TABLE 4-1 IMAGES FROM WIMMERA SITE VISIT

Point of Interest	Image
139 – Cooks Lane Nurrabiel Swamp	
103 – Natimuk – Hamilton Road	

Point of Interest	Image
140 – Toolondo Gun Club Road Red Gum Swamp	
141 – Red Gum Swamp	

Point of Interest	Image
133 – Wonwondah – Toolondo Road Wetland	

Point of Interest	Image
100 – Wonwondah – Toolondoo Road Lake Toolondo Outlet	 

Point of Interest	Image
135 – Officer Station Road Wetland	
136 – Officer Station Road Eldriges Swamp	

Point of Interest	Image
137 – Harrow – Clear Lake Road Clear Lake	
104 – Scott Heard Lights Road Culvert 1.2m x 300mm	

5 HYDROLOGY AND HYDRAULICS

5.1 Overview

The WIM100 project area is the northern most site in the southern Wimmera EL4282 tenement. Due to the very low topographic grade and the complexity of the wetland systems in the WIM100 project area a Rain on Grid (RoG) modelling approach was undertaken in place of RORB modelling. RoG modelling is a more robust way to determine both runoff volumes, peak flow rates and areas of high flood risk due to the complexity of the site. The model is more able to readily identify major flow paths, depressions/wetlands and the complex interactions of overland flow. A RORB model would not be able to resolve these due to its one-dimensional approach. RORB requires separation of flow paths and has no ability to hydraulically model discontinuous flow paths or wetland interactions (aside from a simple stage storage relationship for any storage).

The hydraulic modelling package TUFLOW was adopted for this assessment. TUFLOW is an industry standard one and two-dimensional modelling package which has been used across numerous flood modelling projects across Victoria. The 1D component was utilised to model significant culverts and bridges throughout the model domain, while the 2D component modelled the project area's topography. RoG modelling directly applies rainfall to a topographic grid of the catchment area, identifying all major flow paths through modelling of depth, velocity and hazard.

The modelling focuses on using infiltration losses, hydraulic roughness (modelled as Manning's 'n') and design rainfall intensities to produce runoff volumes and discharge rates throughout the project area. TUFLOW can determine flow hydrographs at any point throughout the model space allowing for detailed hydrological reporting to be undertaken once more specific mine infrastructure/operation information is available or for refinement of the model once a better understanding of the mine area us known.

The following sections are separated into Hydrology and Hydraulics. The Hydrology component details how rainfall has been modelled; application of rainfall depths, infiltration losses and validation to other flow determination techniques. The Hydraulics component details how overland flow has been modelled; topographic representation, hydraulic roughness and initial water level conditions within the hydraulic model.

5.2 Hydrology

5.2.1 Identification of Surface Water Catchments

Surface water catchments across the WIM100 project area were difficult to identify due to the flat topography. As a result, the typical methodology of modelling the catchment areas using GIS techniques proved ineffective. An alternate method was used delineating the catchments using modelling of high intensity rainfall (> 1 in 500 year AEP) to visualise streams and fill all wetlands to determine overflow paths, then delineation of the sub catchments by hand.

Figure 5-1 and Figure 5-2 outline the identified surface water catchments within each tenement. As the Wimmera region has a range of interconnected wetlands, the identified catchments are applicable when overflow between wetlands is not occurring.

WIM100 is predominantly within Catchment 7, with only small sections of Catchment 12 and 6 influencing inflows.

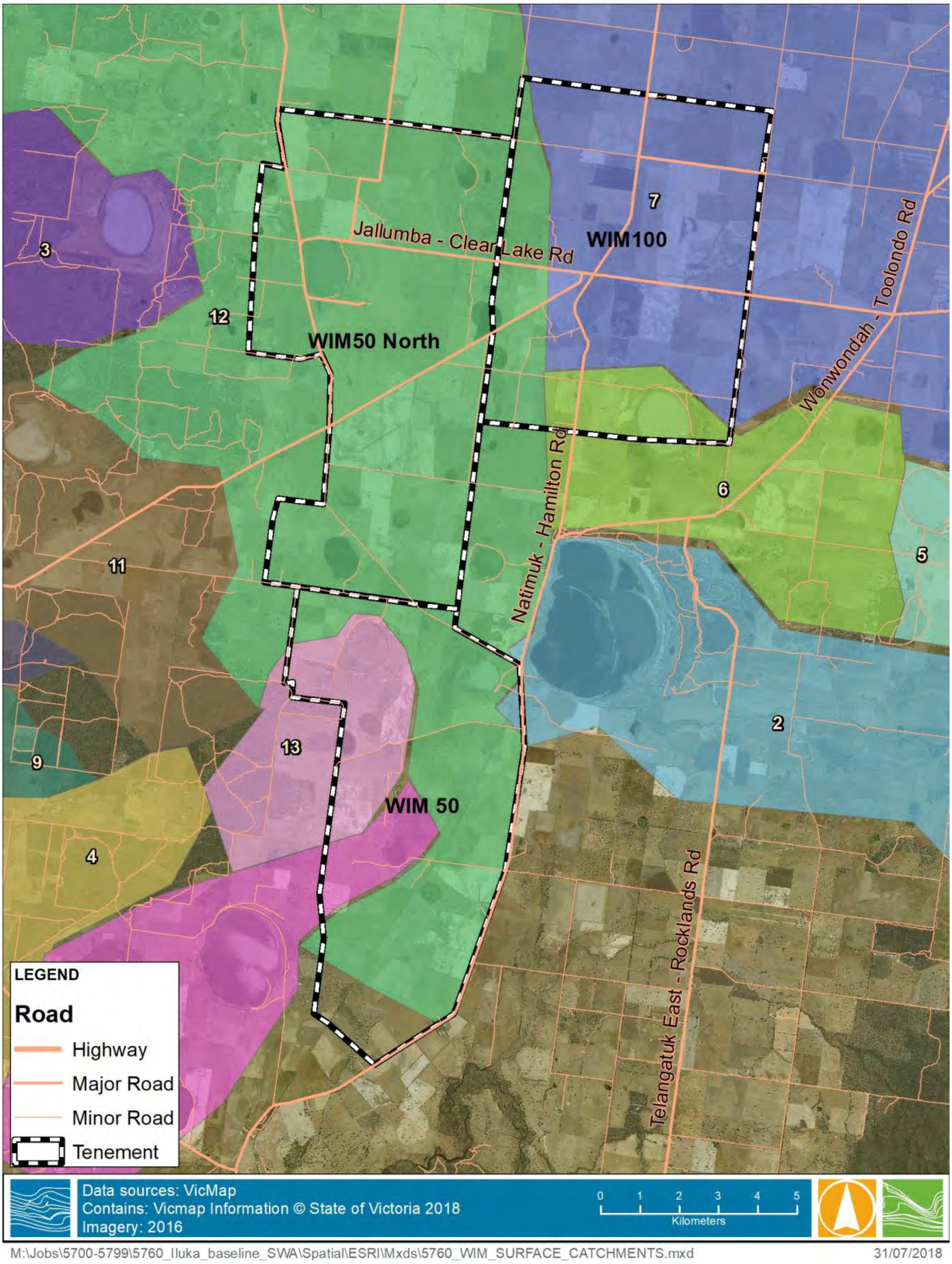

FIGURE 5-1 IDENTIFIED SURFACE WATER CATCHMENTS

FIGURE 5-2 IDENTIFIED SURFACE WATER CATCHMENTS (WIM100)

5.2.2 Seasonal Flow Patterns

As discussed in Section 5.2.1 the topography across the WIM100 project area is very flat, with no defined waterways. As discussed in Section 3.4, no streamflow gauges recording natural catchment runoff exist within the WIM100 project area or upstream catchments. Within the project area and associated catchments natural flow is ephemeral, only occurring in drainage lines immediately post rainfall events. Events are most likely to occur in the months of highest rainfall; June, July, August and September, as shown by the Clear Lake gauge average monthly rainfall totals in Figure 5-3. Without streamflow gauging no calculation of baseflow could be made, and none is expected within the overland flow paths. None has been noted during comments from landholders.

A greater understanding of the potential regular flows within the overland flow paths could be achieved through the creation of a long term catchment scale water balance model. The model could estimate flow within the drainage lines on a daily basis pre and post development. This modelling should be completed during an assessment of the impact mining may have operations; however, this can only be complete when more is understood about the mine operations and is not suitable for inclusion in this type of assessment.

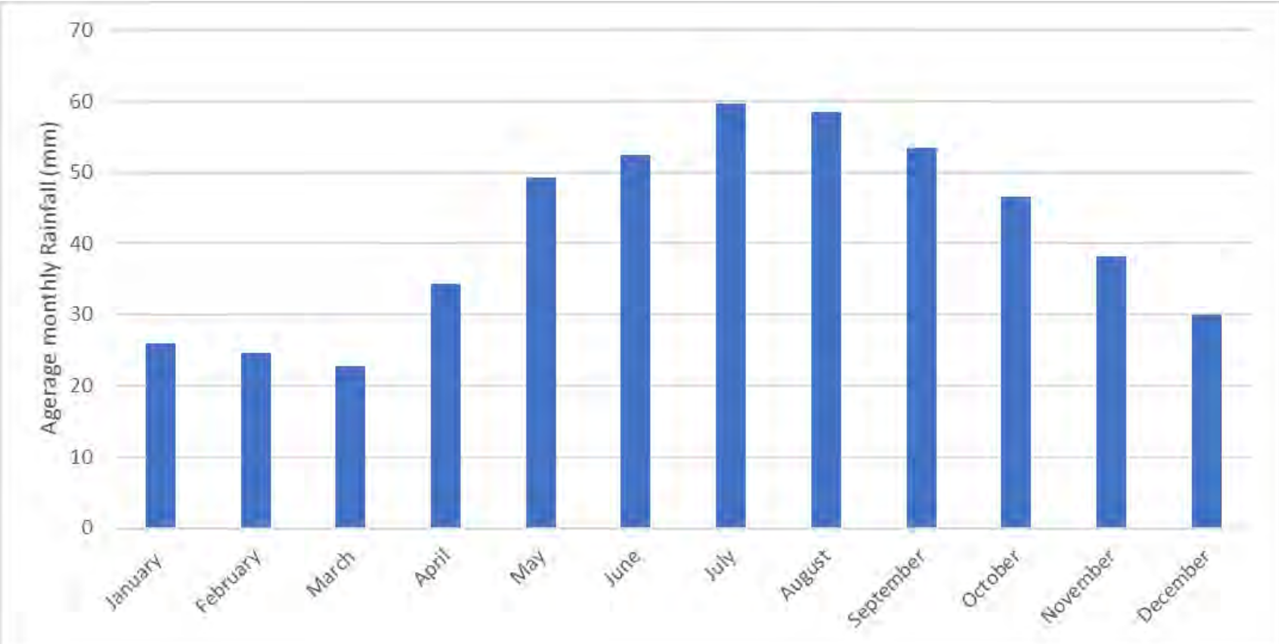

FIGURE 5-3 AVERAGE MONTHLY RAINFALL AT CLEAR LAKE (79008)

5.2.3 Infiltration Losses

There are a range of methods available to estimate infiltration losses within rainfall runoff models (e.g. RORB, URBS etc.). These models are used to convert rainfall to runoff with catchment nodes which are then routed along streams to a catchment outlet. The accumulation of water in low areas, small dams, puddles etc. is generally artificially accounted for in a model's 'initial loss'. Within a RoG model this catchment storage is accounted for by what is stored in the model topography and does not continue to the catchment outlet, as would occur naturally. Therefore, you would generally expect a RoG model to have a lower initial loss than a rainfall runoff model but similar continuing losses.

As discussed in Section 3.7.2, the Natimuk Flood Investigation[2] completed the most relevant rainfall runoff modelling and RoG modelling to the WIM100 project area. The Natimuk project modelled the Natimuk Creek and Little Natimuk Creek catchments in both RORB and a Mike21 RoG model. This included calibration of RORB model over two historic events (December 2010 and January 2011) and completed a full suite of design events (20% AEP to 0.5% AEP) and verification of RoG model to the RORB model using the 1% AEP event. The Natimuk Flood Investigation[2] modelling covered the northern extents of the WIM100 tenement and the loss values determined during the study are considered representative of the WIM100 and WIM50 sites. The extent of the Natimuk Flood Investigation[3] modelling in relation to the WIM100 project area is outlined in Figure 5-4.

The losses adopted in the RORB calibration and design modelling and RoG are shown in Table 5-1.

TABLE 5-1 NATIMUK FLOOD INVESTIGATION – ADOPTED CALIBRATION AND DESIGN LOSSES

Model scenario	Initial Loss (mm)	Continuing Loss (mm/hr)
RORB - September 2010 calibration	10	4.5
RORB - January 2011 calibration	35	4.5
RORB – Design Modelling	20	3
RoG Modelling	10	3

The RoG losses adopted during the Natimuk Flood Investigation[2] are around the expected values by comparison to the RORB modelling, with a lower initial loss and similar continuing loss. They are considered the best available match for the WIM100 catchment given the similarities in location.

The loss values adopted during the study were an Initial Loss (IL) of 10mm and a Continuing Loss (CL) of 3 mm/hr, matching that of the Natimuk Flood Investigation[2] RoG modelling.

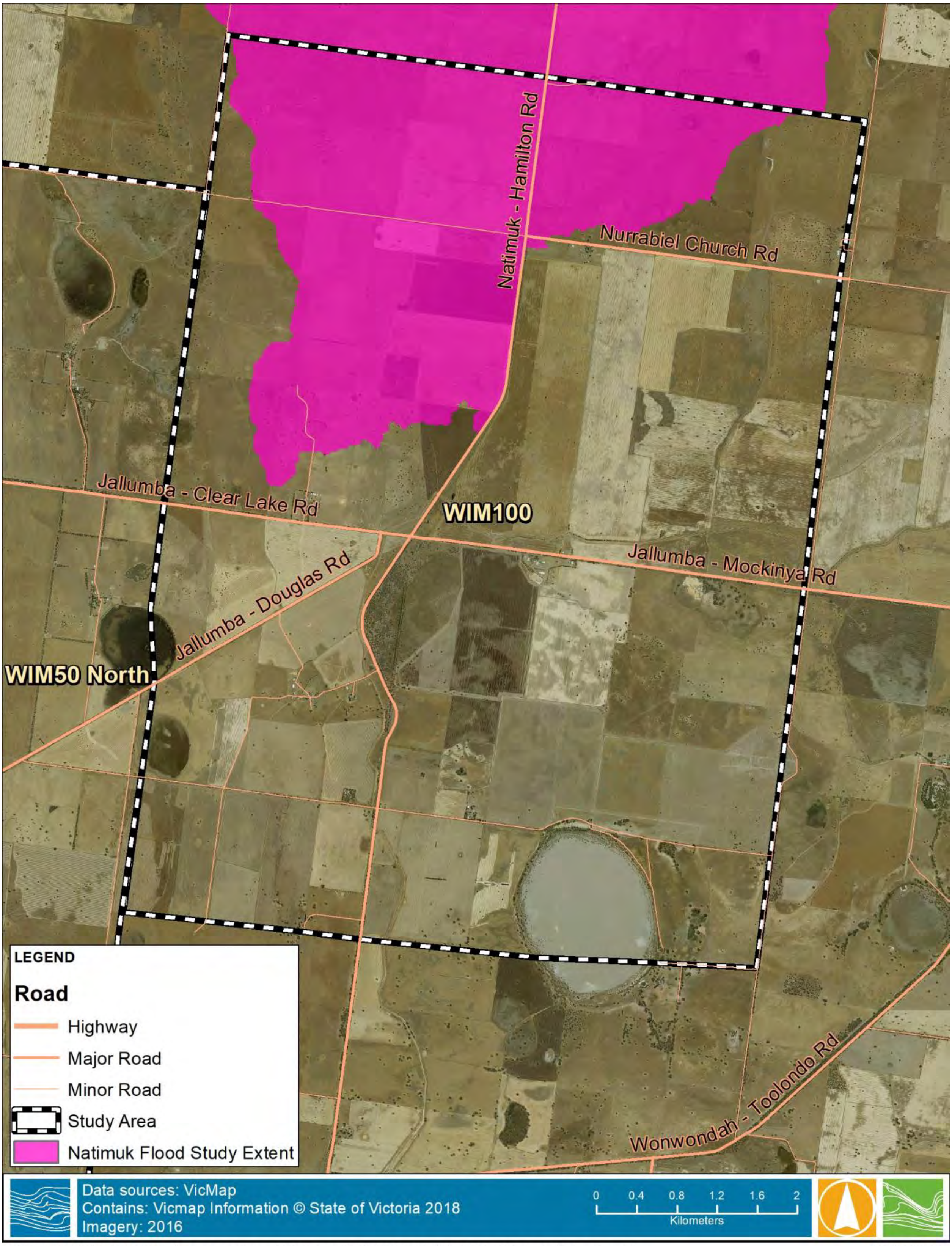

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FIGURE 5-4 NATIMUK FLOOD STUDY EXTENT

5.2.4 Rainfall Intensity, Frequency and Duration

Design rainfall depths were determined at the centroid of the hydraulic model covering the WIM50, WIM50 North and WIM100 project areas using the method recommended in Australian Rainfall and Runoff 2016 (ARR2016)[4], this uses rainfall Intensity, Frequency and Duration (IFD) data produced by the Bureau of Meteorology (BoM) in 2016[5]. The IFD data determined for the WIM sites is show in Figure 5-5.

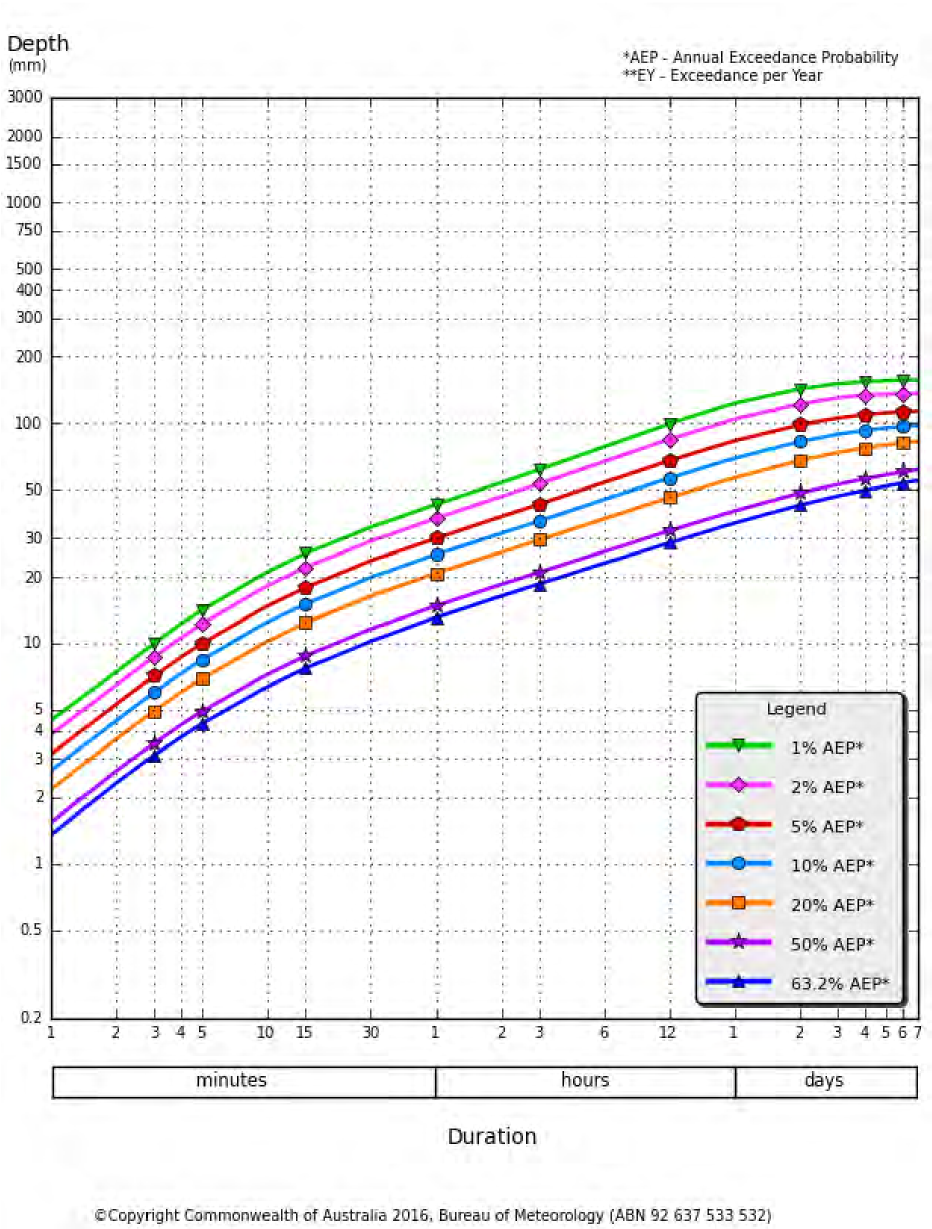

FIGURE 5-5 RAINFALL IFD DATA

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[4] Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2016, Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia

[5] Available here - http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016

5.2.5 Temporal Patterns

Temporal patterns represent a range of 10 hyetographs specifically developed for each region across Australia by Australian Rainfall and Runoff, based on long term historical data. The patterns represent a distribution of rainfall depth through time, providing different storm characteristics. Temporal patterns can be grouped into various categories based on the percentage distribution of rainfall. These categories include front loaded, middle loaded and end loaded events, where the largest rainfall depth is applied to the catchment at different times as shown in Figure 5-7.

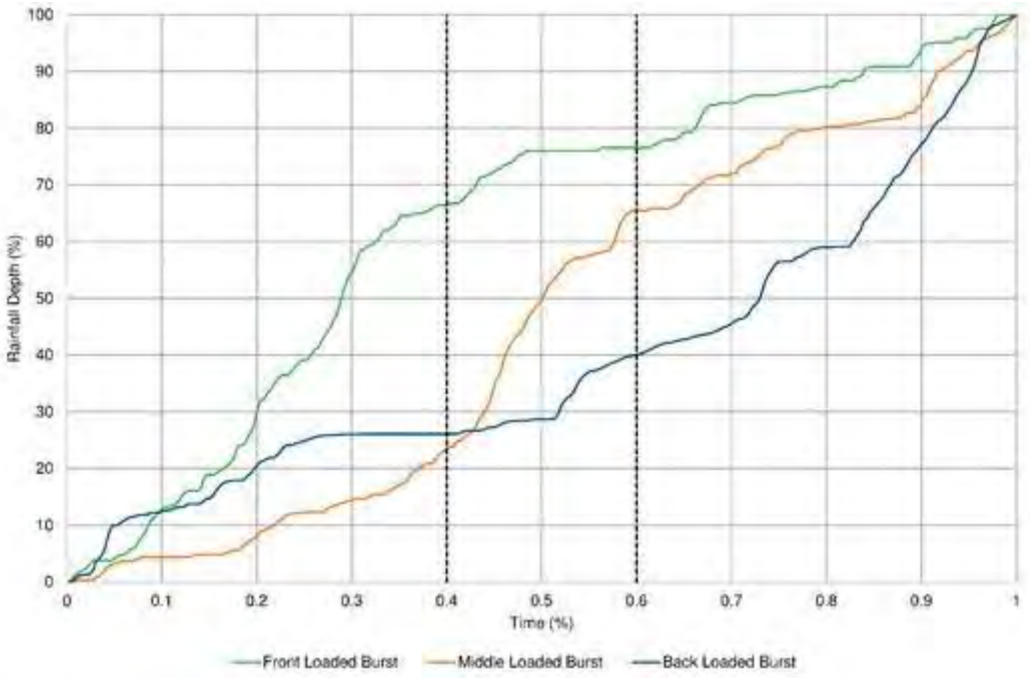

FIGURE 5-6 TEMPORAL PATTTERN BURST TYPE

ARR2016[4] recommends modelling each of the ten patterns, then selecting a single pattern which is representative of the average peak flow or flood level. This is typically selected by comparing hydrological model results, however, due to the flat terrain and number of wetlands, a hydrological model was deemed inappropriate, meaning the hydraulic model was required to select an appropriate temporal pattern. As the catchment area is significantly large, a range of temporal patterns were utilised to determine the most appropriate single pattern. Potential temporal patterns were grouped into similar event types, with five patterns initially run within the model for the 1% AEP event. These events were refined further as discussed in Section 6.1.

Figure 5-7 and Figure 5-8 shows all ten potential temporal patterns and highlights the patterns that were chosen to be modelled in a range of colours. These temporal patterns represent front loaded, back loaded and consistent rainfall across the event durations.

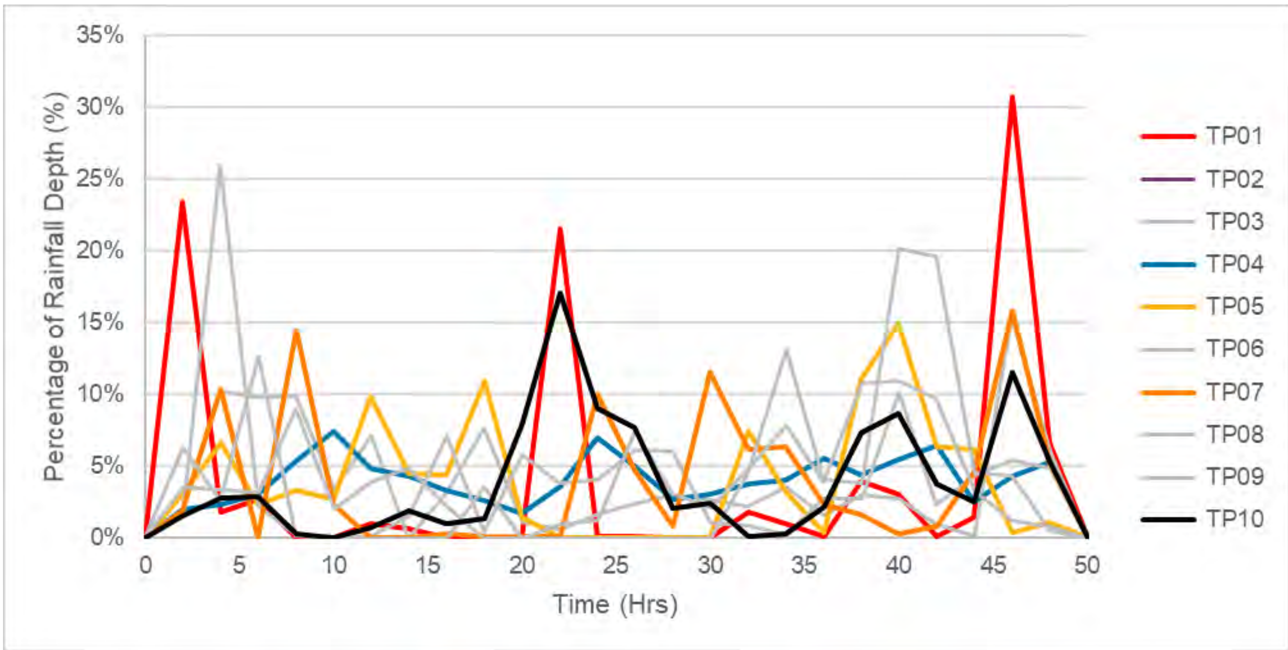

FIGURE 5-7 SELECTED TEMPORAL PATTERNS (COLOURED) (1% AEP, 2880MIN)

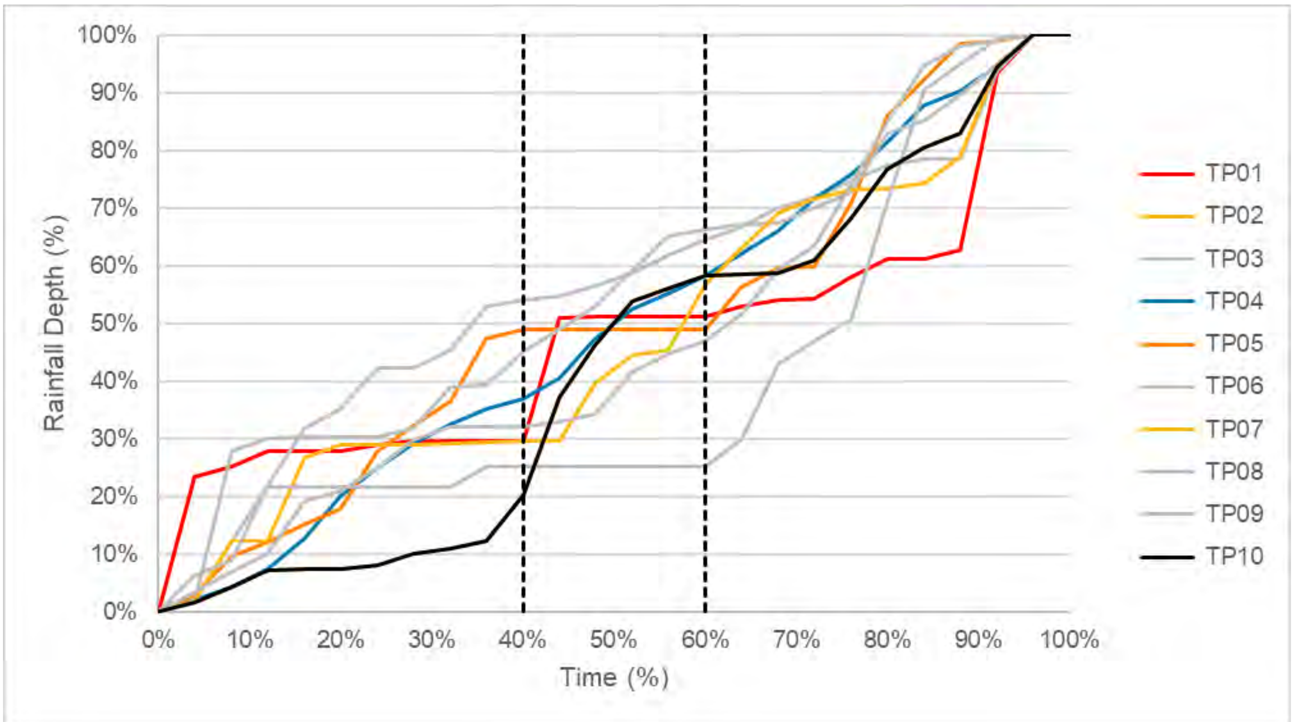

FIGURE 5-8 CUMULATIVE RAINFALL DEPTH - SELECTED TEMPORAL PATTERNS (COLOURED) (1% AEP)

5.3 Hydraulics

5.3.1 Initial Conditions

The initial water level conditions within the hydraulic model assumed all wetlands were dry, aside from Lake Toolondo. Lake Toolondo can be supplied water by Rocklands Reservoir, and has not been dry in the last 10 years due to its size and regulation. The remaining wetlands are generally empty[6] and it is reasonable to assume this condition without any additional data. A sensitivity test can be undertaken with the wetlands full to determine a worst-case scenario and to gain an understanding of their impact, however it is not anticipated the additional water will create additional flow paths. Iluka intends to complete sensitivity testing as part of the impact assessment.

5.3.2 Topographic and Infrastructure Features

As discussed previously, modelling was undertaken across the three project areas within EL4282 (WIM50, WIM50N and WIM100) as a singular RoG TUFLOW model. Due to the size of the area a 15 m topographic resolution Digital Elevation Model (DEM) was used. This resolution was determined appropriate due to the lack of narrow channels and relatively flat and open topography. The DEM used in the TUFLOW model is shown in Figure 5-9. The model grid was resampled from a 2 m resolution DEM, as provided by Wimmera CMA and discussed in the Data Collation Report produced as part of this project. Due to the size of the study area, a 2m grid was not deemed appropriate in order to keep model runtimes reasonable.

Bridge and culverts were not explicitly included in the model, but openings left where infrastructure was known to exist.

Figure 5-9 highlights a ridge along the western edge of the WIM100 project area and a wetland to the south eastern corner (Red Gum Swamp). North of Red Gum Swamp there is a very low area which is likely to be subject to frequent inundation with no obvious ability to drain.

The major barriers to flow include the western ridge, the road network (predominantly the Jallumba – Mockinya Road, Natimuk Hamilton Road and Jallumba – Douglas Road) and the Rocklands Channel. There are also several other GWMWater Stock and Domestic channels obvious within the terrain which may influence overland flows, these include the Natimuk Channel and the Arapiles Channel. These structures can convey/and or block flow, effectively forming a barrier or levee across the hydraulic model. Channel excavation spoil is generally placed as a bund on one or both sides of the channel, which can influence flow paths if not rehabilitated. Channels such as the one shown in Figure 5-10, were readily be identified in the LiDAR, restricting the flow across them in the hydraulic model. Many channels within the WIM100 project area have been decommissioned (as noted in 3.8.1), this process is complete with GWMWater but ongoing with private landholders. Aerial imagery captured in 2019 (Google) give the most up to date snapshot of what channels have been decommissioned and which remain. This imagery north of Jallumba Mockinya Road is shown in Figure 5-11 with the area north of Nurrabiel Church Road shown in Figure 5-12. The imagery shows the Natimuk Channel and Arapiles Channels decommissioned but still labelled by Google.

Figure 5-13 shows (photo captured 4/06/2019) the Natimuk Channel between Nurrabiel Church Road and Quick Sinclair Russells Road has been recently filled, demonstrating the ongoing nature of the decommissioning works. It should be noted the final finished surface post decommissioning varies from channel to channel and along a channel.

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[6] Wimmera Wetlands Hydrology Investigation, Water Technology (2018, Ongoing)

There are four major channels within the WIM100 project area with varying status and several minor channels, the more major channels and their status based on discussion with GWMWater includes:

- Toolondo/Rocklands Transfer Channel
  - The Rocklands Channel is still considered in use to transfer water from Toolondo/Rocklands to Taylors Lake when necessary, but it is not used frequently. The Toolondo/Rocklands Channel is still considered important to the function of GWMWater's supply system and some consideration has been given to piping it. The outcome of this is still uncertain.
- Arapiles Channel
  - The Arapiles Channel was previously used to distribute water as part of the stock and domestic system and has now been superseded by an underground pipeline system (Wimmera Mallee Pipeline). The channel was not large enough to fit within the decommissioning criteria for GWMWater to undertake decommissioning; however, landholders were given the option to decommission the channel (fill to natural surface) and given responsibility for managing the land. This has been completed to a varying degree with some sections filled and others remaining. GWMWater do not have an accurate record of which sections remain and a site visit would be required to accurately determine this information. Based on Iluka Resources site inspections in June 2019[7] and 2019 google imagery the decommissioned state of the channel was as follows:
    - Decommissioned between the Rocklands channel and Nurrabiel Church Road.
    - Remaining between Nurrabiel Church Road and the Natimuk-Hamilton Road
    - Decommissioned west of the Natimuk-Hamilton Road for the first 1,500m
- Natimuk Channel
  - The Natimuk Channel was previously used to distribute water as part of the stock and domestic system and has now been superseded by an underground pipeline system (Wimmera Mallee Pipeline). The channel was not large enough to fit within the decommissioning criteria for GWMWater to undertake decommissioning; however, landholders were given the option to decommission the channel (fill to natural surface) and given responsibility for managing the land. This has been completed to a varying degree with some sections filled and others remaining. It was noted decommissioning of the channel has reduced flows into Lake Natimuk via Little Natimuk Creek. Based on Iluka Resources site inspections in June 2019[8] and 2019 google imagery the decommissioned state of the channel was as follows:
    - Remaining between the Wonwondah-Toolondo Road and the Rocklands Channel just north of Jallumba-Mockinya Road.
    - Decommissioned between the Rocklands channel and Nurrabiel Church Road
- Decommissioned between Nurrabiel Church Road and Quick Sinclair Russells Road

Each of these channels has been defined to some extent within the LiDAR data. This data, outlined in the data collation report, is from 2006. The status of each channel within the modelling extents is outlined below.

- Toolondo/Rocklands Transfer Channel
  - Well represented in the model LiDAR
  - Appears to be present across all recent aerial imagery

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[7] Pers. Comm. Iluka Resources (Marcus Little)
[8] Pers. Comm. Iluka Resources (Marcus Little)

- Arapiles Channel
  - Some sections are not well represented in the model LiDAR
  - Some sections appear to be decommissioned in recent aerial imagery, however, depressions may still be present
- Natimuk Channel
  - Most sections are well represented in the model LiDAR, however, some areas are not
  - Appears to be present in aerial imagery

The remaining channels are all privately owned and maintained, they are broadly considered to be redundant given no allocation is provided to them unless they are used for drainage purposes. Their state will be varied based on the landholder's intent to complete earth works and their current use. There are several private channels that would have formed part of the channel system north of Red Gum Swamp, but these are likely to now be solely used for drainage. Discussion with that landholder and a site visit would be required to confirm this. The channels are not expected to bring significant volumes of water into or out of the WIM100 area given they are designed to transfer water through the area and any excavation of the channel banks to allow water into or out of the channels would be a breach of a landholders agreement with GWMWater (if one exists). The channels are operated regardless of the occurrence of rainfall, with operational decisions made based on water supply needs.

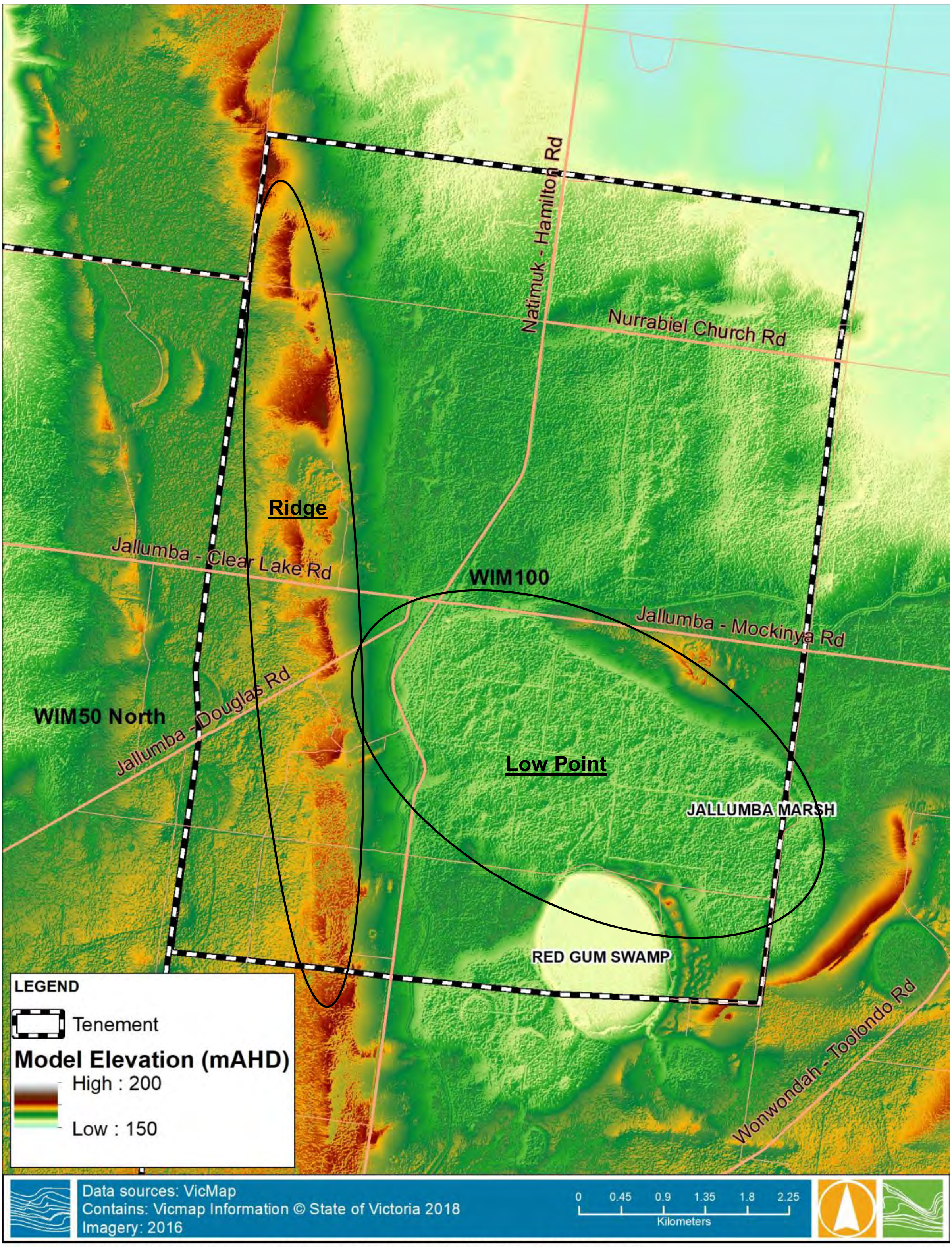

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FIGURE 5-9 TUFLOW MODEL SURFACE ELEVATION

FIGURE 5-10 CHANNEL SYSTEM IN THE WIMMERA PROJECT AREA

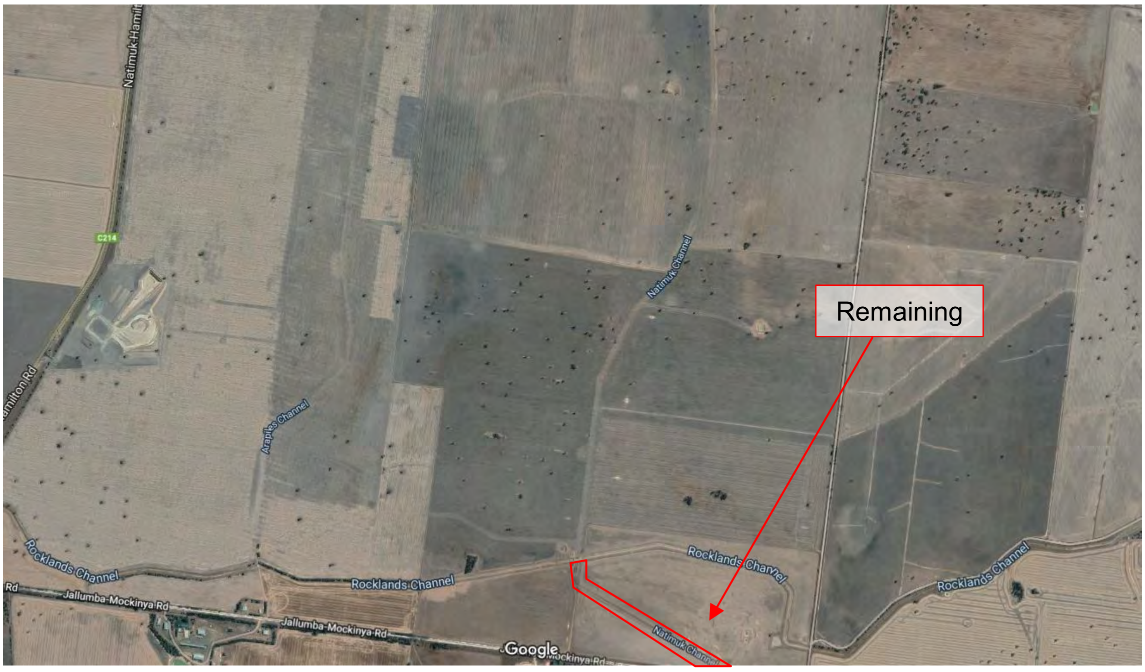

FIGURE 5-11 DECOMISSIONING OF THE ARAPILES AND NATIMUK CHANNELS NORTH OF JALLUMBA MOCKINYA ROAD

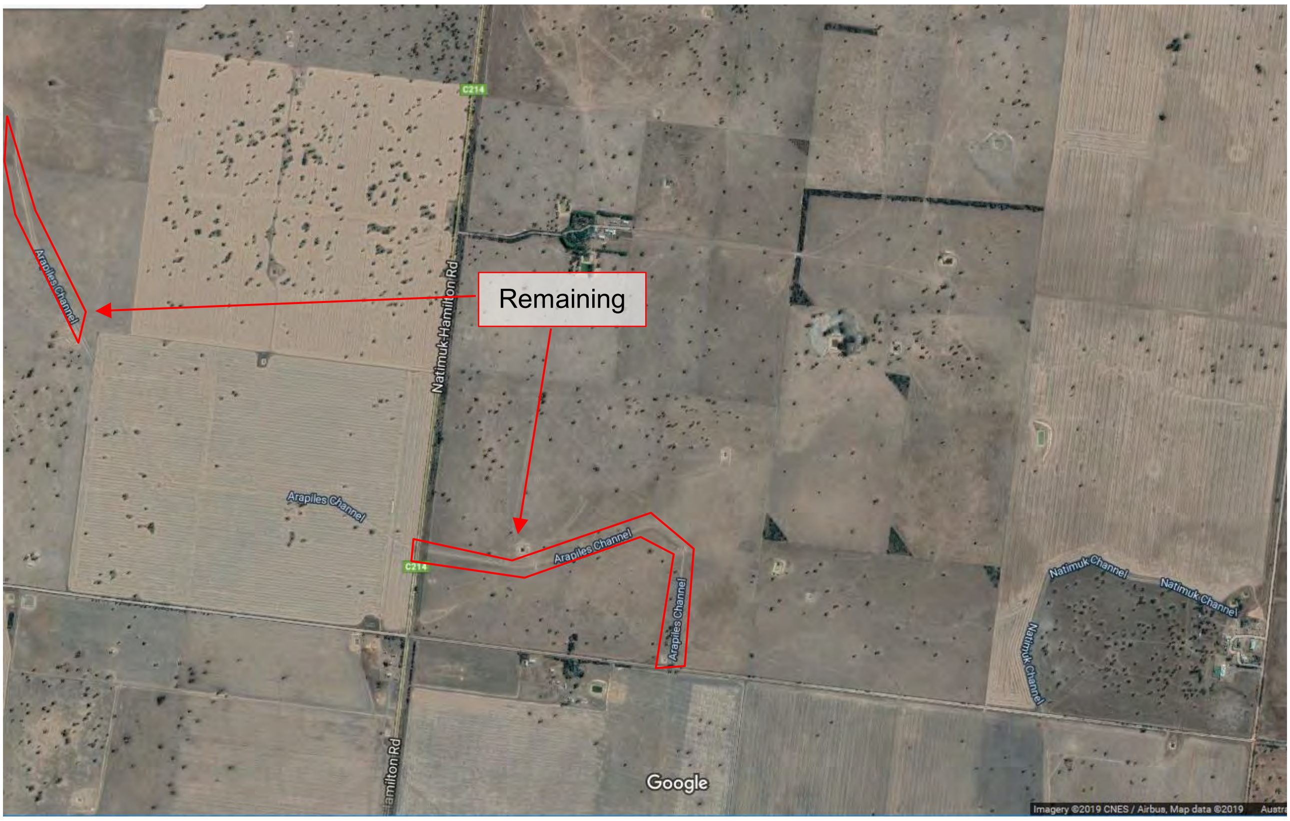

FIGURE 5-12 DECOMISSIONING OF THE ARAPILES AND NATIMUK CHANNELS NORTH OF NURRABIEL CHURCH ROAD

FIGURE 5-13 IMAGE CAPTURED ON THE 04/06/2019, SHOWING DECOMISSIONING OF THE NATIMUK CHANNELS SOUTH OF NURRABIEL CHURCH ROAD

5.3.3 Hydraulic Roughness

Model hydraulic roughness was represented using a Manning's 'n' roughness coefficient. The Manning's 'n' adopted was determined based on Melbourne Water[9] guidelines (Table 5-2) and Chow (1959)[10] (Table 5-3). Given the very consistent land use and vegetation classes a constant Manning's value of 0.04 was adopted for the WIM100 project area. This value covers all types of land use within the region. The only exception to this is minor and major roads, given these are not in the flow paths, lowering the Manning's 'n' value for these areas would not impact on the results.

A Manning's 'n' of 0.04 represents a conservative estimate of roughness as, depending on the time of the year (age of crops, length of grass, etc), roughness within agricultural paddocks could vary between 0.025 and 0.05

An aerial image highlighting the land use types as determined by the planning scheme is shown in Figure 5-14. The planning scheme was initially used to determine the Manning's 'n' roughness values which were verified by aerial imagery.

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[9] Melbourne Water Corporation Flood Mapping Projects Guidelines and Technical Specifications, Melbourne Water (2016)
[10] Open Channel Hydraulics, Chow, V T (1959)

TABLE 5-2 MELBOURNE WATER GUIDELINES FOR MANNINGS N ROUGHNESS COEFFICIENT

Land Use Description	Manning's n
Open Space or Waterway – Minimal Vegetation	0.03 – 0.05
Car Park / Pavement / Wide Driveway / Road	0.018 – 0.04

TABLE 5-3 VALUES OF THE ROUGHNESS COEFFICIENT N - CHOW[11]

Land Use Description	Manning's n
Pasture, No Brush – High Grass	0.03 – 0.05
Cultivated areas – No Crop	0.02 – 0.04
Cultivated areas – Mature row Crops	0.025 – 0.045
Cultivated areas – Mature field crops	0.03 – 0.05
Brush – Scattered brush, heavy weeds	0.035 – 0.07
Brush – Light brush and trees	0.035 – 0.08

[11] Table 5-6, Open Channel Hydraulics, Chow, V T (1959)

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FIGURE 5-14 WIM100 AERIAL IMAGE AND LAND USE

6 RESULTS

6.1 Design Rainfall

Design modelling was undertaken for all AEPs from 20% to 1%. Five temporal patterns were initially modelled for the 1% AEP as outlined in Section 5.2.5. It was apparent that temporal patterns 1 and 5 provided the highest flows across the catchment for the 1% AEP event, therefore these two patterns were modelled for the remaining AEPs. These patterns were ‘end weighted’, meaning most of the rainfall fell towards the end of the event when the initial infiltration losses were consumed, and the catchment wet before the highest burst. Figure 6-1 shows the rainfall depth percentage and timing across all temporal patterns for a 48-hour storm.

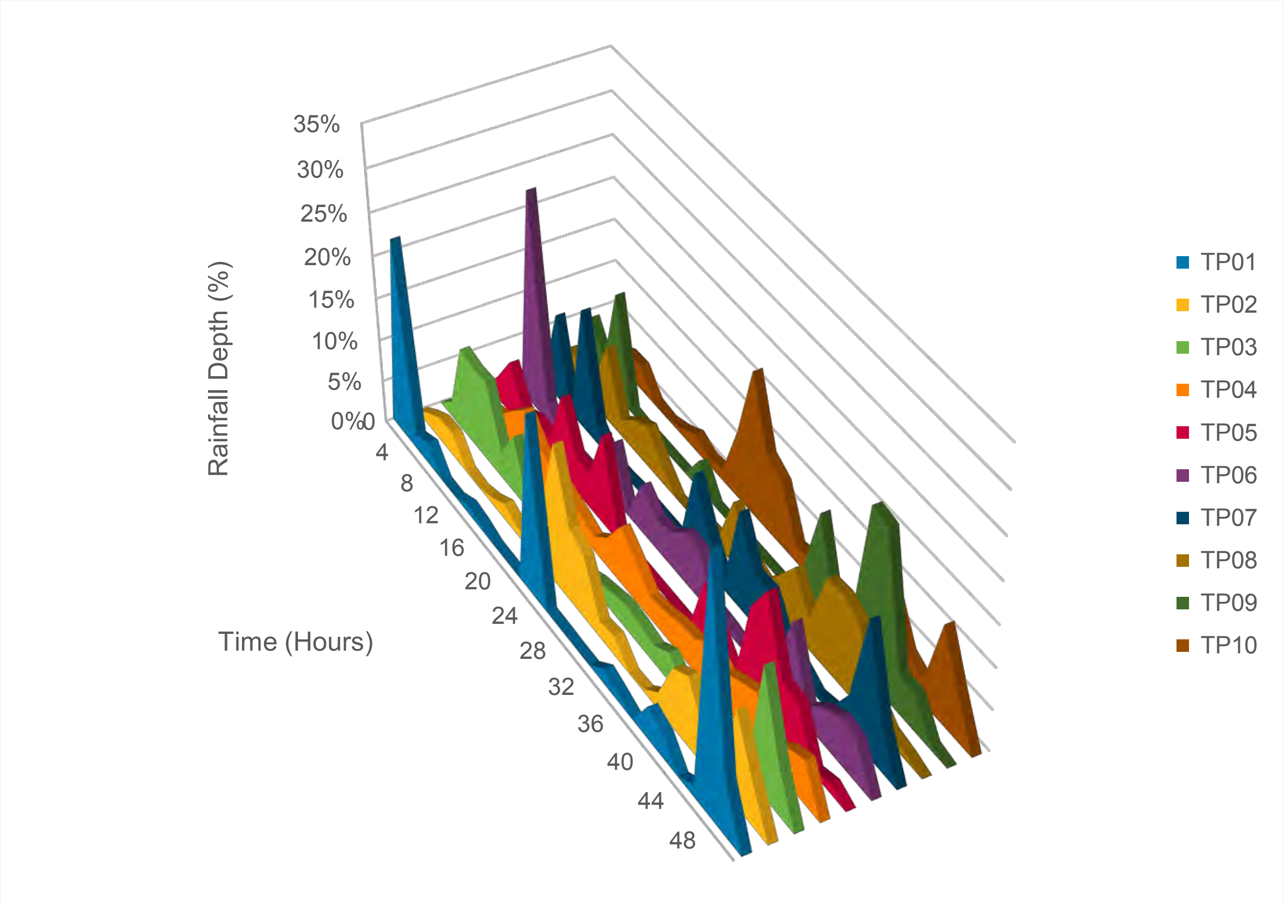

FIGURE 6-1 RAINFALL DAPTH % FOR ALL TEMPORAL PATTERNS

Critical storm duration throughout the catchment was also considered. The 1% AEP event was run for 6 durations including the 3hr, 6hr, 12hr, 24hr, 48hr and 72hr to determine the critical duration. It was found that the 6hr, 12hr and 48hr all produced maximum flow values across different areas of the catchment. Therefore, these three durations were run across all AEPs with the mapped results an envelope of all the maximum depths/velocities for each AEP.

6.2 Calibration and Validation

Apart from the work undertaken for the Natimuk Flood Investigation (see Section 3.2.1), no hydrologic or hydraulic modelling has previously been undertaken for the WIM100 project area, and without streamflow gauges or observed flood heights no calibration to observed flows or flooding can be made.

There are several peak flow estimation methods that can be used for broad comparison to the modelled peak flows determined during this assessment. The most recently developed and recommended method in ARR2016[4] is the Regional Flood Frequency Estimation Tool (RFFE)[12]. This method was used for comparison against the modelled peak flow at the most defined catchment outlet within the model, as shown in Figure 6-2 and Figure 6-3. This location has a sub catchment area of approximately 66km^2.

FIGURE 6-2 RFFE TOOL CATCHMENT OUTPUT LOCATION

[12] Rahman A, Haddad K, Kuczera G and Weinmann E ARR2016 Book 3, Chapter 3 in Australian Rainfall and Runoff - A Guide to Flood Estimation, Commonwealth of Australia - https://rffe.arr-software.org/

FIGURE 6-3 RFFE TOOL CATCHMENT OUTPUT LOCATION - ZOOM

A comparison of the modelled and RFFE Tool estimated peak flows are shown in Table 6-1, the modelled hydrographs are also shown in Figure 6-4. Modelling results have determined a peak flow within the confidence limits of the RFFE Tool for all event but are on the lower side of the range.

TABLE 6-1 REGIONAL FLOOD FREQUENCY ESTIMATION TOOL

AEP (%)	Modelled Peak flow (m^3/s)	RFFE		
		Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	-	11.5	3.80	35.0
20	7.9	21.9	7.46	64.7
10	7.9	30.2	10.3	89.8
5	16.9	40.4	13.5	123
2	37.3	53.6	17.4	166
1	54.4	66.8	21.2	213

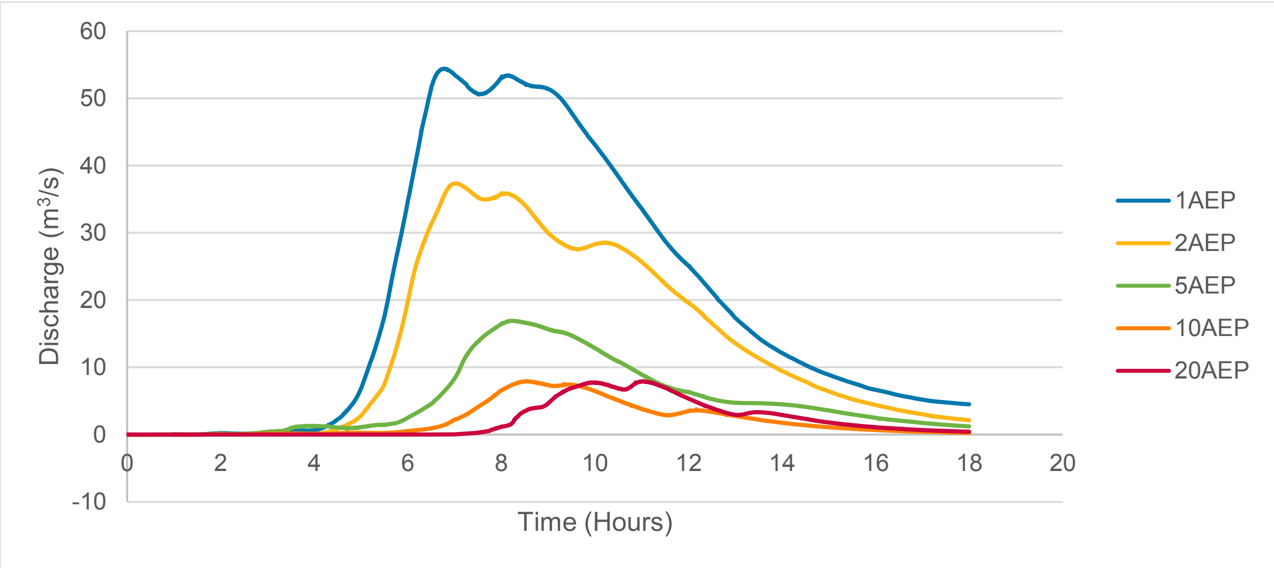

FIGURE 6-4 FLOW AT PRINT POINT 12

As WIM100 is relatively flat, it is not unexpected that the discharge rates sit at the lower extent of the confidence interval. The relatively flat surface results in ponding and storage on the surface, resulting in a lower overall discharge rate as water remains on the surface and does not contribute to overland flow. The RFFE Tool uses generic flood frequency determined peak flows from streamflow gauges in the same region as a subject site to determine a peak discharge and associated confidence interval.

Figure 6-5 compares the WIM100 catchment to other catchments in the region. The WIM100 catchment unlike most gauged catchments given it is within a very flat area with limited concentrated flow paths (therefore limited ability to gauge flows). It is most like Catchment 3, which is the Chetwynd River at Chetwynd (238229). This catchment has an area of 69km^2 and has a greater overall steepness, therefore is expected to have a higher flow.

Catchment 2 is Glenelg River at Big Cord (238231) and is located over 50km away from the Wimmera project area in the Grampians National Park. This gauge is located between two steep ranges with a very flat floodplain and is known to be affected by the regional topography.

The Regional Flood Frequency estimation tool is produced by Australian Rainfall and Runoff and utilises the following methodology to derive flow data:

"The RFFE technique is based on data from 853 gauged catchments. For application, Australia is divided into six data-rich regions, two data- poor/arid regions and six fringe zones. A region-of-influence (ROI) approach was used to form sub-regions within the data-rich regions. In these sub-regions a Bayesian generalised least squares regression was adopted to regionalise the three parameters of the LP3 distribution. In the data-poor/arid regions an index method was applied, using the 10% AEP flood quantile as the index variable. An interpolation procedure is used to derive flood estimates for sites located in fringe zones."[12]

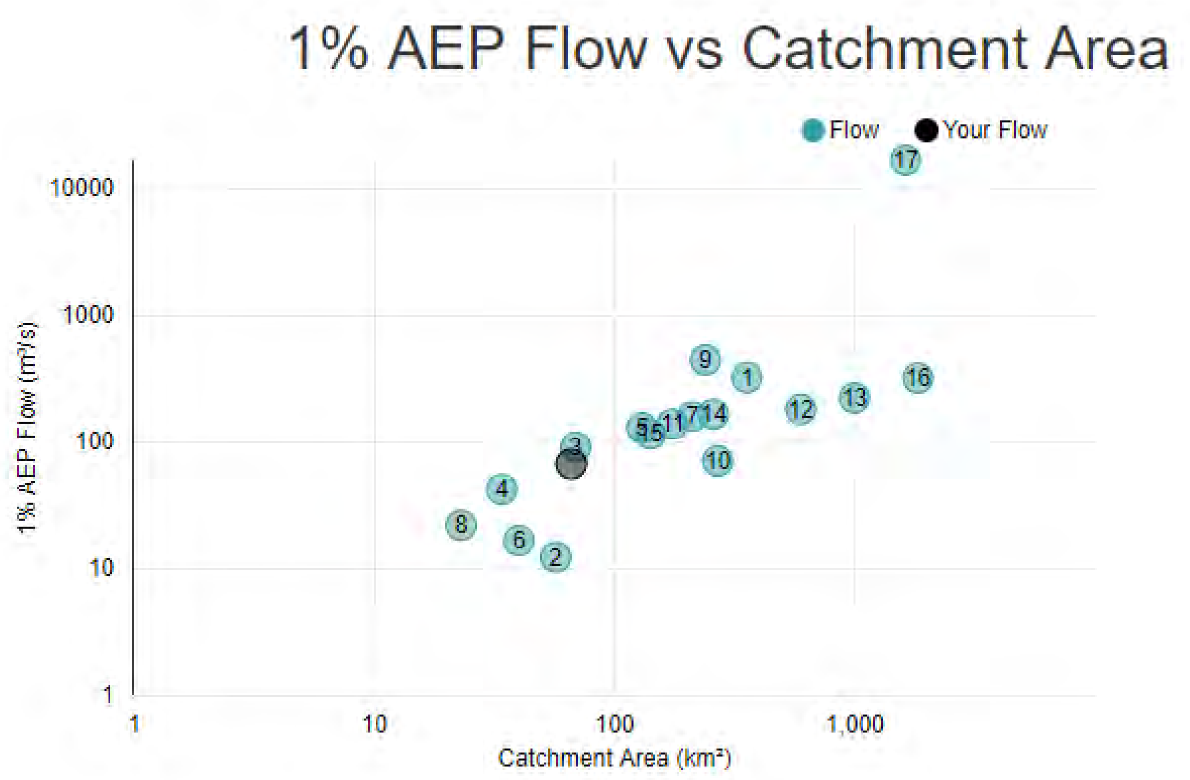

FIGURE 6-5 REGIONAL FLOOD FREQUENCY ESTIMATION TOOL 1% AEP FLOW VS CATCHMENT AREA

The lack of calibration data results in broad verification to observed inundation the only way to confirm the model accuracy.

6.2.1 Wetland Verification

The inundation depth across the WIM100 site was also verified against the wetlands mapping layer produced by SKM. This layer identified all wetlands across the Wimmera region and is shown in Figure 6-6. It is evident that the wetlands identified have been well represented in the modelling as all have an inundation depth.