Summary Report

Apsley Flood Investigation

West Wimmera Shire Council

9 June 2026

Document Status

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Project Details

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ACKNOWLEDGEMENT OF COUNTRY

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

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

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

The symbolism in the artwork includes:

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

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

9 June 2026

Edwin Irvine
Senior Planning Officer
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Via email: EdwinIrvine@westwimmera.vic.gov.au

Dear Edwin

Apsley Flood Investigation

Please see the attached Apsley Flood Investigation Summary Report. The Edenhope and Apsley Flood Investigation reporting was separated into two components for the later stages of the project and final deliverables. These components covered the Edenhope and Apsley townships separately. This report documents a summary of the deliverables completed for Apsley.

Water Technology would specifically like to thank Wimmera CMA, West Wimmera Shire Council and the Apsley community members who gave their time to provide their personal observations of flooding and provide feedback on the flood modelling.

Strong contributions from stakeholders and community members have resulted in improved outcomes from this study, which will assist with flood related land use planning, floodplain risk management, flood emergency response and raising community awareness of individual flood risk.

Yours sincerely

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Senior Principal Engineer
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WATER TECHNOLOGY PTY LTD

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1 INTRODUCTION

1.1 Overview

Water Technology was commissioned by West Wimmera Shire Council (WWSC) to undertake the Apsley Flood Investigation. The Apsley is within West Wimmera Shire Council, located in Victoria's Wimmera region approximately 100 km southwest of Horsham. Apsley is also within the Wimmera Catchment Management Authority (CMA) management area and the Millicent Coast basin. Apsley is located 20 km west of Edenhope and has around 300 residents.

Apsley known to be prone to stormwater flood events, with events recorded in 1971, 1973, 1975, 1981, 1991, 1993, 2011, 2016 and 2022. Apsley is impacted by local waterways and drainage lines flowing towards Newlands Lake west of the township.

There is no current flood study for the township, and current flood risk information is based on information from council, Victoria State Emergency Service (VicSES) and the Wimmera Wetland Hydrology Investigation completed by Water Technology in 2019.

This study has produced reliable flood intelligence for use in emergency management situations and assessed the current flood impact/exposure in terms of annual average damages caused by flooding. It has also produced planning scheme overlays for inclusion in the West Wimmera Shire Council planning scheme.

This report is one of a series documenting the outcomes of the Apsley Flood Investigation, the Data Collation, Model Development and Calibration Report (R01) and Design Modelling Report (R02B) are combined with the Edenhope Flood Investigation (completed parallel with the Apsley Flood Investigation). The Flood Intelligence Report (R03B) and the Summary Report (this report) focused on Apsley. Each reporting stage is shown below:

- R01 – Data Collation, Model Development and Calibration Report.
- R02B – Design Modelling Report.
- R03B – Flood Intelligence Report & Municipal Flood Emergency Plan (MFEP) Documentation.
- **R04B – Final Summary Report – This report.**

Note: Version A indicates Edenhope and version B indicates Apsley.

1.2 Study Area

Apsley is located within western Victoria. Its location with respect to western Victoria is shown in Figure 1-1, with the study area for Apsley shown in Figure 1-2. The major surface water feature in proximity to Apsley is Newlands Lake. Overland flow to the lake traverses from the main road (i.e., Wimmera Highway) through Apsley in two flow paths, before entering the lake. The flow paths are separated as follows:

- The southern flow path is an accumulation of wetland overflows from the broader catchment draining from the east. It crosses the Wimmera Highway immediately east of Apsley and has a defined channel. It is understood the channel was constructed during early settlement of Apsley to expedite flow into Newlands Lake and prevent them from flowing into town north of the Wimmera Highway. The channel flows parallel to Wallace Street, under Laidlaw Street and into the Lake Newlands Reserve. In larger flow events, the Wimmera Highway can divert some water west, toward Splatt Street.
- The northern flow path is a separate isolated catchment, flowing from the north of Apsley into town past the Apsley Recreation Reserve and into a constructed channel through the treed area between Benayeo Road and Apsley Natimuk Road. In large events this channel exceeds it capacity an overland flow can occur to the south, inundating properties north of the Wimmera Highway.

1.3 Previous reporting (and context)

This report follows R01 to R03B and summarises the completed project. This summary report does not delve into technical detail, instead focuses on project outputs and deliverables produced by the study. Readers will be directed to individual reports should additional information be required. The chapters and sections of this report broadly follow the previous reporting from R01 to R03B, with a summary of the key points in each detailed report.

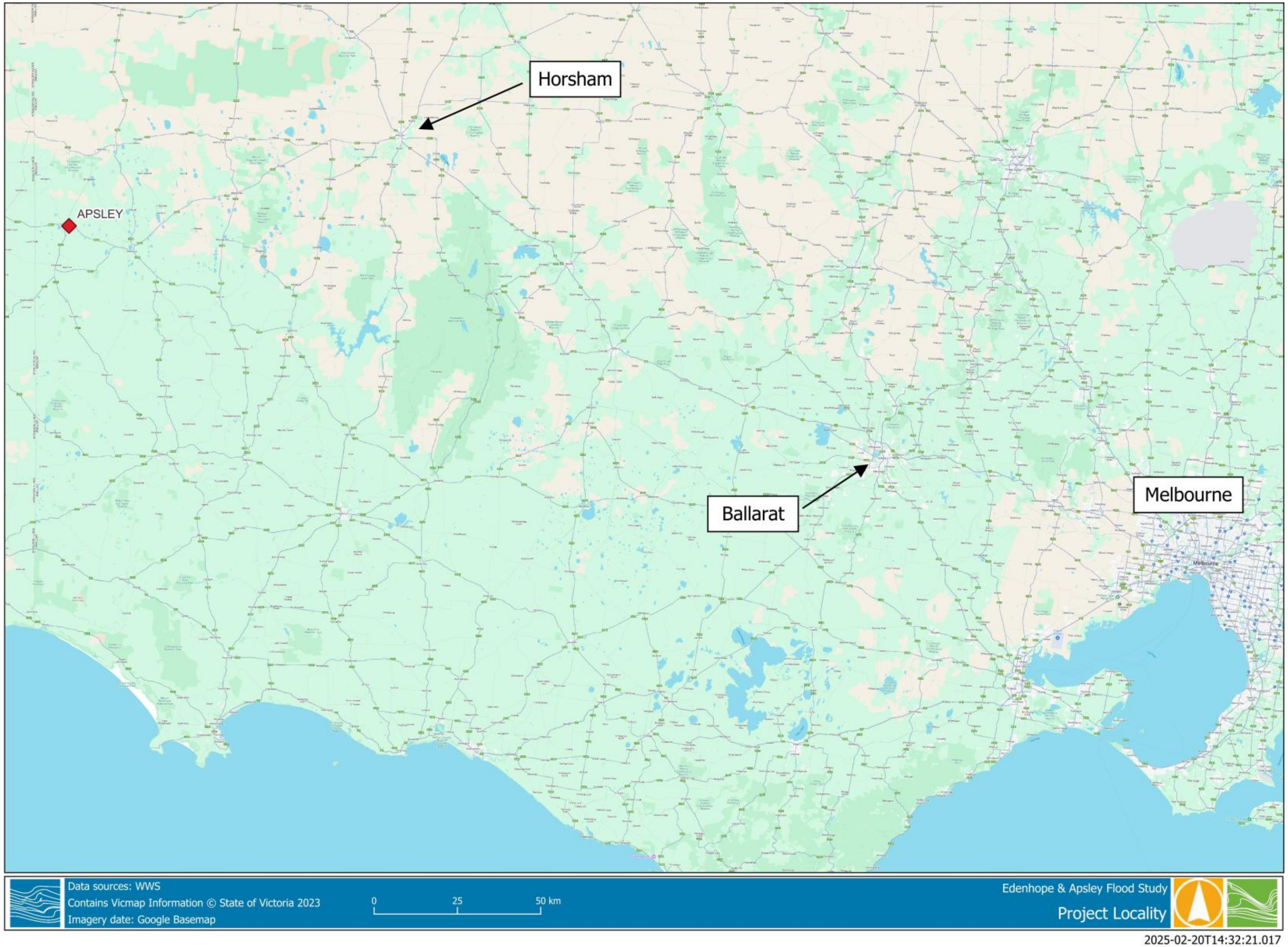

Figure 1-1 Edenhope and Apsley with respect to western Victoria

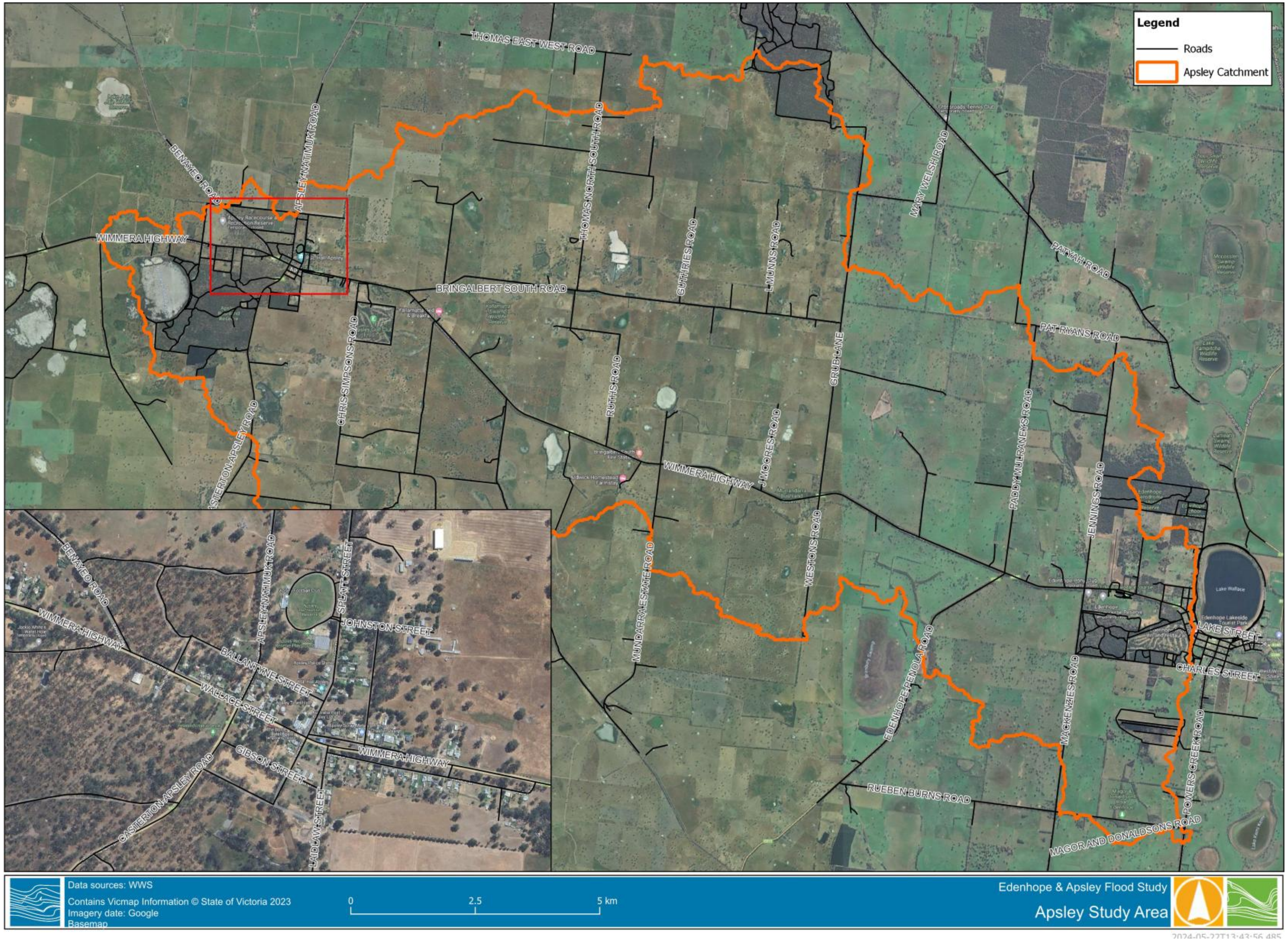

Figure 1-2 Apsley study area

2 DATA COLLATION, MODEL DEVELOPMENT AND CALIBRATION

2.1 Overview

The Data Collation, Model Development and Calibration (R01) describe the collation and review of available data relevant to flooding, and the hydraulic model development and calibration in Edenhope and Apsley (as a joint report).

2.2 Data Collation

Streamflow Data

No active or non-active streamflow gauges within the study areas or in any adjoining catchments.

Storage Data

The only major water storages in the study area is Newlands Lake, immediately downstream of Apsley. Lake Wallace is within the Edenhope catchment to the east.

There is limited recorded water level information available for Newlands Lakes, but Lake Wallace in Edenhope, does have opportunistic water level records or observed dates when the lake was either empty, full or overflowing. Most of this record has been extracted from newspaper articles/photos.

There is a very large number of wetlands across the Apsley catchment, creating a large volume of catchment storage.

Rainfall Data

Daily rainfall data are available for Apsley. However, no sub daily rainfall data is available for Apsley. Edenhope Airport gauge (079099) at Edenhope was used as a reference.

Drainage Infrastructure

Apsley have township scale stormwater infrastructure which are generally open roadside drainage and bridges/culverts under roads.

Topography Data

The model was primarily based on the Wimmera CMA LiDAR dataset (2006). The Wimmera CMA LiDAR covered the entirety of the townships and most of their respective catchments. Areas not covered by the Wimmera CMA LiDAR adopted the VicMap 10m DEM. While the LiDAR was the primary source of topographic information, the model topography was further refined where more accurate or appropriate data was available.

These adjustments included the removal of water from storages, works known to have been undertaken, adjustments at bridges and culverts, and reinforced breaklines along roadways and levees.

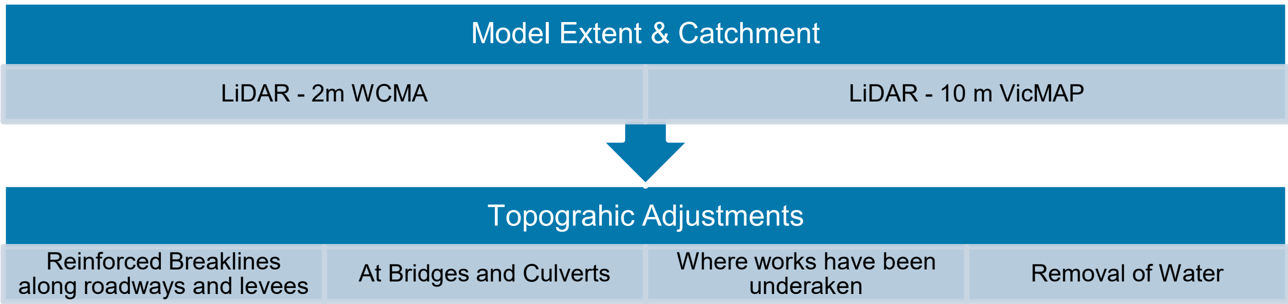

Figure 2-1 Model Topography Methodology

Community Consultation

Two community consultation sessions were held in Apsley as part of the data collation aspect of the project. During the initial community consultation, members of the Apsley community were able to provide a vast history of flooding within the township, as well as provide insights into flood behaviour within the township, providing information on inundation mechanisms, consequences and mitigation options.

2.3 Model Development

This section summarises the modelling methodology for Apsley.

2.3.1 Catchment Analysis

2.3.1.1 Catchment and Characteristics

Apsley has a unique catchment, with several depressions located upstream of both townships scattered throughout the catchments. The size of the depressions varies with some relatively shallow and others covering a significant area.

The identified catchments and topography for Apsley covers 169 km². The catchments have significantly more storage than other catchments in Victoria. The actual area contributing to runoff is dependent upon the upstream connectivity, with many potential semi-terminal depressions located within the catchment.

2.3.1.2 Historic Events

There are no stream gauges located within the Apsley catchment, as such historic flood events have been identified based upon local rainfall gauges, Newlands Lake water level records and consultation with the community. The largest identified recent events included:

- 2011.
- 2016.

2.3.1.3 Antecedent Conditions

The Apsley catchments contain multiple depressions creating a series of swamps, wetlands and lakes all which provide significant catchment storage. Many of these depressions are ephemeral, only experiencing pooling water in periods of prolonged rainfall. The complex connectivity of these wetlands influences flood behaviour within Apsley. Although there are no streamflow gauges available, an assessment of Apsley's record rainfall totals in relation to climatic conditions and preceding rainfall shows that these extremes typically occur during La Niña phases and following periods of sustained rainfall.

In standard practice, flood modelling accounts for this bias toward wetter conditions by adjusting parameters to reflect the combined probability of multiple variables during an event, resulting in design mapping that differs from historical flood patterns.

While this methodology is suitable for typical catchments where flood impacts are largely driven by runoff volume, in Apsley, upstream flooding is more likely influenced by the connectivity of the upstream system during an event.

2.3.2 Hydraulic Modelling

2.3.2.1 Model Extent and Structure

Modelling was developed in the TUFLOW HPC hydraulic modelling software. The model adopted a 1D/2D Rain-on-Grid (RoG) approach, with directly applied rainfall to the upstream catchment. This modelling approach provided a better understanding of overland flow and drainage paths through the township and within the upstream catchment. RoG was considered more appropriate than a standard runoff routing model due to the complex natural upstream storages. As this investigation covered both stormwater and riverine flooding, rainfall was applied in two areas varying the Areal Reduction Factor (ARF).

The model adopted an outflow boundary downstream of Newlands Lake Reserve for Apsley. The outflow boundary adopted a water level vs flow (stage-discharge) curve calculated from the topography. The influence of these boundaries was controlled by the upstream catchment, which act as natural controls to upstream flooding.

2.3.2.2 Model Topography

The model topography was represented with a varying resolution (using Quadtree), with a cell size of 12 m outside of the township and 3 m within the township and across the local catchment. The ability for the resultant model grid to capture finer details was supported by Sub-Grid-Sampling (SGS) of the underlying topography datasets, which was based on detailed 2 m LiDAR.

The topography of the catchments is shown in Figure 2-2.

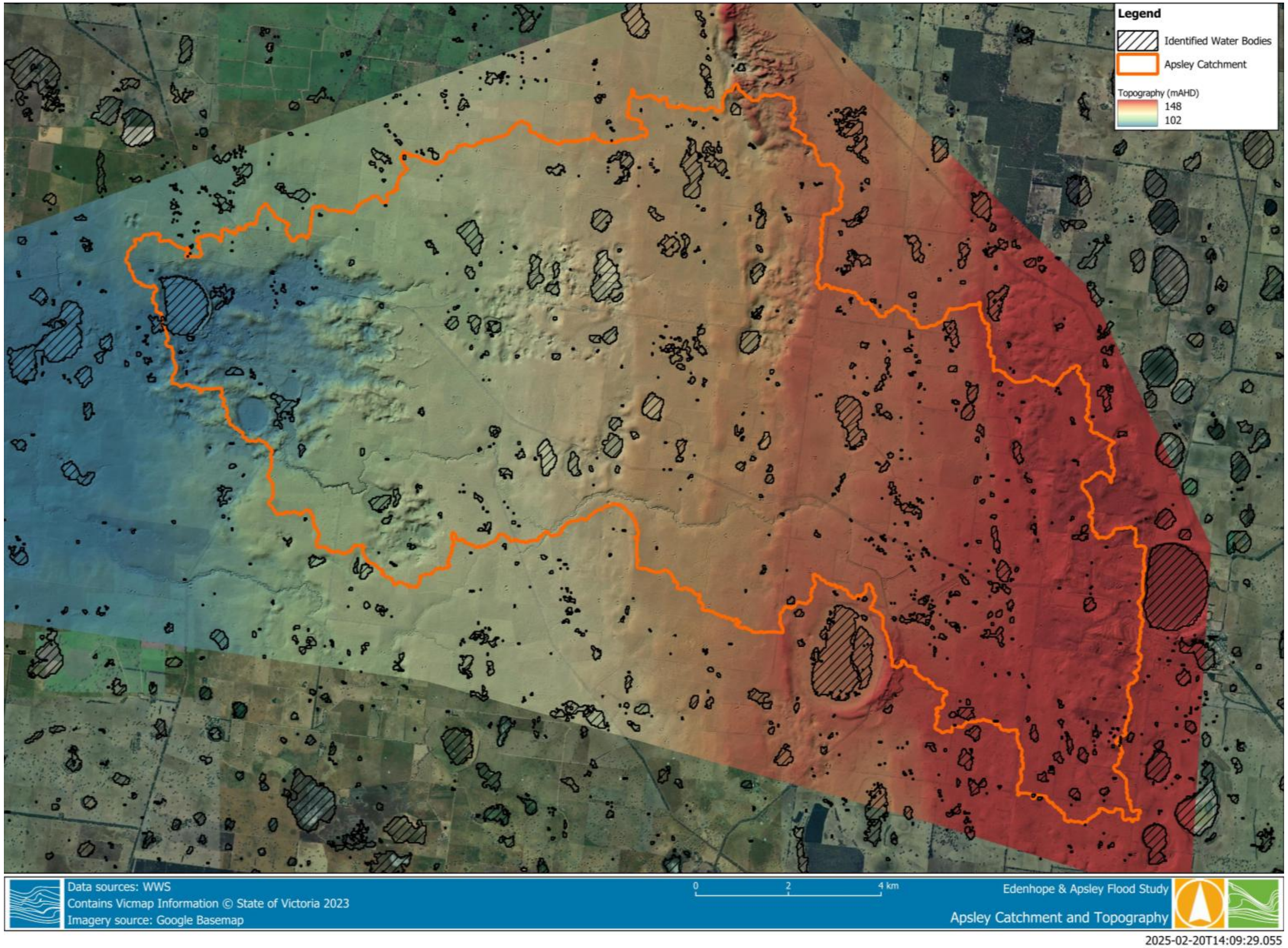

Figure 2-2 Apsley Catchment and Topography

2.3.2.3 Model Roughness

Surface roughness was represented using Manning's 'n'. The adopted Manning's 'n' values are presented in Table 2-1 and shown spatially in Figure 2-5.

Table 2-1 Land Use Manning's 'n' Roughness values

Material	Manning's 'n' value
Rural Residential	0.1
Pasture	0.04
Dense Vegetation	0.095
Waterway Channel	0.03
Roadway (Paved)	0.025
Roadway (Unpaved)	0.035
Lake / Swamp / Wetland	0.05

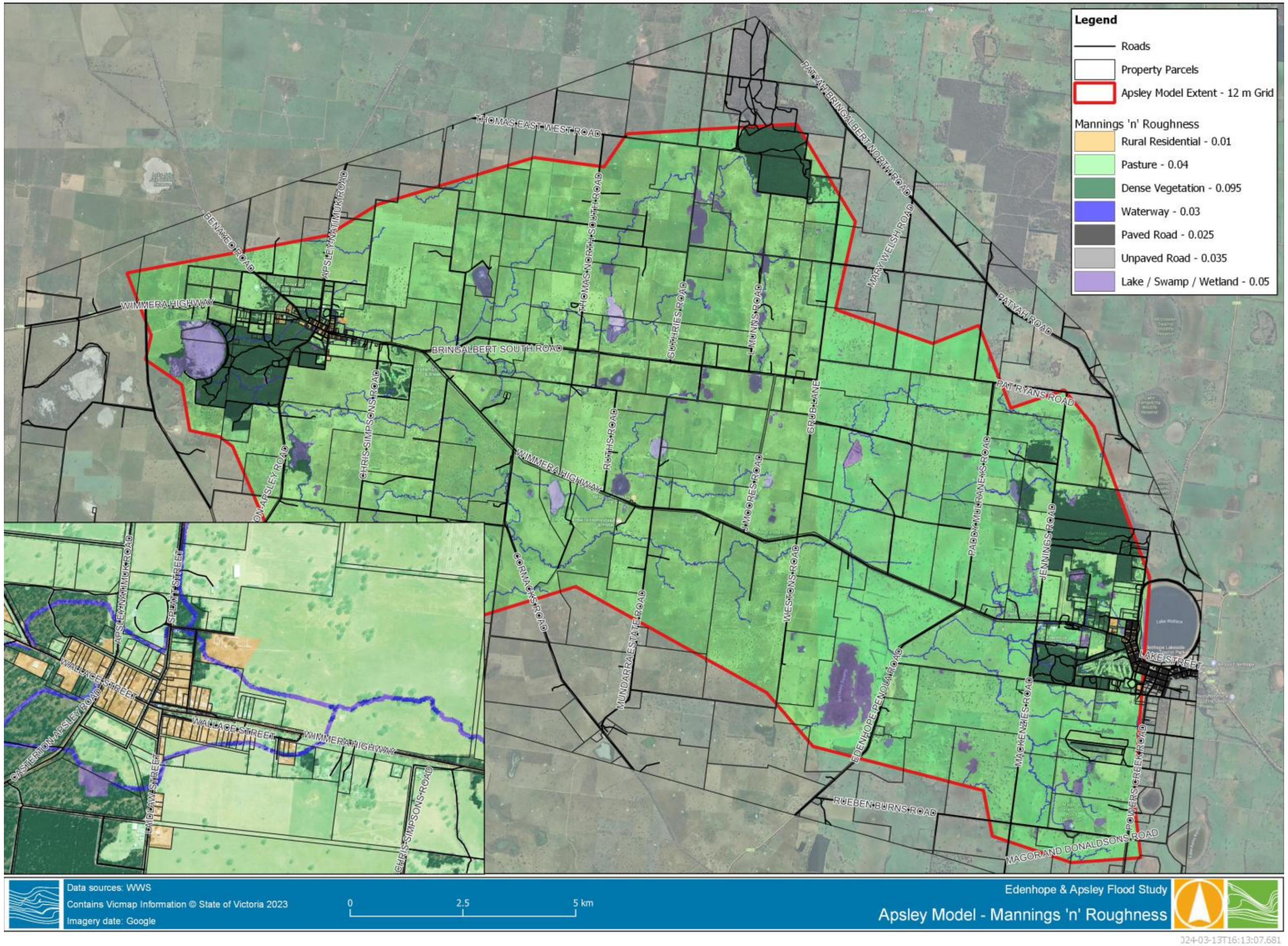

Figure 2-3 Apsley – Model Roughness

2.3.2.4 Model Structures

The drainage infrastructure in Apsley consists of open drains, pipes and pits. The major drainage network (pits and pipes) was provided by WWSC, with the invert levels estimated based on the topography, incorporating a standard cover. Additional culvert measurements were obtained during the site visit.

In total, the Apsley model incorporated 42 pipes and 13 pits. Upstream of the township where flow paths intercepted roadways crossing was artificially removed to ensure connectivity.

2.3.2.5 Rainfall Losses

The empirical method of Initial Loss (IL) and Continuing Loss (CL) was adopted for this flood investigation, and it is the recommended procedure in the Australia Rainfall Runoff guidelines. These losses have been determined based on a regression analysis of 11 catchments within Region 3, using soil moisture in winter, design rainfall and the soil storage as variables to calculate IL and CL

The adopted losses for Apsley are provided in Table 2-2. While this method is appropriate for many catchments, the Apsley catchments are expected to have significantly higher retention losses given the catchment storage.

Table 2-2 Apsley Infiltration Loss Values

	Initial Loss (mm)	Continuing Loss (mm/hr)
ARR Recommendation	21	4.8

To analyse the depression loss potential within the Apsley catchment the catchment topography, preliminary mapping and DEA water observations datasets were used to identify potential water storages and their respective volumes. The volumes were calculated for a range of starting conditions and were then divided by the overall Apsley catchment area. The result provided an estimation of the potential depression losses for the entire catchment under a variety of starting conditions. The result of this analysis is provided in Table 2-3 and identified areas provided in Figure 2-4.Figure 2-4

While the analysis is high-level, it demonstrates that depending on antecedent conditions, the expected initial losses may exceed those recommended by ARR. Particularly once additional loss mechanisms are considered. It also demonstrates that antecedent conditions influence the expected losses and that the two are not independent. Therefore, sensitivity testing will be required on the influence of rainfall losses for a variety of antecedent conditions.

Table 2-3 Apsley Depression Loss - Estimation

<table>
<tr><th>Scenario</th><th>Total Number of Depressions</th><th>Total Volume (m3)</th><th>Catchment Area (ha)</th><th>Estimated Loss (mm)</th></tr>
<tr><td>Depressions Empty</td><td rowspan="3">552</td><td>5.04 x 10^6</td><td rowspan="3">16,867</td><td>29.9</td></tr>
<tr><td>Depressions @ Average Elevation within area</td><td>4.37 x 10^6</td><td>25.9</td></tr>
<tr><td>Depression Almost Full</td><td>2.38 x 10^6</td><td>14.1</td></tr>
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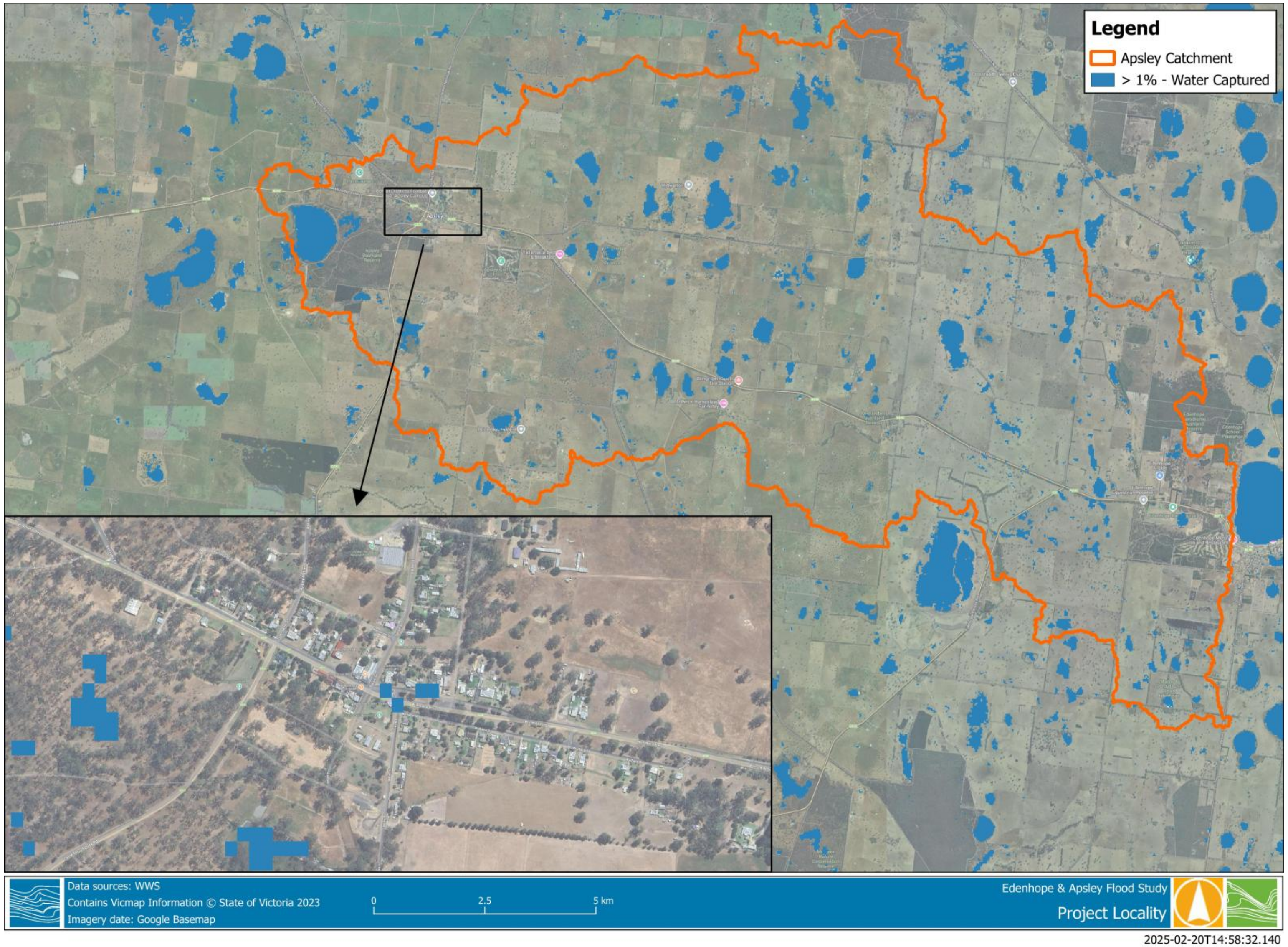

Figure 2-4 DEA Water Observation – 1% Return Frequency

2.4 Model Calibration

2.4.1 Overview

During community consultation for Apsley significantly greater observations of flooding were provided by the community with the modelling matching these observations through adjustment of parameters.

The January 2011 event was modelled iteratively in the Apsley TUFLOW model. Calibration of the model had three primary variables, which included:

- Rainfall infiltration losses.
- Antecedent conditions - note will also influence rainfall losses.
- Mannings 'n' roughness values.

The above parameters were adjusted until the best overall match observations was achieved. The full details of each model simulation are not documented in this report due to the number of iterations. However, the influence of individual parameters is be discussed in design modelling sensitivity in later reporting. It should be noted that the calibration is not considered final, and adjustments are still able to be made once further discussion with the community is complete.

2.4.2 Event Overview

January 2011 was the wettest January on record across many parts of Victoria, causing flooding in over 100 towns. In Apsley, the storm event primarily occurred in the 24 hours prior to 9 am, January 14. During this period 115 mm fell in Apsley. A comparison of the observed rainfall to the BoM IFD curves is shown in Figure 2-5.

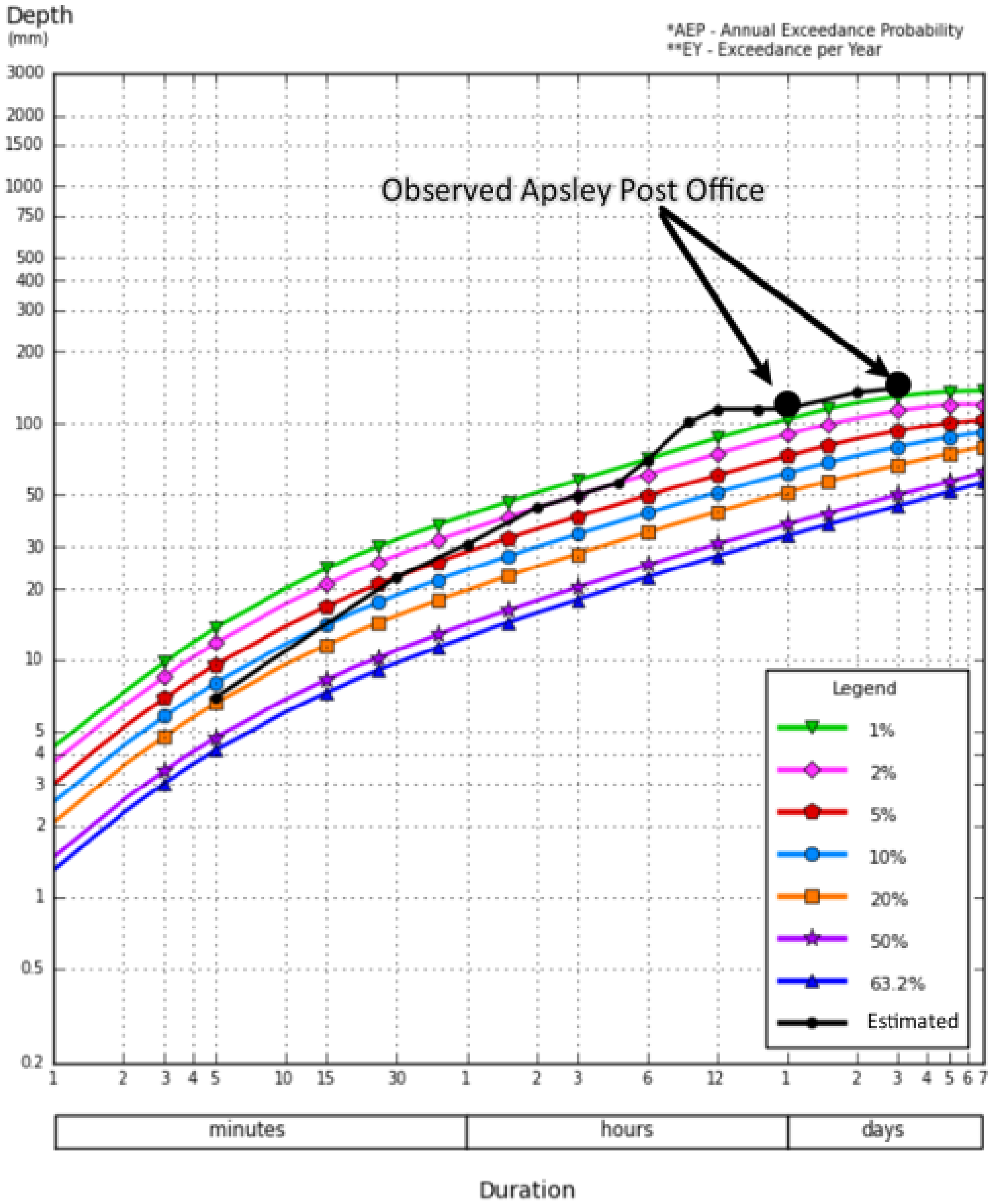

Figure 2-5 IFD curves for Apsley and estimated rainfall intensities – January 2011

2.4.3 Calibration data

Calibration data for the January 2011 event mainly included anecdotal evidence from community members, with some photographs taken during the event. Community consultation and phone interviews indicated the January 2011 event impacted Apsley significantly. It is understood that the following occurred during the event:

- Clubrooms at Apsley Reserve: was protected by sandbags, with inundation around ankle deep experienced. It is understood that Apsley Reserve is impacted from the north, prior to the flow the east. Once flow from the east reaches Apsley, this then proceeds to flow over Splatt Street and into the reserve.
- Properties Along Splatt Street from Johnson Street to around Ballantyne Street: flow from the east (via Church Water Hole) spill toward the reserve, threatening houses in this area. It is understood that most water was directed over the vacant land at 28 Splatt Street, with 32 Splatt Street experiencing inundation and requiring protection via Sandbags.
- Properties south of the main drain alignment between Apsley-Natimuk Road and Benayeo Road: during the 2011 event this drain exceeded its capacity, exacerbated by its inability to drain freely. Excess water drained over Ballantyne Street and to the west of Townsend Street. Photographs and accounts by residents in this area indicate the flood depth likely reached between 200-500 mm deep, described as knee deep at the intersection of Townsend Street and the Wimmera Highway. Figure 2-6 and Figure 2-7 provide some guidance of the inundation experienced; however, it is expected that these were not taken during the peak of the event.
- Properties east of Laidlaw Street, along Wallace Street: this area was heavily impacted by flows from the east. During the 2011 event, several properties, particularly from 1 to 35 Wallace Street, experienced some form of inundation. It is known that the vacant land on Wallace Street experienced inundation, with neighbouring properties requiring protection from sandbagging and pumping. Some discussion with community members indicates that Wallace Street may not have overtopped in the January 2011 event; however, this is not clear. Importantly. it is understood that flooding in this area is solely related to water draining under the Wimmera Highway and not overtopping of the highway from the north into the properties.
- The Apsley Post Office: while this location is understood not to have been inundated in 2011, it served as a key location where flood behaviour was known. It is understood that inundation did occur outside of the Post Office and it was under threat of inundation in 2011.
- The Appley Pub: on the higher side of the Wimmera Hwy and did not experience inundation in the 2011 event.

A summary of the flood behaviour and areas impacted during the 2011 flood event is provided in Figure 2-8. Unfortunately, a lack of surveyed water levels has meant calibration of the modelling was reliant on anecdotal evidence and an understanding of the flood behaviour.

Figure 2-6 Flooding at residences along Townsend Street

Figure 2-7 Flooding at Wallace Street Crossing

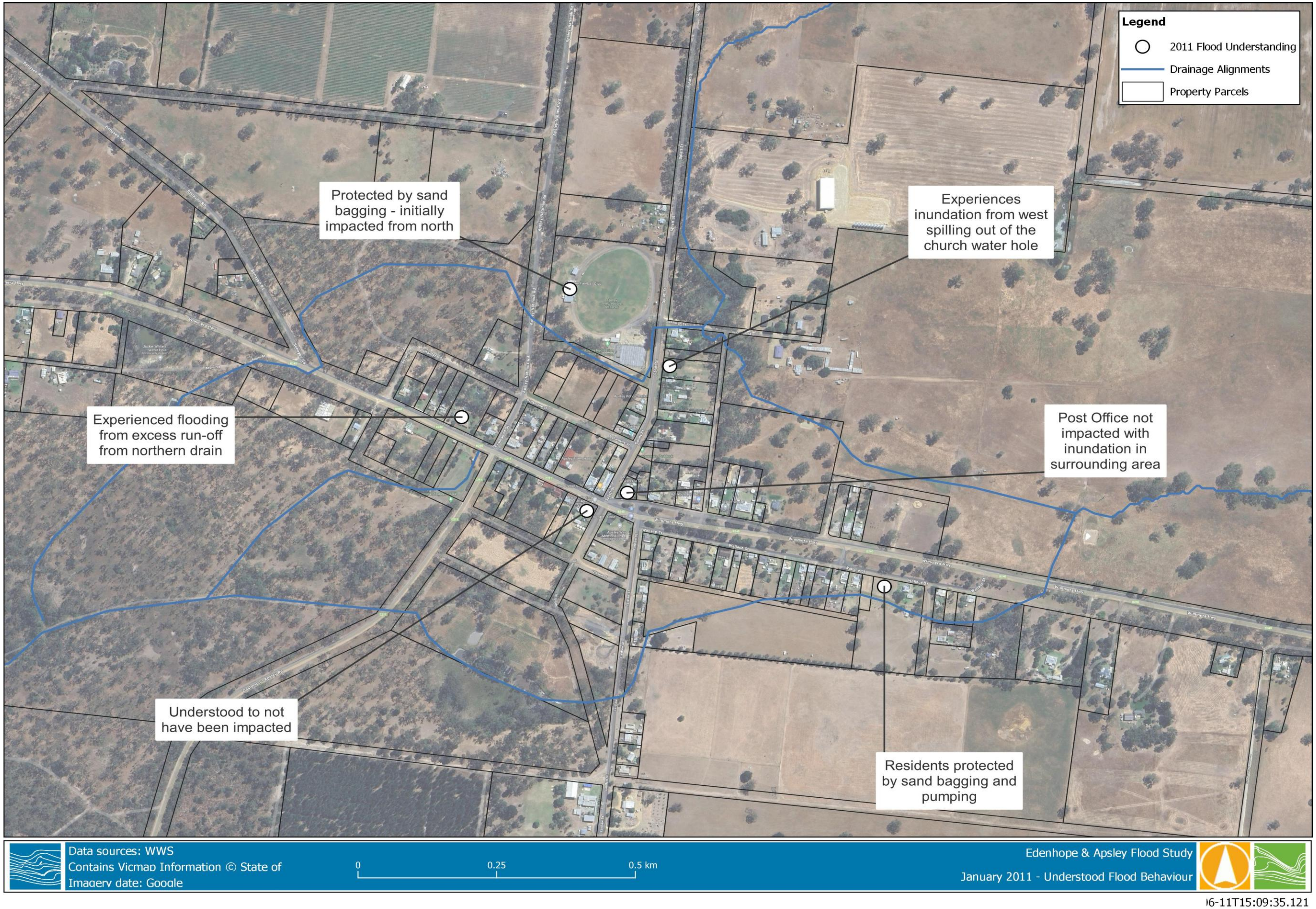

Figure 2-8 Observed flood behaviour within Apsley

2.4.4 Modelled Event & Scenarios

As flooding within Apsley is expected to be heavily reliant upon upstream antecedent conditions, the following scenarios and events were modelled:

- Scenario 1 - January 12th event to pre-wet the catchment, followed by January 14th event. This included the following:
  - Simulation of the January 12th event from 9 am on the 11th of January to 9 pm on the 12th of January (36 hours). This event adopted lower rainfall losses than Scenario 2 & 3, as it is known that the catchment had experienced significant rainfall in December 2010.
  - Simulation of the January 14th event from 9 pm on the 12th of January to 12 pm on the 14th of January (40 hours). Further lowered losses to those applied during the January 12th event.
    - Note for this event varied rainfall losses, to aid in assessing the relationship between antecedent conditions and rainfall losses. Losses were also reduced for this event to ensure the January 12th event resulted in run-off.
- Scenario 2 – January 14th event, adopting a dry upstream catchment.
- Scenario 3 – January 14th event, adopting a wet catchment (DEA 1% Return Frequency – Figure 2-4).
  - Both Scenario 2 and 3, were simulated from 6 am on the 13th of January to 12 pm on the 14th of January (30 hours).
    - Note Scenario 2 and 3 adopted the same losses, this was done so it was easier to assess the sensitivity of a wet catchment. Scenario 1 allowed the assessment of both catchment wetness and variation of rainfall losses.

Losses adopted for the three scenarios are provided in Table 2-4.

Table 2-4 Rainfall Losses Applied to Scenarios

Material	Scenario 1 – January 12		Scenario 1 – January 14		Scenario 2 – January 14		Scenario 3 – January 14	
	IL (mm)	CL (mm/hr)	IL (mm)	CL (mm/hr)	IL (mm)	CL (mm/hr)	IL (mm)	CL (mm/hr)
Rural Residential	10.0	2.0	5.0	1.0	15.0	3.0	15.0	3.0
Pasture	15.0	3.0	5.0	1.0	30.0	4.0	30.0	4.0
Dense Vegetation	20.0	4.0	10.0	2.0	30.0	5.0	30.0	5.0
Waterway Channel	15.0	2.0	5.0	1.0	15.0	2.0	15.0	2.0
Roadway (Paved)	5.0	1.0	5.0	1.0	5.0	1.0	5.0	1.0
Roadway (Unpaved)	10.0	1.0	10.0	1.0	10.0	1.0	10.0	1.0
Lake / Swamp / Wetland	10.0	1.0	0.0	0.0	10.0	1.0	10.0	1.0

2.5 Apsley – 2011 Flood Results

Flood depth mapping for the three scenarios in Apsley was completed, with a comparison of the flood extents presented in Figure 2-9 along with the assessed location. A summary of the key locations and flood results for each scenario is provided in Table 2-5.

The flood results at these locations demonstrate that the flooding experienced within Apsley has a degree of sensitivity to antecedent conditions. While the depth range is within 100 mm and flooding in these locations is controlled by the natural topography and structures, the difference in flood extent upstream of Splatt Street (toward Edenhope) highlights the sensitivity of the catchment, with a significant increase in flood extent between a dry catchment and the two scenarios considering antecedent conditions. Importantly, results of Scenario 1, which lowers rainfall losses with catchment conditions results in the largest flood extent. This indicates that flooding within Apsley is most sensitive when rainfall losses and catchment condition are considered together. The difference in flood extent indicates that during design modelling, sensitivity testing will be required for antecedent conditions.

A summary of the flood behaviour at each location is provided below:

- Apsley Reserve – during the 2011 event, works downstream of Apsley-Natimuk Road were not complete, with the drain known to have limited capacity. This limitation meant during 2011 water filled the reserve until it overtopped (around 105.1 m AHD), along the main drain and along the southern bank of the drain upstream of Apsley-Natimuk Road. These controls cause flooding at the reserve to be driven by the volume of water, and there is a negligible difference in flood depths between scenarios.
- Splatt Street – inundation at Splatt Street is controlled by the available storage in the depression directly to the west, it is referred to as the Church Water Hole. These depressions, in combination with Splatt Street, control flooding in this area. The increased runoff from wet antecedent conditions, increases the extent of which Splatt Street is overtopped and the and the amount of water directed toward the Post Office.
- 72 – 88 Wallace Street – flooding to the rear of these properties is controlled by the amount of water spilling from the main drainage alignment over Ballantyne Street. While there is some variation in flooding at the rear of these properties, flood depths are controlled by the hydraulic controls in Apsley Reserve. However, for the front of these properties, flooding is dependent on antecedent conditions. In the wet condition scenarios, Newlands Reserve fills up to a level that exceeds the road crest of the Wimmera Highway / Wallace Street, controlling flooding on the front of these properties.
- 1 – 35 Wallace Street – flooding at this location is primarily controlled by the upstream culverts, under the Wimmera Highway. While in wet antecedent conditions, significantly more water is flowing from east, the capacity of the culverts and the upstream channel control the amount of water directed south of the Wimmera Highway. Once downstream of the culverts, controls appear to exist within the channel with the upstream water level significantly higher than the downstream of the controls. Based upon the modelling results a significant control impacting the residents upstream of 29-31 Wallace Street, exists within the channel in this location. While this could be an error in the topographic data created by the trees. After discussions with community members, it is far more likely that these controls exist throughout the channel due to degradation over time.

A summary of the flood behaviours at assessed locations is detailed in the Data Collation, Model Development and Calibration Report (R01).

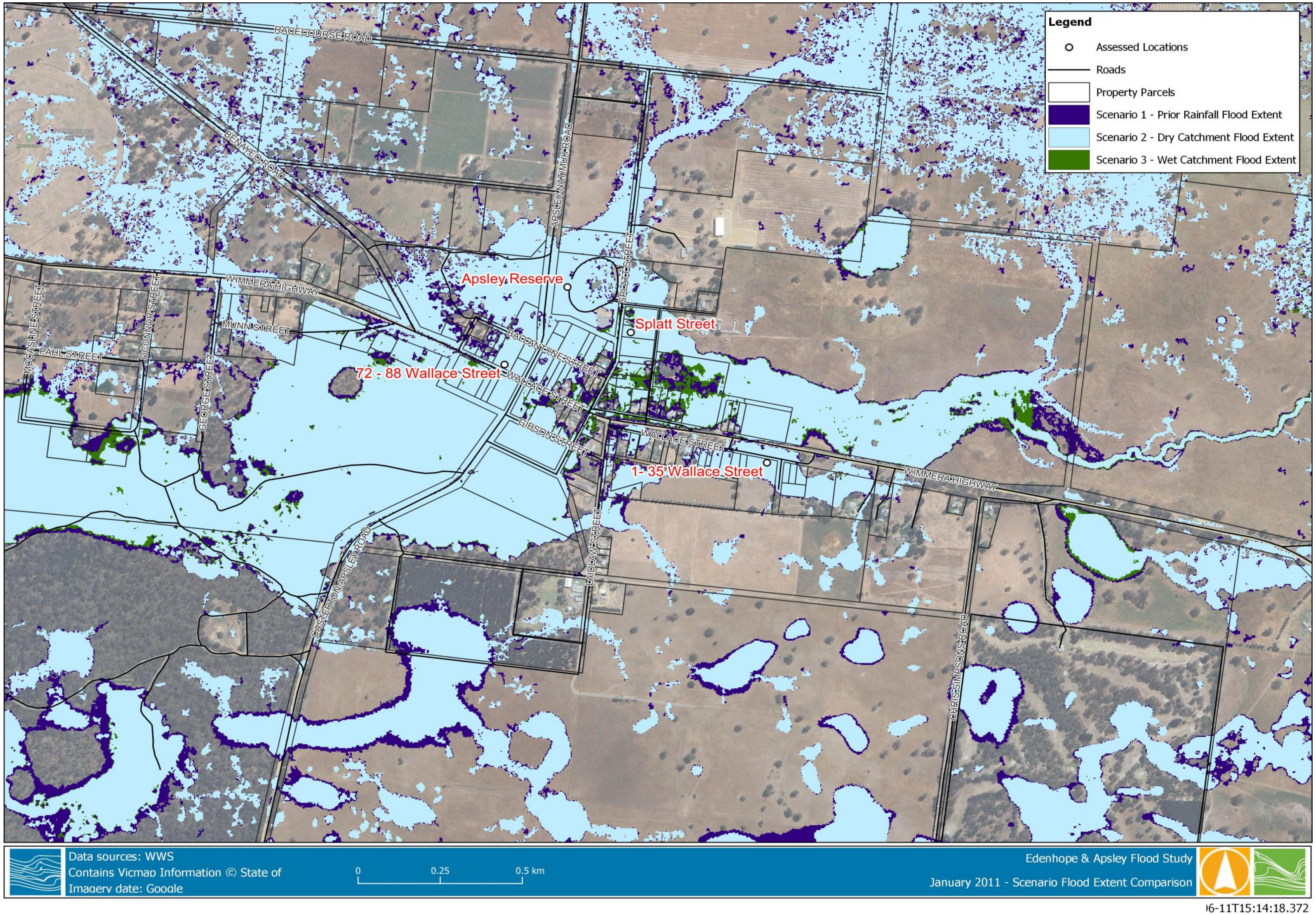

Figure 2-9 Extent Comparison – January 2011

Table 2-5 Modelled Flood Depths at Assessed Locations

Location	Address Assessed	Understood Flood Impact	Expected Flood Depth	Scenario 1 – Flood Depth	Scenario 2 – Flood Depth	Scenario 3 – Flood Depth	Range
Apsley Reserve	Apsley Reserve, Clubrooms	Required sandbagging, with ankle depth inundation experienced in surrounded areas	50-100 mm	135 mm	75 mm	80 mm	60 mm
Splatt Properties	28 Splatt Street	Flow occurring from east to west through properties with vacant parcel inundated	200 – 500 mm	305 mm	220 mm	255 mm	85 mm
72 – 88 Wallace Street	76 Wallace Street	Excess flow from intended drainage route, flowing south inundated properties in this location.	200 – 500 mm	280 mm	200 mm	205 mm	80 mm
1 – 35 Wallace Street	11 Wallace Street	Flow from Edenhope under Wimmera Highway exceeding capacity of channel toward Lake Newlands, impacting residents between 1 to 35 Wallace Street. Potentially exacerbated by backwatering from downstream.	100 – 300 mm	245 mm	180 mm	190 mm	65 mm

3 DESIGN MODELLING

This section summarises the design modelling and sensitivity testing for Apsley. Further detail can be found in the Design Modelling Report (R03B).

3.1 Adopted Parameters for Design Modelling

The adopted design parameters closely aligned with those determined during the January 2011 model calibration. The adopted parameter values were as follows:

- Antecedent conditions – 90th percentile initial water level
- Rainfall losses and pre-burst
  - Initial Loss – 21 mm.
  - Continuing Loss – 4.8 mm / hr.
  - 75th percentile pre-burst rainfall.
- Roughness coefficient – see Table 2-1.
- Critical durations – see

Table 3-1 Finalised critical durations at key catchment locations

1% % 10% AEP	Critical Duration
Apsley township	2 hours
Upstream flow path	12 hours

3.2 Sensitivity Analysis

Model sensitivity testing was conducted, adjusting the model's initial water level, rainfall infiltration and storm duration. The parameter adjustment adopted the following methodology:

- Initial Water – a single run for the 10% and 1% AEP events was completed considering a range of starting water levels in the upstream wetlands to understand their sensitivity to flooding.
- Rainfall Losses – a single run for the 10% and 1% AEP events was modelled adopting half the losses adopted to understand its impact.
- Pre-Burst – Testing of rainfall pre-burst was similar to testing of initial water levels. Contributing the volume of runoff within the model.
- Critical Storm Durations
  - Temporal Patterns – all 10 temporal patterns were run for the 10% and 1% AEP events for both short duration and long duration events. Front, middle and rear loaded temporal patterns were modelled for the remaining AEPs.
  - Durations – for all design modelling a single temporal pattern was run for all durations to identify their respective critical duration/s.

The Apsley model showed some level of sensitivity to antecedent conditions, rainfall losses and pre-burst, roughness coefficient and critical storm duration.

The impact of initial water levels demonstrated that the storages have controlled spill locations and significant volume to attenuate flows. Therefore, the impact to flooding along flow paths within Apsley is similar. The areas impacted are localised to the storages, including the bushland reserved downstream of the township, and were more dependent on long term rainfall than individual rainfall events. This indicates the catchment is not overly sensitive to the initial water levels. Similarly to the impact on roughness coefficient, where the change in roughness values has minimal flooding impact along the flow paths within Apsley.

The rainfall losses and pre-burst, on the other hand, demonstrated some sensitivity to rainfall losses influenced by pre-burst, which was primarily driven by an increase or decrease in the volume of water spilling from the upstream storages.

The parameter testing determined the adopted pre-burst values enabled a conservative flood mapping approach. These values combined with the roughness values calibrated to the recent flood event resulted in a reasonable approach to the parameter value adoption for the design modelling.

3.3 Design Flood Mapping

Figure 3-1 and Figure 3-2 show the flood depths and hazards for 1% AEP flood event, and Figure 3-3 and Figure 3-4 show a zoomed in perspective of Apsley.

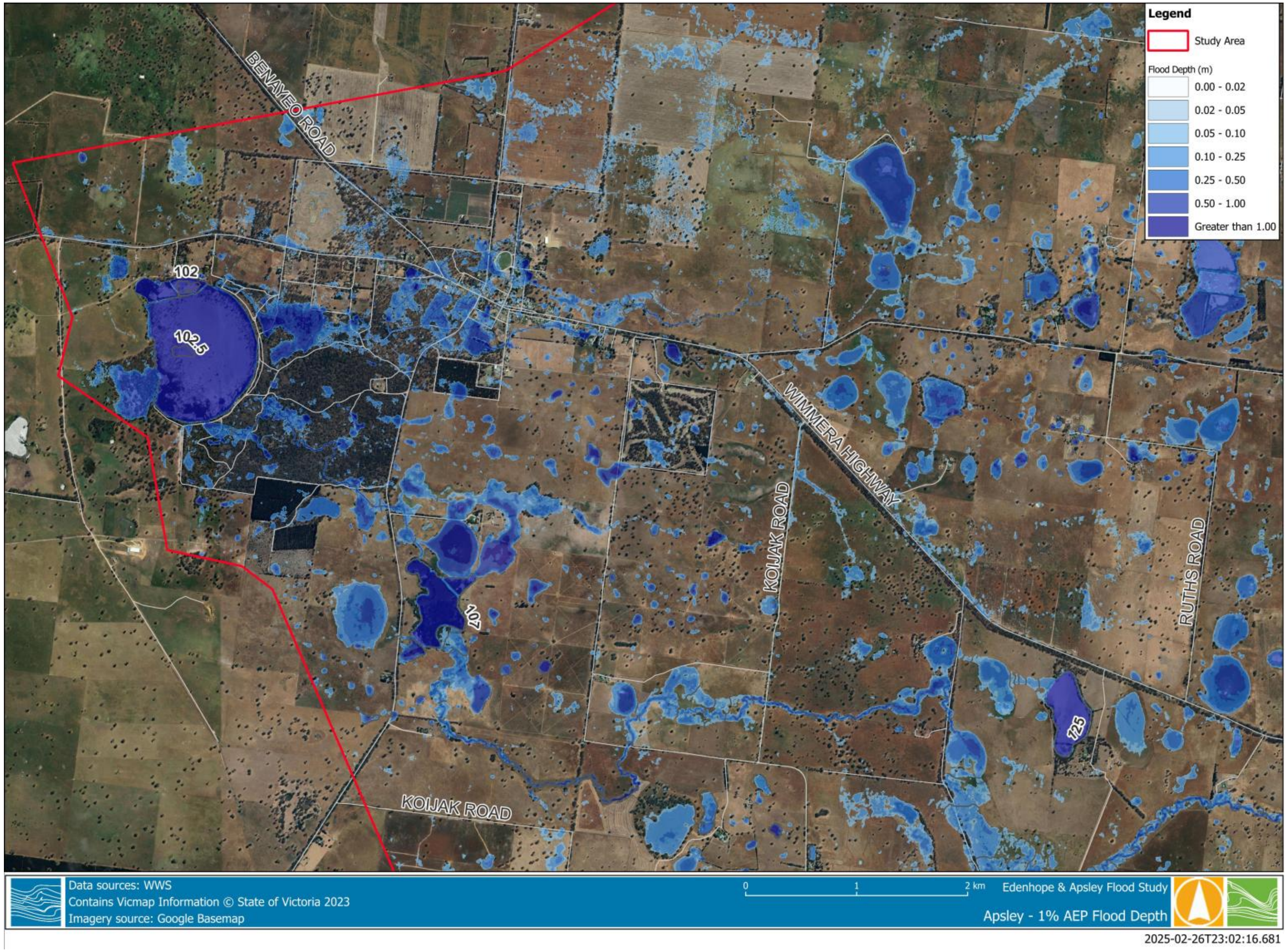

Figure 3-1 Broad extent - 1% flood depth with water surface elevation contours

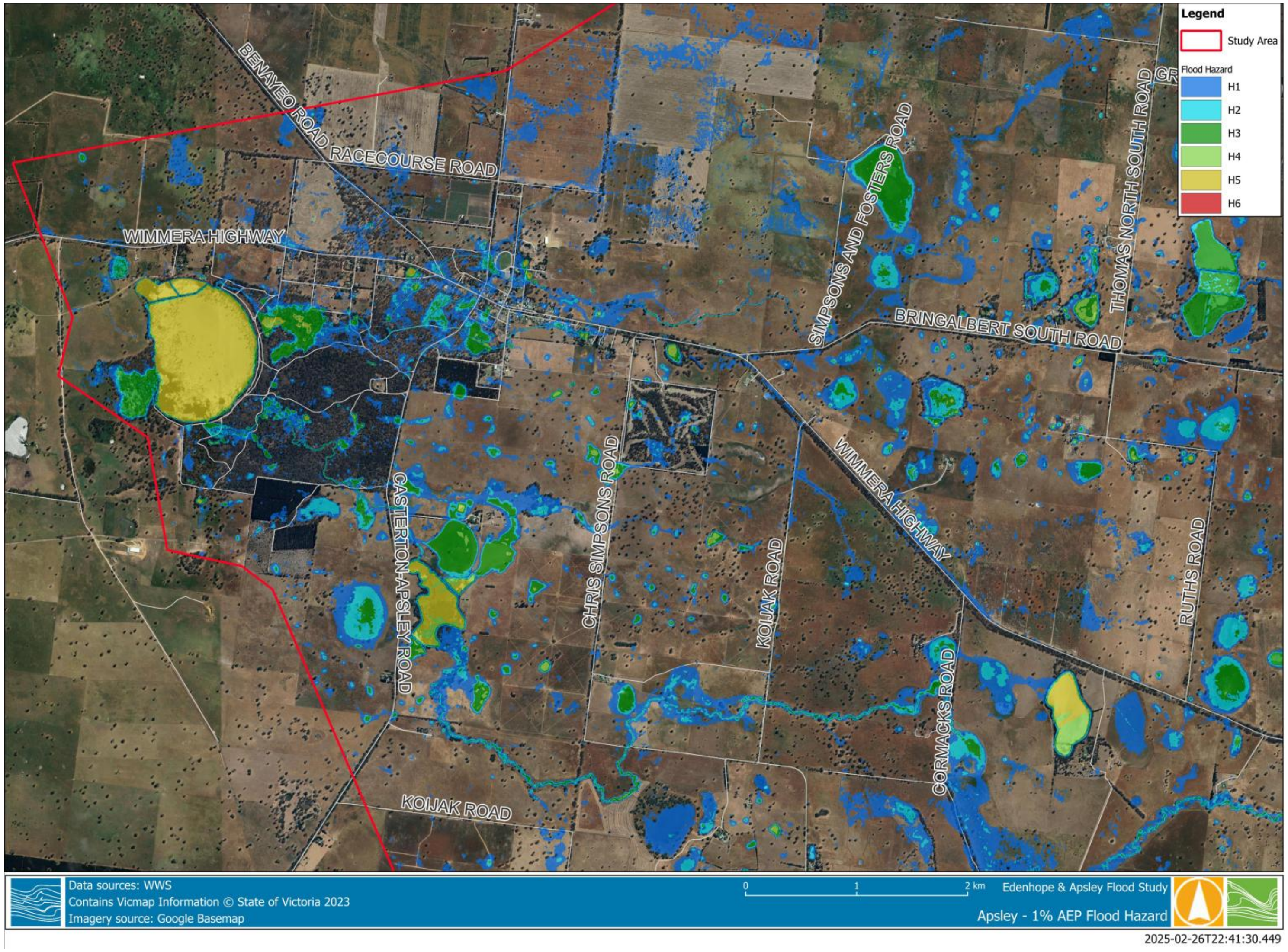

Figure 3-2 Broad extent - 1% flood hazard

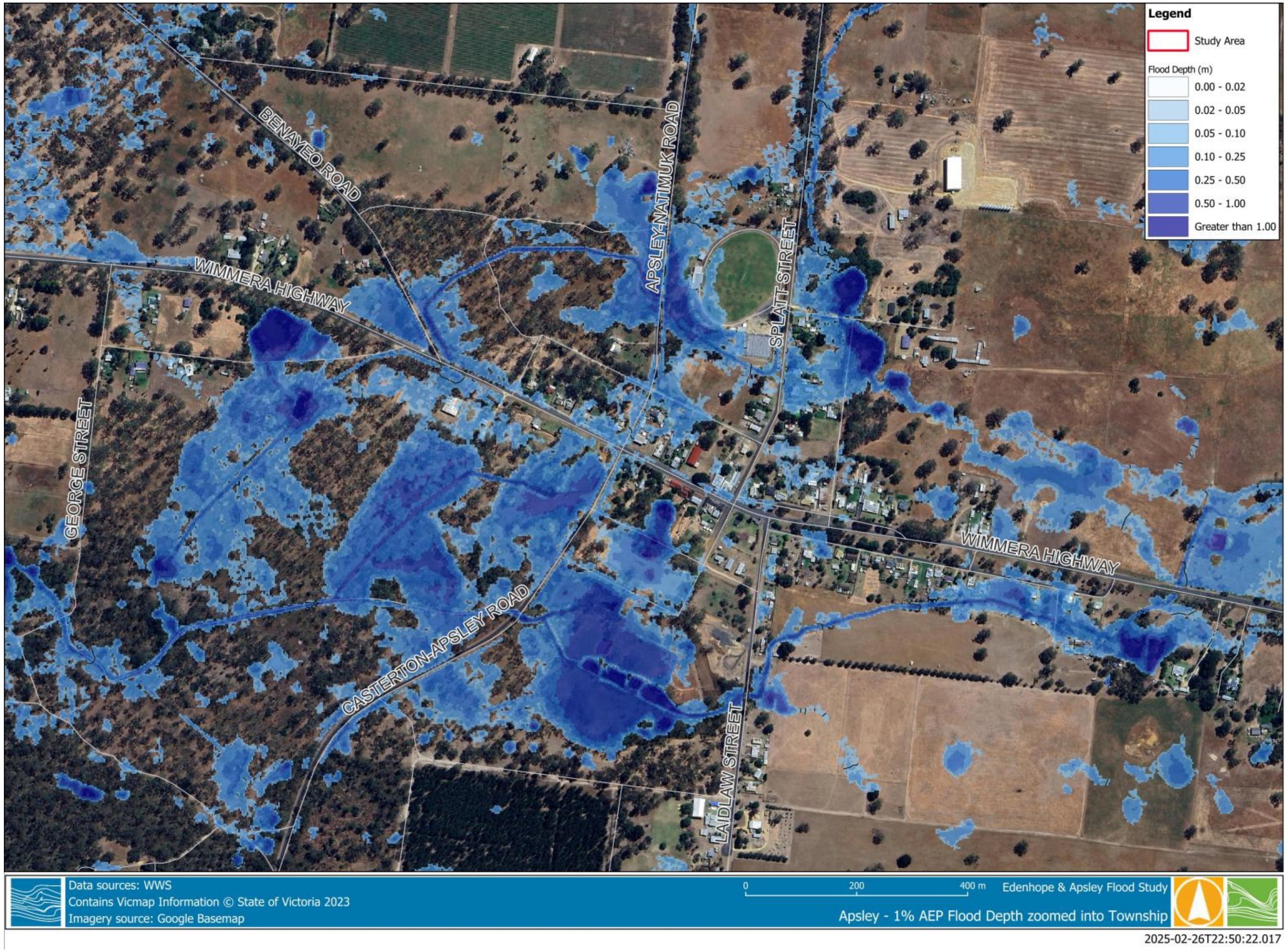

Figure 3-3 Zoomed into Apsley – 1% flood depth

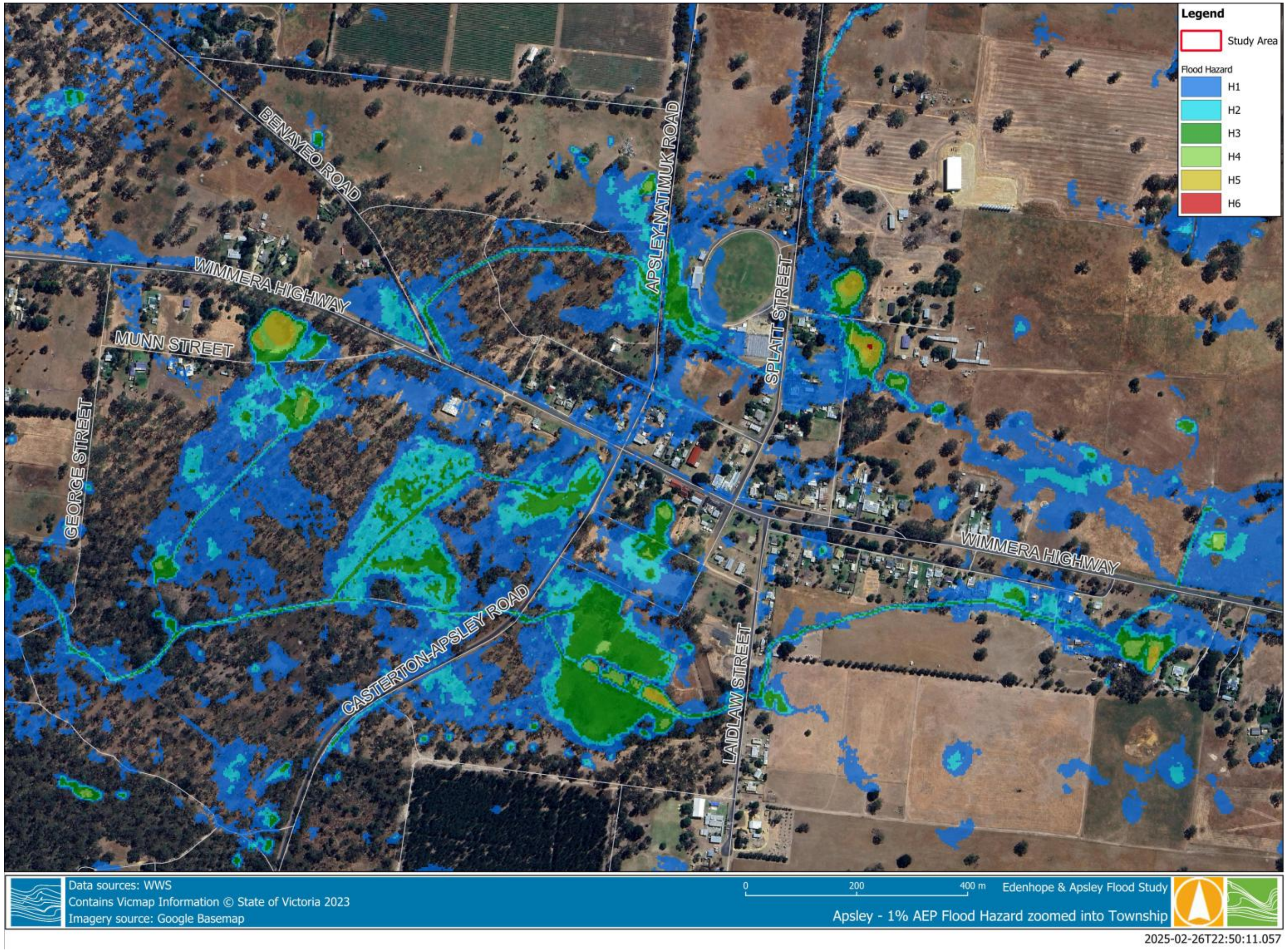

Figure 3-4 Zoomed into Apsley – 1% flood hazard

4 FLOOD INTELLIGENCE

4.1 Overview

This study has produced reliable flood intelligence for use in emergency management situations, with sections intended to be cut and pasted into the West Wimmera Municipal Flood Emergency Management Plan. It assessed the current township flood impact/exposure in terms of annual average damages caused by flooding.

In line with the project brief, the following flood intelligence products were produced:

- Summary table of flood behaviour, impacts, roads, and property inundated, details can be found in the Flood Intelligence Report (R03B).
- Average flood peak travel estimation, see Section 4.2.
- "Flood/No Flood" tool, providing a rough link between observed rainfall and flood magnitude, see Section 4.3.
- Flash flooding monitoring capability.
- "Flood Intelligence Card", describing the key flooding consequence across the study area for each design event, details can be found in R03B.

The flood impacts summary table, flood peak travel estimates, and Flood/No Flood tool have been reproduced herein for reference.

4.2 Flood peak travel time

Definitive information on the time it takes flash flooding (i.e. resulting from heavy rainfall associated with severe weather or thunderstorm activity) to develop (i.e. to arrive at a location) following the start of heavy rain and the time it takes for the maximum water depth/extent to be reached is not available. **Timing is however likely to be short: approximately 120 minutes.**

The time it takes rainfall associated with severe weather or thunderstorm activity to develop into runoff and streamflow is highly dependent on catchment antecedent conditions (dryness). The lack of geographical spread of pluviographs within the catchment increase the difficulty in estimating rainfall-runoff response times.

The speed a flood travels along a waterway is largely dependent on antecedent conditions and the magnitude of the flood. A flood on a 'dry' watercourse will generally travel more slowly than a flood on a 'wet' watercourse (e.g. the first flood after a dry period will travel more slowly than the second flood in a series of floods).

In large floods, often water levels will rise reasonably quickly initially as it travels through the channel, with the peak coming later as the floodplain flow travels through the catchment a little slower. Hence a range of factors including recent flood history, soil moisture and forecast weather conditions all need to be considered when using the following information to direct flood response activities.

The reality that a community at risk can be inundated before the peak of the flood should not be overlooked. In the past, efforts have concentrated on estimating and forecasting the time of the peak, however this can sometimes be detrimental. Messaging should focus on the expected extent and timing of inundation with respect to upstream areas and the broader floodplain, warning can focus on rainfall monitoring and forecasting ensuring predicting the likelihood of a flood.

Table 4-1 shows the typical travel time along two contributing overland flow paths to the Apsley township (from the north and east) for the 1% AEP storm event. The rainfall temporal pattern and the storm duration or the combination of both can be the cause of varying flooding depths and timing at the Apsley township driven by overland flows.

Table 4-1 Timing of Peak Flow

From	To	Typical travel time	Comments	Duration of inundation
Northern Overland Flow Path				
Start of rainfall (catchment)	Start of overland flow towards Apsley	2 – 3 hours	Timing depends on rainfall pattern	Generally <40 hours
Eastern Overland Flow Path				
Start of rainfall (catchment)	Start of overland flow towards Apsley	2 – 4 hours	Timing depends on rainfall pattern	Generally <30 hours

4.3 Flood/No Flood Tool

The Intensity Frequency Duration (IFD) design rainfall data used in the development of the Apsley Flood Study can be utilised along with forecast and observed rainfall data as an early warning tool. The data can be used to identify the likely magnitude of flooding and resulting consequences based on the predicted rainfall depths of an event.

To use the table, plot the total rainfall depth obtained against elapsed time since the start of the event. Exclude very light rain or drizzle when determining the event start point. Plotting of rainfall data should occur periodically as the event progresses. The likelihood and potential severity of flooding can be estimated by checking the rainfall and adopting the nearest curve AEP event as being likely. The table displays intensity-frequency-duration data developed using statistical analysis of a large number of sub daily rainfall gauges, the closest to Apsley being Edenhope Airport (079099). The Flood/No Flood tool can be used in combination with these gauges and/or rainfall observed within the Edenhope catchment.

It may be appropriate to step up or down a level depending on catchment antecedent conditions, for example if the rainfall for a 12-hour duration indicates a 5% AEP event will occur, but the catchment is dry with most farm dams empty, it may be appropriate to “step down” to a 10% AEP event or even lower. Similarly, a very wet catchment will produce a greater response and may justify a “step up” in estimated AEP for response purposes.

The tool can provide a quick reference estimate as to whether there will be a flood and how severe that flood may be, however it must be stressed that the tool cannot provide accurate flood predictions and should not be relied upon entirely. Should life or property be in danger a cautious approach should be taken.

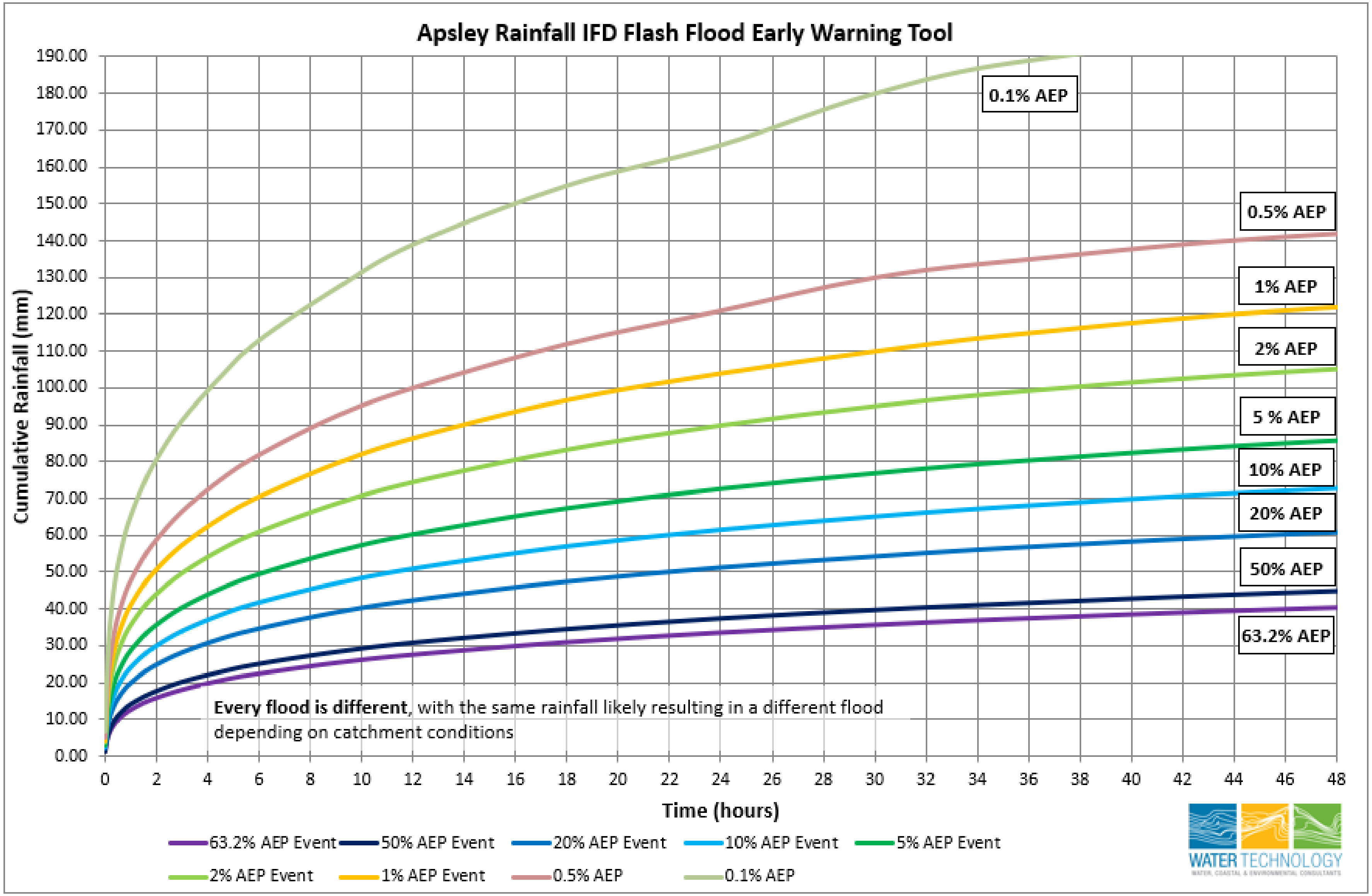

Figure 4-1 Apsley Flood/No Flood Tool

4.4 Municipal Flood Emergency Plan tables

A set of summary tables were developed for Apsley, to be read from top to bottom, with each subsequent larger magnitude event reporting on the incremental changes in consequence across different regions of the study area. This is presented in R03B.

4.5 Monitoring capability for flash flooding

Currently, there is no formal flood warning system in place for Apsley. Additionally, there are no streamflow gauges within the catchment. Given the lack of gauges, official flood warning capability for the catchment and township is limited to the issue of a Flood Watch. Note a Flood Watch is not necessarily guaranteed to be issued prior to flooding.

The closest rain gauges that record sub-daily rainfalls located at Edenhope Airport, approximately 13.1 km from Apsley. The Edenhope Airport gauge reports to the Bureau of Meteorology's website[1].

4.6 Overview of Flooding Consequences

4.6.1 Warning Time

Inundation in the Apsley township impacting properties and infrastructure is caused by overland flow from the eastern region of the catchment. Due to the nature of the critical storm within that catchment, the warning time of the flash flooding at Apsley is limited to less than an hour.

4.6.2 Areas Affected

The flood extent map at Apsley and details on "Flood Impacts and Required Actions" provide guidance on where flooding is likely to occur within the township of Apsley, are described clearly in R03B.

4.6.3 Roads Affected

The main access roads to and from the township of Apsley include the Wimmera Highway, Apsley-Langkoop Road, Apsley-Natimuk Road, Benayeo Road and Bringalbert South Road.

Figure 4-2 and Figure 4-3 outlines the roads which are inundated by flooding in events ranging from the 20% AEP up to the 0.1% AEP event

Details of impassable roads where maximum depths exceed 0.3 m and become unsafe for vehicles can be found in R03B.

4.6.4 Isolated Areas

Flooding across the Apsley township in all AEP events modelled (0.5% AEP down to the 20% AEP) is relatively shallow and/or slow moving (except for local waterways and drainage lines). Therefore, the risk of isolation due to extended periods of road inundation at properties is relatively minimal.

Ingress/egress to and from these properties is possible along the main access roads as shown in the modelling completed in this assessment.

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[1] Bureau of Meteorology Edenhope Airport Gauge - https://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=136&p_display_type=dailyDataFile&p_startYear=&p_c=&p_stn_num=079099

4.6.5 Essential Infrastructure

Apsley Primary School is the only essential infrastructure in Apsley. The primary school grounds are inundated in all AEP events (0.5% AEP down to the 20% AEP). However, the buildings are on high ground and do not become inundated.

4.6.6 Property Inundation

Property inundation has been assessed based on the maximum flooding across the entire property parcel for each AEP event. Properties that did not contain residences or building structures are not reported on in this assessment. Building floor levels with respect to flooding depths have not been considered in this assessment due to the nature of flooding all being below finished floor level, as confirmed by a survey of the Apsley township. **This is because only one flood level was surveyed at one dwelling, the main building floor level. There are several cases where there is a split floor level, and the lower floor level will become inundated.**

The 1% AEP flood extent and the properties flooded during the range of modelled design events are shown in Figure 4-4.

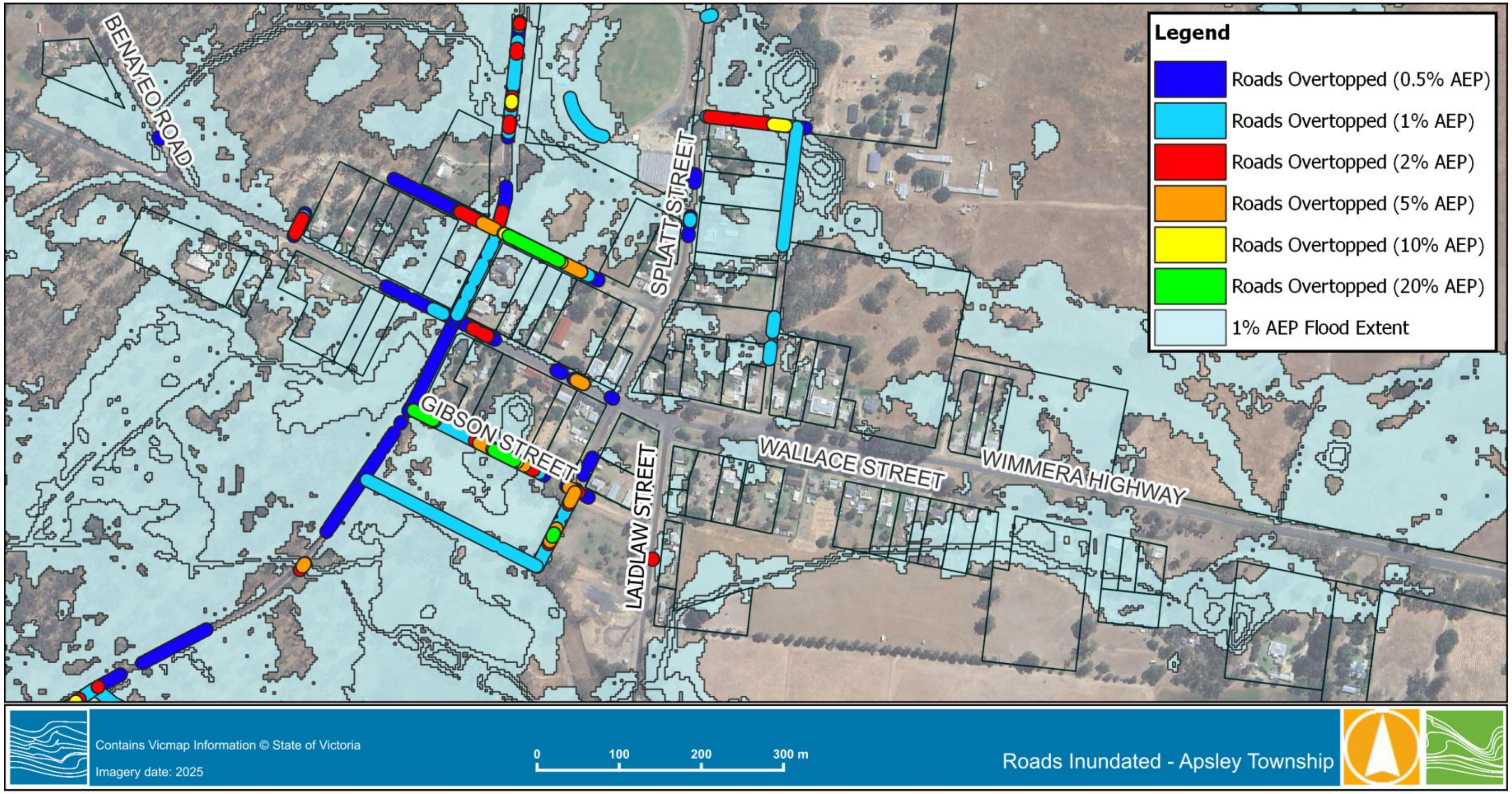

Figure 4-2 Roads overtopping – Apsley Township

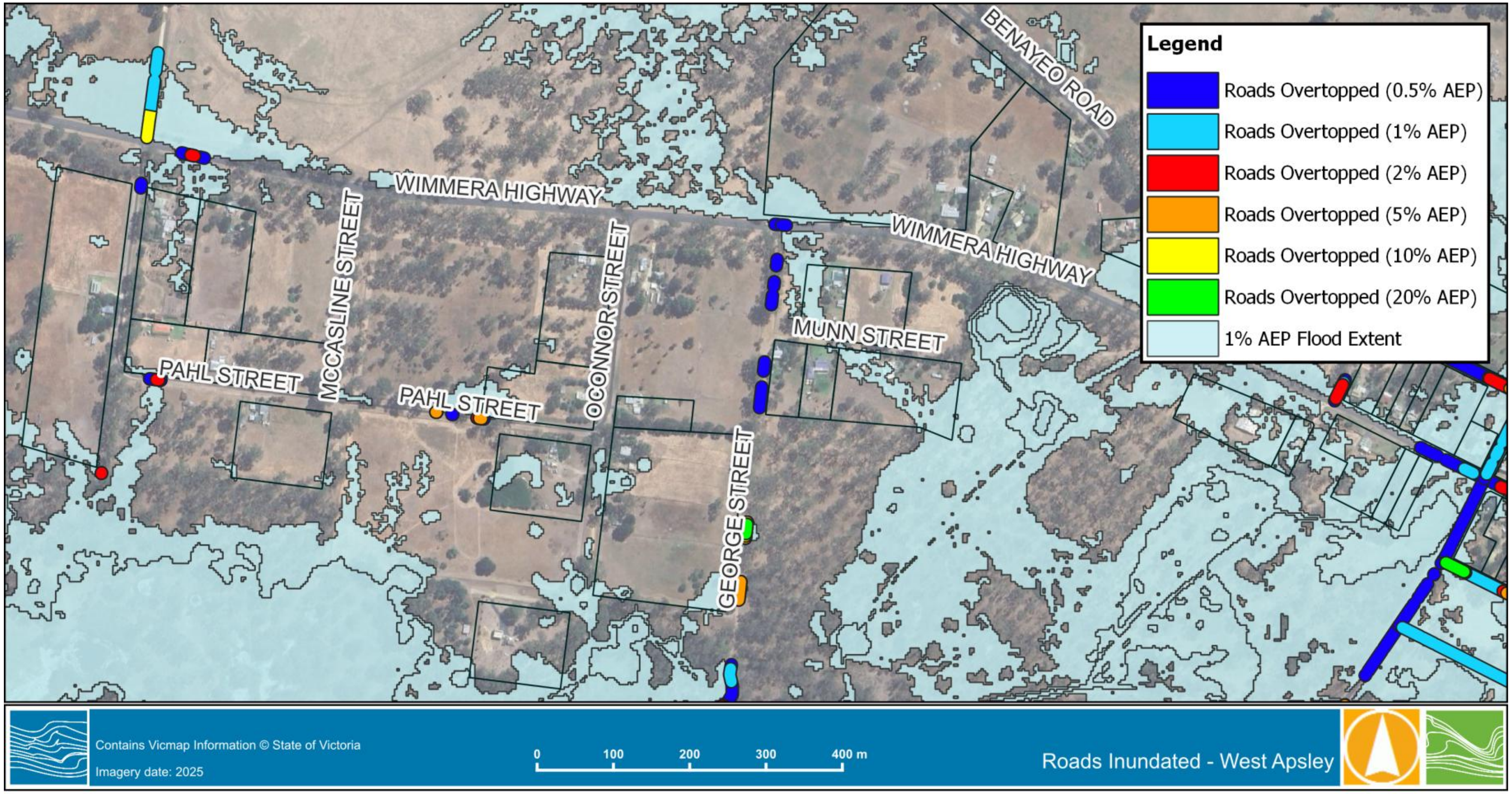

Figure 4-3 Roads overtopping – West Apsley

Figure 4-4 1% AEP - Buildings inundated below floor level

4.7 Flood Intelligence Card

The flood intelligence card describes the key flooding consequences across the study area for each design event. This card can be found in R03B.

4.8 Flood Damage Assessment

A summary of the flood damages with respect to each AEP event has been assessed with respect to the number of properties flooded, direct damage cost, and indirect damage cost. A summary of this information can be found in R03B.

Based on this information, the Average Annual Damage has been calculated to be **$53,927**.

Furthermore, the total cost with respect to each AEP event is presented in Figure 4-5.

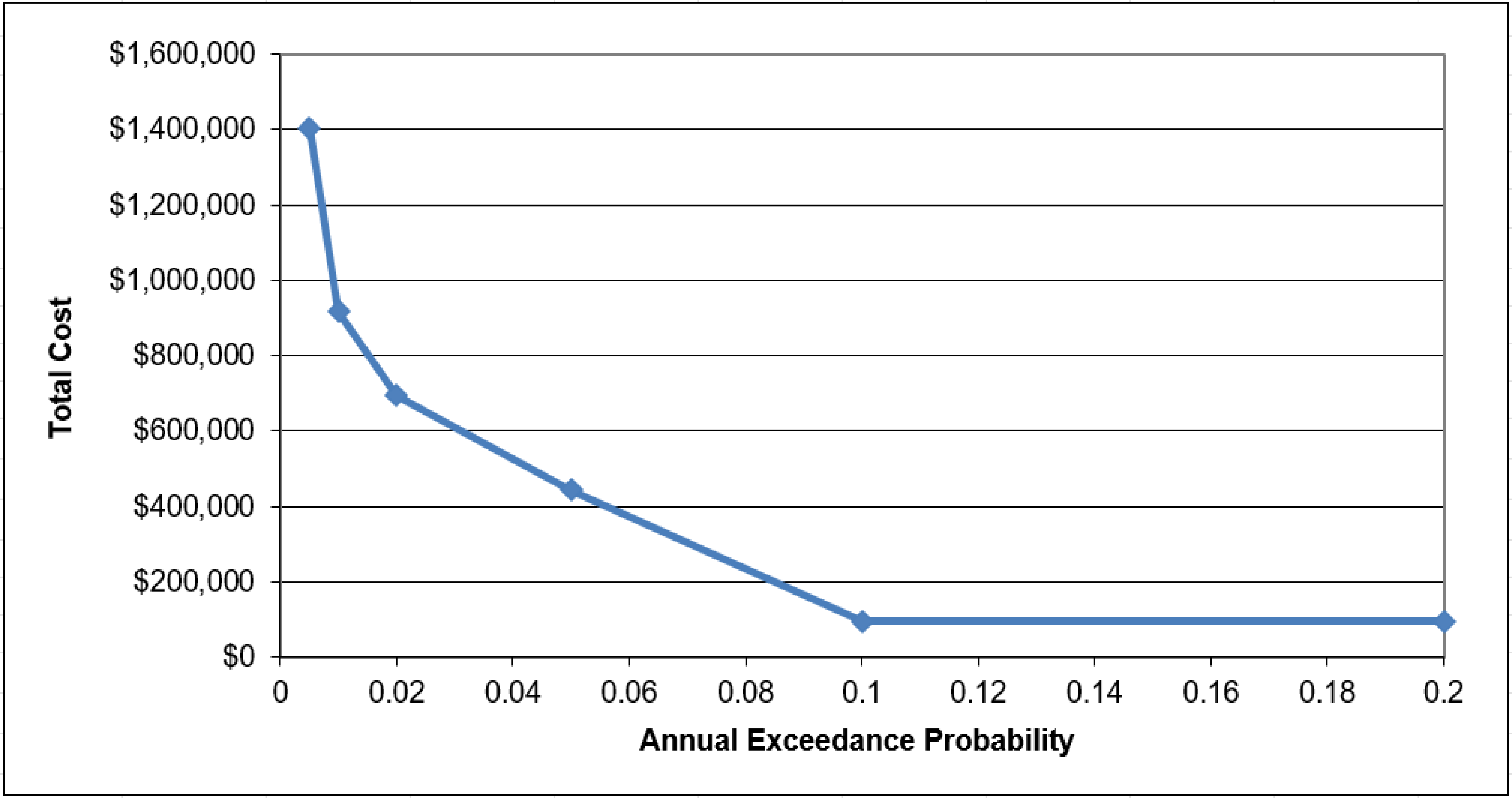

Figure 4-5 Flood Damage Assessment based on AEP Event

4.9 Flood Planning Layers

The flood planning layers produced as part of this study are included in a separate report with the specific purpose of informing a planning scheme amendment.

5 FLOOD MITIGATION ASSESSMENT

5.1 Overview

Four mitigation options for Apsley underwent testing in the hydraulic model, with the aim of reducing the impact of flooding on the township. These options were suggested by the community or the project team comprising of members of West Wimmera Shire Council, Wimmera CMA and Water Technology. The intent was to reduce inundation of buildings in key areas of impact. These areas included:

- The eastern end of Apsley (upstream), along the southern flow path and along Wallace Street.
- Within central Apsley, along the northern flow path. The area of impact included north of Wallace Street and the Apsley Recreation Reserve.

The tested mitigation options included:

- Option 1 – Improved channel conveyance along the main flow path south of the Wimmera Highway.
  - The waterway channel was deepened south of the properties along Wallace Street, between the point at which Wallace Street turns to run parallel to the Wimmera Highway toward Laidlaw Street.
- Option 2 – Increased culvert flow under the Wallace Street (also known as the Wimmera Highway at this location) at around 76 Wallace Street.
  - The culvert under Wallace Street / Wimmera Highway in front of properties 72 and 76 Wallace Street was increased in size to enable more conveyance to the south. This was intended to reduce flooding north of Wallace Street / Wimmera Highway.
- Option 3 – Increased culvert capacity under Apsley-Natimuk Road to enable more conveyance and reduced inundation in the Apsley Recreation Reserve.
  - Increasing the culvert size downstream (west) of Apsley Recreation Reserve at the Apsley-Natimuk Road was trialled to enable more flow through the downstream reserve towards Benayeo Road.
- Option 4 – Increased channel conveyance along the excavated channel between Apsley-Natimuk Road
  - In extension to Option 3, deepening the channel downstream of Apsley-Natimuk Road towards Benayeo Road and south through to the Wimmera Highway was modelled.

Each of these mitigation design layouts and results are discussed in the following sections.

5.2 Option 1

Option 1 aims to reduce the impact of flooding along Wallace Street, from property number 21 to 35. These properties are the first and most likely to be impacted by flooding. The channel flowing to the south of Wallace Street and the impacted properties has been deepened to improve conveyance. Height of deepening is shown in Figure 5-1 across the length of 303.9m channel, ranging from 175 to 479mm. The deepening was undertaken creating a more efficient channel invert with a consistent grade matching in to the existing level at the downstream extent.

Modelling showed a reduction in flood depth upstream at the flood affected properties, with reductions up to 0.15 - 0.2m along the south of properties along Wallace Street. However, modelling also showed an increase in the flood depth behind the open space of the properties along Laidlaw Street, with a maximum increase of 0.013m. No buildings were affected by the increase in the flood level.

Table 5-1 shows the comparison of surveyed floor level and maximum flood level reached in the existing and Option 1 scenarios. The result show none of the buildings are flooded above floor; however, it should be noted the surveyed floor level is of the main building floor level and it is likely some of the builds have split floor levels with a portion of the houses with a lower level. The change in 1% AEP flood depths as a result of Option 1 are shown in Figure 5-2.

Table 5-1 Surveyed Floor Level and Maximum Flood Level at Impacted Properties

Address	Surveyed Floor Level (mAHD)	Maximum Flood Level (mAHD)		Change in flood level (m)
		Existing Conditions	Mitigation Option 1	
1 Wallace Street	106.48	105.85	105.85	0
7 Wallace Street	106.19	105.79	105.76	-0.03
19 Wallace Street	105.98	105.87	105.73	-0.14
21 Wallace Street	106.01	105.75	105.63	-0.12
23 Wallace Street	106.12	105.72	105.60	-0.12
29 Wallace Street	106.22	105.71	105.63	-0.08
31 Wallace Street	106.44	105.70	105.65	-0.05
33 Wallace Street	106.50	105.69	105.64	-0.05
35 Wallace Street	106.36	105.56	105.53	-0.03
41 Wallace Street	106.30	105.41	105.41	0
1 Percy Clark Street	106.16	105.88	105.88	0
7 Laidlaw Street	105.45	105.14	105.14	0
15 Laidlaw Street	105.81	104.89	104.91	0.02

Note: Highlighted cell indicates there is an increased flood level at the listed property but has no adverse impact on the building.

Figure 5-1 Mitigation Option 1 Design Layout

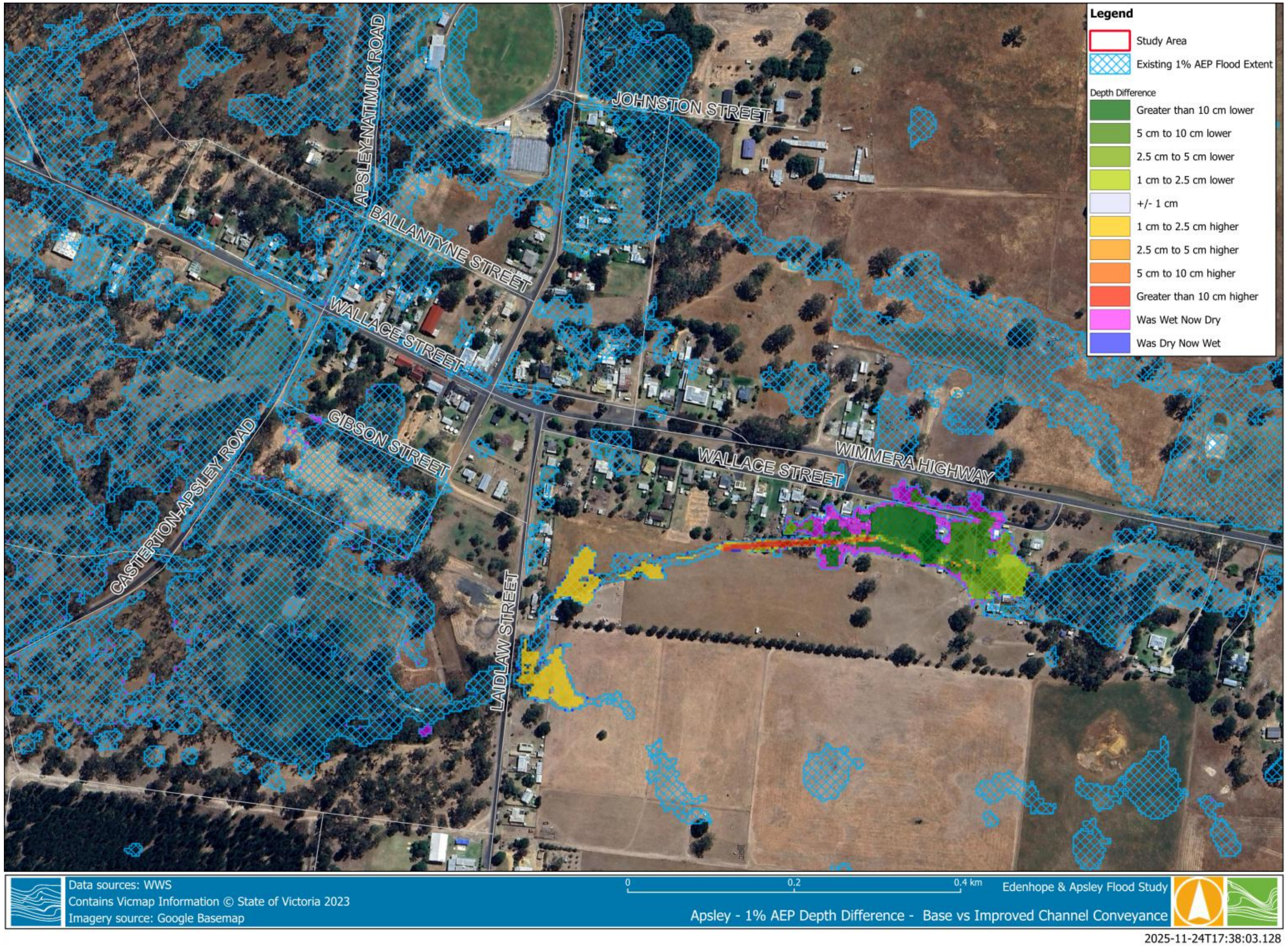

Figure 5-2 1% AEP Difference Plot for Existing (Base) versus Mitigation (Improved Channel Conveyance)

5.3 Option 2

Option 2 aims to reduce the impact of flooding on properties at 72 and 76 Wallace Street by increasing the flow under Wallace Street / the Wimmera Highway. The number of culverts was increased by four (4) times, and the dimensions are listed in Table 5-2. The location is shown in Figure 5-3.

Table 5-2 Wallace Street Culvert Size

Scenario	Width (m)	Height (m)	Number
Existing Conditions	1.2	0.3	2
Mitigation Option 2			8

Modelling showed a reduction in flood depth upstream at the flood affected properties, with reductions as high as 0.013m, around the south of properties 76 Wallace Street. There was also an increase in flood depth downstream of the culvert, reaching up to 0.013m. The buildings were above the flood level in a 1% AEP prior to the mitigation. Therefore, no residential properties were adversely impacted by the increase in culvert size. The area affected by the increase in the flood depth area is located at a reserve, which then flows into the Apsley Bushland Reserve.

Table 5-3 shows the comparison of surveyed floor level and maximum flood level of Existing and Mitigation Option 2.

Table 5-3 Surveyed Floor Level and Maximum Flood Level at Impacted Properties

Address	Surveyed Floor Level (mAHD)	Maximum Flood Level (mAHD)	
		Existing Conditions	Mitigation Option 2
72 Wallace Street	104.78	104.45	104.44
76 Wallace Street	104.86	104.41	104.41

The change in 1% AEP flood depths as a result of Option 2 are shown in Figure 5-4.

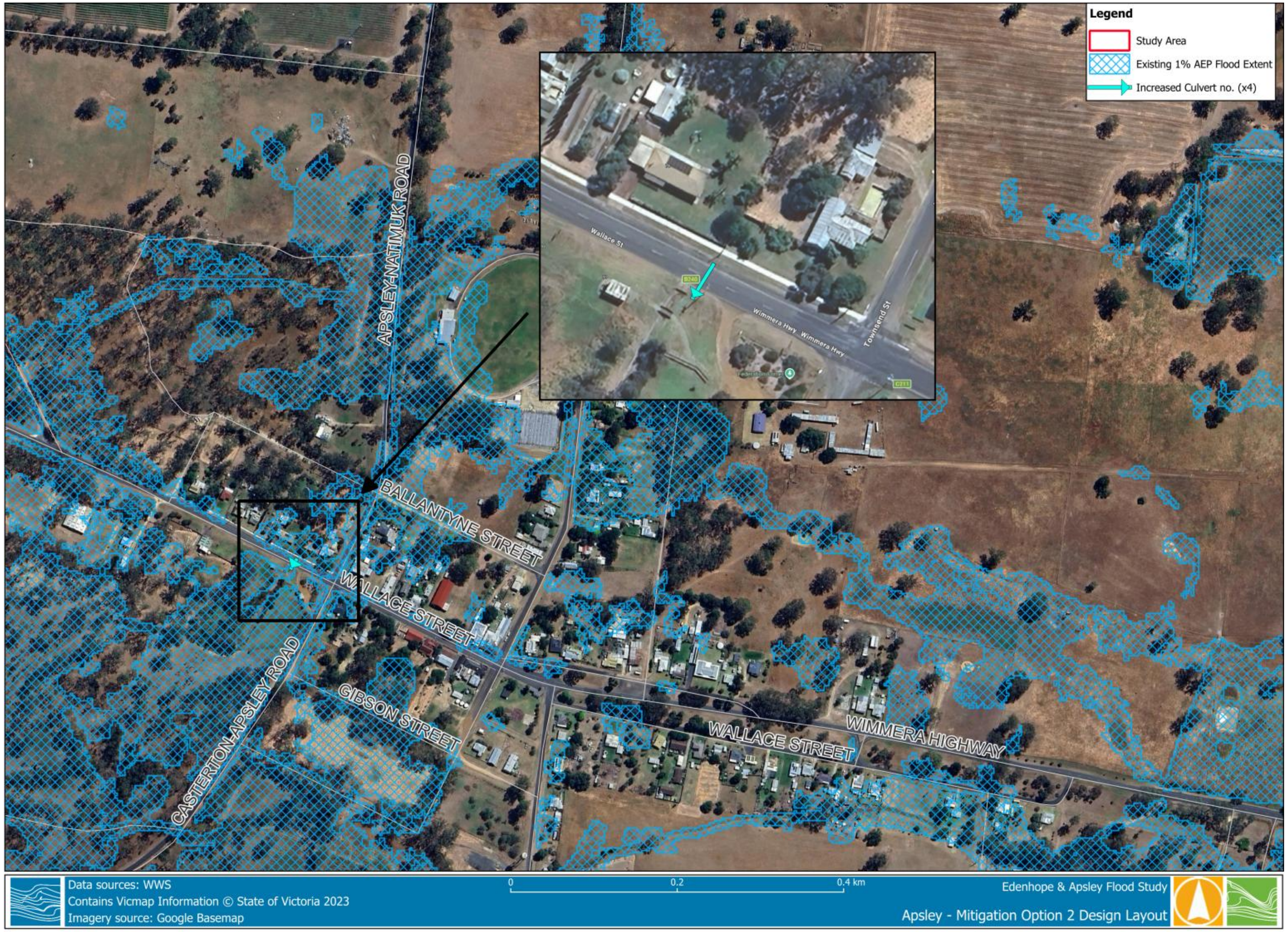

Figure 5-3 Mitigation Option 2 – Culvert Location

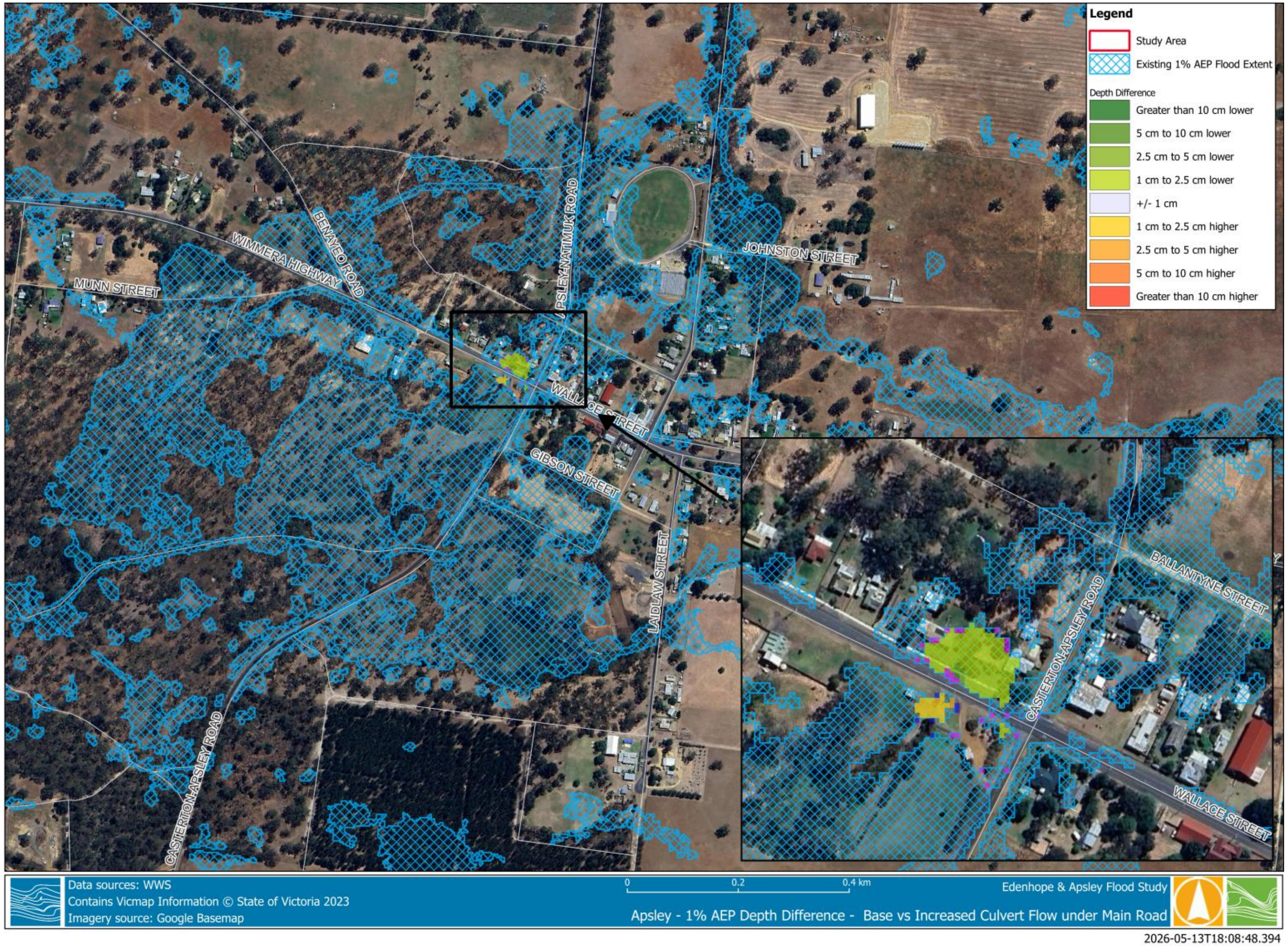

Figure 5-4 1% AEP Difference Plot for Existing (Base) versus Mitigation (increased culvert capacity under Wallace Street / Wimmera Highway)

5.4 Option 3

Option 3 increases the culvert conveyance under the Apsley-Natimuk Road into the downstream bush reserve. This is done conservatively increasing the number of culverts by four times, resulting in a total of twelve (12) culverts under the road, and the dimensions are listed in Table 5-4. The culvert location is shown in Figure 5-5.

Table 5-4 Apsley-Natimuk Road Culvert Size

Scenario	Width (m)	Height (m)	Number
Existing Conditions	1.2	0.6	3
Mitigation Option 3			12

Modelling showed a minimal change in upstream flood depth around the oval, with a small downstream increase.

Modelling has indicated the capacity of the culvert in a 1% AEP event is not a limiting factor to inundation within the Apsley Recreation Reserve. This is likely to be due to the Apsley-Natimuk Road already overtopping and most of the conveyance occurring over the road and limitations with conveyance downstream of the road.

Additional mitigation works further downstream were explored as part of Option 4.

The change in 1% AEP flood depths as a result of Option 3 are shown in Figure 5-6.

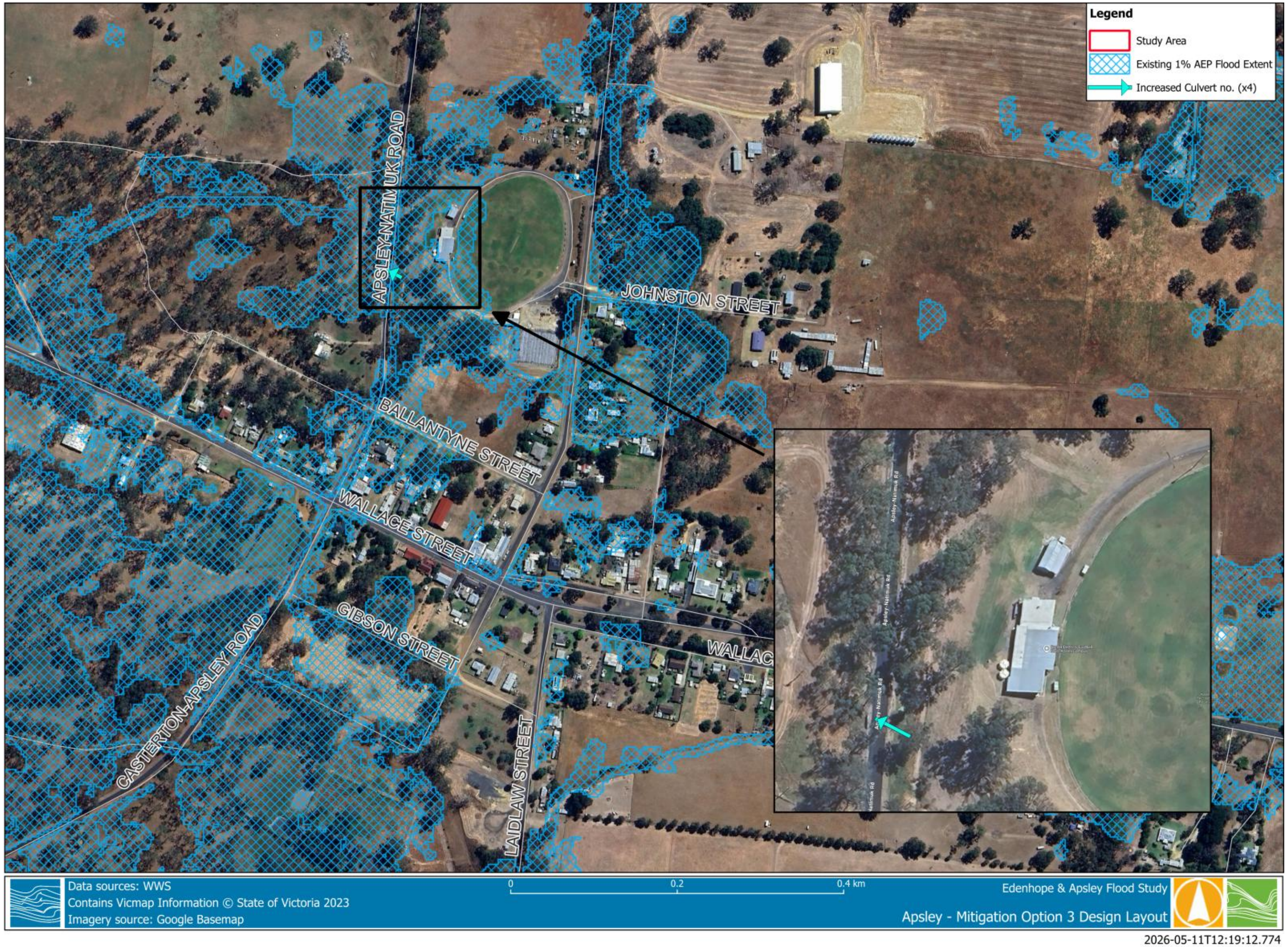

Figure 5-5 Mitigation Option 3 Design Layout

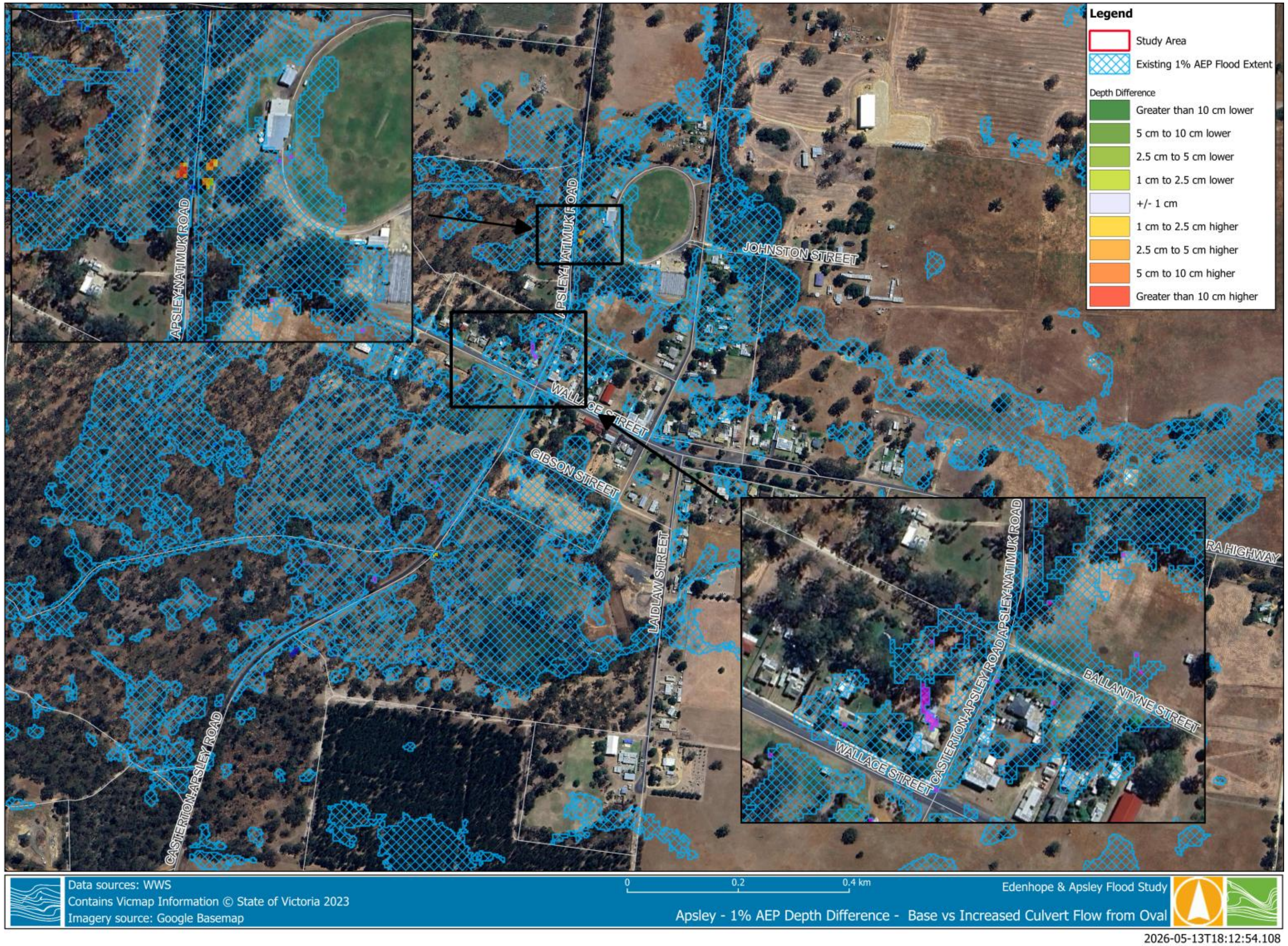

Figure 5-6 1% AEP Difference Plot for Existing (Base) versus Mitigation (Increased Culvert Flow from Oval)

5.5 Option 4

Option 4 was an extension of Option 3, with the channel downstream of the Apsley-Natimuk Road, in the bush reserve, deepened to 103 mAHD across 594m in length to increase conveyance from the culvert. The area of increased conveyance is shown in Figure 5-7.

Modelling showed a reduction in flood depth upstream at the football oval, reaching up to 0.09m. Deepening of the channel increased conveyance to Benayeo Road to Wimmera Highway.

However, the increased conveyance also caused an increased flood depth south of the Wimmera Highway, adversely affecting properties 95 and 105 Wallace Street. The increase in flood depth was as high as 0.02m. No surveyed floor levels are available for these properties therefore it is unknown if the buildings are adversely impacted by the change.

The 1% AEP flood change in flood depth is shown in Figure 5-8.

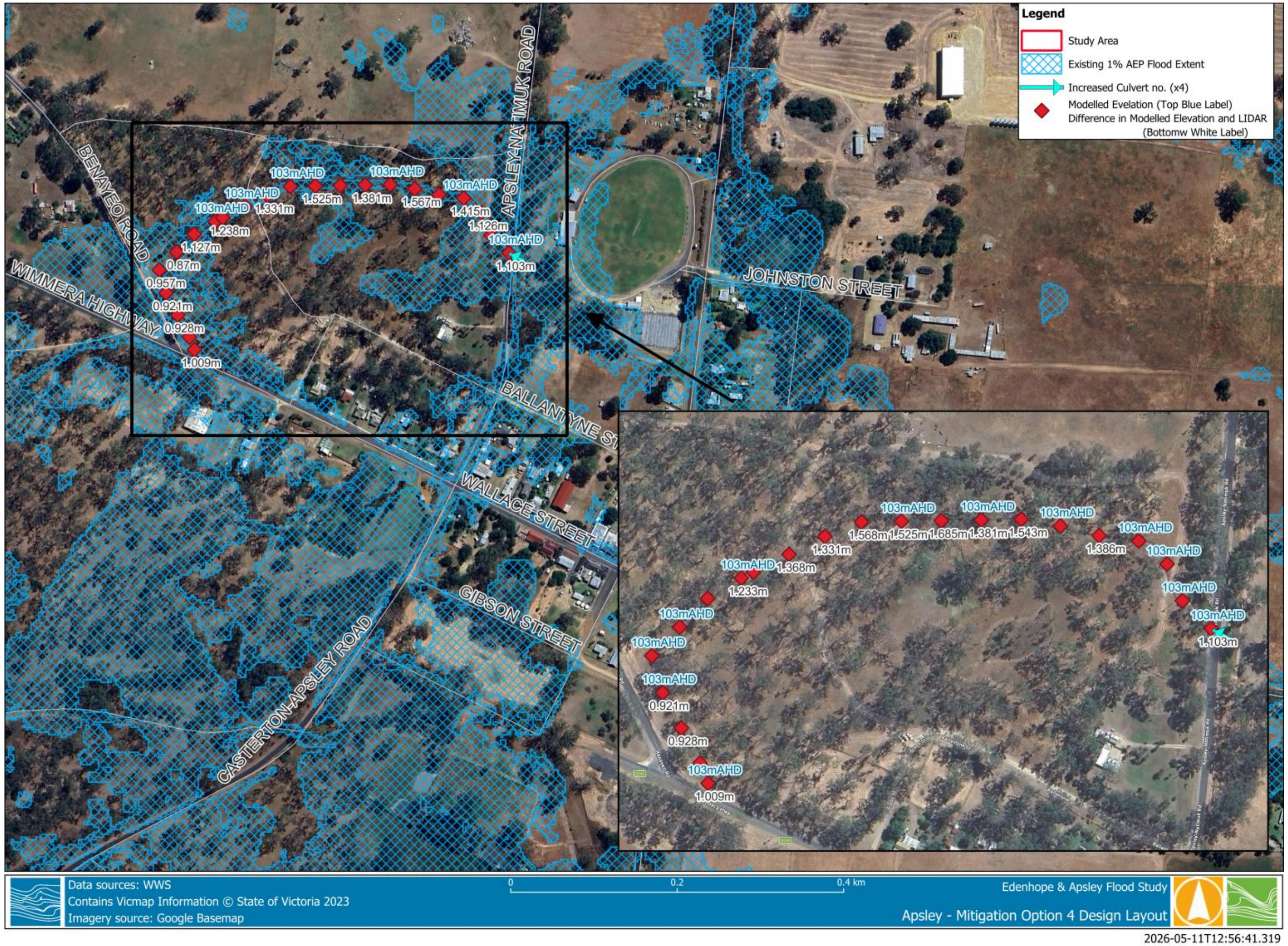

Figure 5-7 Mitigation Option 4 Design Layout

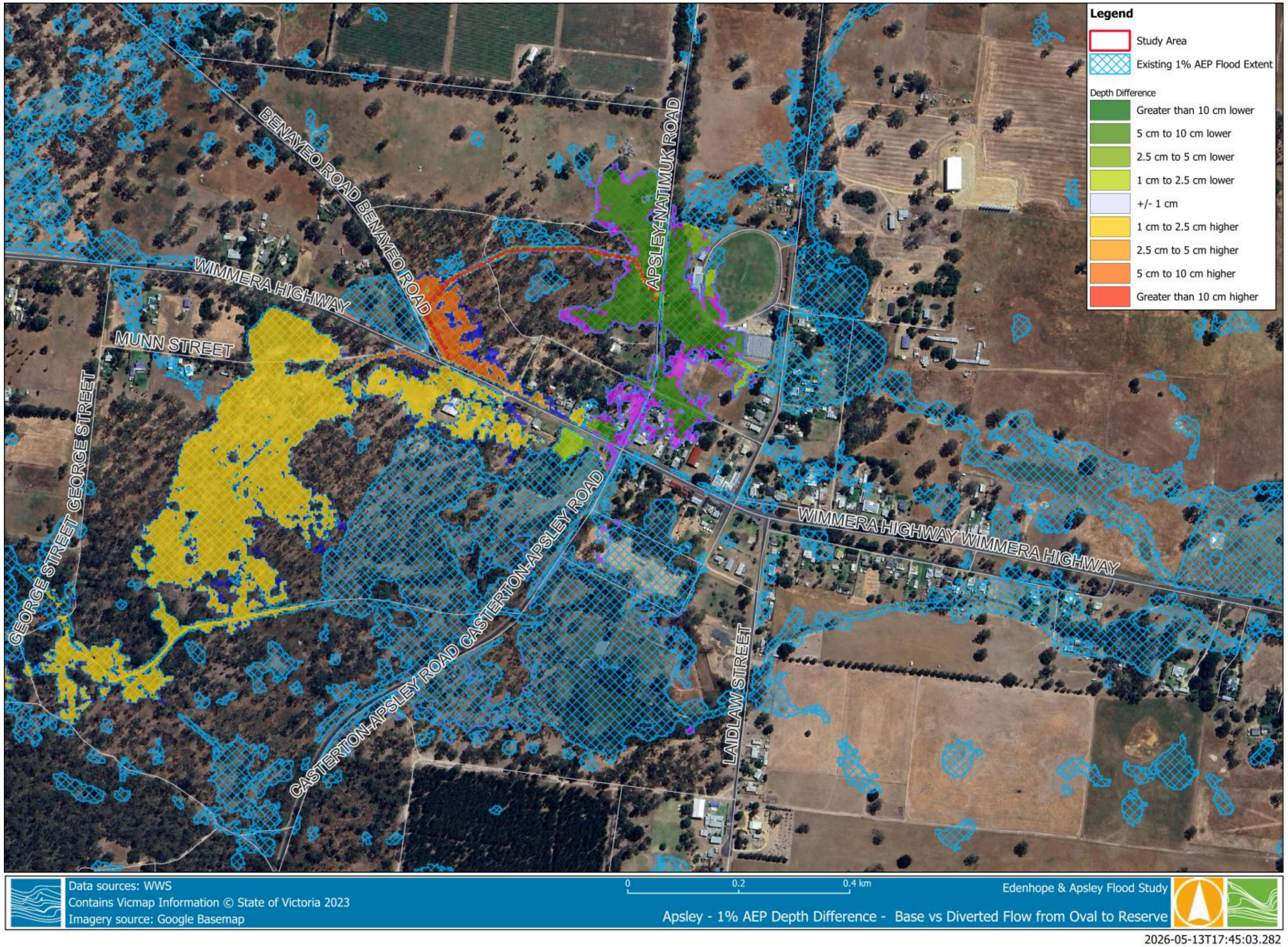

Figure 5-8 1% AEP Difference Plot for Existing (Base) versus Mitigation (Diverted Flow from Oval to Reserve)

5.6 Summary of Mitigation Options

Of the options modelled, Mitigation Option 1 provides the greatest potential to reduce flood risk and damage in Apsley.

Option 1 aims to reduce the impact of flooding along the Wallace Street, from property number 21 to 35 by increasing the conveyance capacity of the channel flowing behind these properties. These properties are not highlighted as flooded above floor level in existing 1% AEP conditions. However, some properties are impacted by the flood extent which prevents a flood free egress route for the residents. This mitigation option reduces the size of the flood extent and provides a non-flooded egress route for most residents, during a 1% AEP event. It is also likely to reduce inundation of lower floor levels within some of the dwellings.

Option 2 does reduce the potential for properties at 72 and 76 Wallace Street to be flooded above floor; however, these properties are not shown to be flooded above floor in a 1% AEP event. This is due to an increase in culvert size from 2.4m (2x) to 9.6m (8x), which aims to allow the floodwaters to not become staggered at the impacted properties and to be redirected downstream across the road into the reserve. The change in result was not significant may be due to grading of the topography at the upstream properties and downstream reserve only has a slope of 0.8%. The neighbouring topography are relatively flat and does not allow floodwaters to be diverted away from the properties quickly.

Option 3 and 4 look to divert the floodwaters from the football oval into the bush reserve across Apsley-Natimuk Road. Option 3 investigate the increase in culvert size from 1.2m (3x) to 14.4m (12x), and Option 4 is built on top of Option 3 with increased culvert size and deepening the channels previously existed in the bush reserve to improve the conveyance. The effective of Option 3 was minimal due to the topography at the culvert is lower than the surrounding terrain, causing the flood waters to be ponded inside the culvert. The addition of Option 4 aims to eliminate the ponding of floodwaters inside the culvert and divert them towards the bush reserve, which then flows into Benayeo Road and Wimmera Highway. The result shows a reduction of flood level at the football oval; however, the diverted floodwaters are pushed towards the downstream to the properties on Wimmera Highway (95 and 195 Wallace Street). The increased in flood depth is less than 2cm, however, the impact on the property buildings are unknown due to surveyed floor level not available.

6 SUMMARY

The Apsley Flood Investigation has produced detailed flood modelling of overland flooding within and surrounding Apsley. The mapping produced is fit for the purposes of flood emergency planning and response alongside statutory and strategic planning. The study has also investigated the current flood impacts in terms of average annual damages and the potential for structural mitigation to reduce those damages. Flood intelligence products have been produced and included in a draft update to the West Wimmera Shire Council Municipal Emergency Management Plan, these are detailed in the Flood Intelligence (R03B) Documentation. The study makes the following recommendations for each of the stakeholder organisations:

- West Wimmera Shire Council
  - Endorse the flood study with the aim of adopting the flood study recommendations.
  - Undertake a planning scheme amendment to update the flood related planning overlays to reflect the flood risk mapping produced by this project.
  - Consider the designation of flood prone land as provisioned under the Building Act
  - Discuss with the Bureau of Meteorology and Wimmera CMA for the consideration of potential flash flood monitoring.
  - Review the information within the Flood Intelligence and Flood Warning Report to undertake an update of the Municipal Emergency Management Plan.
  - Undertake a review of the current response, maintenance and operations documentation with Council staff.
  - Investigate clearing activities at the bridge on Elizabeth Street adjacent to the Lions Park, to remove accumulated flood debris and non-native vegetation.
  - Further consider the potential to progress Mitigation Option 1. In particular land tenure and the practical considerations related to increasing the channel capacity through the highlighted reach of drain.
- Wimmera CMA
  - Endorse the flood study and use the flood mapping data to inform floodplain risk management decisions.
  - Upload the Victoria Flood Database mapping data and the excel spreadsheet of property inundation to FloodZoom.
- Victoria State Emergency Service with assistance from Wimmera CMA and the West Wimmera Shire Council:
  - Continue to engage the community through regular flood awareness programs such as the VICSES FloodSafe program.
  - Update Local Flood Guide.
  - Assist the West Wimmera Shire Council in updating the MFEP.
  - Review the updated MFEP (when available) and discuss with the West Wimmera Shire Council the changes proposed by Water Technology prior to adopting the revised document.
- Future flood events in Apsley should be monitored carefully and compared to the results of this study, with flood levels marked and surveyed where possible. Where flood behaviour appears to disagree with the findings of the study, the reason for the discrepancy should be investigated and an update to the study should be considered.

WATER TECHNOLOGY

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Darwin City NT 0800

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