

Final Report – Draft

Dunmunkle Creek Final Report

Wimmera CMA

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01 May 2018

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Dear Paul

Final Report

This report is the Final Report for the Dunmunkle Creek Flood Investigation. This report supersedes all other reports during the progress of the flood investigation.

We would like to thank Wimmera CMA for engaging us to complete this project and Yarriambiack Shire Council, Northern Grampians Shire Council, Buloke Shire Council, GWMWater, VICSES and DELWP for their technical input into the project, enabling it to be a success. Water Technology would specifically like to thank the community members who gave their time to attend meetings, provide their personal observations of flooding, and feedback on the flood modelling. With their input, the outcomes from this study have been much improved.

Yours sincerely

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WATER TECHNOLOGY PTY LTD



EXECUTIVE SUMMARY

Wimmera CMA commissioned Water Technology to undertake the Dunmunkle Flood Investigation. The study included detailed hydrologic and hydraulic modelling of the Wimmera River and Dunmunkle Creek, covering a large rural area and the township of Rupanyup.

Dunmunkle Creek is in western Victoria, an offtake from the Wimmera River at Glenorchy. The waterway flows north until around Lake Carron at Carron. Dunmunkle Creek has been highly modified by its adaption into a Stock and Domestic water supply channel delivering water to the Mallee. This operation has since ceased with the waterway no longer used for water supply.

Several communities were actively involved in the investigation through community consultation sessions, social media and meetings with a Project Steering Committee containing several community members. The community consultation sessions were largely managed by Wimmera CMA and Yarriambiack Shire Council. The aims of the community consultation were to raise awareness of the study, to identify key community concerns, to provide information to the community and seek their feedback/input regarding the study outcomes, including the existing flood behaviour and proposed mitigation options for the Rupanyup township.

Community meetings were held in Lubeck, Rupanyup, Boolite and Murtoa over three stages. Only one meeting was held in Murtoa during stage 3. The purpose of the three meetings are described below:

- Stage 1 – Introduction to the project, work completed to date, what we hope to achieve, how the community will be engaged and what information we are hoping to receive from them, and discussion of mitigation options. At this meeting, community flood observations were recorded and used during the modelling process.
- Stage 2 – Modelling progress, discussion around historical events, discussion of model calibration and draft 1% AEP flood extents and behaviour. Asked community for suggested mitigation options.
- Stage 3 – Present final mapping, presentation of mitigation option assessments, project outcomes and the progression of the technical information to mitigation and planning scheme implementation.

The primary aims of the streamflow analysis undertaken for this project included:

- Determine calibration events and flows to be used in the hydraulic model.
- Determine design event peak flow and hydrograph shape for input to the hydraulic model at the model boundaries. Design events included 0.2%, 0.5%, 1%, 2%, 5%, 10% and 20% AEP flood events, Probable Maximum Flood (PMF) and climate change scenarios.

High resolution LiDAR was available for the study area, ensuring the topography could be accurately represented in the hydraulic modelling. A series of surveyed road crest and survey transects were used to verify the accuracy of the LiDAR data available for the project.

The LiDAR data was used as a basis for a detailed combined 1D-2D hydraulic model of the study area. The hydraulic modelling suite, MIKE Flexible Mesh was used in this study.

The hydraulic model was calibrated using the January 2011 flood event, the only event with any significant calibration data. The calibration used surveyed flood heights, stream level information, satellite data, linescan data, photographs and anecdotal community observations. The calibrated model was then used to produce design flood mapping. The design flood mapping showed there were 27 buildings flooded above floor in Rupanyup during a 1% AEP flood event.

During the process of the investigation, several structural mitigation options were suggested to reduce the impact of floods in Rupanyup, and across the broader study area. Water Technology considered all proposed



mitigation options, and using a prefeasibility assessment approach, identified the following options to be investigated further:

- Removal or blockage of two 600 mm pipe culverts under the remnant Lubeck-Rupanyup railway embankment.
- Levee protecting Rupanyup on the southern side of Rupanyup preventing Dunmunkle Creek overland flow coming into the township.
- Open the Main Central Channel to allow flow from Glenorchy to Dunmunkle Creek through the flood mitigation channel.
- Remove the Rupanyup water storages.
- Remove the Rocklands Lubeck Channel.
- Permanently Open Dunmunkle Creek Offtake.
- Levee and channel on the eastern side of Rupanyup preventing local catchment inflows from flowing into the township and directing it north toward the existing channel system and through to the Golf Club.

During the progress of the assessment, a flood occurred in September 2016, and as a result partial excavation of the Rupanyup water storages was completed, following the primary recommended mitigation option proposed at the time. As a result, the design modelling was undertaken again, with the revised condition of the Rupanyup water storages, along with revised final mitigation recommendations focused on removing the Rupanyup water storages completely.

Non-structural mitigation measures were also assessed, including a review of the existing flood warning system, the implementation of Land Subject to Inundation Overlay (LSIO) and Flood Overlay (FO) along Dunmunkle Creek and updates to the Yarriambiack Shire Council Municipal Flood Emergency Plan (MFEP).

The Wimmera River at Glenorchy streamflow gauge was found to provide an indication of flow and flood impacts along Dunmunkle Creek. Early predictions to what flow can be expected at this gauge can be determined by the Wimmera River at Glynwylln gauge. These gauges can be used as the basis of a predictive flood warning network.

The investigation made the following recommendations:

1. The Yarriambiack Shire Council and Northern Grampians Shire Council Municipal Flood Emergency Plans be updated with the information provided in the Dunmunkle Creek Flood Investigation Flood Intelligence Report.
2. The Land Subject to Inundation Overlay (LSIO), Floodway Overlay (FO) and associated planning scheme amendment documentation produced as part of this study be adopted in the Yarriambiack Shire Council and Northern Grampians Planning Schemes.
3. The Victorian Flood Database (VFD) should be updated using the outputs of the Dunmunkle Creek Flood Investigation, which have been formatted into the standard VFD outputs.
4. The Dunmunkle Flood Investigation VFD deliverables be uploaded to FloodZoom.
5. The local CFA brigade should be actively engaged in community preparedness education for flooding.
6. The Rupanyup water storages should be decommissioned as per the concept design determined during this project.
7. The levee along Ron Lingham and McIntyres Rd should undergo detailed design and construction to prevent Dunmunkle Creek breakout flow from entering the township.



8. Post removal of the Rupanyup water storages and construction of the levees, the decommissioned state of the storages should be surveyed, and remodelling completed to update the LSIO and FO layers for Rupanyup and update the Yarriambiack Shire Council MFEP.
9. Constructed channels within the Dunmunkle Creek waterway bed and banks should be decommissioned north of the Bryntirion Forest, as far as practically possible, attempting to return Dunmunkle Creek to as natural a state as possible.
10. The Rupanyup community be consulted regarding what they would like to see in place of the removed water storages if that option was to progress. The earthworks assumed for the modelled reservoir removal would be aligned with a lowered land surface that would facilitate the construction of a wetland area. Alternatives may be to remove the storages to ground level and construct some other public asset such as a park or a bike track. Whatever the outcome, the use of that space should ensure that no raised buildings or earthworks obstruct floodplain flow. The cost benefit ratio of the works is expected to be very high and likely to receive government financial support.
11. The potential for stormwater mitigation in Rupanyup should be further considered with the incorporation of the stormwater pipe network, and consideration of the levee, drain and possible pumping solution. Detailed feature survey may be required of the existing stormwater system.
12. The Rocklands Lubeck Channel through the Bryntirion Forest should be assessed for decommissioning considering the native vegetation currently existing on the embankments. Once an understanding of the preferred decommissioning approach is available, modelling of the partial removal should be completed.
13. **Operable infrastructure on the Rocklands Lubeck Channel should be removed to prevent members of community attempting to operate them during a flood (this occurred during January 2011 which could have resulted in loss of life).**
14. Decommissioning of Dunmunkle Creek's embankments should be considered further with regards to potential environmental benefit. While it has been demonstrated there are no real flood benefits, environmental benefit could be gained through returning Dunmunkle Creek to a more natural waterway, slowing the progression of floodwater, supporting biodiversity and reinstating the natural function of the waterway. This return could be made through a combination of revegetation, earthworks and fencing. This would require significant planning and consultation with landholders.
15. Removing the Dunmunkle Creek offtake valve and replacing the structure with a permanently open culvert should be considered allowing natural flows to Dunmunkle Creek.
16. Discussion with GWMWater and landholders in the Boolite area on how restoring a natural channel could be used to engage areas of floodplain that are currently prevented from being inundated by constructed channels but ensure water is not allowed to sit for long periods of time that could cause pasture or crop damage.
17. Use of the Glenorchy streamflow gauge on the Wimmera River to provide triggers for specific flood warnings for Dunmunkle Creek. These triggers can also be included in Flood Bulletins issued by VICSES.
18. Preparation of pre-canned messages based on the flood triggers that can provide tailored and relevant information to those living in the study area.
19. Further engagement with rural landholders so they can understand the impacts of decommissioning channel systems on flooding and to eradicate risky behaviours to divert water during flood events.
20. Further development of the flood observers network in the study area to provide additional real-time information to the ICC. This may involve the implementation of gauge boards so that accurate flood



level references can be made. Development of a phone tree system or similar warning communication for isolated rural landholders in the Dunmunkle Creek catchment.

21. Better identification of vulnerable persons in the study area and appropriate operational measures taken once warnings are received. .



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1 INTRODUCTION

Water Technology was commissioned by Wimmera CMA to undertake the Dunmunkle Creek Flood Investigation. The study included detailed hydrologic and hydraulic modelling of the Wimmera River and Dunmunkle Creek.

This is the Final Study Report, combining all previous reports produced by Water Technology. All previous reporting stages were reviewed by Wimmera CMA and the project Steering Committee. Major reports underwent an independent peer review via a process managed by the Department of Environment, Land, Water and Planning (DELWP). This final report combines the comments received throughout the review process including the independent peer reviewers.

Two reporting stages were completed by Water Technology's project partners:

- Dunmunkle Creek Flood Investigation – Flood Warning Recommendations (Molino Stewart)
- Dunmunkle Creek Flood Investigation – Yarriambiack Shire Council and Northern Grampians Shire Council, planning scheme amendment documentation (Planning and Environmental Design)

These reports are summarised in this report. Further detail can be sourced from the specific reports directly.

1.1 Study Area

Dunmunkle Creek is in western Victoria, approximately 220 km north west of Melbourne. Dunmunkle Creek is a distributary of the Wimmera River and is wholly within the Wimmera CMA management area. During high flows in the Wimmera River, flow is distributed to Dunmunkle Creek through a breakout to the north-west of Glenorchy. The creek flows through Rupanyup and continues north into the southern Mallee, into Lake Carron. The waterway also drains a narrow, localised catchment, with Wimmera River outflows the dominant flood causing mechanism for Dunmunkle Creek. The cause of peak flood levels along Dunmunkle Creek is driven by peak flow in the Wimmera River in the southern reaches of Dunmunkle Creek, with the total volume of distributed Wimmera River flows becoming more important to peak flood levels in the northern reaches of Dunmunkle Creek. In smaller floods (around 20% AEP) inundation along Dunmunkle Creek might only make it to Rupanyup, with the volume of the event hydrograph dictating how far north flow can reach. In larger flood events, flood levels are dominated by peak flows upstream of Banyena-Pimpinio Road, whereas downstream of this point the volume of the event (including preceding rainfall) plays a larger part.

Dunmunkle Creek is a highly modified waterway having previously been part of the Grampians Wimmera Mallee Water (GWMWater) Stock and Domestic supply system. At the time of the reports preparation, decommissioning of channels within Dunmunkle Creek was planned for the 2018/19 financial year, pending completion of the Dunmunkle Creek Decommissioning Works Plan¹.

The Dunmunkle Creek Flood Investigation study area is shown in Figure 1-1.

¹ The Dunmunkle Creek Decommissioning Works Plan was being completed by Water Technology at the time of this reports preparation.

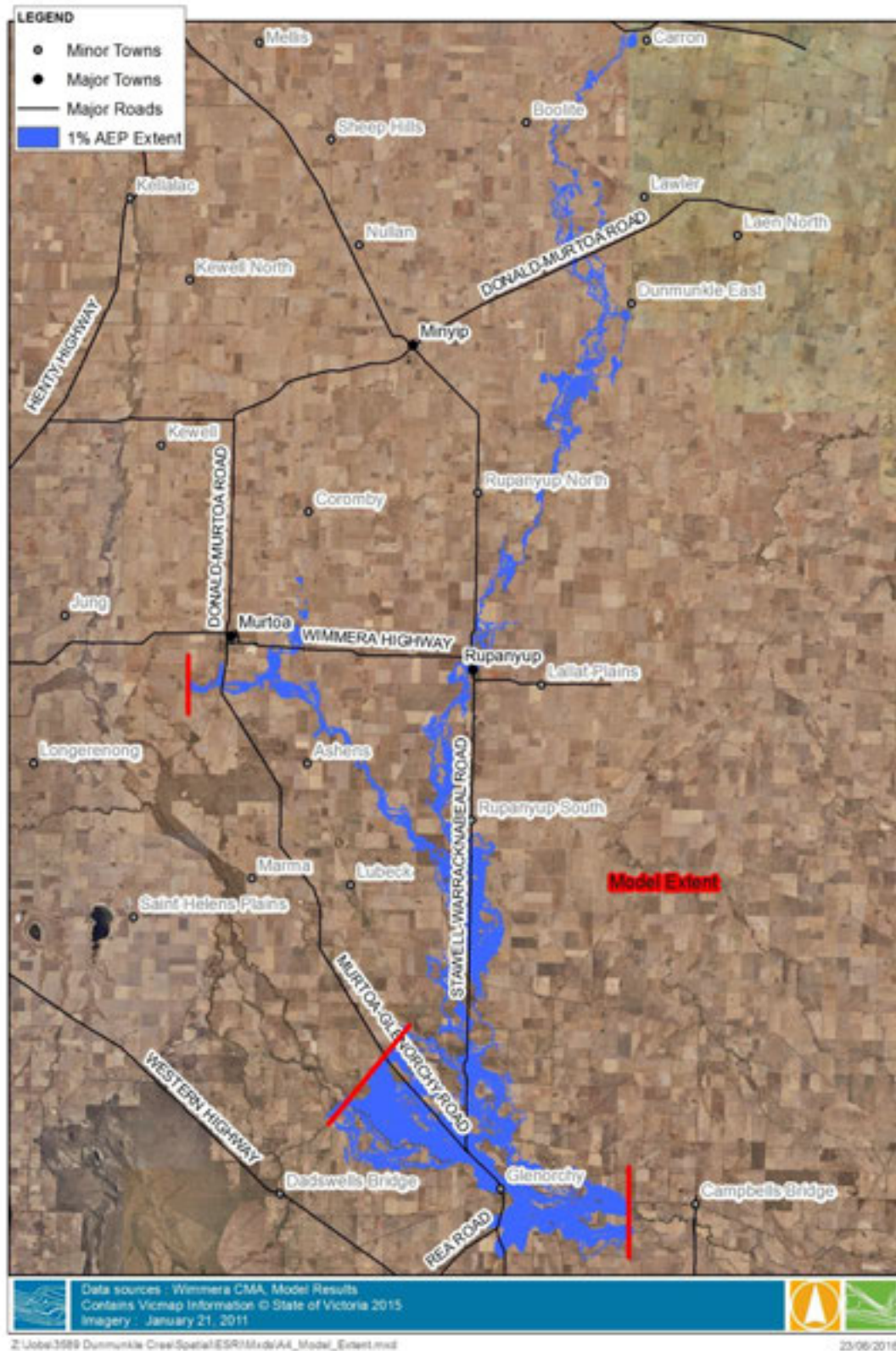


Figure 1-1 Dunmunkle Creek Flood Investigation Study Area



1.2 Project Purpose

The Dunmunkle Creek Flood Investigation was commissioned for a dual purpose:

- To improve the understanding of flooding and resilience for communities along Dunmunkle Creek and its surrounding floodplain, by producing flood intelligence reporting, planning layers, structural flood mitigation options, increased community awareness, etc.
- To assess and recommend potential modifications to the GWM Water Channel Decommissioning program and to ensure the flood impacts of the Channel Decommissioning were well understood.

To achieve those aims the following objectives were achieved throughout the project:

- An understanding of flood behaviour within the township of Rupanyup and the broader Dunmunkle Creek catchment under existing conditions (recognising the likely impact of channel decommissioning already occurred).
- Develop flood level, extent, velocity and depth maps for a range of design flood events for Dunmunkle Creek.
- Develop flood intelligence for use in flood planning and response.
- Assess several mitigation options, specifically considering:
 - Recommend approaches for additional channel decommissioning and flood mitigation;
 - Recommendations for an appropriate flood warning system for the Rupanyup township and rural community;
 - Recommend Planning Scheme amendments that contribute to reducing future risk inclusion in the for the Yarriambiack Shire Council and Northern Grampians Shire Council planning schemes; and,
 - Provide information to update the Flood Emergency Management Plans for both Yarriambiack Shire Council and Northern Grampians Shire Councils.



2 DATA COLLATION AND REVIEW

2.1 Site Visit

A site visit was undertaken on 17th October 2014, by Paul Fennell (Wimmera CMA), Ben Hughes and Ben Tate (Water Technology). The site visit began in Rupanyup and ended at the Dunmunkle Creek Offtake on the Wimmera River. The site visit focused on Rupanyup, the immediate Rupanyup catchment, the general Lubeck area, the Bryntirion State Forest, Dunmunkle Creek between Rupanyup and Glenorchy, and the Dunmunkle Creek offtake at the Wimmera River.

The sites visited during inspection are listed below:

- Rupanyup township
- Rupanyup stormwater catchment
- Bryntirion Reserve
- Rocklands Channel western end
- Rocklands Channel intersection point
- Rocklands Channel at Stawell-Warracknabeal Road
- Dunmunkle Creek at Stawell-Warracknabeal Road
- Dunmunkle Creek along Stawell-Warracknabeal Road
- Dunmunkle Creek at Glenbrook Road
- Melbourne to Adelaide Railway Line at Glenbrook Road
- Dunmunkle Creek offtake
- Swedes Creek offtake

During the site inspection both decommissioned and non-decommissioned channel infrastructure were observed. Figure 2-1 and Figure 2-2 show decommissioned and non-decommissioned sections of the Rocklands Lubeck Channel immediately west and within the Bryntirion Reserve. The brown section of canola indicates the previous channel embankment location. These photos are taken at the same location with the channel outside the reserve decommissioned, and the channel within the reserve still remaining.



Figure 2-1 Decommissioned section of the Rocklands Lubeck Channel (immediately west of the Bryntirion Reserve)



Figure 2-2 Remaining section of the Rocklands Lubeck Channel (Bryntirion Reserve)



2.2 Previous Studies

Previous studies have been completed on Dunmunkle Creek, however these have primarily focused on drainage issues, geomorphic studies and broad scale strategic documents. There has been no detailed flood investigation on Dunmunkle Creek prior to this study. Studies of relevance to this project include:

- Channel Decommissioning Study Report - Draft (Wimmera CMA, 2013)
- Dunmunkle Creek Drainage Plan – Draft Options Paper (GWMWater, October 2011)
- Regulated Streams of the Wimmera – Waterway Action Plan (Wimmera CMA, 2007)
- The flood data transfer project (EGIS Consulting, 2000)
- An estimation of the Volume and Frequency of Cross Catchment Boundary Losses from the Wimmera River System Due to Flows into Swede's Cut (WCMA Board Meeting No. 133)

Several of these studies are of greater significance to this project, these studies were reviewed in greater detail and are documented in this section.

2.2.1 Dunmunkle Creek Drainage Plan, Draft Options Paper – GWMWater (2011)

The Dunmunkle Creek Drainage Plan, Draft Options Paper was prepared as a component to the Regional Drainage Plan intended to address consultation feedback from Local Government, CMAs and members of the public. Public consultation occurred on an individual or group basis rather than open community meetings.

The Draft Options Paper was prepared attempting to meet the Drainage Principles outlined in the drainage plan, listed below:

- Drainage should remain in natural catchments and sub-catchments to prevent cross catchment transfer of surface drainage.
- The point of drainage outfall over a property boundary should remain unchanged.
- Changes in flow rate and volume over a property boundary should not be unreasonable, with a view to minimising:
 - changes in downstream flooding and drainage.
 - the impact of drainage works on other properties.
- Natural pondage or depression areas are to be preserved.
- Adverse impacts on the environment and water quality are to be minimised to protect biological function of wetlands.
- Natural drainage lines may be maintained and enhanced to convey and store water.
- Drainage plans require support from adjoining, downstream and affected landholders.

The Draft Options Paper lists four different channels running along the course of Dunmunkle Creek:

- Main Central Channel
- Dunmunkle Creek South Channel
- Dunmunkle Creek North Channel
- East Karkarooc Channel



In general terms, GWMWater's channel system has operated with channels flowing perpendicular to natural topographic fall achieving the longest water distribution possible. However, in the case of the Dunmunkle Creek system the channels are at the lowest natural point in the topography.

The Options Paper highlights that historically the channel system harvested Dunmunkle Creek inflows to reduce the requirement for releases from headworks. In doing so, the operation of channels meant that drainage flows did not pass along the whole of Dunmunkle Creek but were transferred via the channel system to fill dams.

Channel embankments were constructed along the bed of the Creek in the areas where channels operated. This resulted in a continuous constructed section of channel from north of Glenorchy to Boolite. North of Boolite, Dunmunkle Creek reverts to a more natural profile.

2.3 Topographic Data

2.3.1 Survey Data

As part of this project feature survey was commissioned to better understand the Dunmunkle Creek/Swedes Creek offtake and to verify the various LiDAR datasets available.

Survey was undertaken in the following six locations:

- Dunmunkle Creek Offtake, Campbells Bridge Road (1)
- Horsham-Lubeck Road (2)
- Stawell-Warracknabeal Road, Rupanyup (3)
- Minyip-Banyena Road (4)
- Boolite-Sheep Hills Road (5)
- Birchip Rainbow Road (6)

These locations are shown collectively in Figure 2-3 and discussed individually in the following sections.



21/05/2018



2.3.2 Dunmunkle Creek Offtake Survey

Feature survey of the Dunmunkle Creek offtake was captured to ensure an accurate relationship between the Wimmera River, Dunmunkle Creek and Swede's Cutting could be established. The survey covered the following:

- Four Wimmera River cross sections (two upstream and two downstream of the Dunmunkle Creek offtake)
- Four Dunmunkle Creek cross sections (two upstream and two downstream of the Campbells Bridge Road)
- Campbells Bridge Road height
- Structure invert, obvert and size under Campbells Bridge Road
- Two cross sections of a private access track over the Wimmera River
- Structure invert, obvert and size over the Wimmera River

The survey captured is shown below in Figure 2-4.

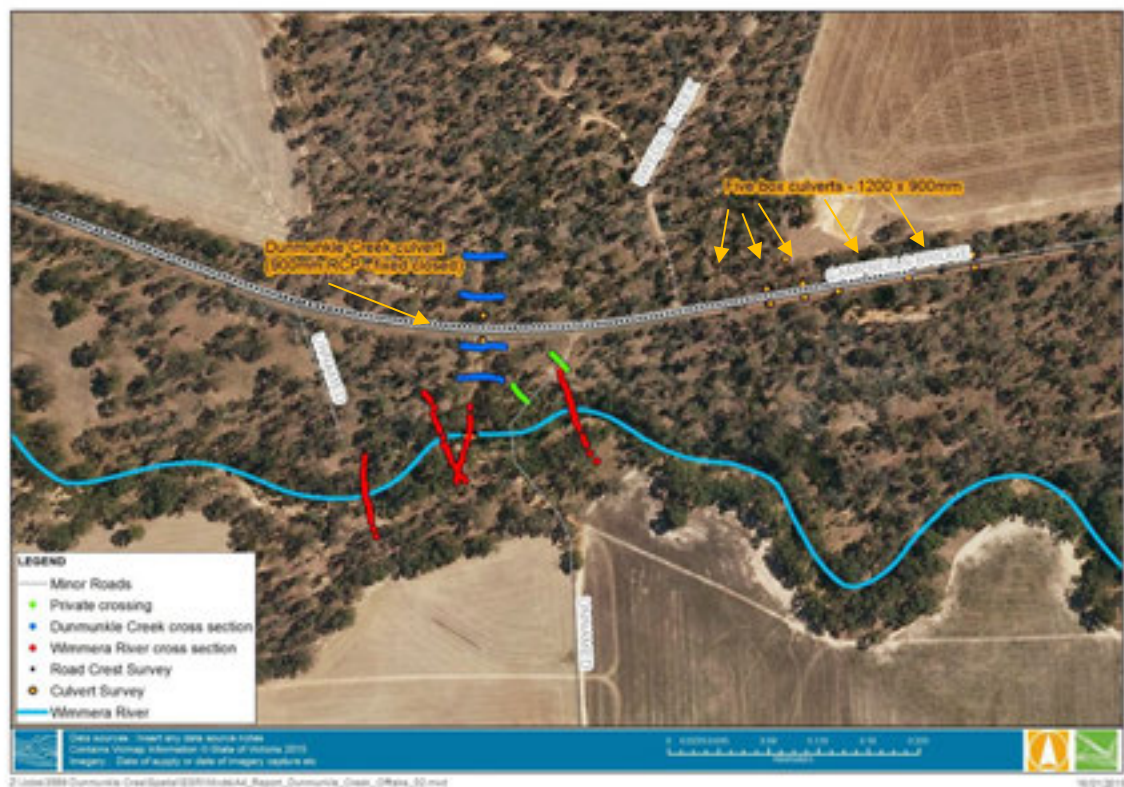


Figure 2-4 Dunmunkle Creek offtake survey

2.3.3 LiDAR Data

2.3.3.1 Availability

There were four LiDAR datasets available for the Dunmunkle Creek Flood Investigation study area:

- South of Wimmera River Trench and Upper Wimmera (Volume 220081008NOM) and Yarriambiack Creek and North East Flat Plains (Volume 220081007NOM)



- Both data sets were completed in the same project but corrected to the ground surface separately.
- Flown in January 2005 by AAM Hatch
- Provided as a 2 m resolution Digital Elevation Model (DEM)
- Stated horizontal accuracy < 1.5 m
- Stated vertical accuracy 0.5 m
- The Meta Data states – “Laser Strike density in some asphalt and road areas is lower than the open paddocks. The coarse asphalt surfaces have reduced the number of returned laser strikes from the 3,000 m flying height in these areas. Asphalt has a lower reflectivity surface offering fewer return signals to the aircraft.”
- 2009-2010 Victorian State Wide Rivers LiDAR Project – Wimmera CMA
 - Flown by Fugro
 - Data covering Dunmunkle Creek was flown 10th October 2010
 - Provided as a 1 m resolution DEM
 - Stated horizontal accuracy – 0.3 m
 - Stated Vertical Accuracy – 0.2 m
- Wimmera Mallee Pipeline Resupply – Dunmunkle Creek (Volume 10723B01NOM)
 - Originally flown by AAMHatch for GWMWater
 - Flown between 25th and 30th September 2006
 - Resupplied to Wimmera CMA for the Dunmunkle Creek Flood Investigation
 - Provided as a 2 m resolution DEM
 - Stated horizontal accuracy < 0.4 m
 - Stated vertical accuracy < 0.15 m

The spatial coverage of each LiDAR dataset is shown in Figure 2-5.

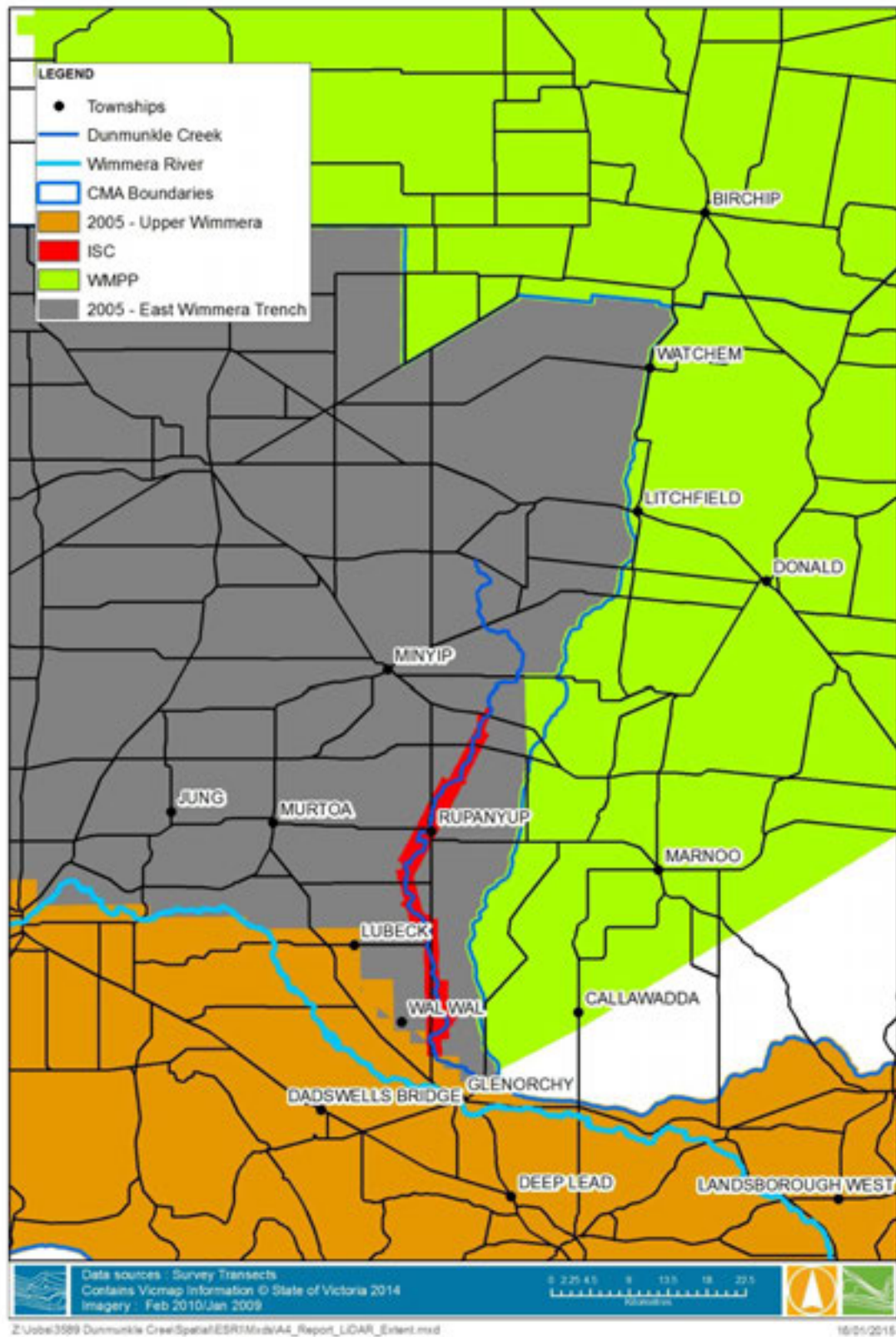


Figure 2-5 LiDAR dataset coverage

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2.3.3.2 Verification

2.3.3.2.1 OVERVIEW

To ensure the topographic data used during this project was accurate and appropriate for use, feature survey was undertaken and compared against the available LiDAR data. This survey was captured along road pavements of low camber to ensure a flat surface which provides a consistent ground surface during the LiDAR capture. Six locations were used as comparison covering each of the four LiDAR datasets as discussed in Section 2.3.1. Each of these locations is discussed in the following sections.

2.3.3.2.2 CAMPBELLS BRIDGE ROAD

As discussed in Section 2.3.2, Campbells Bridge Road was surveyed as part of the Dunmunkle Creek Offtake survey. An 800 m transect was captured along the road, this transect was within the *South of Wimmera River Trench and Upper Wimmera River* LiDAR dataset. The survey and LiDAR levels were compared along the transect. The transect location and topographic comparison are shown in Figure 2-6 and Figure 2-7 respectively.

The comparison showed the surveyed levels are consistently higher than the LiDAR levels, with the average difference in height 0.17 m. Due to this disparity comparisons were also made at each of the extracted Wimmera River and Dunmunkle Creek cross section locations to verify this finding. The location of the cross sections is shown in Figure 2-8 with the level comparisons shown in Figure 2-9 through to Figure 2-12 for the Wimmera River and Figure 2-13 through to Figure 2-16 for Dunmunkle Creek.



Figure 2-6 Campbells Bridge Road transect location

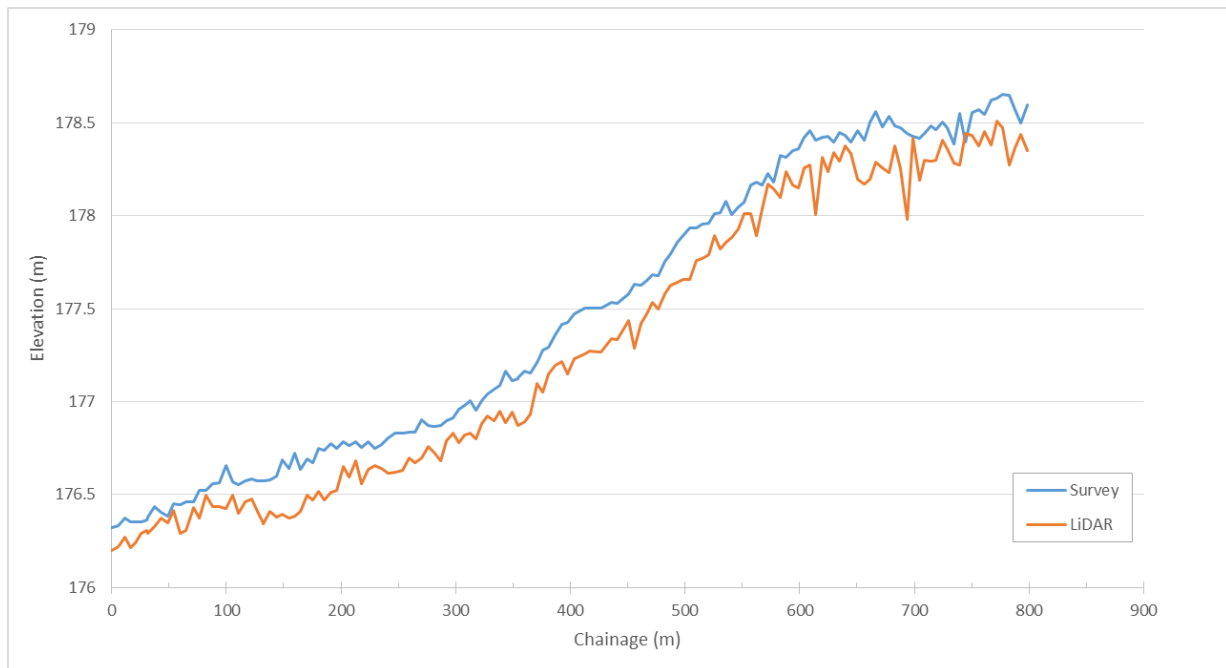


Figure 2-7 Campbells Bridge Road survey and LiDAR level comparison



Figure 2-8 Wimmera River and Dunmunkle Creek cross section locations

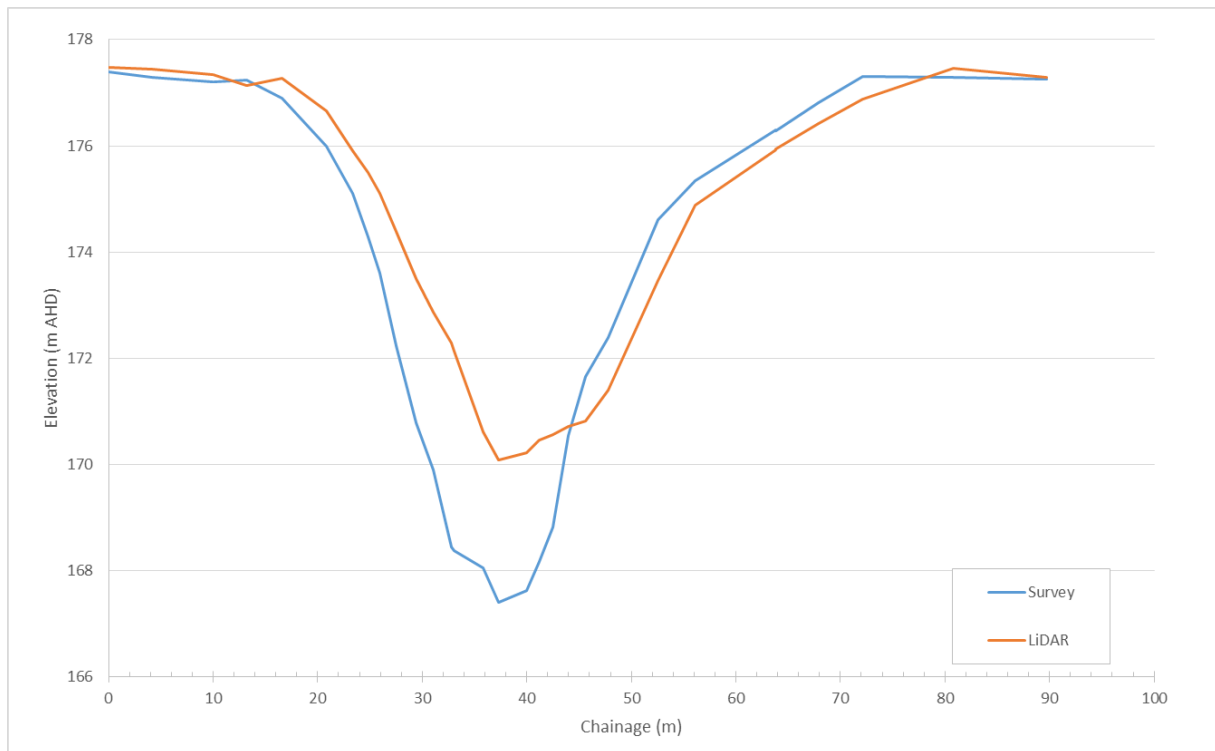


Figure 2-9 Wimmera River cross section 01

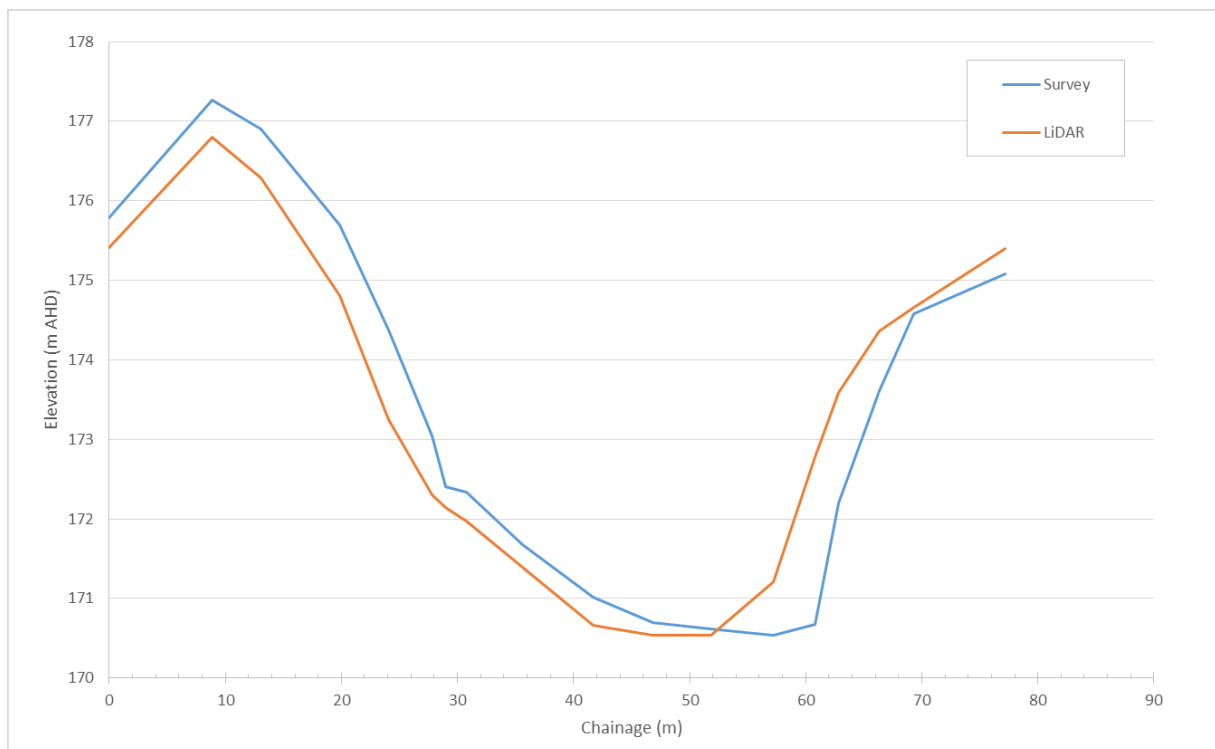


Figure 2-10 Wimmera River cross section 02

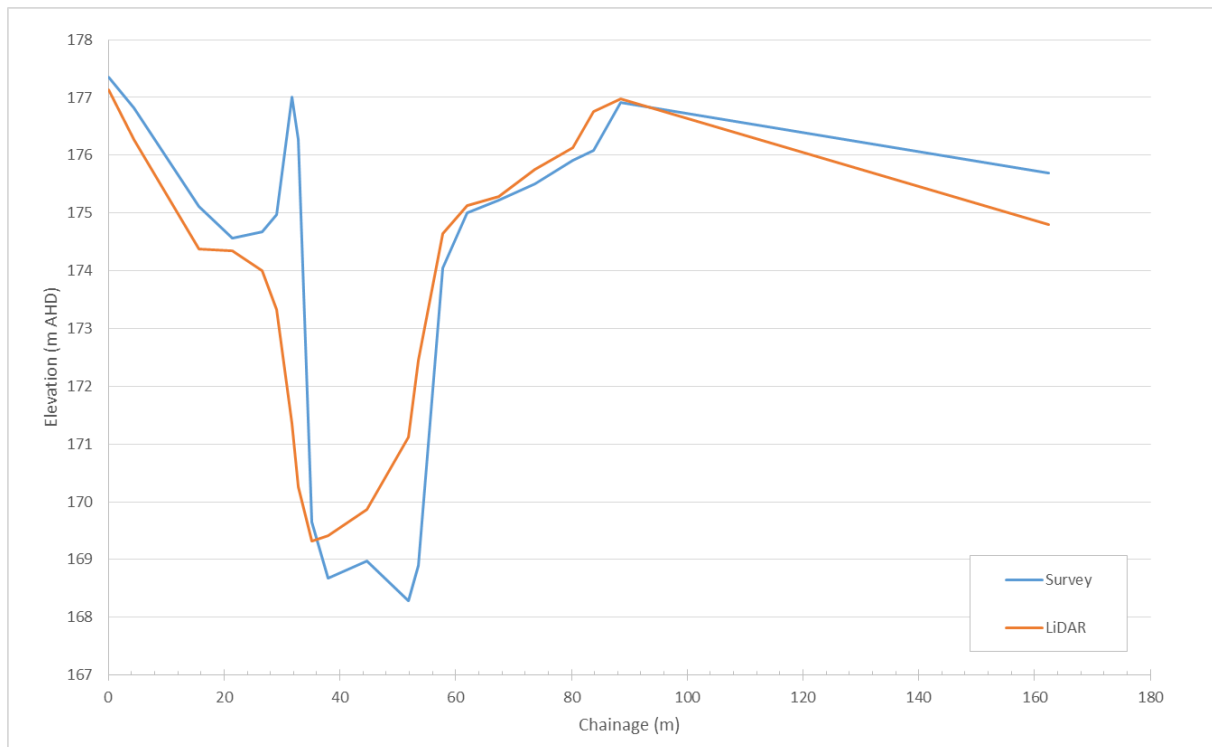


Figure 2-11 Wimmera River cross section 03

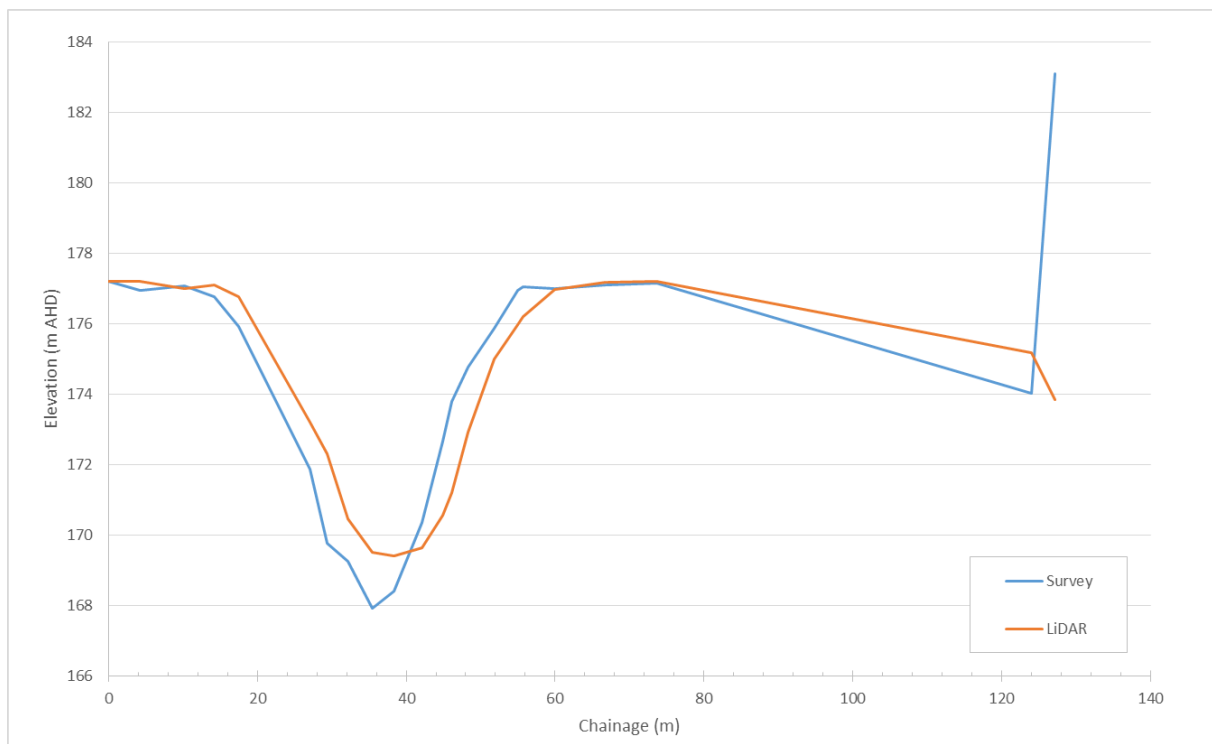


Figure 2-12 Wimmera River cross section 04

In general, the Wimmera River cross sections matched the survey data along the waterway banks very closely with no consistent variability in elevation. Differences in the channel are somewhat expected due to the



likelihood of water in the waterway channel and combination of instream vegetation and horizontal inaccuracies on the banks.

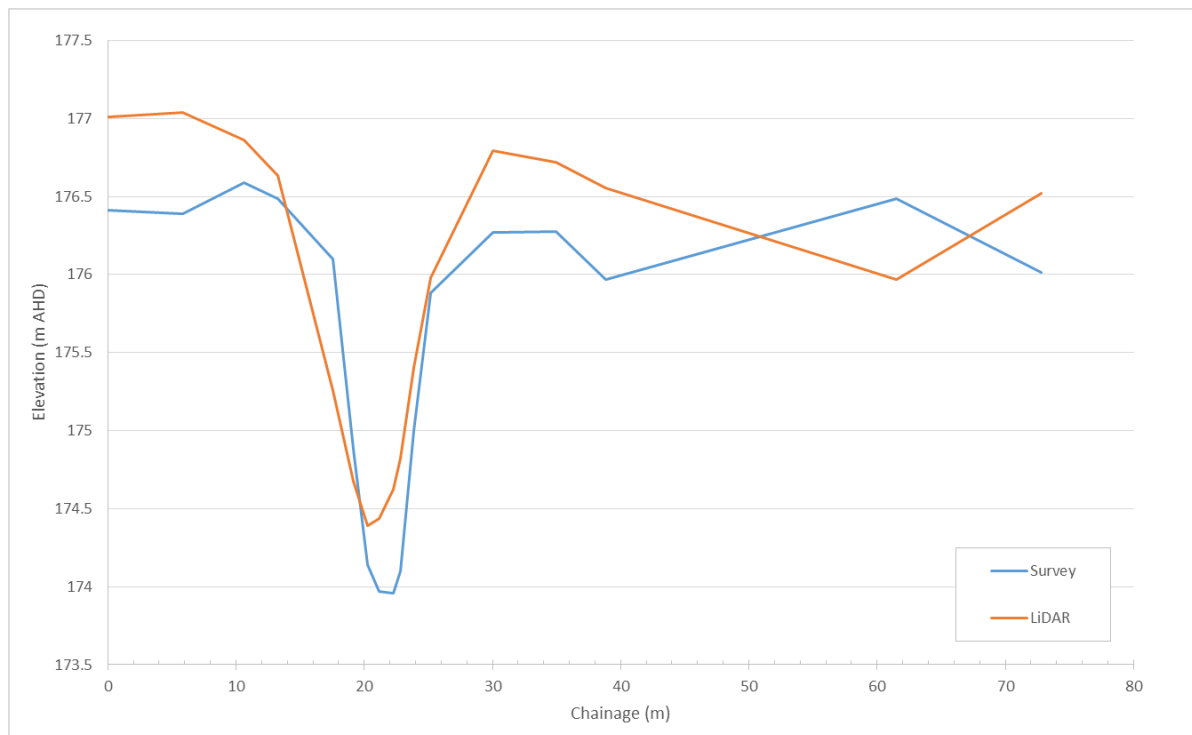


Figure 2-13 Dunmunkle Creek cross section 01

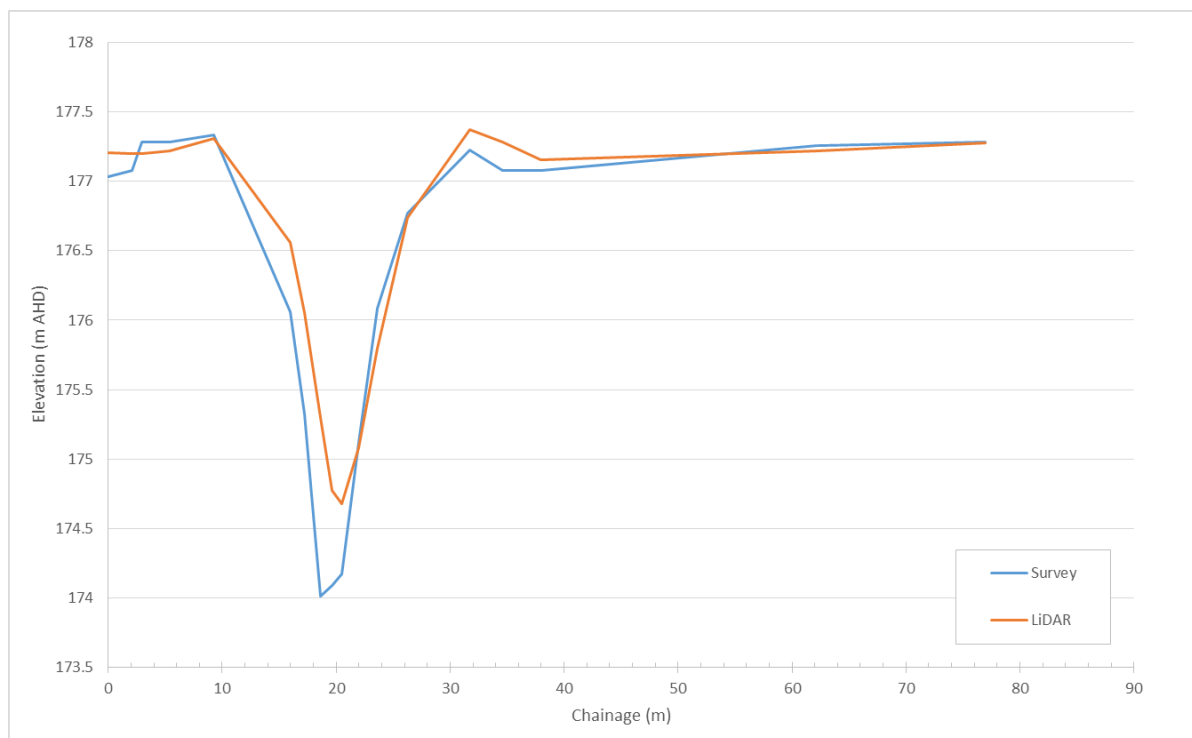


Figure 2-14 Dunmunkle Creek cross section 02

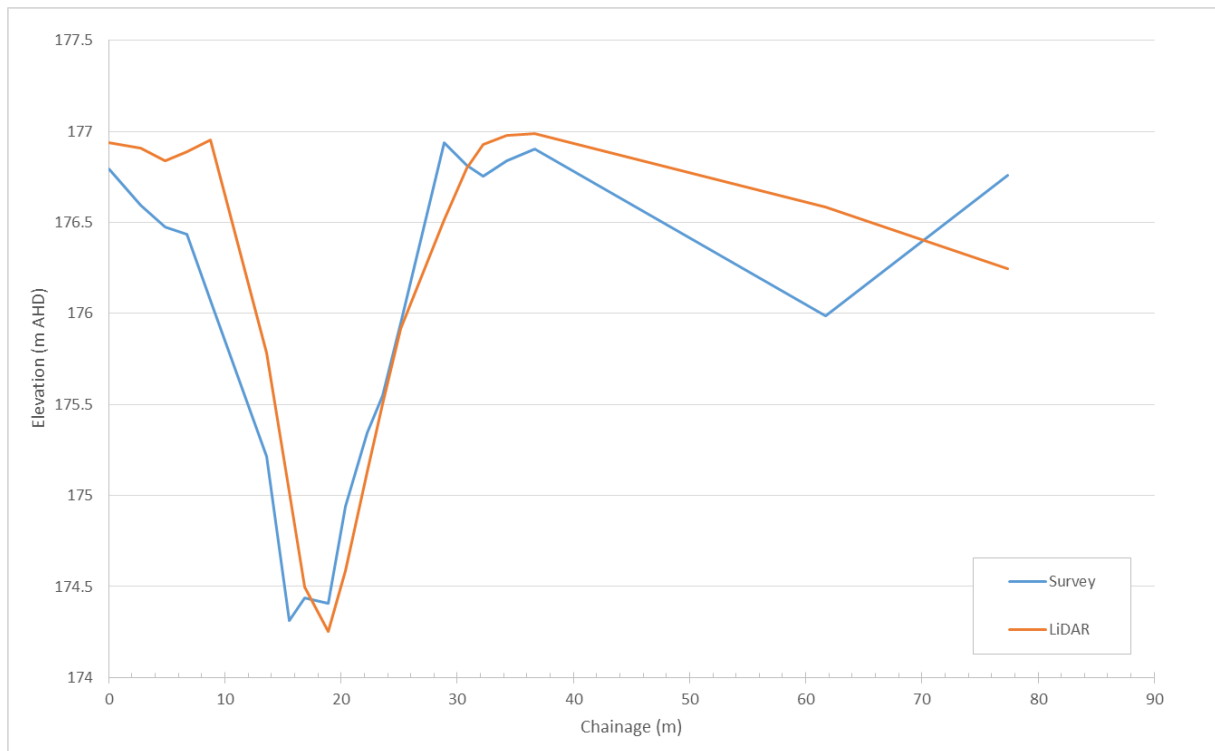


Figure 2-15 Dunmunkle Creek cross section 03

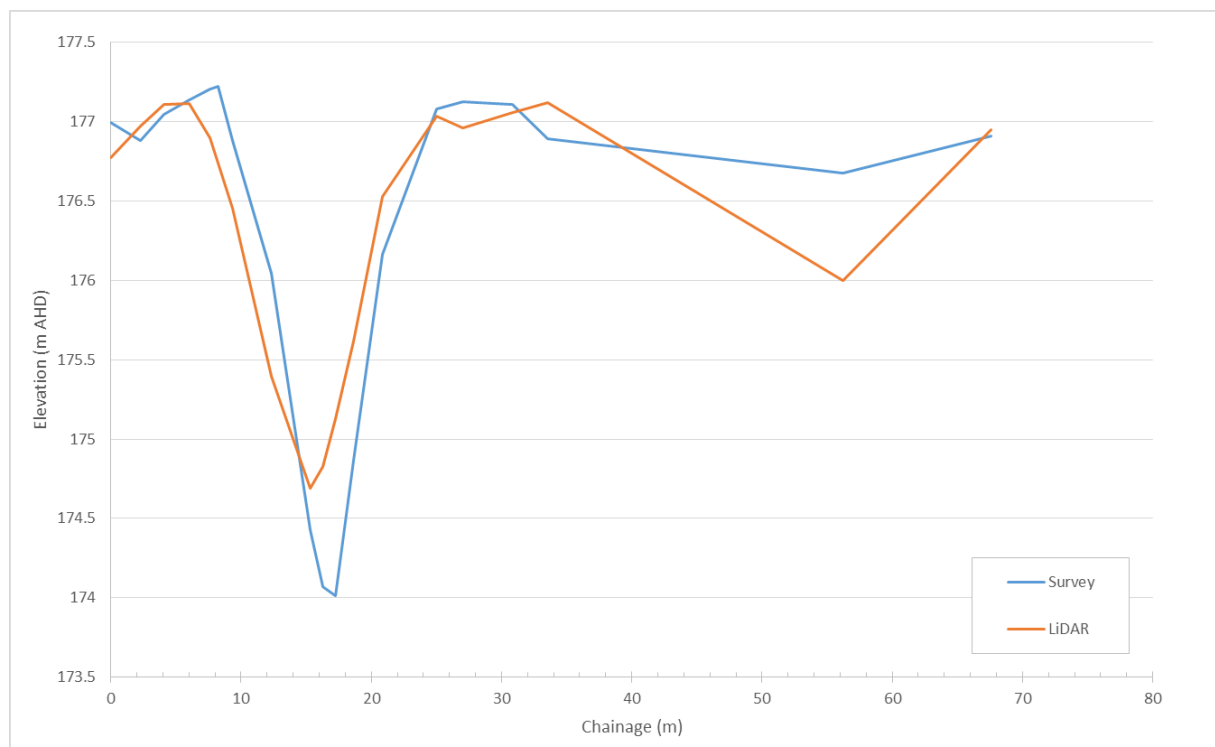


Figure 2-16 Dunmunkle Creek cross section 04

Similar to the Wimmera River cross sections, survey and LiDAR levels matched well along the waterway banks with some differences in the waterway channel. Dunmunkle Creek cross section 01 showed the greatest difference in waterway bank height.



2.3.3.2.3 HORSHAM-LUBECK ROAD

A 600 m transect was surveyed along Horsham-Lubeck Road immediately west of the Warracknabeal Stawell Road. Survey was completed in an area covered by both the *ISC* and *Yarriambiack Creek and North East Flat Plains* LiDAR (2005).

The transect location and topographic comparison between the survey and LiDAR levels are shown in Figure 2-17 and Figure 2-18 respectively.



Figure 2-17 Horsham Lubeck Road transect location

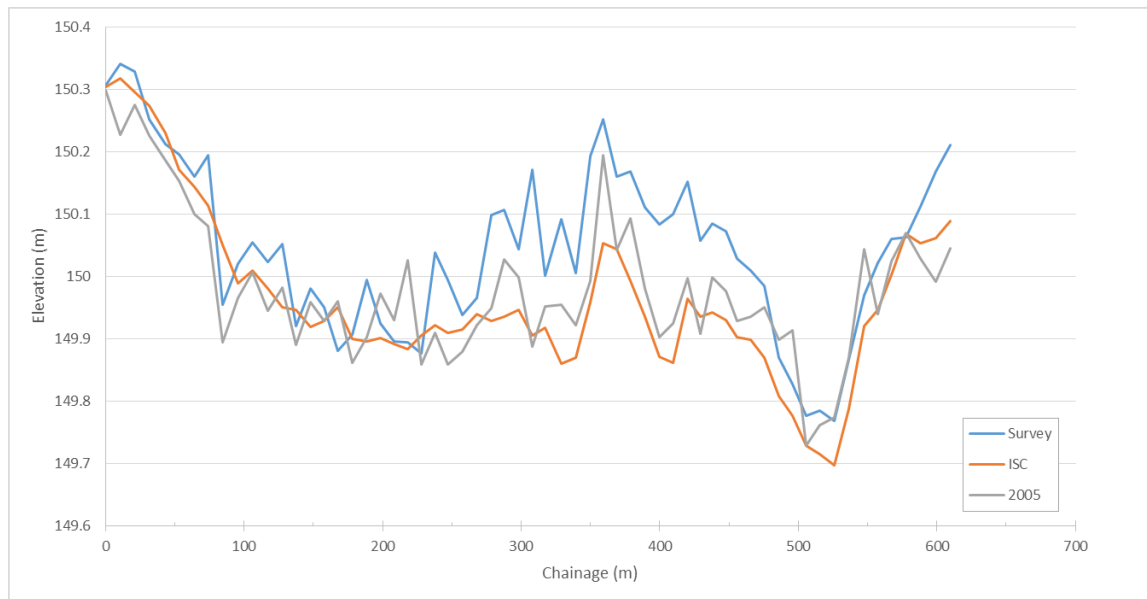


Figure 2-18 Horsham Lubeck Road survey and LiDAR level comparison

The comparison of surveyed and LiDAR levels at Horsham Lubeck Road shows both the ISC and 2005 LiDAR to be lower than the survey. The average, maximum, minimum and standard deviation of each LiDAR dataset and the surveyed levels is shown in Table 2-1. Note that the standard deviation is of approximately the same magnitude as the mean difference indicating that there is a lot of scatter in the comparison.

Table 2-1 Horsham Lubeck Road – Survey and LiDAR comparison

Difference	ISC LiDAR	2005 LiDAR
Mean (m)	-0.08	-0.06
Maximum (m)	0.10	0.13
Minimum (m)	-0.27	-0.28
Standard Deviation (m)	0.08	0.07

2.3.3.2.4 STAWELL-WARRACKNABEAL ROAD

The Stawell Warracknabeal Road was surveyed in Rupanyup, on the western side of the traffic division. The surveyed transect was 500 m long and was covered by both the *ISC* and *Yarriambiack Creek and North East Flat Plains* LiDAR (2005).

The Warracknabeal Stawell Road survey transect location and topographic levels are shown in Figure 2-19 and Figure 2-20 respectively.



Figure 2-19 Stawell Warracknabeal Road transect location

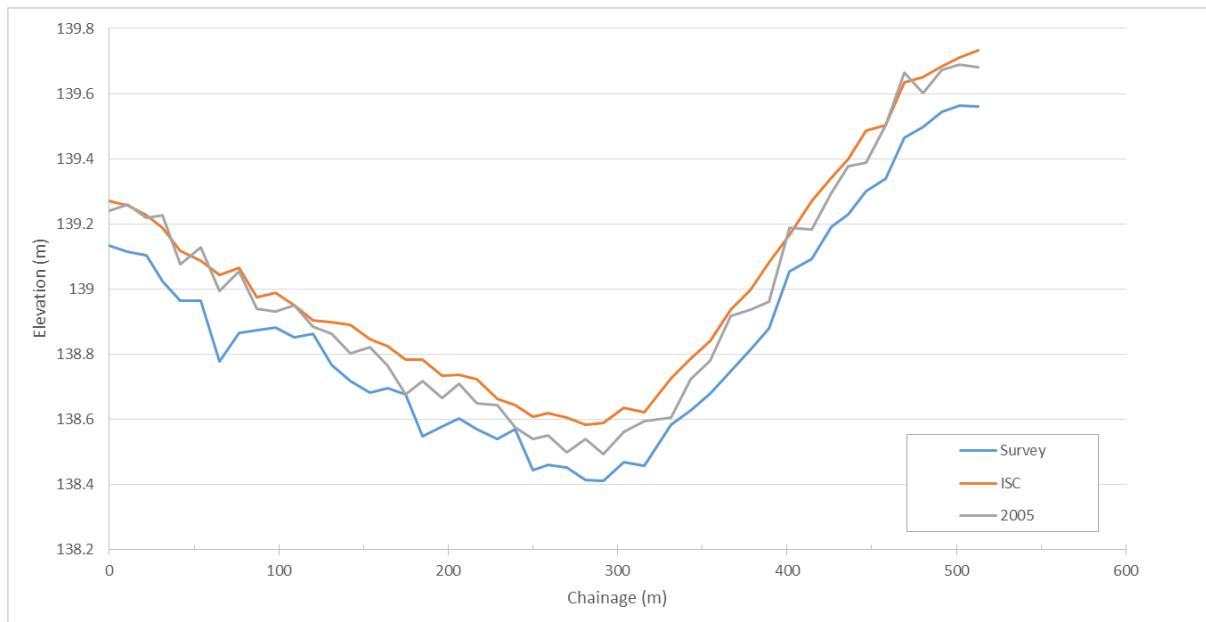


Figure 2-20 Stawell Warracknabeal road survey and LiDAR level comparison

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Comparison of LiDAR and surveyed levels along Stawell Warracknabeal Road in Rupanyup showed the LiDAR to be generally higher than the survey. The mean, maximum, minimum and standard deviation differences between the ISC and 2005 LiDAR against the survey are shown in Table 2-2.

Table 2-2 Horsham Lubeck Road – Survey and LiDAR comparison

Difference	ISC LiDAR	2005 LiDAR
Mean (m)	0.15	0.11
Maximum (m)	0.27	0.22
Minimum (m)	0.04	0.00
Standard Deviation (m)	0.04	0.05

2.3.3.2.5 MINYIP-BANYENA ROAD

The Minyip Banyena Road was surveyed at the Dunmunkle Creek culvert. The surveyed transect was 300 m long and was covered by both the *ISC* and *Yarriambiack Creek and North East Flat Plains* LiDAR (2005).

The Minyip Banyena Road survey transect location and topographic levels are shown in ???



Figure 2-21 Minyip Banyena Road transect location

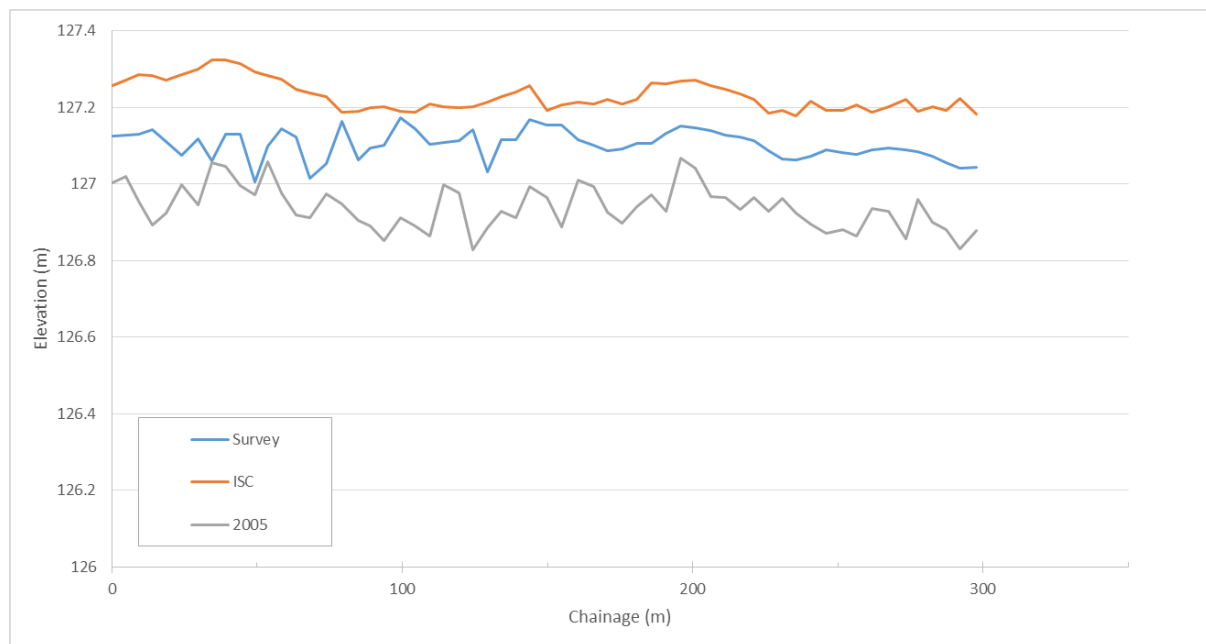


Figure 2-22 Minyip Banyena Road survey and LiDAR level comparison

Comparison of the LiDAR and surveyed levels along Minyip Banyena Road showed the *ISC* levels to be consistently higher, and the *Yarriambiack Creek and North East Flat Plains* LiDAR (2005) to be consistently lower than the surveyed levels.

The mean, maximum, minimum and standard deviation differences between the ISC and 2005 LiDAR against the survey are shown in Table 2-5.

Table 2-3 Horsham Lubeck Road – Survey and LiDAR comparison

Difference	ISC LiDAR	2005 LiDAR
Mean (m)	0.13	-0.16
Maximum (m)	0.29	-0.01
Minimum (m)	0.01	-0.31
Standard Deviation (m)	0.12	-0.17

2.3.3.2.6 BOOLITE-SHEEP HILLS ROAD (LAWLER ROAD)

The Boolite Sheep Hills Road was surveyed at the official end of Dunmunkle Creek. The surveyed transect was 260 m long and was covered by the Yarriambiack Creek and North East Flat Plains LiDAR (2005) only.

The Boolite-Sheep Hills Road survey transect location and topographic levels are shown in Figure 2-23 and Figure 2-24 respectively.



Figure 2-23 Boolite-Sheep Hills Road transect location

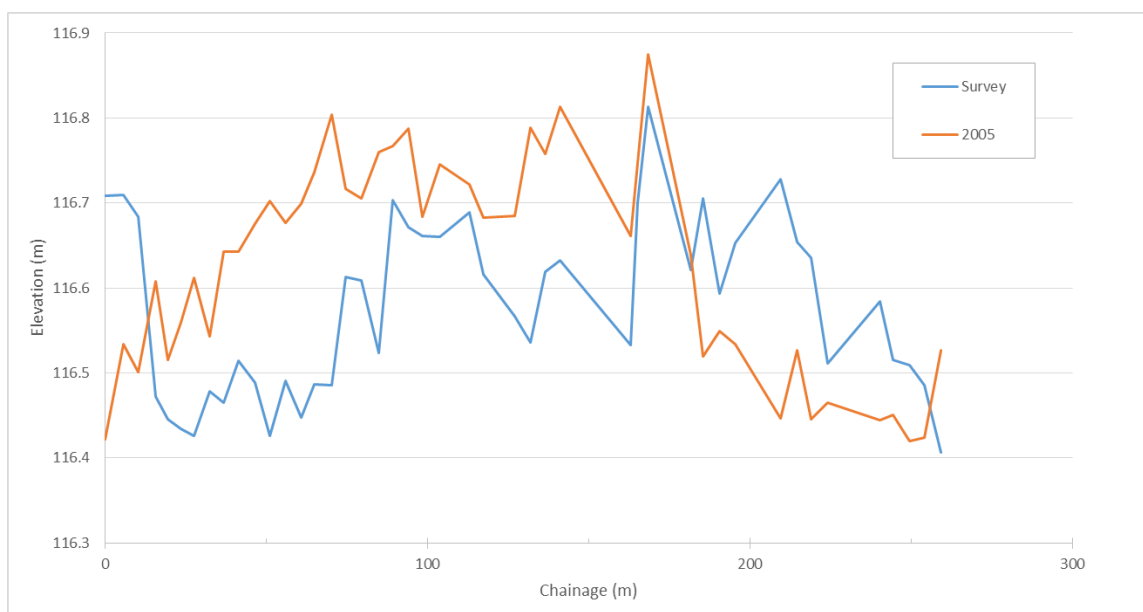


Figure 2-24 Boolite Sheep Hills Road survey and LiDAR level comparison

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Comparison of LiDAR and surveyed levels along the Boolite Sheep Hills Road showed no consistent trend with the LiDAR higher on some areas, and the survey higher in others. The mean, maximum, minimum and standard deviation differences between the 2005 LiDAR against the survey are shown in Table 2-4.

Site observations during the project highlighted that the road is regularly graded with no consideration for water flow levels which may go some way to explaining the variability. Discussions with Yarriambiack Shire Council² indicated that most gravel road crossings would be of this nature.

Table 2-4 Boolite Sheep Hills Road – Survey and LiDAR comparison

Difference	2005 LiDAR
Mean (m)	0.05
Maximum (m)	0.32
Minimum (m)	-0.29
Standard Deviation (m)	0.07

2.3.3.2.7 BIRCHIP RAINBOW ROAD

The Birchip Rainbow Road transect was the furthest transect to the north and the only survey that was completed within the *WMPP* LiDAR dataset. The survey was completed outside the original study extent. The location of the Birchip Rainbow Road transect and the topographic data comparison are shown in Figure 2-25 and Figure 2-26 respectively.

² Pers. Comm.



Figure 2-25 Birchip Rainbow Road transect location

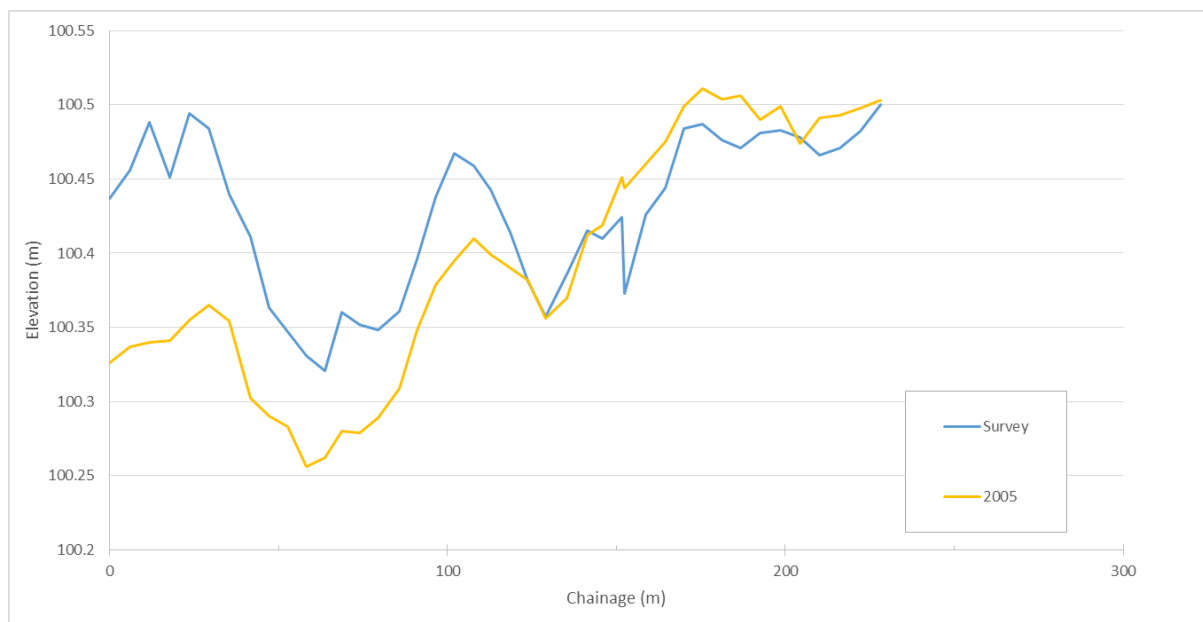


Figure 2-26 Birchip Rainbow Road survey and LiDAR level comparison

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The comparison of surveyed and LiDAR levels shows no trend towards one dataset being higher than the other. The mean, maximum, minimum and standard deviation differences between WMPP LiDAR and the survey are shown in Table 2-5.

Table 2-5 Birchip Rainbow Road – Survey and LiDAR comparison

Difference	WMPP LiDAR
Mean (m)	-0.03
Maximum (m)	0.07
Minimum (m)	-0.15
Standard Deviation (m)	0.06

2.3.3.2.8 SUMMARY AND DISCUSSION

Topographic verification was undertaken across four LiDAR datasets summarised below.

- *South of Wimmera River Trench and Upper Wimmera*
 - Significant for the Wimmera River Offtake, the LiDAR dataset was on average 0.17 m lower than the surveyed road transect. However, the surveyed section of road was re-sealed after the January 2011 flood, potentially adding 0.05 to 0.10 m.
 - The Dunmunkle Creek and Wimmera River cross sections showed matching LiDAR and survey levels
 - All comparisons were within the stated accuracy of the dataset – 0.5 m vertical accuracy
 - The LiDAR was determined to be of sufficient accuracy for use in this project.
- *Yarriambiack Creek and North East Flat Plains*
 - LiDAR levels at each of the road transects showed no consistent bias to being high or low
 - Horsham Lubeck Road - Low (0.06 m average)
 - Warracknabeal-Stawell Road - High (0.11 m average)
 - Minyip Banyena Road - Low (0.16 m average)
 - Boolite Sheep Hills Road – High (0.05 m average)
 - Across all road transects the LiDAR was on average 0.015 m lower than survey, within the stated accuracy of the data of 0.5 m (vertical accuracy)
 - The LiDAR was determined to be of sufficient accuracy for use in this project.
- *2009-2010 Victorian State Wide Rivers*
 - LiDAR levels at each of the road transects showed no consistent bias to being high or low
 - Horsham Lubeck Road - Low (0.08 m average)
 - Warracknabeal-Stawell Road - High (0.15 m average)
 - Minyip Banyena Road - High (0.13 m average)
 - Across all road transects the LiDAR was on average 0.067 m higher than survey, within the stated accuracy of the data of 0.2 m.
 - The LiDAR was determined to be of sufficient accuracy for use in this project.
- *Wimmera Mallee Pipeline Resupply*



- There was only one transect captured in the *Wimmera Mallee Pipeline Resupply* LiDAR data, which showed no consistent bias to being high or low.
- The LiDAR was on average 0.03 m lower than survey, within the stated accuracy of 0.15 m.
- The LiDAR was determined to be of sufficient accuracy for use in this project.

Given all the available datasets were determined as of sufficient accuracy a combination of all datasets were used as a topographic basis for the project. The data used varied depending on the scenario being modelled (i.e. stage in the GWMWater Channel decommissioning), but in general terms the most recent data was used in preference to ensure all potential topographic changes are captured.

2.3.4 Wal Wal Lubeck Landcare Group Report on Water Strategy Survey (Scot Douglas, Land Surveyor, 1993)

Scot Douglas prepared survey of the Wal Wal/Lubeck area to inform a drainage strategy for the Wal Wal Lubeck Landcare Group.

The Drainage Strategy highlights man made constraints on the natural drainage had caused areas of flooding, reporting highlights several general constraints and the following key pieces of infrastructure are mentioned:

- Lubeck Channel
- North Western Railway
- Rocklands Channel
- Wal Wal Channel System

Reporting also highlights Mr Kinsella's wetland as a potential termination point for drainage through the Wal Wal/Lubeck area.

Reporting separated the survey area into five catchment areas with eleven points of discharge. A number of the points of discharge are listed as proposed and haven't been investigated in full as the topographic LiDAR data will show what has been constructed since the 1993 report. The approximate survey area is shown in Figure 2-27.



Figure 2-27 Wal Wal/Lubeck Water Survey Strategy extent



2.3.5 GWMWater Channel Decommissioning Modelling (Water Technology 2014)

GWMWater and Wimmera CMA commissioned the GWMWater Channel Decommissioning Modelling to better understand the potential overland flow paths and drainage points post decommissioning of the GWMWater's earthen channel system.

Drainage lines were identified by modelling the study area using a rain-on-grid technique. Three Average Recurrence Intervals (ARIs) were modelled (20, 50 and 100 year ARI) for a 2 hour critical duration rainfall event. This involved separating the study area into a series of catchments, applying rainfall directly onto the catchments and allowing it to flow following the natural drainage pattern.

The study area with catchment delineation is shown below in Figure 2-28. An example of the results produced is shown in Figure 2-29.



Figure 2-28 Channel Decommissioning Modelling – Study extent and catchment delineation

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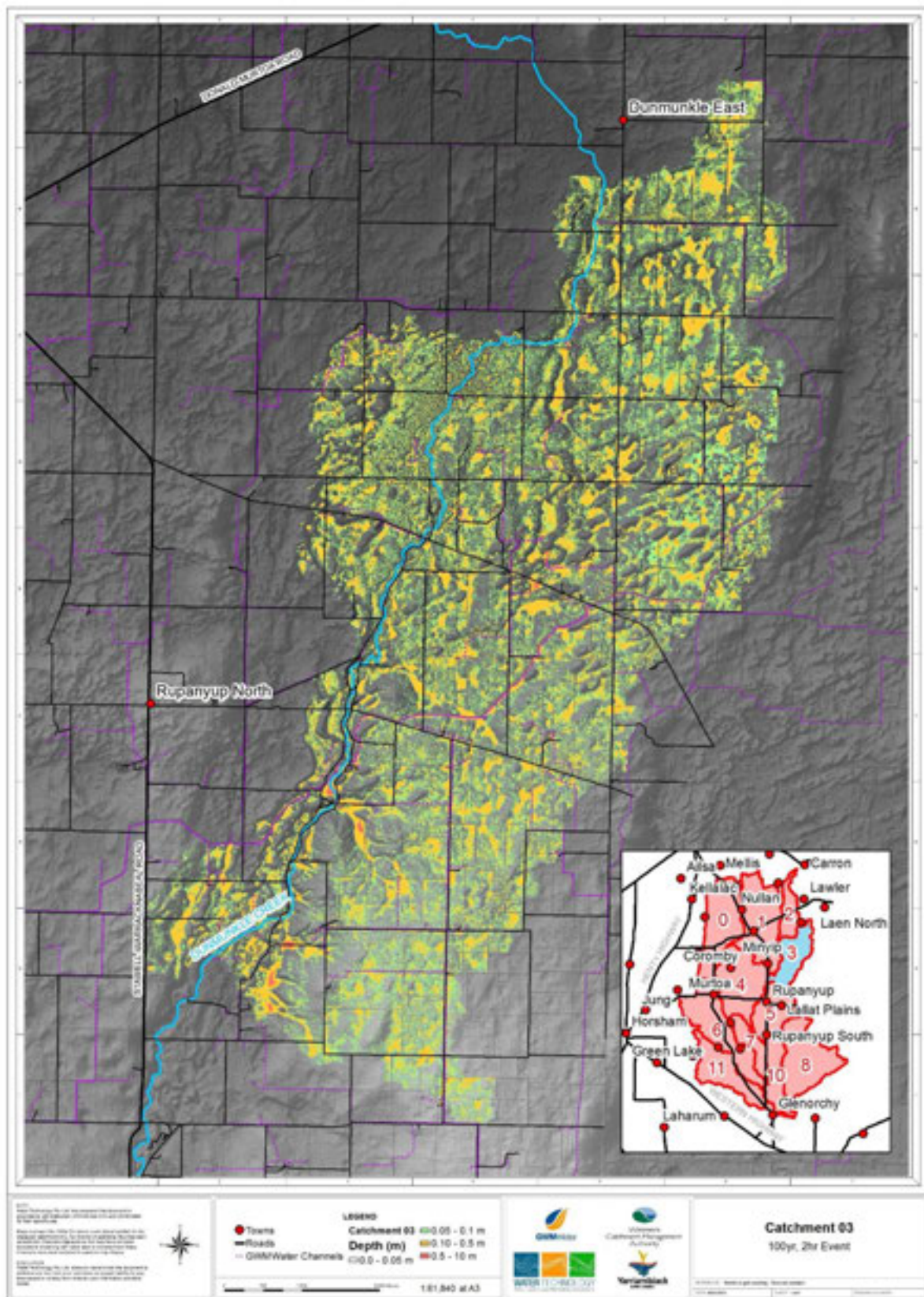


Figure 2-29 Channel Decommissioning Modelling – Catchment 3



2.3.6 GWMWater Rapid Impact Assessment – Channel Decommissioning (Water Technology 2014)

Post January 2011, GWMWater commissioned Water Technology to complete a series of rapid impact assessments, providing a clear set of recommendations for interim works that may be implemented prior to the winter/spring 2011 season. These recommendations were aimed at mitigating the risk of undesired inundation over the coming winter/spring period on a 'no regrets' basis, this approach was used to ensure works occurred rather than proposed changes becoming stuck in the long running debate about what channels should remain and which should be decommissioned.

The following sites relevant to this study were assessed during a site visit and desktop assessment, each site also has a description why the site was visited:

- Main Eastern Channel - Channel between McKays Road and Warranooke Road was infilled causing inundation of private land. As a result, the channel was opened, and water drained to the Rocklands Lubeck Channel.
- Main Central Channel – The Main Central Channel is a natural flow path. Blocks in the channel at road crossings caused water to sit for long periods of time.
- Lubeck Township - A section of the Lubeck Channel along the Horsham-Lubeck Rd was infilled from 3LK Rd to the Marma State Forest. This was thought to have caused inundation through the Lubeck township and its surrounds.
- Bryntirion Reserve – The flow split between the Main Central channel (towards Murtoa) and Dunmunkle Creek (towards Rupanyup) in the Bryntirion Reserve was believed to be influenced by changes to infrastructure.
- East Karkarooc Channel - The East Karkarooc Channel heads north from Rupanyup towards Boolite. The channel makes up a lower (northern) section of Dunmunkle Creek. The East Karkarooc Channel/Dunmunkle Creek is a designated waterway up until it meets Lawler Rd where the channel changes direction to the west and Dunmunkle Creek officially finishes. There is however, a title boundary and distinct tree line where the Dunmunkle Creek drainage line appears to continue on to the north for some distance. GWMWater had blocked the channel structure under Lawler Rd as part of their channel decommissioning as shown in Figure 2-30. This caused flooding upstream of the structure.



Figure 2-30 Blocked culvert at Lawler Road – Dunmunkle Creek/East Karkarooc Channel

Various recommendations were made to divert overland flow and prevent the remaining (at the time of writing) channel system from exacerbating flood levels by capturing and transferring flow in partially decommissioned and blocked sections of channel.

The information included in this report gives a reference to the state of the channel decommissioning during the January 2011 event for each of the sites, providing background information for use in model calibration during this current study.



3 PROJECT CONSULTATION

3.1 Overview

This project included three stages of community consultation, with meetings at three locations within each stage. The stages of community consultation were as follows:

- Stage 1 – Introduction to the project, context, summary of what had been completed to date, what we hoped to achieve, how the community was to be engaged and what information we were hoping to receive from them, and discussion of mitigation options. At this meeting a list of historical peak levels were collated and observed details recorded. This information was used during the modelling process.
- Stage 2 – Modelling progress, discussion around historical events. Discussion of model calibration and draft 1% AEP flood extents and behaviour. Call for mitigation options to be suggested as part of a community based survey.
- Stage 3 – Present final mapping, presentation of mitigation option assessments, project outcomes and the progression of the technical information to mitigation and planning scheme implementation.

Each stage of community consultation included meetings in Lubeck, Boolite and Rupanyup. This section of the report documents the information gathered during these meetings. At all of the community consultation meetings the community focus was largely on what occurred during the January 2011 flood event, how they were impacted and how they could be better prepared.

3.2 Community Consultation Stage 1

3.2.1 Lubeck - 10th November 2014/16th December 2014

An initial meeting was held in Lubeck on 10th November 2014, however, due to an early cereal harvest limited numbers were available for the meeting. As such a second meeting was organised through members of the farming community held on the 16th December 2014.

The number of participants at each meeting and their primary area of interest are listed below:

- 10th November 2014
 - Rupanyup - 2
 - Lubeck - 1
 - Project team - 2
- 16th December 2014
 - Murtoa – 3
 - Lubeck – 4
 - Project Team - 2

At both meetings similar topics were raised and similar concerns existed amongst both groups.

The following information and views were gathered at the Stage 01 Lubeck meetings:

- The channel decommissioning has been broadly completed through the Lubeck area, but the Main Central Channel through the Bryntirion State Forest remains intact, as shown in Figure 3-1.

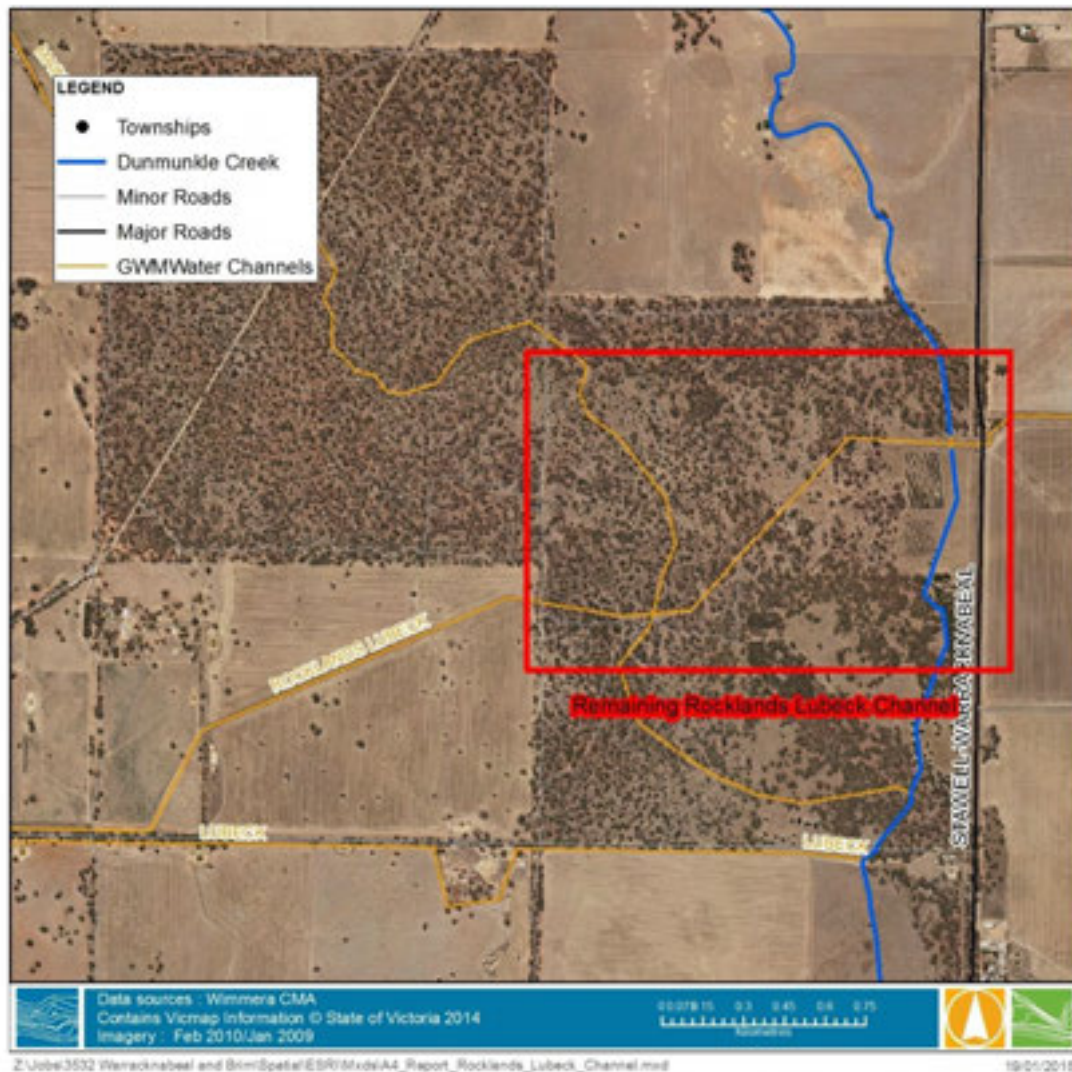


Figure 3-1 Section of remaining channel embankment in the Bryntirion State Forest

- The length of channel remaining in the Bryntirion State Forest must be fully removed with the view being channels should be returned to “natural” conditions.
- Now the channel system has been decommissioned more water will flow towards Murtoa (alleged).
- There is a natural flow split between water flowing along Dunmunkle Creek to Rupanyup and towards Murtoa, this occurs upstream of the Bryntirion State Forest. The comment was made 70% of the water should head towards Murtoa naturally (although unsure what this flow split is based on).
- Removal of all the water storages along the channel system will increase the volume of water flowing along Dunmunkle Creek.
- There are two drainage schemes in place, the one devised by the Wal Wal-Lubeck Landcare Group (as discussed in Section 2.3.4) and another located East of Dunmunkle Creek and north of Raichella Tramline Road. Decommissioning of the channel system leaves the drainage scheme final point of discharge unknown.
- The comment that water should be allowed to flow as it would naturally, was made by several people.



- Water is restricted from moving downstream and it is this water that does the damage.

Members of the community were able to highlight several properties that were directly impacted by inundation and indicate the extent of inundation in areas where linescans and aerial imagery was not available.

3.2.2 Boolite – 11th November 2014

The meeting was attended by the following number of people areas of interest:

- Minyip (6)
- Donald (2)
- Minyip/Boolite (2)
- Sheep Hills (2)
- Study team (3)

The following information was gathered at the Stage 01 Boolite meeting:

- Private earthworks were undertaken along the Dunmunkle Creek channel in some areas during the January 2011 event. These included channel excavation and levee construction.
- Some sections of Dunmunkle Creek were filled prior to January 2011 to increase the viability of cereal cropping. Dates of earthworks are unknown.
- Flood water reached as far as Boolite in 1956.
- There are several swamps along Dunmunkle Creek which are filled by floodwater, this includes Sammy's Lake.
- Roads exacerbated flood levels during January 2011.
- Water took around 2 weeks to get from Boolite to Carron.
- Carron Lake appears to be the northern most point that water reached during the January 2011 event.
- Water remained in the natural depressions/swamps unconnected to Dunmunkle Creek for months at a depth large enough to water ski on.
- During January 2011 road culverts appeared too small to handle the required flow rate in some locations. The Donald Murtoa Road and Borung Highway were both highlighted.

Members of the community were able to highlight several properties that were directly impacted by inundation and indicate the extent of inundation in areas where linescans and aerial imagery was not available.

3.2.3 Rupanyup – 17th November 2014

The meeting was attended by the following number of people areas of interest:

- Rupanyup (4)
- Lubeck (1)
- Study team (4)

The Rupanyup community provided excellent information during the Stage 01 consultation session, two written accounts of the January 2011 event were also submitted. The following information was gathered at the Stage 01 Rupanyup meeting:



- The Rupanyup community was impacted by inundation twice during January 2011, initially by stormwater from south east of the township, then again from the Wimmera River riverine flow distribution to Dunmunkle Creek.
- The township is largely separated into two distinct drainage systems split by the Wimmera Highway.
- In general, the catchment area east of Rupanyup drains into an open drain which flows north to a dam which waters the golf course.
- Dunmunkle Creek flows between two GWMWater storages north of the township that cause a significant constriction in flood flows.
- The Dunmunkle Creek culverts at the Wimmera Highway need to have a larger capacity. The road was overtopped at this location in 2011.
- Allowing water to flow freely is critical, water which is restricted and stands for a long period of time causes most of the damage.
- Determining where the water naturally flows to without the impact of channels is important.

Members of the community were able to highlight several properties that were directly impacted by inundation and indicate the extent of inundation in areas where linescans and aerial imagery was not available.

A timeline of inundation in Rupanyup immediately after the rainfall was developed by a local business owner this timeline is summarised below:

- Sunday, 9th January 2011 – 22.25 mm of rain
- Monday, 10th January 2011 – 5.5 mm of rain
- Tuesday, 11th January 2011 – Heavy rain starts 59.5mm of rain
- Wednesday 12th January 2011 – No rain
- Thursday, 13th January 2011 – Constant rain over day 92 mm recorded
 - 6.30 pm - Beryl Street drainage pipes at capacity, Starbucks Swamp beginning to inundate properties.
- Friday, 14th January 2011
 - 5.00 am – Properties in Dyer Street received assistance from VicSES, Tylers' Hardware and Rural Supplies, 27 Cromie Street kitchen area inundated above floor.
 - 6.30 am – Fire siren sounded to sandbag 53 Steward Street.
 - 7.30 am – 35 Steward Street property inundated.
 - Water levels peaked at around 9 am.
 - 9.30 am – Tylers' Hardware and Rural Supplies, 27 Cromie Street inundated up to 25 mm in the shop front. Traffic was worsening inundation causing waves.

3.3 Community Consultation Stage 2

3.3.1 Lubeck

The meeting was attended by 12 members of the community from the surrounding farming area.

The model calibration was received very well with most attendees comfortable with how the maps replicated the January 2011 event.



3.3.2 Boolite – 31 August 2015

The meeting was attended by 11 members of the community.

Community feedback indicated water was not progressing quite far enough along Dunmunkle Creek. As a result, modifications to the model were made increasing the initial volume of water in the model due to localised catchment contributions.

3.3.3 Rupanyup – 9 September 2015

The meeting was attended by 8 members of the community.

The model calibration was very well received with all areas matching closely, although considerable discussion occurred about the rainfall event prior to flood flows in 2011 and the resultant stormwater impacts not captured by modelling.

3.4 Community Consultation Stage 3

3.4.1 Lubeck – 22nd March 2017

The meeting was attended by the around 8 community members local to the Lubeck area.

The consensus was an agreeance with the modelling produced during the project and there was a general perspective the channel system should be decommissioned as far as practically possible.

3.4.2 Boolite – 21st March 2017

The meeting was attended by around 20 members of the local community, an image captured during the evening is shown in Figure 3-2.



Figure 3-2 Stage 3 - Boolite Community Meeting

There was some concern about the recommendation to decommission parts of the Dunmunkle Creek channel with the fear that water would spill into private agricultural areas that are currently protected from inundation by the constructed channel banks. Those that wanted to keep the channel banks proposed water should be contained in Dunmunkle Creek and discharged to a location further down the system or place created to store it.



3.4.3 Rupanyup – 21st March 2017

The meeting was attended by around 12 members of the local community. An image captured of the community meeting is shown in Figure 3-3.



Figure 3-3 Stage 3 – Rupanyup Community Meeting

The attendees generally agreed with the recommendation to decommission the Rupanyup Water Storages and were comfortable with the model outputs.

3.4.4 Murtoa – 22nd March 2017

The meeting was attended by around 8 members of the community spanning from Rupanyup to Boolite. An image captured of the community meeting is shown in Figure 3-4.



Figure 3-4 Stage 3 – Murtoa Community Meeting

The consensus was an agreeance with the modelling produced during the project and there was a general perspective the channel system should be decommissioned as far as practically possible.



3.5 Community Consultation Summary

Although the community meetings were held across a large geographic range along Dunmunkle Creek there were very similar views held across all communities. The key things the community agreed to regarding the objectives for Dunmunkle Creek are:

- Main Central Channel should be fully decommissioned in the Bryntirion State Forest.
- A better understanding of where the water would naturally flow without channel embankments is required.
- Water should be allowed to flow unhindered by manmade structures.
- Flood mitigation should be provided for more densely populated areas (this is more specific to Rupanyup rather than the regional areas).



4 MODELLING SUMMARY

4.1 Overview

The Dunmunkle Creek study area is large, covering from Glenorchy to north of Boolite. For flows to reach this far north, significant volumes of water must be distributed from the Wimmera River. Breakouts from Dunmunkle Creek near the Bryntirion Forest to the west towards Murtoa are required to be understood, also adding to the significant area that must be covered by hydraulic modelling.

Dunmunkle Creek is part of a formed channel system, with complex interaction with previous channel alignments and drainage schemes, this provides challenges for the hydraulic modelling that requires a tailored well thought out approach.

The hydrology for Dunmunkle Creek is largely Wimmera River dominated, with the exception of flooding in Rupanyup which can also occur via local catchment runoff.

Due to the large study area, Dunmunkle Creek was separated into five model areas. These areas were as follows:

- **Model A – Dunmunkle Creek Offtake**, from upstream of Swedes Cutting to downstream of Glenorchy on the Wimmera River, including all the breakouts to Dunmunkle Creek, and covering Dunmunkle Creek from Glenorchy to near Wal Wal.
- **Model B – Bryntirion State Forest**, from Wal Wal to Ashens-Jacksons Road, covering the flow split through the Bryntirion State Forest separating flow towards Murtoa and Rupanyup.
- **Model C – Rupanyup**, from Ashens-Jacksons Road to Boyds Road, north of Rupanyup. Rupanyup is covered in detail with the townships upstream stormwater catchment also covered.
- **Model D – North of Rupanyup**, from Boyds Road, north of Rupanyup to the Dunmunkle Creek termination point.
- **Model E – Western flow split**, from the disused Rupanyup railway line north-west of the Bryntirion Forest to Yarriambiack Creek.

The extent of each model is shown in Figure 4-1. Flows were routed through each model and onto the next, with each model calibrated to the available data.

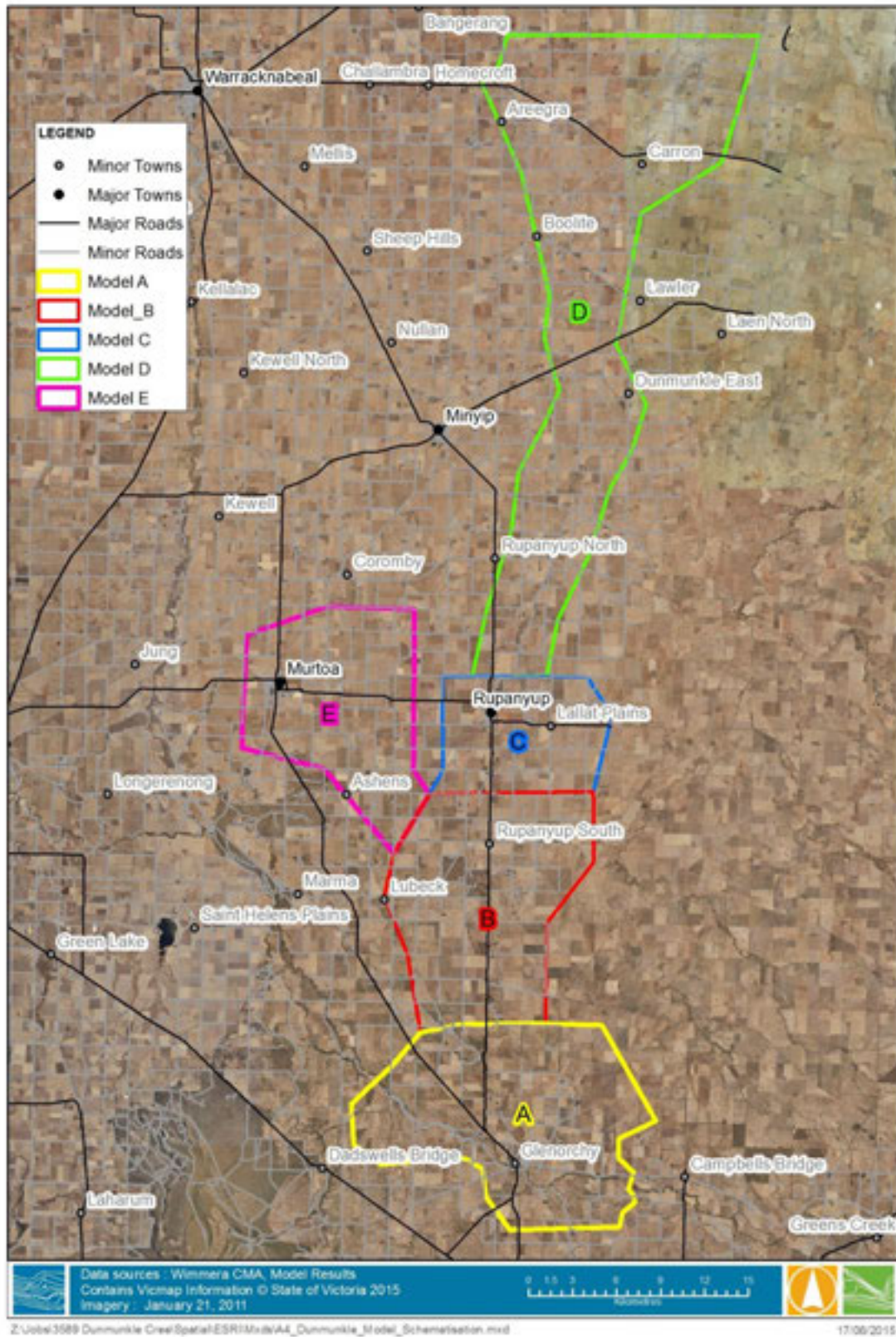


Figure 4-1 Hydraulic model structure



4.2 Calibration

The January 2011 event was chosen for model calibration, comprising the only reliable flood information available. Streamflow gauges at Glynwylln and Glenorchy were used as a basis for Wimmera River calibration and design flows, with streamflow distributed to Dunmunkle Creek estimated using the hydraulic model.

The hydraulic model calibration is discussed extensively in Section 6.1. A summary of the calibration across the five models is shown below:

- **Model A**
 - Wimmera River at Glenorchy gauge levels and heights
 - Peak flow: Obs. - 451 m³/s, Modelled - 457 m³/s
 - Peak water level: Obs. - 168.81 m AHD, Modelled - 168.80 m AHD
 - Timing: Obs. - 15/01/2011 7:30 am, Modelled - 15/01/2011 9:30 am
 - Linescan images – Close match was achieved
 - 22 surveyed peak flood heights - 18 within 0.2 m and 12 within 0.1 m of that surveyed
 - Aerial photography
 - Rapid Eye satellite images
 - Landsat satellite images
- **Model B**
 - Linescan images - Complex flood behaviour due to partially decommissioned channels, close match was achieved
 - 9 surveyed peak flood heights - 8 within 0.2 m and 5 within 0.1 m of that surveyed
 - Aerial photography
 - Rapid Eye satellite images
 - Landsat satellite images
- **Model C**
 - Linescan images – Close match was achieved
 - 11 surveyed peak flood heights - 8 within 0.2 m and 5 within 100 mm of that surveyed
 - Rapid Eye satellite images
 - Landsat satellite images
- **Model D**
 - Rapid Eye satellite images – Close match was achieved
 - Landsat satellite images
- **Model E**
 - Linescan information – Close match was achieved, one overland flow path to the north was not well matched, however impact of direct rainfall on that area was unknown
 - Rapid Eye satellite images
 - Landsat satellite images



4.3 Design

The Wimmera River at Glenorchy stream gauge has been the subject of several flood investigations. Peak design flow estimates were completed during the Glenorchy Flood Study³ and the Wimmera River and Yarriambiack Creek Flows Study⁴. Similarly, this project determined design flows at Glenorchy using peak flow and volume Flood Frequency Analysis (FFA). Peak flows describe the maximum flow during an event, while hydrograph volume is the volume of the event from the beginning of the hydrograph rise to the conclusion of the fall. These flows were applied to Model A and routed through the remaining models.

The design peak flows and volumes for each modelled AEP are shown in Table 4-1

Table 4-1 Design peak flows and hydrograph volumes

AEP (%)	Design Peak Flow		Design Hydrograph Volume
	ML/d	m ³ /s	ML
20	14,500	168	29,400
10	19,900	230	46,200
5	25,020	290	62,400
2	31,700	367	81,500
1	36,600	424	93,900
0.5	41,600	482	104,500

³ Water Technology, 2006 – Glenorchy Flood Study

⁴ Water Technology, 2009 – Wimmera River and Yarriambiack Creek Flows Study



5 JANUARY 2011

5.1 Overview

The observed January 2011 flood inundation provides the most recent example of flooding potential along Dunmunkle Creek. The observed flooding also indicated the potential impact that infrastructure can have (or removal of infrastructure may have) on flood levels. It is difficult to compare the recent January 2011 flood event to other previous or future events given the lack of streamflow gauging and the high level of modification of infrastructure immediately prior, during and post the January 2011 event.

Discussion of the January 2011 event has been extracted from formal data records (rainfall/stream gauges, aerial photography, linescan data, etc.), and anecdotal accounts submitted to Wimmera CMA and collected at the range of community consultation sessions completed, this is discussed further in Section 3.

5.2 Rainfall

Rainfall in mid-January 2011 caused widespread flooding across Victoria, with the Wimmera and North Central regions severely impacted. Initial flooding in the Dunmunkle Creek catchment prior to the 14th of January can be directly attributed to the rainfall that occurred early in the event, with the Wimmera River distributing flow to Dunmunkle Creek after this date. The Wimmera River distribution caused more damage than the initial stormwater inundation. Flooding caused directly by rainfall occurred specifically around Rupanyup.

The Rupanyup (Post Office) rainfall gauge recorded 59.2 mm and 90.0 mm on the 12th and 14th January 2011 respectively, as shown in Figure 5-1. This was verified by a local resident who recorded 59.5 mm and 92 mm for the same dates in Rupanyup. The 90 mm recorded on the 14th was the largest daily recording in the Rupanyup (Post Office) record beginning in 1901. The next largest daily total was 76.5 mm in December 1929.

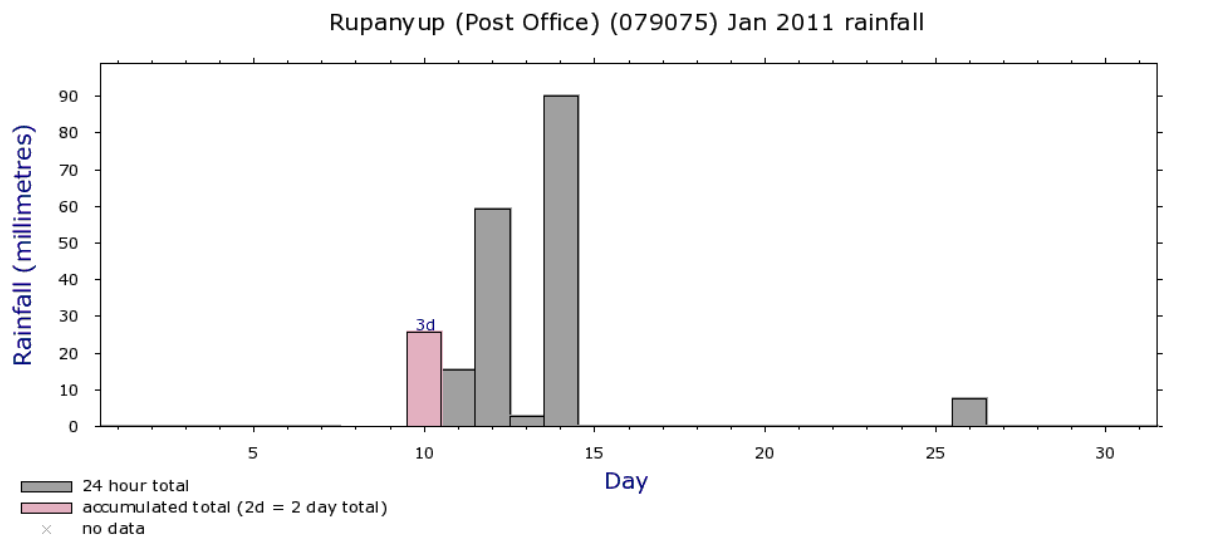


Figure 5-1 Rupanyup (Post Office) January 2011 daily rainfall records

Two nearby pluviograph rainfall gauges captured the sub-daily temporal pattern of the January 2011 rainfall event; Stawell AWS (49 km south of Rupanyup) and Horsham AWS (40 km west of Rupanyup).

Unfortunately, the closest sub-daily gauge at Longerenong (30 km west of Rupanyup) did not record rainfall over the January 2011 event. The rainfall pattern for the next closest gauge, Horsham AWS, is shown in Figure



5-2, with the cumulative rainfall for all three nearby pluviographs shown in Figure 5-3. The rainfall pattern across the two gauges is shown to match closely.

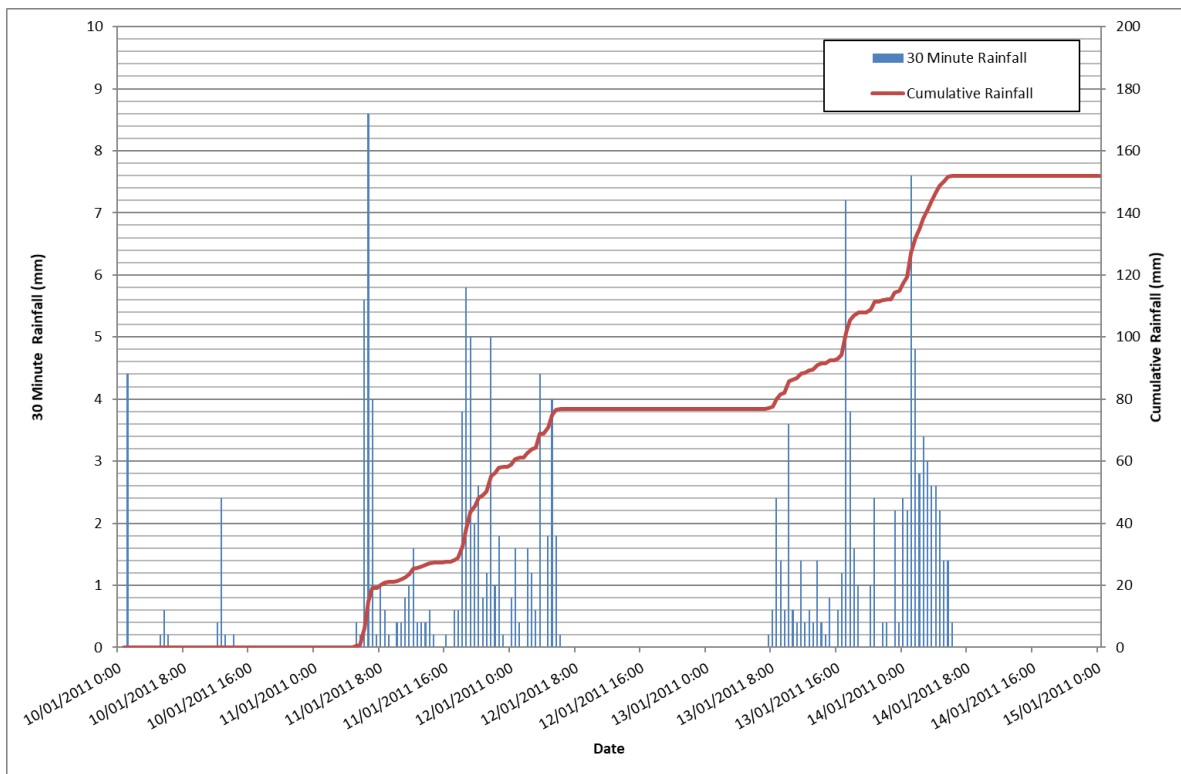


Figure 5-2 Horsham AWS temporal rainfall pattern

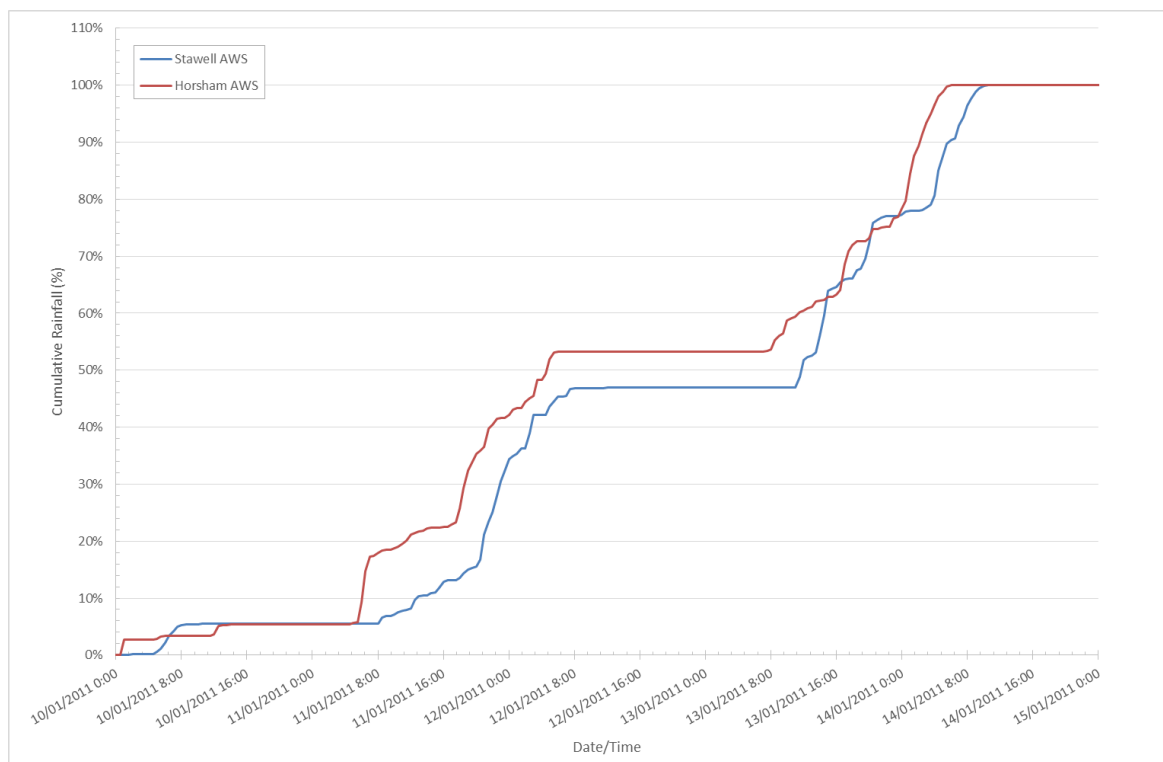


Figure 5-3 Horsham AWS and Stawell AWS cumulative rainfall percentages

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5.3 Streamflow

There are two streamflow gauges on the Wimmera River which can provide an indication on the likely streamflow distribution to Dunmunkle Creek; Wimmera River at Glynwylln (415206) and Wimmera River at Glenorchy (Tail Gauge - 415201). Flows and the associated quality codes recorded at the Glynwylln and Glenorchy gauges is shown in Figure 5-4 and Figure 5-5 respectively.

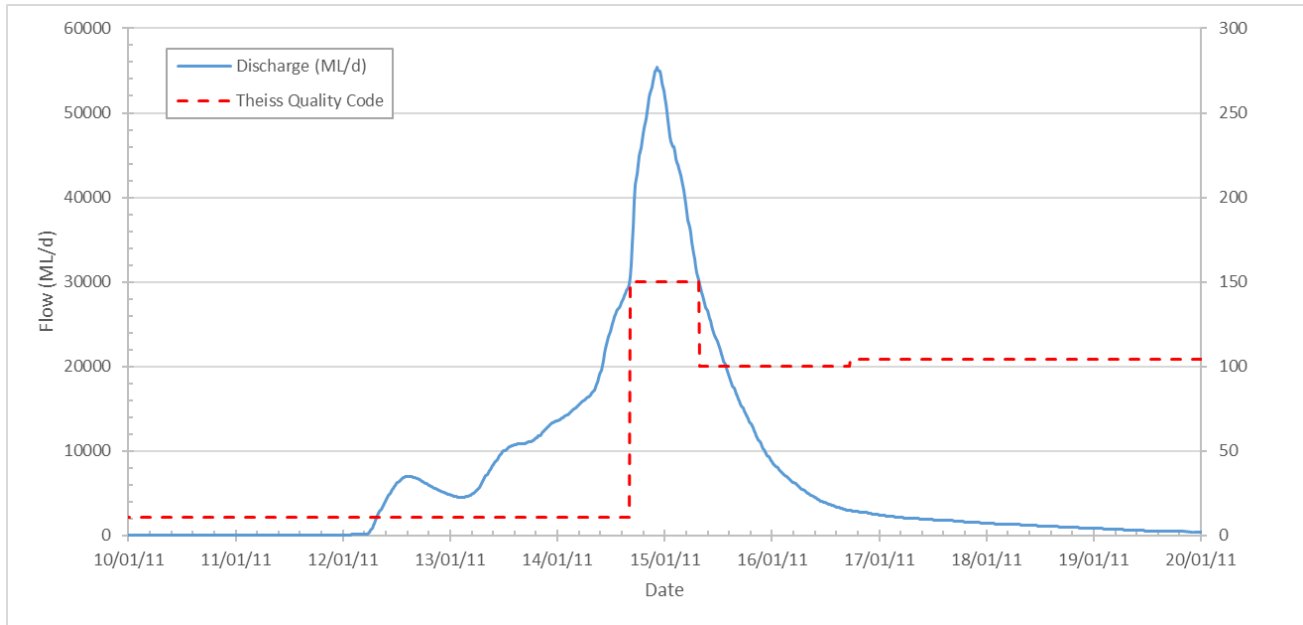


Figure 5-4 January 2011 Event – Flow and quality code at Wimmera River at Glynwylln

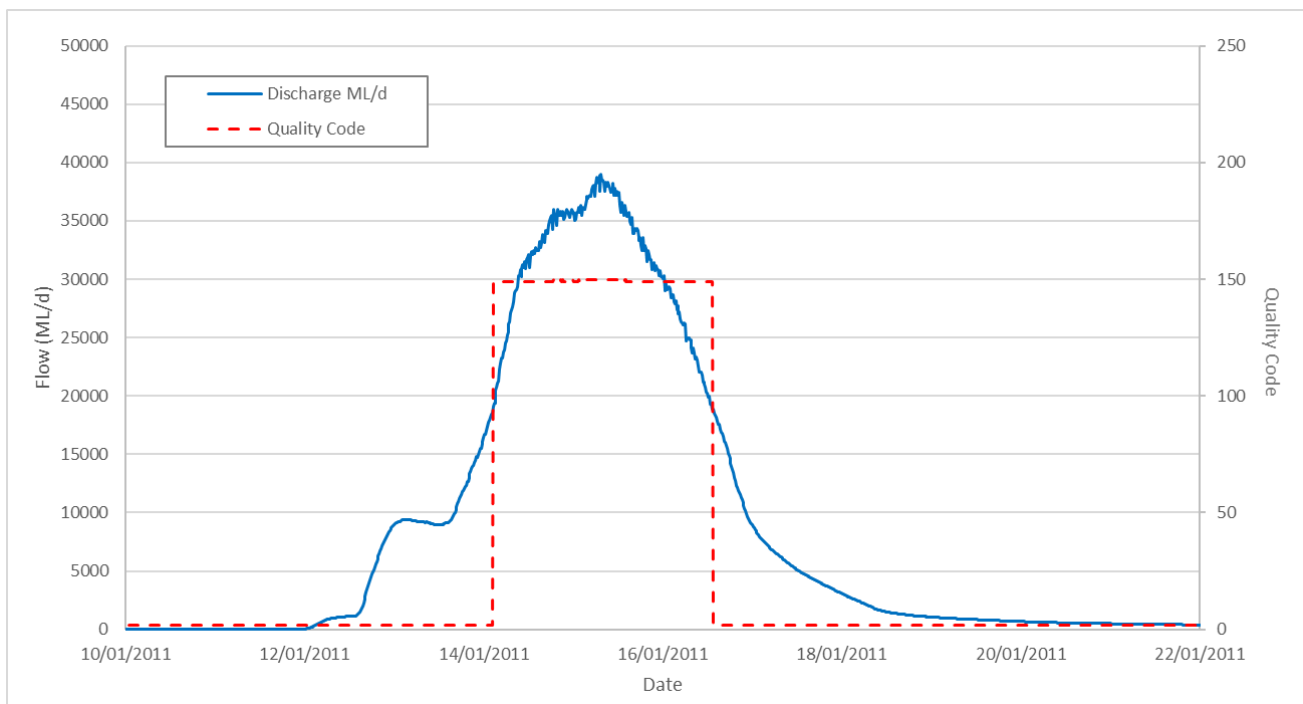


Figure 5-5 January 2011 – Flow and quality code at Wimmera River at Glenorchy



The January 2011 event recorded the highest peak flow on record at both gauging stations, 38,970 ML/d (451 m³/s) and 55,420 ML/d (641 m³/s) at Glynwylln and Glenorchy respectively. In both cases the January 2011 event was far greater than the second largest flood on record.

5.4 Observed Flood Inundation

Flood inundation occurring during the January 2011 event was relatively well recorded with many surveyed peak flood levels, satellite images and linescan data captured. There was also many aerial and ground-based photographs captured by members of the public which were made available to the study team.

5.4.1 Surveyed Peak Flood Levels

There were 47 surveyed flood levels captured relevant to this study. These were located along the Wimmera River at Glenorchy and along Dunmunkle Creek between the offtake and Rupanyup. The surveyed flood marks used in this study are shown in Figure 5-6, with a closer perspective of Rupanyup shown in Figure 5-7.

Unfortunately, most of the flood marks within Rupanyup are associated with flooding of Dunmunkle Creek and not the initial inundation caused by the local rainfall and runoff. However, there are many anecdotal observations from members of the community and ground-based photographs which were used to assess the stormwater inundation.

5.4.2 Linescan Images

Linescan images of the flooding were captured via fixed wing aircraft. The images are black and white, according to the temperature of the ground surface. Light shades of grey represent cool temperatures and dark shades warmer surfaces. In this case the lighter shades indicate flood water.

During the January 2011 event Linescan technology was only in its infancy and flights in the Wimmera were a trial for use elsewhere in the state. The January 2011 inundation was captured upstream of Rupanyup only. The data was captured on the 16th at three times, Glenorchy and the Dunmunkle Creek offtake (7.29 PM), Dunmunkle Creek from Glenorchy to Rupanyup (8.36 PM) and Rupanyup (7.10 PM) itself. All three linescan images are shown in Figure 5-8.

5.4.3 Satellite Imagery

Satellite imagery of the January 2011 event was captured by the U.S. Geological Survey (USGS) Landsat Satellites. This data was sourced to provide information regarding the January 2011 flooding in areas not covered by the available Linescan data. The data gives an indication of the inundation extent at the time the image was captured.

An example of the satellite imagery available for the lower sections of Dunmunkle Creek is shown below in Figure 5-9. Unfortunately, the image has “banding” where no image data was collected due to a malfunctioning sensor. The satellite image was captured 28th January 2011.

5.4.4 Aerial photography

During the January 2011 event a plane was flown along Dunmunkle Creek capturing photos and GPS points along the flight path. The photos were captured on 14th January 2011 with the photo points and flight path along Dunmunkle Creek shown in Figure 5-10.

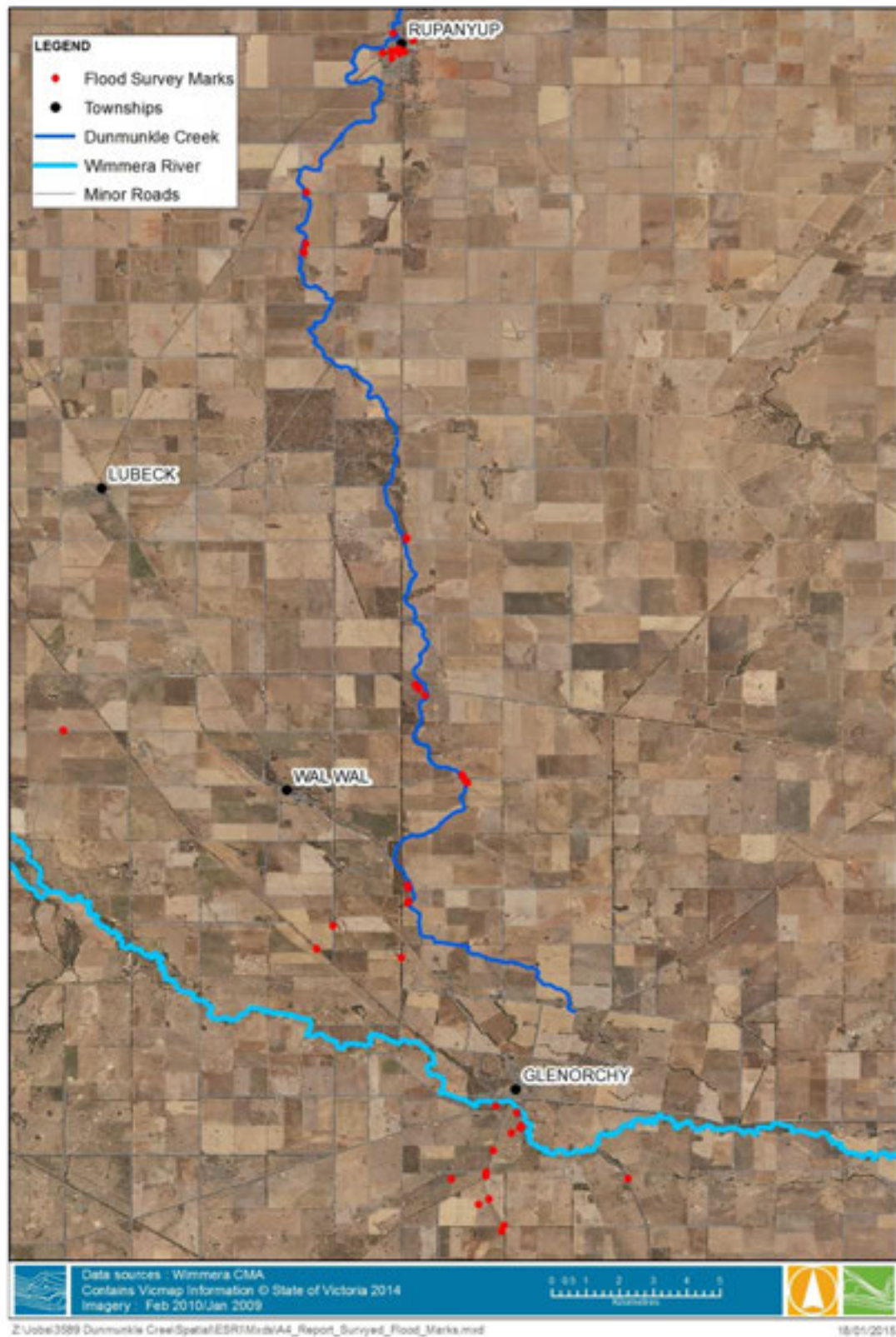


Figure 5-6 January 2011 – Surveyed flood marks relevant to this study

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Figure 5-7 January 2011 – Surveyed flood marks around Rupanyup

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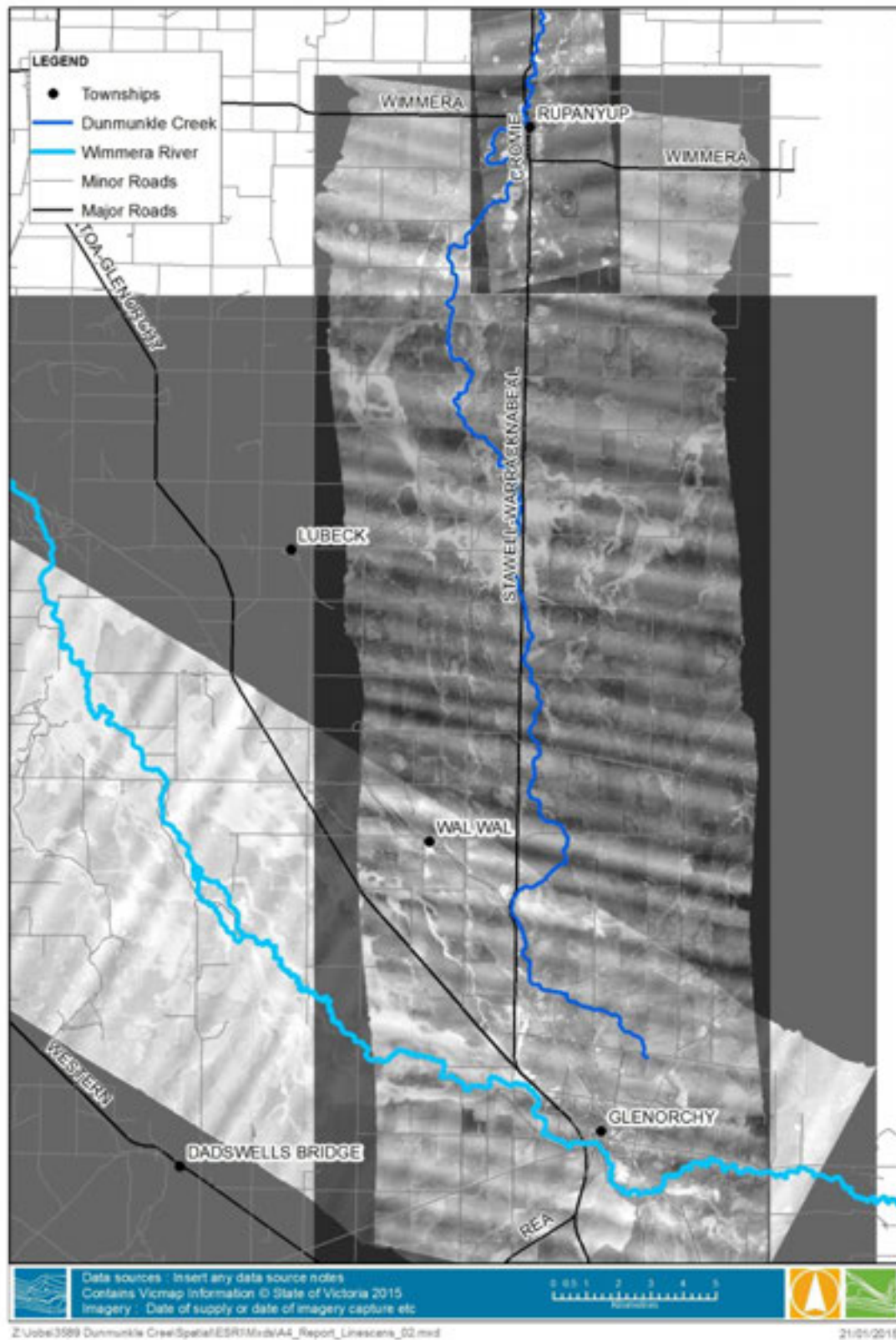


Figure 5-8 January 2011 – Linescan data of Dunmunkle Creek

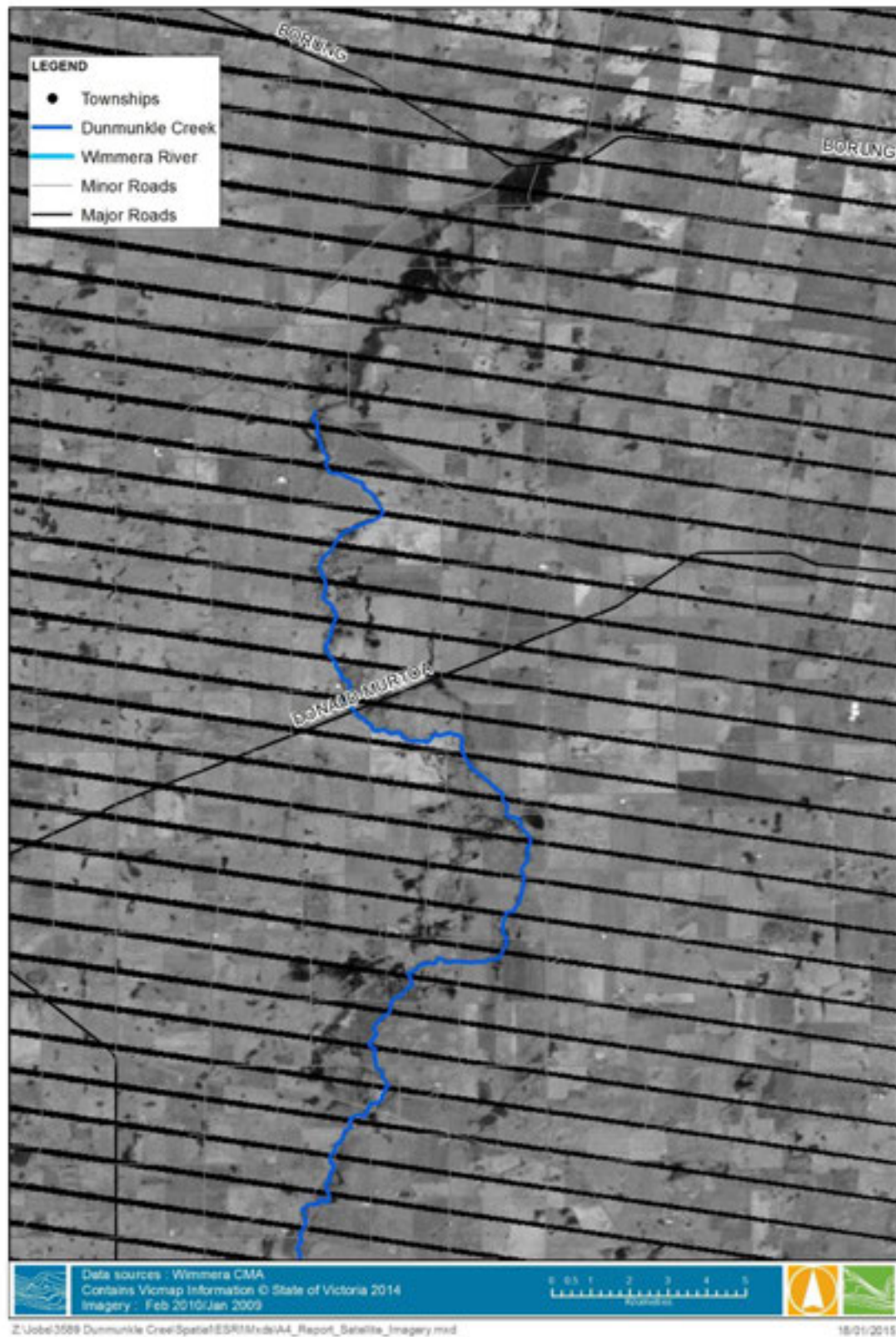


Figure 5-9 Landsat satellite imagery captured of lower Dunmunkle Creek during January 2011

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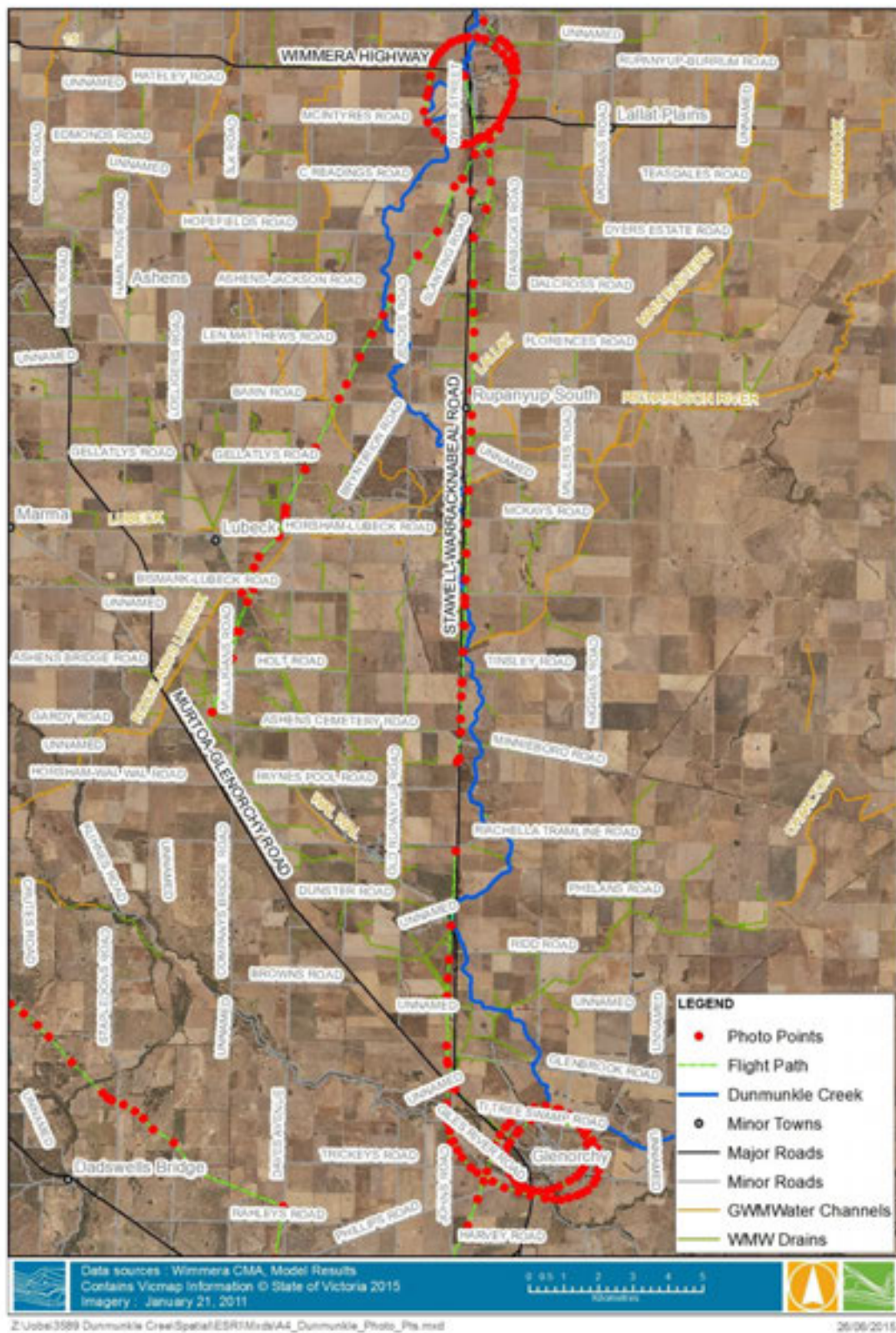


Figure 5-10 January 2011 – Air based photography captured during January 2011



5.5 January 2011 Flood Response Works

Numerous flood mitigation works were undertaken along Dunmunkle Creek during January 2011, this included sandbagging of numerous private properties and modification of the channel embankments and flow control infrastructure.

The major sandbagging activities were focused between Glenorchy and Rupanyup, as well as within Rupanyup itself, as these areas have the largest populations that are prone to above floor inundation. Small scale sandbagging occurred in Rupanyup to mitigate the impact of the inundation caused by direct rainfall runoff, however generally there wasn't sufficient time for the sandbagging to be effective.

Excavation and blockage of the remaining channel system by members of the public did occur. Primarily in the lower Dunmunkle Creek in an effort to prevent inundation of agricultural land. There were also changes made to numerous GWMWater regulating structures throughout the system, the Bryntirion Reserve was highlighted as an area which was a focus of these changes during the initial community consultation sessions. Some very high-risk actions by community members took place, with serious risk to life. Understanding the impact of infrastructure in this area and making recommendations for its future management is a key outcome of this study. This is important, if for no other reason than to avoid similar high-risk actions during future flood events.



6 HYDROLOGY

6.1 Overview

The Dunmunkle Creek study area is large, extending from Glenorchy to north of Boolite. For flows to reach this far north, significant volumes of water must be distributed from the Wimmera River. Breakouts from Dunmunkle Creek near the Bryntirion Forest to the west towards Murtoa also occur, adding to the significant area covered by the hydraulic modelling.

Dunmunkle Creek is part of a formed channel system, with complex interaction with previous channel alignments and drainage schemes, this provides challenges that require a tailored well thought out approach to modelling so as to accurately reflect on-ground conditions.

The hydrology for Dunmunkle Creek is largely Wimmera River dominated, except for flooding in Rupanyup which can also occur via local catchment runoff. Local catchment rainfall can contribute volume to Dunmunkle Creek which exacerbates flooding, but a Wimmera River distribution is generally required for a flood to occur. There is a daily rainfall gauge located in Rupanyup and the closest sub-daily gauge with valid data of January 2011 is in Horsham. The Wimmera River has streamflow gauges upstream of Glenorchy at Glynwylln and 7 km downstream of the Dunmunkle Creek offtake at the Glenorchy Weir tail gauge.

As discussed in Section 5, the January 2011 event was chosen as the basis for model calibration in this study, the event has the only reliable flood information available. Design modelling was completed on the basis of peak flow and four day volume Flood Frequency Analysis (FFA).

Streamflow gauges at Glynwylln and Glenorchy were used as the basis for Wimmera River calibration and design flows, with streamflow distributed to Dunmunkle Creek determined using the hydraulic model.

Stormwater inundation in Rupanyup was undertaken using a Mike21 “rainfall-on-grid” model, the January 2011 event was modelled based on the observed daily totals recorded at Rupanyup and the sub-daily rainfall totals recorded at the Horsham AWS (this was the closest sub daily rainfall gauge).

6.2 Calibration

6.2.1 Wimmera River

As discussed in Section 5, the January 2011 event was chosen as the basis for model calibration in this study, the event has the only reliable flood information available. Streamflow gauges at Glynwylln and Glenorchy were used as a basis for Wimmera River calibration and design flows, with streamflow distributed to Dunmunkle Creek estimated using the hydraulic model.

Calibration of flows was largely completed in the hydraulic model with the Wimmera River inflows iteratively adjusted to match the recorded flows at the Wimmera River at Glenorchy (Tail Gauge), along with the observed peak flood heights. This is discussed as part of the hydraulic model calibration in Section 7.1.

6.2.2 Rupanyup stormwater inundation

Rupanyup stormwater inundation was verified to aerial and ground based photography, along with anecdotal community observations. There could be no hydrology based verification with hydraulic data the only observations.



6.3 Design

6.3.1 Peak flow analysis

The Wimmera River at Glenorchy stream gauge has been the subject of several flood investigations. Peak design flow estimates were completed during the Glenorchy Flood Study³ and the Wimmera River and Yarriambiack Creek Flows Study⁵. Flows were determined using Flood Frequency Analysis (FFA) and a URBS runoff routing model respectively. These analyses were completed prior to the September 2010 and January 2011 events.

A comparison of the design flow estimates determined at the Glenorchy stream gauge during each study is shown in Table 6-1.

Table 6-1 FFA results for all distributions and annual series

Design event (AEP)	Wimmera River and Yarriambiack Creek Flows Study (URBS Model)		Glenorchy Flood Study (FFA)	
	ML/d	m ³ /s	ML/d	m ³ /s
20%	8,700	101	14,100	163
10%	14,900	172	19,000	220
5%	23,000	266	23,500	272
2%	30,100	348	29,000	336
1%	37,600	435	32,800	380
0.5%	43,500	503	36,400	421

An annual series FFA was completed at the Glenorchy gauge as part of this study to determine revised design peak flow estimates at the gauge. The available period of instantaneous record at Glenorchy included 1965-2013 with the period of mean daily flow extending to 1951. In general, mean daily flow records are lower than the peak instantaneous flow due to the average flow smoothing out the sub-daily peak. To translate each recorded mean daily flow into an instantaneous peak flow, a linear relationship of mean daily flow to instantaneous peak flow was determined for the period of instantaneous record (Instantaneous = 1.28 x Mean Daily, R²=0.9927).

The extended period of gauge record was used to complete an annual series FFA in Flike⁶. The analysis was completed on raw annual peaks and a modified annual series with low flow years removed using the Multiple Grubbs Beck test. The determined low flow threshold was 6,600 ML/d, removing 31 years from the 63 year record.

Log Pearson Type 3 (LP3), Generalised Extreme Value (GEV), Generalised Pareto (GP), Gumbel and Log-normal distributions were trialled. Of these distributions the LP3 and Gumbel matched well for both the raw and censored annual series, while GEV and GP matched better using the censored annual series. The Log-normal distribution didn't match well for either series.

A comparison of the FFA results for all distributions for the raw and censored annual series are shown in Table 6-2.

⁵ Water Technology, 2009 – Wimmera River and Yarriambiack Creek Flows Study

⁶ University of Newcastle - Flike Flood Frequency Analysis



Table 6-2 FFA results for all distributions and annual series

AEP (%)	LP3		Gumbel		GEV		GP	
	Raw Data	Low Flow Censoring	Raw Data	Low Flow Censoring	Raw Data	Low Flow Censoring	Raw Data	Low Flow Censoring
20%	14,400	14,200	10,600	14,500	9,600	14,700	10,300	14,900
10%	21,600	20,100	14,300	19,900	18,400	20,300	16,300	20,800
5%	28,000	26,100	17,900	25,000	33,600	25,700	23,600	26,800
2%	35,200	34,000	22,500	31,700	71,900	32,900	35,500	34,800
1%	39,700	39,800	26,000	36,600	126,100	38,300	46,800	40,800
0.5%	43,400	45,500	29,500	41,600	220,200	43,700	60,500	47,000

The tested FFA distributions and annual series that matched the observed data are plotted in Figure 6-1, showing the confidence limits around the 1% AEP design peak flow. The plot shows the Gumbel Raw and low flow censored data had the narrowest confidence limits, followed by the LP3 Raw FFA.

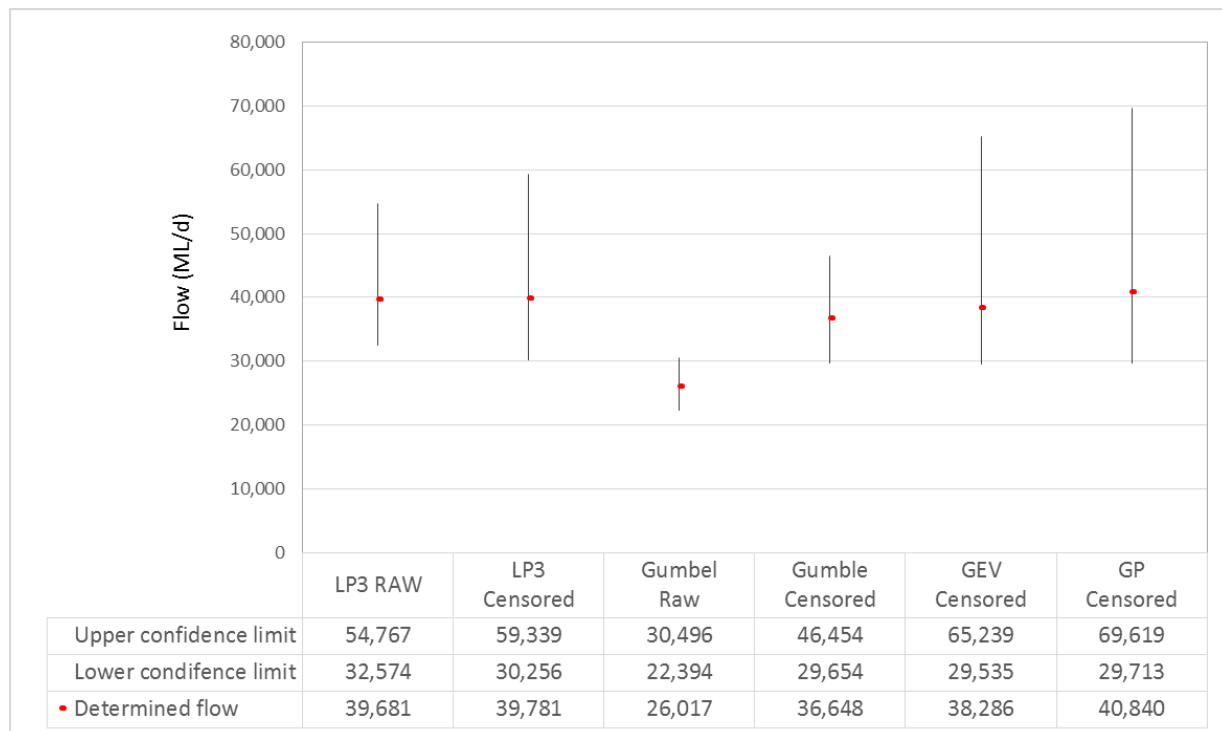


Figure 6-1 1% AEP FFA design flow estimates and confidence limits

The FFA analysis distributions for the Gumbel Raw, Gumbel low flow censored and LP3 raw have the smallest error bounds with their distributions shown in Figure 6-2, Figure 6-3 and Figure 6-4 respectively.

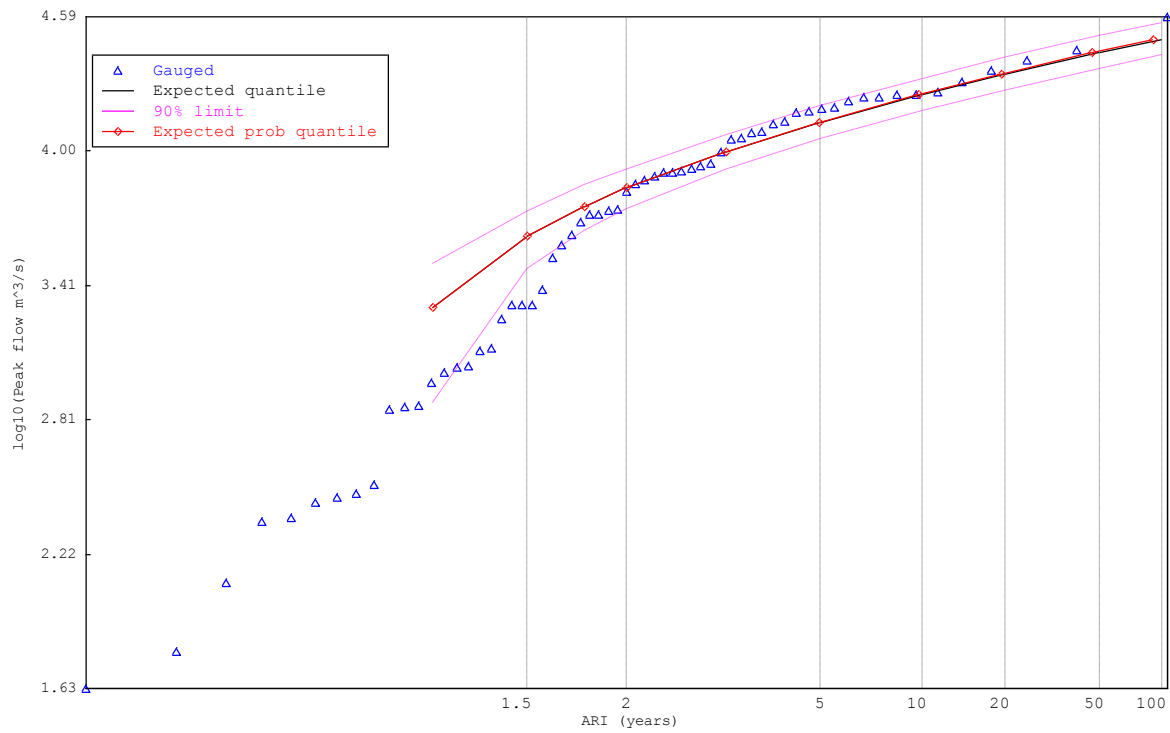


Figure 6-2 Gumbel Distribution – Raw annual series

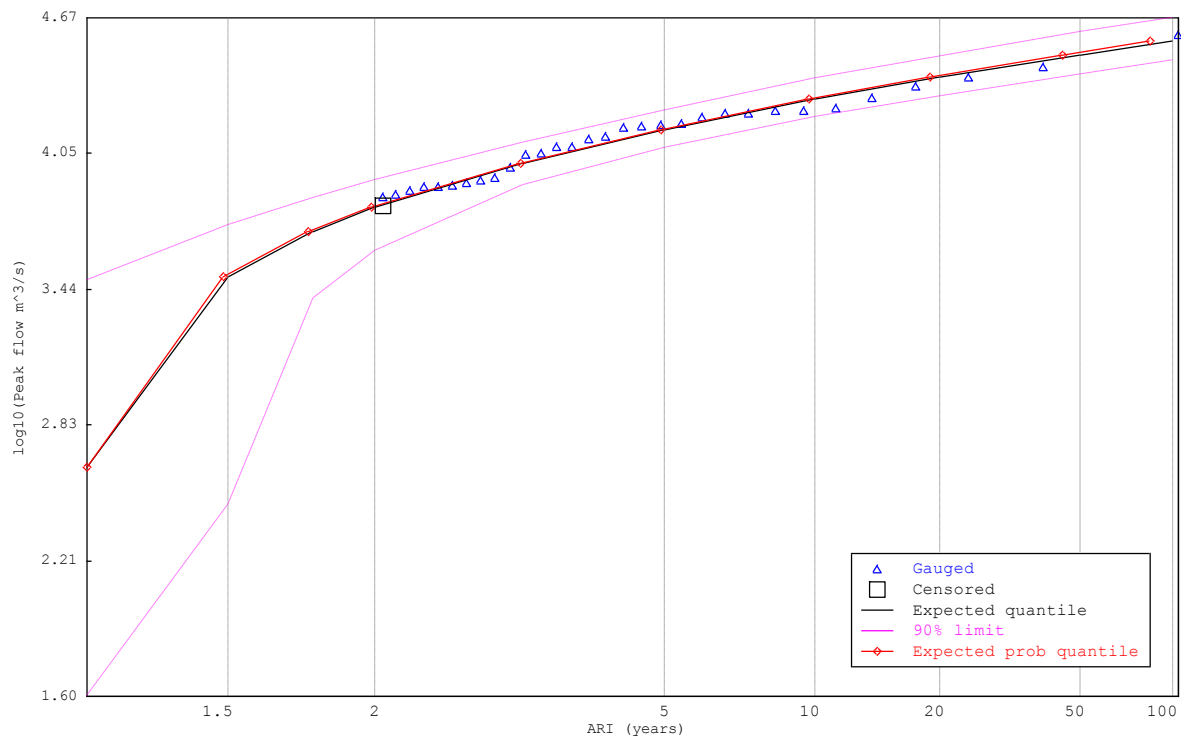


Figure 6-3 Gumbel distribution – Censored annual series

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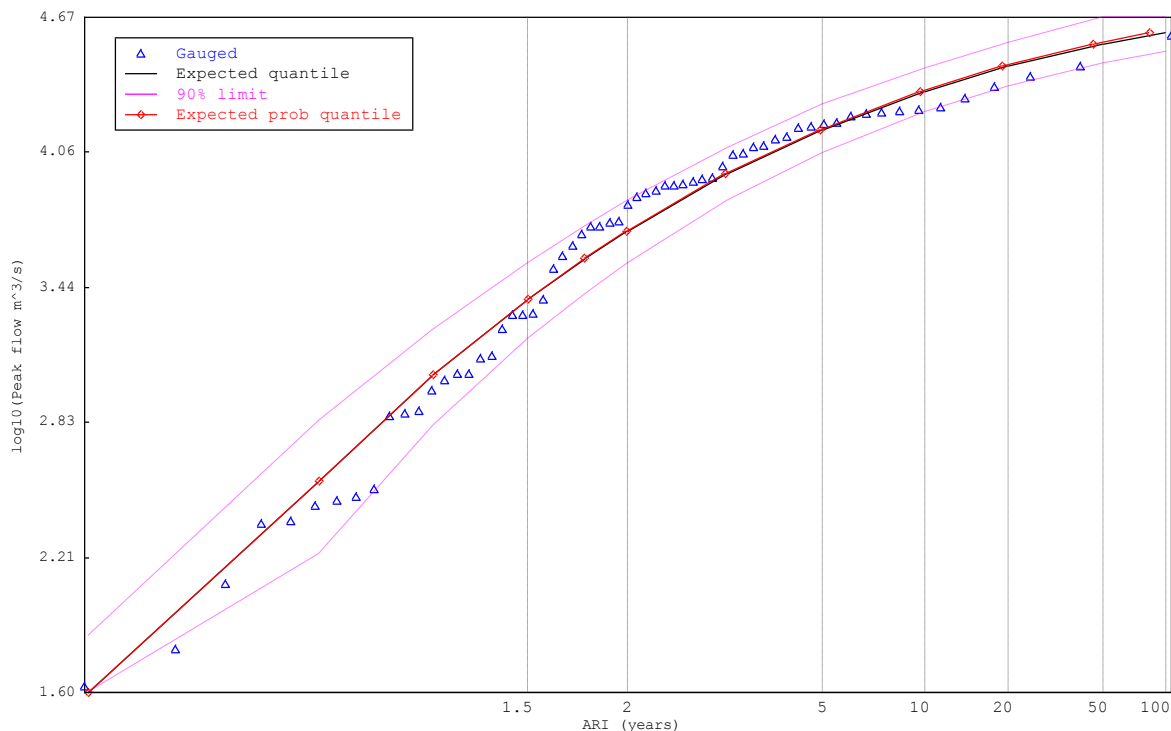


Figure 6-4 LP3 Distribution – Raw annual series

The Gumbel distribution with a raw annual series had the smallest error bounds, however the distribution clearly shows the largest historic event plotted well above the design distribution nearing the upper error bound. There are also several annual peak flows outside the error bounds in the 50-20% AEP range.

The Gumbel distribution with a low flow censoring showed a higher 1% AEP peak flow estimate than the raw data series, with the largest historic event plotted on the design distribution. The error bounds for events less than a 50% AEP are quite large, however this is not considered important to this study as the focus is on events larger than 20% AEP.

The LP3 distribution with a raw annual series shows most of the large historic events plotting below the design distribution. The largest event on record (January 2011) plots well against the design distribution at the upper end of the curve.

6.3.1.1 Discussion

The Gumbel distribution with low flow censoring using the Multiple Grubbs Beck Test was determined as the best fit to the Glenorchy extended annual series. The distribution had the best graphical match to the data in the flow range of interest (20% to 0.5% AEP) and the second lowest error bounds.

The chosen flood frequency distribution and modified annual series match relatively closely with the flows determined by URBS modelling in the Wimmera River and Yarriambiack Creek Flows Study⁴ at high flows. The design estimates for small events are larger than those estimated by URBS in the earlier study. The design estimates are also larger than that determined in the Glenorchy Flood Study³ at high flows but match more closely at lower flows. A comparison of the peak flows is shown in Table 4-1.



Table 6-3 Gumbel distribution with low flow censoring FFA results and previous design flows

AEP (%)	Gumbel with Low Flow Censoring		Wimmera River and Yarriambiack Creek Flows Study ⁴ (URBS Model)		Glenorchy Flood Study ³ (FFA)	
	ML/d	m ³ /s	ML/d	m ³ /s	ML/d	m ³ /s
20%	14,500	168	8,700	101	14,100	163
10%	19,900	230	14,900	172	19,000	220
5%	25,020	290	23,000	266	23,500	272
2%	31,700	367	30,100	348	29,000	336
1%	36,600	424	37,600	435	32,800	380
0.5%	41,600	482	43,500	503	36,400	421

6.3.2 Hydrograph shape

Design hydrographs were determined at the Glenorchy streamflow gauge during the Yarriambiack Creek and Wimmera River Flows Investigation⁴ and Glenorchy Flood Study³. The Yarriambiack Creek and Wimmera River Flows Study⁴ used the BoM developed URBS model of the upper Wimmera River catchment to determine the shape of the inflow hydrographs.

This project used the ratio of event peak flow to event volume determined by a FFA, then matched the ratio to a historic event which could be used for the shape of the design hydrographs.

The three largest events recorded at the Glenorchy gauge (January 2011, September 2010, October 1983 and September 1988) are shown overlayed in Figure 6-5. The events occurred over a three to four day period. The January 2011, September 2010 and October 1983 events all have a very similar shape.

A four-day volume FFA was completed using the same set of flood frequency distributions as completed in the peak flow analysis. The LP3 distribution showed to be the best match for the recorded data. Given the four-day volume FFA distribution used was LP3 while the peak flow distribution was completed using a Gumbel distribution, the peak flow to four-day volume ratio was completed using both distributions as a sensitivity test, comparison to the four largest historic events was also made. The four day volume FFA results and comparisons for the design events are shown in Table 6-4, with the January 2011, September 2010, October 1988 and September 1983 events shown in Table 6-5.

The January 2011 hydrograph's peak flow to four-day volume ratio matches that shown in the FFA results closely using the four-day volume LP3 distribution and the Gumbel peak flow distribution. Given the good ratio and the fact that the January 2011 event was a much larger event than the other historic events, which were all smaller than a 20% AEP event, the January 2011 event was adopted as the basis for hydrograph shape at Glenorchy with design hydrographs scaled to match each design peak flow and volume determined in the FFA.

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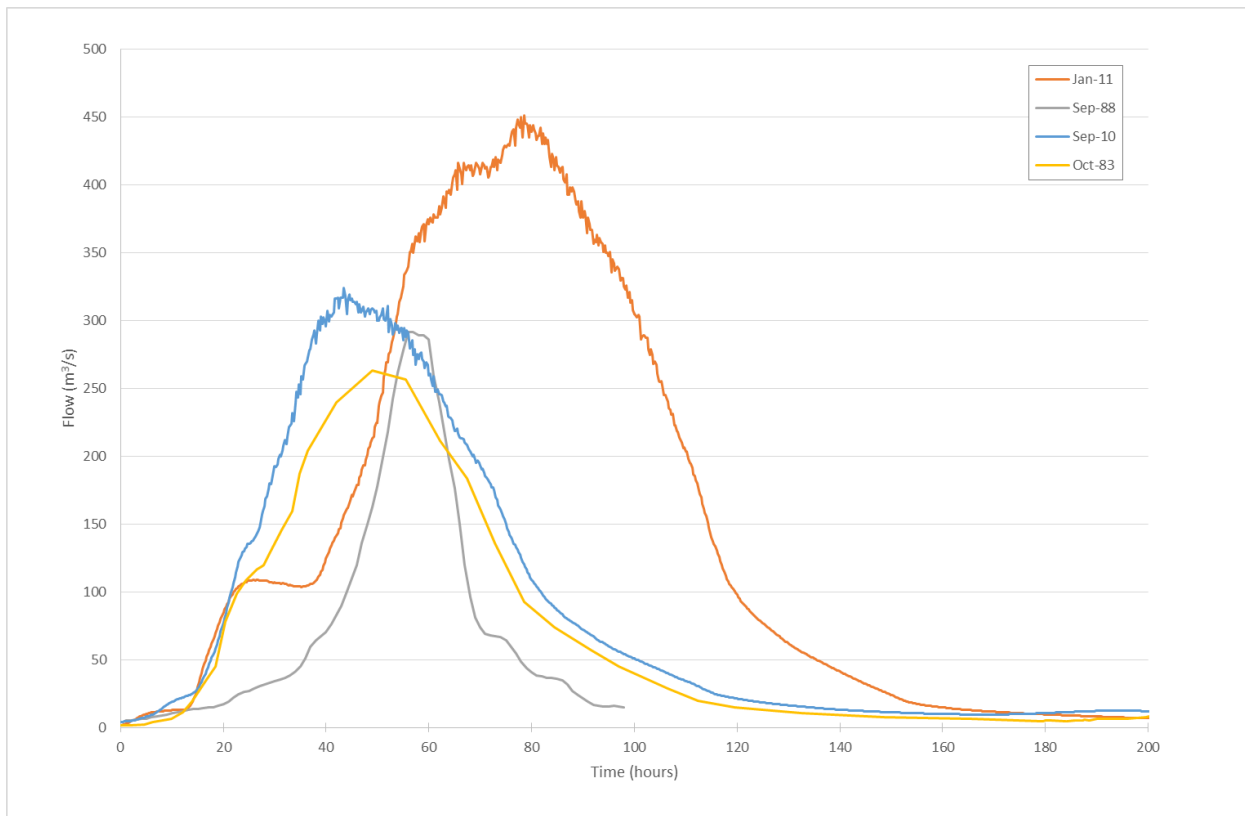


Figure 6-5 LP3 Distribution – Raw annual series

Table 6-4 Design four day volume and peak flow FFA results and ratios

AEP	4 Day volume (ML)	Peak flow (ML/d) (Gumbel)	Peak Flow (ML/d) (LP3)	Ratio (Gumbel)	Ratio (LP3)
20%	29,400	14,500	14,400	2.02	2.04
10%	46,200	19,8900	21,600	2.33	2.14
5%	62,400	25,020	28,000	2.49	2.23
2%	81,500	31,700	35,200	2.57	2.31
1%	93,900	36,600	39,700	2.56	2.37
0.5%	104,500	41,600	43,400	2.51	2.41
Average				2.42	2.25

Table 6-5 Historic event four day volume and peak flow FFA results and ratios

	4 Day Volume (ML)	Peak flow (ML/d)	Ratio
January 2011	95,300	39,000	2.44
September 2010	55,500	28,000	1.98
October 1988	51,600	25,200	2.05
September 1983	47,200	17,700	2.67



6.3.2.1 Discussion

The target 1% AEP flood event hydrographs are shown overlayed on those determined in the Glenorchy Flood Study and Wimmera River and Yarriambiack Creek Flows Study in Figure 6-6. As can be seen the hydrograph shapes are all reasonably similar with the Glenorchy Flood Study comprising a shorter duration event peaking earlier.

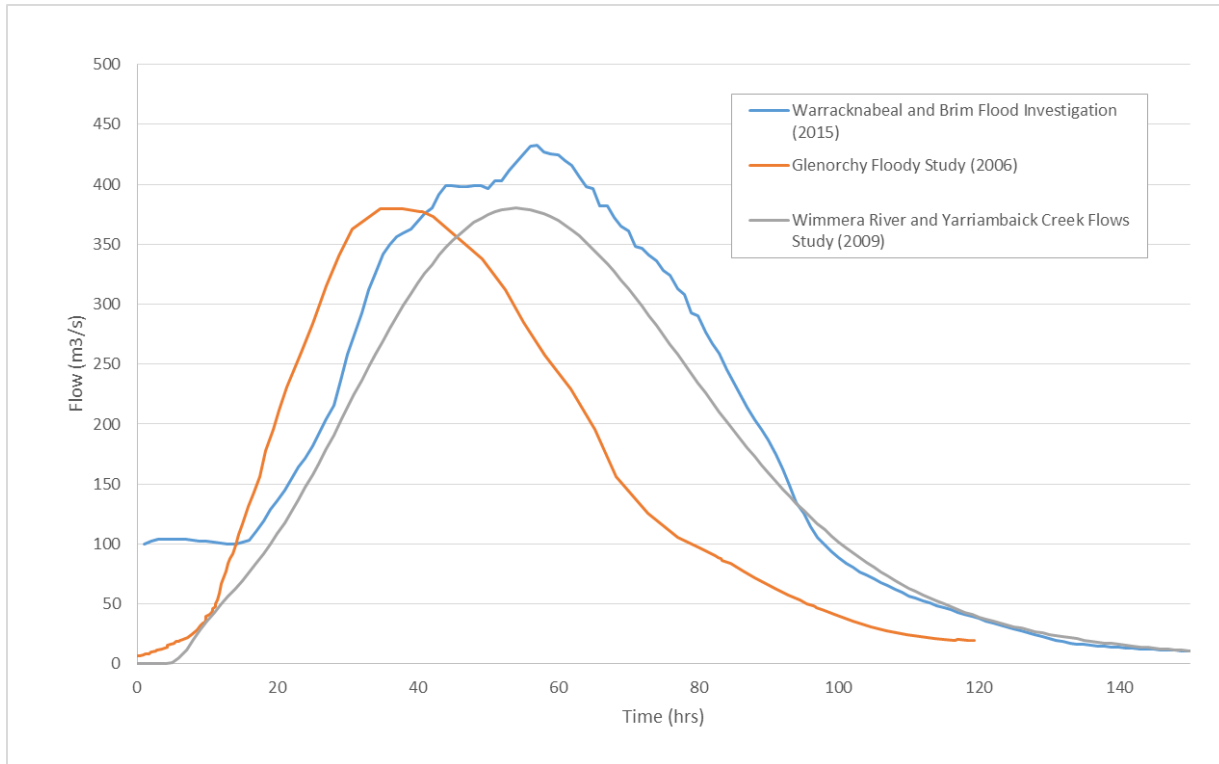


Figure 6-6 1% AEP hydrograph overlayed on hydrographs used in the Glenorchy Flood Study and Wimmera River and Yarriambiack Creek Flows Study

The FFA and design flow hydrographs show the January 2011 event to be between a 0.5 % to 1 % AEP event at Glenorchy. This matches with regional estimates made soon after the January 2011 flood event.

6.3.3 Hydraulic Model Flow Application

The Dunmunkle Creek offtake from the Wimmera River and model boundaries are upstream of the Glenorchy gauge. To account for the Wimmera River flow distributed to Dunmunkle Creek, Swedes Cutting and to the Wimmera floodplain upstream of the Glenorchy gauge, the Glenorchy gauge flows were factored up, and the model run iteratively until the correct flow at the Glenorchy gauge was achieved.

The target 1% AEP flood event hydrograph and that determined by the hydraulic model are shown in Figure 6-7 with a comparison of peak flow for each of the modelled AEPs shown in Table 6-6.



Table 6-6 Peak flow comparison – Target and Modelled AEPs

Event (AEP)	0.5 %	1 %	2 %	5 %	10 %	20 %
Target	492 m ³ /s 42,509 ML/d	433 m ³ /s 37,411 ML/d	374 m ³ /s 32,314 ML/d	296 m ³ /s 25,574 ML/d	235 m ³ /s 20,304 ML/d	168 m ³ /s 14,515 ML/d
Modelled	478 m ³ /s 41,299 ML/d	440 m ³ /s 38,016 ML/d	342 m ³ /s 29,549 ML/d	281 m ³ /s 24,278 ML/d	242 m ³ /s 20,909 ML/d	173 m ³ /s 14,947 ML/d

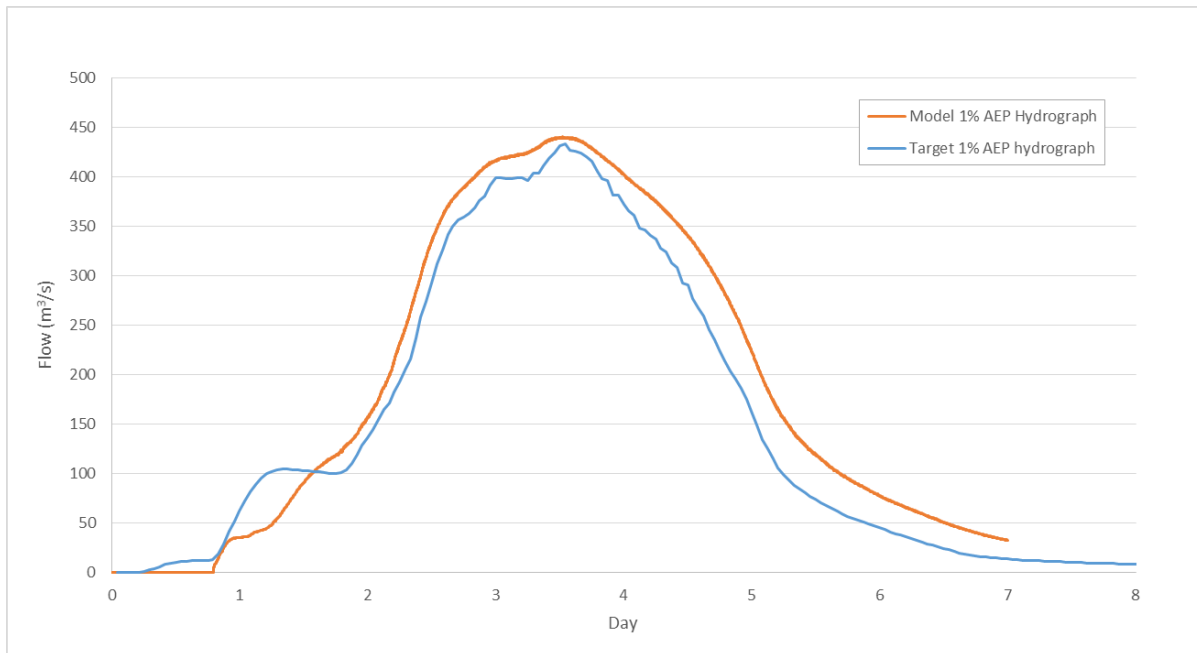


Figure 6-7 Target and modelled 1% AEP hydrographs

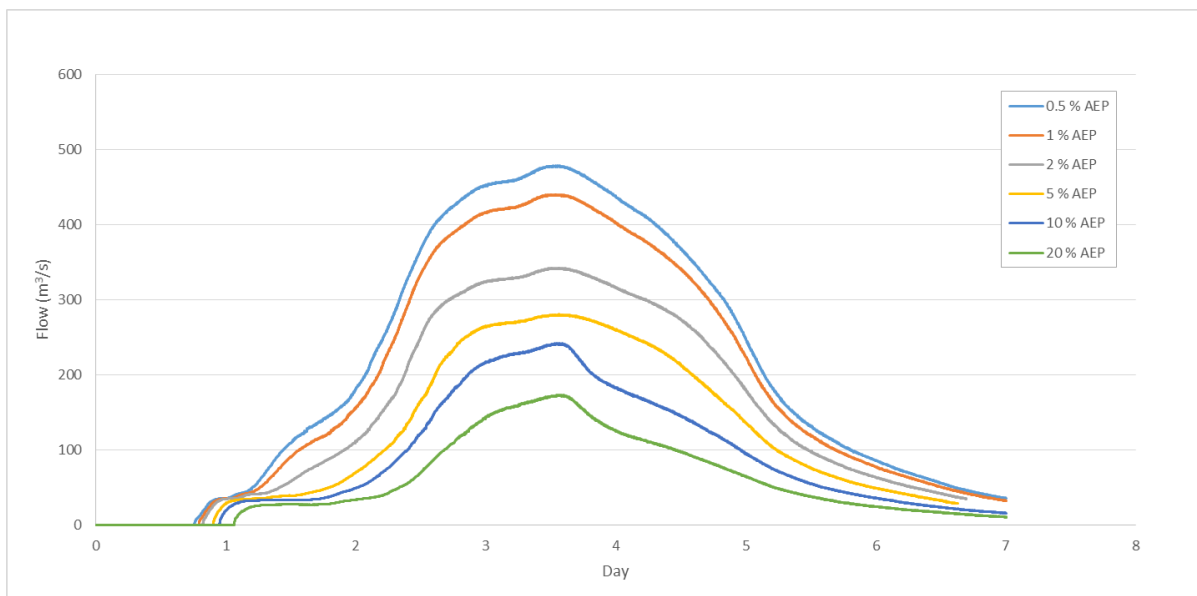


Figure 6-8 Modelled design hydrographs at Glenorchy

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7 HYDRAULICS

7.1 Calibration

7.1.1 Overview

As discussed in Section 6.1, the Wimmera River at Glenorchy streamflow gauge has a significant period of record, spanning from 1910 to current. The chosen calibration event, January 2011, was the largest in the gauge record and 2.6 cm beyond the reliable section of the rating curve. The rating curve was based on 306 gauge ratings, the water level and flow relationship is considered to be good for this gauge.

Flows recorded at the Glenorchy streamflow gauge were used as a basis for the flow distribution to Dunmunkle Creek within Model A. This distribution was then routed along Dunmunkle Creek through Model B, C, D, and E.

As discussed in Section 5.4 there is a range of calibration data available for the January 2011 event. Each model area contains varying amounts of data. In general, the further north along the Dunmunkle Creek system the less calibration data is available, and the heavier the reliance on anecdotal community-based information. The floodplain is also less complex downstream of Rupanyup, with not as much channel infrastructure.

Model calibration was completed using uniform roughness values to decrease the complexity over such a large modelling area.

The following sections discuss the schematisation of each model and calibration to the January 2011 event.

7.1.2 Model A

As discussed, Model A is the most upstream model in the Dunmunkle Creek system and was used to determine the flow split between the Wimmera River and Dunmunkle Creek. The Model A extent and key features are shown in Figure 7-1.

Flows and water levels for the January 2011 event were recorded at the Wimmera River at Glenorchy gauge, this recording is of reasonable accuracy.

To determine Wimmera River inflows to Model A upstream of the gauge, the recorded Glenorchy hydrograph was run as an initial trial to determine what proportion of the model inflow would remain in the Wimmera River and reach the Glenorchy gauge location. Several increases to the model inflow were then made attempting to match the recorded Glenorchy flows with a final multiplier of 1.44 determined as the best match, a lag of four hours was also applied to match the timing of the peak flows, Table 7-1. The recorded Glenorchy hydrograph and the scaled model inflow are shown in Figure 7-2.

A uniform Manning's 'n' of 0.05 was shown to provide the best match of observed and modelled levels, flows and timing. A comparison of modelled and observed hydrographs and water levels are shown in Figure 7-3 and Figure 7-4 respectively.

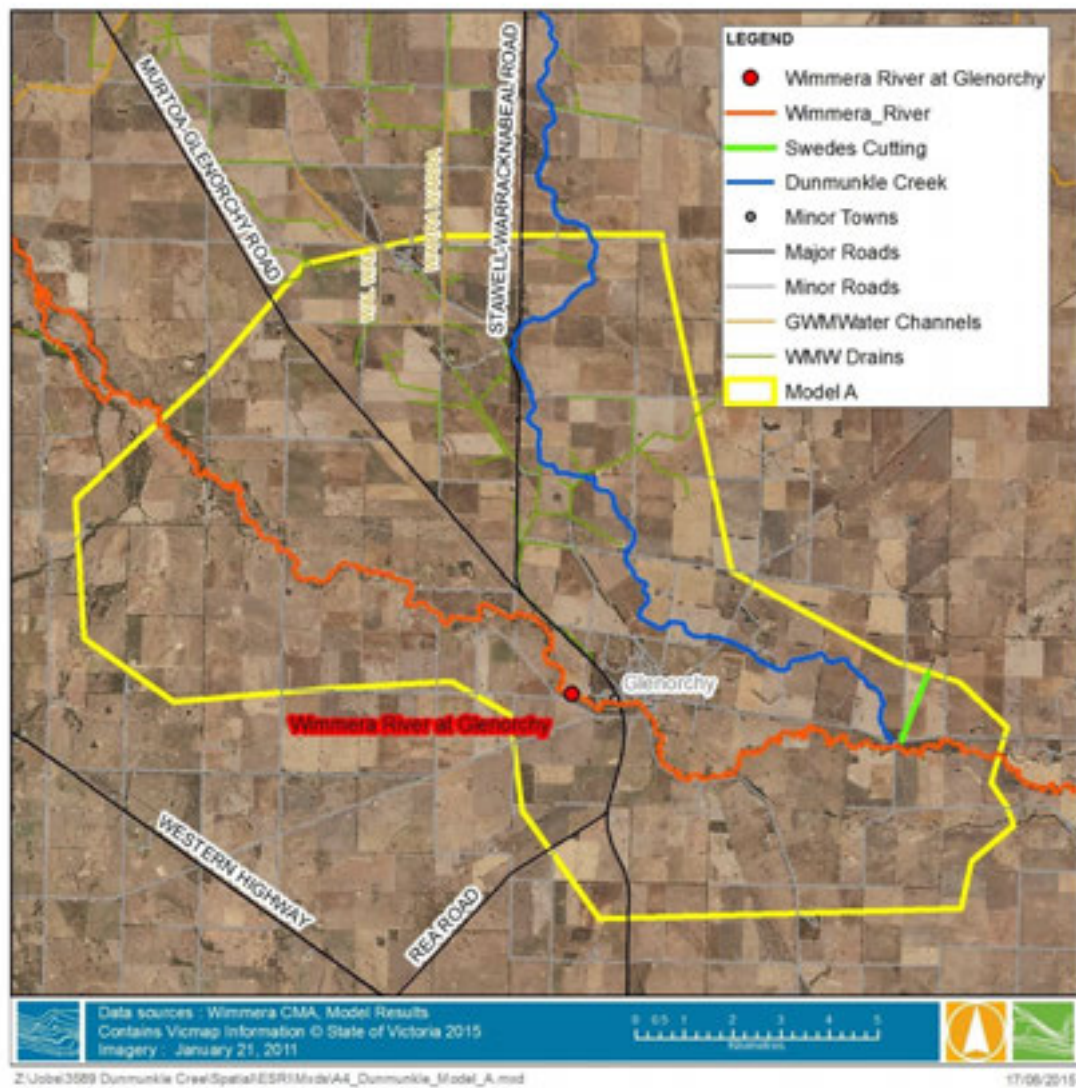


Figure 7-1 Model A - Hydraulic model structure

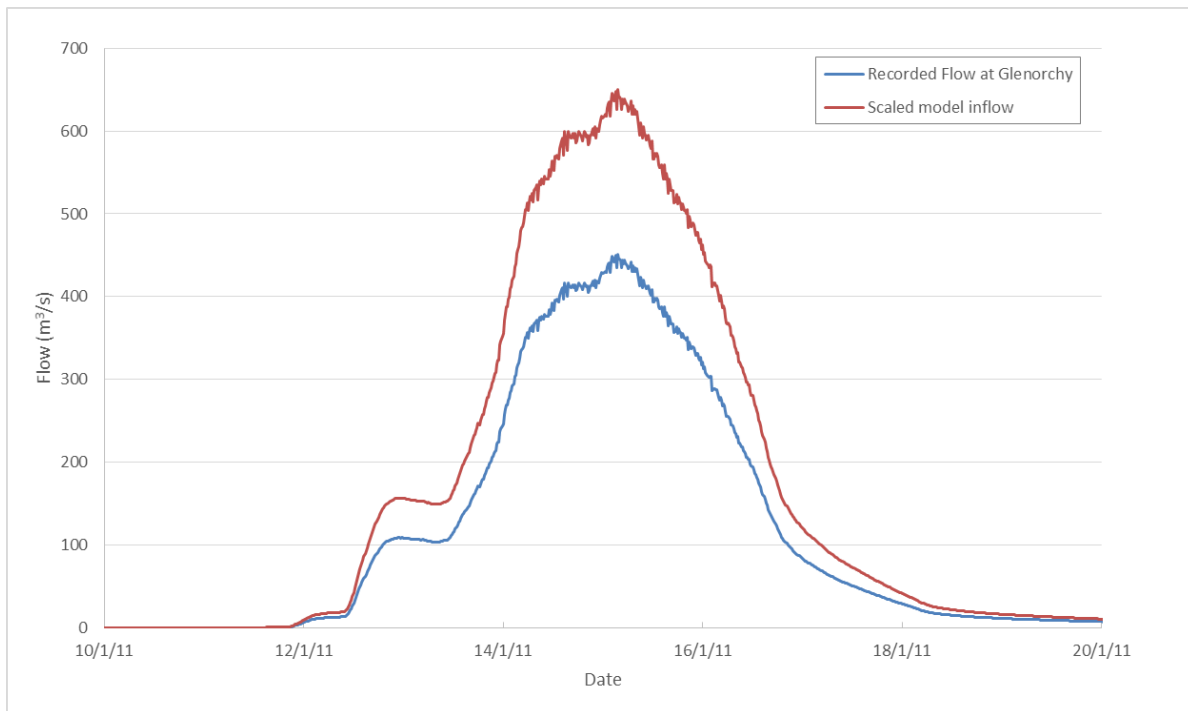


Figure 7-2 Model A – Recorded Glenorchy hydrograph and scaled model inflow

Table 7-1 Wimmera River at Glenorchy – January 2011 peak flow and level comparison

	Observed	Modelled
Peak flow	451 m ³ /s	457 m ³ /s
Peak water level	168.81 m AHD	168.80 m AHD
Timing	15/01/2011 7:30 am	15/01/2011 9:30 am

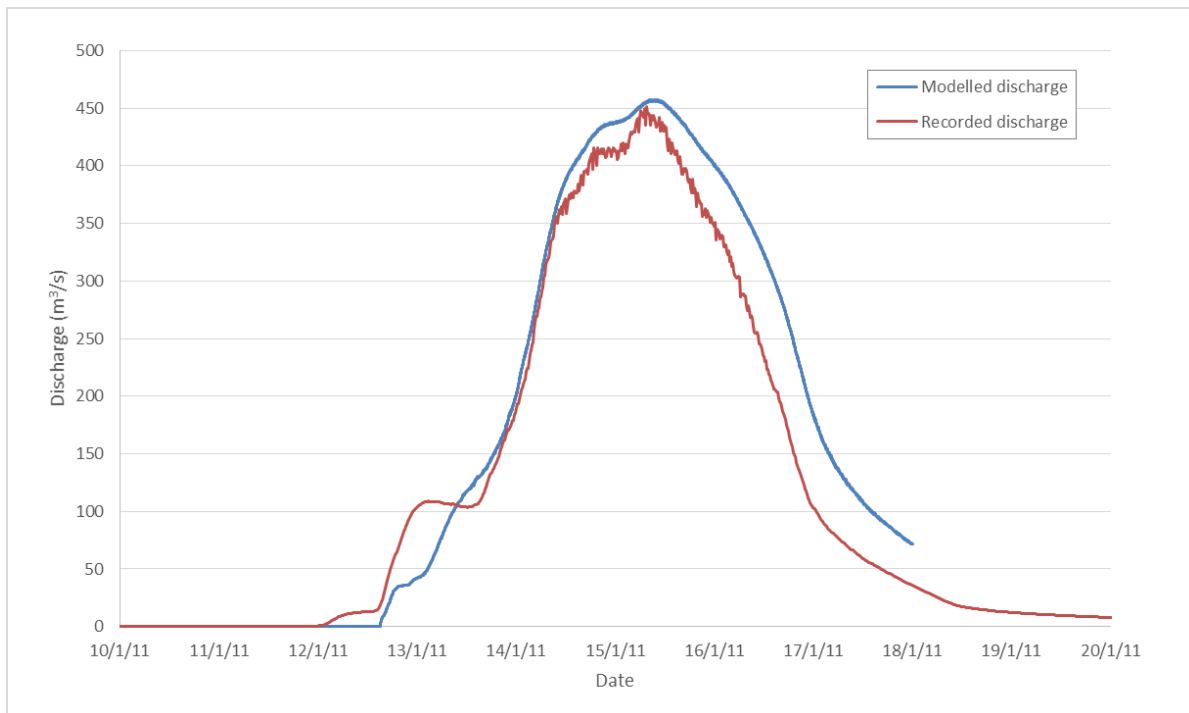


Figure 7-3 Model A – Recorded and modelled hydrographs at the Glenorchy gauge

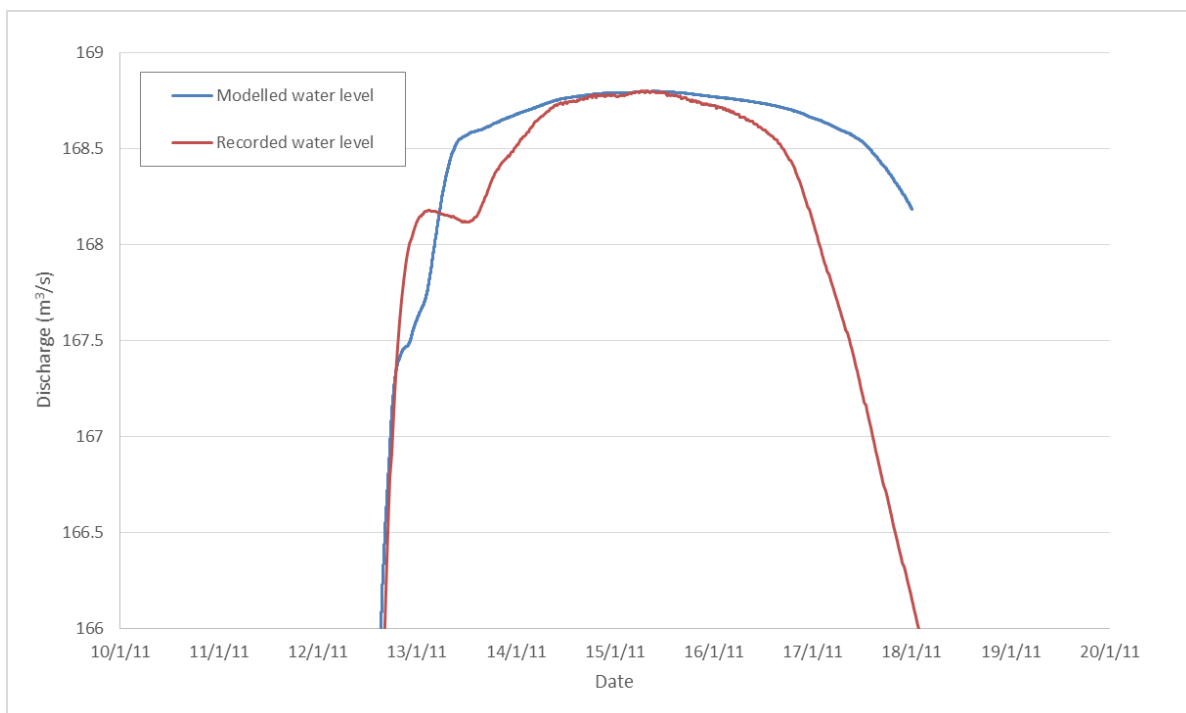


Figure 7-4 Model A – Recorded modelled water levels at the Glenorchy gauge

Additional to the observed flows and water levels at the Glenorchy gauge there were 22 peak flood level survey heights marked by Wimmera CMA staff available for the model calibration and an estimated inundation extent within Model A. The inundation extent was determined by Wimmera CMA based on the available linescan, satellite and aerial photography available. The survey marks and estimated extent are shown in Figure 7-5 along with the Model A extent.

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Figure 7-5 Model A – Peak flood survey marks and estimated January 2011 extent

The model results were compared to the surveyed levels and estimated extents. The difference between the surveyed and modelled maximum flood levels were calculated as:

$$\text{'modelled level – observed survey level'}$$

This resulted in positive values when the modelled value was higher than those observed, and negative when the modelled value was lower than observed.

Of the 22 surveyed flood heights 18 were within 0.2 m and 12 of those were within 0.1 m of that observed. A breakdown of the differences is shown in Table 7-2.



Table 7-2 Model A – Surveyed and modelled peak flood height comparison

Difference (Modelled – Observed)	No. of points within classification
-0.5 m to -0.25 m	1
-0.25 m to -0.2 m	1
-0.2 m to -0.15 m	1
-0.15 m to -0.1 m	1
-0.1 m to 0.1 m	12
0.1 m to 0.15 m	4
0.15 m to 0.2 m	0
0.2 m to 0.25 m	2

The comparison of surveyed and modelled flood heights is shown in Figure 7-6, the difference between modelled and observed levels is colour coded with yellow to red indicating the modelled levels are above that observed and light to dark green indicating the modelled levels are below that observed.

There are four points with a difference between modelled and observed levels greater than 0.2 m, two are indicating the model results are too high and two too low. None of these points are located along Dunmunkle Creek.

The two points where the model results are greater than 0.2 m above the model results are located south and north west of Glenorchy. A closer perspective of these points is shown in Figure 7-7. The figure on the left shows the southern survey points while the figure on the right shows the north western points. The figures also show the linescan captured at 7.30 pm on January 16th, 2011 and estimated January 2011 extent.

In both cases there are other survey points in close proximity to the survey marks that are showing the modelled levels within 0.1 m of that surveyed. In both areas, the modelled extent does exceed the Wimmera CMA estimated extent and the extent of inundation shown in the line scan data, however not by a large amount.

The two points where the model results are less than 0.2 m above the model results are located south east and north west of Glenorchy. A closer perspective of these points is shown in Figure 7-8, the figure on the left shows the south eastern survey point while the figure on the right shows the northern western point. The figures also show the linescan captured at 7.30 pm on January 16th, 2011 and estimated January 2011 extent.

The north western point is more than 0.5 m lower than the surveyed level with only a slight difference between the modelled extent and that observed in the linescan data. The Wimmera CMA estimated extent does exceed the modelled extent by around 50 m in this area. However, the survey point is not within any of the modelled or estimated inundation.

The south eastern point is only marginally greater than 0.2 m lower than the observed level. In this area the modelled inundation extent matches the linescan data and Wimmera CMA estimated extent well.

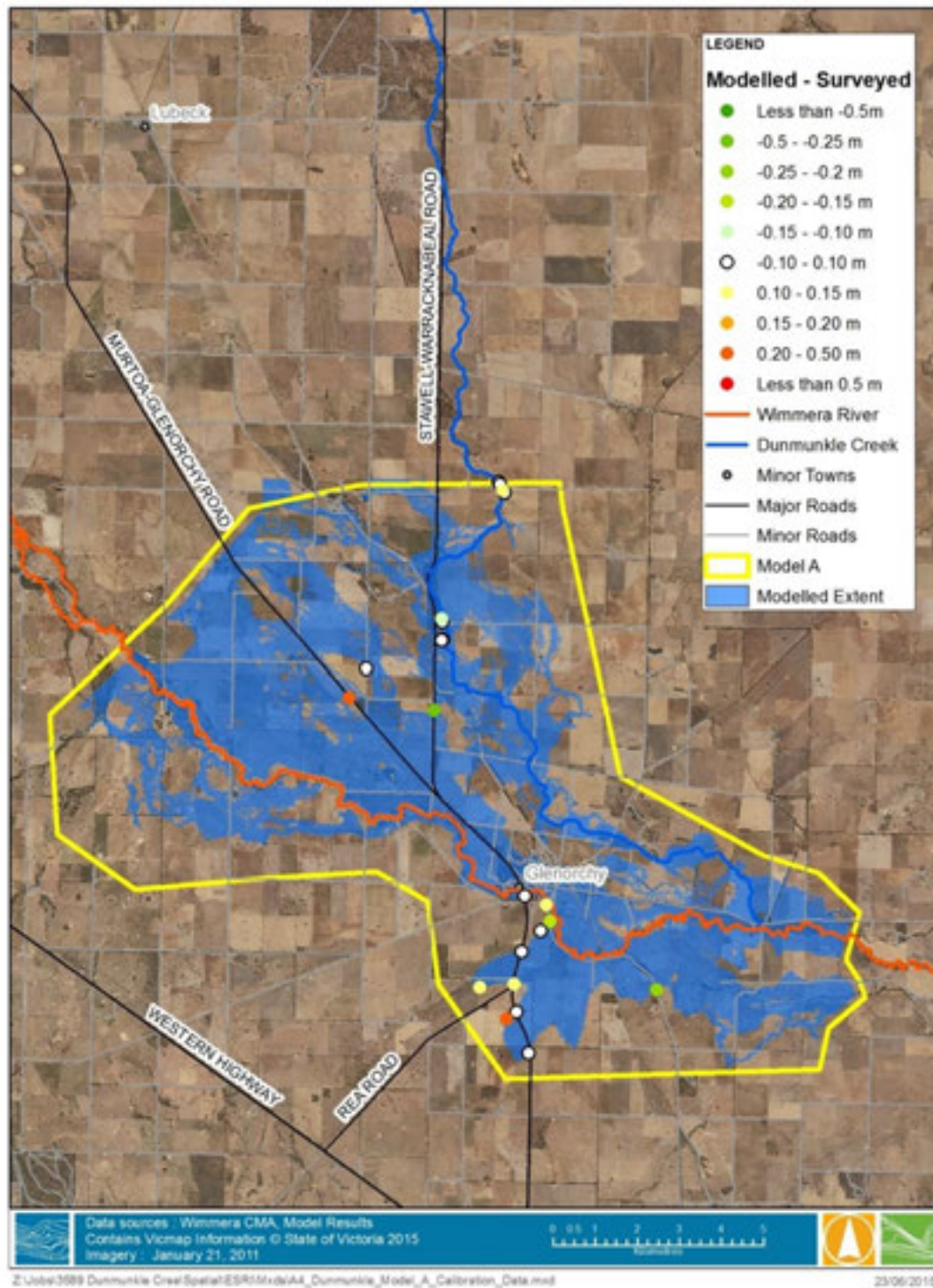


Figure 7-6 Model A – Peak flood height and modelled flood height comparison

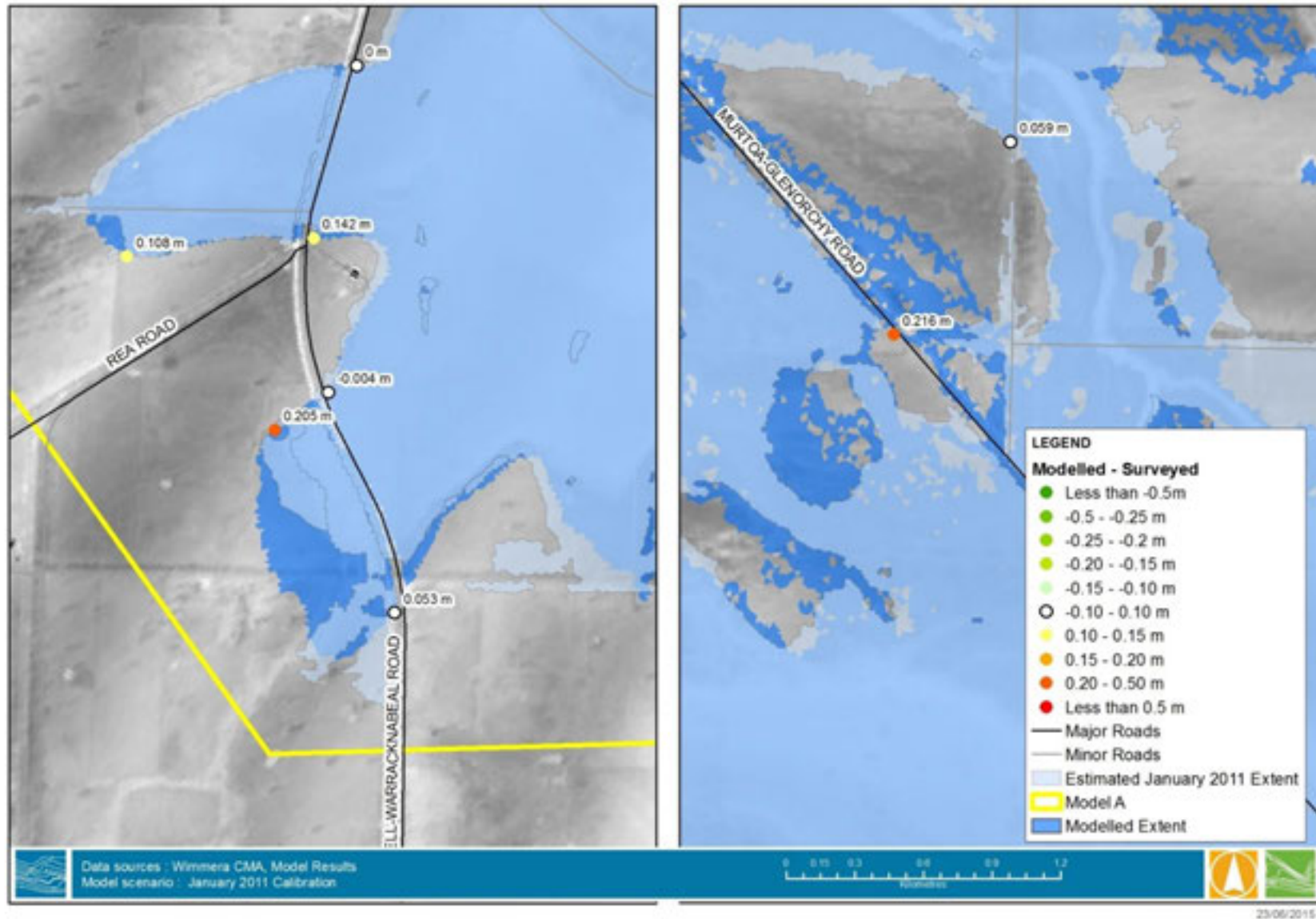


Figure 7-7 Model A – Peak flood height and modelled flood height comparison – Points greater than 0.2 m above observed levels

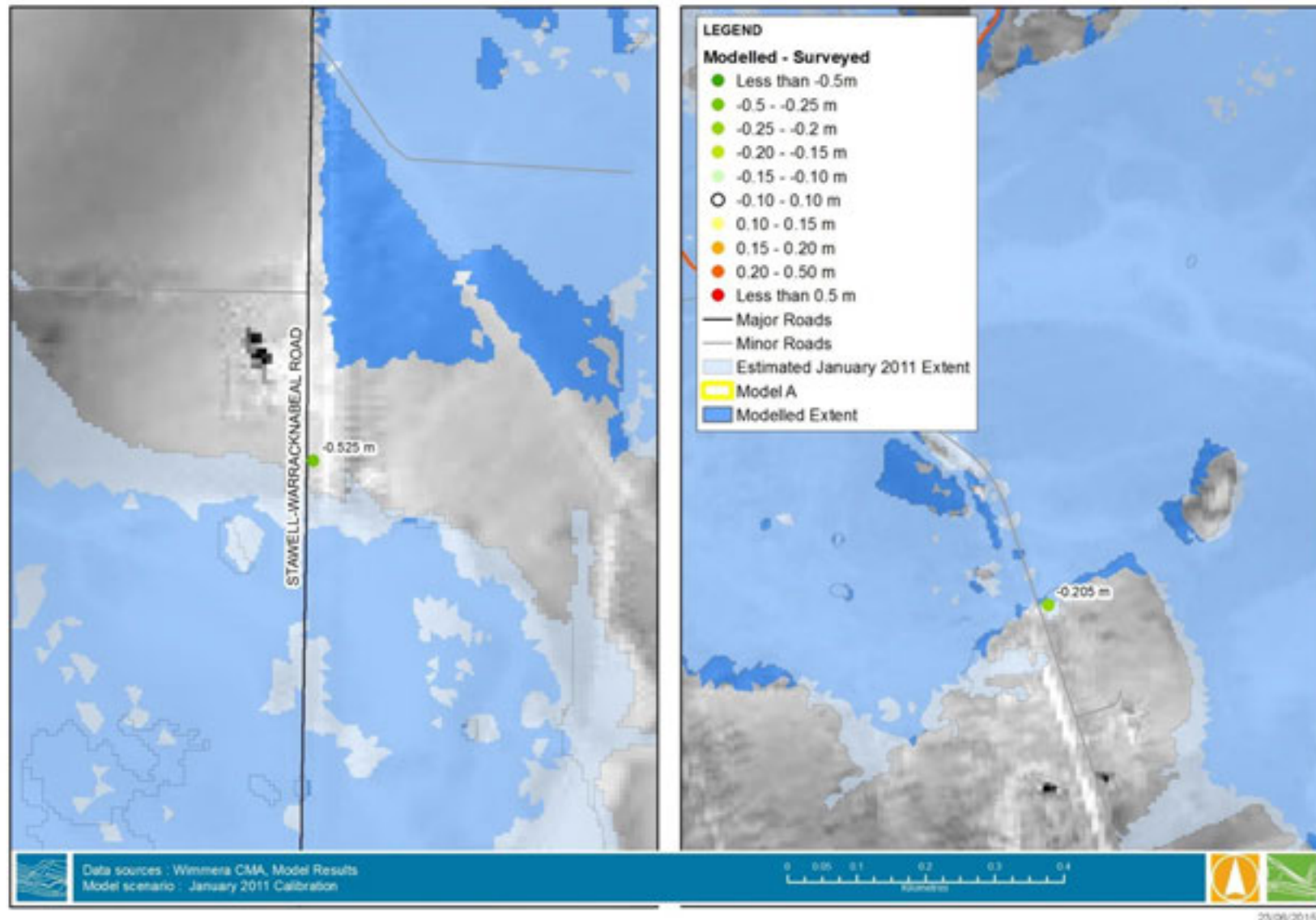


Figure 7-8 Model A – Peak flood height and modelled flood height comparison – Points less than 0.2 m above observed levels



7.1.3 Model B

Model B receives the Dunmunkle Creek flow distribution from Model A and routes it along Dunmunkle Creek to south of Rupanyup. The model contains several key manmade and natural floodplain features including:

- A natural flow distribution from Dunmunkle Creek, west toward Murtoa
- Main Eastern Channel
- Rocklands Lubeck Channel
- Rupanyup South Channel
- Stawell Warracknabeal Road

Model B is by far the most influenced by decommissioned GWMWater channel infrastructure. The model extent and these key features are shown in Figure 7-9.

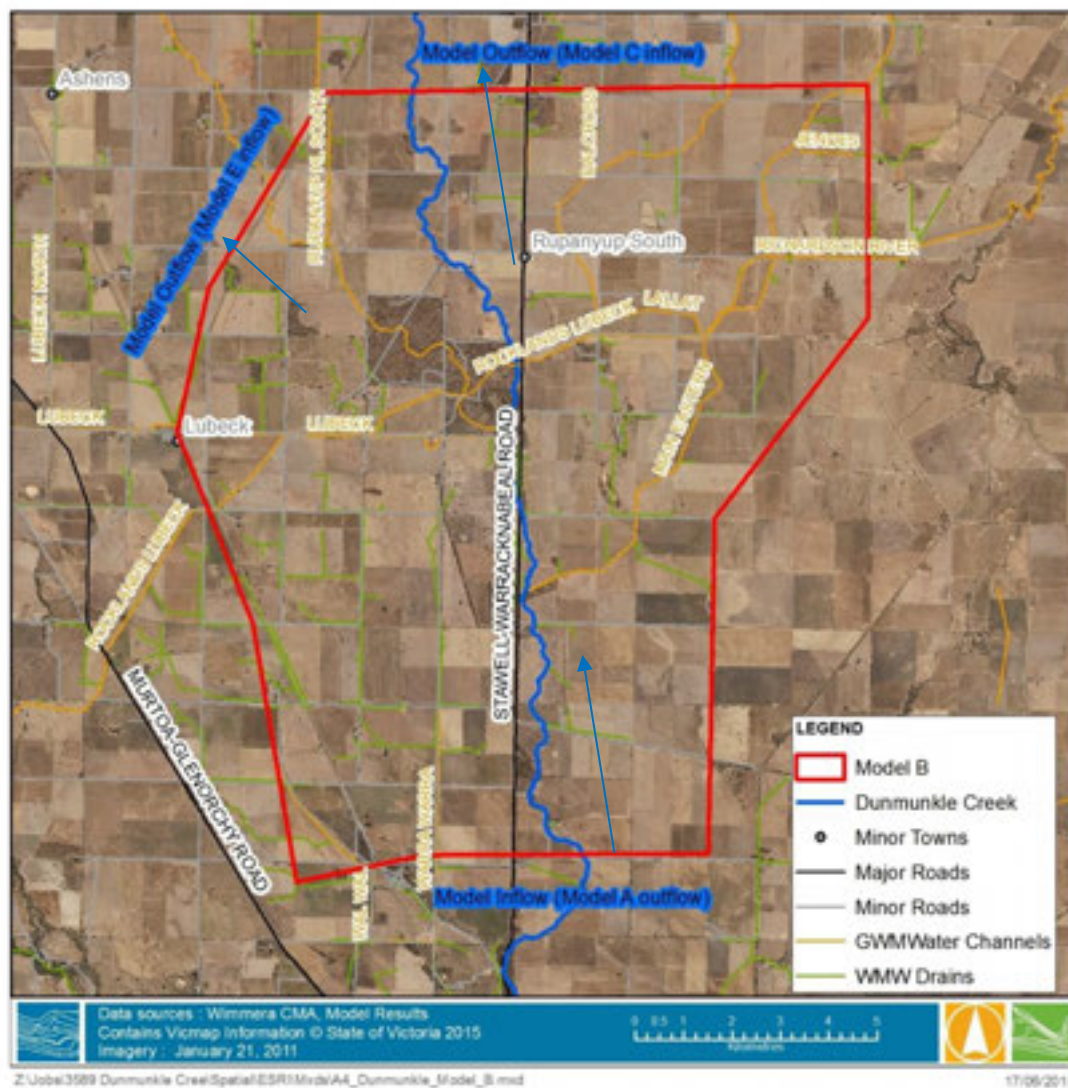


Figure 7-9 Model B - Hydraulic model structure



Post the January 2011 event there were nine peak flood heights surveyed within Model B. These survey points were compared to the modelled water levels. Eight of the nine points show the surveyed level to be within 0.2 m of that surveyed, with five of those within 0.1 m of that surveyed. A breakdown of the difference between the modelled and observed levels is shown in Table 7-3.

Table 7-3 Model B – Surveyed and modelled peak flood height comparison

Difference (Modelled – Observed)	No. of points within classification
-0.1 m to 0.1 m	6
0.1 m to 0.15 m	2
0.15 m to 0.2 m	0
Greater than 0.2 m	1

The difference between the modelled and observed levels is shown in Figure 7-10, the differences are colour coded with yellow to red indicating the modelled levels are above that observed and light to dark green indicating the modelled levels are below that observed. The figure also shows the January 2011 extent linescan data. The point where the surveyed level was greater than 0.2 m above that observed was located south of Minnieboro Road and Ashens Jacksons Road, as shown in Figure 7-11.

There were three surveyed levels in direct proximity to Minnieboro Road, with differences between the surveyed and observed levels varying from 0.327 m to 0.025 m. A review of the surveyed height data showed the southernmost point had a surveyed elevation of 155.597 m AHD, this compared to 155.734 m AHD at the survey point directly south of Minnieboro Road which matched the modelled elevations within 0.025 m. The downstream surveyed peak flood height was higher than the upstream point, indicating an error in the survey has occurred. This error is most likely in the upstream level given the modelled levels match well at the two remaining points. Two of the surveyed levels directly beside the Dunmunkle Creek Channel at Bismark Lubeck Road were not within the modelled flood extent, as shown in Figure 7-12. These points were located either side of a dam with connections to Dunmunkle Creek, values for these points was attributed from the Dunmunkle Creek connection point. This is considered the most appropriate approach given the very flat terrain and clear connection.

There were two areas where the modelled extent did not match that captured in the linescan imagery. Between Minnieboro Road and Tinsley Road the modelled extent exceeds that shown in the linescan data while it does not appear large enough at the eastern end of the Main Eastern Channel. These areas are highlighted in Figure 7-13, with the locations of photos captured on the 14th January also shown, highlighting the aerial photo which best shows both locations. The linescan was flown at 7:10 pm, 16th January 2011. This is around 36 hours after the peak level was reached at the Wimmera River at Glenorchy streamflow gauge. Model results indicate the Dunmunkle Creek channel beginning to exceed its channel capacity in this area at around 4:50 pm, 14th January 2011.

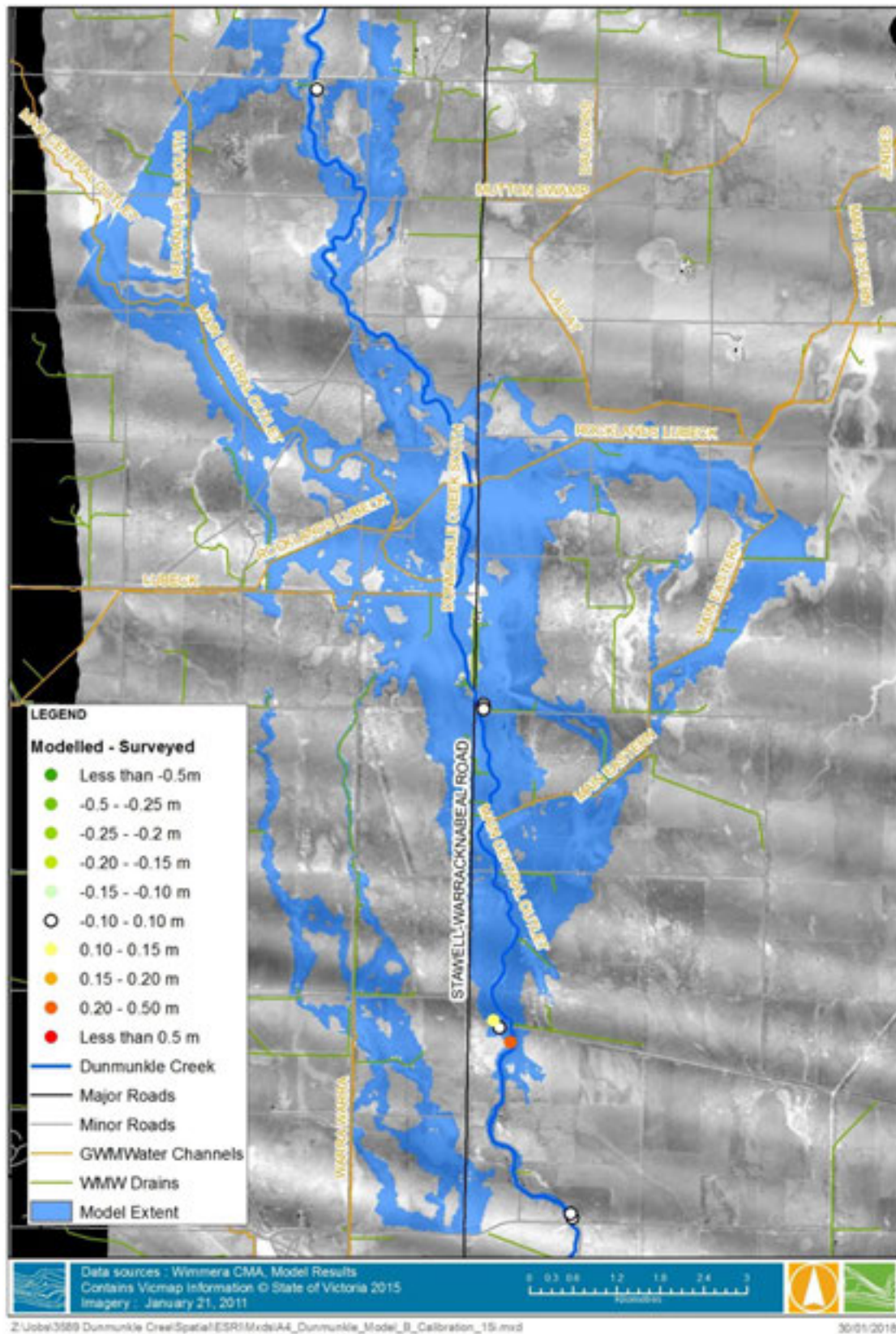


Figure 7-10 Model B – Difference between modelled and observed flood levels

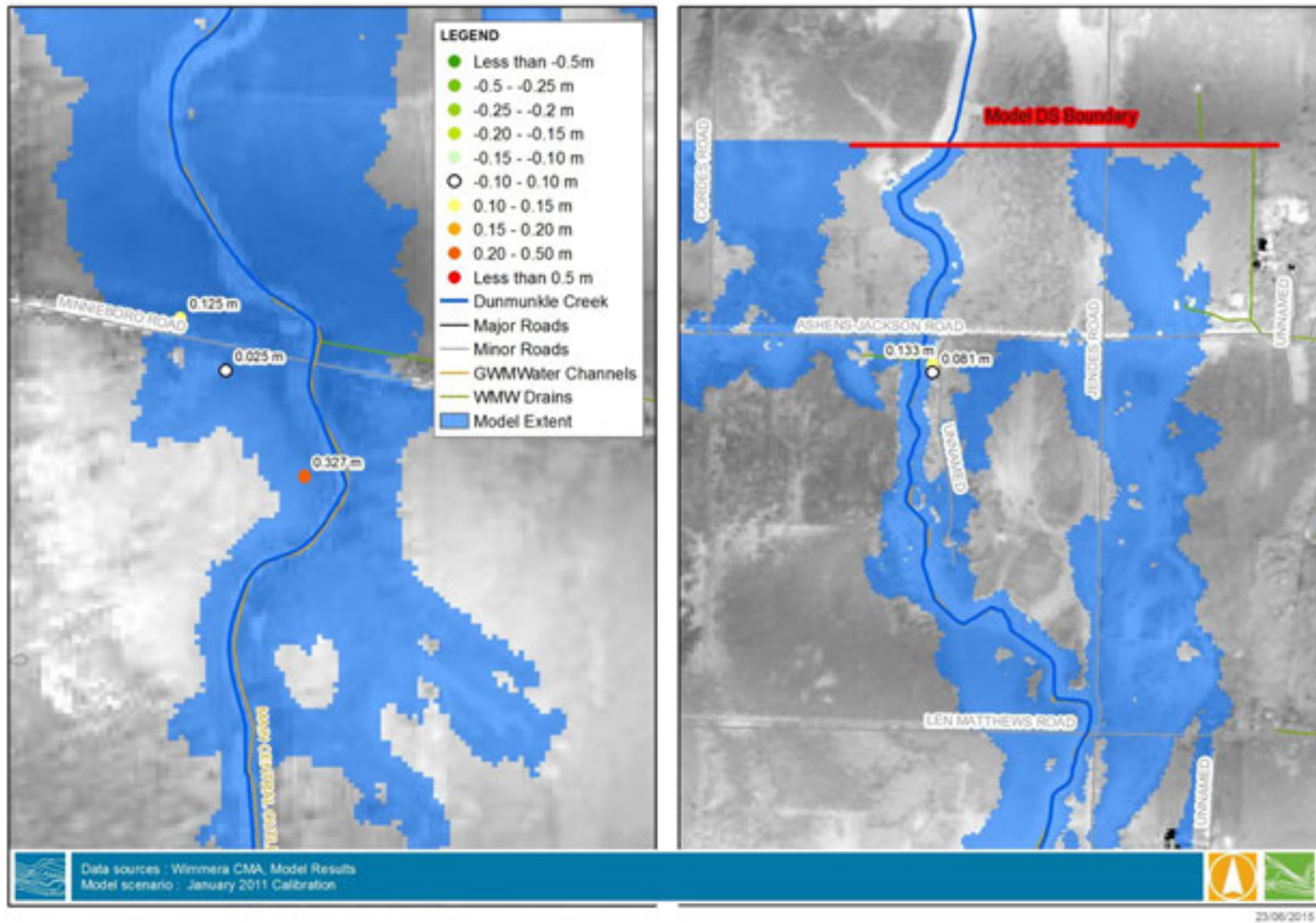


Figure 7-11 Model B – Surveyed flood heights at Minnieboro Road and Ashens-Jackson Road

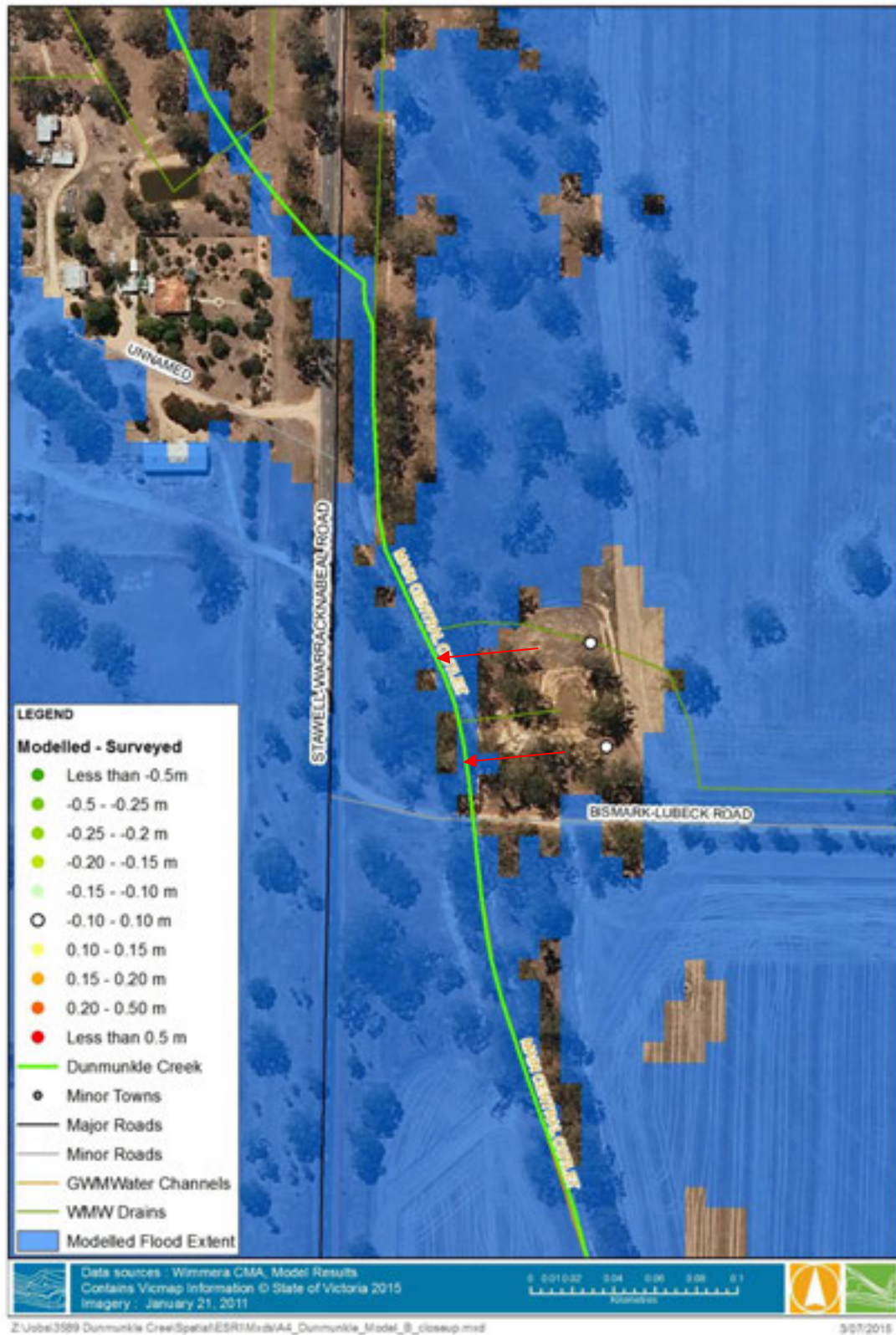


Figure 7-12 Model B – Surveyed flood heights at Bismark Lubeck Road

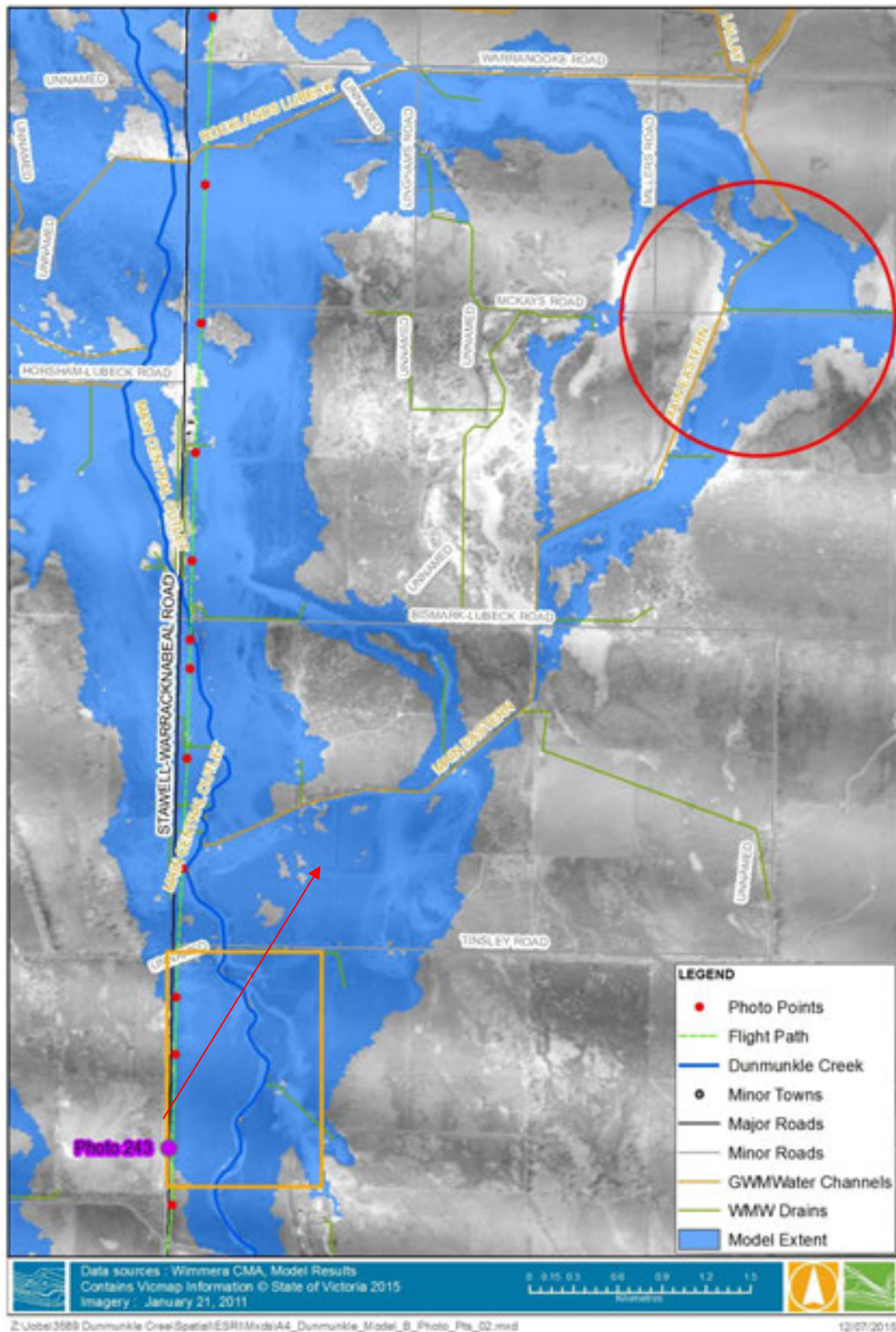


Figure 7-13 Model B – Areas where the modelled and linescan data are not matching well



The aerial photo captured at 11:54 am, 14th January 2011 that best shows the areas highlighted in Figure 7-13 is image 243, as shown in Figure 7-14.



Figure 7-14 Model B – Aerial photo 243 captured at 11:54 am, 14th January 2011

The aerial image shows Dunmunkle Creek inundation exceeded that represented in the linescan image, between Minnieboro Road and Tinsley Road, even though it was captured very early in the event.

It also shows inundation at the eastern end of the Main Eastern Channel when Dunmunkle Creek was only beginning to flood. The Main Eastern Channel was undergoing decommissioning at the time rainfall began in January 2011. There were some sections decommissioned while others remained intact. The model has represented the channel partially decommissioned⁷, with the section from McKays Road to Warranooke Road removed, except for a section in the centre. The sections of decommissioned channel represented in the model are shown in Figure 7-15.

Numerous model simulations were completed, and it was found that the natural flow of water (i.e. without channel embankments) would be to the north, however the remaining length across the low point in the topography forced water to the east.

⁷ Decommissioning advice was provided by Peter Cooper (GWMWater)





7.1.4 Model C

7.1.4.1 Overview

Model C extends from Ashens-Jackson Road to Boyds Road. The model includes the township of Rupanyup. Rupanyup was impacted twice during January 2011, initially by rainfall runoff originating south of the township, then again by the Wimmera River distribution along Dunmunkle Creek.

The model schematisation for Model C required consideration of both direct rainfall induced flooding and inundation caused by Dunmunkle Creek. The model area included the Rupanyup direct catchment area and connected to Model B routing the Wimmera River distributed flow along Dunmunkle Creek.

The Rupanyup direct catchment area was delineated using the ESRI ArcHydro tool and calculated to be approximately 4,050 Ha. The hydraulic model structure for Model C and Rupanyup's direct catchment area is shown in Figure 7-16.

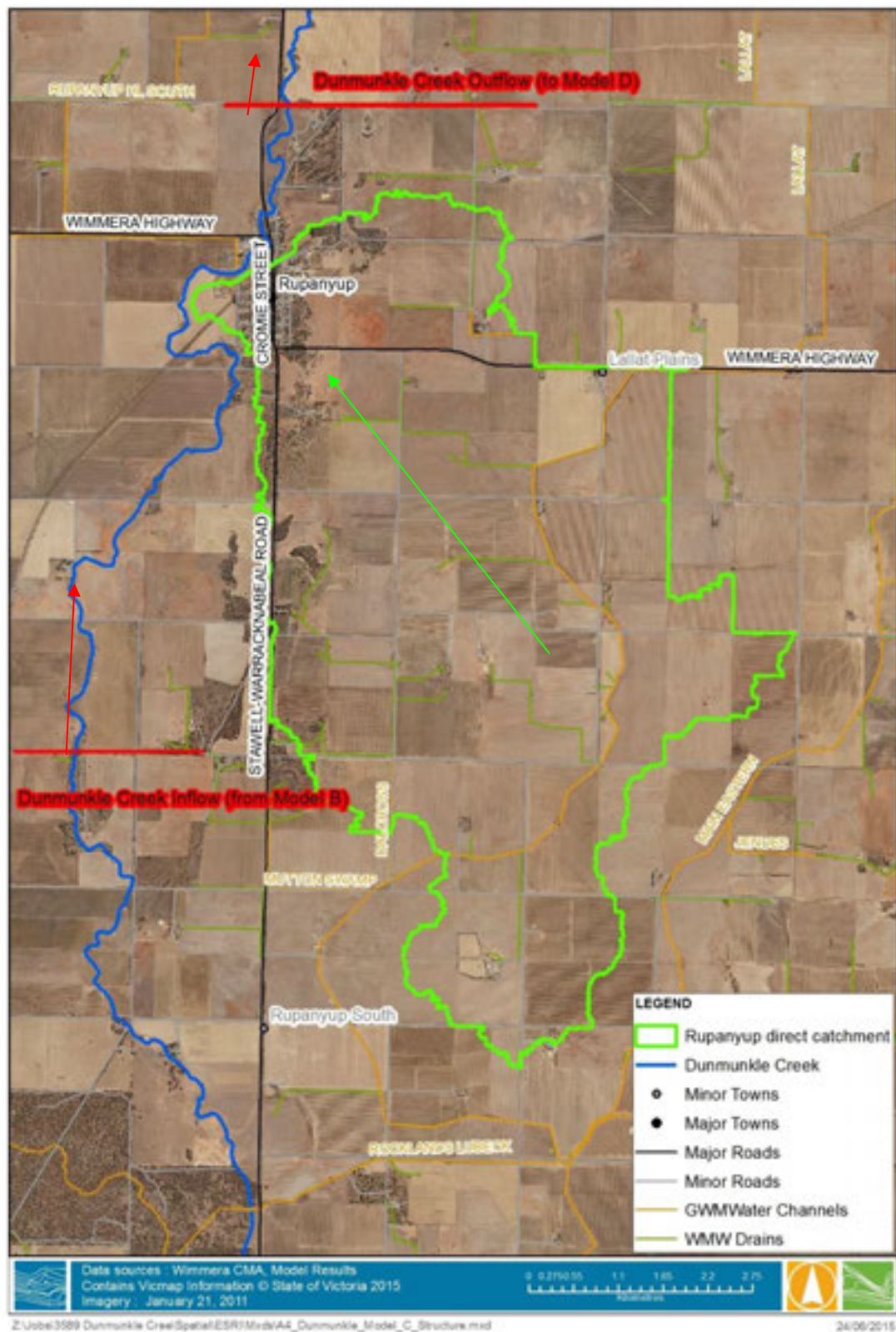


Figure 7-16 Model C - Hydraulic model structure

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Due to the dual sources of inundation at Rupanyup, a rainfall-on-grid model was developed to simulate the direct catchment runoff, which was followed by the Dunmunkle Creek inflow from Model B. Each component was calibrated for the January 2011 event separately.

The model was constructed in DHI's MikeFlood using a standard grid-based model, opposed to the flexible mesh approach taken for models A, B, D and E. The standard gridded approach was adopted because of the relatively small model area.

7.1.4.2 Direct Catchment Runoff

Rain-on-grid modelling of the Rupanyup catchment was completed by applying rainfall to the 2D gridded topography. As discussed in Section 5.2, daily rainfall information is recorded at the Rupanyup Post Office. This gauge is the closest to the Rupanyup catchment and is the best representation of the daily totals that fell upstream of Rupanyup. The daily totals recorded at the gauge for the event are shown in Table 7-3. The closest sub daily rainfall which recorded the January 2011 event was Horsham AWS (40 km west of Rupanyup).

Table 7-4 Rupanyup Daily Rainfall Record

Date	Daily rainfall
January 12 th	59.4 mm
January 13 th	2.8 mm
January 14 th	90.0 mm
Total	152.2 mm

Using the daily totals recorded at the Rupanyup gauge and the sub-daily rainfall pattern recorded at the Horsham AWS gauge, a representation of the rainfall occurring in the Rupanyup catchment was developed. The 30 min rainfall intensity and cumulative rainfall patterns developed are shown Figure 7-17.

The January 2011 rainfall was applied to the Rupanyup direct catchment area with a uniform spatial pattern. Given the small catchment area and broad spread of rainfall across Western Victoria a uniform pattern was considered appropriate.

Post January 2011 there were 11 peak flood heights surveyed, most of these points are in the Rupanyup township. The source of flooding (direct catchment runoff or Dunmunkle Creek) leading to the flood levels surveyed was not well understood by Wimmera CMA or members of the steering committee. Flood levels east of the Warracknabeal Stawell Road are thought to be generated by direct catchment runoff, and flood levels on the western side of Dyer Street are thought to have been generated by Dunmunkle Creek flows. Uncertainty surrounds points located on the western side of Comrie Street. The location of the available survey points is shown in Figure 7-18.

The model calibration was completed by varying the uniform Manning's 'n' roughness value and continuing loss value. No initial loss value was used because much of the initial loss is modelled directly in the hydraulic model by surface water storage in the depressions of the terrain. Adopting no initial loss is a conservative approach.

A uniform Manning's 'n' of 0.05 and a continuing loss of 3.5 mm/hr provided the best match of water levels and timing of inundation.

A comparison of the surveyed and modelled water levels is shown in Figure 7-19.

Of the 11 points surveyed 5 had modelled levels within 0.1 m of that surveyed and 8 within 0.2 m of that surveyed. On the eastern side of Rupanyup, all points were within 0.2 m of the surveyed level.



There were three points showing a difference between the modelled and surveyed water levels of greater than 0.2 m. These points are shown at a closer perspective in Figure 7-20. There is one point with a modelled value more than 0.2 m lower than the surveyed level shown in the left figure and two greater than 0.2 m higher than that surveyed on the right.

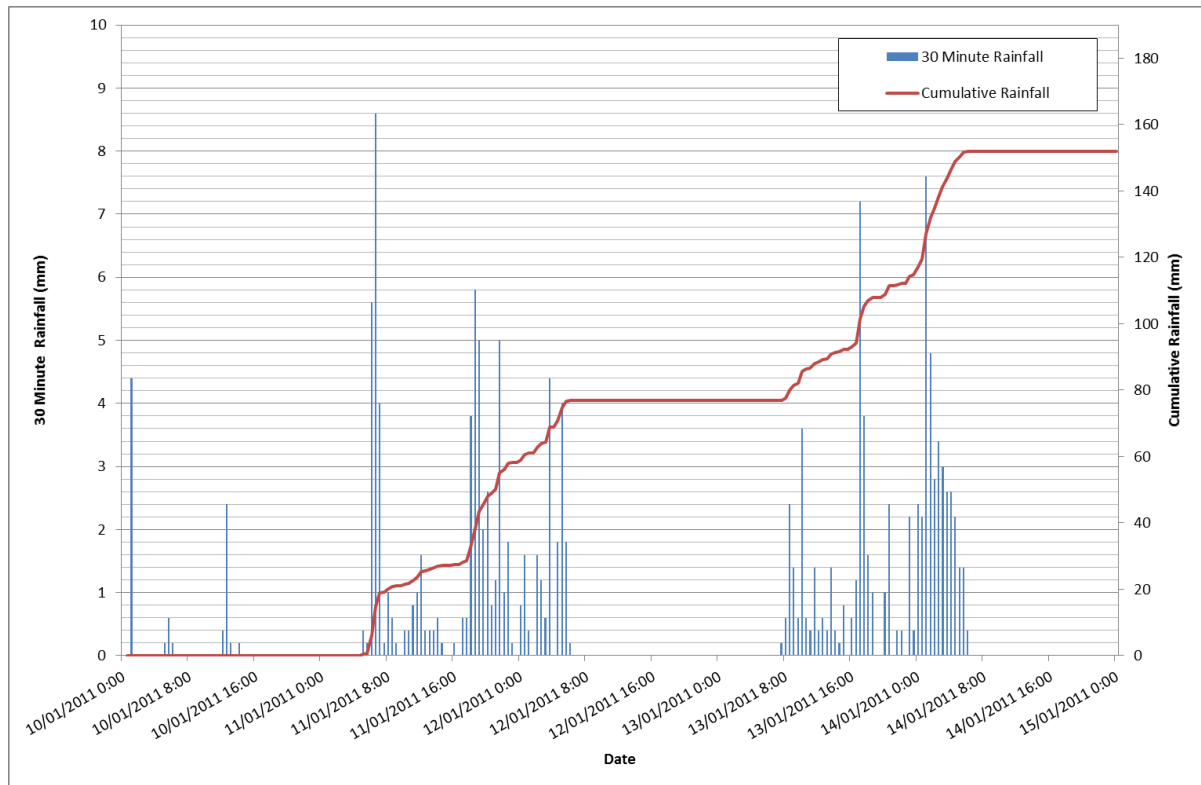


Figure 7-17 Model C – January 2011 Rupanyup developed rainfall pattern



Figure 7-18 Model C – January 2011 Surveyed flood heights



Figure 7-19 Model C – January 2011 direct catchment rainfall peak flood height comparison

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Figure 7-20 Model C – January 2011 direct catchment rainfall peak flood height comparison, differences greater than 0.2 m



The point with modelled water levels greater than 0.2 m lower than that surveyed is on Dunmunkle Creek. Dunmunkle Creek flows are likely to produce the highest water level in this area not the local rainfall and runoff, explaining the difference in surveyed and modelled levels at this location.

The two survey points with modelled levels greater than 0.2 m above that surveyed appears to be errors in the survey levels. The north eastern point (modelled level 0.694 m greater than the surveyed level) shows a surveyed level of 138.127 m AHD, this compares to a LiDAR level of 138.761 m AHD, 0.634 m below the ground surface. The south eastern point (modelled level 0.431 m greater than the surveyed level) shows a surveyed level of 138.578 m AHD, this compares to a LiDAR level of 138.823 m, 0.245 m below the ground surface. Given the LiDAR was demonstrated as of sufficient accuracy (See Section 2.3.3.2), both surveyed points are clearly in error.

The January 2011 direct catchment rainfall was also compared to aerial imagery captured by aircraft on January 14th, 2011, before inundation from Dunmunkle Creek had occurred. A comparison of the modelled inundation and the aerial photography is shown in Figure 7-21. The modelled extents and depths line up closely with those observed in the aerial photography.

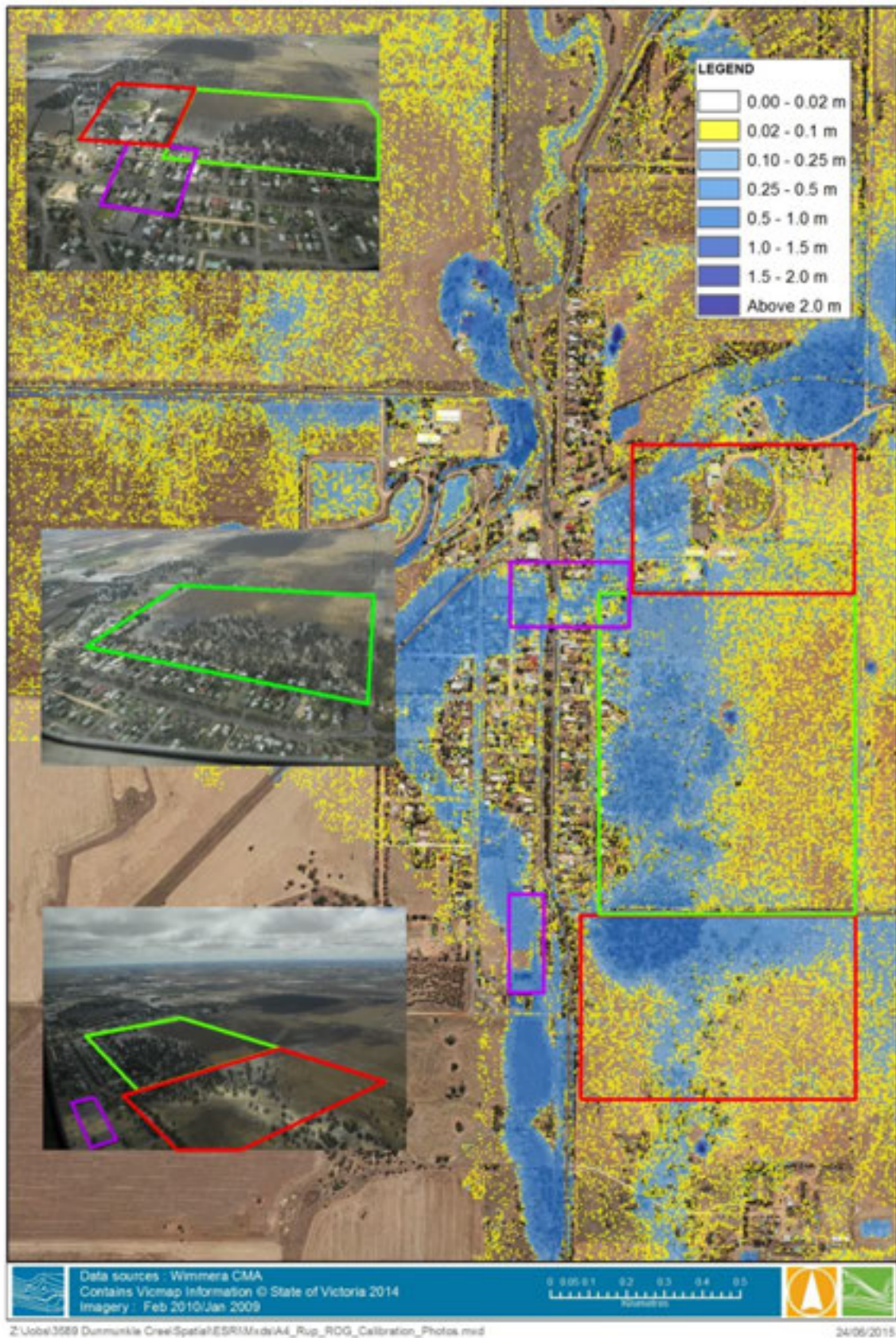


Figure 7-21 Model C – January 2011 direct catchment rainfall and aerial photography comparison

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7.1.4.3 Dunmunkle Creek Inundation

Flow along Dunmunkle Creek was routed from Model B into Model C, the inundation extent generated by Dunmunkle Creek in Rupanyup is shown in Figure 7-22.

Inundation in Rupanyup from Dunmunkle Creek was caused by overland flow immediately upstream of the Rupanyup Railway Line, which separates Dunmunkle Creek from the township further downstream.

A culvert is located on the railway line which allows water from the township to Dunmunkle Creek in small rainfall events, however in Dunmunkle Creek flood events this culvert allows floodwater back into Rupanyup. During January 2011 this culvert was blocked preventing water flowing into the township. A closer perspective of the flood mechanisms in Rupanyup is shown in Figure 7-23, highlighting the inflow and culvert locations.

As discussed previously there were several peak flood heights surveyed in Rupanyup post the January 2011 event. These levels show a consistent level of around 138.6 m AHD in the township, which was reached during the direct rainfall modelling.

Hydraulic modelling using a uniform Manning's 'n' of 0.05 and continuing loss of 3.5 mm/hr resulted in the best match to surveyed levels with the water levels matching well throughout the township. Of eleven points, two recorded stormwater inundation and two were shown to be in error. Of the seven remaining points six showed the modelled water levels to match that surveyed within 0.1 m and one within 0.2 m. Comparison between the surveyed and modelled levels is shown in Figure 7-24.

The modelled extents match observations made by Rupanyup residents during community and steering committee meetings, with water spilling into the township and reaching the Warracknabeal Stawell Road but not overtopping it.

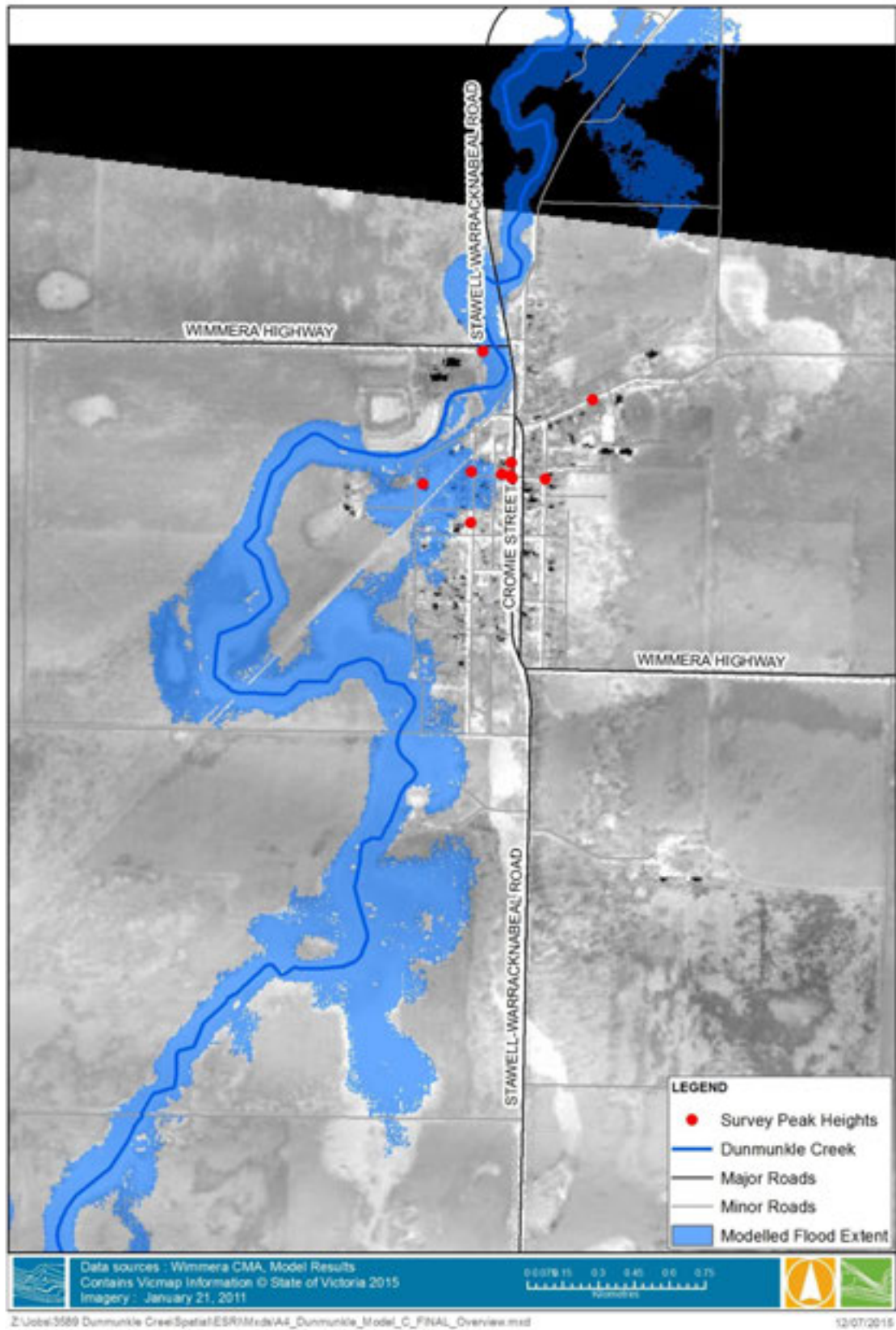


Figure 7-22 Model C – January 2011 Dunmunkle Creek inundation

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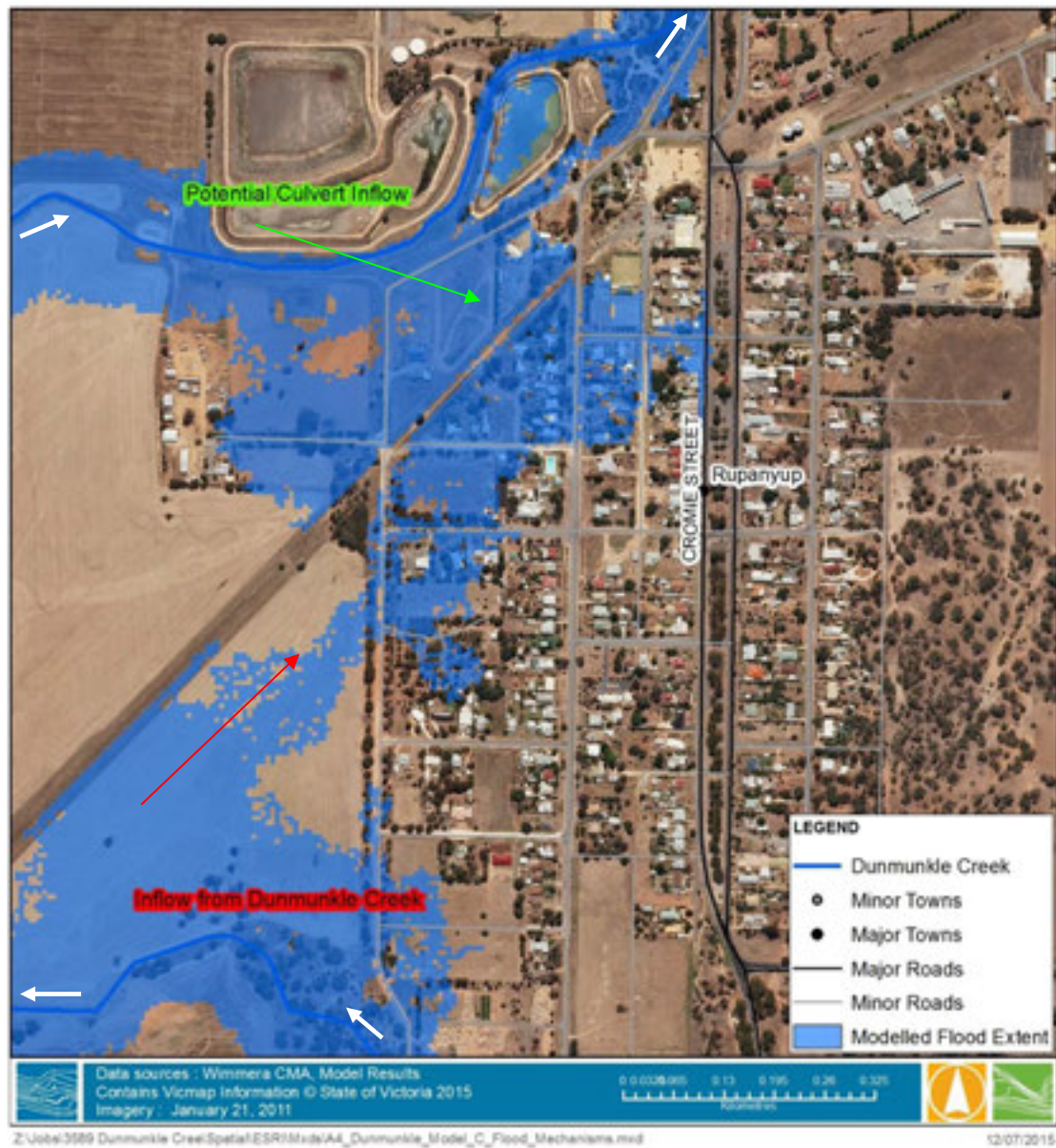


Figure 7-23 Model C – Rupanyup flood mechanisms



Figure 7-24 Model C – January 2011 Dunmunkle Creek inundation, modelled minus surveyed levels

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The model results within Rupanyup are showing a flood level of 138.87 m AHD. This is around 0.05 m above that surveyed. Inundation in the Rupanyup township is caused by a peak flow, high enough to generate overland flow into the township for long enough to fill to a level which will cause damage.

The model results show the overland flow into Rupanyup is less than 0.1 m deep, this leaves a very low margin on both water level and the length of time the water level threshold is exceeded. Numerous sensitivity tests were undertaken during the model calibration process to ensure the water level and duration of inundation are as accurate as possible. Given the shallow depths and importance of this area to determining the flood impact in Rupanyup, it is a potential location for flood mitigation works.

7.1.5 Model D

Model D is the final northern extension of the Dunmunkle Creek modelling. The model routes flow from Model C until it stops flowing and pools in depressions. There are no surveyed levels or Wimmera CMA estimated extents within Model D, with the hydraulic model calibration relying on imagery from Rapid Eye, Landsat Satellites and community observations. The extent of Model D is shown in Figure 7-25. The Rapid Eye and Landsat Satellite images available for Model D are shown in Figure 7-26 and Figure 7-27 respectively.

The Landsat Satellite image (Figure 7-27) shows regular banding in the image, this was due to an error with the satellite image recording equipment.



Figure 7-25 Model D - Hydraulic model structure



Figure 7-26 Model D – Rapid Eye Satellite Imagery

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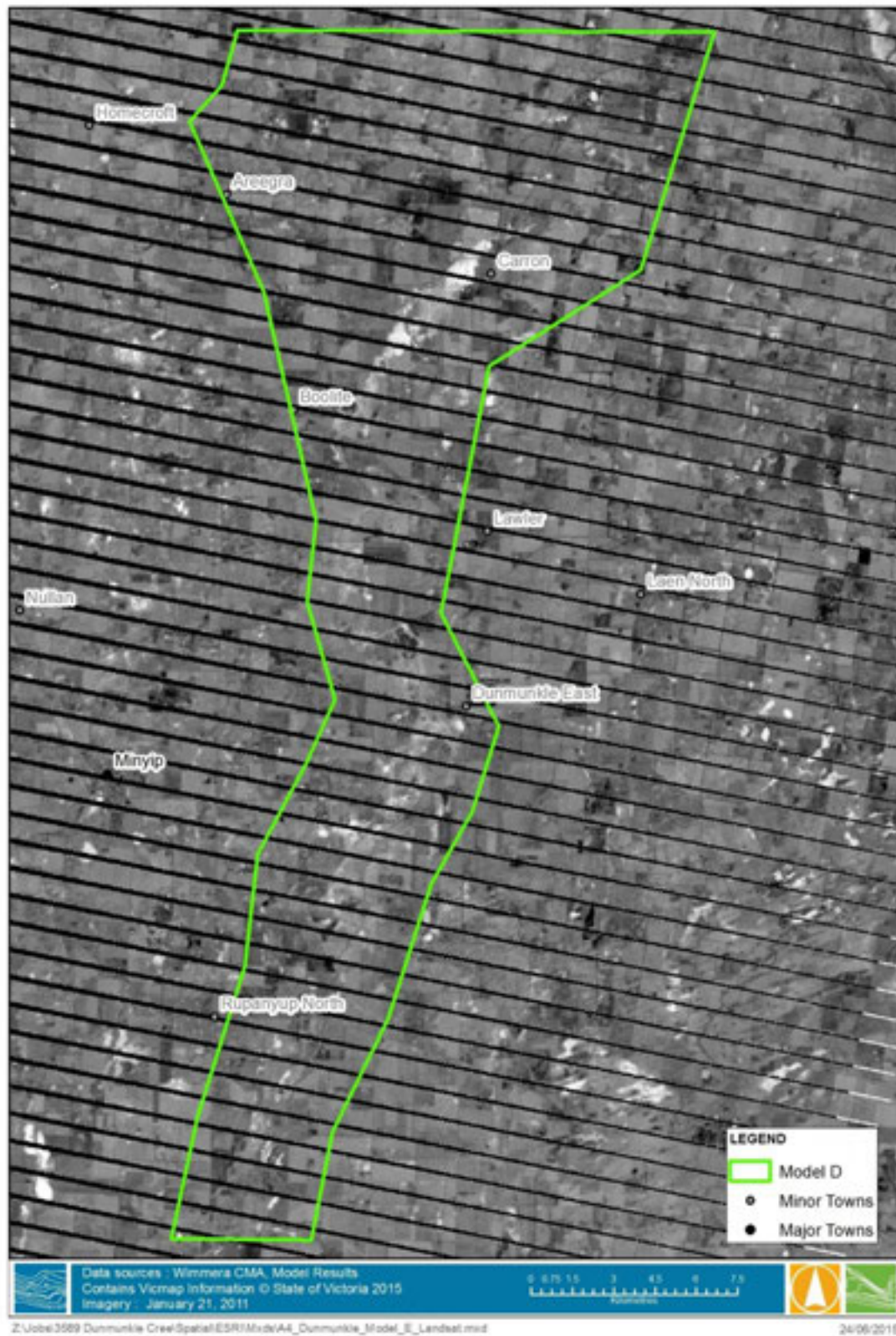


Figure 7-27 Model D – Landsat Satellite Imagery



Within Model D the Rapid Eye satellite provides a clearer picture of the observed inundation and was used for the model calibration. The Rapid Eye satellite image was captured on the 23rd January 2011.

The January 2011 modelled extent overlayed on the Rapid Eye satellite image is shown in Figure 7-28.

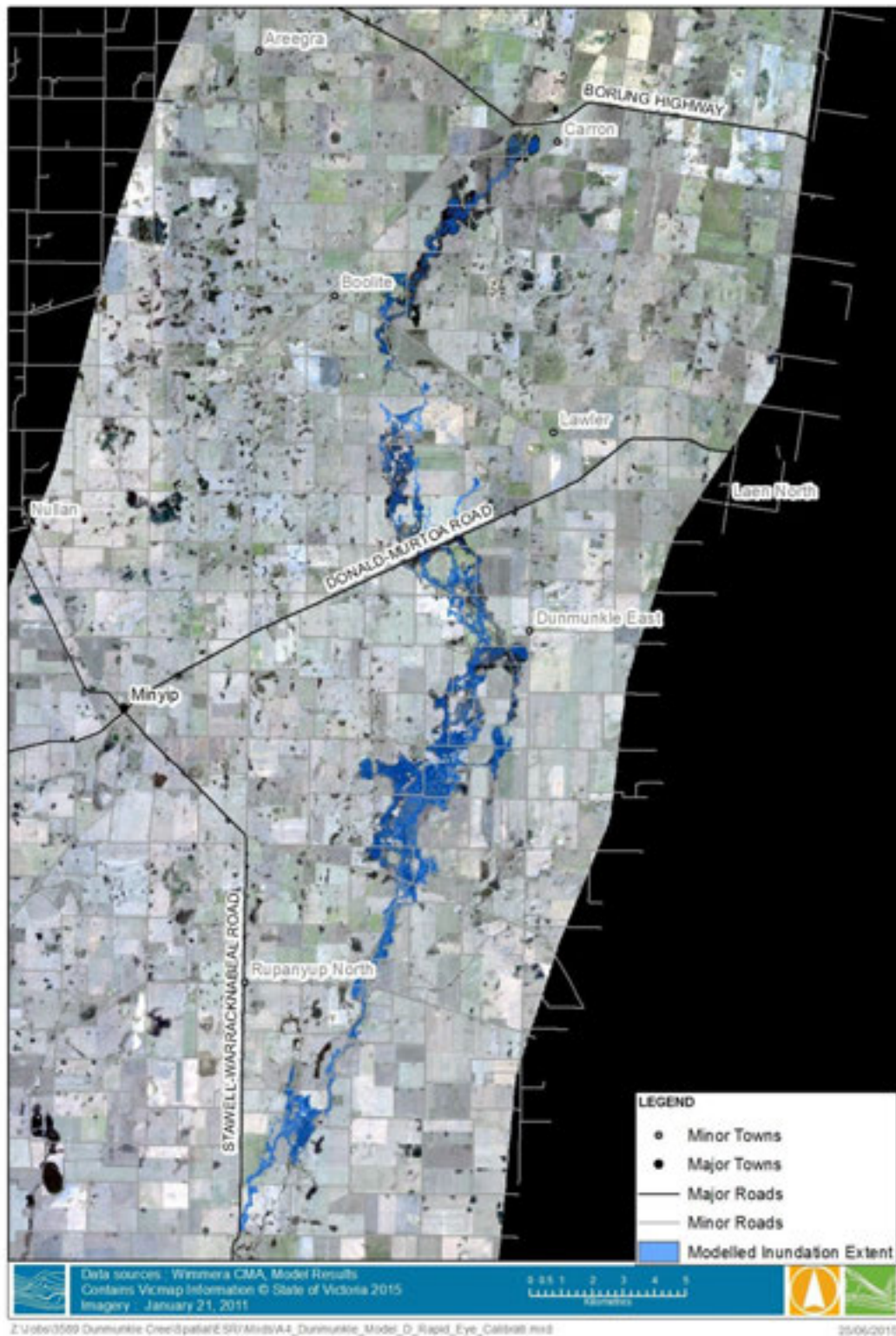


Figure 7-28 Model D – Modelled extent overlayed on the Rapid Eye Satellite Image



7.1.6 Model E

Model E covers a western overland flow path from Model B. As discussed in the Model B calibration, an overland flow path breaks out of Dunmunkle Creek upstream of the Bryntirion State Forest and flows in a north westerly direction through the forest towards Murtoa. Model E extends from the Rupanyup Railway Line to Holtkamps Road to the north, and Tobins Road to the west.

The Model E structure is shown in Figure 7-29.

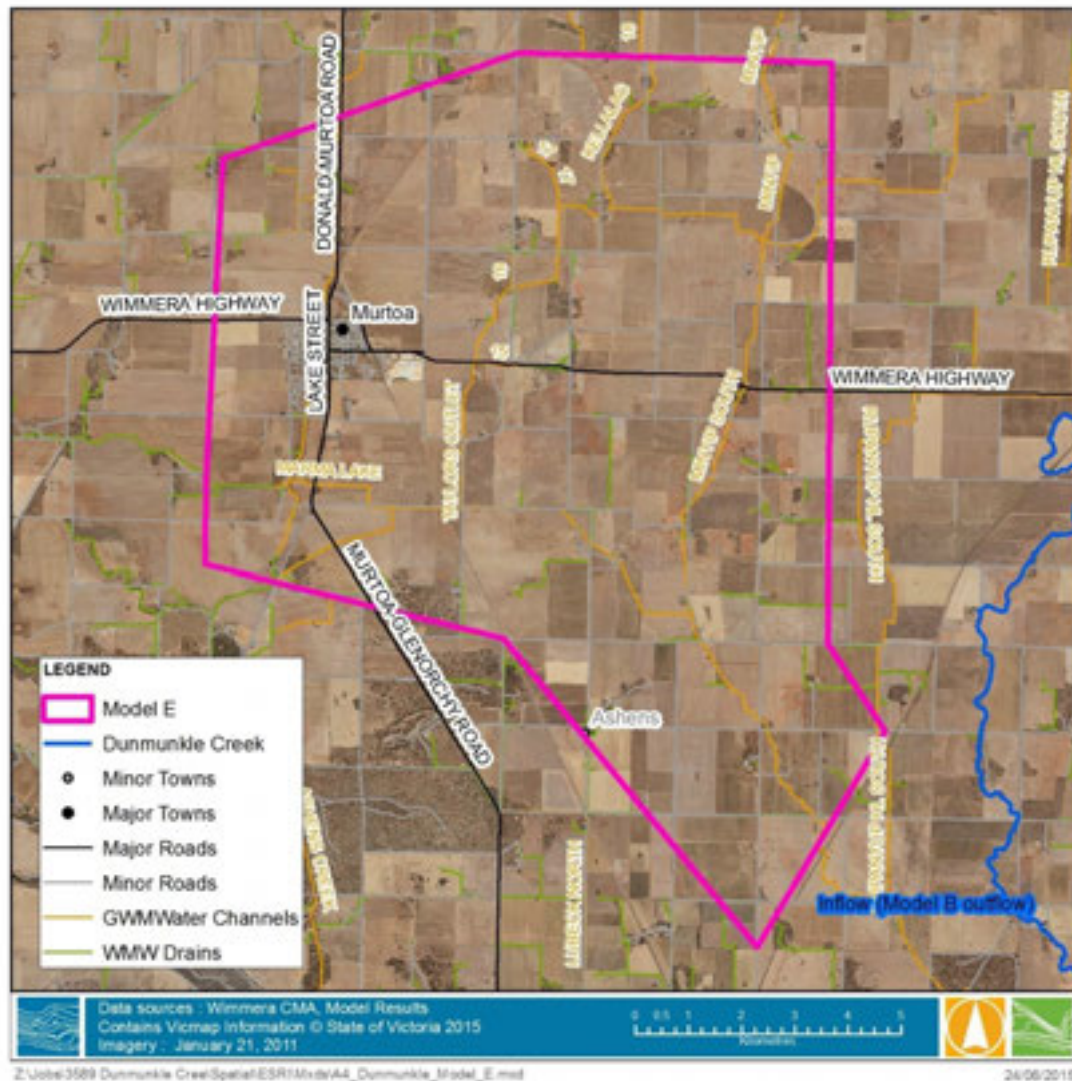


Figure 7-29 Model E - Hydraulic model structure

There were no surveyed peak flood heights available for January 2011 within Model E or Wimmera CMA estimated inundation extent. The Rapid Eye Satellite imagery available does not cover all of Model E, with the LandSat image showing better coverage.

The Rapid Eye and LandSat satellite images are shown in Figure 7-30 and Figure 7-31.

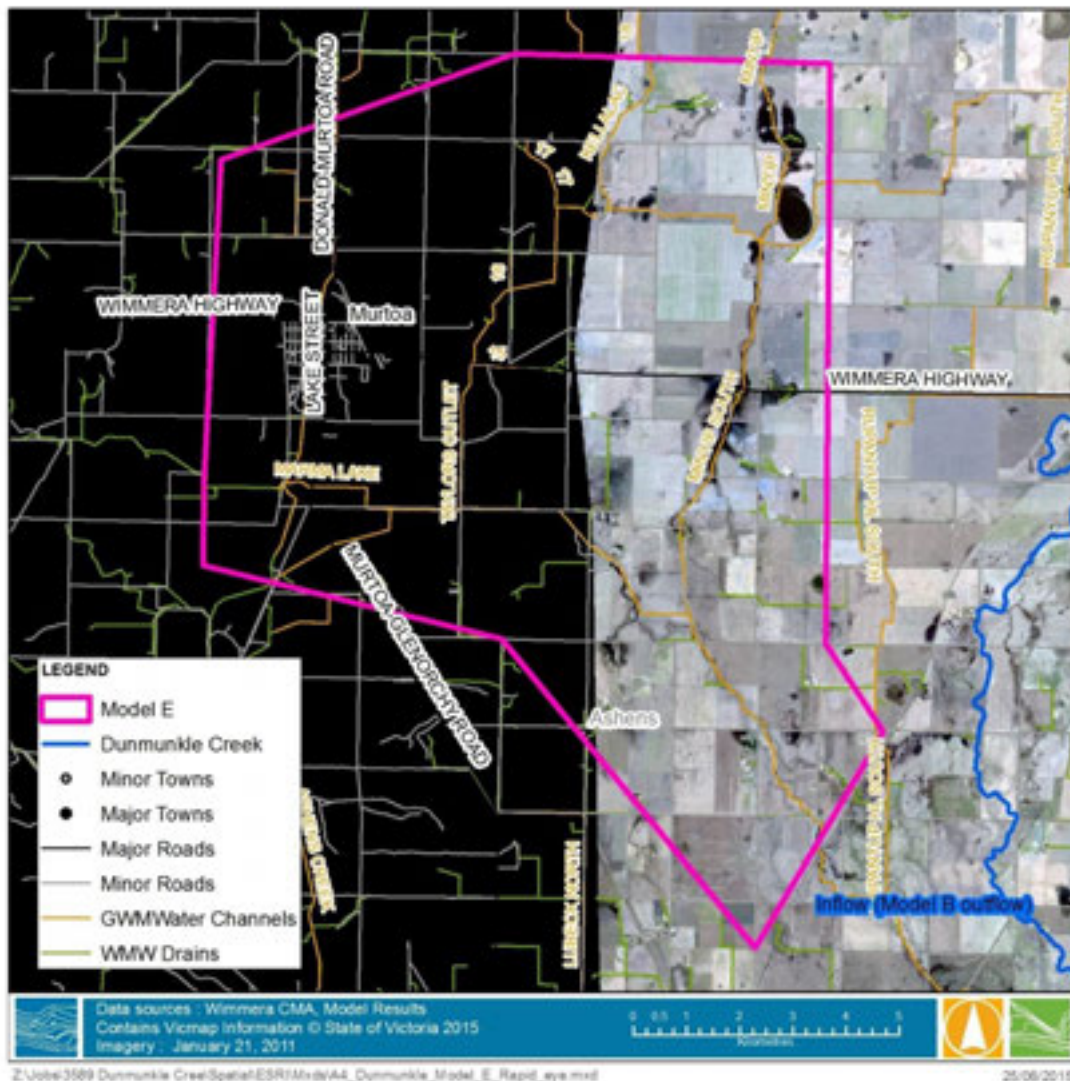


Figure 7-30 Model E – Rapid Eye satellite image

The Rapid Eye satellite imagery captured on the 23rd January 2011 shows the western breakout sometime after peak levels had occurred. The lack of water south of the Rupanyup railway line indicates water has subsided, with water remaining south of the Wimmera Highway at the Minyip South channel crossing. Some of this accumulation is likely to have been caused by direct rainfall runoff.

There is an area of black space on the western edge of the figure, this is the extent of the data collected a part of this study.

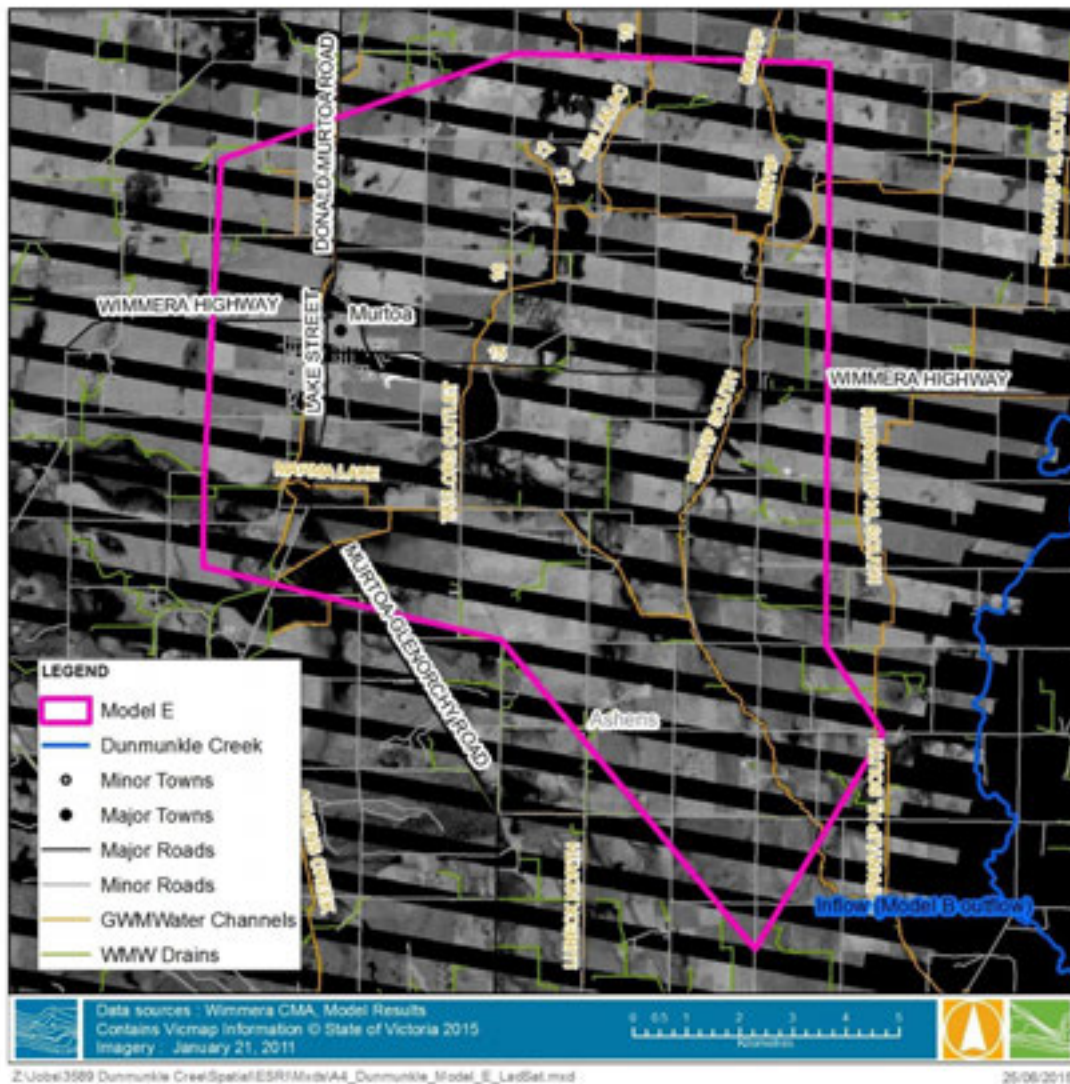


Figure 7-31 Model E – Land Sat satellite image

The Landsat satellite was captured on January 19th. The imagery better represents the observed inundation during January 2011 because of the image's coverage and timing. As discussed in Section 5.4.3, a problem with the image recording device has caused banding in the satellite image. The imagery shows three major flow paths; north along the Minyip South channel, Taylors Outlet Channel and west to Yarriambiack Creek.

The Model E hydraulic model was run using a uniform Manning's 'n' of 0.05. The modelled extents and observed flood levels are shown in Figure 7-32.

The model results show the general flow paths have been well represented, however, flow along the Minyip South Channel distributing water to the north does not appear to have the same level of inundation as shown in the satellite image. It is understood some changes had been made to this channel as part of the GWMWater channel decommissioning immediately prior to the January 2011 event. These changes are not well understood.

The satellite image also shows interaction with Yarriambiack Creek occurred during January 2011. Modelling suggests approximately 2 m³/s of overland flow was entering Yarriambiack Creek from Dunmunkle Creek.

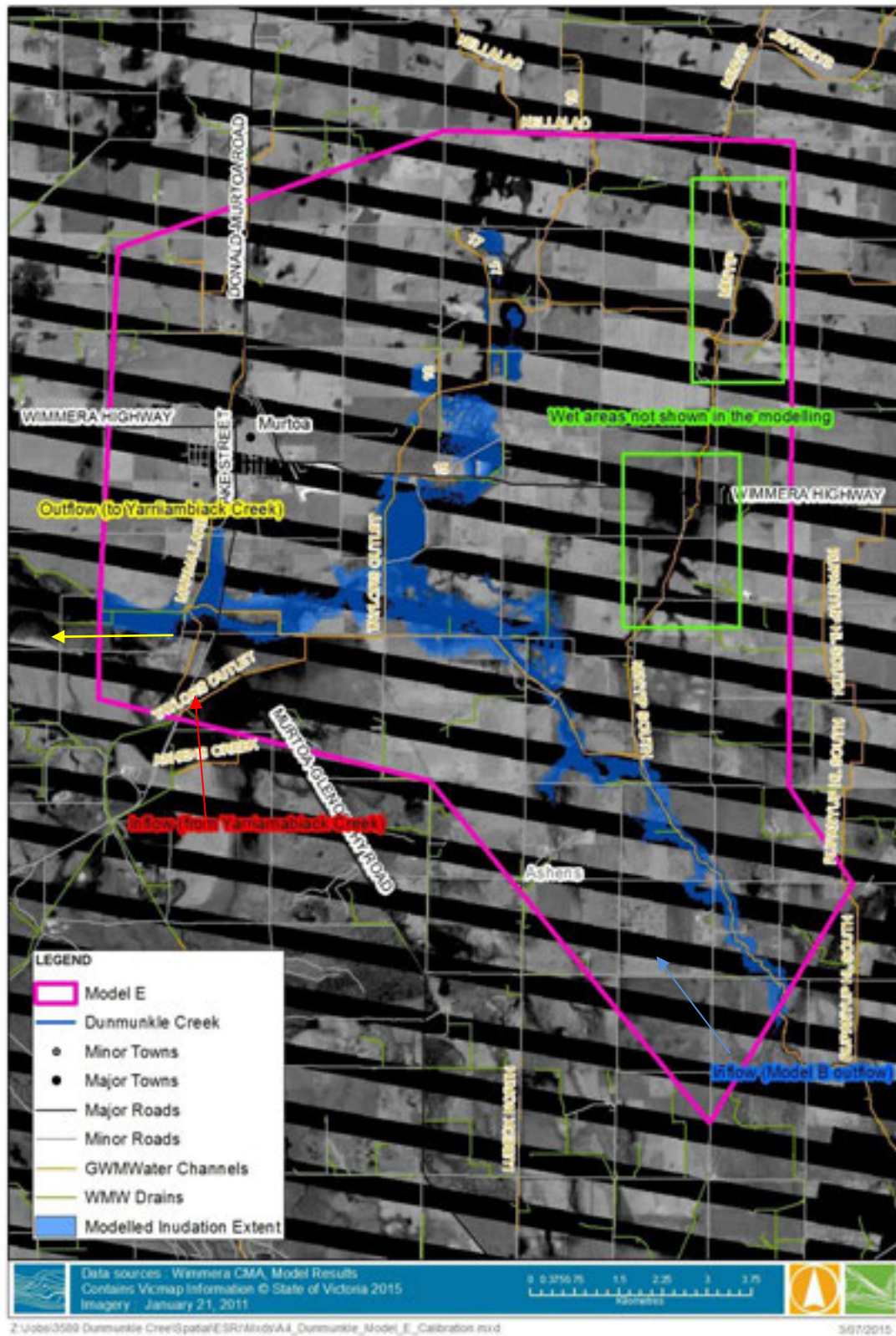


Figure 7-32 Model E – Land Sat satellite image and modelled extents



7.1.7 Discussion

Modelling of the January 2011 event along Dunmunkle Creek has shown how extremely complex the floodplain is with numerous flow paths, and distributions. In general, modelling has matched the January 2011 observations well by using uniform roughness values and ensuring manmade features are well represented in the model topography.

The distribution to Dunmunkle Creek is highly complex with floodwater distributing at the offtake point as well as numerous overland flow points. However, in general it is estimated 20% of the Wimmera River peak flow is distributed to Dunmunkle Creek. Post Bryntirion Reserve, approximately 50% of the peak flow is distributed in a westerly direction, with some interaction with floodwater from Yarriambiack Creek.

The January 2011 model calibration matched the observed data relatively well with some discrepancies around the Main Eastern Channel. Discrepancies around the Main Eastern Channel are likely to be a result of rainfall accumulation, there is also potential for changes to the channel system to have occurred during January 2011 that the study team are unaware of.

7.2 Design

7.2.1 Overview

The hydraulic model calibration was completed using uniform Manning's 'n' values and variable evapotranspiration/seepage losses. The values determined during the model calibration were adopted during the design modelling. These are shown in Table 7-5.

Table 7-5 Design Hydraulic Parameters

Model	Manning's 'n'	Evapotranspiration/Seepage Losses (mm/hr)
A	0.05	0
B	0.05	3.5
C	0.05	3.5
D	0.05	0
E	0.05	0

After the hydraulic model calibration and review by the DELWP technical review panel a series of community meetings were held to confirm the final model calibration results.

During these discussions there were two main areas where community observations of the inundation did not match with that suggested by the modelling. In both cases this was at the ends of the model extent, in areas where flood water was able to accumulate but not continue to flow on in Model E and Model D, these areas are highlighted in Figure 7-33 and Figure 7-34.

- Model D – Community feedback was that the lower end of Model D did not show the maximum inundation and neither did the satellite imagery captured on the 23rd January 2011. Peak flood levels at the lower end did not occur until almost February 2011 with the peak level generated by the volume of water in the Dunmunkle Creek system rather than the peak flow. This indicated modelling may not have a sufficient volume of water in Dunmunkle Creek, potentially due to local tributary inflows. The area of underestimation is shown in Figure 7-34.
- Model E – Community feedback was that a flow path to the north of the Dunmunkle Creek distribution to Murtoa was active during January 2011 but was not flowing in the modelling. This flow path was shown to be inundated in line scan and satellite images of the area, as shown in Figure 7-33. There was uncertainty



whether the water in this area was a product of direct rainfall runoff or part of the Wimmera River distribution to Dunmunkle Creek, there was also some uncertainty on the condition of the Minyip South Channel which flows in that direction and was partially decommissioned during January 2011.

As one measure to ensure that the model represented the volume reaching the lower end of the floodplain more accurately, no evaporation/seepage loss was applied to these downstream models.



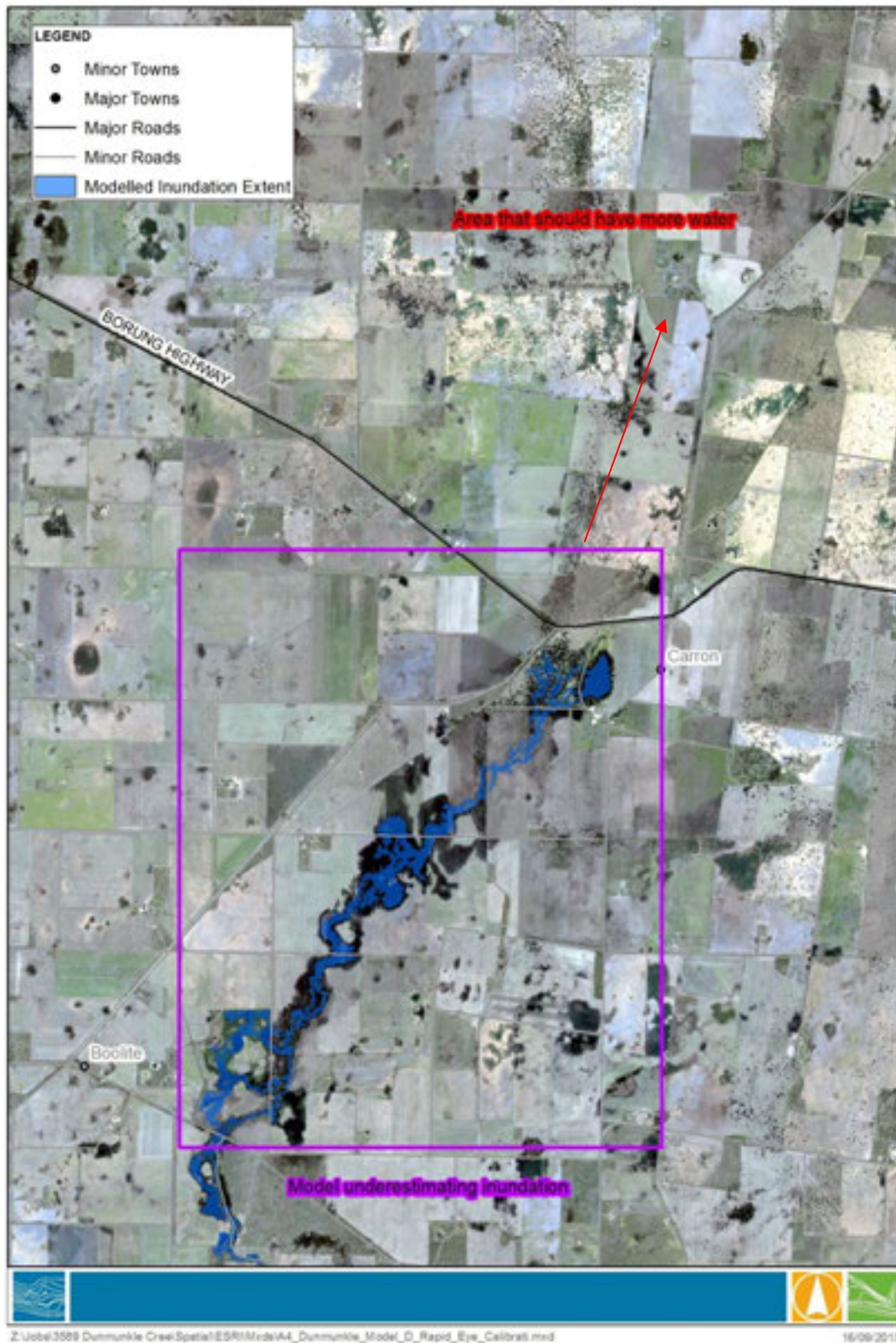


Figure 7-34 Model D – January 2011 areas not matching community observations



7.2.1.1 Model E

The area of disparity in Model E was also highlighted in aerial imagery captured during the January 2011 event and is a clear point of difference between the observed and modelled inundation.

To test the potential sources for this disparity, both increases to peak flow and starting the model with water in the overland flow path were tested. Model E was run increasing the peak flow from that modelled in the January 2011 event at, 18 m³/s, to 28 m³/s. This large increase in flow did not cause a sufficient breakout to replicate the inundation observed during January 2011.

The model was simulated with a starting initial condition of 5 m³/s for 30 hrs (540 ML) along the overland flow path, using the same January 2011 inflow as the initial calibration modelling. This increase in volume in Model E did increase water levels in some areas but did not cause a breakout to the north into the area of disparity. However, it did highlight areas of Model E where the peak flood level is largely generated by the volume of water in a flood event rather than the peak flow. A comparison of the model results with and without the additional volume created by the initial conditions is shown in Figure 7-35.

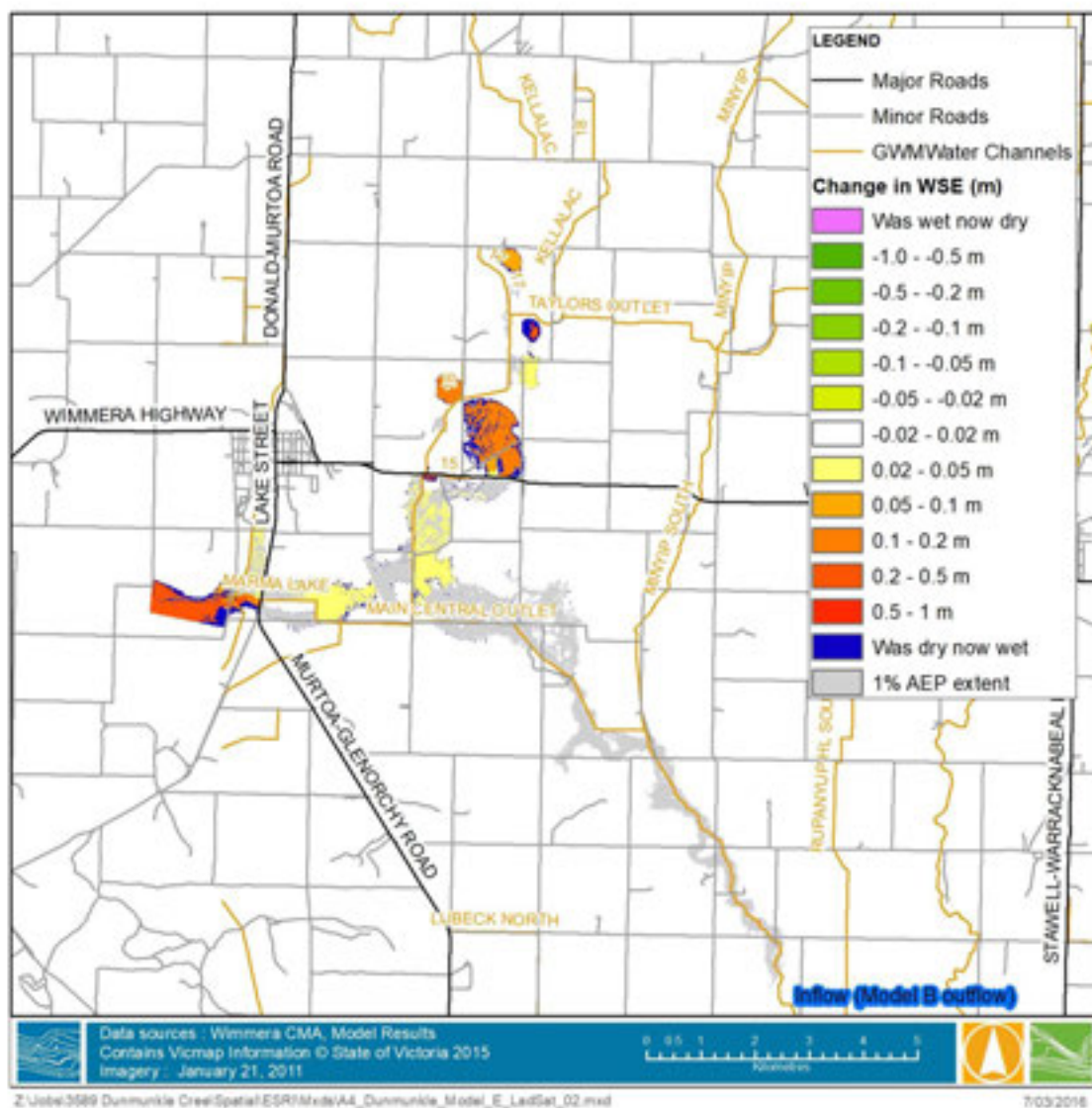


Figure 7-35 Model E – Water level difference plot with initial conditions included



The comparison of model results showed peak flow is the dominating cause of peak flood levels along the main channel, however volume is a contributing factor for flood levels at the northern ends of the terminal wetlands in the area. However, the initial conditions modelling did not cause water to flow into the area highlighted as wet by the community.

Rainfall on grid modelling of the Dunmunkle Creek⁸ system was completed to provide an understanding of overland flow direction and depth during the GWMWater Channel Decommissioning program, this modelling covered the Model E area. The model results showed water pooling in the areas highlighted by the community as inundated during January 2011, this modelling is shown in Figure 7-36 and may suggest local overland flow as the cause of this inundation.

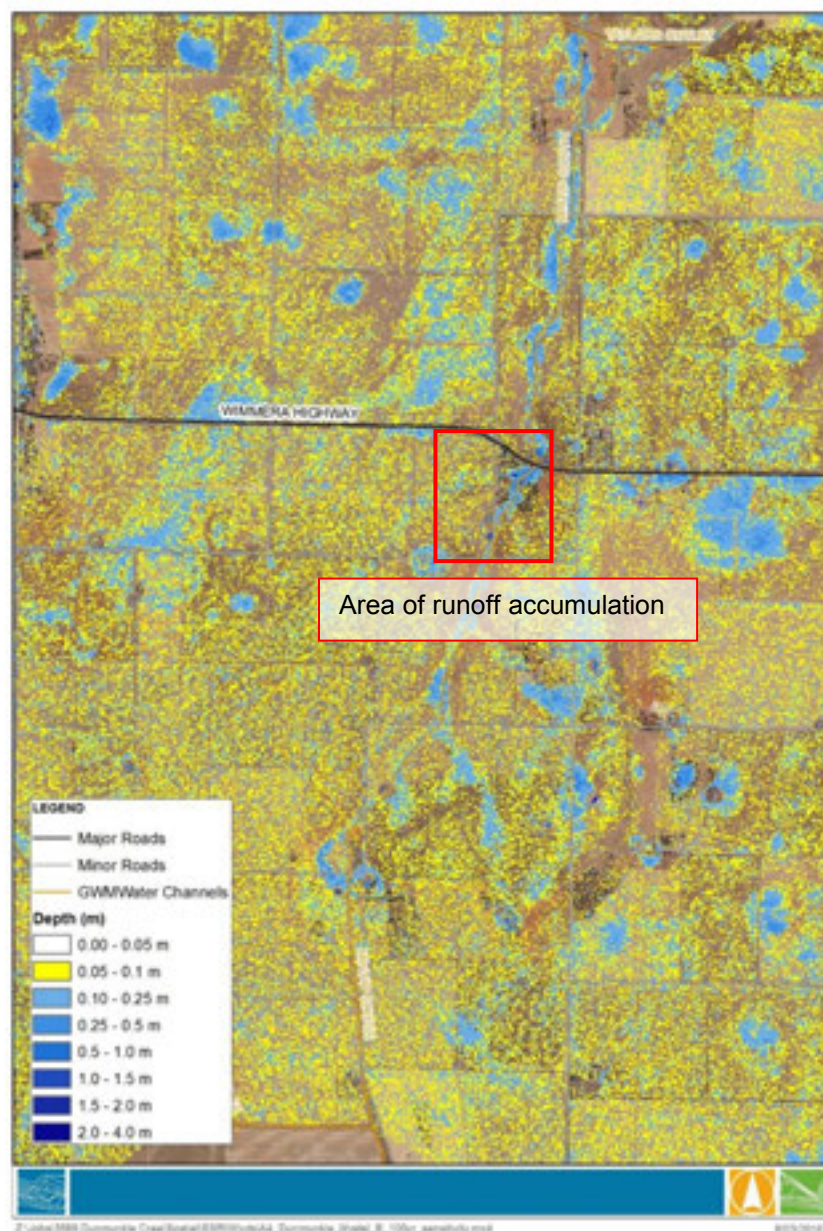


Figure 7-36 GWMWater Channel Decommissioning ROG modelling results

⁸ Water Technology, 2012 – GWMWater Channel Decommissioning ROG Modelling



7.2.1.2 Model D

Given the lower end of Dunmunkle Creek in Model D was not achieving high enough water levels and extents to match January 2011 observations, although the upstream end of Dunmunkle Creek was matching observations, it was thought the volume of flood water reaching the far end of the model may be the reason for the variations. The addition of runoff generated from local catchments was investigated to see if extra volume made enough difference to match January 2011 observations.

The contribution of Dunmunkle Creek's localised catchment area was calculated for the area north of the Bryntirion Forest by delineating the localised catchment area and calculating the local runoff likely to be generated for a range of AEP events and durations.

The catchment delineation was previously determined during the GWMWater Channel Decommissioning modelling⁹ and was calculated to be 30,700 Ha, as shown in Figure 7-37.

The rainfall excess depths across the catchment area were calculated for the 5%, 2% and 1% AEP events for durations of 1, 2, 3, 6, 12, 24, 48 and 72 hrs. The following methodology was undertaken:

- Determine the rainfall depths for each AEP and duration combination using IFD parameters⁹
- Determine rainfall hyetographs for each event using the ARR Zone 2 temporal pattern
- Remove initial and continuing losses. The initial loss represents losses due to water pooling in localised low areas and initial infiltration, and the continuing loss represents evapotranspiration and ongoing seepage through the soil profile. It was determined an initial loss of 40 mm and continuing loss of 3.5 mm/hr would be used. An initial loss of 40 mm is slightly higher than the recommended values in ARR 87 (15-35 mm). However, 40 mm is considered appropriate given the presence of road and rail infrastructure, low catchment grade and high infiltration rates on cropped agricultural ground. The initial loss of 3.5 mm/hr was adopted, the same as that determined from the hydraulic model calibration. These values were considered appropriate.

The volume of rainfall excess was calculated to estimate the possible local catchment contribution to Dunmunkle Creek. The resulting rainfall excess depths and volume contribution to Dunmunkle Creek is shown in Table 7-6.

Table 7-6 Rainfall excess and volume contribution to Dunmunkle Creek

Duration (Hrs)	Total Excess Depth (mm)			Rainfall Excess Volume (ML)		
	5% AEP	2% AEP	1% AEP	5% AEP	2% AEP	1% AEP
1	0.00	1.12	6.54	0	343	2,008
2	0.55	7.64	7.81	168	2,346	2,396
3	3.21	10.30	17.83	984	3,161	5,471
6	6.57	13.76	21.10	2,018	4,222	6,476
12	5.08	8.75	20.77	1,560	2,684	6,374
24	4.44	14.78	25.37	1,364	4,536	7,787
48	1.67	9.29	18.01	513	2,852	5,529
72	0.54	11.90	20.61	164	3,652	6,325

⁹ BoM IFD Online - <http://www.bom.gov.au/hydro/has/cdirswebx/cdirswebx.shtml>



To test the impact of water in Dunmunkle Creek prior to the Wimmera River distribution, initial conditions to Model D were generated by modelling a steady state inflow of 5 m³/s for 80 hrs (1,440 ML), this approximately corresponds to a 5% AEP rainfall excess, for a rainfall duration between 12 hrs and 24 hrs. The difference between the 1% AEP flood event water levels with and without the initial condition was calculated, as shown in Figure 7-38.

The inclusion of initial conditions representing local catchment inflows in the 1% AEP design event better matches community observations during January 2011. The January 2011 and 1% AEP events were very similar. The model results also show limited differences in the upstream end of the model with the downstream sections most impacted.



Figure 7-37 Dunmunkle Creek localised catchment area north of the Bryntirion Forest

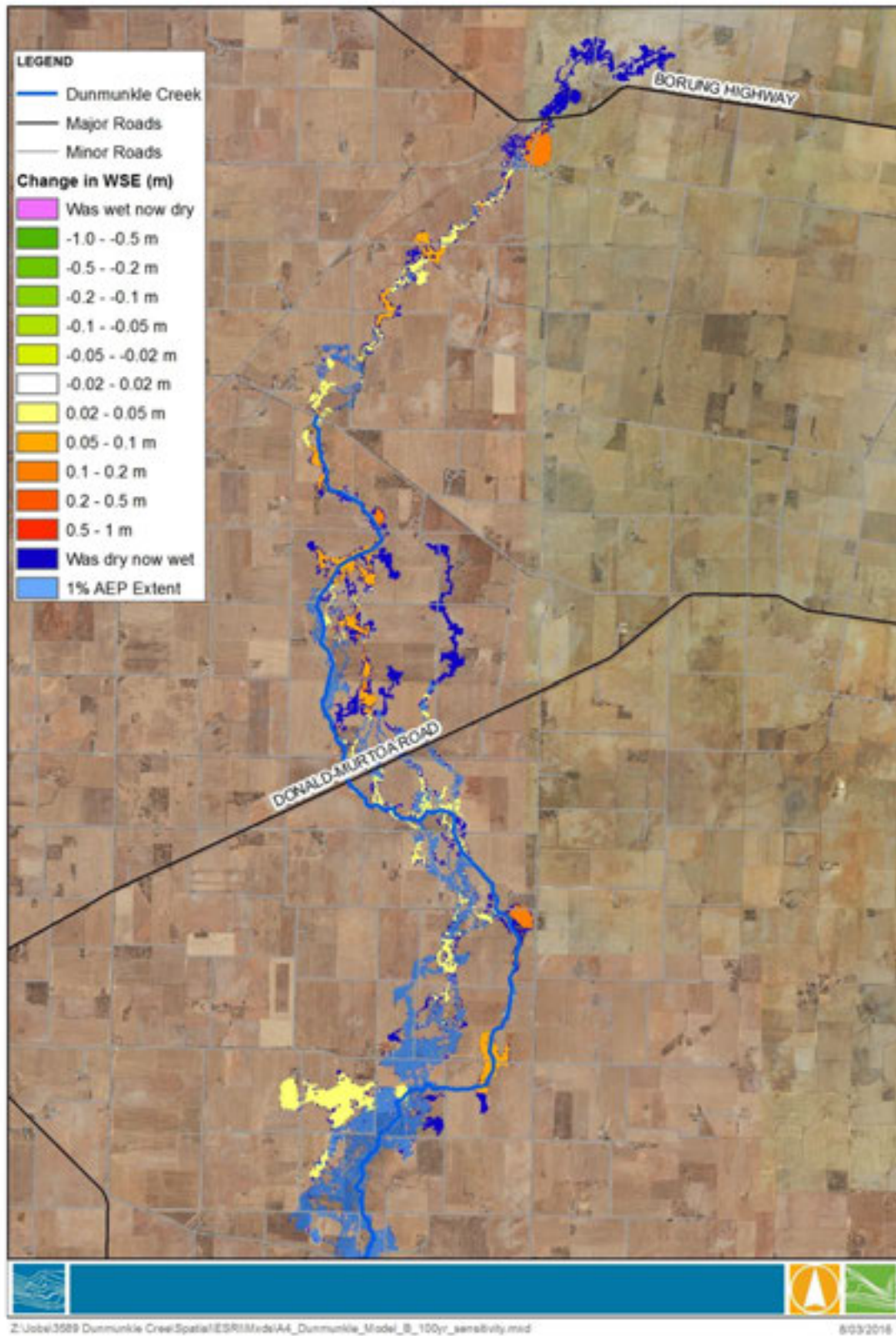


Figure 7-38 Model D - Water level difference plot with initial conditions included

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7.2.2 Results

7.2.2.1 Overview

The inundation characteristics for each modelled design event are discussed below. The discussion around each design event expands on the information available for the previous (smaller magnitude event), similar to how consequence information is outlined in a Municipal Flood Emergency Plan (MFEP) document. Discussion is from upstream to downstream (south to north). The changes resulting from the community consultation discussed in the previous section were included in the final design modelling, this included initial conditions of 5 m³/s for 80 hrs (1,440 ML), (approximately equivalent to a 5% AEP, 12-24 hr local storm event for Model D.

7.2.2.2 20% AEP Design Event

The 20% AEP flood event breaks out from the Wimmera River at the Dunmunkle Creek offtake, this is the only connection point between the Wimmera River and Dunmunkle Creek. Inundation along Dunmunkle Creek is close to one dwelling off Glenorchy Road. Inundation breaks out from the main Dunmunkle Creek channel downstream of Ridd Road and returns to the channel around 1.2 km downstream. There are also two dwellings in close proximity to the inundation, both on Ridd Road either side of Dunmunkle Creek.

Flow in Dunmunkle Creek remains mostly within channel, passing two dwellings on Riachella Tramline Road, one at Minnieboro Road and one on the corner of Tinsley Road and Stawell Warracknabeal Road. Flow breaks out of the Dunmunkle Creek channel between Tinsley Road and the Bryntirion Forrest with inundation either side of the Warracknabeal Stawell Road.

Within the Bryntirion Forest flow is distributed to the Main Central Outlet Channel with some inundation building up behind the remaining section of the Rocklands Lubeck Channel, this is confined to the Bryntirion Forest. Overland flow east of the main channel overtops the Stawell Warracknabeal Road and re-joins the main flow path to the north around halfway along the Bryntirion Forest. Flow along the Main Central Channel only makes it as far as the edge of the Bryntirion Forest.

North of the Bryntirion Forest floodwater is relatively confined to the Dunmunkle Creek Channel getting in close proximity to one dwelling on Bryntirion Road.

Flooding continues north to south of Hopefields Road where it stops, not reaching Rupanyup due to a lack of volume in the event hydrograph.

7.2.2.3 10% AEP Design Event

Similar to the 20% AEP event, flow from the Wimmera River only reaches Dunmunkle Creek at the offtake, however, rather than just the offtake point, flood water is overtopping the road in several locations and flowing into Dunmunkle Creek. Some flow is intercepted by Swedes Cutting with a limited amount directed toward the Richardson River system.

Flood water is in very close proximity (less than 10 m) to the dwelling off Glenorchy Road.

The flood extent is similar to the 20% AEP event until Glenbrook Road where several overland flow paths occur, the largest, directly north across what used to be the Charlton Channel (now decommissioned).

Flooding is in very close proximity (less than 10 m) to the dwelling on Ridds Road, east of Dunmunkle Creek.

The breakout flow upstream of the previous Charlton Channel alignment re-enters Dunmunkle Creek at Marsdale Road.



Between Marsdale Road and Minnieboro Road inundation remains relatively confined, a backwater is observed in close proximity to a dwelling on Minnieboro Road east of Dunmunkle Creek. The backwater originates at Tinsley Road. This backwater was clearly shown in aerial images captured during January 2011.

North of Tinsley Road the pattern of inundation remains similar to that of the 20% AEP event until the Bryntirion Forest where the remaining section of the Rocklands Lubeck channel is a clear restriction to flow. The backwater caused by the channel embankments forces water to the west until it hits the decommissioned section of channel where it flows north into the Main Central Outlet Channel.

Flow along the Main Central Outlet continues on toward Murtoa until around Hopefields Road where it stops.

Flow north of the Bryntirion Forest is relatively confined to Dunmunkle Creek getting in close proximity to two dwellings south of Rupanyup, both are on the eastern side of Dunmunkle Creek.

Inundation reaches the Rupanyup township immediately upstream of the water storages.

7.2.2.4 5% AEP Design Event

Additional to the Dunmunkle Creek offtake point, the Wimmera River contributes flows to Dunmunkle Creek via overland breakout flow upstream of Swedes Creek, which flows over Swedes Cutting.

Along the course of Dunmunkle Creek between its formal course and Glenbrook Road, flood water is relatively confined. At Glenbrook Road water breaks out from Dunmunkle Creek and returns to the Wimmera River (this flow bypasses the Glenorchy streamflow gauge).

The overland flow path over the former Charlton Channel has increased significantly compared to smaller events, and a much larger portion of the Stawell Warracknabeal Road is inundated north and south of Ridds Road.

An overland flow path at Marsdale Road now flows to the north-west isolating two dwellings on Ridds Road and one on Marsdale Road. One dwelling on Ridd Road is inundated below floor on the eastern side of Dunmunkle Creek. The overland flow path along Marsdale Road continues north-west and outside the area covered by this study.

Dunmunkle Creek remains confined from Marsdale Road to Minnieboro Road, with an area of backwater extending to within very close proximity of a dwelling east of Dunmunkle Creek on Minnieboro Road. A breakout from this backwater area occurs to the north east, inundating a large portion of Tinsley Road, inundation also gets within very close proximity to a dwelling on the corner of Tinsley Road and the Stawell Warracknabeal Road.

Inundation through the Bryntirion Forest is increased substantially with large portions of the Lubeck Road inundated, the Rocklands Lubeck Channel causes a restriction to overland flow with some sections overtopping. Through the Bryntirion Forest large portions of the Warracknabeal Stawell Road are inundated.

Flow along the Main Central Outlet Channel has increased with several areas breaking out of the general flow path. Flooding along this flow path extends past Crams Road inundating a wetland area south of the Wimmera Highway. Flooding isolates one property at Hamiltons Road.

North of the Bryntirion Forest, Dunmunkle Creek is relatively confined with several dwellings close to the inundation extent.

Flood water flows through the water storages in Rupanyup and there is some breakout flow toward the Rupanyup Golf Course, inundation gets within very close proximity to a dwelling at Ballantines Road, with potentially below floor inundation occurring.



North of Ballantines Road, overland flow is confined until Dunmunkle Creek Road where it spills out into a large wetland area.

North of Barkers Road it becomes confined with larger areas of inundation at Banyena-Pimpinio Road and downstream of Minyip-Banyena Road.

North of Gun Club Road, flood water is relatively spread out with water flowing in two directions, a more confined flow path along the Dunmunkle Creek North Channel and a broader flow path north of Minyip-Rich Avon Road. Both flow paths are relatively confined and join at two locations, north and south of Delavedovas Road.

Flow is then well confined along the East Karkarook Channel to Lawler Road, from this point flow is more spread out and disconnects from the East Karkarook Channel (currently blocked).

Flood water reaches north of Habels Road.

7.2.2.5 2% AEP Design Event

Very similar flow distribution compared to 5% AEP event from the Dunmunkle Creek offtake point to Ridd Road. The dwelling on Glenorchy Road is now inundated below floor, any lower levels are likely to be inundated.

A dwelling south of Ridd Road, east of Dunmunkle Creek, is also likely to be undated below floor, with lower levels inundated.

An overland flow path along the Warracknabeal Stawell Road is activated immediately north of Marsdale Road, the flow path is broad, inundating agricultural land and stops south of Ashens Cemetery Road.

The inundation extent also increases north of Minnieboro Road widening along the Stawell Warracknabeal Road. The pattern of inundation remains similar to the 5% AEP event until north of the Bryntirion Forest where it spreads out significantly with another overland flow path occurring parallel to Dunmunkle Creek on the eastern side. This overland flow path re-joins Dunmunkle Creek north of Hopefields Road.

A dwelling west of Dunmunkle Creek off C Readings Road becomes isolated. There is significantly more inundation along Dunmunkle Creek in this area with a large breakout from the waterway, under the railway embankment culverts and into the Rupanyup township. This inundation causes above floor inundation of 26 dwellings/commercial buildings and below floor inundation of an additional 35 buildings. The breakout flow pools in Rupanyup and flows to the north east reaching the corner of Gibson Street and Depot Road.

Buildings inundated above floor are located in Wood Street, Westcott Avenue, Dyer Street, Walter Street, Taylor Street, Steward Street, Cromie Street, Gibson Street and the Wimmera Highway.

A breakout from Dunmunkle Creek also occurs through the Rupanyup Golf Course inundating two buildings below floor.

Between J Sudholzs Road and Minyip-Banyena Road the inundation extent remains relatively similar to that determined in the 5% AEP event. Significantly more inundation occurs north of Minyip-Banyena Road with more inundation to the west, north and south of J Woods Road.

The inundation extent along the eastern and western flow paths at the Minyip Rich Avon Road have a similar extent of inundation to the 5% AEP, with more overland flow along the western path. The Donald Murtoa Road is inundated in several locations, flow continues north to the Borung Highway, terminating in a wetland west of Carrion-Lawler Road.



7.2.2.6 1% AEP Design Event

The Dunmunkle Creek offtake and overland flow pattern is very similar to the 2% AEP event with a larger extent and deeper inundation of roads and agricultural areas.

Inundation along a breakout flow path along Wal Wal Station Road is increased.

The general extent and depth of inundation in Rupanyup is increased, with 38 buildings inundated above floor and a further 22 inundated below floor. Additional Streets with buildings flooded above floor include Connolly Parade.

North of Rupanyup inundation follows the same flow paths as the 5% AEP event with increased depth and extent of inundation.

Inundation extends to north of the Borung Highway at around Good Lane.

7.2.2.7 0.5% AEP Design Event

The Dunmunkle Creek offtake and overland flow pattern is very similar to the 1% AEP event from the offtake point to Riachella Tramline Road with a larger extent and deeper inundation of roads and agricultural areas.

The overland flow path at Ashens Cemetery Road west of Dunmunkle Creek is increased compared to the 1% AEP event, with the flow path no longer pooling but continuing on to the north and joining the Murtoa flow split along the Main Central Outlet channel.

Greater inundation is observed through the Bryntirion Forest with an increase in inundation extent east of Dunmunkle Creek, north of Hopefields Lane, this re-joins Dunmunkle Creek.

Inundation in Rupanyup is increased with 49 buildings inundated above floor and a further 41 inundated below floor.

North of Rupanyup, the inundation extent and depths have generally increased with no changes to flow paths.

7.2.3 Probable Maximum Flood

Initially, PMF flows were to be generated using the rapid assessment method detailed by Nathan et al¹⁰. Nathan uses a prediction equation based on a sample of 56 catchments in South Eastern Australia, ranging in size from 1 km² to 10,000 km². The equation derived by Nathan et al (1994) was as follows:

$$Q_p = 129.1 A^{0.616}$$

$$V = 497.7 A^{0.984}$$

$$T_P = 1.062 \times 10^{-4} A^{-1.057} V^{1.446}$$

Where Q_p is the PMF peak flow (m³/s), A is the catchment area (km²).

The area upstream of the Wimmera River at Glenorchy streamflow gauge is 1,953 km², which resulted in a peak flow of 13,740 m³/s. This flow is considered unreasonably high and it was decided that an alternative method to estimate a PMF flow was required. It was decided that the flood frequency analysis would be

¹⁰ Nathan. R. J., Weinmann, P. E. and Gato, S. A. (1994), 'A Quick Method for Estimating Probable Maximum Flood in South Eastern Australia', Water Down Under 94 Conference Proc., Adelaide, November, 1994, pp. 229-234



extrapolated out to the 100,000 year ARI event. The FFA determined a peak flow of 1,024 m³/s. This is considered a much more reasonable estimate as it is approximately double the January 2011 flow.

7.2.4 Climate Change Scenarios

The impacts of climate change were tested by increasing the rainfall intensity by 5% per degree of warming, in line with latest guidance from Australian Rainfall and Runoff¹¹. A scenario of 2°C of warming (i.e. 10% increase in rainfall intensity) was adopted for this sensitivity test. This is consistent with 'Climate Change in Australia Projections'¹² report which suggests for an intermediate climate scenario, a temperature increase of between 1.1°C to 2.0°C is likely for the Southern Slopes of Australia.

The 10% increase in rainfall intensity was applied to the BoM URBS model to determine the increase in peak flow expected at Glenorchy. This relative increase was then applied to the 1% AEP peak flow determined in the Flood Frequency Analysis.

A 10% increase in rainfall intensity resulted in a 20% increase in peak flow at Glenorchy, this resulted in the peak 1% AEP flow increasing from 424 m³/s to 509 m³/s, slightly larger than the 0.5% AEP event. A comparison of the existing and climate change scenario extents around Rupanyup are shown in Figure 7-39.

¹¹ Engineers Australia (2014), Australian Rainfall and Runoff Discussion Paper: An Interim Guideline for Considering Climate Change in Rainfall and Runoff (Draft). Report No. ARR D3

¹² CSIRO. (2005). Climate Change in Eastern Victoria - Stage 1 Report: The effect of climate change on coastal wind and weather patterns. CSIRO.

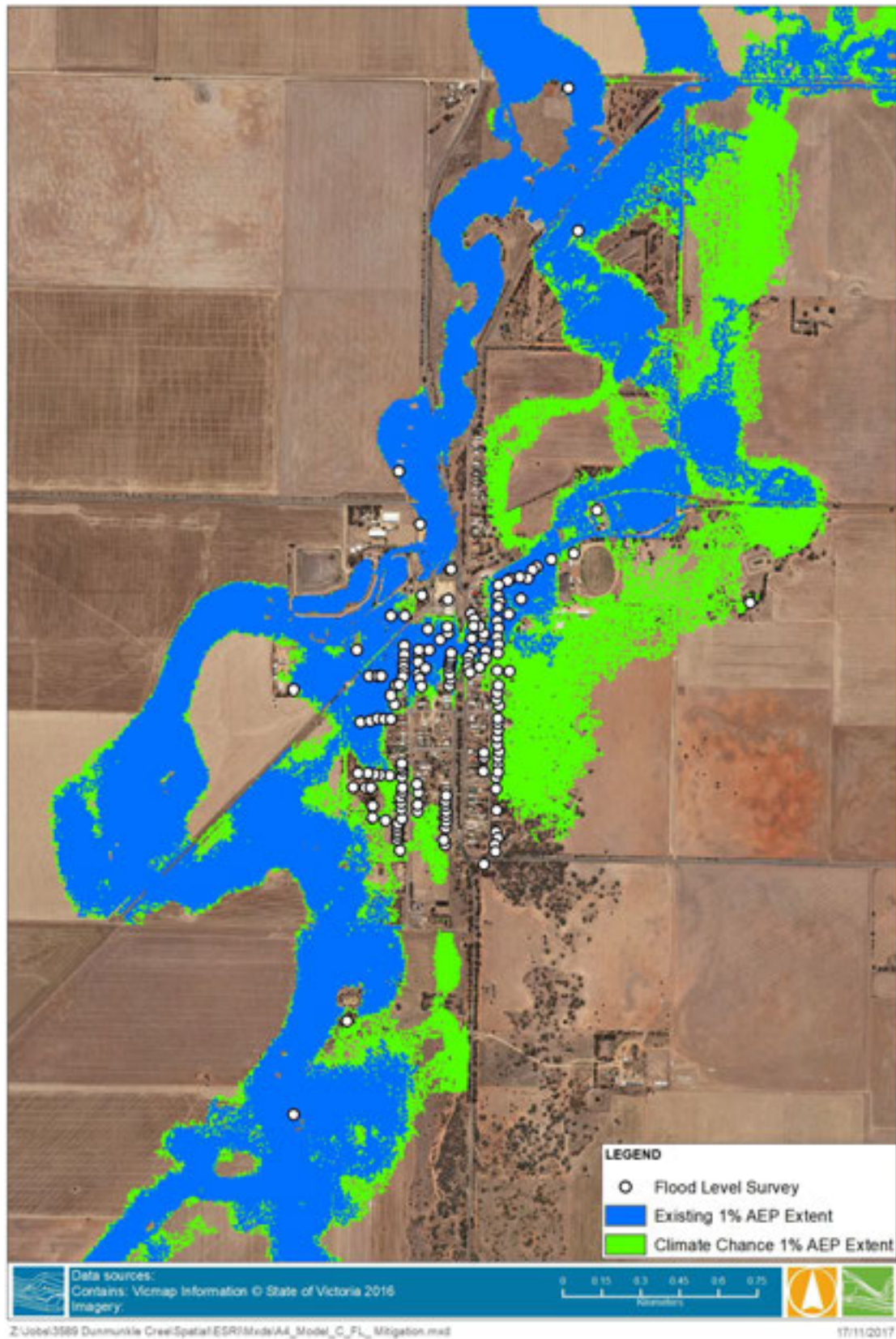


Figure 7-39 Comparison of existing and climate change inundation extents around Glenorchy

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7.2.5 Additional Sensitivity Testing

Additional to the initial conditions and peak flow sensitivity testing discussed for Model D and E, additional sensitivity testing on Model B was undertaken varying the model roughness (Manning's 'n' values) categorising land use and comparing model results with and without continuing losses.

Varying the model roughness according to land use made very little difference in terms of water levels and extents, this is representative of the homogenous nature of Dunmunkle Creek and the associated floodplain. It is also representative of the low velocities and slope in the study area.

Removing the continuing loss of 3.5 mm/hr increased water levels and extent, as shown in Figure 7-40. The increase in water levels was greatest in confined areas, ranging between 0.05 and 0.1 m. The most notable change was the increase in inundation extent with two overland flow paths occurring from the south and one further to the north. These flow paths did not occur to the same extent as shown during January 2011 which was larger than a 1% AEP flood event. During the model calibration process it was also found that without losses in Model B, flow rates in Model C were too high causing excessive inundation in the Rupanyup township. The flood levels in Rupanyup could be reduced, but in order to match the flood levels observed during January 2011 unrealistic Manning's "n" of 0.02 was required. This suggests that the combination of losses adopted and roughness values are providing a reasonable match to observed flooding in January 2011.

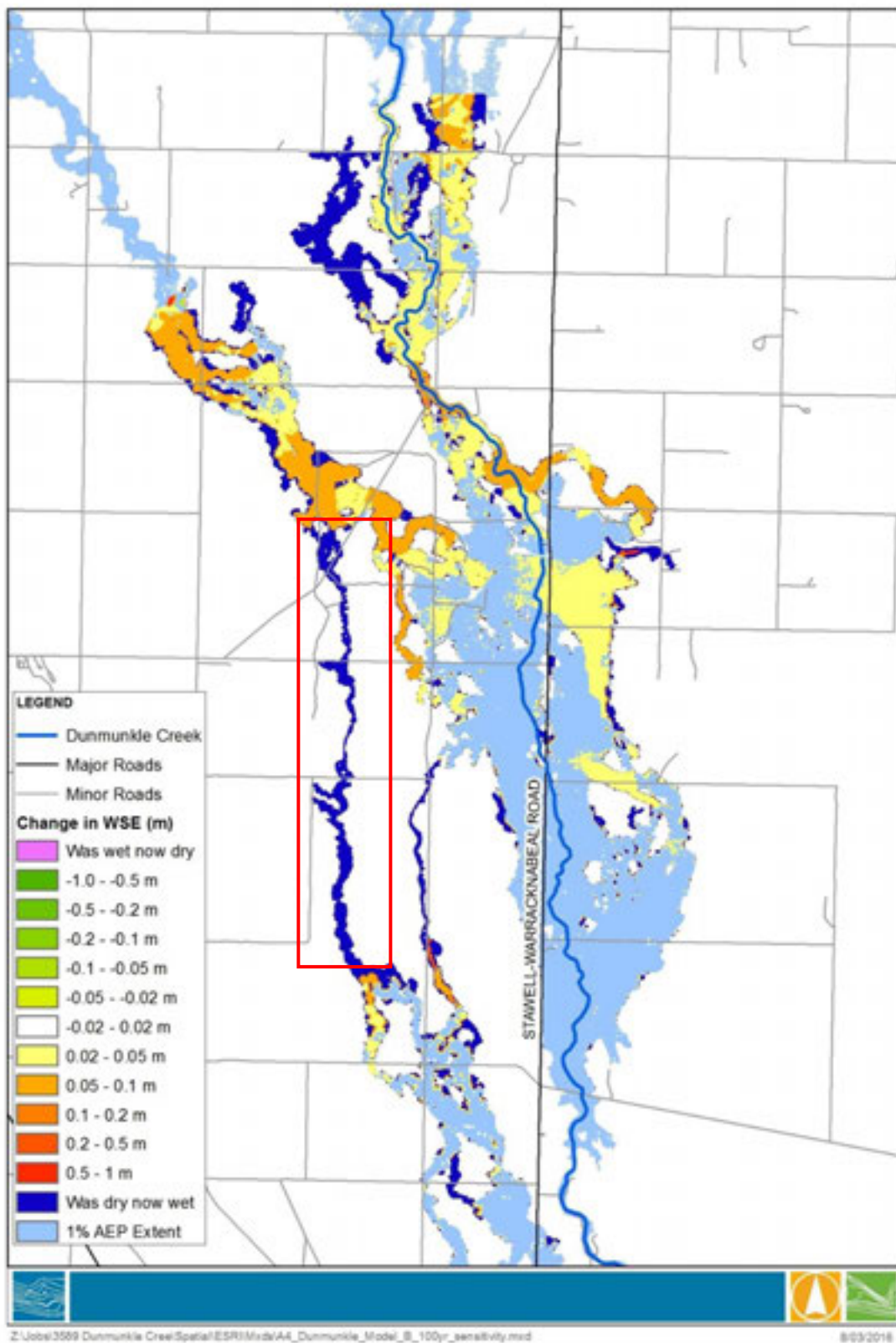


Figure 7-40 Model B – Water level difference plot with no continuing losses

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7.2.6 Inundation potential beyond Carron

The potential for flood water to continue north above Carron was tested through running Model D with a steady state inflow at 5 m³/s for 24 days (total volume of 10,368 ML). The volume of water entering the model far exceeds that occurring in any of the modelled AEPs (except for the PMF).

The model results showed a well-defined flow path as far as Lake Carron. North of Lake Carron the floodplain becomes very wide with a large area north of the Borung Highway inundated up to 1.5 m deep. This area must fill before water is able to flow north. If there was sufficient volume for this area to fill flow would continue north to Watchum Bushland Reserve. This is demonstrated in Figure 7-41.

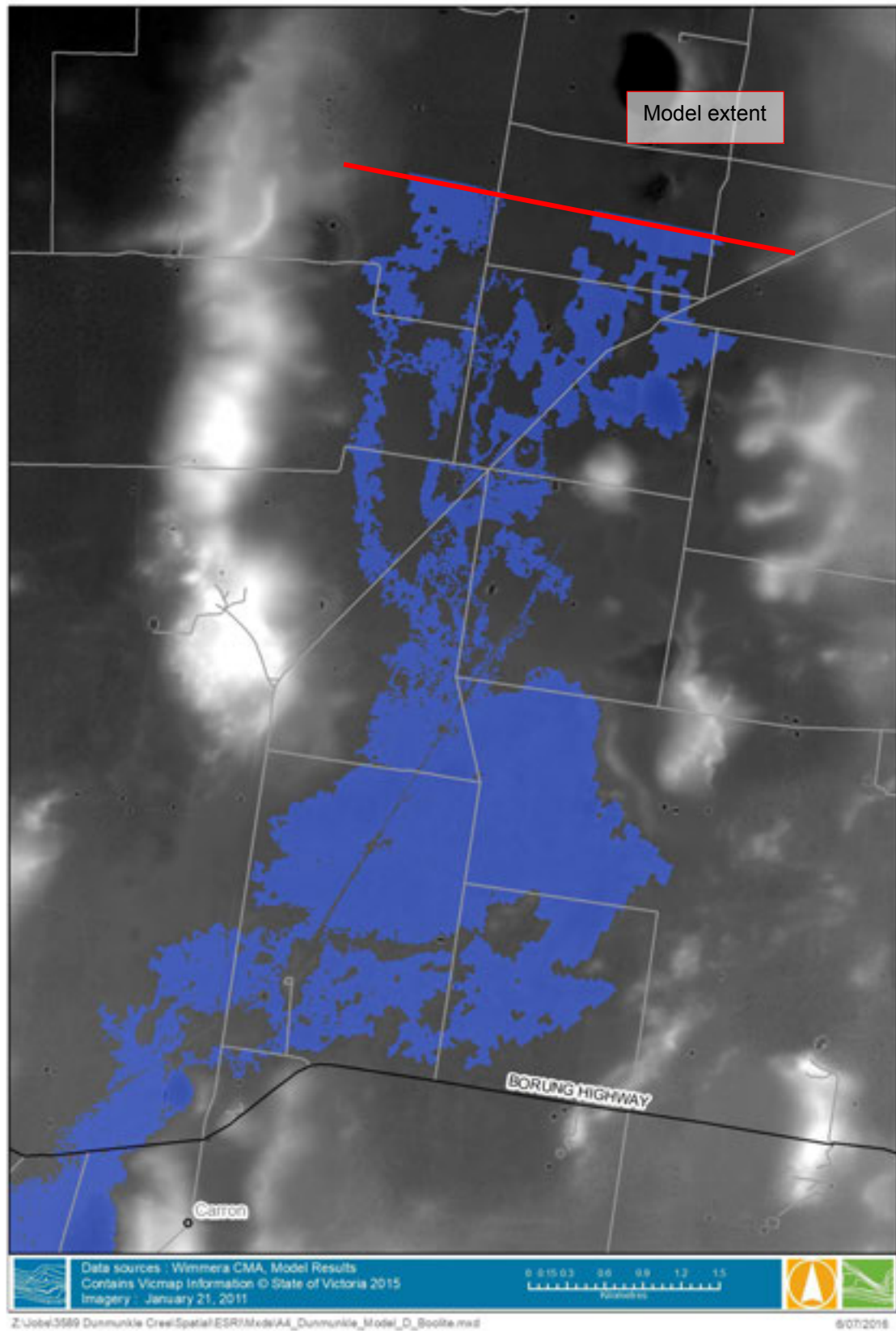


Figure 7-41 Inundation north of Carron

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8 MITIGATION

8.1 Overview

Flood risk and flood damages along Dunmunkle Creek can be reduced via both structural and non-structural mitigation. Non-structural mitigation measures ensure that development doesn't occur in high flood risk areas and that the community is aware of the potential impact a given flood may have and how best to be prepared. Structural mitigation options are engineering solutions focused on reducing flood extent, depth and damage.

8.2 Buildings at Risk of Flooding

8.2.1 Overview

To aid the discussion of mitigation options the 1% AEP extent was used to highlight any potential buildings impacted. Floor level survey captured during the Glenorchy Flood Study³ and floor level survey captured along Dunmunkle Creek as part of this project was used. Each model is discussed individually to break down the understating of potential mitigation on a location basis.

8.2.2 Model A

Of the 64 buildings surveyed during the Glenorchy Flood Study there are 47 within the 1% AEP flood extent. Glenorchy was not a focus of this project; however, the Glenorchy area was covered by the modelling to enable a good understanding of the flow distributed from the Wimmera River to Dunmunkle Creek. There is potential for the GWMWater Channel decommissioning to impact on properties at Glenorchy. For these reasons, Glenorchy flood impacts and mitigation options are discussed briefly in this report.

Floor levels captured previously during the Glenorchy Flood Study³ are shown in Figure 8-1. Ten additional floor levels were captured during this project in the Model A area and are shown in Figure 8-2. Of these ten, six were within the 1% AEP flood extent and four were on the fringe of the extent.

There is potential for broadscale flood mitigation for properties in Glenorchy given their close proximity to one another, however consideration of mitigation for these buildings was outside the scope of this project. On initial inspection broad scale mitigation for Glenorchy is difficult, however the potential for mitigation could be explored in the future. A paper was produced discussing the potential to lift inundated buildings above flood level and the associated costs.

Buildings surveyed as part of this project are much more isolated with limited potential for a collective mitigation scheme. Of the 10 buildings surveyed as part of this project within Model A, none were found to be inundated above floor up to the 0.5% AEP event. Of the 10 buildings, 5 were flooded below floor in the 2% and 1% AEP flood events with an additional building flooded below floor at the 0.5% AEP flood event. All 10 buildings surveyed were within 50 m of the flood extent in a 2% AEP flood event.

The property closest to becoming inundated above floor was on Glenorchy Road, 0.06 m above the 0.5% AEP flood level, this property is highlighted in Figure 8-2.

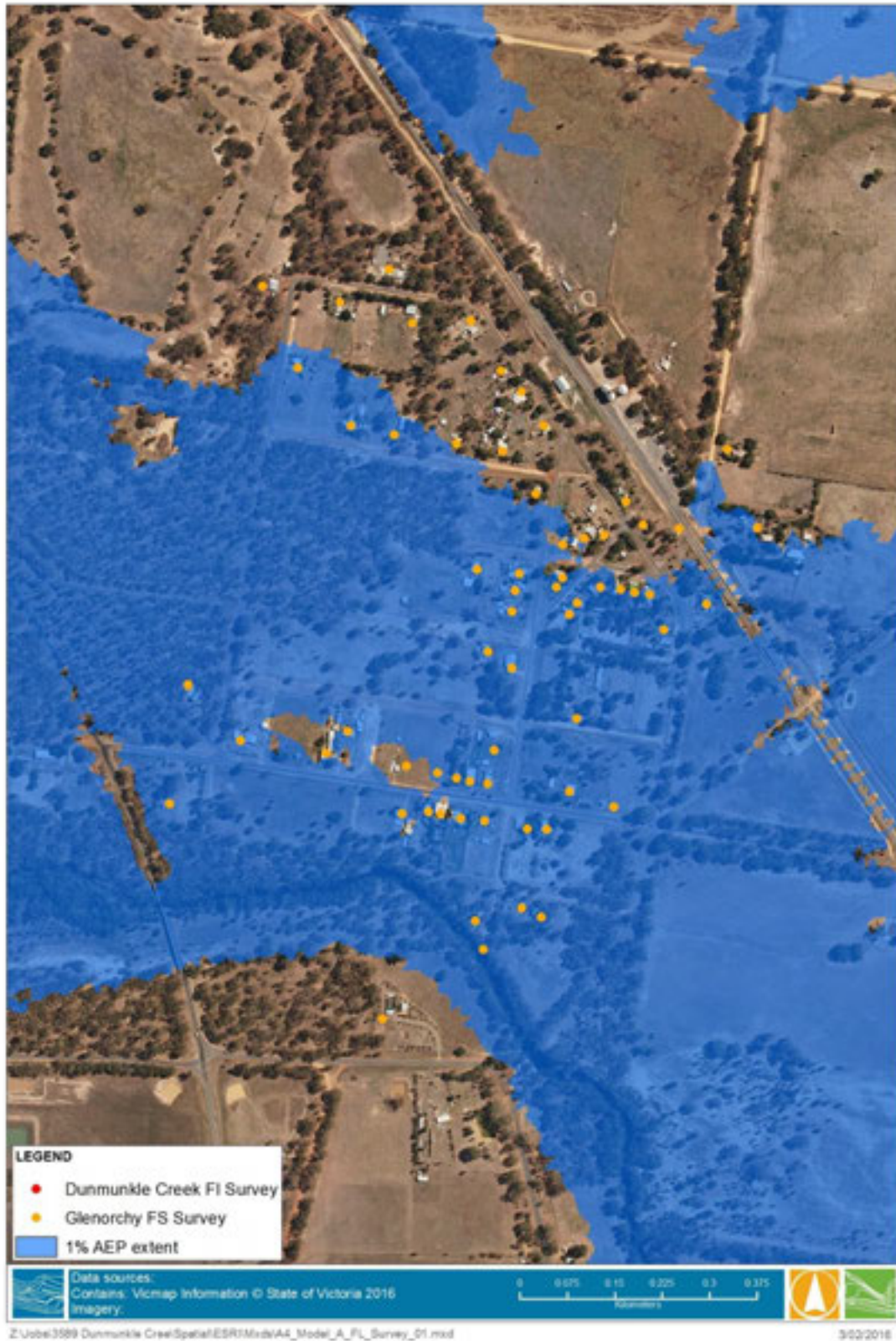


Figure 8-1 Glenorchy Flood Study – Model A Floor Level Survey – Impacted buildings

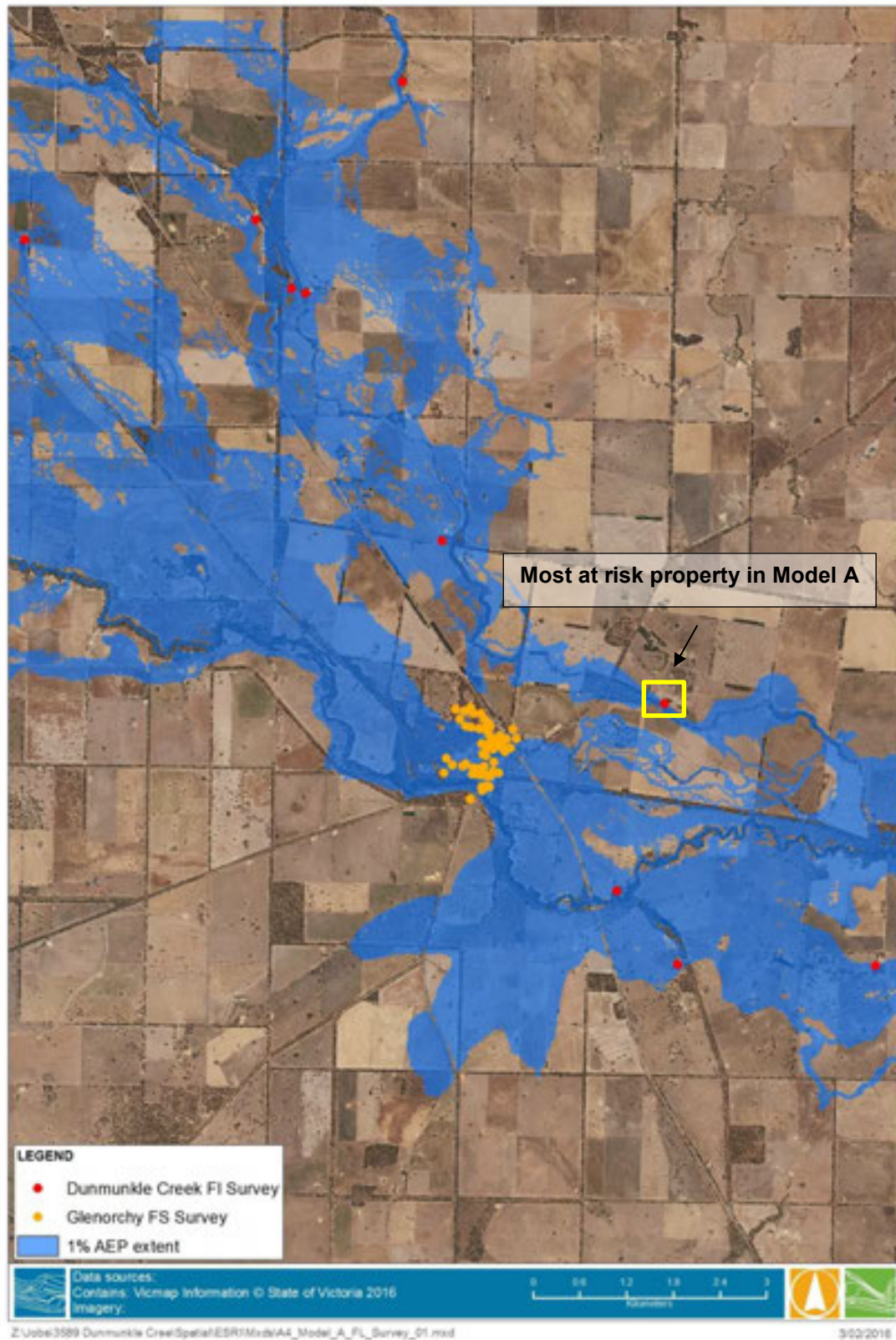


Figure 8-2 Dunmunkle Creek Flood Investigation – Model A Flood Level Survey – Impacted buildings



8.2.3 Model B

There were 11 buildings surveyed within the Model B area. Of these 11 buildings, two were within the 0.5% AEP flood extent, completely surrounded and isolated by floodwaters, however none are flooded above or below floor. All buildings were in very close proximity of the 1% AEP inundation extent, most within 20-50 m. The buildings surveyed within Model B are shown in Figure 8-3.

Similar to Model A, all the buildings within Model B are very isolated with a limited potential for collective mitigation.

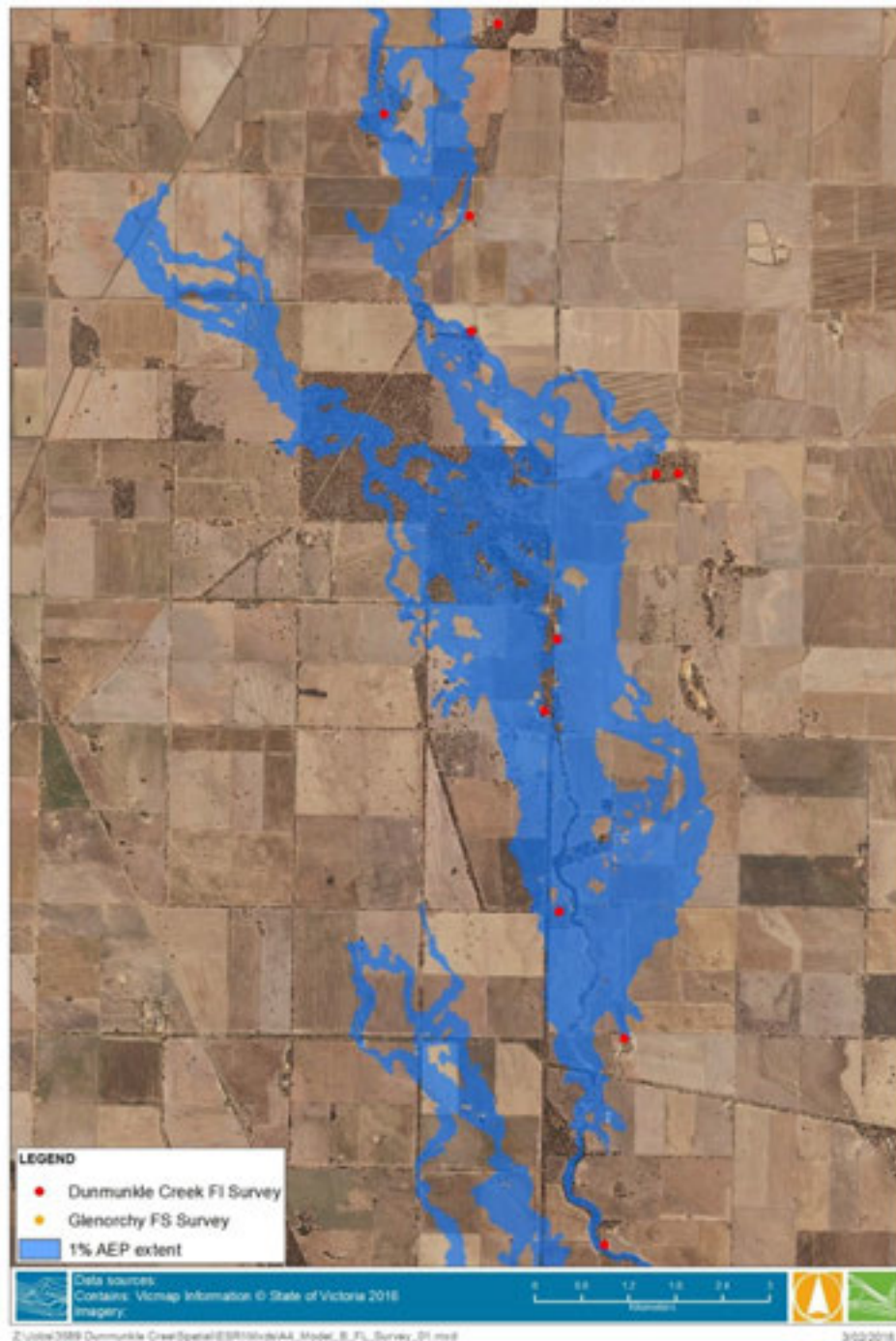


Figure 8-3 Dunmunkle Creek Flood Investigation – Model B Flood Level Survey – Impacted buildings



8.2.4 Model C - Rupanyup

Model C covers the Rupanyup township with significantly more buildings surveyed than within the other model extents. Within Model C, 155 building floor levels were surveyed. Rupanyup is subject to inundation by two separate mechanisms, direct catchment runoff from the 4,050 Ha local catchment area to the south east, and inundation from Dunmunkle Creek. The two sources of inundation have different characteristics; warning time, duration of inundation, hazard etc. In Rupanyup, inundation caused by direct catchment runoff impacts a different area to Dunmunkle Creek inundation, primarily on the eastern side of the Stawell Warracknabeal Road. Dunmunkle Creek inundation has the potential to impact properties on the eastern side of the Stawell Warracknabeal Road, dependent on the mitigation actions that are taken during the event, however most of the inundation caused by Dunmunkle Creek occurs on the western side of the Stawell Warracknabeal Road. Such flooding occurs considerably later due to the larger catchment and distance for water to travel.

Direct catchment runoff and Dunmunkle Creek inundation in Rupanyup are discussed separately below:

- Direct Catchment Runoff – of the 155 buildings surveyed in Rupanyup there are 105 within the 1% AEP flood extent for a 3 hour duration storm event. There are two areas of Rupanyup impacted by stormwater inundation. Properties on the eastern side of Stewart Street, with the area being particularly low lying. The other area of Rupanyup impacted is along what appears to be a former course of Dunmunkle Creek. There is a low flow path through the township which is no longer connected to Dunmunkle Creek but runs parallel. The extent of the 1% AEP 3 hour duration event and properties surveyed are shown in Figure 8-4.
- Dunmunkle Creek Inundation – of the 155 buildings surveyed in Rupanyup there are 75 within the 1% AEP flood extent. The main source of flood water into the township is through water flowing through two 600 mm pipe culverts under the railway embankment (these were blocked during January 2011), and overland flow from the south originating from a Dunmunkle Creek breakout further upstream. The 1% AEP flood extent and properties impacted are shown in Figure 8-5.

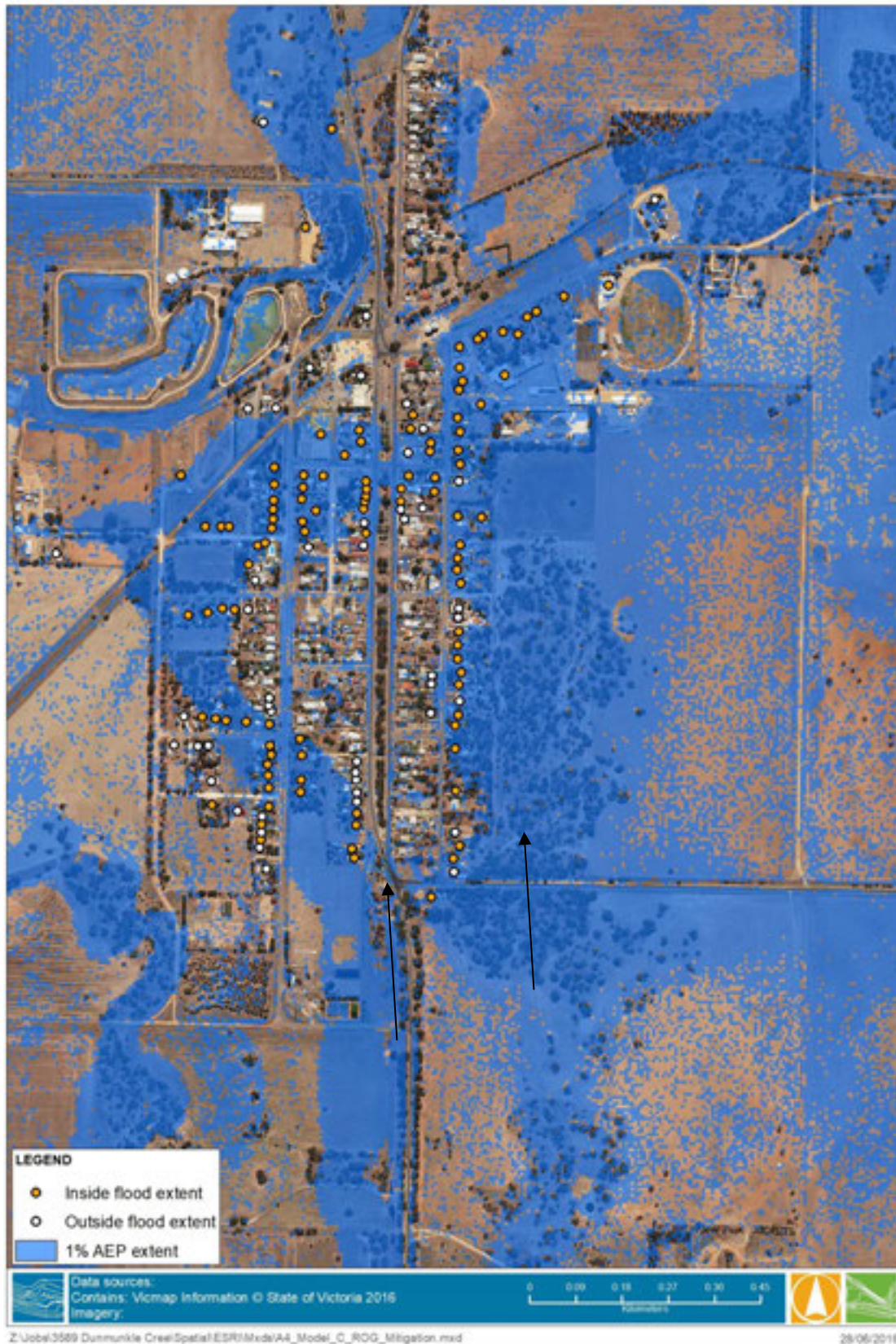


Figure 8-4 Model C – Direct catchment inundation, buildings within the 1% AEP flood extent

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Figure 8-5 Model C - Dunmunkle Creek inundation, buildings inundated above floor for the 1% AEP flood extent

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1.1.1 Model D

There were 8 buildings surveyed within Model D, all at the southern end of the model. None of the buildings were within the 1% AEP flood extent, however all were in direct proximity to inundation.

The 1% AEP flood extent for Model D and the surveyed buildings are shown in Figure 8-6.



Figure 8-6 Model D - Dunmunkle Creek inundation, 1% AEP flood extent and surveyed buildings

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1.1.2 Model E

There were no properties surveyed in Model E as no buildings were within or near the 1% AEP flood extent. The buildings closest to the 1% AEP flood extent were immediately downstream of the Lubeck-Rupanyup Railway line and were still a reasonable distance (30 m minimum) from being inundated. Review of the 0.5% AEP flood extent revealed one property in Model E should have been surveyed. This property is located on the corner of the Wimmera Highway and Excell Road. The 1% AEP flood extent for Model E is shown in Figure 8-7, highlighting the area with the additional property. A closer perspective of the area is shown in Figure 8-8 including the 1% and 0.5% AEP extents. Subsequent floor level survey indicated the dwelling was above the 1% AEP flood level.

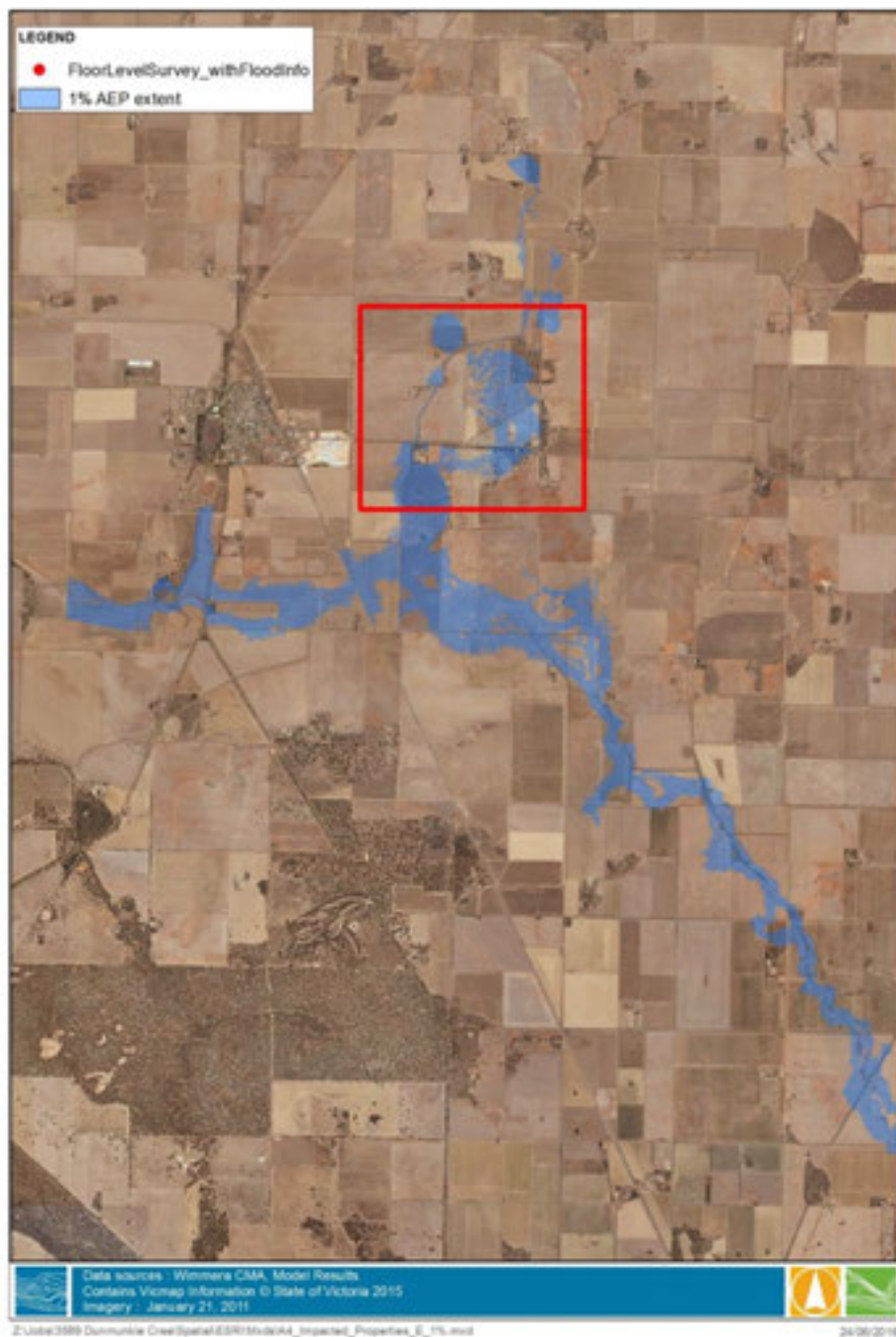


Figure 8-7 Model E - Dunmunkle Creek inundation, 1% AEP flood extent



Figure 8-8 Model E - Dunmunkle Creek inundation, 0.5% and 1% AEP flood extent, highlighting property with missing survey

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8.3 Structural Mitigation

8.3.1 Overview

During this project a flood event occurred in September 2016. Before the flood, removal of the Rupanyup water storages was identified as a preferable mitigation option for Rupanyup. Given the impact of the removal was well understood along with the benefits a recommendation to undertake the works was supported by the ICC, and works were partially undertaken prior to the September 2016 flood event to mitigate flood impacts on Rupanyup, as best as could be practically achieved within the limited time resources available prior to the arrival of floodwaters.

This report separates the structural mitigation assessment into two phases:

- Phase 1, assessment completed prior to the partial water storage removal; and,
- Phase 2, assessment of the partial decommissioning works and further recommendations for full decommissioning.

A concept design was determined in Phase 2, including a revised damages assessment and cost benefit analysis.

8.3.2 Phase 1 – Initial Mitigation Assessment

8.3.2.1 Dunmunkle Creek – Manmade influences

At the inception of this project the GWMWater Channel Decommissioning Program was partially completed with the decommissioning works placed on hold until this project provided its recommendation/s. As part of the community consultation process undertaken during this project it became apparent the community would like Dunmunkle Creek to operate as it would naturally, without intervention or attempts to control and distribute flow. This excluded protection of assets such as dwellings and or agricultural sheds.

Dunmunkle Creek has a large number of existing structures, Table 8-1 lists infrastructure which impacts on flooding along Dunmunkle Creek, the table also includes the following:

- The state of the infrastructure at the time of this reports production (i.e. decommissioned, inoperable, partially decommissioned, etc.); and,
- A description of the assets potential to impact flood flows and any changes to the asset suggested during the course of the project.

The assets are listed upstream to downstream along Dunmunkle Creek (south to north), each asset location is also shown in Figure 8-9.

It is important to note that design modelling undertaken during this project modelled the channel decommissioning and topographic state in the condition at the time of writing, with recommendations based on that condition. This may have changed during the course of this study as the decommissioning program is an active program.



Table 8-1 Dunmunkle Creek – Infrastructure with the potential to influence flood flows

Asset	Detail/State	Suggested Changes from Consultation Meetings
Swedes Cutting, Offtake from the Wimmera River	Swedes Cutting is a constructed channel designed to convey water from the Wimmera River to the Richardson River. It was partially disconnected from the Wimmera River due to works on the Glenorchy-Campbell's Bridge Road where no replacement culverts were constructed. During flood flows exceeding the Wimmera River channel capacity and overtopping the Glenorchy-Campbell's Bridge Road, overland flow intercepted by Swedes Cutting flows toward the Richardson River. This occurred during January 2011.	<p>Community suggestions</p> <ul style="list-style-type: none"> ■ Culverts under the Glenorchy-Campbell's Bridge Road be reinstated allowing flow along Swedes Cutting to the Richardson River. This would allow more floodwater to leave the Wimmera River system and enter the Richardson River at high flows. ■ Allow the Glenorchy-Campbell's Bridge Road to block low flows to Swedes Cutting as the excavation is not a 'natural' feature. <p><i>Source: Community</i></p>
Dunmunkle Creek, Offtake from the Wimmera River	<p>The Dunmunkle Creek offtake from the Wimmera River currently passes underneath the Glenorchy-Campbell's Bridge Road via a 300 mm pipe culvert. A butterfly valve is located on the pipe, the valve was constructed by local landholder.</p> <p>Historically, the valve was used to allow transfer flow along Dunmunkle Creek filling several large pools along the waterway within the Gray Family property, after which point it would be turned off. However, the valve has not been operated in several years. Operation of the valve has been hindered by vandalism, however it is understood the valve could be operated in its current state.</p>	<p>Community suggestions:</p> <ul style="list-style-type: none"> ■ Remove the existing operational pipe under the Glenorchy Campbell's Bridge Road and replace with a nonoperational culvert structure. This would allow lower flows to pass along Dunmunkle Creek under the Glenorchy-Campbell's Bridge Road for agricultural and environmental value. The flow rate and commence to flow could be controlled by the fixed culvert invert and dimensions. <p><i>Source: Community</i></p>

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Asset	Detail/State	Suggested Changes from Consultation Meetings
Main Central Outlet Channel	<p>The Main Central Channel and Dunmunkle Creek are one and the same with the creek having been augmented to allow flows northwards. During operation the Main Central Outlet Channel transferred water from the Wimmera River north, distributing to the Main Eastern Channel. It then becomes the Dunmunkle Creek South Channel north of the Lubeck Channel. This northern reach is discussed separately below.</p> <p>There are several sections of the Main Central Outlet Channel which have had sections of the channel banks removed. It is likely this was to allow local drainage back into the channel.</p> <p>The Main Central Outlet Channel is not connected to the Wimmera River unless the valve at the offtake location is opened or the Glenorchy-Campbells Bridge Road is overtopped. There are also a series of valves on the channel at the Warracknabeal Stawell Road which block flow along the Main Central Outlet Channel and a series of channel blocks put in place by GWMWater during their channel decommissioning works.</p> <p>Not only does the channel take distributed water from the Wimmera River when the control structure is operated, it also receives water from a broad drainage channel through Glenorchy. This channel picks up Wimmera River flood water running through the township. Due to the channel blocks this water cannot continue along the Main Central channel. These blocks were not in place during January 2011 allowing the Glenorchy drainage channel to operate as designed.</p> <p>It is understood this channel was constructed for flood mitigation purposes by Northern Grampians Shire Council.</p>	<p>Steering Committee Suggestions:</p> <ul style="list-style-type: none"> ■ Decommissioning of the channel and structure. ■ Opening of the channel blocks downstream of the Glenorchy Drainage Channel confluence <p><i>Source: Steering Committee</i></p>



Asset	Detail/State	Suggested Changes from Consultation Meetings
Charlton Channel	<p>The Charlton Channel offtakes from the Main Central Outlet to the east, intersecting several channels along the way until it reaches Charlton. The channel runs perpendicular to the direction of Dunmunkle Creek flood flows. Linescan data captured during the January 2011 event and flood modelling completed as part of this project has shown the channel does not cause a significant backwater.</p> <p>The channel has been removed as part of the GWMWater Channel Decommissioning Project and therefore not included in the design modelling component of this project.</p>	There have been no suggestions to reinstate the Charlton Channel, however it has been included in this discussion due to any perceived impact on flood flows.
Main Eastern Channel	<p>Prior to decommissioning, the Main Eastern Channel transferred water from the Main Central Outlet Channel to the east, intersecting with the Rocklands Lubeck Channel and the Richardson River Channel. The Channel ran perpendicular to the direction of Dunmunkle Creek flood flows.</p> <p>During January 2011 the channel was partially decommissioned and significantly altered the distribution of floodwater not only through transferring floodwater in channel but blocking floodwater from flowing to the north.</p>	There have been no suggestions to reinstate the Main Eastern Channel (which has been fully decommissioned), however it has been included in this discussion due to its large impact on flood flows.
Lubeck Channel	<p>Prior to decommissioning the Lubeck Channel ran east west along the Horsham - Lubeck Road. The majority of the channel has been decommissioned as part of the GWMWater Channel Decommissioning Program. During January 2011 there were reports of the channel directing Dunmunkle Creek flood flows into the Lubeck township. These reports came from numerous sources.</p>	<p>Community Suggestion:</p> <ul style="list-style-type: none"> Fully decommission the Lubeck Channel. <p><i>Source: Community</i></p>

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Asset	Detail/State	Suggested Changes from Consultation Meetings
Dunmunkle Creek South Channel	<p>The Dunmunkle Creek South Channel passes underneath the Rocklands Lubeck Channel and flows north through Rupanyup. It becomes the Dunmunkle Creek North Channel north of the Taylors Outlet Channel. This section is discussed separately below.</p> <p>A large structure exists at the intersection of the Dunmunkle Creek South Channel and the Rocklands Lubeck Channel. This structure passes Dunmunkle Creek flood flows under the channel, when the structure reaches capacity, floods flow over the top of the channel embankments and either flow into the Rocklands Lubeck Channel or overtop both embankments and continue along Dunmunkle Creek (Dunmunkle Creek South Channel)</p> <p>No decommissioning has occurred along the Dunmunkle Creek South Channel</p>	<p>Steering Committee Suggestion:</p> <ul style="list-style-type: none"> Remove the Rocklands Lubeck Channel structure and allow the Dunmunkle Creek South Channel (Dunmunkle Creek) to continue at its natural grade. <p><i>Source: Steering Committee</i></p>
Rocklands Lubeck Channel	<p>The Rocklands Lubeck Channel runs perpendicular to the direction of Dunmunkle Creek flood flows. Prior to decommissioning it ran from Rocklands, through Lubeck and transferred water north, running parallel to Dunmunkle Creek to the east.</p> <p>The Channel was in place during January 2011 and caused a significant blockage to flood flows along its length. This is clearly shown in Linescan images. Since January 2011 it has been partially decommissioned with all sections removed but those in the Bryntirion Forest Reserve. The channel currently stops at these points. During January 2011 attempts to operate structures within the Bryntirion Forest were at significant risk to loss of life and their removal should be a priority.</p>	<p>Community Suggestions:</p> <ul style="list-style-type: none"> Complete removal of the Rocklands Lubeck Channel and all associated structures within the Bryntirion Forest Remove as much of the Rocklands Lubeck Channel as practical, allowing flow to the north given the amount of vegetation now growing around it. <p><i>Source: Community</i></p>

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Asset	Detail/State	Suggested Changes from Consultation Meetings
Lubeck – Rupanyup Railway (Murtoa flow path)	<p>The Lubeck – Rupanyup Railway has been decommissioned by the removal of the tracks and sleepers with the majority of the embankment remaining. A flow distribution from Dunmunkle Creek flows toward Murtoa intersecting the Railway line. The railway embankment had a significant impact on flood flows during January 2011.</p> <p>Since January 2011, a large portion of the embankment between Barn Road and Len Matthews Road has been removed by a local landholder.</p> <p>Design modelling completed as part of this project has included removal of the embankment to represent the current conditions at the time of writing.</p>	<p>There has been no suggestion to reinstate the railway embankment. However, at the time of writing it does not appear the correct approval process has been followed in removing the embankment. Removal of the embankment has been shown to increase downstream levels locally, no increases at building locations were observed.</p>



Asset	Detail/State	Suggested Changes from Consultation Meetings
Lubeck – Rupanyup Railway (at Rupanyup)	<p>The Lubeck – Rupanyup Railway at Rupanyup has the potential to impact on the Rupanyup township in two locations, upstream of Rupanyup at the Dunmunkle Creek (Dunmunkle Creek South Channel) crossing and within the township where flood water is able to flow under the embankment through two 600 mm pipe culverts.</p> <p>During January 2011 a small amount of flood water flowed along the railway embankment into the township. The 600 mm pipe culverts under the railway embankment were blocked by local landholders preventing any additional water entering the township. A large head drop across the railway embankment was observed during January 2011 with the Dunmunkle Creek side much higher. Hydraulic modelling of Rupanyup has confirmed the large difference in water levels between either side of the embankment if the culverts are blocked.</p> <p>Design modelling of Rupanyup has been completed with the pipe culverts open allowing Dunmunkle Creek floodwater to flow into the Rupanyup township due to no formalised procedure for them to be blocked. The impact of blocking the culverts on properties on the western side of the railway embankment is also relatively unknown.</p>	<p>Steering committee suggestions for modification of the railway embankment culverts have been made. These include:</p> <ul style="list-style-type: none"> ■ Place non return valves on the culverts ■ Remove the culverts entirely ■ Place operational valves on the culverts. <p><i>Source: Steering Committee</i></p>



Asset	Detail/State	Suggested Changes from Consultation Meetings
GWMWater water storages	<p>There are two large GWMWater water storages in Rupanyup which are placed either side of Dunmunkle Creek (Dunmunkle Creek South Channel).</p> <p>The storages are not currently in use by GWMWater and no longer required.</p> <p>During January 2011 a large head drop was observed between the storages. It has been confirmed the storages cause a large restriction to flow with a significant head loss across the restriction.</p> <p>During September 2016 parts of the upstream and downstream embankments on one of the storages was excavated to allow flow through the storage. This was completed immediately before the flood event occurred.</p>	<p>Steering committee suggestions:</p> <ul style="list-style-type: none"> ■ Remove the storages completely. ■ Remove the southern storage and use the northern storage for retention of water. ■ Turn the storages into an open wetland and link to the existing walking tracks. <p><i>Source: Steering Committee</i></p>
Dunmunkle Creek North Channel	<p>The Dunmunkle Creek North Channel flows north after the Taylors Outlet Channel and becomes the East Karkarooc Channel north of Laen School Road.</p> <p>No channel decommissioning has occurred along the Dunmunkle Creek North Channel.</p>	<p>Steering committee suggestion:</p> <ul style="list-style-type: none"> ■ Remove all embankments along the Dunmunkle Creek North Channel and allow it to take a more natural form. <p><i>Source: Steering Committee</i></p>
East Karkarooc Channel	<p>The East Karkarooc Channel flows north from Laen School Road still following the natural Dunmunkle Creek flow path until Lawler Road at Boolite where it deviates to the north west ending north of Brim East.</p> <p>The Lawler Road crossing has been blocked as part of the GWMWater Channel Decommissioning program.</p>	<p>Steering committee suggestions:</p> <ul style="list-style-type: none"> ■ Open the culverts and allow water to flow north along Dunmunkle Creek. <p><i>Source: Steering Committee</i></p>



Asset	Detail/State	Suggested Changes from Consultation Meetings
Donald Murtoa Road	The Donald Murtoa Road runs perpendicular to the direction of Dunmunkle Creek, the road was shown to be a restriction to flow during the January 2011 event and in design modelling completed as part of this project.	<p>Community suggestion:</p> <ul style="list-style-type: none">■ Enlarge the culverts to alleviate upstream flooding of agricultural land. <p><i>Source: Community</i></p>





8.3.2.2 Structural Flood Mitigation Prefeasibility Assessment

8.3.2.2.1 OVERVIEW

Each mitigation option was assessed to determine its likely impact and feasibility, highlighting any property which may be negatively impacted by the construction of the option. Mitigation solutions using changes to existing infrastructure were listed and described separately to construction of new infrastructure, however all options are rated together. The full list of suggested mitigation measures are summarised below in Table 8-2 and shown in Figure 8-10, Figure 8-11 and Figure 8-12.

Table 8-2 Suggested mitigation options

Option No.	Detail	Source
Changes to Existing Infrastructure		
1	Open Swedes Cutting	Community
2	Permanently Open the Dunmunkle Creek Offtake – remove valve in culvert	Community
3	Open the Main Central Channel to allow flow through Glenorchy to Dunmunkle Creek via a flood mitigation channel	Council, Water Technology
4	Remove the Rocklands Lubeck Channel	Community
5	Block/Remove culverts under the Lubeck –Rupanyup Railway	Community, CMA, Water Technology
6	Remove the GWMWater water storages	Community
7	Remove Dunmunkle Creek North Channel Embankments	Community
8	Enlarge Donald Murtoa Road Culverts	Water Technology
New Infrastructure		
9	Levee protecting Rupanyup from Dunmunkle Creek overland flow coming into the township from the south	Wimmera CMA, Water Technology
10	Levee and channel on the eastern side of Rupanyup preventing local catchment inflows from flowing into the township and directing it north toward the existing channel system and through to the Golf Club	Community

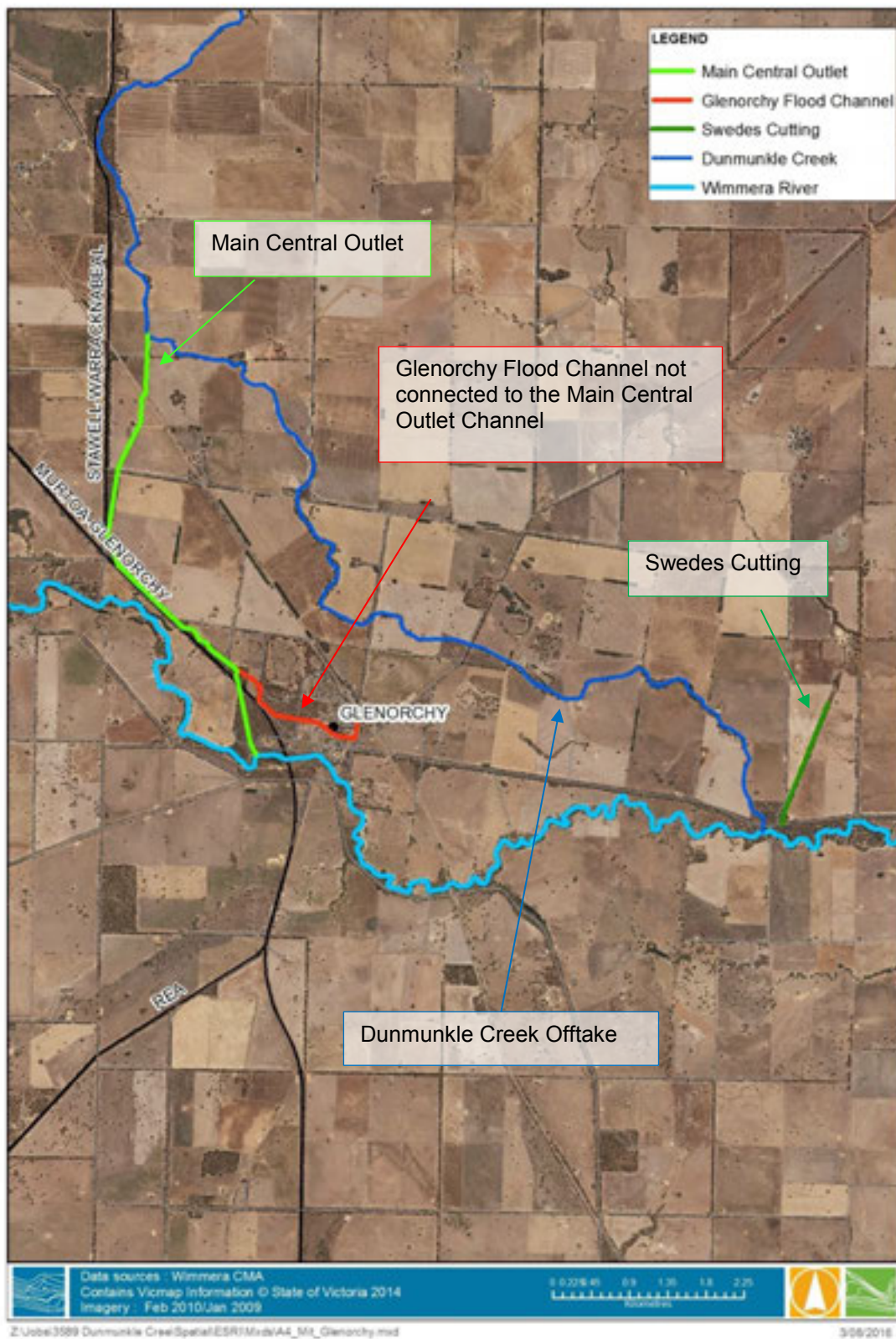


Figure 8-10 Suggested mitigation options – Upper Dunmunkle Creek

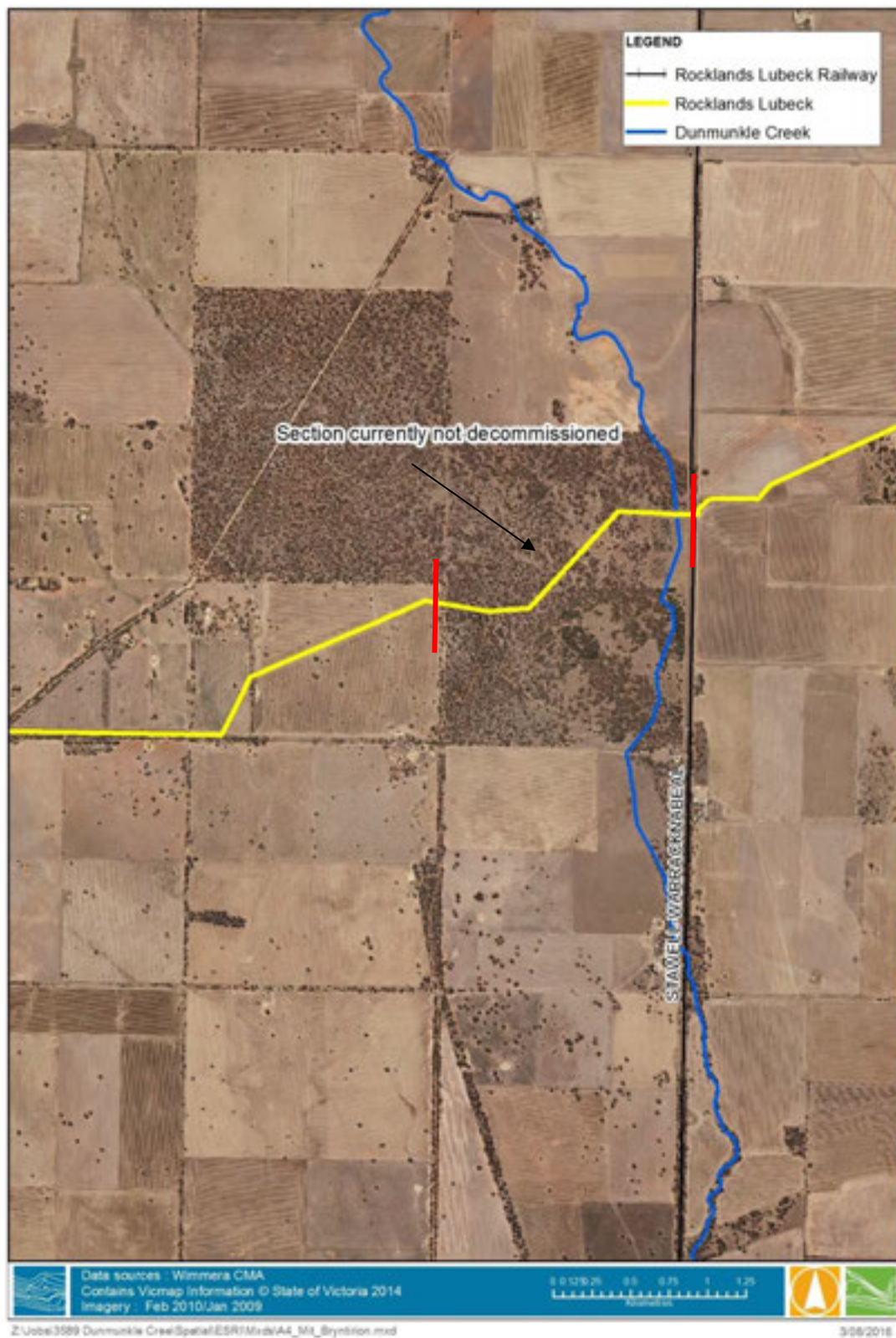


Figure 8-11 Suggested mitigation options – Mid Dunmunkle Creek

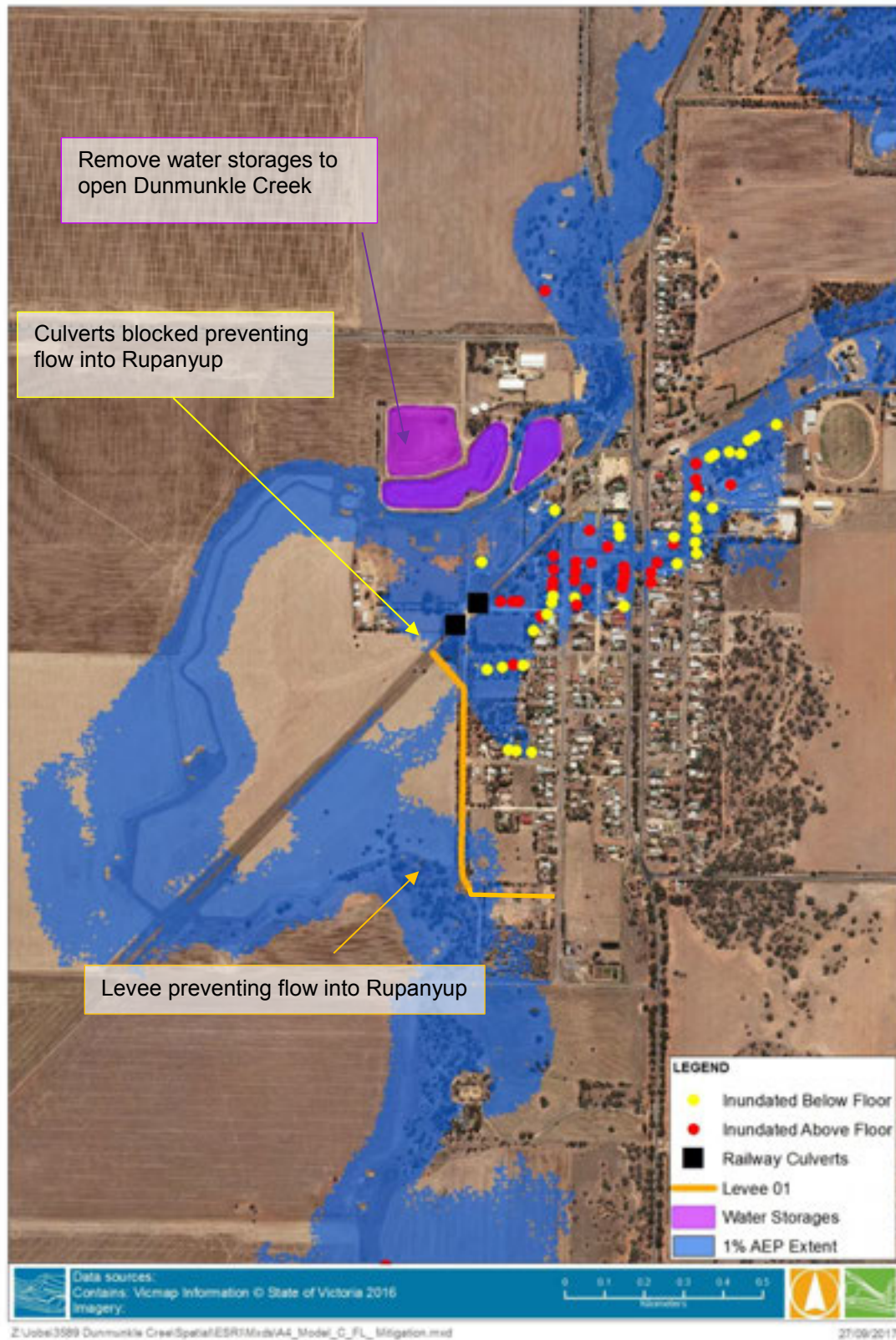


Figure 8-12 Suggested mitigation options – Rupanyup 1% AEP inundation and floor level flooding

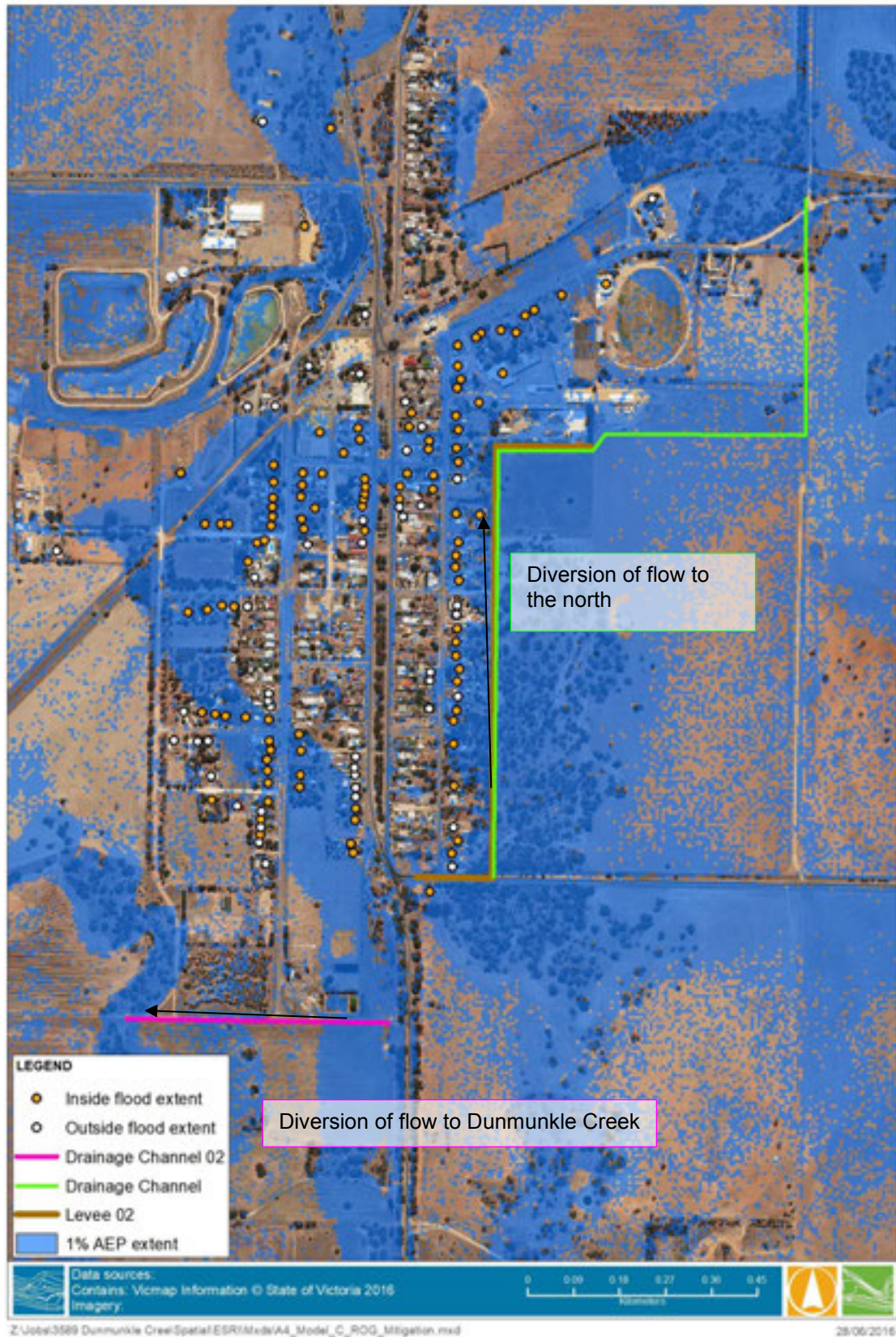


Figure 8-13 Suggested mitigation options – Rupanyup Stormwater



8.3.2.2.2 ASSESSMENT CRITERIA

Each mitigation option was assessed against a number of criteria; potential reduction in flood damage, cost of construction, feasibility of construction and environmental impact. The score for each criterion was based on a ranking system of 1 to 5, with 1 being the worst score and 5 the best. Each criteria score was then weighted according to the weighting shown in Table 8-3 below. The reduction in flood damage was the most heavily weighted criteria as this is really the main objective for all flood mitigation.

Table 8-3 Prefeasibility assessment criteria

Score	Reduction in Flood Damages	Cost (\$)	Feasibility/Constructability	Environmental Impact
Weighting	2	1	0.5	0.5
5	Major reduction in flood damage	Less than \$50,000	Excellent (Ease of construction and/or highly feasible option)	None
4	Moderate reduction in flood damage	\$50,000 – \$100,000	Good	Minor
3	Minor reduction in flood damage	\$100,000 – \$500,000	Average	Some
2	No reduction in flood damage	\$500,000 – \$1,000,000	Below Average	Major
1	Increase in flood damage	Greater than \$1,000,000	Poor (No access to site and/or highly unfeasible option)	Extreme

8.3.2.2.3 ASSESSMENT

Each of the suggested mitigation options was assessed using the outlined assessment criteria. Table 8-4 reviews and scores each mitigation option against the four criteria and calculates a total score for each option. The options with the higher scores indicate the more appropriate mitigation solutions for each location. While these options were reviewed and recorded individually it is important to consider a combination of options when developing a flood mitigation scheme.



Table 8-4 Prefeasibility assessment criteria

No.	Mitigation Option		Criteria					Score
			Damages Reduction	Cost	Feasibility	Environmental Impact	Comments	
Existing Infrastructure								
1	Open Cutting	Swedes	2	5	3	5	<p>Opening of Swedes Cutting would allow more water to exit the Wimmera River system and enter the Richardson River. This would occur at lower flows but there is unlikely to be any increase in peak flows during large high flow events.</p> <p>It is unlikely to cause any reduction in flood damages.</p>	13
2	Permanently Dunmunkle Offtake	Open Creek	2	5	5	5	<p>Removing the valve at the current Dunmunkle Creek Offtake from the Wimmera River would remove any uncertainty on what should occur preceding or during a flood event. The capacity of the replacement culverts would dictate the frequency and magnitude of flows along Dunmunkle Creek, however given the amount of water distributed to Dunmunkle Creek in large floods there is unlikely to be much change during these events with more of an impact during low flow events.</p> <p>Replacing the valve with a permanent structure is likely to result in more water flowing towards Rupanyup, especially in more frequent events, however this is unlikely to result in much of a reduction in flood damage along the Wimmera River.</p> <p>There may be some environmental benefit to allowing low flows to distribute from the Wimmera River to Dunmunkle Creek and would be in line with the general community view</p>	14



						that the waterway should be returned to its natural state as best possible.	
3	Open the Main Central Channel to allow flow through Glenorchy to Dunmunkle Creek via the flood mitigation channel	4	5	5	5	<p>The Main Central Channel was the outlet for a channel through Glenorchy used to convey flood water. Given the Main Central Channel has been blocked during the GWMWater Channel Decommissioning this water now has no outlet.</p> <p>It is likely opening this channel will cause an increase in Wimmera River floodwater distributed to Dunmunkle Creek but may also reduce flood damages in Glenorchy. The channel blocks could be easily removed.</p>	18
4	Remove the Rocklands Lubeck Channel	4	4	3	3	<p>The Rocklands Lubeck Channel has been decommissioned for the majority of its length, with the exception of the section within the Bryntirion Forrest. This section is remaining along with the Dunmunkle Creek subway immediately west of the Stawell Warracknabeal Road.</p> <p>Preliminary modelling has shown removal of this section of channel causes a change in the flow split between Rupanyup and Murtoa, with more water flowing towards Murtoa (Model E) after the channel is removed. There are significantly less impacted properties along this flow path.</p> <p>There is a serious issue of community members attempting to operate the structures on the Rocklands Lubeck Channel. Operating this infrastructure during a flood event has the potential to cause loss of life and it is imperative the structures be removed to prevent this occurring in the future.</p>	15
5	Block/Remove culverts under the Lubeck – Rupanyup Railway	5	5	5	5	Blocking the culverts under the Lubeck Rockland Railway line caused a significant reduction in flood damages in Rupanyup during January 2011, however this may have increased flood levels on the western side of the railway. There are several buildings in this area.	20



						Modification to the two 600 mm pipe culverts is an obvious mitigation solution but increasing flood levels for properties not benefiting from the works must be considered.	
6	Remove the Rupanyup water storages	4	3	4	5	<p>The GWMWater Rupanyup water storages are a clear restriction to flood flows in Dunmunkle Creek. The storages are no longer required and able to be decommissioned.</p> <p>Their removal is likely to reduce flood levels upstream and increase them downstream.</p>	15.5
7	Remove Dunmunkle Creek North Channel Embankments/ East Karkarooc Channel	2	3	3	3	Removal of the channel embankments along the Dunmunkle Creek North Channel/East Karkarooc is unlikely to cause any reduction in flood damages. There is some potential for localised changes to flood extents however these would need to be looked at individually on a site specific scale to determine whether they would be justified.	10
8	Enlarge Donald Road Culverts	2	4	4	5	Culverts at the Donald Murtoa Road cause a clear restriction in the capacity of Dunmunkle Creek. However, increasing their capacity is unlikely to cause reduction in flood damages with no buildings benefited by the upstream reduction in flood extent. Only agricultural land would be benefited.	12.5
Additional Infrastructure							
9	Levee protecting Rupanyup on the southern side of Rupanyup preventing Dunmunkle Creek overland flow coming into the township	5	4	4	5	<p>A levee on the southern side of Rupanyup would prevent overland flow entering the township. Flow coming into the township via the overland flow path is very shallow making the required levee relatively small.</p> <p>Construction of the levee could be used in combination with a change to the railway culverts preventing flow into Rupanyup at both inflow points.</p>	18.5



10	Levee and channel on the eastern side of Rupanyup preventing local catchment flows from flowing into the township and directing it north toward the existing channel system and through to the Golf Club and a diversion channel south of Rupanyup directing runoff into Dunmunkle Creek	5	3	3	3	<p>Flows from the Rupanyup localised catchment area to the south east can inundate a large number of properties in town. The introduction of a levee and channel east of Rupanyup redirecting flow toward the north and the Rupanyup Golf Course is possible and would alleviate these issues. However the levee and drain would be on private property.</p> <p>The properties impacted are in a clear low point and during community consultation it was raised the area was formerly a swamp.</p> <p>The impact of increasing flow to Dunmunkle Creek is unknown at this stage, but is not likely to be significant if the works were done in conjunction with the Dunmunkle Creek levee and culvert works. It is also likely to require a structure to prevent floodwater backing up the diversion channel.</p>	16
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Using the prefeasibility assessment above, the 10 mitigation options were ranked by weighted score. Their ranking is shown below in Table 8-5.

Table 8-5 Weighted prefeasibility mitigation scores

Rank	Option No.	Mitigation Option	Weighted Score
1	5	Block/Remove culverts under the Lubeck –Rupanyup railway embankment	20
2	9	Levee protecting Rupanyup on the southern side of Rupanyup preventing Dunmunkle Creek overland flow coming into the township	18.5
3	3	Open the Main Central Channel to allow flow through Glenorchy to Dunmunkle Creek via a flood mitigation channel	18
4	6	Remove the GWMWater water storages in Rupanyup	16.5
5		Levee and channel on the eastern side of Rupanyup preventing local catchment inflows from flowing into the township and directing it norther to toward the existing channel system and through to the Golf Club	16
6	4	Remove the Rocklands Lubeck Channel and associated operational infrastructure	15
7	2	Permanently Open Dunmunkle Creek Offtake	14
8	8	Enlarge Donald Murtoa Road Culverts	12.5
9	1	Open Swedes Cutting	13
10	7	Remove Dunmunkle Creek North Channel Embankments	10



8.3.2.3 Flood Mitigation Assessment

8.3.2.3.1 OVERVIEW

In the list of suggested mitigation options considered in the prefeasibility assessment there were several options that were highly likely to provide a reduction in flood damages. There were also several changes to existing GWMWater infrastructure that were likely to provide a reduction in flood damages and are in line with the intent to remove redundant infrastructure.

Several options were recommended for modelling or further assessment to test their potential impact:

- Removal or blockage of two 600 mm pipe culverts under the remnant Lubeck-Rupanyup railway embankment
- Levee protecting Rupanyup on the southern side of Rupanyup preventing Dunmunkle Creek overland flow coming into the township
- Open the Main Central Channel to allow flow from Glenorchy to Dunmunkle Creek through the flood mitigation channel
- Remove the Rupanyup water storages
- Remove the Rocklands Lubeck Channel
- Permanently Open Dunmunkle Creek Offtake
- Levee and channel on the eastern side of Rupanyup preventing local catchment inflows from flowing into the township and directing it north to toward the existing channel system and through to the Golf Club

Given the community concern raised at the northern end of Dunmunkle Creek, further discussion of the modelled and observed inundation in that area was also determined necessary.

8.3.2.3.2 REMOVAL OR BLOCKAGE OF TWO 600 MM PIPE CULVERTS UNDER THE REMNANT LUBECK-RUPANYUP RAILWAY EMBANKMENT

Overview

There are two sets of twin 600 mm pipe culverts under the Lubeck-Rupanyup railway embankment. The performance of these pipes in the current stormwater system is unknown due to a number of changes to the system since they were constructed. The culverts were blocked during January 2011 as they were allowing water from the north western side of the embankment into the most densely populated area of Rupanyup. The location of the pipe culverts is shown in Figure 8-14.

Model results

The 1% AEP flood event for Rupanyup was modelled with the removal of the railway culverts. Modelling was completed to understand the potential detrimental impact to properties on the northern side of the railway embankment and the flood level decrease that could be achieved on the southern side. A comparison of the model results to existing conditions is shown in Figure 8-15. As anticipated blockage or removal of the culverts causes an increase on the northern side of the railway embankment and lower levels on the southern side. Overland flow from the upstream side of the railway still flows into the major residential area. The water level increases on the northern side of the railway line area around 0.03 m, in this area there are two properties flooded above floor. These properties are flooded to a greater depth. On the southern side of the railway embankment removing or blocking the culverts has caused a 0.06 m decrease in flood levels.

A closer perspective of the area impacted by the blockage or removal of the railway culverts is shown in Figure 8-16.



Figure 8-14 Removal or blockage of the Rupanyup railway embankment culverts

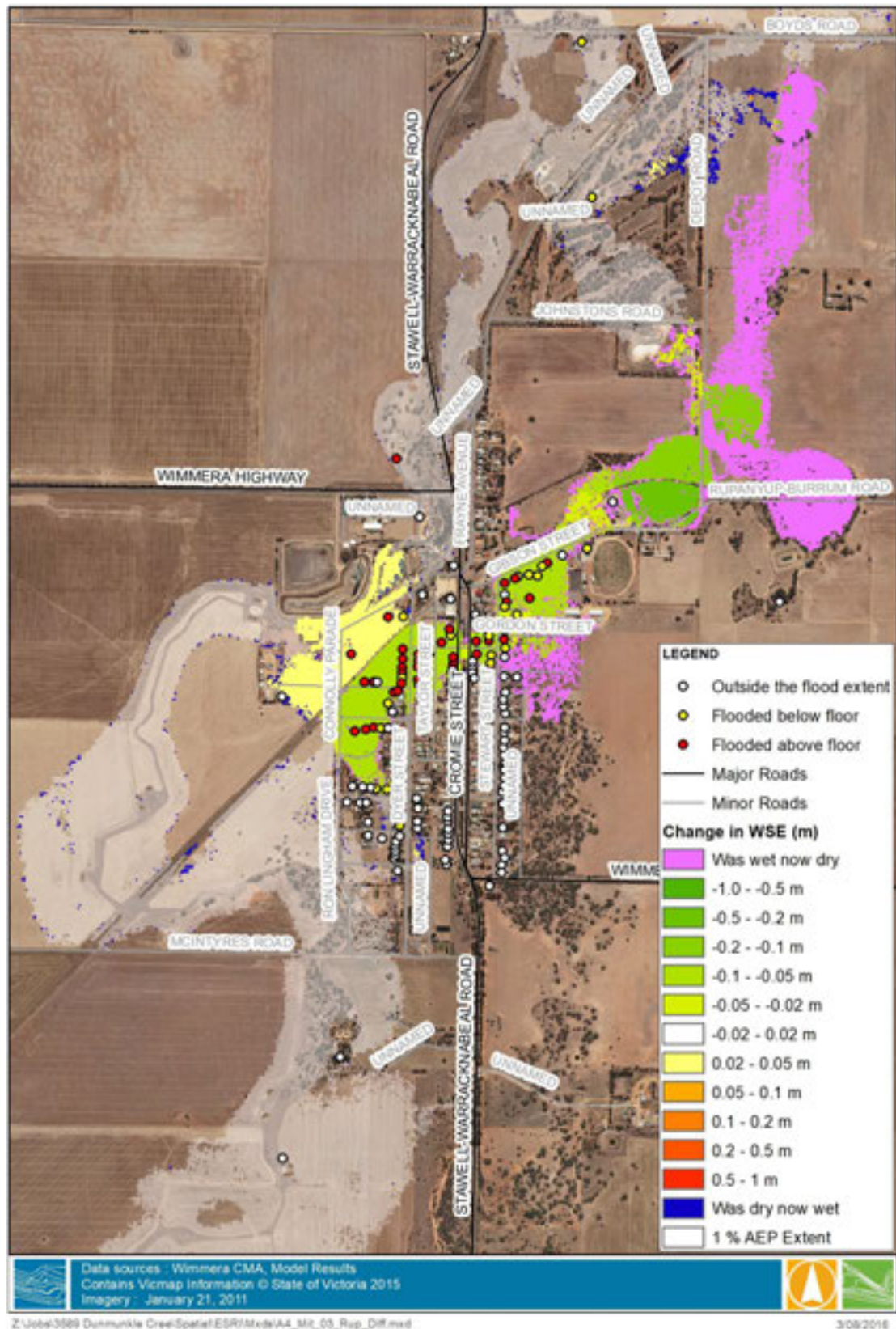


Figure 8-15 Difference in water levels caused by the removal or blockage of the Rupanyup railway embankment culverts

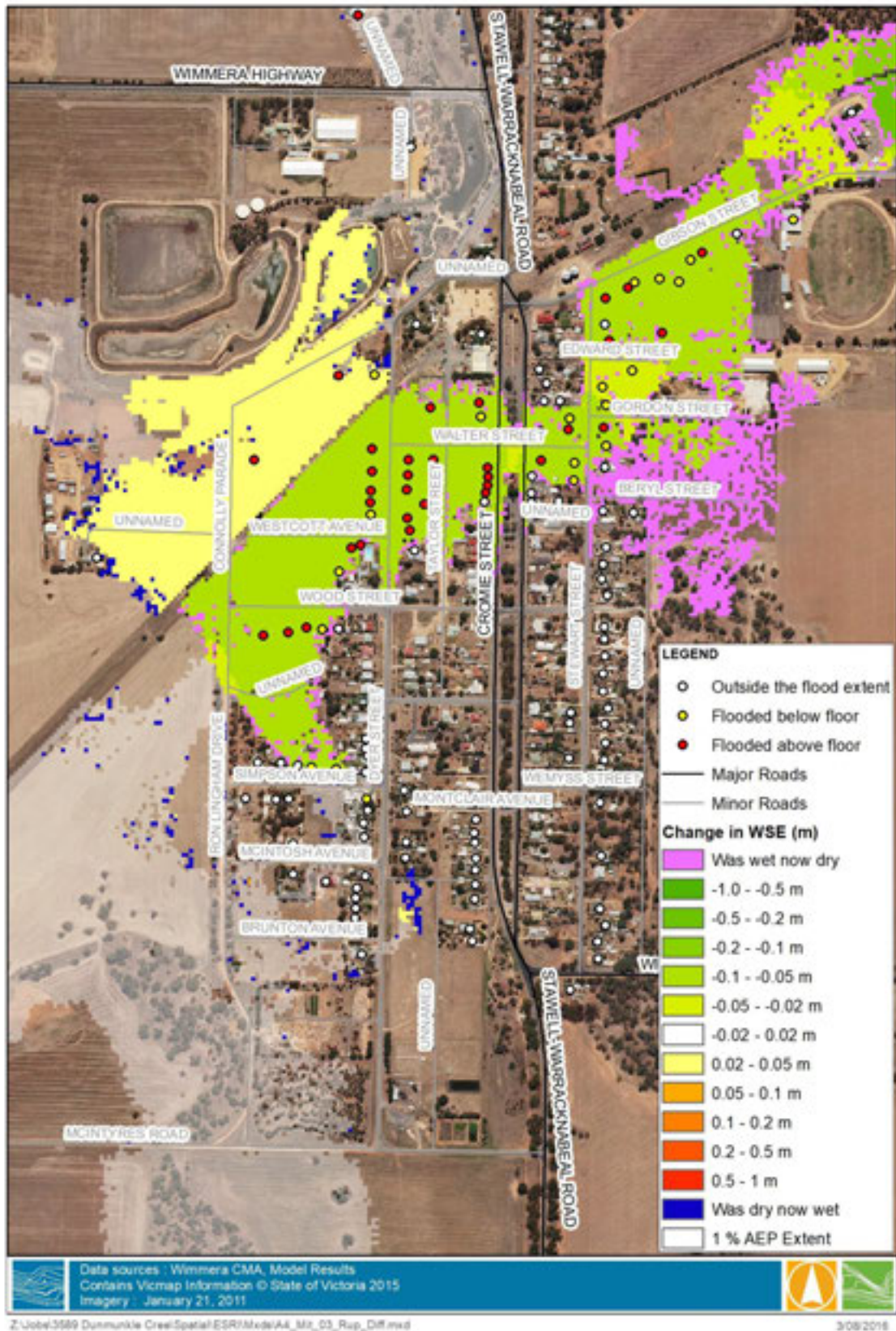


Figure 8-16 Difference in water levels caused by the removal or blockage of the Rupanyup railway embankment culverts – closer perspective of Rupanyup



Discussion

Blocking the railway embankment culverts alone doesn't have a major impact on the water levels due to the overland flow south of the railway embankment still causing inundation within the larger residential area. During January 2011 blocking of the culverts is expected to have had a much larger impact due to lower water levels in Dunmunkle Creek, which resulted in the overland flow into Rupanyup being considerably less. The difference between the January 2011 event (which was slightly larger than a 1% AEP event) and the 1% AEP event modelled here is the decommissioning of the Main Eastern Channel. As discussed in Section 7.1.7, the decommissioning of the Main Eastern Channel caused increases in water level within Rupanyup.

If removal or blockage of the railway embankment culverts was to be considered as a viable mitigation option, it would need to be combined with a levee preventing overland flow along the railway line and property specific mitigation for the dwellings on the northern side as they will be flooded to a greater depth.

8.3.2.3.3 LEVEE PROTECTING RUPANYUP PREVENTING DUNMUNKLE CREEK OVERLAND FLOW COMING INTO THE TOWNSHIP

Overview

In the 2%, 1% and 0.5% AEP events, water can flow overland into the Rupanyup township on the upstream side of the Lubeck-Rupanyup Railway embankment, as shown in Figure 8-17. In a 2% AEP event there is a defined flow path into the township, this spreads considerably in the 1% and 0.5% AEP events. In all events Ron Lingham Road must be overtopped for water to enter the township.

This option wasn't modelled individually, because alone it is unlikely to be a viable option due to water crossing the railway line at the 600 mm pipe culverts. This option is tested further as part of the final preferred package of flood mitigation options in Section 8.3.2.3.9.

There is potential for the levee to be constructed temporarily prior to a flood event if time allowed. However, this would need to be an agreed action as part of any flood response. Given that the levee required is quite low, it is recommended that the levee be constructed permanently.



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8.3.2.3.4 OPEN THE MAIN CENTRAL CHANNEL TO ALLOW FLOW FROM GLENORCHY TO DUNMUNKLE CREEK THROUGH THE FLOOD MITIGATION CHANNEL

Overview

The Main Central Channel is currently blocked by the combination of closed/filled in structures and several channel blocks. Concern was raised by Northern Grampians Shire Council that the blocks prevented flow along a drainage channel through Glenorchy and may increase flood levels in the area.

Review of the LiDAR revealed the drainage channel does not discharge to the Main Central Channel but a small dam. This is highlighted in Figure 8-18. A site inspection revealed the dam spilled to another dam before spilling into the floodplain and the Main Central Channel

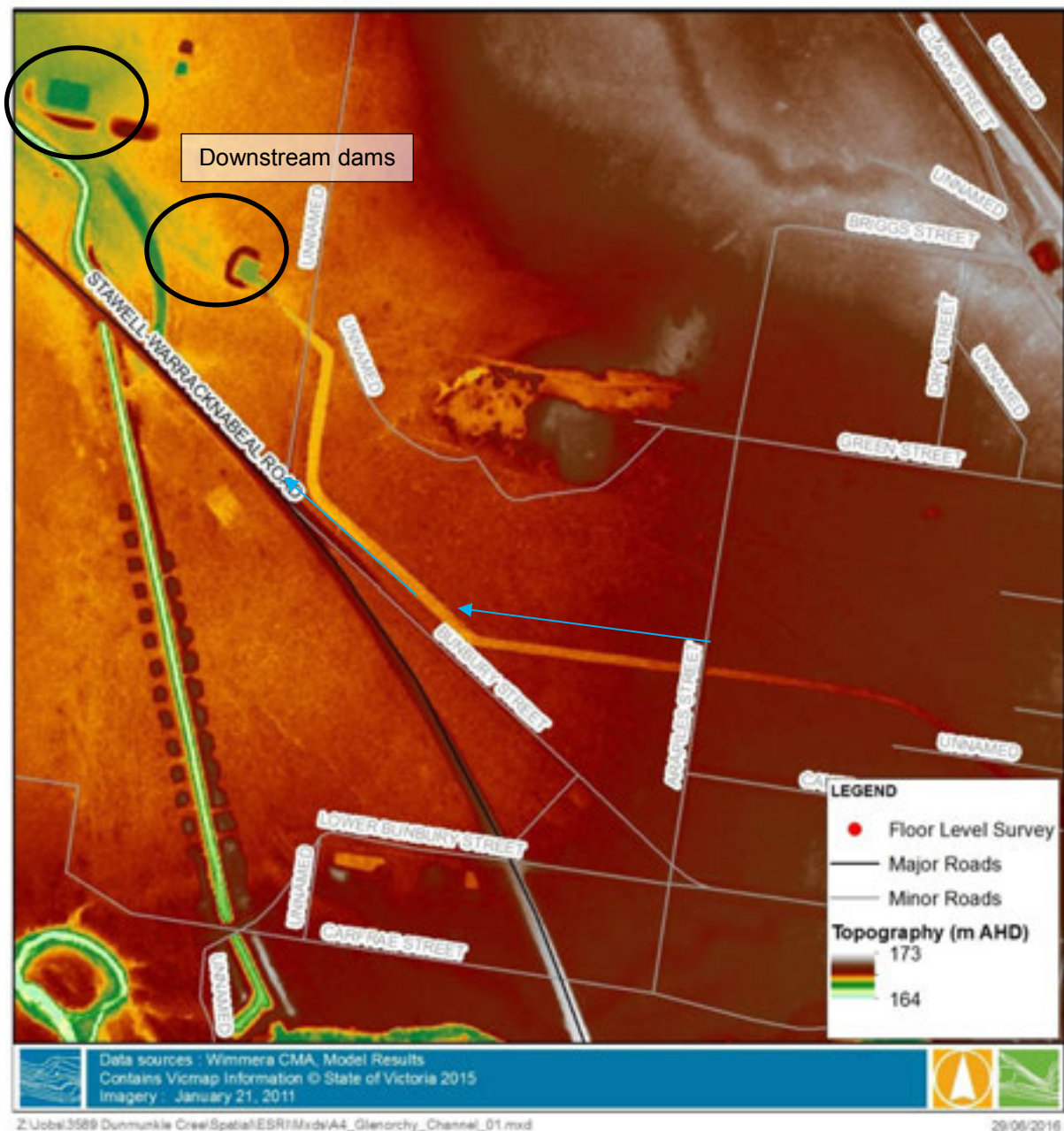


Figure 8-18 Glenorchy drainage channel and dam



Discussion

The drainage channel was shown not to flow into the Main Central Channel directly, with flow directed to a small dam. Any flow excess to the channel capacity or volume exceeding the dam capacity is likely to flow along the eastern edge of the channel embankment and be unhindered by the channel blocks.

If the channel was constructed to drain the Glenorchy township, then the channel should be designed to efficiently transfer water to Main Central Channel. The drain is not considered to provide any benefits during large floods with the capacity relatively minor and widespread flooding at as low as a 10% AEP. However, some consideration to the efficiency of Glenorchy's stormwater system should be considered.

8.3.2.3.5 REMOVE THE RUPANYUP WATER STORAGES

Overview

There are three storages north west of the Lubeck-Rupanyup railway line in Rupanyup. The storages are located at one of the lowest points in Rupanyup with the Dunmunkle Creek channel flowing between them. The reservoirs significantly constrain Dunmunkle Creek and the associated floodplain.

In the 1% AEP flood event, the drop in water level from one end of the reservoirs to the other is approximately 0.8 m, a significant difference given the extremely flat nature of the Dunmunkle Creek Floodplain. The reservoirs have been labelled as 01, 02 and 03, as shown in Figure 8-19.



Figure 8-19 Rupanyup Reservoirs and 1% AEP flood extent

Reservoir 02 is clearly causing the most restriction, as shown by the considerable narrowing of the 1% AEP flood extent.

To test the potential flood benefits of removing the storages, modelling was completed with the complete removal of reservoir 2 and 3. The change in the model topography between the existing and completely removed scenario is shown in Figure 8-20.

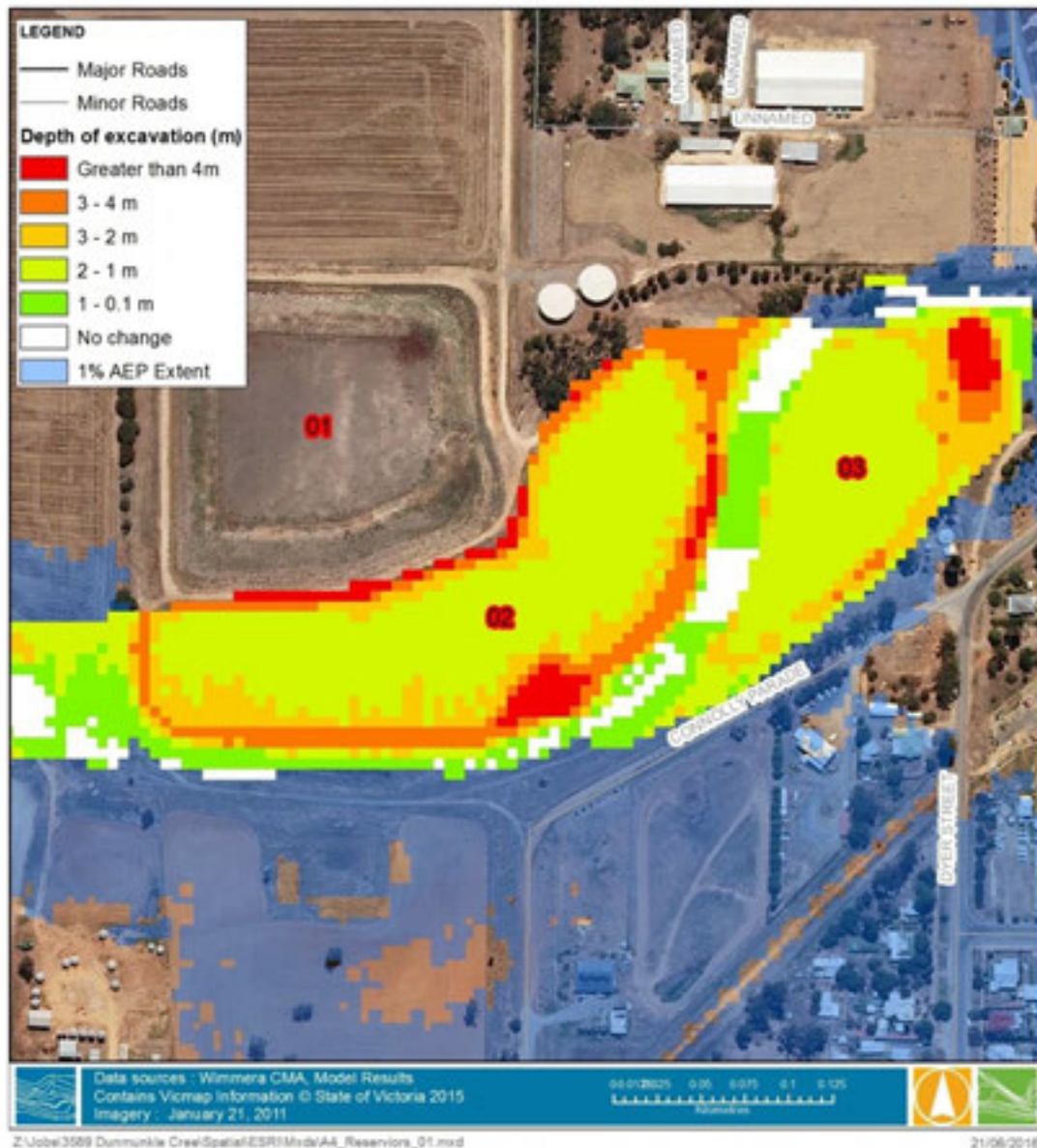


Figure 8-20 Change in model topography with removal of the Rupanyup Reservoirs

Model Results

Removal of the reservoirs was modelled as an individual option using the 1% AEP flood event. Comparison between the existing and mitigation model results was made in a similar manner to removing the pipe culverts underneath the railway line, subtracting the existing conditions results from those in the mitigation scenario. This results in positive values where the mitigation solution has caused increases in water levels and negative values where there has been decreases. The comparison between model results is shown in Figure 8-21.



The model results show a significant decrease in model extent, the removal of the reservoirs has resulted in the extent no longer reaching the railway embankment and therefore no flow through the 600 mm railway culverts is observed. Overland flow is still observed on the upstream side of the railway embankment into the residential area of Rupanyup. There are increases in water level downstream of the reservoir removal with building in the direct vicinity of the water level increases.

A closer perspective of the Rupanyup residential area south east of the railway line is shown in Figure 8-22, with the areas of water level increase downstream of the reservoir removal shown in Figure 8-23.

The model results show that reservoir removal was sufficient to decrease water levels back up through the Dunmunkle Creek railway bridge but some overland flow still reaches the Rupanyup residential area, impacting dwellings in Wood Street, Westcott Avenue and Dyer Street.

The flood level increases at three buildings downstream of the Wimmera Highway, this includes two weatherboard dwellings and a corrugated iron shed. The shed is located directly north of the Wimmera Highway and flooded above floor for events greater than a 5% AEP. With removal of the reservoirs, the shed would be subjected to an increase in flood depth of 3 cm. The dwellings are located off Boyds Road at the golf club and Ballantines Road. Neither property is flooded above floor in the 1% AEP event for existing or developed conditions, however the water level does increase by 3 cm and 5 cm respectively.

Discussion

Overland flow into the Rupanyup township from the south could be prevented by a short levee as discussed in Section 8.3.2.3.3. This would remove all inundation in residential areas with only the area downstream of the Wimmera Highway containing buildings flooded above and below floor.

Combining the removal of the Rupanyup water storages with a levee along Ron Lingham Drive or further to the east is discussed further in Section 8.3.2.3.9.

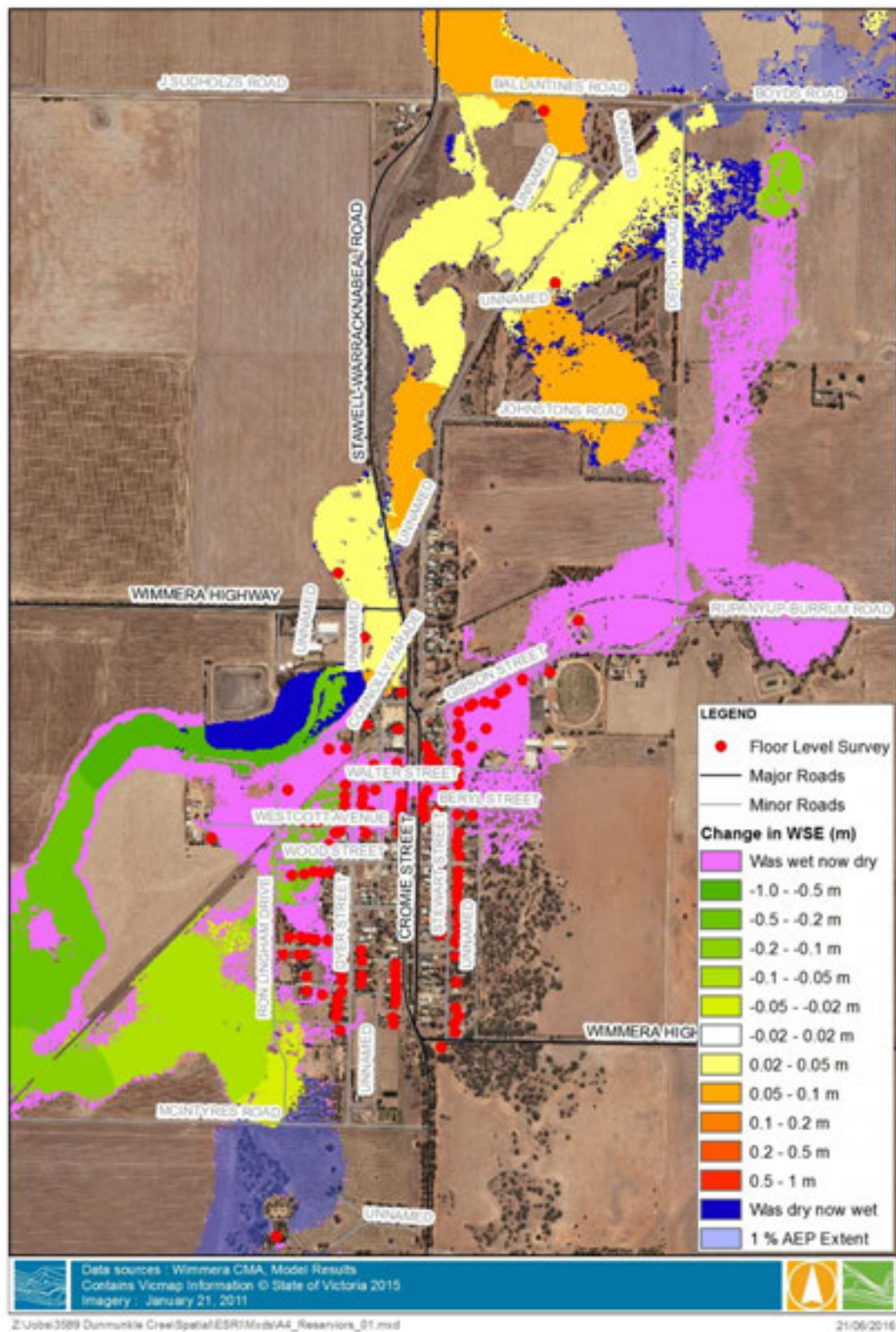


Figure 8-21 Rupanyup Reservoirs – Change in model water levels due to removal

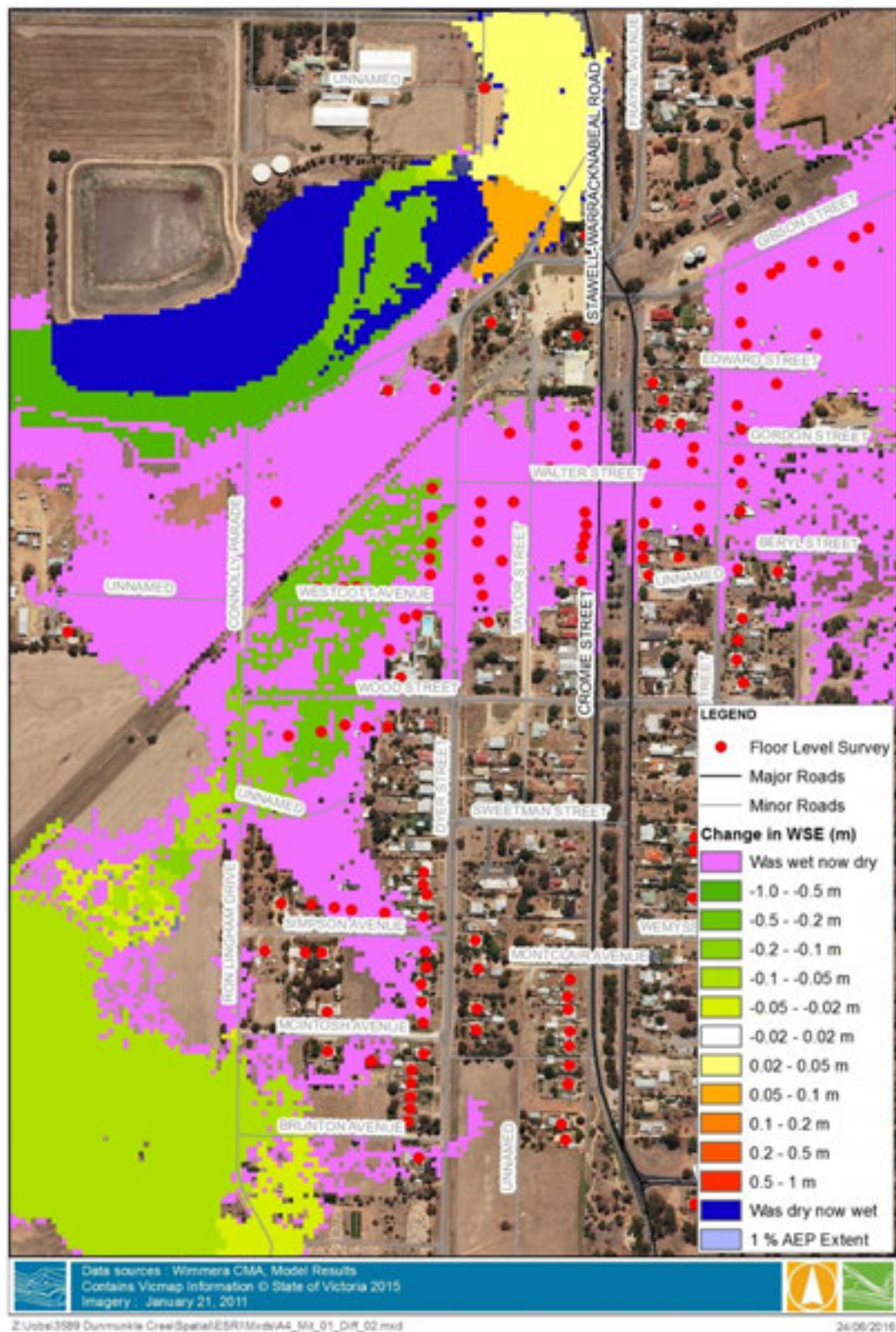


Figure 8-22 Rupanyup Reservoirs – Change in model water levels due to removal, a closer perspective of the Rupanyup residential area

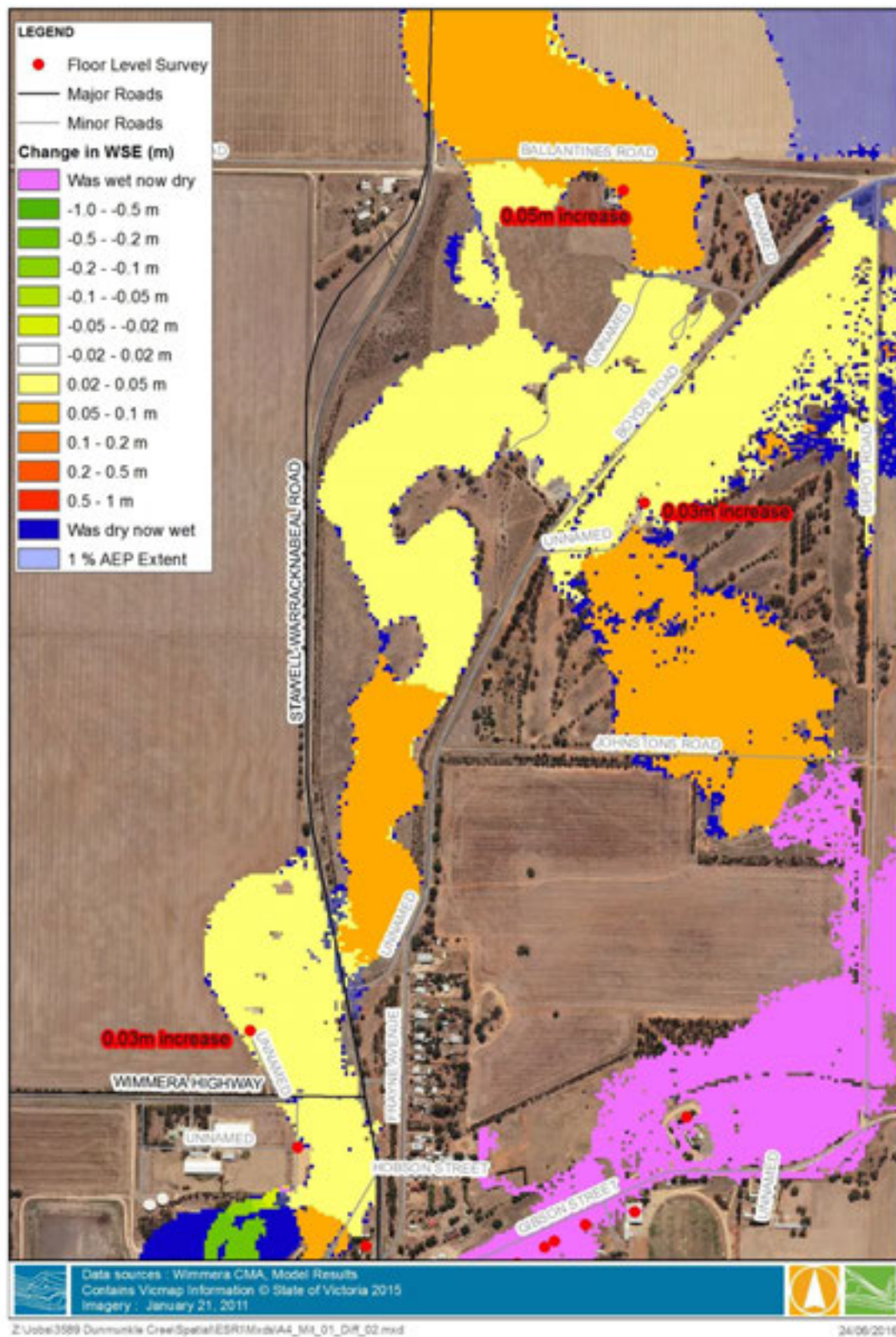


Figure 8-23 Rupanyup Reservoirs – Change in model water levels due to removal, area of increase



8.3.2.3.6 COMPLETE DECOMMISSIONING OF ROCKLANDS LUBECK CHANNEL AND TAYLORS OUTLET CHANNEL

Overview

The removal of the Rocklands Lubeck Channel and Taylors Outlet Channel and was not proposed as a mitigation option, more an assessment of the changes to flood levels as a result of finalising the channel decommissioning. As discussed in the Hydraulic Model Calibration Report produced as part of this project it was demonstrated the channel decommissioning changed the distribution of flood water between Dunmunkle Creek flowing to the north, and the overland flow towards Murtoa.

Modelling

The change in water levels because of decommissioning the Rocklands Lubeck and Taylors Outlet Channel is shown in Figure 8-24. The removal of the Rocklands Lubeck Channel through the Bryntirion Forest has caused more water to flow toward Murtoa, and less toward Rupanyup. In general, the changes are relatively minor and are less than 5 cm along both flow paths, this is discussed further below.

A closer perspective of the changes in Rupanyup is shown in Figure 8-25, with the area of major change on the Murtoa flow path shown in Figure 8-26. There is a dwelling that is expected to be inundated to a higher degree on the Murtoa overland flow path, this is also highlighted in Figure 8-26.

Discussion

The change in flow distribution by removal of the Rocklands Lubeck Channel does not appear to have any adverse impact on buildings, however removal of the Taylors Outlet Channel does appear to influence flood levels at one dwelling on the corner of Excell Road and the Wimmera Highway. The removal of the channel prevents water from flowing north and fills a low area where the dwelling is located. The dwelling has a floor level of 136.31 m AHD and a ground surface of 135.50 m AHD at the dwelling. The flood level at this location with the complete decommissioning is 135.89 m AHD, resulting in the dwelling floor level 0.44 m above flood level. The dwelling does become inundated below floor due to the decommissioning. There is some uncertainty in the degree to which flow is enabled to move north due to the decommissioning with generalised assumptions made on the decommissioned state of the channels. In some cases the remaining depression post decommissioning may allow for a formal drain, the modelling assumes only small depression remains.

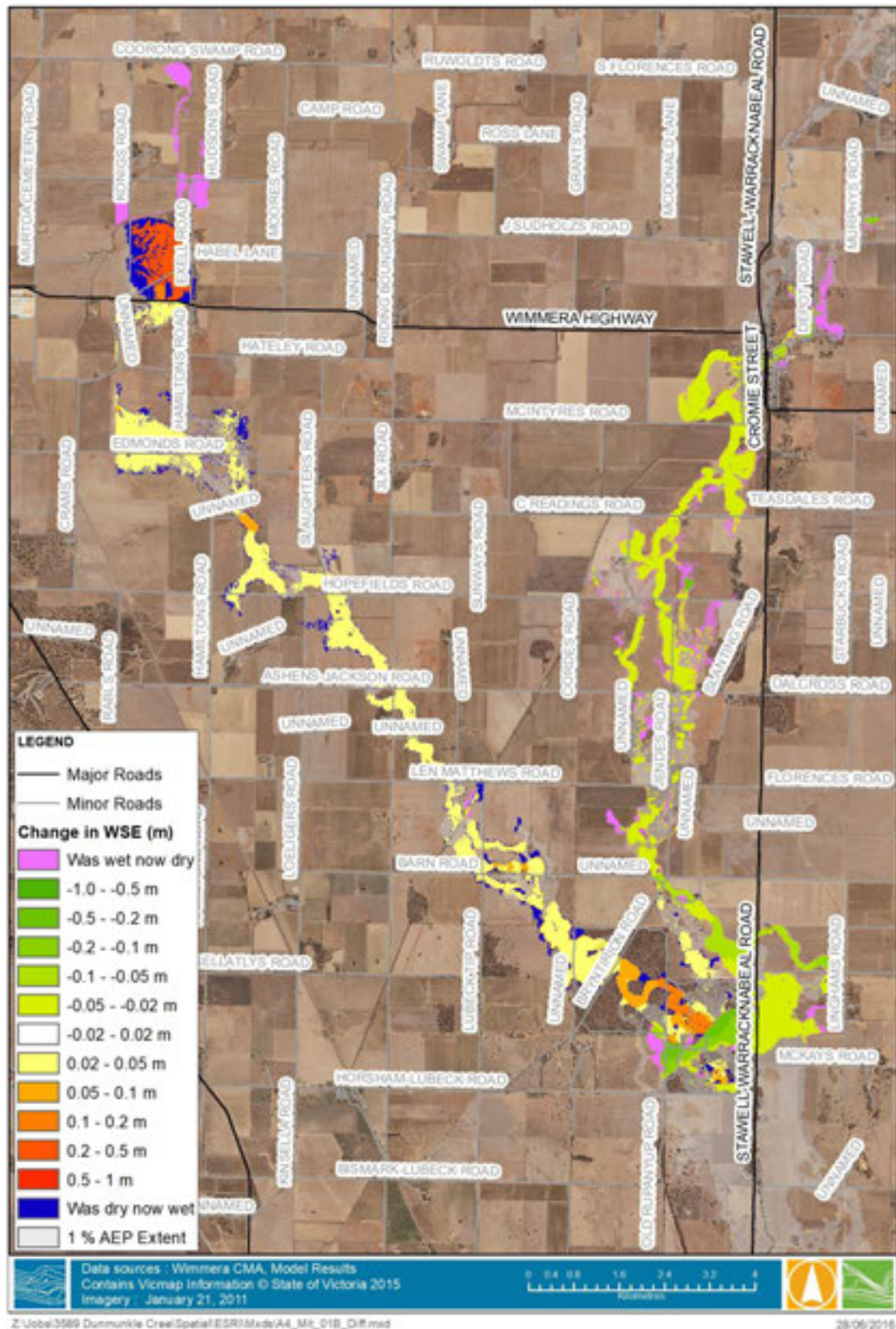


Figure 8-24 Channel Decommissioning – Change in model water levels due to removal

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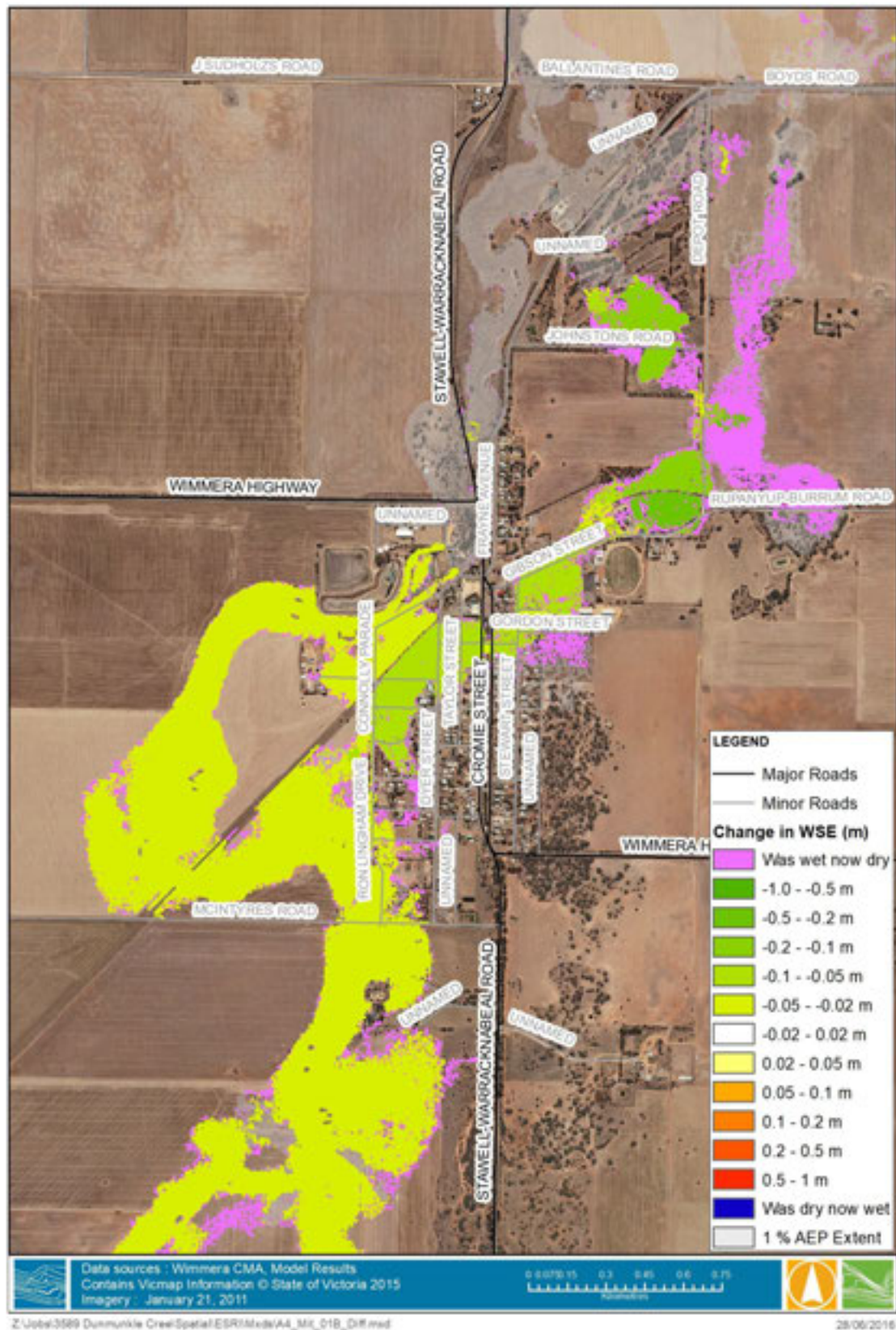


Figure 8-25 Channel Decommissioning – Change in model water levels due to removal in Rupanyup

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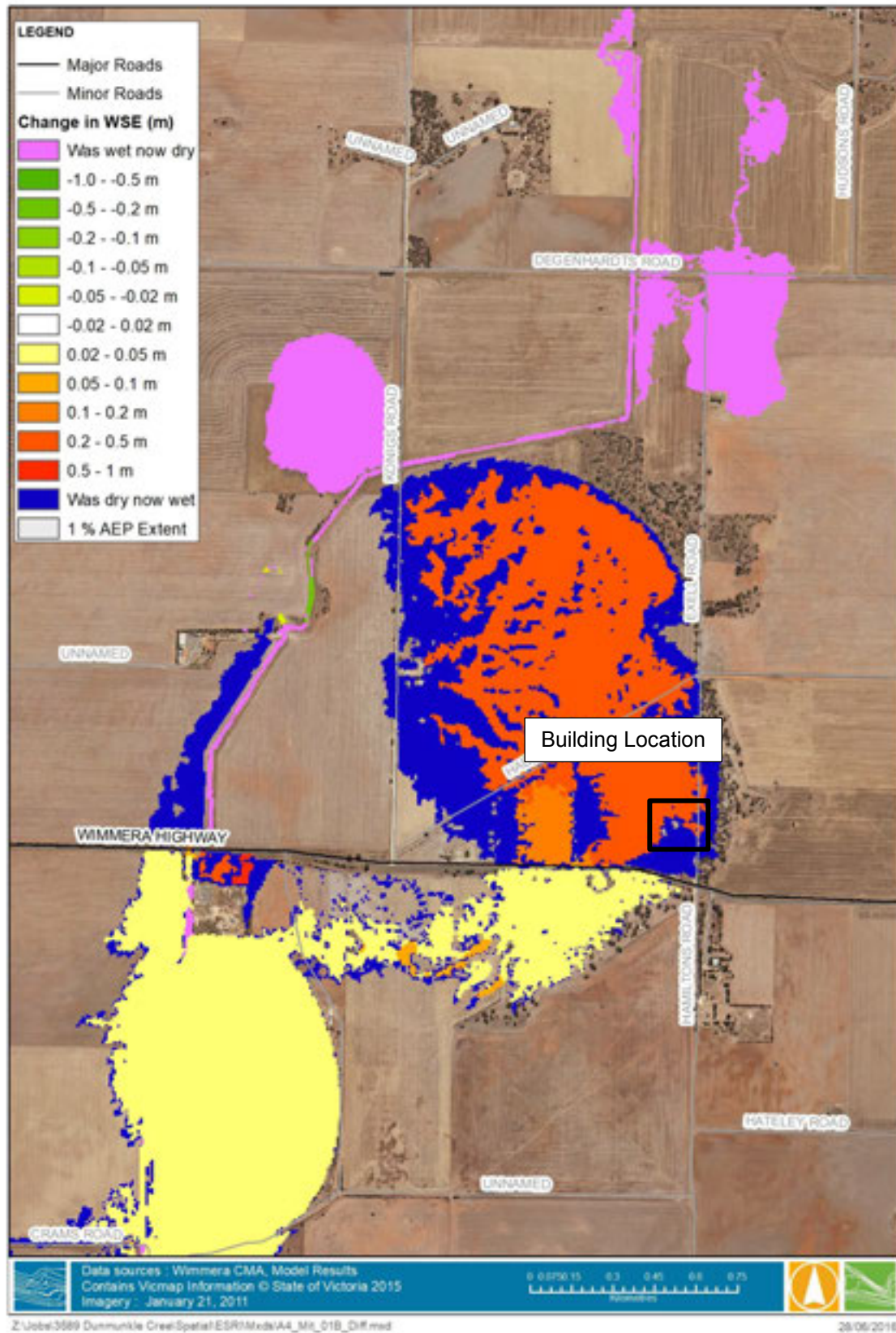


Figure 8-26 Channel Decommissioning – Change in model water levels due to removal north of the Wimmera Highway at Murtoa

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8.3.2.3.7 PERMANENTLY OPEN DUNMUNKLE CREEK OFFTAKE

Overview and Discussion

Permanently opening the Dunmunkle Creek Offtake and removing the potential to operate the structure would restore flows along Dunmunkle Creek to a more natural flow regime. The modelling completed in this project went as low as a 20% AEP event, at this point water was already out of bank in the Wimmera River and overtopping the Campbells Bridge Road. The damages assessment has shown no buildings are flooded above floor until a 5% AEP event. There are numerous areas of both private and public land inundated at a 20% AEP event however the contribution of the existing pipe culvert if open would be extremely small given its diameter (300 mm).

A permanently open pipe structure would not impact on flood levels in large events as far more water overtops the road than flows through the pipe. The only real benefit for having an open pipe would be to improve smaller in channel natural flows down Dunmunkle Creek for environmental purposes and remove the potential for disputes over the operation of the current butterfly valve.

8.3.2.3.8 STORMWATER LEVEE EAST OF RUPANYUP

Overview and Discussion

Rupanyup was flooded during January 2011 by direct catchment runoff. As discussed in Section 8.2.4, the properties at risk of stormwater inundation were highlighted using a Rainfall on Grid model, modelling the 2hr 1% AEP storm event. Initially, modelling was completed to determine the potential mitigation for the stormwater inundation. This conceptual mitigation scenario is shown in Figure 8-27, combining a levee and drain on the eastern side of Rupanyup and a drainage channel to the west. The modelling was able to give an initial estimate of the required levee height, but was not of sufficient resolution to allow for channel designs to be undertaken or inclusion of the complete stormwater pipe network in Rupanyup. There is potential that this could be combined with a pump station to improve the draining of the stormwater inundation.

The stormwater inundation from local catchment runoff was not a major focus of this investigation. It is acknowledged that there are properties at risk of flooding from stormwater in Rupanyup. A stormwater solution incorporating a levee, a drain and possibly a pump could be investigated further.

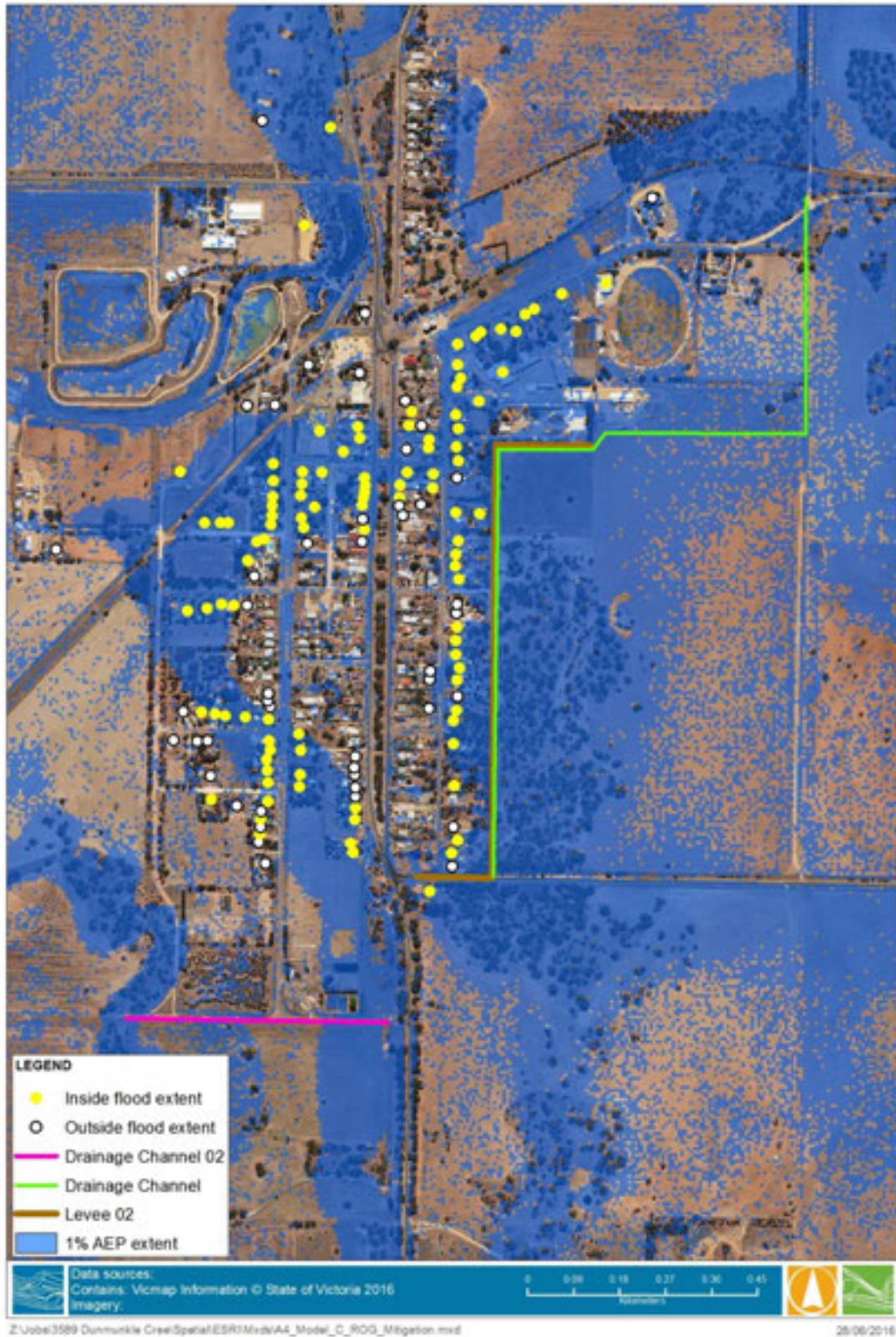


Figure 8-27 Rupanyup stormwater mitigation with existing 2hr 1% AEP storm flood extent



8.3.2.3.9 COMBINED OPTION 1

Overview

Considering the modelling of the individual options described in the sections above, a number of options were combined to provide a full solution for Dunmunkle Creek flooding in Rupanyup. Combining the removal of the Rupanyup water storages and a levee to the west of Rupanyup, above floor flooding in Rupanyup from Dunmunkle Creek can be completely removed.

Combined Option 1 did not include any upstream works, i.e. decommissioning of the Rockland Lubeck Channel through the Bryntirion Forest. Even though these works are likely to be carried out, the final decommissioning is somewhat unknown due to site constraints; large native trees, access etc.

Discussion with Yarriambiack Shire Council and the Project Steering Committee during the fifth Dunmunkle Steering Committee Meeting indicated that the preferred method for designing a levee south west of Rupanyup is to increase the road deck of Ron Lingham Drive and McIntyres Road. The storages to be removed and length of Ron Lingham Drive to be increased is shown in Figure 8-28.

Model Results

Modelling was completed with the removal of the water storages and increasing the height of Ron Lingham Drive and McIntyres Road to above flood level. The water storages were removed in the same way as discussed in Section 8.3.2.3.5.

Changes to the 1% AEP peak water levels as a result of the mitigation works are shown in Figure 8-29, with a closer perspective of the Rupanyup residential area shown in Figure 8-30.

The combination of removing the water storages and an increase to Ron Lingham Drive and McIntyres Road has completely removed inundation from the Rupanyup residential area. The same increases downstream of the Wimmera Highway were observed as the removal of the water storages alone, ranging from 2-5 cm at downstream buildings. The buildings impacted by slight increases in water level were still not flooded above floor.



Figure 8-28 Water storage removal and increase to Ron Lingham Drive and McIntyres Road

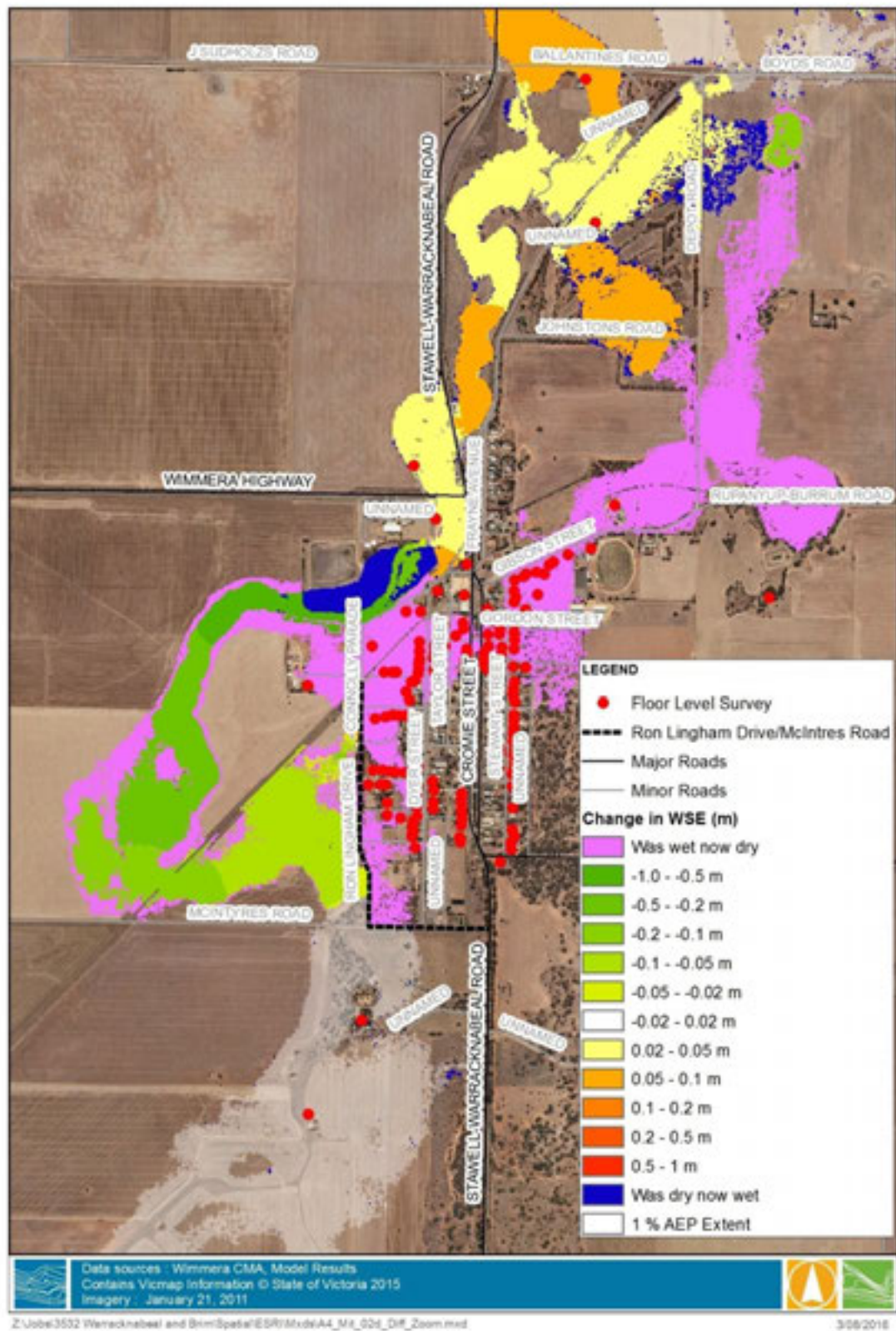


Figure 8-29 Changes to peak 1% AEP water levels as a result of removing the water storages and increase to Ron Lingham Drive and McIntyres Road

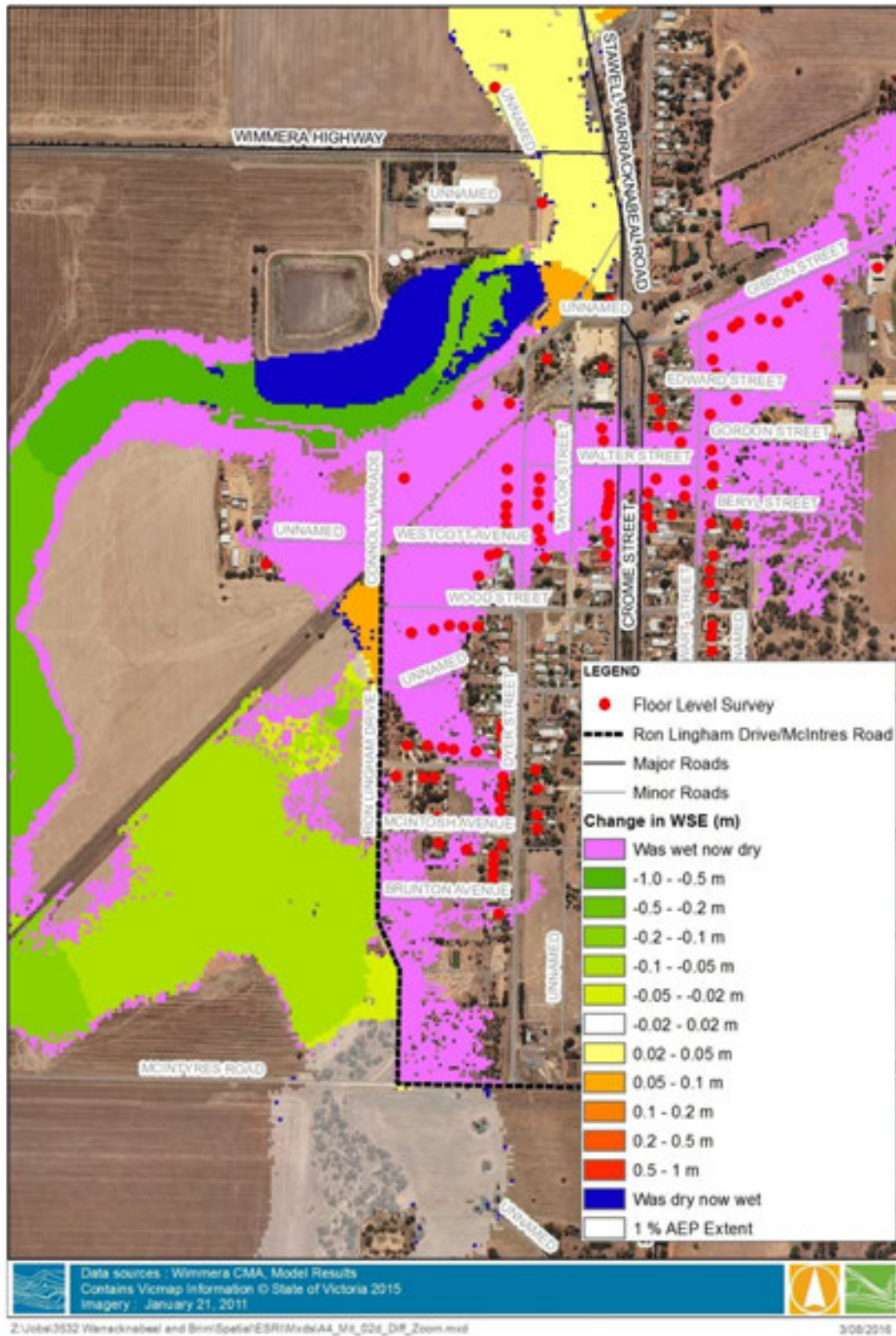


Figure 8-30 Changes to peak 1% AEP water levels as a result of removing the water storages and increase to Ron Lingham Drive and McIntyres Road, Rupanyup residential area



8.3.3 Phase 2 – Final Mitigation Assessment

8.3.3.1 Modelling

8.3.3.1.1 REVISED DESIGN MODELLING

Survey of the Rupanyup water storages was undertaken in early September 2017 to ensure an accurate representation of the excavation completed prior to the September 2016 floods could be included in revised design modelling. This survey was undertaken as photogrammetry with an Unmanned Aerial Vehicle (UAV).

The survey extent and topography data collected is shown in Figure 8-31, with aerial imagery captured shown in Figure 8-32.

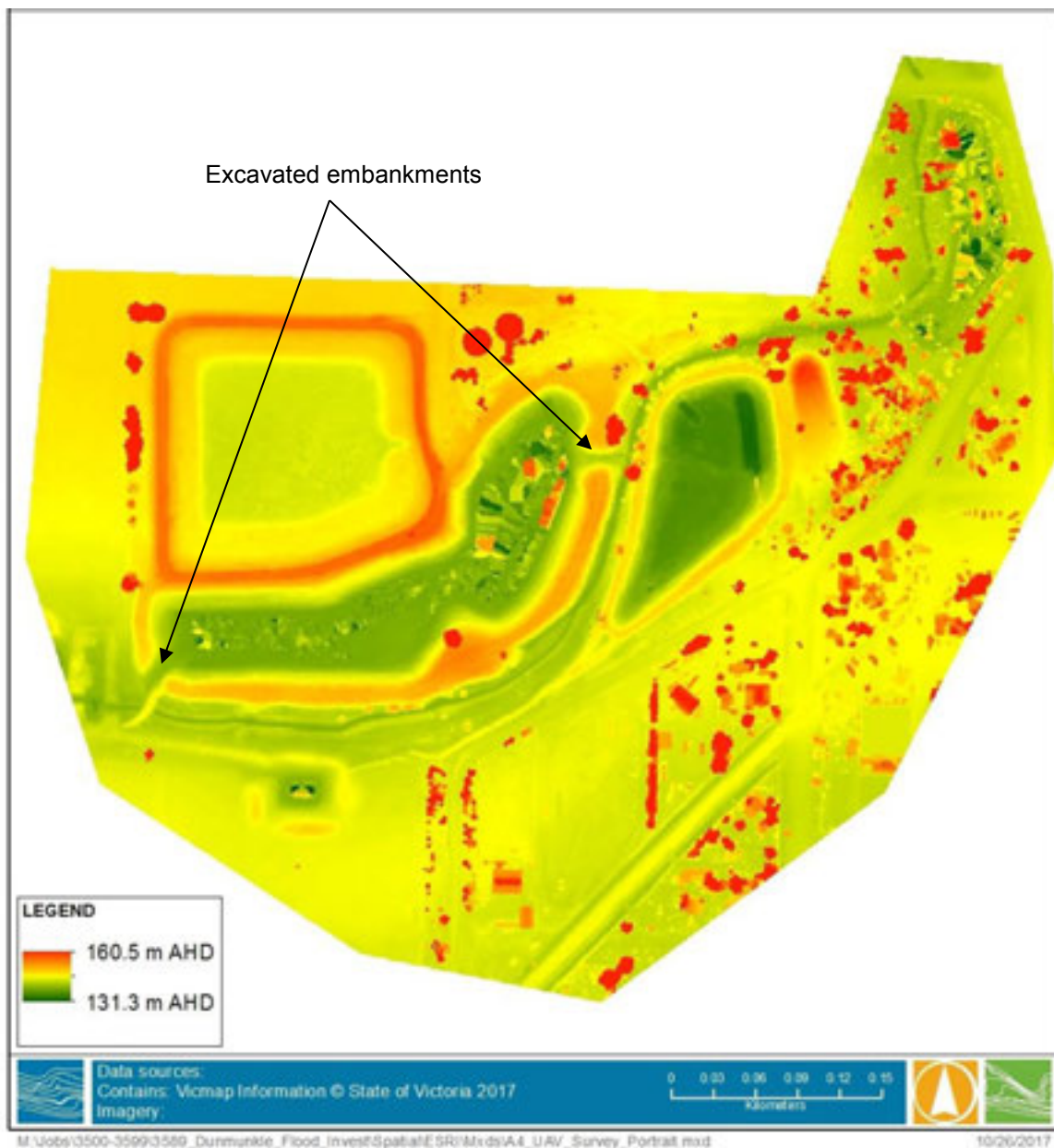


Figure 8-31 Topography captured by the photogrammetry survey of the Rupanyup water storages



Figure 8-32 Aerial image of the Rupanyup water storages captured during the UAV survey

The inclusion of the excavated embankments and the impacts on design flood model extents from Rupanyup downstream was investigated. Model C (Rupanyup) and Model D (Rupanyup to Carron) were rerun with the design changes for the full suite of design events.

The revised 1% AEP extents for Model C and Model D are shown in Figure 8-33 and Figure 8-34 respectively.

The changes implemented during September 2016 did cause minor benefits, but the capacity of the excavations made in the reservoir embankments were similar to the Dunmunkle Creek channel capacity.

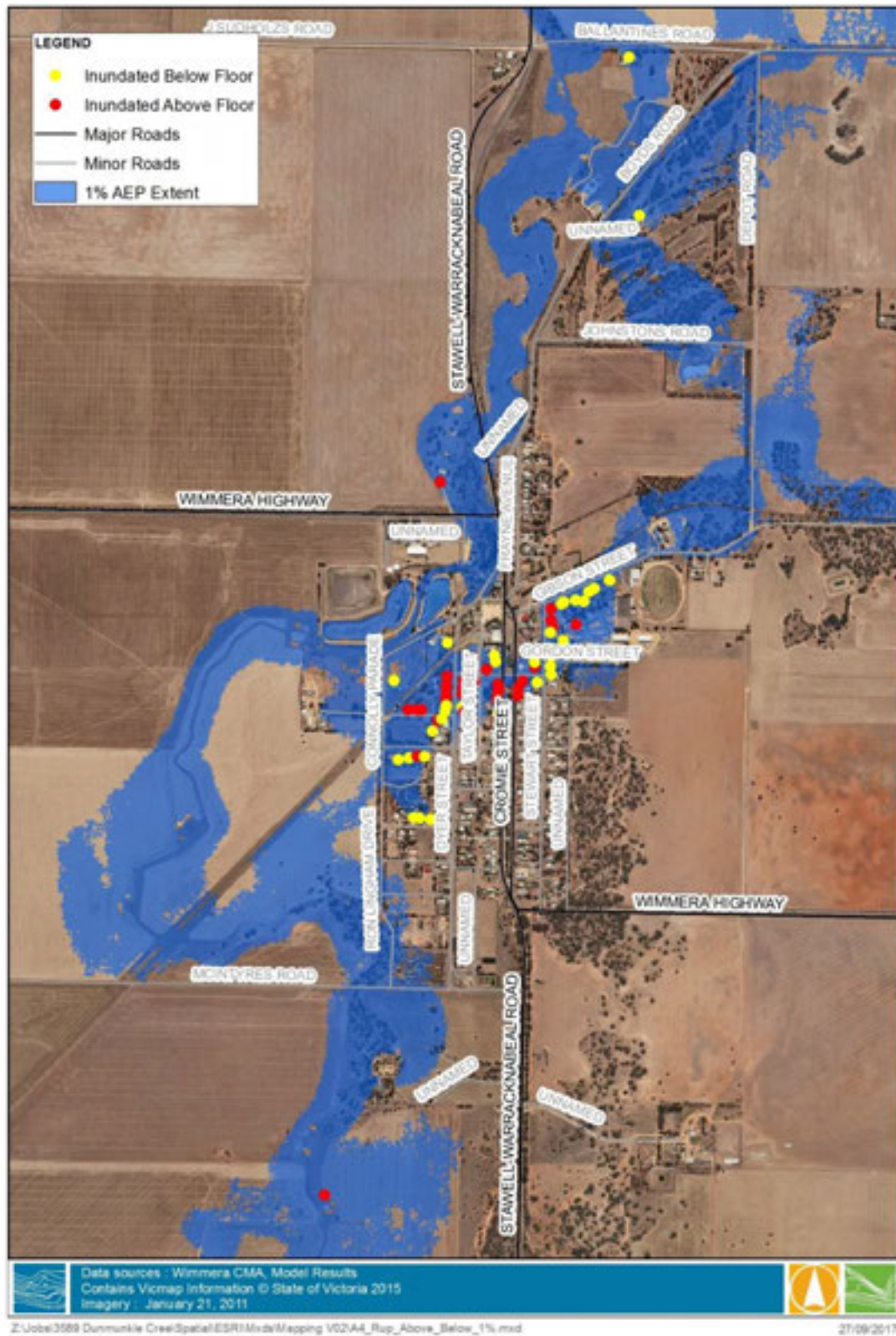


Figure 8-33 Model C (Rupanyup) – 1% AEP extent and properties impacted

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Figure 8-34 Model D – 1% AEP extent and properties impacted



8.3.3.1.2 MITIGATION MODELLING

Mitigation assessment of the Rupanyup water storage removal undertaken in Phase 1 modelled a complete removal of the water storage embankments to the invert of Dunmunkle Creek, to ensure the maximum potential benefit was realised. In Phase 2 an iterative approach to determine the optimal level of decommissioning was undertaken. This considered the benefit that could be achieved in terms of reducing the number of inundated properties, while minimising the required earthworks.

Several iterations were completed with an excavation of the storage embankments to a level of 138.5 m AHD, resulting in a similar reduction in flood extent and depth to Phase 1, while reducing the required excavation.

A schematic of the removal is shown in Figure 8-35, while the change in 1% AEP water levels and extent in Rupanyup is shown in Figure 8-36, and the area downstream of Rupanyup is shown in Figure 8-37.

Downstream of Rupanyup there are increases in flood extent and flood level, these increases reach a maximum of 4 cm at private buildings, with a dwelling on Ballantines Road flooded below floor. This dwelling was flooded below floor in the pre-works scenario, with 12 cm of freeboard between the 1% AEP flood level and the floor level, this is reduced to 8 cm in the revised water storages decommissioning scenario.

A shed immediately north of the Wimmera Highway is also flooded above floor (on ground level) by 2 cm greater in the water storages decommissioning scenario.

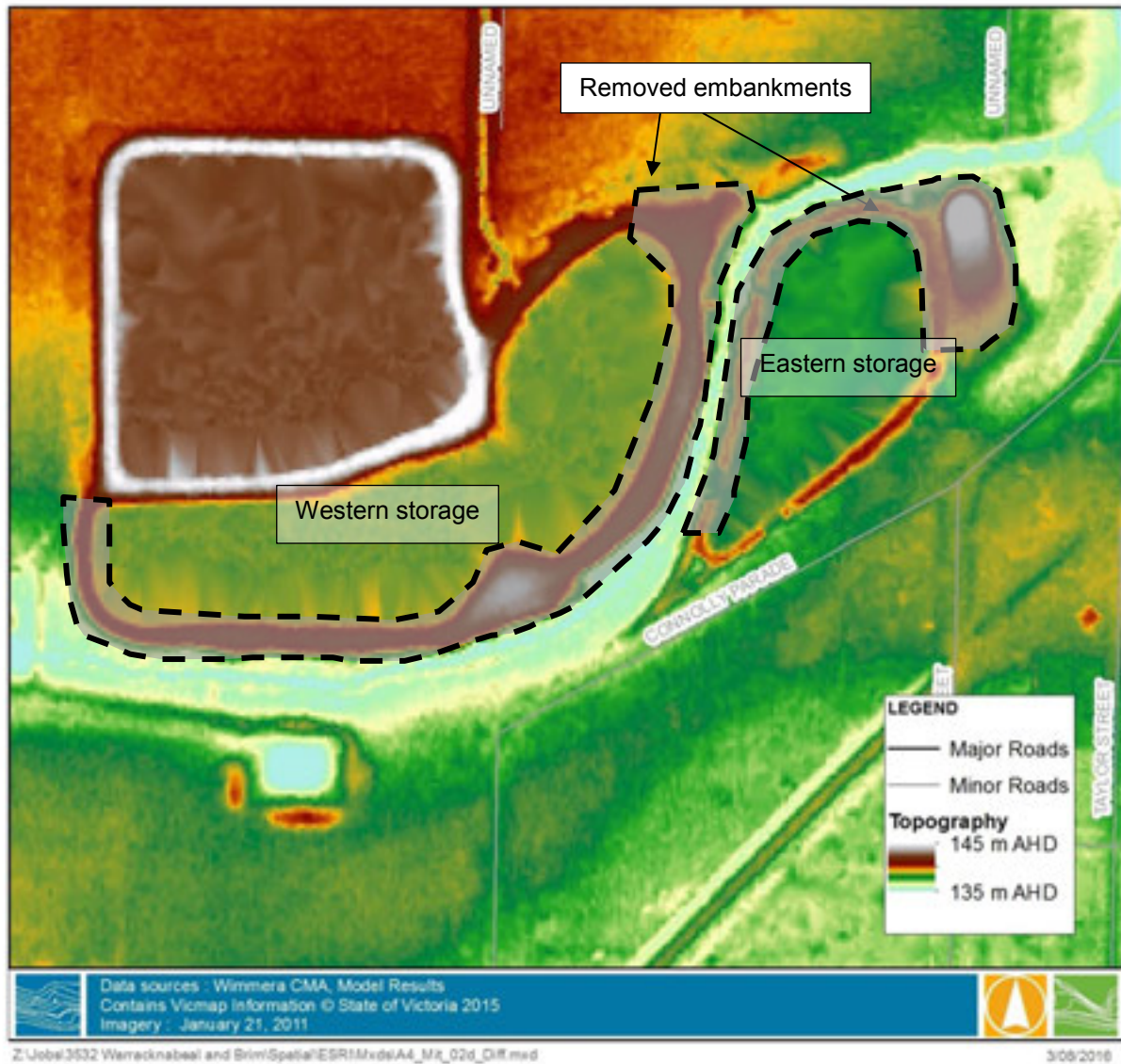


Figure 8-35 Recommendation for water storages decommissioning

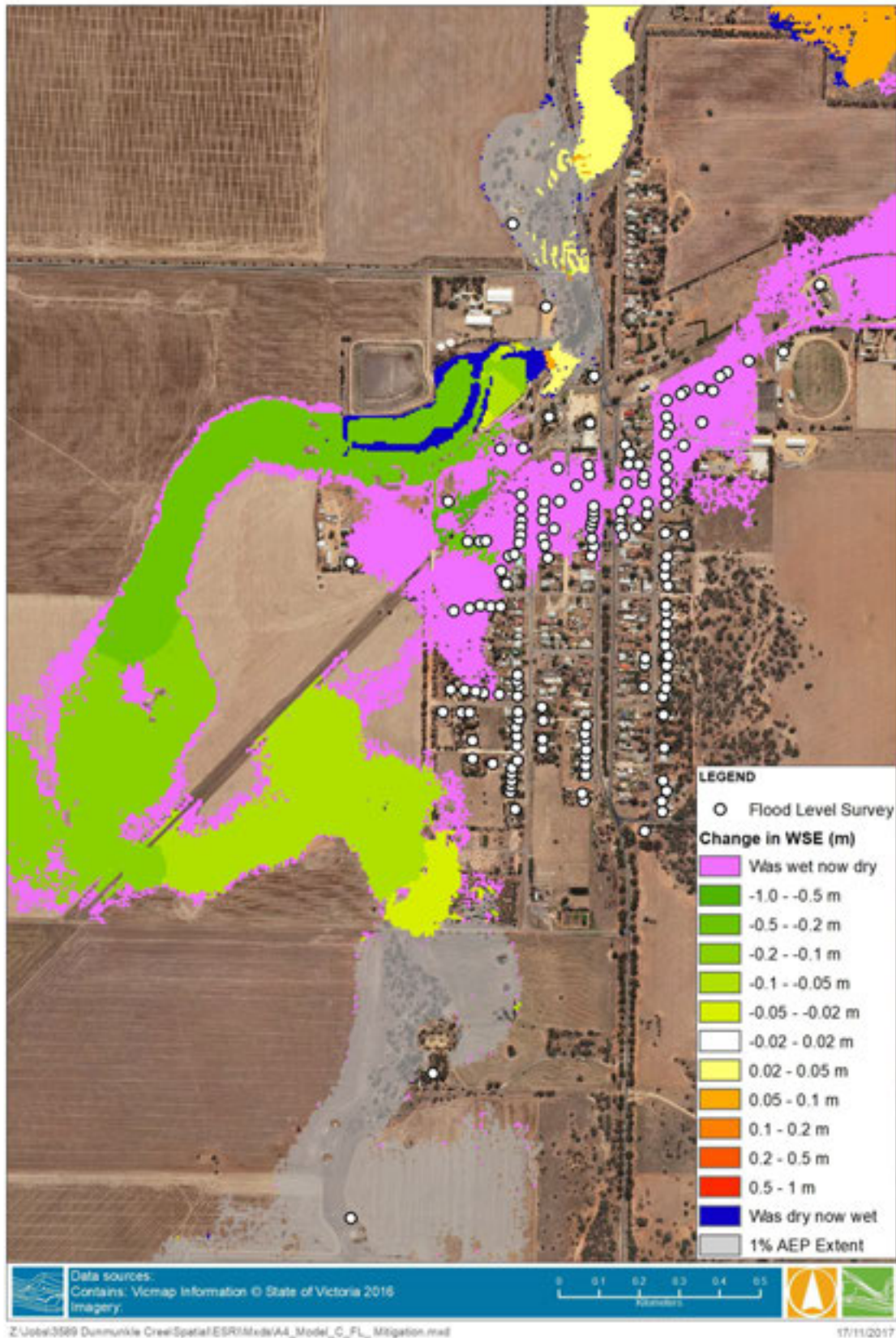


Figure 8-36 Change in 1% AEP flood levels in Rupanyup because of the water storage removal

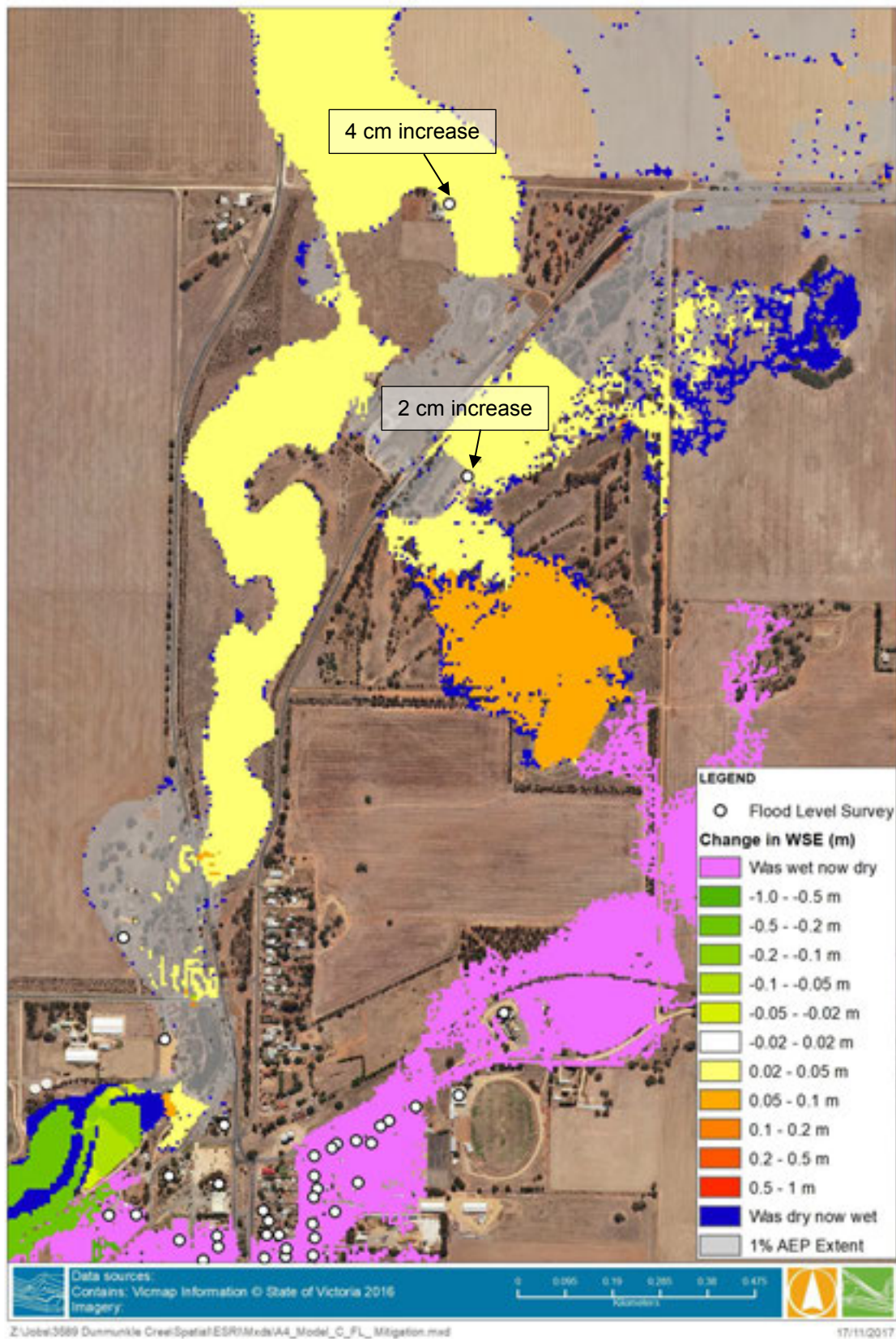


Figure 8-37 Change in 1% AEP flood levels downstream of Rupanyup because of the water storage removal

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8.3.3.1.3 DISCUSSION AND SUMMARY

Removal of the Rupanyup water storages by GWMWater is a requirement of their decommissioning, and will be a very cost effective flood mitigation solution. Modelling has demonstrated removal to a level of 138.5 m AHD prevents inundation through the township on either side of the railway embankment. At this level, the finished level of the decommissioned storages would be 1 to 1.2 m above the current Dunmunkle Creek channel bed and the water storage embankments would be reduced by 2.5 to 4.0 m in height. There is also a high area of topography downstream of the second storage that would need to be removed. This is around 5.8 m above the required finished surface. The western water storage has an invert level of 136.5 to 136.8 m AHD, requiring fill of around 2.0 to 1.5 m, while the eastern water storage has an invert of 135.5 to 135.8 m AHD, requiring fill of around 2.5 to 3.0 m.

A basic assessment of the cut/fill volume required for each storage and each section of removed embankment is shown below in Table 8-6.

Table 8-6 Cut/Fill volume requirements.

Storage/Embankment	Volume (m ³)
Western Storage	33,100 (fill)
Western Bank	39,600 (cut)
Eastern Storage	11,100 (fill)
Eastern Bank	22,900 (cut)
Balance	5,200 (cut)

8.3.3.2 Concept Design

8.3.3.2.1 OVERVIEW

The concept design of the modelled mitigation option presented above requires significant earth works to remove the water storages as well as a reasonable length of elevated road deck. To quantify these changes approximate costs were attributed to both sets of works.

8.3.3.2.2 WATER STORAGE REMOVAL

Based on changes to the model topography an estimated 51,000 m³ was moved from embankments and placed into the two storages. There are several options to consider for the final removal design, this includes:

- Existing services infrastructure
- Final design intent of the area, i.e. park, wetland, BMX bike track, etc.
- Maintenance requirements.
- Whether the spoil will be placed elsewhere or disposed of.
- Works on Waterway Licence requirements

8.3.3.2.3 ROAD LEVEL INCREASE

During Phase 1 modelling a section of Ron Lingham Drive and McIntyres Road was inundated in the mitigation scenario and a level increase or resurfacing for a 900 m length of road was recommended, the majority of this was on Ron Lingham Drive. In Phase 2, this was not shown to be as large an issue due to some slight reductions in flood level in the mitigation scenario. However, the changes to Ron Lingham Drive and



MacIntyres Road are still recommended to allow a degree of freeboard. In the Phase 2 mitigation scenario, an increase in water level of 5 cm would result in flood water flowing into Rupanyup.

The level of road height increase was calculated using a 0.3 m freeboard above the 1% AEP flood level, the length of road to be increased in height is shown in Figure 8-38. The increases are colour coded according to the increase required along the road. The increases vary from 0.2 m to 1.2 m at the southern end of Ron Lingham Drive. There may be some potential to reduce the level of road deck increase by limiting the protection to exclude the cemetery. However, levees would be required on private property.

A long section of the ground surface, 1% AEP peak water level and road crest height is shown in Figure 8-39. In this area the 0.5% AEP peak flood height is around 0.1 m above the 1% AEP flood level, so the proposed 0.3 m freeboard will protect the town against larger flood events.



Figure 8-38 Required road height increases including 0.3 m freeboard above the 1% AEP flood level

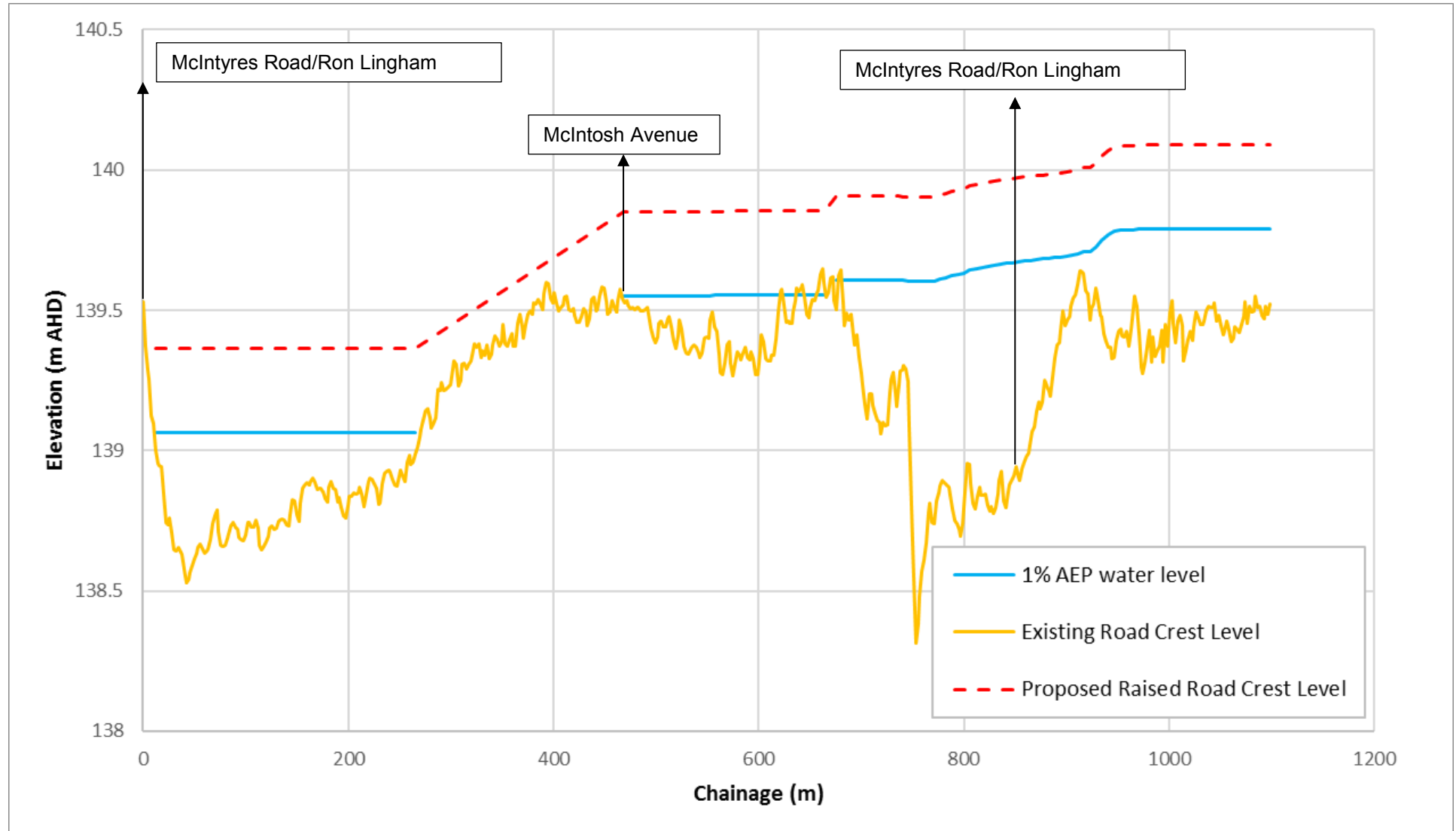


Figure 8-39 Existing and proposed road crest with 1% AEP flood level longitudinal section



8.3.3.3 Flood Damages Assessment

8.3.3.3.1 OVERVIEW

A flood damage assessment for the study area was undertaken using the range of design events modelled (20%, 10%, 5%, 2%, 1% and 0.5% AEP design events) for existing conditions. The damage assessment was used to determine the monetary flood damage for existing conditions.

Water Technology has developed an industry best practice flood damage assessment methodology that has been previously utilised for a number of studies in Victoria, combining aspects of the Rapid Appraisal Method, ANUFLOOD and other relevant flood damage literature. The NSW Office of Environment and Heritage stage damage curves are utilised, which represent far superior damage estimates at low depths above floor and for below floor flooding. Previously utilised ANUFLOOD stage damage curves tended to underestimate current day damages at low flood depths.

The model results for all mapped flood events were processed to calculate the numbers and locations of properties affected. This included properties with buildings inundated above floor, properties with buildings inundated below floor and properties where the building was not impacted but the grounds of the property were. In addition to the flood affected properties, lengths and damages of flood affected roads for each event were also calculated.

Agricultural damages were included in the damages assessment of the entire study area. Agricultural areas were delineated by areas classified as Farm Zone. The predominant agricultural activity along Dunmunkle Creek is broad acre cropping, a damages rate of \$250/Ha inundated was applied within the Farm Zone, this value was determined from the Rapid Appraisal Method¹³. In practice the impact of above floor flooding can be very different dependent upon the timing of the flood (in the planting /harvest cycle) along with the duration of inundation.

The Average Annual Damage (AAD) was determined as part of the flood damage assessment. The AAD is a measure of the flood damage per year averaged over an extended period. This is effectively a measure of the amount of money that must be put aside each year in readiness for when a flood may happen in the future.

The AAD was calculated for the entire study area and within Rupanyup township alone. This enables the modelled mitigation options for Rupanyup to be compared to the existing conditions damages in the township alone rather than including the broader study area agricultural damages.

8.3.3.3.2 EXISTING CONDITIONS

The flood damage assessment for existing conditions over the entire study area is shown below in Table 8-7. The total damage estimated from Dunmunkle Creek flooding in a 1% AEP event is approximately \$14.6 million. The Average Annual Damages (AAD) for existing conditions is estimated at approximately \$1,075,000.

The flood damage assessment for existing conditions within the Rupanyup township alone is shown below in Table 8-8. The total damage estimated from Dunmunkle Creek flooding in Rupanyup during a 1% AEP event is approximately \$1,496,000. The Average Annual Damages (AAD) for existing conditions is estimated at approximately \$29,000.

¹³ DNRE (2000), Rapid Appraisal Method



Table 8-7 Existing conditions damages over the entire study area

ARI (years)	200yr	100yr	50yr	20yr	10yr	5yr
AEP	0.5%	1%	2%	5%	10%	20%
Residential Buildings Flooded Above Floor	32	17	8	0	0	0
Commercial Buildings Flooded Above Floor	16	10	4	0	0	0
Properties Flooded Below Floor	1055	1022	806	713	302	233
Total Properties Flooded	1103	1049	818	713	302	233
Direct Potential External Damage Cost	\$7,355,000	\$6,991,000	\$5,004,000	\$4,108,000	\$1,171,000	\$716,000
Direct Potential Residential Damage Cost	\$1,845,000	\$1,056,000	\$399,000	\$0	\$0	\$0
Direct Potential Commercial Damage Cost	\$613,000	\$278,000	\$65,000	\$0	\$0	\$0
Total Direct Potential Damage Cost	\$9,812,000	\$8,325,000	\$5,469,000	\$4,108,000	\$1,171,000	\$716,000
Total Actual Damage Cost (0.8*Potential)	\$7,850,000	\$6,660,000	\$4,375,000	\$3,286,000	\$936,000	\$573,000
Infrastructure Damage Cost	\$5,629,000	\$4,841,000	\$3,900,000	\$2,606,000	\$1,501,000	\$965,000
	\$3,699,000	\$3,193,000	\$2,579,000	\$1,855,000	\$1,200,000	\$906,000
Total Cost	\$17,178,000	\$14,693,000	\$10,854,000	\$7,748,000	\$3,638,000	\$2,444,000
Average Annual Damage (AAD)		\$1,075,000				



Table 8-8 Existing conditions damages over the Rupanyup township

ARI (years)	200yr	100yr	50yr	20yr	10yr	5yr
AEP	0.5%	1%	2%	5%	10%	20%
Residential Buildings Flooded Above Floor	32	17	8	0	0	0
Commercial Buildings Flooded Above Floor	16	10	4	0	0	0
Properties Flooded Below Floor	130	100	30	9	1	0
Total Properties Flooded	178	127	42	9	1	0
Direct Potential External Damage Cost	\$424,000	\$323,000	\$102,000	\$18,000	\$500	\$0
Direct Potential Residential Damage Cost	\$1,845,000	\$1,056,000	\$399,000	\$0	\$0	\$0
Direct Potential Commercial Damage Cost	\$613,000	\$278,000	\$65,000	\$0	\$0	\$0
Total Direct Potential Damage Cost	\$2,881,000	\$1,657,000	\$567,000	\$18,000	\$500	\$0
Total Actual Damage Cost (0.8*Potential)	\$2,305,000	\$1,326,000	\$453,000	\$15,000	\$400	\$0
Infrastructure Damage Cost	\$215,000	\$170,000	\$77,000	\$14,000	\$0	\$0
Total Cost	\$2,520,000	\$1,496,000	\$530,000	\$28,000	\$400	\$0
Average Annual Damage (AAD)		\$29,000				



8.3.3.3.3 WATER STORAGE REMOVAL

Flood mitigation focussed on Rupanyup, being the location with the majority of people and residential property at risk of flooding.

The damages assessment was carried out in the same manner as described above for the Combined Option 1, based on damages in Rupanyup only. The flood damages assessment for Combined Option 1 is shown in Table 8-9. The total damage estimated from Dunmunkle Creek flooding in Rupanyup for the 1% AEP event was reduced to just \$111,000. The Average Annual Damages for Rupanyup in Combined Mitigation Option 1 was reduced to **\$5,000**, this compares to the existing Average Annual Damage of \$24,000, **an average saving of \$24,000 every year**.

Table 8-9 Water Storage Removal damages over the Rupanyup township

ARI (years)	200yr	100yr	50yr	20yr	10yr	5yr
AEP	0.5%	1%	2%	5%	10%	20%
Residential Buildings Flooded Above Floor	4	0	0	0	0	0
Commercial Buildings Flooded Above Floor	1	1	1	0	0	0
Properties Flooded Below Floor	56	22	12	10	2	0
Total Properties Flooded	61	23	13	10	2	0
Direct Potential External Damage Cost	\$127,000	\$51,000	\$38,000	\$29,000	\$500	\$0
Direct Potential Residential Damage Cost	\$219,000	\$0	\$0	\$0	\$0	\$0
Direct Potential Commercial Damage Cost	\$23,000	\$22,000	\$20,000	\$0	\$0	\$0
Total Direct Potential Damage Cost	\$369,000	\$73,000	\$58,000	\$29,000	\$500	\$0
Total Actual Damage Cost (0.8*Potential)	\$295,000	\$58,000	\$46,000	\$23,000	\$400	\$0
Infrastructure Damage Cost	\$92,000	\$53,000	\$35,000	\$15,000	\$0	\$0
Total Cost	\$387,000	\$111,000	\$81,000	\$38,000	\$400	\$0
Average Annual Damage (AAD)	\$5,000					



8.3.3.4 Benefit Cost Analysis

8.3.3.4.1 MITIGATION OPTION COST

The estimated cost of the recommended mitigation is **\$439,000**. This includes **\$188,000** for an increase to Ron Lingham Drive and **\$95,000** for removal of the Rupanyup water storages in construction costs. The road level increase cost estimate includes a 300 mm gravel road pavement for the full 1.1 km length. Note that only 900 m requires raising, but resurfacing would likely be completed along the entire length. The cost of removing the water storages was determined by information provided by GWMWater. A breakdown of costs for each set of works is shown in Table 8-10 and Table 8-11. A 30% contingency cost was included along with engineering and administration costs. It should be noted that these costs are based on estimated rates and should be checked during the detailed design phase.

The costing rates were based on Melbourne Water rates for earthworks and construction costs and a comparison to cost estimates for similar works for other flood studies.

An annual maintenance cost (1.5% of the total construction cost) was factored in for the channel and levee works. No maintenance was included for the road upgrades as they will fall within the existing road budget.

Table 8-10 Ron Lingham Drive and McIntyre Road Costs

	Works Description	Estimated Construction Cost	Estimated Annual Maintenance Cost
Combined Option 1	Ron Lingham Drive and McIntyre Road	\$187,625	\$0
	Engineering Fee @ 15%	\$28,144	\$0
	Administration Fee @ 9%	\$19,419	\$0
	Contingencies @ 30%	\$56,288	\$0
	FORECAST EXPENDITURE	\$291,475	\$0

Table 8-11 Water Storage Removal Costs

	Works Description	Estimated Construction Cost	Estimated Annual Maintenance Cost
Combined Option 1	Water storage removal	\$95,000	\$1,425
	Engineering Fee @ 15%	\$14,250	
	Administration Fee @ 9%	\$9,833	
	Contingencies @ 30%	\$28,500	
	FORECAST EXPENDITURE	\$147,583	\$1,425



8.3.3.4.2 BENEFIT COST RATIO

The results of the benefit-cost analysis are shown below in Table 8-12. For this analysis, a net present value model was used, applying a 6% discount rate over a 30-year project life. The benefit cost ratio should ideally be equal to or greater than 1, meaning that the long-term benefit of flood mitigation equals or exceeds the long term costs. Removal of the Rupanyup water storages is clearly a cost-effective solution with a benefit cost ratio of 2.08, with the addition of increasing Ron Lingham Drive and McIntyre Road this decreases to 0.7.

Table 8-12 Benefit Cost Analysis

	Existing Conditions	Water Storage Removal, Ron Lingham Drive and McIntyre Road raising	Water Storage Removal Only
Average Annual Damage	\$29,000	\$5,000	\$5,000
Annual Maintenance Cost	-	\$1,425	\$1,425
Annual Cost Savings	-	\$22,575	\$22,575
Net Present Value	-	\$317,459	\$317,459
Capital Cost of Mitigation	-	\$439,058	\$147,583
Benefit-Cost Ratio	-	0.7	2.2

8.3.3.5 Channel changes along the northern end of Dunmunkle Creek

8.3.3.5.1 OVERVIEW

As discussed in Section 7.2.2, flood water only reaches the lower ends of Dunmunkle Creek during events equal to or greater than a 5% AEP. In events of this magnitude the channel capacity is exceeded and out of bank flows occur. At the lower ends of Dunmunkle Creek peak flood heights are dictated by the volume of water that flows along Dunmunkle Creek rather than the peak flow. This is due to the system being terminal, with higher volumes allowing the flood flows to spread further down the floodplain.

There are some sections of Dunmunkle Creek that remain in bank during the 5% AEP event between the Donald Murtoa Road and Boolite, as shown in Figure 8-40. In this section both the 1% AEP and 2% AEP flood event have areas where flow spills from the main channel, with no out of bank flows during the 5% AEP flood event (shown in orange).

Throughout all the community consultation undertaken for the Dunmunkle Creek Flood Investigation the universal message from the community has been for agricultural property along Dunmunkle Creek to be inundated as it would occur in a 'natural' flood flow regime, meaning no properties are worse or better off as a result of the channels constructed in the bed of Dunmunkle Creek. The concern in the Boolite area has predominantly been that the channelisation of Dunmunkle Creek along its length expedites the water flowing north by preventing it from spilling to the floodplain as it once naturally would have done.

To assess the potential to force water to spill from the Dunmunkle Creek channel in sections where it remains in channel for the 5% AEP flood event two scenarios were modelled:

- Removing the channel embankments and putting restrictions to 100% of the channel depth to natural surface
- Removing the channel embankments and filling the Dunmunkle Creek channel to 0.3 m from natural surface



Channel capacity restrictions were put in at 9 locations in the most confined areas of the 5% AEP flood extent south of Lawler Road, these locations are shown in Figure 8-41.

Each scenario was modelled for the 1% and 5% AEP flood events and a comparison made to existing conditions.

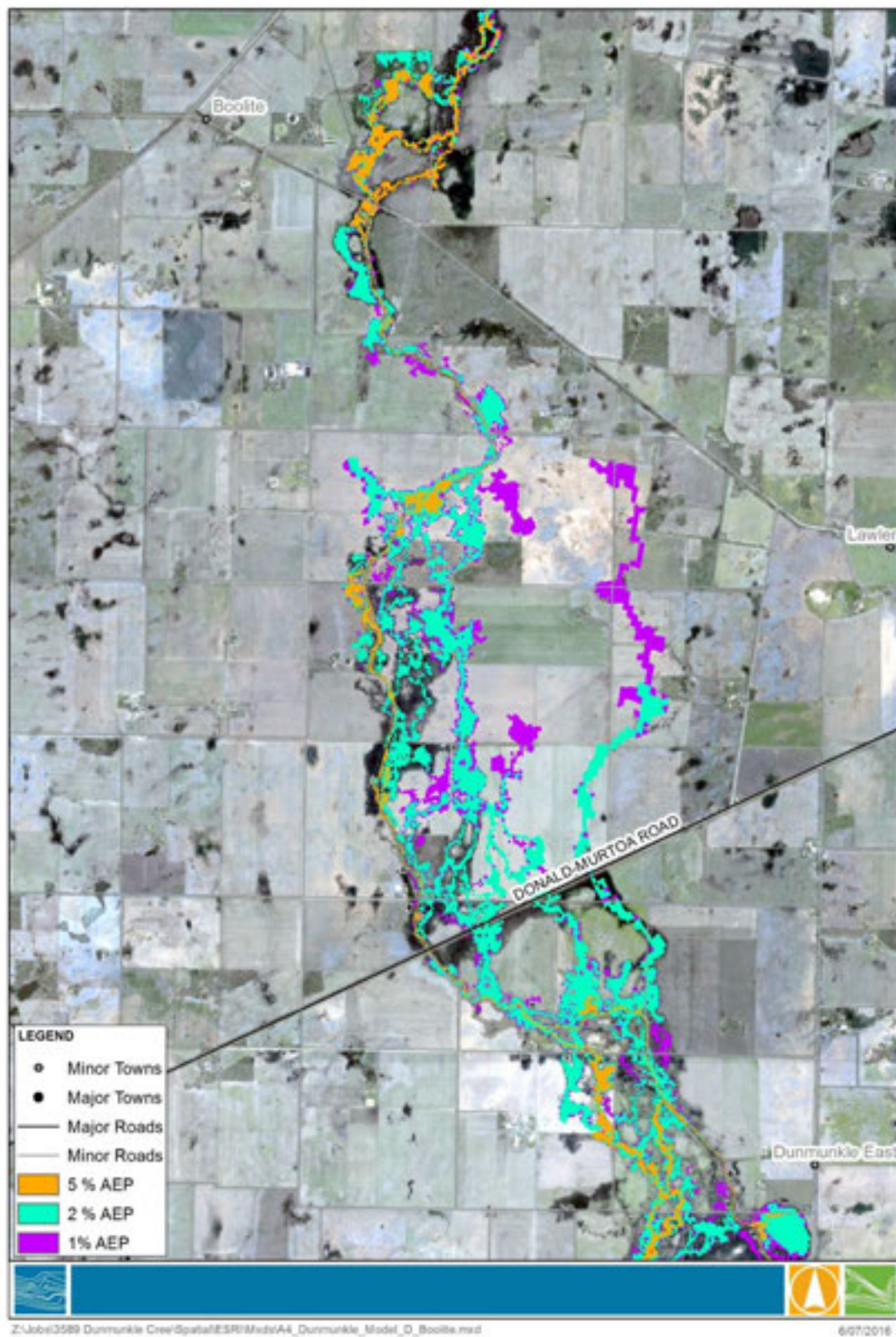


Figure 8-40 Inundation in between Donald Murtoa Road and Boolite



Figure 8-41 Channel block locations south of Lawler Road, Boolite

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8.3.3.5.2 MODELLING

Channel restriction to 100% of channel depth

The 1% AEP flood event is not confined to the Dunmunkle Creek channel in its lower reaches, with water spilling out in almost all locations. Placing 100% channel restriction south of Lawler Road causes more water to breakout of the channel with an increase in depth of up to 0.2 m, but the majority of increases are less than 0.1 m and there is a limited increase in inundation extent. There is a small decrease in extent at the northern end, north of Carron but the area inundated remains basically the same with water flowing around the channel restrictions in the already inundated areas. The change in water levels and extent due to 100% channel restrictions in a 1% AEP flood event are shown in Figure 8-42.

Existing conditions modelling for the 5% AEP event is much more confined than the 1% AEP event and the channel restrictions cause much larger increases in flood extent. The restrictions force water out of Dunmunkle Creek in numerous locations and prevent it from flowing north of Lawler Road. The volume of the 5% AEP flood flow in Dunmunkle Creek fills the floodplain and doesn't progress further. It should be noted that modelling of the event was extended by 1 week duration as the progression of flood flows was significantly slowed by the restrictions and it took much longer for flood water to progress downstream. The change in water levels and extent due to 100% channel restrictions in a 5% AEP flood event are shown in Figure 8-43.

Channel restriction to 300 mm from natural surface

Given the large decrease in downstream inundation and the 100% channel restriction ceasing progression of Dunmunkle Creek in a 5% AEP flow event, the modelled restrictions in Dunmunkle Creek was reduced. The creek was filled in locations to allow 300 mm of airspace in the creek between the top of the fill and the surrounding natural surface adjacent to the creek. This creates a series of weirs along the creek, which can store water and slow the progression of flood waters without entirely filling the creek channel capacity.

In a 1% AEP flood event the difference between the existing and partially restricted flood levels was similar to that of the 100% restricted scenario but slightly less pronounced. There were areas with an increase in flood depth upstream of the restrictions, but the increase in flood extent was relatively minor. There was a decrease in the inundation extent north of Carron, less than that observed in the 100% channel restriction scenario. The change in water levels and extent due to channel fill 300 mm from the natural surface in a 1% AEP flood event are shown in Figure 8-44.

In a 5% AEP flood the difference between the existing and partially restricted flood levels was reduced compared to the 100% restriction scenario. This is particularly noticeable at the upper end of the partially restricted sections. At the lower end the extent is larger under the partially restricted scenario due to more water reaching south of Lawler Road. Water is able to flow north of Lawler Road with a slight reduction in extent at the very downstream end of the floodplain. The change in water levels and extent due to channel fill 300 mm from the natural surface in a 5% AEP flood event are shown in Figure 8-45.

8.3.3.5.3 DISCUSSION

Modelling of channel blocks within Dunmunkle Creek has demonstrated that the natural floodplain can be engaged at flood events as low as a 5% AEP while still allowing water to progress along Dunmunkle Creek. The degree of the blocks can alter the locations that are inundated and how far inundation progresses to the north. The degree to which works are undertaken will be dependent on the goals of the community and Wimmera CMA. It is recommended that areas which would naturally flood in frequent events be targeted, these may be areas with existing native vegetation present. Community meetings suggested that partial restrictions are an attractive solution to slow smaller floods.

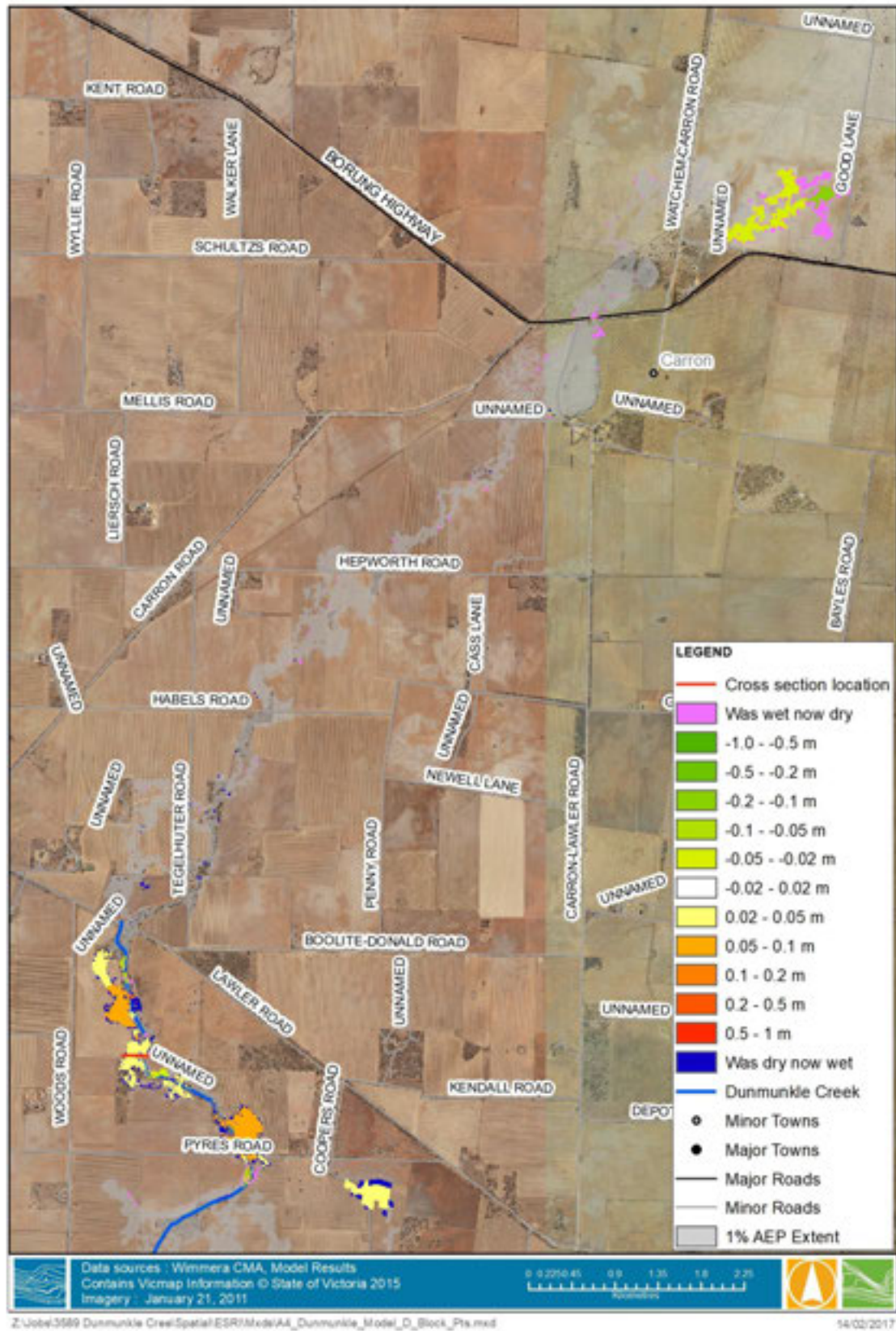


Figure 8-42 1% AEP - Impact of 100% channel blocks

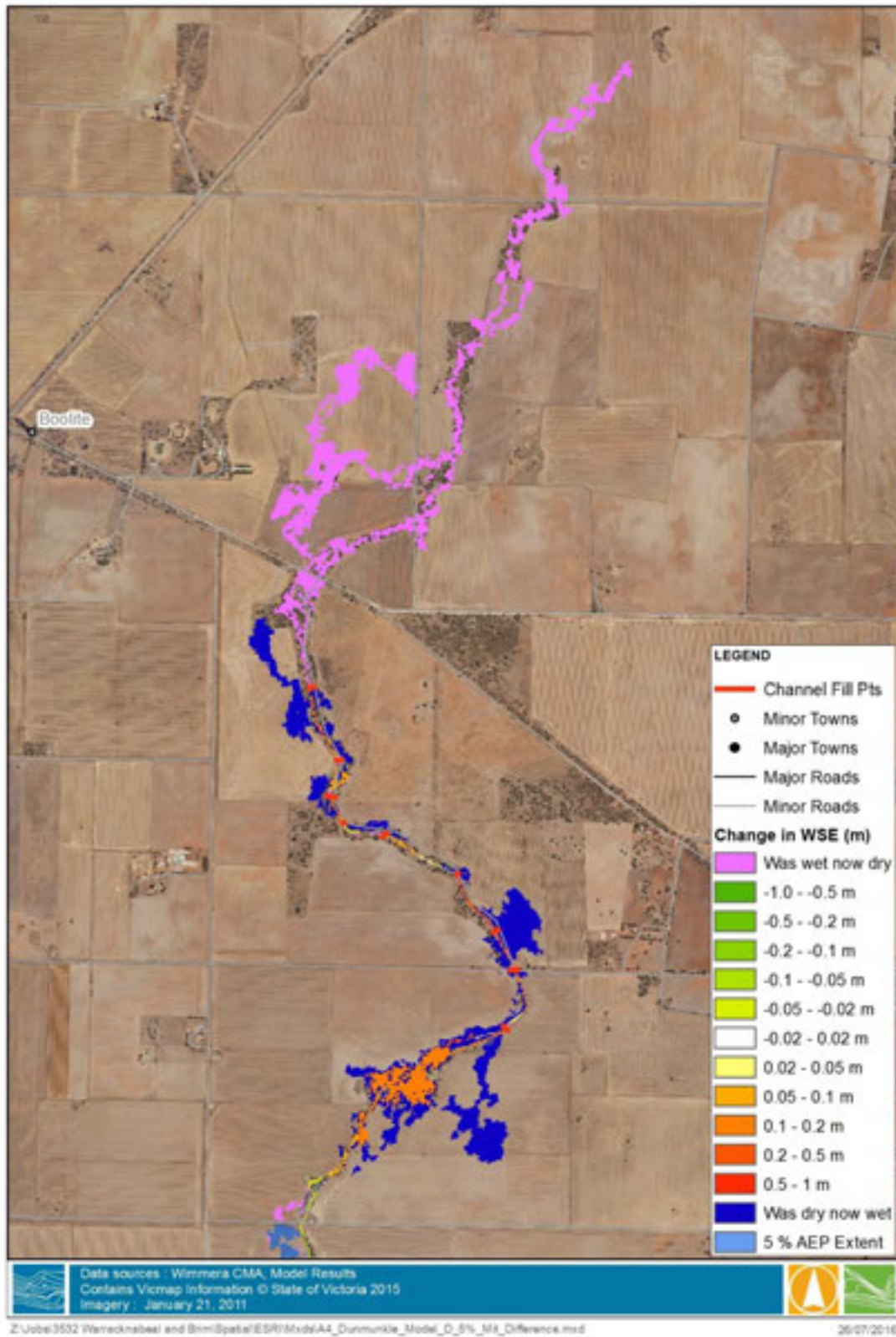


Figure 8-43 5% AEP - Impact of 100% channel blocks

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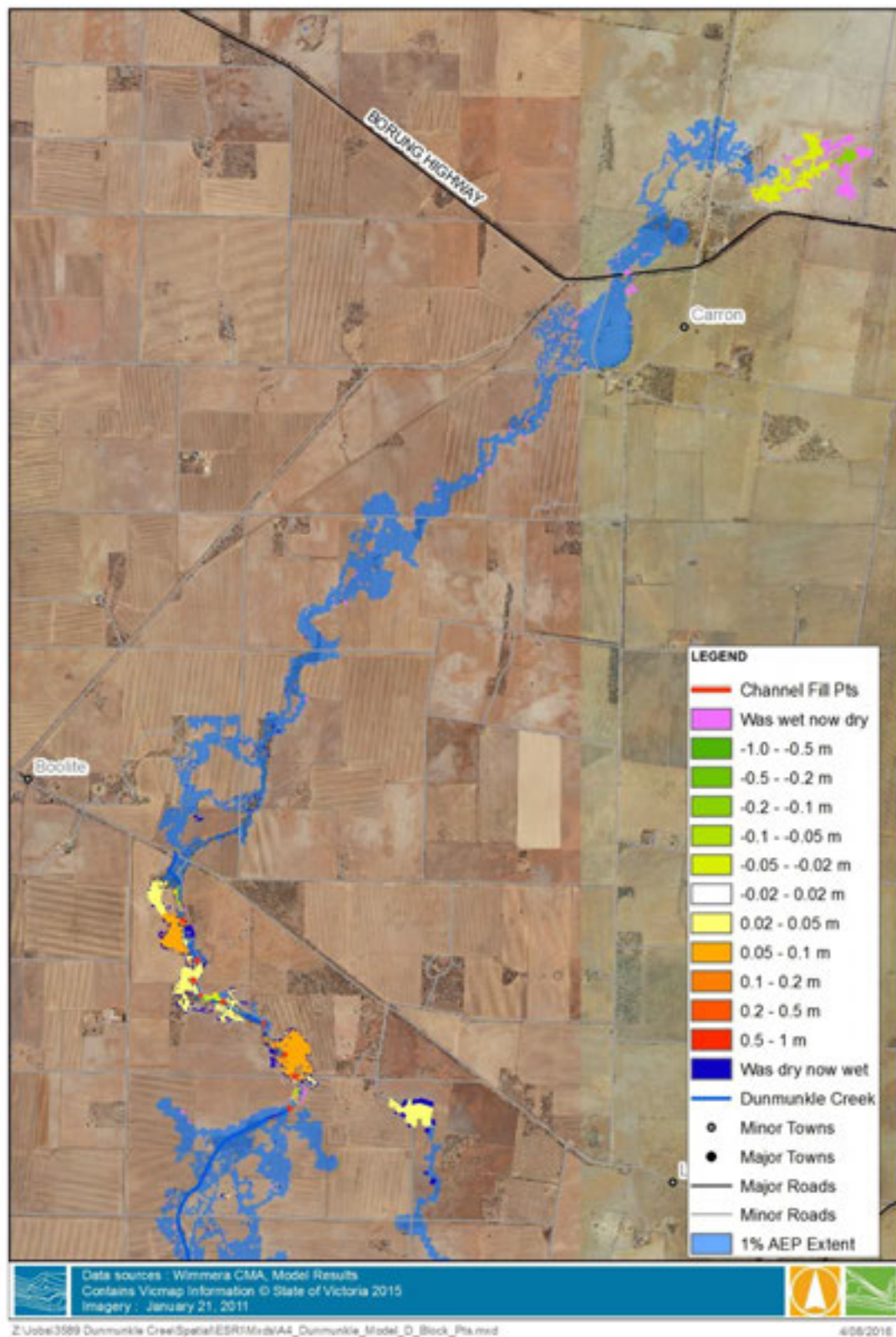


Figure 8-44 1% AEP - Impact of channel blocks to 300mm from natural surface

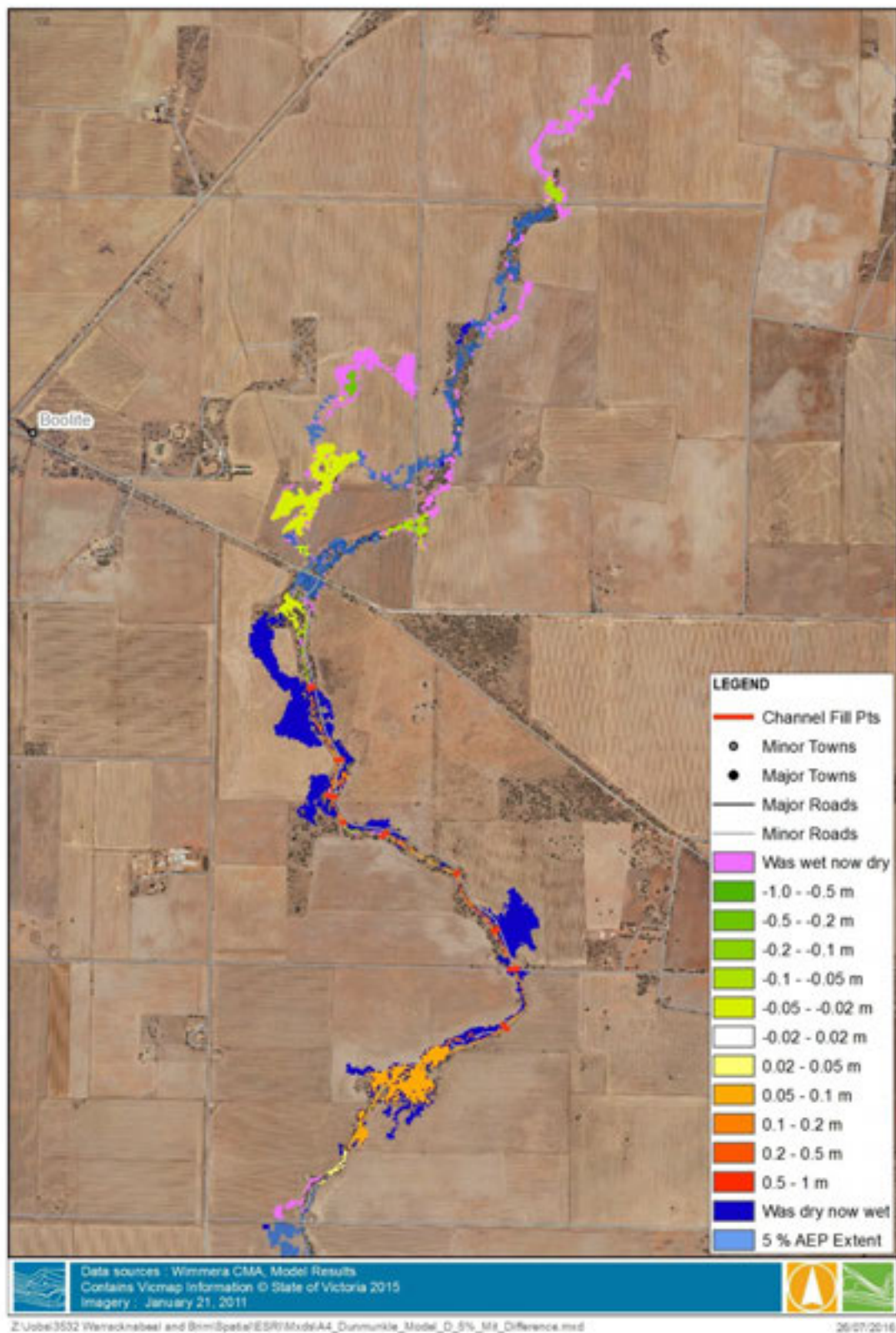


Figure 8-45 5% AEP - Impact of channel blocks to 30cm from natural surface

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8.3.3.6 Summary and Recommendations

Throughout the production of this report the community's ideas and views on flood mitigation were considered and used as the basis for the technical work completed. Numerous ideas on the potential channel removal and flood mitigation scenarios are based on conversations at community and steering committee meetings. These suggested options were tested using a prefeasibility assessment ranking system to determine which options warranted detailed modelling. The detailed modelling was used to assess the reduction in damages resulting from the mitigation options and the most comprehensive flood mitigation solution. The final combined option reduced the Average Annual Damages from \$44,000/year to \$5,000/year with a cost benefit ratio of 0.7. This indicates funding the mitigation solution costs less than the damage caused by a flood on an average annual basis and is a strong case for government funding.

The split of floodwater between the Murtoa overland flow path and Dunmunkle Creek (towards Rupanyup) was shown to be influenced by the presence of the Rocklands Lubeck Channel. Removal of the channel would redistribute more water to the west toward Murtoa, however the additional flow does not adversely impact any buildings.

There are several recommendations for further work that could be undertaken to ensure flood mitigation works for Dunmunkle Creek are as cost effective and sustainable as possible:

- The Rupanyup community be consulted regarding what they would like to see in place of the removed water storages if that option was to progress. The earthworks assumed for the modelled reservoir removal would be aligned with a lowered land surface that would facilitate the construction of a wetland area. Alternatives may be to remove the storages to ground level and construct some other public asset such as a park or a bike track. Whatever the outcome, the use of that space should ensure that no raised buildings or earthworks obstruct floodplain flow. The cost benefit ratio of the works is expected to be high and likely to receive government financial support.
- Post community consultation a concept plan of the area should be developed and modelled to determine the best arrangement prior to detailed design.
- The potential for stormwater mitigation in Rupanyup should be further considered with the incorporation of the stormwater pipe network, and consideration of the levee, drain and possible pumping solution. Detailed feature survey may be required of the existing stormwater system.
- The Rocklands Lubeck Channel through the Bryntirion Forest should be assessed for decommissioning considering the native vegetation currently existing on the embankments. Once a preferred decommissioning strategy is completed, modelling of the recommended removal should be completed.
- **Operable infrastructure on the Rocklands Lubeck Channel should be removed to prevent members of community attempting to operate them during a flood (this occurred during January 2011 which could have resulted in loss of life).**
- Further consideration of decommissioning of Dunmunkle Creek's embankments should be made with regards to environmental benefit. While it has been demonstrated there is no real benefit in terms of flood impacts, environmental benefit could be gained through returning Dunmunkle Creek to a more natural waterway. This return could be made through a combination of revegetation, earthworks and fencing. This would require significant planning and consultation with landholders.
- Discussion with GWMWater and landholders in the Boolite area on how channel restrictions could be used to engage areas of floodplain that are currently prevented from being inundated by constructed channels whilst ensuring floodwater is not allowed to sit for long periods of time that could cause pasture or crop damage.



8.4 Non-structural mitigation

8.4.1 Overview

There are a range of non-structural mitigation options possible to reduce flood damages, these include:

- Land use planning;
- Flood warning and response; and,
- Flood awareness.

During this project, sub-consultants Planning and Environmental Design and Molino Stewart were engaged to assist with reviewing the current non-structural flood mitigation arrangements for the land use planning and flood warning, response and awareness.

The below sections summarise their individual reports, if further detail is required, please refer to:

- Planning and Environmental Design (2016), Planning Scheme Amendment Documentation – Dunmunkle Flood Investigation.
- Molino Stewart (2016), Dunmunkle Flood Investigation - Flood Warning Assessment and Recommendations Report.

8.4.2 Land Use Planning

The Victoria Planning Provisions (VPPs) contain several controls that can be employed to provide guidance for the use and development of land that is affected by inundation from floodwaters. These controls include the Floodway Overlay (FO), the Land Subject to Inundation Overlay (LSIO), the Special Building Overlay (SBO), and the Urban Floodway Zone (UFZ).

Section 6(e) of the Planning and Environment Act 1987 enables planning schemes to 'regulate or prohibit any use or development in hazardous areas, or areas likely to become hazardous'. As a result, planning schemes contain State planning policy for floodplain management requiring, among other things, that flood risk be considered in the preparation of planning schemes and in land use decisions.

Guidance for applying flood controls to Planning Schemes is available from the Department of Environment, Land, Water and Planning's (formerly Department of Planning and Community Development's (DPCD)) Practice Note on Applying Flood Controls in Planning Schemes.

Planning Schemes can be viewed online at <http://services.land.vic.gov.au/maps/pmo.jsp>. It is recommended that the planning scheme for this project's study area is amended to reflect the flood risk identified by this project.

This study has produced draft LSIO and FO layers for inclusion in the Yarriambiack Shire Council and Northern Grampians Shire Council Planning Schemes. The LSIO is representative of the 1% AEP extent of inundation, while FO represents a higher flood risk, combining 1% AEP flood depths and velocities. As specified by Wimmera CMA the FO was defined by depths greater than 0.5 m and a velocity depth product greater than 0.4 m²/s. Figure 8-46 shows the proposed FO for the entire study area, with a closer perspective of the Rupanyup township shown in Figure 8-47.

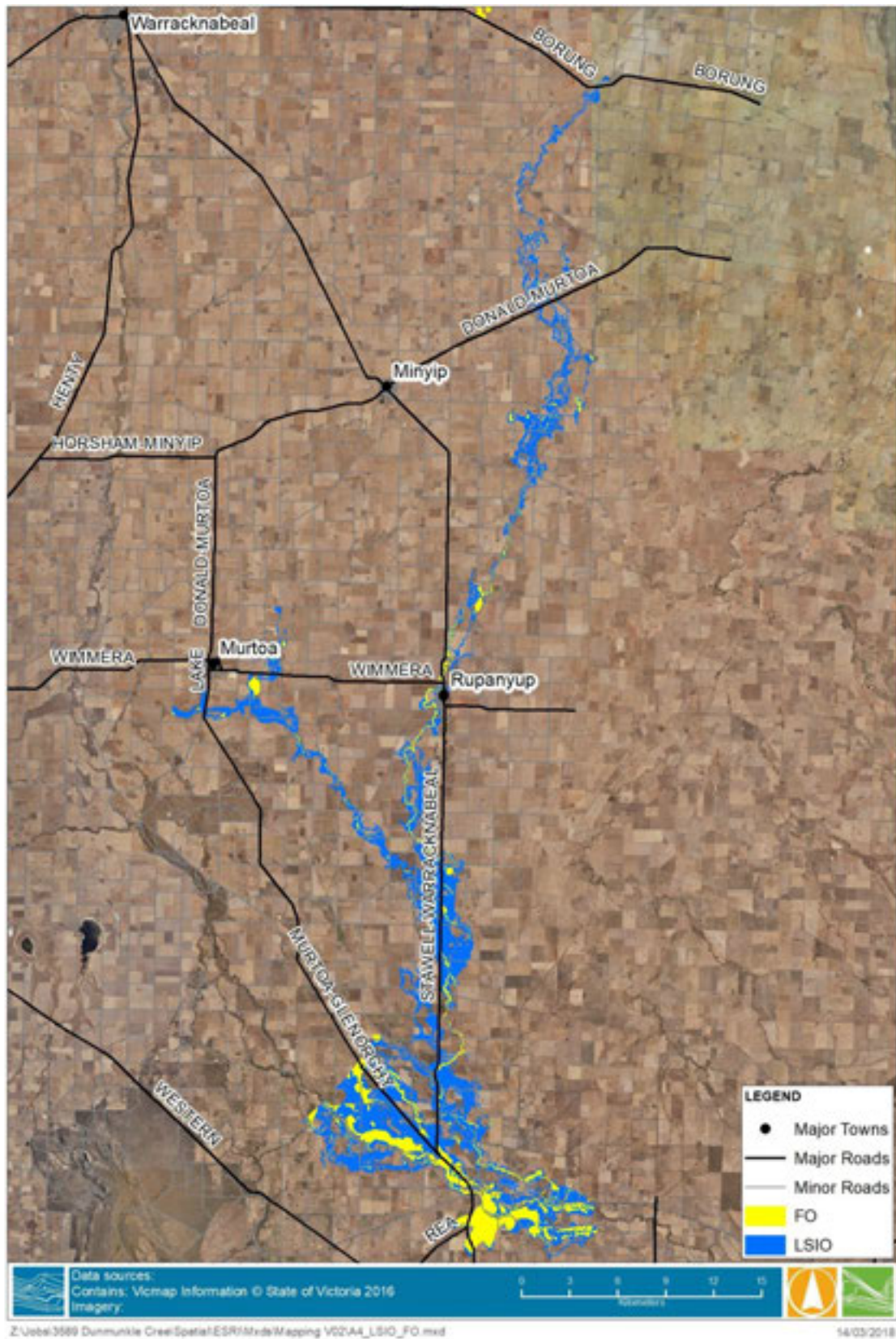


Figure 8-46 Flood Overland and Land Subject to Inundation Overlay covering the study area

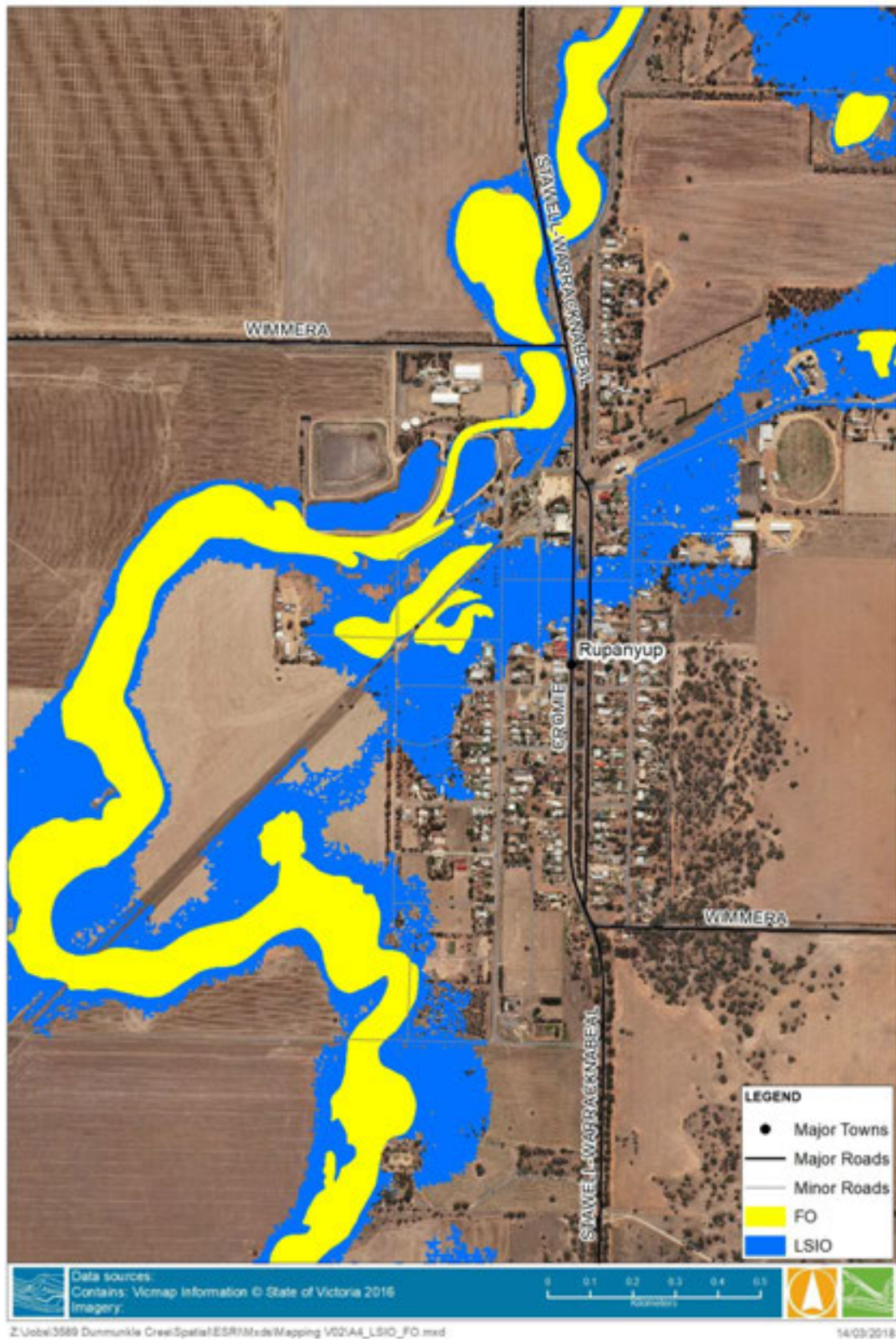


Figure 8-47 Flood Overland and Land Subject to Inundation Overlay in Rupanyup



8.4.3 Flood Warning Recommendations

8.4.3.1 Overview

An objective of the Dunmunkle Flood Investigation was to identify options for improved flood warning arrangements. Below is a summary of the full Dunmunkle Flood Investigation – Total Flood Warning System (TFWS) Assessment¹⁴. The objectives of the flood warning system assessment were:

- To conduct an assessment of the existing flood warning system for the investigation area; and,
- To recommend improvements to form a TFWS based on the assessment.

8.4.3.2 Total Flood Warning Systems

In practice, flood warning systems provide individuals and communities with time to carry out actions to protect themselves, and if possible, aspects of their properties including stock and pets.

As part of best practice in flood risk management in Australia, flood prediction and warning is viewed as an important treatment option for residual flood risk for existing and future development in the floodplain (Australian Emergency Management Institute, 2013, page 82).

In Australia, the concept of the ‘total flood warning system’ (TFWS) has been used to describe the full range of elements that must be developed if flood warning services are to be provided effectively. The lead guiding document for the development of the TFWS in Australia is Manual 21 – Flood Warning (Attorney-General’s Department, 2009).

According to Manual 21 (page 6), at its simplest, the TFWS consists of six components:

1. Prediction - Detecting changes in the environment that lead to flooding and predicting river levels during the flood.
2. Interpretation - Identifying in advance the impacts of the predicted flood levels on communities at risk.
3. Message Construction - Devising the content of the message which will warn people of impending flooding.
4. Communication – Disseminating warning information in a timely fashion to people and organisations likely to be affected by the flood.
5. Response - Generating appropriate and timely actions from the threatened community and from the agencies involved.
6. Review - Examining the various aspects of the system with a view to improving its performance.

Manual 21 (page 7) stresses that for the TFWS to “work effectively, these components must all be present, and they must be integrated rather than operating in isolation from each other.”

When designing a TFWS, Manual 21 (pages 7-8) advises that the following points need to be addressed:

- The system must meet the needs of its clients including identifying:
 - levels of flooding at which warnings are required

¹⁴ Molino Stewart (2017), Dunmunkle Flood Investigation – Total Flood Warning System Assessment



- the impacts at the different levels of flooding
- warning time the community requires and what can be provided
- appropriate subject matter content for warning messages
- the ways in which warning messages are to be disseminated
- the frequency of warning updates.
- The system must be part of the emergency management arrangements established by the relevant State or Territory as defined in disaster or emergency management plans.
 - The review of the system must be carried out by all emergency agencies and by the community itself.
 - The roles of the emergency agencies must be clearly defined for each component of the system.
 - The system must be incorporated into the wider floodplain management.
 - The system should be regularly tested and maintained.

Some researchers such as Molino et al (2011) believe that there are additional preliminary components required for an effective TFWS, including understanding the flood risk that the TFWS operates under, the impact of prior community flood education and the guidance provided by emergency management action plans (e.g. Municipal Flood Emergency Plans). This more holistic TFWS framework is shown in Figure 8-48 and is adopted for analysis in this project.

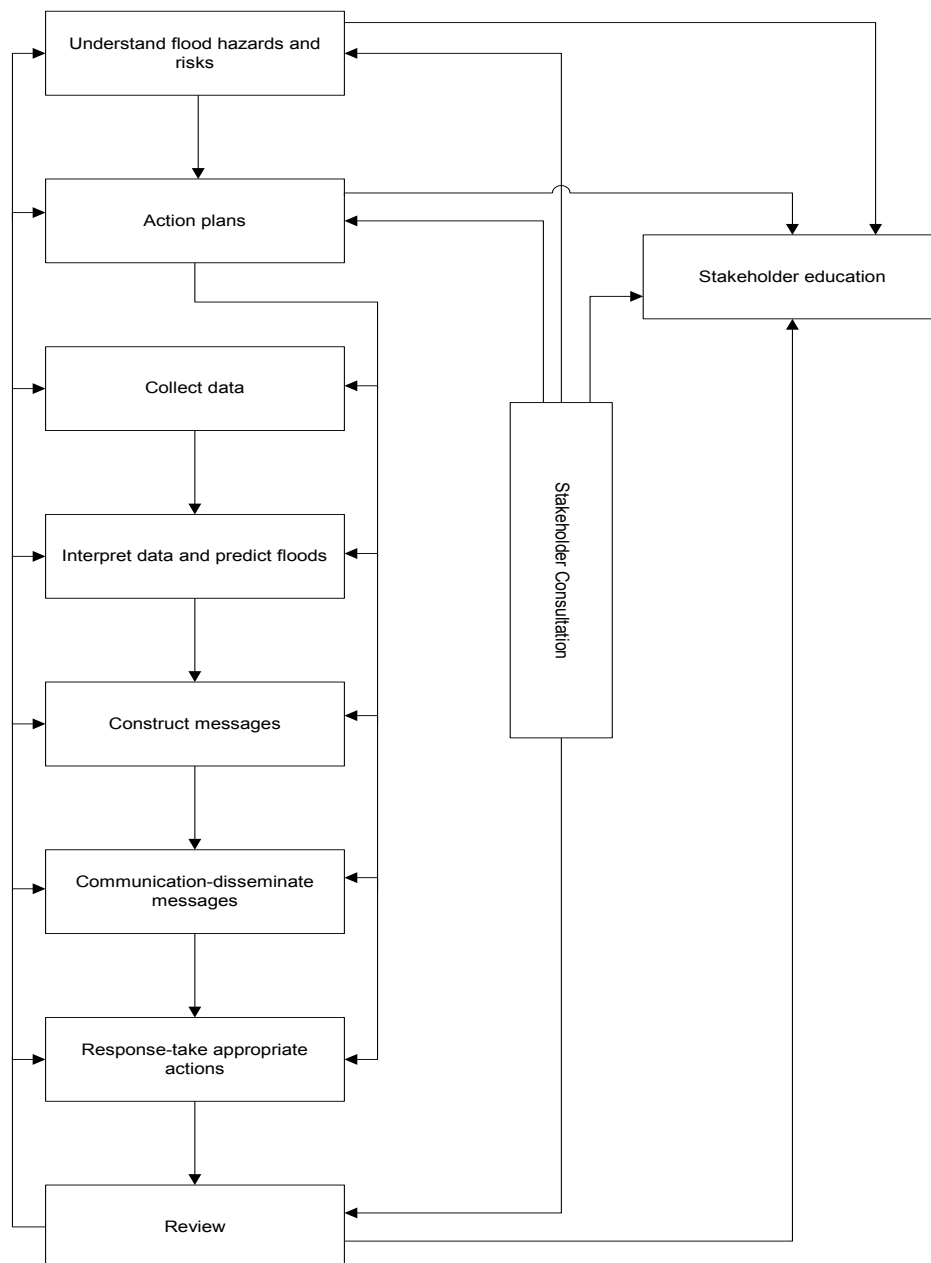


Figure 8-48 The Total Flood Warning System (source: Molino et al, 2011)

8.4.3.3 Improvements to form a TFWS

Based on an assessment of existing flood warning system the following improvements are recommended to form a TFWS according to the TFWS building blocks.

8.4.3.3.1 UNDERSTANDING THE FLOOD RISK

There is good agency and Council understanding of flood risk in Rupanyup and the Dunmunkle Creek catchment due to this project. However, flood risk needs to be communicated to local residents, including current and prospective landowners. Wimmera CMA should update all flood maps and reports on its website so current details of property flood risk will be available to the community. There are many alternative pathways to making flood data available to community, including online flood mapping portals.



At this stage there is no Land Subject to Inundation Overlay (LSIO) or Floodway Overlay (FO) along Dunmunkle Creek, so these details do not appear on a Section 32 certificate issued to property owners. To help the understanding of flood risk, it is recommended that Yarriambiack Shire Council and Northern Grampians Shire Council use the mapping from this project to implement a planning scheme amendment and introduce Land Subject to Inundation Overlay (LSIO) and Floodway Overlay (FO) along Dunmunkle Creek.

Community education (Section 4.3) should also inform the communities in the study area of their flood risk.

Recommendation 1: Provide readily available details to local communities of their flood risk through the Wimmera CMA website (or a flood mapping portal), planning scheme amendments, Section 32 certificates and ongoing community education.

8.4.3.3.2 EMERGENCY MANAGEMENT PLANNING

The Yarriambiack Shire Council Flood Response Plan should be upgraded to the current Municipal Flood Emergency Plan template and include information from the Dunmunkle Creek Flood Study. The Northern Grampians Shire Council Municipal Flood Emergency Plan should be updated to include information from the Dunmunkle Creek Flood Study.

Recommendation 2: The Yarriambiack Shire Council and Northern Grampians Shire Council Municipal Flood Emergency Plans should be updated to include information from the Dunmunkle Flood Study.

8.4.3.3.3 COMMUNITY FLOOD EDUCATION

VICSES is the lead agency for community flood education and engagement, with support from Wimmera CMA, Yarriambiack Shire Council and Northern Grampians Shire Council.

There has been no targeted local community education in the study area, including flood warning education, although some engagement activities have been instigated by Wimmera CMA (e.g. with rural landholders regarding the impact of decommissioning on flooding).

VICSES plans to look at recruiting for the Dunmunkle SES Unit and aims to raise flood awareness through this process. It will also use the outcomes of this flood investigation to engage with the local community about how it would like to learn about flooding and flood warning.

From this TFWS assessment, content of local community education activities could include:

- An understanding of flood risk (with and without the removal of the water storages at Rupanyup)
- Web-based property specific flood risk information
- Details of local triggers (e.g. at the Glenorchy gauge) and what people should do at these levels
- An understanding of evacuation routes and the location of evacuation centres
- Background to flood warnings issued by the BoM and other services (e.g. radar maps, pluviographs)
- An understanding of the range of ways that warning messages are sent to the communities in the study area including for those without internet access
- Messaging related to not driving etc. in floodwaters
- Stock food and water in readiness for isolation, up to 72 hours
- Encouragement to help others including neighbours and those requiring assistance
- Encouragement to participate in the establishment and review of the TFWS



Recommendation 3: Educate the communities in the study area about aspects of the TFWS including their flood risk, local flood warning triggers for action and the warnings that they will receive if a flood is imminent.

8.4.3.3.4 DATA COLLECTION

As noted, for riverine flooding there are no streamflow gauges on Dunmunkle Creek. However, as a consistent portion of the Wimmera River peak is distributed to Dunmunkle Creek, the two streamflow gauges on the Wimmera River (Glynwylln and Glenorchy) can provide a relatively good indication of potential flood impacts in the study area.

The installation of a streamflow gauge immediately upstream of Rupanyup was analysed using a benefit-cost assessment process (Molino Stewart, 2013). Utilising the Flood Damage Assessment Summary data for Rupanyup and noting that the installation of a new streamflow gauge costs approximately \$25,000 plus \$10,000 O&M per year, it was found that the benefit-cost ratio of this option would be very low (0.16) over a 20 year cycle. It would be even lower with the removal of Rupanyup water storages, as this treats the riverine flood risk for events up to a 1% AEP.

The option of an additional streamflow gauge between the Dunmunkle Creek offtake and the Wimmera River / Concongella Creek junction (e.g. located at Campbells Bridge) was also analysed. This gauge could provide more warning lead time (e.g. up to six hours) due to its closer proximity to the confluence. This would give a slightly higher benefit-cost ratio of 0.41 over a 20 year cycle.

Both options are not recommended on economic grounds, particularly if the Rupanyup water storages are removed, as this treats the riverine flood risk for events up to a 1% AEP.

The installation of a pluviograph at Rupanyup was also assessed. It is difficult to calculate improved warning lead time as a result of obtaining sub-daily readings from a local station. Also, the damages data available is for riverine flooding (Water Technology, 2016c). However, an estimation using the cost of installing a pluviograph at \$10,000 plus 5,000 O&M per year, gives an estimated benefit-cost ratio for this option of between 1 and 2. A pluviograph will provide data that the local SES unit and community can use to understand drainage overflows and respond to flooding due to local intense rainfall events. There is also some additional merit for the farming community and the use of a gauge for short term farm operation.

8.4.3.3.5 PREDICTION

Prediction depends largely on the forecast modelling by the BoM and the data collection.

The use of a flood warning trigger for the commencement of flow from the Wimmera River into Dunmunkle Creek should be used by the BoM. This trigger level could be 14,200 ML/d (20% AEP) at the Glenorchy gauge. The recognition of this trigger by the BoM in its flood warnings for the region would increase the flood warning lead time by up to 24 hours (thus giving Rupanyup up to two days warning).

Recommendation 5: Use a flood level trigger at the Glenorchy gauge to warn Dunmunkle Creek communities about the breakout of flow from the Wimmera River into Dunmunkle Creek.

8.4.3.3.6 INTERPRETATION

There are mechanisms in place (e.g. in the Victorian Floodplain Management Strategy) to improve the coordination and interoperability of ICCs including interpretation of flood warning data. This study provides a basis for interpretation coupled with the upgraded Yarriambiack Shire Council and Northern Grampians Shire Council MFEP (e.g. using flood intelligence cards). Data obtained from this flood investigation should be uploaded to FloodZoom.



Use of a temporary gauge close to Rupanyup would provide a slightly better benefit-cost ratio than a permanent streamflow gauge (due to lower set up costs). However, it will have little benefit in increasing warning lead times, particularly if the BoM provides local catchment warnings using the flood trigger concept.

The BoM will not use a temporary gauge for determining or providing a warning. If there is to be a warning and flood class levels the gauge must be permanent. The reality of being able to position a temporary gauge is not practical when considering the other issues associated with gauges throughout the catchment and the complex floodplain flow which breaks out into Dunmunkle Creek.

The use of flood observers particularly in the upper catchment will enable more real-time data to assist the ICC to better understand the flood scenario as it unfolds. Simple gauge boards could be installed at relatively low cost to enable the flood observers to reference a particular flood level.

Recommendation 6: Construct a series of gauge boards and further develop the flood crowdsourcing program to enable people to provide real-time flood height observations to the ICC. These observations will need to be tied to gauge boards at road crossings or notable locations on Dunmunkle Creek.

8.4.3.3.7 MESSAGE CONSTRUCTION

Improvements are being made to further improve messaging (e.g. in Flood Bulletins) emanating from the ICC. Victoria is aligning respective warning levels, protocols and language with NSW and Queensland to ensure consistency¹⁵.

Based on the flood warning trigger from the Glenorchy gauge, a series of pre-canned messages could be included in Flood Bulletins and other communications.

Recommendation 7: Compile a series of pre-canned messages related to the flood warning triggers from the Glenorchy gauge for inclusion in Flood Bulletins and other communications.

8.4.3.3.8 MESSAGE COMMUNICATION

Message communication is being improved at a state level including the transfer to the EM-COP system and recent upgrades to Emergency Alert. The use of the Emergency Vic website can also enable local residents to receive flood warnings.

A 'phone tree' or similar localised communication method for isolated properties should be supported to augment the other warning communication mediums coming through general community knowledge, the outputs of this study and VICSES.

There also may be merit in using the Rupanyup CFA siren as an extra warning mechanism (e.g. for stormwater flooding) although it is viewed as a 'dumb' warning (i.e. it does not provide information, only heads-up of an emergency). CFA requirements are provided at <http://www.cfa.vic.gov.au/warnings-restrictions/community-alert-sirens/>.

Local stormwater flood warnings for Rupanyup will need to be communicated by the SES Unit and CFA (e.g. to vulnerable persons) by phone call and/or doorknocking.

Recommendation 8: Establish a 'phone tree' or similar localised communication method for isolated properties.

¹⁵ Pers. Comm VICSES



Recommendation 9: Explore the possibility of the Rupanyup CFA siren as an extra warning mechanism.

8.4.3.3.9 RESPONSE

From anecdotal and demographic evidence, it appears that there is a relatively high level of social capital in the study area. In the 2011 floods people helped each other including with sandbagging. As noted previously, VICSES is aiming to increase volunteer numbers in the local SES Unit.

There should be more community education for several of the issues, including an understanding of different flood scenarios, flood triggers and what to do, and the risks of moving through floodwaters.

Particularly due to the reasonably high level (10%) of the population that require assistance, Yarriambiack Shire Council should ensure that all people requiring assistance are in its Vulnerable Persons Register as required by the Vulnerable People in Emergencies Policy.

Recommendation 10: Ensure that all people requiring assistance in Yarriambiack Shire and Northern Grampians Shire Council are in the Vulnerable Persons Register.

8.4.3.3.10 COMMUNITY PARTICIPATION

There was no system for community participation in the establishment, operation and review of the current flood warning system. Possible processes for this to occur include by crowdsourcing flood observations, through community membership of existing committees (e.g. Yarriambiack Shire Council Flood Response Plan Sub-Committee) and through community workshops or forums.

Recommendation 11: Identify and implement ways for community members in the study area to participate in the establishment, operation and review of the TFWS.

8.4.3.3.11 REVIEW OF THE TFWS

The Victorian Government has made DELWP accountable for the coordination of TFWS services at the state level. It is also accountable for documenting a state-level TFWS service development plan. DELWP is doing this in consultation with VICSES, BoM, Melbourne Water, CMAs, LGAs, water corporations and other stakeholders as required.

The TFWS service development plan will be informed by the rolling three-year implementation plans coming out of the regional floodplain management strategies. In preparing those regional strategies, the CMAs and Melbourne Water will systematically assess the existing TFWS services provided to the flood-prone communities in their region, using the state-wide assessment framework currently being developed by DELWP. They will also assess the TFWS service needs of each flood-prone community.

According to the Victorian Floodplain Management Strategy (page 50), “the Inspector General for Emergency Management has developed an assurance regime to meet its obligation to develop an audit framework for the Total Flood Warning Service. The assurance regime includes:

- a mapping process to describe the Total Flood Warning Service
- a framework to facilitate the collection of consistent, relevant and quantifiable information or data to support rigorous monitoring and assessment of the performance of the Total Flood Warning Service
- a three-year schedule of assurance activities, proactive and reactive reviews to test all aspects of the Total Flood Warning Service.”

As well as the proactive reviews undertaken as part of the regional floodplain management strategies, DELWP will monitor and review how each TFWS performs when it is needed. Each TFWS will, as a matter of course, be reviewed after a major flood.



Future reviews of the TFWS in the study area should be undertaken through this centralised process. However, local communities should have the opportunity to participate in any review of the TFWS.

8.4.3.3.12 INTEGRATION OF THE TFWS COMPONENTS

As discussed there is a need to understand how the components of the TFWS are integrated. This could be shown in the new MFEP as a flow chart or graphic such as that in the Victorian Floodplain Management Strategy.

In practice, it is important to consider all TFWS components outlined in this report as a minimum and to ensure in review, that all components are well coordinated and linked.

Recommendation 12: Describe the integration of the local TFWS in the Yarriambiack Shire MFEP, and in the Northern Grampians Shire MFEP and annual assessment of relevancy of the TFWS through the Municipal Emergency Management Plan Committee.

Recommendation 13: Ensure that the integration of the TFWS is included as part of future TFWS reviews in the study area.



9 FLOOD INTELLIGENCE

9.1 Project Scope and Objectives

This project allowed for an update of flood response plans for Yarriambiack Shire Council (YSC), Northern Grampians Shire Council (NGSC) and Buloke Shire Council (BSC) covering Dunmunkle Creek from its offtake point on the Wimmera River to north of Boolite.

Specific flood intelligence reporting allowed for an update of Appendices A, B, C, D, E and F of the Municipal Flood Emergency Plans, this was provided in the Dunmunkle Creek Flood Investigation Flood Intelligence Report. This included specific information about the Dunmunkle Creek area including the communities of Glenorchy, Lubeck, Rupanyup and Boolite.

9.2 Existing Flood Intelligence

9.2.1 Streamflow and rainfall gauges

There are several rainfall gauges and one streamflow gauge within the study area. Rainfall gauges include:

- Boolite (078050) (Discontinued)
- Areegra (078050) (Discontinued)
- Minyip (078059)
- Minyip Post Office (078029)
- Burrereo (078053) (Discontinued)
- Burrum (079006 (Discontinued))
- Rupanyup Post Office (079075)
- Lubeck (Roslyn) (019096) (Discontinued)
- Glenorchy (079015)

There are no sub daily rainfall gauges located in the study area, however there are several in close proximity to Dunmunkle Creek including:

- Warracknabeal (78007)
- Longerenong AWS (79028)
- Stawell AWS (79105)
- Horsham AWS (79100)

The only streamflow gauge within the study area is Wimmera River at Glenorchy (579001). However, there are other Wimmera River streamflow gauges which can provide information on the flows expected, these include Wimmera River at Glynwylln and Wimmera River at Eversley.

9.2.2 Existing Flood Mitigation

Numerous flood mitigation works were undertaken along Dunmunkle Creek during January 2011, this included sandbagging of numerous private properties and modification of the channel embankments and flow control infrastructure.



Major sandbagging activities were focused between Glenorchy and Rupanyup, as well as within Rupanyup itself, as these areas have the largest populations that are prone to above floor inundation. Small scale sandbagging occurred in Rupanyup to mitigate the impact of the inundation caused by direct rainfall runoff, however generally there wasn't sufficient time for the sandbagging to be effective.

Excavation and blockage of the remaining channel system by members of the public did occur. Primarily in the lower Dunmunkle Creek in an effort to prevent inundation of agricultural land. There were also changes made to numerous GWMWater regulating structures throughout the system, the Bryntirion Reserve was highlighted as an area which was a focus of these changes during the initial community consultation sessions. Some very high-risk actions by community members took place, with serious risk to life. Understanding the impact of infrastructure in this area and making recommendations for its future management was a key outcome of this study. This is important, if for no other reason than to avoid similar high-risk actions during future flood events.

The filling of two sets of pipe culverts underneath the railway embankment at Rupanyup was also undertaken. This was done to prevent water from entering the Rupanyup township through the culverts, as the railway embankment was separating Dunmunkle Creek from the Rupanyup township. This action slightly exacerbated flood levels on the northern side of the embankment but significantly reduced inundation on the southern side. Both sides are populated, however the majority of the township is on the southern side.

In September 2016, some cuts were made in the Rupanyup Water Storages, as the flood mitigation modelling of this project at the time recommended the banks of the storages be decommissioned. A key recommendation of the Dunmunkle Creek Flood Investigation is to fully decommission the water storages in Rupanyup, this along with levee works, protects the township from inundation in a 1% AEP event.

9.3 Description of Major Waterways and Drains

9.3.1 Riverine Flooding

Flooding along Dunmunkle Creek is driven by high flows in the Wimmera River, with the Wimmera River distributing water to Dunmunkle Creek upstream of the Glenorchy township.

The required flow rates in the Wimmera River to commence flow to Dunmunkle Creek is less than a 20% AEP event at 14,200 ML/d. Typically high flows are driven by high rainfall totals in the upper Wimmera River catchment. There are several stream flow gauges along the Wimmera River that can provide early guidance to the expected flooding along Dunmunkle Creek, these include the Wimmera River at Eversley (415207/579005) Wimmera River at Glynwylln (415206/579009) and Wimmera River at Glenorchy (415201/579001).

There is one major township along Dunmunkle Creek within the Wimmera CMA area; Rupanyup. There are also two smaller communities at Lubeck and Boolite as well as numerous rural properties impacted by flooding along Dunmunkle Creek.

9.3.2 Stormwater Flooding

Stormwater-induced flooding from local catchment runoff is likely to cause minor inundation of road and agricultural land. Risk to built assets is greatest in and around Rupanyup. Stormwater modelling of the township was completed during the Dunmunkle Creek Flood Investigation and is presented in the following sections.

Stormwater events have the potential to cause inundation of dwellings and access to private property in Rupanyup but outside the township the risk is less due to the very flat terrain resulting in low depths and velocities. However, access may be limited in some locations due to boggy conditions.



9.3.2.1 Rupanyup

Rupanyup suffered from stormwater inundation in several locations across town during January 2011, these included:

- | | |
|---|-----------------|
| ■ Cromie Street | ■ Walter Street |
| ■ Stewart Street (primarily the eastern side) | ■ Gordon Street |
| ■ Edward Street | ■ Beryl Street |
| ■ Gibson Street | |

Stormwater modelling of the township has also indicated stormwater could become an issue west of Cromie Street in Wood Street and Dyer Street. Stormwater modelling of the 2 hour 1% AEP event is shown in Figure 9-1.

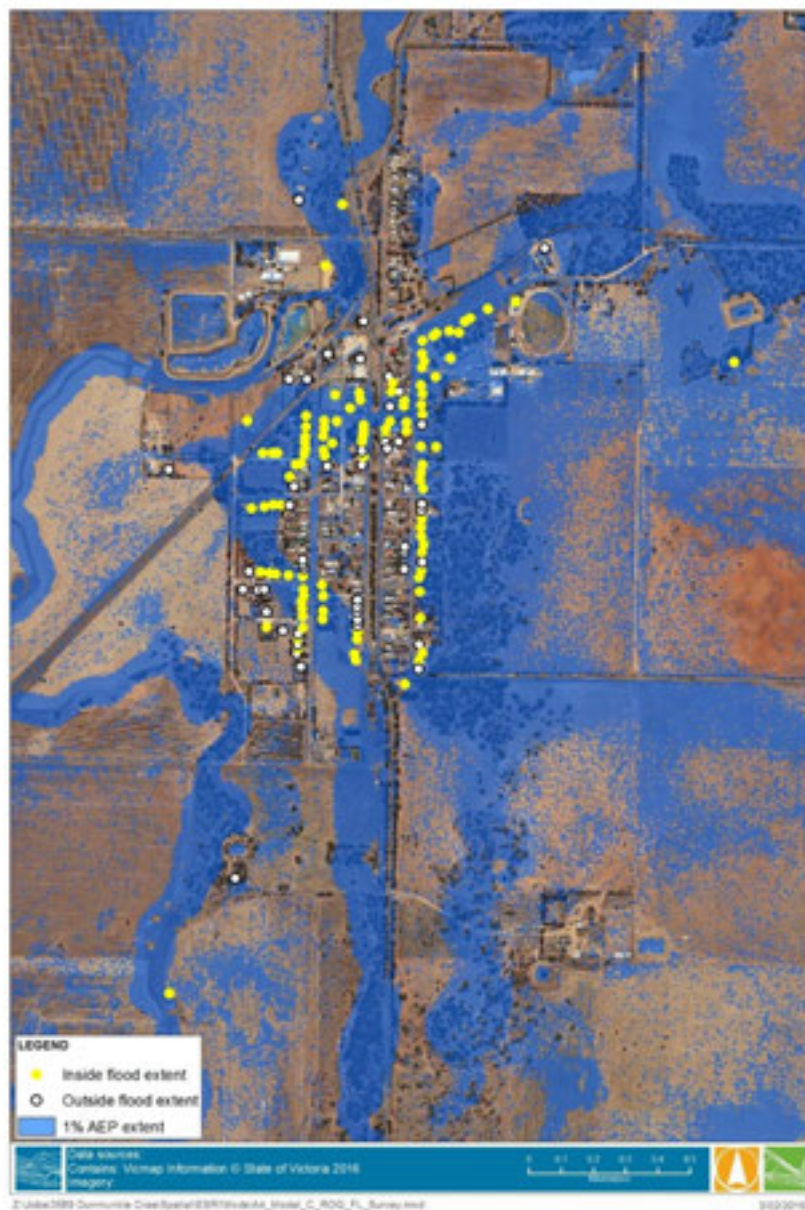


Figure 9-1 Rupanyup – Areas impacted by stormwater inundation (extent shows the 2 hour 1% AEP extent)



9.4 Other Infrastructure

9.4.1 Levees

There is only one set of purpose built levees along Dunmunkle Creek, located at Rupanyup. During January 2011 the levee was only partially constructed and overtopped, there are no formal management arrangements for the levee or agreed levee crest height, the works completed in September 2016 allows **some** water to be bypassed to the north of the levee through the Rupanyup Reservoir. The levee location is shown in Figure 9-2.



Figure 9-2 Remnant sections of levee



9.4.2 Channels and Channel Structures

During January 2011 there were several Stock and Domestic channels and associated operational infrastructure that interacted with the Dunmunkle Creek Floodplain influencing drainage and floodwater. The majority of these channels have since been removed or modified post-January 2011 but some remain.

Remaining channels with the potential to cause impact on flood levels and extents listed south to north are:

- Dunmunkle Creek valve at Campbells Bridge Road (damaged at the time of this reports production but is believed to be operable) – the valve is in a 300 mm diameter pipe operated from above on the upstream side of the road
- Main Central Outlet Channel at Glenorchy (channel blocks in place at the southern end)
- Rocklands Lubeck Channel (remaining section in the Bryntirion Forest)
- Main Central Outlet Channel (through the Bryntirion Forrest)
- Dunmunkle Creek South Channel (north of Rupanyup)
- Dunmunkle Creek North Channel

It is important to note no operation of operational infrastructure should be undertaken without a full understanding of the potential consequences and approval from the relevant authority.

Under no circumstance should channels be filled/excavated/blocked/operated or altered in any way preceding or during a flood event without a full understanding of the potential consequences and approval from the relevant authority.

9.4.3 Roads

During a large flood event there are numerous roads that will be inundated and potentially un-trafficable.

Isolation of residents along Dunmunkle Creek area can occur via inundation of several major roads, the below lists these roads:

- Wimmera Highway at Rupanyup
- Stawell Warracknabeal Road between Glenorchy and the Bryntirion Forest.

Several minor roads may also be inundated by Dunmunkle Creek flood flows including:



- North of Glenorchy to Rupanyup
 - Campbells Bridge Road
 - Hunts Road
 - Swedes Creek Road
 - All Glenorchy Township
 - Glenbrook Road
 - McCullum Road
 - Dean Horse Lane
 - Stawell Warracknabeal Road
 - Ti Tree Swamp Road
 - Hunts Scour Road
 - Ridd Road
 - Old Rupanyup Road
 - Dunster Road
 - Wal Wal Station Road
 - Richella Tramline Road
 - Osollivan Road
 - Paynes Pool Road
 - Minniboro Road
 - Ashens Cemetery Road
 - Bismark Lubeck Road
 - Horsham Lubeck Road
 - McKays Road
 - Lingham Road
 - Warranook Road
 - Bryntirion Road
 - Barn Road
 - Rup South Road
 - Warranooke Road
 - Len Matthews Road
 - Jendes Road
 - Hopperfield Road
 - C Readings Road
 - McIntyres Road



- Rupanyup Township
 - Brunton Avenue
 - Ron Lingham Drive
 - McIntosh Avenue
 - Simpson Avenue
 - Mont Clair Avenue
 - Wemyss Street
 - Dyer Street
 - Wood Street
 - Westcott Avenue
 - Connolly Parade
 - Taylor Street
 - Walter Street
 - Stewart Street
 - Beryl Street
 - Gordon Street
 - Edward Street
 - Gibson Street
 - Wimmera Highway



■ North of Rupanyup

- | | |
|-----------------------------|---------------------------|
| ■ Johnsons Road | ■ Minyip-Rich Avon Road |
| ■ Boyds Road | ■ Mcleod Road |
| ■ Ballantines Road | ■ Kirby Road |
| ■ Depot Road | ■ Switchback Road |
| ■ Lallat North Road | ■ Dunmunkle Estate Road |
| ■ Dunmunkle Creek Road | ■ Griffin Road |
| ■ Barkers Road | ■ Delavedovas Road |
| ■ Dunmunkle Creek East Road | ■ Smiths Road |
| ■ Banyena-Pimpinio Road | ■ McLachlans Road |
| ■ McLoughlin Lane | ■ Walkers Road |
| ■ Minyip Banyena Road | ■ Prynes Road |
| ■ Jess Road | ■ Lawler Road |
| ■ F Krelle Road | ■ Boolite Sheephills Road |
| ■ Gun Club Road | ■ Tegelhuter Road |
| ■ Olneys Road | ■ Habels Road |
| ■ J Woods Road | ■ Hepworth Road |

During the January 2011 event, the Stawell-Warracknabeal Road was closed by VicRoads between Stawell and Warracknabeal as all of this portion was inundated by either Wimmera River or Dunmunkle Creek.

9.4.4 Railway Embankment Culverts

There are two pipe culverts underneath the railway embankment in Rupanyup. These culverts are able to allow water from Dunmunkle Creek to the southern side of the railway embankment and the most densely populated area of Rupanyup during large floods. During January 2011 these culverts were blocked preventing water from inundating dwellings; however modelling has shown this blockage caused minor increases in water levels on the northern side of the railway embankment and the properties to the north. The location of the railway culverts is shown in Figure 9-3.



Blocking of these culverts in future flood events should be carefully considered. While it does provide benefit to the majority of residents in Rupanyup it will detrimentally impact on those north of the railway line (by several centimetres). If the culverts were blocked it is recommended specific flood mitigation be undertaken at the properties shown in Figure 9-4.





Figure 9-4 Properties requiring specific individual flood mitigation if railway embankment culverts are blocked – mapping shows the 1% AEP extent

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9.4.5 Rupanyup Water Storages

Within Rupanyup there are two redundant water storages currently owned by GWMWater. These storages have become redundant due to the Wimmera Mallee Pipeline Project and decommissioning of the Stock and Domestic channel system. These storages are shown in Figure 9-5. The storages are located either side of Dunmunkle Creek and cause a significant constraint to the Dunmunkle Creek floodplain. Storage 2, as labelled in Figure 9-4, is the major impacting structure. During flooding in September 2016 the upstream and downstream ends of Storage 2 were excavated to allow flow to pass through the storage. The excavation was relatively minor by comparison to what could have ideally been completed but was the best attempt possible given the emergency situation.

Mitigation modelling undertaken during the Dunmunkle Creek Flood Investigation has shown removal of the storages can cause a large reduction in flood levels and extent upstream, and prevent Dunmunkle Creek from reaching a level high enough to flow through the railway embankment culverts into the majority of the dwellings in Rupanyup.

If there is enough forewarning the water storage embankments could be removed more than their previous excavation to increase the capacity of Dunmunkle Creek. It must be noted that removal of the water storage embankments must be a fully considered decision with all appropriate parties consulted. The focus of removal, if determined appropriate, should be on allowing flow through Storage 2, similar to the September 2016 excavation but larger in extent, parts of the Storage 3 embankments could also be removed to achieve a greater impact.

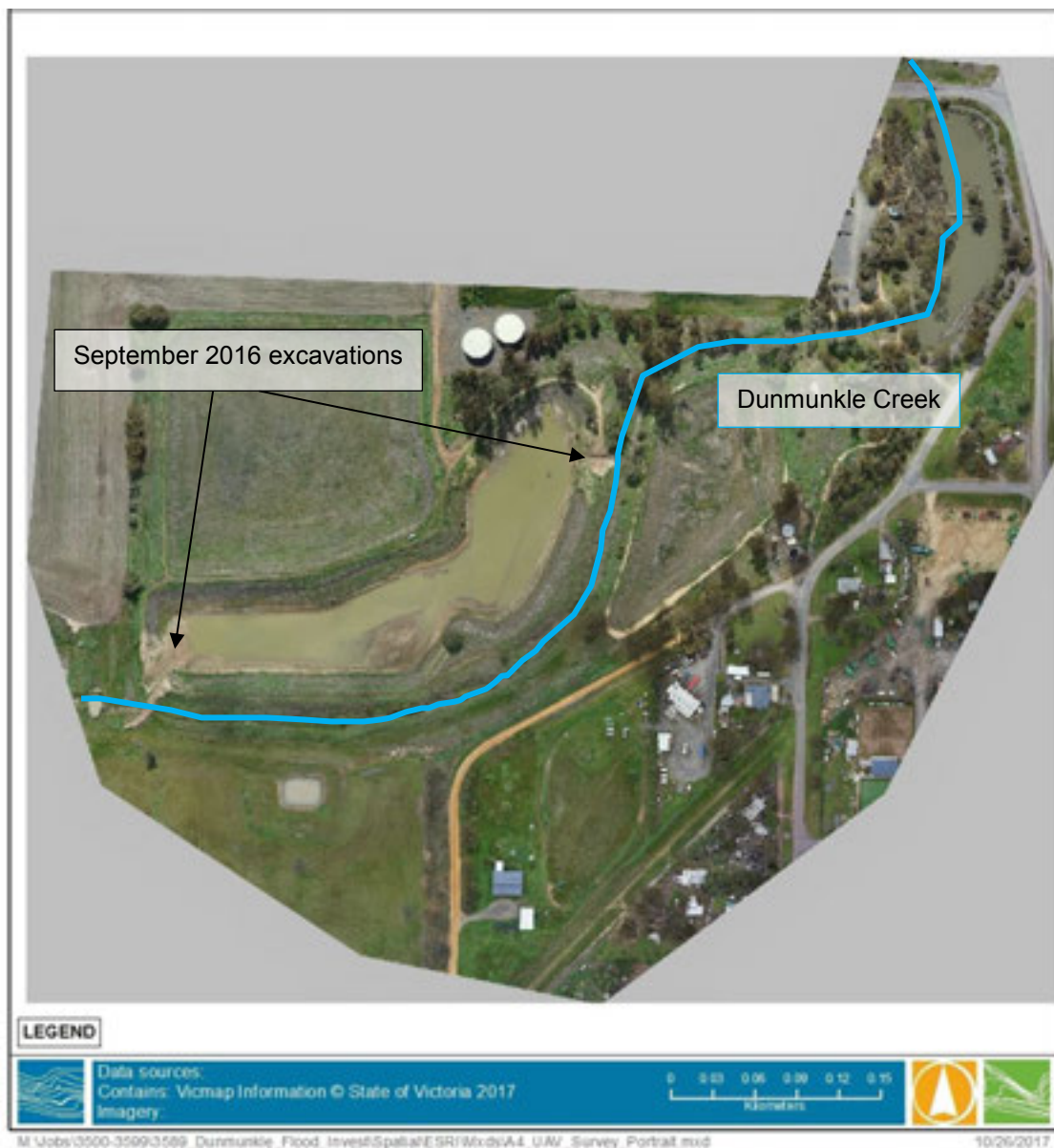


Figure 9-5 Rupanyup Water Storages

9.5 Typical Flood Peak Travel Times (Appendix B)

There is a lack of sub daily rainfall gauges in the Wimmera River upper catchment; however there are a number of streamflow gauges along the Wimmera River that can be used to provide an indication of when Wimmera River flows will break out into Dunmunkle Creek. Verification of flow along Dunmunkle Creek can then be made through community observations.

The speed a flood hydrograph moves along a waterway is 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), and big floods tend to travel faster than small floods. In large floods often the front of the peak may come through reasonably quickly as it travels through the channel, then the peak will come later as the



floodplain flow travels a little slower. Hence, the size of the flood, recent flood history, soil moisture, landuse conditions (i.e. crop size) and forecast weather conditions all need to be considered when using the following information to direct flood response activities.

Wimmera River floods travel slowly within the main stream, the rate of rise is slow, peaks are long and flat and the rate of fall is generally around 3 to 5 times the rate of rise.

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 Dunmunkle Creek floodplain, warning can focus on the progression of floodwater along Dunmunkle Creek ensuring monitoring of the progress of a flood. The below table shows the timing of peak inundation in Rupanyup will occur approximately 24-32 hrs after it is observed at the Wimmera River gauge at Glenorchy, and speed of peak inundation will slow dramatically north of Rupanyup.

Figure 9-6 and Figure 9-7 below show the flood timing for the January 2011 and September 2010 event at gauges along the Wimmera River.

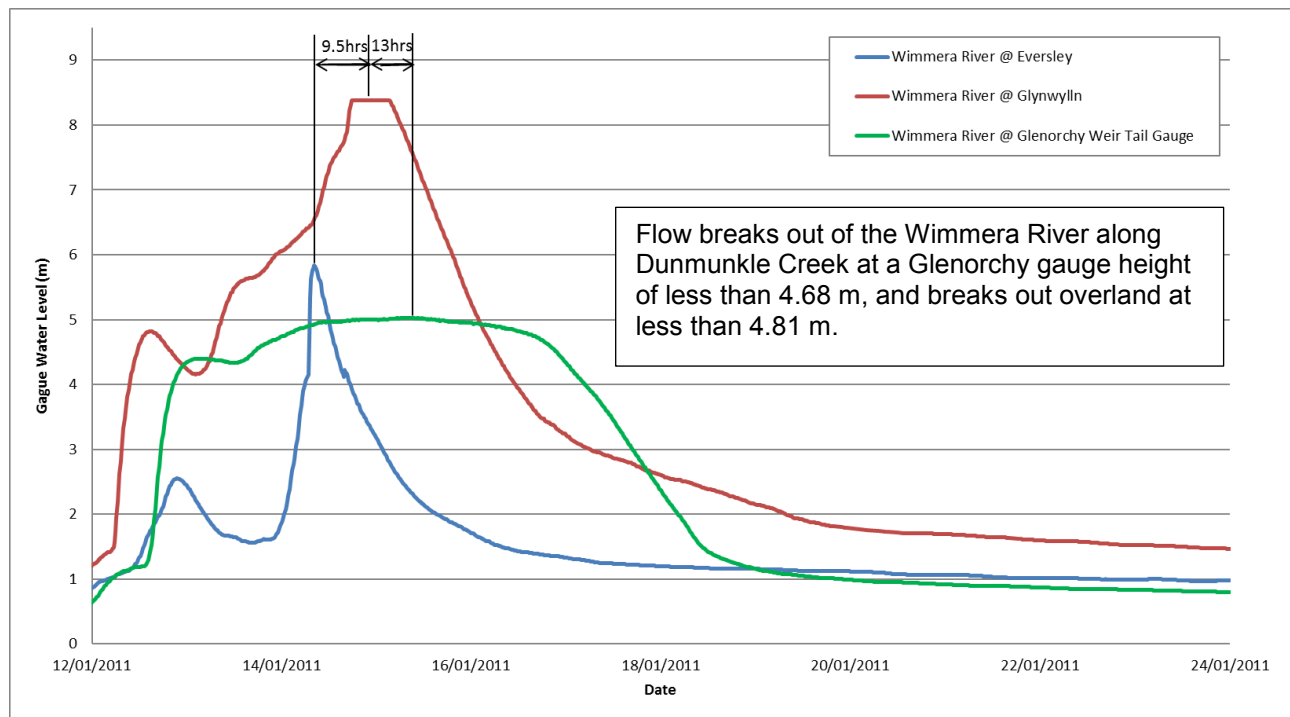


Figure 9-6 January 2011 - Gauged water levels and travel times

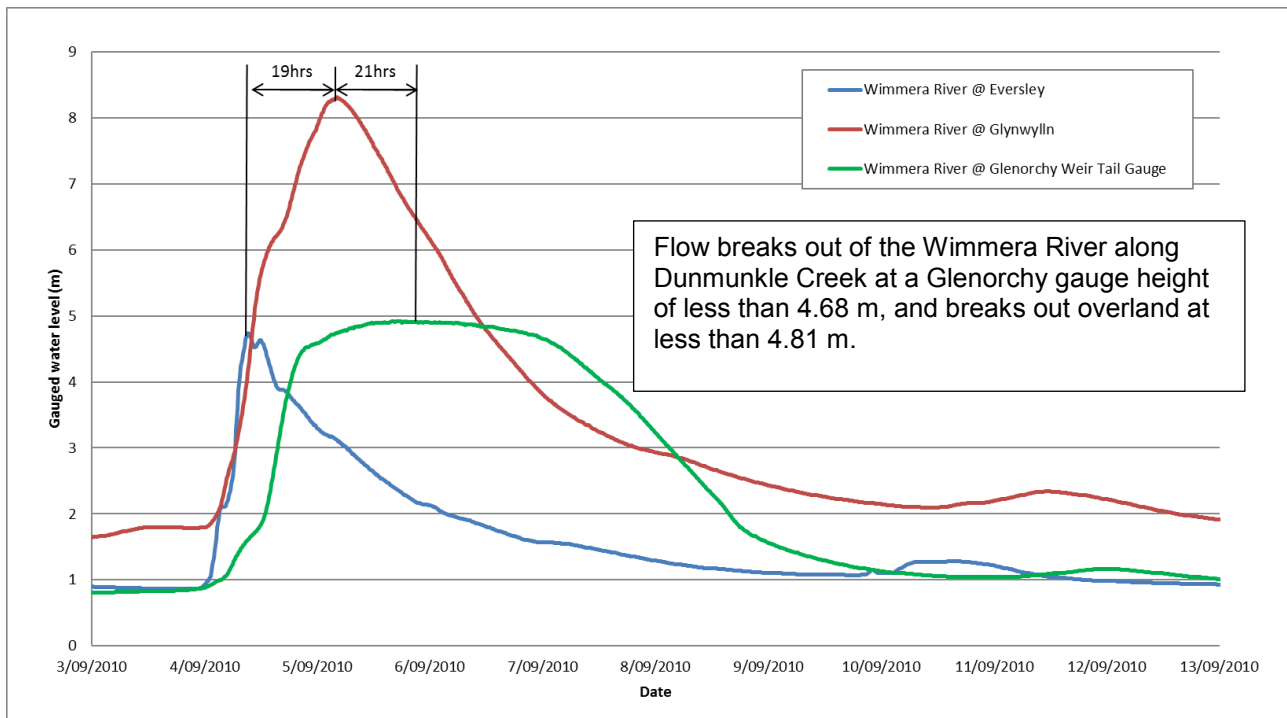


Figure 9-7 September 2010 - Gauged water levels and travel times

Error! Reference source not found. Below documents travel times observed during the most recent events on the Wimmera River with time zero representing the time of peak at Eversley. Travel times were calculated as the time that the **peak** of the event takes to move from one gauge to the next. Note that the onset of flooding can occur before the peak water level occurs. CMA/DELWP knowledge should be used for additional travel time information where flood warning gauges are not available. The travel time between Glenorchy and Rupanyup was 28.5 hrs in the January 2011 event. Given the potential for large difference in the magnitude of these events constant monitoring of the travel time along Dunmunkle Creek is required.

Table 9-1 Timing of peak flow on the Wimmera River for historic events – Timing beginning at the Wimmera River at Eversley streamflow gauge

Reach	September 2016	January 2011	September 2010
Wimmera River at Eversley	0	0	0
Wimmera River at Glynwylln	22 hrs	9.5 hrs	19 hrs
Wimmera River at Glenorchy	37 hrs	22.5 hrs	40 hrs
Dunmunkle Creek at Rupanyup	140-160 hrs	51 hrs	Unknown



9.6 Dunmunkle Creek Flood Emergency Plan – Including North of Glenorchy, Lubeck, Rupanyup and Boolite (Appendix C)

9.6.1 Overview of Flooding Consequences

Flooding of Dunmunkle Creek impacts the communities of Lubeck, Rupanyup and Boolite. The most densely populated area along Dunmunkle Creek is Rupanyup with a number of farm houses distributed along Dunmunkle Creek.

Inundation from direct catchment rainfall can cause flooding of properties below and above floor in Rupanyup, this was observed during January 2011 and stormwater flood modelling of Rupanyup was completed as part of the Dunmunkle Creek Flood Investigation.

High flows in the Wimmera River have the potential to cause flooding in Dunmunkle Creek. Flooding of Dunmunkle Creek north of the Wimmera Highway is expected to begin simultaneously with flooding in Glenorchy, as the Dunmunkle Creek offtake point is immediately upstream of the township. For a more detailed understanding of travel time refer to Section **Error! Reference source not found.**

The number of properties impacted for a range of design events is shown below in Table 9-2, the design events are outlined for the Wimmera River at Glenorchy as this gauge gives the best indication of the predicted flooding along Dunmunkle Creek with the current partially decommissioned state of the Rupanyup Water Storages.

Table 9-2 Summary of flood affected properties along Dunmunkle Creek

Summary of number of flood affected properties along Dunmunkle Creek between the Wimmera River and the area north of Boolite for current EXISTING CONDITIONS						
	Design Flood (AEP)					
	20%	10%	5%	2%	1%	0.5%
Discharge at Wimmera River Gauge @ Glenorchy (ML/d)	14,531	19,884	25,020	31,667	36,648	41,611
Gauge height at Wimmera River Gauge @ Glenorchy (m)	4.68*	4.81	4.89	4.96	5.01	5.05
Residential Buildings Flooded Above Floor	0	0	0	8	17	32
Commercial Buildings Flooded Above Floor	0	0	0	4	10	16
Land Parcels Flooded Below Floor	233	302	713	806	1022	1055
Total Land Parcels Flooded	233	302	713	818	1049	1103

* 4.68 m is above the Minor Flood Level at Glenorchy (4.00m) and below the Moderate Flood Level (4.75 m). These flood class levels are reflective of flood risk in Glenorchy rather than along Dunmunkle Creek, no implied downstream impacts are to be used for setting of Flood Class Levels but rather the levels should reflect the impact immediately surrounding the gauge.



9.6.1.1 Infrastructure Impacts

Other infrastructure may be impacted, a summary of this infrastructure covering all AEPs includes:

- The Rupanyup Ambulance Station – Access may be limited by stormwater
- Lubeck Fire Station (CFA) - Access can be limited from the east due to inundation of Stawell Warracknabeal Road
- Dunmunkle Health Services – Access can be limited due to stormwater inundation
- Rupanyup Primary School
- Rupanyup Bowls Club
- Rupanyup Recreation Reserve – can be impacted by both stormwater and floodwater from Dunmunkle Creek
- Yarriambiack Shire Council Offices in Rupanyup – Access can be limited due to stormwater inundation
- Boolite Recreation Reserve - Access can be limited from the east

9.6.1.2 Isolation Risks

There is significant isolation risk for residents along Dunmunkle Creek, reporting the risk of isolation along Dunmunkle Creek was separated into five segments:

- Wimmera River to Riachella Tramline Road;
- Riachella Tramline Road to Ashens Jacksons Road on Dunmunkle Creek and the Hurleys Road on the Murtoa Overland Flow Path;
- Ashens Jacksons Road to Ballantines Road (Rupanyup/Dunmunkle Creek)
- Hurleys Road to Gulbin Road (Murtoa Overland Flow Path)
- Ballantines Road to Boolite (Dunmunkle Creek)

These isolations are largely due to road closures and/or inundation of private access. The description below refers to events up to a 0.5% AEP event.

Due to the warning time available, evacuation of community members at a higher risk should be possible. If there is an unexpected rainfall event causing localised stormwater inundation evacuation via private property may be possible, however consent and advice from the landholder should be sought prior to accessing private land.

9.6.2 Wimmera River to Riachella Tramline Road

Inundation of Campbells Bridge Road will prevent access from Glenorchy to the east, with Hunts Road and Swedes Creek Road also inundated to the north.

Glenorchy Road north of Ti Tree Road becomes inundated by Dunmunkle Creek preventing access between two dwellings east of Glenorchy Road and Glenorchy. One of these is in very close proximity to Dunmunkle Creek and inundated below floor during the 2% AEP event. Both properties can evacuate to the north.

A dwelling immediately west of Dunmunkle Creek at 217 Glenbrook Road is completely surrounded and inundated below floor. Access to the dwelling is via Glenbrook Road with extensive inundation in both east and west directions.

There is a property isolated at 1435 Stawell-Warracknabeal Road (Glenorchy) due to inundation of the Stawell Warracknabeal Road in either direction.



Two properties at 18 Ridd Road immediately east of Stawell Warracknabeal Road are isolated and completely surrounded by floodwater with the eastern dwelling inundated below floor.

Two dwellings are isolated at 21 Marsdale Road their private access off Marsdale Road immediately north of the Stawell Warracknabeal Road intersection. Isolation is caused by inundation of Stawell Warracknabeal Road and Marsdale Road.

Inundation of Riachella Tramline Road causes isolation of 160 Riachella Tramline Road (Wal Wal), access located immediately east of Dunmunkle Creek.

9.6.3 Riachella Tramline Road to Ashens Jacksons Road on Dunmunkle Creek and the Hurleys Road on the Murtoa Overland Flow Path

Between Minnieboro Road and Riachella Tramline Road there are two properties isolated by flooding along Dunmunkle Creek. The first is at 48 O'sullivan's Road, O'sullivan's Road crossing Dunmunkle Creek itself. Further to the north, 39 The Wattles Road is accessed off Stawell-Warracknabeal Road with private access over Dunmunkle Creek. Neither property is flooded below or above floor for events up to 0.5% AEP, 48 O'Sullivan's Road comes in very close proximity to the 0.5% AEP extent.

There are two properties at risk of inundation between Minnieboro Road and Tinesley Road. 105 Minnieboro Road is accessed from Minnieboro Road immediately east of Dunmunkle Creek. Flood water comes in very close proximity to the dwelling via a backwater from the north. The second property is at 2432 Stawell-Warracknabeal Road, accessed off the Stawell-Warracknabeal Road immediately south of Tinsley Road and west of Dunmunkle Creek. This property is flooded below floor.

Between Horsham-Lubeck Road and Bismark-Lubeck Road there are two properties isolated by floodwater; 2780 and 2683 Stawell-Warracknabeal Road, Isolation is caused by inundation of the Warracknabeal Stawell Road. Buildings around the dwellings at each property are likely to be inundated at events up to the 0.5% AEP event.

There are two properties south of Warranooke Road 119 and 114 Lingham's Road, in very close proximity to inundation caused by a backwater from Dunmunkle Creek overland flow. In the 0.5% AEP event neither property is inundated below floor and access/egress may be possible to the east along Warranook Road.

North of the Bryntirion Forrest there are properties at 105 Bryntirion Road and 3128 Stawell Warracknabeal-Road isolated. Both Bryntirion Road and Stawell-Warracknabeal Road are inundated.

3288 Stawell-Warracknabeal Road north of the Bryntirion Forest is a significant distance from the floodwater but may be isolated due to inundation/closure of the Warracknabeal-Stawell Road.

111 Len Matthews Road is in close proximity to inundation during the 0.5% AEP event, however not subject to below floor inundation or direct isolation.

Between Len Jacksons Road and Ashens Jackson Road, 227 Ashen Jackson Road is inundated below floor by Dunmunkle Creek flooding. Additionally, the dwelling is isolated by inundation of their private access, Ashens-Jackson Road and Jendes Road.

9.6.4 Ashens Jacksons Road to McIntyres Road

Immediately north of Dalcross Road, 84 Ashen Jackson Road, is isolated. The property is not subject to below floor flooding for events up to the 0.5% AEP event. Access/egress to the site may be possible to the east along Dalcross Road with Stawell-Warracknabeal Road and the western end of Dalcross Road inundated.



Between Hopefields Road and C Readings Road, 245 C Readings Road is surrounded by floodwater and isolated in the 0.5% AEP event. The property private access is inundated as well as the connecting public road, C Readings Road. The property is located immediately to the west of Dunmunkle Creek.

South of the Rupanyup township there is one property isolated at 3973 Stawell-Warracknabeal Road, several buildings around the dwelling are likely to be inundated during a 0.5% AEP event.

9.6.5 Rupanyup Township

Inundation of Rupanyup is separated by a railway line running to the north and east of the most densely populated area. There are 6 dwellings between the railway line and the Wimmera Highway that are near to inundation. Of these, two are flooded above floor in a 0.5% AEP flood event, both accessed off Conolly Parade, and one is flooded below floor, accessed off Dyer Street.

- 66 Conolly Parade (Above floor)
- 55 Conolly Parade (Above floor)
- 1 Dyer Street
- 2 Dyer Street (Below floor)
- 4 Cromie Street
- 89 Wimmera Highway

On the south eastern side of the railway line there are two entry points for floodwater; overland flow from Dunmunkle Creek, which enters the township prior to the railway embankment crossing; and through the railway culverts either side of the Connelly Parade Westcott Road intersection. The railway culverts were blocked during the January 2011 flood event reducing the inundation on the south eastern side of the railway line but more than likely increasing inundation on the north western side.

The two potential flood mechanisms are shown in Figure 9-8.

On the south eastern side of the railway line there is potential for 128 buildings to be inundated or close to inundated in a 0.5% AEP flood event, of these, 49 building are flooded above floor. In a 1% AEP flood event, 27 buildings are flooded above floor, these buildings are spread around Rupanyup and are located as follows:

- 8 Wood Street
- 5, 7 and 9 Westcott Avenue
- 9, 10, 11, 12, 13, 14, 16 and 19 Dyer Street
- 1, 4 and 5 Walter Street
- 17 Taylor Street
- 14, 21, 23, 22-24, 27-29, 32 and 34 Cromie Street
- 1, 3 and 16 Stewart Street
- 7 Edward Street

At 96 Wimmera Highway there is also a shed inundated above floor, west of the Stawell-Warracknabeal Road. There are several buildings east of Frayne Avenue (14-46) that have the rear of their properties inundated with the potential for some sheds and other outbuildings to be inundated.



Overland flow passing through the Rupanyup township causes inundation on the eastern side of Dunmunkle Creek through to the golf course with the associated buildings potentially flooded below floor during a 0.5% AEP event. 32 Ballintines Road also has the potential to be flooded below floor.

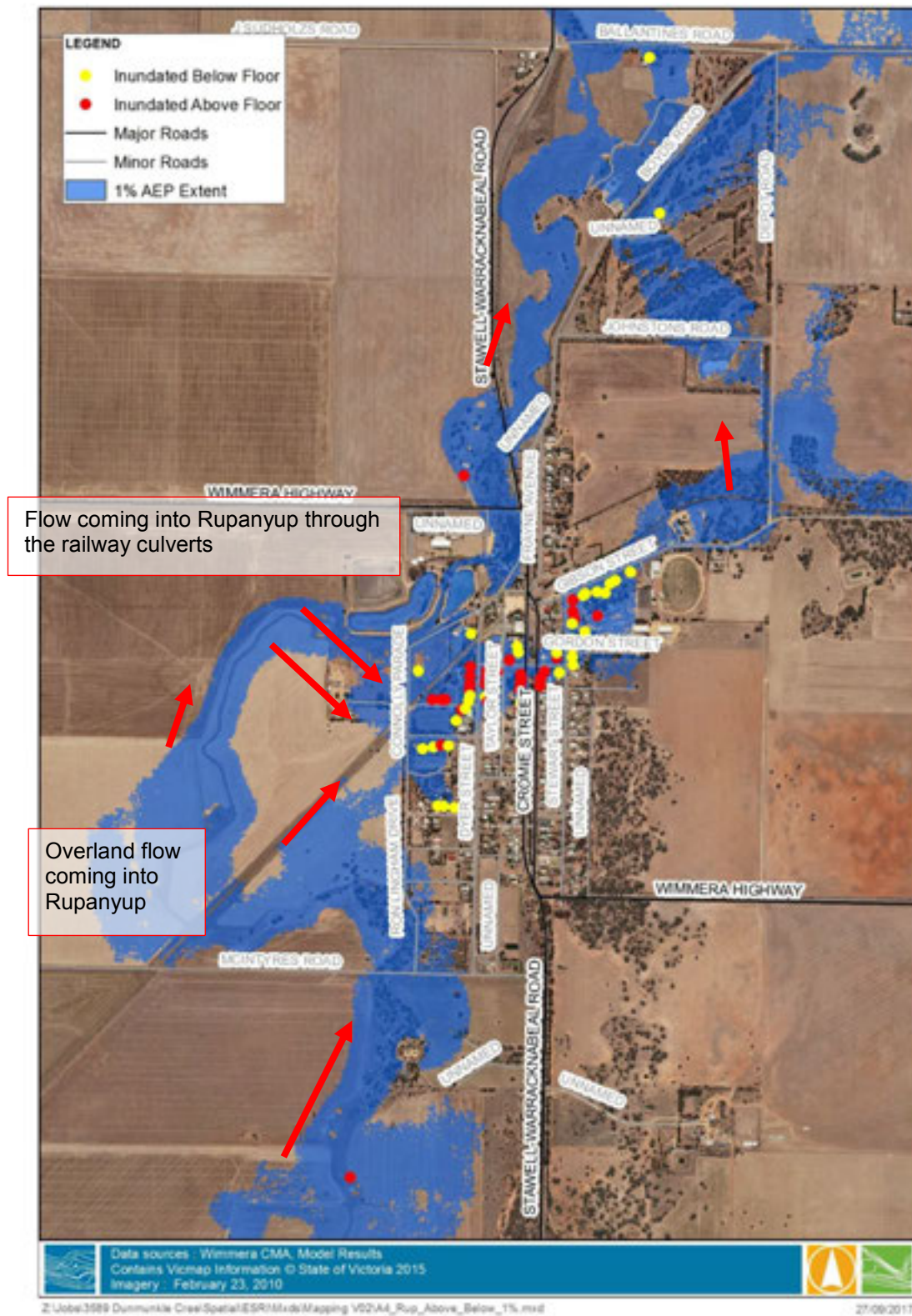


Figure 9-8 Rupanyup Flood Mechanisms – overland flow from the south west along the railway ling and breakout flow from the north west through the railway culverts

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9.6.6 Hurleys Road to Gulbin Road (Murtoa Overland Flow Path)

The Murtoa overland flow path is initiated for flood events greater than a 20% AEP. During a 10% AEP flood event the width of inundation is relatively narrow. 690 3LK Road is likely to have access prevented to the north with inundation of 3LK Road and Ashens-Jackson Road.

387 Hamiltons Road has its private access inundated, however, it may be possible for access/egress to occur on internal roads to Edmonds Road, then to the north.

The Murtoa overland flow path can cause a distribution of flow to the north from around Crams Road. The flow fills a lower area between Crams Road and the Wimmera Highway, then overtops the Wimmera Highway in two potential locations between Crams Road and Hamiltons Road, connecting low points in the terrain with narrow flow paths.

In this area there are two buildings at risk including:

- On the north western corner of Excell Road and the Wimmera Highway, there is a property flooded below floor
- 62 Konigs Road is flooded below floor with the access along Konigs Road inundated

The Murtoa flow path continues on to the west where it joins the Wimmera River distribution to Yarriambiack Creek.

9.6.7 Ballantines Road to Boolite (Dunmunkle Creek)

North of Ballantines Road, buildings are predominantly farm houses and agricultural-related infrastructure. None are inundated above or below floor for the 0.5% AEP event. The locations of properties in close proximity to flooding, or where access is potentially restricted by floodwater are listed below:

- East of Dunmunkle Creek Road
- South of Barkers Road
- South Kennedy Lane
- North of Jess Road
- North of Minyip Banyena Road (surrounded by floodwater during a 0.5% AEP event)
- West of Olneys Road
- North of Minyip – Richardson Road (private access inundated)

In general, these properties are likely to have access or egress in an alternate direction to the floodwater unless noted.



10 RECOMMENDATIONS

The Dunmunkle Creek Flood Investigation has implemented a very rigorous approach to understanding the flood risk and has engaged with the local community to ensure their knowledge of the floodplain informed the study. The below recommendations were made following the findings of this study:

1. The Yarriambiack Shire Council and Northern Grampians Shire Council Municipal Flood Emergency Plans be updated with the information provided in the Dunmunkle Creek Flood Investigation Flood Intelligence Report.
2. The Land Subject to Inundation Overlay (LSIO) and Flood Overlay (FO) and associated planning scheme amendment documentation produced as part of this study be adopted in the Yarriambiack Shire Council and Northern Grampians Planning Schemes.
3. The Victorian Flood Database (VFD) should be updated using the outputs of the Dunmunkle Creek Flood Investigation, which have been formatted into the standard VFD outputs.
4. The Dunmunkle Flood Investigation VFD deliverables be uploaded to FloodZoom.
5. The local CFA brigade should be actively engaged in community preparedness education for flooding.
6. The Rupanyup water storages should be decommissioned as per the concept design determined during this project.
7. The levee along Ron Lingham and McIntyres Rd should undergo detailed design and construction to prevent Dunmunkle Creek breakout flow from entering the township.
8. Post removal of the Rupanyup water storages and construction of the levees, the decommissioned state of the storages should be surveyed, and remodelling completed to update the LSIO and FO layers for Rupanyup and update the Yarriambiack Shire Council MFEP.
9. Constructed channels within the Dunmunkle Creek waterway bed and banks should be decommissioned north of the Bryntirion Forest, as far as practically possible, attempting to return Dunmunkle Creek to as natural a state as possible.
10. The Rupanyup community be consulted regarding what they would like to see in place of the removed water storages if that option was to progress. The earthworks assumed for the modelled reservoir removal would be aligned with a lowered land surface that would facilitate the construction of a wetland area. Alternatives may be to remove the storages to ground level and construct some other public asset such as a park or a bike track. Whatever the outcome, the use of that space should ensure that no raised buildings or earthworks obstruct floodplain flow. The cost benefit ratio of the works is expected to be very high and likely to receive government financial support.
11. The potential for stormwater mitigation in Rupanyup should be further considered with the incorporation of the stormwater pipe network, and consideration of the levee, drain and possible pumping solution. Detailed feature survey may be required of the existing stormwater system.
12. The Rocklands Lubeck Channel through the Bryntirion Forest should be assessed for decommissioning considering the native vegetation currently existing on the embankments. Once an understanding of the preferred decommissioning approach is available, modelling of the partial removal should be completed.
13. **Operable infrastructure on the Rocklands Lubeck Channel should be removed to prevent members of community attempting to operate them during a flood (this occurred during January 2011 which could have resulted in loss of life).**



14. Decommissioning of Dunmunkle Creek's embankments should be considered further with regards to potential environmental benefit. While it has been demonstrated there are no real flood benefits, environmental benefit could be gained through returning Dunmunkle Creek to a more natural waterway, slowing the progression of floodwater, supporting biodiversity and reinstating the natural function of the waterway. This return could be made through a combination of revegetation, earthworks and fencing. This would require significant planning and consultation with landholders.
15. Removing the Dunmunkle Creek offtake valve and replacing the structure with a permanently open culvert should be considered allowing natural flows to Dunmunkle Creek.
16. Discussion with GWMWater and landholders in the Boolite area on how restoring a natural channel could be used to engage areas of floodplain that are currently prevented from being inundated by constructed channels but ensure water is not allowed to sit for long periods of time that could cause pasture or crop damage.
17. Use of the Glenorchy streamflow gauge on the Wimmera River to provide triggers for specific flood warnings for Dunmunkle Creek. These triggers can also be included in Flood Bulletins issued by VICSES.
18. Preparation of pre-canned messages based on the flood triggers that can provide tailored and relevant information to those living in the study area.
19. Further engagement with rural landholders so they can understand the impacts of decommissioning channel systems on flooding and to eradicate risky behaviours to divert water during flood events.
20. Further development of the flood observers network in the study area to provide additional real-time information to the ICC. This may involve the implementation of gauge boards so that accurate flood level references can be made. Development of a phone tree system or similar warning communication for isolated rural landholders in the Dunmunkle Creek catchment.
21. Better identification of vulnerable persons in the study area and appropriate operational measures taken once warnings are received.

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Fax (03) 9558 9365

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Fax (08) 8357 8988

Geelong

PO Box 436
Geelong VIC 3220
Telephone 0458 015 664

Wangaratta

First Floor, 40 Rowan Street
Wangaratta VIC 3677
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Level 3, 43 Peel Street
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Perth

Ground Floor
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Gippsland

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