Flood Intelligence & Mapping

Chetwynd Flood Intelligence and Flood Mapping

West Wimmera Shire

14 June 2018

WATER TECHNOLOGY
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Robyn Evans
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West Wimmera Shire
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Dear Robyn

Chetwynd Flood Intelligence and Flood Mapping

Please find attached the flood intelligence and mapping report for Chetwynd. If you have any queries, please don't hesitate to contact me.

Yours sincerely

Ben Hughes
Principal Engineer

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WATER TECHNOLOGY PTY LTD

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1 INTRODUCTION

The development of flood intelligence and flood mapping for the Chetwynd community assists West Wimmera Shire Council and the community of Chetwynd to better understand their flood risk and prepare for future flood events. This report outlines the flood modelling process and interprets the flood mapping to deliver valuable flood intelligence.

Chetwynd is located approximately 75 km north-west of Hamilton and 35 km north of Casterton. The catchment area is approximately 187 km^2 and extends from Wando Dale Road to the Glenelg River. The rural community of Chetwynd is predominantly a farming community with a small population scattered across the catchment. Figure 1-1 shows the study area along with community interest points. The most significant point is the community centre, which sustained damage in the last significant flooding event.

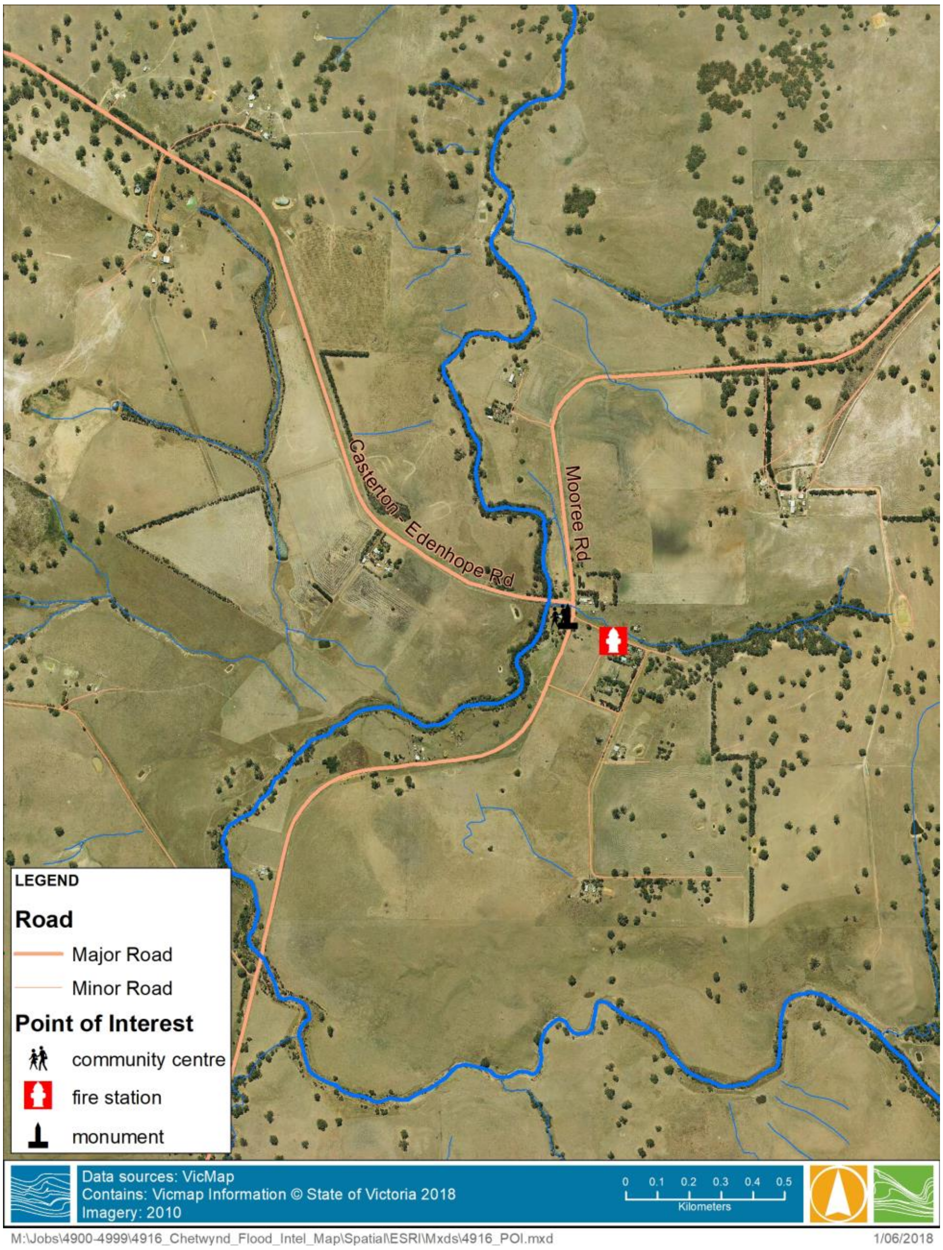

FIGURE 1-1 AREA OF INTEREST

2 METHODOLOGY

This section details the methodology used to determine flood flows (hydrology) and flood behaviour (hydraulics) in the study area. The hydrology used flood frequency analysis techniques along with rainfall-runoff modelling with RORB software, while the hydraulics was completed using TUFLOW software. The flood modelling was not calibrated to historic events, but rather used multiple flow estimation methods to verify the design hydrology and used community observations to verify design flood mapping.

2.1 Hydrology

2.1.1 RORB Model Construction and Parameters

RORB is a rainfall-runoff modelling program that uses rainfall data and various catchment characteristics to generate a streamflow hydrograph. The model build and simulation are described below.

2.1.1.1 Catchment and Reach Delineation

The Chetwynd catchment was delineated using LiDAR (Light Detection and Ranging) data captured between November and December of 2009. LiDAR is a laser surveying technique that allows the land surface to be accurately surveyed over large areas. It is routinely used in flood investigations. The ESRI terrain modelling software ArcHydro was used to delineate the catchment into 19 sub-areas and associated drainage reaches. The sub-area and reach delineation is shown in Figure 2-1.

The objective of the delineation was to ensure that the catchment runoff pathways were appropriately represented, and that the model had enough sub-areas to allow an appropriately attenuated hydrograph to be generated at the upstream boundary of the hydraulic modelling. Generally, three to five sub-areas are preferred upstream of any hydrograph location, to ensure the model attenuates the runoff in a realistic fashion.

2.1.1.2 Fraction Impervious

The estimated percentage of impervious surface within each sub catchment was represented by a Fraction Impervious (FI). The varying FI throughout the catchment was determined using both recent satellite imagery and the VicMap Planning Zones. A range of land uses were adopted throughout the catchment, with the main three being open space (including farming and greenspace), residential and industrial zones. Table 2-1 shows the adopted FI value for each land use. To determine the most appropriate FI value for each sub-area, an area weighted average was used. Figure 2-2 and Figure 2-3 demonstrates the planning zone areas and determined FI values for each sub catchment respectively.

TABLE 2-1 ADOPTED FI VALUES FOR CHETWYND CATCHMENT

ZONE DESCRIPTION	FRACTION IMPERVIOUS
Farming Zone	0.1
Residential Zone	0.6
Road Zone	0.7
Rural Living Zone	0.2

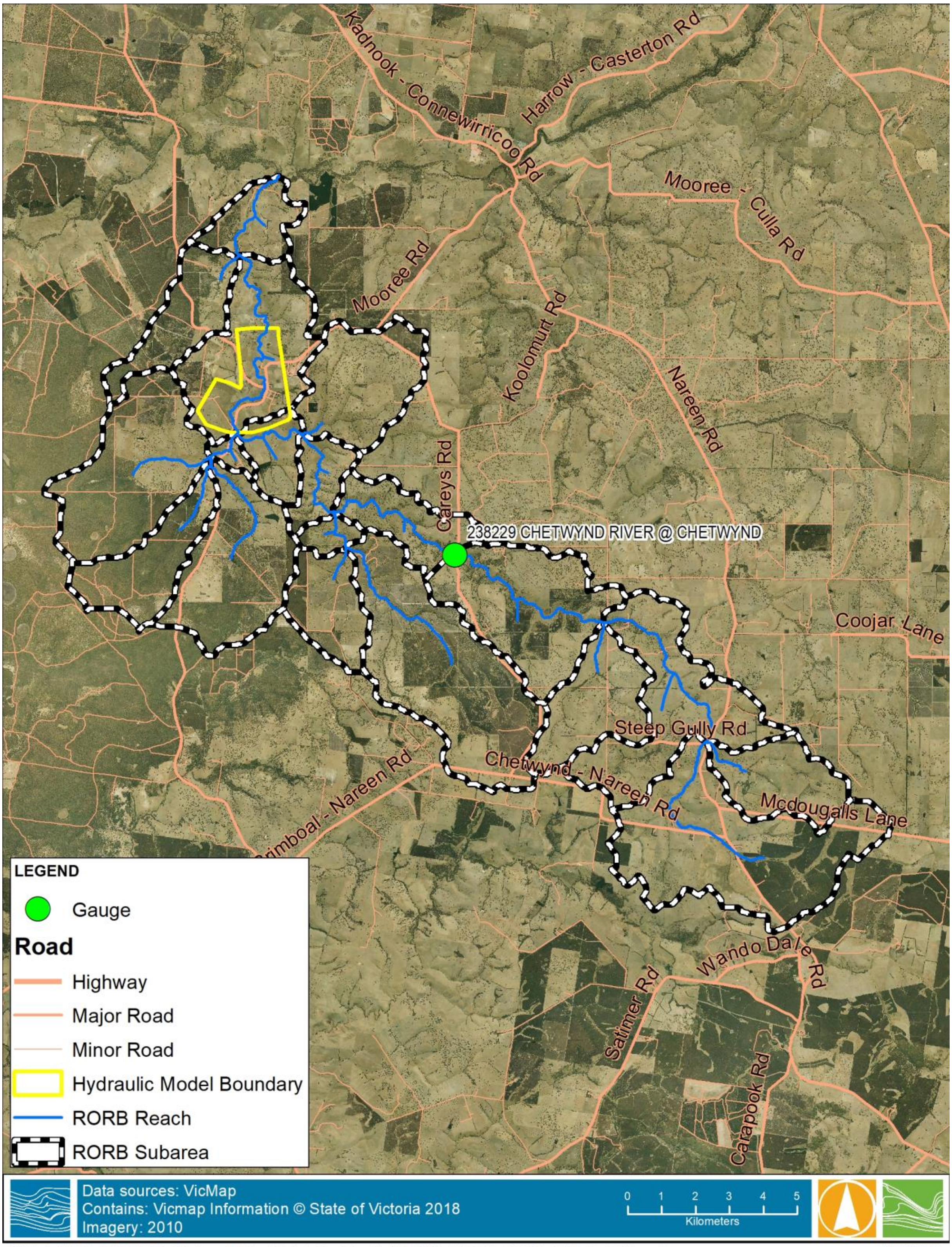

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FIGURE 2-1 RORB MODEL SUB-AREAS AND REACHES

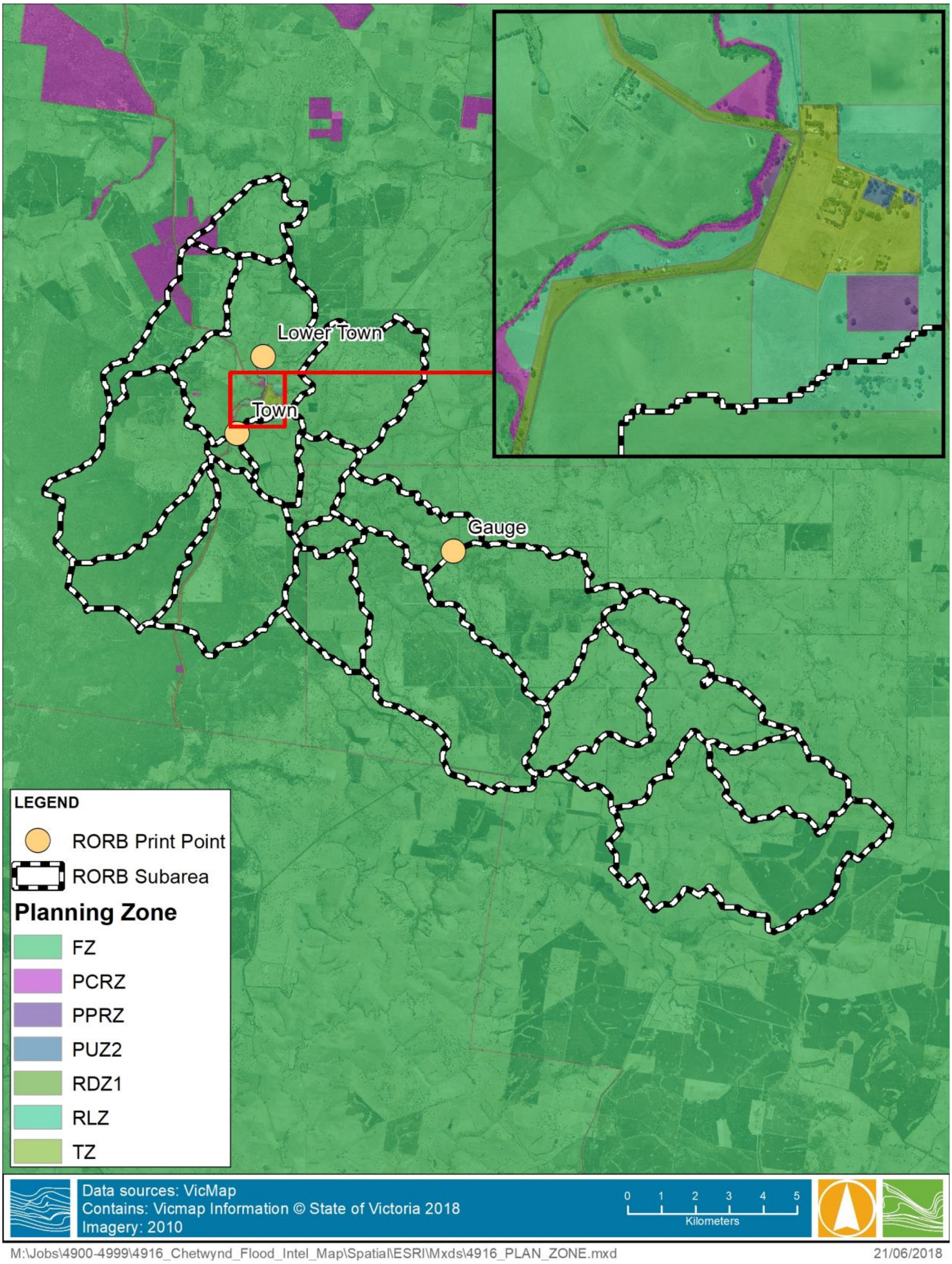

FIGURE 2-2 PLANNING ZONES (TO DETERMINE FRACTION IMPERVIOUS)

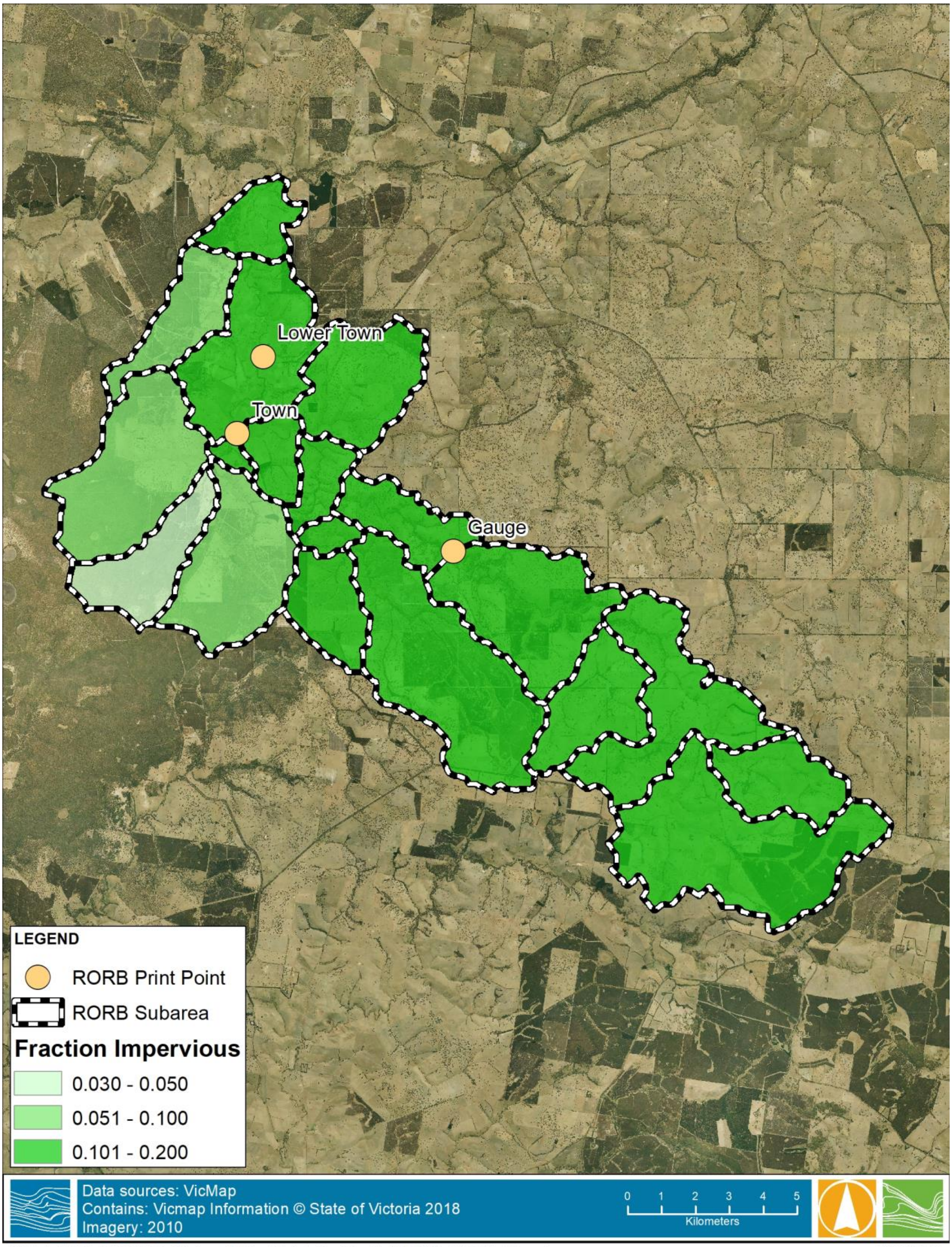

FIGURE 2-3 FRACTION IMPERVIOUS VALUES

2.1.1.3 Rainfall Depth

Rainfall depths for the Chetwynd catchment were determined using the latest Australian Rainfall and Runoff (2016) recommendations. Areal reduction factors and temporal patterns were sourced from the ARR Data Hub[1], while the intensity frequency duration (IFD) rainfall depths were sourced from the Bureau of Meteorology (BoM) online IFD tool[2]. Both data sets were based on the coordinates of the catchment centroid.

Rainfall depths for rare events (rarer than 0.5% AEP) are only supplied for storm durations greater than 24 hours. Therefore, the rainfall depths for short durations for these rare events were extrapolated using the growth factors from the infrequent events.

2.1.1.4 Losses

Losses for the Chetwynd catchment RORB model were initially determined using ARR2016 Book 5, Chapter 3 methods[3]. This included both mapped regional estimates and equation-based estimates. The loss values were then calibrated following the procedure outlined in Section 2.1.2.

The Chetwynd catchment sits within the ARR2016 Region 3 as shown in Figure 2-4.

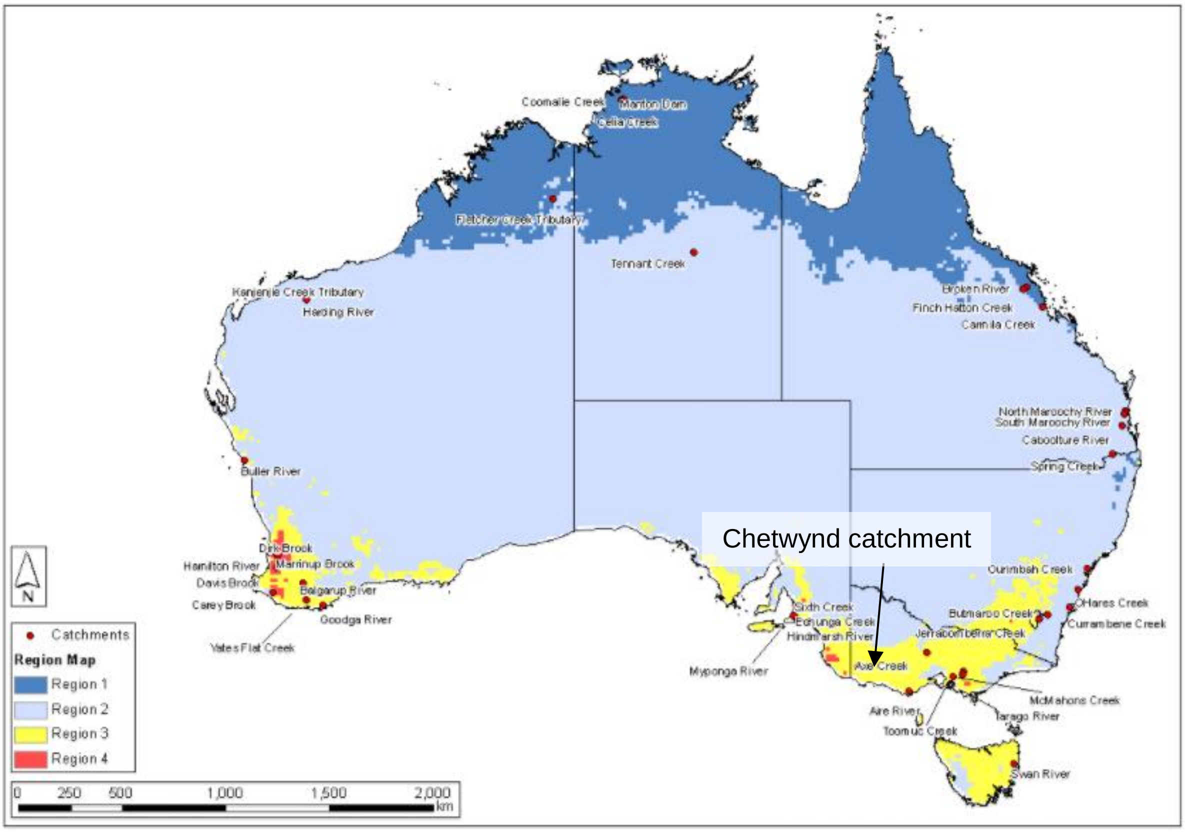

FIGURE 2-4 REGIONS ADOPTED FOR LOSS PREDICTION EQUATIONS

1 http://data.arr-software.org/
2 http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016
3 http://arr.ga.gov.au/arr-guideline

The equation-based loss formula are provided below from Book 5 Chapter 3 of ARR2016. IL_s (Storm Initial Loss) and CL (Continuing Loss) equations are outlined below.

$$IL_s = -1.57 * s0_{wrt} + 0.14 * DES_{RAIN_{24HR}} + 18.8$$

$$CL = 0.03 * DES_{RAIN_{24HR}} + 0.06 * SOmax + 5.1$$

Where IL_s is the storm Initial Loss (mm); CL is the Continuing Loss (mm/h); s0_wtr is the soil moisture in the surface store in winter season (mm); DES_RAIN_24HR is the design Rain Intensity (I24,50) (mm); and SO_{max} is the maximum storage of the surface soil layer (mm).

Based on median input values these equations determined an IL_s value of 22.0 mm and a CL of 4.7 mm/hr.

ARR2016, Book 5, Chapter 3, Figure 5.3.18 and Figure 5.3.19 also outline median IL_s and CL values of 30 mm and 6 mm/hr respectively for the Chetwynd catchment, as shown in Figure 2-5 and Figure 2-6.

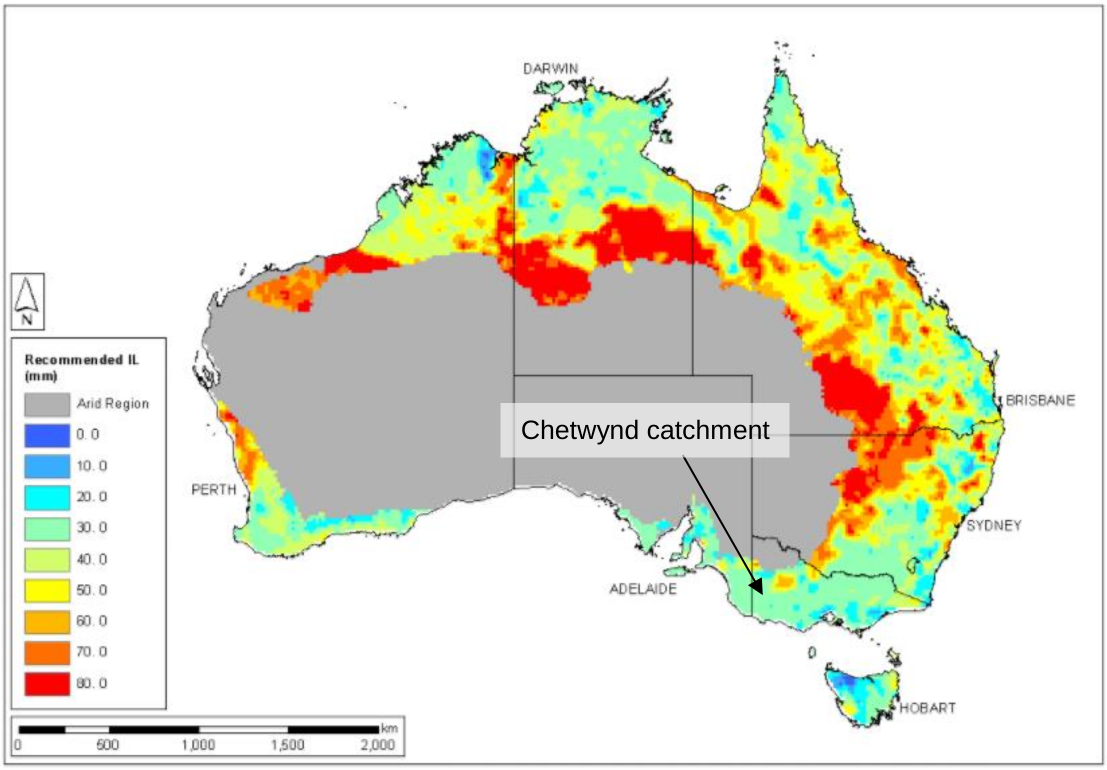

FIGURE 2-5 ARR RECCOMENDED MEDIAN IL_S VALUES

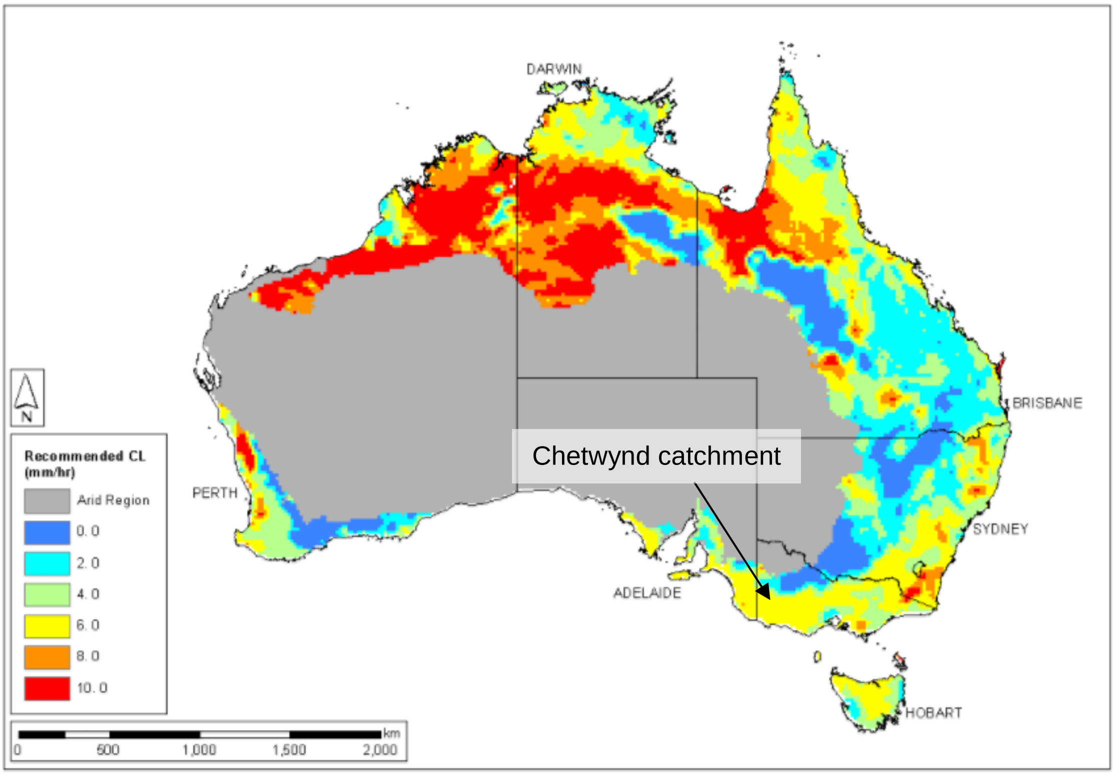

FIGURE 2-6 ARR RECCOMENDED MEDIAN CL VALUES

The rainfall depths from the BoM and the temporal patterns are all based on bursts not complete storms. The IL_s numbers above are for complete storms not bursts. So to adjust the IL_s to be representative of the burst rainfall, the pre-burst rainfall depths from ARR can be subtracted from the IL_s to give an IL_b value to be used in the design estimation. Pre-burst rainfall depth vary by event duration and frequency, and may range between 1 and 4 mm. There are several other RORB models developed as part of previous projects in the region. Several catchments in the same region including Kensington Creek and Bonshaw Creek utilised the ARR2016 guidelines, while previous models of Yarrowee River and Canadian Creek utilised ARR1987 guidelines. The losses adopted for these models are displayed in Table 2-2.

TABLE 2-2 EXISTING LOSS PARAMATERS FOR SIMILAR CATCHMENTS

Model	Initial Loss	Continuing Loss
Casterton Flood Investigation*	20 mm	2 mm/hr
Skipton Flood Investigation*	15.2 mm	2.8 mm/hr
Harrow Flood Investigation	35 mm	5 mm/hr

*These models utilise ARR1987 guidelines.

As can be seen in the above section, the IL and CL values can vary dramatically depending on the estimation method adopted. The IL and CL values were tested in RORB, with peak flows validated to flood frequency analysis peak flows at the Chetwynd River at Chetwynd gauge, following the process described in Section 2.1.2.

2.1.1.5 RORB Kc

Kc is the primary model routing parameter within RORB, dictating attenuation along model reaches. In gauged catchments the Kc value is one of the major parameters used to calibrate the RORB model, varying peak flow and timing. There are several different equation-based estimates of Kc available for Victoria, these are outlined in Table 2-3.

TABLE 2-3 EQUATION BASED KC ESTIMATES

Description	Equation	Kc estimate
Victoria (Mean Annual Rainfall <800mm)	$kc = 0.49 * A^{0.65}$	14.74
Victorian based data (Pearse et al, 2002)	$kc = 1.25 * \mathrm{D_{av}}$	27.87
Australian based data (Dyer, 1994)	$kc = 1.14 * \mathrm{D_{av}}$	25.42
Australian based data (Yu, 1989)	$kc = 0.96 * \mathrm{D_{av}}$	21.41

A = Area (km²); D_{av} = Average reach distance (km)

The final Kc parameter was verified through comparison to flood frequency analysis peak flows (discussed in Section 2.1.2), and a value of 20.0 was adopted. From Table 2-3 it is evident that this is a reasonable value as it falls within the range of calculated Kc estimates.

2.1.2 RORB Model Parameter Verification Process

As the Chetwynd catchment has a streamflow gauge located midway in the catchment with a reasonable history of data, a verification process of the RORB design flows was undertaken. The Chetwynd River at Chetwynd (238229) gauge is shown in Figure 2-1.

To verify the RORB design flows a flood frequency analysis of the annual peak flow series from the Chetwynd River at Chetwynd was completed. To complete the flood frequency analysis the gauge details were reviewed to ensure the gauge record was reliable.

2.1.2.1 Gauge Reliability

The streamflow gauge is currently located immediately downstream of Careys Road and has a weir structure for measuring the flow. The weir structure has changed over time, summarised in Table 2-4.

TABLE 2-4 CHETWYND RIVER AT CHETWYND (238229) GAUGE HISTORY

Gauge Weir Structure Type	Start Date	End Date
Sheet Piling Weir	March 1967	March 1977
Concrete Weir	March 1977	February 1984
Measuring Weir	February 1984	September 2016

These changes have resulted in very different stage-discharge curves for the monitoring site. Figure 2-7 shows all stage-discharge curves throughout the life of the gauge. Figure 2-8 shows the stage-discharge curve just prior to September 2016, when the gauge was destroyed during the flood. Figure 2-9 shows the most recent stage-discharge curve developed after the gauge was repaired. As shown the most recent rating-curve has not had enough gauging events to establish a reliable rating curve.

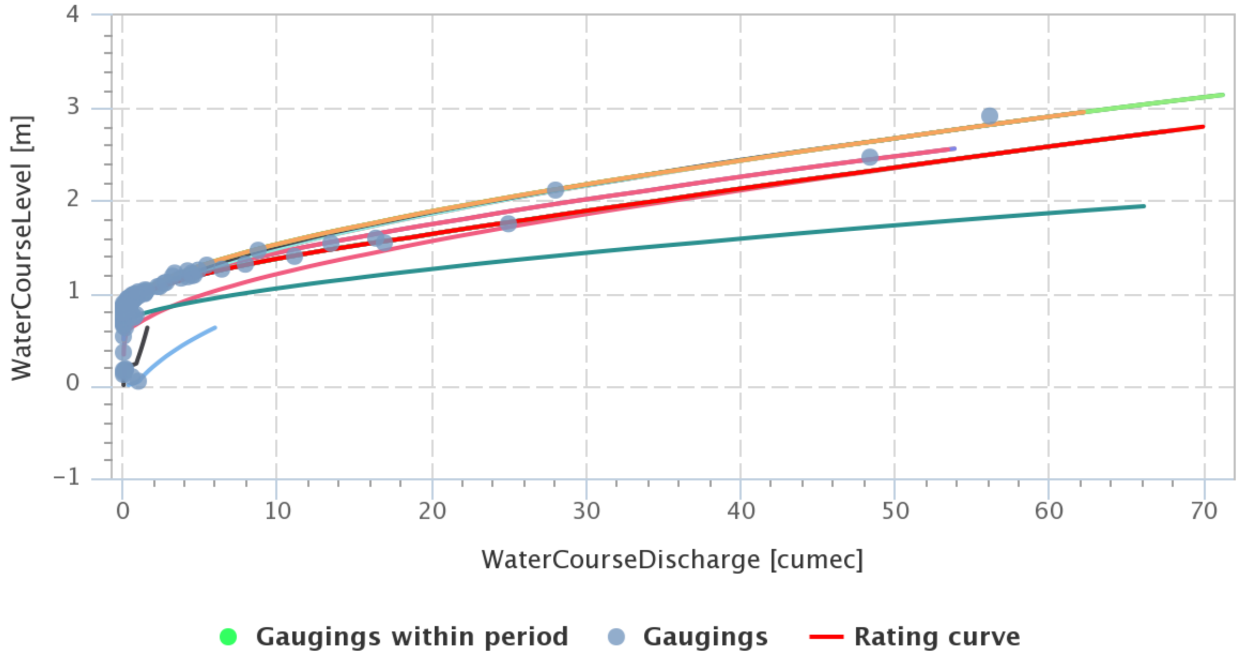

FIGURE 2-7 FULL HISTORY STAGE DISCHARGE CURVE

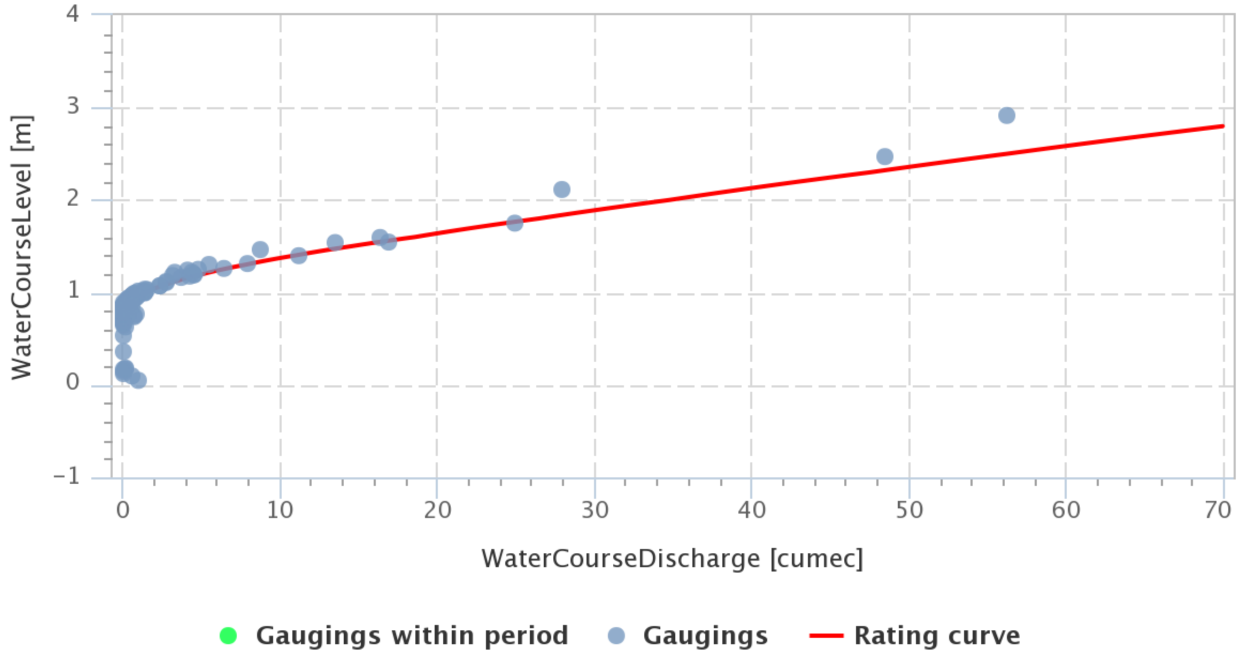

FIGURE 2-8 PRE-SEPTEMBER 2016 STAGE DISCHARGE CURVE

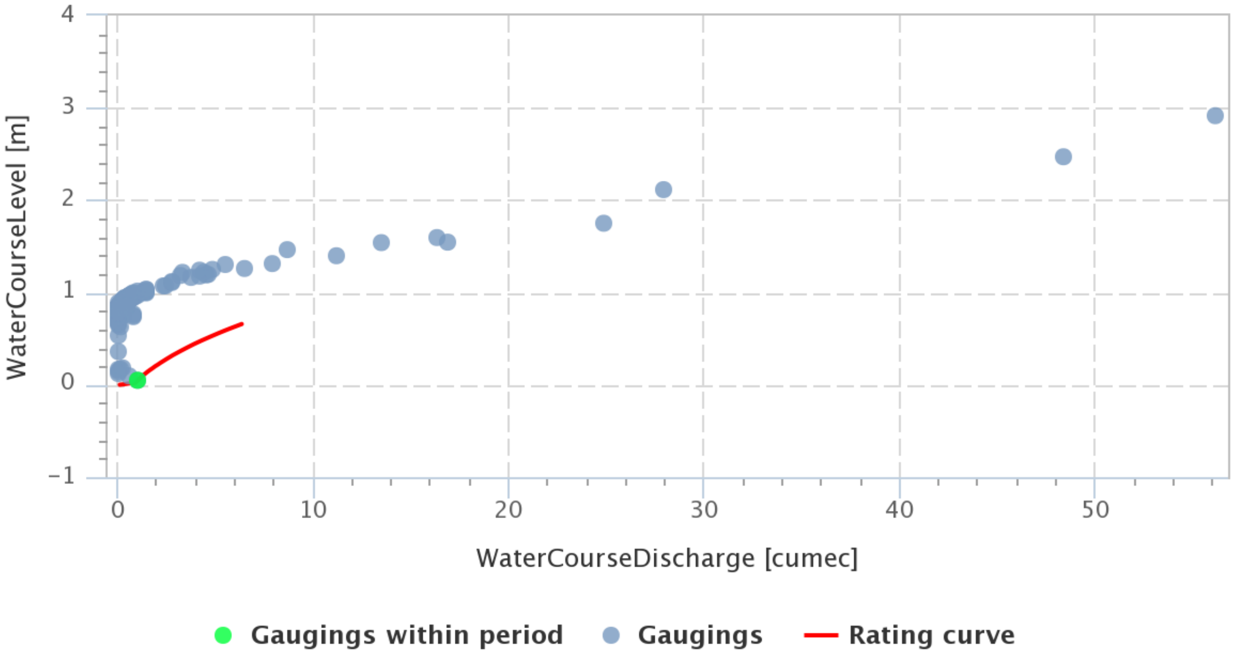

FIGURE 2-9 POST-SEPTEMBER 2016 STAGE DISCHARGE CURVE

The stage-discharge curve plots above show that the largest gauging event was for a flow of around 55 m^3/s, with a water level just below 3 m on the gauge. There is therefore significant uncertainty in any flow estimates in the gauge record beyond 55 m^3/s, and the probability assigned to design flows in excess of this flow rate in the flood frequency analysis is also likely to be highly uncertain.

As the gauge data has a level of uncertainty, LiDAR topography was used to investigate the likely flood behaviour at the gauge location. Figure 2-10 shows the topography near to the gauge location and identifies the raised road that constricts flood flow upstream of the gauge, and shows a small waterway flowing into Chetwynd River immediately downstream of the bridge. Figure 2-11 shows a photo of the gauge location from Careys Road. Figure 2-12 and Figure 2-13 shown the elevation profiles at the gauge location, showing the flat water profile upstream of the weir at around 154.5 m AHD, and the banks of the river set at around 156 to 156.5 m AHD. At levels above 156 m AHD flood water is likely to break out of bank, this is only 1.5 m above the weir crest, so it is likely that water is out of bank at relatively low flows. This ability for the rating curve to accurately predict floodplain flow is uncertain, so this topographic investigation further highlights the uncertainty in the reliability of the streamflow gauge estimates during large flood events.

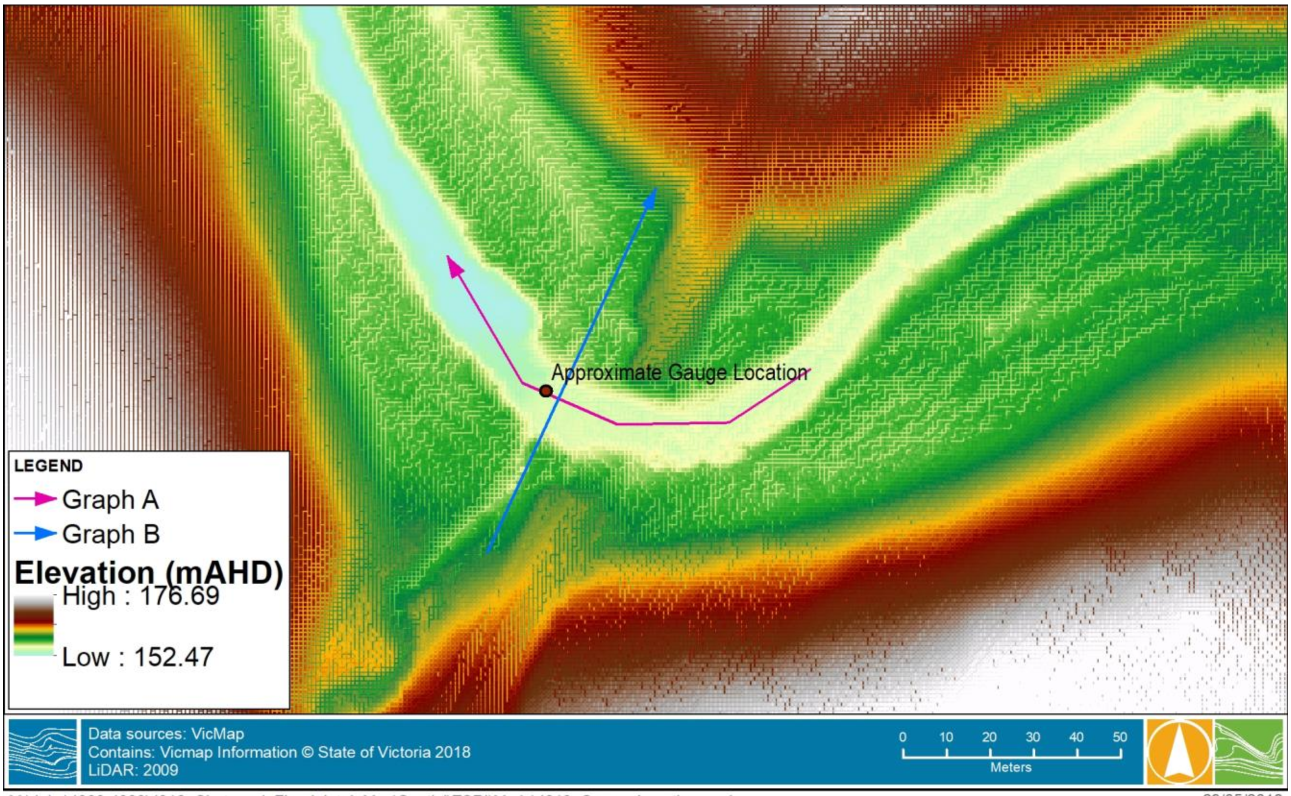

FIGURE 2-10 TOPOGRAPHY NEAR THE GAUGE LOCATION

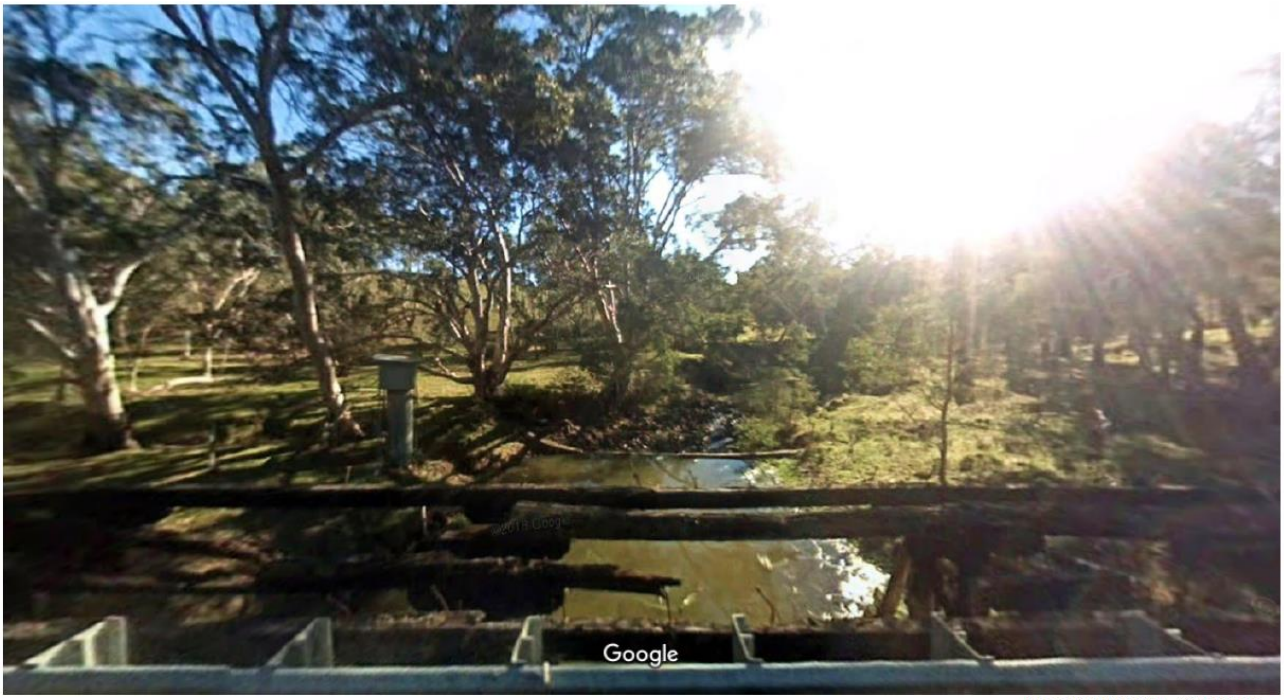

FIGURE 2-11 GAUGE LOCATION (MAY 2008)

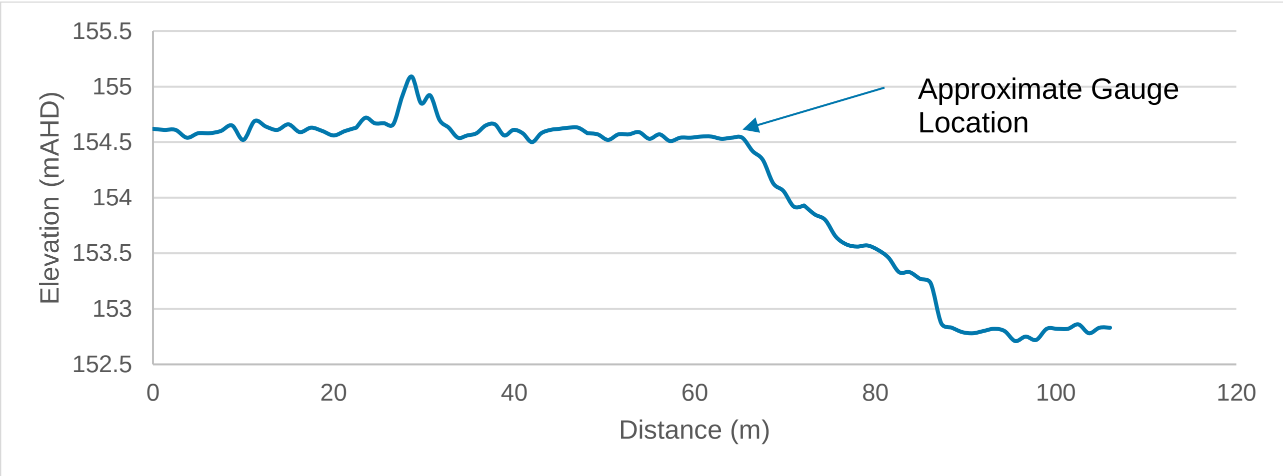

FIGURE 2-12 GRAPH A – RIVER PROFILE

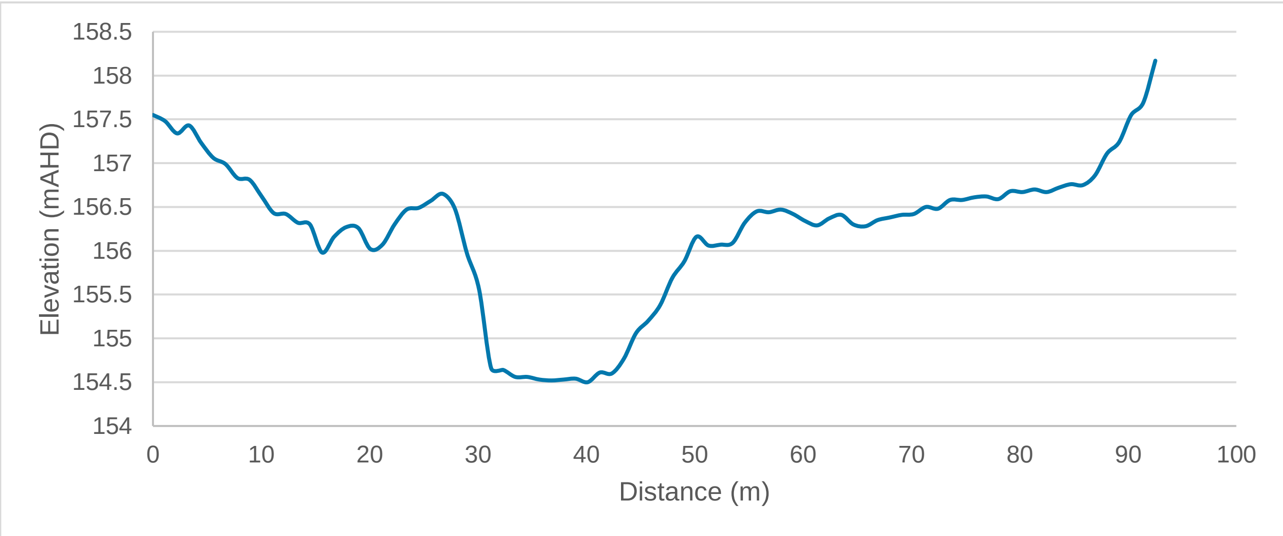

FIGURE 2-13 GRAPH B – FLOODPLAIN PROFILE

2.1.2.2 Flood Frequency Analysis

A flood frequency analysis was undertaken using the annual series of peak flows from the Chetwynd River at Chetwynd gauge for the period 1967 to 2016. A flood frequency analysis uses the gauge flows and fits them to a statistical model to assign a probability to a given flow rate. The widely accepted Log Pearson III statistical distribution model was adopted for this analysis.

As described above, the gauge record is uncertain at flows above 55 m^3/s. As such the flood frequency analysis was only considered reliable below this flow rate, with the RORB modelling design flows considered more reliable for larger flows. Therefore, the RORB modelling was verified to the 20% and 10% AEP (5 and 10 year ARI) peak flows from the flood frequency analysis, and the RORB flows adopted for the rarer events.

Figure 2-14 provides the results of the flood frequency analysis.

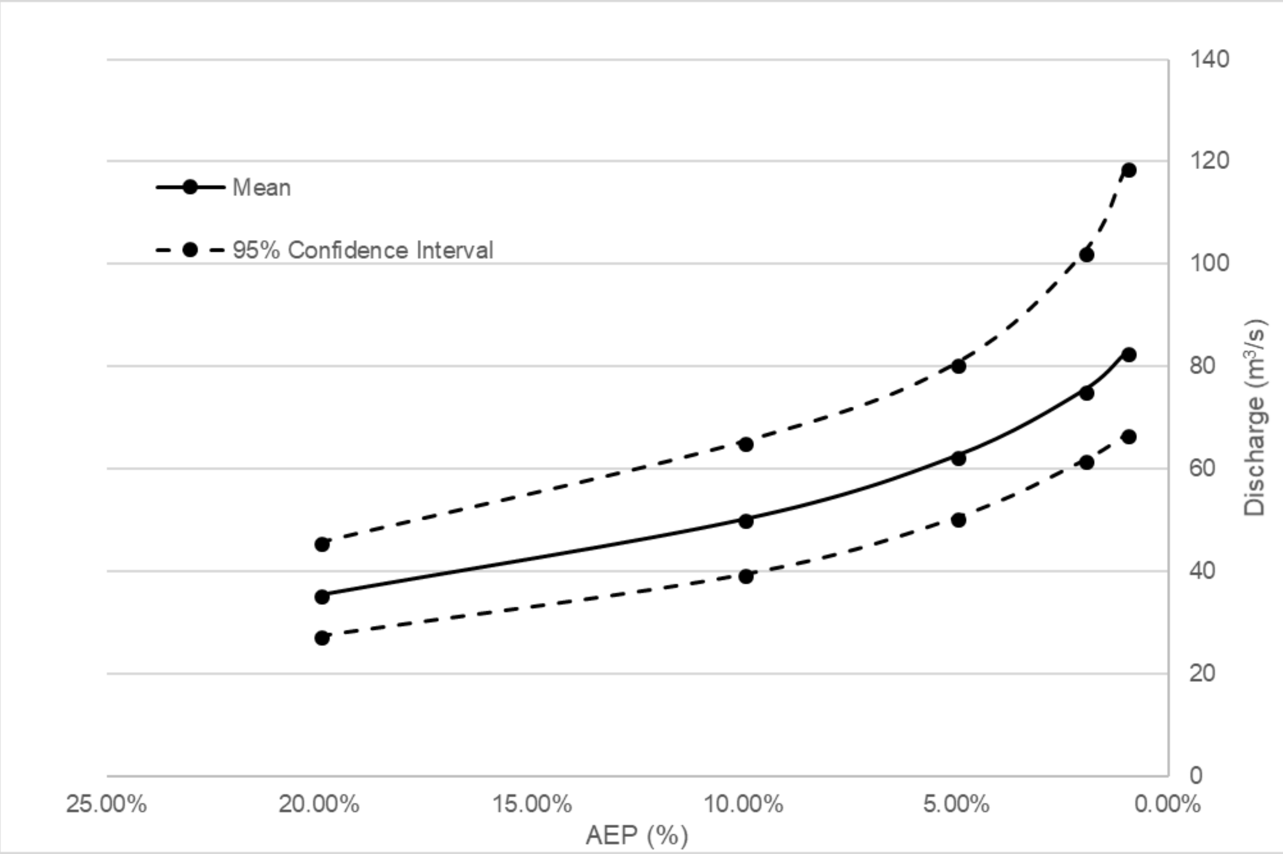

FIGURE 2-14 FLOOD FREQUENCY ANALYSIS RESULTS (1967 – 2016) (AT GAUGE)

2.1.2.3 RORB Validation Process

Given the large range of possible rainfall loss values and possible Kc values, the RORB model was run for design scenarios and the peak flow at the Chetwynd River at Chetwynd gauge were compared to the flood frequency analysis. As discussed above the aim was to vary the RORB parameters until a match was achieved for the 20% and 10% AEP events.

RORB was run for design storms using both the Monte Carlo method, sampling from temporal patterns and the initial loss distribution as described in ARR2016. RORB was also run for design storms using the Ensemble method, also described in ARRR2016.

The initial RORB design storm runs used the loss parameters provided by the ARR Data Hub and the Kc value estimated using the Pearse et. al. equation. These values were then varied until a good match of peak flow was achieved with the flood frequency analysis. Table 2-5 shows the initial values and final calibrated RORB loss and Kc values.

TABLE 2-5 CALIBRATED RORB PARAMETERS

Parameter	Initial Loss (mm)	Continuing Loss (mm/h)	Kc
Data Hub Values	22.0	4.7	27.87
Calibrated Parameters	11.0	2.0	20.00

Figure 2-15 shows the peak flow results from the flood frequency analysis along with both the initial and calibrated parameter RORB peak flow results at the Chetwynd River at Chetwynd gauge. It is evident that using the calibrated RORB parameters with the Monte Carlo and Ensemble approaches both produce very similar peak flows to the smaller events of the flood frequency analysis, however fail to match the large events. As discussed previously, there is low confidence in the streamflow gauge rating curve at high flows, and the flood frequency analysis is unreliable for large floods.

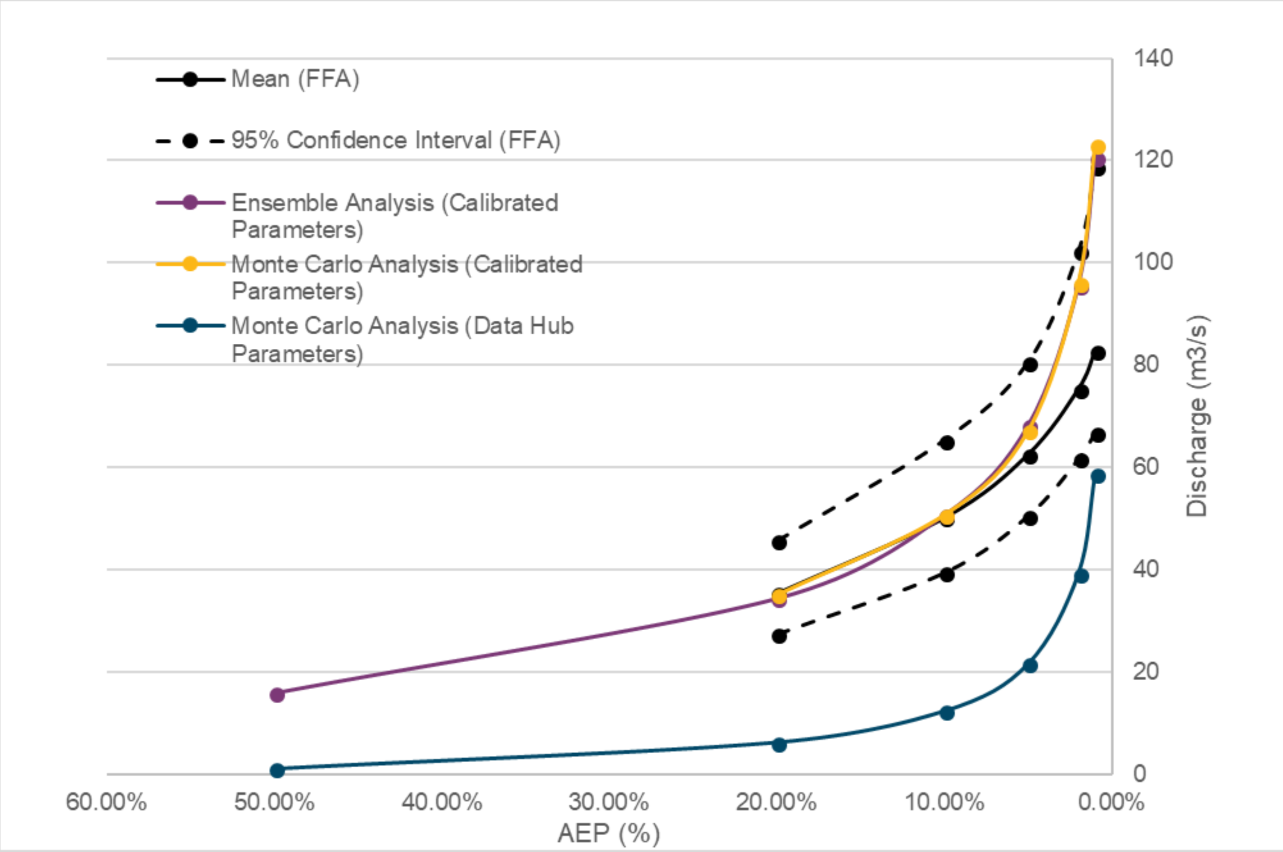

FIGURE 2-15 CALIBRATION RESULTS COMPARED TO FLOOD FREQUENCE ANALYSIS (AT GAUGE)

The similarities between the Monte Carlo and Ensemble RORB peak flows provide confidence in the RORB model results, and the calibrated RORB parameters were adopted for design modelling in the hydraulic model.

2.1.2.4 Regional Flood Frequency Estimation Validation

To further verify the RORB peak flow results, the ARR Regional Flood Frequency Estimation Model (ARFFE) was used to calculate a typical discharge for the catchment to the gauge location. This is accompanied by confidence intervals at 5% to 95%. ARFFE peak flow estimates are shown in Table 2-6, Figure 2-16.

The ARFFE model determined peak flows larger than the RORB modelling for all design events, with a 1% AEP peak flow of 157 m^3/s compared to a RORB 1% AEP Monte Carlo peak flow of 123 m^3/s. The RORB 1% AEP Monte Carlo peak flow was closer to the ARFFE model than the flood frequency analysis, which estimated a flow of 80 m^3/s.

TABLE 2-6 ARR REGIONAL FLOOD FREQUENCY ESTIMATION MODEL RESULTS (AT GAUGE)

AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	18.5	6.15	55.1
20	29.9	10.5	84.5
10	38.6	13.6	110
5	47.8	16.6	139
2	61.1	20.4	185
1	72.0	23.3	225

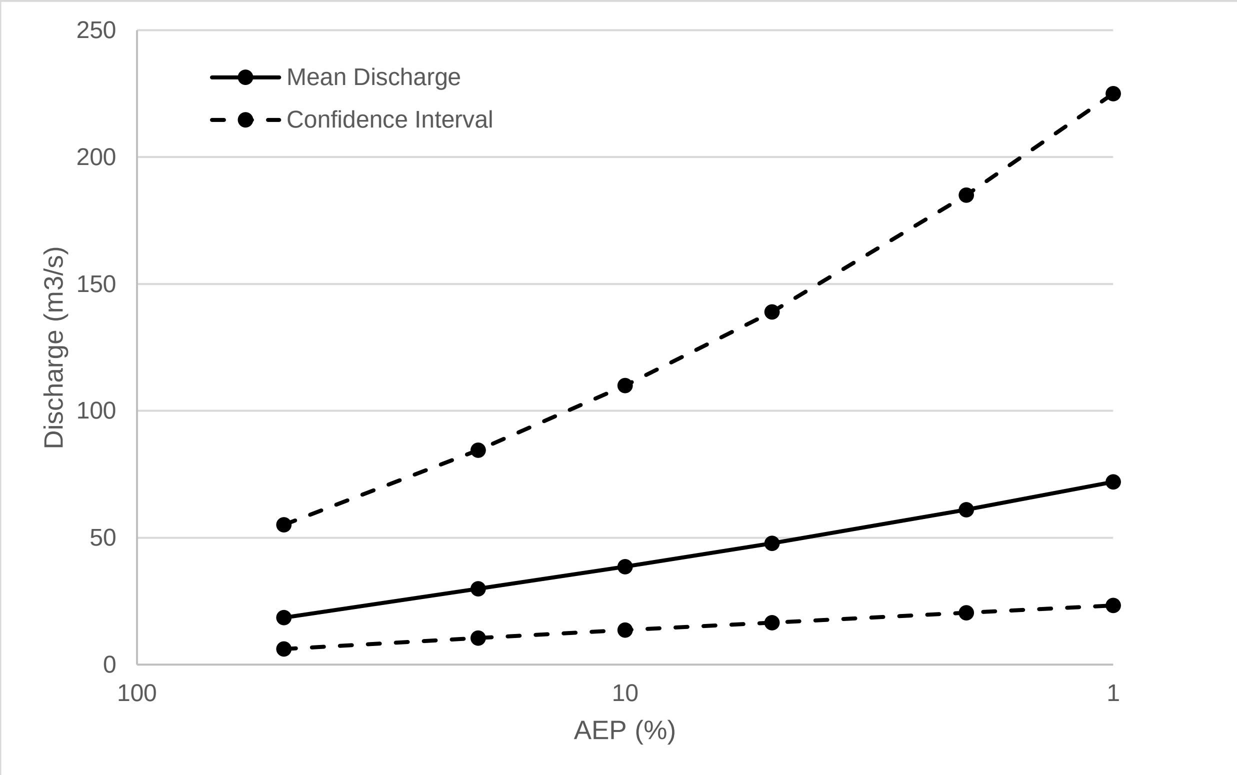

FIGURE 2-16 ARR REGIONAL FLOOD FREQUENCY ESTIMATION MODEL RESULTS (AT GAUGE)

2.1.3 Design Modelling

As discussed above the RORB model was run for design storms using both the Monte Carlo and Ensemble approaches as described in ARR2016, using the validated model parameters (Kc=20, IL=11 mm, CL=2 mm/hr).

The RORB modelling showed that the 6 and 12 hour storm durations were critical across the range of design events, producing the peak flow in the Chetwynd River at the Chetwynd township. The peak design flows adopted for each design event in the Chetwynd River at Chetwynd are provided in Table 2-7. The 6 and 12 hour storm duration hydrographs were both selected for each design event and used as inflows to the hydraulic model and are shown in Figure 2-17 and Figure 2-18. The hydraulic model used the RORB hydrograph upstream of the township as the main inflow boundary, with the sub-area runoff over the town added as an inflow to the hydraulic model at a point located in the middle of the sub-area directly into the waterway.

TABLE 2-7 ADOPTED DESIGN PEAK FLOWS FOR CHETWYND RIVER AT CHETWYND TOWNSHIP AND CHETWYND GAUGE LOCATION

Location	Discharge (m^3/s)						
	50%	20%	10%	5%	2%	1%	0.50%
Town	32	77	101	142	207	273	340
Gauge	14	35	51	67	96	123	152

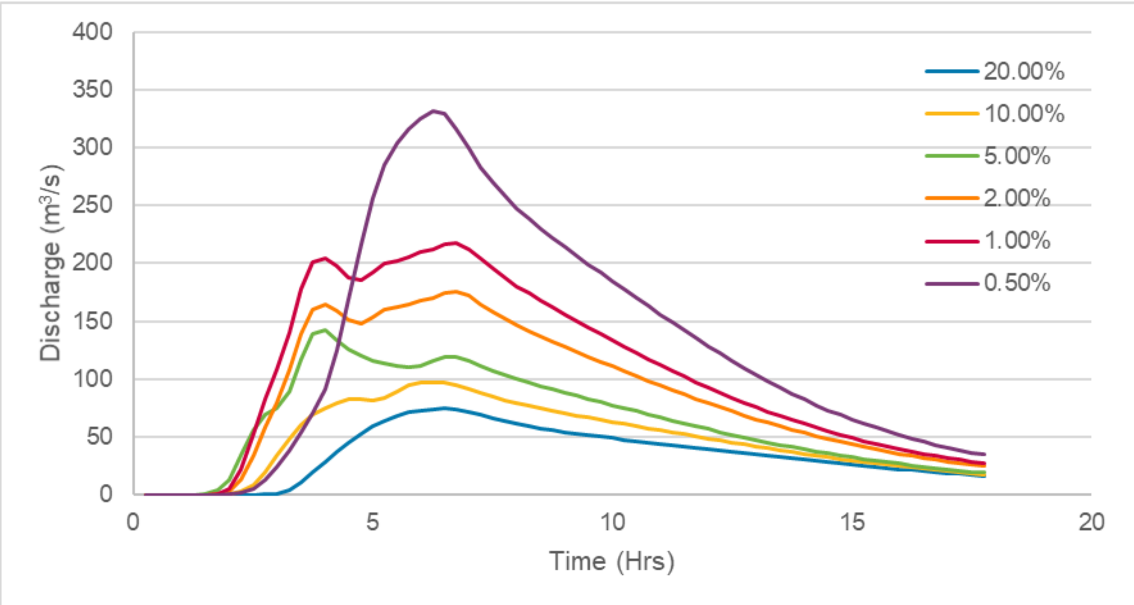

FIGURE 2-17 DISCHARGE AT TOWN FOR ALL AEPS (6 HR DURATION)

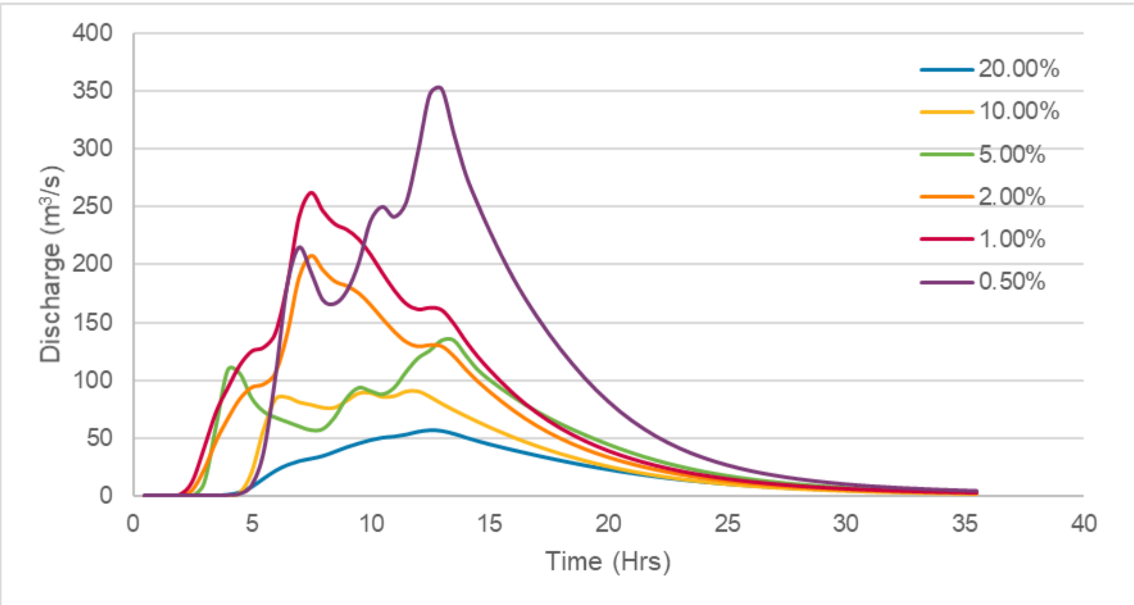

FIGURE 2-18 DISCHARGE AT TOWN FOR ALL AEPS (12 HR DURATION)

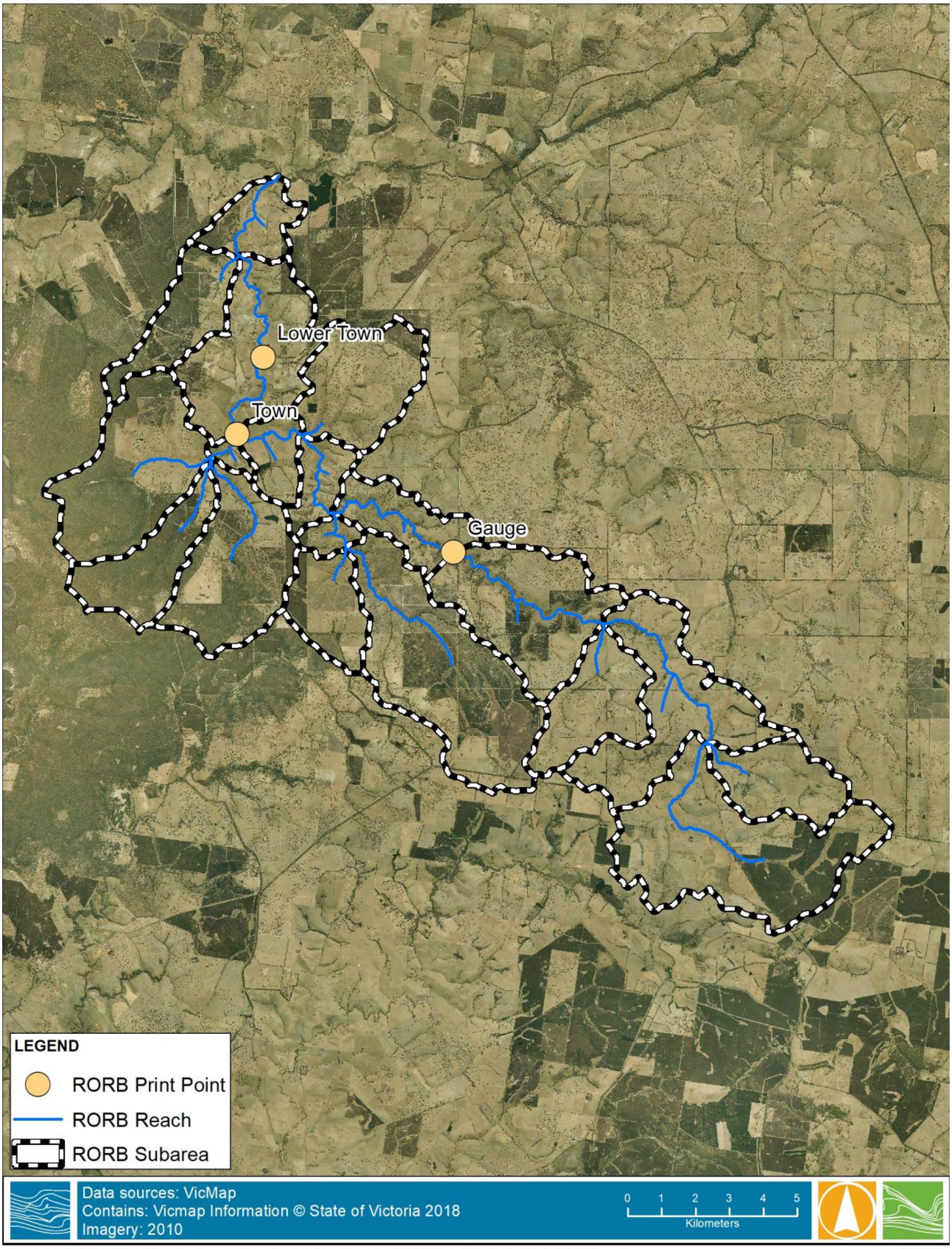

FIGURE 2-19 CHETWYND HYDROGRAPH PRINT POINTS

2.2 Hydraulics

The flood modelling and mapping area covers the Chetwynd River floodplain from upstream of the bridge crossing of Casterton-Edenhope Road south of town through to a location roughly 2 km north of town. Figure 2-20 shows the flood model area and inflow boundary locations.

A detailed 2D hydraulic modelling approach was adopted for this study. Given the small mapping area, a 3x3 m grid resolution was adopted, which was fine enough to represent the river in 2D, which is typically 15 m wide. The hydraulic modelling suite TUFLOW was utilised in this study. TUFLOW is a widely used hydraulic model that is suitable for the analysis of overland flows in urban and rural areas. TUFLOW has four main inputs:

- Topography and drainage infrastructure data;
- Inflow data (based on catchment hydrology);
- Roughness; and,
- Boundary conditions.

This section of the report defines the scope of the hydraulic analysis, details the hydraulic model construction, and discusses the hydraulic model results.

The design events modelled included the 20%, 10%, 5%, 2%, 1% and 0.5% AEP events.

2.2.1 Boundary Conditions

2.2.1.1 Model Inflows

The TUFLOW model contained two inflow boundaries, with the flows extracted from the RORB model (as summarised in Section 2.1). The main inflow boundary for the Chetwynd River was located upstream of the Casterton-Edenhope road crossing to the south of town. Another minor inflow location was used to introduce the local runoff of the catchment through the model area downstream of the upstream boundary, and was located downstream of the river bend 300 m to the north of Howletts Lane. Figure 2-20 shows the model inflow locations.

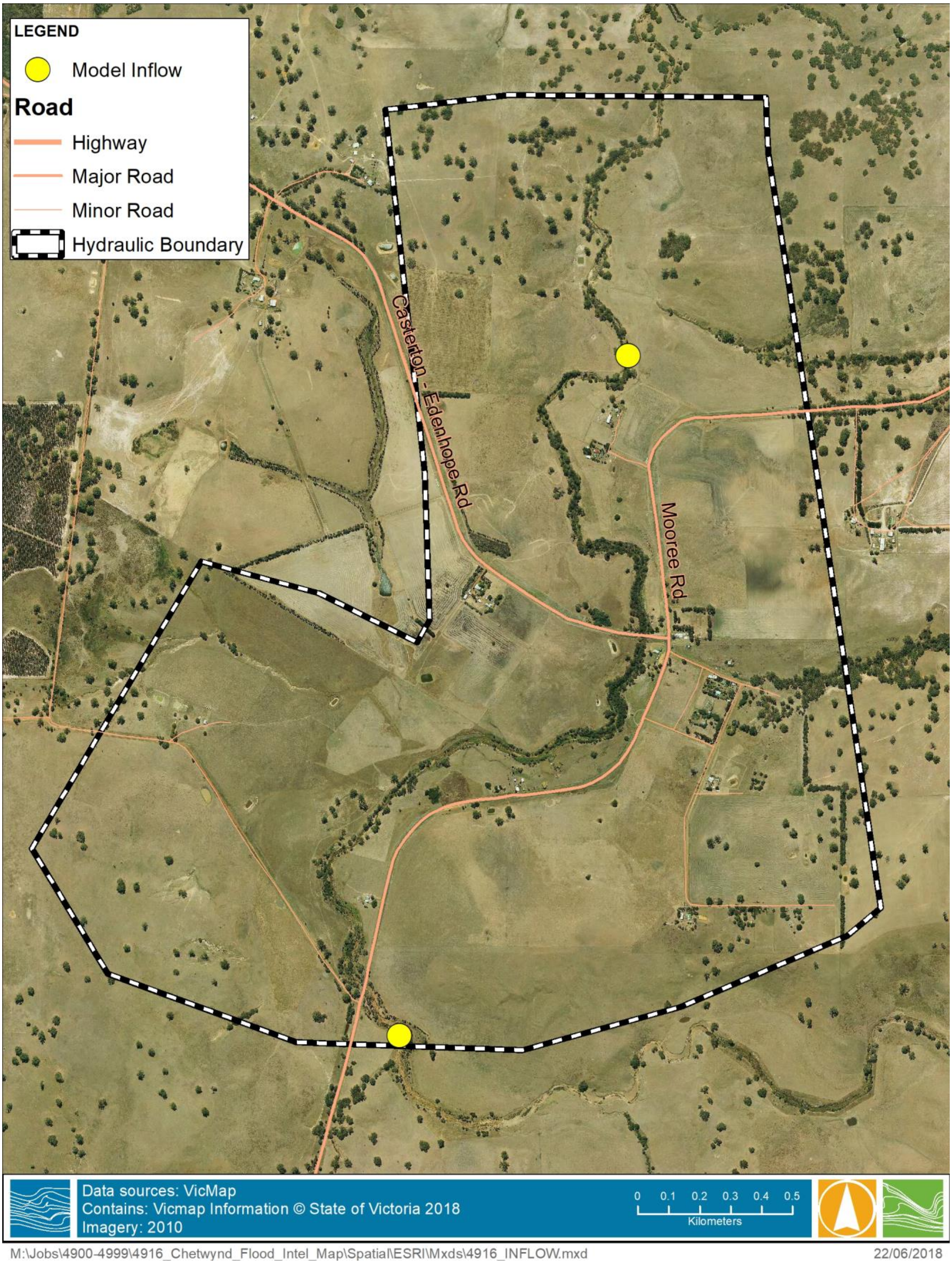

FIGURE 2-20 MODEL DOMAIN AND INFLOW LOCATIONS

2.2.1.2 Model Outflows

The hydraulic model had one hydraulic outflow boundary at the downstream end of the model. The outflow was modelled as a height/discharge boundary (HQ), this boundary allows water to exit the model based on a stage-discharge curve generated by TUFLOW which uses the model topography, roughness and surface slope to calculate a discharge for various heights.

2.2.2 Grid Extent and Resolution

The model topography was based on LiDAR data captured in 2009 through the 2009-10 Victorian State Wide Rivers LiDAR Project Glenelg Hopkins CMA. The LiDAR dataset was provided as a 1x1 m grid resolution Digital Elevation Model (DEM), which was resampled to a 3x3 m grid resolution for input into the hydraulic model, as shown in Figure 2-21.

A key consideration in determining the grid size was the trade-off between accurate representation of the streamflow paths and reasonable model run times. Although smaller grid sizes can provide higher resolution results, they also significantly increase the run times. A 3x3 m grid was found to represent the channel in sufficient detail along with other hydraulic features of the floodplain.

Bridges were modelled simply in 2D only, with the 2D grid representing the bridge opening through the structures.

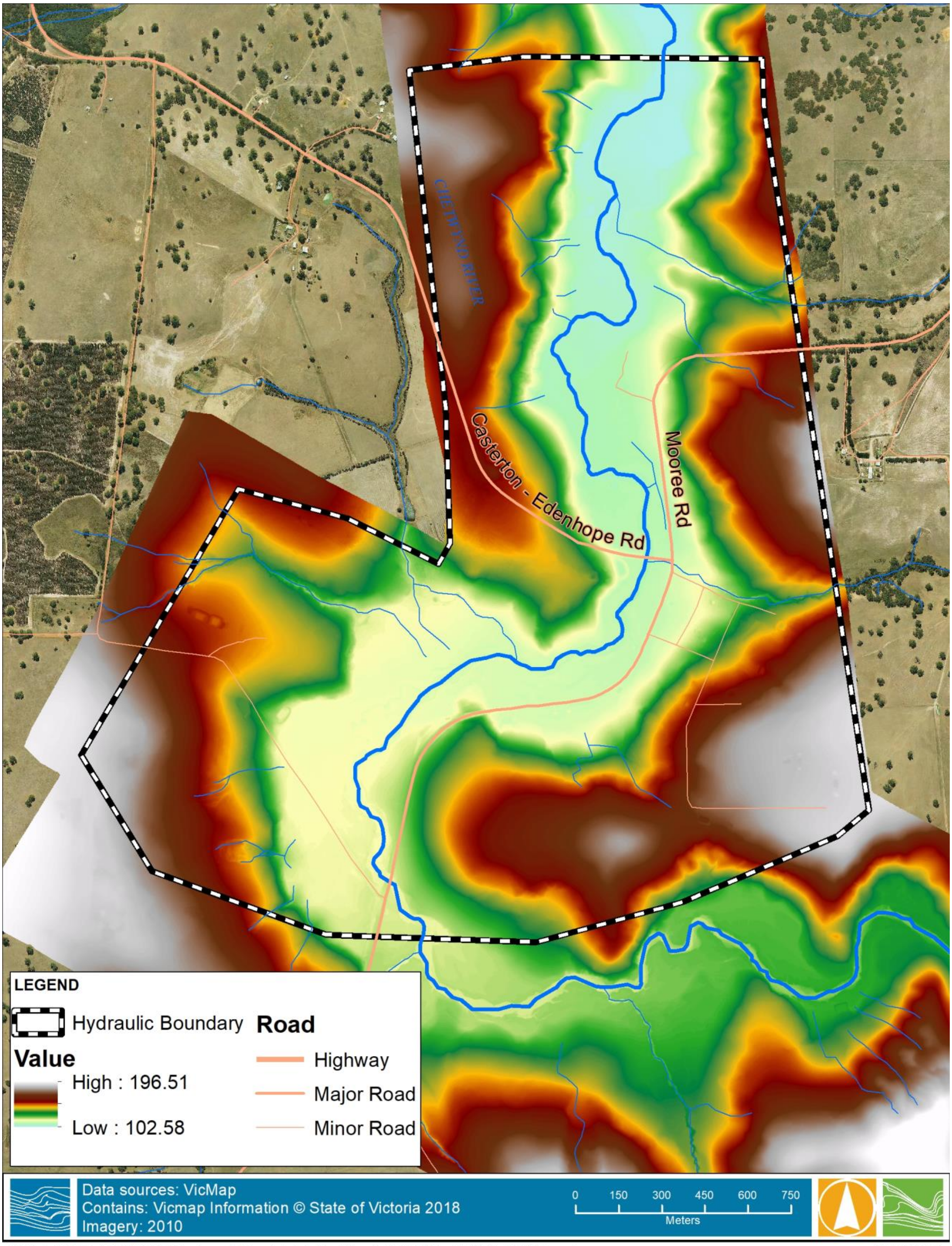

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FIGURE 2-21 DIGITAL ELEVATION MODEL

2.2.3 Hydraulic Roughness

Hydraulic model roughness is a measure of the floodplains resistance to flow. A high roughness representative of dense vegetation will result in lower velocities and higher water levels, with a low roughness representative of a paved road resulting in higher velocities and lower water levels. Table 2-8 outlines standard Manning's 'n' roughness values from the VicRoads Road Design Guidelines, these roughness values were adopted in the hydraulic model.

Land use was classified over the model area as shown in Figure 2-22 using VicMap planning layers and aerial imagery.

TABLE 2-8 MANNINGS 'N' ROUGHNESS VALUES FROM VICROADS ROAD DESIGN GUIDELINES

Land Use	Manning's 'n'
Residential - Urban (higher density) - when building footprints and remainder of parcel are modelled together (with one roughness value)	0.350
Residential - Rural (lower density) - when building footprints and remainder of parcel are modelled together (with one roughness value)	0.150
Residential Footprint - Urban (higher density) - when building footprints are modelled separately to remainder of parcel	0.400
Residential - Urban (higher density) - when building footprints are modelled separately to remainder of parcel	0.100
Residential Footprint - Rural (lower density) - when building footprints are modelled separately to remainder of parcel	0.400
Residential - Rural (lower density) - when building footprints are modelled separately to remainder of parcel	0.050
Industrial/Commercial or large buildings on site	0.300
Significant Drainage Easement (regardless of zone type)	0.050
Open Space or Waterway - minimal vegetation	0.040
Open Space or Waterway - moderate vegetation	0.060
Open Space or Waterway - heavy vegetation	0.090
Open water (with reedy vegetation)	0.060
Open water (with submerged vegetation)	0.020
Car park/pavement/wide driveways/roads	0.020
Railway line	0.125
Concrete lined channels	0.016

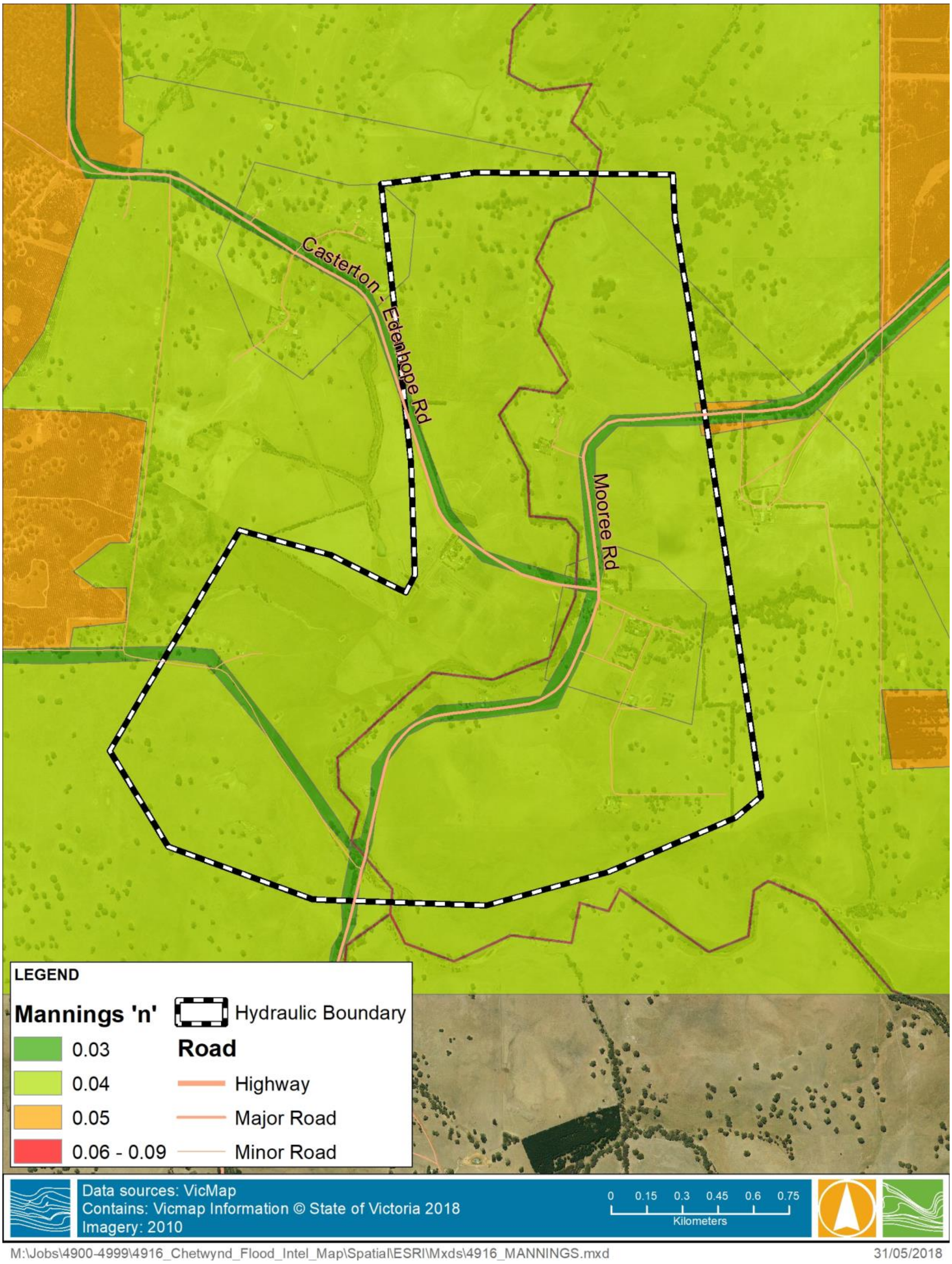


FIGURE 2-22 MANNINGS N ROUGHNESS VALUES

3 FLOOD MAPPING AND INTELLIGENCE

Hydraulic modelling was undertaken for the 6 and 12 hour duration events for the 20%, 10%, 5%, 2%, 1% and 0.5% AEP events. Flood inundation extents for all events are shown in Figure 3-2, with detailed mapping provided in Appendix A. Detailed maps of depth, velocity and hazard (measured as the product of velocity and depth) from Appendix A and property inundation from Appendix B, were provided as standalone PDF maps.

A property inundation assessment was undertaken to determine the maximum water level across all residential properties within the floodplain of the Chetwynd River. The mapping for this assessment is shown in Appendix B. It is evident that a significant number of properties are inundated in a 1% AEP event, including large sections of Mooree Road.

As a result of the significant inundation to a range of properties, a flood consequence table has been established to allow emergency services and council to quickly understand the likely impacts of flooding and plan accordingly. Table 4-1 describes the key flooding consequences across the study area for each design event, this outlines property inundation and access/egress for properties within the floodplain.

The table was developed to be read from top to bottom, with each subsequent larger magnitude event reporting on the incremental changes in consequences. For example, if the reader wants to understand the consequences of a 2% AEP event, then the flood characteristics should be read for the 20%, 10%, 5% and 2% AEP events in succession. It is also recommended that the reader refer to the standard PDF maps provided with this study.

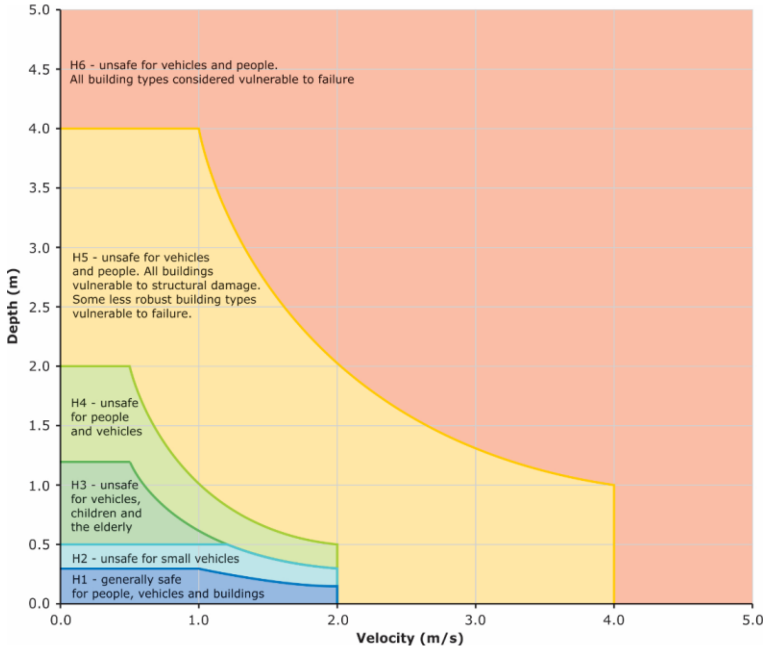
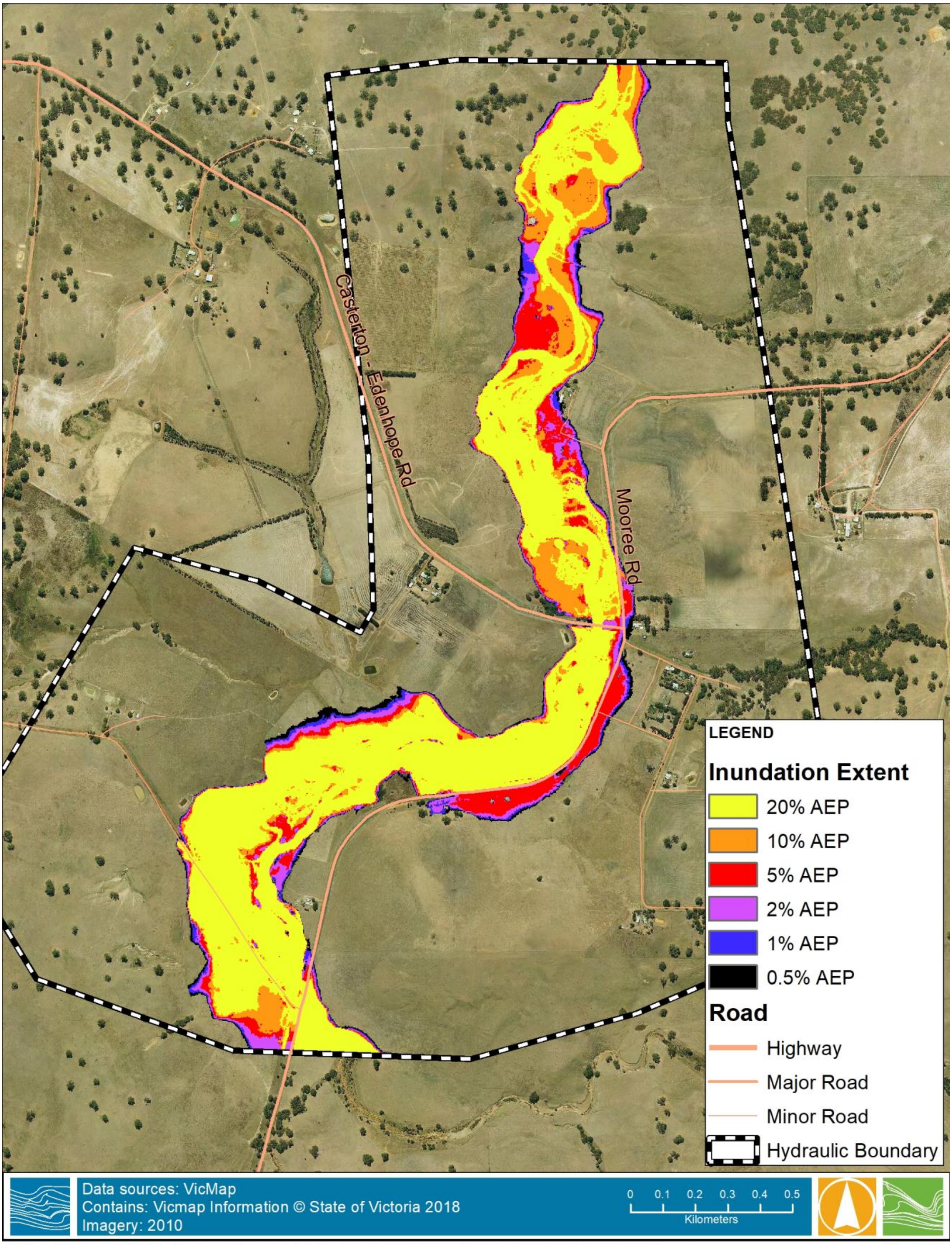


FIGURE 3-1 FLOOD HAZARD CURVES (SMITH ET AL, 2014)

The consequences have been described in terms of depth of inundation, using the following key depth thresholds:

- Depths of 0.5 to 1 m, generally unsafe for vehicles, children and elderly
- Depths of 0.3 to 0.5 m, unsafe for small vehicles
- Depths below 0.3 m, generally safe for vehicles, people and buildings

The reasoning behind these specific depths relates to Australian Rainfall and Runoff Book 6 Chapter 7: Safety Design Criteria, as shown in Figure 3-1 below.



M:\Jobs\4900-4999\4916_Chetwynd_Flood_Intel_Map\Spatial\ESRI\Mxds\4916_INUNDATION_EXTENTS.mxd 1/06/2018

FIGURE 3-2 INUNDATION EXTENTS (ALL AEPS)

TABLE 3-1 SUMMARY OF FLOODING CONSEQUENCES

Flooding Event	Flood Consequences/ Impacts	Key Roadways Inundated – Access and Egress	Actions
20% AEP Rainfall Depth: 36.1mm (6hrs) Flow at Chetwynd Gauge: 35.06m^3/s*	■ Water flowing over road at Chetwynd Cemetery Road ■ Water Flowing over road at Casterton-Edenhope Road at southern bridge crossing ■ Residential Structures inundated at Casterton-Edenhope Road ■ Flood water surface 1.2 m below Casterton-Edenhope bridge deck	■ Chetwynd Cemetery Road and Casterton-Edenhope Road flooded below 0.3 m depth.	■ Monitor rainfall and water levels ■ Preparation of implementation of evacuation plan ■ Issue minor flooding alert pertaining to driving through flood waters and property inundation ■ Place “Water over road” signs for Chetwynd Cemetery Road and Casterton-Edenhope Road
10% AEP Rainfall Depth: 43.7mm (6hrs) Flow at Chetwynd Gauge: 50.78m^3/s*	■ Residential Structures Inundated at Howletts Lane ■ Water flowing over road at Mooree Road ■ Flood water surface 1.06 m below Casterton-Edenhope bridge deck	■ Chetwynd Cemetery Road now flooded between 0.3 and 0.5 m depth. ■ Mooree Road flooded below 0.3 m depth.	■ Place “Water over road” signs for Casterton-Edenhope Road and Mooree Road ■ Place “Road Closed” signs for Chetwynd Cemetery Road
5% AEP Rainfall Depth: 51.9mm (6hrs) Flow at Chetwynd Gauge: 67.22m^3/s*	■ Water Flowing over road at Casterton-Edenhope Road near intersection of Mooree Road ■ Flood water surface 0.93 m below Casterton-Edenhope bridge deck	■ Howletts Lane flooded below 0.3 m depth.	■ Place “Water over road” signs for Howletts Lane

Flooding Event	Flood Consequences/ Impacts	Key Roadways Inundated – Access and Egress	Actions
2% AEP Rainfall Depth: 81.6mm (12hrs) Flow at Chetwynd Gauge: 96.09m³/s*	■ Flood water surface 0.65 m below Casterton-Edenhope bridge deck	■ Chetwynd Cemetery Road now flooded greater than 0.5m depth ■ Mooree Road and Casterton-Edenhope Road now flooded between 0.3 and 0.5 m depth	■ Place "Road Closed" signs for: ■ Mooree Road ■ Casterton-Edenhope Road ■ Emergency services must not attempt access to Chetwynd Cemetery Road
1% AEP Rainfall Depth: 95.0mm (12hrs) Flow at Chetwynd Gauge: 123.15m³/s*	■ Flood water surface 0.41 m below Casterton-Edenhope bridge deck	■ Mooree Road and Casterton-Edenhope Road now flooded above 0.5 m depth ■ Howletts Lane now flooded between 0.3 and 0.5 m depth	■ Place "Road Closed" signs for: ■ Howletts Lane ■ Emergency services must not attempt access to Chetwynd Cemetery Road, Mooree Road or Casterton-Edenhope Road
0.5% AEP Rainfall Depth: 110.0mm (12hrs)^ Rainfall Depth: 140.0mm (24hrs) Flow at Chetwynd Gauge: 152.25m³/s*	■ Flood water surface 0.1 m below Casterton-Edenhope bridge deck	■ No Additional Inundation	■ Emergency services must not attempt access to Chetwynd Cemetery Road, Mooree Road or Casterton-Edenhope Road

*Note that all floods are different, and different rainfall patterns falling on dry or wet catchments may respond differently. The rainfall and streamflow numbers in the above table should be used as a guide to selecting which flood map to use to plan for a flooding emergency.
^Rainfall values for AEPs less than 1% for a 12hr storm have been extrapolated.

APPENDIX A
FLOOD MAPPING – DEPTH, VELOCITY, HAZARD

APPENDIX B
PROPERTY INUNDATION MAPPING

Melbourne

15 Business Park Drive
Notting Hill VIC 3168
Telephone (03) 8526 0800
Fax (03) 9558 9365

Brisbane

Level 3, 43 Peel Street
South Brisbane QLD 4101
Telephone (07) 3105 1460
Fax (07) 3846 5144

Adelaide

1/198 Greenhill Road
Eastwood SA 5063
Telephone (08) 8378 8000
Fax (08) 8357 8988

Perth

Ground Floor
430 Roberts Road
Subiaco WA 6008
Telephone 0438 347 968

Geelong

PO Box 436
Geelong VIC 3220
Telephone 0458 015 664

Gippsland

154 Macleod Street
Bairnsdale VIC 3875
Telephone (03) 5152 5833

Wangaratta

First Floor, 40 Rowan Street
Wangaratta VIC 3677
Telephone (03) 5721 2650

Wimmera

PO Box 584
Stawell VIC 3380
Telephone 0438 510 240

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