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Report

Shepparton Mooroopna 1% AEP Flood Mapping Project

Greater Shepparton City Council

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GOULBURN BROKEN CATCHMENT MANAGEMENT AUTHORITY

GREATER SHEPPARTON

Front Cover Image: Shepparton 1974 Flood

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EXECUTIVE SUMMARY

The supplementary Shepparton Mooroopna 1% AEP Flood Mapping Project has investigated flood behaviour within the study area and developed a detailed understanding of the flood risk profile through Shepparton and Mooroopna. The study provided an update to the mapping provided in the Shepparton Mooroopna Flood Mapping and Intelligence Study[1] undertaken in 2019 and supersedes the flood modelling undertaken for the 1% AEP flood event and incorporates Climate Change modelling. The updated modelling has provided a dataset for the Goulburn Broken Catchment Management Authority (GBCMA) and Greater Shepparton City Council (GSCC) to prepare planning controls for a proposed planning scheme amendment in line with the latest industry guidelines.

A review of the peak design flows for Broken and Goulburn River Flood Study[2] 2018 HARC report was undertaken and confirmed the model inflows used in the 2019 Water Technology study were appropriate and were again adopted in this study, following revised calibration using TUFLOW HPC. The conversion of the model to TUFLOW HPC has significantly increased model resolution throughout the study area while reducing model simulation time.

Flood model results are generally aligned with the results from the 2019 study, with localised changes due to development or changes to floodplain controls (irrigation channels/drains) as a result of the irrigation modernisation project. Importantly, the supplementary modelling reassessed flood risk for the Shepparton and Mooroopna areas and identified locations along the Goulburn River, Broken River and Seven Creeks that pose a high flood risk. Flood mapping data developed during this study has been provided in the Victoria Flood Database format (now called Spatial Data Specification) and is recommended for upload to FloodZoom enabling emergency response agency staff access to the data.

The study has also carried out the following assessments:

- Key bridge blockage.
- Pipe blockage.
- Levee failures in the lower Goulburn River floodplain.
- Climate Change Analysis (Increased Flows)

The assessments found the likelihood of blockage to major structures was relatively low due to catchment characteristics. A conservative blockage approach showed relatively minor impacts, again due to characteristics of the wide and flat floodplain. The reduction in model simulation time will enable future assessment of mitigation or infrastructure works to occur much faster, allowing for assessment of multiple options. Climate Change modelling results suggested the peak flood levels throughout the study area increased by around 150mm compared with existing conditions.

[1] Water Technology 2019, *Shepparton Mooroopna Flood Mapping and Flood Intelligence Study*
[2] HARC 2018, *Goulburn and Broken Rivers Flood Study*, Hydrology Report

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1 INTRODUCTION

Water Technology undertook the supplementary Shepparton Mooroopna 1% AEP Flood Mapping project following the completion of Shepparton Mooroopna 1% AEP Flood Mapping and Flood Intelligence Project for Goulburn Broken Catchment Management Authority (GBCMA) and Greater Shepparton City Council (GSCC) in 2019. The aim of this project was to update the existing floodplain mapping based on the latest available information and produce mapping that can be used to inform a planning scheme amendment to amend flood controls (Land Subject to Inundation Overlay, Floodway Overlay and Urban Floodway Zone) for the study area in the Greater Shepparton Planning Scheme. The key driver for this project was the availability of updated LiDAR captured in late 2019. The new LiDAR dataset provides a more accurate representation of the ground topography compared to LiDAR captured more than ten years ago. Furthermore, the study involved updates to the previously developed TUFLOW model, including the use of latest model software, changes to topographic features and hydraulic structures within the floodplain, following the completion of the modelling used in the Shepparton Mooroopna Flood Mapping and Intelligence Project[1]. The May 1974 and October 1993 flood events used in the 2019 study were again used to calibrate the hydraulic model before proceeding the 1% AEP design modelling. Additional Climate Change modelling incorporating an increase in design flows similar to the 0.5% AEP hydrology and the Broken and Goulburn Investigation carried out by HARC[2] in 2018, was also undertaken.

2 BACKGROUND

Shepparton and Mooroopna are situated on the Goulburn River at the confluence with the Broken River and Seven Creeks. The study area extended upstream of Shepparton to Toolamba and downstream of Shepparton to Loch Garry on the Goulburn River, upstream of Shepparton to Kialla East on the Broken River and upstream of Shepparton to Kialla West on Seven Creeks. Figure 2-1 shows the hydraulic model and flood mapping extent used for the 1% AEP mapping. The Seven Creeks inflow boundary was placed upstream of the East Goulburn Main Channel for the Climate Change analysis (Section 6).

[1] Water Technology 2019, Shepparton Mooroopna Flood Mapping and Flood Intelligence Study
[2] HARC 2018, *Goulburn and Broken Rivers Flood Study*, Hydrology Report

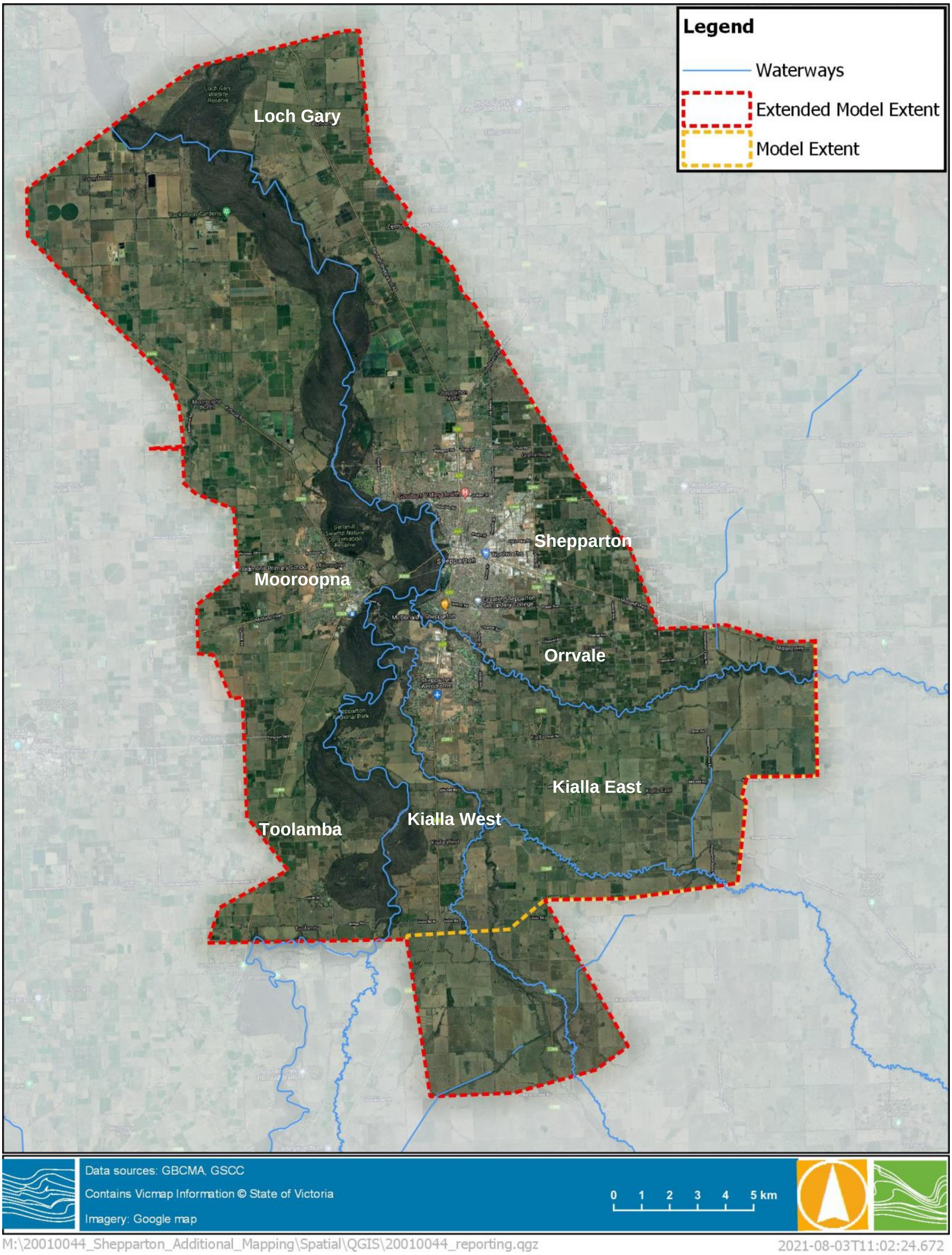

FIGURE 2-1 HYDRAULIC MODEL EXTENT

3 METHODOLOGY

The TUFLOW model developed as part of the Shepparton Mooroopna Flood Mapping and Flood Intelligence Project was updated for several reasons following the completion of the study in 2019. This section documents the changes made on the TUFLOW model.

3.1 Model Resolution and Schematisation

The TUFLOW model developed in the 2019 Shepparton Mooroopna Flood Mapping and Flood Intelligence Project[1] was a TUFLOW Classic model which was built as multi-domain model. The majority of the model used a 10 m grid resolution and the Goulburn River downstream of the Shepparton Golf Course was modelled at a 20 m resolution.

Since the completion of the 2019 project, TUFLOW HPC has been introduced which utilises graphics computing power (GPU cards) to improve computational efficiency, and models can therefore be run with finer grid resolution within a reasonable run time. TUFLOW Classic is an implicit finite model and utilises CPU processing power. TUFLOW HPC is an explicit solver of the 2D Shallow Water Equation and is both volume and momentum conserving. Improvement in model simulation time is achieved through the processing power of GPUs as well as the ability to use an adaptive time step, that can provide further efficiencies for model simulations.

In this project, the TUFLOW – Classic model used in the previous project was converted to a TUFLOW – HPC model with a 5x5 m grid resolution and produced outputs at 2.5 metre resolution. This reduced model simulation time for design events from 80-90 hours down to around 12 hours. A comparison of flood levels for the 1% AEP Goulburn dominant event was compared for the TUFLOW Classic and TUFLOW HPC schematisation early in the project. Flood levels were around 1-2cm higher in the Goulburn River upstream of Shepparton, while through Shepparton results were less than 1cm different. Further downstream, the TUFLOW HPC results were slightly lower (2-5cm) than the TUFLOW Classic. This is likely due to the model resolution through this area changing from 20m to 5m as well as the change in solution scheme (implicit to explicit). Overall the levels across most of the study area are similar and do not show major differences.

3.2 Model Topography

The GBCMA and GSCC were able to secure LiDAR for Shepparton, Kialla and Mooroopna townships in late 2019. This LiDAR is a significant update on the previously available LiDAR captured in 2011 as part of the Index of Stream Condition (ISC) project. The LiDAR was captured as part of the Department of Environment, Water, Land and Planning's (DELWP) CIP program. Full metadata and capture details are available via the GBCMA or DELWP. The LIDAR dataset was provided to Water Technology as a 1m resolution Digital Elevation Model (DEM) which covers much of the model area.

It is recommended that GBCMA and GSCC request new developments within the study area floodplain provide a design surface or equivalent to allow the model to be updated on a continual basis ensuring the model stays relevant and reduces the requirement for LiDAR to be flown regularly.

3.2.1 Verification of new 2019 LiDAR

The new LiDAR captured in late 2019 was verified to existing field survey taken on the Midland Highway bridge between Shepparton and Mooroopna (The Causeway). Seven additional road survey transects were made available by GBCMA in late 2020 to further strengthen the verification and check for any spatial bias in the accuracy of the new 2019 LiDAR. The 2019 LiDAR was compared to the surveyed elevations across the seven new transects, along with the existing survey. The new 2019 LiDAR was found to be consistently around 4 - 5cm lower than the surveyed levels, and never outside the expected LiDAR accuracy of ± 10cm outlined in the Metadata, at any of the eight transects. The verification found the new 2019 LiDAR is suitable to be used for the revised hydraulic modelling. Further details of the LiDAR verification can be found in Appendix A.

3.3 Bridge structures

Water Technology undertook a site visit to the study area and measured several key bridge structures that were not previously included in the model or were modelled with a simple approach. Additional bridge structure information under Pyke Road in the Drain 11 irrigation channel was also added in the model provided by GBCMA. A summary of the additional bride structure information is outlined in Table 3-1.

TABLE 3-1 SUMMARY OF BRIDGE STRUCTURE UPDATES

Waterway	Location	Modelling approach	Status
Unnamed Creek	Wanganui Rd	2D – Layered Flow	Updated from 1D XS
Broken River	Archer Rd	1D – Bridge/Weir	Updated from 1D XS
Seven Creek	Mitchell Rd	1D – Bridge/Weir	Updated from 1D XS
Seven Creek	Goulburn Valley Hwy	1D – Bridge/Weir	Updated from 1D XS
Seven Creek	Raftery Rd	1D – Bridge/Weir	Updated from 1D XS
Tributary from Goulburn River	Midland Highway (Daishs Bridge)	2D – Layered Flow	Existing, required update
Drain 11	Pyke Rd	1D – Bridge/Weir	Newly added (provided by GBCMA)

3.4 Culvert crossings and stormwater pipe network

The previous model incorporated pipes within Shepparton and Mooroopna greater than 750mm diameter. An updated GSCC pipe network dataset was provided and around 600 additional pipes were included in the updated model. Again, only pipes greater than 750 mm diameter were added to the model. The focus of this modelling was riverine flooding and most of the stormwater pipes largely deal with local stormwater. Figure 3-1 shows the major pipes that were included in the TUFLOW model.

Several culvert crossings under Toolamba Road and the railway were also captured during the site visit. These culverts were also added to the model.

In addition, GSCC provided design plans for works in Kialla that discharge stormwater from a residential development to Waterbird Creek and works on Midland Highway completed in 2014 as part of the Regional Floodway Works. Pipes were added to the model as shown in Figure 3-2.

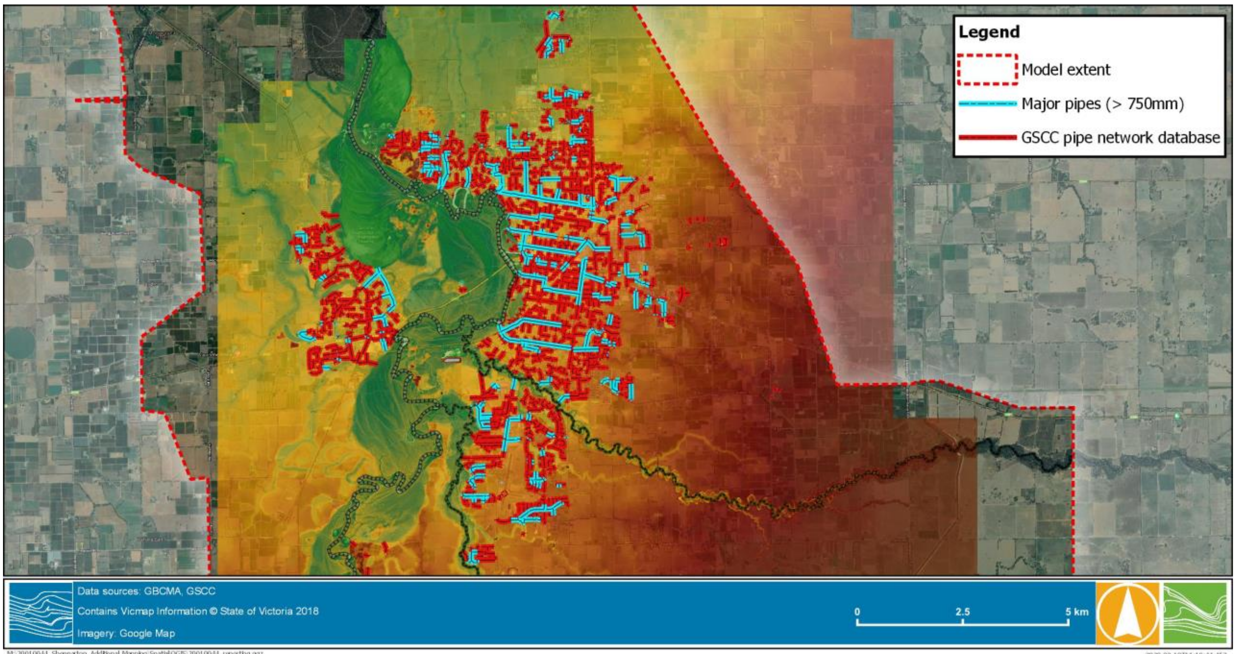

FIGURE 3-1 GSCC PIPE NETWORK DATABASE

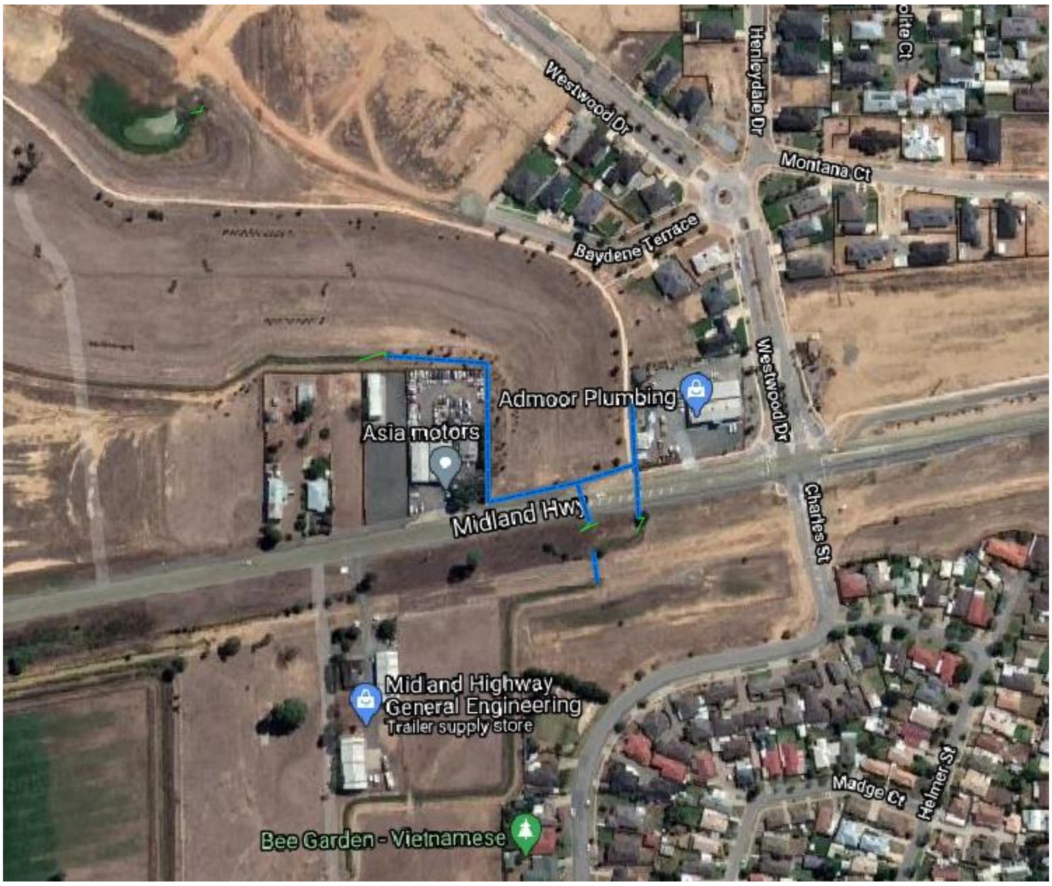

FIGURE 3-2 2014 REGIONAL FLOODWAY WORKS IN MIDLAND HIGHWAY

4 MODEL CALIBRATION

The October 1993 and May 1974 flood events used in the 2019 study were used again to calibrate the hydraulic model. Several minor changes to timing and inflow contribution allowed the model calibration to provide a closer replication of the events compared to the previous modelling. The changes were relatively minor and didn't impact design results significantly. The updated calibration ensured the change in schematisation did not significantly change the design levels significantly from the 2019 study and confirms the new software and solution scheme adopted is appropriate.

4.1 October 1993 Calibration

The model was calibrated to 66 survey points for the October 1993 flood event, giving confidence in the reliability of the reproduced flood behaviour. Calibration plots are shown in Figure 4-4. Of the 66 survey flood marks located within the study area, comparison between modelled and surveyed levels showed the following:

- 29 (44%) points were within +/- 100 mm.
- 17 (26%) points were within +/- 100 - 200 mm.
- 15 (23%) points were within +/- 200 - 300 mm.
- 2 (3%) points were below 300mm.
- 3 (5%) points were above 300mm.

On average the 66 observed flood levels that sit within the modelled flood extent show an average difference of 20 mm or below the surveyed flood marks, with a standard deviation of 209 mm.

The overall trend showed the modelled flood levels had no bias higher or lower than the surveyed flood levels and were predominately well within the satisfactory error interval expected for model calibration. Comparison with the previous calibration suggests there are several calibration points along the Broken River floodplain which are now lower than the previous calibration. This is due to the fact that the previous calibration utilised a LiDAR data set that was lowered by 100mm. The updated LiDAR used for the current study matches feature survey much closer in this area.Figure 4-1 below shows a plot of the water level at the Goulburn River at Shepparton gauge, comparing the model results to gauged data. The graph shows the rising and falling limbs of the modelled hydrograph are well represented within the model, and the peak elevation is approximately 110 mm higher than the gauged data.

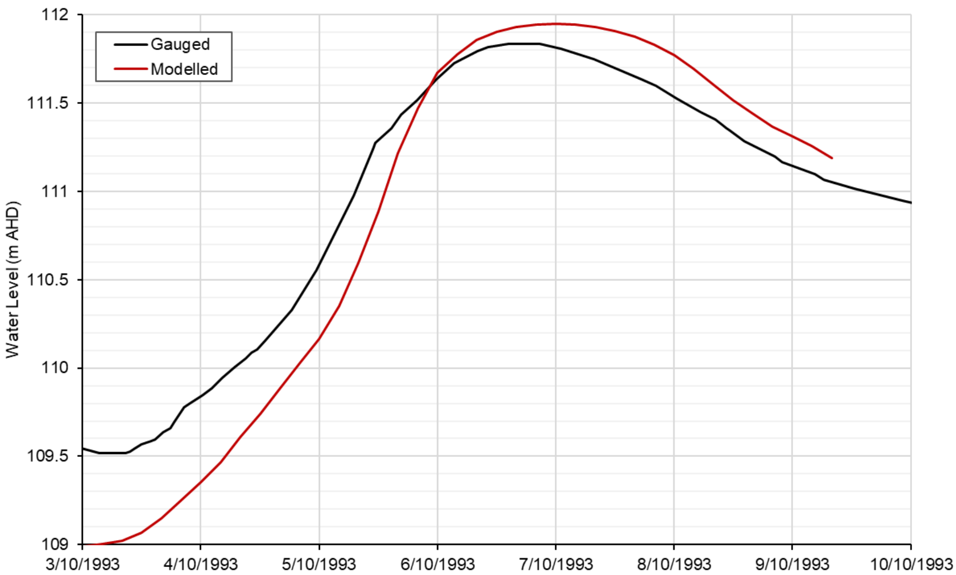

FIGURE 4-1 MODELLED AND GAUGED WATER LEVELS FOR THE GOULBURN RIVER AT SHEPPARTON (1993)

Figure 4-2 shows the modelled and observed water levels at the Broken River at Orrvale gauge, the graph shows the rising limb of the modelled hydrograph arrives slightly later than the gauged data, the peak elevation is well represented in the model, despite overestimating the peak by 157 mm. There is limited streamflow data for Seven Creeks at Kialla West for the 1993 flood event. A 36-hour period which shows the peak passing the gauge was captured, and is shown against the modelled flood levels in Figure 4-3. The model has the peak slightly delayed, however appears to represent the gauged hydrograph shape well.

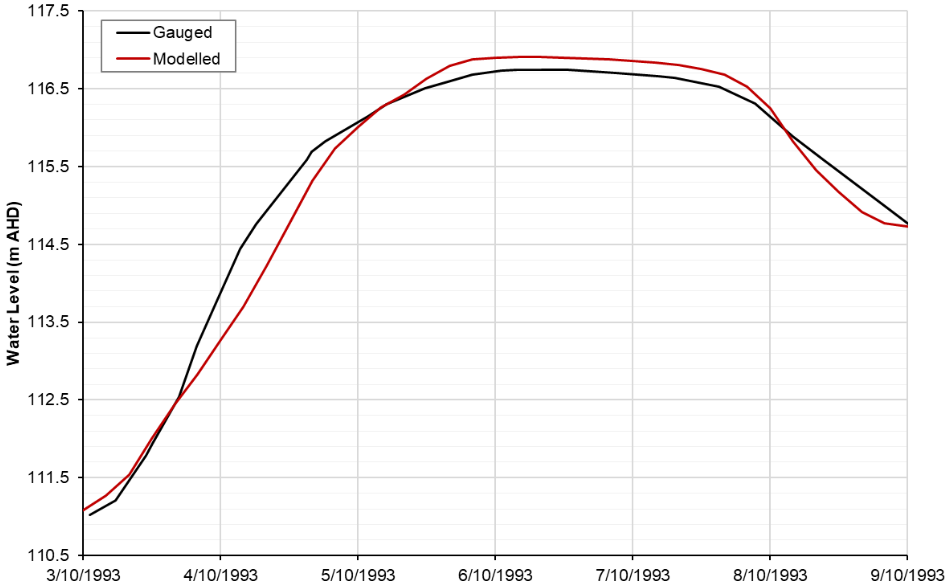

FIGURE 4-2 MODELLED AND GAUGED WATER LEVELS FOR THE BROKEN RIVER AT ORRVALE (1993)

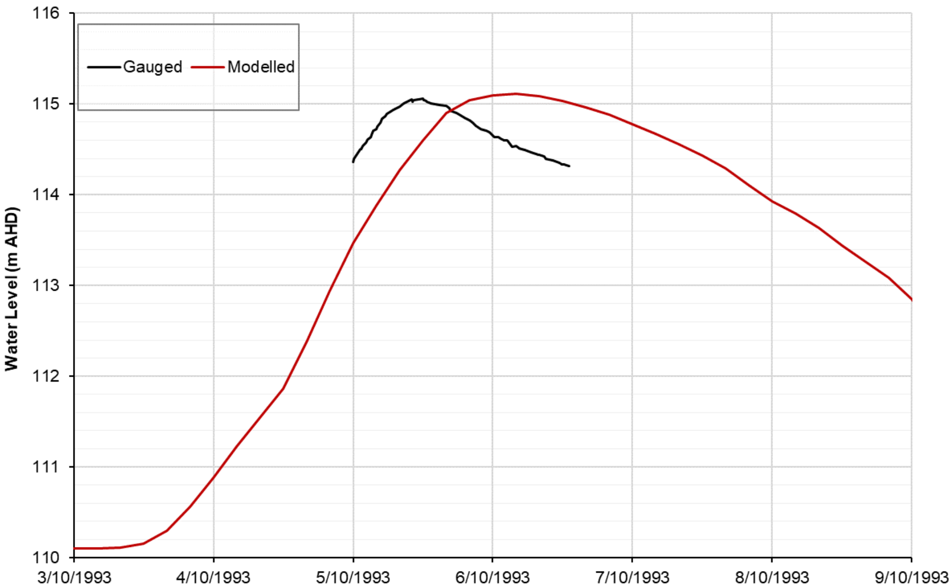

FIGURE 4-3 MODELLED AND GAUGED WATER LEVELS FOR THE SEVEN CREEKS AT KIALLA WEST (1993)

The modelled flood extent matched observations, gauged river heights and aerial photographs very well, and was deemed an acceptable calibration result. Figure 4-6 shows the water surface profiles along the three main waterways for the 1993 flood event. These are plotted with the chainage distance of the waterway along the x – axis and the running distances (provided by the GBCMA) have also been included at key features along the waterways.

4.1.1 Flood Behaviour

In the lead up to the October 1993 flood, the Goulburn River had sustained high water levels for the majority of September. The Broken River and Seven Creeks during this time were relatively low until they both received large inflows that started around 3rd October and lasted until early on the 9th October. The Goulburn River peaked again at the same time and stayed high until around the 16th October when it finally receded. Even though the peak in the Goulburn River was not as high upstream of Shepparton as it was in September, the combination of the three systems caused a peak water level of approximately 11.7 m at the Gauge in Shepparton on Wednesday 6th October.

Upstream of Shepparton on the Goulburn River, most of the flow was contained within the lower floodplain. The flows in the Goulburn River, Broken River and Seven Creeks were all larger than 2010, particularly in Seven Creeks where significant overbank flood flow occurred in surrounding low lying areas. Parts of Shepparton were inundated during the event and significant areas downstream of Shepparton were also inundated, particularly around the water treatment plant. The 1993 flood event is referred to as a 'Broken River and Seven Creeks dominant event'. This refers to the two systems mentioned being the dominant flood causing mechanism and the flows recorded on these systems being of higher magnitude compared to the Goulburn River during the flood event.

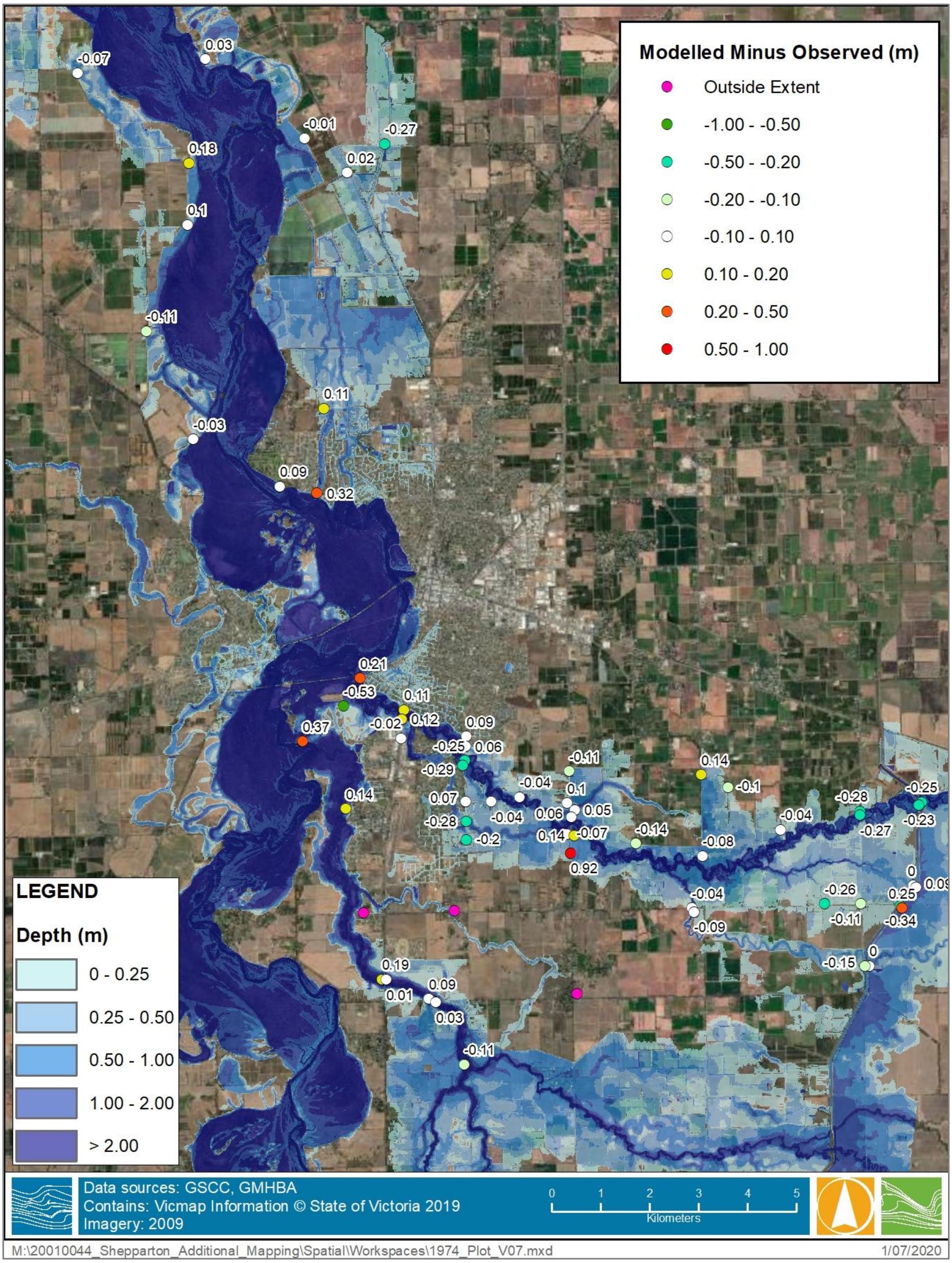

FIGURE 4-4 HYDRAULIC MODEL CALIBRATION PLOT – OCTOBER 1993 EVENT

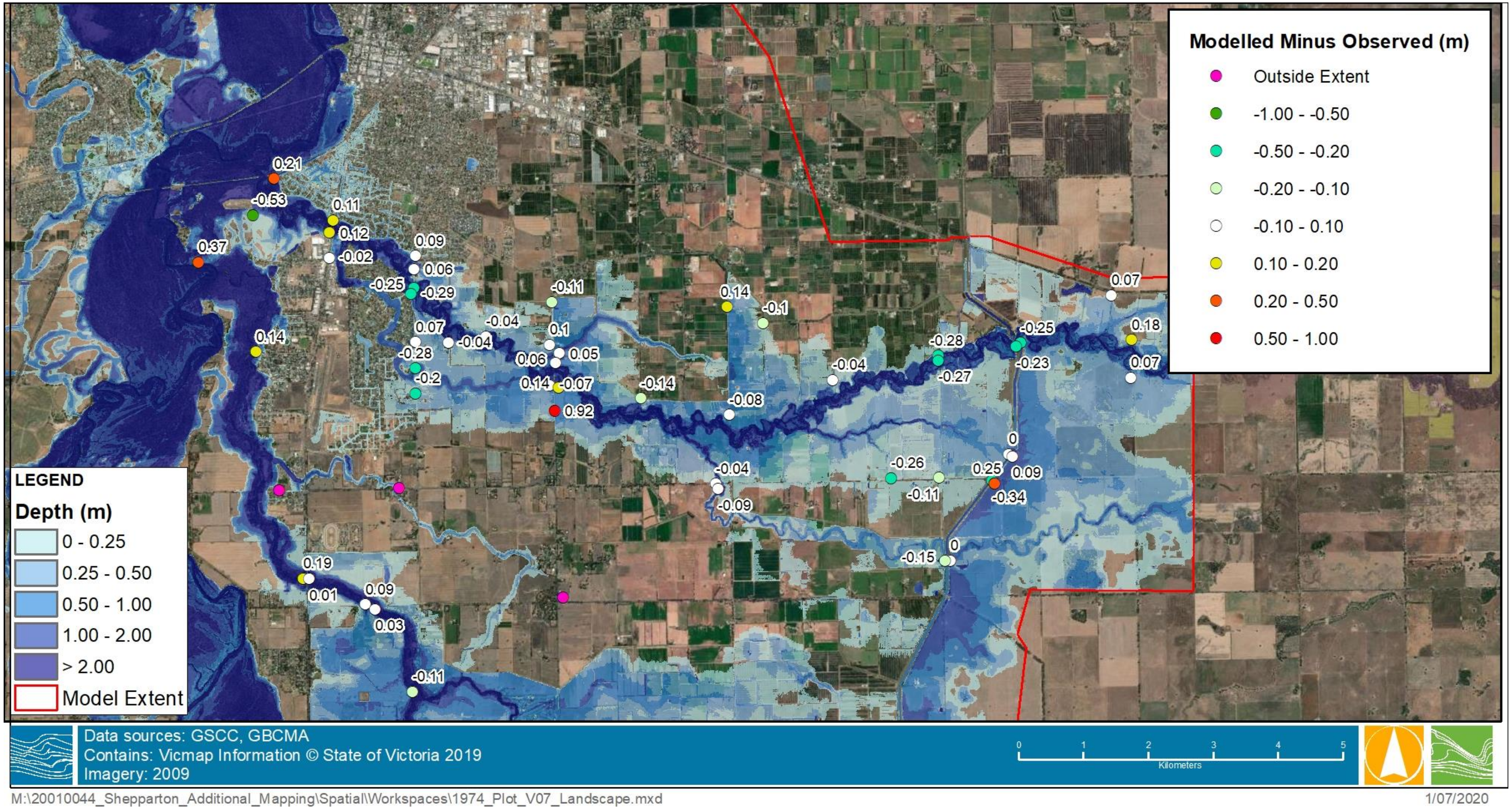

FIGURE 4-5 HYDRAULIC MODEL CALIBRATION PLOT – OCTOBER 1993 EVENT (BROKEN RIVER)

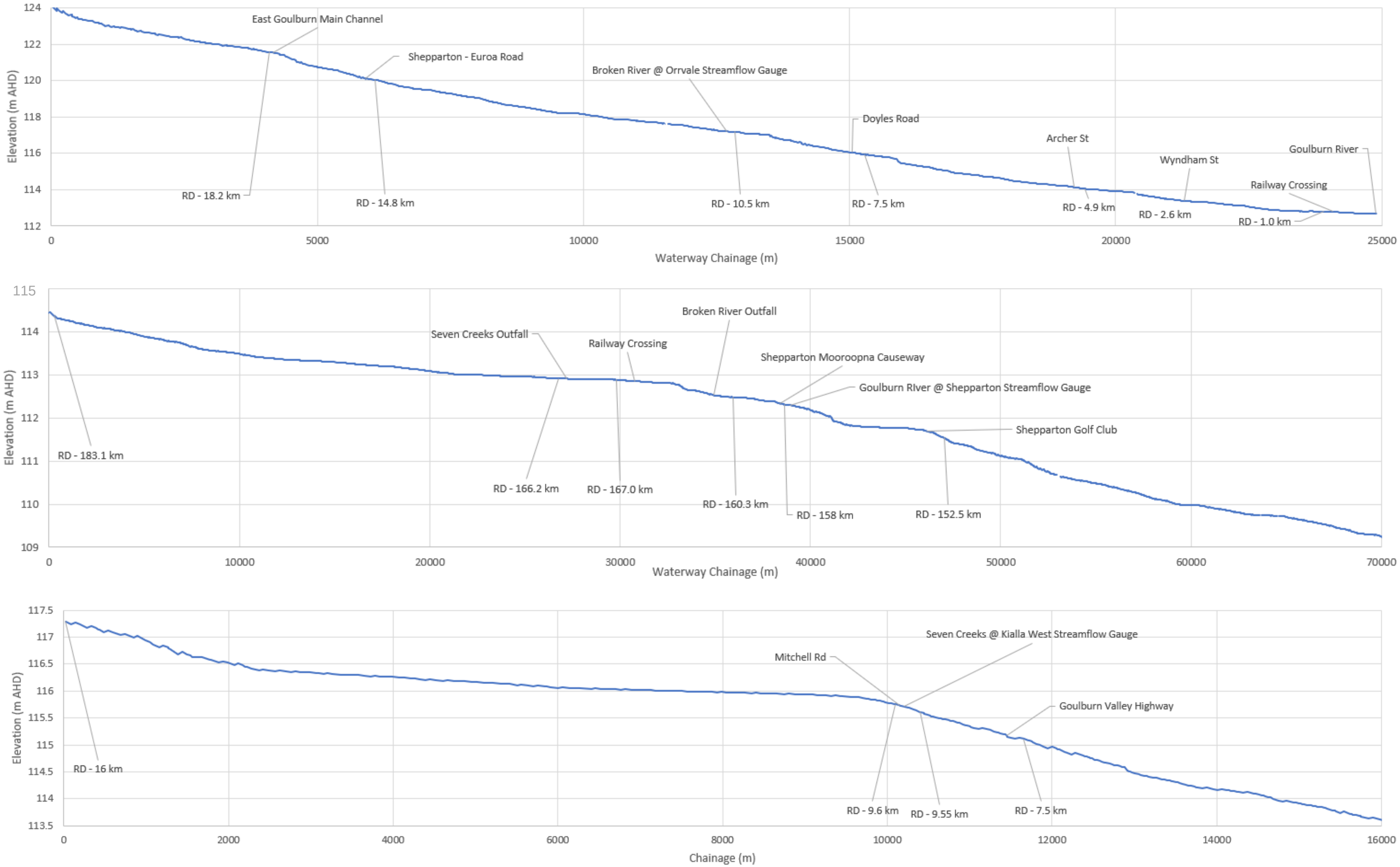

FIGURE 4-6 WATER SURFACE PROFILES – 1993 FLOOD EVENT (FROM TOP: BROKEN RIVER, GOULBURN RIVER, SEVEN CREEKS)

4.2 May 1974 Validation

There were 377 flood marks available in the VFD for the May 1974 flood event. A number of these appear to be duplicates and 114 of these points were classified with a reliability of 'Good' or 'High'. Only the surveyed points with this level of reliability were used to validate the hydraulic model, giving confidence to the reliability of the reproduced flood behaviour. Validation plots of the May 1974 flood event are shown in Figure 4-8 and Figure 4-9. Of the 115 survey flood marks used the following comparisons between modelled and observed levels were made:

- 52 (46%) points were within +/- 100 mm.
- 38 (33%) points were within +/- 100 - 200 mm.
- Approximately 79% of the modelled validation points were within 200 mm.
- 8 (7%) points were within +/- 200 300 mm.
- 9 (8%) points were below 300mm.
- 3 (2.5%) points were above 300mm.
- 5 (3.5%) points were not in the modelled flood extent.

On average the modelled water levels were 17 mm below the surveyed flood marks, with a standard deviation of 174 mm. The overall trend showed that the modelled flood levels were slightly lower than the previous modelled levels submitted as part of the Shepparton Mooroopna Flood Mapping and Flood Intelligence study. There was a much closer fit to the surveyed flood levels with majority within the satisfactory error interval expected for flood model calibration.

Figure 4-7 shows a comparison of modelled and observed water levels at the Goulburn River at the Shepparton gauge. The graph show the rising limb of the modelled hydrograph arrives slightly earlier than the gauged data, but matches the rate of rise extremely well. The peak elevation is approximately 28 mm lower than the gauged data, and the falling limb recedes at a very similar rate to that gauged.

Due to the distance between upstream gauge locations and the upstream extent of the model, the timing of inflow hydrographs involved estimated timing for the three river systems. A much closer match between the modelled and observed 1974 data has been achieved by making the following changes to the inflow hydrograph timings from the Shepparton-Mooroopna Flood Mapping and Flood Intelligence Study:

- Moving the Goulburn River inflows back 6-hours.
- Moving the Broken River inflows forwards 7-Hours.

These two changes appear to have slightly changed the peak in timing at the Goulburn River gauge. This then allowed the model to replicate the rise and fall of the modelled gauge as well as the distribution of modelled levels compared with surveyed levels. Given the previous modelling model took 7-days compared to 1-day of simulation time, the refinement to the extent that we now have was not previously practical.

No streamflow data for the Broken River at Orrvale or the Seven Creeks at Kialla West gauge exists for the 1974 flood event. Both gauges were installed in 1977.

Figure 4-10 shows the water surface profiles along the three main waterways for the 1974 flood event. These are plotted with the chainage distance of the waterway along the x – axis and the running distances (provided by the GBCMA) have also been included at key features along the waterways.

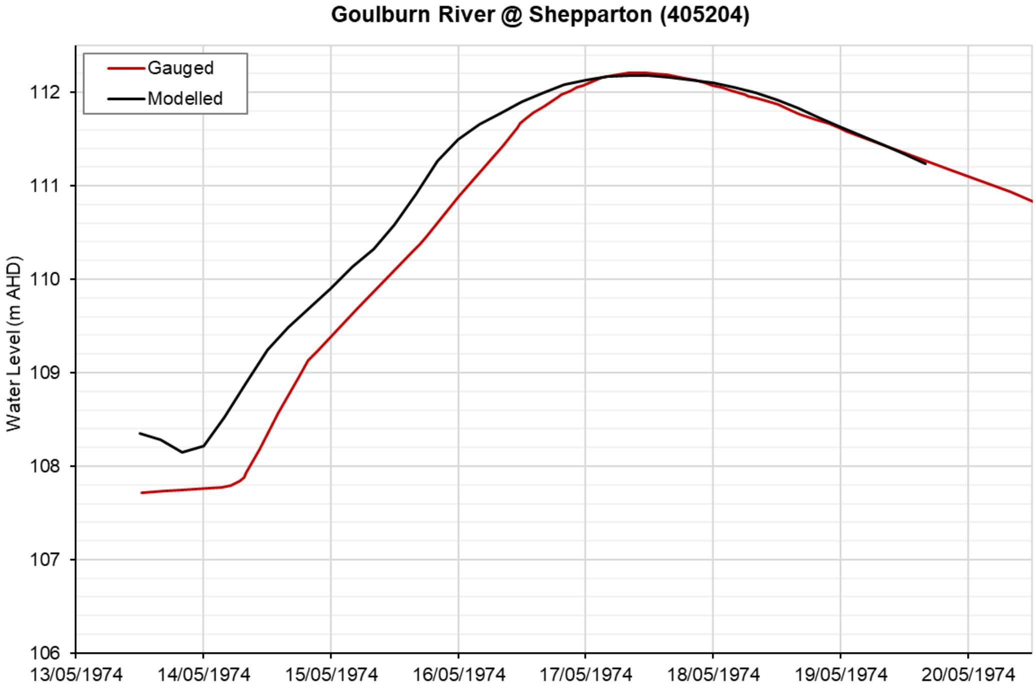

FIGURE 4-7 MODELLED AND GAUGED WATER LEVELS (GOULBURN RIVER AT SHEPPARTON) 1974

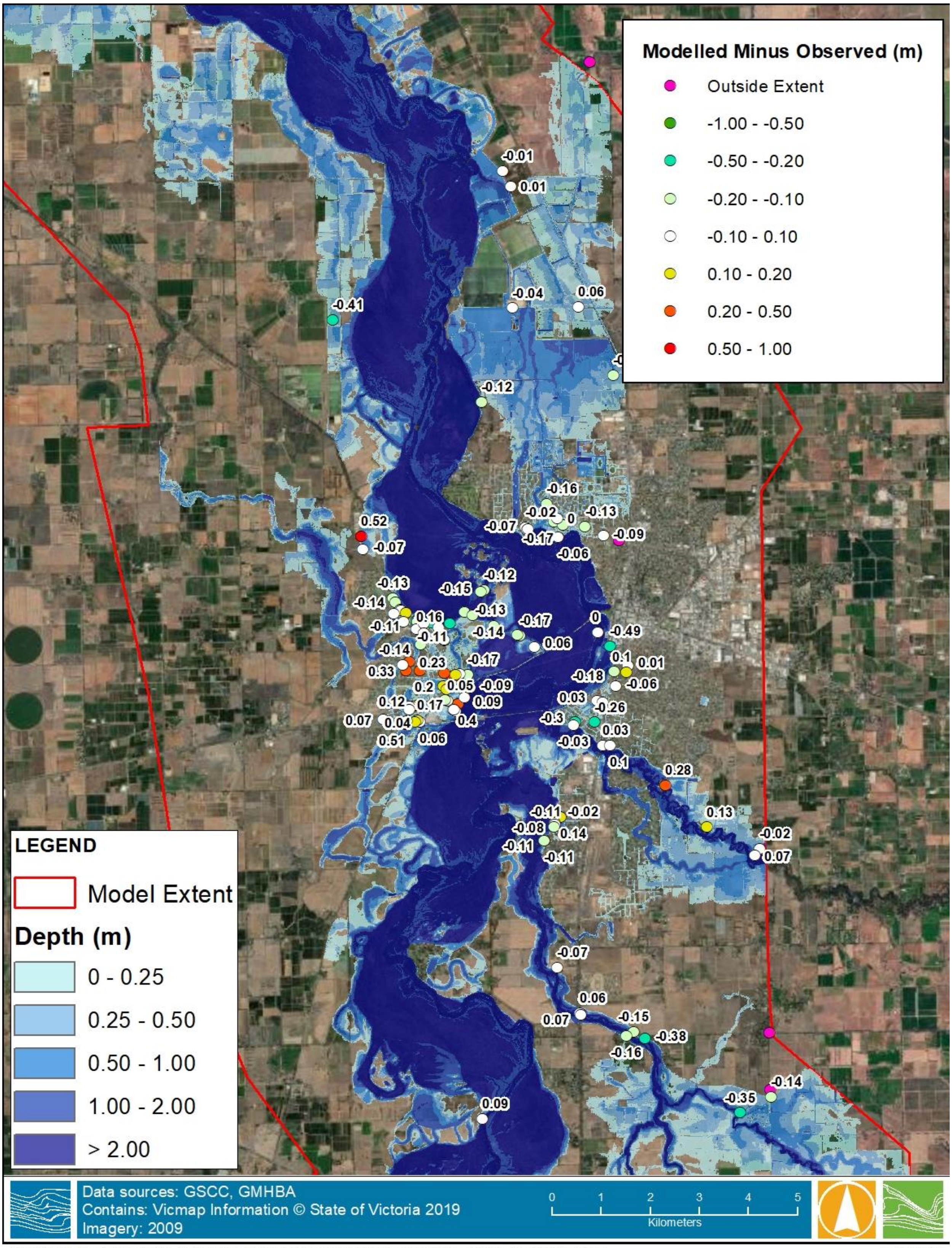

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FIGURE 4-8 HYDRAULIC MODEL VALIDATION PLOT – MAY 1974 EVENT

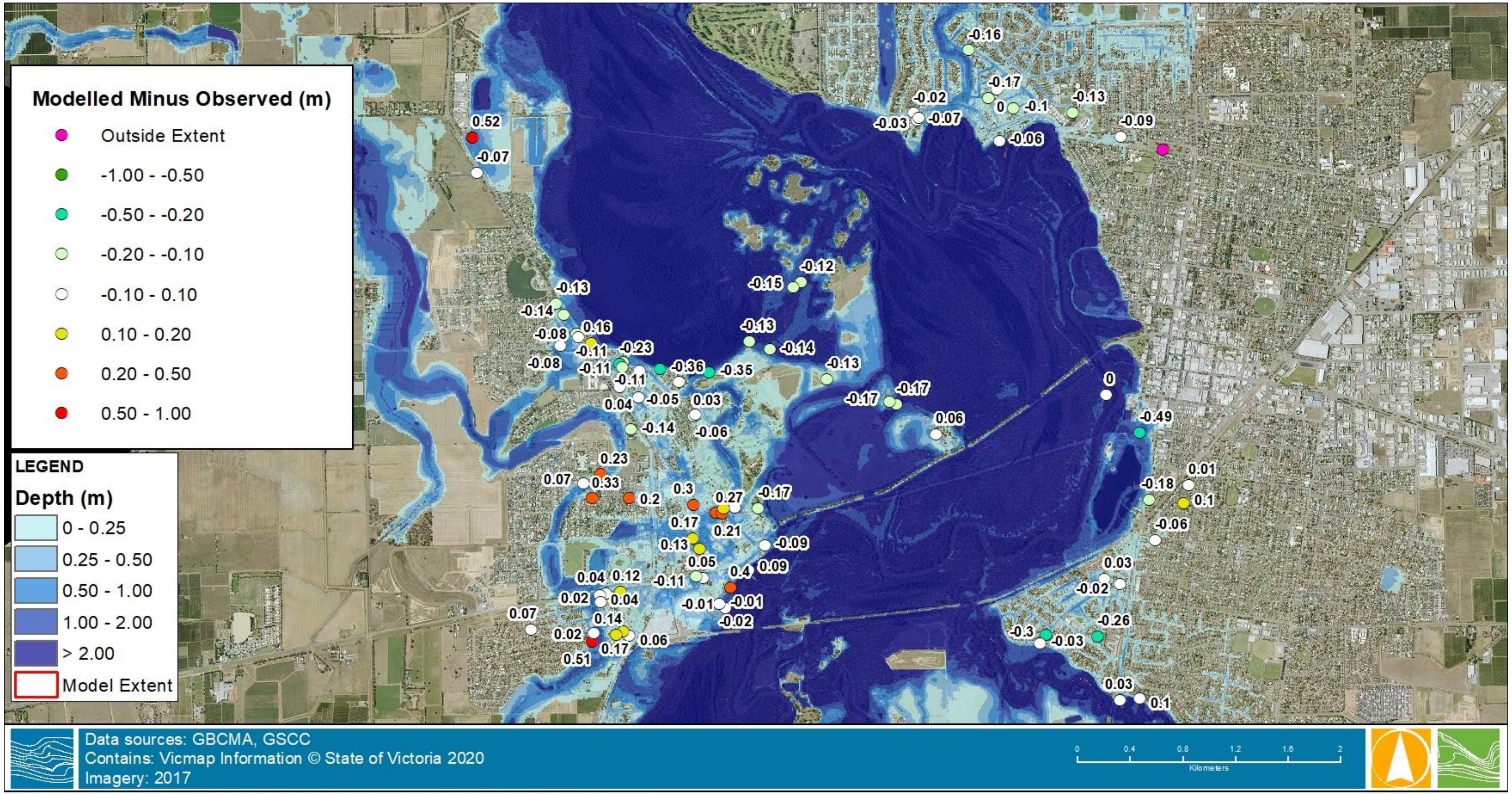

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FIGURE 4-9 HYDRAULIC MODEL VALIDATION PLOT – MAY 1974 EVENT (TOWNSHIP)

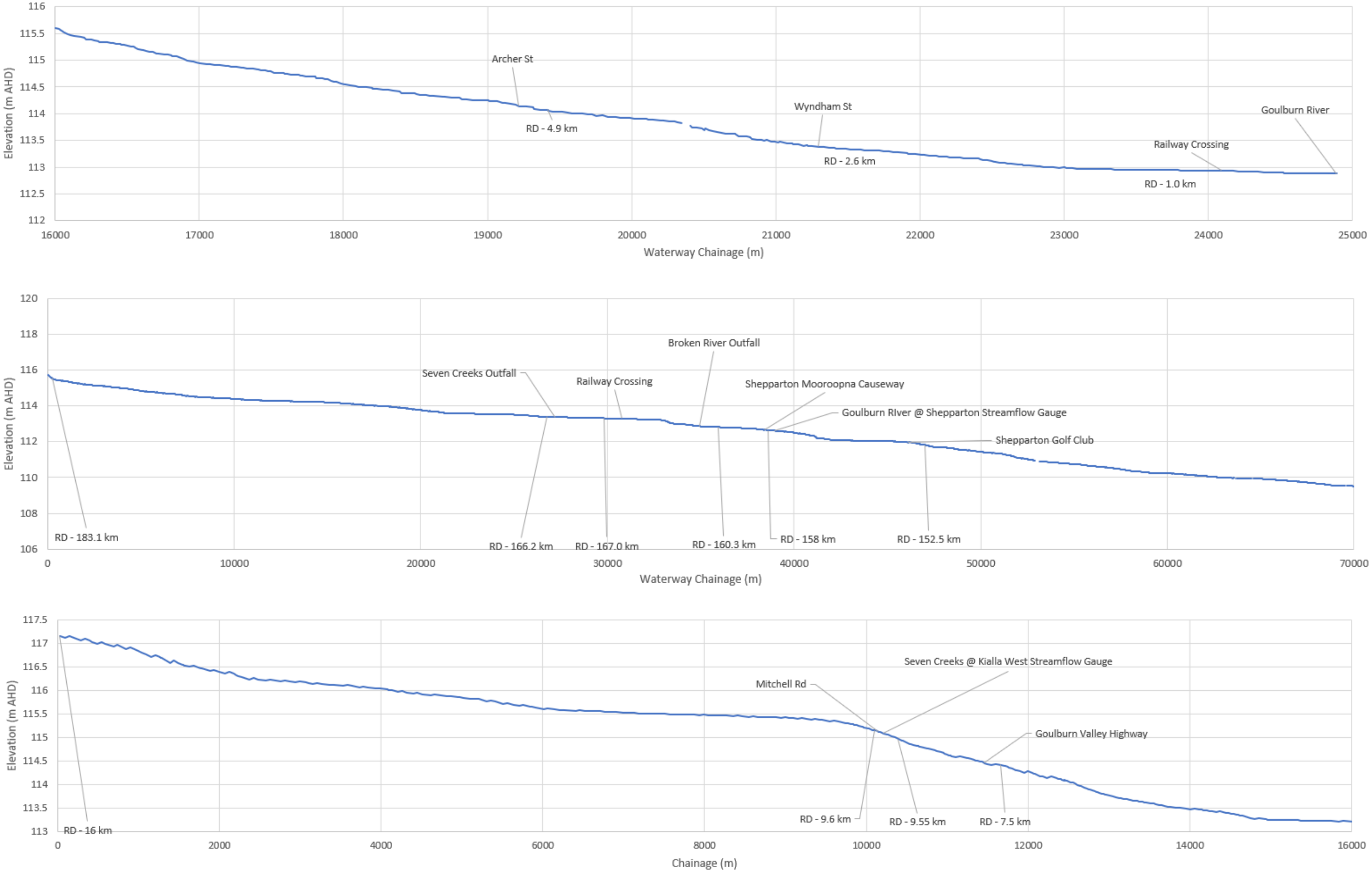

FIGURE 4-10 WATER SURFACE PROFILE – 1974 MODELLED FLOOD EVENT (FROM TOP: BROKEN RIVER, GOULBURN RIVER, SEVEN CREEKS)

5 DESIGN MODELLING

5.1 Hydrology Analysis

5.1.1 Hydrological comparisons

Review and comparison between hydrological findings of the Goulburn and Broken Rivers Flood Study[2] and the Shepparton Mooroopna Flood Mapping and Flood Intelligence Study[1] with the focus on the 1% AEP was undertaken.

The HARC study in 2018 developed and calibrated a rainfall runoff model (RORB) for the entire Goulburn and Broken Rivers catchment upstream of Loch Garry. A joint probability approach with sampling model inputs from statistical distribution was used for design event hydrological modelling. The hydrological model was then verified with at site gauged flood frequency curves. Design hydrographs were generated by RORB and their timing and volumes were based on adopted model parameters.

The hydrologic analysis completed by Water Technology in the 2019 study adopted a flood frequency analysis at gauges within the catchment. The design hydrographs for the 1% AEP event were derived based on 1974 and 1993 hydrographs. The 1974 hydrograph shape was adopted for the Goulburn River while the 1993 hydrographs were scaled for Broken River and Seven Creek systems, as these historic events were the closest gauged events to the 1% AEP design flow.

A comparison of the design peak flows for 1% AEP event for the two studies at key gauges are summarised in Table 5-1 below. The HARC study produced slightly higher peak flows in Goulburn River while peak flow was slightly lower in Broken River. Overall, both studies derived similar estimates for 1% AEP event and it is unlikely these minor differences in peak flows will relate to noticeable differences in peak flood levels.

TABLE 5-1 COMPARISON OF 1% AEP DESIGN PEAK FLOWS AT VARIOUS GAUGE LOCATIONS

location	HARC (2018) - m^3/s	Water Technology (2019) - m^3/s
Goulburn River		
Murchison	1,990	1,766
Shepparton	2,540	2,468
Broken River		
Benalla	1,032	1,192
Orrvale	-	556
Seven Creeks		
Kialla West	-	899

5.1.2 Design flow in Ardmona Drain 11

The Ardmona Drain 11 (south of Mooroopna) was identified as an additional inflow to be included to the hydraulic model since the completion of the modelling for the 2019 flood study. The 1% AEP flow was taken from the Goulburn Valley Freight Logistics Link Flood Assessment[3] in which a hydraulic analysis was undertaken for the Drain 11 catchment based on earlier hydrology developed by GHD in 2009[4]. Locations of the hydraulic model input flows are shown in Figure 5-1.

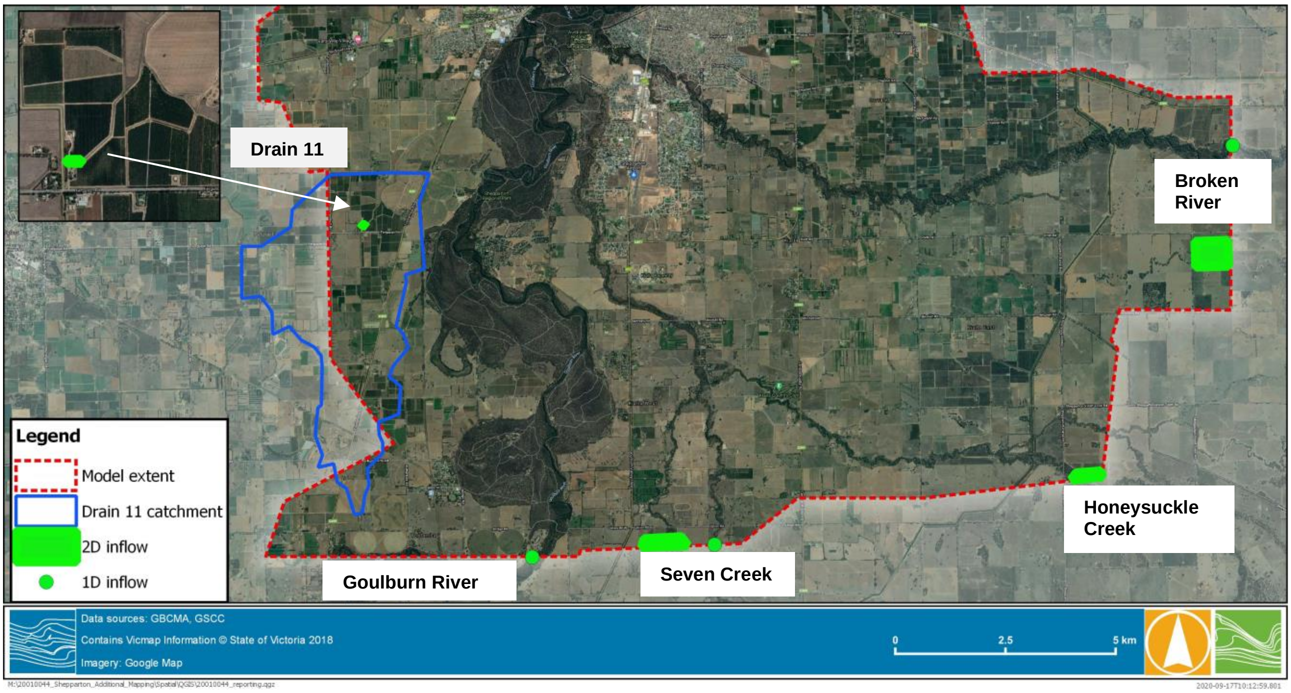

FIGURE 5-1 HYDRAULIC MODEL BOUNDARIES

5.2 Modelling Results

Following updates to the hydraulic model and the flood hydrology review, flood mapping using TULFOW – HPC (at a 5 x 5 m grid) was produced for the study area. The 1% AEP Goulburn River dominant and the 1% AEP Broken River dominant events were simulated. Flood modelling results were spliced to produce the maximum depth, velocity, water surface elevation and depth x velocity product for mapping and the preparation of flood zone and overlay controls. The following section shows the key flood maps produced from the modelling covering the TUFLOW extent. Final flood modelling outputs were clipped to downstream of the East-Goulburn Main Channel. Figure 5-2 and Figure 5-3 display mapping of flood depth and water surface elevation respectively for the updated modelling. The combined 1% AEP Water Surface Profile is shown in Figure 5-3.

Comparison of the design flood levels to previous events can be used to further validate the design modelling. A comparison of the 1% AEP flood levels (combined Goulburn Dominant and Broken/Sevens Dominant) has been compared with two flood events. The two events compared are the 1974 flood event, which was a Goulburn Dominant and considered close to a 1% AEP on the Goulburn River and the 1993 flood event which was a Broken Dominant event and is considered close to a 1% AEP on the Broken River. The comparison plots are shown in Figure 5-4 and Figure 5-5. The results show that for the majority of the study (excluding several isolated areas) the 1% AEP design levels are above the modelled levels for the two historic flood events.

[3] Water Technology 2017, *Goulburn Valley Freight Logistics Link Flood Assessment*
[4] GHD 2009, *Goulburn Valley Freight Logistics Link, Functional Design Report*

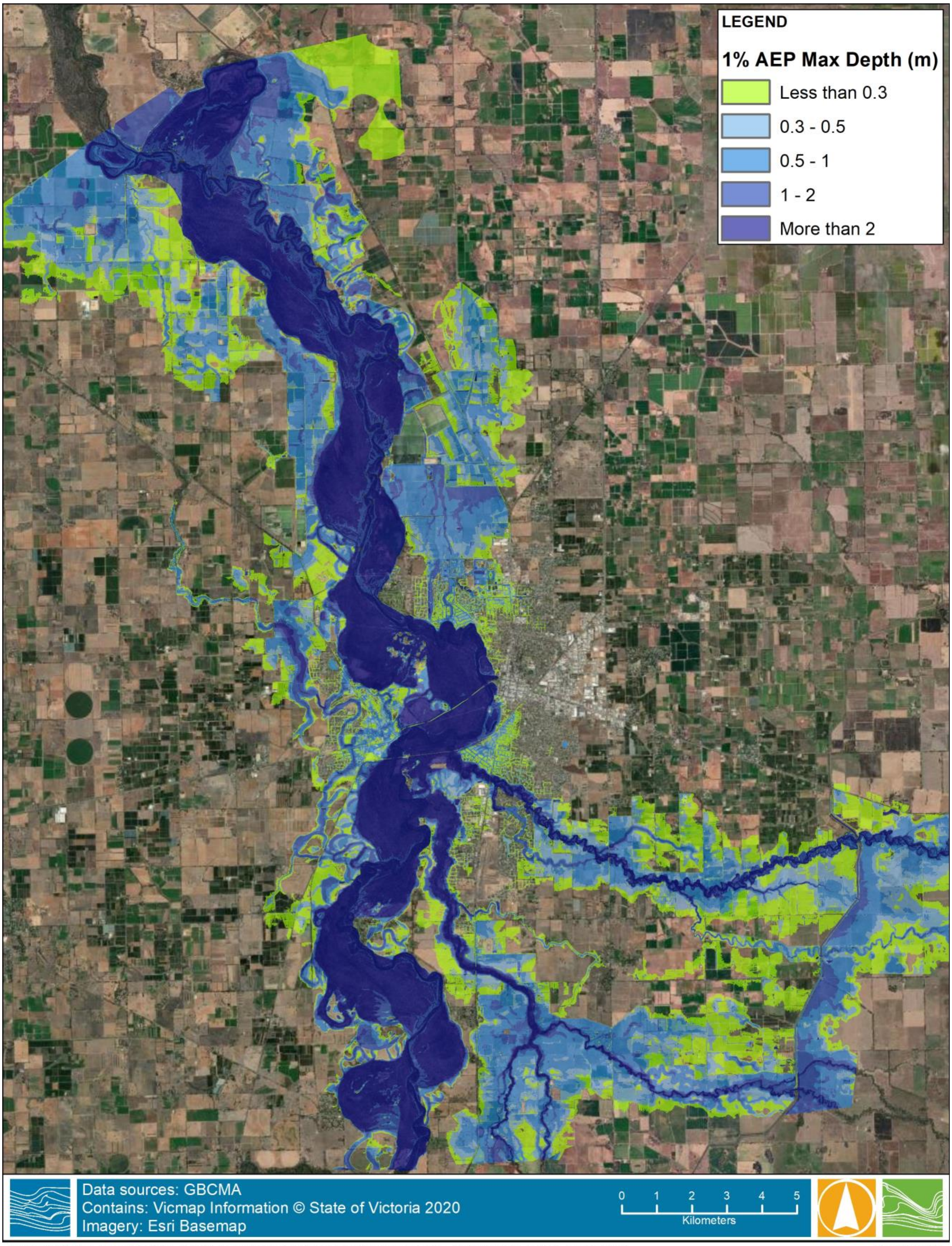

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FIGURE 5-2 1% AEP FLOOD DEPTH

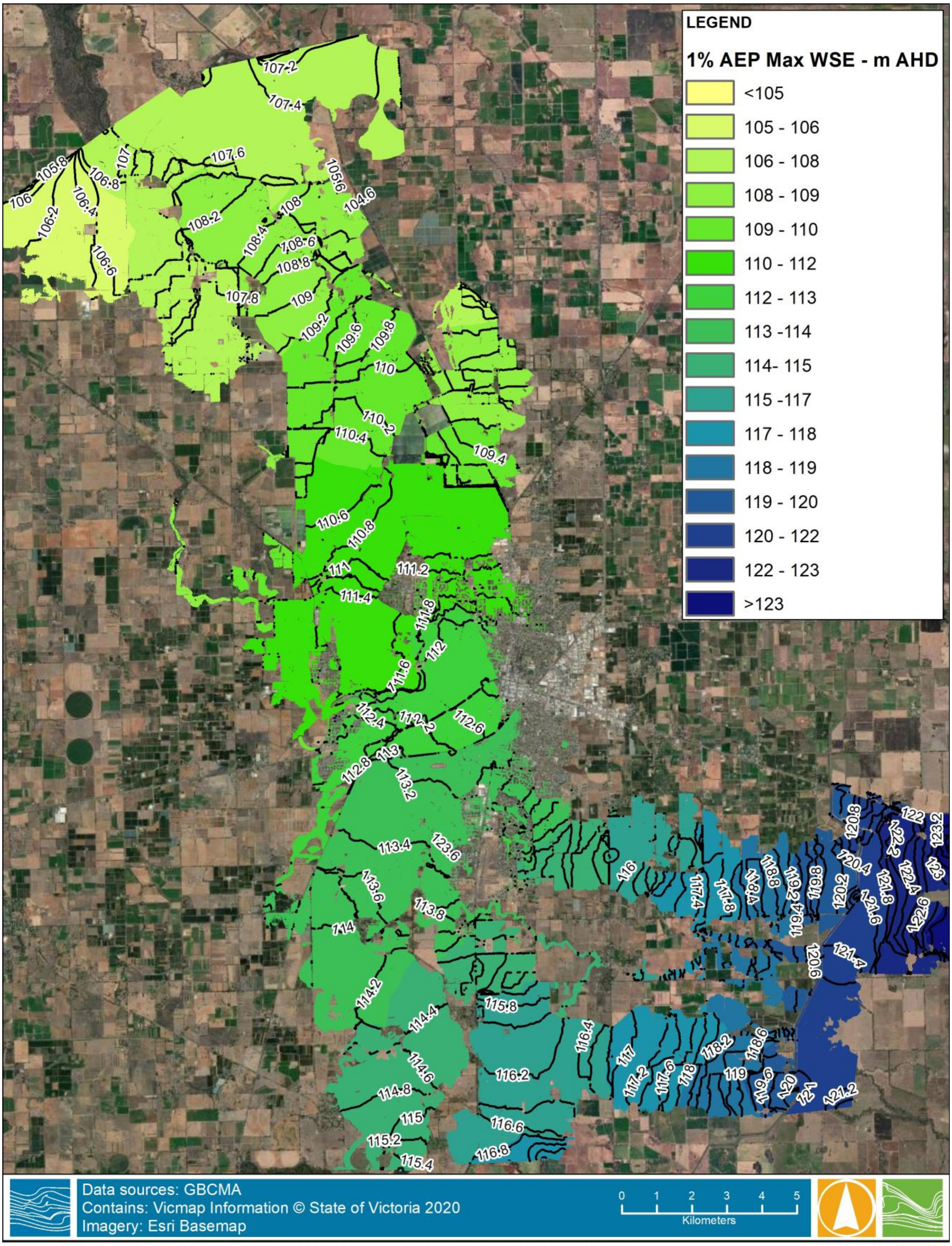

FIGURE 5-3 1% AEP WATER SURFACE ELEVATION

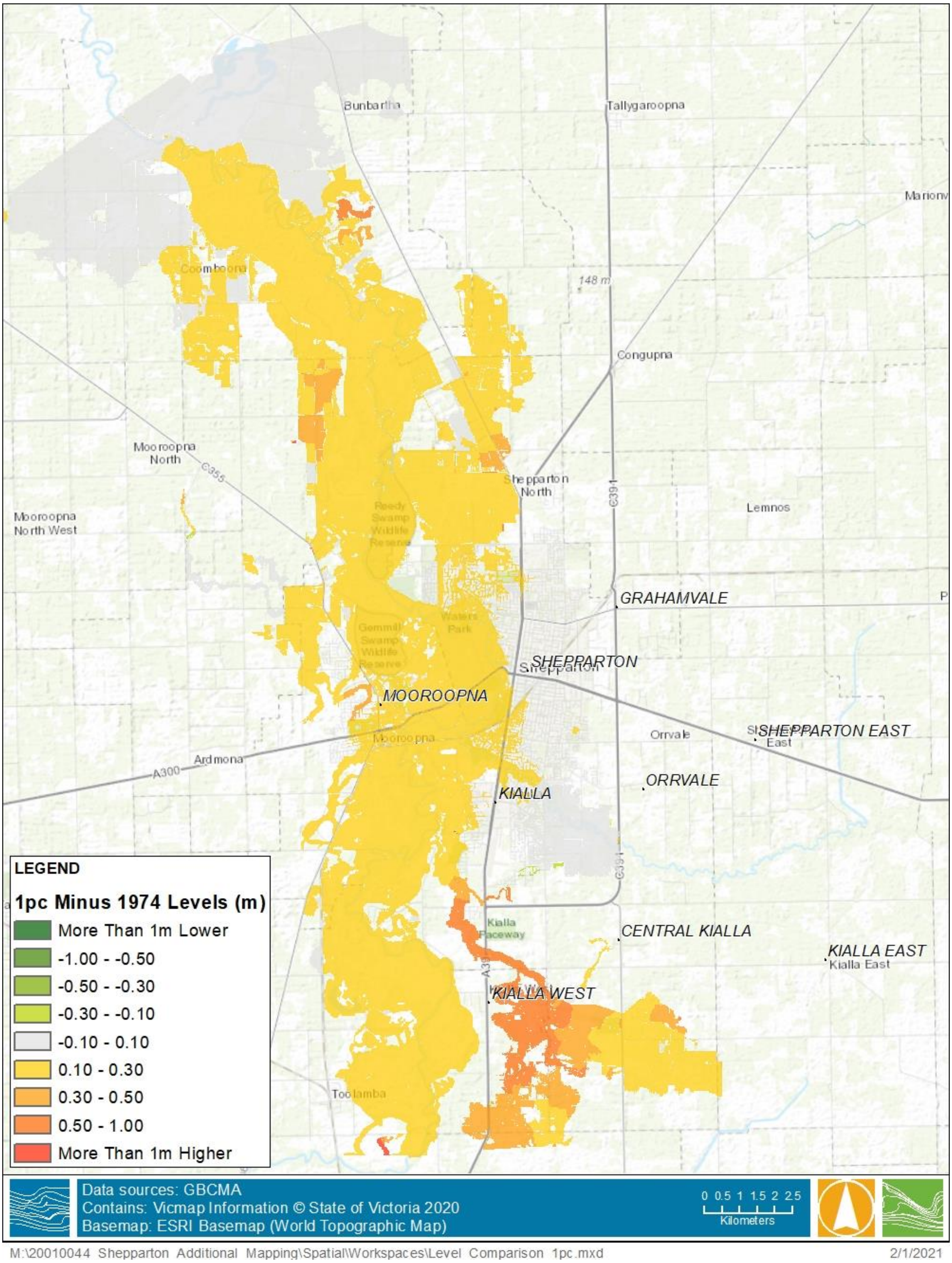

FIGURE 5-4 1% AEP FLOOD LEVELS MINUS 1974 MODELLED LEVELS

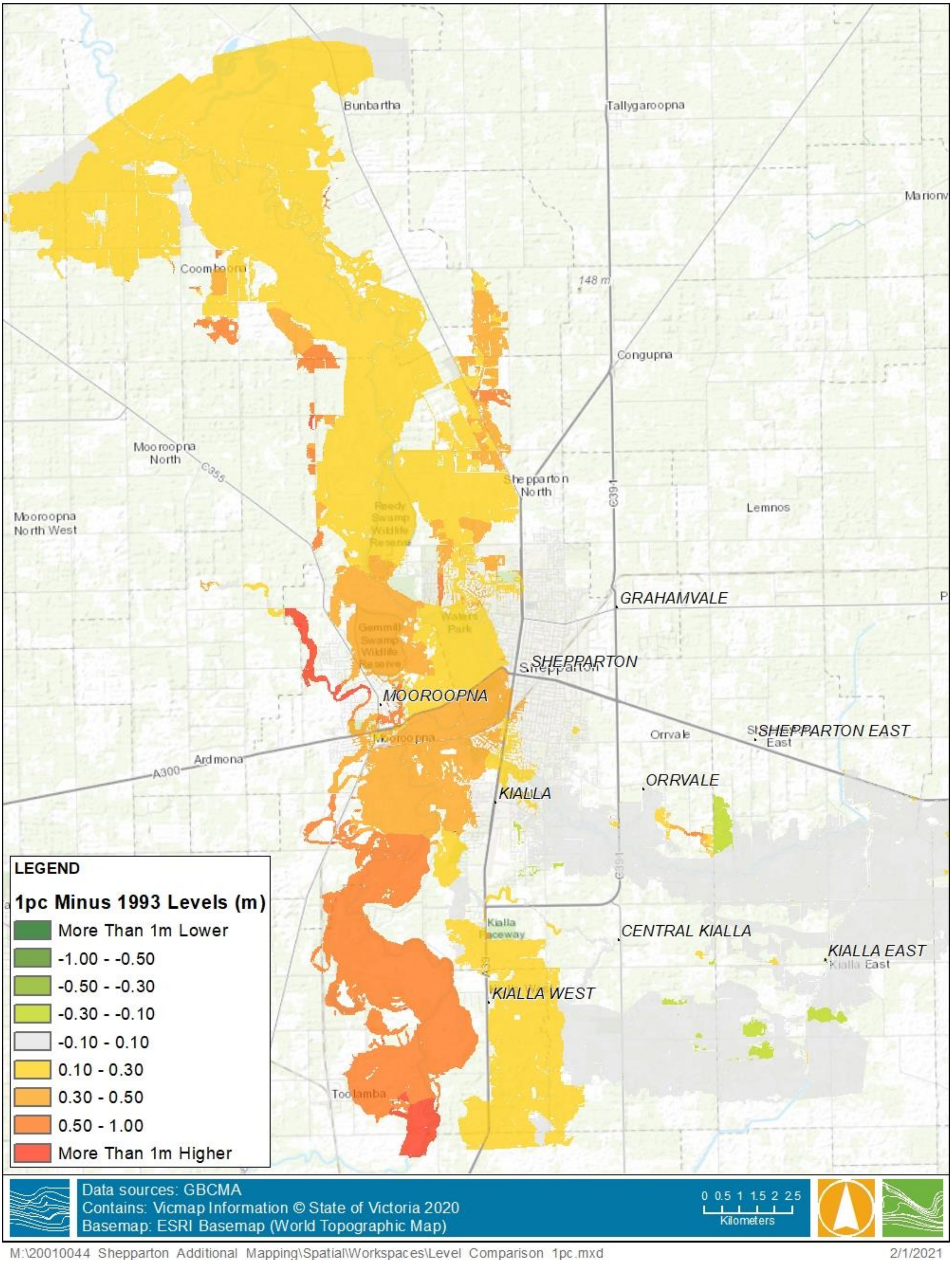

FIGURE 5-5 1% AEP FLOOD LEVELS MINUS 1993 FLOOD LEVELS

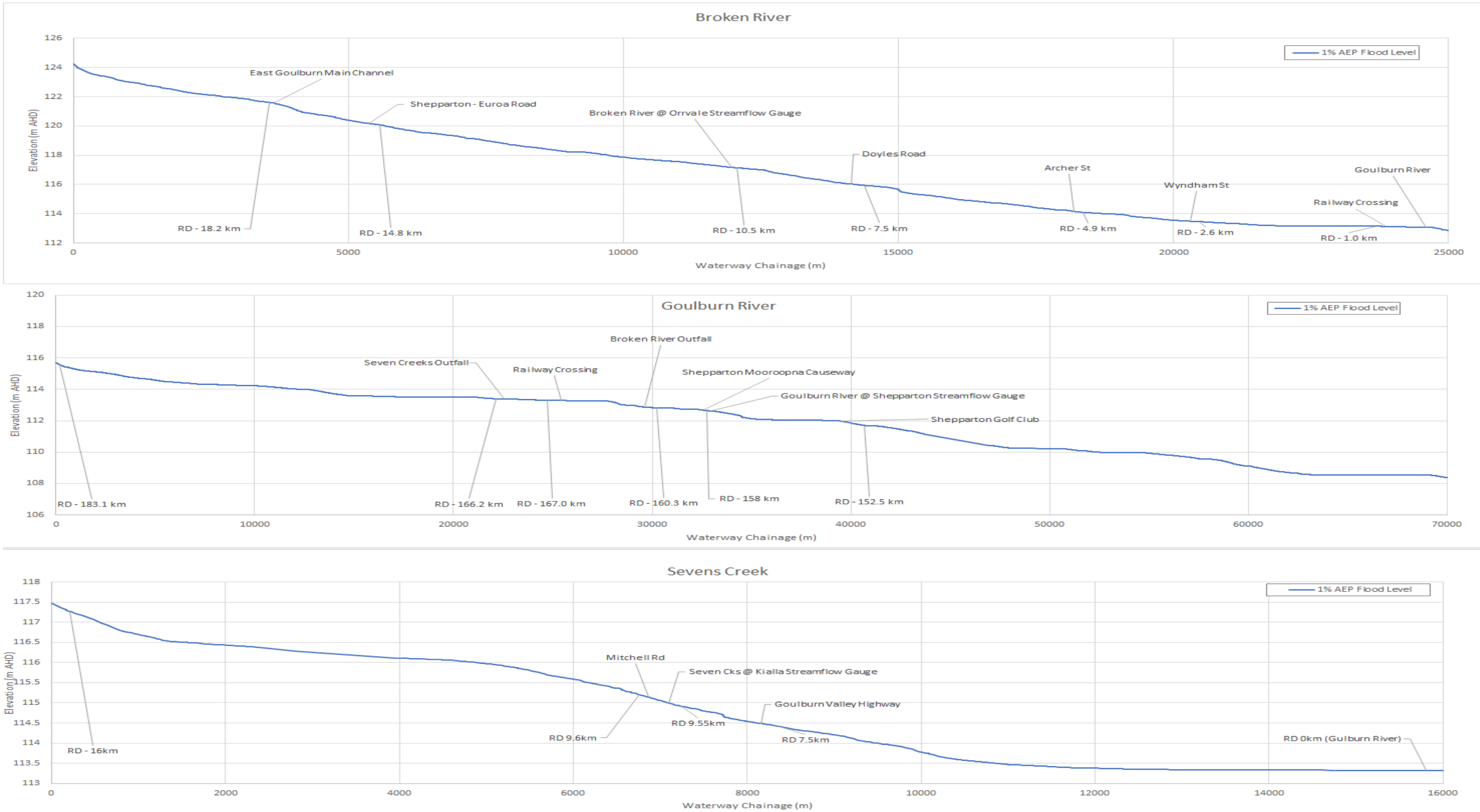

FIGURE 5-6 WATER SURFACE PROFILE (COMBINED 1% AEP FLOOD LEVEL)

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

6 CLIMATE CHANGE MODELLING

6.1 Overview

To date, there is limited guidelines for climate change modelling for large catchments such as the Broken and Goulburn River catchments. Applying a standard increase in rainfall intensity such as an RCP factor of 8.5 over 16,000 km^2 catchment may not be appropriate as the likelihood of increase in rainfall intensity may be offset due to antecedent catchment conditions (associated with a typically drier catchment).

ARR2019 offers advice on increased design rainfall intensities associated with a range of climate change scenarios. Projected changes from Global Climate Models (GCMs) can be explored for fourteen 20-year periods and the four Representative Concentration Pathways (RCPs) for greenhouse gas and aerosol concentrations that were used to drive the GCMs. The RCPs are designated as 2.6, 4.5, 6.0 and 8.5, and are named according to radiative forcing values (W m-2) in the year 2090 relative to pre-industrial values. The GBCMA previously engaged HARC to undertake a climate change assessment for the broader catchments using the RCP 4.5 pathway to the year 2090. The year 2090 represents ARR's furthest forecast in time.

The hydrologic modelling showed the peak flow estimates at several gauges within the catchment are closely aligned with the 0.5% AEP estimates as determined by Water Technology in the 2019 study[1] (Table 6-1). To assess the impact of the future climatic conditions, the hydrology (0.5% AEP flows) developed as part of the Water Technology study were adopted for the climate change assessment. The Water Technology hydrology was adopted for completeness as it incorporated flows from the Seven Creeks and Honeysuckle Creek systems as well as other tributaries including Pranjip Creek and Castle Creeks.

TABLE 6-1 COMPARISON OF CLIMATE CHANGE DESIGN FLOW ESTIMATES

Gauge location	RCP4.5 - 2090 (HARC 2021) – m^3/s	0.5% AEP (Water Technology 2019) – m^3/s
Goulburn River at Murchison	2,380	1,927
Goulburn River at Shepparton	3,090	2,984
Broken River at Benalla	640	641

6.2 Climate Change Inflows

The climate change modelling for this investigation consists of assessing the Goulburn and Broken/Sevens Dominant events to determine the impact of independent flood events as well as the combination of results for planning purposes. For the Goulburn Dominant event, a combination of 0.5% AEP flow for the Goulburn River with a 1% AEP flow for the Broken River and 2% AEP flow for the Seven Creeks was applied in the hydraulic model. For the Broken/Seven Creeks Dominant event, a combination of 0.5% AEP flows for the Broken River and Seven Creeks with a 2% AEP flow for the Goulburn River was applied in the model. The Table 6-2 below summarises the climate change inflows used in both event scenarios. The green indicates the Goulburn Dominant event while the orange indicates the Broken/Sevens Dominant event.

TABLE 6-2 ADOPTED CLIMATE CHANGE DESIGN INFLOW SUMMARY

AEP	Goulburn River	Broken River	Seven Creeks
2%	1434 m^3/s	623 m^3/s	779 m^3/s
1%	1882 m^3/s	734 m^3/s	950 m^3/s
0.5%	2043 m^3/s	840 m^3/s	1108 m^3/s

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The climate change inflow hydrographs at each inflow boundary location (see Figure 5-1) were developed based on the 1% AEP hydrographs shape and proportional split at the inflow boundaries.

Discussions with the GBCMA identified that the East Goulburn Main Channel (EGMC) is having a significant hydraulic control on floodplain behaviour in extreme flood events that is not accounted for within the hydrology modelling. A sensitivity analysis was undertaken to evaluate the impacts of the EGMC on floodplain behaviour by extending the model boundary and inflow locations for the Seven Creeks floodplain upstream (south-east of the EGMC) as displayed in Figure 6-1.

The sensitivity analysis showed that flood levels were impacted by around 150-200 mm (lowered) when inflows were placed upstream of the EGMC compared with when they were placed downstream. This identified that the channel was having a significant impact on flood levels. Further analysis of the Granite Creeks Regional Flood Study (Water Technology, 2018) flood modelling results which modelled flood events up to 0.5% AEP at a regional scale also showed a decrease in flood levels across the EGMC of around 100-150 mm and a decrease of 15-20% peak flows through the EGMC. This modelling did not include Broken River inflows which are known to extend into Sheepwash Creek and the Honeysuckle Creek Floodplain.

The Flood Frequency Analysis (FFA) undertaken to determine design flow rates at the key gauge locations (Broken River at Orrvale and Seven Creeks at Kialla West) do not take into account the impact of such a hydraulic control, nor does the hydrology modelled as part of the HARC investigation. The FFA undertaken as part of the Shepparton-Mooroopna Flood Mapping and Intelligence Study (2019) showed the 1993 flood event was close to a 1% AEP event on the Broken River and Seven Creeks system which provides a high degree of certainty for flows up to that magnitude. The identification of the impact of the hydraulic control on higher flows suggests that the 0.5% AEP should be placed upstream of the EGMC.

Given the Broken River and Honeysuckle Creek inflow locations are located upstream of the EGMC, the Seven Creeks inflows were also placed upstream for the Climate Change modelling.

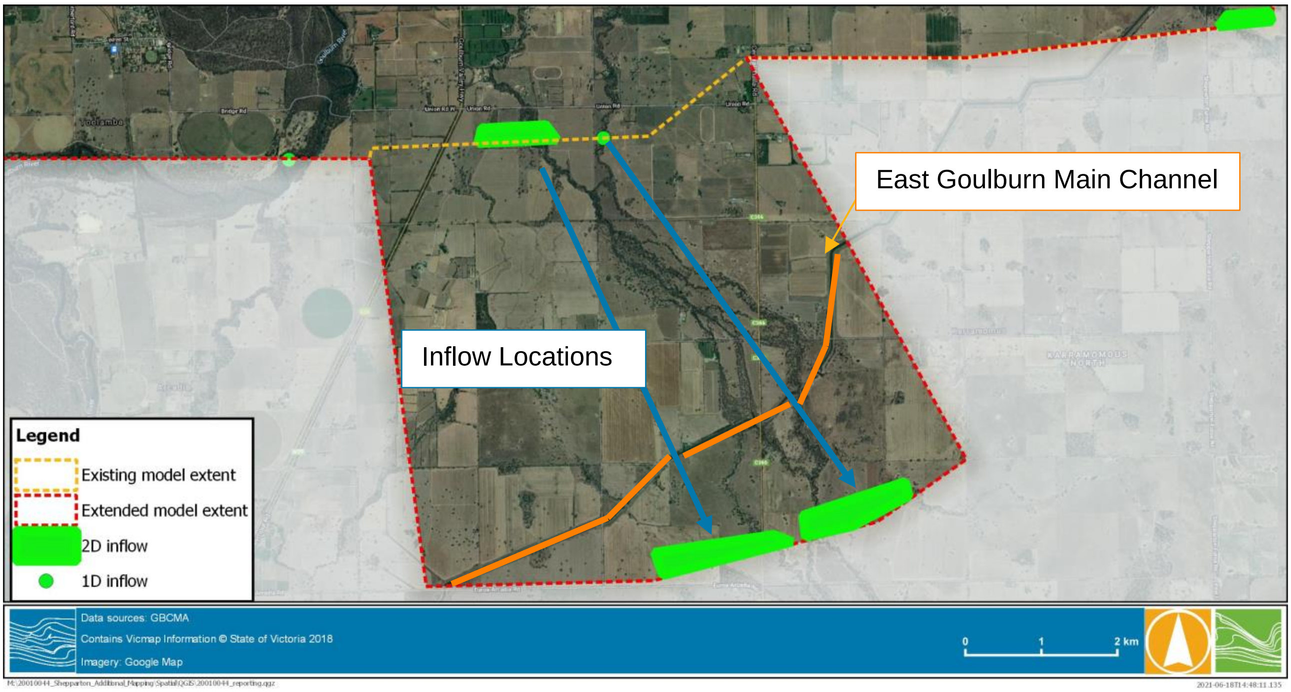

FIGURE 6-1 EXTENDED MODEL BOUNDARY AND INFLOW LOCATIONS AT SEVEN CREEKS

6.3 Modelling Results

Changes to the peak flood levels at the three key gauge locations under climate change conditions are summarised in Table 6-3 and Table 6-4. Hydraulic modelling results show a broad increase in peak flood levels across the study area of around 100-150 mm (Figure 6-2) for the combined results (i.e. maximum of Goulburn dominant and Broken/Seven dominant). Higher increases are shown along the Seven Creeks system between the Goulburn River and Goulburn Valley Highway where the floodplain is confined due to irrigation and drainage infrastructure, these areas also have a slight increase in flood extent. Peak flood depths and water surface elevations are shown in Figure 6-3 and Figure 6-4.

TABLE 6-3 GAUGE LEVEL COMPARISON – GOULBURN RIVER AT SHEPPARTON

Scenario	Existing Conditions (m)	Climate Change (m)	Difference (m)
Goulburn River Dominant	12.19	12.34	0.15
Broken River/ Seven Creeks Dominant	12.12	12.27	0.15

TABLE 6-4 GAUGE LEVEL COMPARISON – BROKEN RIVER AT ORRVALE & SEVEN CREEKS AT KIALLA WEST

Streamflow Gauge	Existing Conditions (m)	Climate Change (m)	Difference (m)
Broken River at Orrvale	8.58	8.64	0.16
Seven Creeks at Kialla West	8.39	8.57	0.17

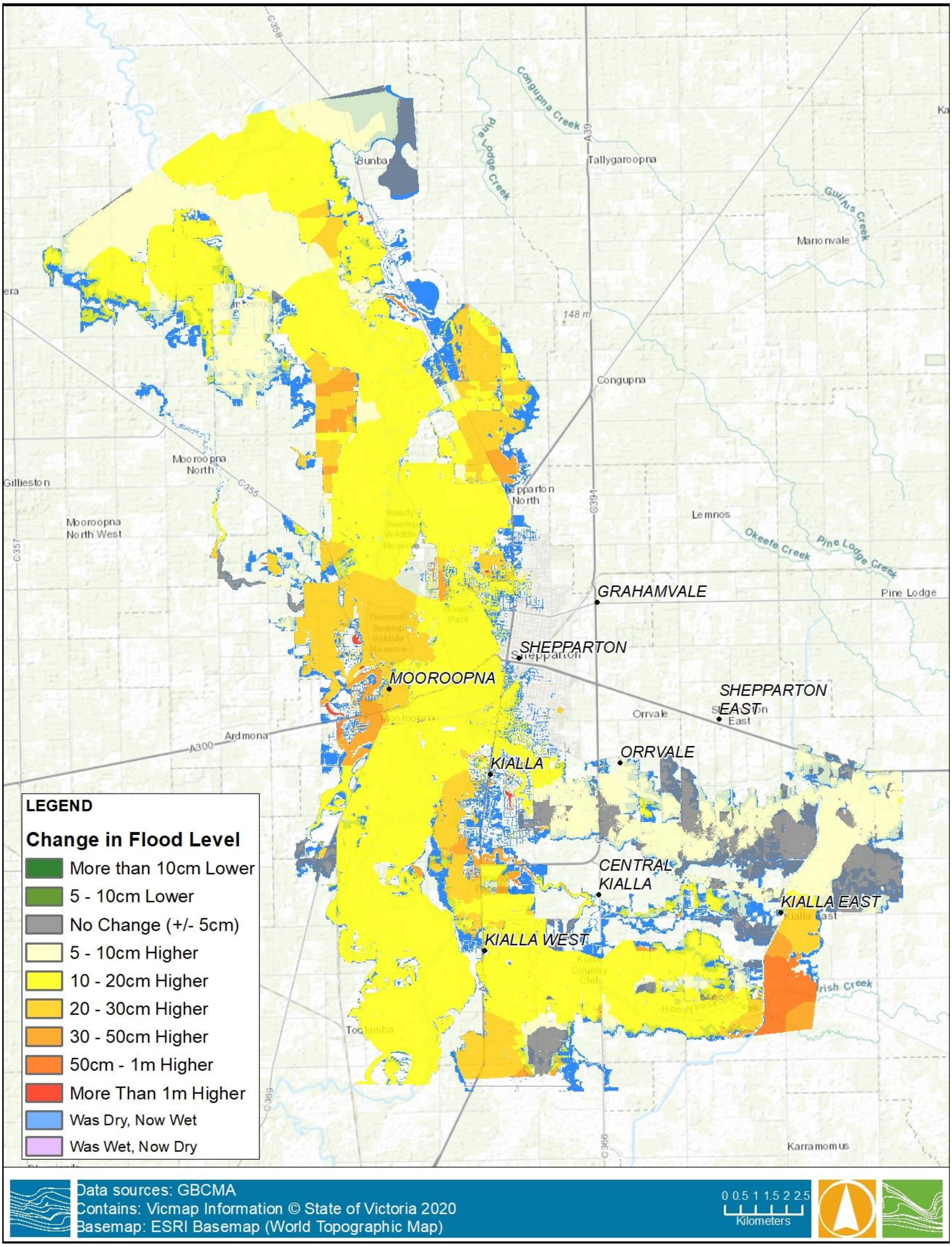

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FIGURE 6-2 CLIMATE CHANGE FLOOD LEVELS MINUS 1% AEP FLOOD LEVELS

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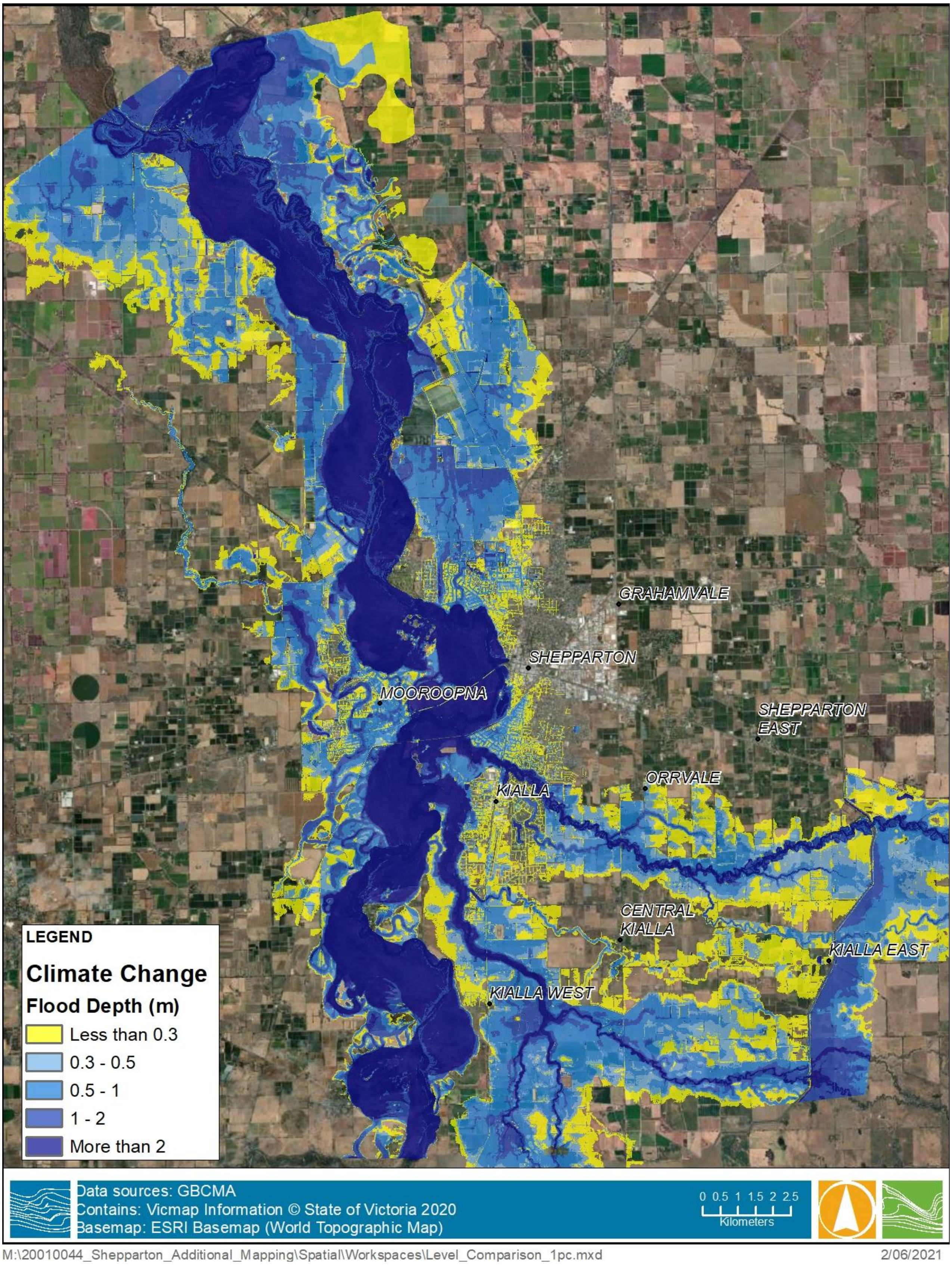

FIGURE 6-3 CLIMATE CHANGE FLOOD DEPTH

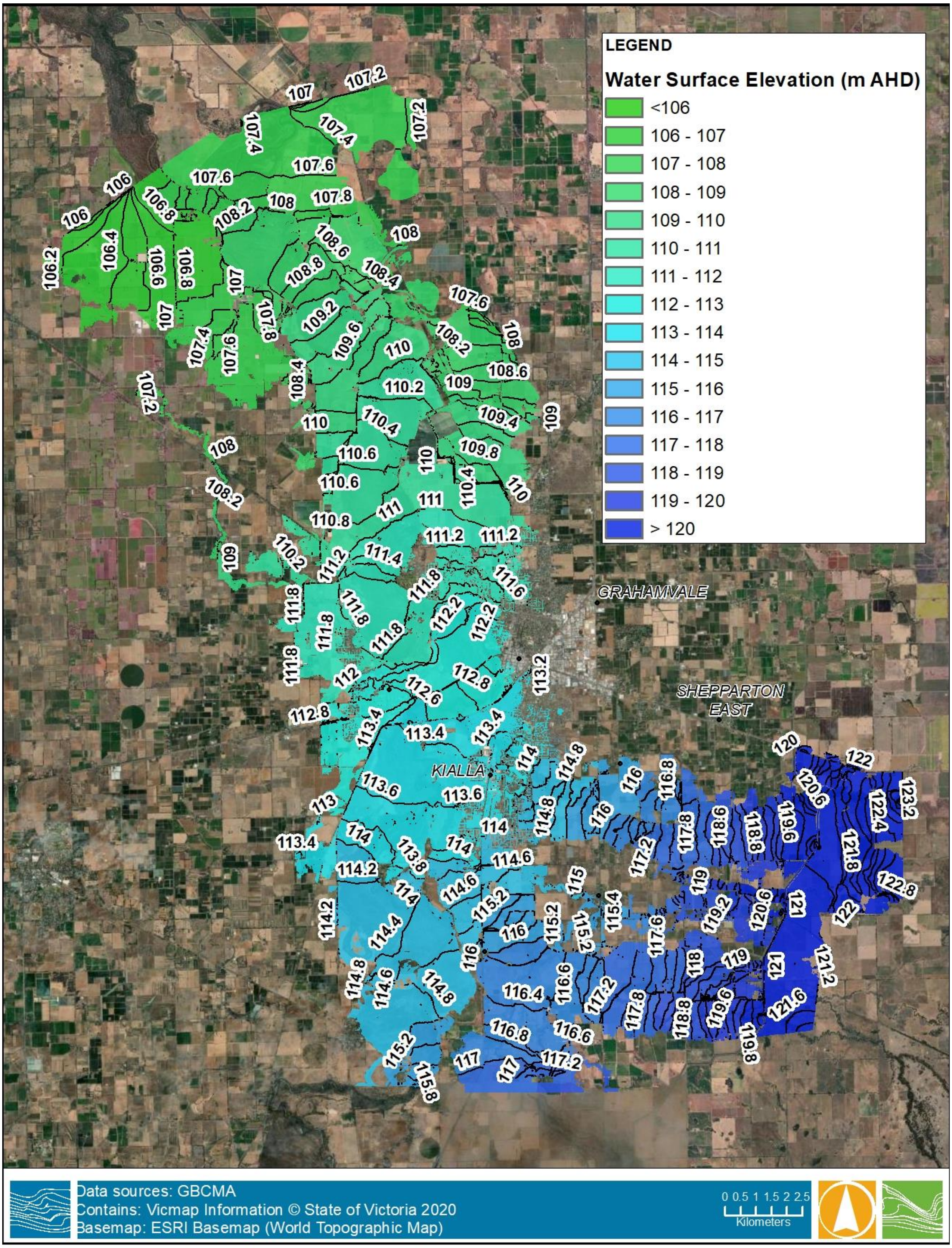

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FIGURE 6-4 CLIMATE CHANGE WATER SURFACE ELEVATION

7 WATERWAY CROSSING – BLOCKAGE ASSESSMENT

7.1 Bridge Blockage

An Australian Rainfall and Runoff (ARR) 2019 blockage assessment was undertaken for the key bridge structures included in the model. Table 7-1 shows the blockage applied for the bridges assessed. It is important to note that this blockage assessment was conducted via desktop study as not all bridges were visually inspected and was carried out on the 1% AEP 'existing conditions'. ARR2019 suggests that site inspections or historic blockage instances are critical to estimate the likelihood of blockage level.

The assessment undertaken followed the blockage guidelines outlined in ARR2019. An example of the ARR blockage form and summary table have been included in Appendix B. Judgements made in this assessment in terms of debris availability, mobility and transportability were subjective. In general, the availability of debris impacting the study area is relatively low. Vegetation along the Goulburn River is the primarily possible debris source to potentially impact structures; however, structures along the Goulburn River and floodplain are generally of significant size. The East Goulburn Main Channel located upstream of Shepparton on the Seven Creeks and Broken River Systems is also likely to limit significant debris being mobilised into the study area.

The assessment found several bridges had zero likelihood of blockage due to the factors outlined above. As a conservative approach, bridges openings across the Midland Highway Causeway were tested with 50% blockage to assess the potential flood impact. As a further conservative approach, all bridges listed below were blocked at the same time. To identify the impact of bridge blockages on flood risk, both the 1% AEP Goulburn dominant and 1% AEP Broken River dominant events were simulated with the proposed blockage levels. The maximum flood levels were then compared with existing conditions (0% blockage).

Modelling results found the greatest impact of the blockage in the floodplain was immediately upstream of the structures (as expected). Generally the increase was between 2-5cm with some increases of around 100mm immediately upstream of The Causeway and through parts of the Mooroopna Township. The blockages resulted in two new areas of flood extent (north-west of Mooroopna and South of Kialla Lakes). As mentioned above, this is a relatively conservative assumption based on the cumulative impacts of the ten structures identified being blocked at the same time.

TABLE 7-1 SUMMARY OF BRIDGE BLOCKAGE ANALYSIS

Modelling technique	Bridge location	Recommended Blockage level	Modelled blockage level
1D bridge	Seven Cks @ Mitchell Rd	50%	50%
1D bridge	Seven Cks @ Goulburn Valley Hwy	50%	50%
1D bridge	Seven Cks @ Raftery Rd	10%	10%
1D bridge	Broken River @ Archer Rd	50%	50%
2D layered flow constriction	unnamed Ck @ Wanganui Rd	0%	50%
2D layered flow constriction	Geraghtys Bridge (Midland Hwy)	25%	50%
2D layered flow constriction	Wongs Bridge (Midland Hwy)	0%	50%
2D layered flow constriction	Boolbadah Bridge (Midland Hwy)	0%	50%
2D layered flow constriction	Daishs Bridge (MidlandHwy)	50%	50%
2D layered flow constriction	McGuires Bridge (Midland Hwy)	0%	50%

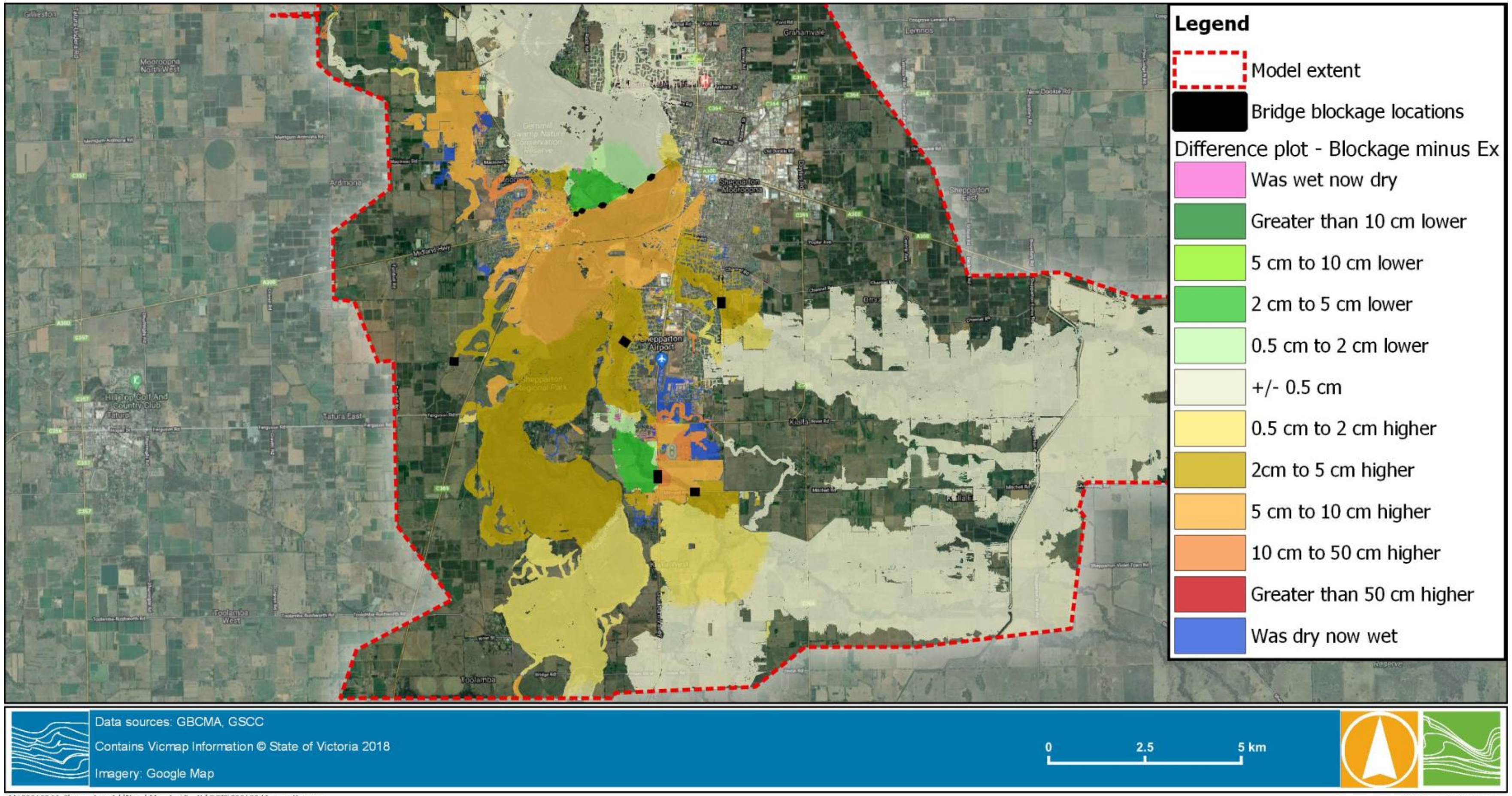

FIGURE 7-1 DIFFERENCE PLOT BRIDGE BLOCKAGE ASSESSMENT 1% AEP BROKEN RIVER

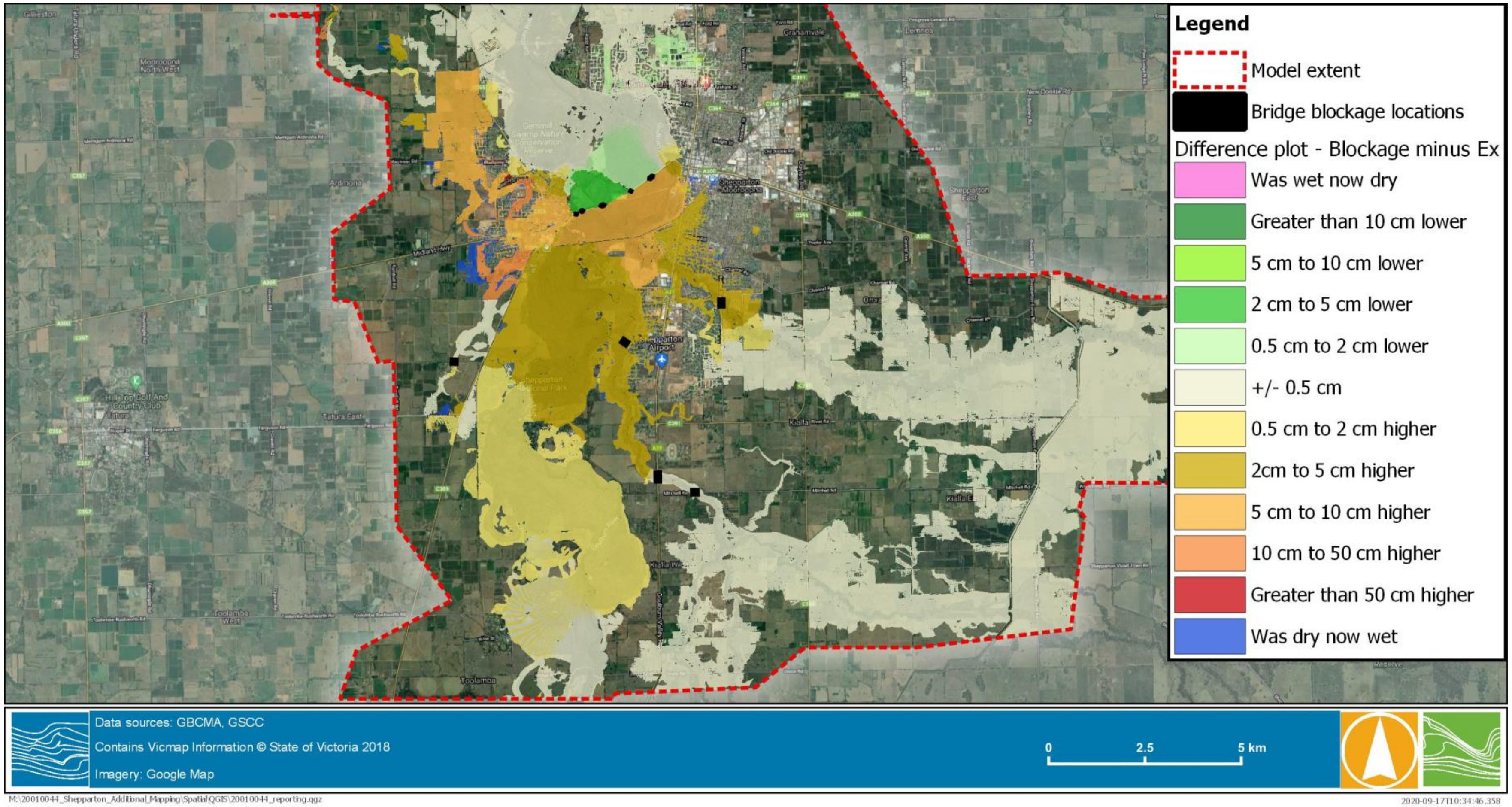

FIGURE 7-2 DIFFERENCE PLOT BRIDGE BLOCKAGE ASSESSMENT 1% AEP GOULBURN RIVER

7.2 Culverts/Pipe Blockage

A pipe blockage assessment was conducted for several major pipe alignments within the urban areas as shown in Figure 7-3. These pipes were assigned a 100% blockage factor and modelled for a 1% AEP Goulburn River dominant flow. The pipe alignments identified were selected as they provide a connection back to the floodplain from urban areas.

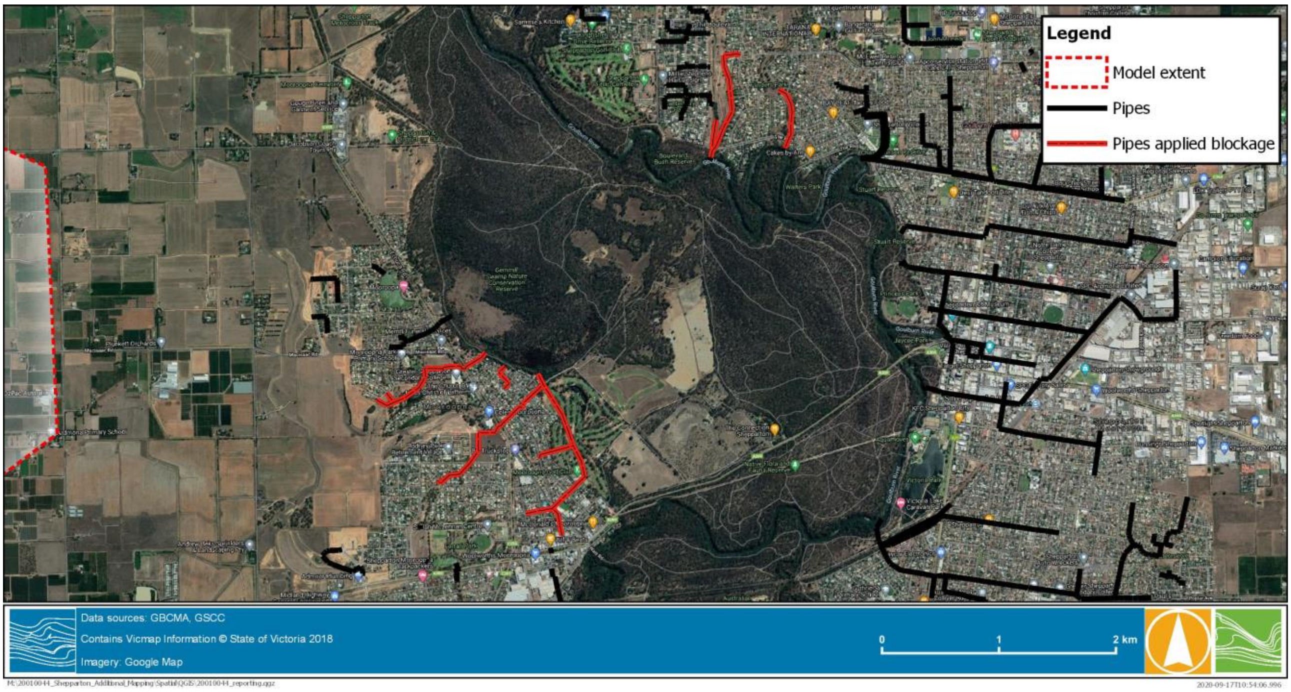

FIGURE 7-3 LOCATIONS OF PIPE BLOCKAGE

Figure 7-4 shows a water level comparison of "blocked" and existing conditions. The comparison shows blockage of these major pipes does not significantly impact peak flood levels. This is a result of the relatively minor capacity of the pipe network in comparison to the overland flow across the floodplain.

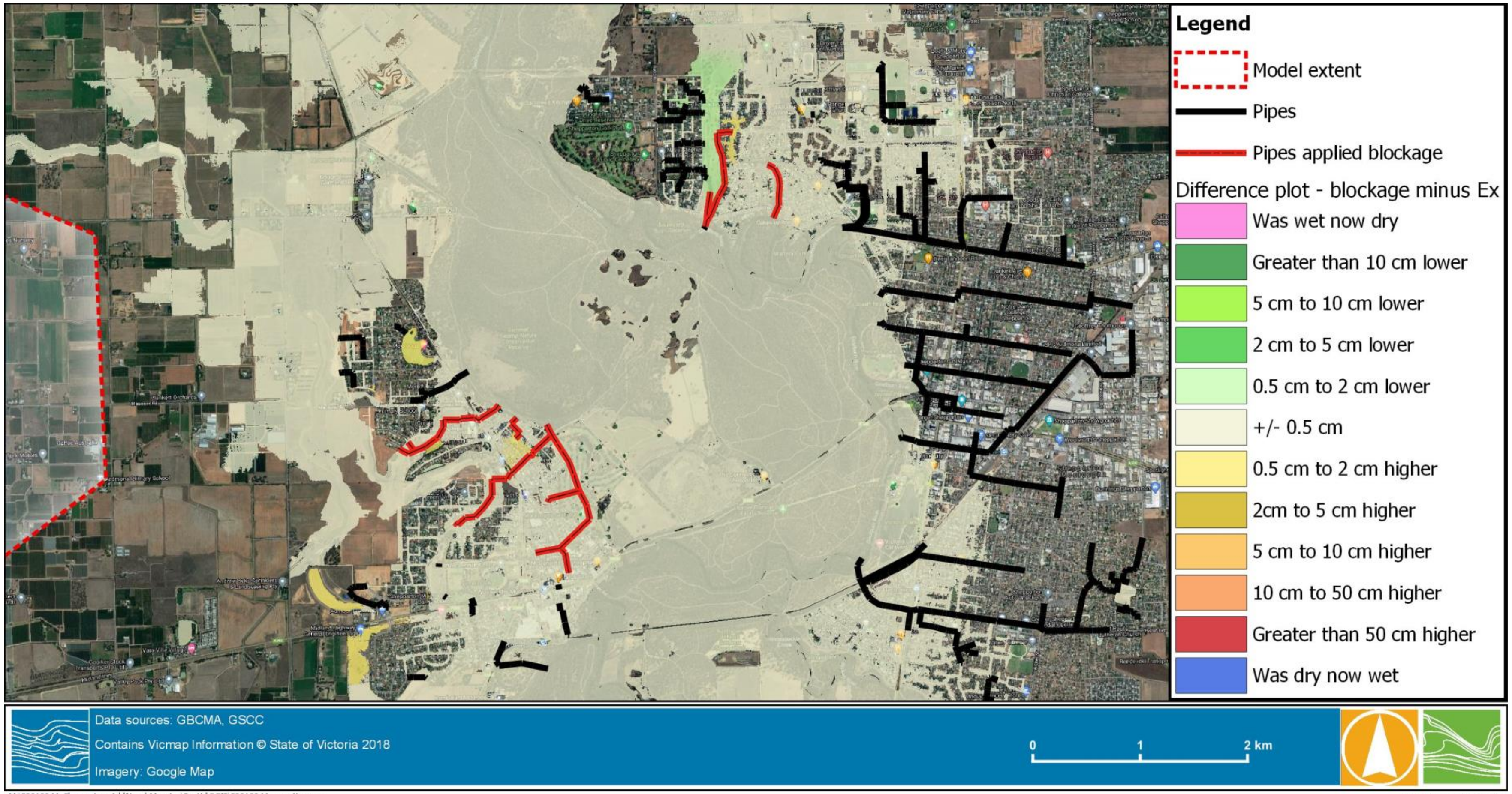

FIGURE 7-4 FLOOD LEVEL DIFFERENCE PLOT (CULVERT BLOCKAGE ASSESSMENT)

8 LEVEE REMOVAL ANALYSIS

The impact of earthen levee failures upstream of Loch Garry Wildlife Reserve was assessed by running an additional 1% AEP Goulburn River dominant flow simulation with sections of the levees removed from the model topography. The potential locations of levee failure were determined through discussions with GBCMA and based on a previous levee analysis undertaken in 2005[5]. The locations determined are shown in Figure 8-1. Levee failure scenario modelling was tested with two runs, one for levees to the west of the Goulburn River and the other for levees to the east of the river. Model results were then merged and compared to existing conditions.

To model the levee failure condition, the levees at these locations were removed from the topography for a distance of approximately 60 metres. An example of the model topography after removing the levee is shown in Figure 8-2.

Figure 8-3 shows a comparison of peak 1% AEP flood levels between the levee failure scenario and existing conditions. A large area of private property has increased in peak flood levels by 20 cm to the west of the Goulburn River while the increase to the east of the Goulburn River side is relativaly minor. Results demonstrate the impact of the levee failure at these locations is relatively minor and localised. These levees are overtopped in a 1% AEP event. Levee breaches are likely to show more of a significant impact on flood levels and extents for flood events with flows less than 40,000ML/d.

FIGURE 8-1 LOCATIONS OF LEVEE FAILURES

[5] Water Technology 2005, *Hydraulic Modelling Analysis for the Lower Goulburn River*. Prepared for GBCMA

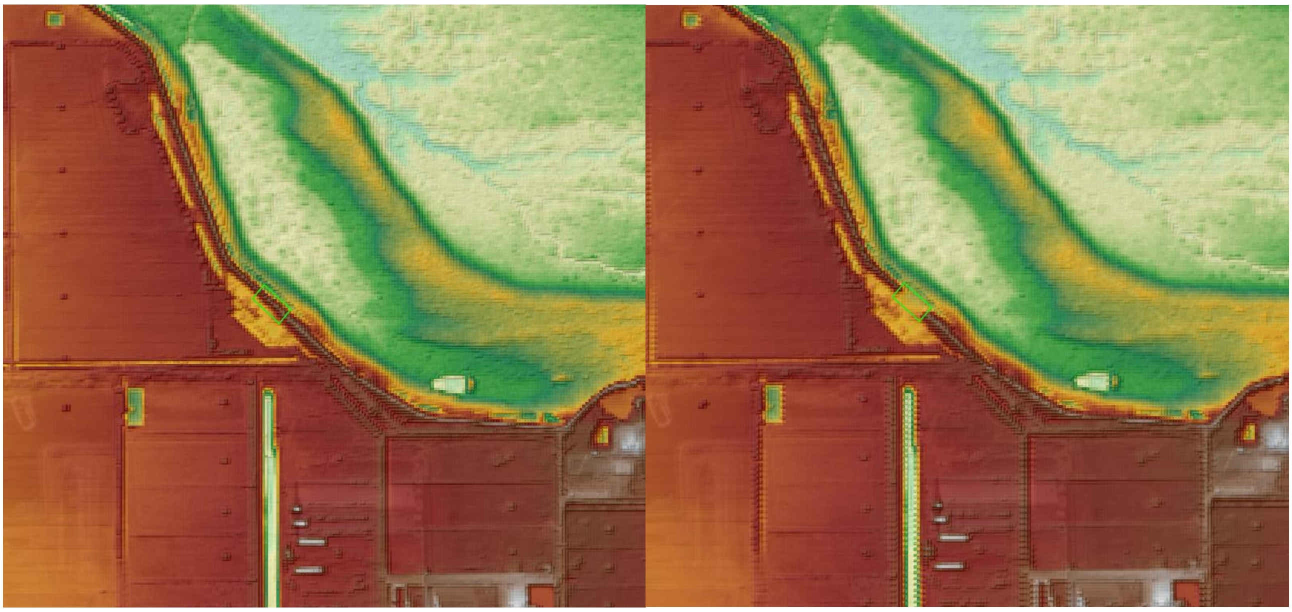

FIGURE 8-2 EXAMPLE OF REMOVAL OF LEVEE – LEFT: BEFORE, RIGHT: AFTER

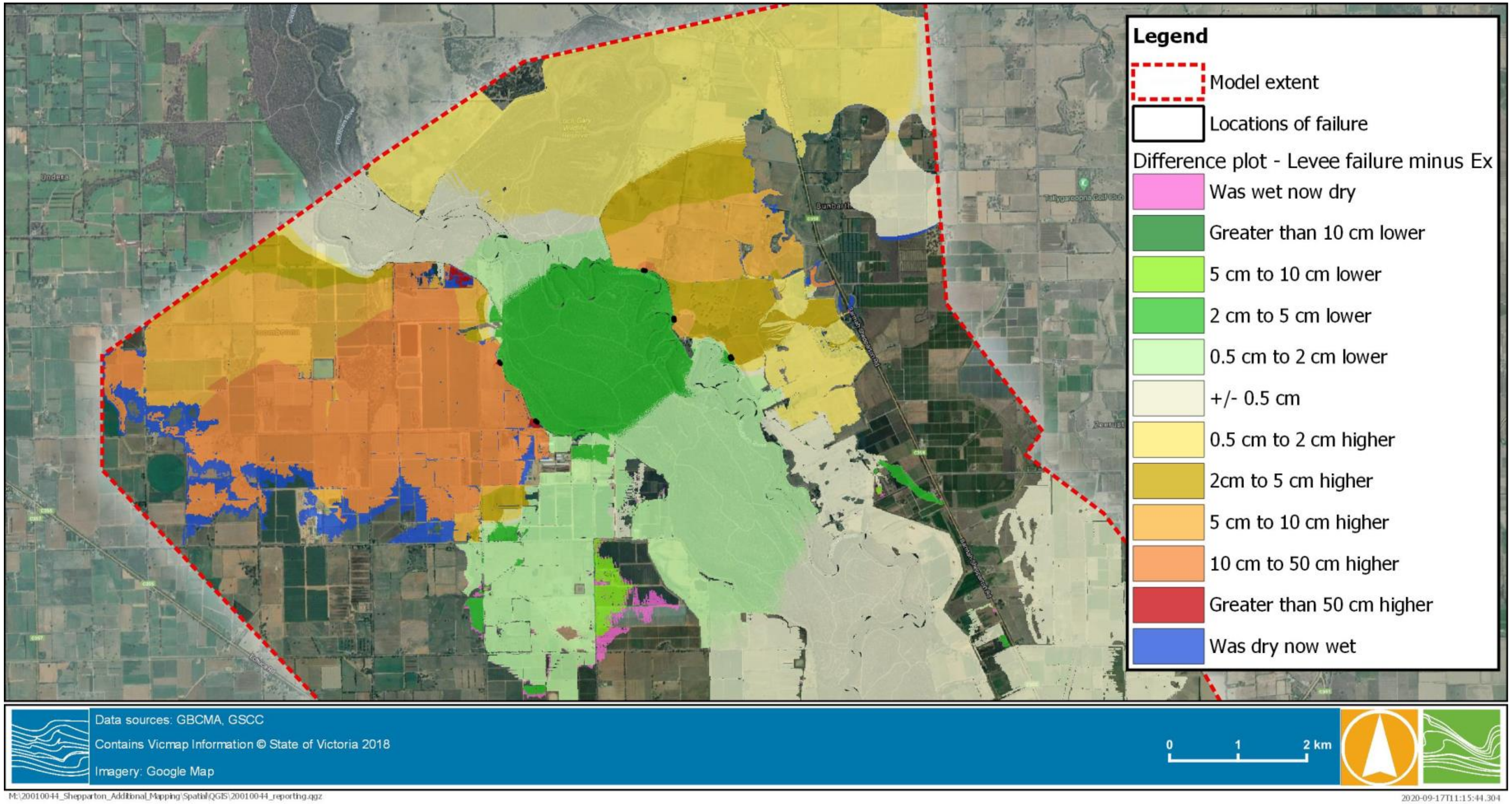

FIGURE 8-3 FLOOD LEVEL DIFFERENCE PLOT – LEVEE FAILURE SCENARIO MODELLING

9 PLANNING CONTROLS

9.1 Overview

Flood related planning controls are used as a mechanism to control flood risk through identifying areas subject to inundation. Flood modelling and mapping outputs are used to highlight areas which should be subject to these controls. Areas of identified high flood risk are often reviewed and changes recommended as more up to date information (best and latest) becomes available. It is understood GSCC are looking to undertake a planning scheme amendment as a result of the updated mapping produced in this study. Current flood related planning controls are based on flood modelling developed as part of the 2002 Shepparton-Mooroopna Floodplain Management Study (Sinclair Knight Merz)[6]. The modelled developed as part of the 2002 study has since been updated with the latest modelling described within this report. A comparison of peak flood levels across the study area shows the differences between the current study (1% AEP and Climate Change) and the 2002 study 1% AEP flood levels. The results show that on average, the flood levels are higher throughout Shepparton and surrounding areas. The levels in the Kialla area are lower in the current study compared with the 2002 study as shown in Figure 9-1.

9.2 Victoria Planning Provisions

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

Section 6.2(e) of the Planning and Environment Act 1987 enables planning schemes to ‘regulate or prohibit any use or development in hazardous areas, or areas likely to become hazardous’. As a result, planning schemes contain State planning policy for floodplain management requiring, among other things, that flood risk be considered in the preparation of planning schemes and in land use decisions.

Guidance for applying flood controls to Planning Schemes is available from the Department of Environment, Land, Water and Planning’s (DELWP) Planning Practice Note 12[7] on Applying the Flood Provisions in Planning Schemes, and The Victorian Floodplain Management Strategy (DELWP, 2016). The objectives of the state planning policy framework[8] for floodplain management is to assist in 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.
- Floodplain areas of environmental significance or of importance to river health.

Planning Schemes can be viewed online at https://www.planning.vic.gov.au/. It is recommended that the planning scheme for this project’s study area is amended to reflect the flood risk identified by this project.

[6] Shepparton-Mooroopna Floodplain Management Study (2002), developed by Sinclair Knight Merz for GSCC
[7] DELWP Planning Practice Notes, accessed from https://www.planning.vic.gov.au/resource-library/planning-practice-notes
[8] Victorian Floodplain Management Strategy (2016), accessed from https://www.water.vic.gov.au/__data/assets/pdf_file/0017/53711/Victorian-Floodplain-Management-Strategy-Introduction-Section-1.pdf

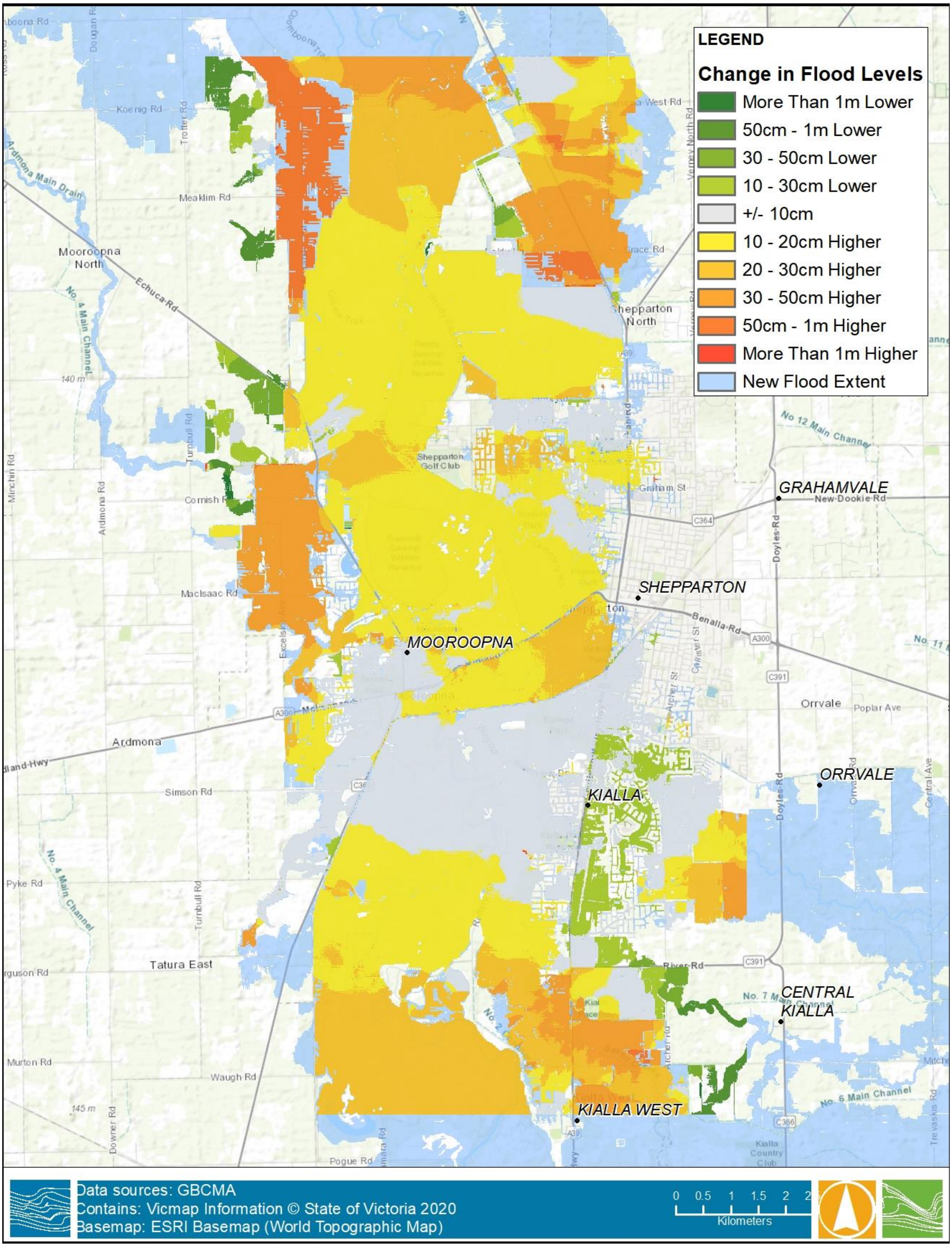

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FIGURE 9-1 CHANGE IN FLOOD LEVEL (1% AEP CLIMATE CHANGE 2021 MINUS SKM 2002 FLOOD LEVELS)

9.3 Current Controls

GSCC currently have three planning controls related to flooding. These are summarised below and shown in Figure 9-2.

- **Land Subject to Inundation Overlay (LSIO)** – defines the floodplain fringe and lower hazard areas within the 1% AEP flood extent
  - Land Subject to Inundation Overlays are planning scheme controls that apply to land affected by flooding associated with waterways, natural flow paths and drains. Such areas are commonly known as floodplains. The LSIO is used to identify flood fringe areas of the floodplain where flooding depths and velocities are typically lower.

  The LSIO identifies lands in flood fringe areas with shallow or slow moving water.
- **Floodway Overlay (FO)** – defines the high hazard portion of the floodplain
  - Floodway Overlays apply to land that is identified as carrying active flood flows associated with waterways, natural flow paths and drains. The overlay is characterised by areas impacted by deep and or fast flowing floodwaters during the 1% AEP flood event.
- **Urban Floodway Zone (UFZ)** – defines flooding high hazard areas and major flow paths within the urban areas
  - The UFZ identify waterways, major flood paths, drainage depressions and high hazard areas within urban areas which have the greatest risk and frequency of being affected by flooding.

9.4 Recommended Updates

This project has provided the modelling outputs and the preparation of the planning controls for the Greater Shepparton Planning Scheme. It is understood the GBCMA and GSCC are currently undertaking the preparation of proposed zoning and overlays based on the updated mapping and may adopt the Climate Change modelling results. The classification of controls based on ARR2019 is summarised below.

- UFZ delineation criteria assesses depth and velocity of water over the area in question during a 1% AEP flood event as follows:
  - Areas classified meeting the criteria below and within the Shepparton/Mooroopna Township Boundary
    - Depth greater than or equal to 0.3 or 0.5 metes; and
    - Velocity greater than or equal to 3.0 metres per second;
    - The product of depth multiplied by velocity greater than or equal to 0.3 m^2 per second
- FO delineation criteria assesses depth and velocity of water over the area outside of the township boundary during a 1% AEP flood event as follows:
    - Depth greater than or equal to 0.3 or 0.5 metes; and
    - Velocity greater than or equal to 3.0 metres per second;
    - The product of depth multiplied by velocity greater than or equal to 0.3 m^2 per second
- LSIO is delineated as any other flooded area within the 1% AEP flood extent outside of these criteria.

The flood mapping data developed during this study has been formatted into the Victoria Flood Database format and it is recommended that this be uploaded to FloodZoom to allow emergency response agency staff access to the data. Updates to the current GBCMA flood Portal are also recommended for events other than the 1% AEP events which have modelled as part of this study.

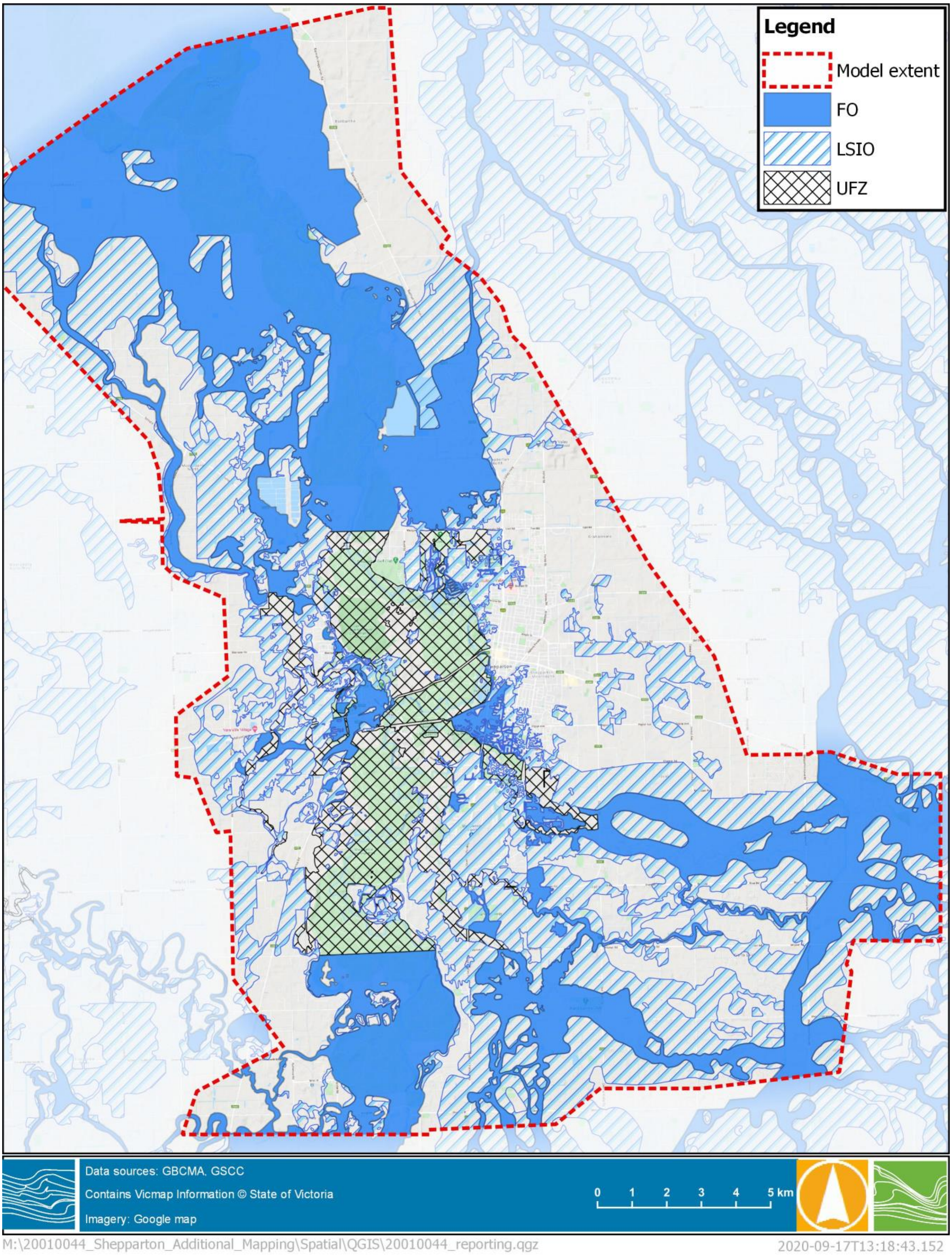


FIGURE 9-2 EXISTING FLOOD RELATED PLANNING CONTROLS IN SHEPPARTON

10 SUMMARY AND NEXT STEPS

The hydraulic modelling undertaken for the supplementary 1% AEP Shepparton Mooroopna Flood Mapping and Flood Intelligence Project has provided an update to the previous 2019 study. A review of the peak design flows for Broken and Goulburn River Flood Study from the 2018 HARC report was undertaken and confirmed the model inflows used in the 2019 Water Technology study were appropriate and were again adopted in this study following revised calibration using TUFLOW HPC.

Flood model results are generally aligned with the results from the 2019 study, with localised changes due to development or changes to floodplain controls (irrigation channels/drains) as a result of the irrigation modernisation project. Importantly, the supplementary modelling reassessed flood risk for the Shepparton, Kialla and Mooroopna areas and identified locations along the Goulburn River, Broken River and Seven Creeks that pose a high flood risk.

The study has significantly increased model resolution throughout the study area while at the same time reducing model simulation time. This has allowed for blockage assessments and the impact of potential levee failures in the lower Goulburn floodplain. The assessments found the likelihood of blockage to major structures was relatively low due to catchment characteristics. A conservative blockage approach was undertaken and showed relatively minor impacts, again due to characteristics of the wide and flat floodplain. The reduction in model simulation time will also allow for any future mitigation or infrastructure works to be assessed much faster, allowing for an assessment of multiple options.

The adopted mapping for the 1% AEP event includes climate change. Given the minor changes to the modelling results and the conservative approach to blockages and levee failure, these factors (blockage/levee failure) were not included in the revised 1% AEP flood mapping. The flood mapping data developed during this study has been formatted into the Flood Spatial Data Specification (formerly known as Victoria Flood Database) format and it is recommended for upload to FloodZoom to allow emergency response agency staff access to the data.

A recommendation from the 2019 study was for Council to endorse the flood study (which has occurred) before putting it out for public comment with aim of adopting the flood study and implementing a planning scheme amendment to update the flood related planning zone and overlays to introduce new flood related planning controls into the planning scheme. The updated modelling has provided a dataset for GBCMA and GSCC to prepare planning controls for a proposed planning scheme amendment in line with the latest industry guidelines.

Utilising the updated model, it is recommended that the staged modelling events (based on Goulburn dominant, Broken dominant and neutral events) be simulated and used to updated mapping datasets on both FloodZoom and the GBCMA FloodPortal.

It is also recommended that GBCMA and GSCC request new developments within the study area provide design surfaces or equivalent to enable the model to be updated on a continual basis ensuring it stays relevant and reduce the requirement for LiDAR to be flown regularly. Further to this, any major stormwater pipe outfalls should also be kept on record to allow for easy incorporation into the model. There are potentially areas within the study area that are susceptible to flooding and inundation during large storm events that are not connected to the flood extents shown in the modelled results. This includes areas in south-east of the study area where water may become trapped from localised hydraulic controls (irrigation channels). It is recommended that an assessment of these areas be undertaken and included in the proposed updated planning controls.

Further investigation of high flow regimes including flows from the Granite Creeks Flood Study as well as Broken River flows from Gowangardie may provide clarification of the impact of the EGMC at extreme flood events. To date, a model of this size has not been developed however design hydrology is available.

APPENDIX A
LIDAR VERIFICATION

A-1 2019 LiDAR

The Goulburn Broken Catchment Management Authority (GBCMA) and the Greater Shepparton City Council (GSCC) were able to secure LiDAR to be flown for the Shepparton and Mooroopna Townships in late 2019. This LiDAR is a significant update on the previously available LiDAR captured in 2011 as part of the Index of Stream Condition (ISC). The LiDAR was captured as part of the Department of Environment, Water, Land and Planning's (DELWP) CIP program. Full metadata and capture details are available via the GBCMA or DELWP. The LIDAR dataset was provided to Water Technology as a 1m resolution Digital Elevation Model (DEM) which covers much of the town as shown in Figure 10-1.

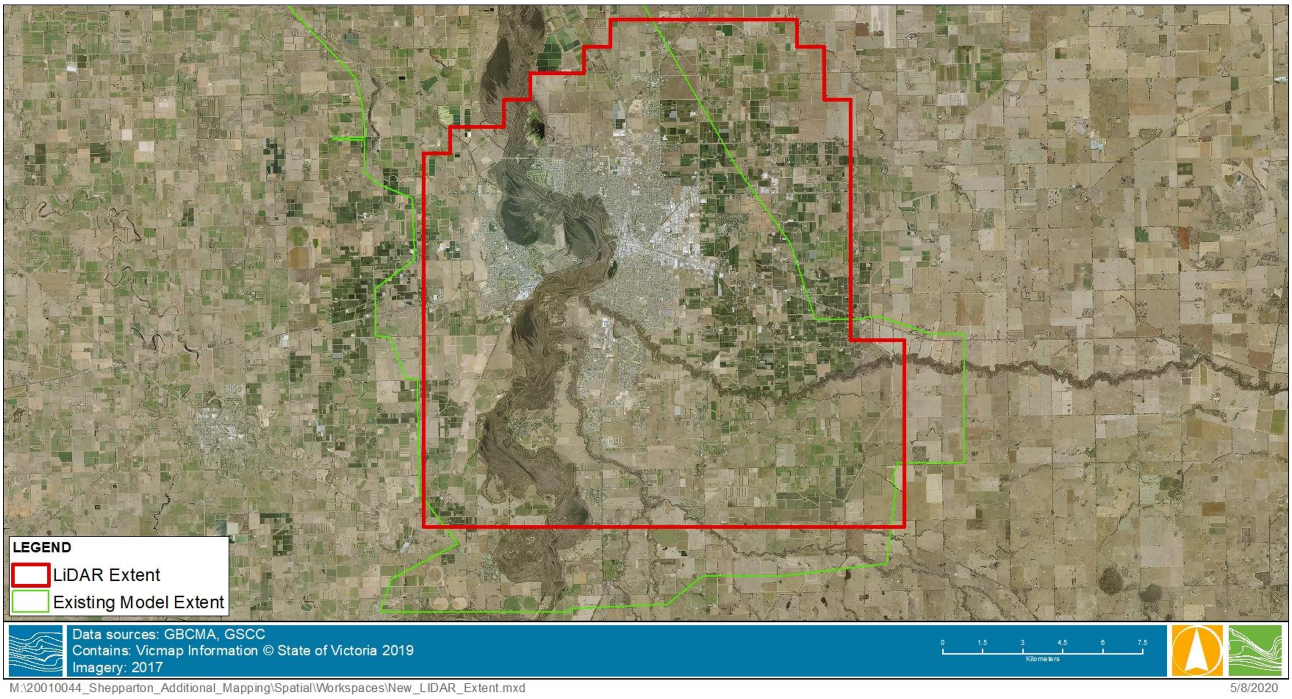


FIGURE 10-1 2019 LIDAR EXTENT

A-2 original Verification of new 2019 LiDAR

The new 2019 LiDAR was previously verified with an accurate road elevation survey transect taken on the Midland Highway bridge between Shepparton and Mooroopna (The Causeway). The transect location is shown in Figure 10-2.

The surveyed elevations were compared with the new LiDAR as shown Figure 10-3, and the minimum, maximum, mean and standard deviations of the difference between the LiDAR and surveyed elevations were tabulated, presented in Table 10-1 (along with the comparison of previous 2011 and 2007 LiDAR).

TABLE 10-1 COMPARISON RESULTS: 2007, 2011, AND 2019 LIDAR MINUS SURVEY

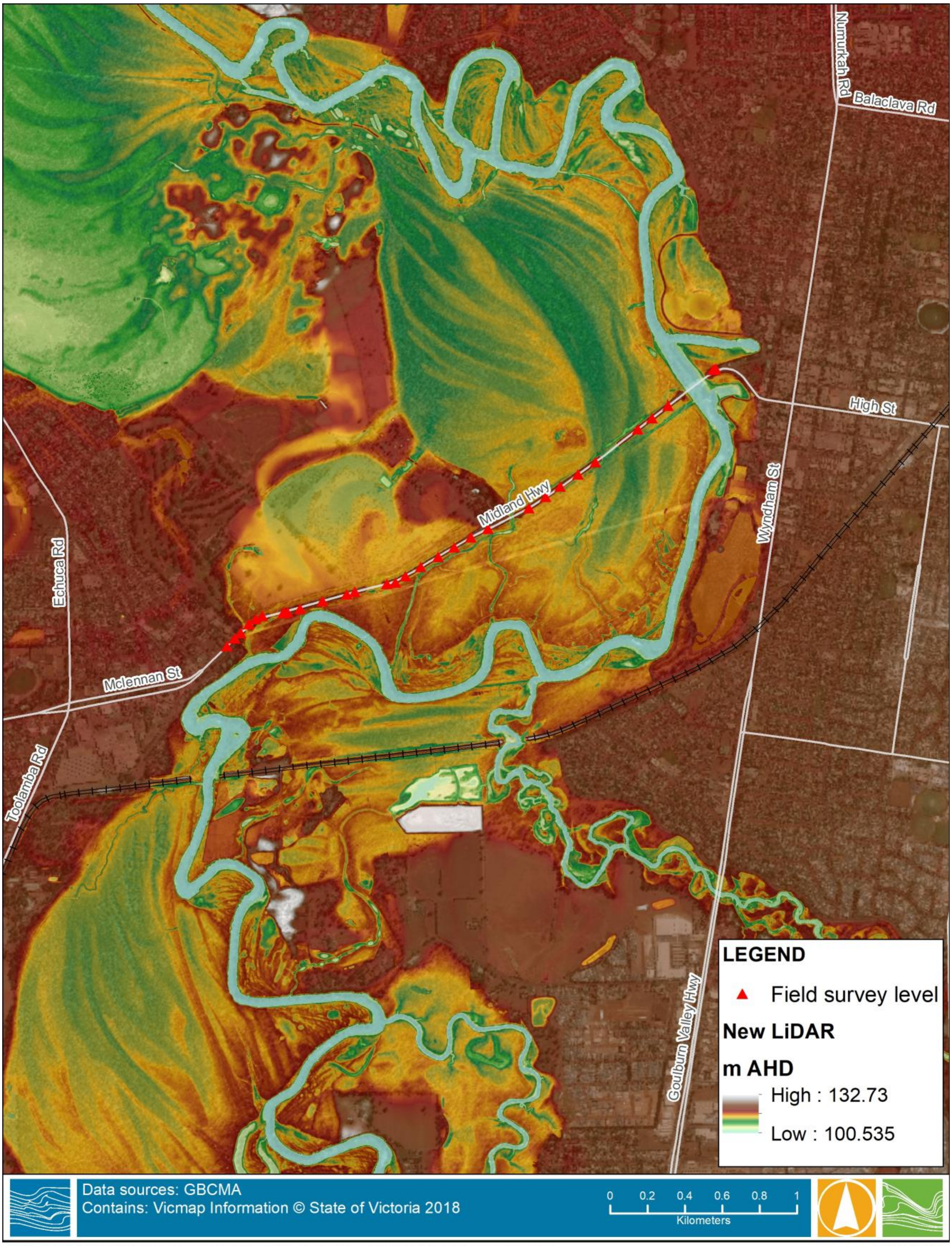
	ISC 2011	FSS 2007	2019 LiDAR
Average Difference (m)	-0.002	-0.083	-0.043
Standard Deviation	0.050	0.039	0.050

	ISC 2011	FSS 2007	2019 LiDAR
Min (biggest difference below survey)	-0.140	-0.210	-0.198
Max (biggest difference above survey)	0.100	-0.010	0.037

Overall, the new 2019 LiDAR seems to be slightly lower than the surveyed levels with a mean difference of around 4 cm and a standard deviation of 5 cm for this particular location. Based on this assessment, the LiDAR data appears suitable for use in the revised hydraulic model.

The new 2019 LiDAR was also compared with the old LiDAR datasets used in previous modelling. Difference plots were created to compare the differences in elevation between new LiDAR and the old LiDAR as displayed in Figure 10-4 and Figure 10-5.

The areas of development since the previous LiDAR was flown (2007 and 2011) identified previously were captured in the new LiDAR. It should be noted that previous LiDAR flown was after a flood event in 2017. It is not surprising to see the new LiDAR shows lower levels at most of the floodplain areas and the river channel than the old LiDAR as the new LiDAR was captured during dry season. As a result, it is believed that the new LiDAR provides better and more accurate representation of the floodplain topographic features.



M:\Jobs\6500-6599\6525_Greenhill_Road_Mt_Helen\Spatial\ESRI\Mxds\Memo_figs.mxd 28/02/2020

FIGURE 10-2 FIELD SURVEY TRANSECT AND NEW LIDAR

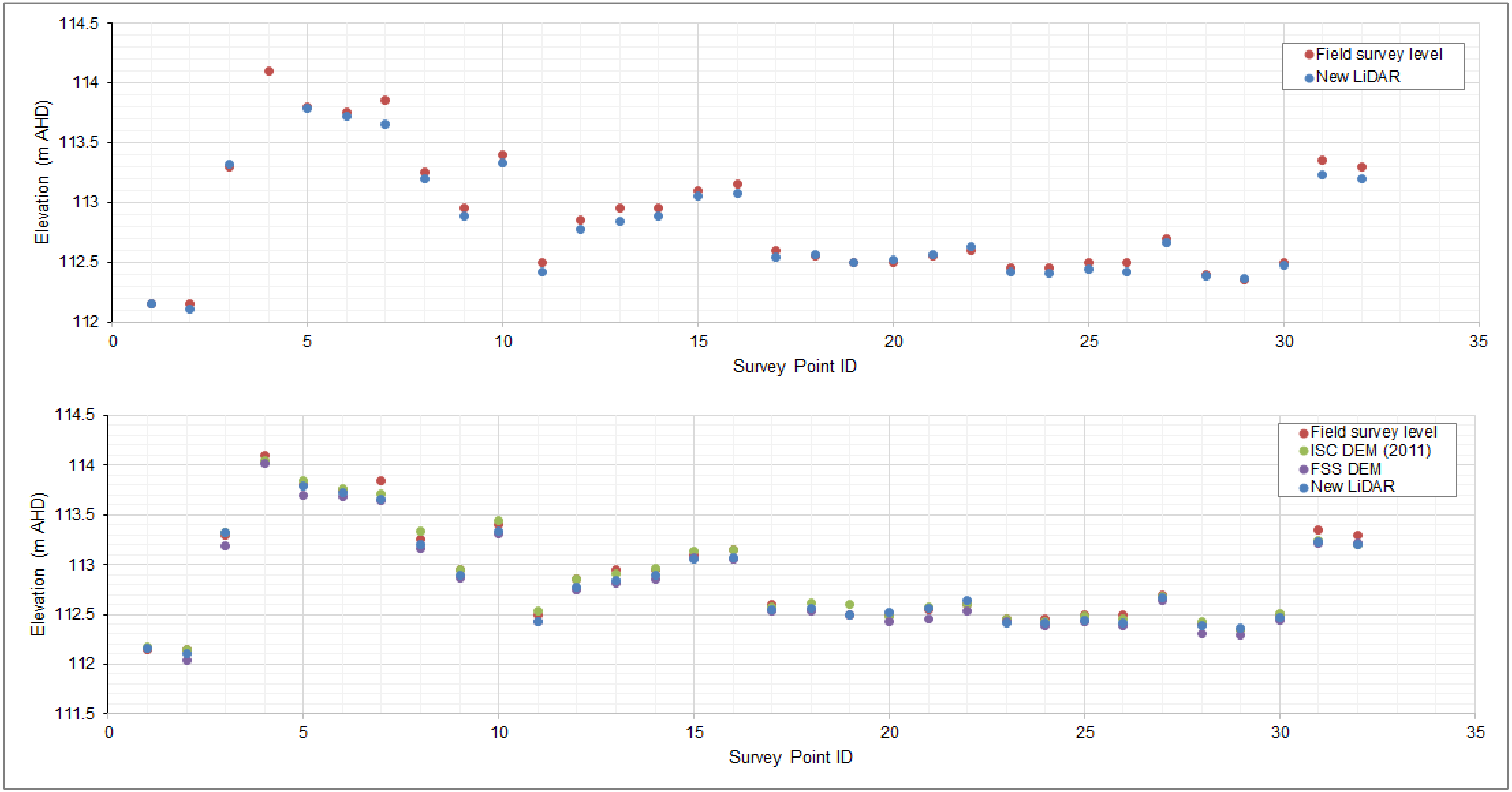


FIGURE 10-3 NEW LIDAR COMPARISON WITH EXISTING FIELD SURVEY LEVELS AS WELL AS WITH PREVIOUS LIDAR DATASETS

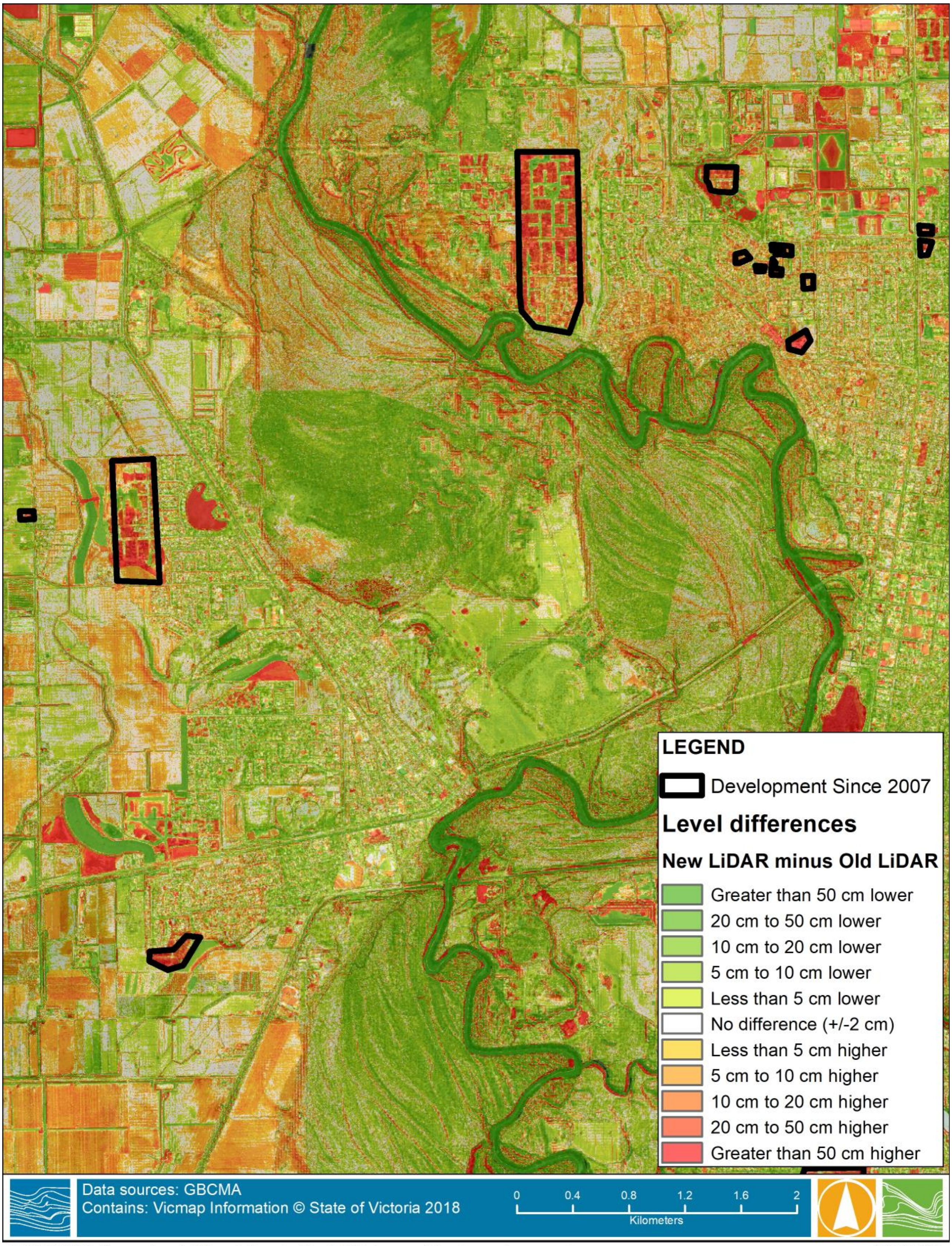


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FIGURE 10-4 COMPARISON BETWEEN NEW LIDAR AND OLD LIDAR – NORTH OF MIDLAND HIGHWAY

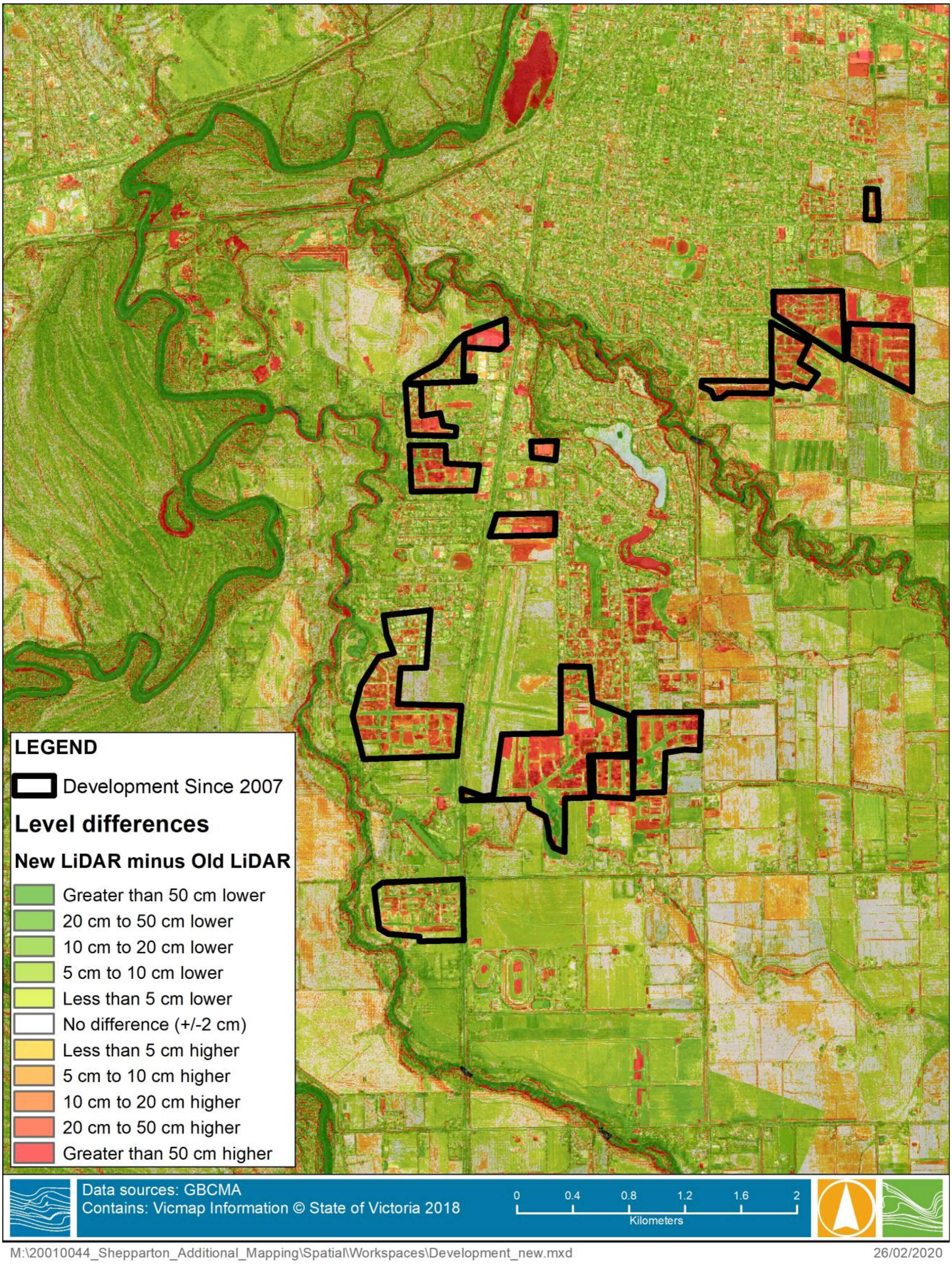


FIGURE 10-5 COMPARISON BETWEEN NEW LIDAR AND OLD LIDAR – SOUTH OF MIDLAND HIGHWAY

A-3 Additional Verification of 2019 LiDAR

Seven new road survey transects were made available by GBCMA in late 2020 to further strengthen the verification and check for any spatial bias in the accuracy of the new 2019 LiDAR. The locations of the seven new transects (transects 2 – 8) are shown in Figure 10-6 along with the original transect (1).

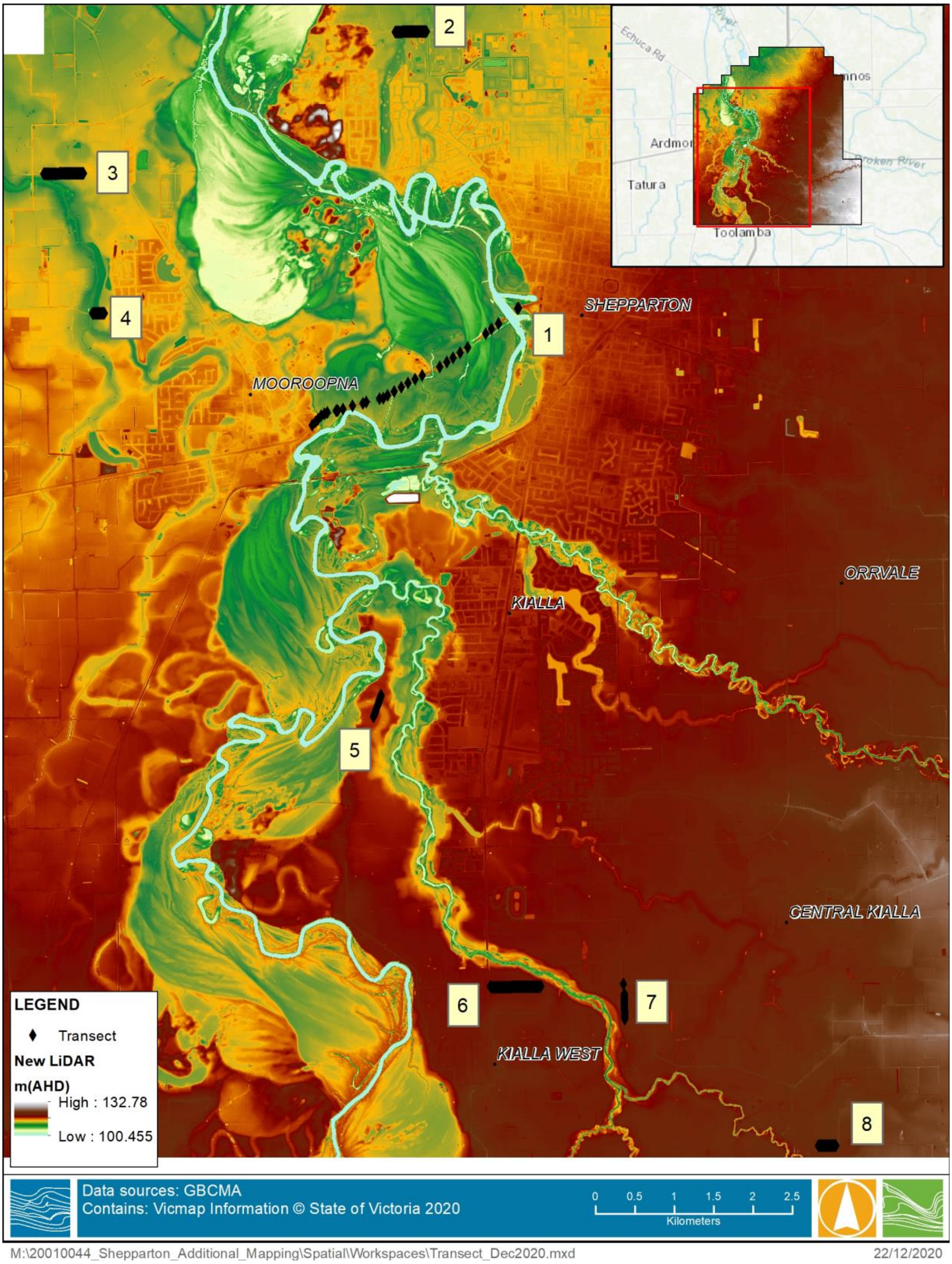


FIGURE 10-6 ADDITIONAL SURVEY TRANSECT LOCATIONS

The 2019 LiDAR was compared to the surveyed elevations across the seven new transects, as per the original comparison. The results of the survey comparison for all eight transects (one original, and seven new transects) are presented in Table 10-2.

TABLE 10-2 ADDITIONAL COMPARISON RESULTS: 2019 LIDAR MINUS SURVEY

Transect ID	Min (biggest difference below survey)	Max (biggest difference above survey)	Average Difference (m)	Standard Deviation
Transect 1 – Causeway (original)	-0.198	0.037	**-0.043**	0.050
Transect 2 – Shep North	-0.116	0.007	**-0.040**	0.028
Transect 3 – Mooroopna North	-0.102	0.002	**-0.048**	0.024
Transect 4 – Mooroopna	-0.033	0.009	**-0.015**	0.012
Transect 5 – Seven Cks Estate	-0.102	-0.008	**-0.047**	0.022
Transect 6 – Kialla West	-0.082	0.033	**-0.045**	0.018
Transect 7 – Kialla West	-0.109	0.151	**-0.052**	0.042
Transect 8 – Central Kialla	-0.158	-0.068	**-0.092**	0.019

A review of these results shows that the new 2019 LiDAR appears to be consistently around 4 - 5cm lower than the surveyed levels, and never outside the expected LiDAR accuracy of ± 10cm on average, at any of the eight transects.

Thus, Water Technology suggest that the new 2019 LiDAR is suitable to be used for the revised hydraulic modelling.

A-4 TUFLOW Model update

The existing TUFLOW model developed as part of the Shepparton-Mooroopna Flood Mapping and Flood Intelligence Study was updated with the incorporation of new LiDAR. The new LiDAR extent does not completely cover the current modelling area as shown in Figure 10-7. As a result, the new LiDAR is used to overlay on top of the old LiDAR datasets where available.

The existing model was built with a combination of 20 m and 10 m grid resolution using TUFLOW multi-domain. The TUFLOW model has been updated with higher modelling resolution of 10m grid size across the entire model area for calibration purposes.

A-4-1 2D Z Shape Changes

A series of “2d_zsh” layers to ensure the model capture topographic features, such as the top of the bank of irrigation channels. With the update of new LiDAR, these “2d_zsh” layers need to be updated according to the new LiDAR values. The “2d_zsh” point layers were buffered to circles by 5m in diameter and the highest elevations with each circle were captured from the new LiDAR. These elevation values were used to update the existing values within the “2d_zsh” point layers. An example of “2d_zsh” layers for irrigation channels near Midland Highway is shown in Figure 10-8.

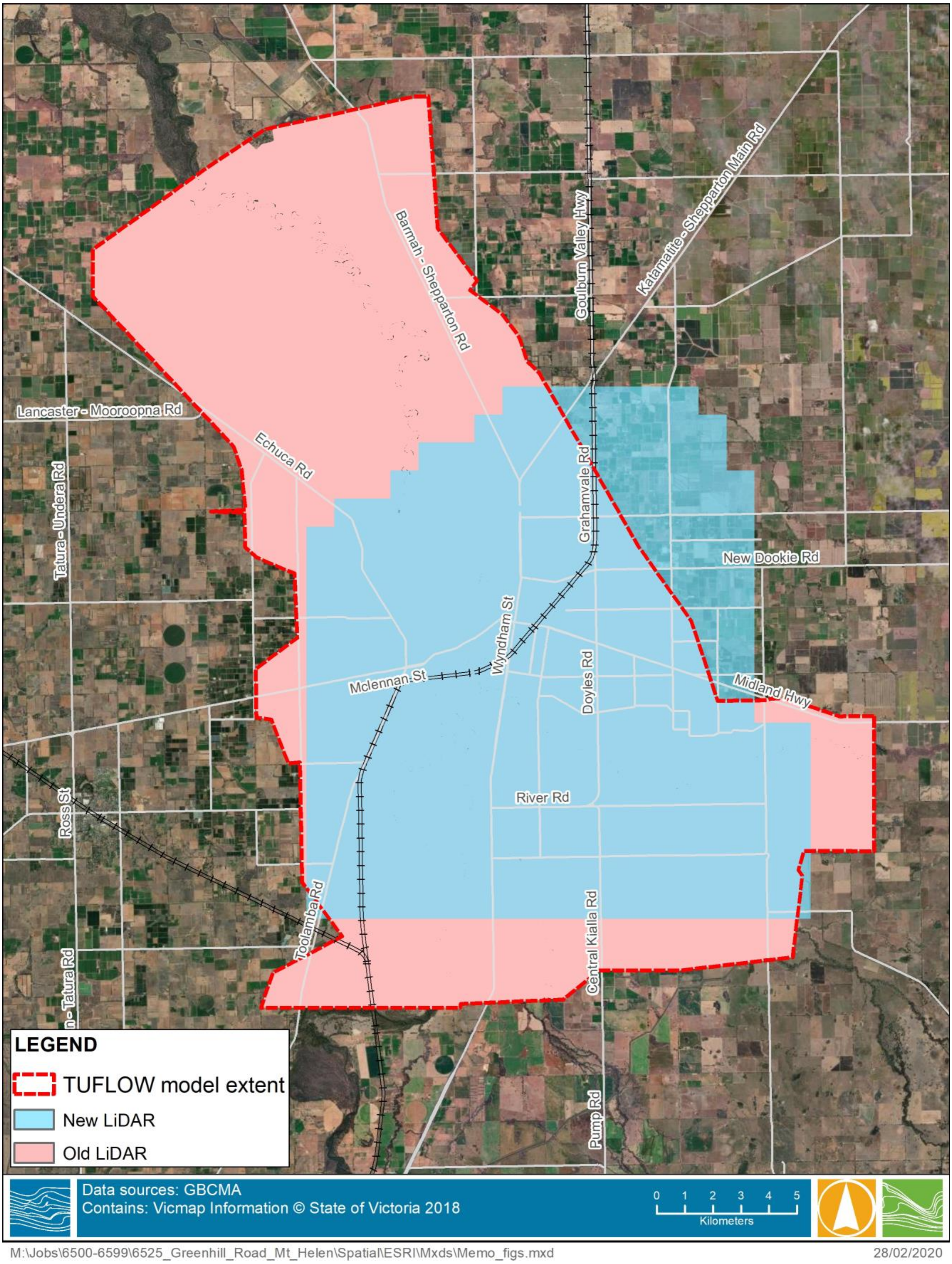


FIGURE 10-7 NEW LIDAR AND OLD LIDAR EXTENTS

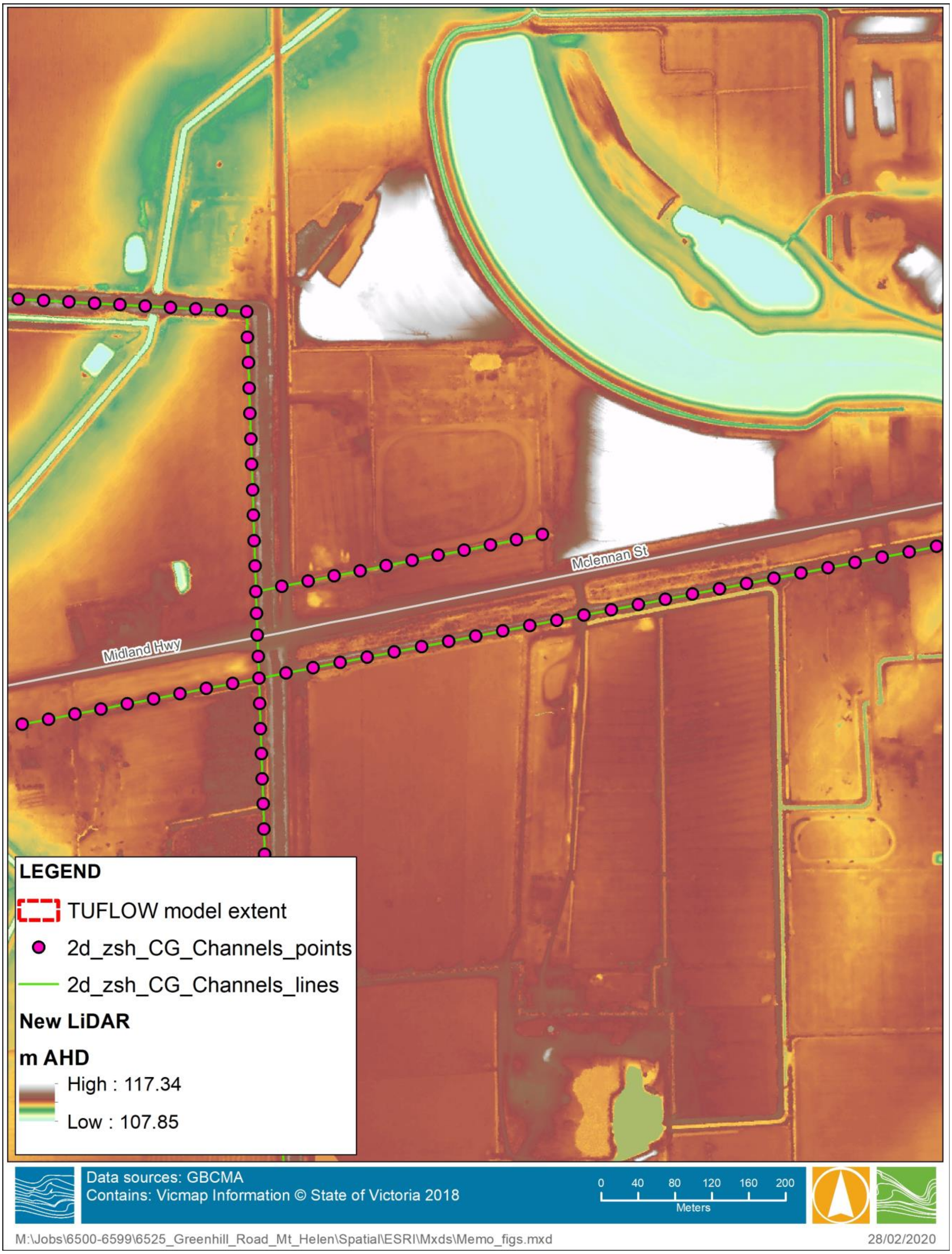
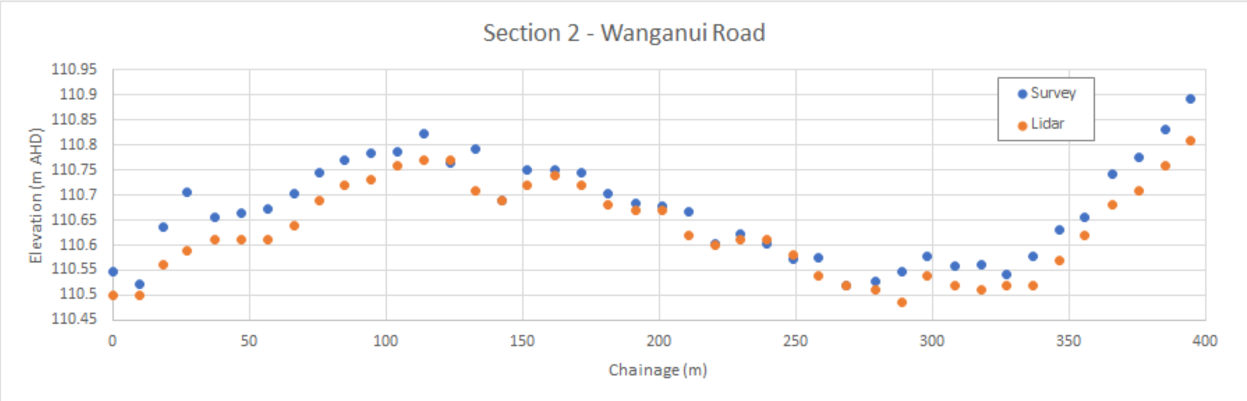
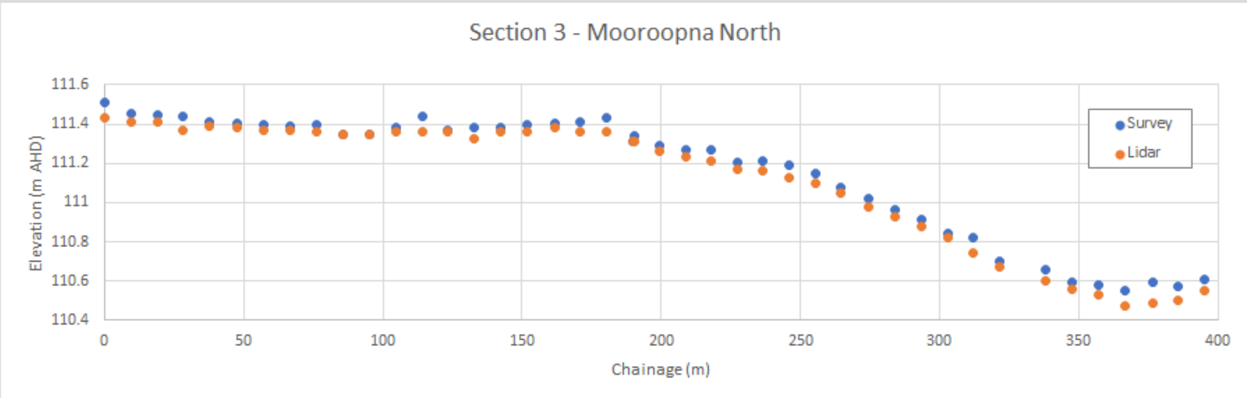
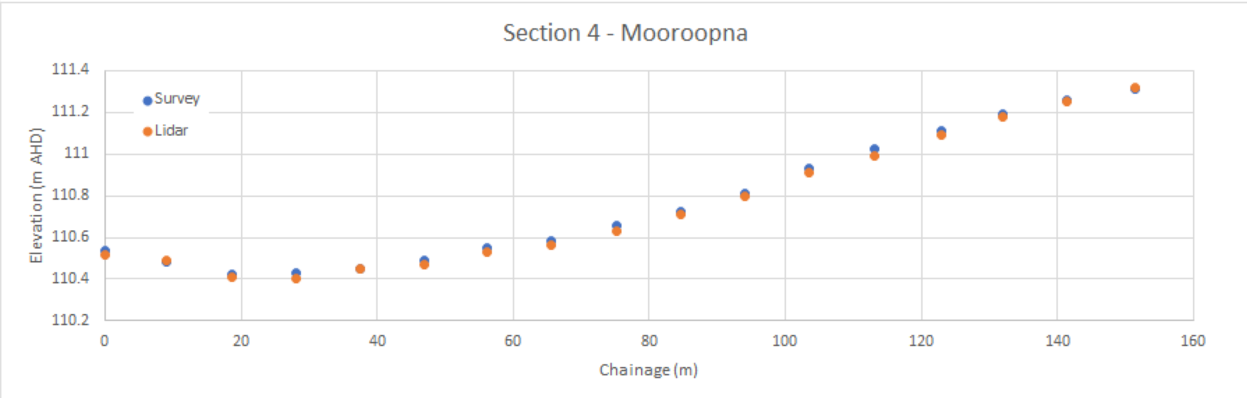


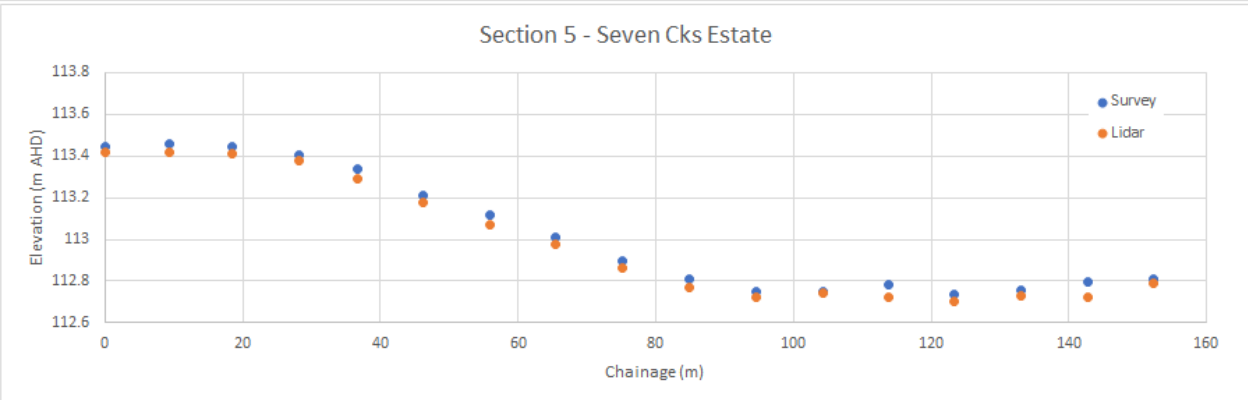
FIGURE 10-8 EXAMPLE OF "2D_ZSH" LAYERS FOR THE BANK OF IRRIGATION CHANNELS

A-5 Transect Survey









A-6 ARR Blockage Assessment

		1	2	3	4	5		Design Blockage Level (inlet)				Vertical Opening	
Bridge Structure	**Debris Type and dimensions**	**Debris Availability**	**Debris Mobility**	**Debris Transportability**	**Debris potential**	**Adjustment for AEP**	**Ajusted Debris potentail**	**L10**	**W (span width)**	**H (invert to soffit)**	**Inlet Blockage**	**adjust L10**	**Inlet Blockage**
Seven Cks @Mitchell Rd	floating	M	M	M	M	1%	M	15	10	2.5	50%	7.5	50%
Seven Cks @ Goulburn Valley Hwy	floating	M	M	M	M	1%	M	15	8	5	50%	not applicable	
Seven Cks @ Raftery Rd	floating	M	M	M	M	1%	M	15	15	4.5	10%	7.5	50%
Broken River @ Archer Rd	floating	M	M	M	M	1%	M	15	13	4	50%	7.5	50%
Goulburn River @ Midland Hwy	floating	M	M	M	M	1%	M	15	10	8	50%	not applicable	
Unamed Ck @ WanganuiRd	non-floating	L	M	L	L	1%	L	2	10	1	0%	1	0%
Geraghtys Bridge (Midland Hwy 1)	floating	M	M	L	L	1%	L	15	10	4	25%	not applicable	
Wongs Bridge (Midland Hwy 2)	floating	M	M	L	L	1%	L	15	20	2	0%	7.5	25%
Boolbadah Floodway (Midland Hwy 3)	floating	M	M	L	L	1%	L	15	30	2.5	0%	7.5	25%
Daishs Bridge (Midland Hwy 4)	floating	M	M	M	M	1%	M	15	10	4	50%	not applicable	
McGuires Bridge (Midland Hwy 5)	floating	M	M	L	L	1%	L	15	40	3	0%	7.5	25%

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