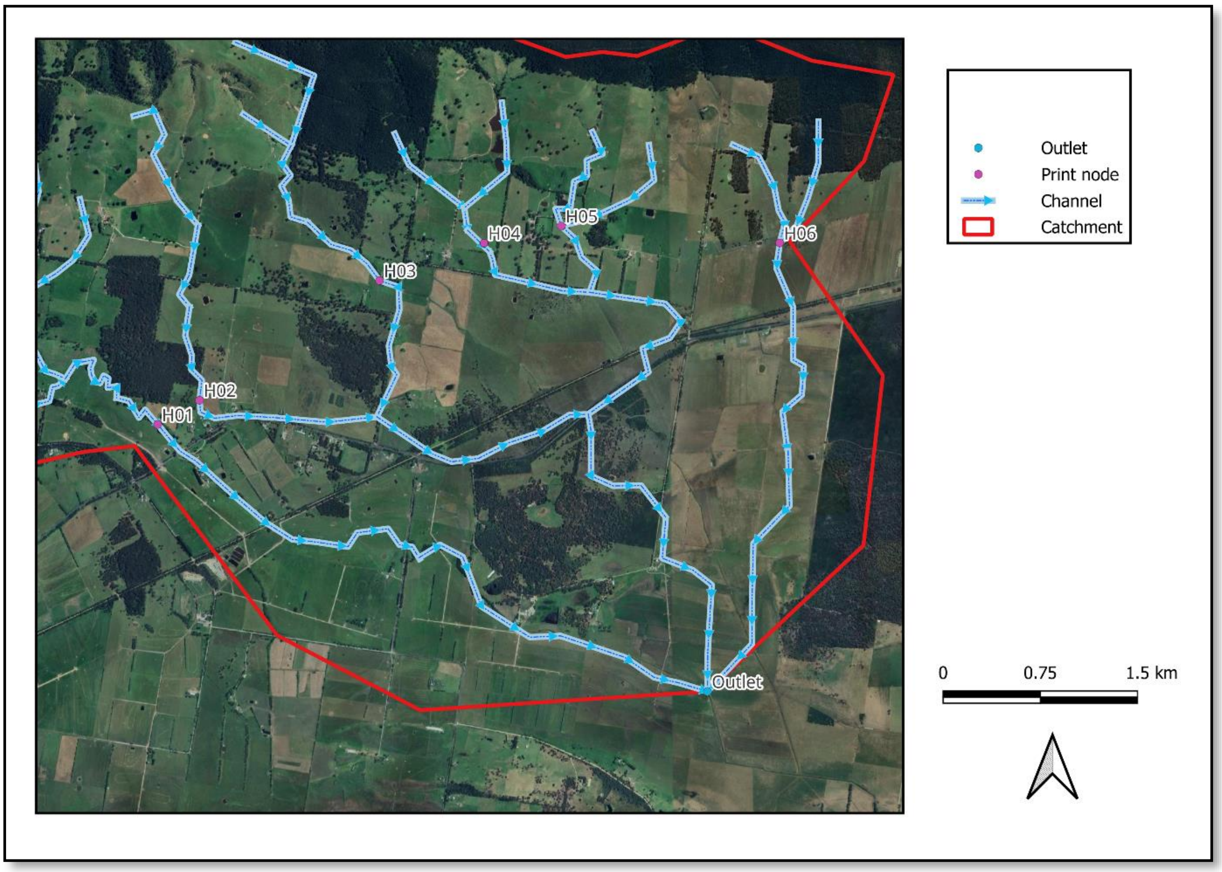


Figure 2-2 RORB Hydraulic model sub-area delineation with Outlet, Subarea and Junction nodes



Intensity Frequency Duration (IFD) Parameters

Storm data (Table 3) was generated using Intensity-Frequency-Duration (IFD) parameters sourced from the Bureau of Meteorology IFD program (Bureau of Meteorology, 2024).

Table 3 IFD Table for Hedley (Centroid: - 38.6375 (S), 146.4875 (E))

	AEP						
Duration	**50%**	**20%**	**10%**	**5%**	**2%**	**1%**	**0.50%**
1 min	1.6	2.21	2.65	3.11	3.75	4.27	4.78
2 min	2.72	3.84	4.67	5.53	6.81	7.81	8.89
3 min	3.66	5.14	6.23	7.37	9.03	10.3	11.7
4 min	4.46	6.23	7.52	8.87	10.8	12.3	13.9
5 min	5.15	7.16	8.63	10.2	12.3	14	15.8
10 min	7.68	10.6	12.7	14.8	17.8	20.3	22.6
15 min	9.39	12.9	15.5	18.1	21.7	24.7	27.5
20 min	10.7	14.7	17.7	20.7	24.9	28.3	31.6
25 min	11.8	16.3	19.5	22.9	27.6	31.4	35.1
30 min	12.7	17.6	21.1	24.8	30	34.2	38.3
45 min	14.9	20.8	25.1	29.6	35.9	41.1	46.2
1 hour	16.7	23.4	28.3	33.4	40.7	46.7	52.7
1.5 hour	19.4	27.4	33.3	39.5	48.4	55.7	63.1
2 hour	21.7	30.7	37.4	44.4	54.6	63	71.5
3 hour	25.3	36	43.9	52.4	64.5	74.5	84.9
4.5 hour	29.6	42.1	51.6	61.5	75.8	87.8	100
6 hour	33.1	47.1	57.7	68.8	84.8	98.2	112
9 hour	38.7	55.1	67.4	80.4	98.8	115	132
12 hour	43.2	61.4	75	89.4	110	127	147
18 hour	50.3	71	86.6	103	127	147	171
24 hour	55.7	78.3	95.4	114	139	161	189
30 hour	60.1	84.2	102	122	150	173	208
36 hour	63.7	89	108	129	158	183	222
48 hour	69.5	96.5	117	139	171	198	242
72 hour	77.5	107	129	153	188	217	265
96 hour	82.9	113	136	161	197	228	276
120 hour	86.8	118	141	166	202	233	282
144 hour	89.9	121	144	169	204	236	284
168 hour	92.5	124	147	171	204	236	285

Loss Model

RORB generates rainfall excess (runoff) by subtracting losses at each time-step from the rainfall occurring in that period. The “initial loss followed by a continuing loss” loss model was adopted. The adopted initial loss and continuing loss for pervious areas were 29 mm and 3.8 mm/hr respectively as recommended by ARR datahub when using the catchment centroid (Figure 2-3).

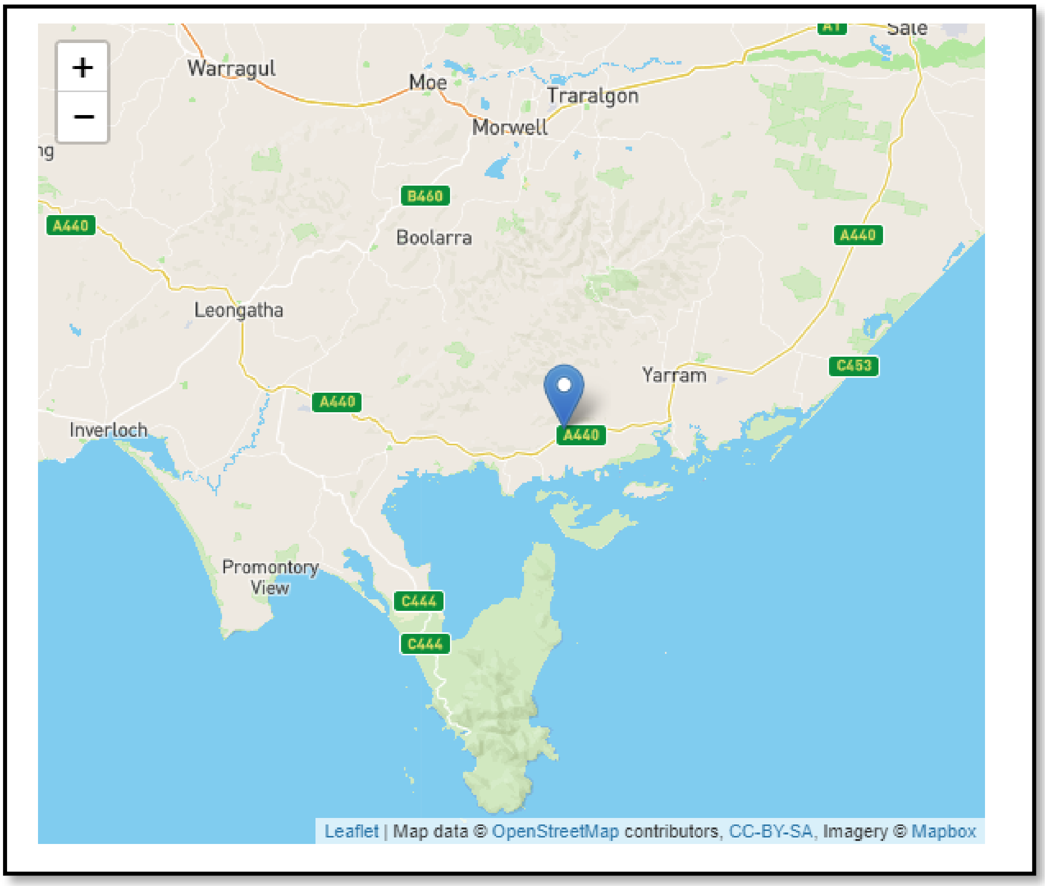


Figure 2-3 Position of Catchment outlet derived from ARR Datahub

A Kc value of 13.61 was reviewed using the regional equation (Equation 1) for eastern Victoria regions with mean annual rainfall greater than 800 mm. This value was compared to the "Victorian" equation (Equation 2) from Pearse et al. (2002) of 7.84 and the Aus Wide equation from Yu (1989) of 6.02. Initial runs found that a Kc of 13.61 gave a flow significantly less than the expected RFFE. The lower value of 6.02 was adopted due to the closer fit to the 1% AEP flow (Figure 2-4).

Equation 1:

$K_c = 2.57A^{0.45}$ (ARR Book 7, Eqn 7.6.15, Hansen et al. (1986a, b))

Equation 2:

$K_c = 1.25d_{av}$ ("Victorian" equation from Pearse et al. (2002))

Equation 3:

$K_c = 0.96d_{av}$ (Aus Wide Yu (1989) data from Pearse et al. (2002)

Table 4 RORB parameters

m	Kc	IL	CL
0.8	6.02	29.0	3.8

Monte Carlo Simulation

Design flood estimation within RORB was undertaken using the Monte Carlo simulation method for the catchment. The Monte Carlo approach involves undertaking thousands of simulations where the stochastic factors (such as rainfall, temporal patterns and initial loss) are sampled to represent the joint probability of such factors to provide a more realistic representation of the flood peak.

The Monte Carlo method was selected as it recognises that design floods (e.g. peaks flows) can result from a variety of combinations/factors, rather than from a single combination as is assumed with the typical 'design event' approach. For example, the same peak flood could result from a large, front-loaded storm on a dry catchment, or a moderate, more uniformly distributed storm on a saturated catchment.

The simulation used a range of rainfall depths, durations, temporal patterns and initial losses to produce a flood frequency distribution curve. Initial loss values are taken by sampling within an expected variability range of the original value (i.e. 29 mm), while rainfall depths/durations, temporal patterns and areal reduction factors are drawn from the information sourced by the ARR Data Hub. The flood frequency distribution curve is used to estimate the peak flow for each AEP event and identify critical storm durations and temporal patterns within the Monte Carlo result output.

Results from the Monte Carlo simulation fit within the acceptable range of values given by RFFE tool (Figure 2-4). A critical duration of 9hrs produced the maximum flows for 10, 5, 2, and 1 percent AEPs and a critical duration of 12hrs produced a maximum flow for the 20 and 0.5 percent AEPs (Table 5).

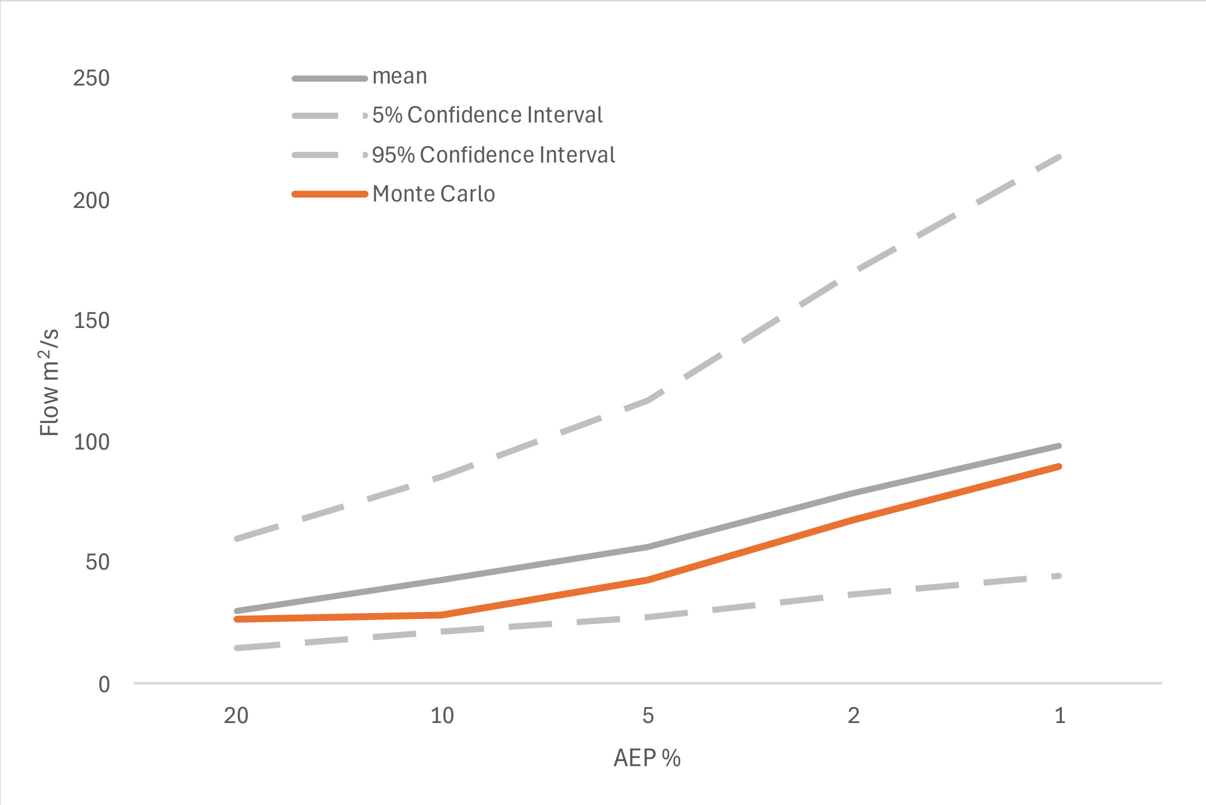


Figure 2-4 Monte Carlo results from RORB plotted against RFFE values.

Table 5 Table of RORB parameters derived from Monte Carlo Runs and used as a basis the Design runs.

AEP	Depth	m	CL	**TP**	**IL**	**Flow (m^2/s)**
9 Hour						
10	63.8	0.8	3.8	16	25.52	28.54
5	75.9	0.8	3.8	18	14.21	46.47
2	92.9	0.8	3.8	25	17.4	71.57
1	109.2	0.8	3.8	21	22.91	93.14
12 hour						
20	58.8	0.8	3.8	5	11.89	26.5
0.5	137.5	0.8	3.8	29	19.43	119.33

Benchmarking ARR2019 for Victoria by Erin Hughes and David Stephens has made recommendations for the use of ARR2019 data on ungauged catchments due to likelihood that the "use of the standard ARR2019 design inputs tends to underestimate modelled design peak flow between 10% and 1% AEPs when compared to gauged at-site flood frequency analysis". Hughes and Stephens (2019) made recommendations that for catchments in loss region 3, the ARR Data Hub 75th percentile ratio of pre-burst rainfall be adopted instead of median ratio values as a way of reducing bias towards underestimation of flows. Therefore, design storms were run with parameters listed in Table 5 and with pre-burst applied at the 75th percentile.

2.5 RORB RESULTS

Results of design storms with 75th percentile preburst patterns included (Table 2-6), demonstrated that flows were a closer match to the RFFE results (Figure 2-5).

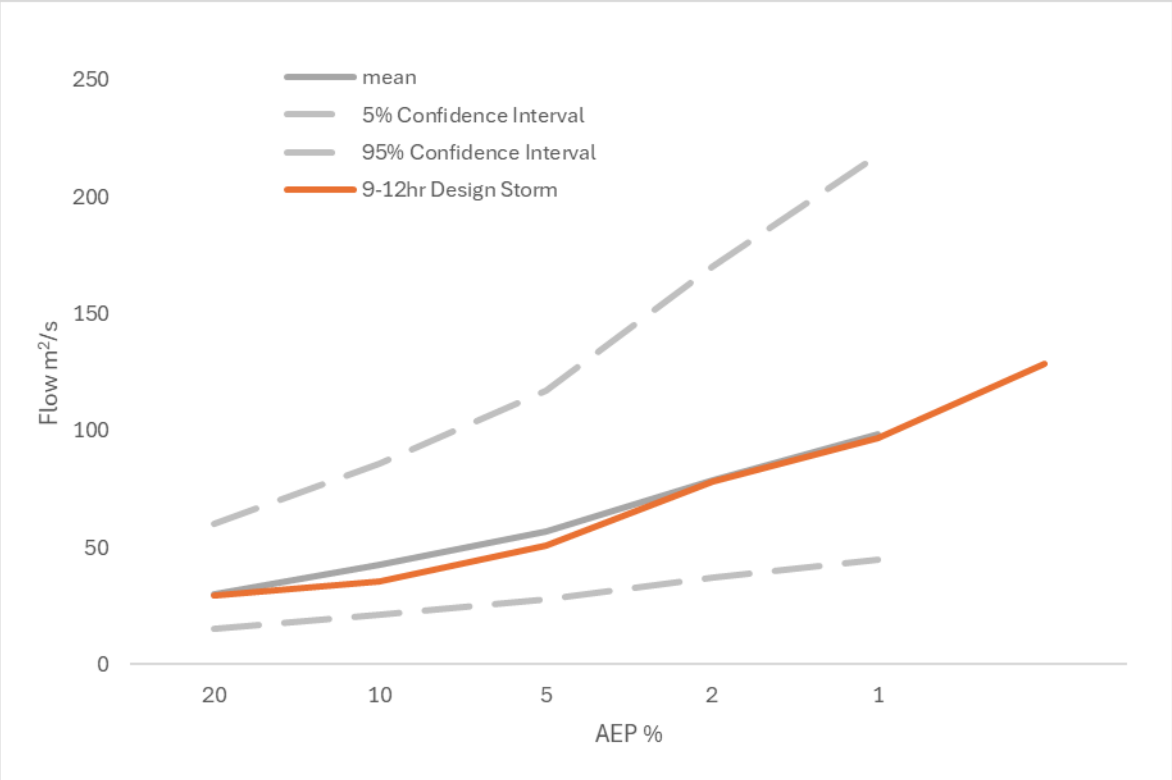


Figure 2-5 RORB design storm results with pre-burst applied at 75th percentile

Table 6 RORB Design flows at model outlet from the 9 and 12 Hour critical storm duration (12 hour flows in bold)

Average Exceedance Probability (AEP)	Flow at outlet based on RORB design run model
%	m^3/s
20	**29.53**
10	35.45
5	50.87
2	78.01
1	96.68
0.5	**128.4**

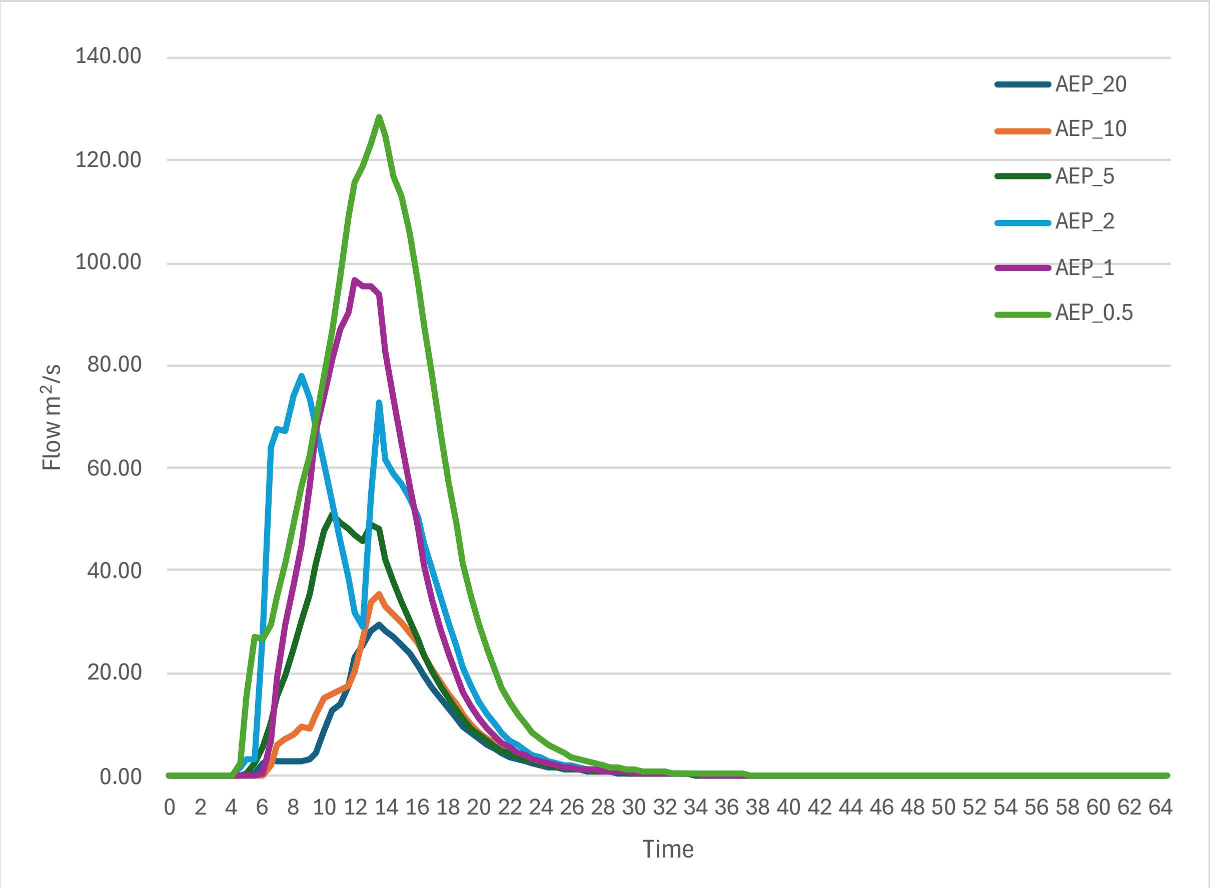


Figure 2-6 9 and 12-hour RORB hydraulic model results from catchment outlet

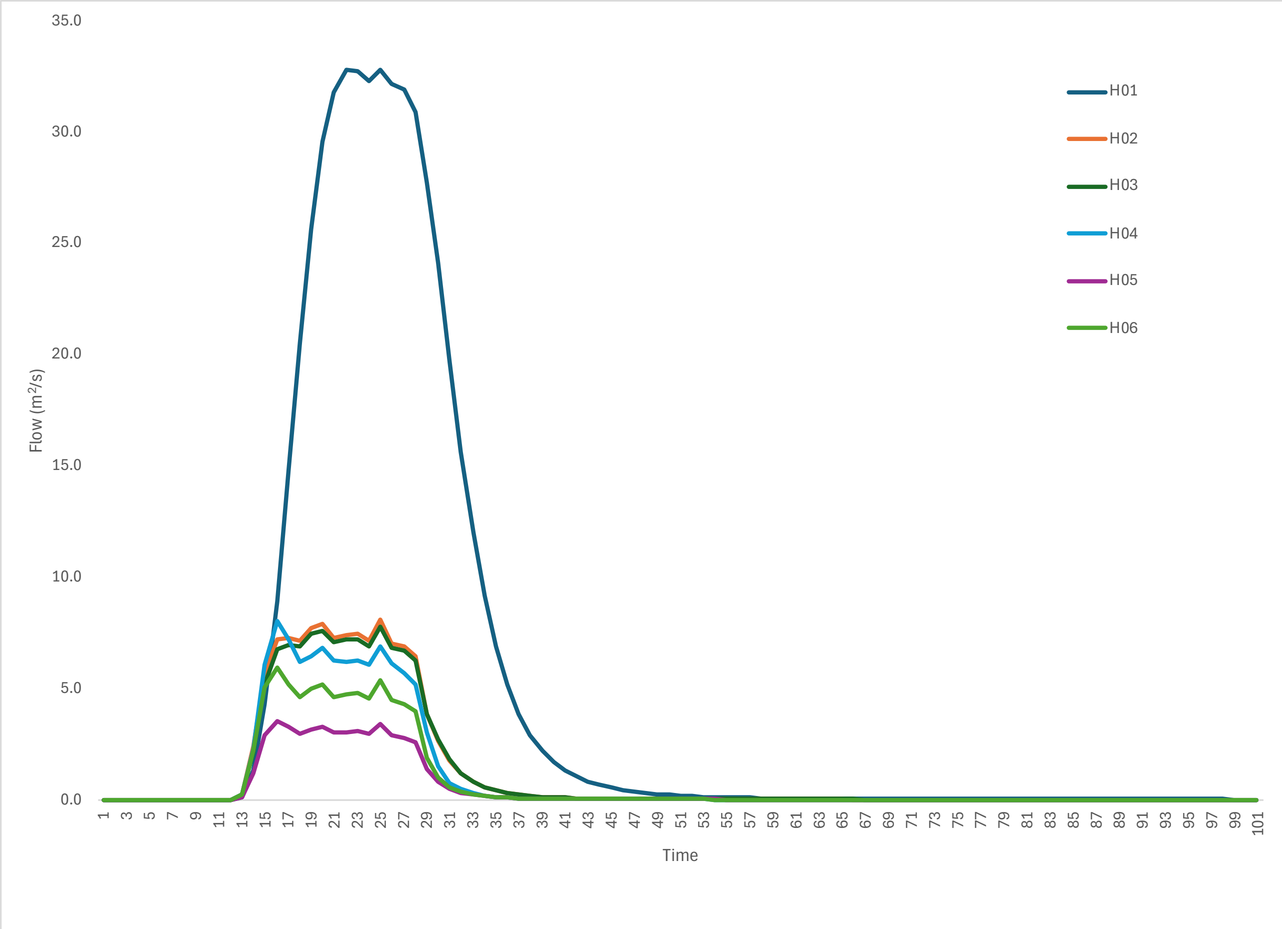


Figure 2-7 Modelled flows at each of the six print nodes for the AEP 1% storm

Sensitivity analysis
Sensitivity of RORB results to variation in the parameters adopted (for example, ±10 or 20% change in the parameters)

Assumptions
The use of regional data in an ungauged catchment is standard practice, however, the results are expected to have higher level of uncertainty attached. Acknowledgement within runoff routing models that catchment flood response is non-linear in nature has improved the reliability of extreme flood prediction.

3 HYDRAULIC MODELLING

This section provides a description of the TUFLOW modelling process undertaken for the catchment. A 2-dimensional TUFLOW hydraulic model was developed as part of this study with the aim of flood mapping the catchment for the calibration and design flood events. TUFLOW is a computer program that models depth-averaged, one and two-dimensional free-surface flows and is used to simulate the hydrodynamic behaviour of rivers, floodplains and urban drainage environments. The software is well-suited to small scale catchment studies such as the Hedley Flood Study, as it is equally capable of modelling stream network and floodplain environments such as those found in the Nine Mile Creek environments.

3.1 MODEL DESCRIPTION

To produce flood extents, depths, velocities and other hydraulic properties for the study area a 2D hydraulic model was developed using TUFLOW. The area modelled within the 2D domain comprises a total area of 49.84 km^2 which represents the entire region of Hedley and surrounding infrastructure. Nine Mile Creek, including its floodplains and the town of Hedley, were represented in the 2D domain.

Model Schematisation

The floodplain topography and other significant hydraulic features, such as roads and bridges, were represented within the 2D domains. A 2D domain with a 1m grid resolution was used to represent the floodplain. The major watercourse, Nine Mile Creek was represented in the 2D domain of the hydraulic model. External inflows boundaries were applied to the model to represent flow from Nine Mile Creek. No internal inflow boundaries were modelled.

3.2 HYDRAULIC MODELLING OVERVIEW

The following sections provide an overview of methodology and assumptions used to establish the key elements of the hydraulic model.

TUFLOW Model Version

Model runs were performed with the 2020-01-AB-iSP-w64 HPC build of TUFLOW

Design Event Modelling

The hydraulic model was run for several design events as well as the calibration events are discussed below. The following events were run in the hydraulic model:

- 20% AEP (5 year ARI) event;
- 10% AEP (10 year ARI) event;

- 5% AEP (20 year ARI) event;
- 2% AEP (50 year ARI) event;
- 1% AEP (100 year ARI) event; and
- 0.5% AEP (200 year ARI) event.

Model Extent

Consideration was given to the following in constructing the model:

• Desired accuracy to meet the study's objectives.
• Topographic data coverage and resolution.
• Location of controlling features (e.g. Catchment Stream outlet and out of channel flow).

The upper bounds of the 2D domain were established based upon the final convergence of Nine Mile Creek as it exits the upper catchment in addition to LiDAR data extent, while the lower boundaries were based on the extent of available single origin LiDAR data. The area modelled within the 2D domain comprises a total area of 49.84 km^2 which represents the entire area of Hedley and surrounding infrastructure (Figure 3-1).

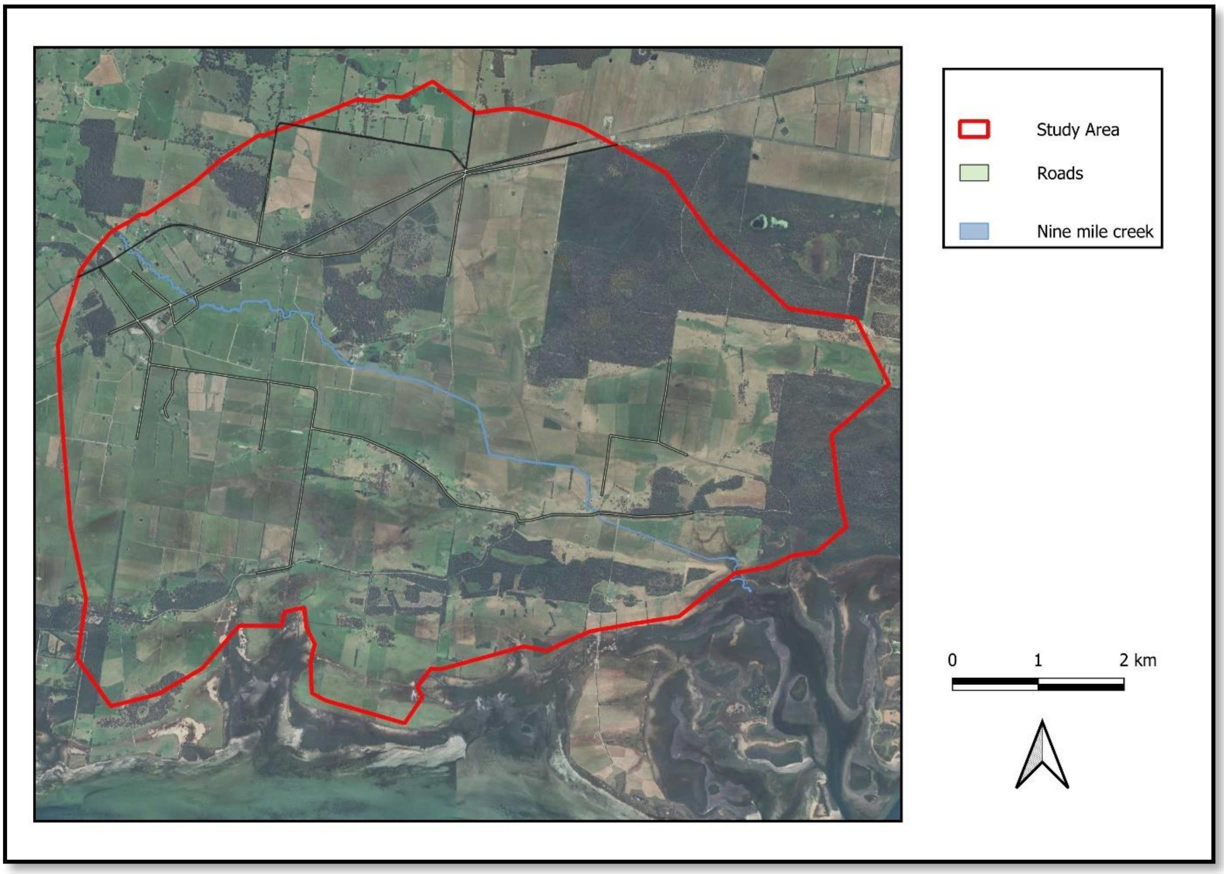


Figure 3-1 TUFLOW Hydraulic Model Extent

3.3 2D Domain

Topography

The geometry of the 2D floodplain and watercourses were established by constructing a uniform grid of square elements from the DEM. This TUFLOW grid (or zpt layer) provides the topography for the hydraulic model. The DEM used in the hydraulic model was based the LiDAR available to the WGCMA (Table 3-1). The extent of the two LiDAR layers used for the model DEM are shown in Figure 3-2. The two files were merged using the Mosaic To New Raster tool in ArcGIS pro. Surface imperfections in the DEM were filled using the fill tool and the DEM was converted to an ASCII file for use in TUFLOW using the asc_to_asc tool.

Table 7-1 Digital Elevation Dataset Summary

Dataset	Resolution	Vertical Accuracy (1 sigma)
2010-11 Floodplains LiDAR Stage 2 – West Gippsland	1m x 1m	± 0.1
Coastal and MID LiDAR – Level 3 (2008-2010)	1m x 1m	± 0.1

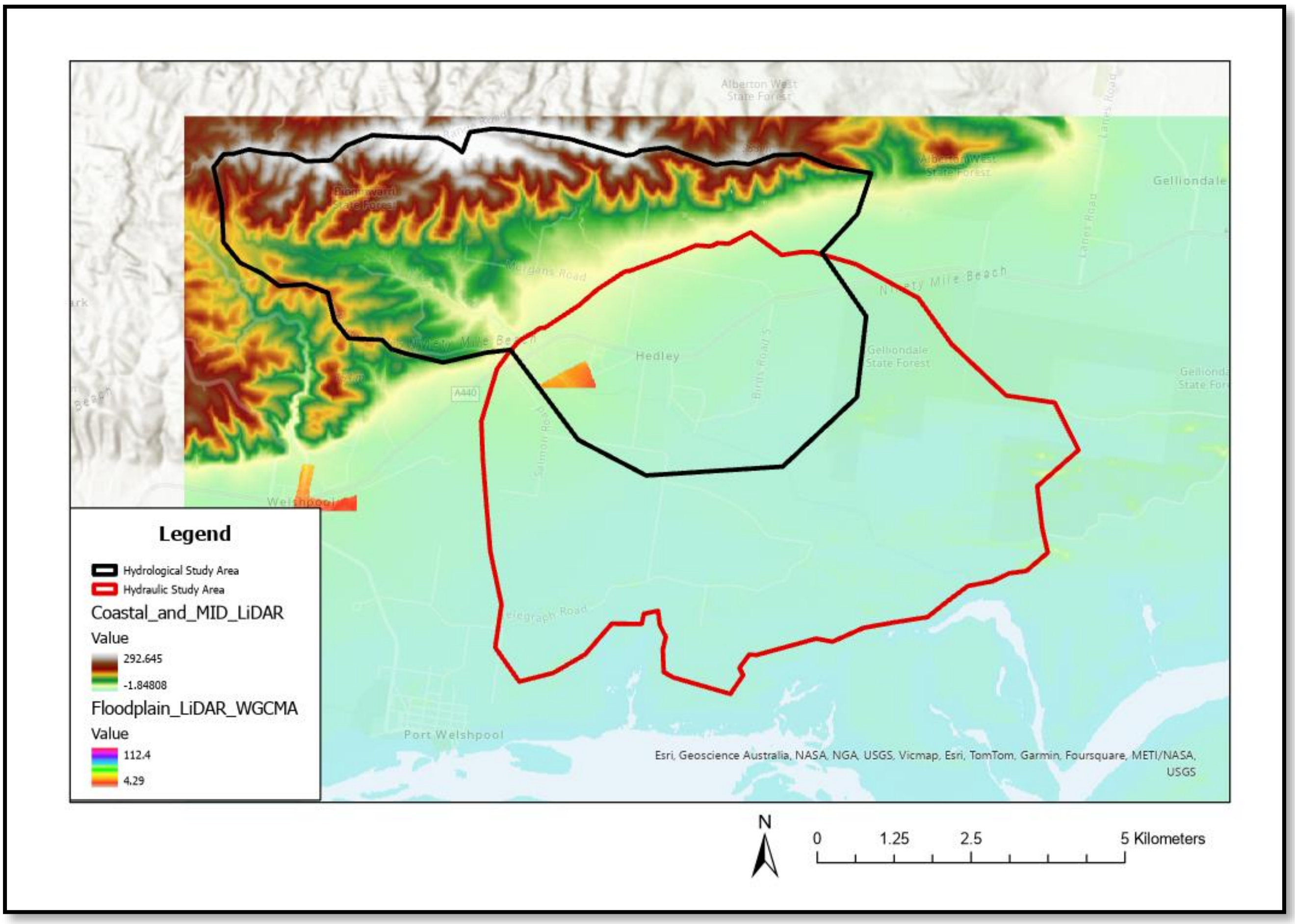


Figure 3-2 Available DEM data for Hydraulic Model

Grid Resolution

One of the key considerations in establishing a 2D hydraulic model relates to the selection of an appropriate grid element size. Element size affects the resolution, or degree of accuracy, of the representation of the physical properties of the study area as well as the size of the computer model and its resulting run times. TUFLOW samples elevation points at the cell centres, mid-sides, and corners therefore, a 4 m cell size results in DEM elevations being sampled every 2 m. Selecting a very small grid element size will result in both higher resolution and longer model run times.

TUFLOWs HPC simulation mode uses an adaptive timestep. The grid size that was adopted for this model is 1x1 m.

3.4 2D Hydraulic Features

It is important to ensure that large (2D grid size or larger) impediments and constrictions to flow are properly incorporated in the TUFLOW model. A site inspection was undertaken in the initial stages of the study to gain an appreciation of local features influencing flooding behaviour. Some of the key observations from the site inspection included the location and dimensions of existing infrastructure including bridges and culverts.

Bridges

Bridge structures were modelled as 2D flow constrictions (2d_lfsch) The layered flow constriction also allows for typical bridge characteristics such as bridge deck height and thickness as well as any blockages associated with guard or handrails to be incorporated directly in the 2D domain. Photographs and locations of the major bridge structures modelled are shown in Figure 3-3 and 3-4 respectively.

A. Rail Trail Bridge

B. South Gippsland Highway- Nine Mile Creek Bridge

C. Rail Trail - Nine Mile Creek Bridge

D. Rossiters Road - Nine Mile Creek Bridge

E. Telegraph Road - Nine Mile Creek Bridge

F. Gippsland Highway Box culvert

Figure 3-3 Nine Mile Creek Bridge Structures and Culverts in Hedley

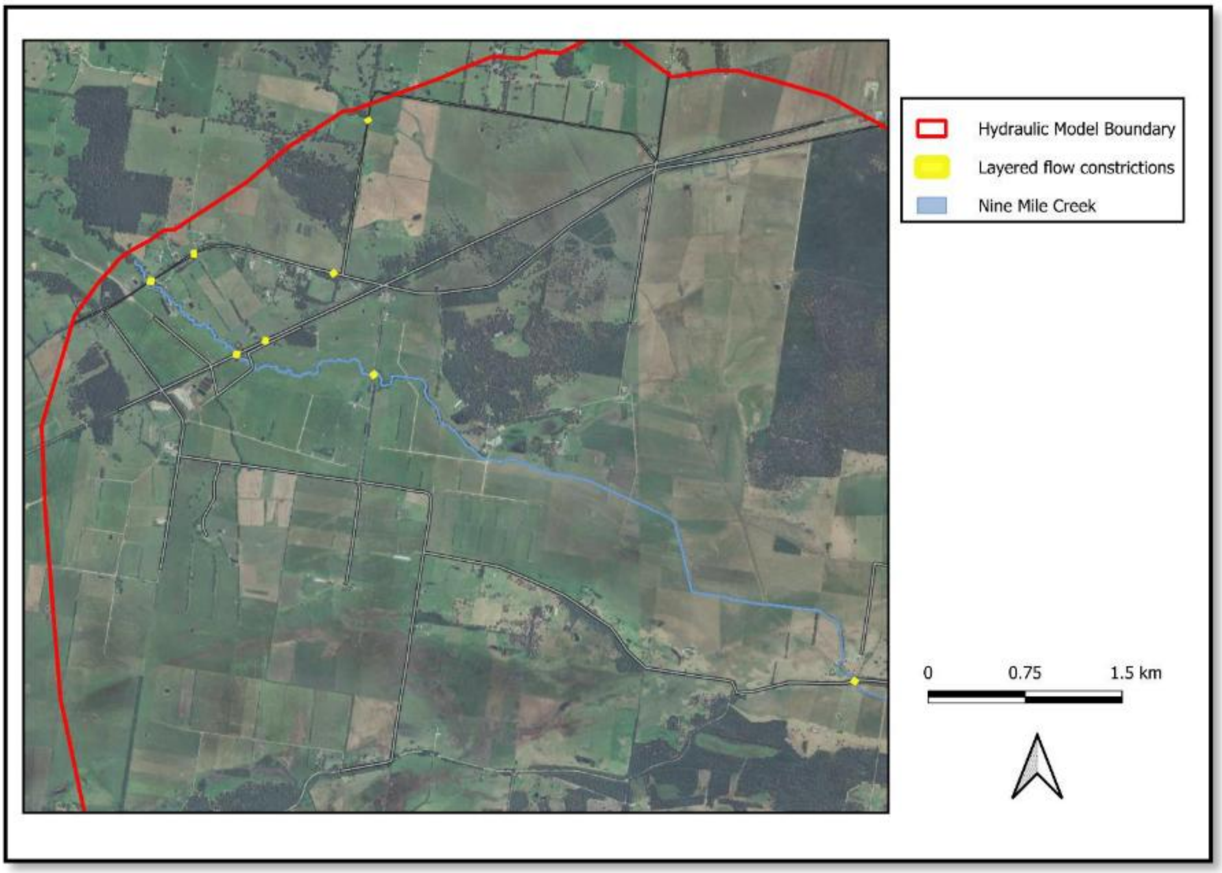


Figure 3-4 Location of Bridges within the model domain

As previously mentioned, bridge crossings have been modelled as a TUFLOW 'layered flow constrictions' embedded in the 2D model. The form loss coefficient for the various parts of the bridge (Layer 1 to Layer 3) have been determined using typical values in accordance with Australian Rainfall and Runoff Guidelines (2019) and are shown below in Table 3-2.

Table 7-2 Major Modelled Bridge attributes (letters referencing images in 3-3)

Parameters	South Gippsland Highway (B)	Rail Trail (C)	Rossiters Road (D)	Telegraph Road (E)
Pier blockage (%)	5	10	10	20
Pier Form Loss	0.15	0.12	0.22	0.3
Deck soffit level (m+DTM)	28.4	22.97	13.78	4.9
Deck Depth (m)	0.6	0.55	0.4	0.4
Deck blockage (%)	100	100	100	100
Deck Width (m)	8	3.5	6.5	4.8
Rail Depth (m)	0.85	1.4	0.5	0.5
Rail blockage (%)	30	30	50	35

Surface Roughness

The Manning's roughness coefficient represents friction losses associated with the bed material of a channel/floodplain, and drag losses associated with vegetation or other obstructions. The Mannings values that have been used throughout the model were derived from the Australian Rainfall and Runoff Guidelines (2019) as per Table 6.2.1 – Values of Roughness Coefficient n for different channel conditions and Table 6.2.2 - Valid Manning 'n' Ranges for Different Land Use Types (Ball, et al., 2019). Table 3-2 displays the Manning's coefficient and land use categories described within the model. The roughness coefficients in the study area were derived from satellite images, planning zone maps and field observations and digitised into land-use polygons representing zones of similar loss characteristics within the study area (Figure 3-3).

Table 7-3 Mannings Roughness (n) Values applied to the model for different land use types (Source: (Ball, et al., 2019).

Land Use Type	**Mannings 'n' Value**	
	Below 0.03m	Above 0.1m
Residential areas	0.2	0.4
Dams	0.01	0.01
Moderate Vegetation	0.04	0.08
Vegetated Waterways	0.01	0.08
Paved /Unpaved Roads	0.02	0.02
Pasture/grass	0.03	0.02

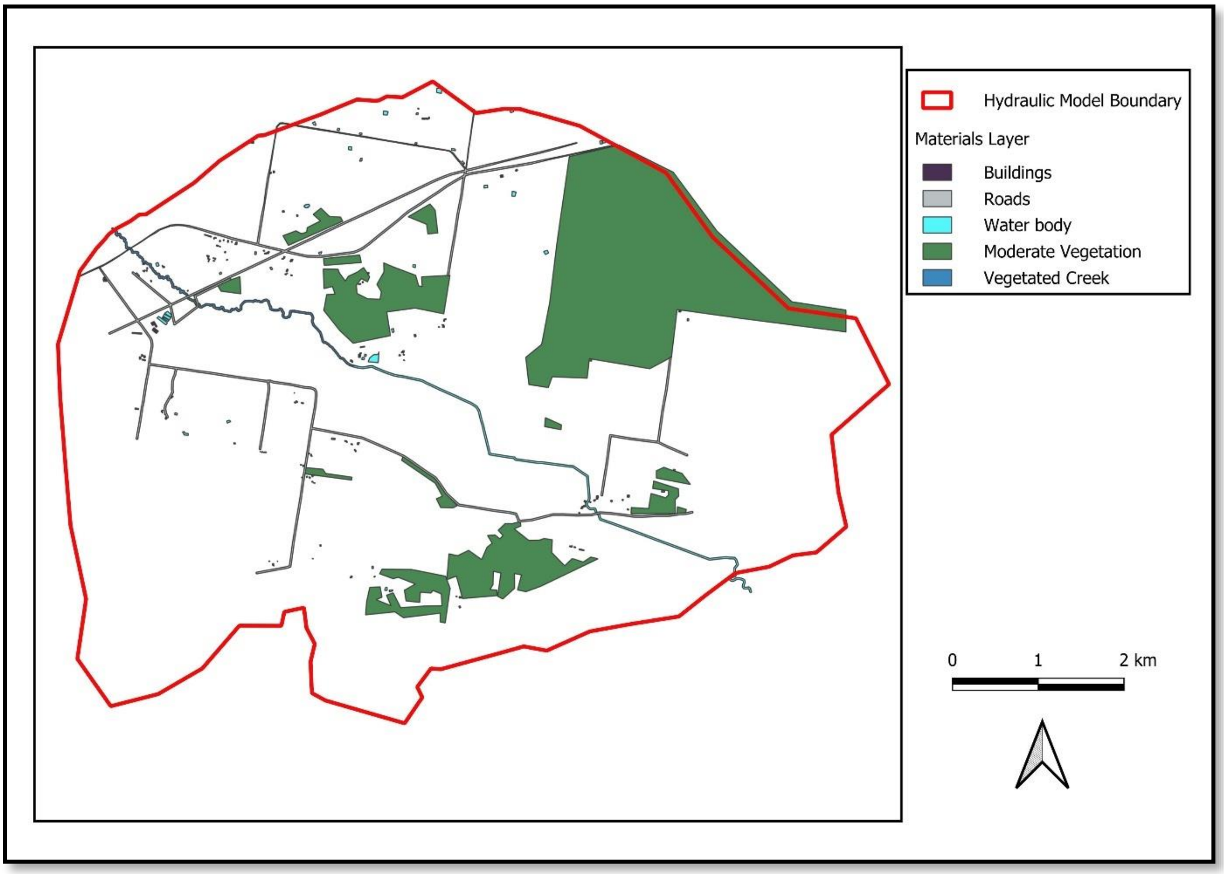


Figure 3-5 Materials layer with allocated Manning's n surface roughness

Buildings

Buildings were simulated in the hydraulic model for the town as a materials layer within the 2D domain.

Topographic updates

Z points derived from LiDAR alone may not adequately capture changes in topographic breaks such as road crests and creek beds in flood models. These topographic breaks can be reinforced in TUFLOW as a 2d Shape layer. A 2d shape layer polygon was created to reinforce the bed of Nine Mile Creek particularly around the lower reaches where vegetation interferes with LiDAR representation (Figure 3-6). Nine Mile Creek was represented as a ADD shape with a Z attribute of -1.0m which effectively lowers the Z pt elevation by 1.0 m.

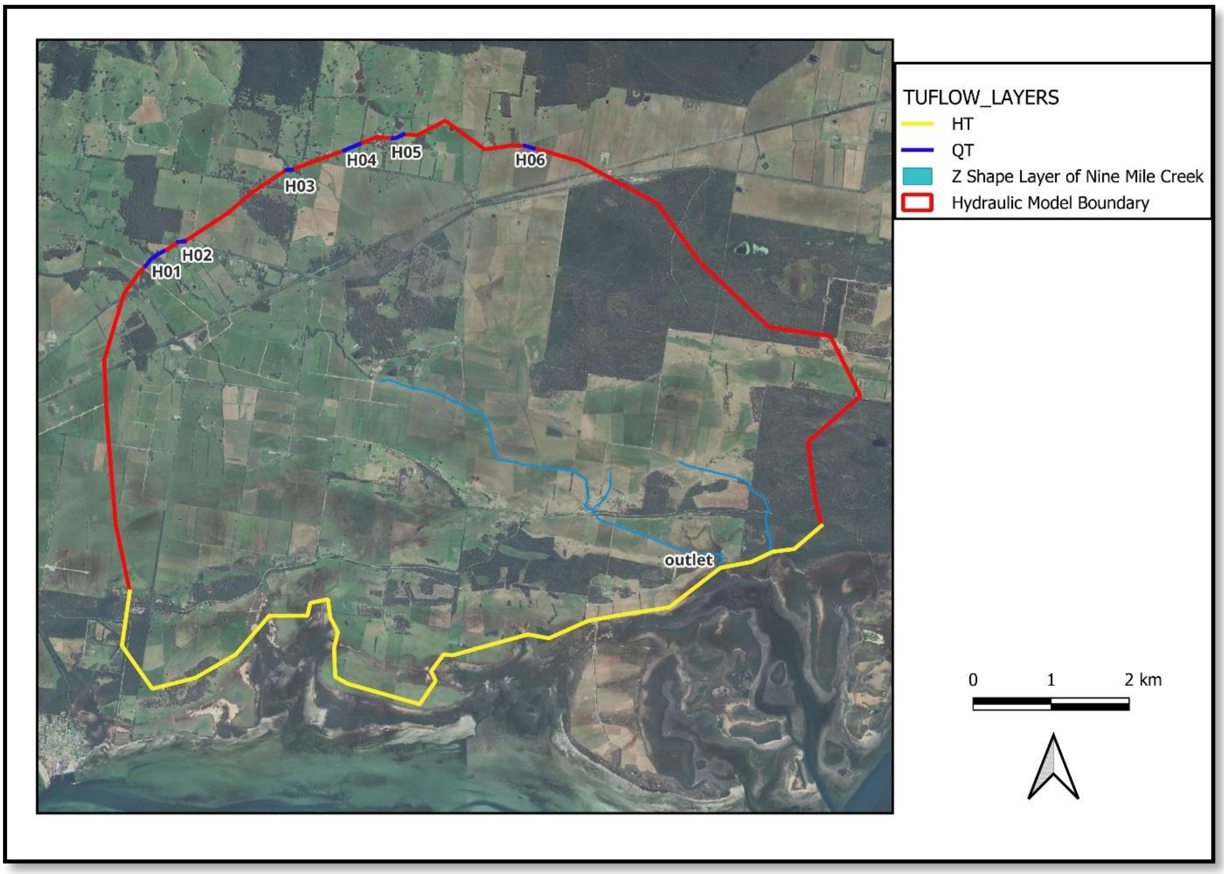


Figure 3-6 Modified Z Shape polygon used to reinforce the lower end of the Nine Mile Creek bed within the model boundary.

3.5 Boundary Conditions

A hydraulic model requires inflow boundaries and outlet boundaries to allow water into and out of the model in a realistic manner. The external inflow boundaries accounts for flow generated from outside of the model extents (external boundaries). Flow is removed from the model through downstream boundaries, which are generally a fixed water level or a stage discharge relationship.

The TUFLOW model for Hedley has been modelled with six external flow vs time (QT) upstream boundaries the largest of which is associated with Nine Mile Creek (Figure 3-8). The model outflow boundaries were applied as Head versus Time (HT) boundary which assigns a water level to the node based on a water level versus time curve. Terrain slope was used as the outflow boundary condition and was calculated based on the gradient/slope between points on either side of the model extent. Water levels on the estuary /outflow side were set at 1.63m in accordance with current climate water levels for Port Welshpool (Table E2 in The Effect of Climate Change on Extreme Sea Levels along Victoria's Coast, (McInnes, Macadam, & O'Grady, 2009)).

Table 8 Extract of Port Welshpool data from Table E2 in (McInnes, Macadam, & O'Grady, 2009)

Location	Current Climate	2030			2070			2100		
		1	2	3	1	2	3	1	2	3
Port Welshpool	1.63	1.78	1.84	1.83	2.10	2.27	2.33	2.45	2.68	2.73

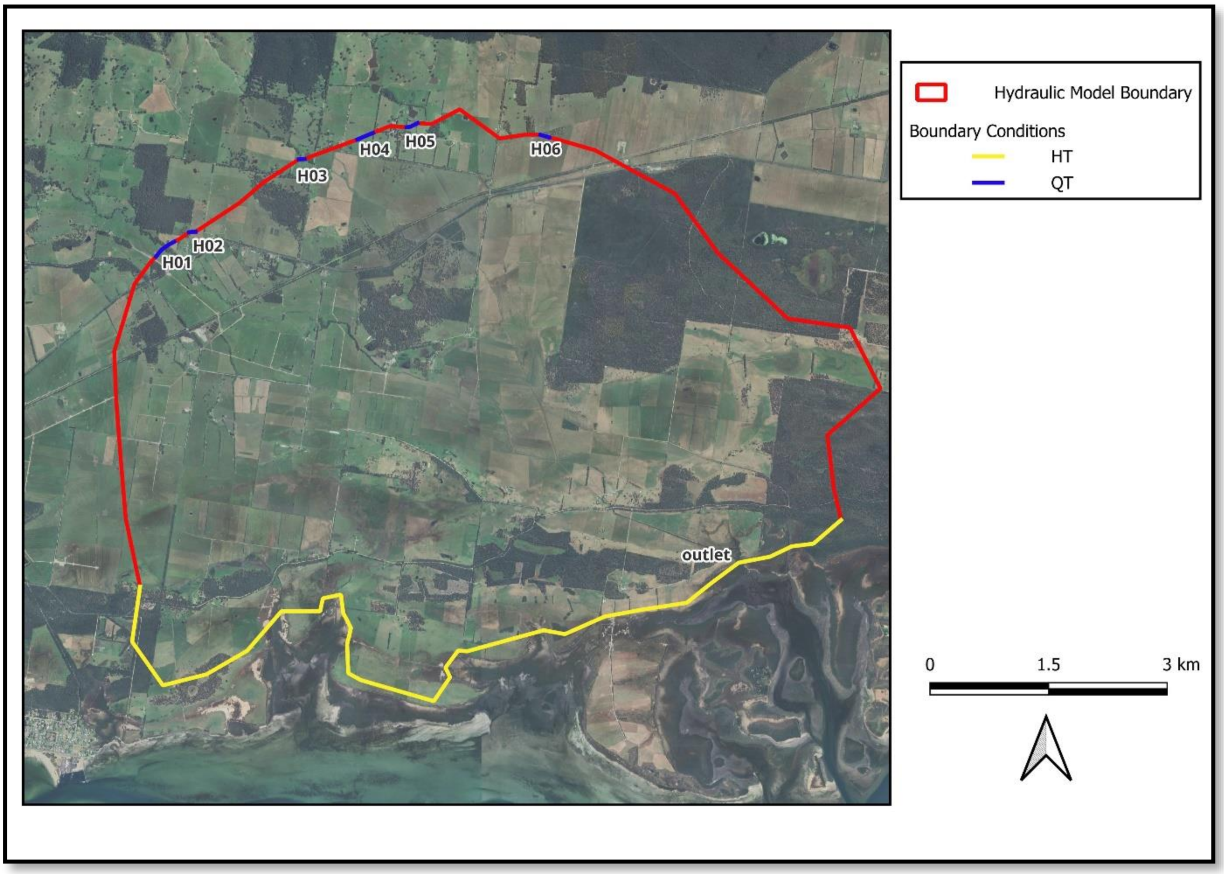


Figure 3-7 Model extents, showing inflow and outflow boundaries

Rainfall polygons

Rainfall polygons apply a rainfall depth to active cells within the 2d_code layer based on the input hyetograph (Figure 3-8). The input hyetograph in mm verse time, is applied using a stepped approach which holds the rainfall constant for the time interval. The rainfall excess hyetographs are based on BOM IBD values (Table 3) as transformed through the RORB design runs (see Figure 3-9 for 9hr 1%AEP event). Rainfall was applied in a single centralised 43.77 km^2 polygon (Figure 3-8). No adjustments were made to spatial rainfall and the attributes f1 and f2 were held at a value of 1, i.e. 100% of specified rainfall is used. Initial losses were applied within the RORB design run as per Table 5 and CL 3.8 mm/hr. Depth varying roughness values are used in direct rainfall models to reflect the bed roughness at shallow depths Mannings surface roughness values were assigned to material IDs in accordance with Table 3-3. To differentiate between shallow sheet flow and flooding a Map Cutoff Depth command was added and set to 0.05m.

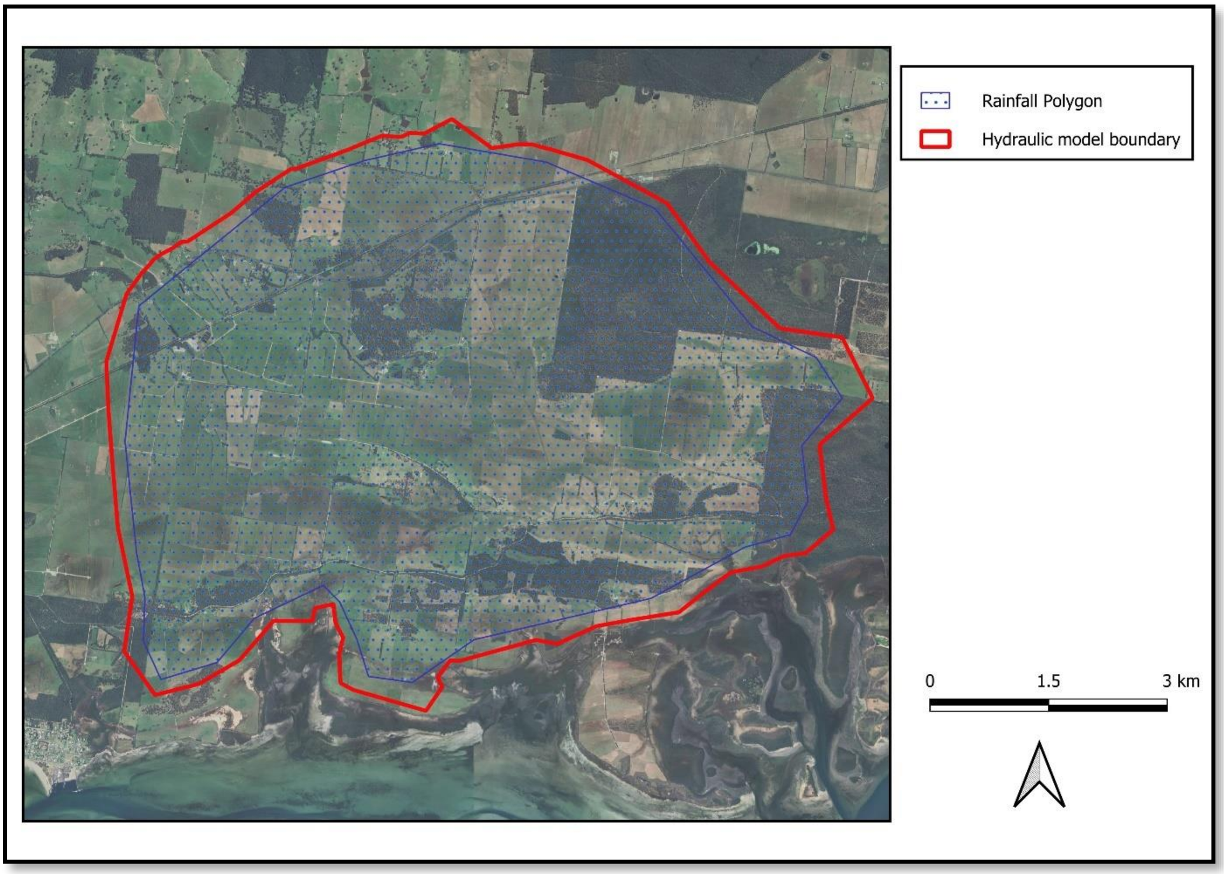


Figure 3-8 Rainfall polygon extent

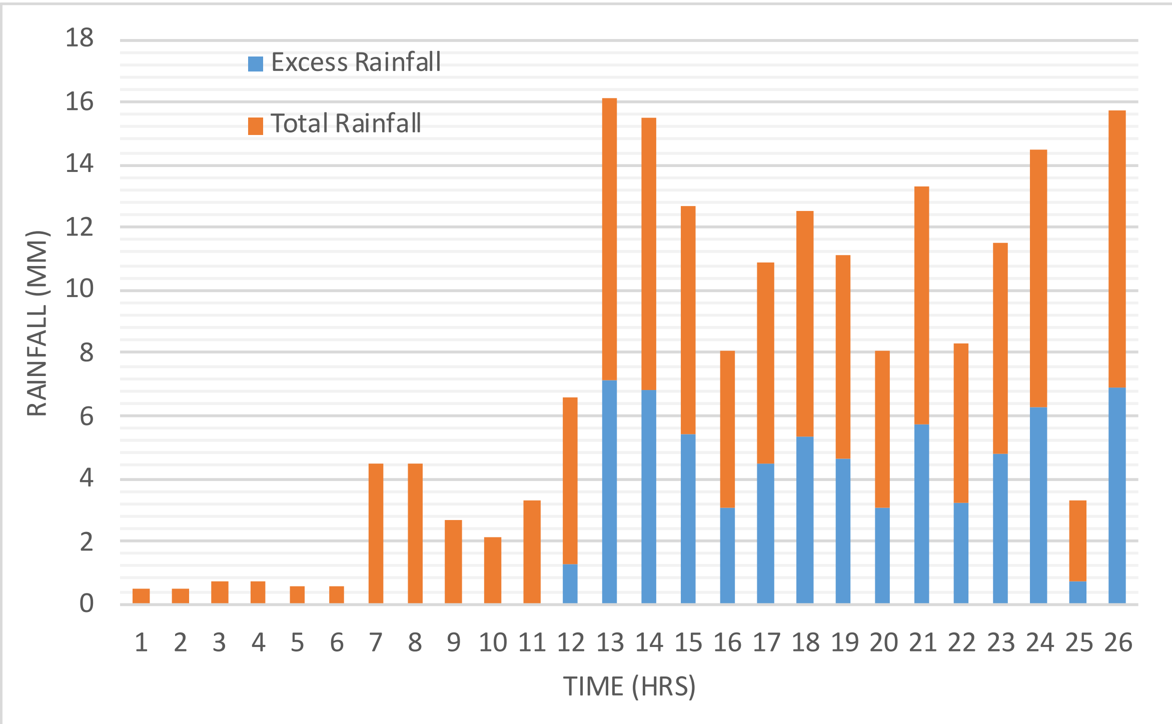


Figure 3-9 Example RORB generated rainfall hyteograph for 9hr 1% AEP event

3.6 CLIMATE CHANGE SCENARIOS

Climate change scenarios were calculated based on Interim Climate Change Factors given by the ARR datahub in line with CSIRO and BOM (2015) recommendations. The WGCMA uses an RCP 8.5 projected to the year 2100. Values obtained for the Welshpool catchment were plotted in an Excel spreadsheet and extrapolated according to the linear equation below (Equation4).

Equation 4:

$$y = 0.0021x - 4.2501$$

The RCP 8.5 for the year 2100 was determined to be equivalent to an 18.3% increase in rainfall. Climate change factors were applied in the BC Database through a calculation in Column 6 in which a multiplication factor is applied to the Column 2 (<aep><dur>.csv) values.

4 REFERENCES

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