Horsham Bypass – Stage 2 of Phase 2
Options Assessment

March 2015

ISO 9001 QEC22878
SAI Global

DOCUMENT STATUS

Version	Doc type	Reviewed by	Approved by	Date issued
Exhibition v01	Report	Ben Hughes	Ben Hughes	26/03/2015

PROJECT DETAILS

Project Name	2369-01R01ExV01
Client	VicRoads/AECOM
Client Project Manager	Shannon Bolton
Water Technology Project Manager	Ben Hughes
Report Authors	Ben Hughes
Job Number	2369-01
Report Number	R01
Document Name	Horsham Bypass Hydrology and Hydraulics Assessment

15 Business Park Drive
Notting Hill VIC 3168

Telephone (03) 9558 9366
Fax (03) 9558 9365

ACN No. 093 377 283
ABN No. 60 093 377 283

EXECUTIVE SUMMARY

AECOM Australia Pty Ltd were engaged to assist VicRoads in undertaking the Horsham Bypass Planning Study, this report forms part of Stage 2 of the project. The purpose of the study is to determine the optimum realignment route for the Western Highway at Horsham.

As part of the study, a number of specialist investigations were undertaken to rank five bypass alignment options. This report focuses on the hydrological and hydraulic impacts of the five options from a floodplain perspective and has been undertaken by Water Technology Pty Ltd.

A review of the policy and legislative requirements of the bypass alignment was undertaken during Stage 1 of Phase 2 of this project. These were summarised specific to the hydrology and floodplain hydraulics study:

- Avoid or minimise impacts on areas of ecological sensitivity, floodplain function and heritage significance to the extent practicable; and
- Provide a balanced outcome giving consideration to environmental, economic and social factors providing best value benefits for the lowest project cost.

The review of policy and legislative requirements refined the primary objective of this report to compare each of the alignment options ensuring no negative floodplain impacts would be observed in a 100 year ARI event while assessing each option on the potential drainage infrastructure that would be required to pass flood flows.

To determine the likely floodplain impact and potential infrastructure required by the alignments, an existing hydraulic model of the east Horsham area was extended to cover the five bypass alignments.

The existing conditions were modelled using the extended model using the 100 year and 10 year ARI events. The 100 year ARI event was used to compare each bypass option for the number of waterway/floodplain intersections, length of road required to be raised above flood level, potential number of culvert locations and potential number of bridge locations while the 10 year event was used to assess the likelihood of out of bank flows at a lower ARI. The design features for each option will be able to manage the 100 year ARI flooding risk but would add cost to the project. The information determined during this study will be used to cost the construction of each option during the economic analysis with all bypass options designed so that they will meet the 100 year ARI flood level and will not further impact flood levels in the affected areas.

Options to the west side of Horsham were determined as the most preferable (Option 12 and 5A) as they crossed the Wimmera River and Burnt Creek floodplains at confined locations, minimising the drainage infrastructure required to pass the 100 year ARI flow. On the other hand, options to the east of Horsham, had significant interaction with overland flow from both waterways.

The table below shows each of the options and their respective Rating and Rank.

Option	Rating	Rank	Explanation
Option 5A	Neutral	2	Option 5A has the shortest waterway/floodplain intersection length and there is potential to increase the size of the current Burnt Creek culverts at the Western Highway. Flow from the Wimmera River could be passed via one large structure.
Option 11	Poor	3	Option 11 has four major waterway/floodplain intersection points, all dominated by the Wimmera River. Several stretches of the alignment would require significant culverts and potentially more than one bridge structure.
Option 12	Neutral	1	Option 12 interacts with floodplain flows at Burnt Creek and the Wimmera River. Both are relatively confined areas of floodplain. The alignment is likely to require two bridge structures.
Option B2	Poor	6	Option B2 interacts with both Burnt Creek and the Wimmera River. The major downside of this options is the length of low Wimmera River floodplain that would require a bridge structure.
Option D	Poor	**5**	Similar to Option B2, D interacts with both Burnt Creek and the Wimmera River. The major downside of this option is still the length of Wimmera River floodplain that would require a bridge structure.

Each bypass alignment option rating and rank was based on its interaction with the 100 year ARI extent. However, if the appropriate flood mitigation infrastructure is put in place, free passage of flood water during the 100 year ARI event is possible. This would reduce the potential impact of each alignment on 100 year ARI flood levels to zero. The cost of the infrastructure required for each alignment option will vary significantly depending on the length of bridge or number of culverts required. Infrastructure designed to allow free passage of a 100 year ARI flood event will have the capacity to pass flood flows of more frequent events; however a latent risk exists that an event larger than a 100 year ARI magnitude could cause afflux upstream of a bypass alignment causing damage to private property. This potential needs to be assessed once a more detailed design of the preferable alignment's drainage features are completed.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

AECOM Australia Pty Ltd were engaged to assist VicRoads in undertaking the Horsham Bypass Planning Study, this report forms part of Stage 2 of the project. The purpose of the study is to determine the optimum realignment route for the Western Highway at Horsham (**Figure 1**) to enable a road reservation and associated planning scheme controls to be implemented in the future. The road reservation would ease heavy vehicle traffic volumes currently experienced on the Western Highway between Melbourne and Adelaide and significantly reduce the adverse impacts to amenity within the Horsham town centre.

Figure 1 Section of the Western Highway proposed to be bypassed at Horsham

1.1 Background

VicRoads commissioned a planning study in order to recommend a preferred route alignment for a future Western Highway bypass of Horsham. In June 2009, a broad analysis of 14 possible Horsham bypass route options suggested by the local community and other stakeholders was completed. This is reported in the *Western Highway Realignment at Horsham - Strategy and Consultation Report* (PB, 2009) (Phase 1 Report).

In July 2011, Stage 1 of Phase 2 of the Horsham Bypass was completed by AECOM. An alternative multi-criteria assessment method and desktop assessment to review and assess the validity of the Phase 1 report and its key findings was undertaken. In addition to the options identified in Phase 1 of the assessment, further options were identified and an assessment of all these options was undertaken to determine a shortlist of options to undergo further investigation during Stage 2 of Phase 2. The five options recommended for further investigation (5A, 11, 12, A2 and B2) were presented at a community information session held in Horsham on 26 May 2011 as part of a public consultation program. As a result of the consultation, one option (A2) was removed from further consideration.

Four options (5A, 11, 12 and B2) were therefore investigated in more detail with the results of the analysis presented to the community as part of a public consultation program on 10 December 2012. A hybrid of Option B2 and Option 11 (Option D) was also subsequently assessed.

Following on from the options assessment, AECOM has been engaged to check and update this report as appropriate to address any changes in policy and legislation since the initial assessment. This is in preparation for exhibition of a proposed planning scheme amendment for the preferred option(s).

1.2 Assessment Process

Stage 2 of Phase 2 involved undertaking selected detailed technical investigations, with the scope of these investigations informed by the desktop study undertaken in Stage 1 and the outcomes of the community consultation.

As part of Stage 2 of Phase 2, the OBEM methodology was applied in this assessment, to identify a preferred alignment/s in consideration of environmental, social and economic issues. **Figure 2** provides an overview of the Stage 2 of Phase 2 methodology.

Specialist studies undertaken as part of the Stage 2 options assessment were:

- Flora and fauna
- Land use planning
- Social impact assessment
- Cultural heritage assessment
- Agricultural assessment
- Hydrology and hydraulic assessment
- Traffic impact assessment
- Business Impact Assessment.

The Stage 2 of Phase 2 Shortlisted Options were assessed against the project objectives and assessment criteria using the method outlined in **Section 5.0**. A summary report identifying the option(s) with the best overall performance was developed from the outputs of the specialist studies.

The refined options were tested at a workshop with representatives from VicRoads, HRCC, the core project team, and project specialists. At this workshop, the benefits and dis-benefits of the various alignment options will be discussed in detail, along with any suggested amendments to the alignments that may enhance the outcomes. The results of the assessments will be compiled and presented to the community to seek their input, for possible further refinement of the options.

The options assessment workshop and community consultation resulted in the recommendation of a preferred route, as reported in a “Route Adoption Report”.

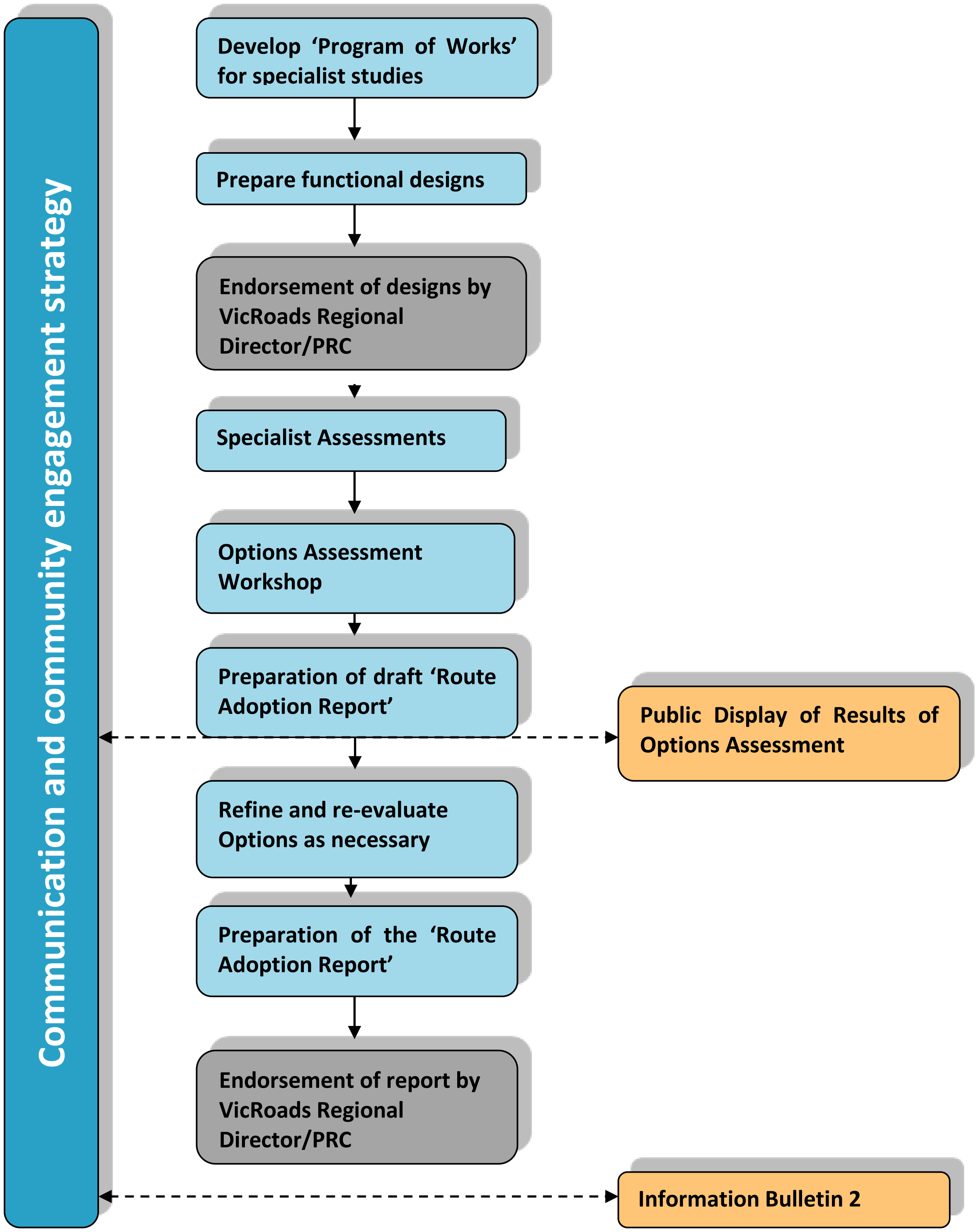

Figure 2 **Stage 2 of Phase 2 methodology overview**

2.0 PURPOSE OF REPORT

The specialist studies outlined in **Section 1.2** will be undertaken to identify a preferred alignment/(s) option(s) of the Horsham Bypass in consideration of environmental, social and economic issues.

This report assesses the key areas of flood impact associated with the four route options, as part of Stage 2 Options Assessment.

The major evaluation criteria used in identifying the preferred alignments are:

- Number of waterway/floodplain intersection points with the alignment option;
- Depth of water at these intersection points;
- Width and length of the bypass alignment intersecting with the waterway/floodplain; and
- Flow rate passing through the bypass alignment route at the waterway intersection point.

Descriptions of the options to be investigated in this assessment are outlined in **Section 3.0**.

3.0 DESCRIPTION OF OPTIONS

The five options investigated as part of this assessment (**Figure 3**) are as follows:

- **Option 5A**

  This 13.2 kilometre route is the shortest bypass option. It starts from the existing Western Highway near West Road and continues west towards the Wimmera River. It crosses the river and the Wimmera Highway to the south-west of Horsham. The route reconnects with the existing Western Highway to the north of the O'Brees and Curran Roads intersection. Using this bypass option, the length of journey along the Western Highway between Green Lake and Dahlen would be 22.7 kilometres.

- **Option 11**

  This Option bypasses Horsham to the east and north of town. It is 20.1 kilometres in length and leaves the Western Highway to the east of Horsham at West Road and re-joins the Western Highway to the north of Horsham immediately south of the aerodrome. This option crosses the Henty Highway to the north-east of Horsham. Using this bypass option, the length of journey along the Western Highway between Green Lake and Dahlen would be 23.8 kilometres.

- **Option 12**

  Option 12 bypasses Horsham to the south and west of town. It is 20.8 kilometres long and crosses the Henty Highway south of Horsham and the Wimmera Highway to the south-west of Horsham to re-join the Western Highway near Dooen School Road. Using this bypass option, the length of journey along the Western Highway between Green Lake and Dahlen would be 23.8 kilometres.

- **Option B2**

  This Option bypasses Horsham to the east and north of town. It is 17.9 kilometres long and leaves the Western Highway near Burnt Creek, crosses the Henty Highway and heads in a north-west direction to pass east of the aerodrome to re-join the Western Highway near Dooen School Road. Using this bypass option, the length of journey along the Western Highway between Green Lake and Dahlen would be 22 kilometres.

- **Option D**

  Option D is a combination of the southern part of Option B2 and the northern part of Option 11. This option bypasses Horsham to the east and north of town. It is 16 km in length and leaves the Western Highway near Burnt Creek, crosses the Henty Highway and rejoins the Western Highway to the north of Horsham immediately south of the aerodrome. Using this bypass option, the length of journey along the Western Highway between Green Lake and Dahlen would be 23 kilometres.

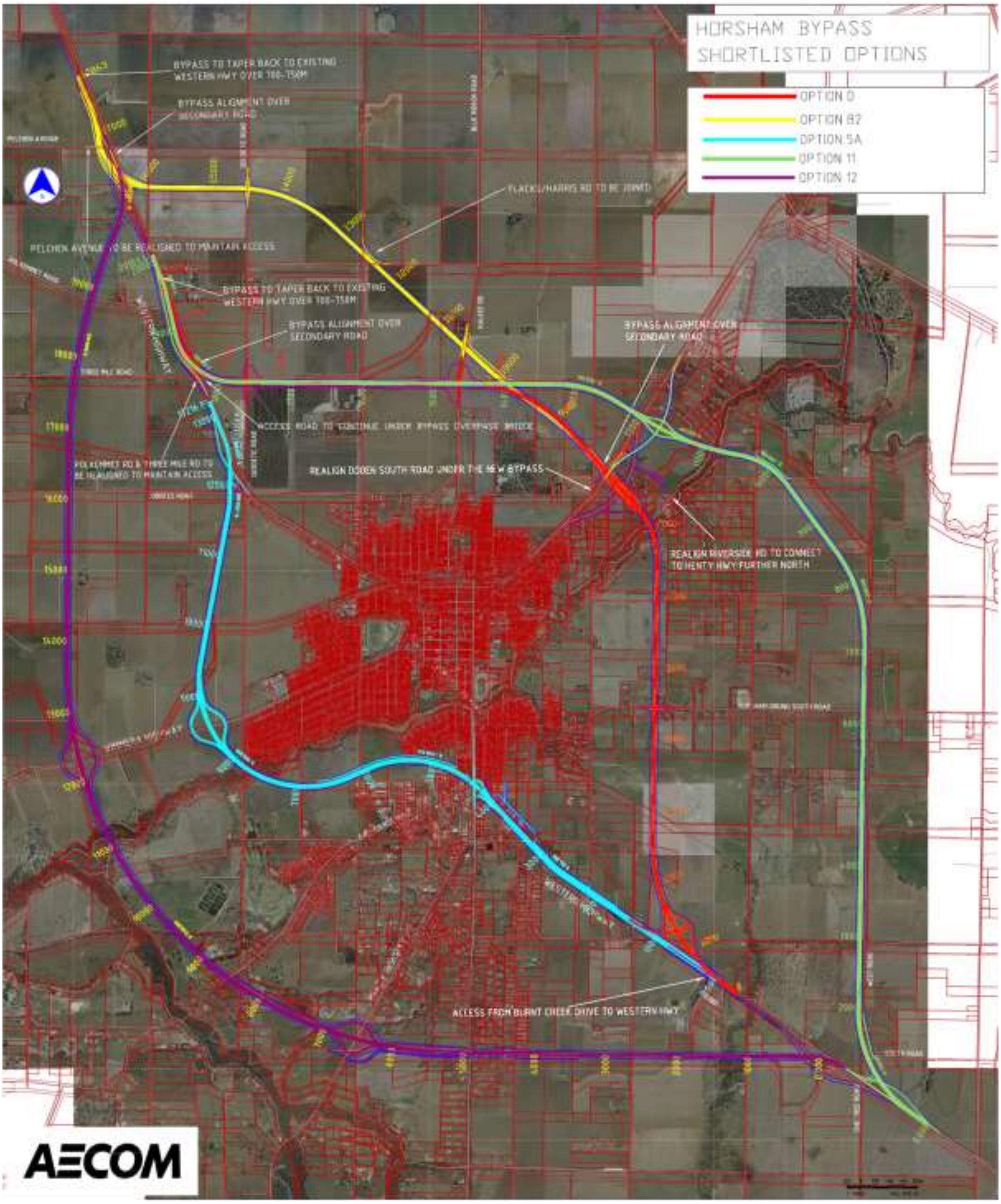

Figure 3 **Layout of Five Alignment Options**

4.0 POLICY AND LEGISLATION

This section introduces the key legislation and policy that is relevant to the Hydrology and Hydraulics assessment.

4.1 State Planning Policy Framework

State Planning Policy Framework (SPPF) outlines two policies critical to meeting Objective 1. These are *Floodplain Management* and *Catchment Planning and Management.*

13.02-1 Floodplain management

To assist the protection of:

- Life, property and community infrastructure from flood hazard;
- The natural flood carrying capacity of rivers, streams and floodways;
- The flood storage function of floodplains and waterways; and
- Floodplain areas of environmental significance or of importance to river health.

14.02-1 Catchment planning and management

To assist the protection and, where possible, restoration of catchments, waterways, water bodies, groundwater, and the marine environment

Both of these policies aim to ensure any changes to a waterway or its associated floodplain allow the free flow of flood water without hindrance or negative environmental impact. This is relevant to this study as all alignment options will have interaction with at least one waterway/waterway floodplain.

4.2 Local Planning Policy Framework

Local Planning Policy Framework (LPPF) outlines two policies critical to meeting Objective 1. These are very similar to the SPPF policies discussed above in Section 4.1. The policies are *Floodplain Management Policy* and *Resource protection policy.*

22.10 Floodplain Management Policy (objective)

- To minimise flood risk and promote sustainable use and development of the floodplain;
- To ensure development and land use on the floodplain is compatible with flood risk;
- To ensure that where permitted, development in the floodplain maintains the free passage and temporary storage of floodwaters; minimises flood damage; will not cause any significant rise in flood level or flow velocity; will not cause any impact on adjacent property;
- To discourage the intensification of zonings/land use in the floodplain of the Wimmera River and other waterways;
- To recognise the natural flood carrying capacity of rivers, streams and wetlands and the flood storage function of floodplains;
- To protect surface and ground water quality, and preserve important wetlands and areas of environmental significance; and
- To minimise risk associated with overland flow of storm water.

22.02 Resource protection policy (objective)

To ensure the thorough assessment of applications for use and/or development of land which have the potential to impact upon land and water resources.

Similarly both policies aim to ensure any changes to a waterway or its associated floodplain allow the free flow of flood water without hindrance or negative environmental impact. The LPPF also focuses on the protection of water resources and ability to harvest water from catchment areas. This is relevant to this study as all alignment options will have interaction with at least one waterway/waterway floodplain.

5.0 OPTIONS ASSESSMENT METHODOLOGY

The Objective-Based Evaluation Method (OBEM) was applied to this assessment. An overview of the OBEM is presented in **Figure 4**.

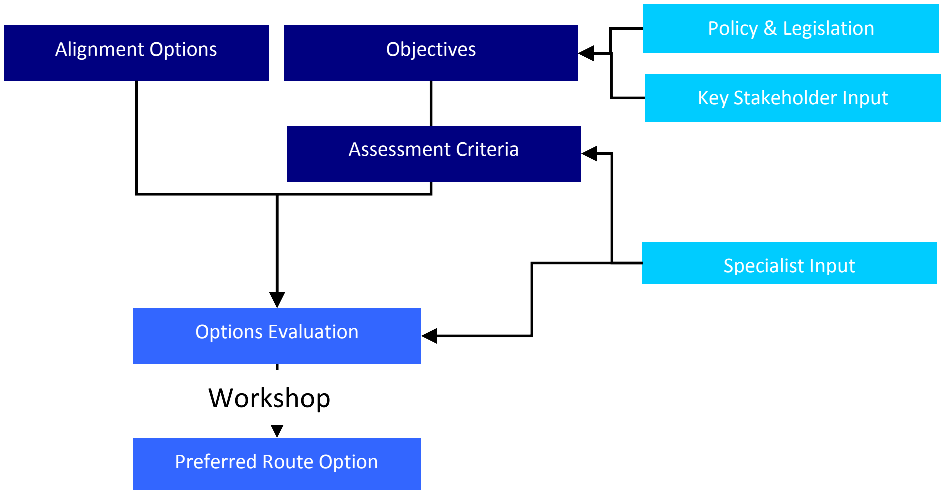

Figure 4 Overview of proposed methodology

As shown in **Figure 4**, two inputs are used in this assessment:

1) **Alignment Options:** The options reflect a need to balance an efficient transport network with environmental and social values. The alignment options are described in **Section 3.0** and a map of all alignments are provided in **Figure** 43.

2) **Objectives and Assessment Criteria**: Objectives that were developed in Stage 1 of Phase 2 were reviewed and refined for this specialist study. The most relevant objectives determined in Stage 1 of Phase 2 were:

   - Objective 1 - Avoid or minimise impacts on areas of ecological sensitivity, floodplain function and heritage significance to the extent practicable; and
   - Objective 2 - Provide a balanced outcome giving consideration to environmental, economic and social factors providing best value benefits for the lowest project cost.

   The objectives reflect relevant national and state legislation and relevant policies applicable.

   The analysis for this study was undertaken using the 100 year ARI event as a basis to rank each of the alignment options in terms of the drainage infrastructure that would be required to pass free flow.

   It is possible for each of the proposed alignment options to cause no impact on the passage of flood flows, providing each option had the required level of drainage infrastructure. Each alignment is also assessed on the potential number of structures they would require to pass the required flow at multiple locations.

   Therefore, the objectives were refined to ensure no negative floodplain impacts would be observed in a 100 year ARI event by the alignment option while assessing each option on the potential drainage infrastructure that would be required to pass flood flows.

   Refined objectives, indicators and assessment criteria relevant to this specialist study are outlined in **Table 1**.

Table 1 Objectives Relevant to Floodplain Impacts

Original Project Objective	Refined Project Objective	Indicator	Assessment Criteria
Avoid or minimise impacts on areas of ecological sensitivity, floodplain function and heritage significance to the extent practicable	Free passage flood water during a 100 year ARI event	Option is able to realistically allow free floodplain flow	Number of wetland and waterway crossings and 100 year ARI crossings Length alignment within 100 year ARI extent Peak flow rate required to be passed.
Provide a balanced outcome giving consideration to environmental, economic and social factors providing best value benefits for the lowest project cost	Approximate cost of drainage infrastructure required for each alignment option	Length of inundated area impacted Depth of inundation at alignment option	Potential number/type of culverts/bridges required and cross sectional area required to pass the existing 100 year ARI flows

As part of the option assessment, each alignment has been assessed against defined criteria. The set of rating criteria used across all specialist studies for Stage 2 of Phase 2 is provided in **Table 2**. However, as each of the alignment options have the potential to cause no negative floodplain impacts and the purpose of this component is to mitigate the impact/cost of the potential alignment, the rating system has been revised and is shown in **Table 3**.

Table 2 Initial ratings table for evaluating arterial options

<table>
<tr><th colspan="2">Descriptors</th><th>Ratings</th><th colspan="2">Descriptors</th></tr>
<tr><td>- Best practice
- Strong level of compliance</td><td>Significant benefits state wide</td><td>Very Well</td><td colspan="2" rowspan="3">Positive Impacts</td></tr>
<tr><td>- Improved practice
- Good policy compliance
- Positive impact</td><td>Significant benefits for the region</td><td>Well</td></tr>
<tr><td>- Partial policy compliance
- Positive impact</td><td>Significant benefits at a local level or moderate benefits over a larger area</td><td>Moderately Well</td></tr>
<tr><td>No distinct positive impacts</td><td>Minimal benefits, even at the local level.</td><td>Neutral</td><td>Minimal if any impact for local areas. Potentially some impact for a small number of individuals.</td><td>No distinct negative impacts</td></tr>
<tr><td colspan="2" rowspan="3">Negative Impacts</td><td>Moderately Poor</td><td>High level of impact for local area or moderate level of impact over a broader area.</td><td>- Policy non-compliance
- Negative impact</td></tr>
<tr><td>Poor</td><td>High level of impact for the region.</td><td>- Policy non-compliance
- High Negative impact</td></tr>
<tr><td>Very Poor</td><td>High level of impact state wide.</td><td>- Policy non-compliance
- Major negative impact</td></tr>
</table>

Table 3 Revised hydrological ratings table for evaluating arterial options

<table>
<tr><th colspan="2">Descriptors</th><th>Ratings</th><th colspan="2">Descriptors</th></tr>
<tr><td>- Best practice
- Strong level of compliance</td><td>Significant benefits state wide</td><td>Very Well</td><td colspan="2" rowspan="3">Positive Impacts</td></tr>
<tr><td>- Improved practice
- Good policy compliance
- Positive impact</td><td>Significant benefits for the region</td><td>Well</td></tr>
<tr><td>- Partial policy compliance
- Positive impact</td><td>Significant benefits at a local level or moderate benefits over a larger area</td><td>Moderately Well</td></tr>
<tr><td>No distinct positive impacts</td><td>Minimal benefits, even at the local level.</td><td>Neutral</td><td>Minimal infrastructure required to pass flow</td><td>Ability to realistically achieve no negative floodplain impacts</td></tr>
<tr><td colspan="2" rowspan="3">Negative Impacts</td><td>Moderately Poor</td><td>Moderate level of drainage infrastructure required</td><td>Potential ability to realistically achieve no negative floodplain impacts</td></tr>
<tr><td>Poor</td><td>High level of drainage infrastructure required.</td><td>Unlikely to realistically achieve no negative floodplain impacts</td></tr>
<tr><td>Very Poor</td><td>Very high level of drainage infrastructure required.</td><td>Very unlikely to realistically achieve no negative floodplain impacts</td></tr>
</table>

Bypass alignment options that cause any undesirable change to flood inundation extent, depth or water levels are considered to have a negative impact. This impact is assessed by the necessary drainage infrastructure required to prevent these changes (e.g. small culverts would classify as minimal infrastructure, whereas large bridges would classify as major infrastructure). There could only be a positive floodplain impact as the result of a bypass alignment if the option resulted in flood mitigation which benefited all parties. Private property (dwellings and other infrastructure) are located up and downstream of all the proposed bypass options causing any change to the existing flood inundation extent, depth and water levels to impact both positively and negatively on landholders dependent on their location.

6.0 METHODOLOGY

6.1 Overview

As part of the Hydrology and Hydraulics Assessment of the five considered Horsham Bypass alignment options (Options 5A, 11, 12, B2 and D), Water Technology constructed a hydraulic model covering all alignment options. This model is an extension of an existing hydraulic model covering the east Horsham area developed in 2009, as part of the Wimmera River and Yarriambiack Creek Flows Study[1], this model is one of four models produced for the study. The hydraulic model was developed in DHI's MikeFlood. The model was extended to analyse the impact of the proposed bypass alignments and determine a ranking for the options. **Figure 5** shows the previous and revised model extents.

The modelling completed included the following waterways:

- Wimmera River (Horsham Lubeck Road to Horsham-Noradjuha Road)
- Mackenzie River (Nunkerri Road to the Wimmera River)
- Burnt Creek (Clynes Road to the Wimmera River)

Bungalally Creek (Bakers Road to the Wimmera River)Hydrology used across previous studies was reviewed and compared to revised Flood Frequency Analyses (FFA) to confirm model inflows.The model was verified against observed levels and extents from the January 2011 flood event as well as 100 year ARI levels and extents estimated during the previous study.

In the Horsham area, the January 2011 event was the largest in living memory. The event exceeded flood levels observed in 1909 in several locations. The event is broadly considered as between a 100 to 200 year ARI event in the Horsham area based on modelling undertaken during the Wimmera River and Yarriambiack Creek Flows Study[1].

Design flow rates, water levels and extents were determined for the 100 year and 10 year ARI events. These parameters were used to estimate the size of the required infrastructure at each floodplain or waterway crossing point and therefore rank the proposed bypass options in terms of potential impact to the floodplain and potential cost of mitigating this impact.

[1] Water Technology 2009 – Wimmera River and Yarriambiack Creek Flows Study

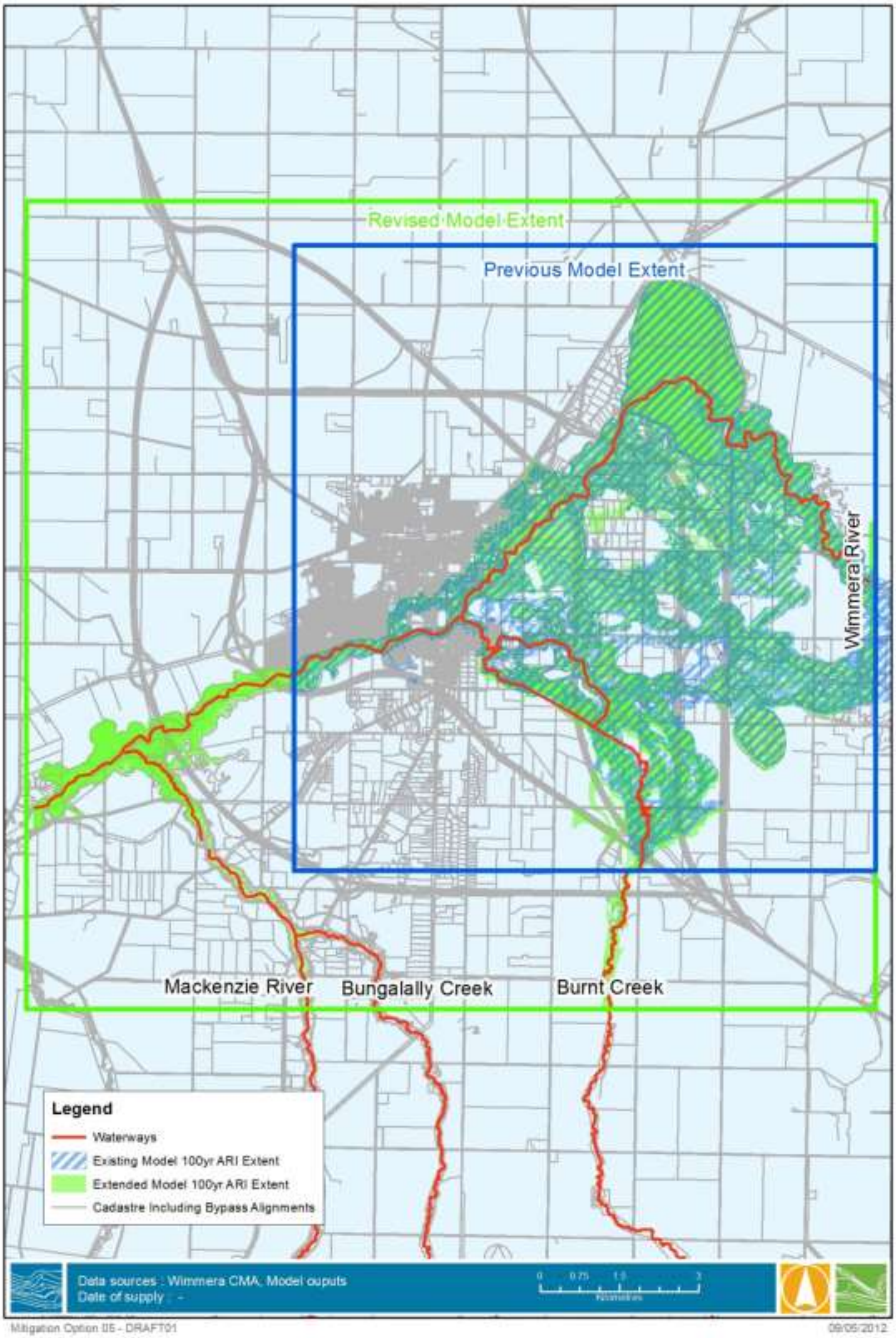

Figure 5 Modelled extents

6.2 Hydrology

Previous modelling of the East Horsham Area completed in 2009 used the runoff routing model, Unified River Basin Simulator (URBS), to estimate flood hydrographs at each of the model inflow points. URBS is a networked conceptual runoff and streamflow routing program based on catchment geometry and topographic data that calculates flood hydrographs from rainfall and other channel inputs.

The URBS model was originally developed by the Bureau of Meteorology in 2004. The model covered the Wimmera Basin to Dimboola. During the 2009 study, changes to the model were undertaken to enhance its ability to accurately predict flood flows at model inflow points, by inserting hydrograph output points to be inserted to the hydraulic model boundaries.

The inflow points to the model shown in **Figure 5** are located on the Wimmera River downstream of the Drung-Jung Road Bridge and Burnt Creek at the Western Highway.

To complete an extension of the existing MikeFlood hydraulic model (discussed in Section 6.3), additional inflow points were required on the Mackenzie River and Bungalally Creek. The Burnt Creek boundary was also extended to further upstream of the Western Highway, the Wimmera River inflow point was able to remain downstream of the Drung-Jung Road Bridge. Flows at Mackenzie River, Bungalally Creek and Burnt Creek were extracted from the Updated URBS Model.

To determine the necessary inflows to the extended hydraulic model, analysis of the previous study URBS modelling was undertaken by comparison with existing and revised FFA at each of the available gauge locations relevant to the extended model.

6.2.1 Streamflow Gauging

An assessment of the available streamflow gauge records has been undertaken to assist in determining the model inflows for the hydraulic model verification and design model runs.

This assessment has been separated into Wimmera River gauges and tributary gauges.

6.2.1.1 Tributary Gauges

The Burnt Creek, Mackenzie Creek and Bungalally Creek systems are interlinked at the upper end of their catchments. Burnt Creek separates from the Mackenzie River, where it flows further to the east in the same general northerly direction. In a similar fashion, Bungalally Creek offtakes from Burnt Creek midway down its system, it then joins the Mackenzie Creek prior to the Wimmera River.

There are three gauges located across the system. These gauges and their available period of record are shown below in **Table 4**. The location of each waterway and the gauges throughout the system is shown in **Figure** 14**6**.

Table 4 Gauges on the Mackenzie, Burnt and Bungalally Creek systems

Gauge	Period of Record
Mackenzie River at Mackenzie Creek	1988 - Current
Burnt Creek at Wonwondah East	1983 - Current
Bungalally Creek at Mackenzie Creek	1983 – 01/12/1993

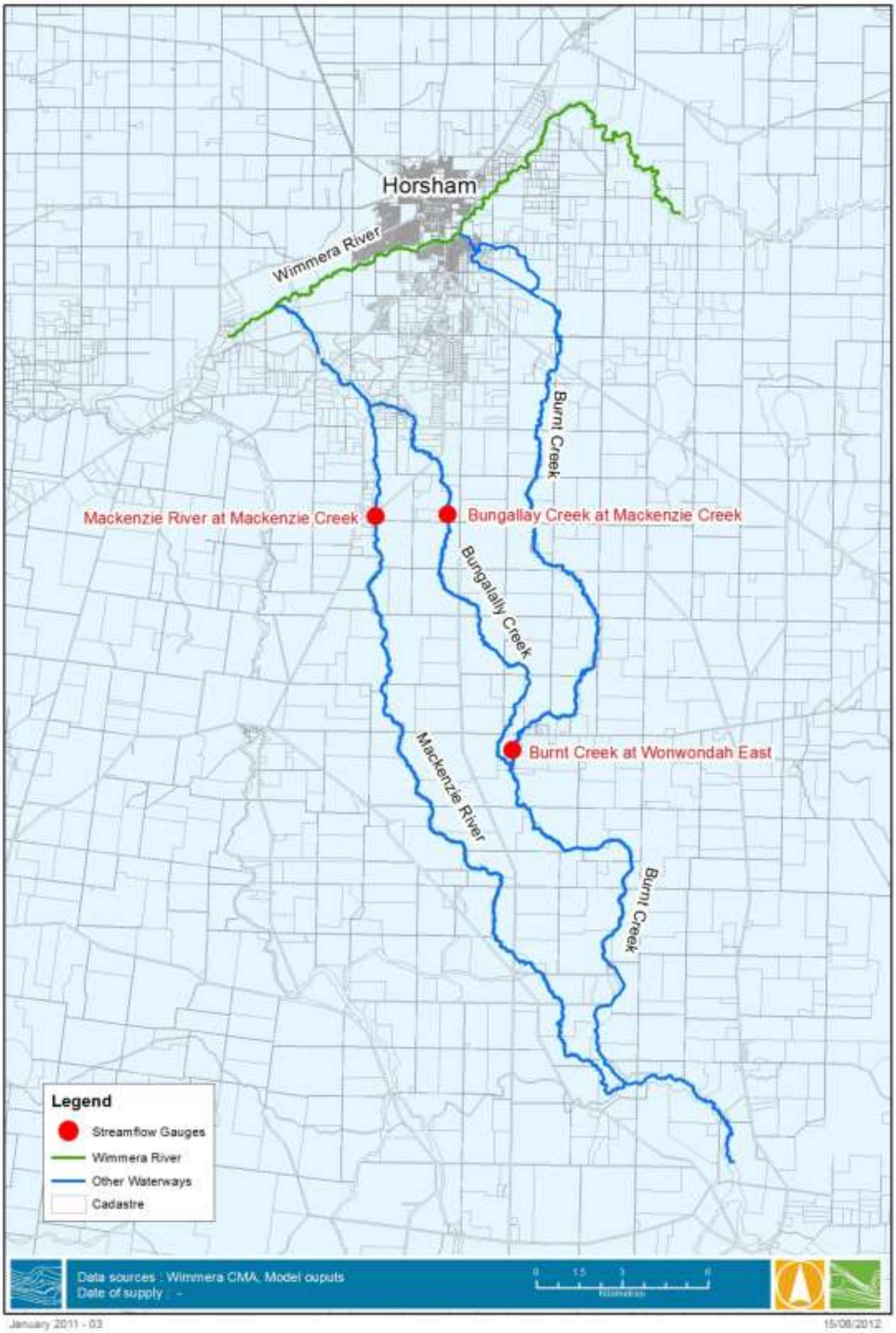

Figure 6 **Mackenzie Creek, Burnt Creek and Bungalally Creek**

Of the available stream flow records, Mackenzie Creek and Burnt Creek had the longest period of record. These gauges recorded the January 2011 event and are currently in operation. The Bungalally Creek gauge record however, only contains approximately 10 years of instantaneous record and does not include the January 2011 event.

The Mackenzie River gauge is located approximately 2.5 km upstream (south) of the extended model boundary. The location of the streamflow gauge in relation to the model boundary is shown overleaf in **Figure 7**.

The Burnt Creek gauge is located downstream of the natural Bungalally Creek offtake point however due to manmade changes in both waterways the gauge is now located upstream of the offtake point. **Figure 8** shows the offtake area and manmade influences on flow.

Flow from Burnt Creek into Bungalally Creek is no longer transported via the natural channel due to overland blockages caused by the North-East Wonwondah Road, the Laharum Road and the Rocklands Channel. Burnt Creek now has a weir structure and is connected to Rocklands Channel - flood flows are either transported overland or through the Rocklands Channel.

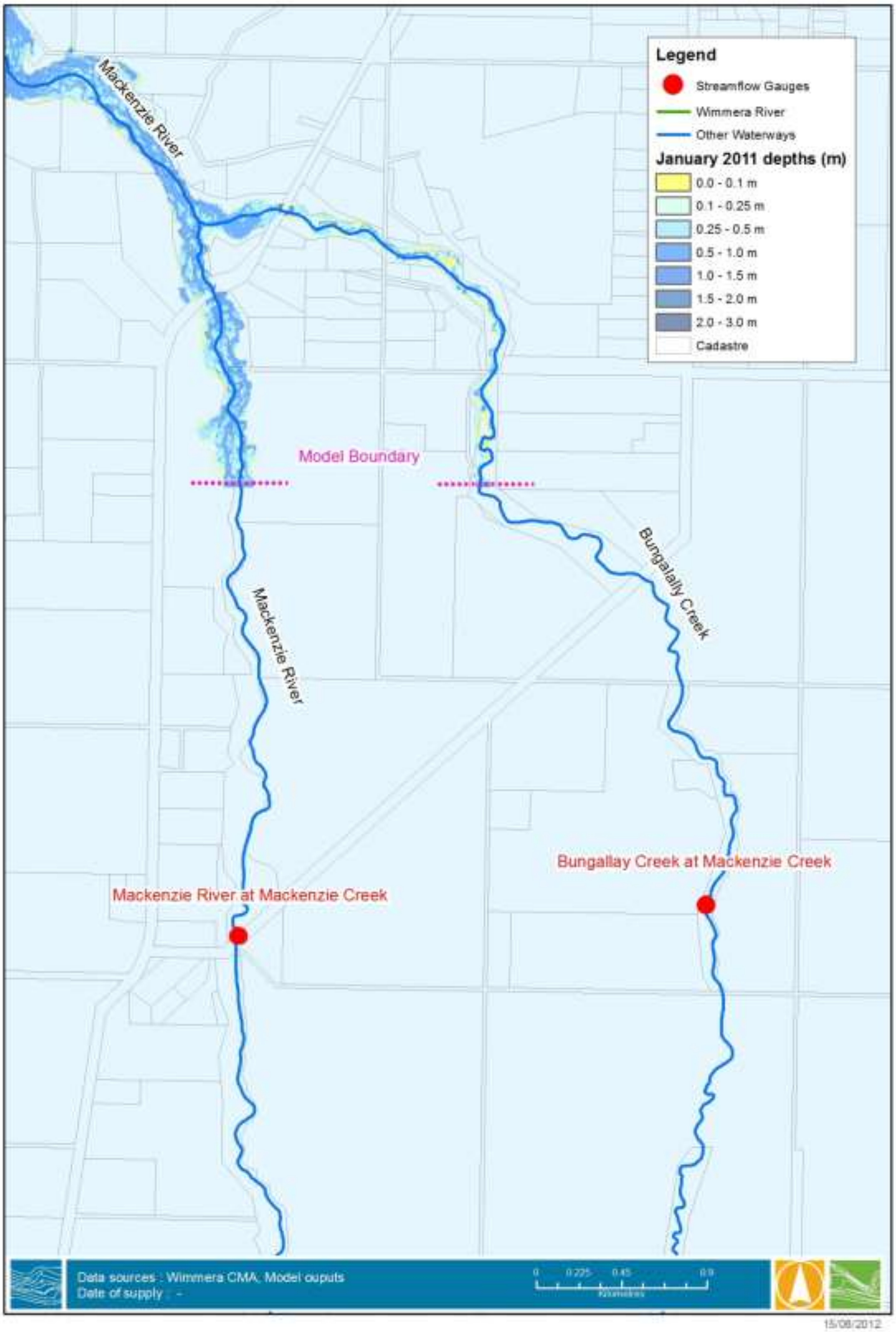

Figure 7 **Mackenzie Creek and Bungalally Creek gauge locations in respect to model boundaries**

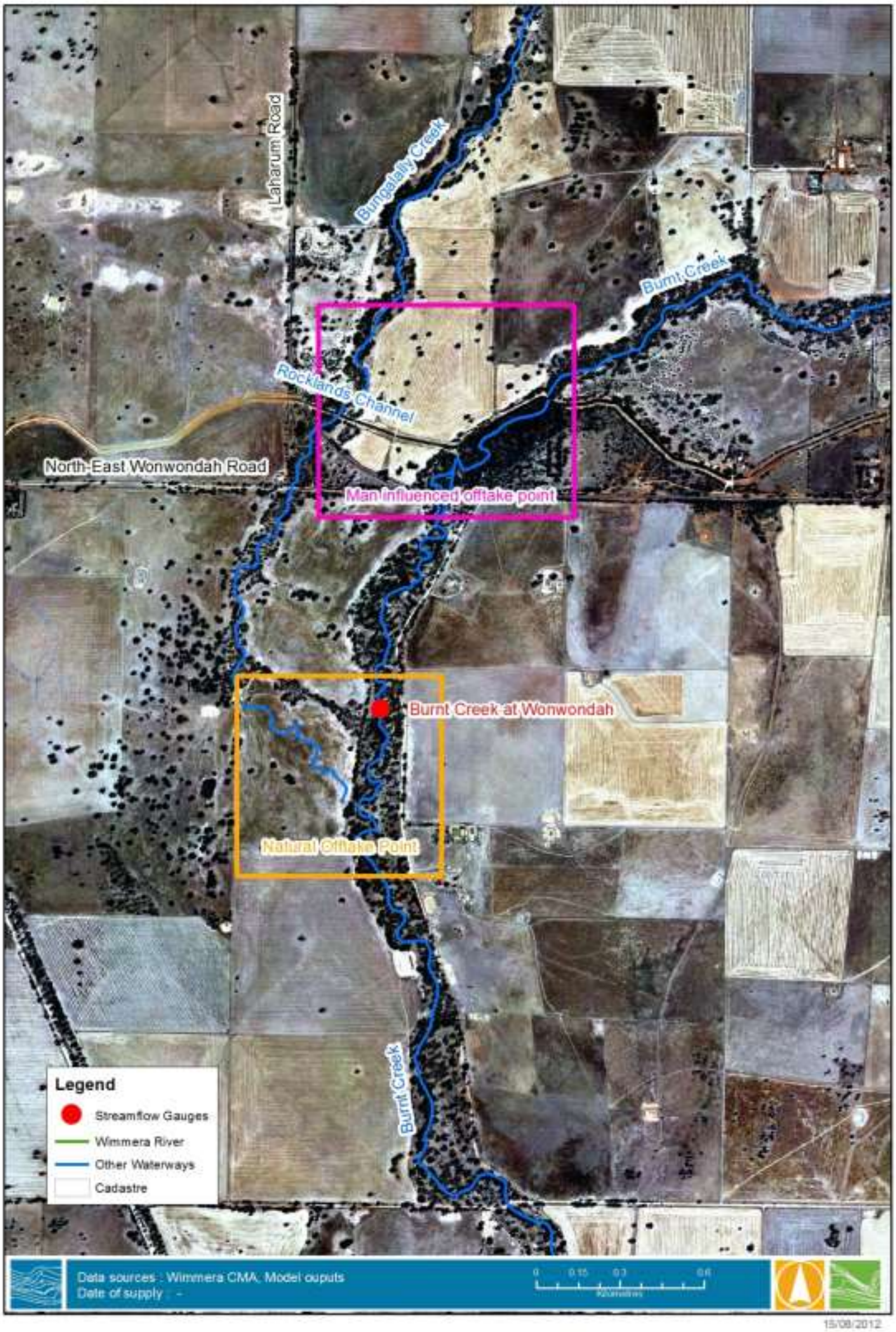

Figure 8 Bungalally Creek offtake and manmade changes influencing flow

GWMWater (Andrew Barton pers. com. to Ben Hughes [Water Technology]) estimate that during flood flows Bungalally Creek takes approximately 20% of the total Burnt Creek flow prior to the offtake, leaving the remaining 80% to pass down Burnt Creek to the Wimmera River.

For the period of gauging overlap (08/07/1988 – 01/12/1993) five significant events resulting in flow down both Burnt Creek and Bungalally Creek were recorded. These occurred in September of 1993, 1992, 1991, 1989 and 1988, as shown in **Figure 9**.

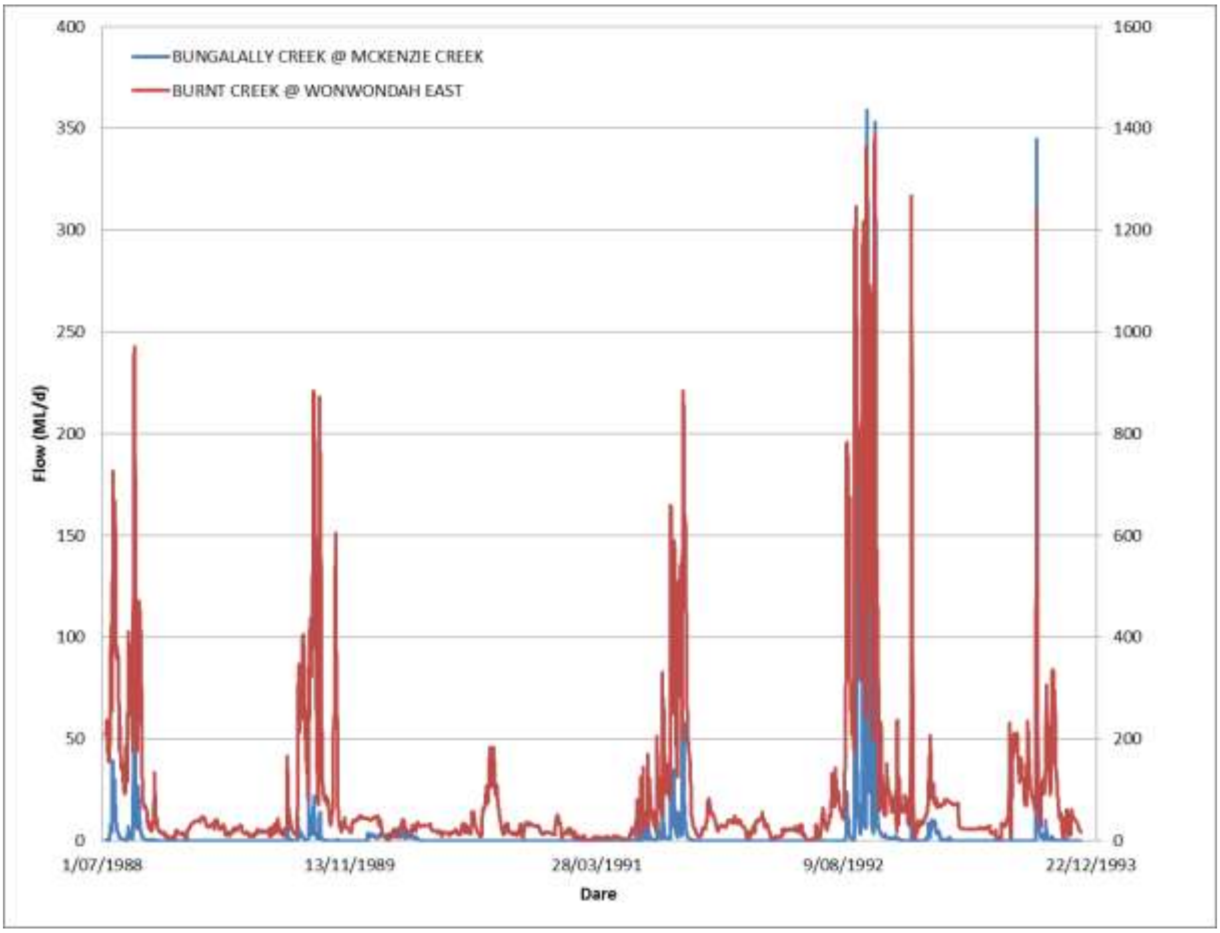

Figure 9 **Bungalally Creek and Burnt Creek flows for the period of record overlap**

For these events, the relationship between flow on Burnt Creek at Wonwondah and Bungalally Creek at McKenzie Creek is shown in **Table 5**.

Table 5 **Gauges on the Mackenzie, Burnt and Bungalally Creek systems**

Gauge	Event Peak Flow				
	Sep-88	Sep-89	Sep-91	Sep-92	Sep-93
Burnt Creek at Wonwondah East	970.1	884.5	884.0	1364.4	1239
Bungalally Creek at McKenzie Creek	94.1	21.9	57.9	358.8	344.6
Ratio (Bungalally Creek: Burnt Creek)	9.70%	2.48%	6.55%	26.30%	27.81%

The peak flows indicate that a lower flow is distributed to Bungalally Creek. At higher flows between 25-30% of the Burnt Creek, flow at Wonwondah East is distributed to Bungalally Creek.

6.2.1.2 Wimmera River Gauges

There are three Wimmera River streamflow gauges that are relevant to the study area. These gauges are located at Glenorchy, Drung and Walmer, as shown in **Figure 10**.

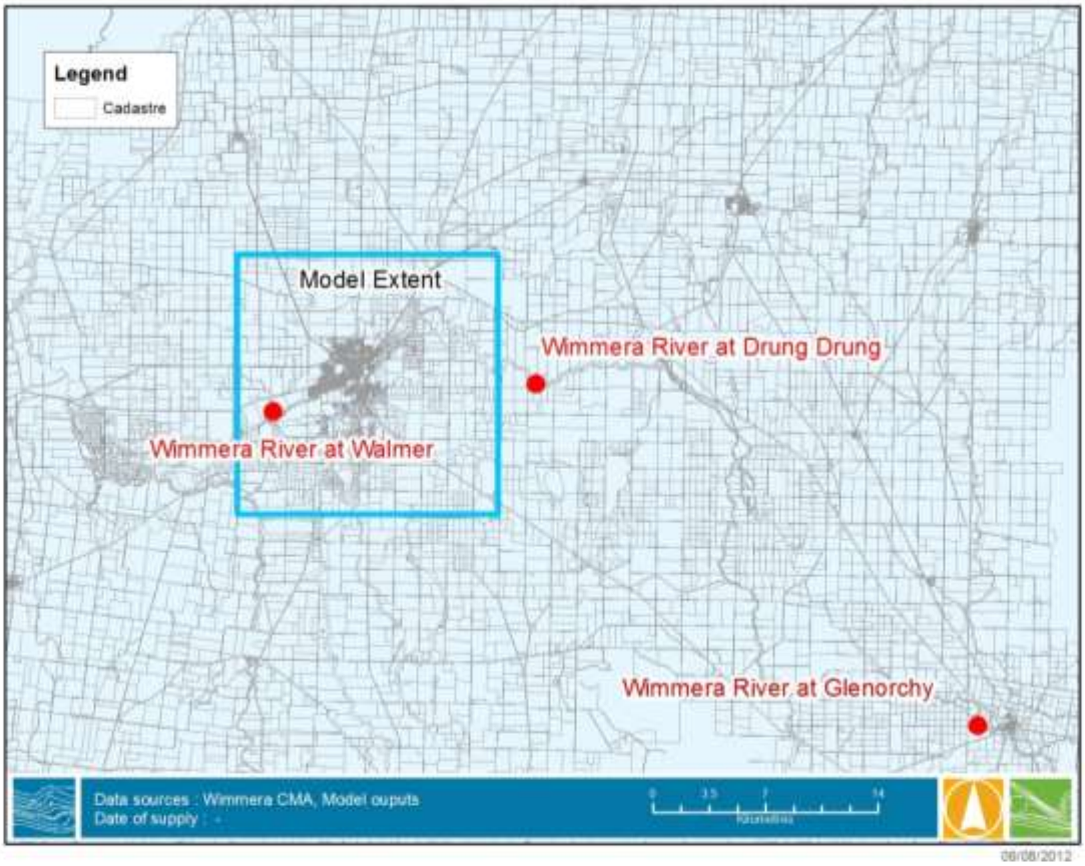

Figure 10 Wimmera River gauges relevant to this study

The periods of records for these gauges are shown in **Table 6**.

Table 6 Gauges on the Mackenzie, Burnt and Bungalally Creek systems

Gauge	Period of Record
Wimmera River at Glenorchy	1964 - Current
Wimmera River at Drung	1978 - Current
Wimmera River at Walmer	1889 - Current

The Drung Drung gauge does not record all flows passing along the Wimmera River. At high flows, flood water travels around the gauge by passing up Yarriambiack Creek and back to the Wimmera River through Two Mile Creek - recordings of flow at the gauge are only a partial representation of flow entering the study area. The Glenorchy and Walmer gauges are considered to be a better representation of flow in the Wimmera River during high flows – as a result, the gauge on the Wimmera River at Drung Drung has not been assessed during the FFA.

6.2.2 URBS

The original URBS model was developed by the BoM to forecast potential flooding.

URBS uses three model parameters α (channel storage parameter), β (catchment storage parameter), m (degree of non-linearity of flood response). The parameters identified during the 2009 study were - α = 0.4, β = 0.3, m = 0.8.

The URBS model predicted flows at gauge locations within the model extent. These gauges were:

- Wimmera River at Glenorchy
- Burnt Creek at Western Highway
- Wimmera River at Walmer
- Mackenzie River at McKenzie Creek.

The model was calibrated using flood events in 1981, 1983, 1988, 1992 and 1996 and was separated into two sections, upstream of Glenorchy and Glenorchy to Dimboola. During the 2009 study, the URBS model was revised to reflect the effluent flows to Yarriambiack Creek and the flow interaction between the Mackenzie River and Burnt Creek at Distribution Heads.

Yarriambiack Creek effluent from the Wimmera River was determined hydraulically through the development of a hydraulic model covering the Yarriambiack Creek offtake point and Yarriambiack Creek itself. As discussed in **Section 6.2.1.2**, flow passing from the Wimmera River into Yarriambiack Creek does re-enter the Wimmera River via Two Mile Creek.

The assumed flow split between the Mackenzie River and Burnt Creek at Distribution Heads was estimated to be 2:1 (Mackenzie River flows: Burnt Creek contribution). Analysis was undertaken by determining a rating curve for the flow split over a series of events as shown in **Figure 11**. This split is considered to be conservative.

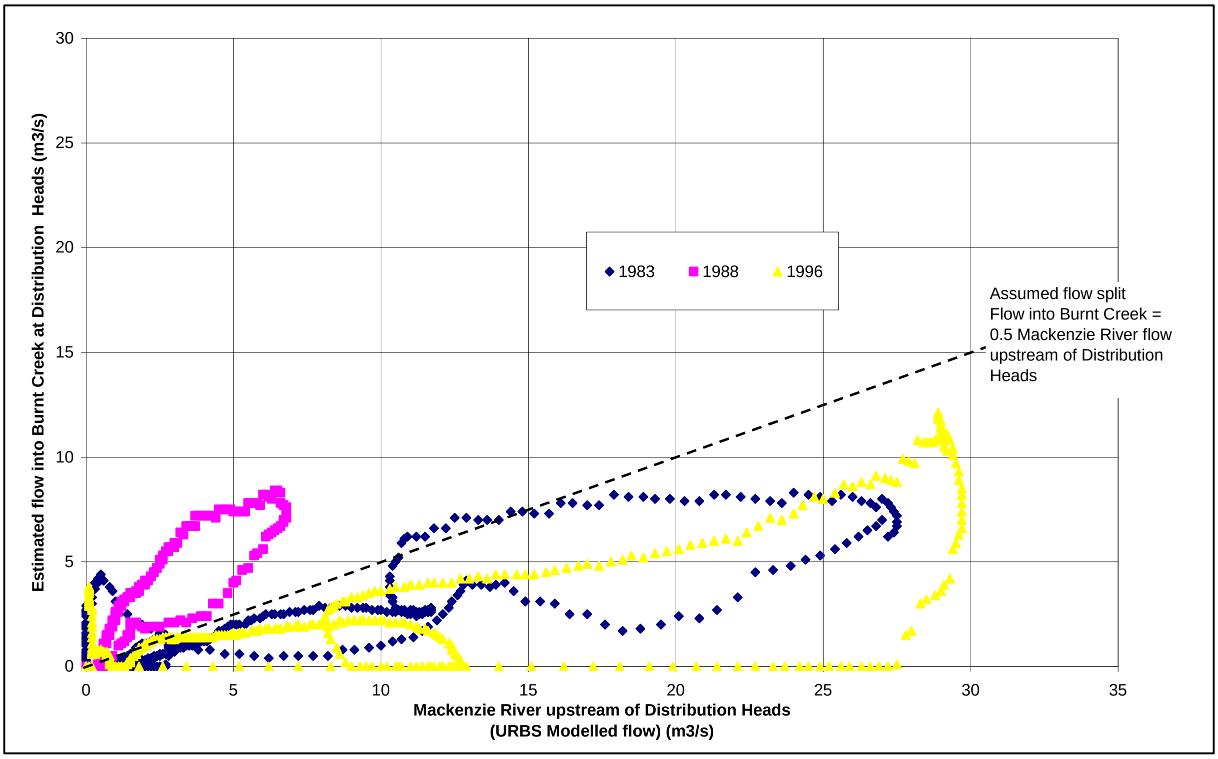

Figure 11 **Relationship between the Mackenzie River upstream of Distribution Heads and Burnt Creek at Distribution Heads.**[1]

These changes are documented in full in the Wimmera River - Yarriambiack Creek Flow Modelling Study Report[2]. This report, assessing the proposed Horsham Bypass alignments, only presents a summary of the changes that are relevant to this study and presents the final parameters used in the prediction of flood flows.

6.2.3 Flood Frequency Analysis

During the previous 2009 investigation, FFA were undertaken or documented at the following stream flow gauges:

- Wimmera River at Glenorchy (Glenorchy Flood Study[3])
- Burnt Creek at Wonwondah East (Wimmera River and Yarriambiack Creek Flows Study[2])
- Wimmera River at Walmer (Horsham Flood Study[4]).

Graphical representations of these analyses are shown in **Section 12.1**.

As part of this study, each FFA was extended to include the years up to 2011. Each analysis was undertaken using the same methodology as the previous respective study, using a Log-Pearson Type 3 probability distribution and the same low flow thresholds.

An FFA was also undertaken at the Mackenzie River at McKenzie Creek gauge but no comparison to previous studies has been made.

The length of record analysed for each gauge for the previous and current study is shown below in **Table 7**.

Table 7 Flood Frequency Analysis length of record analysed

Gauge	Study	Analysis Length
Wimmera River at Glenorchy	Revised FFA	1964 - 2011
	Previous Study	1964 - 2001
Burnt Creek at Western Highway	Revised FFA	1966 - 2011
	Previous Study	1966 - 2001
Wimmera River at Walmer	Revised FFA	1889 – 2011
	Previous Study	1889 - 2001
Mackenzie River at McKenzie Creek	Revised FFA	1988 - 2011

A graphical representation of the updated FFA for each gauge within the study area is shown in **Section 12.2**.

The results of the previous and current analyses are shown in **Table 8**. The table also shows the Revised URBS predicted peak flow rates at each of the available gauge locations.

[2] Water Technology, 2009 - Wimmera River - Yarriambiack Creek flow modelling
[3] Water Technology, 2006 – Glenorchy Flood Study
[4] Water Technology, 2003 – Horsham Flood Study

6.2.4 Discussion

The extension of the data analysed in each gauge FFA has shown a general increase in the estimated flow rate for each ARI. This is due to the significant rainfall and subsequent flood events that were observed in later 2010 and early 2011.

A comparison between Revised URBS and FFA peak flows is shown in **Table 8**.

Table 8 Flood Frequency Analysis results and comparison

Gauge	Study	5 Year ARI	10 Year ARI	20 Year ARI	50 Year ARI	100 Year ARI	200 Year ARI
Wimmera River at Glenorchy	URBS	8726	14861	22982	30067	37584	43459
	Revised FFA	13791	19576	25297	32742	38259	43653
	Previous Study	14100	18995	23529	29033	32851	36390
Burnt Creek at Western Highway	URBS	1719	2255	4329	6134	8001	9158
	Revised FFA	1143	1800	2569	3766	4812	5984
	Previous Study	1216	1808	2460	3415	4204	5050
Wimmera River at Walmer	URBS	13910	18749	25315	32573	38707	45619
	Revised FFA	13202	19110	25251	33765	40497	47467
	Previous Study	13010	18551	24221	31950	37966	44112
Mackenzie River at McKenzie Creek*	URBS	717	1339	2281	3361	4173	5227
	FFA	931	1656	2572	4139	5647	7483

* Only short record available and FFA should only be considered indicative

The comparison has shown the FFA and URBS peak flow rates are relatively similar.

The revised FFA with an extended period of record matches the Revised URBS peak flows more closely than previous studies. In all cases the Revised URBS model peak flow predictions were higher than that of the previous studies and the inclusion of the 2010-2011 rainfall events has increased the flow rate for each ARI.

6.2.5 Model Inflows

6.2.5.1 Model Verification Inflows

6.2.5.1.1 Mackenzie River and Bungalally

To verify the extended model results along the Mackenzie River and Bungalally Creek, the January 2011 event was modelled and compared to aerial images. Aerial images were captured via fixed wing aircraft and are referred to as ‘linescans’. The linescans show a greyscale image of the ground surface, with water shown as a darker shade.

The Mackenzie River at Mackenzie Creek gauge is in very close proximity to the model boundary and therefore provides a good indication on the flow entering the model. The flow recorded at the gauge was used as a direct inflow to the hydraulic model.

Due to the uncertainty surrounding this relationship, a number of flow splits were modelled distributing 20, 30 and 40% of the Burnt Creek flow from Wonwondah East to Bungalally Creek.

The peak flows modelled at the Mackenzie River and Bungalally Creek model boundaries are shown in **Table 9**.

Table 9 Peak inflows for the Mackenzie River and Bungalally Creek for each model scenario

Gauge	Event Peak Flow (ML/d)		
	Scenario 1 (20%)	Scenario 2 (30%)	Scenario 3 (40%)
Mackenzie River	4295 (50 m3/s)		
Bungalally Creek	311 (3.6 m3/s)	475 (5.5 m3/s)	631 (7.3 m3/s)

6.2.5.1.2 Wimmera River and Burnt Creek inflows

The model was originally intended to be verified against observed levels and extents from the January 2011 flood event but flows recorded during the January 2011 event were found to be incomplete. Two areas of significant overland flow from breakouts from the Wimmera River were un-gauged. Due to the uncertainty surrounding the January 2011 flow on the Wimmera River, it was determined the extended model would be verified against previous model predictions using the 100 year ARI event for the area of model overlap, only utilising the observed January 2011 event for broad comparisons.

6.2.5.2 Design Modelling Inflows

Previous modelling completed in 2009 adopted URBS model outputs for hydraulic model inflows as the difference between the URBS model peak flows and FFA peak flows for each ARI was within the 95% confidence limits of the FFA.

As the extension of the gauge record used in each FFA has shown a closer match to the URBS estimated peak flows, the URBS model flows were adopted for this study.

Peak discharges for the 100 year ARI at the model inflow locations are shown below in **Table 10**.

Table 10 Design event peak inflows

Gauge	100 Year ARI
Wimmera River downstream of Drung Jung Road	36,290 ML/d (420 m3/s)
Burnt Creek at upstream of the Western Highway	4,147 ML/d (48 m3/s)
Bungalally Creek at Bakers Road	1,814 ML/d (21 m3/s)
Mackenzie River at McKenzie Creek	4,147 ML/d (48 m3/s)

6.3 Hydraulics

6.3.1 Model extent

The previous MikeFlood model contained two inflow points, Burnt Creek and the Wimmera River. The revised MikeFlood model was extended to cover each of the bypass options in full. This extension required the inclusion of the Mackenzie River and Bungalally Creek.

The extent of each model and each of the waterways impacting on the area is shown in **Figure 5**.

6.3.2 Model Verification

6.3.2.1 Wimmera River and Burnt Creek

For verification of the revised extended model, the 100 year ARI inflow hydrographs for Burnt Creek and Wimmera River were adopted from the previous 2009 model. The model boundary location for the Wimmera River was identical, but for Burnt Creek was further upstream than in the 2009 model. Flow rates from the previous and revised models were compared at the Wimmera Highway. This comparison also included flows recorded during the January 2011 event, as shown below in **Table 11**.

Table 11 Modelled and observed flows

Scenario	Burnt Creek	Wimmera River at the Wimmera Highway
Existing Model 100 year ARI Peak Inflow	4180 ML/d (48.4 m3/s)	36490 ML/d (422.3 m3/s)
Extended Model 100 year ARI Peak Inflow	4180 ML/d (48.4 m3/s)	34650 ML/d (401.0 m3/s)
January 2011 Peak Flow at Wonwondah East	157 ML/d (18.2 m3/s)	32940 ML/d (381.3 m3/s)

The comparison of peak flows has shown the peak flow for the Wimmera River during January 2011 to be marginally below the 100 year ARI event flow rate estimated in both the previous and revised modelling. However, the Burnt Creek peak flow is well below the estimated 100 year ARI peak.

A comparison of the extended and previous 100 year ARI model extents over the area of model overlap has shown the extents differ in some areas. **Figure 12** shows the extents overlayed with the previous 100 year ARI extent shown in a hatched blue and the extended model 100 year ARI extent in green. Three areas are highlighted as showing areas of differing extent.

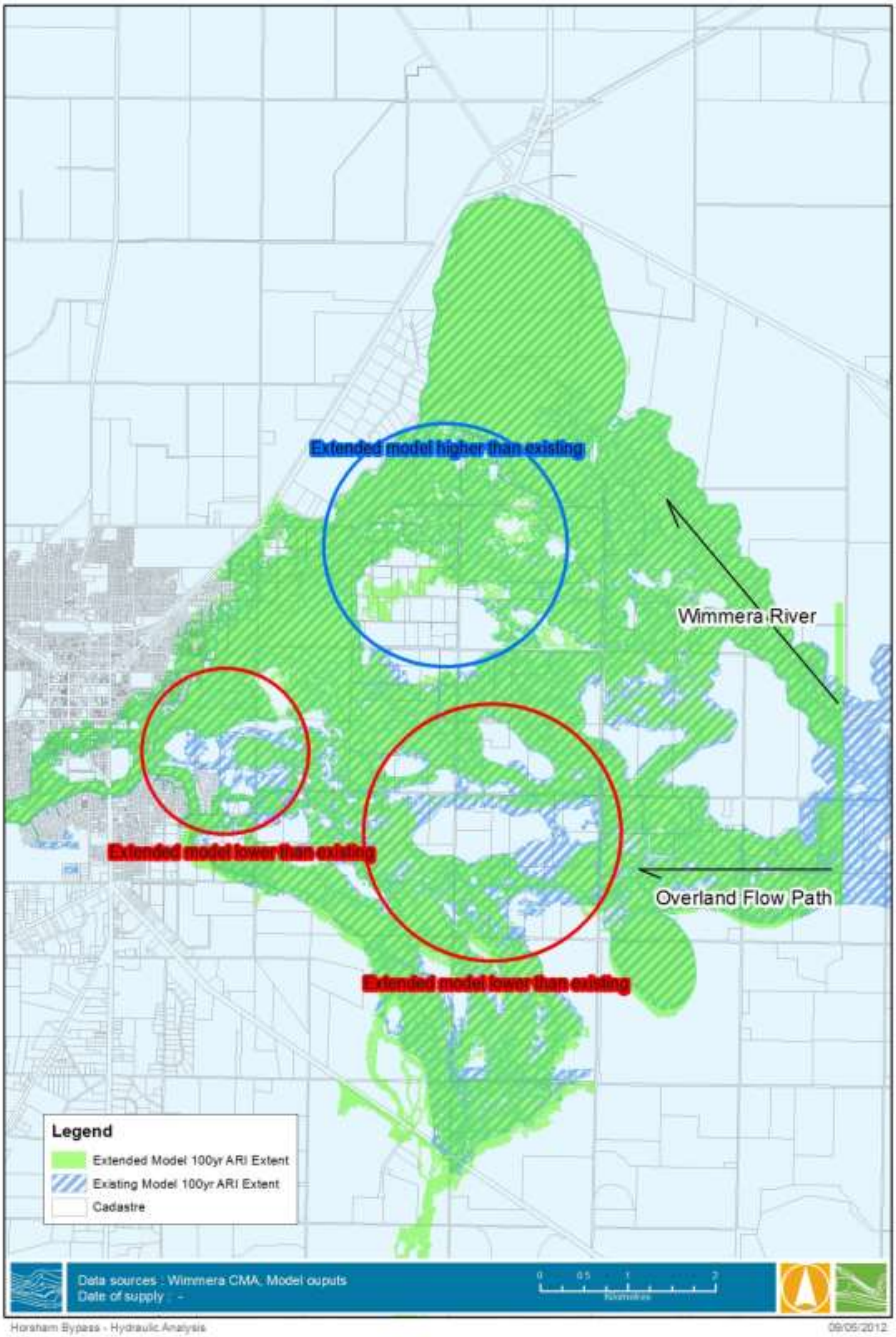

Figure 12 Existing and Extended 100 year ARI extents

The areas of major discrepancy are shown along the two major flow paths. The extended model is showing higher water levels and slightly more inundation along the Wimmera River and less along the overland flow path to the south.

The extended model is showing higher water levels along the Wimmera River than previous modelling with less flow passing overland.

Water levels in the extended model are elevated by approximately 0.1 m along the Wimmera River and reduced by 0.2 m in some areas of inundation along the overland flow path. This is due to subtle changes in the topography between models and the extension of model boundaries, particularly in the Burnt Creek area.

Figure 13 shows both the existing and extended model inundation extents for the 100 year ARI event compared to the January 2011 observed extent, shown in red. The comparison shows the observed January 2011 extent more closely matches the 100 year ARI extent predicted by the extended model. The observed extents are smaller along the overland flow path to the south and larger along the Wimmera River.

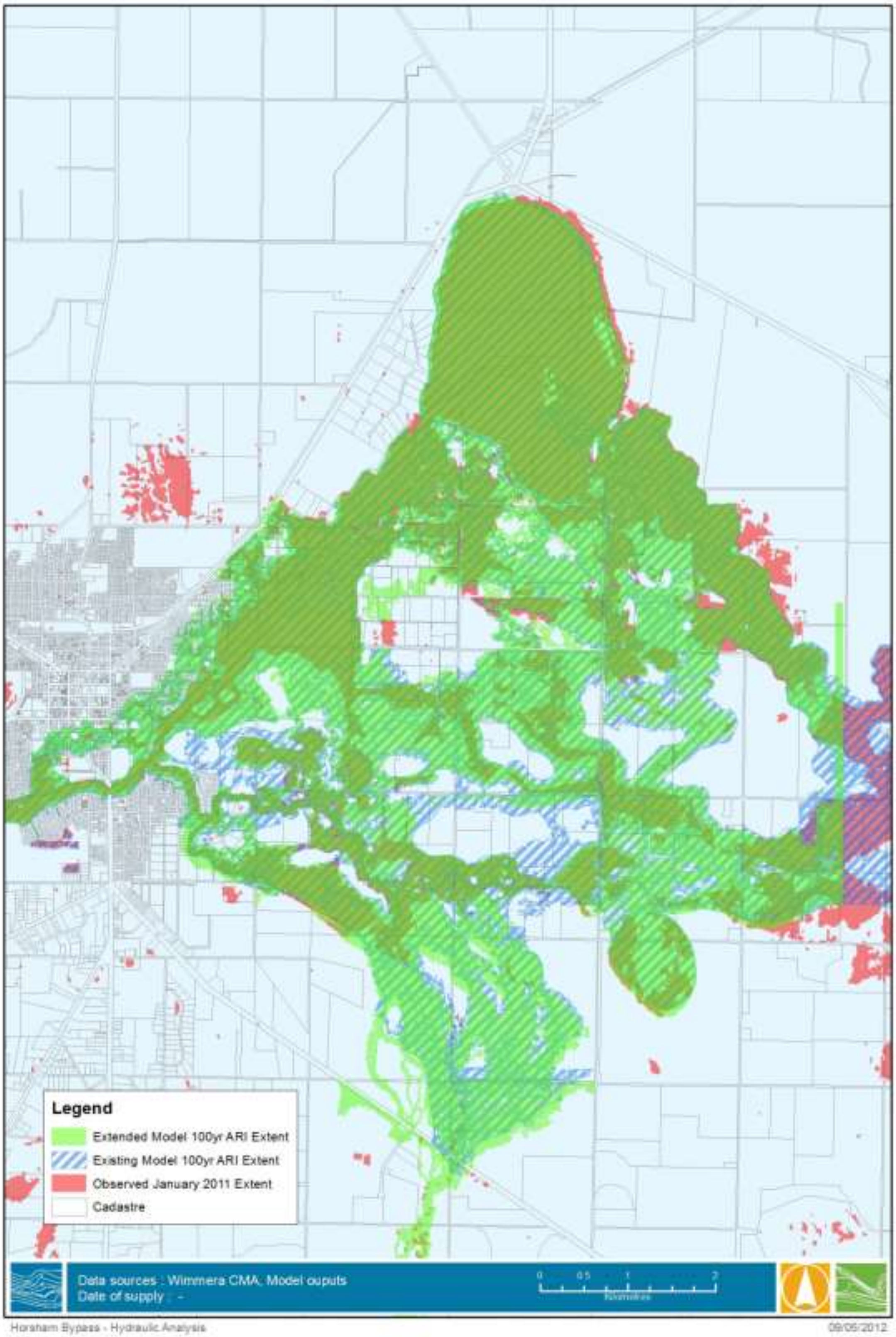

Figure 13 Existing and Extended 100 year ARI extents

6.3.2.2 *Comparison and discussion*

Modelled and observed flows shown in **Table 11** indicate the January 2011 peak flow was approximately 20 m^3/s and 40 m^3/s lower than the 100 year ARI extended and previous model flow rates respectively at the Western Highway Bridge in Horsham. This indicates model estimates of the inundation extent along the Wimmera River should be relatively similar to those observed during the January 2011 event.

A zoomed-in section of the southern overland flow path is shown in **Figure 14**. The previous model extent is much larger to the west (downstream) of West Road than both the extended model results and the January 2011 observed extents.

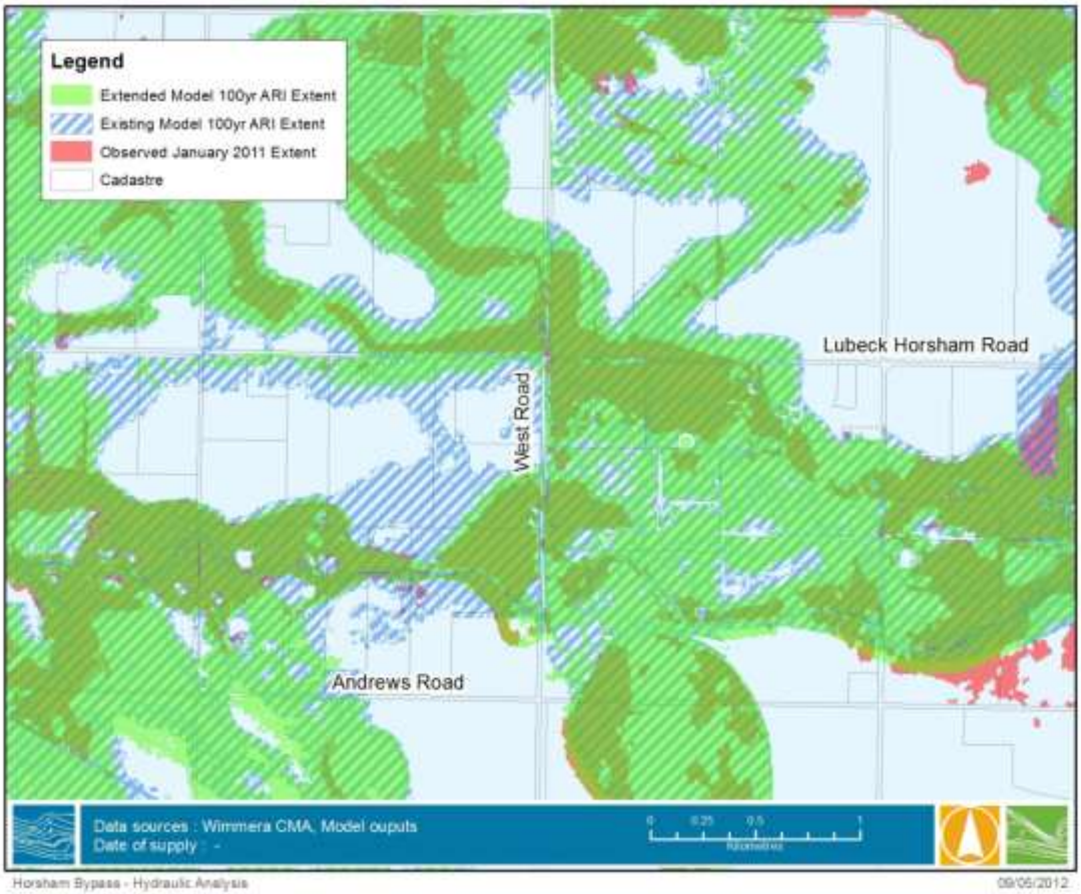

Figure 14 Existing and Extended 100 year ARI extents compared to the observed January 2011 extent along the southern floodplain overland flow path.

A zoomed-in section of the Wimmera River is shown in **Figure 15**. The 100 year ARI extent predicted by the extended model exceeds that of the previous model predictions. In some areas the observed January 2011 extent exceeds both model extents.

In these areas, the January 2011 extent was anecdotally observed to be larger than predictions of the 100 year ARI event, matching more closely with the extended model[5].

[5] Discussion at the East Horsham Flood Plan Community Meeting, 01/07/2012 at the Drung Golf Course attended by Ben Hughes of Water Technology

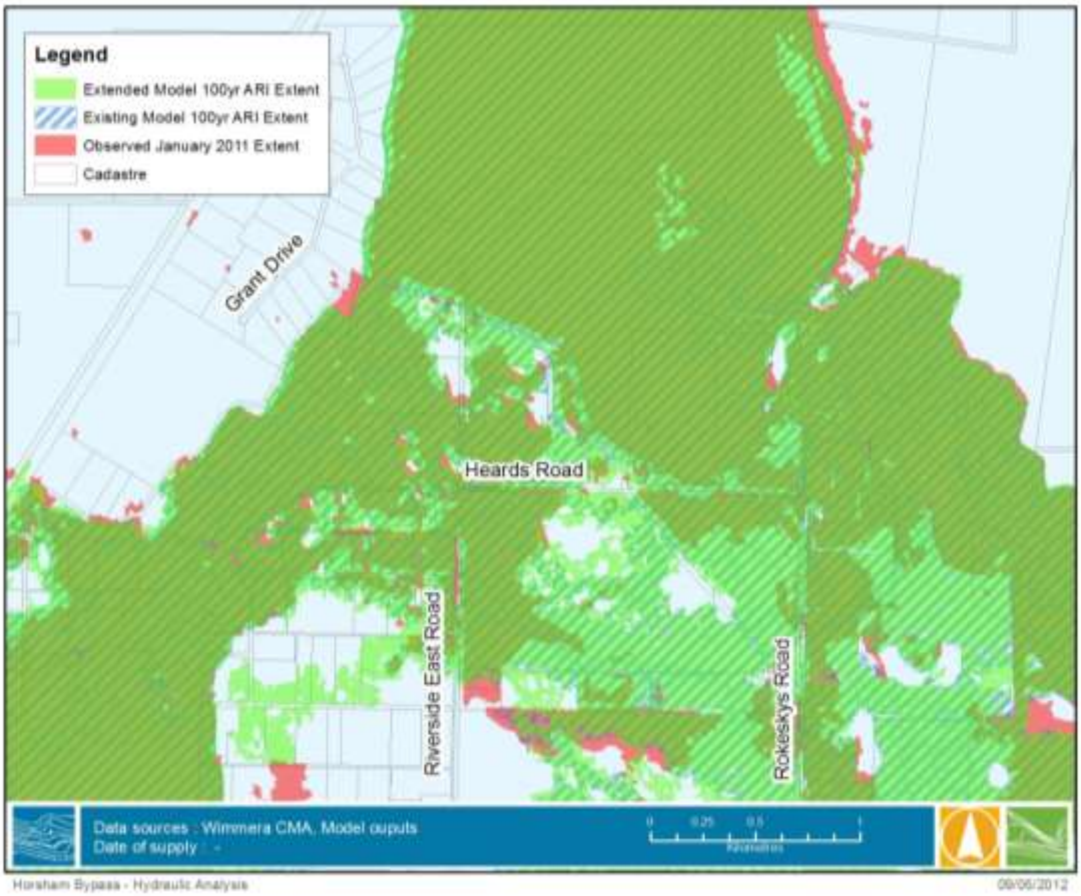

Figure 15 **Existing and Extended 100 year ARI extents compared to the observed January 2011 extent along the river to the northeast of Horsham.**

Figure 16 shows the area directly east of Horsham, most notably the previous model showed inundation through the confluence of Burnt Creek and the Wimmera River whereas the extended model did not. This area is impacted by Burnt Creek rather than the Wimmera River and the change in extent is a product of an extended model boundary and the inclusion of the Western Highway Bridge over the Wimmera River. The area directly east of Horsham was not inundated during January 2011, indicating the extended model is showing a better fit the observed January 2011 extent than the previous model developed in 2009.

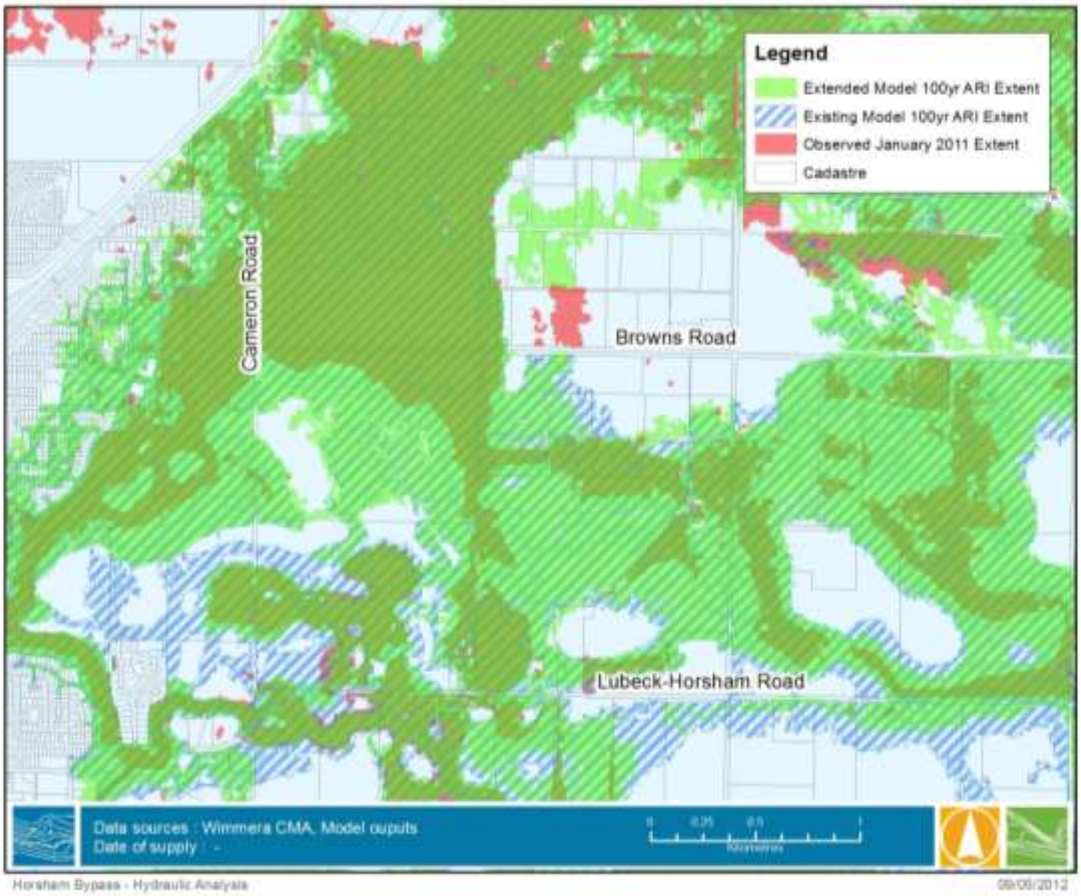

Figure 16 **Existing and Extended 100 year ARI extents compared to the observed January 2011 extent on the overland flow path to the east of Horsham.**

Each extent is shown individually over the extent of model overlap in Appendix B.

6.3.3 Bungalally Creek and the Mackenzie River

Sensitivity modelling was completed increasing the flow split on Bungalally Creek from 20-30-40% of the Burnt Creek Flow, increased the water level in both the Mackenzie River and Bungalally Creek.

An approximate rise of 5-10 cm in Bungalally Creek was observed when increasing the proportion of Burnt Creek flow from 20-30% and in increase of 1-2 cm in the Mackenzie River. Similarly, when increasing the Burnt Creek flow proportion from 30-40% an increase of an additional 5-10cm was observed in Bungalally Creek and 1-2cm in the Mackenzie River.

Of the three model scenarios, allocations of 30% and 40% of the Burnt Creek flow to the Bungalally Creek has shown the best match with linescans flown during the January 2011 event.

Figure 17 below shows transparent model results overlayed on the linescan data for Scenario 2 (an allocation of 30% Burnt Creek flow to Bungalally Creek). Scenario 1 (20% of Burnt Creek flow) and 3 (40% of Burnt Creek flow) are shown at the rear of this document.

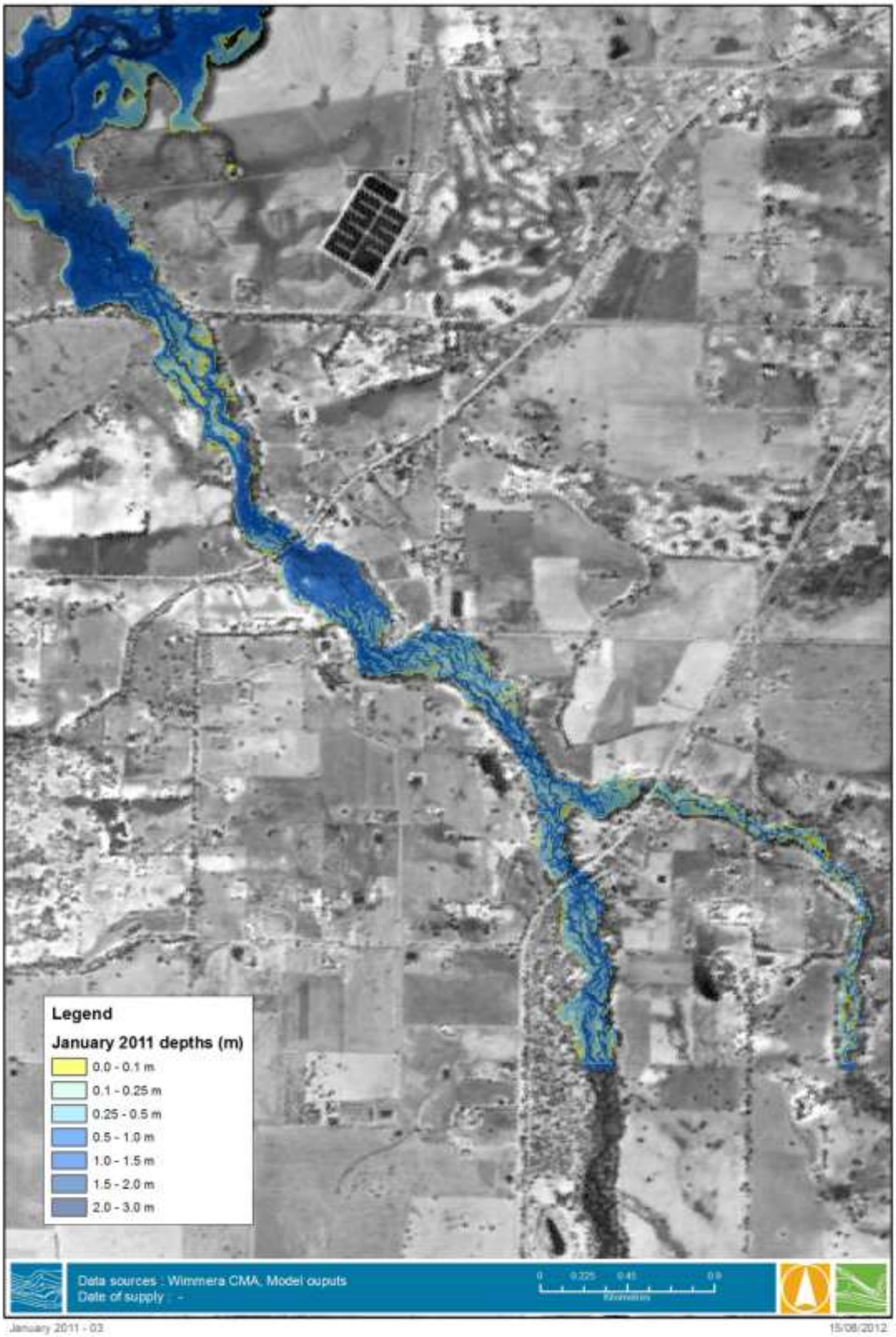

Figure 17 **January 2011 Bungalally Creek and Burnt Creek model results overlaid on linescans flown during January 2011 utilising Scenario 02 (30% of Burnt Creek flow allocated to Bungalally Creek).**

6.3.4 Verification Summary

6.3.4.1 Wimmera River and Burnt Creek

The observed flood extents during January 2011 match more closely with the estimated 100 year ARI event in the area of model overlap for the extended model as compared to the previous 2009 model.

The extended model is considered to provide a better representation of the existing conditions and is considered to accurately produce flood levels and extents across the study area.

6.3.4.2 Mackenzie River and Bungalally Creek

Model extents matched the observed linescan data flow during January 2011. Flows gauged on the Mackenzie River at McKenzie Creek are considered to be fit for use in the hydraulic model.

A combination of modelling a range of inflows into Bungalally Creek, receipt of anecdotal evidence and interpretation of statistical analysis has indicated approximately 30% of the gauged flow on Burnt Creek at Wonwondah East passes down Bungalally Creek during a high flow event.

7.0 MODEL RESULTS

7.1 100 year ARI event

Design flood modelling for the 100 year ARI event was completed using the hydraulic model parameters determined during the hydraulic model verification. Model results of the 100 year ARI event show similar extents to the January 2011 event. **Figure 18** shows the 100 year ARI model extent overlayed with each of the bypass alignment options.

East of Horsham there are significant areas of overland flow originating from the Wimmera River. These flow paths formed due to a confined channel and open floodplain. The overland flows re-enter the Wimmera River upstream of the confluence with Burnt Creek. Some flow is pushed through the Horsham township but this also re-enters slightly further downstream. These overland flow paths impact on the eastern alignment options 11 and B2

Once the Wimmera River has passed the Horsham Weir, the channel and floodplain remain relatively confined until the confluence with the Wimmera River.

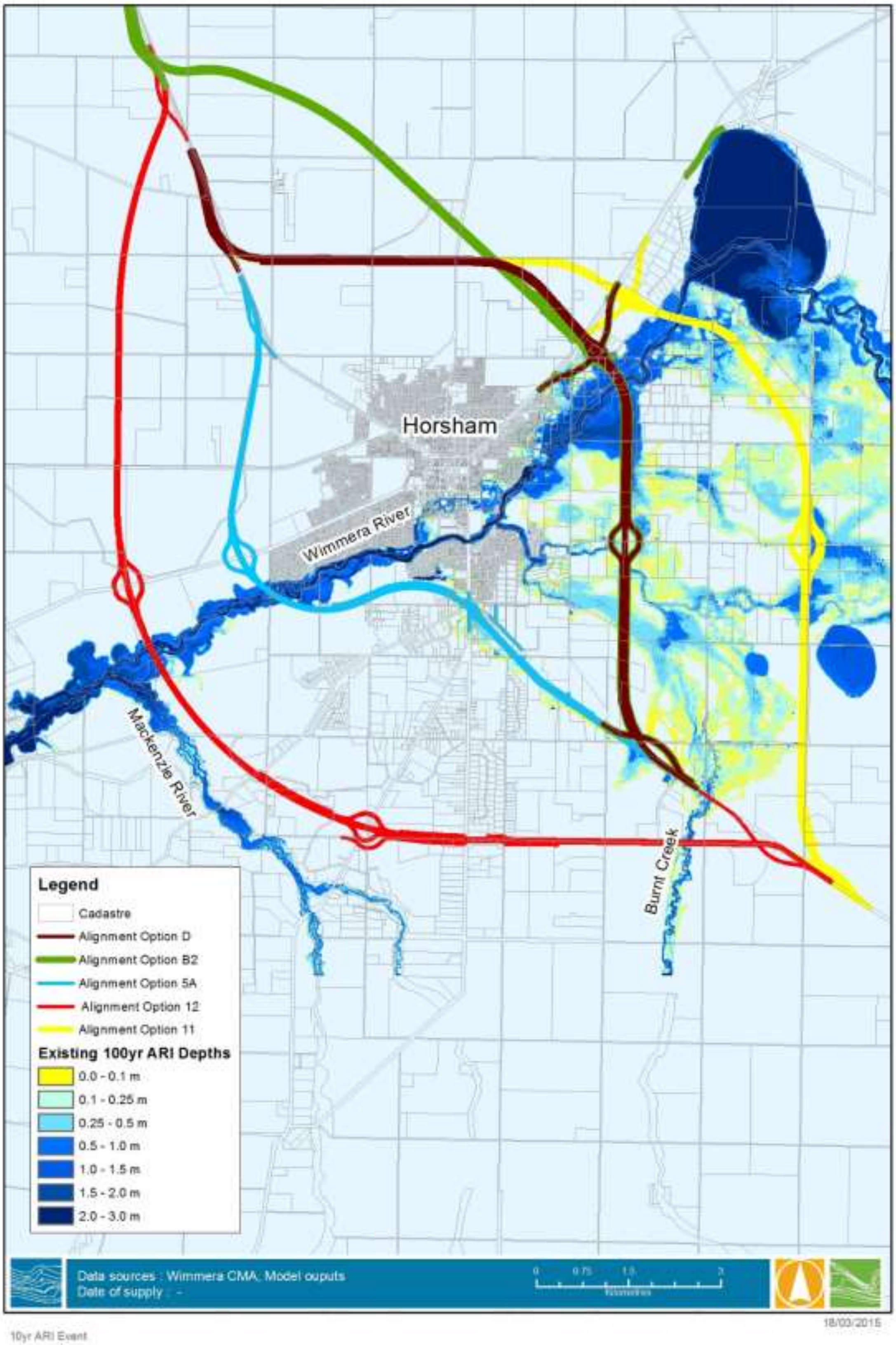

Figure 18 100 year ARI model results and each of the assessed bypass options

7.2 10 year ARI event

Design flood modelling for the 10 year ARI event was completed using the hydraulic model parameters determined during the hydraulic model verification. The 10 year ARI event has considerably smaller areas of inundation along the Wimmera River but still shows overland inundation along Burnt Creek post the Western Highway. This inundation is quite shallow. **Figure 19** shows the 10 year ARI model extent overlayed with each of the bypass alignment options.

As mentioned, east of Horsham the dominant floodplain inundation is caused by Burnt Creek, this inundation impacts on alignment option 2b.

These overland flow paths impact on the eastern alignment options 11 and B2.

Similar to the 100 year ARI event, inundation on the Wimmera River remains relatively confined until the Mackenzie River.

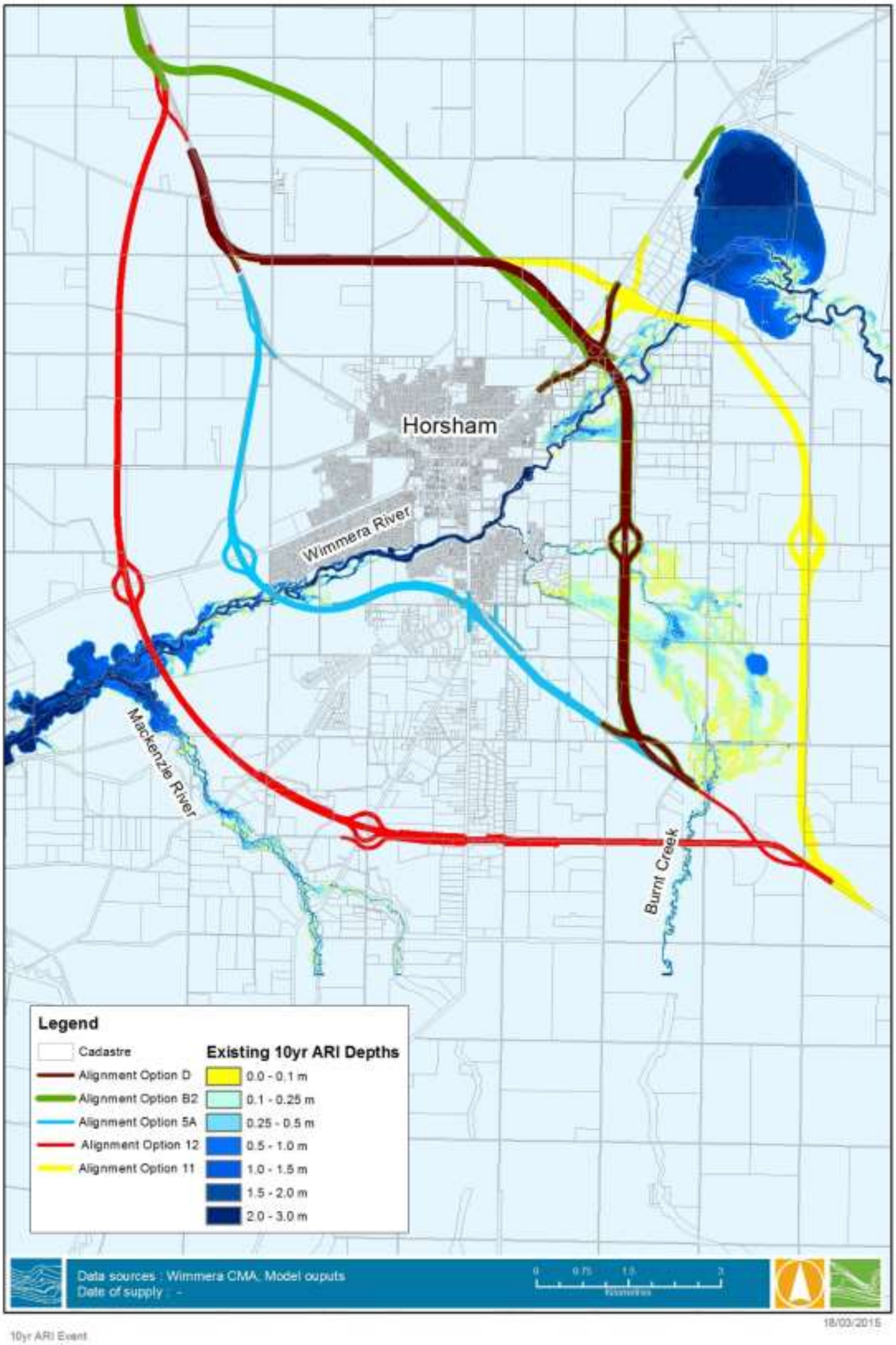

Figure 19 **10 year ARI model results with each bypass option overlayed**

8.0 OPTIONS ASSESSMENT

8.1 Overview

Each of the Horsham Bypass Alignments were assessed for their potential impact to floodplain inundation and broad cost based on the number of waterway crossings (defined by the 10 year ARI event) and the number of floodplain crossings (defined by the 100 year ARI extent). Each of these crossings are discussed subjectively for the 10 year ARI event with each crossing interrogated individually for the 100 year ARI event, detailing the following information:

- Maximum width of inundation
- Maximum depth of inundation
- Maximum required flow rate.

The design features for each option will be able to manage the 100 year ARI flooding risk but would add cost to the project. The information determined during this study will be used to cost the construction of each option during the economic analysis with all bypass options designed so that they will meet the 100 year ARI flood level and will not further impact flood levels in the affected areas.

8.2 Option 5A

As discussed in **Section 3.0**, Option 5A starts from the existing Western Highway near West Road and continues west towards the Wimmera River. It crosses the river and the Wimmera Highway to the south-west of Horsham. The route reconnects with the existing Western Highway to the north of O'Brees and Curran Roads intersection.

Figure 20 shows the alignment of Option 5A, the alignment has little interaction with the Wimmera River, Burnt Creek or Mackenzie River floodplains.

There is some water pushed along the upstream side of the existing Western Highway towards Horsham due to an undersized structure. This is upstream of the Option 5A offtake point and would be solved by increasing the structure capacity.

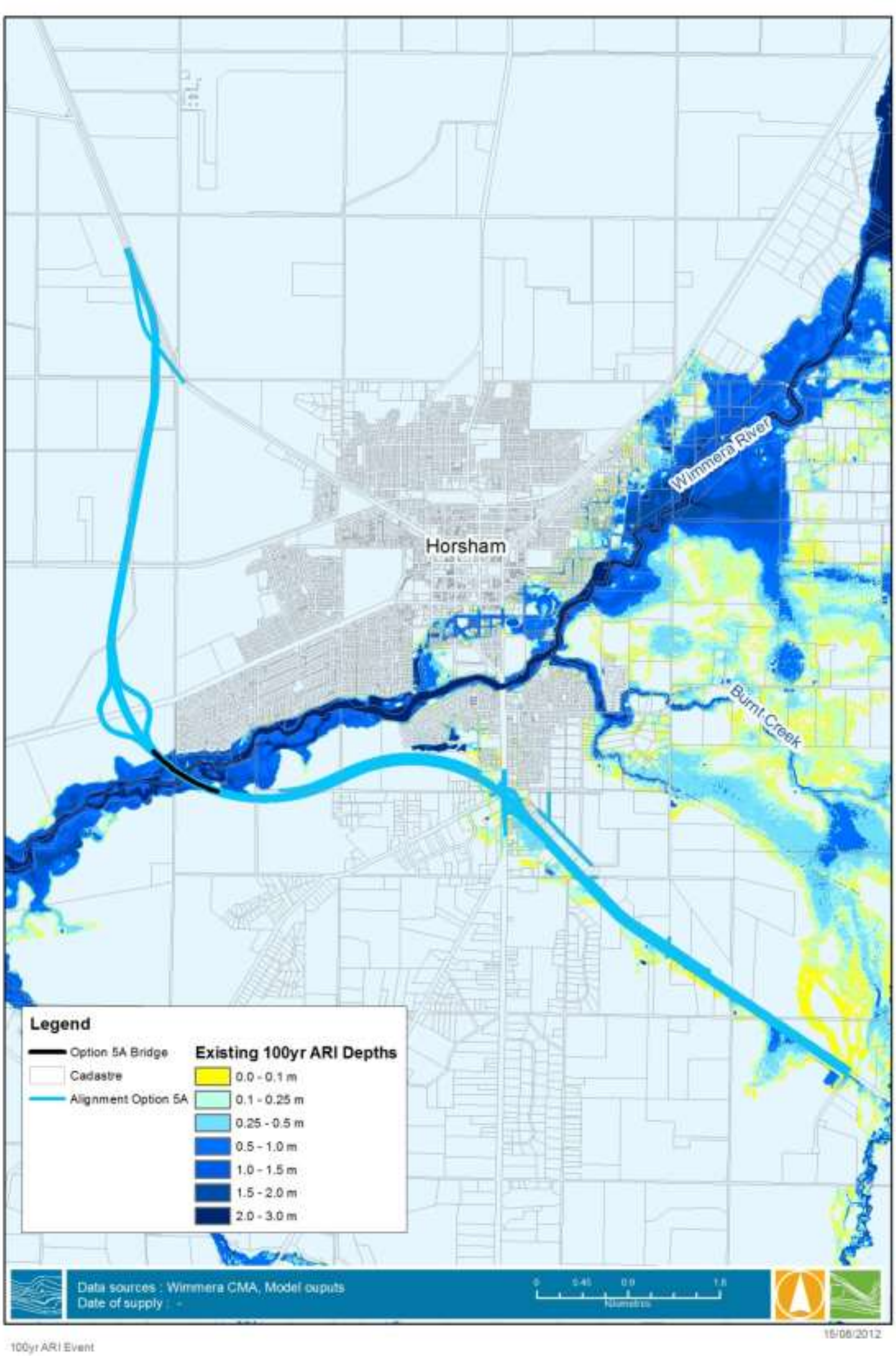

Figure 20 Option 5A

A structure located at the Wimmera River would be required along Option 5A to pass flood flows up to a 100 year ARI event unhindered. The location of the structure is shown in **Figure 20** and a zoom shown in **Figure 21**.

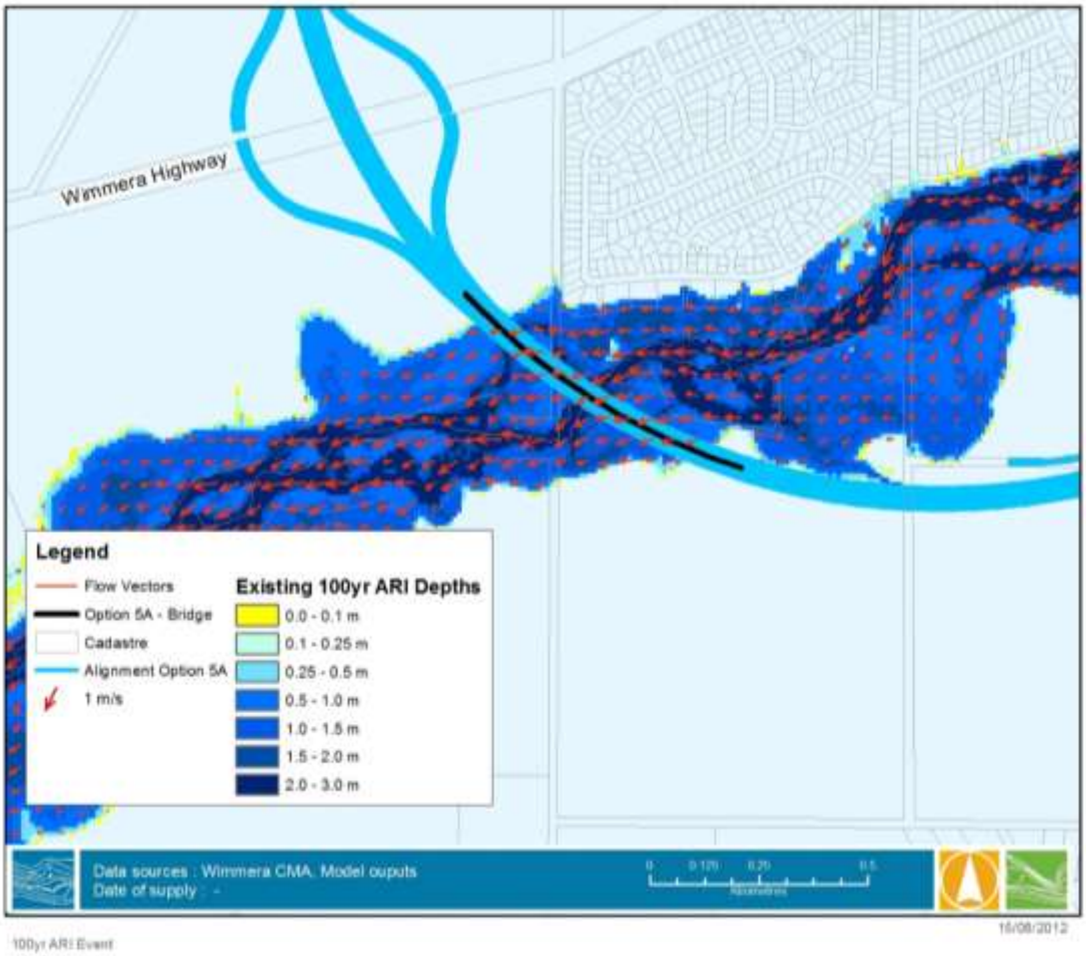

Figure 21 **Option 5A – Structure 01**

A cross-section was extracted showing the topography and maximum water levels along the centreline of the bypass option as highlighted in **Figure 21** by a black line. These cross-sections are shown in **Figure 22**.

The maximum water level observed at the required structure is 125.5 m AHD, showing a maximum depth of approximately 5.2 m. The length of the structure would be approximately 580m.

Extracting a discharge line at this point has shown a maximum discharge of 34,560 ML/d (400 m^3/s) during the 100 year ARI event.

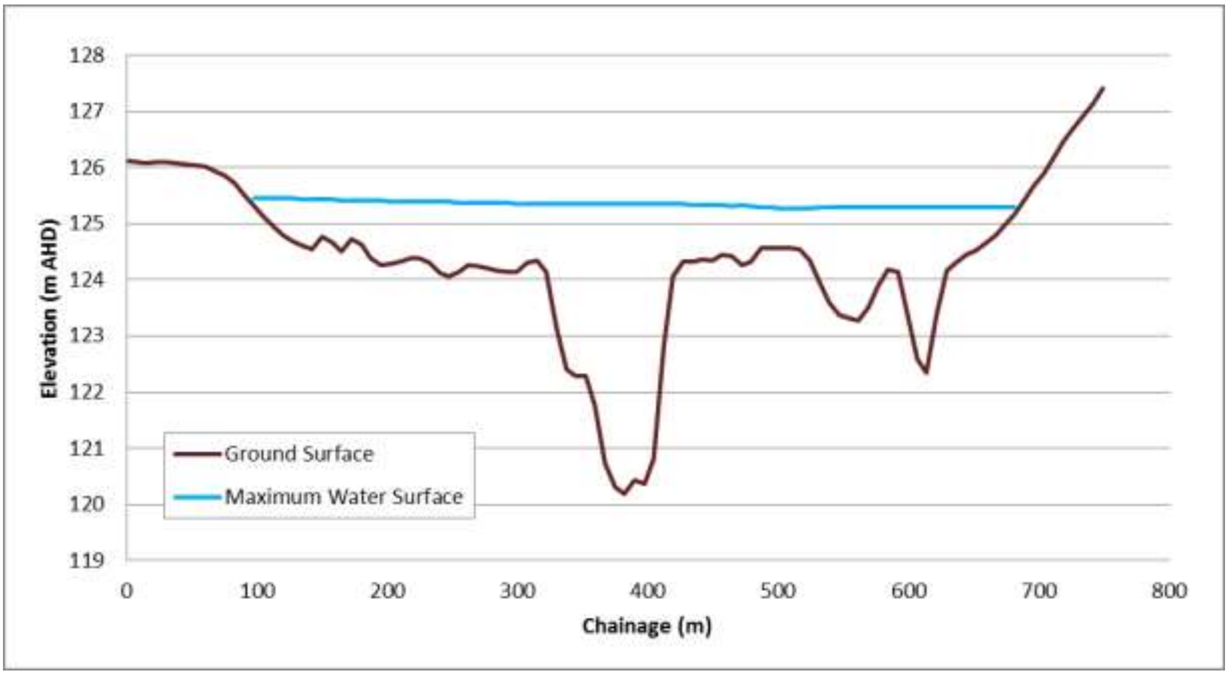

Figure 22 Option 5A – Structure 01 – Ground surface and water level cross sections

A summary of the analysis taken to rank each alignment option is shown below in **Table 12** with discussion shown in Table 13.

Table 12 Option assessment summary for Option 5a

Summary – Option 5a	
No. of flood water intersection points	1.0
Maximum River Depth (m)	5.2 m
Maximum Floodplain Depth (m)	1.3 m
Average Depth (m)	1.5 m
Floodplain intersection length (m)	580 m

Table 13 Option assessment summary for Option 5A - Discussion

Option 5a	
Objective Free passage flood water during a 100 year ARI event Drainage infrastructure required for each alignment option	**Indicator** Option is able to realistically allow free floodplain flow **Assessment Criteria** Number of wetland, waterway crossings and 100 year ARI crossings Length alignment within 100 year ARI extent Flow required to be passed.
Methodology The 100 year ARI event has been modelled and the floodplain conditions at the points of floodwater and alignment option intersection were reviewed.	
Rating **Neutral**	**Description (provide location detail)** Option 5A has one waterway intersection point. This point is over a relatively confined reach of the Wimmera River. To allow free passage of flow a bridge would be required to be constructed. The bridge and/or other drainage infrastructure would be required to pass a peak flow of 34,560 ML/d (400 m^3/s), over a 580 m length. The option has some floodplain benefits. If the Burnt Creek culverts at the Western Highway were upgraded to an adequate capacity, flow would not be pushed towards Horsham along the Western Highway. During flooding observed during January 2011 event measures were taken to prevent this flow from inundating areas of the Highway.

8.3 Option 11

As discussed in **Section 3.0**, Option 11 bypasses Horsham to the east and north of town. It leaves the Western Highway to the east of Horsham at West Road and re-joins the Western Highway to the north of Horsham immediately south of the Horsham Aerodrome. This option crosses the Henty Highway to the north of Horsham.

Figure 23 shows the alignment of Option 11, the alignment has a heavy interaction with the Wimmera River floodplain but very little on Burnt Creek or Mackenzie Creek.

Flood water will be required to pass underneath Option 11 at four major locations with other shallower areas requiring drainage.

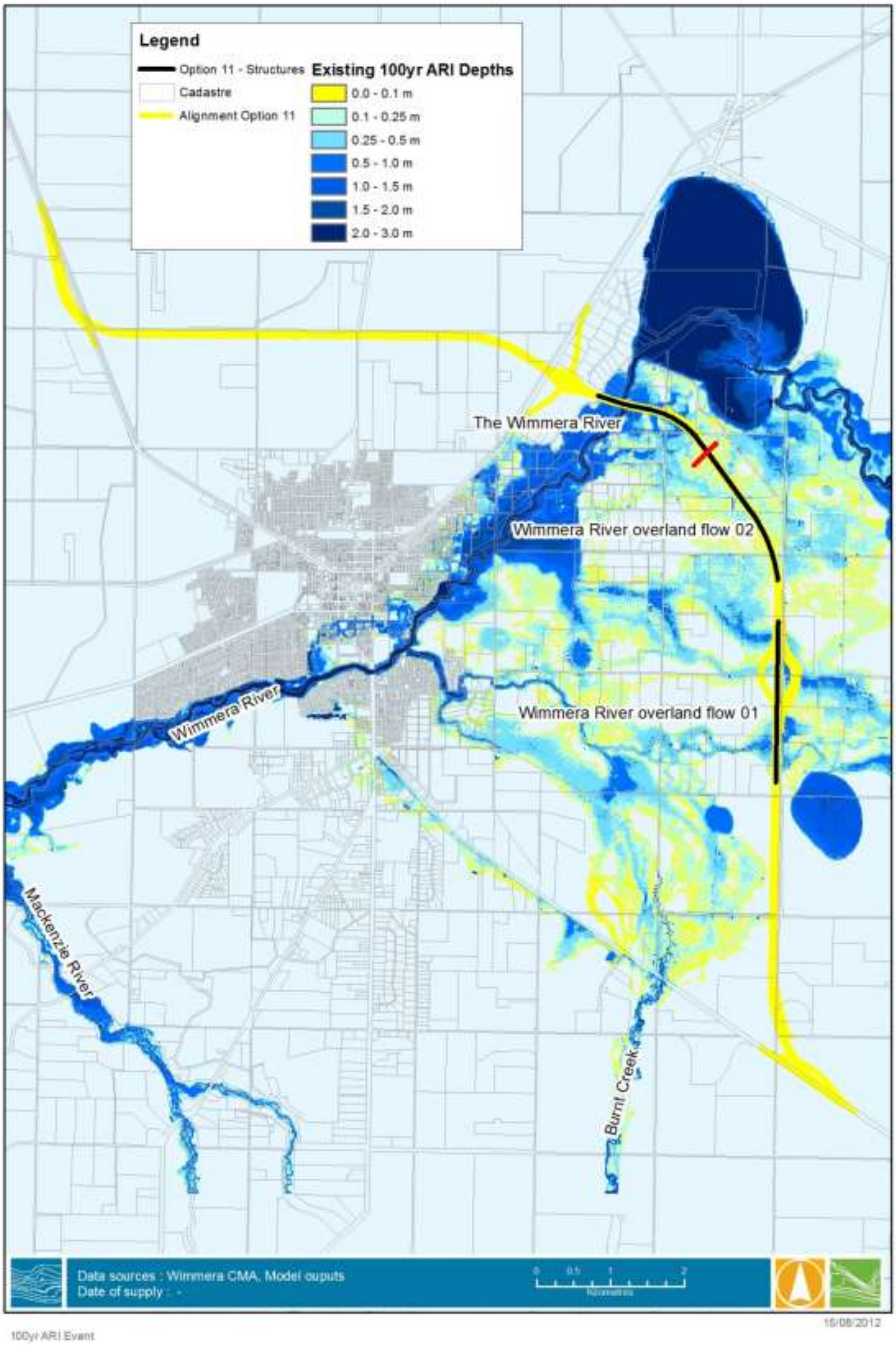

Figure 23 Option 11

Locations along Option 11 that would be required to pass flood flows at up to a 100 year ARI event are highlighted in **Figure 23**. These points are separated as Wimmera River overland flow 01 **(Figure 24)** and Wimmera River overland flow 02 **(Figure 25)** and the Wimmera River **(Figure 26).**

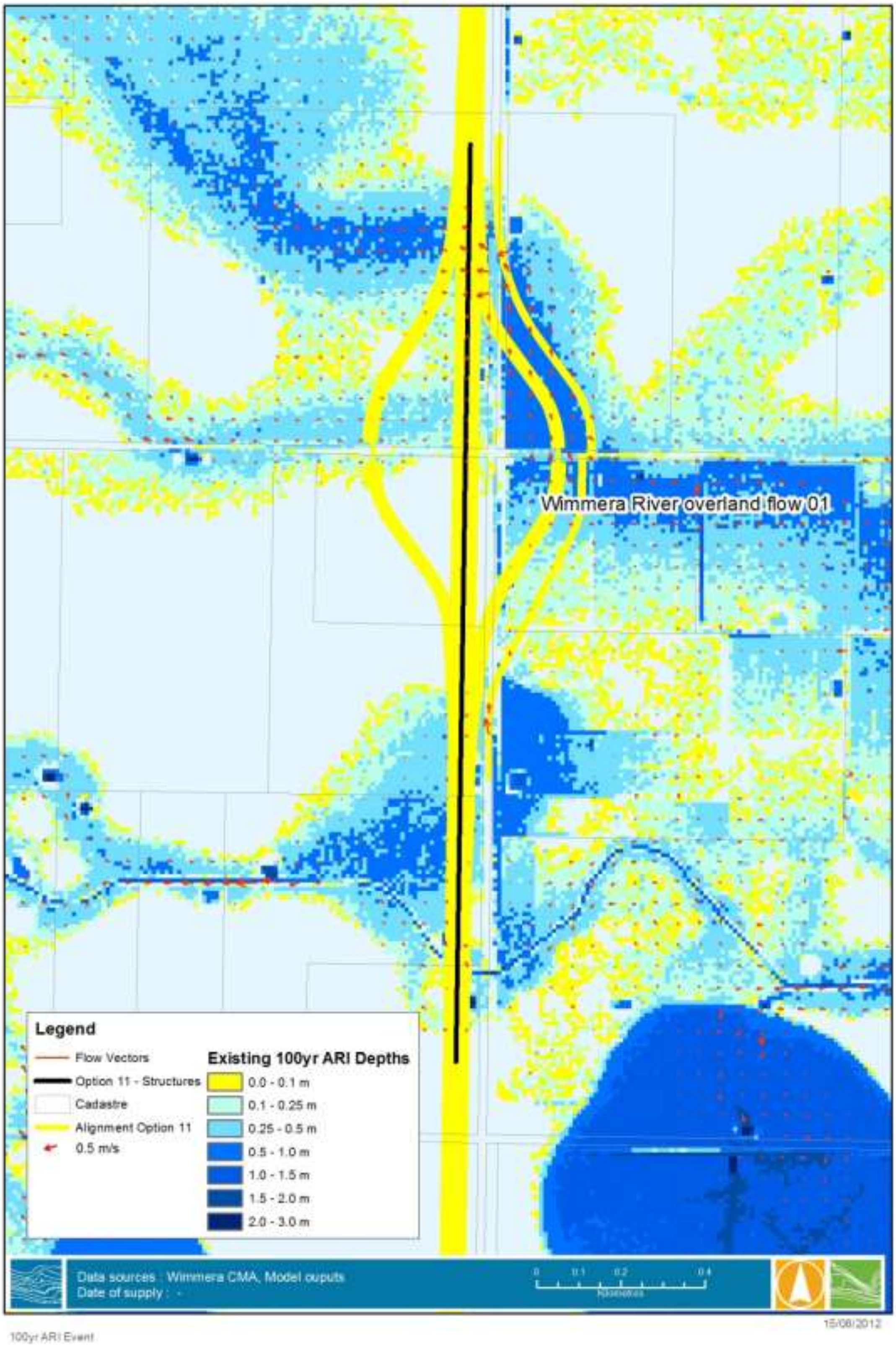

Figure 24 **Wimmera River overland flow path 01**

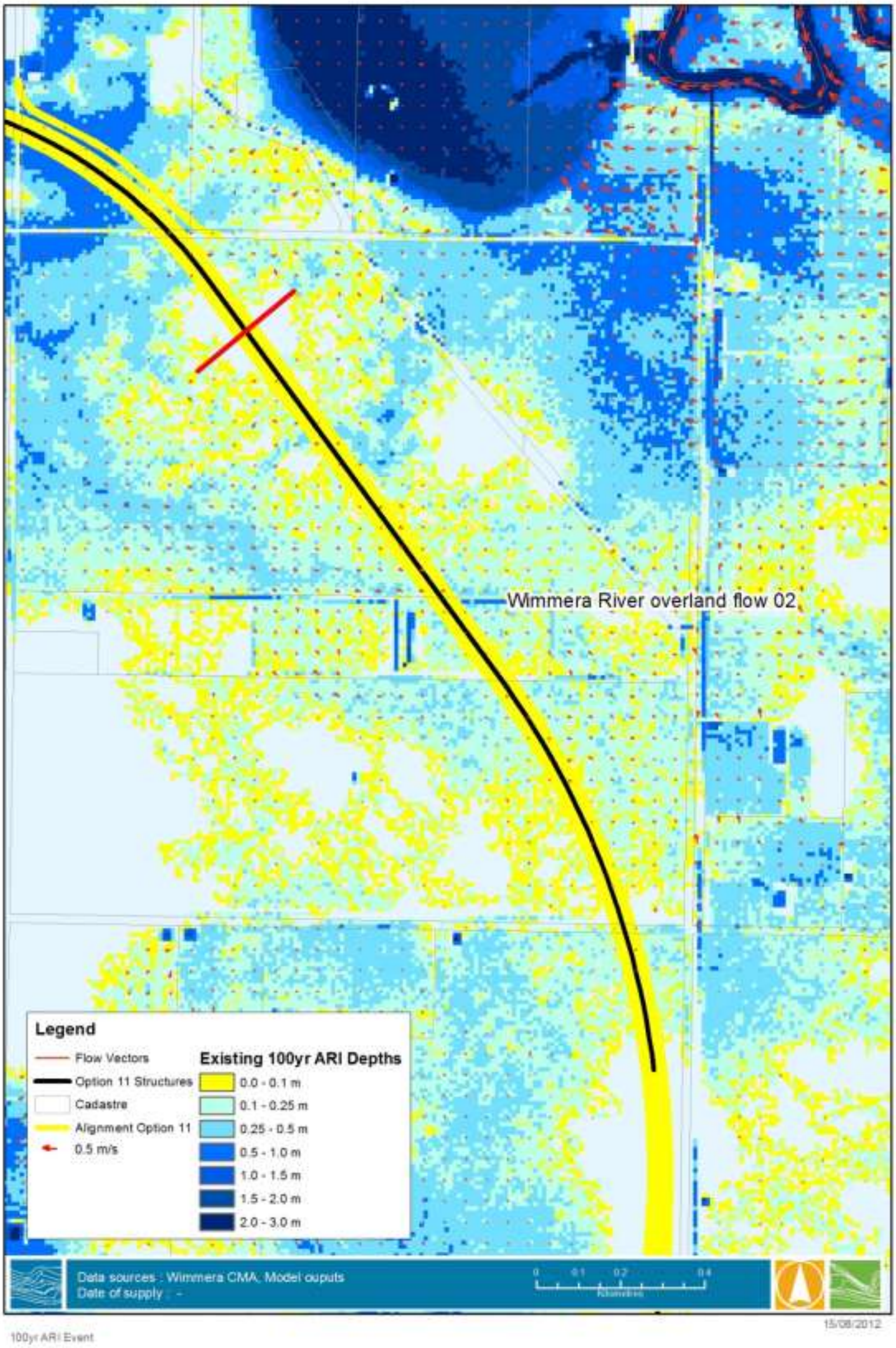

Figure 25 **Wimmera River overland flow path 02**

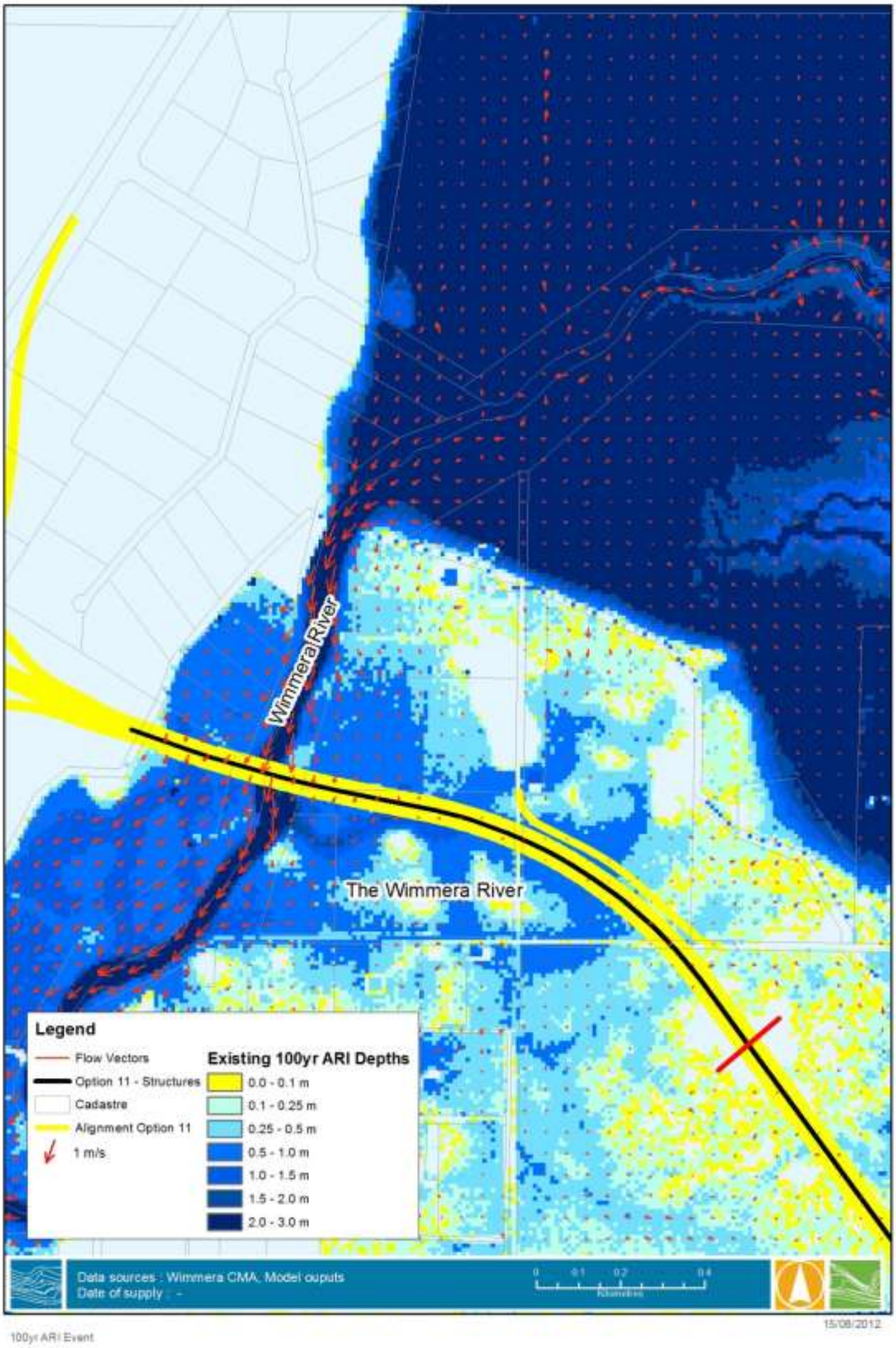

Figure 26 Wimmera River flow path 01

The Wimmera River overland flow path 01 shown in **Figure 24** is largely flow perpendicular to the bypass option. It is separated into two major flow distribution points, north and south of the Horsham Lubeck Road. In the current scenario water that passes underneath Option 11 must also pass over or under West Road. **Figure 24** shows water restricted behind West Road, the presence of water supply channel along West Road may also cause some constriction.

Under existing conditions, the northern and southern flow paths pass peak discharges of 2,700 ML/d (31.5 m^3/s) and 950 ML/d (11 m^3/s) respectively. **Figure 27** shows a cross section of the existing topography and maximum water level observed in a 100 year ARI event. The maximum water level reaches approximately 129.35 and 129.2 m AHD in the northern and southern flow paths. The maximum depth observed is approximately 0.6 m. The length of these flow paths is approximately 650 m each, with the average depth 0.3 m.

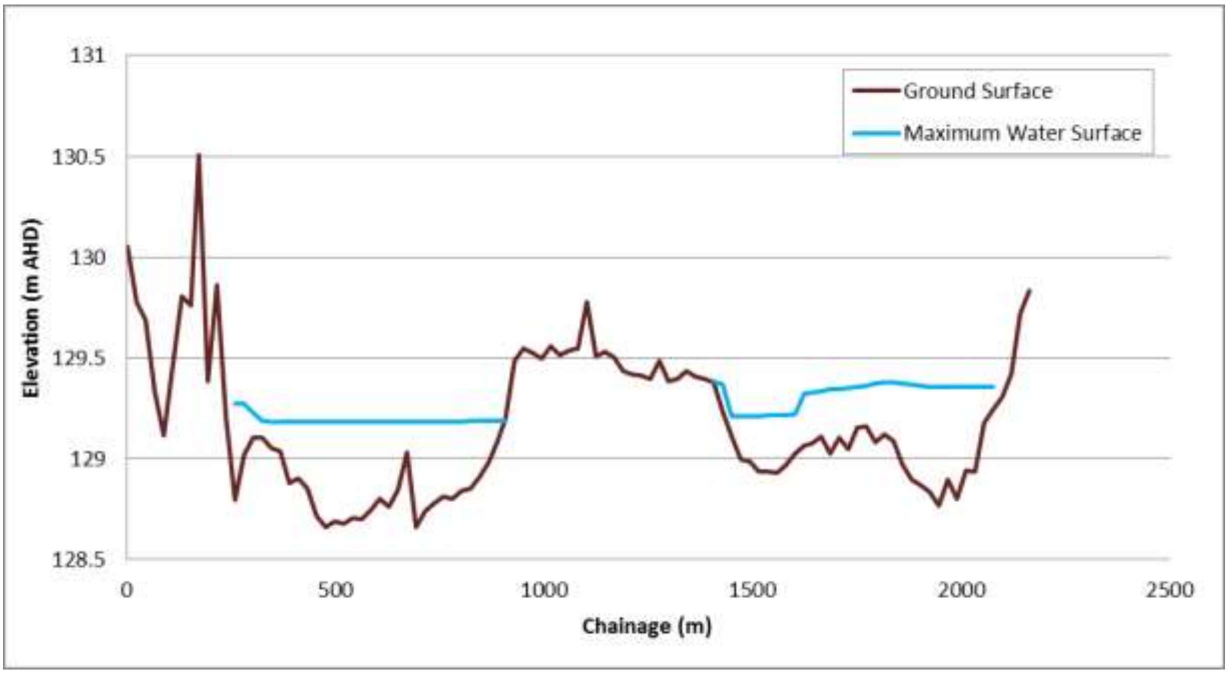

Figure 27 **Cross section and maximum water level along Option 11 at Wimmera River flow path 01**

Wimmera River overland flow 02 is less direct than Wimmera River overland flow 01; flow is much shallower and may be able to be controlled into a drainage system to allow for fewer drainage points underneath the bypass option. The maximum depth is along Wimmera River overland flow path 02 is approximately 0.4 m. A cross section of the existing topography and the maximum waster surface elevation in the 100 year ARI event is shown in **Figure 28**.

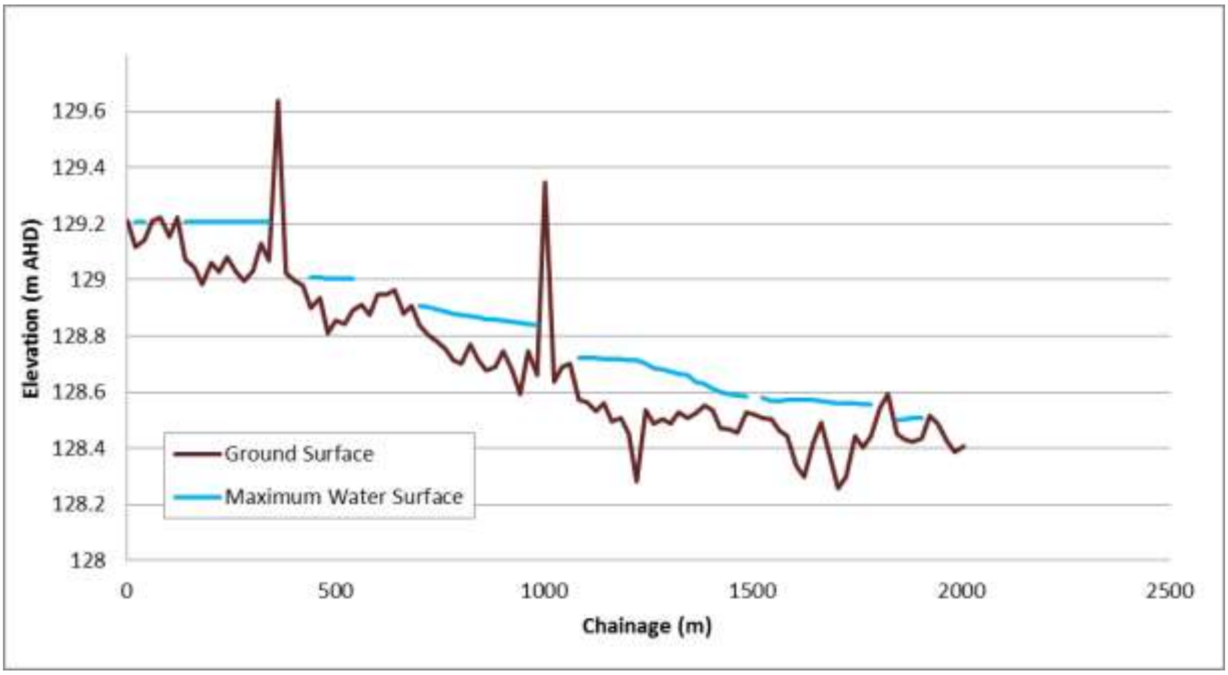

Figure 28 **Cross section and maximum water level along Option 11 at Wimmera River flow path 02**

The Wimmera River flow path is much more significant than the two previous overland flow paths. Option 11 passes through an area subject to significant depth of inundation reaching approximately 6 m at the Wimmera River and 1.3 m in the floodplain. The maximum water level observed in a 100 year ARI event is approximately 128.3 m AHD with the maximum discharge 30,240 ML/d (350 m^3/s). The length of Option 11 that intersects with the Wimmera River is approximately 1500 m.

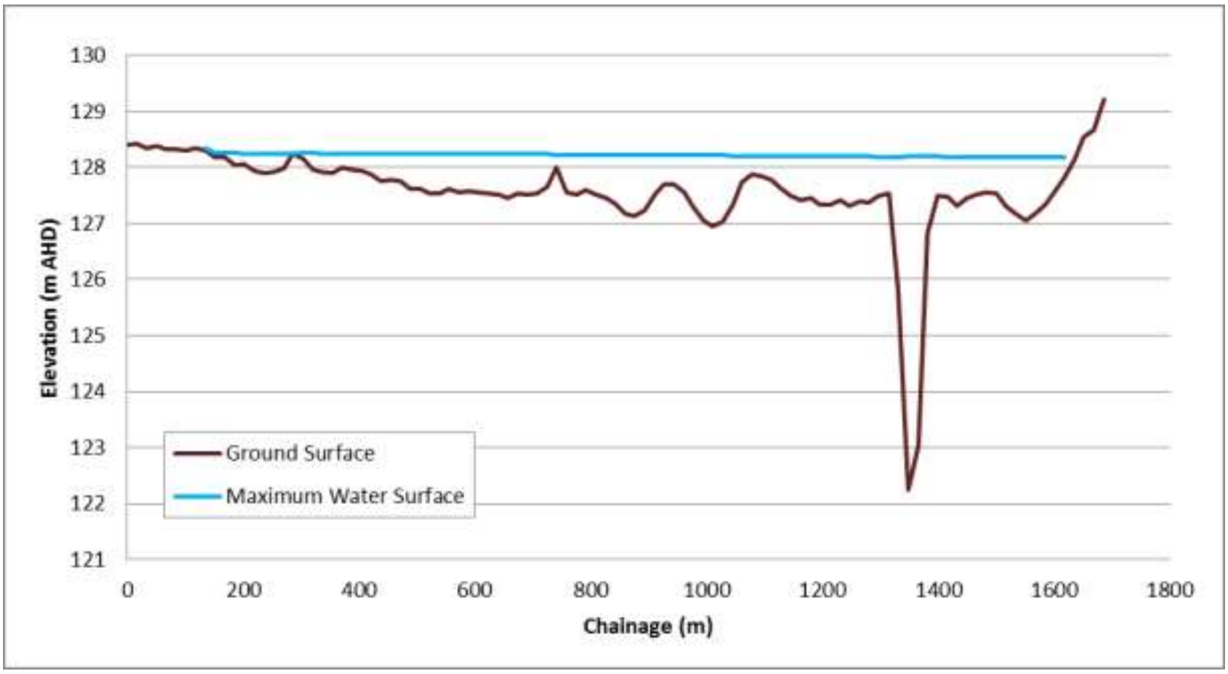

Figure 29 **Cross section and maximum water level along Option 11 at Wimmera River flow**

A summary of the analysis taken to rank each alignment option is shown below in **Table 14** with discussion shown in **Table 15**.

Table 14 Option assessment summary for Option 11

Summary – Option 11	
No. of flood water intersection points	4
Maximum River Depth (m)	6 m
Maximum Floodplain Depth (m)	1.3 m
Average Depth (m)	0.4 m
Floodplain intersection length (m)	4200 m

Table 15 Option assessment summary for Option 11 - Discussion

<table>
<tr><th colspan="2">Option 11</th></tr>
<tr><td rowspan="2">Objective
Free passage flood water during a 100 year ARI event

Drainage infrastructure required for each alignment option</td><td>Indicator
Option is able to realistically allow free floodplain flow</td></tr>
<tr><td>Assessment Criteria
Number of wetland, waterway crossings and 100 year ARI crossings
Length alignment within 100 year ARI extent
Flow required to be passed.</td></tr>
<tr><td colspan="2">Methodology

The 100 year ARI event has been modelled and the floodplain conditions at the points of floodwater and alignment option intersection were reviewed.</td></tr>
<tr><td>Rating

Poor</td><td>Description (provide location detail)
Option 11 has four major waterway intersection points. These points are all dominated by the Wimmera River.

There are two distinct flow paths to the southern end of the alignment that may be passed via culverts. The total length of road impacted at the southern end is 1300m at an average depth of 0.3 m on existing conditions.

The remainder of the floodplain flow is very broad with the potential requirement for changes to the up and downstream topography to re-direct and control flow through a number of culverts to minimise the amount of drainage infrastructure required. This is likely to impact on flood levels in on neighbouring properties.

The main intersection with the Wimmera River is approximately 1500 m long with a maximum floodplain depth of 1.3 m. This section of Option 11 requires significant flow</td></tr>
</table>

Option 11	
	area and the use of culverts may not be sufficient to maintain water levels upstream of the alignment.

8.4 Option 12

As discussed in **Section 3.0**, Option 12 bypasses Horsham to the south and west of town. The alignment crosses the Henty Highway south of Horsham and the Wimmera Highway to the south-west of Horsham to re-join the Western Highway near Dooen School Road.

Figure 30 shows the alignment of Option 12, the alignment interacts with Burnt Creek and the Wimmera River. Both waterways are relatively confined at the point of their intersection.

A closer perspective of the interaction with Burnt Creek and the Wimmera River are shown in **Figure 31** and **Figure 33** respectively.

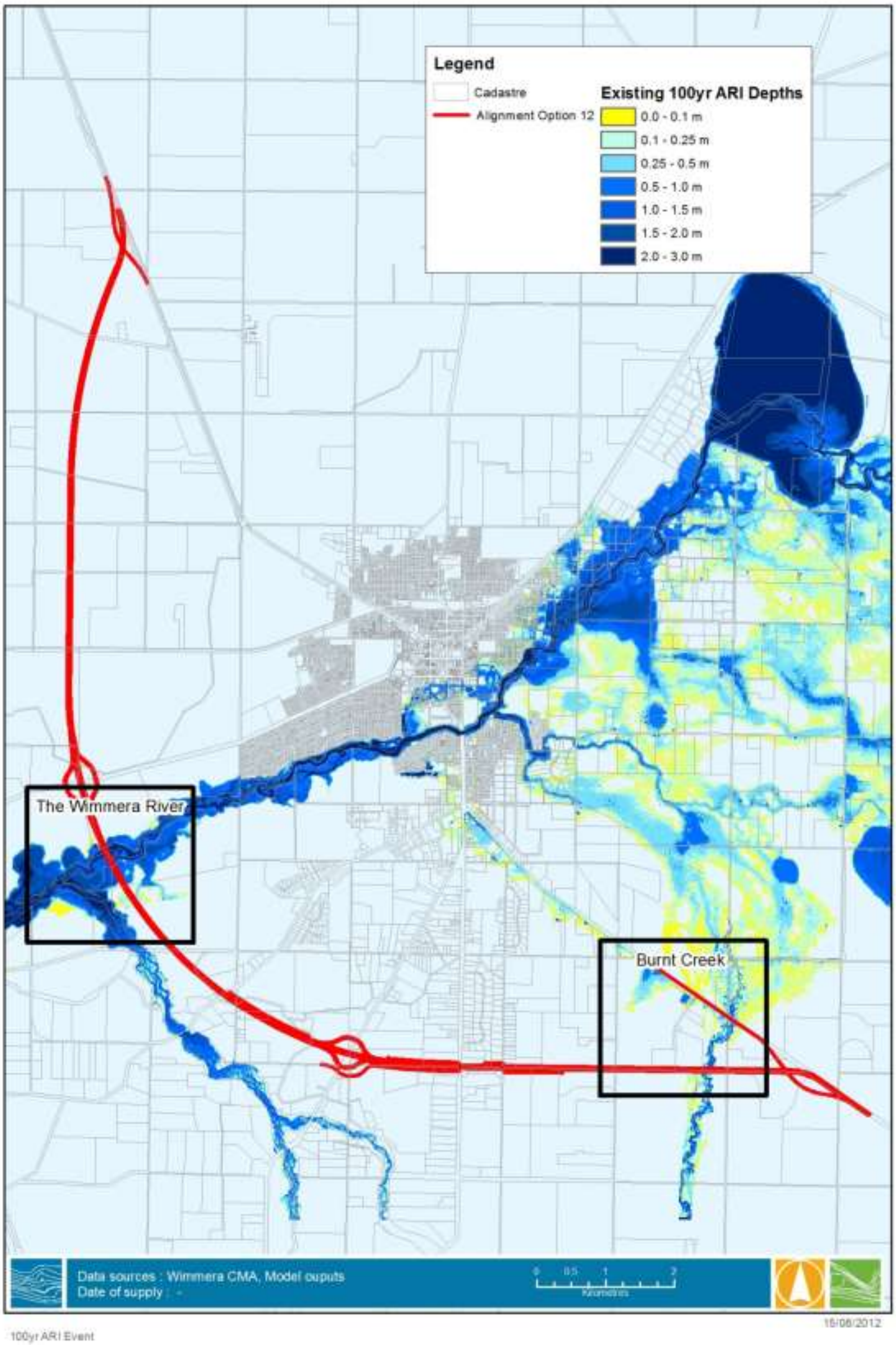

Figure 30 Option 12

Figure 31 shows a zoom of the intersection between Burnt Creek and Option 12. The waterway is relatively confined with a low degree of overland flood flow; this is in contrast to the pattern of flow on the northern side of the existing Western Highway.

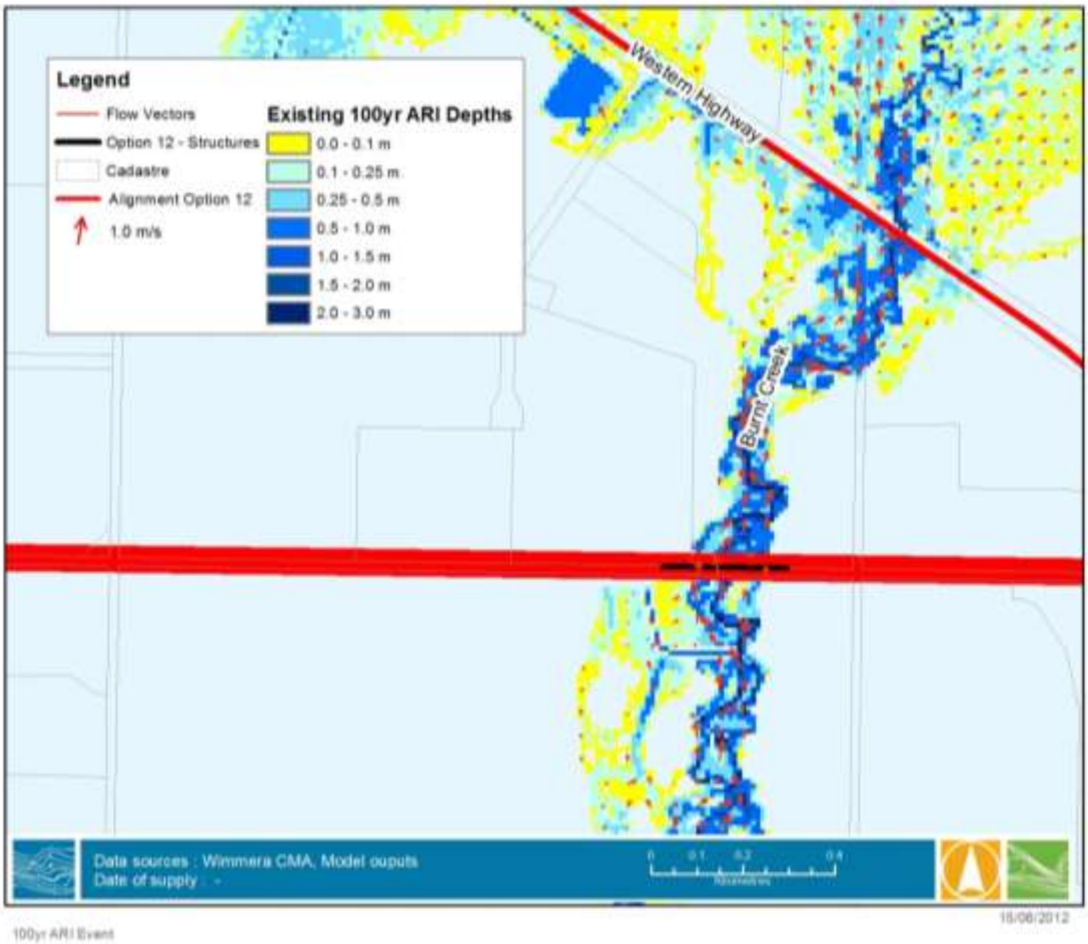

Figure 31 **Option 12 – Burnt Creek and Option 12**

Figure 32 shows a cross section of ground surface and the maximum water level where Burnt Creek would be required to pass underneath Option 12.

The maximum depth at this point is 1.4 m with the maximum water level 133.7 m AHD. Burnt Creek passes a maximum of 4,200 ML/d (48.5 m^3/s). The flow width of Burnt Creek at Option 12 is 140 m.

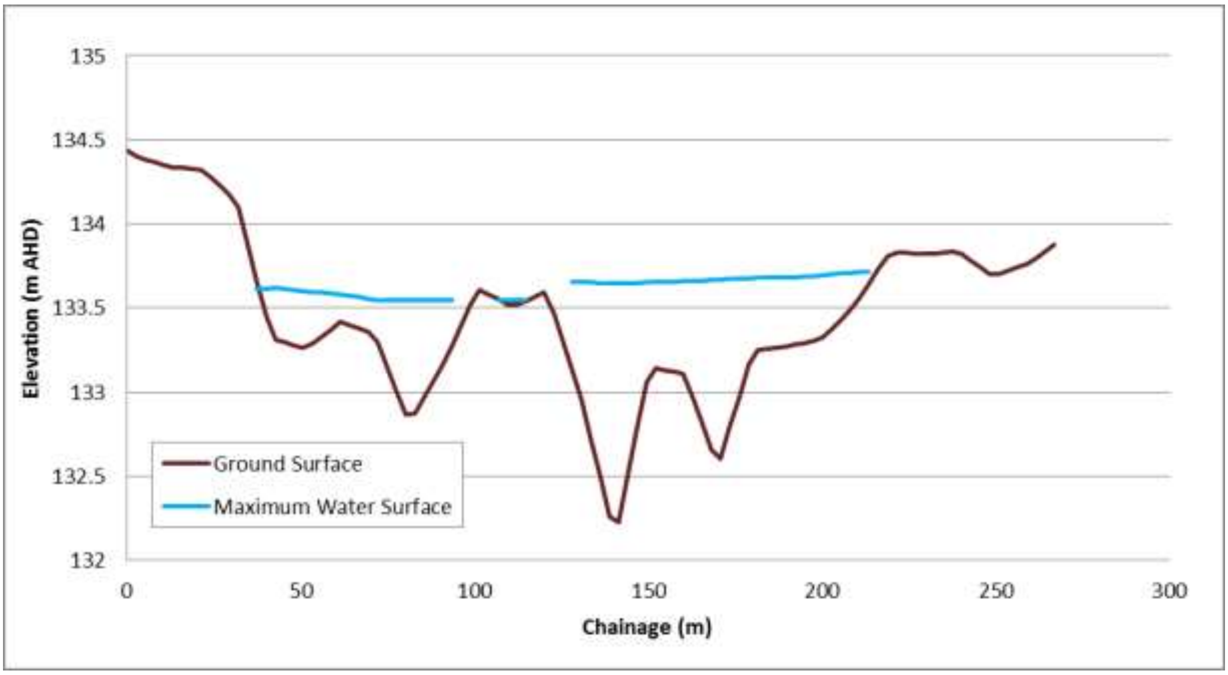

Figure 32 **Option 12 – Burnt Creek and Option 12 cross section of water level and ground surface**

Figure 33 shows the crossing point of Option 12 and the Wimmera River. The alignment crosses the main river branch as well as a shallower section of out of bank flow.

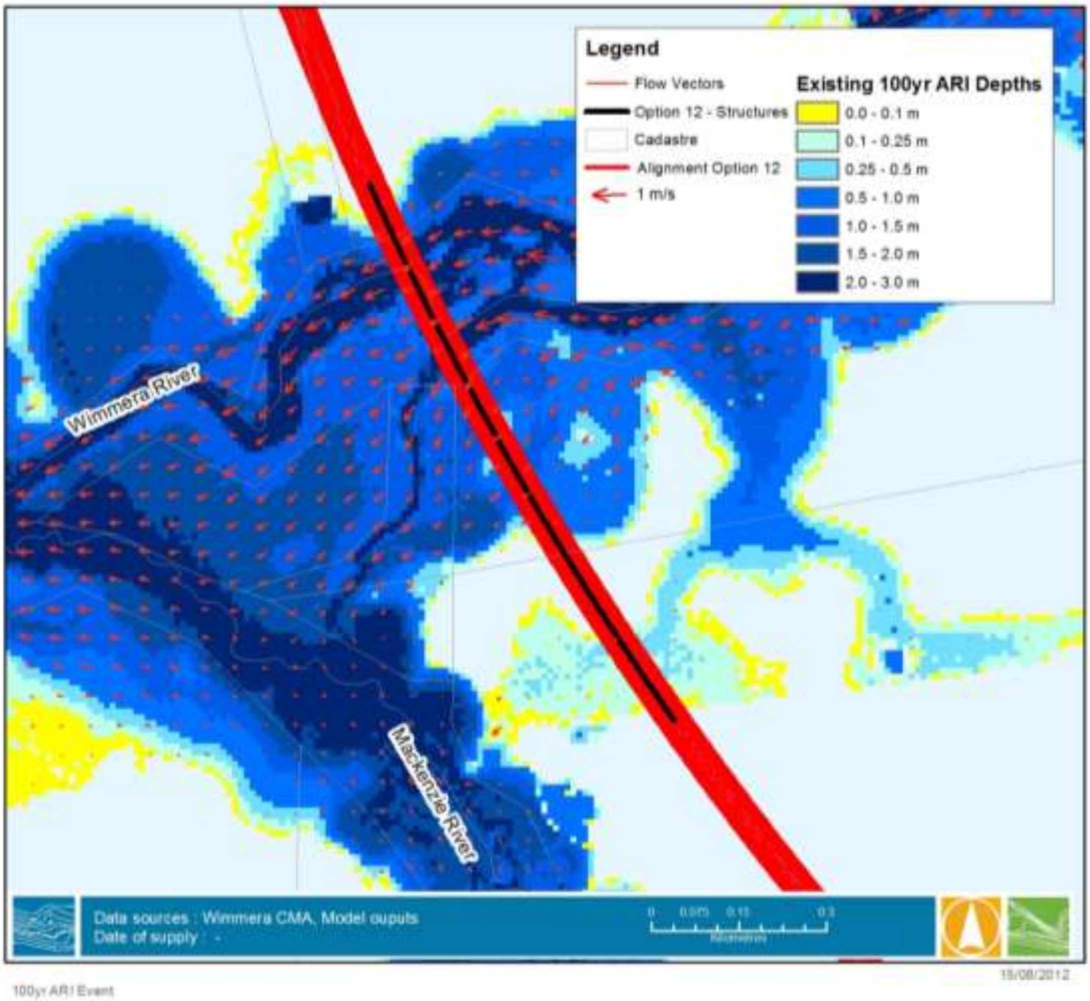

Figure 33 **Option 12 –Wimmera Creek and Option 12 cross section of water level and ground surface**

A cross-section of the ground surface and the maximum water level at the intersection point of the Wimmera River and Option 12 is shown in **Figure 34**. The shallower section of floodplain flow reaches a maximum depth of 0.2 m covering a distance of approximately 150 m. The Wimmera River however reaches a maximum depth of approximately 6 m covering approximately 660 m.

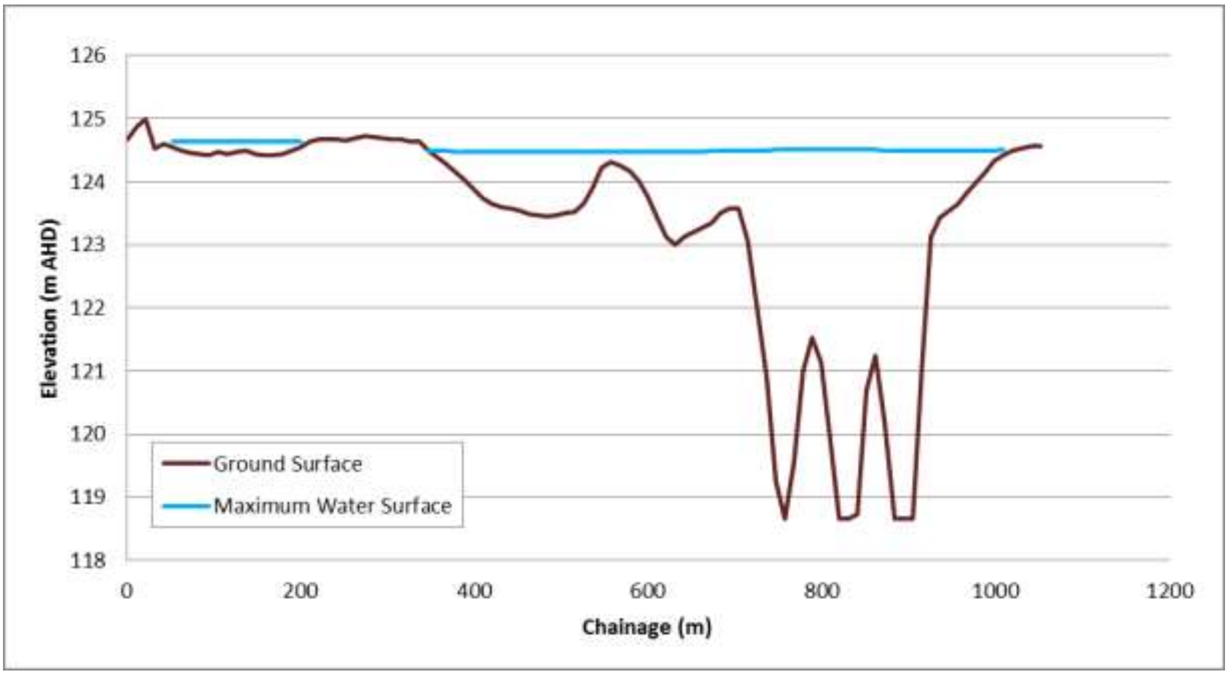

Figure 34 **Option 12 – Burnt Creek and Option 12 cross section of water level and ground surface**

A summary of the analysis taken to rank each alignment option is shown below in **Table 16** with discussion shown in **Table 17**.

Table 16 **Option assessment summary for Option 12**

Summary – Option 12	
No. of flood water intersection points	2
Maximum River Depth (m)	6.0 m
Maximum Floodplain Depth (m)	1.5 m
Average Depth (m)	1.0 m
Floodplain intersection length (m)	980 m

Table 17 Option assessment summary for Option 12 - Discussion

Option 12	
Objective Free passage flood water during a 100 year ARI event Drainage infrastructure required for each alignment option	**Indicator** Option is able to realistically allow free floodplain flow **Assessment Criteria** Number of wetland, waterway crossings and 100 year ARI crossings Length alignment within 100 year ARI extent Flow required to be passed.
Methodology The 100 year ARI event has been modelled and the floodplain conditions at the points of floodwater and alignment option intersection were reviewed.	
Rating **Neutral**	**Description** Option 12 interacts with floodplain flows at two major locations, Burnt Creek and the Wimmera River. Both are relatively confined areas of floodplain. The Burnt Creek intersection reaches a maximum depth 1.4 m passing a maximum flow rate of 4,200 ML/d (48.5 m^3/s) over a distance of approximately 140 m. The Wimmera River intersection with Option 12 can be separated into two flow paths, the major flow path and an area of shallow floodplain flow. The shallow flow could be easily transferred via culverts while the major river flow would be require a bridge structure with depths reaching 6 m and averaging 1.5 m over 660 m AHD.

8.5 Option B2

As discussed in **Section 3.0**, Option B2 bypasses Horsham to the east and north of town. It leaves the Western Highway west of Burnt Creek, crosses the Henty Highway and heads in a north-west direction to pass east of the Horsham Aerodrome to re-join the Western Highway near Dooen School Road.

Figure 35 shows the alignment of Option B2, the alignment interacts with Burnt Creek and the Wimmera River passing through an especially deep section of the Wimmera River floodplain.

The intersection with Burnt Creek is post the Western Highway where Burnt Creek spreads out considerably. It then re-crosses Burnt Creek and Wimmera River overland flows.

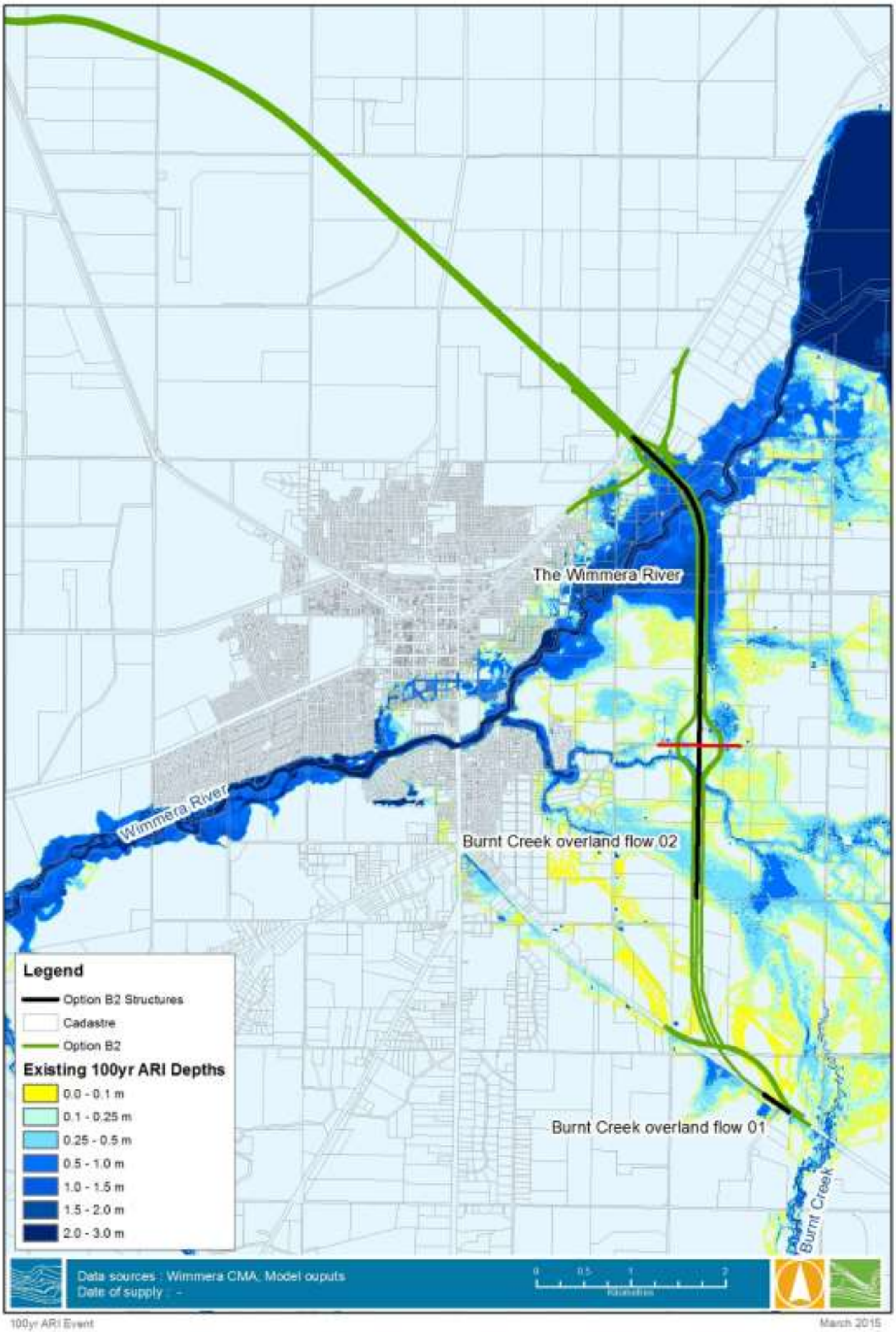

Figure 35 Option B2

B2 can be characterised into overland flow from Burnt Creek, streamflow in Burnt Creek, overland flow from the Wimmera River and streamflow in the Wimmera River. Closer perspectives of these intersections are below shown in **Figure 36**, **Figure 38** and **Figure 40**.

Figure 36 shows the initial Burnt Creek interaction with Option Revised B2. A breakout from Burnt Creek overtops the current Western Highway alignment at a shallow depth, inundating the Option Revised B2 alignment. This is due to an undersized culvert at the intersection of the Western Highway and Burnt Creek and could be prevented if the culvert structure was enlarged allowing water to pass more freely upstream of the alignment. If the Burnt Creek structure was to be replaced a capacity increase may be necessary. A Works on Waterways permit may be required for these works, the Wimmera Catchment Management Authority is the referral authority in this case.

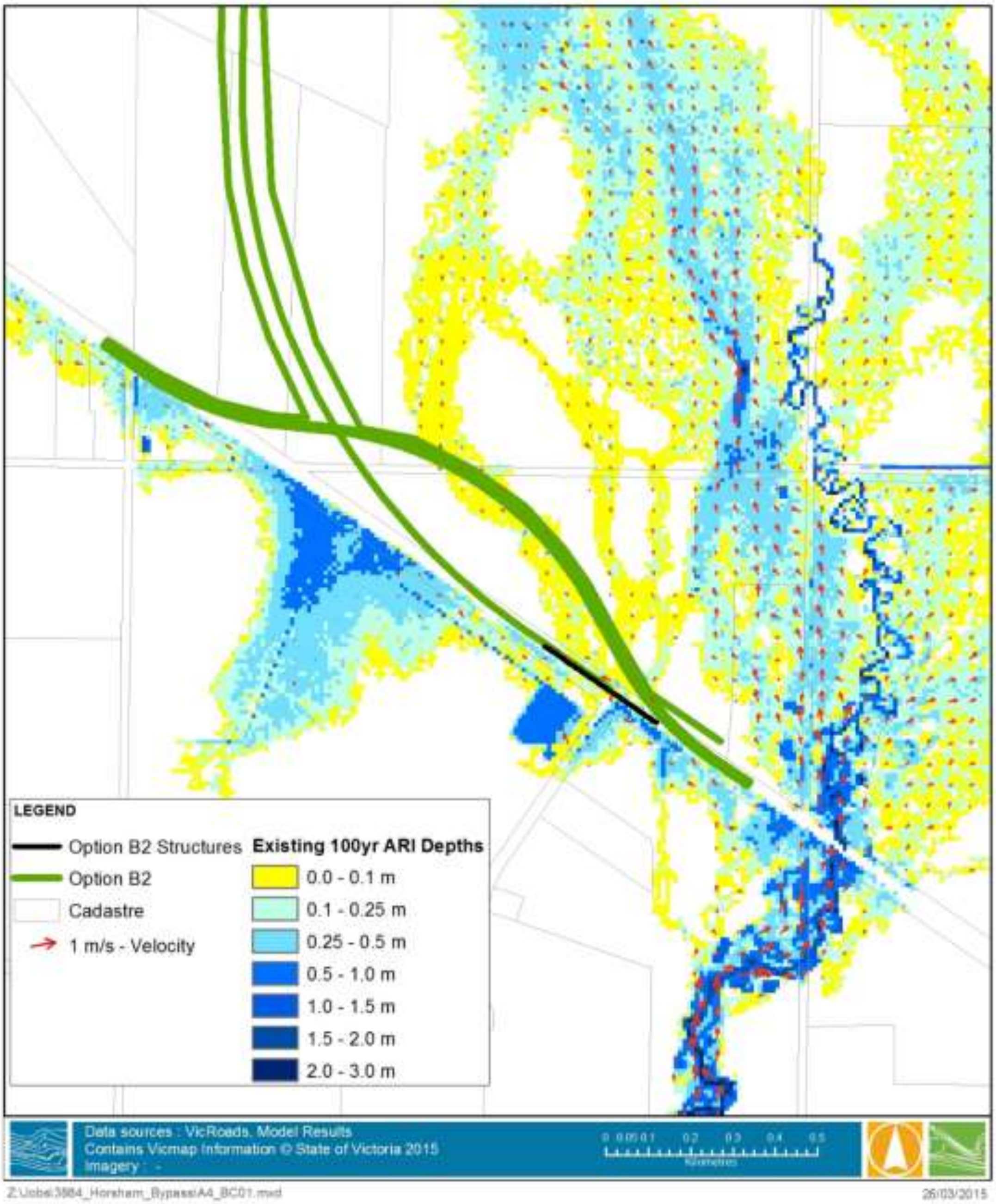

Figure 36 **Option B2 –Burnt Creek overland flow 01.**

Figure 36 shows a long-section of the ground surface and maximum water level along the centre of alignment B2 from upstream to downstream, black line in **Figure 36** indicates the length of the long-section. The maximum depth is relatively shallow at approximately 17 cm. Peak discharge at the intersection of Option B2 is relatively minor.

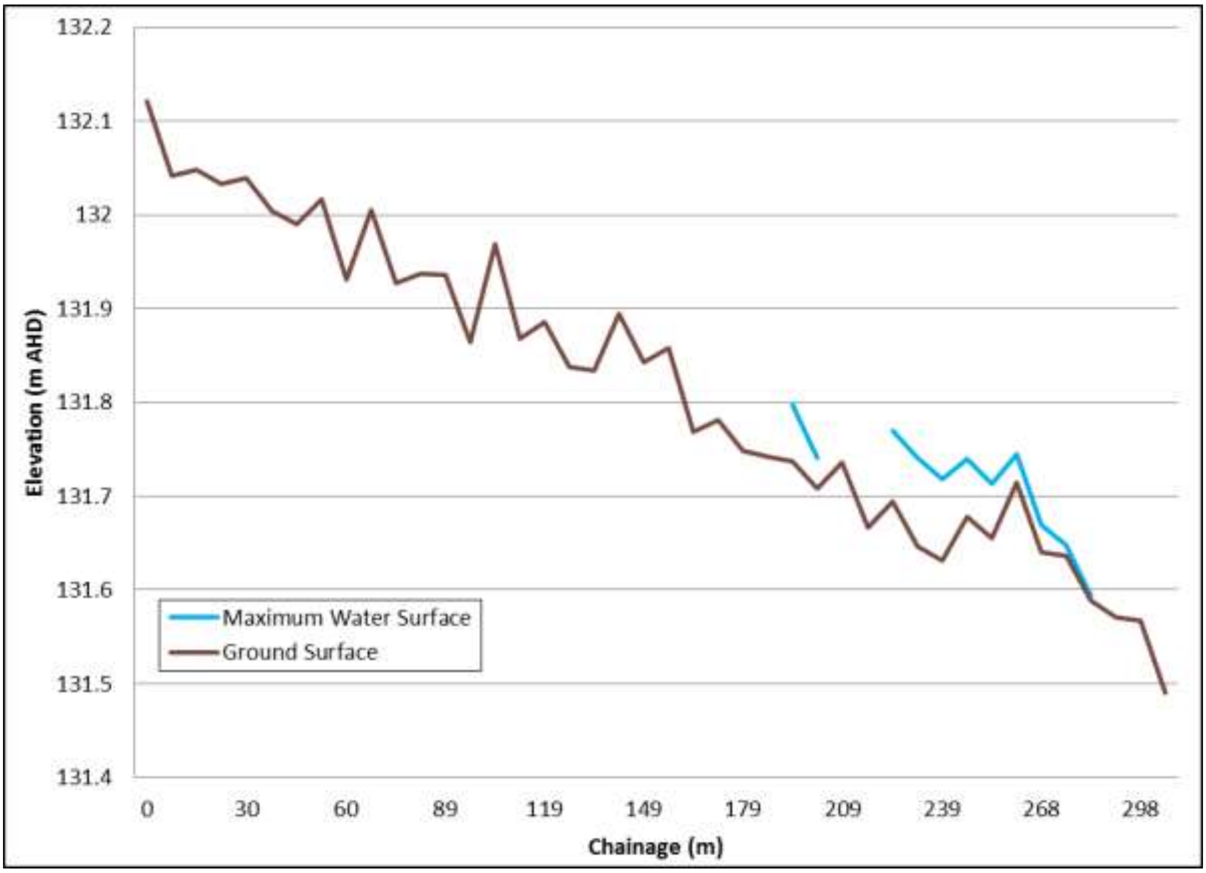

Figure 37 **Option B2 –Burnt Creek overland flow 01 – ground and maximum water level cross-section**

Figure 38 shows a closer perspective of Burnt Creek Overland Flow 02. The alignment crosses an area of broad overland flow with a maximum depth of approximately 0.5 m; this section of overland flow is approximately 850 m wide. The alignment then passes over Burnt Creek reaching a depth of 1.15 m.

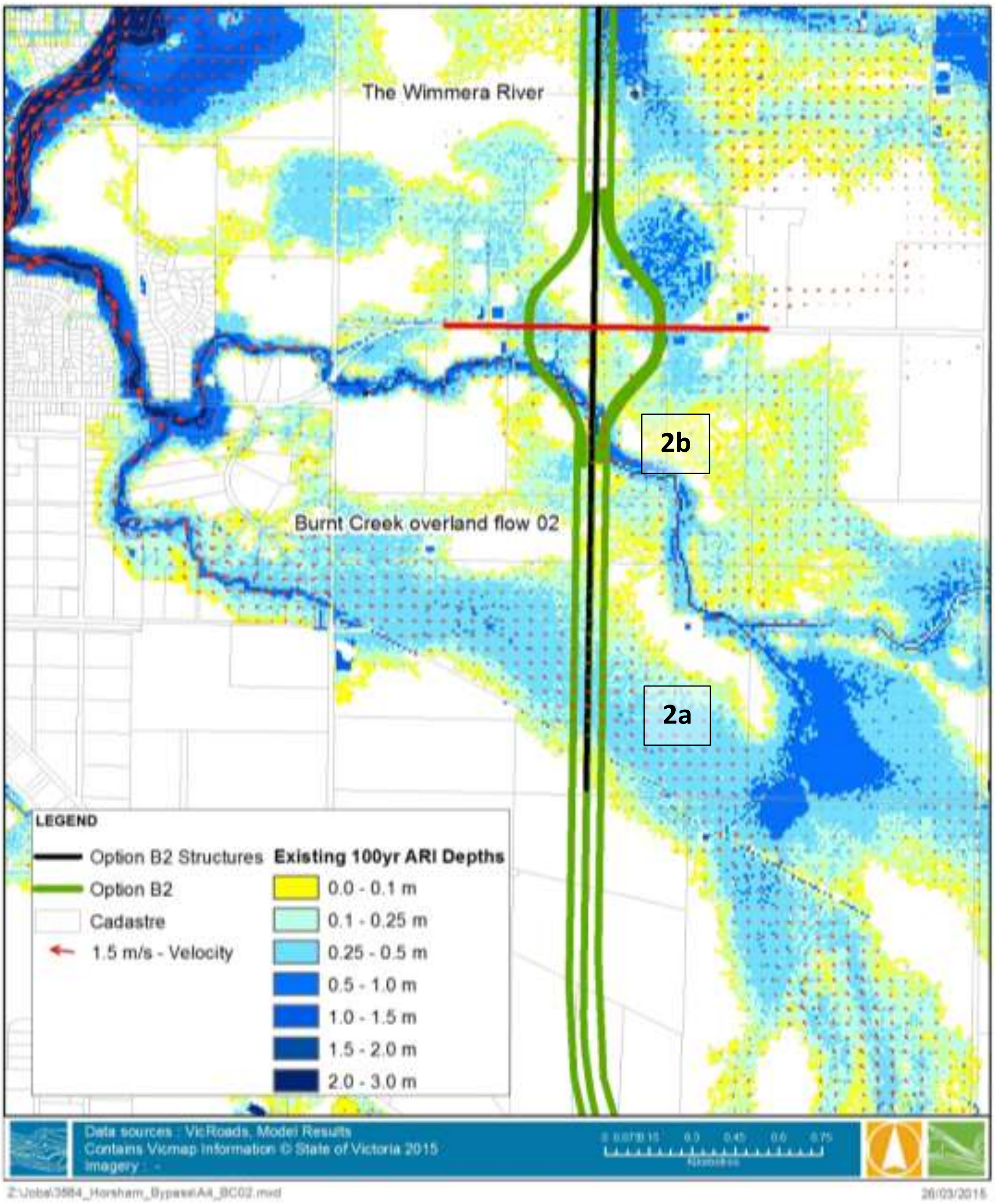

Figure 38 **Option B2 –Burnt Creek overland flow 02**

Figure 39 shows a closer perspective of the interaction between Option B2 and the Wimmera River. The alignment passes through a lower area of floodplain showing significant depth during the 100 year ARI event, before it crosses the Wimmera River perpendicular to the flow direction.

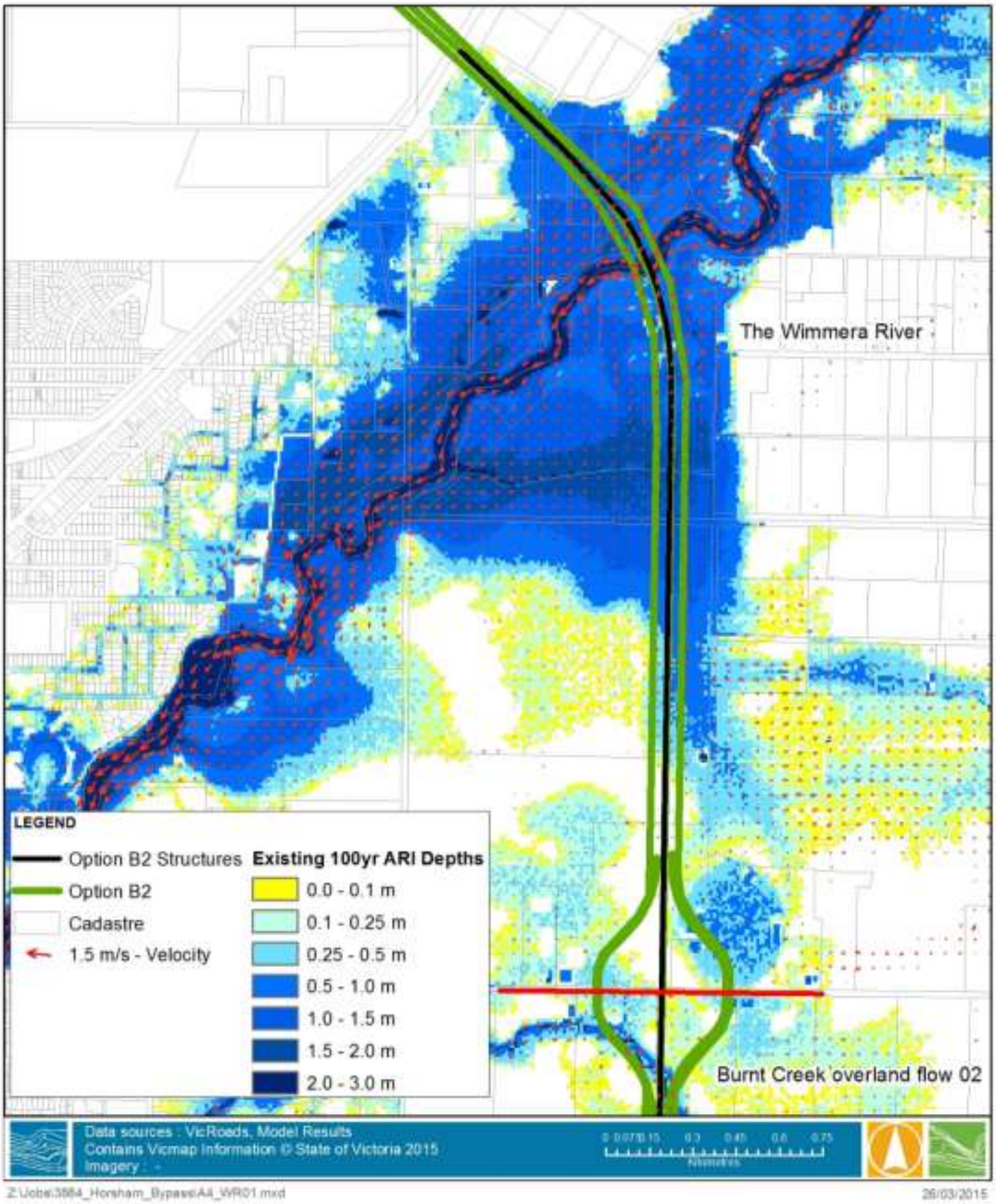

Figure 39 **Option B2 – Intersection with the major Wimmera River flow path**

Figure 40 shows cross-sections of topography and maximum water level extracted along the waterway and floodplain crossing points with Burnt Creek overland flow 02 and the Wimmera River. The cross-sections show slope on the maximum water surface elevation as the option alignment does not pass directly perpendicular to the Burnt Creek's flow direction.

The Wimmera River reaches a maximum depth of approximately 5.6 m and a water surface elevation of 127.8 m AHD. The maximum floodplain depth reaches 1.65 m. The length of inundation along the alignment is approximately 3 km.

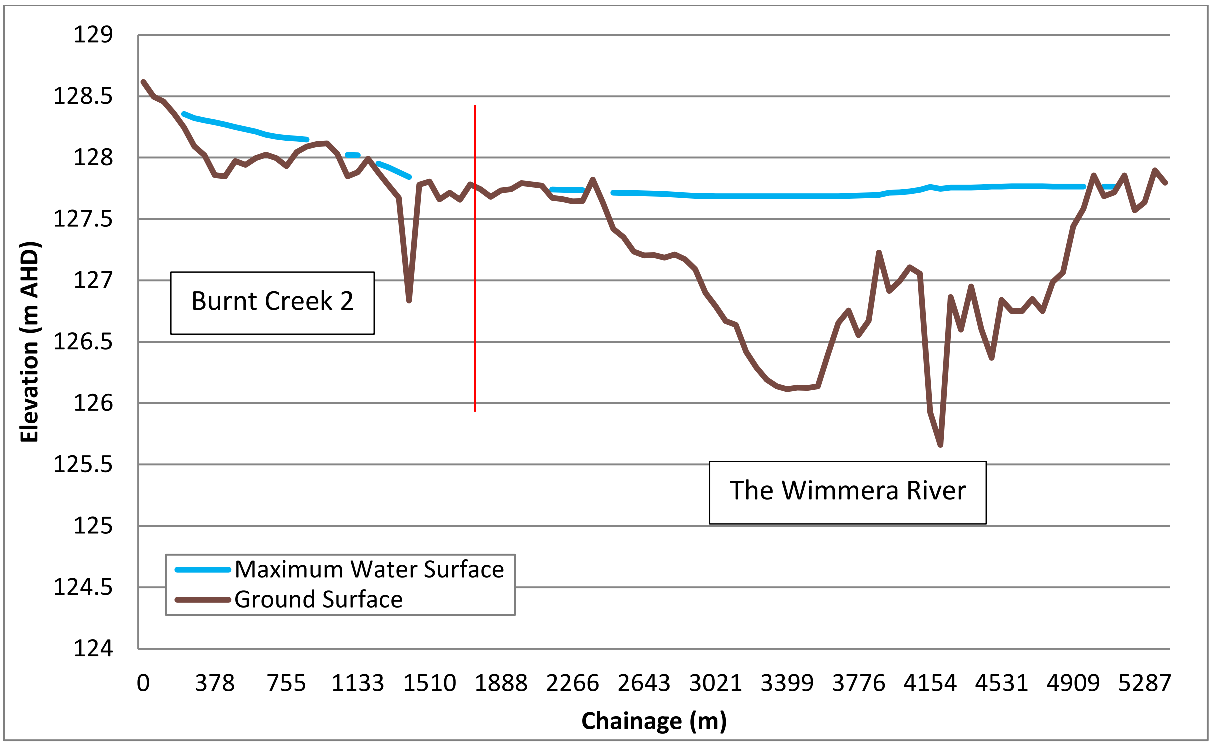

Figure 40 **Option B2 – Burnt Creek overland flow 02 and Wimmera River**

The peak discharge of Burnt Creek Overland Flow 02 at the intersection of Option B2 is approximately 6,825 ML/d (79 m^3/s).

A summary of the analysis taken to rank alignment Option B2 is shown below in **Table 18**Error! Reference source not found., as well as for options B2 and 11 for comparison purposes. Discussion of Option B2 is shown in **Table 19**Error! Reference source not found..

Table 18 **Option assessment summary for Option B2**

Summary – Option B2	
No. of flood water intersection points	3
Maximum River Depth (m)	5.6 m
Maximum Floodplain Depth (m)	1.65 m
Average Depth (m)	0.57 m
Waterway intersection length (m)	4,710 m

Table 19 Option assessment summary for B2 - Discussion

Option D	
Objective Free passage of flood water during a 100 year ARI event Drainage infrastructure required for each alignment option	**Indicator** Option is able to realistically allow free floodplain flow **Assessment Criteria** Number of wetland, waterway crossings and 100 year ARI crossings Length of alignment within 100 year ARI extent Flow required to be passed
Methodology The 100 year ARI event has been modelled and the floodplain conditions at the points of floodwater and alignment option intersection were reviewed.	
Rating **Poor**	**Description (provide location detail)** Option B2 interacts with floodplain flows at two major locations, Burnt Creek and the Wimmera River. Burnt Creek intersects with the bypass alignment twice, once through overland flow immediately after the existing Western Highway and another further along the alignment. There is potential to upgrade the existing culverts at the Western Highway to prevent water being pushed toward Horsham. The Wimmera River flow intersection with Option D is significant. The alignment passes through a section of low floodplain for approximately 2.8 km. The average depth of this intersection is approximately 0.9 m and is likely to require a lengthy bridge structure.

8.6 Option D

Option D is a combination of the southern part of Option B2 and the northern part of Option 11. Option D bypasses the Horsham township to the east and north. It diverges from the current Western Highway alignment west of Burnt Creek, heads due north and crosses the Wimmera River and Henty Highway to the north of Horsham, merging Gatehouse Road. It then re-joins the current Western Highway alignment immediately south of the Horsham Aerodrome.

Figure 41 shows the alignment of Option D. The alignment interacts with Burnt Creek and the Wimmera River, passing through an especially deep section of the Wimmera River floodplain.

The first intersection between Option D and Burnt Creek is a breakout from the general watercourse alignment; it then crosses Burnt Creek, overland flow from the Wimmera River and the major flow path of the Wimmera River.

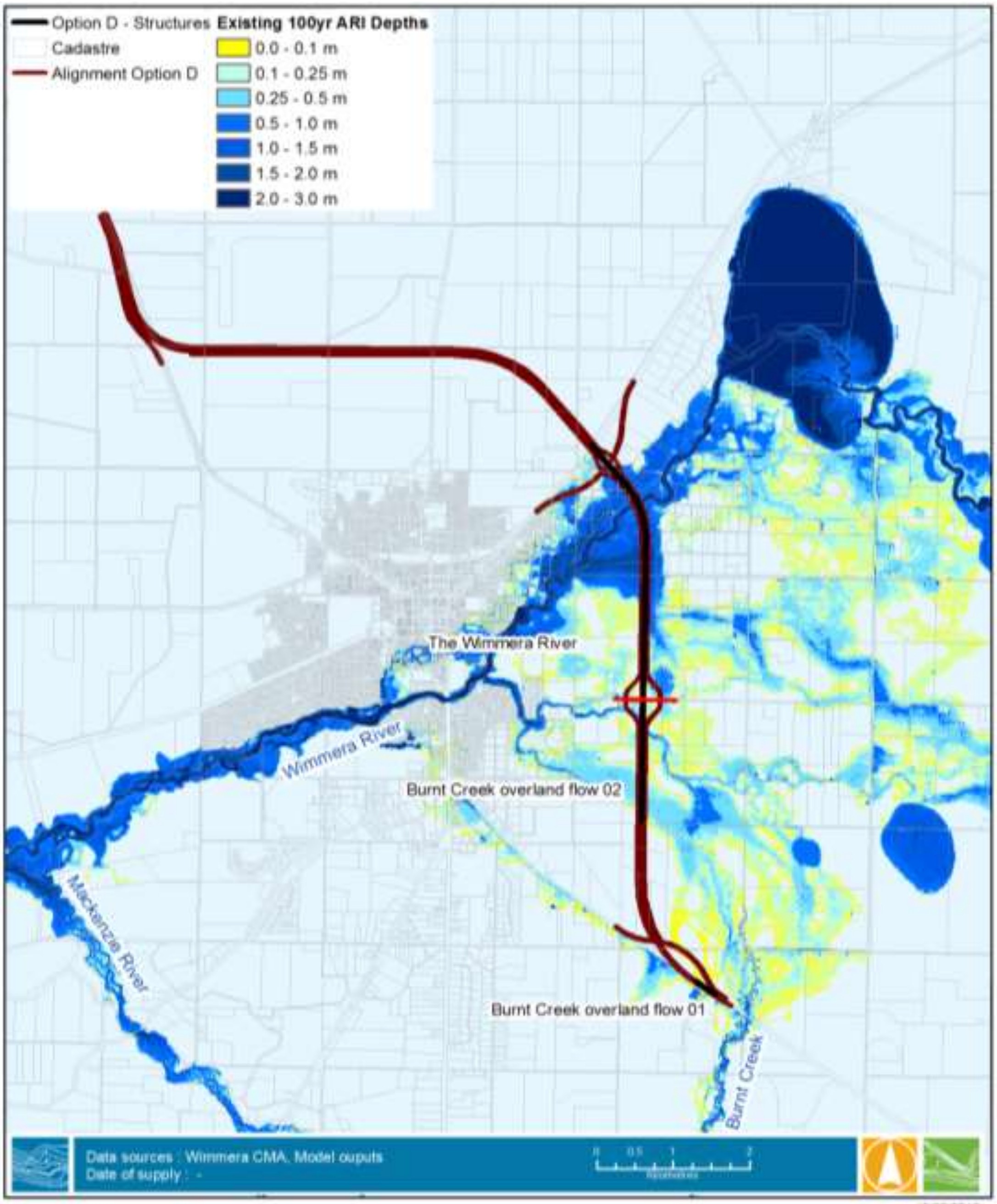

Figure 41 **Option D alignment and depths in the 100 year ARI event**

Option D floodplain interaction can be characterised into overland flow from Burnt Creek, streamflow in Burnt Creek, overland flow from the Wimmera River and streamflow in the Wimmera River. Closer perspectives of these intersections are below shown in **Figure 42, Figure 44**, **Figure 45**.

Figure 42 shows the initial Burnt Creek interaction with Option D. A breakout from Burnt Creek overtops the current Western Highway alignment at a shallow depth, inundating the Option D alignment. This is due to an undersized culvert at the intersection of the Western Highway and Burnt Creek and could be prevented if the culvert structure was enlarged allowing water to pass more freely upstream of the alignment.

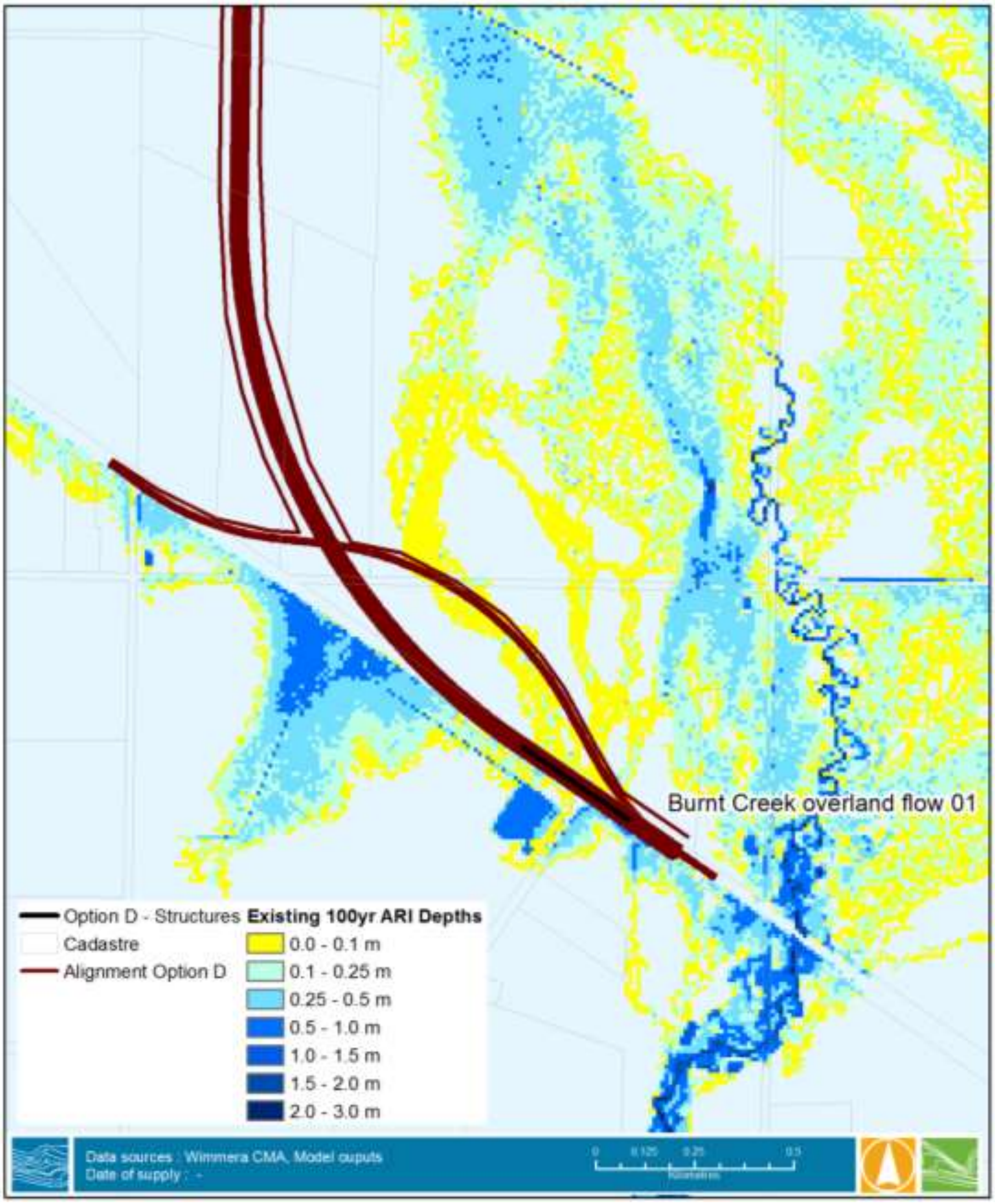

Figure 42 **Option D – Burnt Creek overland flow 01**

Figure 43 shows a long-section of the ground surface and maximum water level along the centre of alignment D from upstream to downstream, black line indicates the length of the long-section. The maximum depth is relatively shallow at approximately 0.17 m. Peak discharge at the intersection of Option D is 173 ML/d (2 m^3/s).

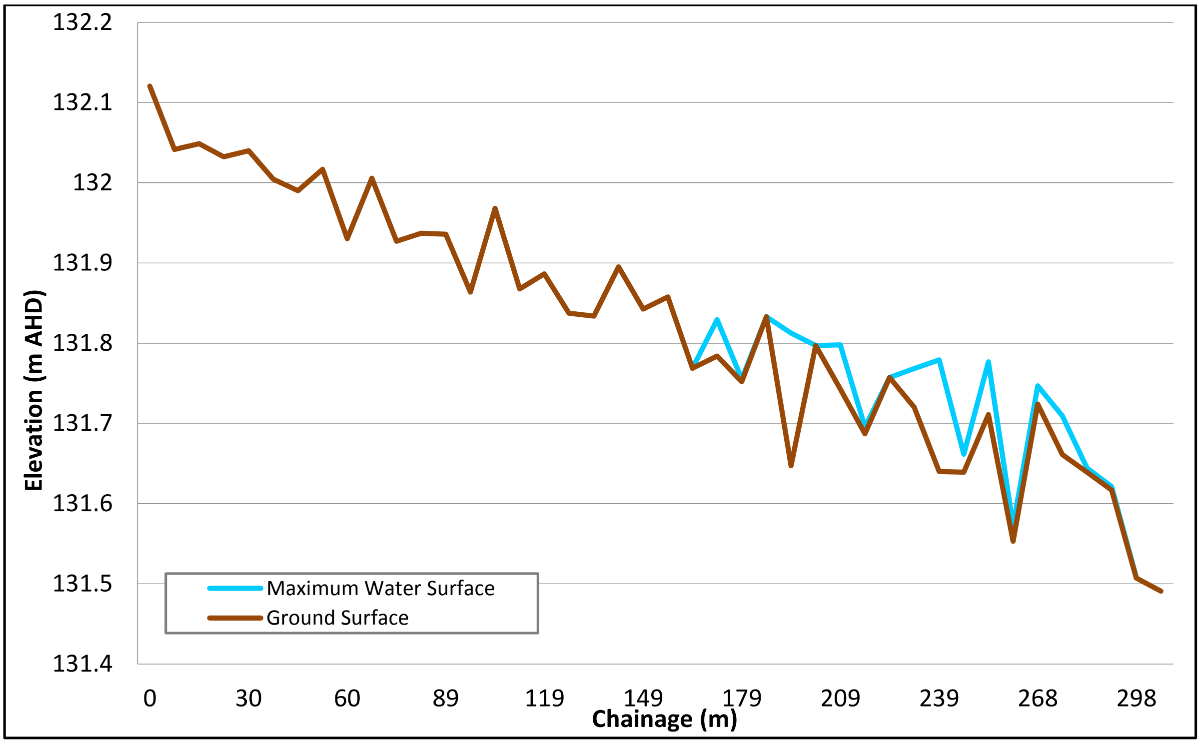

Figure 43 **Option D – Burnt Creek overland flow 01 – ground and maximum water level cross-section**

Figure 44 shows a closer perspective of Burnt Creek Overland Flow 02. The alignment crosses an area of broad overland flow with a maximum depth of approximately 0.5 m; this section of overland flow is approximately 850 m wide. The alignment then passes over Burnt Creek reaching a depth of 1.15 m.

The peak discharge of Burnt Creek Overland Flow 02 at the intersection of Option D is approximately 6,825 ML/d (79 m^3/s).

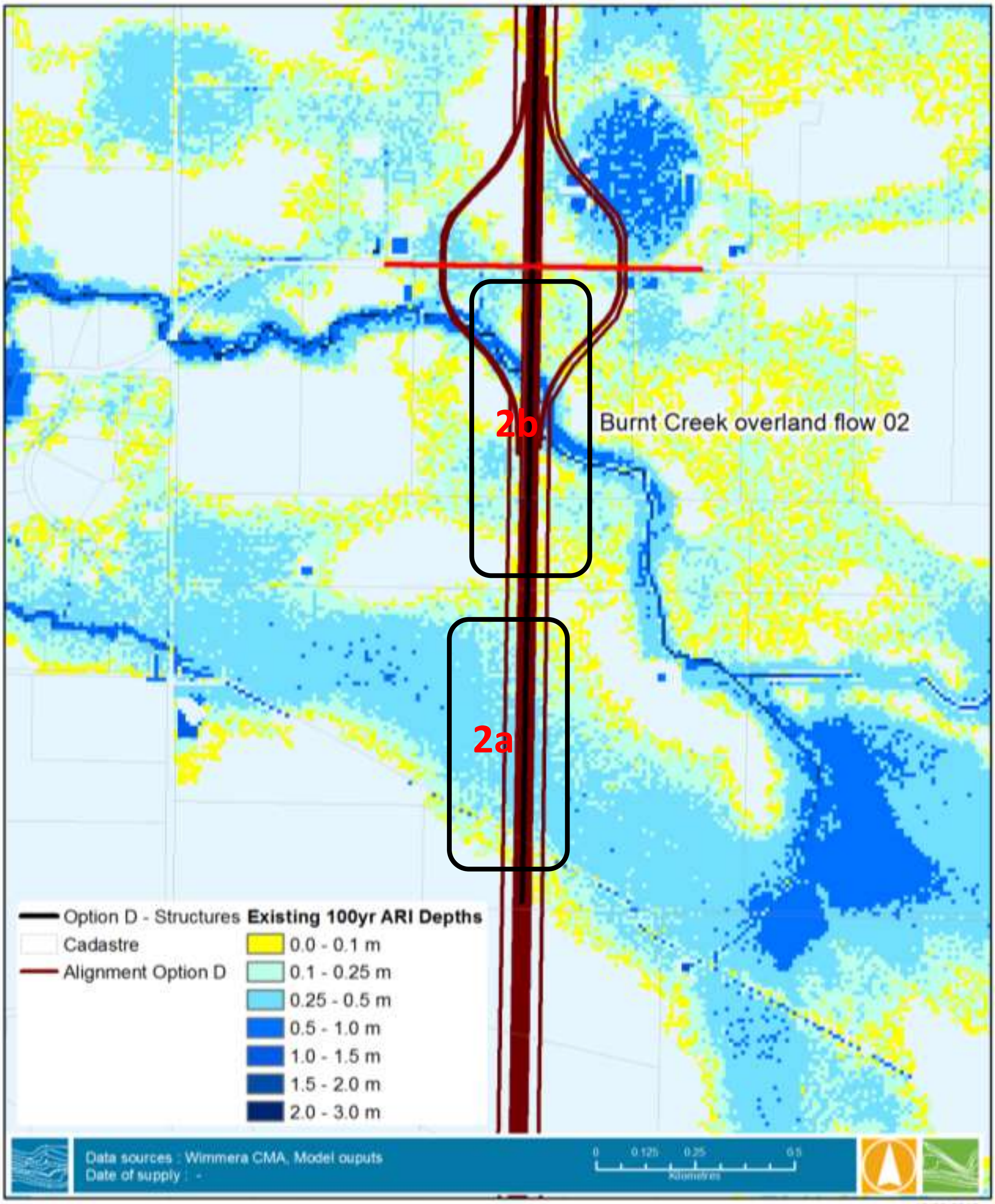

Figure 44 **Option D –Burnt Creek overland flow 02**

Figure 45 shows a closer perspective of the interaction between Option D and the Wimmera River. The alignment passes through a lower area of floodplains showing significant depth during the 100 year ARI event, before it crosses the Wimmera River perpendicular to the flow direction.

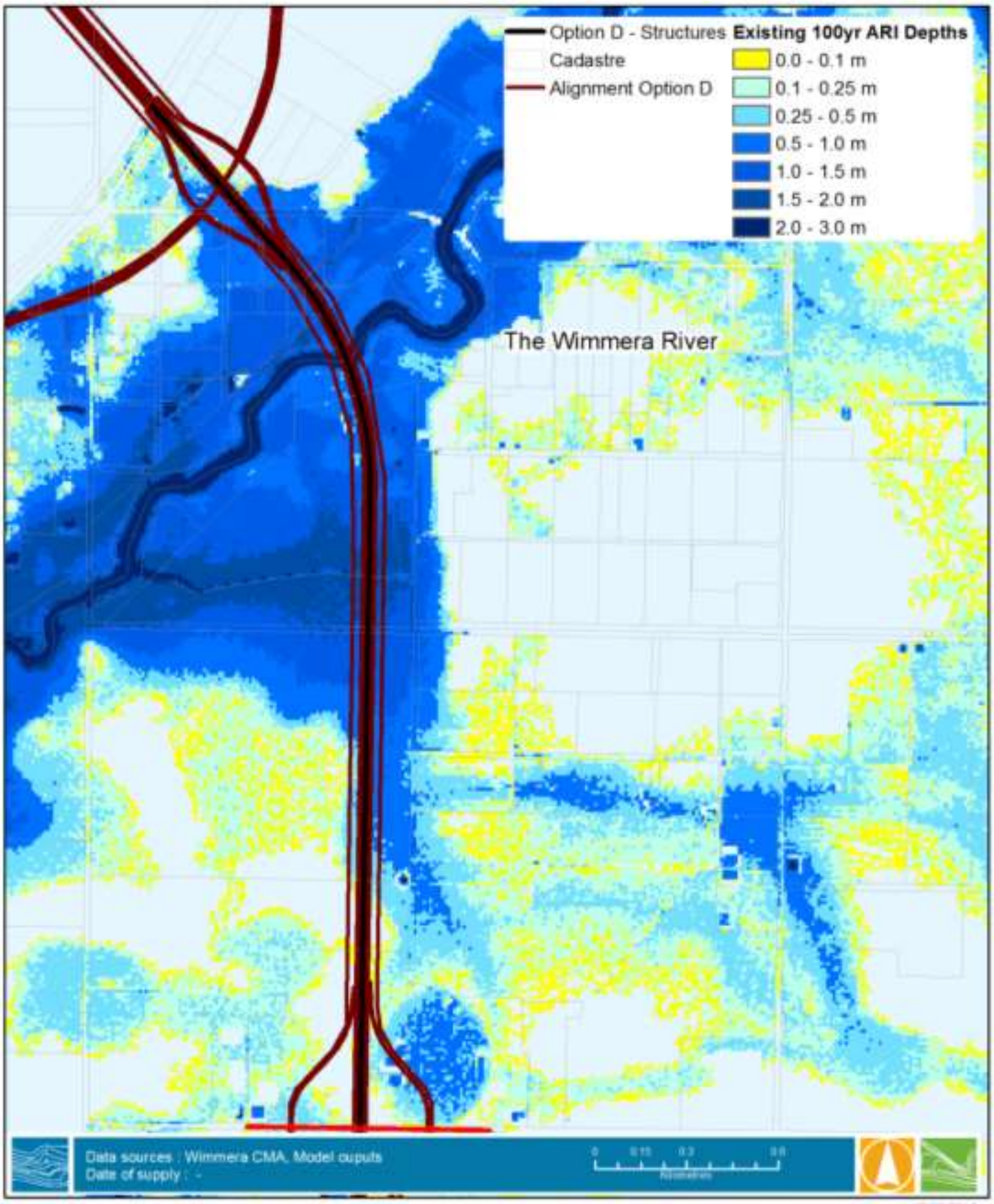

Figure 45 **Option D – Intersection with the major Wimmera River flow path**

The Wimmera River reaches a maximum depth of approximately 5.6 m and a water surface elevation of 127.8 m AHD. The maximum floodplain depth reaches 1.65 m. The length of inundation along the alignment is approximately 3 km.

Figure 46 shows cross-sections of topography and maximum water level extracted along the waterway and floodplain crossing points with Burnt Creek overland flow 02 (**Figure 44**) and the Wimmera River (**Figure 45**). The cross-sections show slope on the maximum water surface elevation as the option alignment does not pass directly perpendicular to the Burnt Creek's flow direction.

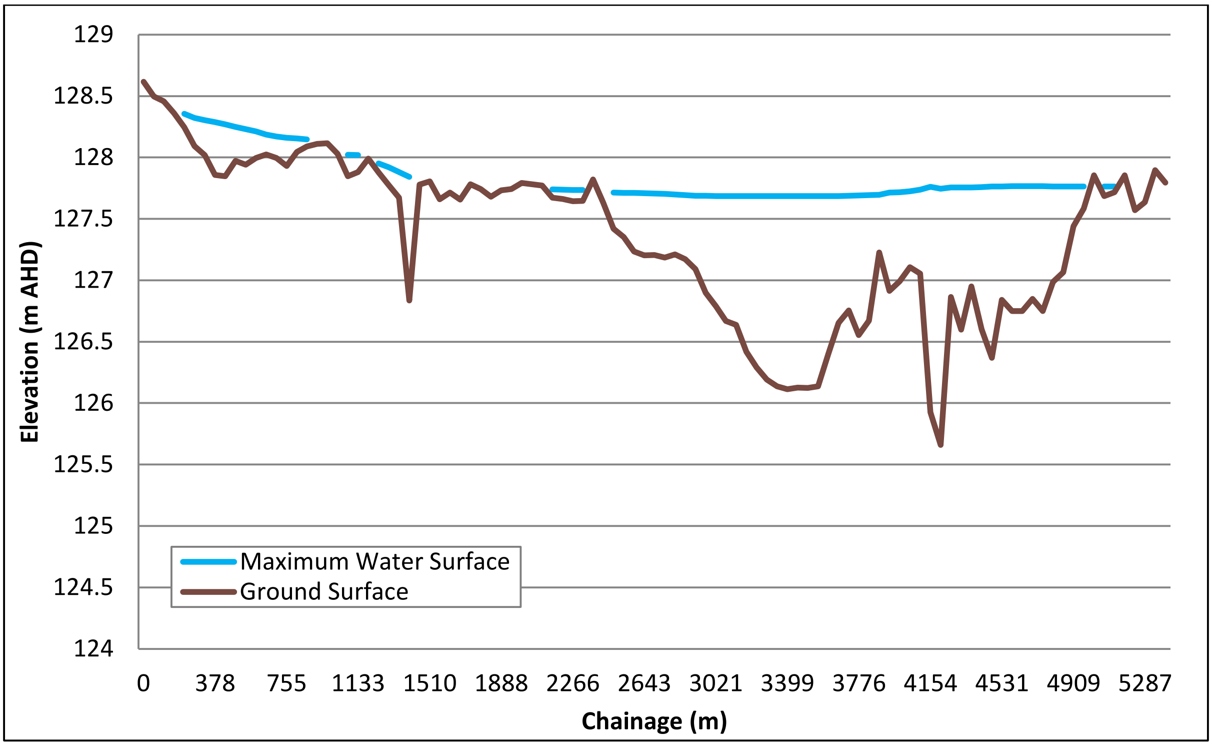

Figure 46 **Option D – Burnt Creek overland flow 02 and Wimmera River**

A summary of the analysis taken to rank the alignment of Option D is shown below in **Table 20**Error! Reference source not found.. Discussion of Option D is shown in **Table 21**Error! Reference source not found..

Table 20 Option assessment summary for Option D

Summary	Option D
No. of flood water intersection points	3
Maximum River Depth (m)	5.6 m
Maximum Floodplain Depth (m)	1.65 m
Average Depth (m)	0.57 m
Floodplain intersection length (m)	4710 m

Table 21 Option assessment summary for Option D - Discussion

Option D	
Objective Free passage flood water during a 100 year ARI event Drainage infrastructure required for each alignment option	**Indicator** Option is able to realistically allow free floodplain flow **Assessment Criteria** Number of wetland, waterway crossings and 100 year ARI crossings Length alignment within 100 year ARI extent Flow required to be passed
Methodology The 100 year ARI event has been modelled and the floodplain conditions at the points of floodwater and alignment option intersection were reviewed.	
Rating **Poor**	**Description** Option D interacts with floodplain flows at two major locations, Burnt Creek and the Wimmera River. Burnt Creek intersects with the Option D bypass alignment twice, once through overland flow immediately after the existing Western Highway and another further along the alignment. There is potential to upgrade the existing culverts at the Western Highway to prevent water being pushed toward Horsham. The Wimmera River flow intersection with Option D is significant. The alignment passes through a section of low floodplain for approximately 2.8km. The average depth of this intersection is approximately 0.9 m and is likely to require a lengthy bridge structure.

8.7 Summary

Table 22 below shows a summary of each alignment option assessment. Each bypass alignment option has been rated and ranked based on its interaction with the 100 year ARI extent. However, if the appropriate flood mitigation infrastructure is put in place, free passage of flood water during the 100 year ARI event is possible. This would reduce the potential impact of each alignment on 100 year flood levels to zero.

The cost of the infrastructure required for each alignment option will vary significantly depending on the length of bridge or number of culverts required. Infrastructure designed to allow free passage of a 100 year ARI flood event will have the capacity to pass flood flows of more frequent events; however a latent risk exists that an event larger than a 100 year ARI magnitude could cause afflux upstream of a bypass alignment causing damage to private property the risk of this occurring is the same across all five options. However, the consequences of afflux are dependent on the proximity to dwellings and other assets. A factor of safety can be built applied to any option reducing the risk of the design capacity being exceeded. This needs to be assessed once a more detailed design of the preferable alignment's drainage features are completed.

Table 22 Summary of overall ratings for each option

Option	Rating	Rank	Explanation
Option 5A	Neutral	**2**	Option 5A has the shortest waterway/floodplain intersection length and there is potential to increase the size of the current Burnt Creek culverts at the Western Highway. Flow from the Wimmera River could be passed via one large structure.
Option 11	Poor	**3**	Option 11 has four major waterway/floodplain intersection points, all dominated by the Wimmera River. Several stretches of the alignment would require significant culverts and potentially more than one bridge structure.
Option 12	Neutral	**1**	Option 12 interacts with floodplain flows at Burnt Creek and the Wimmera River. Both are relatively confined areas of floodplain. The alignment is likely to require two bridge structures.
Option B2	Poor	**5**	Option B2 interacts with both Burnt Creek and the Wimmera River. The major downside of this option is the length of low Wimmera River floodplain that would require a bridge structure.
Option D	Poor	**5**	Similar to Option B2, D interacts with both Burnt Creek and the Wimmera River. The major downside of this option is still the length of Wimmera River floodplain that would require a bridge structure.

.

9.0 CONCLUSION

Of the five potential alignment options, Options 12 and 5A are likely to have the lowest level of floodplain impact. These two options will require the least amount of earthworks to bring the road level above the 100 year ARI flood level and they will require the least drainage infrastructure.

Options 11 will require longer bridge structures at the Wimmera River as well as numerous culverts to pass overland floodplain flow.

Option B2 and D are the least preferable options due to the length of bridge structure that would be required to pass through a low lying section of floodplain.

Options on the eastern side of Horsham (11, B2 and D) have the potential to significantly alter floodplain flow - this alteration may provide some flood mitigation to Horsham but may also increase flood levels upstream of the bypass option.

The current culvert arrangement at Burnt Creek on the Western Highway is undersized and increase in its capacity should be considered for any of the alignment options.

10.0 ADDITIONAL ASSESSMENT

10.1 Overview

Option B2 was assessed in further detail using the hydraulic model. Previously the hydraulic model was used to define the waterway intersection points and drainage requirements of each assessed alignment option under the existing floodplain conditions.

The additional assessment more rigorously assessed B2 by creating a design scenario with the inclusion of the B2 Option alignment and bridge/culvert infrastructure required to maintain no impact on 100 year ARI water levels.

The existing conditions model was modified by inserting the B2 alignment into the model creating a barrier to flood flows in the Wimmera River, Burnt Creek and their associated floodplains. The barrier prevented water from overtopping onto the design road pavement with all flow required to pass through culverts or bridge infrastructure. For large span bridges on Burnt Creek and the Wimmera River, piers were incorporated into the model, whereas culverts were used for broad floodplain flows.

10.2 Infrastructure assumptions

A concept design of the infrastructure required to pass riverine and floodplain flows was completed by AECOM while costing each of the bypass options for the Options Assessment[6]. AECOM assumed three structures would be constructed covering flow in Burnt Creek and the associated floodplain north of the current Western Highway alignment. No structure was included at the current Western Highway alignment and the Wimmera River was assumed to have one large bridge structure.

On advice from AECOM[7] individual culverts are assumed to be a width of 1.8 m with bridge spans of 30 m between piers used across the general floodplain and 50 m across the Wimmera River. Piers were assumed to be 1.2 m wide and 7 m long.

The detail of the structures assumed by AECOM is shown in **Table 23** with the location of each structure show in **Figure 47**.

Table 23 Conceptual drainage infrastructure for Option B2

Waterway Crossing	Length (m)	Structure Type
Burnt Creek overland flow 02a	480	Culverts
Burnt Creek overland flow 02b	200	Culverts
Burnt Creek overland flow 02c	80	Bridge
Wimmera River	1,960	Bridge

[6] Horsham Bypass – Stage 2 Options Assessment – AECOM, 2013
[7] Pers. Comm. Jeff Keys (AECOM) – 30/09/2013

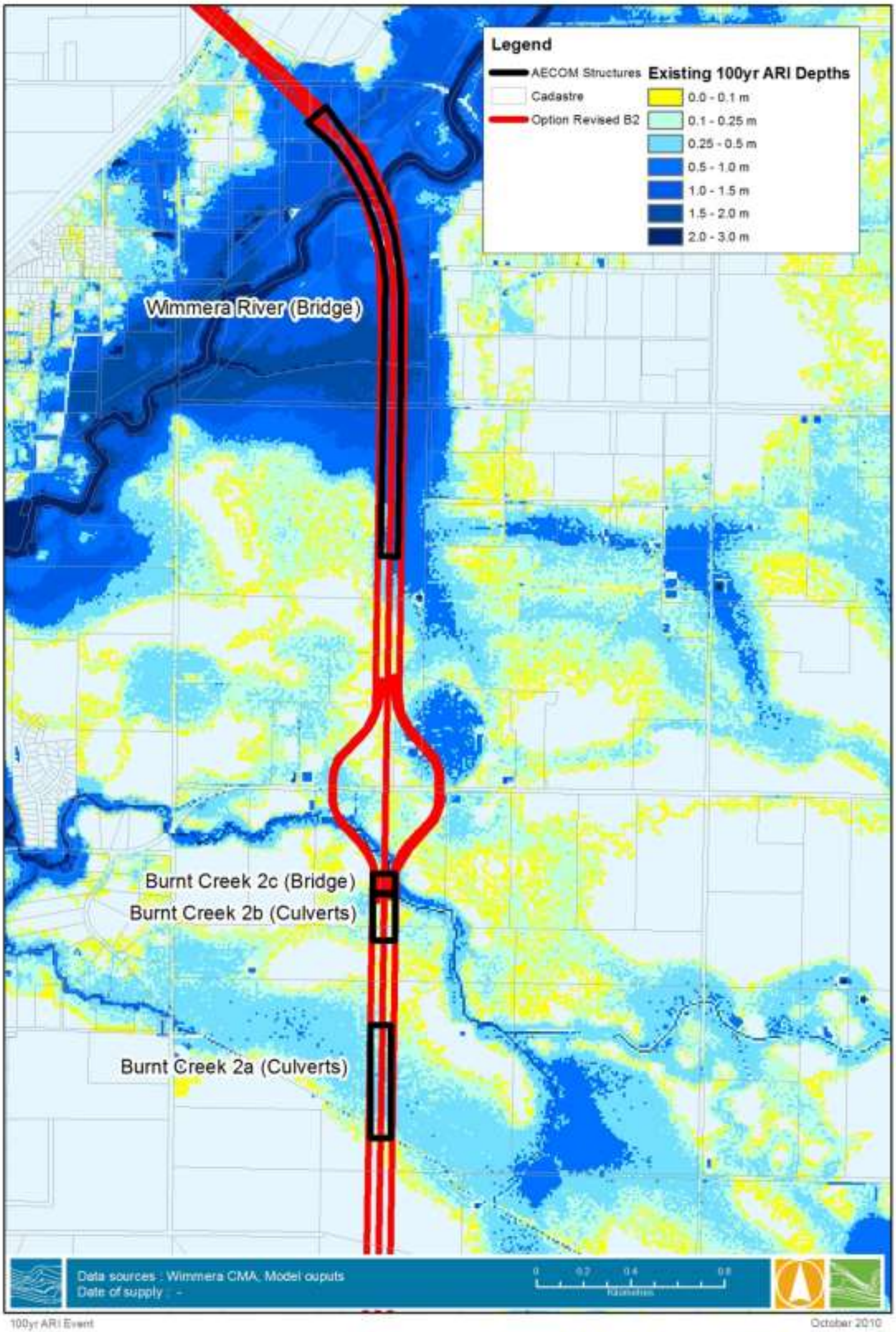

Figure 47 Option B2 – Bridge and culvert locations from AECOM concept design

10.3 Hydraulic Modelling

10.3.1 Overview

Two culvert/bridge scenarios were modelled; assessing the maximum potential to match the waterway flow area in existing conditions (Scenario 01) and a minor reduction in waterway flow area as per AECOM's conceptual design (Scenario 02). Bypass entry and exit ramps were not modelled in either scenario; however the ramps will exist in the final option and will be assessed in the final detailed design. In instances where the entry and exit ramps run parallel to floodplain infrastructure the bridge/culverts would be required to be duplicated (e.g. Burnt Creek).

The length of bridge and culvert structures for each scenario is shown in **Figure 48**.

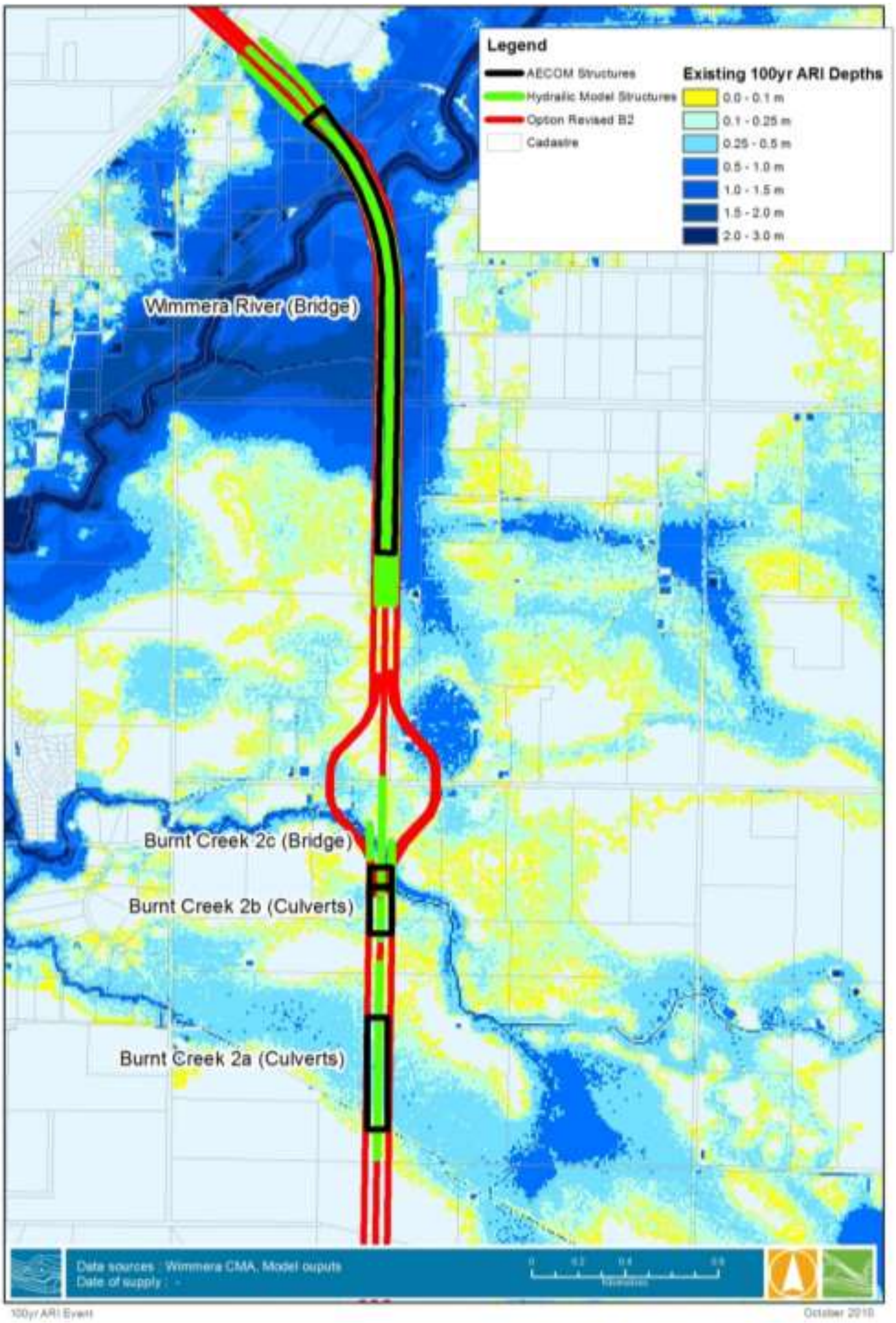

Figure 48 **Option B2 – Bridge and culvert locations and length modelled in Scenario 01 and 02**

10.3.2 Scenario 01

Option B2 was modelled with the inclusion of two bridges and two major culvert locations. The two bridges spanned over the Wimmera River and Burnt Creek with culvert locations separated into multiple sets of culverts to minimise the number of culverts required. This also allowed for an accurate representation of required infrastructure. During the assessment the length of bridge and culvert structures attempted to best match the existing waterway flow area available, resulting in the lowest upstream afflux.

The number of culverts modelled at each location is shown below in **Table 24**, culverts were modelled at 1.8 m x 0.9 m as per instructions from AECOM. The final design culvert depth will be determined by the depth at each location. This is expected to be less than 0.9 m. It is likely that the number of culverts could be significantly reduced higher up on the floodplain by draining floodplain flow toward the major flow paths with large banks of culverts at those locations. This potential should be investigated at a later design stage with the current estimate considered conservative

Table 24 Modelled drainage infrastructure for Option B2

Waterway Crossing	Culvert bank No.	Length (m)	No. of culverts
Burnt Creek overland flow 02a	1	20	10
	2	300	150
	3	180	90
	4	10	5
	5	20	10
	6	30	15
Burnt Creek overland flow 02b	1	30	15
	2	40	5
Burnt Creek overland flow 02d	1	10	5
	2	20	10
	3	40	20

Bridge infrastructure was modelled using the inclusion of bridge piers. The hydraulic modelling software MIKE21 includes the ability to incorporate bridge pier resistance within a singular grid cell. Resistance to flow due to the piers is modelled by calculating the current induced drag force on each individual pier segment and equating this force with a shear stress contribution.

The pier locations for each bridge are shown in the model results, the Wimmera River and Burnt Creek bridges are approximately 2,600 m and 160 m long respectively.

10.3.2.1 Model Results

The incorporation of the B2 alignment and the bridge/culvert infrastructure in Scenario 01 causes some minor changes in maximum water surface elevation.

Changes to the maximum Water Surface Elevation (WSE) caused by the B2 Alignment and the modelled infrastructure are presented as a difference plot. Positive values indicate an increase in WSE, negative values indicate a decrease. **Figure 49** shows the colour scheme used in the results display. Varying shades of green indicate a decrease in water levels, while yellow through to orange indicate an increase.

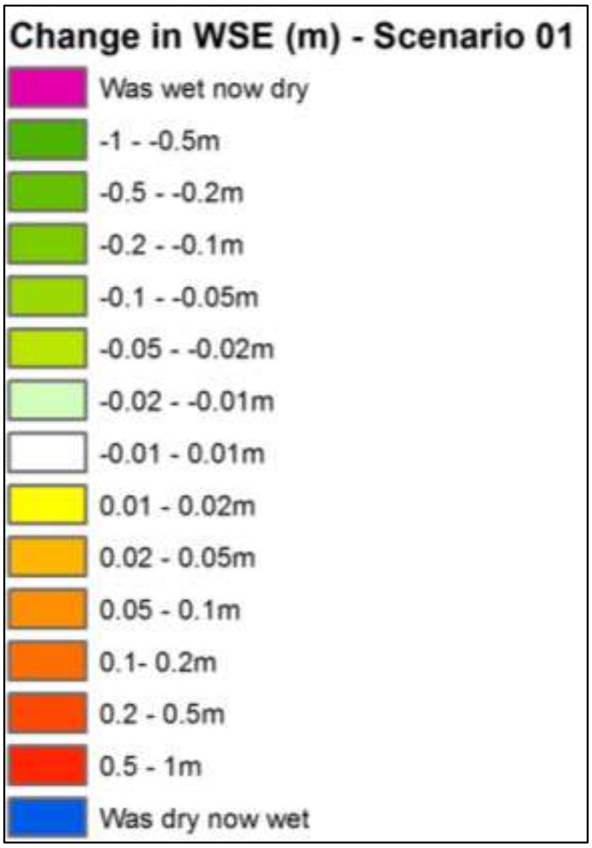

Figure 49 Change in Water Surface Elevation mapping display

Changes to the maximum WSE over the entire bypass alignment are shown in **Figure 50**, with a closer view of Burnt Creek and the Wimmera River shown in **Figure 51** and **Figure 52** respectively.

Model results show no change across the majority of the model extent. Slight increases are observed at the Burnt Creek Bridge and culvert structures. Light green downstream of the bypass alignment indicates a decrease of 1 cm.

The increases at Burnt Creek at the culvert and bridge structures are localised and reach a maximum of 1.5 cm. The increases do not impact on any surrounding buildings but increases are observed on private land.

Model results show no change in the maximum WSE at the Wimmera River structure.

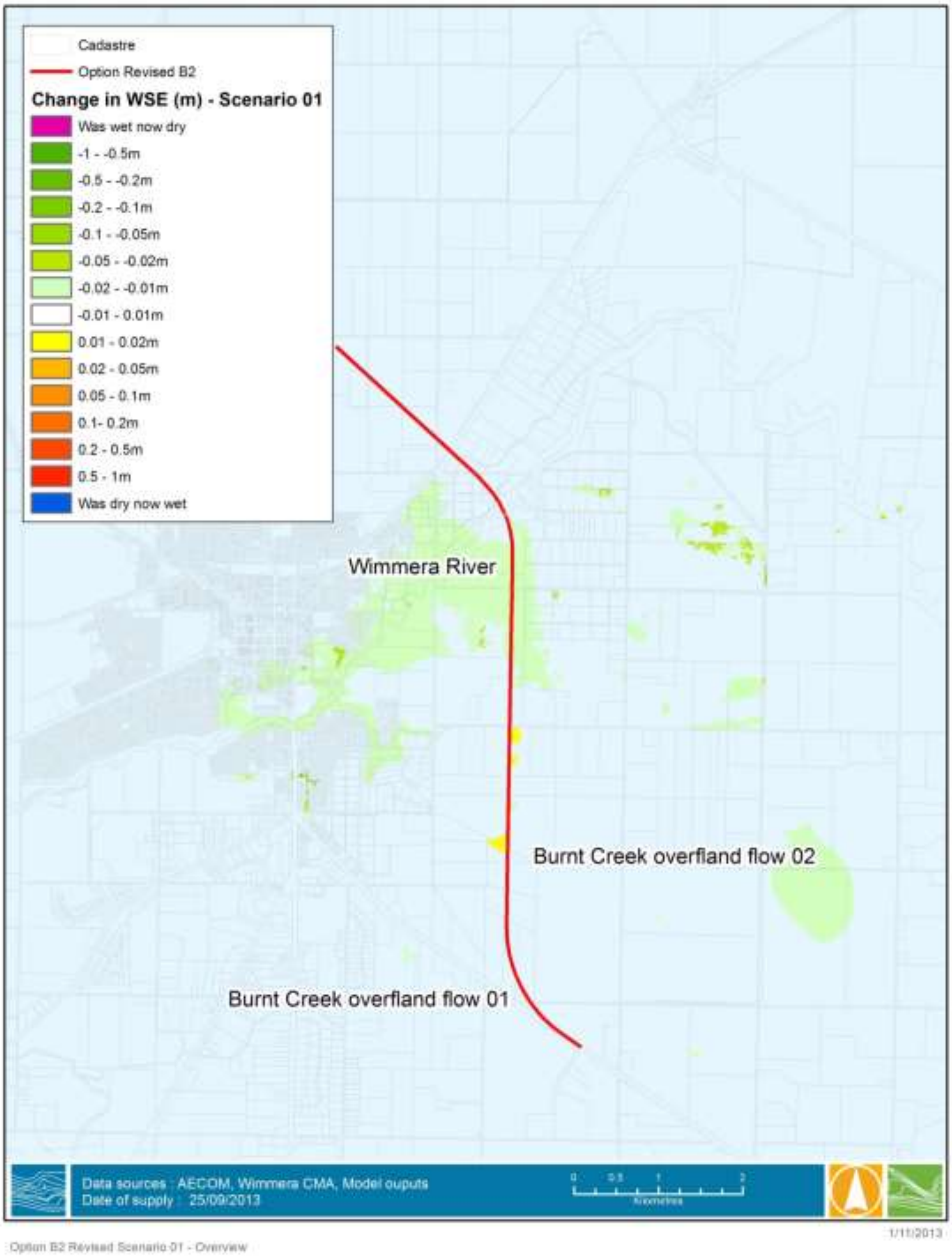

Figure 50 **Scenario 01, change in Water Surface Elevation over the B2 bypass alignment**

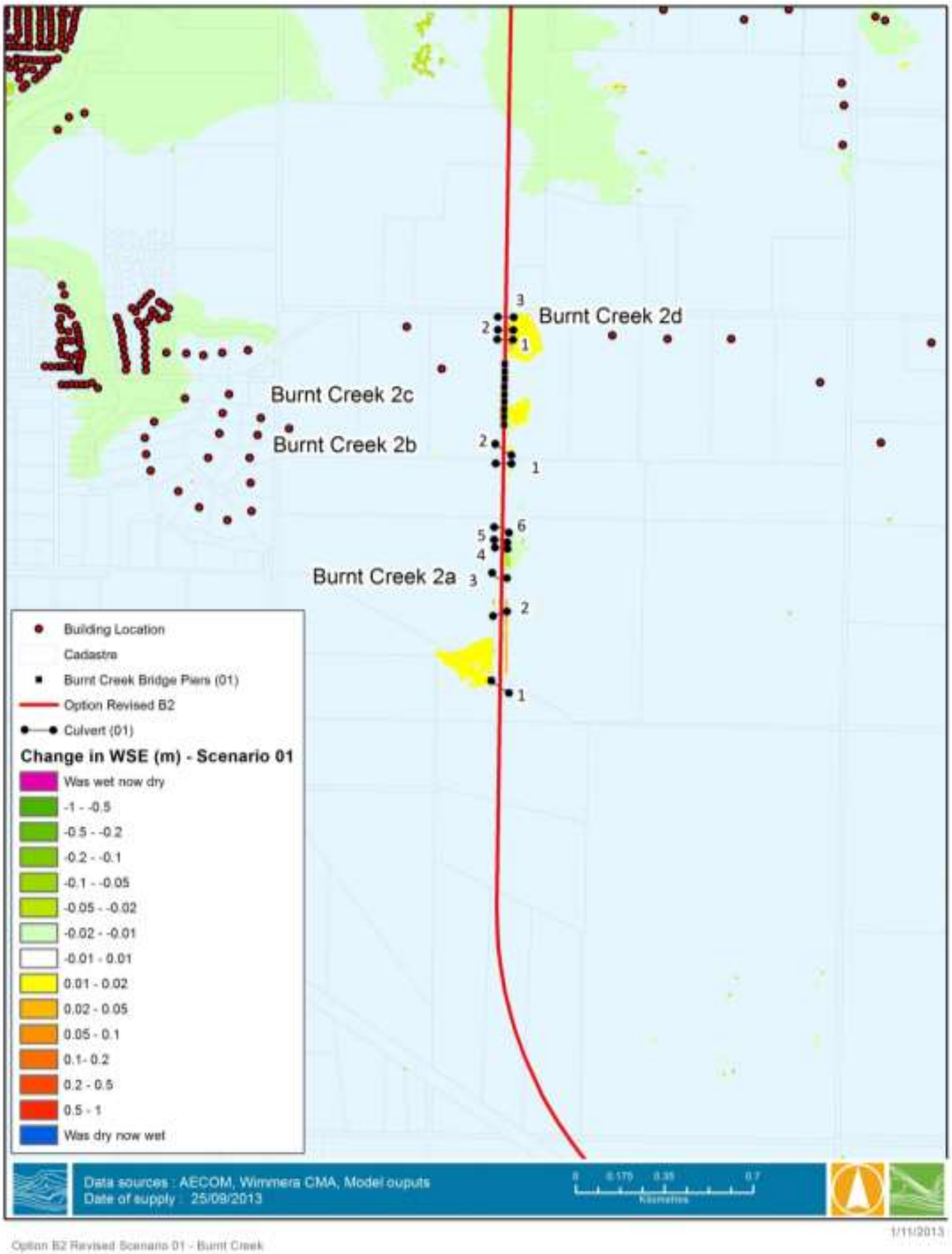

Figure 51 Scenario 01, change in Water Surface Elevation at Burnt Creek

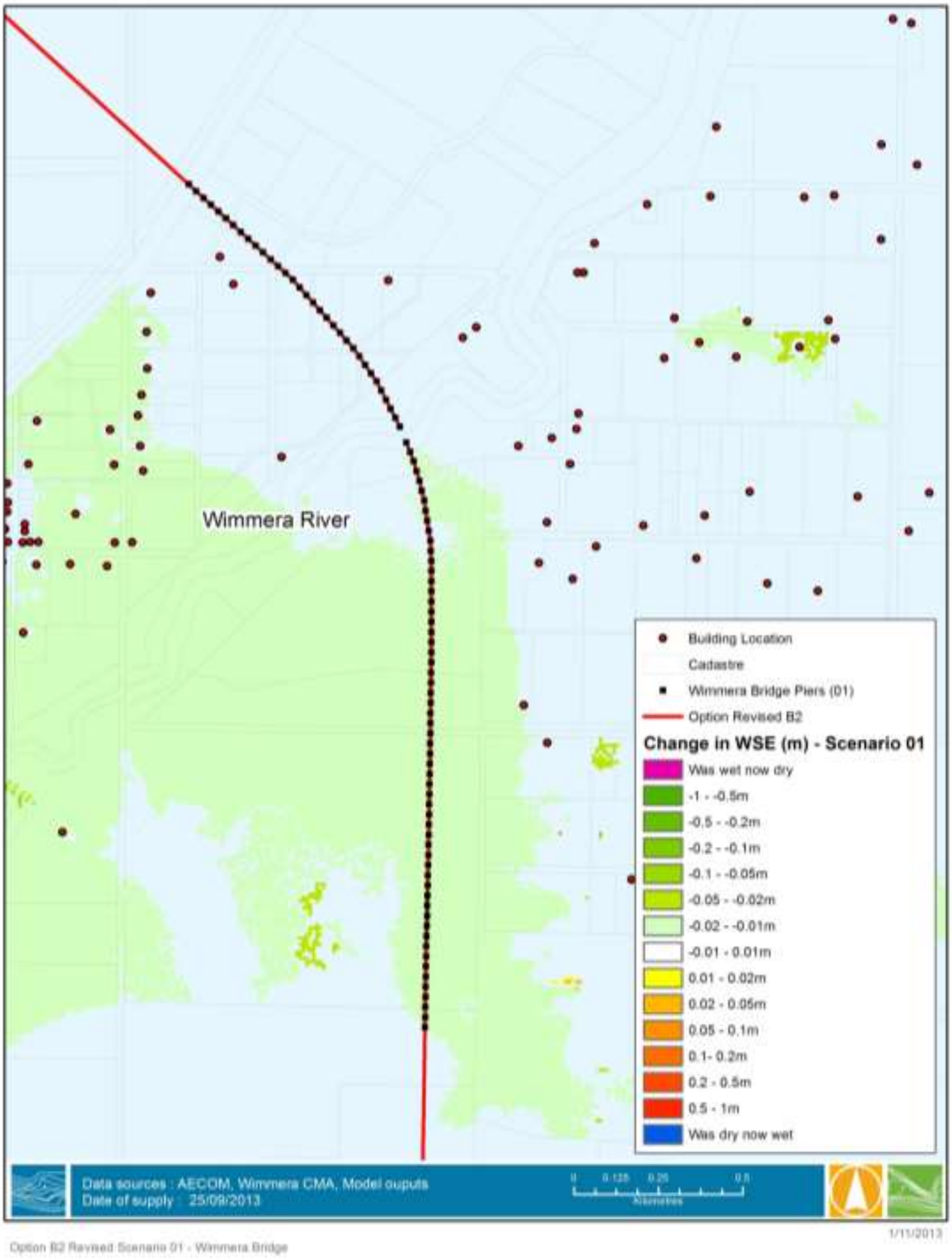

Figure 52 **Scenario 01, change in Water Surface Elevation at the Wimmera River**

10.3.3 Scenario 02

Similar to Scenario 01 Option B2 was modelled with the inclusion of two bridges and two major culvert locations. The length of bridge and culverts structures match AECOM's conceptual estimates.

The number of 1.8 m x 0.9 m culverts modelled at each location is shown below in Table 25.

Table 25 Modelled drainage infrastructure for Option B2

Waterway Crossing	Culvert bank No.	Length (m)	No. of culverts
Burnt Creek overland flow 02a	1	480	240
Burnt Creek overland flow 02b	1	200	100

The bridge infrastructure was defined using piers similar to Scenario 01. The Burnt Creek and Wimmera River Bridge pier locations are shown in conjunction with the model results.

10.3.3.1 Model Results

The hydraulic model results are displayed in the same manner as Scenario 01 with the change caused by the bypass alignment and its associated infrastructure showing slight changes in the maximum water surface elevation for Scenario 02. These are predominantly surrounding the major waterway structures at Burnt Creek and the Wimmera River.

The change to maximum water levels as a result of the B2 alignment and associated drainage infrastructure incorporated in Scenario 02 is shown in **Figure 53** with a zoom of Burnt Creek and the Wimmera River shown in **Figure 54** and **Figure 55** respectively.

The model results show increases in water surface level at both the Wimmera River and Burnt Creek. Increases at Burnt Creek are larger than that at the Wimmera River.

The largest increases at Burnt Creek are at the Burnt Creek Bridge, with increases also at Burnt Creek overland flow 2b. The increases at the Burnt Creek Bridge reach a maximum of 15 cm immediately upstream of the bypass alignment and 5 cm at the bridge. These increases reduce to approximately 5 cm at 150 m upstream of the bridge and 0.2 cm 300 m upstream of the bridge. The closest building upstream of the bypass alignment is not impacted and is outside the flood extent.

At the Wimmera River Bridge the reduction in bridge length at the northern end has caused an increase in WSE upstream of the bypass alignment. The increase reaches a maximum of 1.5 cm at the section of reduced bridge length and 0.5 cm at the bridge structure itself. There is one building impacted by the increase which reaches 0.6 cm. This building has a floor level approximately 30 cm above the existing 100 year ARI flood level.

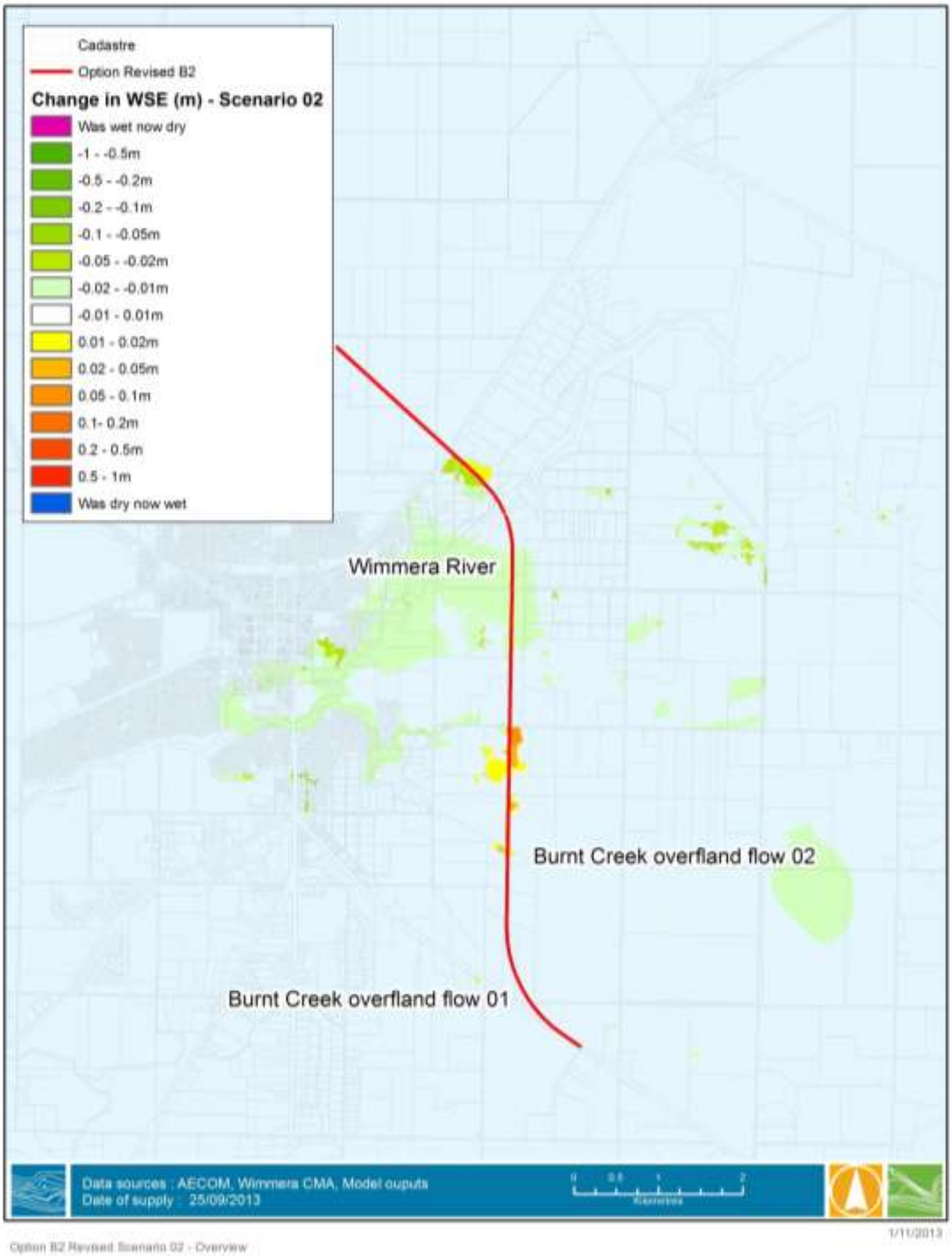

Figure 53 Change in maximum water levels across the model extent

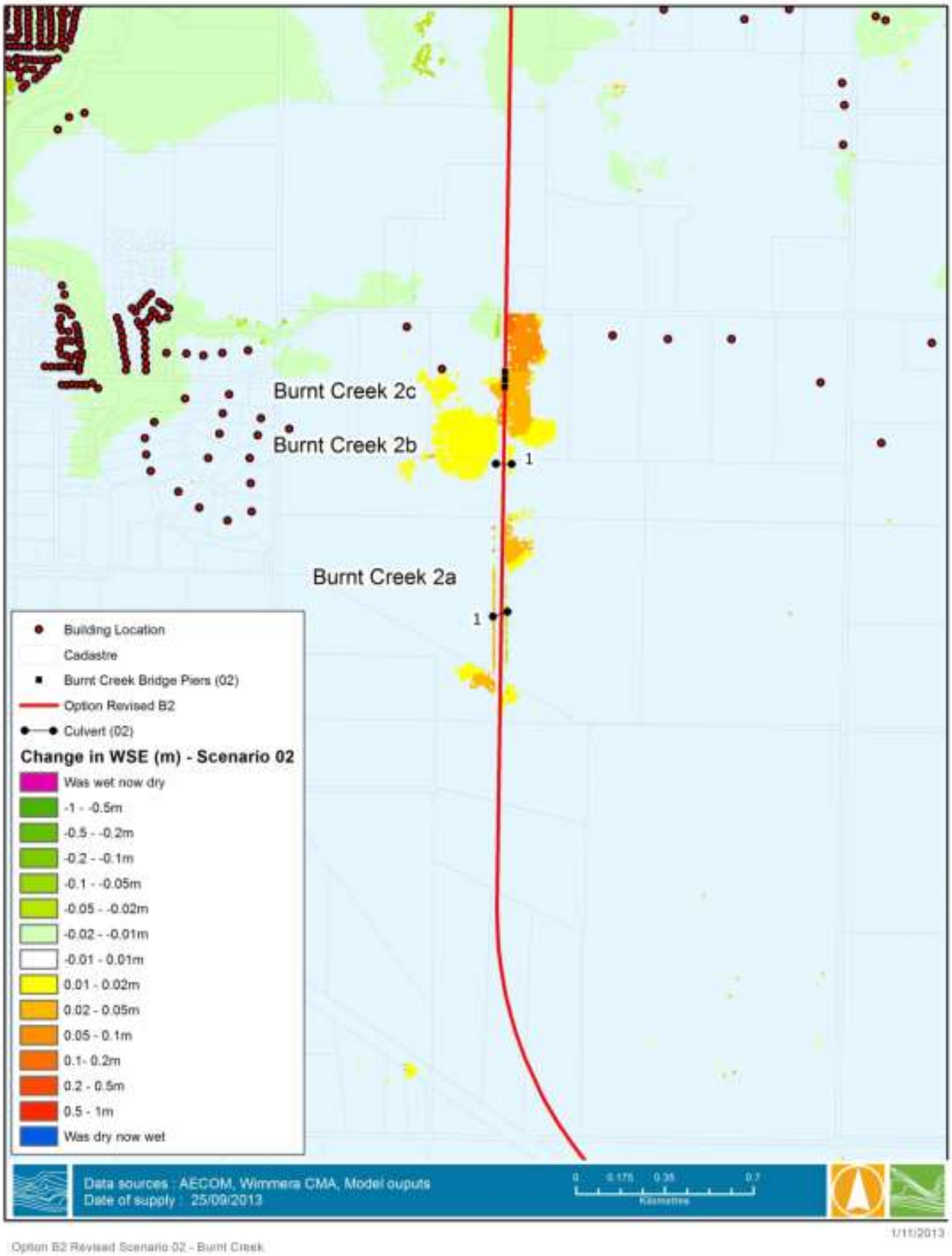

Figure 54 **Change in maximum water levels at Burnt Creek**

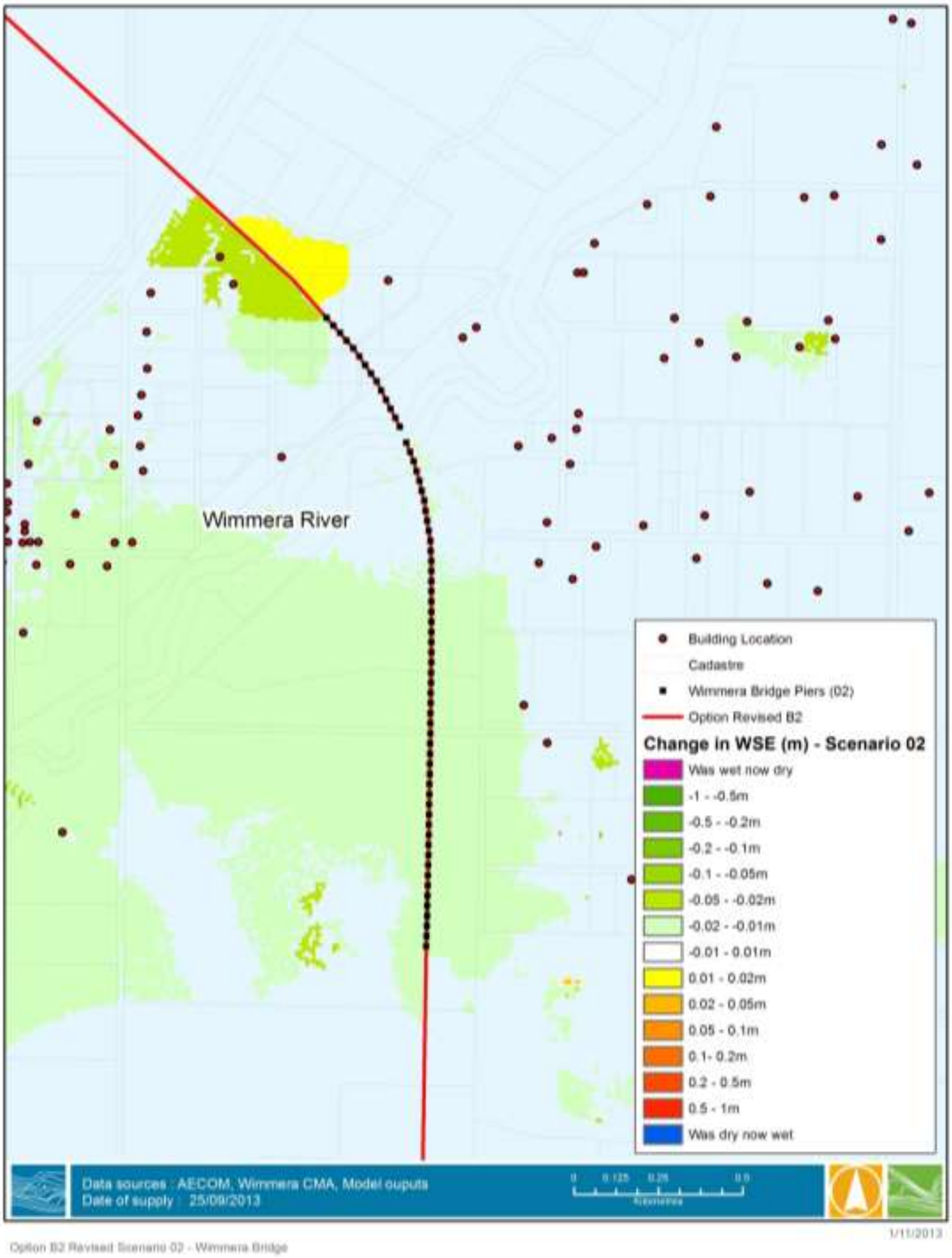

Figure 55 **Change in maximum water levels at the Wimmera River**

10.4 Discussion

Scenario 01 has larger floodplain infrastructure and shows negligible change to WSE, with the maximum change 1.5 cm immediately upstream of the Burnt Creek culvert/bridge configuration. No buildings or major infrastructure are impacted as a result of the bypass alignment and associated floodplain infrastructure in Scenario 01.

Scenario 02 includes a lesser length of floodplain structures and shows larger changes to WSE. At Burnt Creek a maximum of 15 cm is observed immediately upstream of the bypass alignment, however no buildings are impacted and the afflux is reduced to zero at approximately 300 m from the alignment. The Wimmera River Bridge shows an increase of 1.5 cm immediately upstream of the bypass, this increase impacts on one building with a 0.6 cm increase; however the building floor level is approximately 30 cm above flood level.

The major difference between the scenarios is the bridge infrastructure at Burnt Creek and the Wimmera River. The Wimmera River Bridge modelled in Scenario 01 is 400 m longer at the northern end and 200 m longer at the southern end than in Scenario 02. The Burnt Creek structure is also approximately 80 m shorter. At both of these locations an increase in infrastructure would reduce the impact of the bypass.

10.5 Recommendations/Conclusion

It is recommended VicRoads meet with Wimmera CMA to discuss the model results presented in this report. A solution between Scenario 01 and 02 is considered possible, mitigating the additional cost caused by the increase in bridge infrastructure. Water Technology also believes additional optimisation can be made reducing the number of culverts required by strategic spacing and placement.

11.0 ACRONYMS, GLOSSARY AND REFERENCES

Acronyms

Abbreviation	Expanded Term
ARI	Average Recurrence Interval
AEP	Average Exceedance Probability
BoM	Bureau of Meteorology
FFA	Flood Frequency Analysis
WCMA	Wimmera Catchment Management Authority

Glossary

Term	Definition
Annual Exceedance Probability (AEP)	Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded; it would occur quite often and would be relatively small. A 1%AEP flood has a low probability of occurrence or being exceeded; it would be fairly rare but it would be relatively large.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level. Introduced in 1971 to eventually supersede all earlier datum.
Average Recurrence Interval (ARI)	Refers to the average time interval between a given flood magnitude occurring or being exceeded. A 10 year ARI flood is expected to be exceeded on average once every 10 years. A 100 year ARI flood is expected to be exceeded on average once every 100 years.
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Design flood	A significant event to be considered in the design process; various works within the floodplain may have different design events. E.g. some roads may be designed to be overtopped in the 1 in 1 year or 100%AEP flood event.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.

Term	Definition
Flash flooding	Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain which causes it.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
Flood frequency analysis	A statistical analysis of observed flood magnitudes to determine the probability of a given flood magnitude.
Flood hazard	Potential risk to life and limb caused by flooding. Flood hazard combines the flood depth and velocity.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Flood storages	Those parts of the floodplain that are important for the temporary storage, of floodwaters during the passage of a flood.
Geographical information systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of the principal watercourses in a catchment. Mainstream flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.
Management plan	A document including, as appropriate, both written and diagrammatic information describing how a particular area of land is to be used and managed to achieve defined objectives. It may also include description and discussion of various issues, special features and values of the area, the specific management measures which

Term	Definition
	are to apply and the means and timing by which the plan will be implemented.
Ortho-photography	Aerial photography which has been adjusted to account for topography. Distance measures on the ortho-photography are true distances on the ground.
Peak flow	The maximum discharge occurring during a flood event.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Average Recurrence Interval.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Topography	A surface which defines the ground level of a chosen area.
WSE	Water Surface Elevation, meters above sea level.

References

Water Technology, 2009 - Wimmera River - Yarriambiack Creek flow modelling

Water Technology, 2006 – Glenorchy Flood Study

Water Technology, 2003 – Horsham Flood Study

12.0 APPENDIX A –FREQUENCY ANALYSIS

12.1 Previous Studies

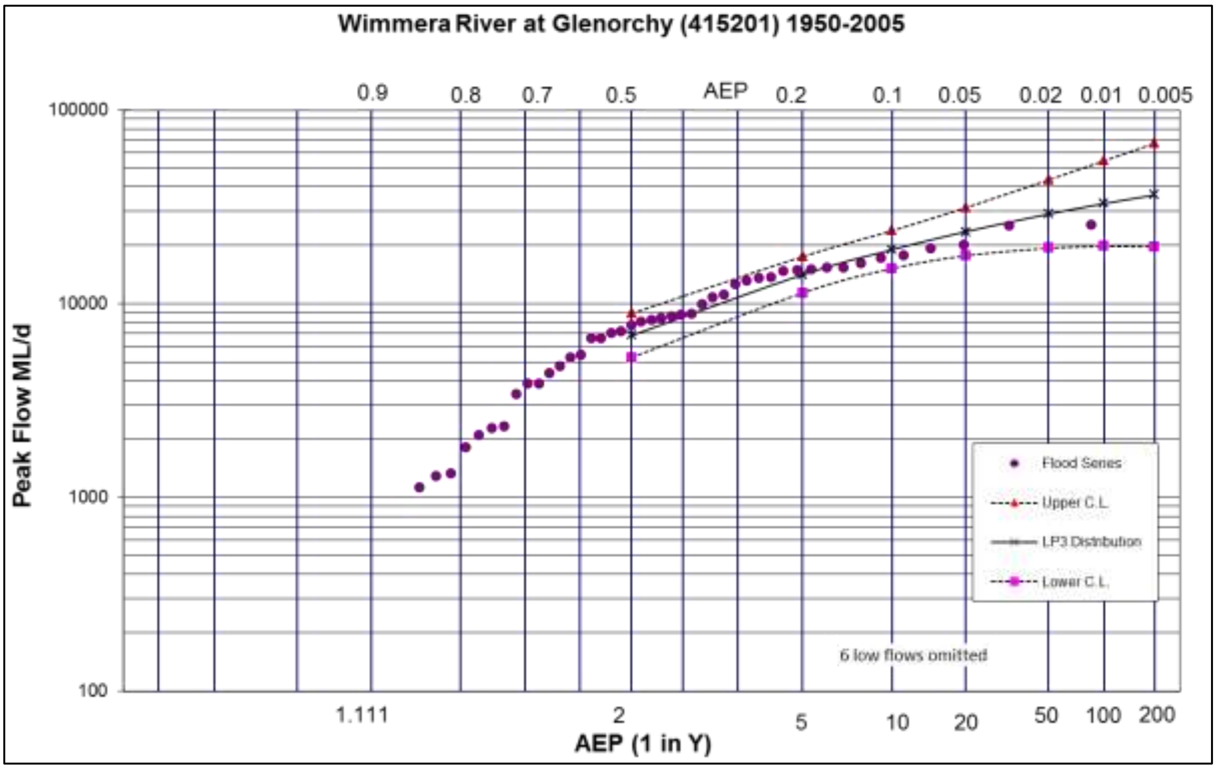

Figure 56 **Wimmera River at Glenorchy – Glenorchy Flood Study, 2006**

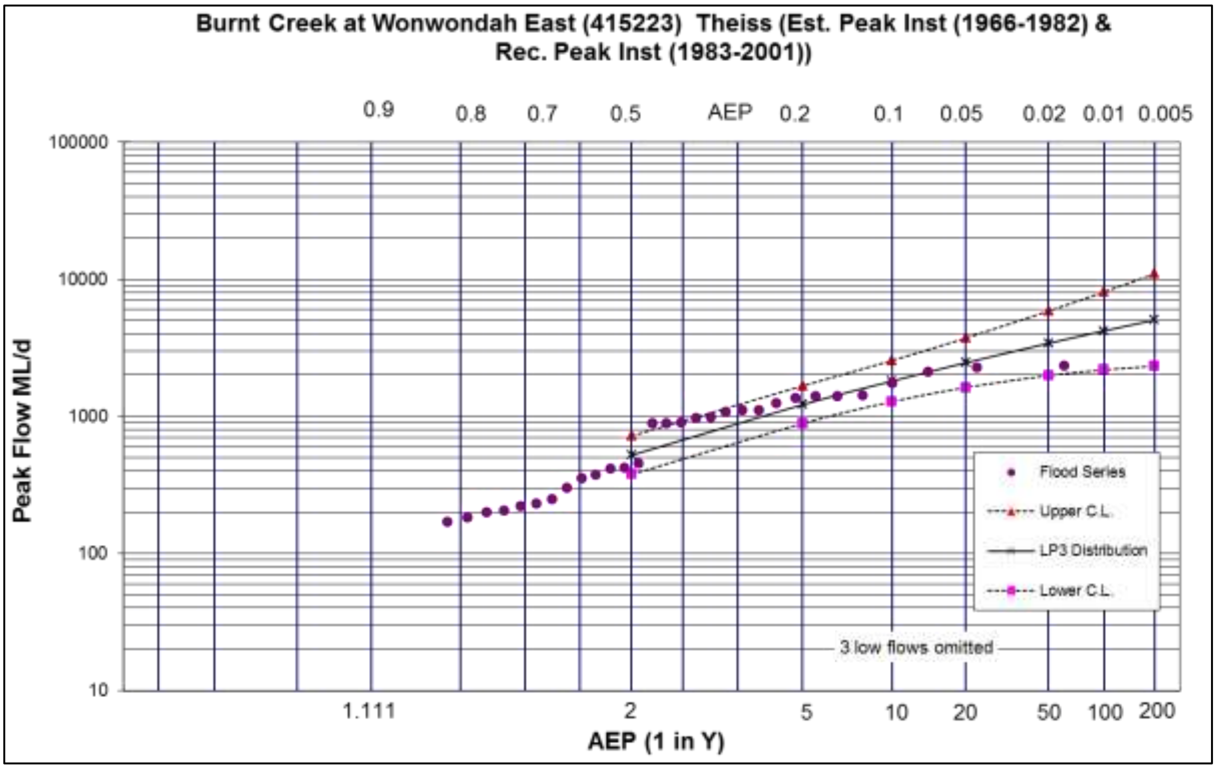

Figure 57 **Burnt Creek at Wonwondah East – Wimmera River and Yarriambiack Creek Flows Study, 2009**

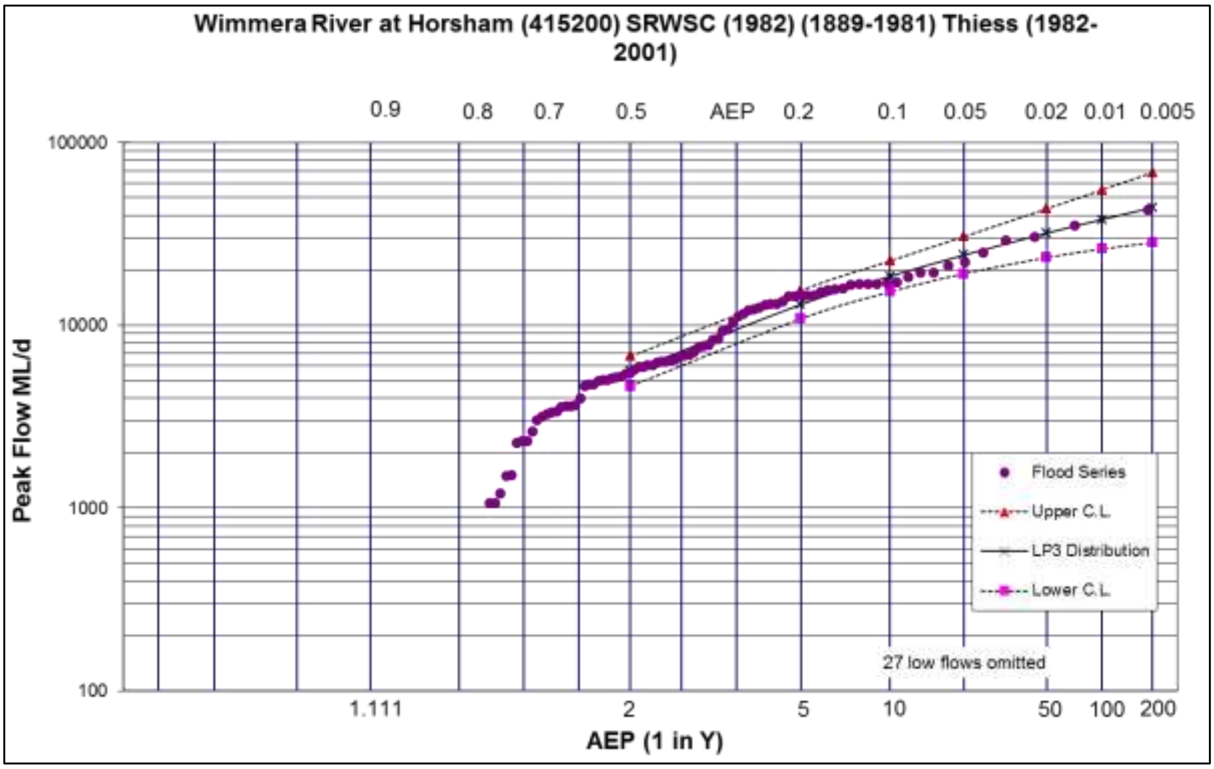

Figure 58 Wimmera River at Horsham – Wimmera River and Yarriambiack Creek Flows Study, 2009

12.2 Updated Flood Frequency Analysis

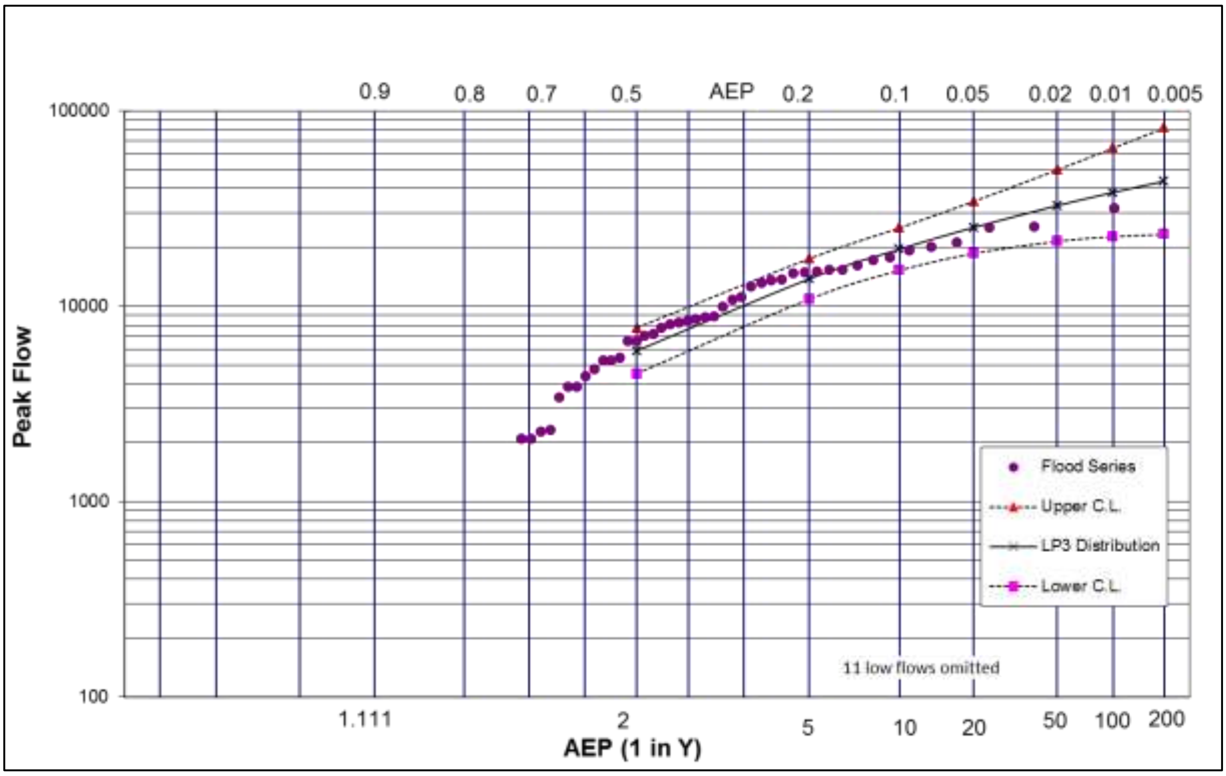

Figure 59 Wimmera River at Glenorchy – Revised

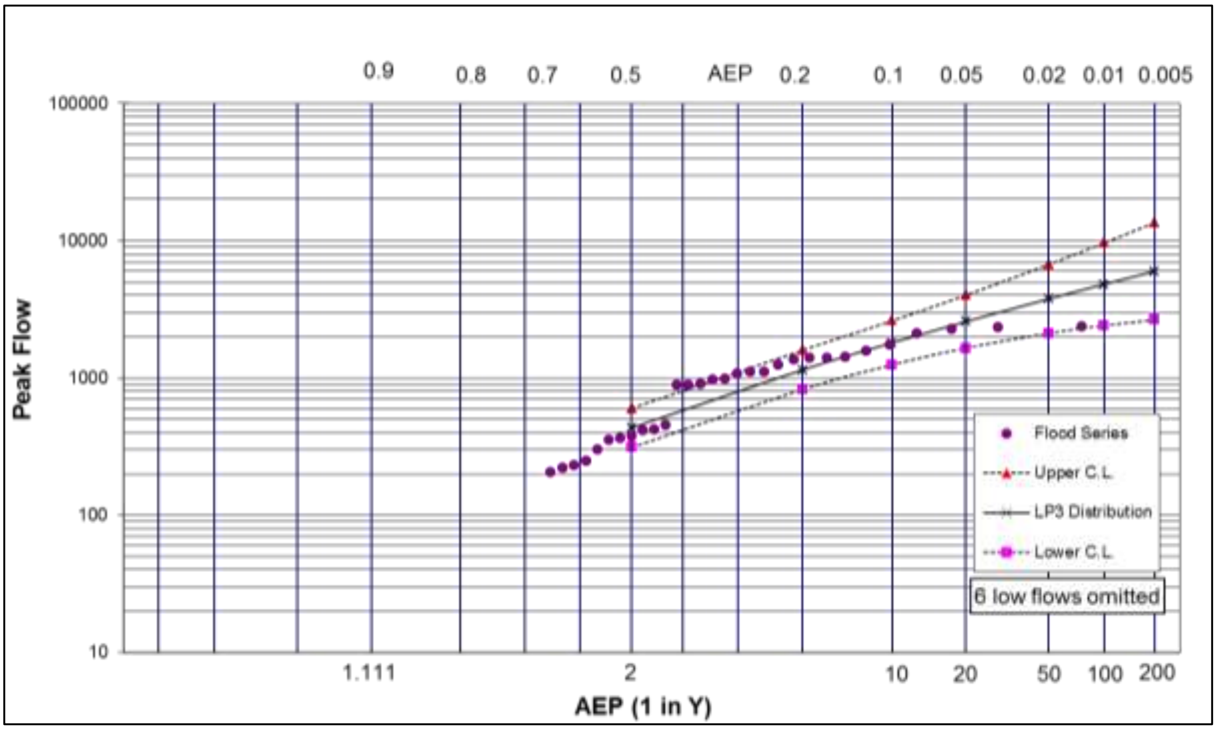

Figure 60 **Burnt Creek at Wonwondah East – Revised**

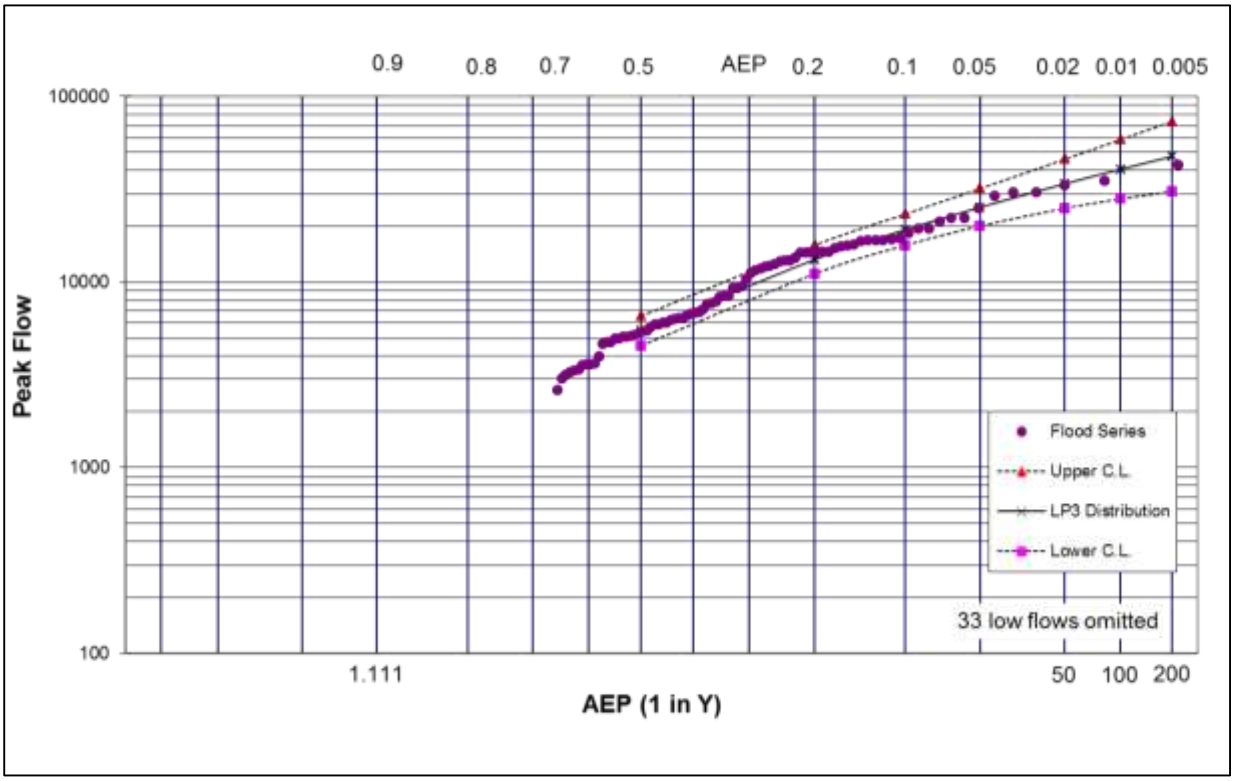

Figure 61 **Wimmera River at Horsham – Revised**

13.0 APPENDIX B - MODEL VERIFICATION

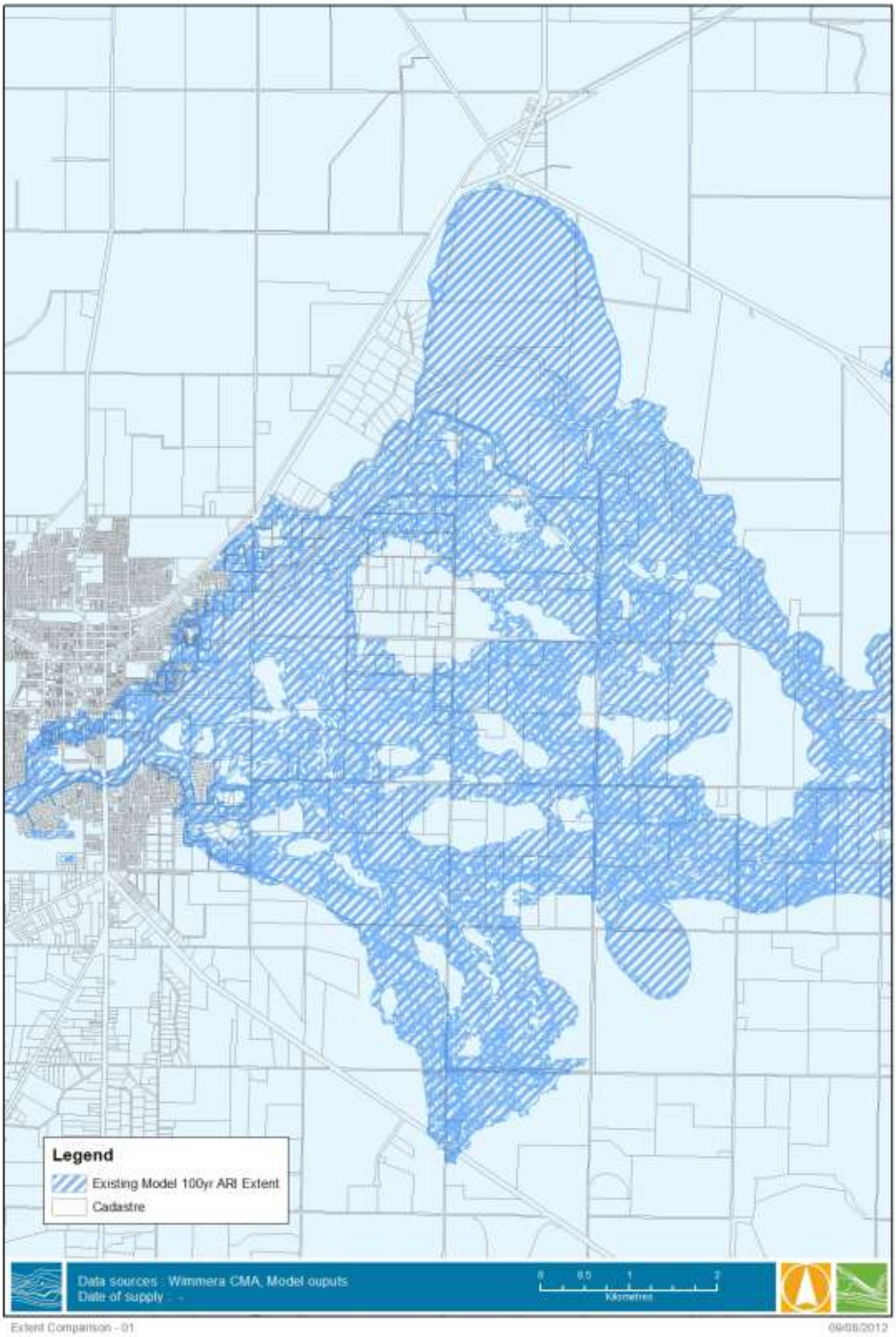

Figure 62 Previous study 100 year ARI model extent

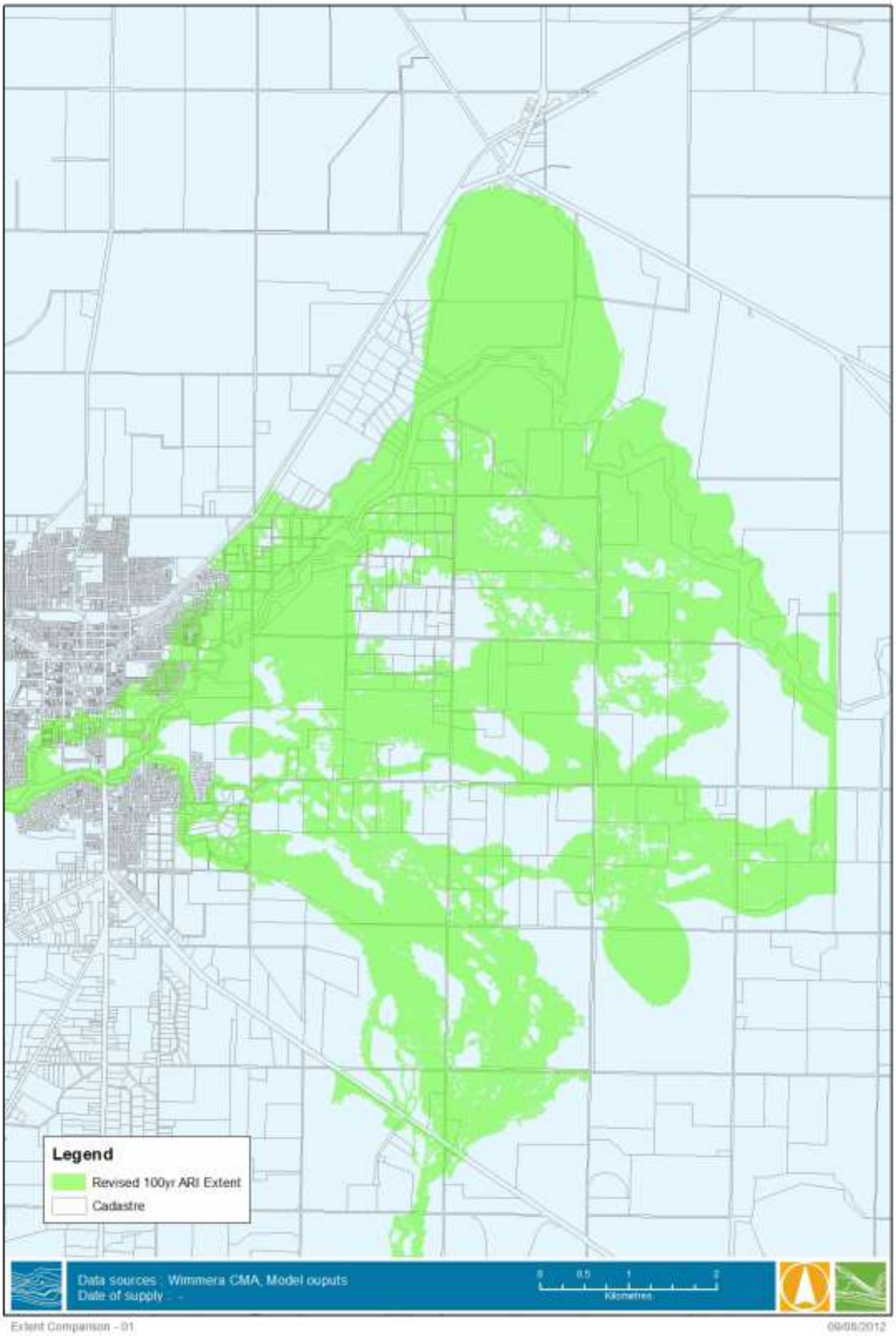

Figure 63 Revised extended model 100 year ARI model extent

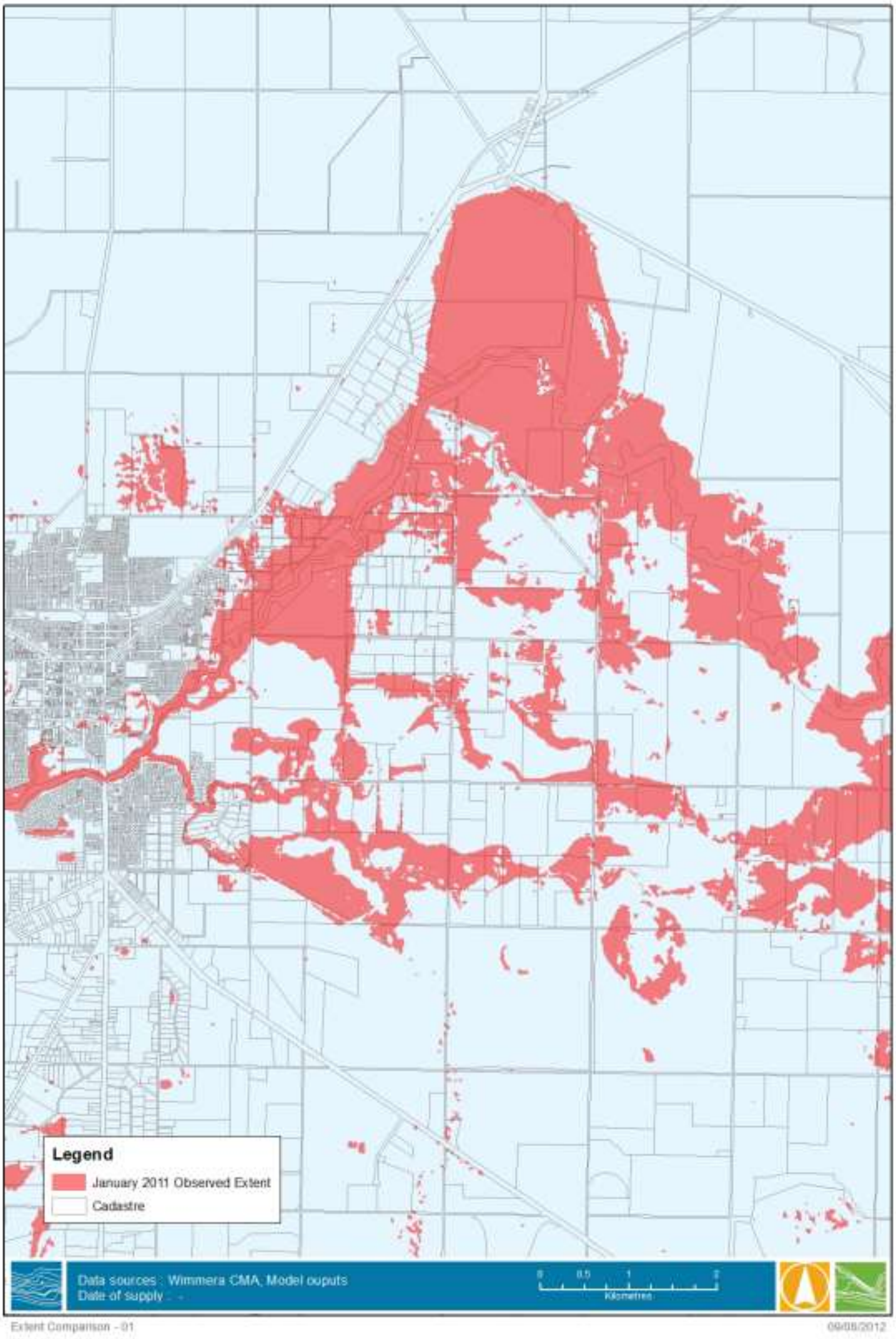

Figure 64 **January 2011 event observed extent**

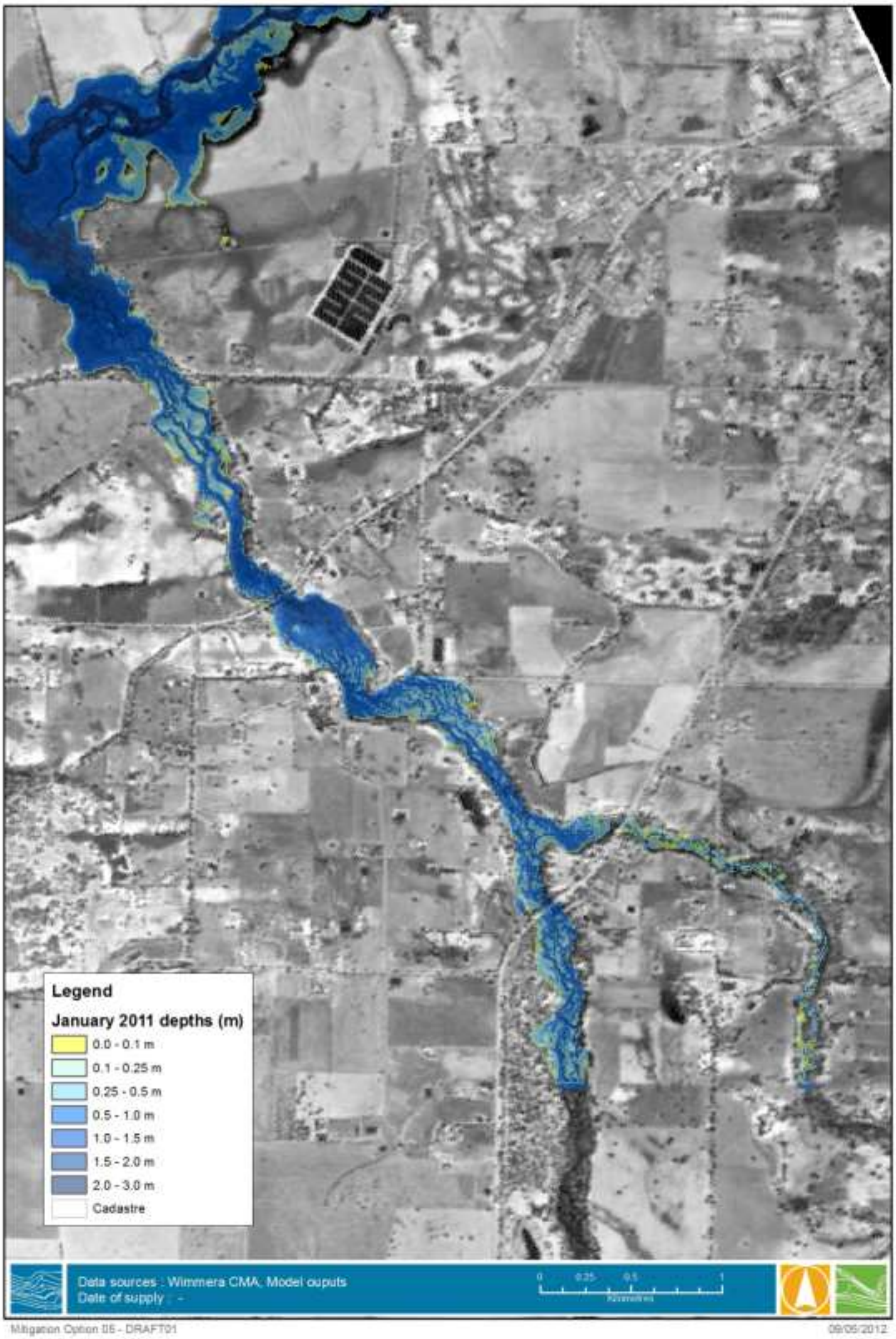

Figure 65 **Scenario 1, January 2011, Mackenzie River inflow – Mackenzie River at McKenzie Creek, Bungalally Creek inflow – 20% Burnt Creek at Wonwondah East**

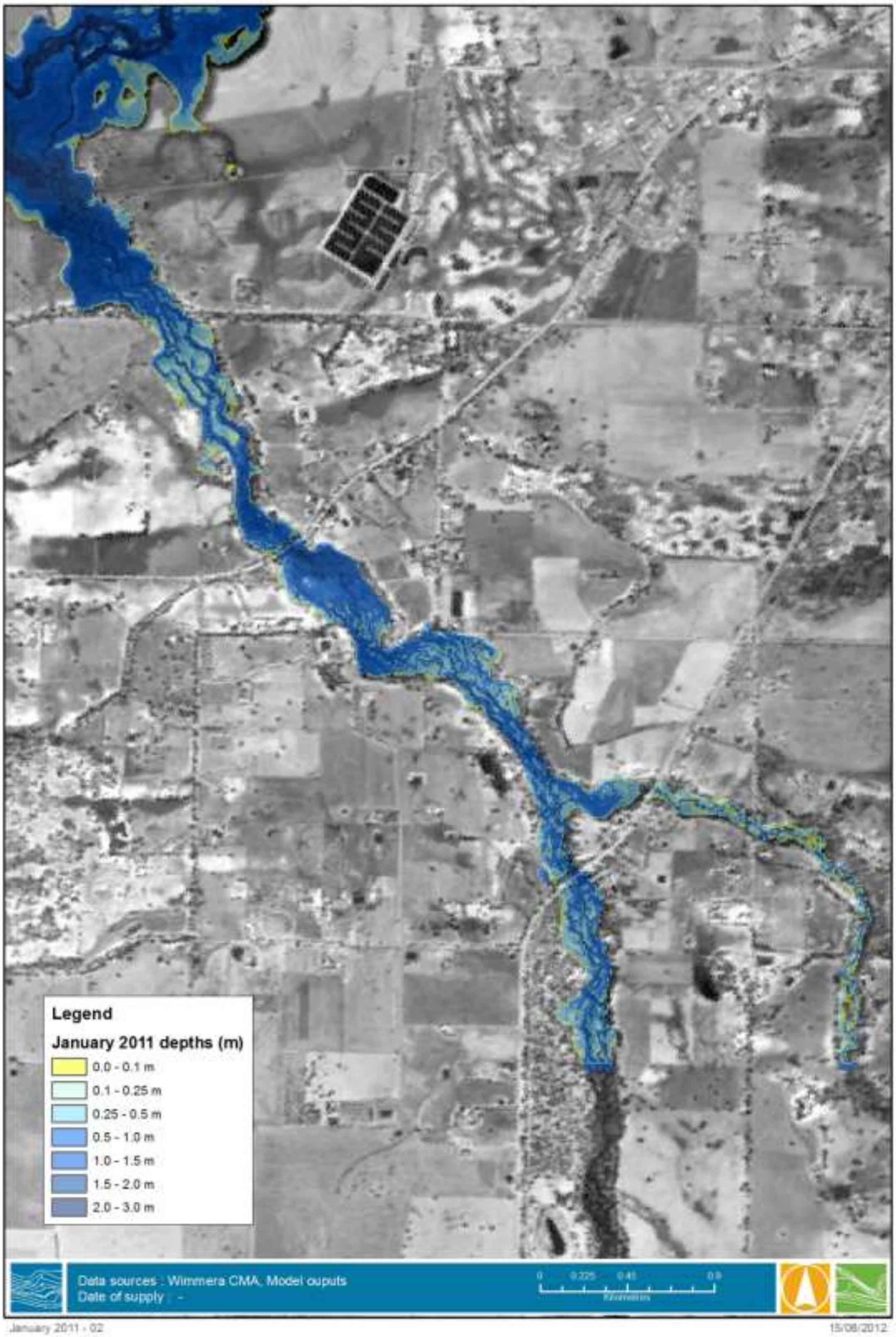

Figure 66 **Scenario 3, January 2011, Mackenzie River inflow – Mackenzie River at McKenzie Creek, Bungalally Creek inflow – 40% Burnt Creek at Wonwondah East**