Traralgon Flood Study – Summary Report

June 2016

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PROJECT DETAILS

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Cover Photo: Traralgon CBD flooding, September 1993. Looking South-West towards the Princes Highway and Franklin Street.

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- Adam Dunn (West Gippsland CMA)
- Lance King (Latrobe City Council)
- Rebecca Lett (Department of Environment Land Water and Planning)

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GLOSSARY OF TERMS

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 of extreme magnitude.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level. Introduced in 1971 to eventually supersede all earlier datums.
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. The AEP is the ARI expressed as a percentage.
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 design flood is a probabilistic or statistical estimate, being generally based on some form of probability analysis of flood or rainfall data. An average recurrence interval or exceedance probability is attributed to the estimate.
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.
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 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.
Intensity frequency duration (IFD) analysis	Statistical analysis of rainfall, describing the rainfall intensity (mm/hr), frequency (probability measured by the AEP), duration (hrs). This analysis is used to generate design rainfall estimates.
LiDAR	Spot land surface heights collected via aerial light detection and ranging (LiDAR) survey. The spot heights are converted to a gridded digital elevation model dataset for use in modelling and mapping.
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.
Probable Maximum Flood	The flood that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in a particular drainage area.
RORB	A hydrological modelling tool used in this study to calculate the runoff generated from historic and design rainfall events.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.
Topography	A surface which defines the ground level of a chosen area.

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1. INTRODUCTION

1.1 Overview

Following the recent flood events affecting Traralgon during June 2007, July 2011, June 2012 and June 2013, Water Technology was commissioned by the West Gippsland CMA to undertake the Traralgon Flood Study. This study included detailed hydrological and hydraulic modelling of Traralgon Creek and the Latrobe River, flood mapping of Traralgon, recommendations for flood mitigation works, and a review of planning controls.

The following Summary Report (R05), provides a summary of four detailed standalone reports produced earlier in the project. This report acts as an executive summary of the entire study. A description of each of the staged reports is included below.

R01 - Traralgon Flood Study – Data Review (Water Technology 2016a)

Review of flood related information for the study area, a review of available topographic and structure data (bridges and culvert information), and verification of topographic data. The report also provided a proposed outline of the hydrologic analysis and hydraulic modelling methodology.

R02 - Traralgon Flood Study - Hydrology (Water Technology 2016b)

Hydrologic modelling and analysis report, summarising results of flood frequency analysis, RORB modelling, estimation of design event, and probable maximum flood hydrographs.

R03 - Traralgon Flood Study - Hydraulics (Water Technology 2016c)

Hydraulic modelling report providing details of hydraulic model construction and calibration, sensitivity tests, and results of design event simulations.

R04 - Traralgon Flood Study – Assess and Treat Risk (Water Technology 2016d)

Includes mitigation prefeasibility and modelling, flood intelligence, flood warning and planning control review.

R05 - Traralgon Flood Study – Summary Report (Water Technology 2016e) – this report

Summary of all four reports described above.

These five reports detail the approaches adopted, the findings and recommendations, of the Traralgon Flood Study. The five reports are supported by a number of standalone PDF flood maps and digital deliverables.

1.2 Study Catchment and Floodplain

The Traralgon Creek catchment has an area of approximately 178 km^2 extending 35 km south from the confluence with the Latrobe River, to a maximum elevation of 750 m AHD at Mount Tassie, shown in Figure 1-1. The catchment is well defined, with Traralgon Creek consisting of a single main waterway through the centre of the long narrow catchment. Traralgon Creek then meanders onto the flatter floodplain for the remaining 20 km until it reaches the Latrobe River. The city of Traralgon lies on the northern reaches of Traralgon Creek immediately upstream of the Latrobe River floodplain. The upper catchment is primarily forested, including plantations, whilst the lower catchment is generally farmland with the exception of the urban areas surrounding Traralgon.

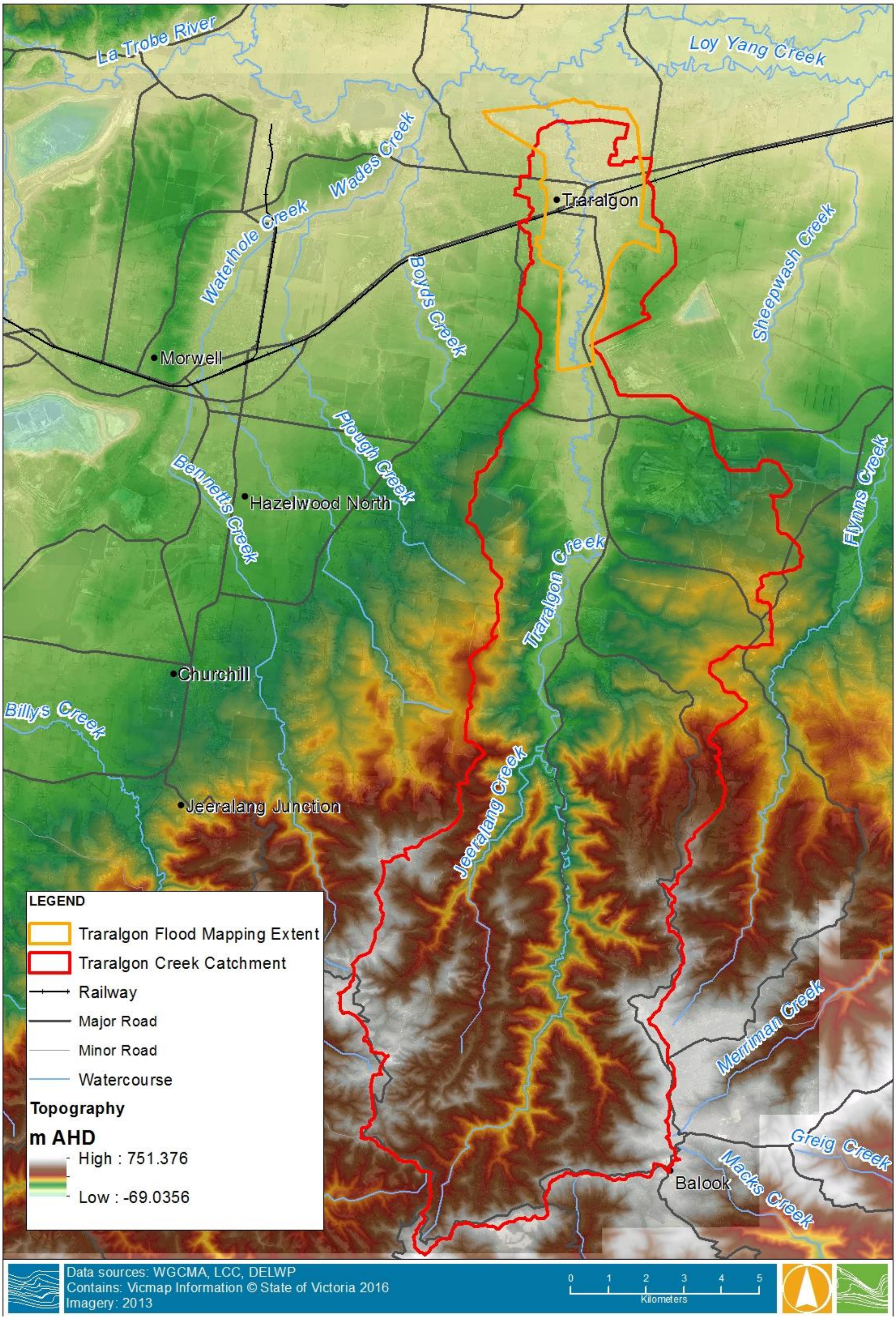

Figure 1-1 Traralgon Creek catchment extent highlighting the study area

2. DATA REVIEW

Shortly after the project inception meeting a detailed review was undertaken of all available flood related information as well as topographic data, structure information, and hydrological data. Details of this review are provided in the Data Review (R01), while a short overview is provided below.

2.1 Flood Related Studies

Traralgon has been the subject of numerous flood related studies and associated mitigation works on the Traralgon Creek and Latrobe River from the 1970s. Table 2-1 summarises the available reports that were reviewed as part of this study to date.

Table 2-1 Summary of Previous Studies

Year	Study	Type	Notes
1979	State Rivers & Water Supply Commission. Report on Flooding from Traralgon Creek (Stage 1)	Flood Study	Hydrology and hydraulics assessment of flooding, including flood frequency, catchment model and 1D hydraulic model. (1% AEP estimate = 20,000 ML/day, RORB)
1979	Gutteridge, Haskins & Davey Pty Ltd. Traralgon Creek Flood Study (Stage 2)	Flood Mitigation Study	Assessment of flooding concerns and proposed channel improvement works
1981	Gutteridge, Haskins & Davey Pty Ltd. Traralgon Creek Flood Study (Stage 3)	Management Study	Flood damages and costing for mitigation works and floodplain management strategy
1984	State Rivers & Water Supply Commission. Traralgon Creek Flood Study – Summary Report	Summary Document	Summary of previous flood study reports and preferred floodplain management strategy
1984	Gutteridge, Haskins & Davey Pty Ltd. Report on Flooding Characteristics South of Shakespeare Street	Development Assessment	Extension of previous modelling south of Shakespeare Street and assessment of developments within this reach
1984	Rural Water Commission of Victoria. Traralgon Flood Mitigation Proposal – Approved Scheme	Flood Mitigation Design	Outline of the approved flood mitigation measures
1995	Department of Conservation and Natural Resources. Documentation and Review of 1993 Victorian Floods Volume 1 & 2	Flood Review	Review of 1993 flood event in Traralgon, including historic gauging information and mitigation scheme performance summary. (1% AEP estimate = 23,000 ML/day, FFA)
1996	Department of Natural Resources and Environment. Traralgon Flood Mitigation Scheme – Levee Audit Report	Levee Audit	Condition assessment of the 360 m long levee system either side of Peterkin St between the railway line and the Princes Highway
2000	Bureau of Meteorology. Traralgon Creek Flood Forecasting Correlations	Hydrologic Investigation	Summary of correlations of hydrologic data for flood forecasting purposes. Includes gauge site information
2000	SKM. Traralgon Creek Floodplain Management Study	Flood study and management plan	Hydrologic, hydraulic and flood mitigation assessment, including flood frequency, catchment model and 2D hydraulic model.

Year	Study	Type	Notes
			Flood damages and mitigation costings. (1% AEP estimate = 21,170 ML/day, RORB)

2.2 Historic Flood Information

Historic flood data recorded in the Victorian Flood Database (VFD) is summarised in Table 2-2 below. The flood extent for 1978 was derived from aerial photography, and the extent for 1993 was based on detailed flood mapping. Further historical information from the Latrobe City Council, West Gippsland CMA, steering committee members and the general public (including photos and anecdotal evidence) was also collated.

Table 2-2 Historic Flood Events

Event	Description	Data available
Dec 1934		Observed Flood level at railway bridge
Feb 1951		Observed Flood levels at several locations
Aug 1951		Observed Flood levels at several locations
June 1952		Observed Flood levels at several locations
June 1978	Largest flood on record at the time 72 residential, 2 commercial and 7 public buildings were flood affected above floor	Digitised flood extent (VFD) Large number of surveyed flood marks Gauged streamflow at 119 m^3/s (73% of peak) Infrared colour and black and white aerial photographs after flood peak Level recorders at Franklin St and Shakespeare St bridges
Sep 1993	Largest flood on record 24 residential and 3 commercial buildings were flood affected above floor and an additional 99 properties flood below floor Slightly larger than 1978, but floodplain management works reduced flooding impacts	Digitised flood extent (VFD) Large number of surveyed flood marks Aerial photography during flood event
Nov 1995	Slightly smaller than 1993, 0.04 m lower at the Traralgon Gauge 24 residential and 3 commercial buildings were flood affected above floor and an additional 99 properties flood below floor	
June 2007	First flood event since flood warning system installed No houses were flooded	Surveyed flood marks
July 2011	Smaller than 2007	
June 2012	Largest event since 1995 10 residential properties flooded above floor	
June 2013	Smaller than 2011	

2.3 Topographic Data

2.3.1 Available Datasets

Aerial LiDAR (Light Detection and Ranging) survey is available for the Traralgon area from three different sources:

- 2010 Victorian State Wide Rivers LiDAR Project - West Gippsland CMA
- 2010-2011 Floodplains LiDAR Project
- 2008 Southern Rural Water LiDAR Project

Additional field survey including several transects, river cross sections and culverts was carried out to verify the Lidar data, provide an estimate of channel capacity and fill data gaps of important hydraulic structures

2.3.2 Data Verification

The three LiDAR datasets that were used for the construction of the hydraulic model were compared against the field survey data. The survey data included several cross sections of the Traralgon Creek and two transects located at Howitt Street, on the southern side of the Bairnsdale Railway and to the north of the CBD along Bradman Boulevard.

While the *Rivers* LiDAR set showed the highest accuracy within the two transects surveyed, the *Floodplains* data is rated at a higher vertical accuracy compared to the *Rivers* data. Additionally the *Floodplains* LiDAR data covers a larger area than the *Rivers* LiDAR. Therefore Water Technology recommended utilising the *Floodplains* LiDAR set with a vertical shift of 250 mm in the hydraulic model build for the Traralgon Creek combined with the *SRW* LiDAR for the Latrobe River section of the model. The LiDAR can't penetrate water within the channel, therefore channel cross section information was used for setting channel profiles throughout the hydraulic model to gain an accurate channel capacity.

2.3.3 DEM Development

As mentioned previously, the *Floodplains* Lidar dataset with a vertical shift was used to generate the digital elevation model for the hydraulic model. Initially, the Latrobe River was modelled at a 15 m grid resolution while the Traralgon city and urban area was modelled with a 3 m grid resolution.

2.4 Structure Information

There are several key hydraulic structures within the Traralgon located on Traralgon Creek. These hydraulic structures play an important role in flood events ranging from small, frequent events through to large, rarer flood events. Several of these structures within and around the CBD include; the Melbourne-Bairnsdale Railway line; Whittakers Road; Princes Highway; and Franklin Street. Information on these structures was obtained through the Latrobe City Council, WGCMA as well as a site visit on October 16, 2014. Bridge piers, deck heights and culvert dimensions were sourced and added to the hydraulic model.

2.4.1 Pit and Pipe Network

The Traralgon stormwater drainage network was incorporated in the 1D/2D hydraulic model using pipe and pit information provided by the LCC. A significant data gap was identified in the pit and pipe network, therefore considerable engineering judgement was applied to the drainage network. The changes made to the existing database ensure the pit and pipe network functioned within the hydraulic model and were noted in the GIS database.

2.5 Hydrological Data

2.5.1 Rainfall Data

The average annual rainfall at Traralgon is 620 mm. A steep rainfall gradient exists over the catchment with average annual rainfall reaching 1,500 mm in the headwaters. At the catchment centroid the average annual rainfall is around 670 mm. Numerous daily rainfall sites are in operation in and around the catchment. Key stations, including current stations and stations operating over historic flood events are listed in Table 2-3. Pluviograph (sub-daily rainfall) stations in and around the Traralgon Creek catchment are listed in Table 2-4. Figure 2-1 shows the locations of the daily and pluvio rainfall stations around the Traralgon Creek catchment.

Table 2-3 Daily rainfall stations around Traralgon Creek catchment

Gauge No.	Location	Period	Years
85009	Traralgon EPA	2000-2014	14
85086	Traralgon	1902-1964	62
85017	Callignee South	1932-1985	54
85007	Traralgon Creek (Balook)	1999-2014	14
85008	Balook	1905-1962	57
85005	Traralgon Creek (Mount Hooghly	2000-2008	8
85006	Le Roy (Taylors Rd Quarry)	2000-2009	8
85062	Morwell (Mail Centre)	1887-2004	117
85011	Blackwarry	1888-1975	87
85101	Tarra Valley	1952-1990	38
85105	Hazelwood North	1939-1994	55
85139	Traralgon (Cora lynn)	1892-1918	23
85150	Hazelwood Sec	1963-1993	30
85170	Traralgon L.V.W.& S.B.	1967-1999	32
85236	Callignee North	1956-2014	57
85281	Traralgon Creek At Koornalla	2000-2014	14
85169	Traralgon Post Office	1964-1967	3
85264	Novacs	1968-1986	18
85299	Koornalla Traralgon Ck Rd	1964-1967	2
85280	Morwell (Latrobe Valley Airport)	1984-2014	30
85307	Jeeralang North	2009-2014	5

Table 2-4 Pluviograph stations around the Traralgon Creek catchment

Gauge No.	Location	Period	Years
85098	Yallourn	1936-1948	12
85170	Traralgon LVW & SB	1961-1979	18
85236	Callignee North	1961-2013	50
85263	Murrays Balook	1974-1978	3.2
85264	Novacs	1968-1978	10
85265	Macks Creek	1975-1978	3.4
85280	Morwell (Latrobe Valley Airport)	2005-2014	9.3

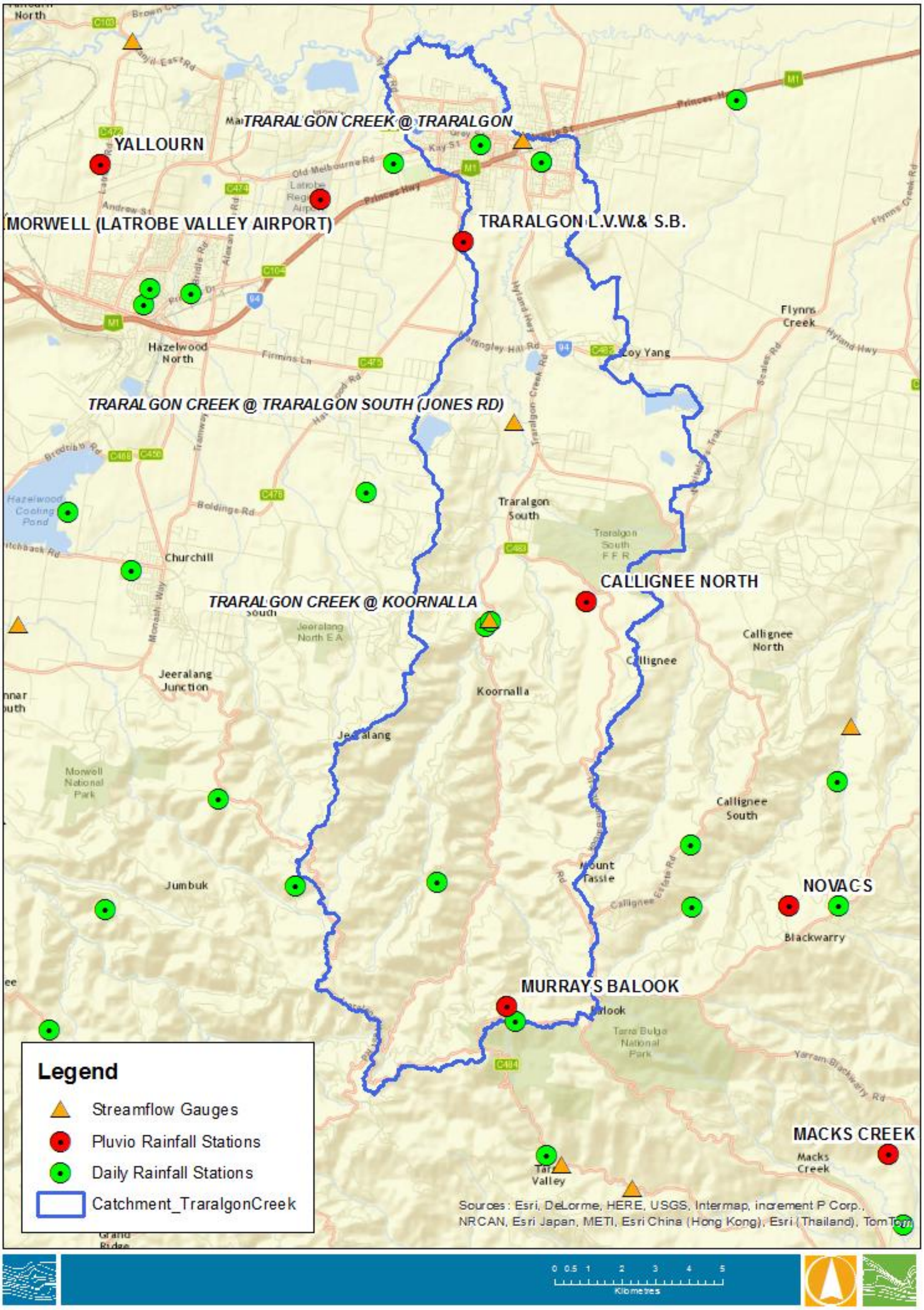

Figure 2-1 Daily Rainfall, Pluvio and Streamflow Stations around Traralgon Creek catchment

2.5.2 Streamflow Data

Gauge Locations

Three streamflow gauges operate in the catchment (Table 2-5). The Traralgon Creek @ Traralgon gauge is located within the city centre of Traralgon alongside the Princes Highway. The Traralgon South and Koornalla gauges are located upstream of the Traralgon urban area. The gauge at Traralgon was moved 300 m upstream from Wright St to the Princes Highway in August 1998 to improve the rating of higher flows as water was known to flow around the Wright St gauge in large flood events (BoM, 2000). The Wright St gauge was kept in operation for several years to ensure consistency between the gauges. The gauge zero was also changed at Wright St from 29.929 m AHD to 31.929 m AHD on 23 April 1987, and is now listed as 32.673 m AHD. It is unknown when the latest change occurred. The changes to the gauge have direct implications on the flows measured in high flow events and have a bearing on the annual peak series and flood frequency analysis. Water Technology investigated this further during the hydrology stage of the study.

Table 2-5 Streamflow gauges in Traralgon Creek catchment

Gauge No.	Location	Period	Years	Catchment Area (km^2)
226023	Traralgon Creek @ Traralgon	1960-2014 (incomplete)	54	189
226415	Traralgon Creek @ Traralgon South (Jones Road site)	1997-2014	17	128
226410	Traralgon Creek @ Koornalla	1953-2014	60	89

Rating Curves

A review of the three streamflow gauges was carried out during the hydrology stage of the project. This identified several inconsistencies with the data due to the location of the gauges changing, altered gauge zero values and a number of different rating curves being used over time.

The Traralgon gauge published water levels and flows were plotted and clearly show a number of rating curves were used on the Traralgon gauge over the 54 year period (Figure 2-2). This is because the gauge location has moved during the period, the gauge datum has been adjusted and waterway works have altered the channel geometry.

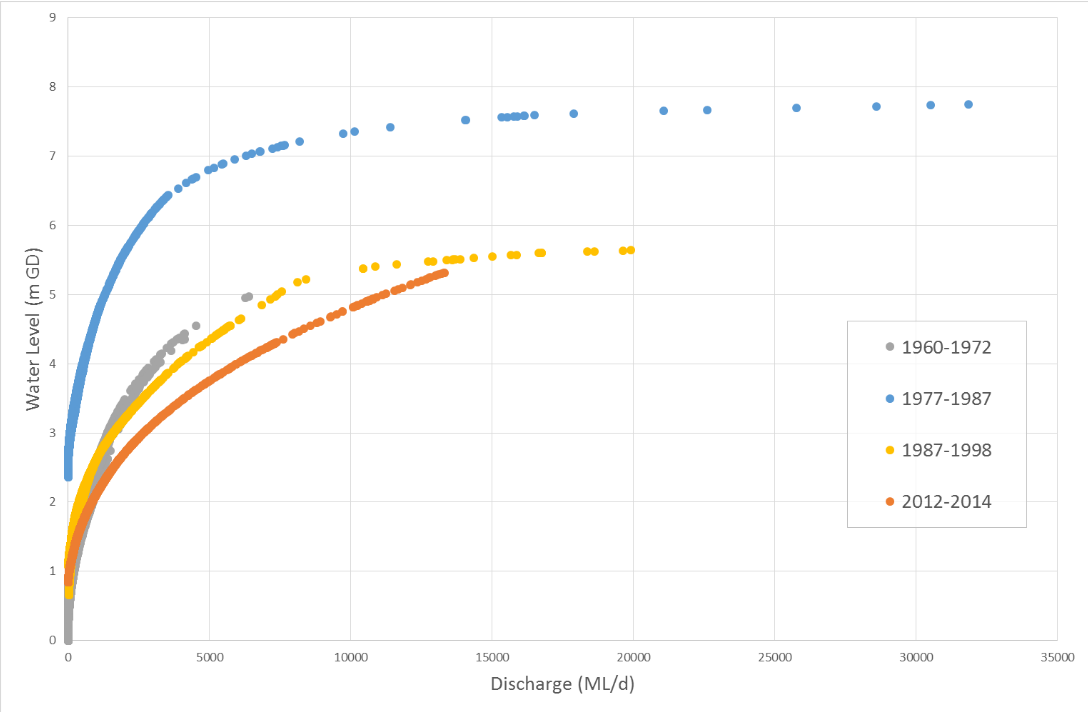

Figure 2-2 Water Level vs. Discharge Plot for Traralgon gauge (226023) showing variation in rating curves across period of record

The Traralgon South gauge was used to guide timing and shape of the hydrograph only as in large events the flow estimate at this gauge has considerable uncertainty.

The Traralgon Creek at Koornalla gauge was used for calibration of the hydrological model noting the uncertainty, along with the Traralgon gauge. The latest rating table was established in May 2012, just prior to the June flood event and is officially considered reliable for flows up to just 2,420 ML/d, corresponding to a gauge height of 2.1 m. The unreliable section of the rating table continues to 14,170 ML/d at a gauge height of 4.19 m.

3. PROJECT CONSULTATION

3.1 Overview

An important element of the flood mapping study was the active engagement of residents in the study area. This engagement was developed over the course of the study through community consultation sessions and meetings with a Steering Committee. The aims of the community consultation were as follows:

- To raise awareness of the study and to identify key community concerns; and
- To provide information to the community and seek their feedback/input regarding the study outcomes including the existing flood behaviour and proposed flood mapping extents.

3.2 Steering Committee

The flood mapping study was led by a Steering Committee consisting of representatives from West Gippsland Catchment Management Authority (WGCMA), Latrobe City Council (LCC), Department of Environment Land Water and Planning (DELWP), Victorian State Emergency Service (VicSES) and community members from Traralgon.

The Steering Committee met on four occasions at key points throughout the study, to review study progress, provide comments regarding results, and manage the development of the study.

3.3 Community Consultation

The main aim of the community engagement process was to provide information regarding the development of the study and to seek feedback, both verbally and through the use of online methods. All community meetings were supported by media releases to local papers and meeting notices.

The public consultation process was coordinated by West Gippsland CMA and Latrobe City Council. The following community meetings were held as part of the consultation process:

- Initial community meeting, 9th December, 2014 in Traralgon – The first public meeting was held to outline the objectives of the study to the community and to receive any flood information the community may be able to provide;
- Second community meeting, 31st March, 2015 – this meeting was to provide an update on the project and to gather additional flood intelligence information from the community.
- Third community meeting, 29th September 2015 – This meeting presented the results of the flood modelling. Community feedback was sought on the flood modelling results and potential mitigation ideas.

The community provided knowledge of a range of previous floods. An especially large range of data from the 1993 flood was provided, and could be compared to the 1% AEP and 2% AEP events due to the similarity in magnitude.

An ArcGIS online portal presenting the flood mapping was published allowing for public comment, with several minor comments from the community being noted.

A flood questionnaire focused on the Traralgon area was also circulated to the community through the West Gippsland CMA. The questionnaire focused on potential mitigation options within Traralgon as well as asking for additional flood mitigation suggestions. There were several responses from community members, however the main issues identified were associated with flash flooding as a result of stormwater issues that were not covered within the scope of this project.

4. FLOOD BEHAVIOUR

4.1 Overview

Riverine flooding in Traralgon usually occurs due to prolonged heavy rainfall in the upper catchment around Mt Tassie. Localised rainfall throughout Traralgon is likely to cause flash flooding issues but will generally cause only a minor rise in Traralgon Creek levels.

The flood behaviour associated with catchment flooding mechanisms has been assessed using a range of industry standard approaches and tools:

- Hydrological analysis – this involves the analysis of the magnitude of previous flood events in the catchment, the development of a rainfall-runoff model for the entire Traralgon Creek catchment, and the prediction of the likelihood of future flood events of a given magnitude.
- Hydraulic analysis – the physical understanding of how a given flood event may behave as the Traralgon Creek flow breaks out of bank through the Traralgon urban area. A hydraulic model was used to predict the extent of flooding, flood depths and flow velocities for a range of possible future flood events.

The different flood mechanism and the results of the hydrologic and hydraulic analysis for the study area are discussed in detail in the following sections.

4.2 Hydrology

Detailed information on the hydrology can be found in the Hydrology Report (R02).

4.2.1 Streamflow Gauging

The three streamflow gauge stations within the catchment were used to help calibrate the hydrological model for the three calibration events. Given the inconsistencies with the streamflow gauge rating curves at Traralgon South and Koornalla, the Traralgon gauge was the only gauge deemed suitable for flood frequency analysis and calibration purposes. A detailed analysis of each gauge was undertaken and is presented in the Section 3.3 of the Hydrology Report (R02).

4.2.2 Flood Frequency Analysis

A flood frequency analysis was used to estimate the magnitude of flood events at the Traralgon Creek at Traralgon gauge in terms of a probability of occurrence. This allows the quantification of previous flood events and also enables the estimation of the frequency of future flood events.

The flood frequency analysis was based on an annual series of maximum flows at the gauge for the full record of data. Historic flood peaks were also included based on flood information received for the gauge. Further details are provided in Section 3.4 of the Hydrology Report (R02). The design flows resulting from the flood frequency analysis at the gauge are given in Table 4-1, which also shows the comparison of previous flood frequency analysis on the Traralgon gauge. Given the reasonable length of record and the good fit of the Log Normal distribution, these peak design flows are considered to be a good predictor of flood probability (assuming no on-going or future climate trends).

Table 4-1 FFA Peak Flow Estimates for Traralgon Creek at Traralgon

AEP	Peak Design Flow (ML/d) (Water Tech 2016)	Peak Design Flow (ML/d) (SKM, 2000)	Peak Design Flow (ML/d) (SRWSC, 1979)
10%	7,700	8,550	6,650
5%	11,100	11,840	9,590

2%	16,700	16,850	14,690
1%	21,900	21,170	19,870

4.2.3 Hydrologic Modelling

A hydrological model of the catchment was developed for the purpose of extracting design flows to be used as boundary conditions in the Traralgon hydraulic model. The rainfall-runoff program, RORB (Version 6) was used for this study.

RORB is a non-linear rainfall runoff and streamflow routing model which is used for calculation of flow hydrographs in drainage and stream networks. The model requires catchments to be divided into subareas, connected by a series of conceptual reach storages. Design storm rainfall is input to the centroid of each subarea. Specified losses are then deducted, and the excess routed through the reach network. The RORB model setup is shown in Figure 4-1.

There are three streamflow gauges within the catchment which were used to calibrate the RORB model, Traralgon Creek at Traralgon (226023), Koornalla (226410) and Traralgon South (226415). RORB parameter selection was based on calibration to the Koornalla and Traralgon gauges and comparison to accepted regional methods, and the design flows were validated against the flood frequency analysis. The approach for the selection of routing and loss parameters is outlined in the Hydrology Report (R02). Three recorded events were used for the calibration of the RORB hydrologic model; namely the September 1993, June 2012, and June 2013 floods. Each of these events was represented with a unique temporal and spatial rainfall pattern generated from local rainfall gauge records. The outflow hydrographs from the RORB model were then compared to stream gauges at two locations; Traralgon, and Koornalla.

The shape, peak and timing of the fitted hydrographs at Koornalla agreed well with gauged data. The rising limb and the height and timing of the peak were well matched in all three events, however the volume in the falling limb was slightly underestimated, particularly in 1993. The shape, volume and peak at Traralgon was also very well matched, with the falling limb matching slightly better than at Koornalla. The rising limb at Traralgon for 2013 was slightly early in this smaller flood event, which is one reason why such high initial loss was applied to the downstream interstation area.

The K_c values applied for each of the interstation areas are similar to those used in the previous SKM flood study (SKM, 2000), which used 12, 8 and 10 for Koornalla, Traralgon South and Traralgon respectively. The initial losses tend to be higher than expected design values, however the continuing losses tend to reasonable.

With the RORB model calibrated to three historic flood events, design flood events were then generated within RORB using design rainfall estimates. Design rainfalls were calculated for the 10%, 5%, 2%, 1% and 0.5% AEP events using the Intensity-Frequency-Duration analysis from AR&R (1987). The IFD parameters were obtained from the Bureau of Meteorology's IFD program website (www.bom.gov.au/water/designRainfalls/ifd) for the catchment centroid. Design loss estimates were developed and tested, with values compared to the flow values developed from the FFA at Traralgon to determine the best fit for design hydrology. These parameters and the results of the sensitivity testing are shown in section 3.5.8 in the Hydrology Report (R02). Design events flows were then generated with the peak flows for Traralgon Creek at Traralgon are shown in Table 4-2.

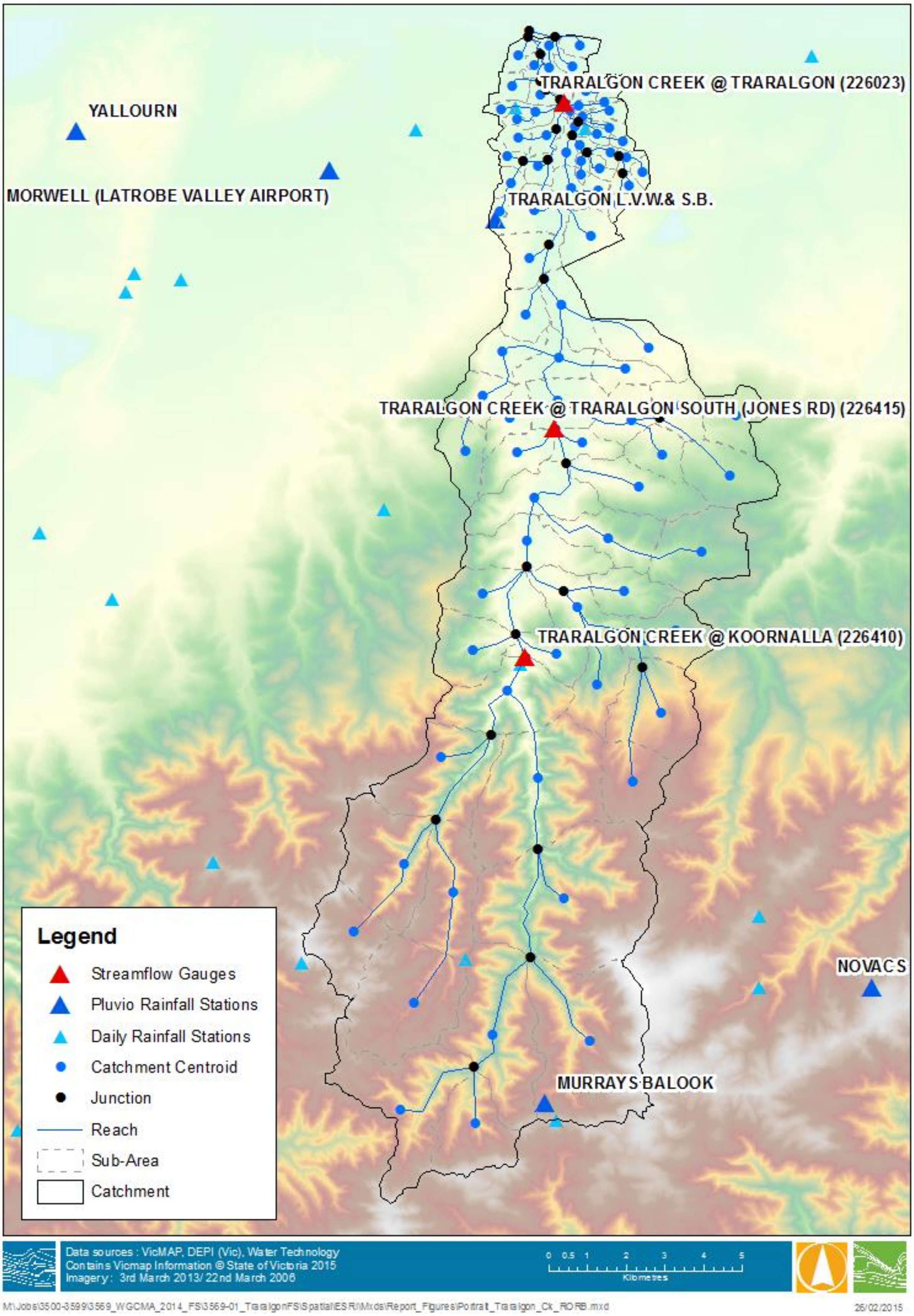

Figure 4-1 RORB Model Structure

Table 4-2 Adopted Peak Flows for Traralgon Creek at Traralgon

AEP	RORB Design Flow (m^3/s)	FFA Design Flow (m^3/s)	RORB Design Flow (ML/d)	FFA Design Flow (ML/d)
10%	104	89	9,000	7,700
5%	144	128	12,400	11,100
2%	193	193	16,700	16,700
1%	252	253	21,800	21,900
0.5%	314	325	27,200	28,100

4.2.4 Sensitivity Analysis

Sensitivity Analysis of the impacts of bushfire and climate change were assessed to provide an estimate of changed flow conditions. The climate change sensitivity analysis involved an increase of 10% in rainfall intensity applied to the rainfall burst. The bushfire sensitivity analysis involved increasing impervious fraction for all Farming Zone (Forestry) and Public Conservation and Resource Zone areas (0.1 under existing conditions) to 0.3, 0.7 and 0.9 to represent a low, moderate and high severity burn across the catchment. The results of the sensitivity analysis are shown in Table 4-3 and Table 4-4, shpwing that moderate and high intensity bushfire has the potential to significantly increase peak flows, even more so than the impact of climate change.

Table 4-3 Comparison of peak flows for increases in rainfall intensity due to climate change

AEP	Current Conditions		Scenario of 2°C of Warming		Increase in Flow (%)
	Burst Rainfall Depth (mm)	RORB Design Flow (ML/d)	Burst Rainfall Depth (mm)	RORB Design Flow (ML/d)	
10%	98.8	9,000	108.7	11,500	28
5%	115.0	12,400	126.5	15,900	28
2%	137.4	16,700	151.2	20,800	25
1%	155.5	21,800	171.0	26,400	21
0.5%	174.5	27,200	192.0	32,200	18

Table 4-4 Comparison of peak flows for increases impervious fraction due to bushfire

AEP	Unburned Catchment (ML/d)	Low Intensity Bushfire (ML/d)	Moderate Intensity Bushfire (ML/d)	High Intensity Bushfire (ML/d)
10%	9,000	11,200	15,900	17,600
5%	12,400	14,500	20,600	22,100
2%	16,700	19,800	25,600	26,800
1%	21,800	24,300	30,300	31,600
0.5%	27,200	29,800	35,300	36,700

4.2.5 Probable Maximum Flood

The Probable Maximum Flood (PMF) is the flow generated from the theoretical maximum precipitation for a given duration under current climate conditions. A PMF Estimate for Traralgon Creek at Traralgon was prepared using the Quick Method of Nathan et al. (1994). This method applies a set of empirical equations to compute a triangular PMF hydrograph and is applicable to southeast

Australian catchments from 1 to 10,000 km^2 that do not have large lakes or storages. For the Traralgon Creek catchment, 271,470 ML/d was calculated as the PMF maximum flow rate.

4.3 Hydraulics

4.3.1 Overview

This section discusses the application of the hydraulic model to simulate flood behaviour (extents, depth, velocities) for a range of flood magnitudes.

The hydrologic analysis previously discussed, provided flood inflow hydrographs for the hydraulic model. These inflow hydrographs were routed through the calibrated hydraulic model. This enabled the modelling of flood depths, extents and velocities over a range of flood magnitudes. It also provided a tool for understanding the flood behaviour across the study area.

A detailed description of the hydraulic model setup, calibration, validation, sensitivity tests and design event simulation is provided in the Hydraulic Report (R03). This section summarises the general model development and key outcomes from the hydraulic modelling investigation.

4.3.2 Hydraulic Modelling

The original proposed extent of the 2D model was approximately 6.8 x 7.8 km in size. It was proposed to split the model into two domains to provide adequate resolution within the urban areas whilst maintaining manageable run times. A grid size of 3 m provided adequate resolution through Traralgon, with the Latrobe River floodplain area modelled on a coarser grid resolution (15 m). Following the initial hydraulic modelling, sensitivity of the Latrobe River levels on flood levels within Traralgon Creek was undertaken. This found the impact of the Latrobe River did not extend up into the Traralgon urban area. Therefore the model was reduced to a single domain model of 3 m resolution and the Latrobe River floodplain was removed from the model.

The modelling process involved the following stages:

- Model setup and calibration to the three calibration events (1993, 2012 and 2013).
- Validation and sensitivity tests (boundary conditions and materials roughness).
- Design flood simulations (events from 10% AEP through to 0.5% AEP).

The calibration, validation, and sensitivity assessments are an iterative investigative process and all outcomes from these stages inform the final design flood simulations.

4.3.3 Understanding Flood Behaviour

After modelling a range of design flood events, the key flood behaviour was described for each. This allows emergency managers or Traralgon residents to understand the flood risk and the likely consequences for events of varying magnitudes. ***When using Table 4-5 to identify particular consequences for a given flood event, the reader should read all rows of consequences above the selected magnitude design event.***

Table 4-5 Summary of Flood Behaviour for Various Flood Events

Flood Class Level	Design Event	Modelled Flood Height at Traralgon Gauge	Flood Consequences
Minor (3.50 m)	<20% AEP	4.00	Bert Thompson Reserve, Victory and Newman Park may experience some flooding
Moderate (4.00 m)	20% AEP	4.30	Franklin Street and Whittakers Road bridges are close to overtopping. Railway Underpass flooded
	2013 Historical Flood	4.30	
Major (4.50 m)	20% to 10% AEP	4.50	Shakespeare St, Peterkin St overtop.
	10% AEP	4.81	Gwalia Street flooded Some breakout flooding along George Street and significant flooding along Franklin Street. Area upstream of Shakespeare Street likely to flood and overtop Traralgon Creek Road Paul Street Flooded ASIC building carpark flooded **Number of properties flooded above floor = 1**
	5% AEP	5.25	Traralgon Creek Road overtopped and significant flooding along Whittakers Road (including Milton Court, Moonabeal Court and Tennyson Street) and Howitt Street, including some properties flooded above floor George, Franklin, Berry and Davidson Street significantly impacted (including Willow Court) ASIC building on Grey Street likely to be inundated Properties at Phelan Street likely to completely flooded **Number of Residential properties flooded above floor = 8** **Number of Commercial properties flooded above floor = 5**
	2% AEP	5.59	Recreation Reserve flooded and further flooding along Shakespeare Street Stockland Shopping centre carpark flooded, Grey Street (Tyers Road overtopped) Properties along Munro Street and Peterkin to be flooded George, Franklin, Berry and Davidson Street significantly impacted (including Willow Court) flooded above floor Atherley Street properties flooded

			Widespread flooding above floor throughout urban area **Number of properties flooded above floor = 29** **Number of Commercial properties flooded above floor = 11**
	1% AEP	5.99	Atherley Street and Harney Place likely to flooded (including some above floor) Further properties on Tennyson Street flooded above floor Gwalia Street Flooded Princess Highway inundated on westbound lane (at Post Office Place) **Number of properties flooded above floor = 90** **Number of Commercial properties flooded above floor = 13**
	0.5% AEP	6.36	Properties along Gwalia Street Flooded Princess Highway Overtopped Post Office Place CBD inundated around Post Office Place & Grey Street Chisholm Court, Le Grange, Alfred Close, Latrobe Crescent Flooded Mapleson Drive likely to be cut off Bradman Boulevard, Waterford Court, Oxford Place, Bowral Way Flooded **Widespread residential and commercial properties flooded above floor.** **Number of properties flooded above floor = 154** **Number of Commercial properties flooded above floor = 16**

4.3.4 Flood Damages

A flood damages assessment was undertaken for the study area under existing conditions. The flood damages assessment determined the monetary flood damages for design floods (20%, 10%, 5%, 2%, 1% and 0.5% AEP events). The flood damage assessment was also undertaken for the final mitigation package.

Water Technology has developed an industry best practice damage assessment methodology that has been utilised for a number of studies in Victoria, combining aspects of the Rapid Appraisal Method, ANUFLOOD, more recent damage curves from the NSW Office of Environment and Heritage, and other relevant flood damage literature. The model results for all mapped flood events were processed to calculate the numbers and locations of properties affected. This included properties with buildings inundated above floor, properties with buildings inundated below floor and properties where the building was not impacted but the grounds of the property were. In addition to the flood affected properties, lengths of flood affected roads for each event were also calculated.

Under existing conditions, the 1% AEP damage was calculated at $ 6.8M with 90 residential properties flooded above floor and 13 commercial properties also flooded above floor. The average annual damage (AAD), a measure of the average flood damage, per year over an extended period was estimated for existing conditions to be **$ 360,000**. The AAD is an estimate of the cost of flooding to the community that includes both public and privately owned assets.

5. ASSESS AND TREAT RISK

5.1 Flood Mitigation

A report detailing the flood risk and options to treat the flood risk within Traralgon was produced following design mapping (R04). Four mitigation options were presented to the steering committee and community meeting held in September 2015. The four options are listed below, however are covered in more detail later in this section.

1. **Traralgon Bypass Embankment** – the construction of a retarding basin upstream of the Traralgon at the location where a proposed bypass is planned. This aims to provide a significant reduction in large out of bank flows through Traralgon.
2. **Whittakers Road Levee Scheme** – A permanent levee with a number of temporary barriers placed around a group of residential properties from Shakespeare Street along to the railway embankment.
3. **Floodway works downstream of Phelan St** – using earthworks to provide a more efficient floodway downstream of Phelan St. This aims to increase the efficiency of water getting through the northern end of the city during out of bank flood events.
4. **Removal of the Water Treatment pond downstream of Traralgon** – The removal or realignment of a water treatment pond at the northern end of the Traralgon Creek floodplain. This would increase the efficiency of water travelling on the Traralgon Creek floodplain onto the Latrobe River floodplain.

The feedback provided from the options was generally positive, most people agreed that any options that provided a reduction in flooding in the township should be investigated.

A prefeasibility assessment was carried out on these options and the Traralgon Bypass Embankment and the Whittakers Road levee scheme were chosen to investigate further including hydraulic modelling and costing. Flood damage assessments and a benefit-cost analysis were also carried out for the two mitigation options, with the results shown below in Table 5-1. The Whittakers Road levee scheme has a low benefit-cost ratio. The Traralgon Bypass Embankment study was far more complex and requires further investigation into the cost and benefit of the option. However given that a retarding basin embankment is likely to save the bypass project around $30M in having to construct a major bridge across the floodplain it is likely to be an attractive option to the State. In addition the retarding basin option significantly reduces the flood prone land throughout Traralgon and may enable further development throughout the city. This option has many benefits and should be considered further.

Table 5-1 Mitigation Impacts and Cost - Benefit

	Existing Conditions	Mitigation Option 1 (Traralgon Bypass Embankment)	Mitigation Option 2 (Whittakers Rd Levee)
Properties Flooded (1% AEP)	319	174	248
Properties Flooded Above Floor (1% AEP)	90	4	54

1% AEP Damages	$6,779,053	$ 1,129,262	$ 4, 882,928
AAD	$358,777	$ 196,150	$ 314,881
Cost - Benefit	N/A		0.30

5.2 Planning Controls

An assessment of the existing planning controls for Traralgon was undertaken by Edwin Irvine resulting in a document outlining a number of recommended planning scheme amendments which could be implemented to further treat flood risk within Traralgon “Latrobe Planning Scheme Flood Controls Review – Traralgon Flood Investigation”. This recommends the rezoning of current Urban Floodway Zone (UFZ) as it significantly restricts development as well as taking flooding into account during a development plan. Further planning outputs for the project include a revised draft Floodway Overlay and a Land Subject to Inundation Overlay produced in the Treat and Assess Risk Report (R04) and shown in Figure 5-1. This would reflect the updated flood modelling and mapping produced during this study. The report also recommends the WGCMA and Latrobe City Council undertake a planning scheme amendment process to incorporate new LSIO and FO mapping into the Latrobe Planning Scheme as soon as possible.

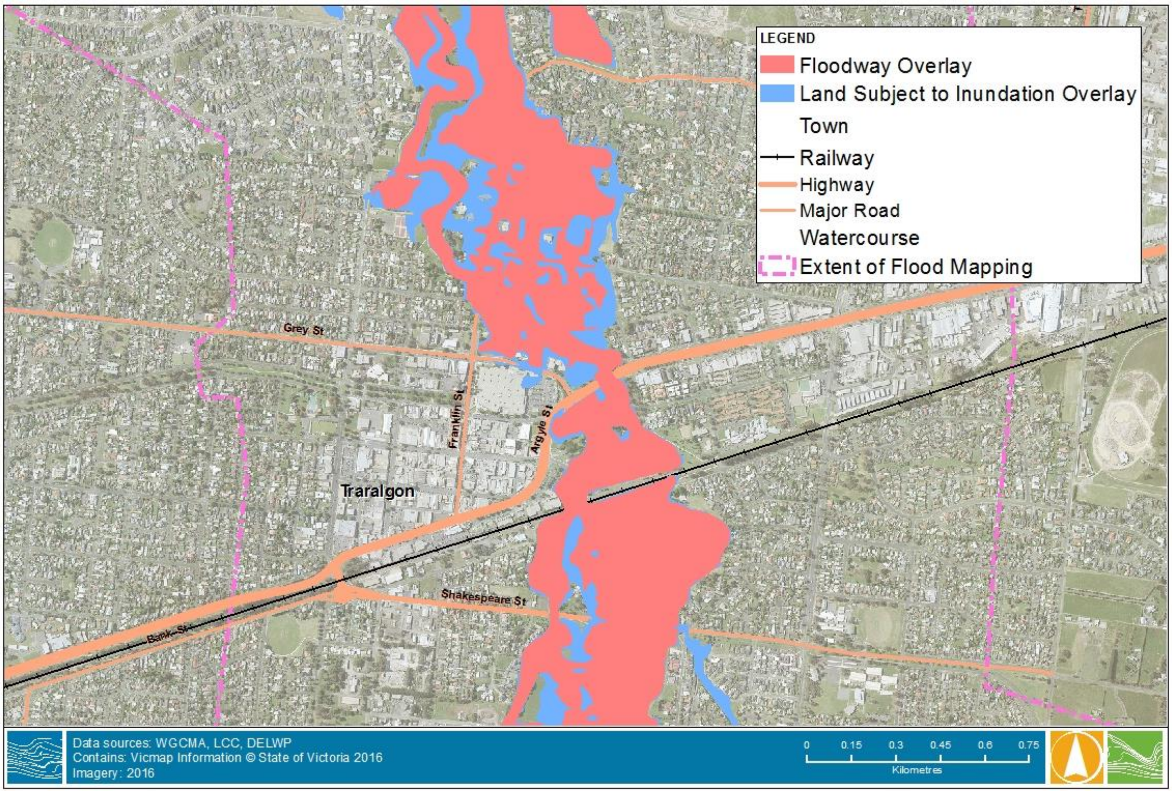

Figure 5-1 Draft LSIO and FO Extents

6. FLOOD BEHAVIOUR AND INTELLIGENCE OUTPUTS

6.1 Overview

The flood behaviour and intelligence outputs developed as part of the Traralgon Flood Study are described in this section.

6.2 Model Result Outputs

The model result data including grids and extents have been provided in specified Victorian Flood Database (VFD) format for each flood event. The following result components were generated:

- Flood level, flood depth, flood velocity and flood hazard grids
- Flood elevation contours
- Flood extent data
- Hydrographs at key locations
- Long-section of river water levels

Grids and shapefiles (ESRI/VFD format), and Data tables (Excel csv/xlsx format) were provided on a Study USB on completion of the study.

6.2.1 Data Sets

The following datasets were provided as shown in Figure 6-1.

Grids

Gridded datasets of model results were provided for the following:

- Design events (10%, 5%, 2%, 1%, 0.5%AEP and PMF events) – maximum depth, hazard, velocity and water surface elevation.
- Calibration events (1993, 2012, and 2013 events) – maximum depth and water surface elevation.
- Model Topography

The hydraulic analysis provides regular grid of flood elevations across the hydraulic model study area. The flood extent was defined by converting the 3 m grid flood elevations grid to an extent polygon. The extent was smoothed to remove the sharp edges of the grid cells for cartographic / presentation purposes.

Flood depths were classified for mapping using the following classifications:

- 0 m to 0.25 m
- 0.25 m to 0.50 m
- 0.50 m to 1.00 m
- 1.00 m to 2.00 m
- Greater than 2.00 m

Vector Data

ERSI shapefiles in VFD format were provided for the following:

- Peak flood extents
- Peak flood elevation contours
- Mapping limits
- Recommended Flood Overlay & Land Subject to Inundation Overlay

Data Tables

Data tables in excel CSV format were provided for the following:

- A list of all properties impacted by the design flood events detailing property location, address and maximum depth of flooding at each property.
- Flood damages for all design events under existing conditions as well as the two mitigation options modelled. This allowed for the average annual damages to be assessed.

6.2.2 Maps

The flood response inundation maps have been produced for the following design flood events:

- 0.5% AEP event
- 1% AEP event
- 2% AEP event
- 5% AEP event
- 10% AEP event
- 20% AEP event

Each map includes:

- Flood extent,
- Flood level contour at 1m intervals,
- Depth of inundation,
- Identification of essential services,
- Major Road/street names
- Cadastral base
- Gauge height indication for the Traralgon Creek at Traralgon.

Copies of the maps were provided as PDFs, and in Appendix A of the Hydraulics Report (R03). A mapping limits layer was provided in the vector data. An example maximum depth plot for the 1% AEP flood event is shown in Table 6-1.

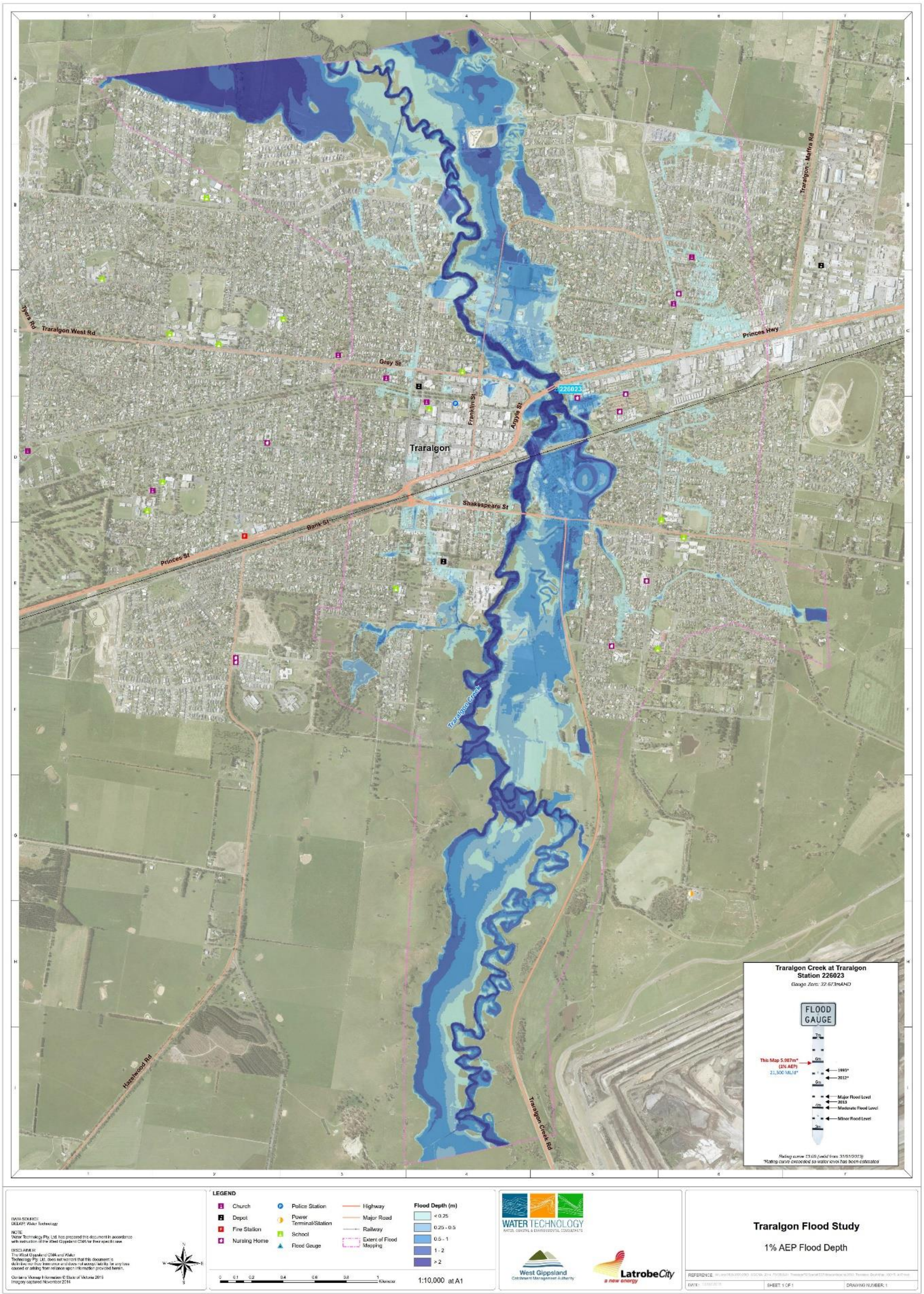

Figure 6-1 1% AEP Maximum Flood Depth Map

6.3 Gauge Height Relationships

For each design flood event the model results were interpreted to provide information on the relationship between the flood level at Traralgon River at Traralgon gauge and the equivalent design flood magnitude (in % AEP and ARI (years)). The gauge heights are shown in Table 6-1.

Table 6-1 Traralgon Creek at Traralgon Gauge Heights for Design Flood Events

Gauge Height (m)	Flood level at Gauge (m AHD)	Design Flood Event AEP (%)	Design Flood Event ARI (years)
4.30	36.98	20	5
4.81	37.48	10	10
5.25	37.92	5	20
5.59	38.26	2	50
5.99	38.66	1	100
6.36	39.03	0.5	200

6.4 Study Deliverables

The study deliverables provide a comprehensive set of data that support the study outcomes. The deliverables were supplied on a study USB and consisted of background data and outputs as listed below:

- Digital copies of study reports in PDF format.
- Digital copies of the maps (PDF format)
- GIS datasets for the model results (ArcGIS VFD format and Excel csv format)
- Digital elevation models

There is a readme.txt file on the USB that describes the directory structure of the data contained on the USB.

7. SUMMARY OF THE INVESTIGATION

7.1 Overview

The hydraulic modelling undertaken for the Traralgon flood study identified locations within Traralgon that pose a high flood risk. The modelling has also identified a number of potential mitigation options to reduce flood risk, with several of these being modelled to show significant benefits in terms of reducing the frequency and magnitude of flooding. The mitigation options identified along with the updated planning information aim to treat the existing risk.

7.2 Key Outcomes

In undertaking this study a number of important aspects of flood risk relevant to the Traralgon Creek catchment become apparent. These are summarised as follows.

Traralgon Creek Hydrology – A thorough investigation into the Traralgon Creek hydrology was undertaken to provide an estimate of design flows and hydrographs for a range of AEP events. The effective warning time for the catchment is limited, with travel times from the upstream streamflow gauges relatively short.

Hydraulic Characteristics – Overbank flows of the Traralgon Creek through Traralgon were identified through the hydraulic modelling undertaken for this project. The results of the hydraulic modelling have been used to undertake mitigation modelling and a review of flood warning and planning controls within Traralgon.

Assess and Treat Risk - Using the hydraulic modelling results, several mitigation options were investigated, costed and modelled to assess the impact on flooding. A flood damages assessment was completed on the existing flood conditions as well as the proposed mitigation options. This allowed for a cost-benefit analysis to be undertaken for the mitigation options.

7.3 Conclusions & Recommendations

Based on the study process and outcomes the following conclusions have been noted:

- Parts of the Traralgon urban area are susceptible to regular out of bank flooding through much of Traralgon located within the floodplain. Private properties are inundated at flows greater than 5% AEP.
- Through the series of steering committee and community meetings, many community members understand that the Traralgon Creek floods and the associated areas where flooding occurs more frequently. Most understand that flooding is a natural occurrence however the potential flood risk to lives and private assets is of concern.
- It was identified that accessing information about an approaching flood event was often difficult to obtain. Currently the Bureau of Meteorology (BoM) provide flood warnings via the BoM website, while streamflow data is also available through a different section of the website as well as through the DELWP data monitoring website.
- Mitigation of flooding within Traralgon is a difficult task and has been assessed in a number of previous flood studies. For the purposes of this study, Water Technology assessed in detail two mitigation options which have not previously been assessed.
- The mitigation options assessed within this study have a positive impact on reducing flood risk within Traralgon. The Whittakers Road levee has a weak benefit-cost ratio and will be difficult to attract the required funding. The Traralgon Bypass Embankment option could deliver significant reductions to flood risk through Traralgon and provides large cost savings to this future infrastructure project.

- The Traralgon Bypass Embankment option should be viewed as a long term concept and will require significant further detailed investigation. This would involve consultation with a number of key stakeholders including the Loy Yang Open Cut mine operator AGL Energy.

- A review of the existing planning scheme was undertaken suggested LSIO and FO planning maps were produced. From this, it is recommended the WGCMA and Latrobe City Council undertake a planning scheme amendment process to incorporate new LSIO and FO mapping into the Latrobe Planning Scheme as soon as possible.
- The WGCMA and Latrobe City Council consider all recommendations provided within the accompanying "Latrobe Planning Scheme Flood Controls Review – Traralgon Flood Investigation" provided by Planning and Environmental Design, for inclusion into a revision of the Latrobe Planning Scheme.

- The Municipal Flood Emergency Plan (MFEP) was updated with flood intelligence from this study. This should be utilised during future floods. It is recommended that the current format of the MFEP be revised. It is different to other MFEPs across the State. The flood intelligence section of the Assess and Treat Risk Report (R04), would provide a valuable resource during a flood emergency.

With regard to the study outcomes, the following recommendations are provided:

- Further detailed assessment of mitigation options modelled and costed would be required to proceed to the next stage of implementation, with the bypass embankment modelling project being handed to VicRoads to consider. Water Technology feel that this option is worth pursuing in conjunction with VicRoads as the embankment is likely to cost far less than a bridged option and would provide considerable flood protection to many properties within Traralgon. This would provide the opportunity to unlock several areas of land within the city, currently restricted due to flood risk. This option is opportunistic, and would be difficult to retrofit once the bypass is constructed. It is strongly recommended that this option be pursued with all relevant stakeholders.
- The development of a community portal that incorporated several key pieces of information regarding flooding specific to Traralgon in one place may reduce some of the confusion about where this information can be obtained. Allowing community members to get important information will likely raise the resilience of locals to potential flooding issues. This information may include any warnings issued by the BoM, the three streamflow gauges on Traralgon Creek, telemetered rainfall gauges and a radar image of the area to show if there is more rain approaching. Flood mapping allowing community members to easily understand future flood behaviour and assess their personal flood risk could also be easily included within a community portal.
- Latrobe City Council should consider the implementation of a planning scheme amendment to introduce the new LSIO and FO mapping into the planning scheme.

8. REFERENCES

Please note the references listed below is a combination of references from all reports mentioned within this study.

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Traralgon Flood Study – Data Review (R01)

March 2016

DOCUMENT STATUS

Version	Doc type	Reviewed by	Approved by	Distributed to	Date issued
v01	Report	Ben Tate	Ben Tate	Linda Tubnor	09/12/2014
V02	Report	Ben Tate	Ben Tate	Linda Tubnor	30/04/2015
Final	Report	Ben Tate	Ben Tate	Linda Tubnor	04/03/2016

PROJECT DETAILS

Project Name	Traralgon Flood Study
Client	West Gippsland Catchment Management Authority
Client Project Manager	Linda Tubnor
Water Technology Project Manager	Richard Connell
Report Authors	Richard Connell, Ben Tate
Job Number	3569
Report Number	R01
Document Name	3569-01_R01v03a.docx

Cover Photo: Traralgon CBD flooding, September 1993. Looking South-West towards the Princes Highway and Franklin Street.

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1. INTRODUCTION

Following the recent flood events affecting Traralgon during June 2007, July 2011, June 2012 and June 2013, Water Technology was commissioned by the West Gippsland CMA to undertake the Traralgon Flood Study. This study included detailed hydrological and hydraulic modelling of Traralgon Creek and the Latrobe River, flood mapping of Traralgon, recommendations for flood mitigation works, and a review of planning controls.

This report details the data review which took place at the beginning of the project to identify the available data, verify that data and comment on any data gaps. This report is one of a series of reports documenting the outcomes of the Traralgon Flood Study.

- **R01 - Data Review Report (Water Technology 2016a) – this report**
- R02 - Hydrological Report (Water Technology 2016b)
- R03 - Hydraulic Report (Water Technology 2016c)
- R04 - Assess and Treat Risk Report (Water Technology 2016d)
- R05 - Summary Report (Water Technology 2016e)

These five reports detail the approaches adopted, the findings and recommendations, of the Traralgon Flood Study. The five reports are supported by a number of standalone PDF flood maps and digital deliverables.

2. DATA REVIEW

2.1 Previous Studies

Traralgon has been the subject of numerous flood related studies and associated mitigation works on the Traralgon Creek and Latrobe River from the 1970s. Table 2-1 summarises the available reports that have been reviewed as part of this study to date.

Table 2-1 Summary of Previous Studies

Year	Study	Type	Notes
1979	State Rivers & Water Supply Commission. Report on Flooding from Traralgon Creek (Stage 1)	Flood Study	Hydrology and hydraulics assessment of flooding, including flood frequency, catchment model and 1D hydraulic model. (1% AEP estimate = 20,000 ML/day, RORB)
1979	Gutteridge, Haskins & Davey Pty Ltd. Traralgon Creek Flood Study (Stage 2)	Flood Mitigation Study	Assessment of flooding concerns and proposed channel improvement works
1981	Gutteridge, Haskins & Davey Pty Ltd. Traralgon Creek Flood Study (Stage 3)	Management Study	Flood damages and costing for mitigation works and floodplain management strategy
1984	State Rivers & Water Supply Commission. Traralgon Creek Flood Study – Summary Report	Summary Document	Summary of previous flood study reports and preferred floodplain management strategy

Year	Study	Type	Notes
1984	Gutteridge, Haskins & Davey Pty Ltd. Report on Flooding Characteristics South of Shakespeare Street	Development Assessment	Extension of previous modelling south of Shakespeare Street and assessment of developments within this reach
1984	Rural Water Commission of Victoria. Traralgon Flood Mitigation Proposal – Approved Scheme	Flood Mitigation Design	Outline of the approved flood mitigation measures
1995	Department of Conservation and Natural Resources. Documentation and Review of 1993 Victorian Floods Volume 1 & 2	Flood Review	Review of 1993 flood event in Traralgon, including historic gauging information and mitigation scheme performance summary. (1% AEP estimate = 23,000 ML/day, FFA)
1996	Department of Natural Resources and Environment. Traralgon Flood Mitigation Scheme – Levee Audit Report	Levee Audit	Condition assessment of the 360 m long levee system either side of Peterkin St between the railway line and the Princes Highway
2000	Bureau of Meteorology. Traralgon Creek Flood Forecasting Correlations	Hydrologic Investigation	Summary of correlations of hydrologic data for flood forecasting purposes. Includes gauge site information
2000	SKM. Traralgon Creek Floodplain Management Study	Flood study and management plan	Hydrologic, hydraulic and flood mitigation assessment, including flood frequency, catchment model and 2D hydraulic model. Flood damages and mitigation costings. (1% AEP estimate = 21,170 ML/day, RORB)

2.2 Historic Flood Information

Significant historic flood events have been compiled from available sources and are listed in Table 2-2. The largest flood on record at the Traralgon Creek Gauge in Traralgon was the June 1978 event. Since this event, significant structural mitigation measures have been undertaken that significantly alter the flooding conditions within Traralgon. Although there is a significant amount of available observed flood information for the 1978 event, the topography at the time of the event is not well defined. Therefore, the September 1993 flood event is the largest flood event in Traralgon with conditions that largely represent current catchment and floodplain conditions. A large amount of data is available for the 1993 event, including a digitised flood extent, surveyed flood levels, floor levels and numerous flood photographs, collated for Hydrotechnology's report on the 1993 Gippsland floods.

Historic flood data recorded in the Victorian Flood Database (VFD) is summarised in Figure 2-1 and Figure 2-2 below. The flood extent for 1978 was derived from aerial photography, and the extent for 1993 was based on detailed flood mapping.

Table 2-2 Historic Flood Events

Event	Description	Data available

December 1934		Observed Flood level at railway bridge
February 1951		Observed Flood levels at several locations
August 1951		Observed Flood levels at several locations
June 1952		Observed Flood levels at several locations
June 1978	Largest flood on record at the time 72 residential, 2 commercial and 7 public buildings were flood affected above floor	Digitised flood extent (VFD) Large number of surveyed flood marks Gauged streamflow at 119 m^3/s (73% of peak) Infrared colour and black and white aerial photographs after flood peak Level recorders at Franklin St and Shakespeare St bridges
September 1993	Largest flood on record 24 residential and 3 commercial buildings were flood affected above floor and an additional 99 properties flood below floor Slightly larger than 1978, but floodplain management works reduced flooding impacts	Digitised flood extent (VFD) Large number of surveyed flood marks Aerial photography during flood event
November 1995	Slightly smaller than 1993, 0.04 m lower at the Traralgon Gauge 24 residential and 3 commercial buildings were flood affected above floor and an additional 99 properties flood below floor	
June 2007	First flood event since flood warning system installed No houses were flooded	Surveyed flood marks
July 2011	Smaller than 2007	
June 2012	Largest event since 1995 10 residential properties flooded above floor Relief centre established at Latrobe Performing Arts Centre	
June 2013	Smaller than 2011	

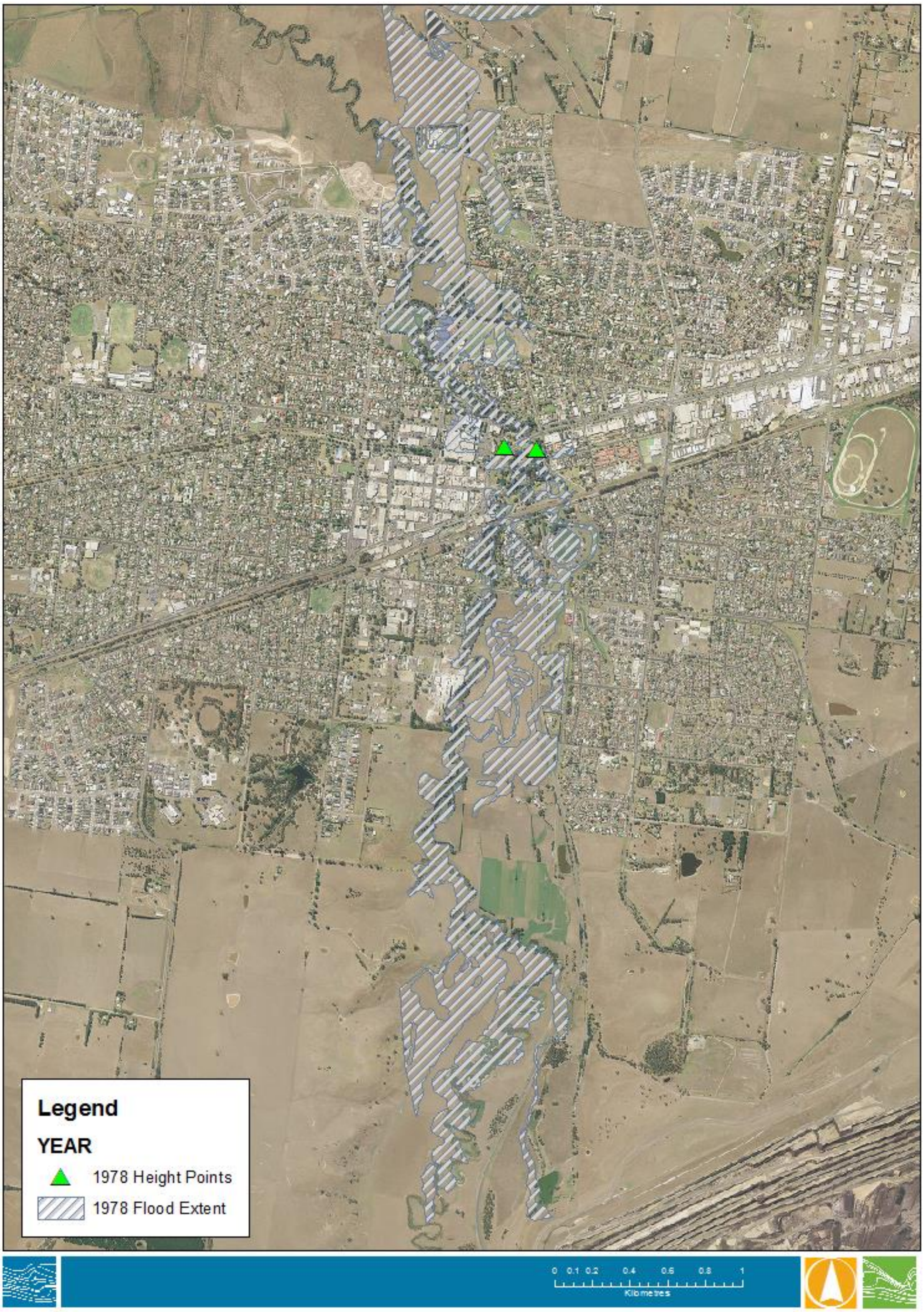

Figure 2-1 June 1978 flood information in VFD

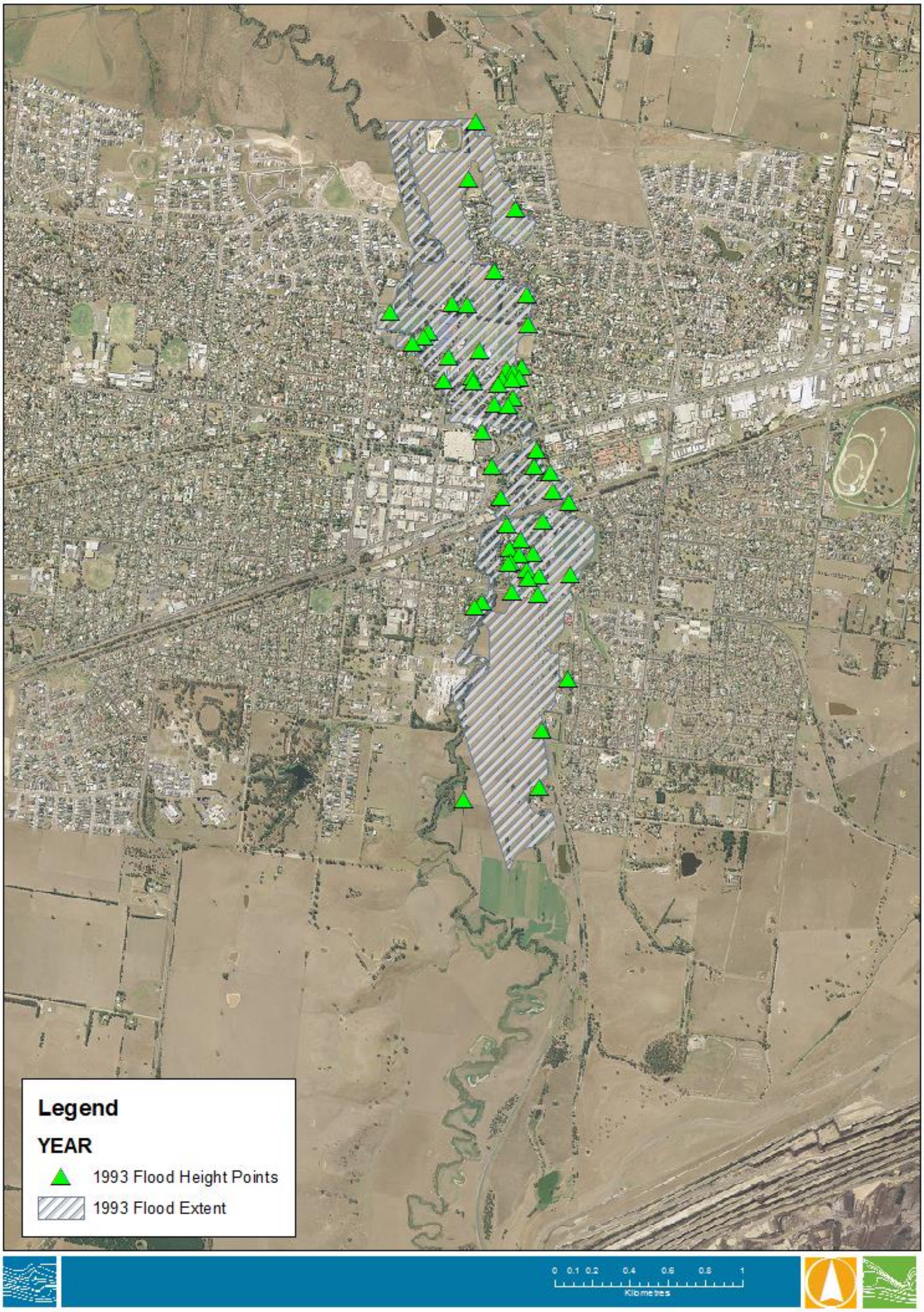

Figure 2-2 September 1993 flood information in VFD

2.3 Imagery

Non-flood aerial imagery is available for March 2013 (Colour). Extensive flood aerial photography is available for the September 1993 event in Colour in the Hydrotechnology (1995) flood review and from various other hard copy photographs. Hard copy photographs are also available for other events including November 1995, 1998 in the upper Traralgon Creek, and for June 2012. There is also extensive images of the 2011, 2012 and 2013 flood events online.

2.4 GIS and Survey Data

Aerial LiDAR (Light Detection and Ranging) survey is available for the Traralgon area from three different sources:

- 2010 Victorian State Wide Rivers LiDAR Project - West Gippsland CMA
- 2010-2011 Floodplains LiDAR Project
- 2008 Southern Rural Water LiDAR Project

Extents of the three datasets are shown in Figure 2-6, Figure 2-7 and Figure 2-8. A comparison of the three different datasets where they overlap is shown in Figure 2-9, Figure 2-10 and Figure 2-11. Cross sections at locations on Traralgon Creek and Latrobe River are shown in Figure 2-3, Figure 2-4 and Figure 2-5. There is a vertical offset of approximately 0.15 m between the River LiDAR and the Southern Rural Water LiDAR in the floodplain areas with the Rivers LiDAR being higher, however the water level in the Latrobe River is lower in the Rivers LiDAR. All three datasets appear to be interpolated within the channel rather than representing the true bathymetry below the water line. The Floodplains LiDAR and Southern Rural Water LiDAR datasets are reasonably consistent in the overlapping areas. The Rivers LiDAR DEM is also higher than the Floodplains DEM in most areas, except for the channel of Traralgon Creek where the Rivers LiDAR is slightly lower again. The differences in the datasets is summarised in Table 2-4. Feature survey was used to verify the LiDAR datasets and assist in the selection of datasets for modelling. Key metadata for the two datasets is given in Table 2-3.

Given the Floodplains and Southern Rural Water DEMs are rated to a higher accuracy and covers the whole extent, the two datasets were used in preference to the Rivers LiDAR for modelling. A coarse (10 m resolution) DEM was available from VicMap for the whole Traralgon Creek catchment and was used for catchment delineation purposes.

Verification survey was required to establish the datum for which to develop the final merged DEM for use in the hydraulic modelling. Survey was undertaken in the Traralgon area with several river cross sections and road transects to verify the LiDAR to be fit for modelling purposes. Details of the verification of the LiDAR are covered in more detail later in this section.

Table 2-3 Key metadata for LiDAR datasets

Dataset	Source	Date of Capture	Vertical accuracy (1 sigma)	Resolution	Geoid
2010 Victorian Rivers LiDAR Project	LiDAR	Feb-Nov 2010	0.20 m	1 m	AUSGeoid09
2010-2011 Floodplains LiDAR Project	LiDAR	Dec 2010 – Feb 2011	0.10 m	1 m	AUSGeoid09
2008 Southern Rural Water	LiDAR	Jan-Aug 2008	0.10 m	1 m	???

Table 2-4 Summary of differences between LiDAR datasets

Dataset	Mean Difference	Standard Deviation	Max Difference	Min Difference
Rivers Minus Floodplains	0.20 m	0.20	7.56 m	-10.36 m
Rivers Minus Southern Rural Water	0.19 m	0.16	6.22 m	-3.96 m
Southern Rural Water Minus Floodplains	0.09 m	0.17	5.37 m	-2.60 m

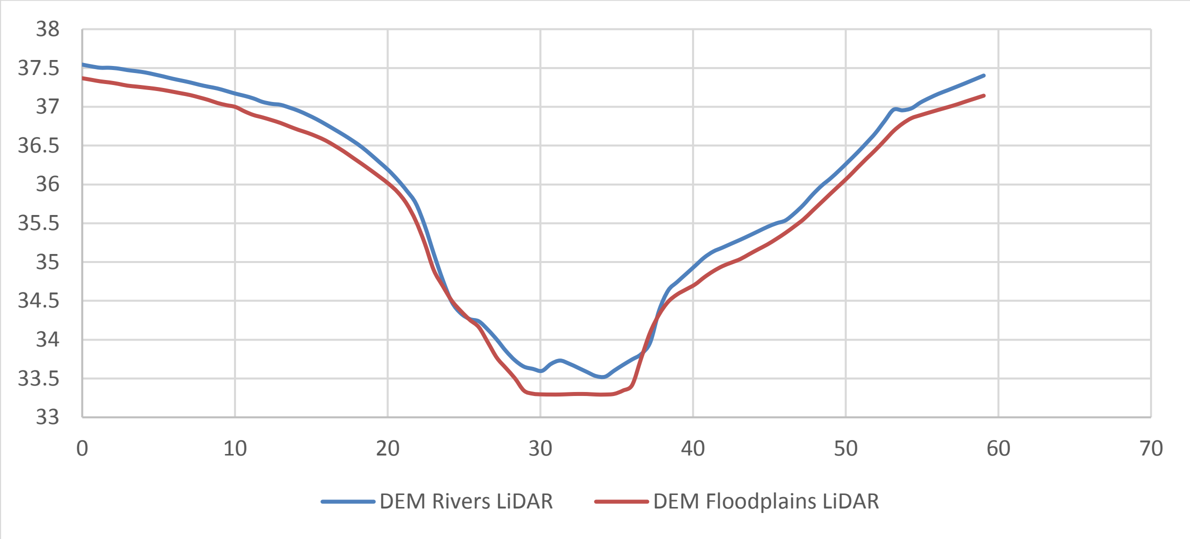

Figure 2-3 LiDAR Cross section comparison - Traralgon Ck between Princes Hwy & Wright St

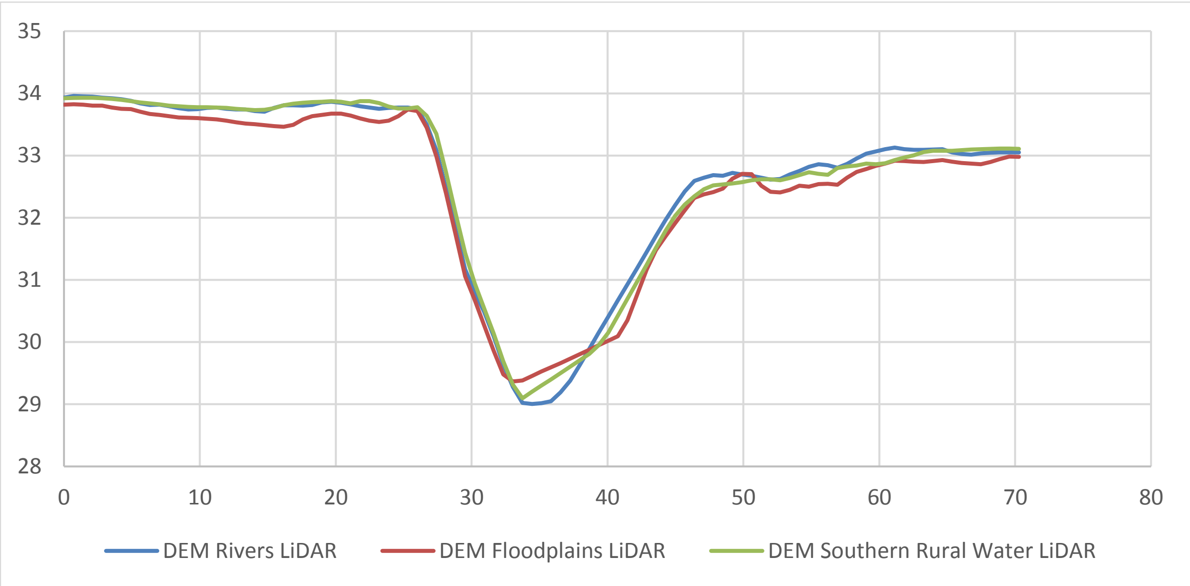

Figure 2-4 LiDAR Cross section comparison - Traralgon Ck near Waste Water Treatment Plant

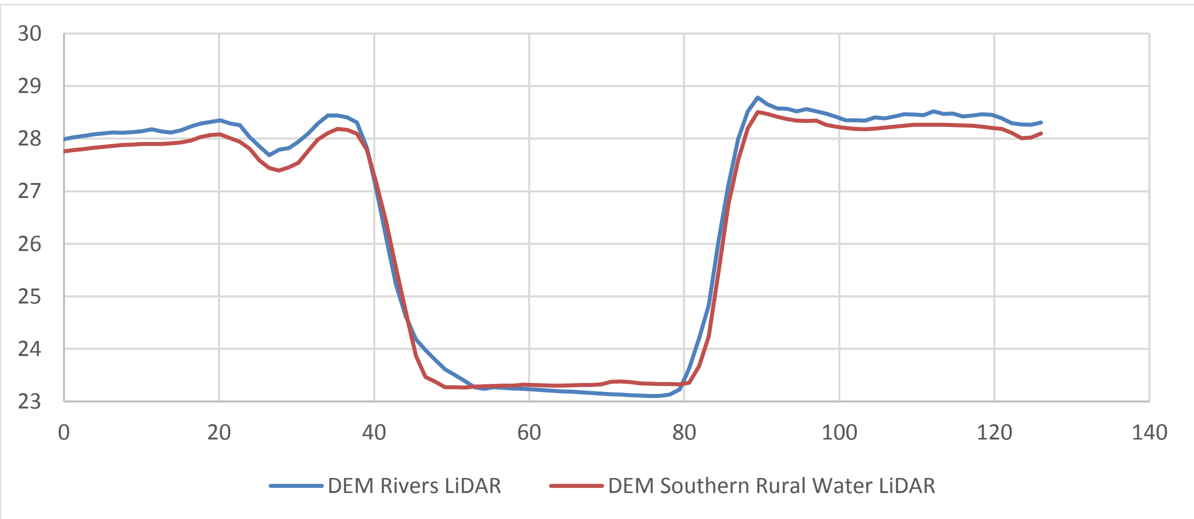

Figure 2-5 LiDAR Cross section comparison - Latrobe River ds Confluence with Traralgon Ck

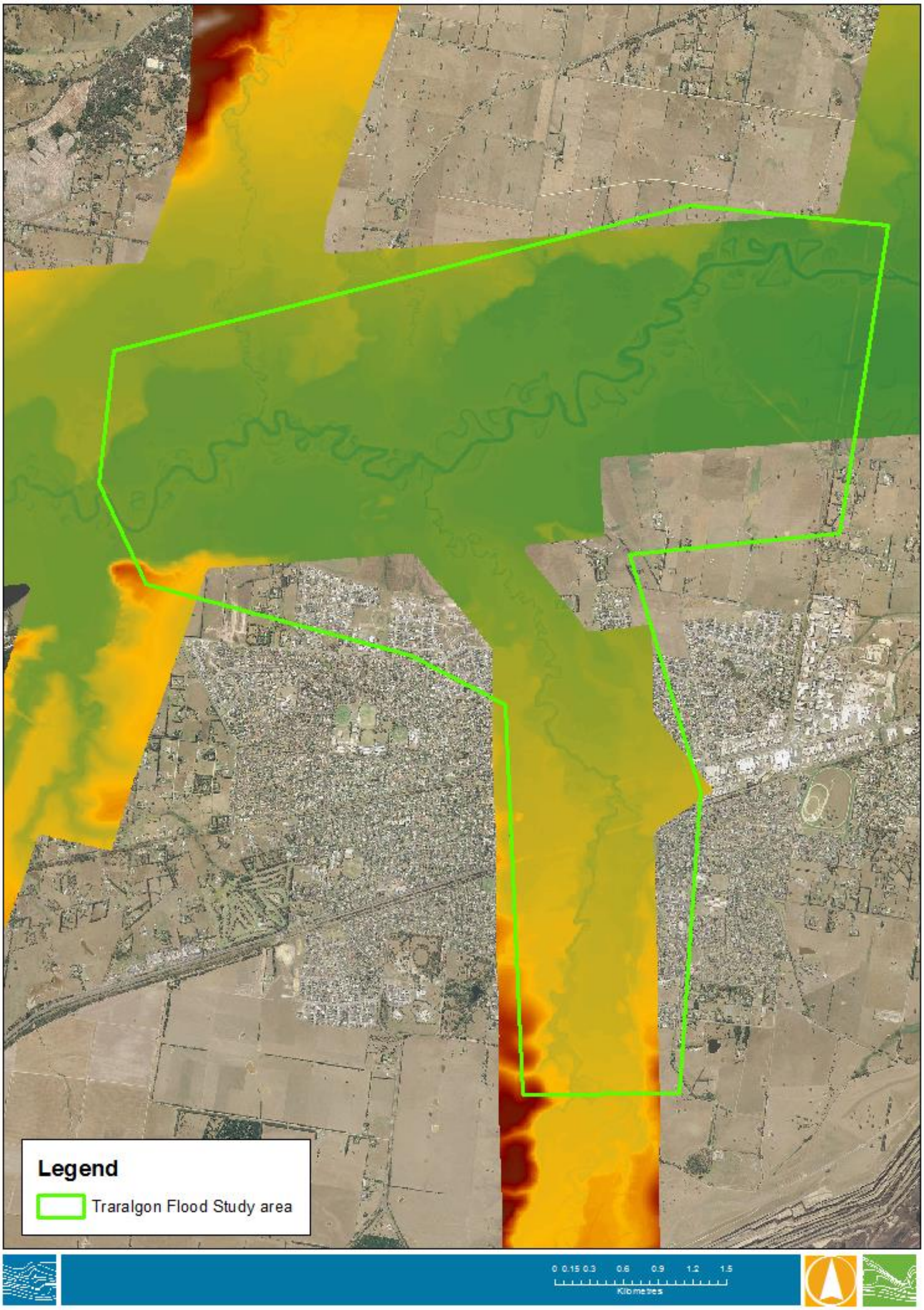

Figure 2-6 Rivers LiDAR DEM extent

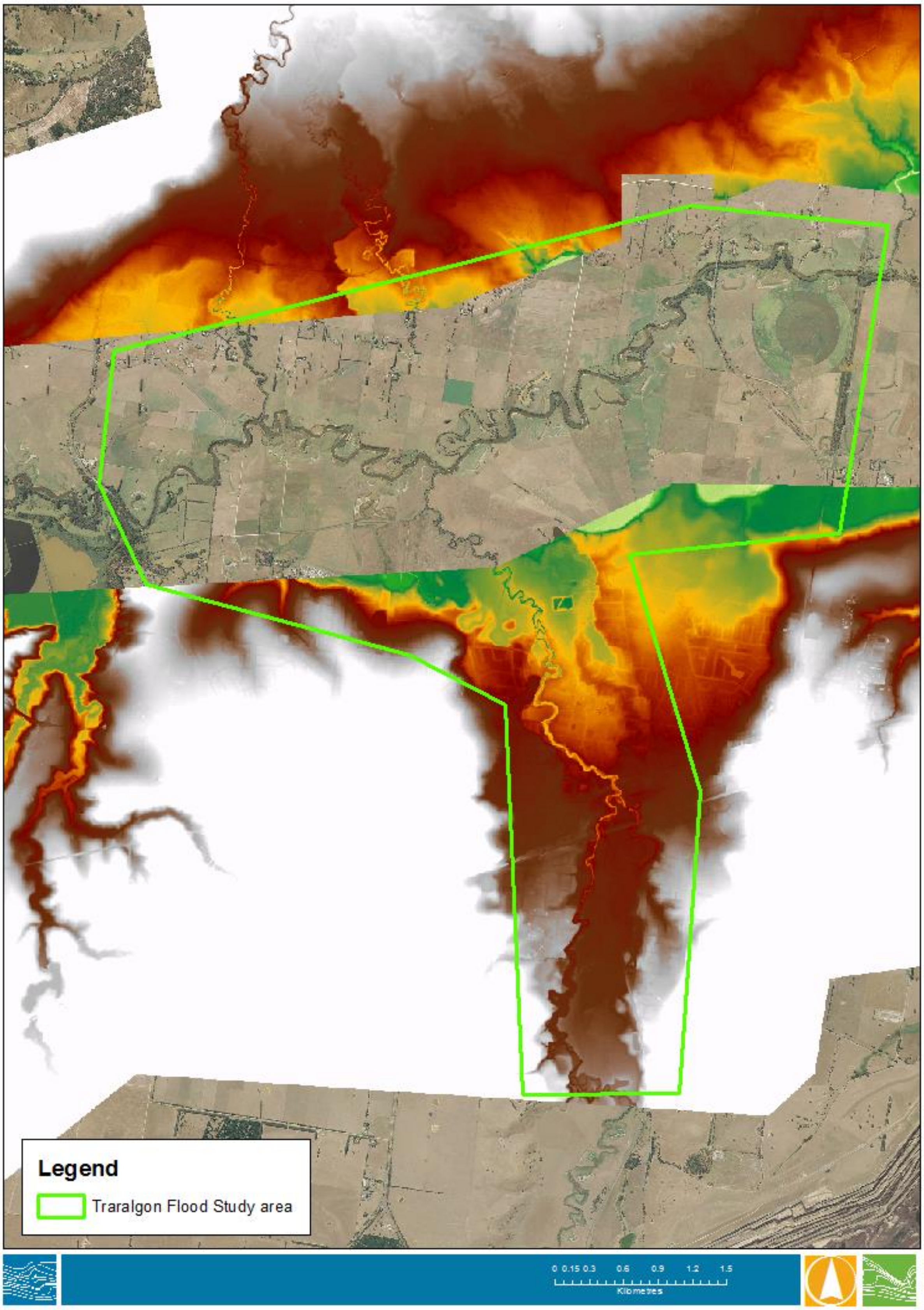

Figure 2-7 Floodplains LiDAR DEM extent

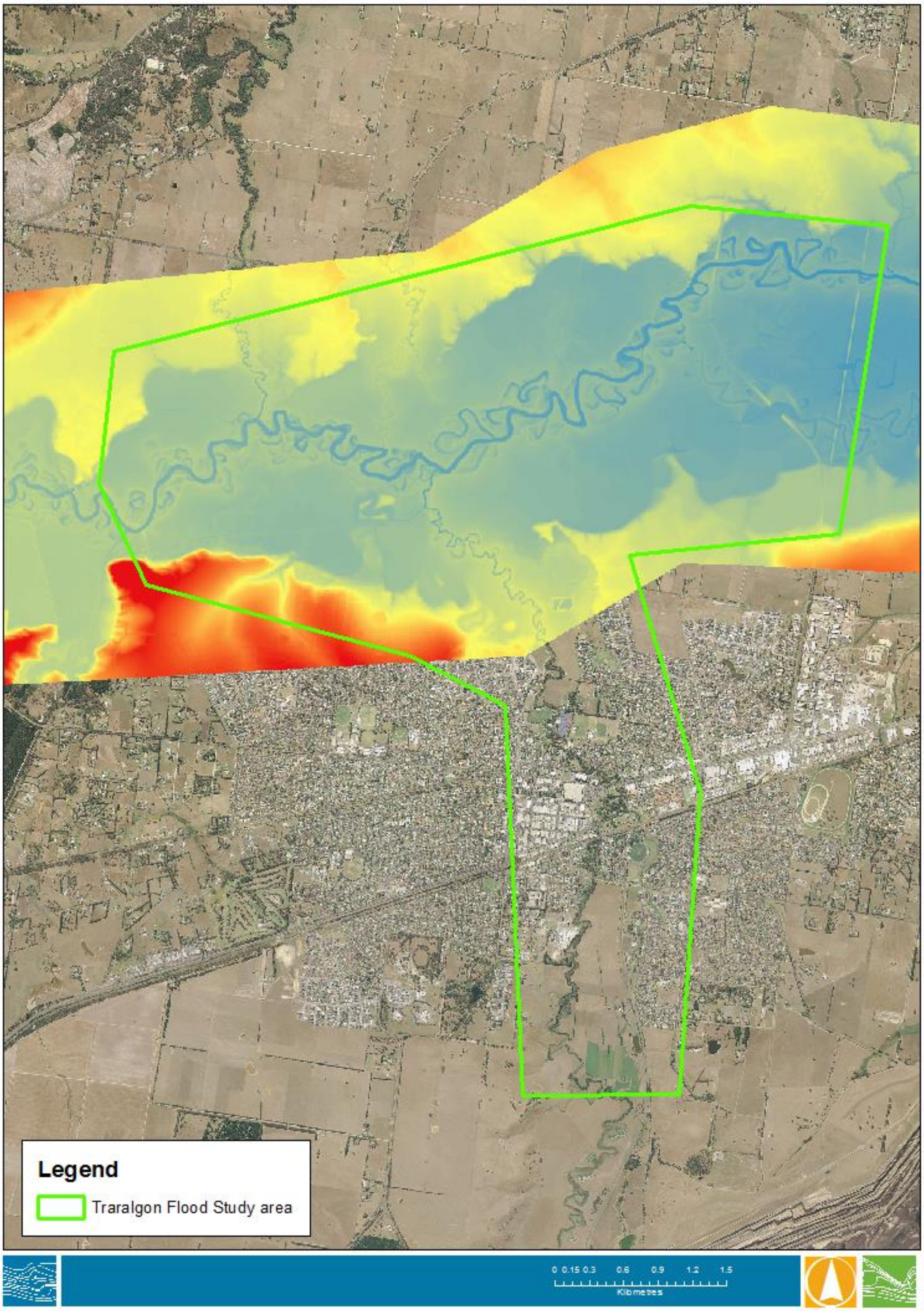

Figure 2-8 Southern Rural Water LiDAR DEM extent

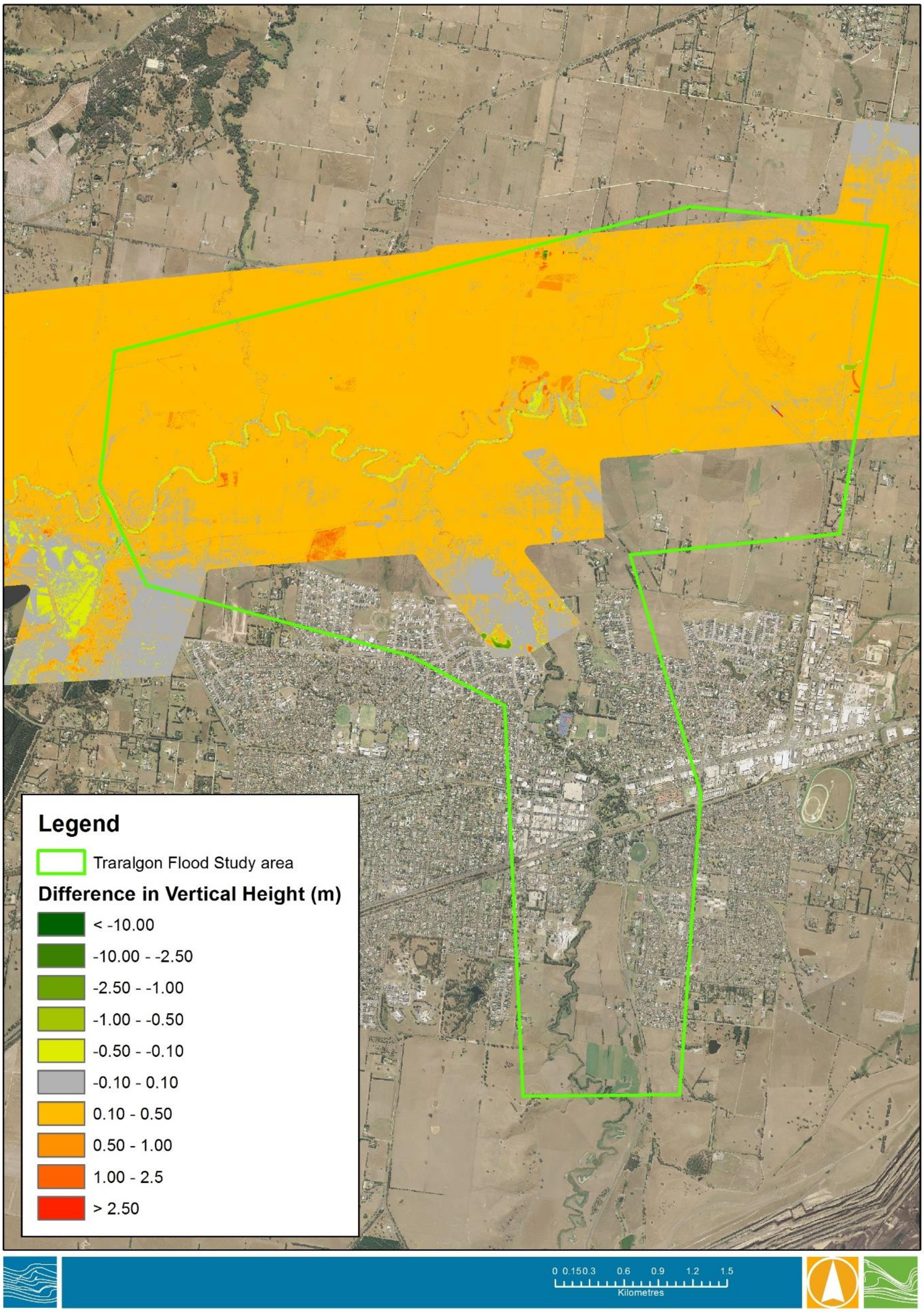

Figure 2-9 LiDAR comparison - Rivers LiDAR DEM minus Southern Rural Water LiDAR DEM

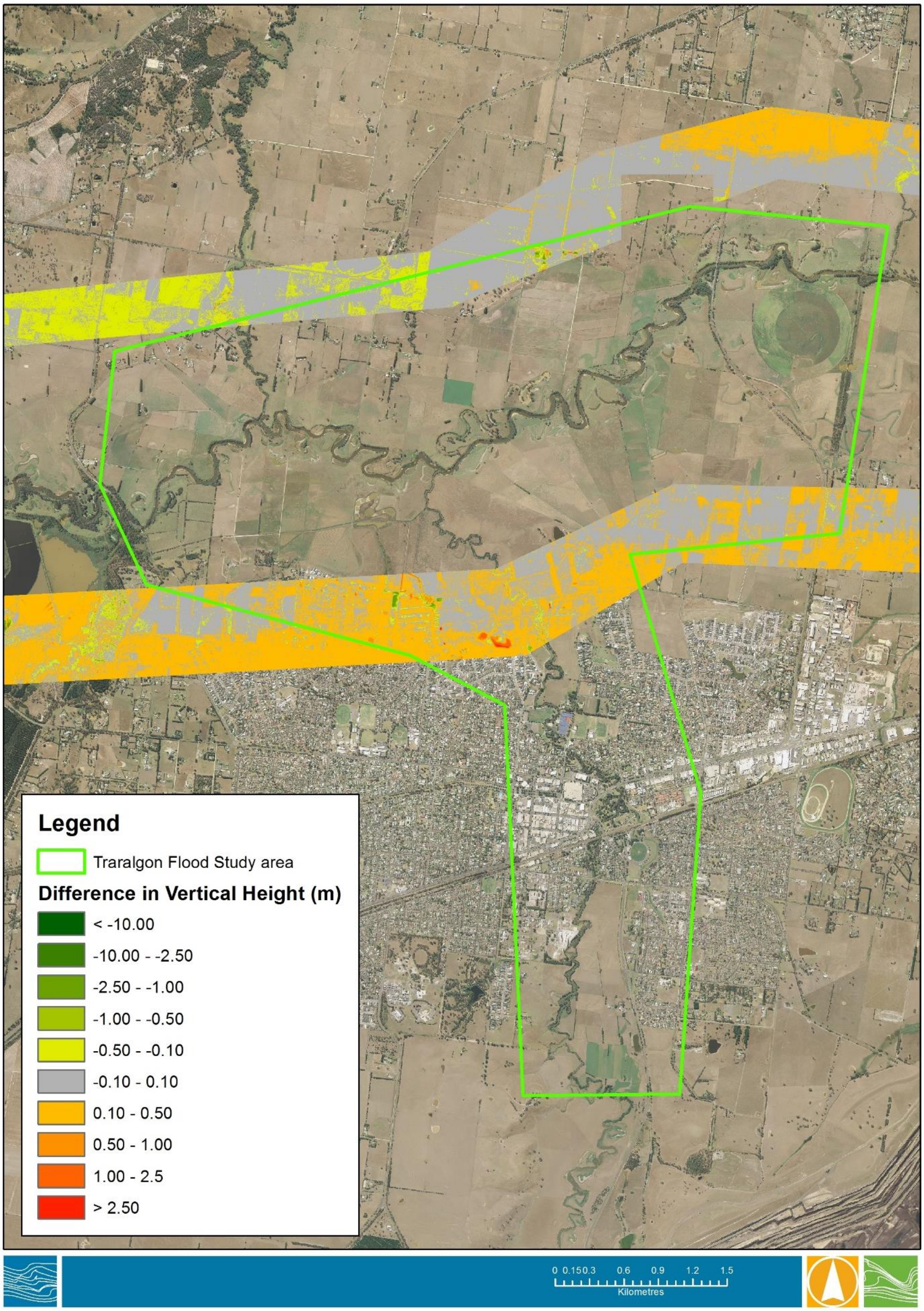

Figure 2-10 LiDAR comparison – Southern Rural Water LiDAR DEM minus Floodplains DEM

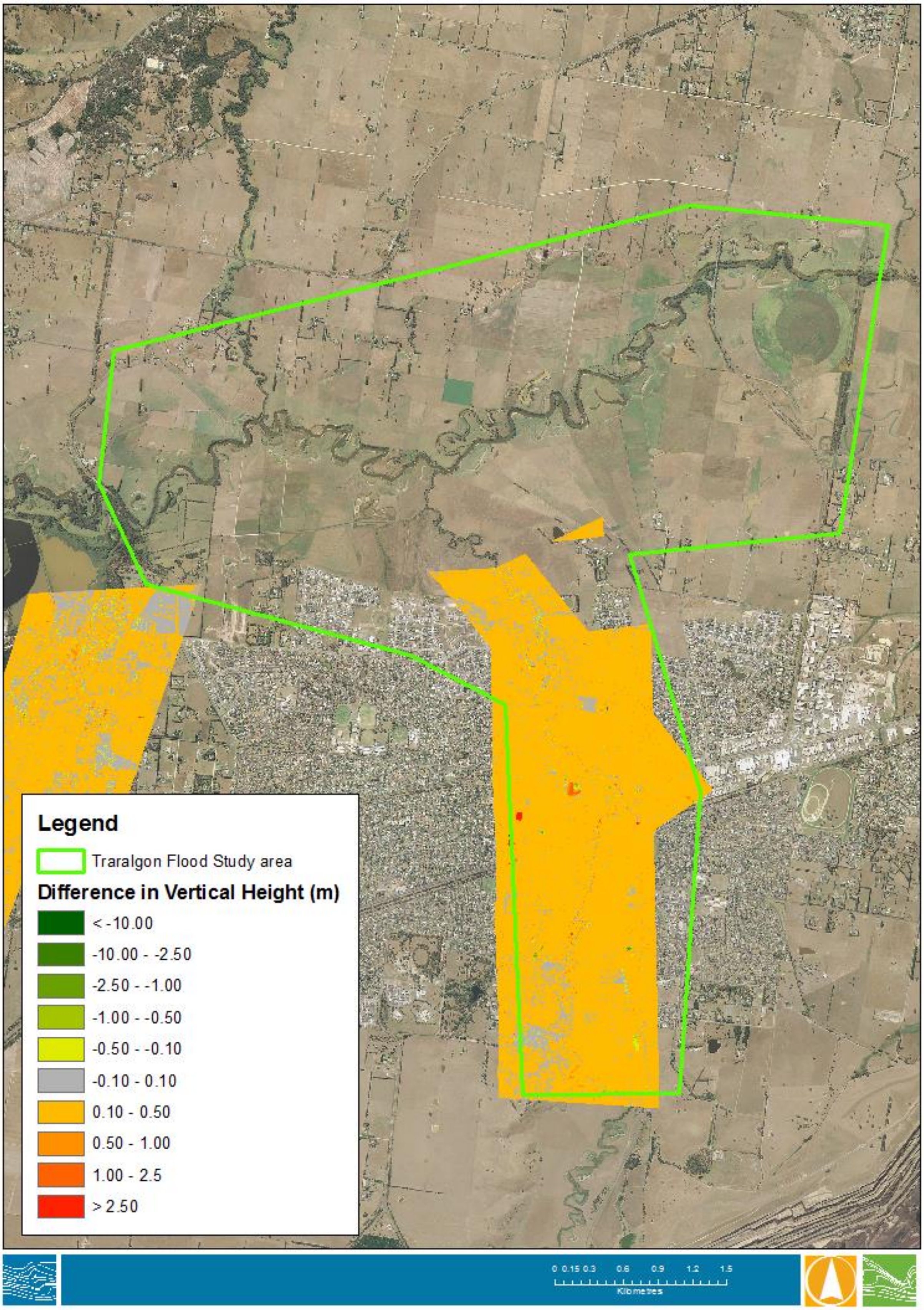

Figure 2-11 LiDAR comparison - Rivers LiDAR DEM minus Floodplains LiDAR DEM

Upon receiving the commissioned feature survey undertaken by Beveridge Williams, Water Technology undertook an assessment of the available LiDAR datasets for the Traralgon area. The three LiDAR datasets that were proposed to be used for the construction of the hydraulic model were compared against the survey data. The survey data included several cross sections of the Traralgon Creek and two transects located at Howitt Street, on the southern side of the Bairnsdale Railway and to the north of the CBD along Bradman Boulevard.

The results of the two transects analysed against the available LiDAR are shown in Table 2-5 and Table 2-6. Both transects as well as several cross sections obtained of Traralgon Creek showed the *RIVERS* and *SRW* (Bradman Boulevard only) LiDAR datasets matched extremely well, being generally within 50 mm, while the *Floodplains* data set showed differences of around 200-250 mm. The *RIVERS* dataset had two large outliers along the Howitt St transect which were due to processing techniques undertaken by DELWP where bridges are removed. Once these points were removed from the statistics, it showed that the *RIVERS* LiDAR dataset had an average difference of 0.01 m as shown in Table 2-5.

For the hydraulic model build, the *SRW* data was used for the majority of the Latrobe River section of the model (the 15 m floodplain grid). For the detailed model of the Traralgon Creek, the *Floodplains* LiDAR set covers a larger area than the *Rivers* throughout the city as well as having a higher vertical accuracy as shown in Table 2-3, making it the preferred LiDAR set. To offset the differences in surveyed and LiDAR values, a vertical shift of +250 mm was be applied to *Floodplains* LiDAR. As shown below in Figure 2-12 and Figure 2-13 the modified LiDAR matches well with the surveyed transects.

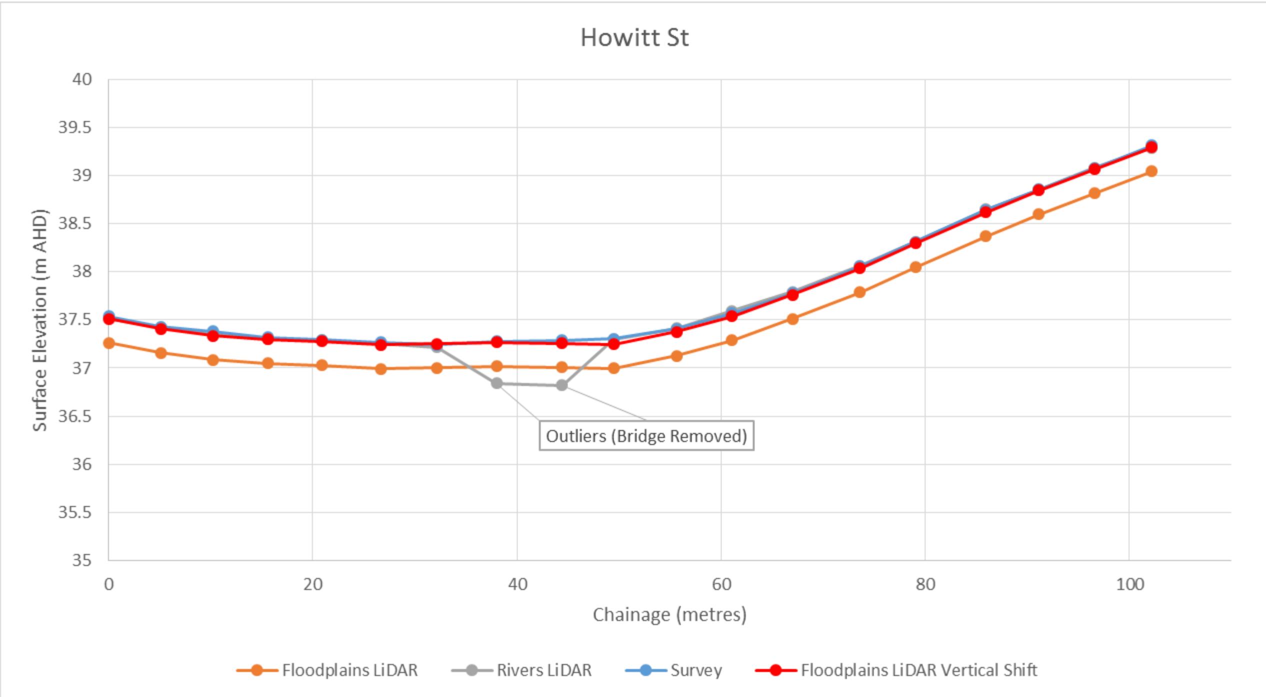

Figure 2-12 Howitt Street LiDAR/Survey Comparison

Table 2-5 Howitt Street Survey/LiDAR Statistics

LiDAR Set	Floodplains	Rivers	Southern Rural Water	Rivers (2 points removed)

MIN	0.241	-0.025	NA	-0.025
Max	0.305	0.469	NA	0.034
Average	0.272	0.059	NA	0.012
SD	0.014	0.141	NA	0.015

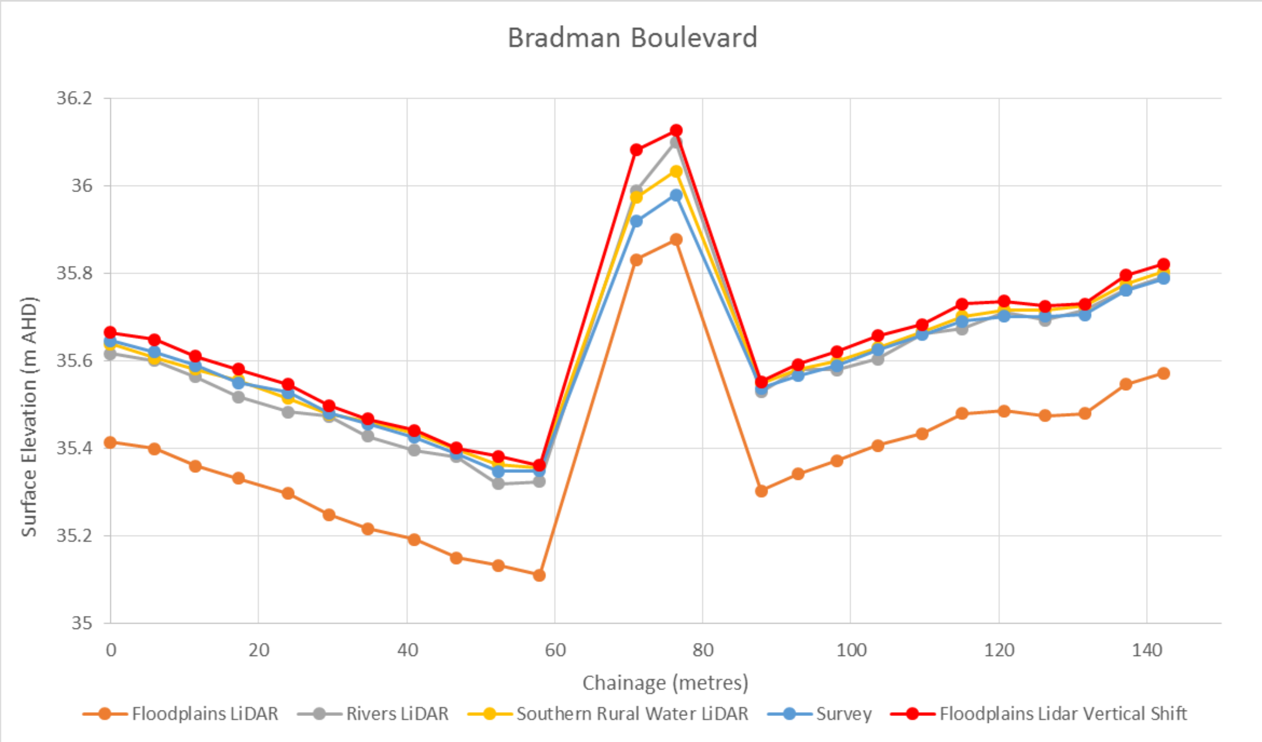

Figure 2-13 Bradman Boulevard Survey/LiDAR Comparison

Table 2-6 Bradman Boulevard Survey/LiDAR Statistics

LiDAR Set	Floodplains	Rivers	Southern Rural Water
MIN	0.087	-0.120	-0.054
Max	0.239	0.045	0.014
Average	0.215	0.024	-0.011
SD	0.038	0.035	0.016

Seven channel cross sections of the Traralgon Creek were taken around the Traralgon CBD. All cross sections show the difference in topography within the channel as LiDAR fails to penetrate the water surface as shown in Figure 2-14. This gives an inaccurate reading in areas of the channel containing water, therefore these channel cross sections form the basis in defining the topography of the channel in areas underwater. Defining the waterway channel capacity helps in the calibration of the hydraulic model by providing a more accurate representation of the conveyance within the channel.

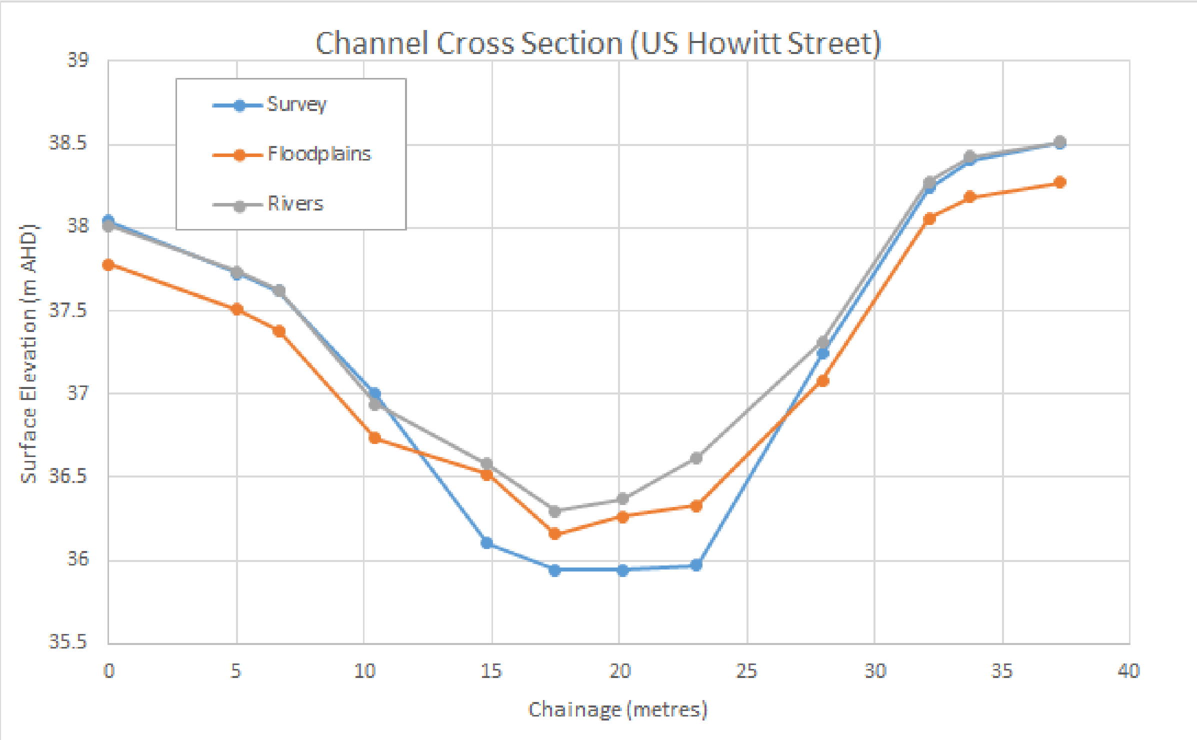

Figure 2-14 Channel Cross Section upstream of Howitt Street

While the *Rivers* LiDAR set showed the highest accuracy within the two transects surveyed, the *Floodplains* data is rated at a higher vertical accuracy compared to the *Rivers* data. Additionally the *Floodplains* LiDAR data covers a larger area than the *Rivers* LiDAR. Therefore Water Technology recommended utilising the *Floodplains* LiDAR set with a vertical shift of 250 mm in the hydraulic model build for the Traralgon Creek combined with the *SRW* LiDAR for the Latrobe River section of the model. This vertical shift does not help resolve the channel surface in areas underwater, hence channel cross section information assists in setting channel profiles throughout the hydraulic model to gain an accurate channel capacity.

2.5 Drainage Information

GIS layers of local pits, pipes and outfalls were provided by Latrobe City Council (Figure 2-15), and the dimensions of the pipes and pits were provided in a separate database that relates to the GIS data. The database contains pipe diameters, lengths and pit depths, however it is missing invert levels for the pipes and pits. The accuracy of the locations and attributes is unknown and council has advised that errors in the data are common. Water Technology converted the pit depth to an invert depth using LiDAR surface at the pit location, as a rough estimate, but is the best information available. Additional bridge and culvert information was sought from VicRoads and feature survey undertaken.

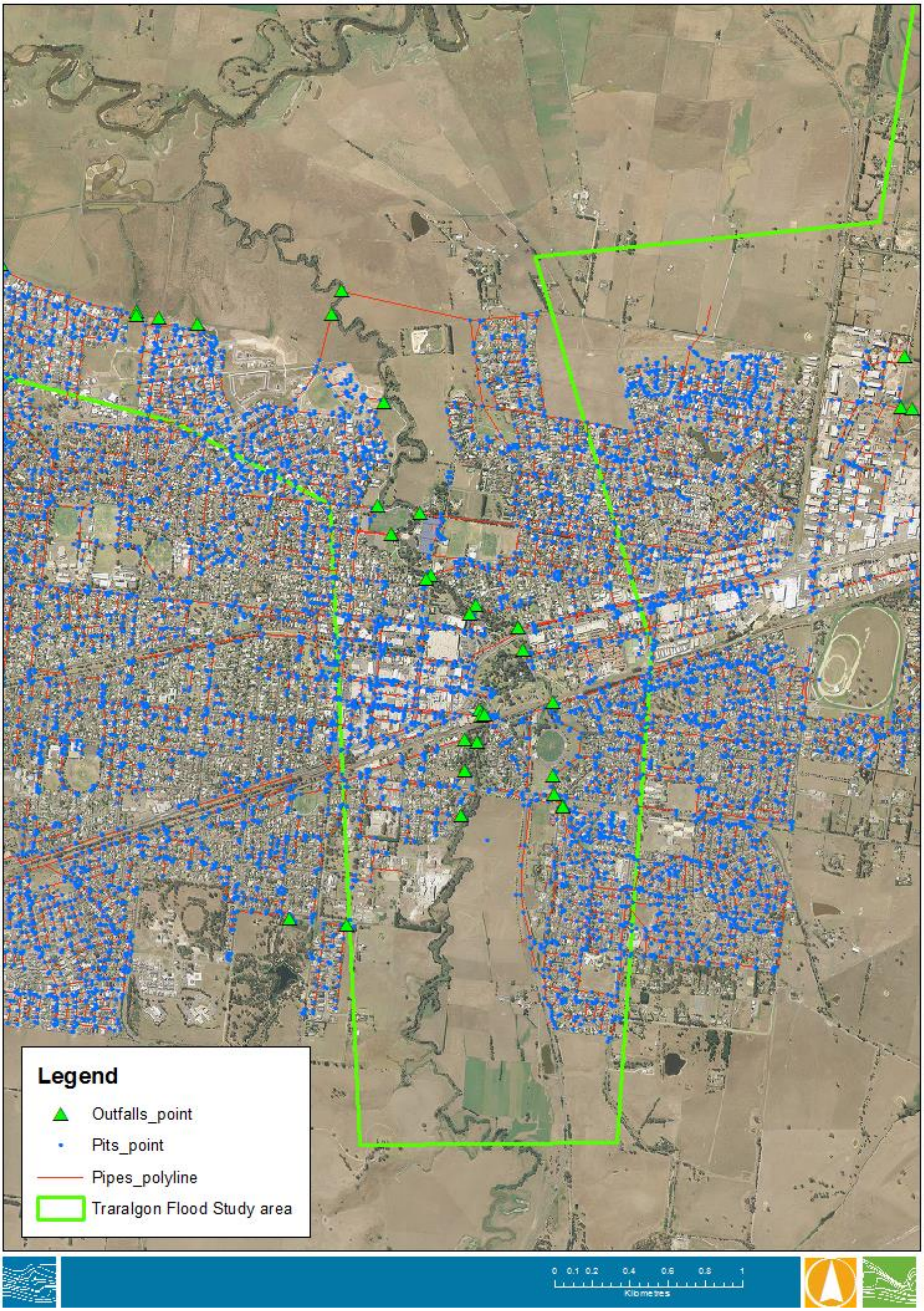

Figure 2-15 Drainage GIS layers (Latrobe City Council)

2.6 Streamflow Data

Three streamflow gauges operate in the catchment (Table 2-7). The Traralgon Creek @ Traralgon gauge is located within the city of Traralgon alongside the Princes Highway. The Traralgon South and Koornalla gauges are located upstream of the city. The gauge at Traralgon was moved 300 m upstream from Wright St to the Princes Highway in August 1998 to improve the rating of higher flows as water was known to flow around the Wright St gauge in large flood events (BoM, 2000). The Wright St gauge was kept in operation for several years to ensure consistency between the gauges. The gauge zero was also changed at Wright St from 29.929 m AHD to 31.929 m AHD on 23 April 1987, and is now listed as 32.673 m AHD. It is unknown when the latest change occurred. The changes to the gauge have direct implications on the flows measured in high flow events and have a bearing on the annual peak series and flood frequency analysis. Water Technology investigated this further during the hydrology stage of the study.

Table 2-7 Streamflow gauges in Traralgon Creek catchment

Gauge No.	Location	Period	Years	Catchment Area (km^2)
226023	Traralgon Creek @ Traralgon	1960-2014 (incomplete)	54	189
226415	Traralgon Creek @ Traralgon South (Jones Road site)	1997-2014	17	128
226410	Traralgon Creek @ Koornalla	1953-2014	60	89

Prior to the flood warning system being launched in October 1999, the Koornalla and Traralgon South gauges were upgraded and new ratings curves established using hydraulic modelling (SKM, 2000). The locations of the gauges are shown in Figure 2-18.

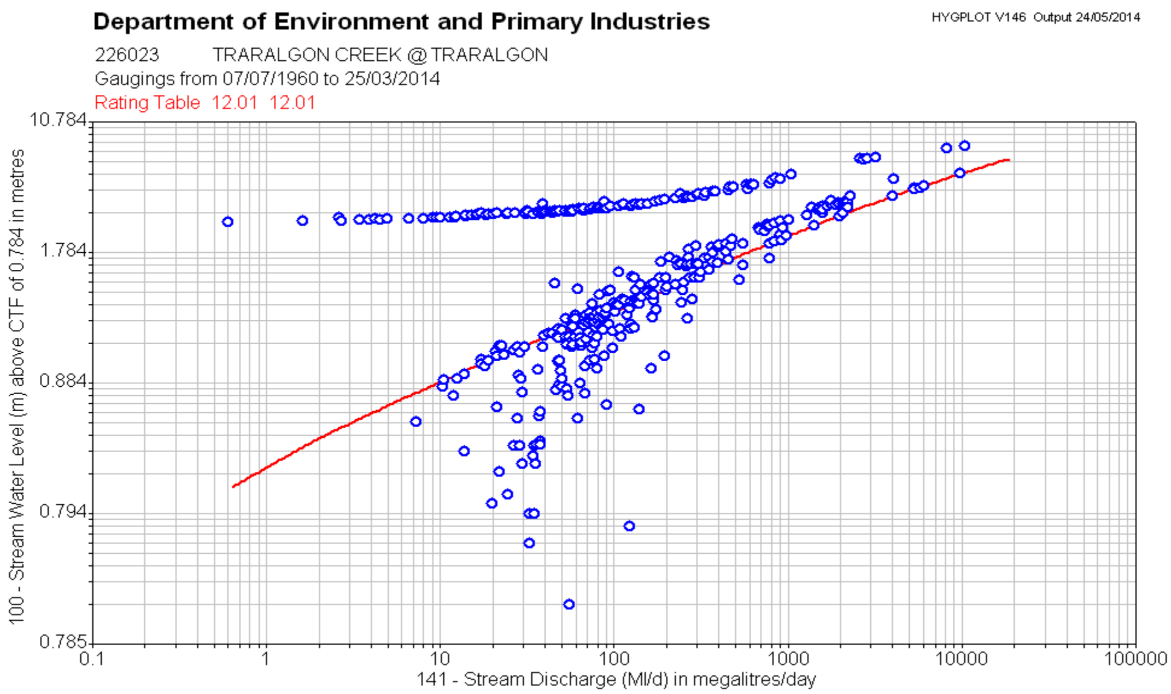

Figure 2-16 Rating Curve for 226023 Traralgon Creek @ Traralgon

The rating curve for the Traralgon Creek @ Traralgon Gauge (226023) is shown in Figure 2-16 and shows that there has been a change to the rating at the site at some point given the two distinct bands of values. Figure 2-17 shows the recorded gauge readings, which clearly shows the inconsistencies in the gauge datum. Red lines indicate the 2 m change in datum and the change to gauge location. After the flood event in 1978, a flood study was commissioned and mitigation works recommended a significant alteration to the Traralgon Creek waterway within Traralgon to reduce flood levels in the city. These works were carried out during the 1980s and significantly increased the channel capacity at the Traralgon Creek at Traralgon gauge site. Therefore, any new rating curves derived for this gauge should not be applied to flows prior to the mitigation works being completed.

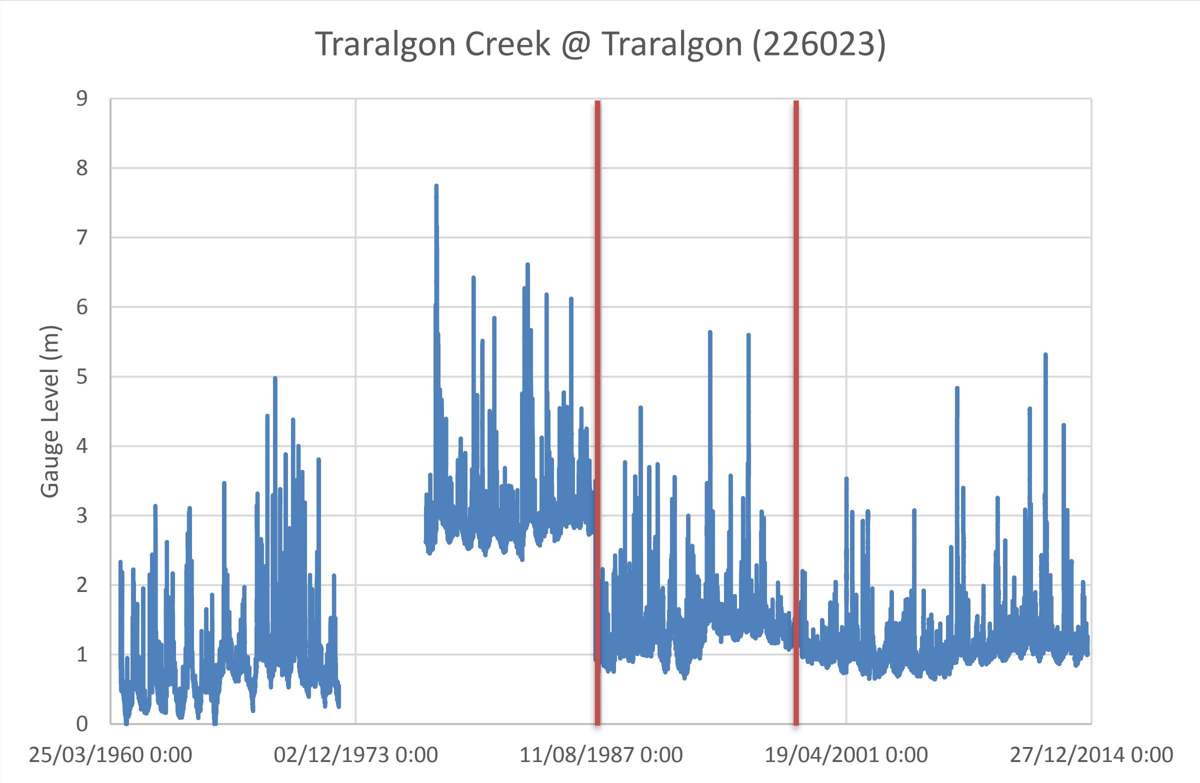

Figure 2-17 Recorded Gauge Levels for Traralgon Creek at Traralgon

2.7 Rainfall Data

The average annual rainfall at Traralgon is 620 mm. A steep rainfall gradient exists over the catchment with average annual rainfall reaching 1,500 mm in the headwaters. At the catchment centroid the average annual rainfall is around 670 mm.

Numerous daily rainfall sites are in operation in and around the catchment. Key stations, including current stations and stations operating over historic flood events are listed in Table 2-8. Pluviograph (sub-daily rainfall) stations in and around the Traralgon Creek catchment are listed in Table 2-9. Figure 2-18 shows the locations of the daily and pluvio rainfall stations around the Traralgon Creek catchment.

Table 2-8 Daily rainfall stations around Traralgon Creek catchment

Gauge No.	Location	Period	Years
85009	Traralgon EPA	2000-2014	14
85086	Traralgon	1902-1964	62
85017	Callignee South	1932-1985	54
85007	Traralgon Creek (Balook)	1999-2014	14
85008	Balook	1905-1962	57
85005	Traralgon Creek (Mount Hooghly	2000-2008	8
85006	Le Roy (Taylors Rd Quarry)	2000-2009	8
85062	Morwell (Mail Centre)	1887-2004	117
85011	Blackwarry	1888-1975	87
85101	Tarra Valley	1952-1990	38
85105	Hazelwood North	1939-1994	55
85139	Traralgon (Cora lynn)	1892-1918	23
85150	Hazelwood Sec	1963-1993	30
85170	Traralgon L.V.W.& S.B.	1967-1999	32
85236	Callignee North	1956-2014	57
85281	Traralgon Creek At Koornalla	2000-2014	14
85169	Traralgon Post Office	1964-1967	3
85264	Novacs	1968-1986	18
85299	Koornalla Traralgon Ck Rd	1964-1967	2
85280	Morwell (Latrobe Valley Airport)	1984-2014	30
85307	Jeeralang North	2009-2014	5

Table 2-9 Pluviograph stations in and around the Traralgon Creek catchment

Gauge No.	Location	Period	Years
85098	Yallourn	1936-1948	12
85170	Traralgon LVW & SB	1961-1979	18
85236	Callignee North	1961-2013	50
85263	Murrays Balook	1974-1978	3.2
85264	Novacs	1968-1978	10
85265	Macks Creek	1975-1978	3.4
85280	Morwell (Latrobe Valley Airport)	2005-2014	9.3

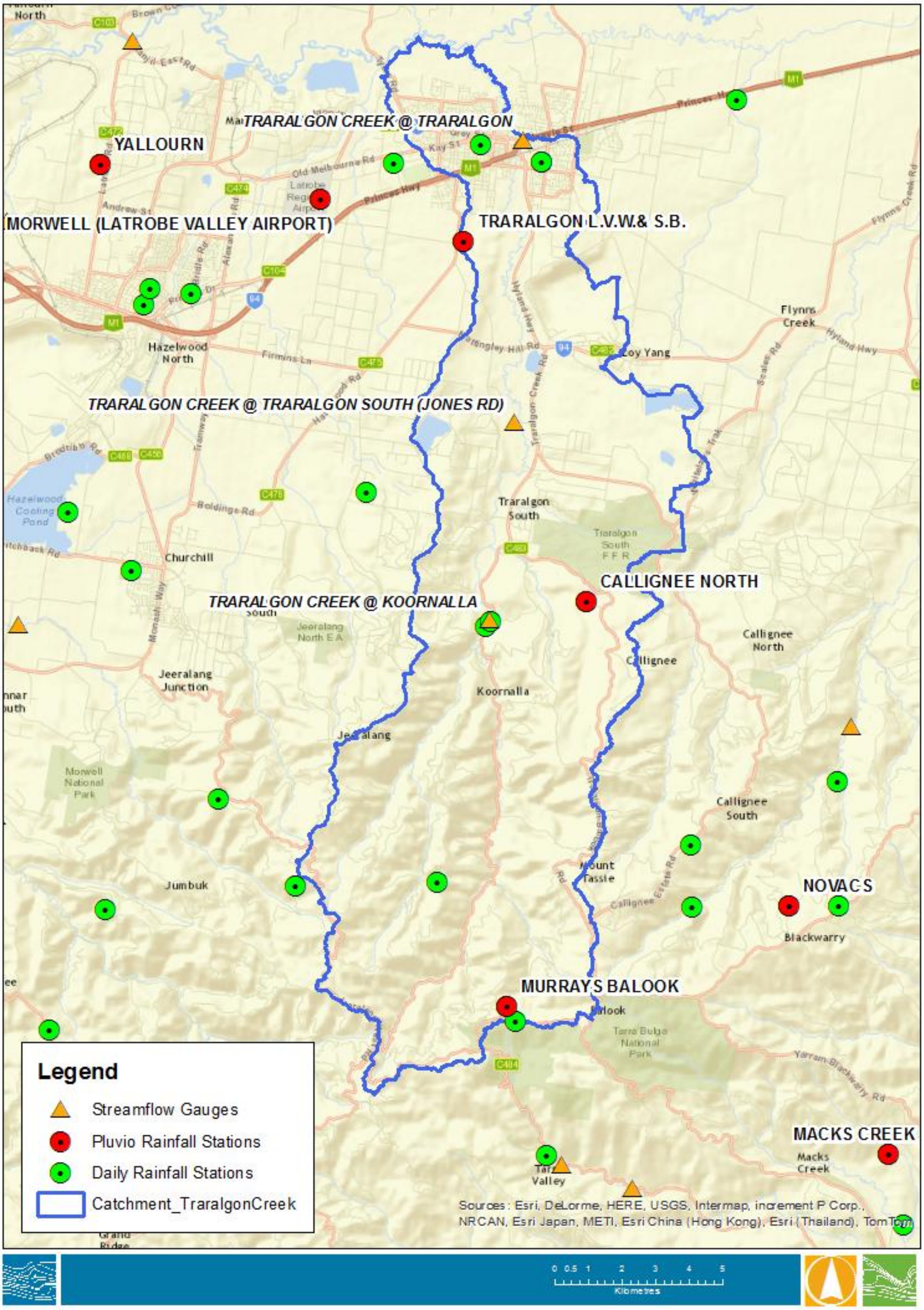

Figure 2-18 Daily Rainfall, Pluvio and Streamflow Stations around Traralgon Creek catchment

2.8 Flood Warning System

The flood warning system consists of eight rain gauges and three streamflow gauges located strategically throughout the catchment. Two of these rainfall gauges are no longer active. The aim of the system is to provide at least six hours warning of the flood peak at Traralgon. The warning time however is very dependent on the characteristics of the storm as the time to peak from the beginning of the rainfall event can vary significantly.

BoM gauges at Koornalla and Traralgon South were upgraded in conjunction with the 2000 flood study for flood warning purposes. These two gauges along with the Princes Highway at Traralgon gauge are the primary streamflow gauges used for the flood warning system for Traralgon. Peak stage correlations from Koornalla to Traralgon South, and from Traralgon South to Traralgon were developed by the BoM along with an URBS Rainfall Runoff model for the Traralgon Creek catchment to extend warning times to Traralgon. Flood class levels have been defined for the Traralgon gauge with the Major flood level adjusted to 4.8 m from 4.5 m at the gauge after a review by Thiess in June 2012.

The eight real-time rainfall gauges included in the flood warning system and their period of record are listed in Table 2-10. The rainfall gauges are used to provide early estimates of hydrograph peaks prior to rises in the streamflow gauges.

Table 2-10 Flood Warning System Rainfall Gauges

Gauge No.	Location	Period	Years
226814	Mt Tassie	1998-2014	16
226816	*Mt Hooghly*	*1999-2008*	*9*
226817	*Taylors Rd Quarry*	*1999-2009*	*10*
226818	Balook	1999-2014	15
226819	Callignee North	1999-2014	15
226410	Koornalla	1995-2014	19
226415	Traralgon South	1999-2014	15
226815	Traralgon EPA	1999-2014	15

Note 226816 and 226817 gauges no longer in use.

2.9 Flood Mitigation Scheme

The Traralgon flood mitigation scheme was constructed in response to the 1978 flooding following the 1979 flood study and 1984 flood mitigation proposal. The flood mitigation scheme was originally intended to protect residential land and improve flood warning. The implemented components of the scheme consists of:

- Levees along Peterkin St and Phelan St and associated stormwater retarding basin
- Channel excavation works
- Lowering of Franklin St and bridge modification
- Earth works along both banks from Shakespeare St to north of tennis courts
- Penstocks and flood gates installed on all major drainage outlets to the creek

The construction of the scheme was completed in 1988. Not all of the works recommended in the 1984 report were implemented. The flood mitigation scheme was first tested during the September 1993 flood, resulting in a significant reduction in flood damages compared to 1978 from a similar flood magnitude.

3. SITE INSPECTION

A site inspection was undertaken by representatives from Water Technology, West Gippsland CMA and Latrobe Shire Council on 16 October 2014. Key locations visited are shown in Table 3-1.

Table 3-1 Key locations visited by project staff, on 16 October 2014

Location/Notes	Photo
Walk Bridges • Walk bridges over Traralgon Creek upstream of the Princes Hwy have hinges on the rails so that they can be folded down during flood events to avoid build-up of debris.	
Culvert under Whittakers Rd	
Peterkin St Levee • Levee system consists of earthen levee, brick fence, high section of road and another earthen levee. Small RB behind levee drains stormwater during flood event from local catchment and store the water until the creek is low enough for it to drain.	

Location/Notes	Photo
Princes Hwy Streamflow Gauge • Gauge was moved from Wright St to Princes Hwy in August 1998 • Significant waterway works in the 1980s have altered the cross section at the gauge site	
Traralgon Ck Waterway Works • Large amounts of fill were removed from the floodplain within Traralgon to increase conveyance of flood water during high flow events	
Wright St Walk Bridge • New Walk Bridge over Traralgon Creek nearing completion.	

Location/Notes	Photo
Oak Tree • Oak Tree in Traralgon North is significant for historic flooding • Reference point in many photos	
Oval in new development • Oval acts as flood storage • Large culverts to east of oval	
Pine plantations in the upper catchment, large sediment load observed on road side drains and in waterways in recently harvested areas.	

Location/Notes	Photo
Culverts under intersection of Shakespeare St and Mapleson Drive	
Culverts under Railway line	
Stormwater surcharge pit between Ormond Road and Shakespeare St	

4. MODELLING METHODOLOGY SCOPING

4.1 Hydrology and boundary conditions

4.1.1 Catchment flooding

Model Build / Development

A RORB hydrological model was developed of the entire Traralgon Creek catchment to the confluence with the Latrobe River, which includes the hydraulic model extent. ESRI's ArcHydro was be used to delineate the catchment, with a minimum of 3 to 5 sub-areas schematised upstream of any required streamflow hydrograph. Print locations were included at all locations where flow is required such as at tributaries, streamflow gauges and model boundaries.

Model Calibration

The model was be calibrated to three events selected from the 1993, 1995, 2007, 2011, 2012 and 2013 flood events for which gauged information is available. The chosen events were the largest event (1993), the smallest recent event (2013), and the 2012 flood event. Local daily and sub-daily rainfall gauges were used to construct a spatial pattern of rainfall for the historic events. Local sub-daily rainfall gauges were used as temporal patterns for the historic storm event. Given the density of sub-daily rainfall stations in the catchment, different sub-areas were assigned different temporal patterns based on their proximity to sub-daily rainfall stations. Model parameters *kc*, *m*, *IL* and *CL* were then developed for each event by calibrating to the available streamflow gauge.

The design events 0.5%, 1%, 2%, 5% and 10% AEP have been simulated for a range of storm durations.

Hydrological Design Modelling

A flood frequency analysis was undertaken for the Princes Hwy gauge to determine peak flow and volume for the design annual exceedance probabilities specified in the brief.

The current IFD curves were utilised for design rainfalls. At the time the hydrology for the project was undertaken, the revised curves were not recommended to be used in practice until the revised AR&R manual was finalised. The revised IFD curves were be modelled, however, as part of a sensitivity analysis.

RORB model design parameters (*kc, m, IL, CL*) were determined in the hydrology phase of the project. Adjustment of design parameters may be undertaken given a verification process, comparing RORB modelling to flood frequency analysis, Australian Rainfall and Runoff regional estimates and other streamflow estimation techniques.

The design events consider a range of storm durations with a focus on critical durations for Traralgon Creek at Traralgon. All critical durations were simulated in the hydrological model, with critical duration (36 hours) modelled in the hydraulic model.

The final adopted design model parameters were utilised to produce hydrographs at all hydraulic model boundaries for the 0.5%, 1%, 2%, 5%, and 10%, AEP flood events.

The probable maximum flood (PMF) discharge was estimated using the rapid assessment method developed by Nathan *et. al.* (1994).

The impacts of climate change were also tested in the hydrology by increasing the rainfall intensity by an agreed amount in line with available literature, most likely an increase of 32% as advised in the report *Climate Change in Australia* (CSIRO, 2007). A recent report from Engineers Australia discusses interim guidelines for considering climate change in rainfall and runoff (EA, 2014).

The impacts of bushfires were tested by adjusting the fraction impervious of the Traralgon Creek sub-catchments to reflect an agreed severity of bushfire. For example Blackham et al (2012) provides values of equivalent percentage impervious for different levels of burn severity, based on BAER (2009). This was tested in the hydrology phase of the project.

4.2 Hydraulics

A 1D-2D unsteady TUFLOW hydraulic model of Traralgon and surrounds was developed. The hydraulic model consisted primarily of a 2D grid model of the city, creeks and floodplains, with hydraulic structures incorporated as dynamically coupled 1D elements.

4.2.1 2D Model Schematisation

Grid Extent and Resolution

The original proposed extent of the 2D model area is shown in Figure 4-1. The model is approximately 6.8 x 7.8 km in size. It was proposed to split the model into two domains to provide adequate resolution within the urban areas whilst maintaining manageable run times. A grid size of 3 m is proposed to provide adequate resolution in Traralgon, however the Latrobe River floodplain area was modelled on a coarser grid resolution (most likely 15 m - i.e. a multiple of the finer 3 m grid). Following the initial hydraulic modelling, sensitivity of the Latrobe River levels on flood levels within Traralgon Creek was undertaken. This found the impact of the Latrobe River did not extend up into the Traralgon city area. Therefore the model was reduced to a single domain model of 3m resolution and the Latrobe River floodplain was removed from the model. The final hydraulic model extent is shown in

Boundary Conditions

An Inflow hydrograph boundary was applied at the upstream extent of Traralgon Creek along with source inflow hydrographs along the creek within the model as required. The downstream boundary was initially located on the Latrobe River and set to either a constant water level or slope based on the outcomes of the Latrobe River Flood Study (Cardno, 2014). An inflow boundary was also applied at the upstream extent of the Latrobe River to provide a realistic hydraulic gradient and backwater effect of coincidental flooding in the Latrobe River. When the model was reduced to a single domain, the downstream boundary was placed on Traralgon Creek using a static water level from the Latrobe River Flood Study.

Roughness

Land cover types were assessed using aerial photography and industry standard roughness values will be adopted. Sensitivity analysis of these roughness parameters was also undertaken.

4.2.2 1D Model Elements

Bridge, culvert and pipe structures were incorporated in the model as 1D structures. These are coupled to the 2D grid at their upstream and downstream ends. A map showing the pipes included in the model is shown in the hydraulic report.

Standard roughness values, inlet and outlet losses were applied based on the available information on material, geometry and inlet condition of the structures.

4.2.3 Model Calibration

The hydraulic model was calibrated to the three events chosen from the hydrological modelling. There is significant amounts of data available within the study area for all of the recent flood events since 1993. Surveyed water levels, flood photography, gauge readings and anecdotal evidence were used to calibrate the hydraulic model.

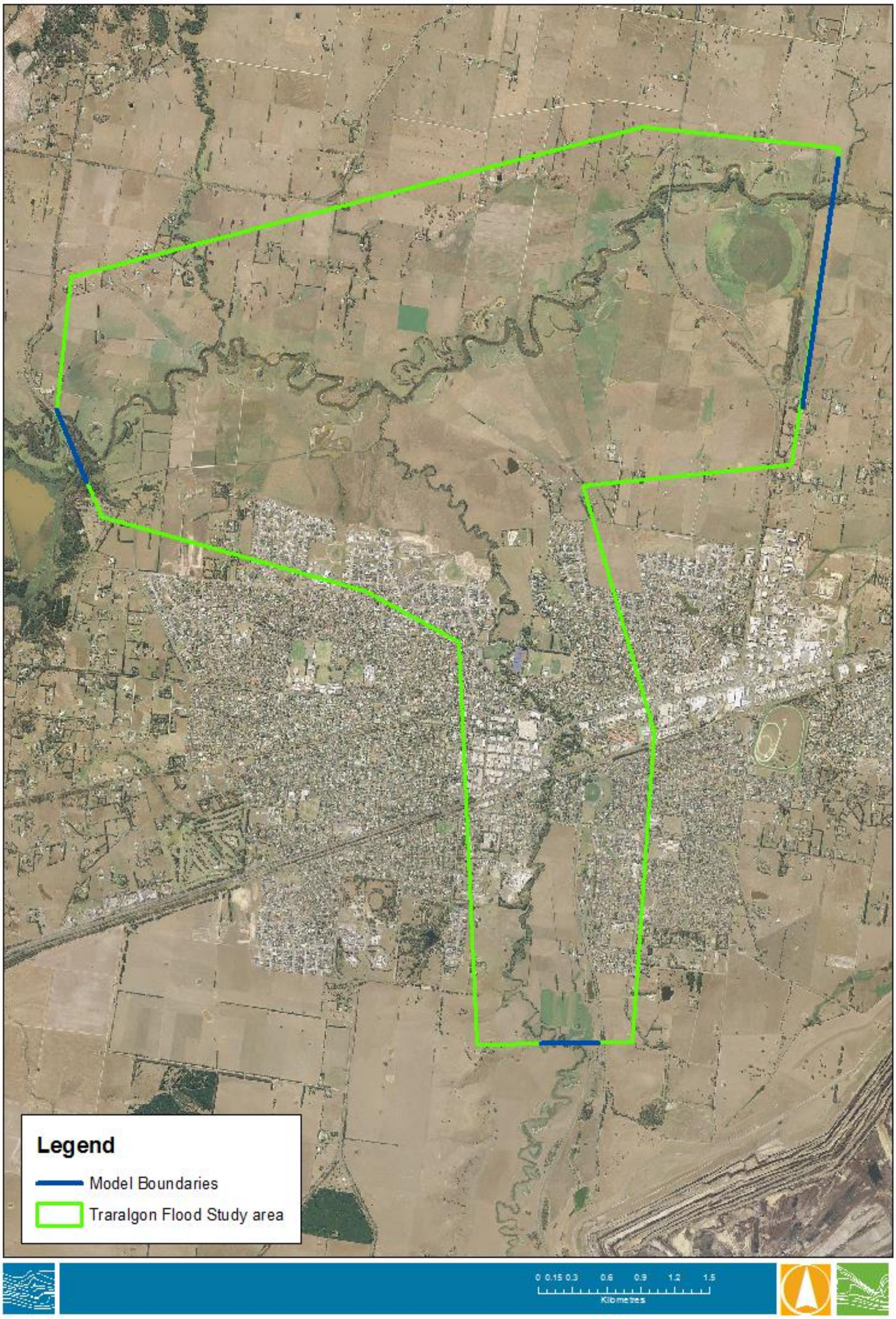

Figure 4-1 Initial Hydraulic Model Extent and boundaries

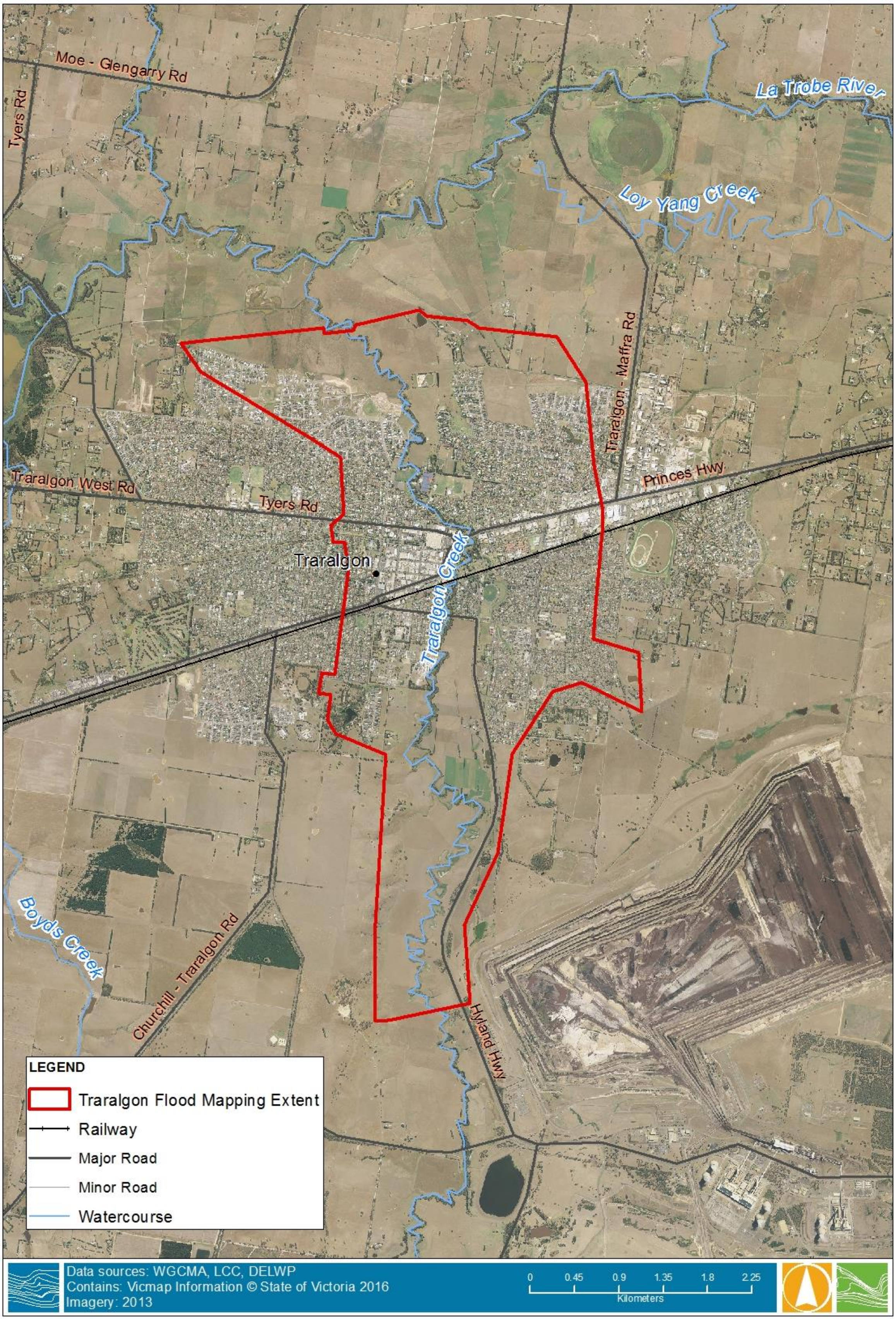

Figure 4-2 Final Hydraulic Model Extent

5. DATA GAPS

The following data gaps were identified during the data review stage of the project, each gap identified is listed below with an outcome of how this was dealt with:

- Historic Rating Tables
    - Water Technology investigated the appropriateness of the historic rating curves (i.e. anecdotal accounts of water bypassing Wright St gauge), and the implications for the annual flow series and flood frequency analysis. The 1993 flow modelled was adjusted to better match the historic flood levels in the city. This is covered in more detail in the hydrology (R02) and hydraulics (R03) reports.
- Feature Survey to validate LiDAR
    - Verification survey was commissioned by WGCMA and used to adjust the LiDAR as reported earlier in the project.
- Cross section survey
    - A number of cross sections were taken along the Traralgon Creek as part of the survey scope outlined earlier in the report
- Bridge and culvert feature survey
    - Feature survey was carried out on a number of culverts and structures. Any features within the drainage network that were identified as a data gap utilised engineering judgement to provide an estimate of the feature.

6. NEXT STEPS

Following the acceptance of the data review report, the hydrological modelling stage of the project was undertaken. This is covered in the Hydrology (R02) report (Water Technology 2016b).

7. REFERENCES

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Water Tech, 2016d *Traralgon Flood Study – Assess and Treat Risk*. Water Technology. Report prepared for West Gippsland CMA

Water Tech, 2016e *Traralgon Flood Study – Summary Report*. Water Technology. Report prepared for West Gippsland CMA

Traralgon Flood Study – Hydrology (R02)

March 2016

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PROJECT DETAILS

Project Name	Traralgon Flood Study
Client	West Gippsland Catchment Management Authority
Client Project Manager	Linda Tubnor
Water Technology Project Manager	Richard Connell
Report Authors	Richard Connell, Ben Tate
Job Number	3569-01
Report Number	R02
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Cover Photo: Traralgon CBD flooding, September 1993. Looking South-West towards the Princes Highway and Franklin Street.

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1. INTRODUCTION

Following the recent flood events affecting Traralgon during June 2007, July 2011, June 2012 and June 2013, Water Technology was commissioned by the West Gippsland CMA to undertake the Traralgon Flood Study. This study included detailed hydrological and hydraulic modelling of Traralgon Creek and the Latrobe River, flood mapping of Traralgon, recommendations for flood mitigation works, and a review of planning controls.

This report details the Hydrological analysis undertaken for the Traralgon Creek catchment, this involved a rigorous assessment of available rainfall and streamflow data, a Flood Frequency Analysis, the development and calibration of a RORB model and the development of design hydrographs to be used in the hydraulic modelling of Traralgon. This report is one of a series of reports documenting the outcomes of the Traralgon Flood Study.

- R01 - Data Review Report (Water Technology 2016a)
- **R02 - Hydrological Report (Water Technology 2016b) – this report**
- R03 - Hydraulic Report (Water Technology 2016c)
- R04 - Assess and Treat Risk Report (Water Technology 2016d)
- R05 - Summary Report (Water Technology 2016e)

These five reports detail the approaches adopted, the findings and recommendations, of the Traralgon Flood Study. The five reports are supported by a number of standalone PDF flood maps and digital deliverables.

2. STUDY AREA

Traralgon is a regional city with over 30,000 permanent residents and is approximately 150 km east of Melbourne. The city lies above and to the south of the Latrobe River floodplain and is bisected by Traralgon Creek, which flows north through the Traralgon CBD. The Loy Yang open cut coal mine lies to the south of the city on the eastern side of Traralgon Creek.

Traralgon Creek breaks its banks approximately 2.5 km upstream of Traralgon during medium to high flow events, creating an anabranch on the eastern side of the floodplain. This anabranch joins with local catchment drains and flows around the showgrounds forming Doorty Creek, eventually re-joining Traralgon Creek just upstream of the Princes Highway. The study area is shown in Figure 2-1.

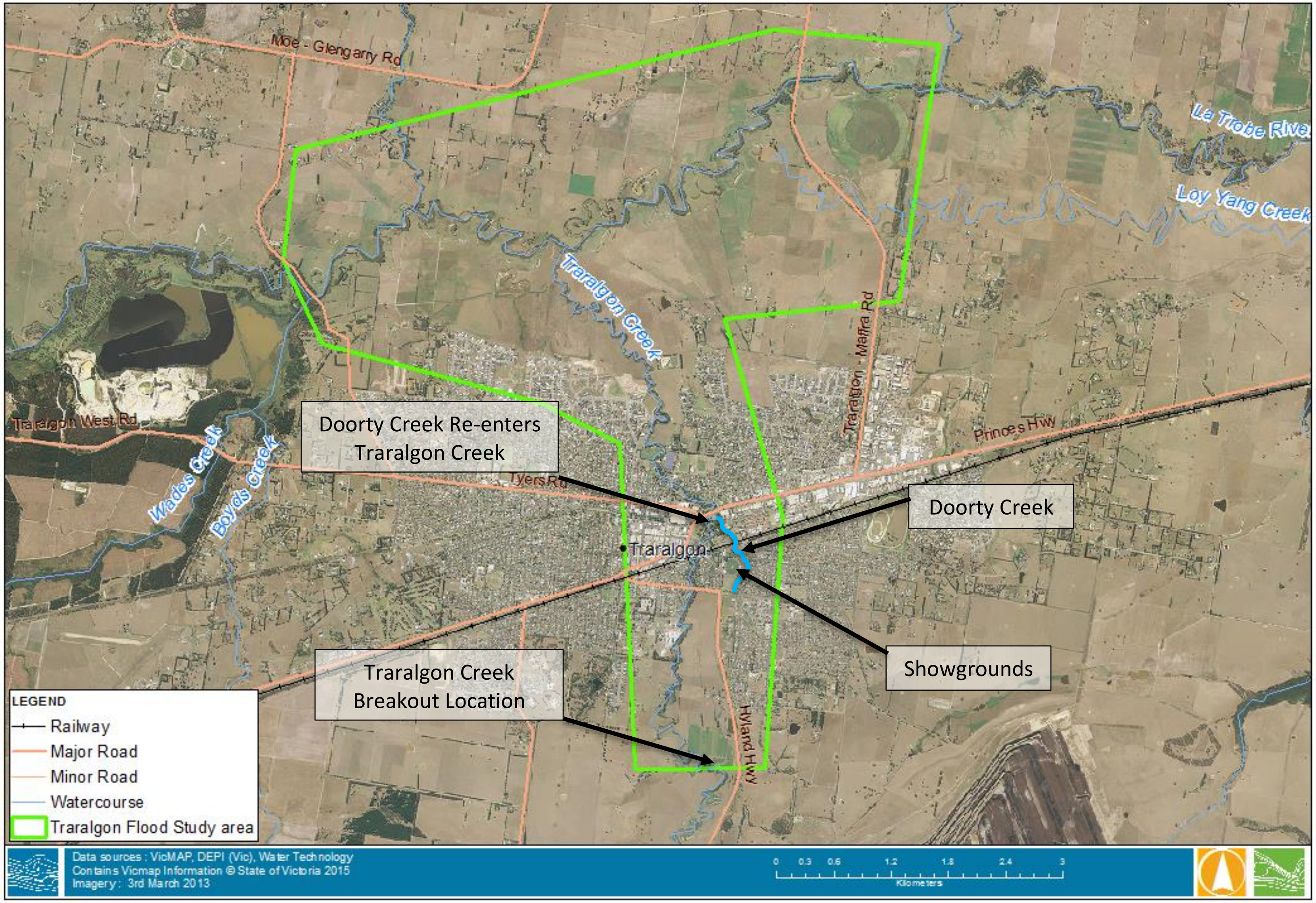

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Figure 2-1 Traralgon Study Area

3. HYDROLOGY

3.1 Overview

The hydrological analysis for Traralgon consisted of a review of the hydrological context of the study area followed by flood frequency analysis and hydrologic modelling using RORB. The RORB model was calibrated on three gauged events and parameter sets for design were validated against flood frequency analysis and regional flow estimates.

3.2 Catchment Description

The Traralgon Creek catchment has an area of approximately 178 km^2 extending 35 km south from the confluence with the Latrobe River to a maximum elevation of 750 m AHD at Mount Tassie, shown in Figure 3-1. The catchment is well defined, with Traralgon Creek consisting of a single main waterway through the centre of the long narrow catchment. Jeeralang Creek is the only major tributary joining Traralgon Creek at Koornalla with a number of other minor tributaries draining the catchment. The headwaters of Traralgon Creek are on the northern slopes of the Strzelecki Ranges, where the creek falls steeply for approximately 15 km until just upstream of Koornalla. Traralgon Creek then meanders onto the flatter floodplain for the remaining 20 km until it reaches the Latrobe River. The city of Traralgon lies on the northern reaches of Traralgon Creek immediately upstream of the Latrobe River floodplain. The upper catchment is primarily forested, including plantations, whilst the lower catchment is generally farmland with the exception of the urban areas surrounding Traralgon. The Loy Yang open cut coal mine is situated on the eastern side of the catchment between Traralgon South and Traralgon.

There are three streamflow gauges on Traralgon Creek, at Koornalla (226410), Traralgon South (226415) and Traralgon (226023), which are summarised in Table 3-1. The Traralgon Gauge was originally located upstream of the Wright St footbridge (226023A), and was relocated to just upstream of the Princes Hwy bridge (226023B) in August 1998.

Table 3-1 Streamflow gauges in Traralgon Creek catchment

Gauge No.	Location	Period	Years	Catchment Area (km^2)
226023	Traralgon Creek @ Traralgon	1960-2014 (incomplete)	54	189
226415	Traralgon Creek @ Traralgon South (Jones Road site)	1997-2014	17	128
226410	Traralgon Creek @ Koornalla	1953-2014	60	89

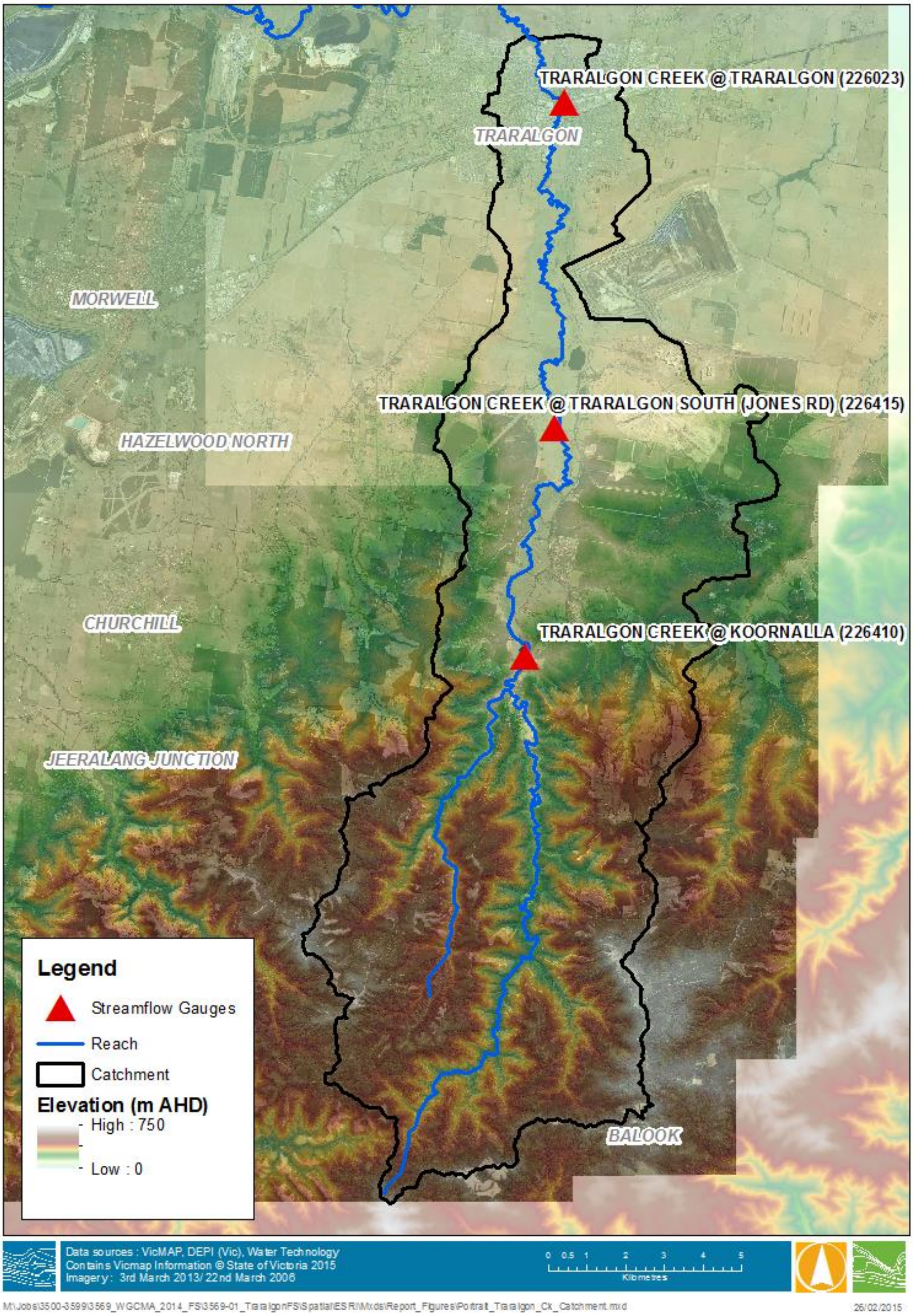

Figure 3-1 Traralgon Creek Catchment

3.3 Streamflow Gauge Review

3.3.1 Traralgon Creek at Traralgon (226023)

The Traralgon Creek at Traralgon gauge (226023) has 16 years of instantaneous gauge height records for its current location just upstream of the Princes Highway. The gauge was previously situated just upstream of the Wright Street footbridge approximately 300 m downstream and was operated periodically from June 1961 until September 1998. Daily readings are available from 1961 until it became telemetered in February 1969. In May 1972 the recorder was discontinued but occasional readings were still taken. The recorder was reinstated in November 1977, fortunately in time to record the June 1978 flood event, the largest on record at the time. The 1978 flood event was reliably gauged at the peak of the flood and lists the peak flow as 14,300 ML/day in the Blue Book (RWC, 1987). The DELWP Water Measurement Information System website lists the peak flow as 31,860 ML/day, which is incorrect and appears to be an application of a recent rating curve to an historic water level that was using a different datum. It is recommended that DELWP review and update their data to reflect the true flow records through this period.

The gauge again went offline from July 1983 to November 1988 due to modifications of the waterway undertaken during this period. Although the gauge was reinstated, the previous rating table was not valid due to the substantial changes in geometry of the channel. Additionally, during flood events high flows were known to bypass the gauging station. This led to the station being moved to upstream of the Princes Highway in September 1998.

The rating table was revised during the June 2012 flood event, the largest on record at the gauge's current location upstream of the Princes Highway Bridge. The rating for the current gauge is officially considered reliable up to flows of 11,230 ML/d corresponding to a gauge height of 5.00 m. The June 2012 flood event peaked at 5.32 m, which means the peak flow is in the unreliable section of the rating table.

Plotting of the published water levels and flows from the gauge clearly show a number of rating curves were used over the 54 year period (Figure 3-3). This is because the gauge location has moved during the period, the gauge datum has been adjusted and waterway works have altered the channel geometry. The changes in gauge datum and channel geometry are also reflected in the gauging plot (Figure 3-2), with the distinct band of higher water levels reflecting the rating table used from 1977 to 1987. In these flow gauging plots, CTF indicates the gauge's Commence to Flow value.

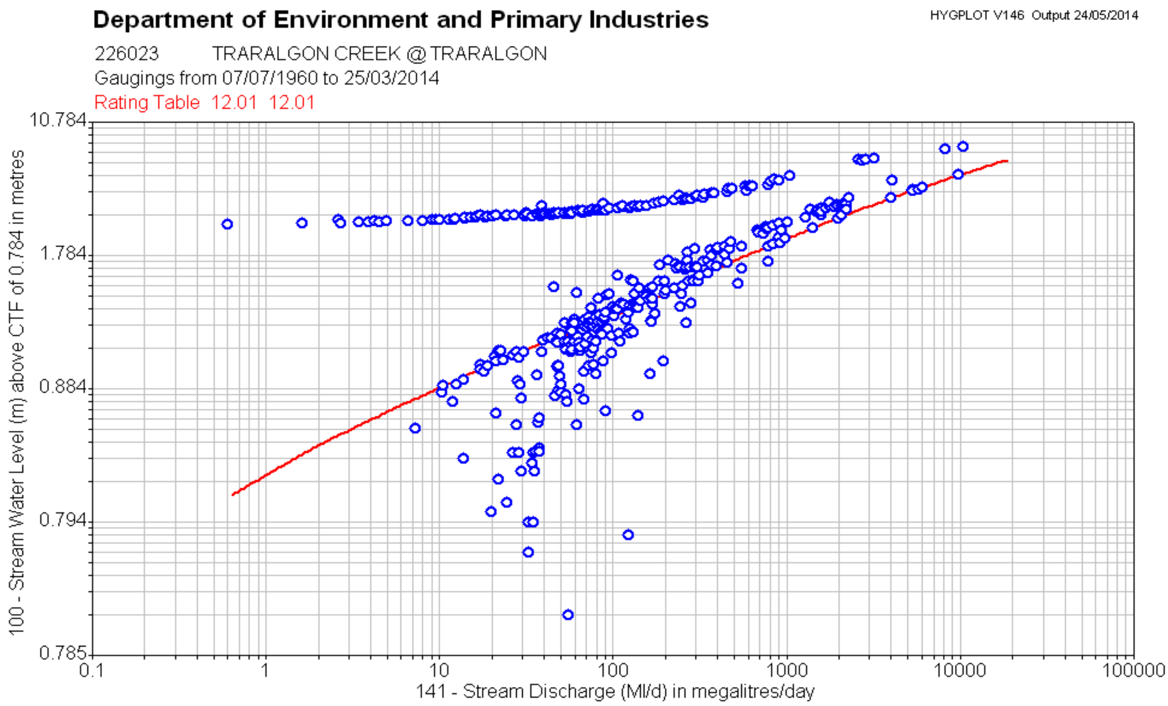

Figure 3-2 **Rating Curve for 226023 Traralgon Creek @ Traralgon**

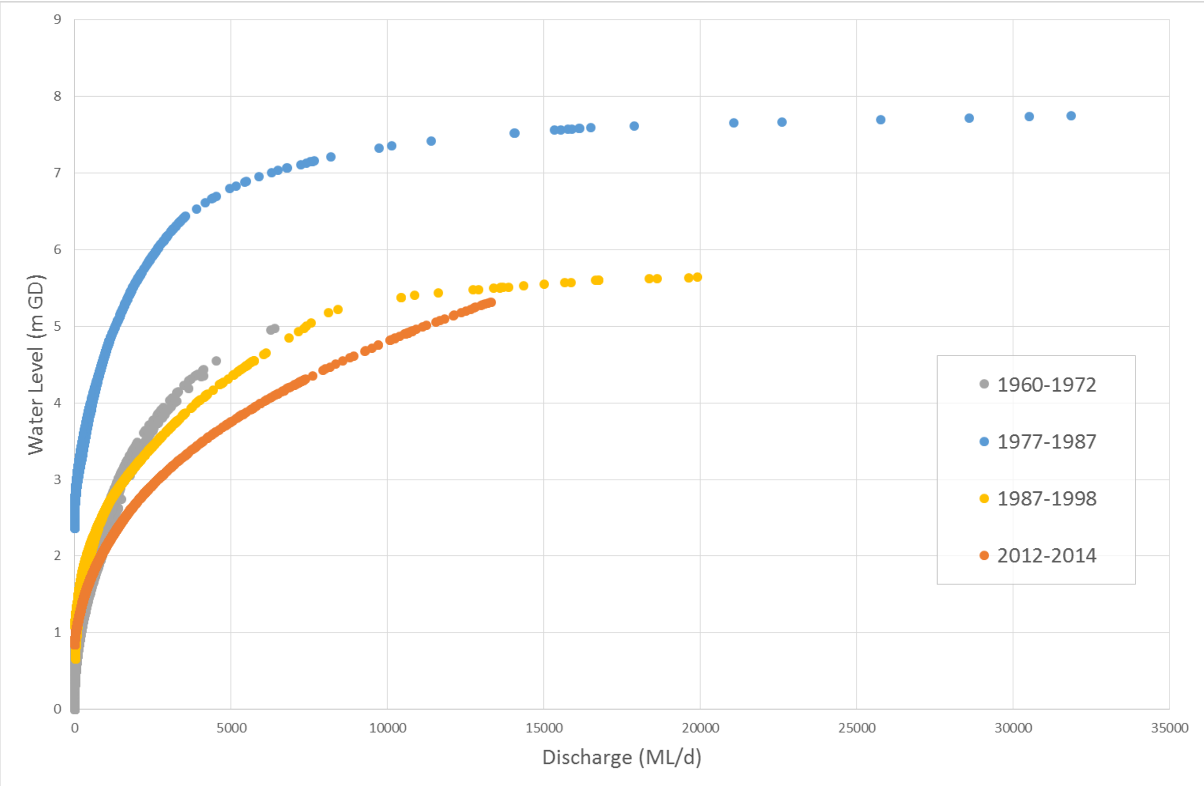

Figure 3-3 **Water Level vs. Discharge Plot for Traralgon gauge (226023) showing variation in rating curves across period of record**

3.3.2 Traralgon Creek at Traralgon South (226415)

The Traralgon Creek at Traralgon South Gauge (226415) has been operating since June 1974, however it is considered unreliable due to a lack of gauge readings at high flows. Daily readings were recorded from 1974 through to December 1986, at which time the gauge was decommissioned. It was re-established in July 1997 after it was upgraded to be telemetered. At this point it was reporting gauge heights in AHD, until August 1998 where the gauge readings reverted to a gauge datum. The latest rating table was established during the June 2012 flood event and is officially considered reliable up to flows of 2,940 ML/d, corresponding to a gauge height of 3.8 m. The unreliable section of the rating table continues to 4,150 ML/d at a gauge height of 4.0 m. This study assessed a large range of events but is primarily concerned with the larger flood events, well beyond the reliable section of this rating curve. The Traralgon South gauge was used to guide timing and shape of the hydrograph only as in large events the flow estimate at this gauge has considerable uncertainty. The rating curve and gauge readings are shown in Figure 3-4. Notably, only one gauging is situated on the rating curve (presumably associated with the levels being in AHD), so it is difficult to assess the current rating curve with respect to the gauge recordings.

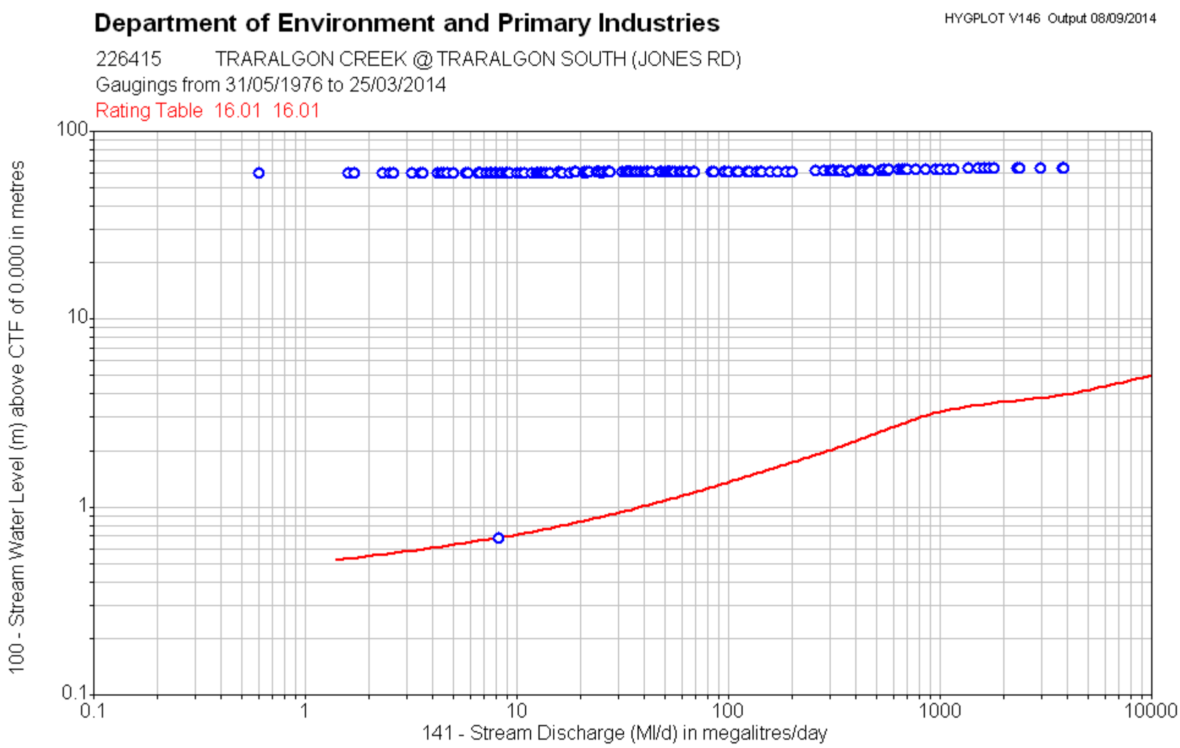

Figure 3-4 Rating Curve for 226415 Traralgon Creek @ Traralgon South

3.3.3 Traralgon Creek at Koornalla (226410)

The Traralgon Creek gauge at Koornalla (226410) was established in July 1953 and has continuous gauge records to date. From 1953 to 1961 daily staff readings were taken, at which point it became telemetered. From February 1974 to October 1992 the gauge heights were recorded in AHD, accounting for the band of gauge recordings much higher than the current rating curve.

The latest rating table was established in May 2012, just prior to the June flood event and is officially considered reliable for flows up to just 2,420 ML/d, corresponding to a gauge height of 2.1 m. The unreliable section of the rating table continues to 14,170 ML/d at a gauge height of 4.19 m. Whilst this is officially unreliable for flows of the magnitudes of the calibration events, the rating curve and corresponding gauge recordings (Figure 3-5) show a reasonable correlation, but it must be emphasised that there is significant uncertainty in higher flow estimates. This gauge was used for calibration of the hydrological model noting the uncertainty, along with the Traralgon gauge.

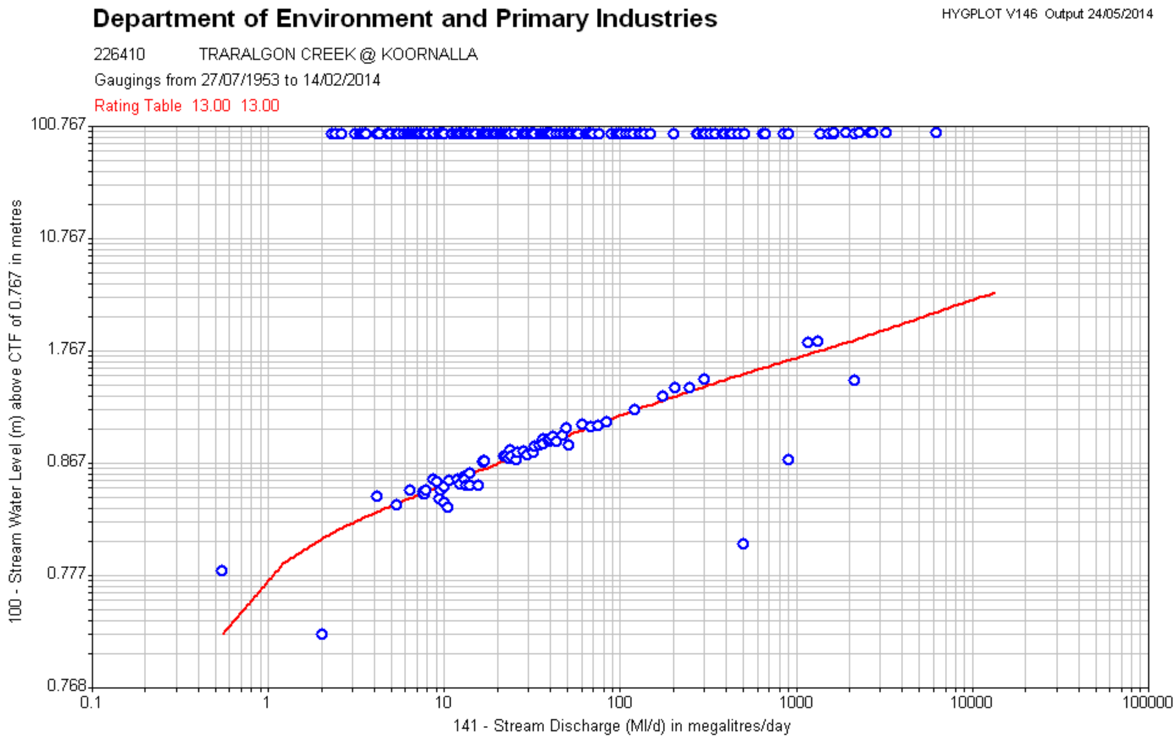

Figure 3-5 Rating Curve for 226410 Traralgon Creek @ Koornalla

3.4 Flood Frequency Analysis

3.4.1 Overview

Flood frequency analysis (FFA) allows the estimation of peak flows of selected Annual Exceedance Probability (AEP) events based on a statistical analysis. FFA was undertaken for Traralgon Creek at the Traralgon gauge (226023) in order to provide peak flow estimates at Traralgon for verification/adjustment of the RORB hydrologic model results.

The FFA was undertaken on the annual flow series from the gauge records using the recommended analysis program FLIKE. FLIKE uses a Bayesian approach to parameter fitting (either the Global Probabilistic or Quasi-Newton fitting algorithms) to the records in order to assess the return period of different magnitude flows. There are a number of probability distributions which can be used to undertake an FFA, including the Log Pearson III, Log-Normal, Generalised Pareto, Generalised Extreme Value and Gumbel distributions and a selection of these are applied in the analysis, with the 'best fit' distribution adopted in the final assessment.

The flow series analysis assumed that the flow year was aligned with the calendar year which is appropriate given the typically wet winter and dry summer climate of the region.

3.4.2 Traralgon Creek at Traralgon

Annual maximum flows were extracted from the gauge record for Traralgon Creek at Traralgon gauge (226023) and are listed in Table 3-2. A variety of sources were used to supplement the data missing from the DELWP dataset, and to resolve any inconsistencies as described in Section 3.3, in particular the 1978 flow estimate. Unless specified, peak flow is sourced from DELWP's Water Measurement Information System website.

Table 3-2 Summary of annual peak flows for Traralgon Creek at Traralgon (226023)

Year	Max Flow (ML/d)	Year	Max Flow (ML/d)	Year	Max Flow (ML/d)	Year	Max Flow (ML/d)
1961	1,050*	1975	2,000*	1989	5,740	2003	720+
1962	2,060*	1976	3,020*	1990	3,210	2004	740+
1963	1,440*	1977	2,760*	1991	2,760	2005	2,840+
1964	2,080*	1978	14,300**	1992	1,590	2006	390+
1965	760*	1979	570**	1993	17,000++	2007	10,200+
1966	1,810*	1980	3,880**	1994	2,810	2008	830+
1967	550*	1981	2,270***	1995	16,745	2009	3,370+
1968	4,080*	1982	410**	1996	1,710	2010	1,860+
1969	6,390	1983	3,510***	1997	460	2011	8,530+
1970	4,110	1984	3,160**	1998	1,120+	2012	13,310
1971	2,800	1985	2,630**	1999	320+	2013	7,340
1972	910*	1986	1,040**	2000	890+	2014	900
1973	1,680*	1987	650	2001	4,200+		
1974	2,290*	1988	3,270	2002	2,820+		

**Adopted from 1979 Flood Study (SRWSC 1979)* ***Adopted from Blue Book (RWC 1987)*
****Adopted from HydroTechnology Report on 1993 Floods (HT 1995)* *+Estimated by applying latest rating table to DEPI Gauge Heights*
++Revised as a result of hydraulic model calibration

Historic floods are known to have occurred in 1934, 1951 and 1952. The magnitude of these events in relation to more recent events is largely unknown and has therefore been excluded for the purposes of this analysis.

The FFA was undertaken with the annual peak flows using the Log Pearson III, Log-Normal, Generalised Pareto and Gumbel distributions. The Grubbs Beck flow filtering found there to be no low flow outliers. The Log-Normal distribution was found to have the best fit, as shown in Figure 3-6, producing narrower 90% confidence limits than the other distributions. The FFA resulted in a 1% AEP flow estimate of 21,900 ML/d with 5-95% confidence limits of 14,800 to 35,400 ML/d, as summarised in Table 3-3.

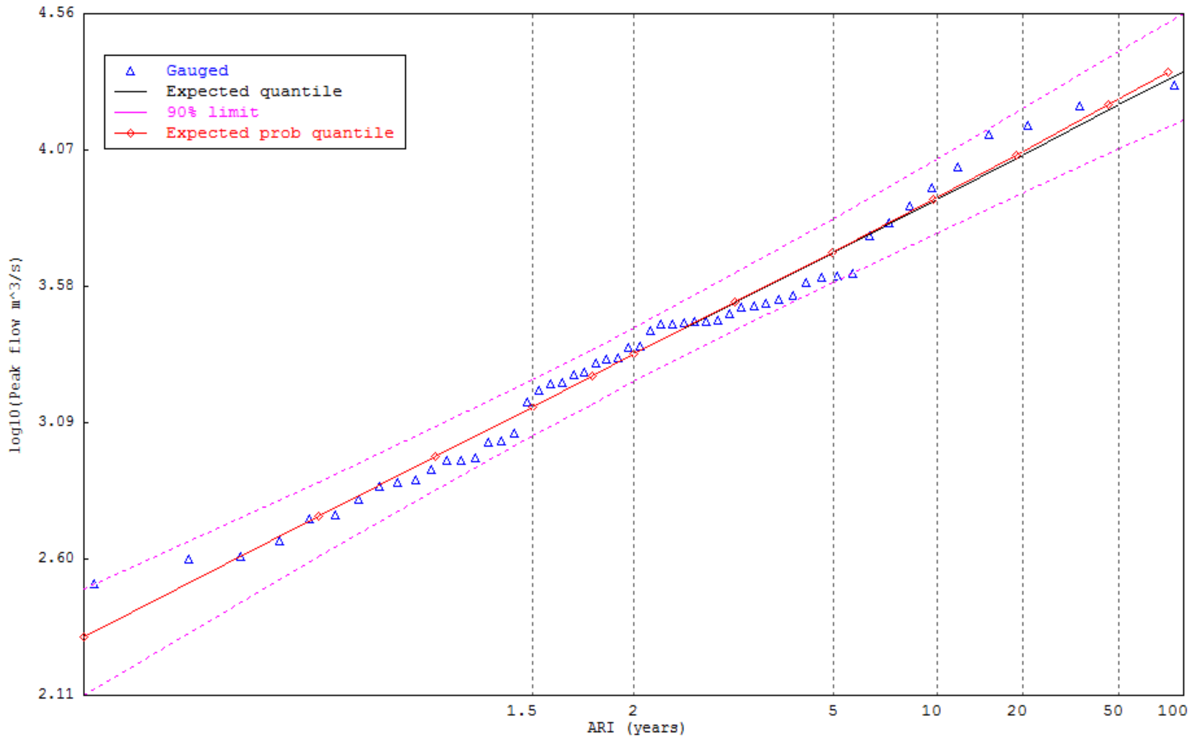

Figure 3-6 Log Normal distribution fitted to annual series for Traralgon Creek at Traralgon

Table 3-3 FFA Peak Flow Estimates for Traralgon Creek at Traralgon (226023)

AEP/Event	Peak Flow Estimate (m^3/s)		Peak Flow Estimate (ML/d)	
	Log Normal (1983 – 2014)	5-95% Confidence Limits	Log Normal (1983 – 2014)	5-95% Confidence Limits
2013	*85*		*7,340*	
10%	89	(67 - 124)	7,700	(5,800 – 10,700)
2011	*99*		*8,530*	
2007	*118*		*10,200*	
5%	128	(93 - 187)	11,100	(8,100 – 16,100)
2012	*154*		*13,310*	
1978	*166*		*14,300*	
2%	193	(135 - 299)	16,700	(11,600 – 25,800)
1995	*194*		*16,745*	
1993	*197*		*17,000*	
1%	253	(171 - 409)	21,900	(14,800 – 35,400)
0.5%	325	(213 - 546)	28,100	(18,400 – 47,200)

3.4.3 Comparison to Regional and Previous Estimates

Estimates of peak flows using the Australian Regional Flood Frequency (ARFF) method and from previous studies by SKM (2000), and State Rivers and Water Supply Commission (1979) are shown in Table 3-4.

The SKM (2000) estimates align closely to that of the current FFA, while the SRWSC (1979) estimates are slightly lower (as they do not include the 1993 or 1995 floods). The ARFF peak flow estimates at the low end of the design curve are similar to the SRWSC (1979) estimates. The ARFF estimates are much lower than all other flow estimates at the higher end of the design curve.

The current FFA is broadly consistent with previous work, however it provides more credible estimates than the previous analyses, as it includes more gauged data including recent large flood events and uses current best practice FFA techniques as recommended in the revised Australian Rainfall and Runoff guidelines.

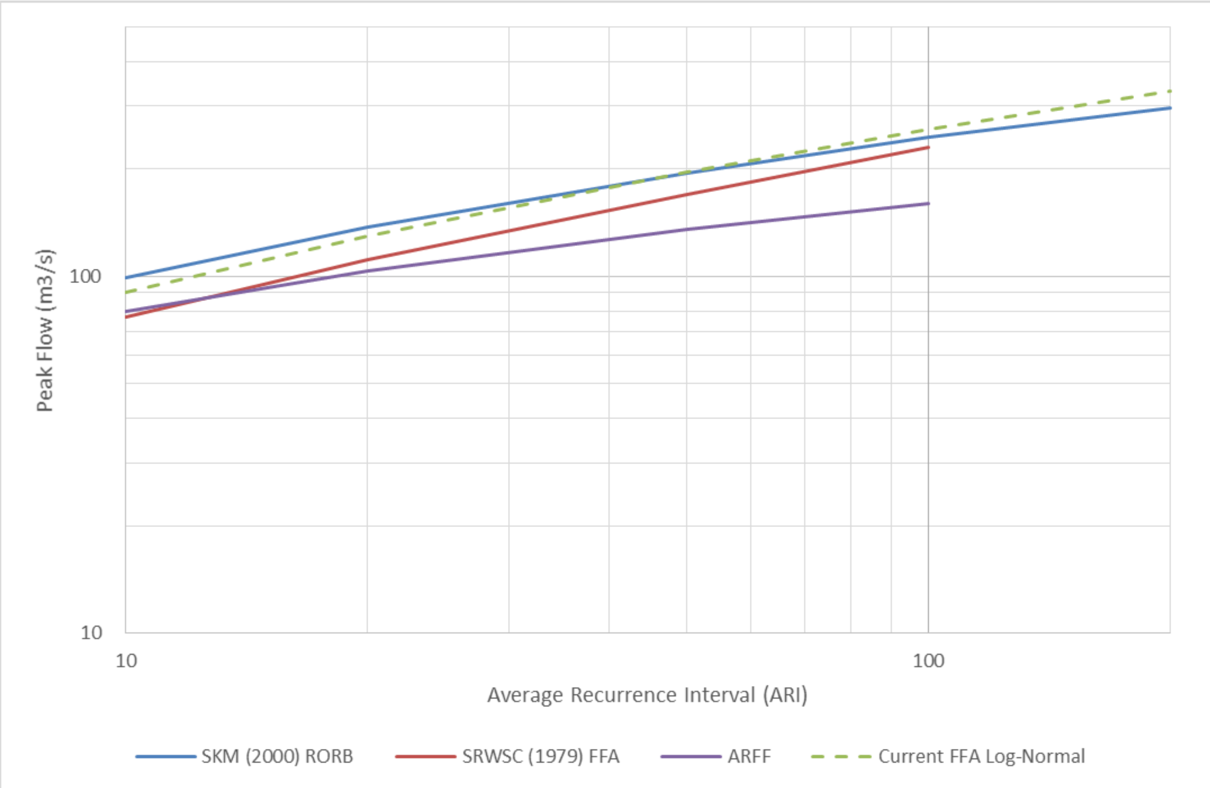

Figure 3-7 Comparison of Peak Flow Estimate Methods

Table 3-4 ARFF Flow Estimates and previous Flood Frequency Estimates for Traralgon gauge

AEP	Peak Design Flow (ML/d) ARFF	Peak Design Flow (ML/d) (SKM, 2000)	Peak Design Flow (ML/d) (SRWSC, 1979)
10%	6,880	8,550	6,650
5%	8,940	11,840	9,590
2%	11,730	16,850	14,690
1%	13,850	21,170	19,870
0.2%	-	25,660	-

3.5 Hydrological Modelling

3.5.1 Overview

A hydrological model of the catchment was developed for the purpose of extracting design flows to be used as boundary conditions in the Traralgon hydraulic model. The rainfall-runoff program, RORB (Version 6) was used for this study.

RORB is a non-linear rainfall runoff and streamflow routing model which is used for calculation of flow hydrographs in drainage and stream networks. The model requires catchments to be divided into subareas, connected by a series of conceptual reach storages. Design storm rainfall is input to the centroid of each subarea. Specified losses are then deducted, and the excess routed through the reach network.

There are three streamflow gauges within the catchment which were used to calibrate the RORB model. The Traralgon Creek gauge at Traralgon (226023) has 54 years' flow record from 1961-2014, covering the 1993, 2012 and 2013 flood and other smaller floods. As noted in Section 3.3.1 the gauge has had a series of changes to datum, cross sectional geometry and location, which has led to inconsistencies in the rating curves used over the period. The Traralgon Creek gauge at Koornalla (226410) has a similar record period, and a reliable rating curve for recent events (since 1998). The Traralgon Creek at Traralgon South (226415) gauge has a shorter record and a lack of gauge recordings at high flows, therefore the rating curve is officially considered unreliable for medium to large flood events. Parameter selection was based on calibration to the Koornalla and Traralgon gauges and comparison to accepted regional methods, and the design flows were validated against the flood frequency analysis. The approach for the selection of routing and loss parameters is outlined in the following sections.

3.5.2 RORB Model Development

The ArcHydro tool was used to determine the initial delineation of catchments, sub-catchments and drainage paths of Traralgon Creek for input to the hydrologic model (Figure 3-8). The catchment was split into 87 sub-catchments with areas ranging from 0.1 to 13.6 km^2. A RORB model was then constructed of the catchment using miRORB (MapInfo RORB tools).

The RORB model was at a resolution adequate to resolve the main drainage paths and sub-catchments, and to provide smooth hydrographs for the hydraulic model. If there is less than 3 subareas upstream of a hydrograph extraction location, RORB may produce peaky hydrographs due to a lack of appropriate catchment routing. Downstream of the Traralgon South gauge the delineation of sub-catchments was at a finer resolution to better represent the local catchments closer in the urban areas of Traralgon. Interstation areas were used to separate the RORB model parameters upstream of the Traralgon South and Koornalla gauges as the upper catchment is very steep compared to the lower catchment on the floodplain.

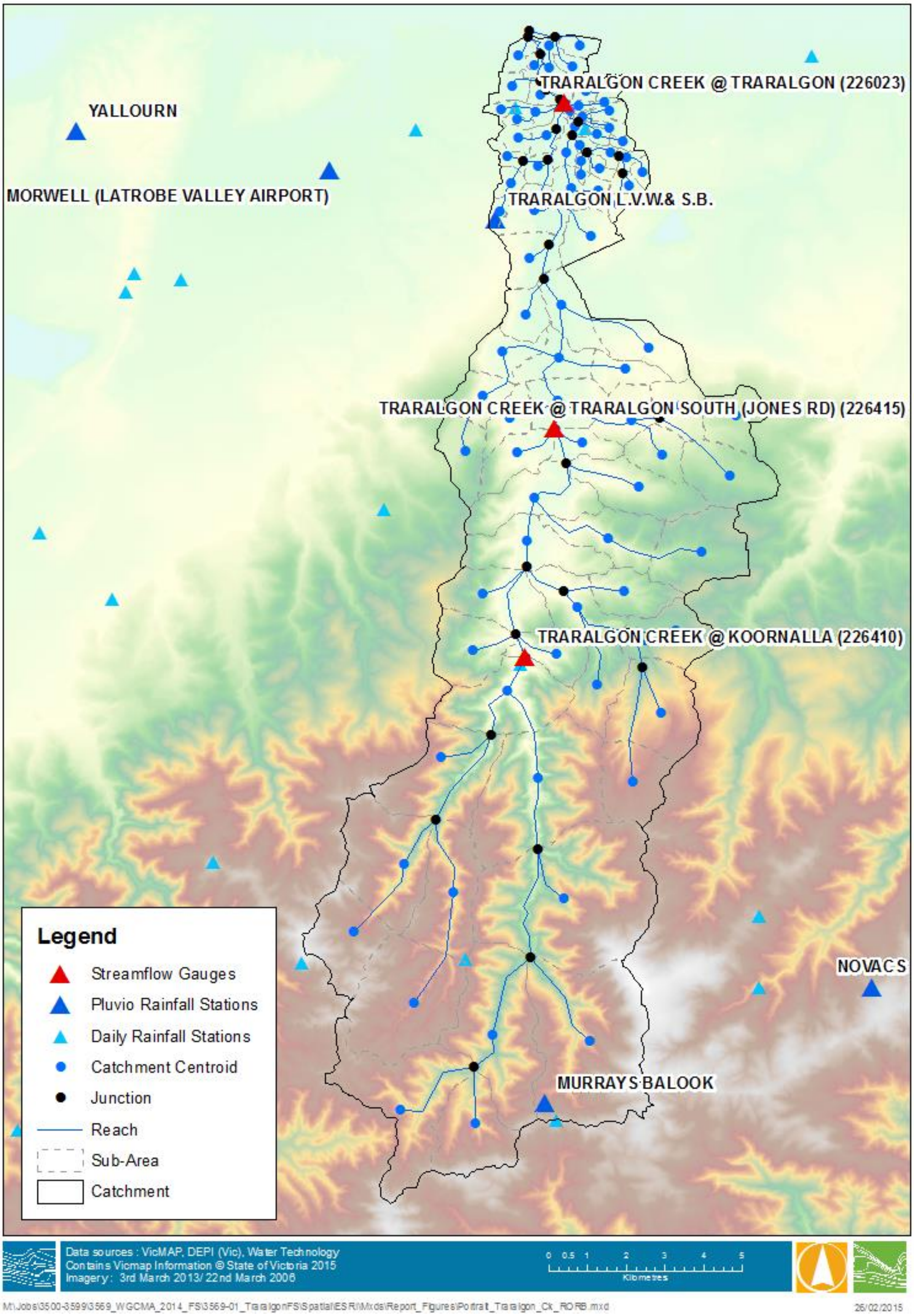

Figure 3-8 RORB model structure

3.5.3 Fraction Impervious

The fraction impervious (FI) was included in the hydrologic model by applying a representative FI for each planning zone, as listed in Table 3-5. The planning zones used for designation of FIs are shown in Figure 3-9. The values chosen to represent each planning zone were adopted from Melbourne Water's MUSIC guidelines (2010).

Table 3-5 Fraction Impervious Designation for Planning Zones

Zone Code	Zone Description	Fraction Impervious (FI)
C1Z – C2Z	Commercial (1 – 2) Zone	0.9
FZ	Farming Zone	0.1
FZ	Farming Zone - Forestry*	0.1
IN1Z – IN3Z	Industrial (1 – 3) Zone	0.9
LDRZ	Low Density Residential Zone	0.2
MUZ	Mixed Use Zone	0.7
PCRZ	Public Conservation and Resource Zone	0
PPRZ	Public Park and Recreation Zone	0.1
PUZ1	Public Use Zone - Service and Utility	0.05
PUZ2	Public Use Zone - Education	0.7
PUZ3	Public Use Zone - Health and Community	0.7
PUZ4	Public Use Zone - Transport	0.7
PUZ6	Public Use Zone - Local Government	0.7
GRZ1	General Residential Zone 1	0.45
NRZ1	Neighbourhood Residential Zone	0.45
RGZ1	Residential Growth Zone 1	0.45
RGZ2	Residential Growth Zone 2	0.6
RDZ1	Road Zone - Category 1	0.7
RDZ2	Road Zone - Category 2	0.6
RLZ2, RLZ3, RLZ4, RLZ6	Rural Living Zone	0.2
SUZ1	Special Use Zone 1	0.6
TZ	Township Zone	0.55
UFZ	Urban Flood Zone	0

**Farming Zone was split into farming and forestry areas to allow sensitivity to imperviousness caused by bushfire to be tested.*

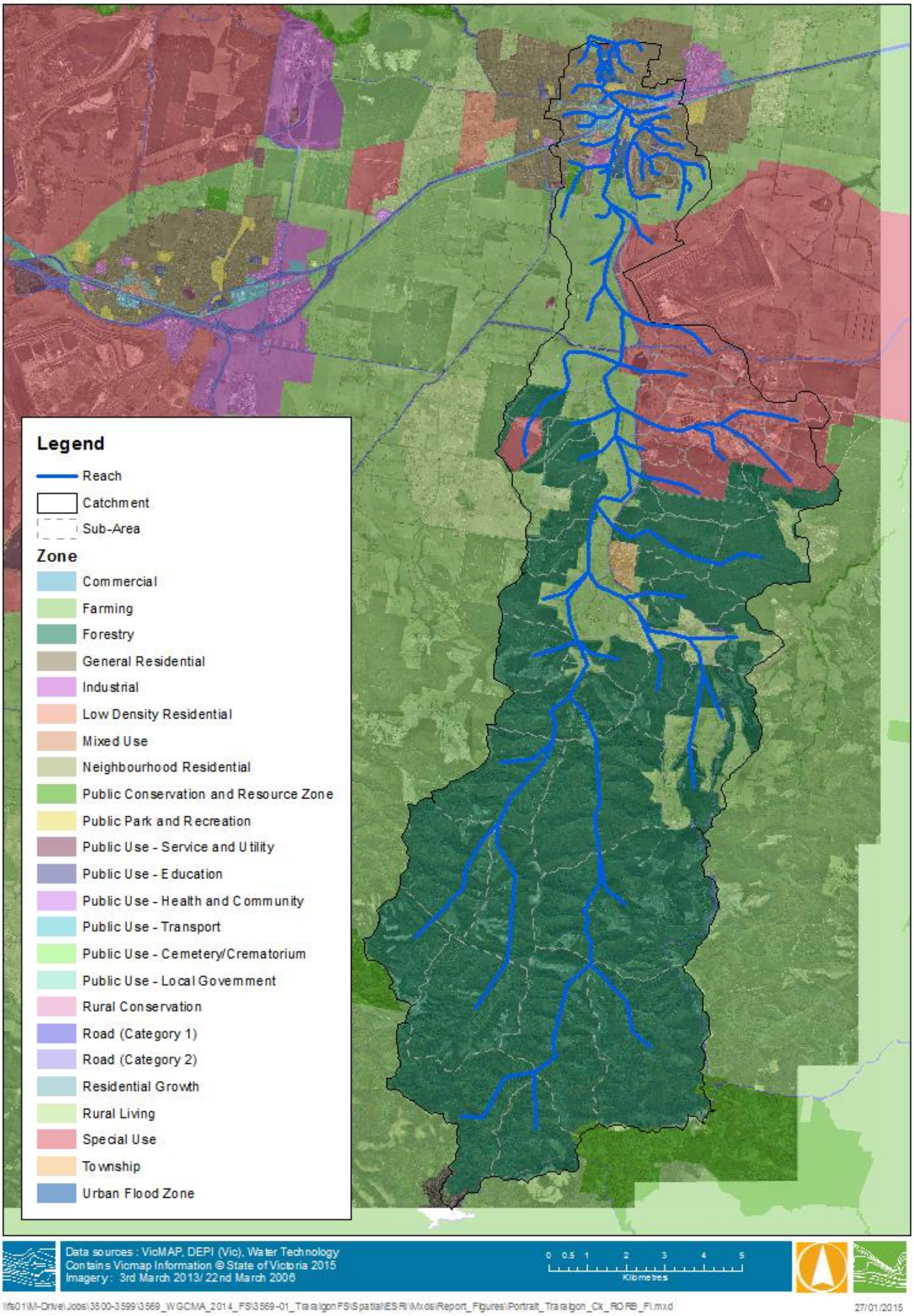

Figure 3-9 Planning Overlay used for Fraction Impervious

3.5.4 Calibration Events

Three recorded events were used for the calibration of the RORB hydrologic model; namely the September 1993, June 2012, and June 2013 floods. Each of these events was represented with a unique temporal and spatial rainfall pattern generated from local rainfall gauge records. The outflow hydrographs from the RORB model were then compared to stream gauges at two locations; Traralgon, and Koornalla.

Figure 3-10 to Figure 3-12 shows the spatial rainfall pattern across the catchment for the three calibration events, with Figure 3-13 to Figure 3-15 showing the temporal patterns for the available rainfall pluviographs.

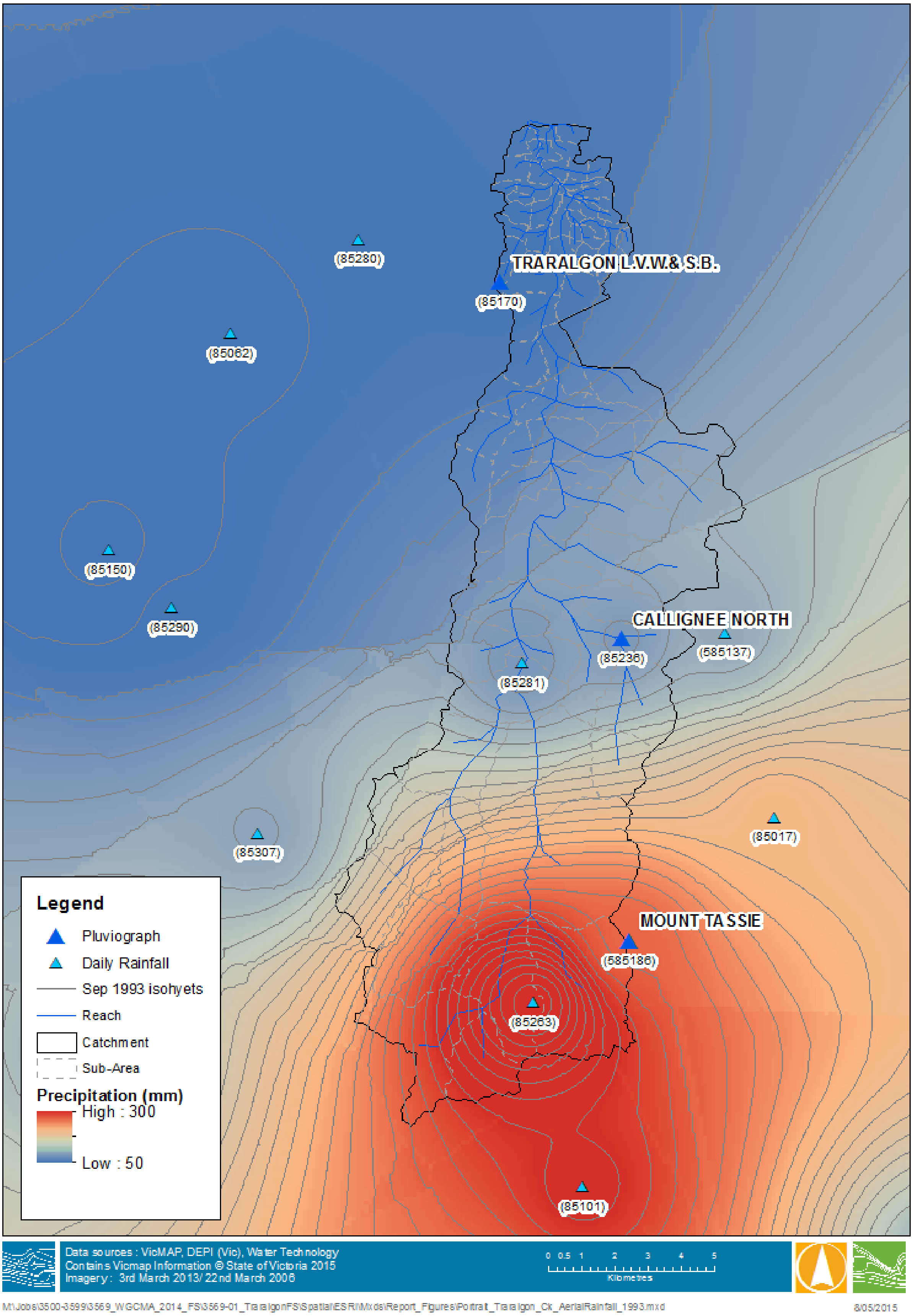

Figure 3-10 Total rainfall across the catchment for the September 1993 calibration event

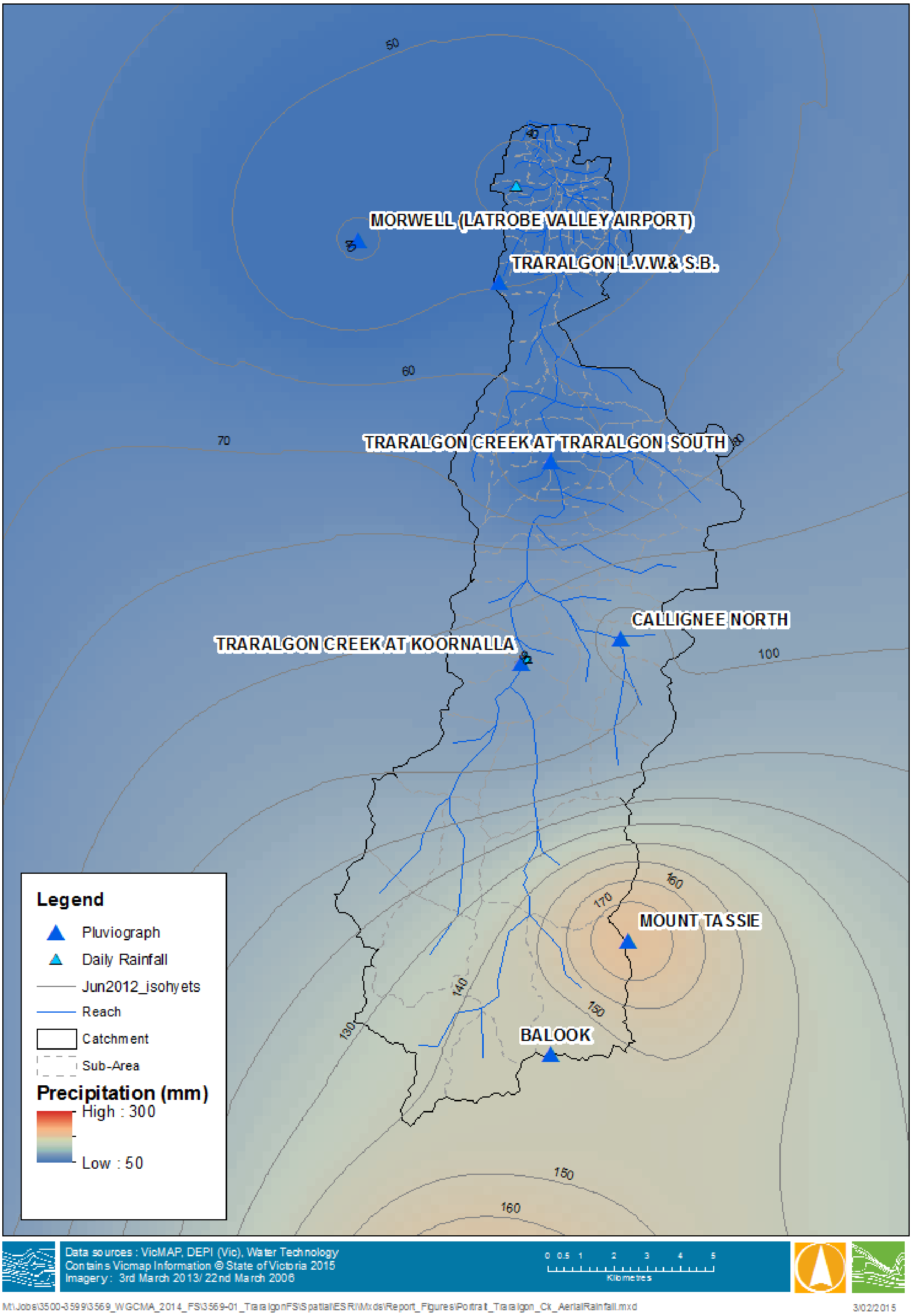

Figure 3-11 Total rainfall across the catchment for the June 2012 calibration event

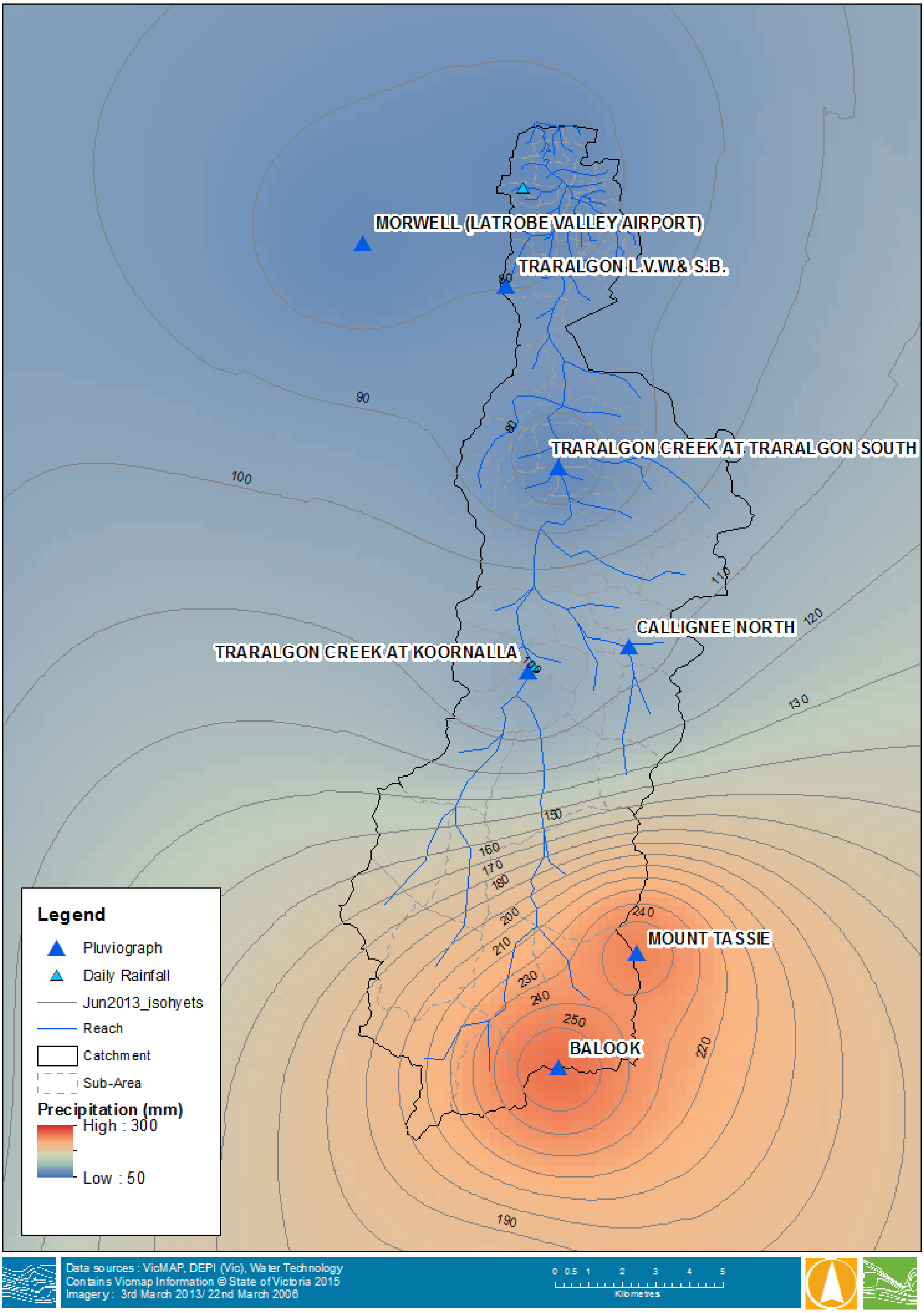

Figure 3-12 Total rainfall across the catchment for the June 2013 calibration event

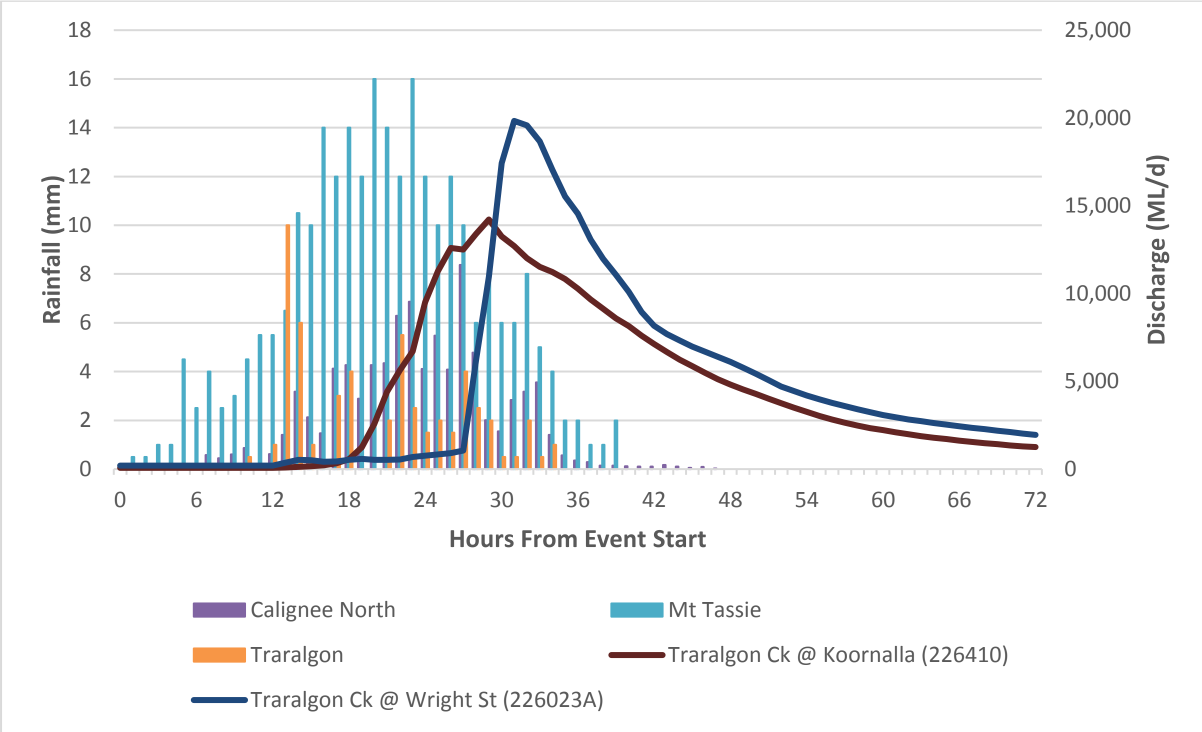

Figure 3-13 Calibration event hyetographs and instantaneous flow hydrographs for the September 1993 calibration event

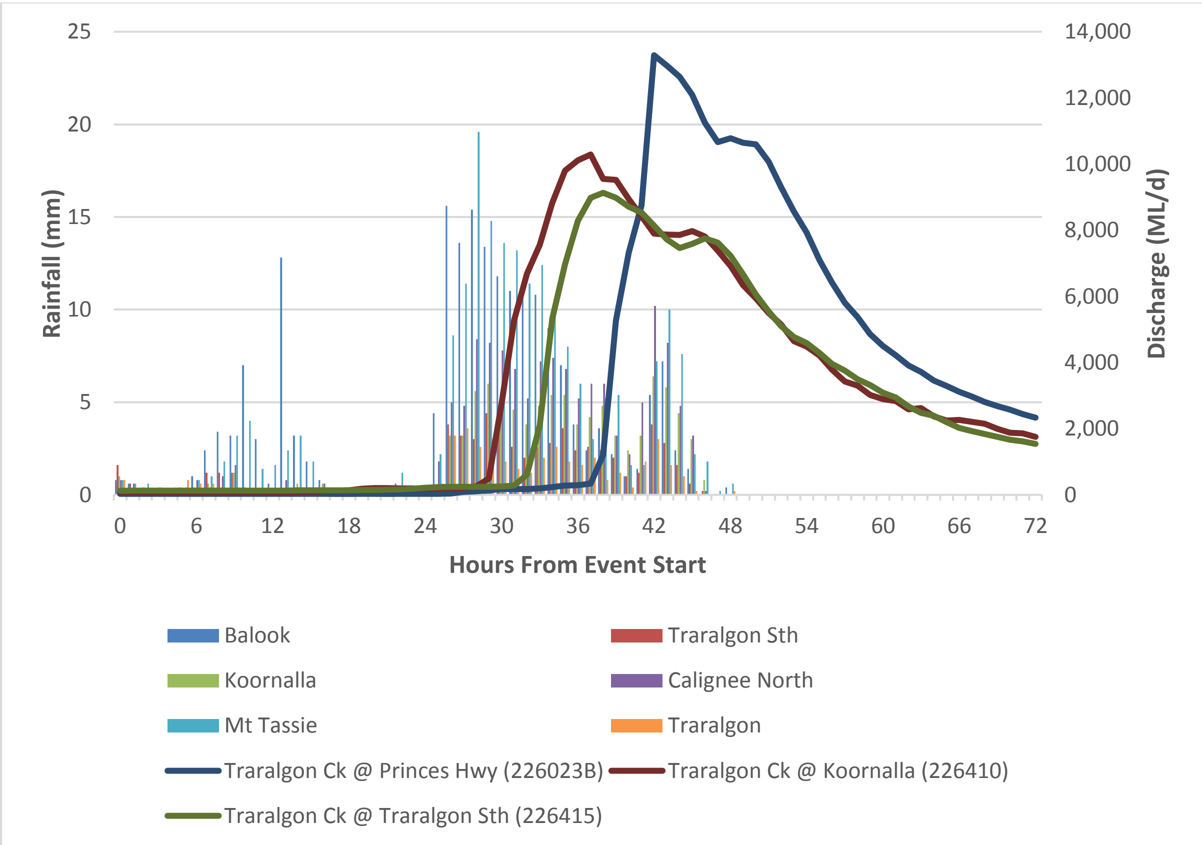

Figure 3-14 Calibration event hyetographs and instantaneous flow hydrographs for the June 2012 calibration event

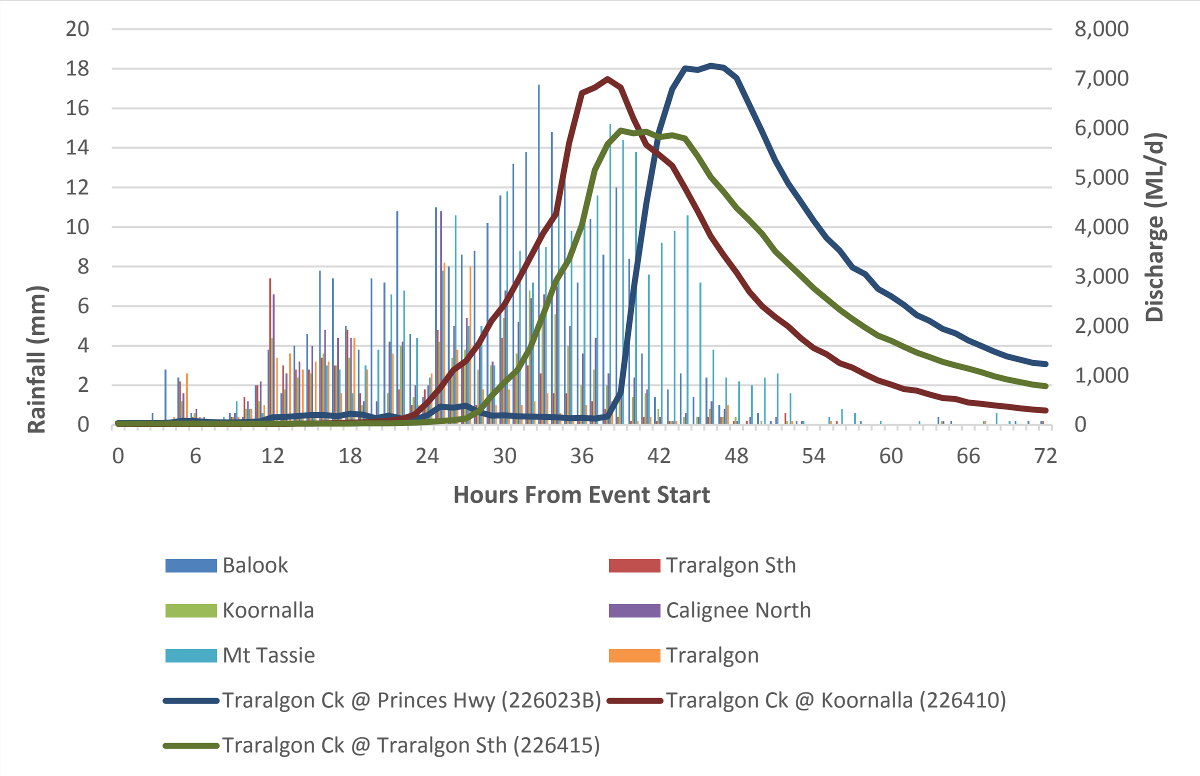

Figure 3-15 Calibration event hyetographs and instantaneous flow hydrographs for the June 2013 calibration event

3.5.5 Calibration of RORB Parameters

The RORB model was run using the initial loss/continuing loss model. The RORB storage and loss parameters k_c, m, initial loss (IL) and continuing loss (CL) were fitted for each calibration event to give the best fit to the observed hydrographs. The routing parameter k_c was set using a combination of calibration and regional equations. The exponent m was set to 0.8 as per RORB default, with no justification for varying the m parameter.

A number of regional equations for the calculation of k_c are recommended in ARR87 and the RORB manual, these were used to guide the initial selection of this parameter (Table 3-6).

Table 3-6 Regional equations for the calculation of k_c

Source	Koornalla	Traralgon Sth	Traralgon
Aust wide Yu (1989) (Pearse et al 2002)	7.8	6.1	7.4
Vic MAR>800 mm - Eq 3.21 ARR87 (Book V)	18.9	14.6	13.7
Vic MAR<800 mm - Eq 3.22 ARR87 (Book V)	8.7	6.0	5.5
Aust wide Dyer (1994) (Pearse et al 2002)	9.3	7.2	8.8
Victoria data (Pearse et al, 2002)	10.2	7.9	9.7
Default RORB	20.2	15.1	14.1

The final calibrated model parameters for each event are summarised in Table 3-7. The fit of the RORB modelled hydrographs to the gauged hydrographs at the Koornalla, Traralgon South and Traralgon gauges for each calibration is shown in Figure 3-16, Figure 3-17, and Figure 3-18.

Table 3-7 RORB Calibration Parameters

Event	k_c	m	IL (mm)	CL (mm/hr)
Koornalla (226410)				
1993	15.0	0.8	40	4.5
2012	13.0	0.8	5	3.0
2013	11.0	0.8	10	5.2
Traralgon South (226415)				
1993	8.0	0.8	30	2.0
2012	8.0	0.8	20	3.0
2013	8.0	0.8	60	4.0
Traralgon (226023)				
1993	10.0	0.8	30	2.0
2012	11.0	0.8	20	3.0
2013	10.0	0.8	80	3.0

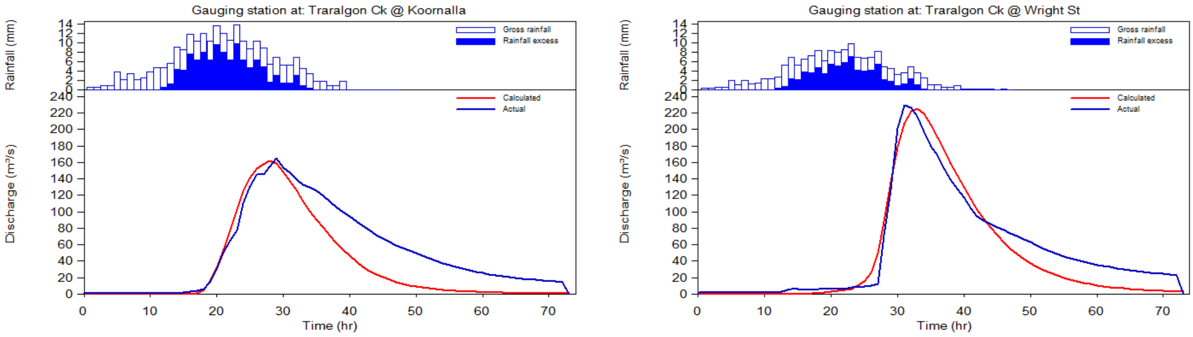

Figure 3-16 Calibration plots for September 1993

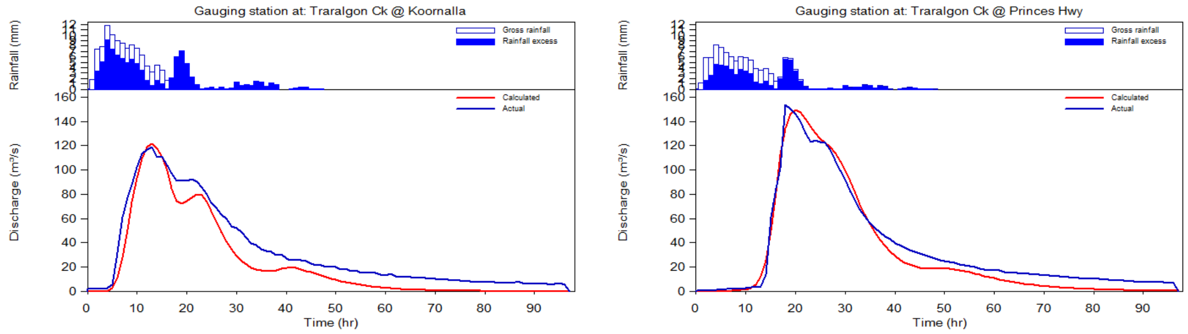

Figure 3-17 Calibration plots for June 2012

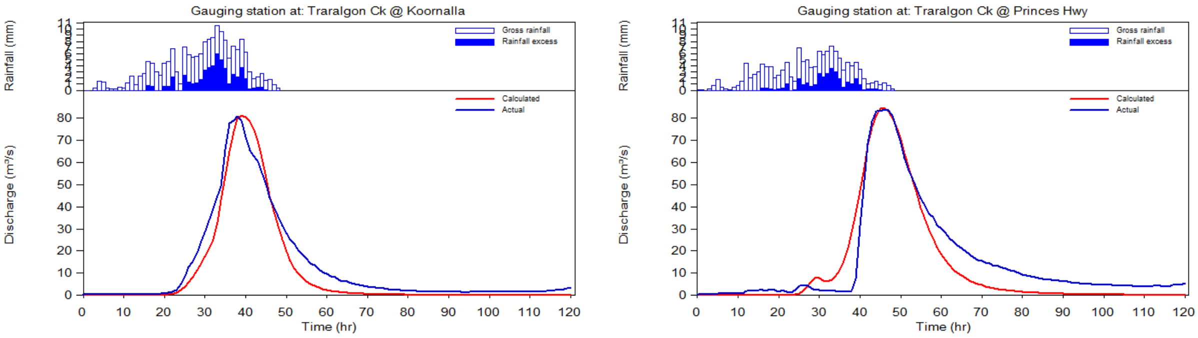

Figure 3-18 Calibration plots for June 2013

The shape, peak and timing of the fitted hydrographs at Koornalla agrees well with gauged data. The rising limb and the height and timing of the peak are well matched in all three events, however the volume in the falling limb is slightly underestimated, particularly in 1993. The shape, volume and peak at Traralgon was also very well matched, with the falling limb matching slightly better than at Koornalla. The rising limb at Traralgon for 2013 was slightly early in this smaller flood event, which is one reason why such high initial loss has been applied to the downstream interstation area.

The K_c values applied for each of the interstation areas are similar to those used in the previous SKM flood study (SKM, 2000), which used 12, 8 and 10 for Koornalla, Traralgon South and Traralgon respectively. Compared to the regional equations in Table 3-6, the K_c values are well within the range, and were very similar to the K_c regional equation of Pearse et al (2002). The initial losses tend to be higher than expected design values, however the continuing losses tend to reasonable.

3.5.6 Design Rainfall Estimates

Design rainfalls were calculated for the 10%, 5%, 2%, 1% and 0.5% AEP events using the Intensity-Frequency-Duration analysis from AR&R (1987). The IFD parameters were obtained from the Bureau of Meteorology's IFD program website (www.bom.gov.au/water/designRainfalls/ifd) for the catchment centroid (Table 3-8).

Table 3-8 IFD parameters

2yr (50% AEP) 1hr rainfall intensity (mm/hr)	18.06
2yr (50% AEP) 12hr rainfall intensity (mm/hr)	4.10
2yr (50% AEP) 72hr rainfall intensity (mm/hr)	1.30
50yr (2% AEP) 1hr rainfall intensity (mm/hr)	41.18
50yr (2% AEP) 12hr rainfall intensity (mm/hr)	7.45
50yr (2% AEP) 72hr rainfall intensity (mm/hr)	2.44
Skew	0.37
F2	4.23
F50	15.15

Comparisons were made with the new IFDs developed for Project 1 of the Australian Rainfall and Runoff Revision Project (Engineers Australia, 2014). On average the new IFD approach had rainfall depths around 3% lower than ARR87 (for 1%-10% AEP events), with some AEP/duration values up to 13% lower. For the 1% AEP event the new IFD rainfall depths were within 1% of the old rainfall estimates for durations from 6 to 18 hours. The 1987 IFD parameters were adopted to be consistent with existing methods for areal reduction factors, design losses and hydrologic parameter estimates, which were developed with the older IFD information. It is believed that the new IFD parameters will be adopted along with other revised design rainfall methods at a later date when Australian Rainfall and Runoff is finalised and officially released and agencies require the updated methodology to be used.

Unfiltered temporal patterns from AR&R (1987) for Zone 1 were applied for the design events, as recommended in Hill et al. (1998) for use with their design losses. Rainfall depths were applied uniformly across the catchment.

Areal reduction factors from Siriwardena and Weinmann (1996) were applied to the point design rainfall estimates. These areal reduction factors are recommended for use in Victoria instead of the original AR&R values (Hill et al. 1998). These have now been recommended for adoption in the ARR Project 2 Stage 2 report (Engineers Australia, 2012).

3.5.7 Design Loss Estimates

Design losses were estimated by the design loss prediction equations developed by Hill et al (1998) and (Hill et al. 2014). The losses recommended in ARR87 consistently overestimated peak flows. The Hill et al (1998) losses, in combination with the new areal reduction factors from Siriwardena and Weinmann (1996), produced peaks that were more consistent with the results of flood frequency analysis.

The initial loss using the earlier Hill et al (1998) method is calculated by first calculating the storm initial loss using Equation 1, then the burst initial loss (Equation 2). The burst initial loss varies with storm duration and accounts for the embedded nature of AR&R design rainfalls (Hill et al 1998). The continuing loss is estimated using Equation 3.

Storm initial loss:

$$IL_s = -25.8BFI + 33.8 \qquad (1)$$

Burst initial loss:

$$IL_b = IL_s \left\{1 - \frac{1}{1+142\frac{\sqrt{duration}}{MAR}}\right\} \qquad (2)$$

Continuing loss:

$$CL = 7.97BFI + 0.00659PET - 6.00 \qquad (3)$$

The ARR Project 6 Stage 3 report (Hill et al. 2014) contains new recommended initial and continuing loss equations, as shown below. No recommendation has been made for the conversion of storm initial loss to burst initial loss.

Storm initial loss:

$$IL_s = 16.7 + 0.141P_{24h}^{2\%} - 0.291MedianAPI \qquad (4)$$

Continuing loss:

$$CL = 3.0\ mm/hr \qquad (5)$$

The values of the input parameters to the previous equations are as follows:

- Median API 34 mm
- BFI 0.34
- PET 1,002 mm
- MAR 970 mm
- $P_{24h}^{2\%}$ 122 mm

The design loss estimates produced by both methods are given in Table 3-9. The design initial losses tend to be lower than those calibrated in RORB, while the continuing losses tend to be similar. The Project 6 losses (Hill et al. 2014) are only slightly smaller than the ARR87 losses (Hill et al. 1996).

Table 3-9 Design loss parameter estimates

Source	IL_s (mm)	IL_b (mm)	CL (mm/hr)
Hill et al (1998)	25	8-14 (for 9-72 hour events)	3.3
Project 6 Stage 3 Report (Hill et al. 2014)	24	-	3

3.5.8 Design Flood Validation

Various k_c and loss values were compared to the FFA at Traralgon (including historical events) to determine the best fit for the design hydrology. The ARR Project 6 Stage 3 Report (Hill et al. 2014) did not find evidence of variation of loss values with AEP, a finding which is consistent with a range of previous studies. Therefore, rather than varying losses to fit the design flows exactly to the FFA, the validation process was aimed at selecting a single set of loss parameters which provided a reasonable fit across the whole range.

Initial loss values ranging from 15 mm to 60 mm were tested with a preference for values closer to the lower end of the calibration results (30 mm) and higher end of the design loss equation estimates (25 mm). The k_c values tested were within the calibration values, with values of 13, 8 and 10 for Koornalla, Traralgon South and Traralgon respectively were found to produce the hydrograph most consistent with measured data. Continuing losses ranged from 2 to 5 mm/hr with a preference to values within the design loss parameter range (3.0 – 3.3 mm/hr). Selected results are shown in Figure 3-19 below.

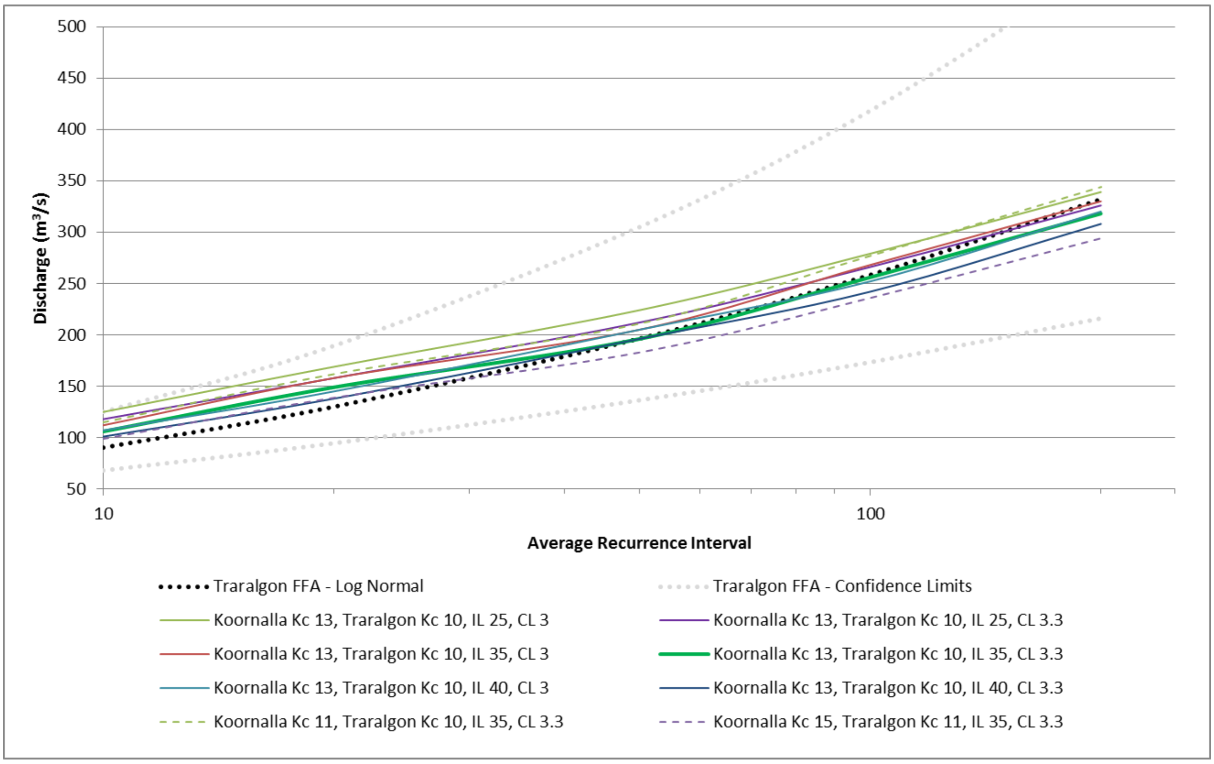

Figure 3-19 RORB peak flow results for various k_c and IL values

3.6 Design Flows and Hydrographs

The routing and loss parameters summarised in Table 3-10 were found to produce a reasonable fit to the FFA while also lying within the range of calibration values and were thus adopted for design event modelling. The resulting hydrographs are shown in Figure 3-19. Note that for this project the RORB model design event flows were given similar confidence with the flood frequency analysis due to the issues with the gauge data and rating curve. Therefore the design flows have adopted the RORB results and have not adjusted the flows to the flood frequency analysis.

The adopted RORB flows for the 10% and 5% AEP are 15-18% higher than those from the FFA, with the 2%, 1% and 0.5% RORB flows being 0-4% lower than the FFA flows. The 36 and 48hour durations resulted in very similar design hydrographs at Traralgon, with peak flows almost identical.

The September 1993 event recorded a peak flow of 19,900 ML/d at Traralgon, which lies between a 2% and a 1% AEP event. Hydraulic modelling of the 1993 calibration event using this flow rate found the modelled flood levels to be uniformly low across the model. The peak inflow into Traralgon Creek was revised to a conservative estimate of 17,000 ML/d given the uncertainty of the gauged flow. Once adopted, modelled flood levels throughout the city matched considerably closer than previously when using a peak flow of 19,900ML/d. The June 2012 event recorded a peak flow of 13,310 ML/d at Traralgon, which lies between a 5% and a 2% AEP event. And the June 2013 event recorded a peak flow of 7,340 ML/d at Traralgon, which lies between a 20% and a 10% AEP event.

Table 3-10 Recommended design parameters

k_c			m	IL (mm)	CL (mm/hr)
Koornalla	Traralgon South	Traralgon			
13	8	10	0.8	35	3.4

Table 3-11 Recommended design peak flows for Traralgon Creek at Traralgon (226023)

AEP	RORB Design Flow (m^3/s)	FFA Design Flow (m^3/s)	RORB Design Flow (ML/d)	FFA Design Flow (ML/d)
10%	104	89	9,000	7,700
5%	144	128	12,400	11,100
2%	193	193	16,700	16,700
1%	252	253	21,800	21,900
0.5%	314	325	27,200	28,100

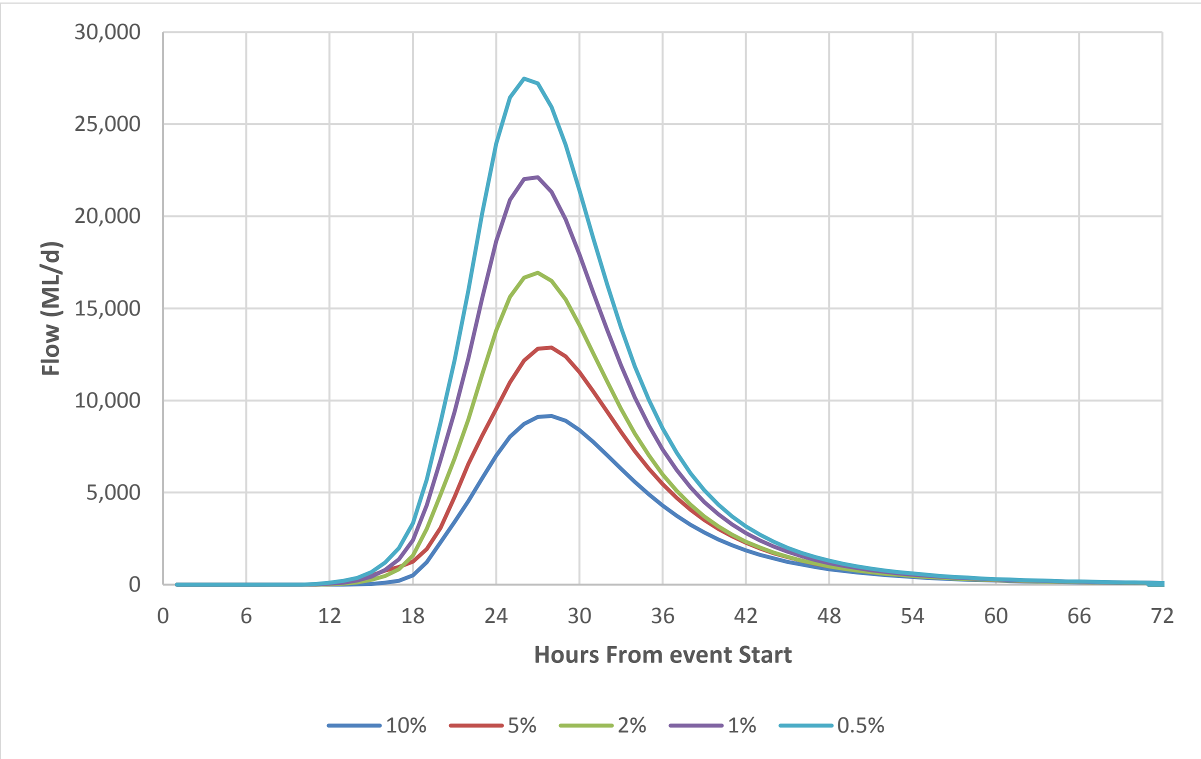

Figure 3-20 Traralgon Creek at Traralgon design flood hydrographs

3.7 Sensitivity Analysis

3.7.1 Climate Change

The impacts of climate change were tested by increasing the rainfall intensity by 5% per degree of warming, in line with latest guidance from Australian Rainfall and Runoff (Engineers Australia 2014). A scenario of 2°C of warming (i.e. 10% increase in rainfall intensity) was adopted for this sensitivity test. This is consistent with 'Climate Change in Australia Projections' (CSIRO, 2015) report which suggest for an intermediate climate scenario, a temperature increase of between 1.1°C to 2.0°C is likely for the Southern Slopes of Australia, which includes the Traralgon Creek catchment.

The 10% increase in rainfall intensity was applied to the burst rainfall depth in the RORB storm files for each of the design events for the critical duration. The results of the climate change sensitivity test are summarised in Table 3-12 and shown in Figure 3-21. The increase in flows from a 10% increase in rainfall intensity are more evident in the more frequent events, with a 28% increase in flow in the 10% AEP design event compared to an 18% increase in flow in the 0.5% AEP design event. The proportional increases in flows are larger than the proportional increases in rainfall intensities due to the rainfall losses assumed in the design parameters.

Table 3-12 Comparison of peak flows for increases in rainfall intensity due to climate change

AEP	Current Conditions		Scenario of 2°C of Warming		Increase in Flow (%)
	Burst Rainfall Depth (mm)	RORB Design Flow (ML/d)	Burst Rainfall Depth (mm)	RORB Design Flow (ML/d)	
10%	98.8	9,000	108.7	11,500	28
5%	115.0	12,400	126.5	15,900	28
2%	137.4	16,700	151.2	20,800	25
1%	155.5	21,800	171.0	26,400	21
0.5%	174.5	27,200	192.0	32,200	18

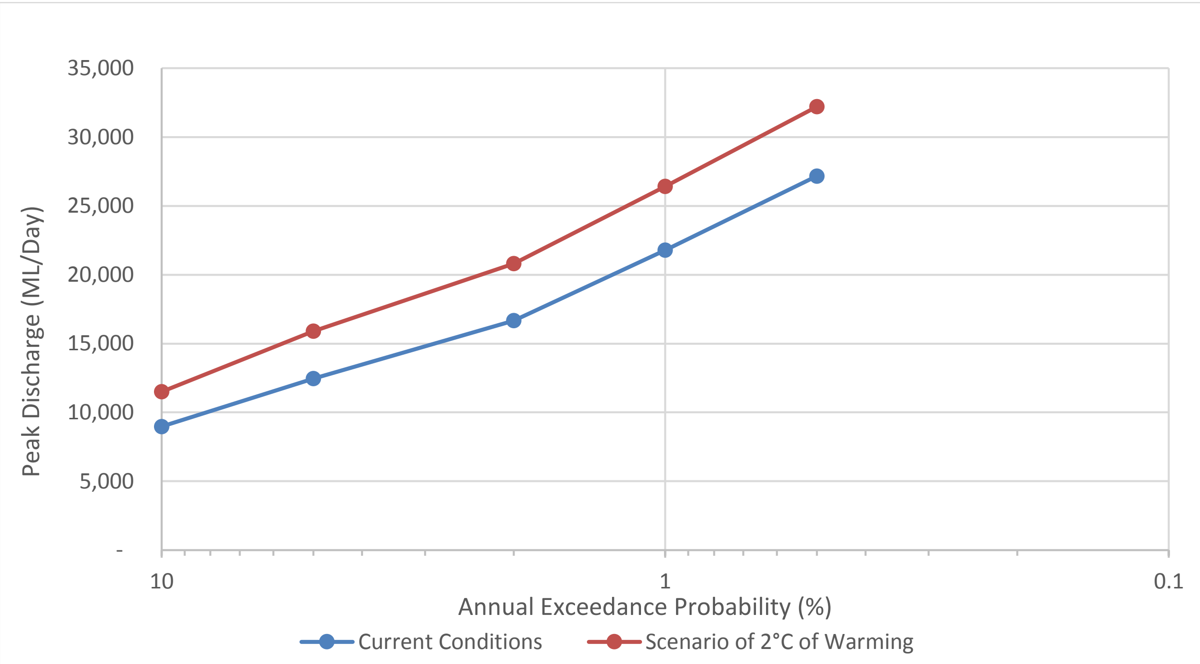

Figure 3-21 Climate change sensitivity comparison for Traralgon Creek at Traralgon

3.7.2 Bushfire

The impacts of bushfires were tested by adjusting the fraction impervious of the Traralgon Creek sub-catchments to reflect an agreed severity of bushfire. For example Blackham et al (2012) provides values of equivalent percentage impervious for different levels of burn severity, based on BAER (2009) (Table 3-13).

Table 3-13 Equivalent percentage impervious for different levels of burn severity

Burn severity	Equivalent percentage impervious
Unburned	0.1
Low	0.3
Moderate	0.7
High	0.9

The impervious fraction for all Farming Zone (Forestry) and Public Conservation and Resource Zone areas across the catchment were increased to 0.3, 0.7 and 0.9 to represent a low, moderate and high severity burn across the catchment. The resulting fraction impervious for each of the sub-catchments in the RORB model were then recalculated for each scenario and input into the RORB model and run for the range of design events. As expected, the increase to fraction impervious had a significant impact on flows generated from the catchment.

Table 3-14 Comparison of peak flows for increases impervious fraction due to bushfire

AEP	Unburned Catchment (ML/d)	Low Intensity Bushfire (ML/d)	Moderate Intensity Bushfire (ML/d)	High Intensity Bushfire (ML/d)
10%	9,000	11,200	15,900	17,600
5%	12,400	14,500	20,600	22,100
2%	16,700	19,800	25,600	26,800
1%	21,800	24,300	30,300	31,600
0.5%	27,200	29,800	35,300	36,700

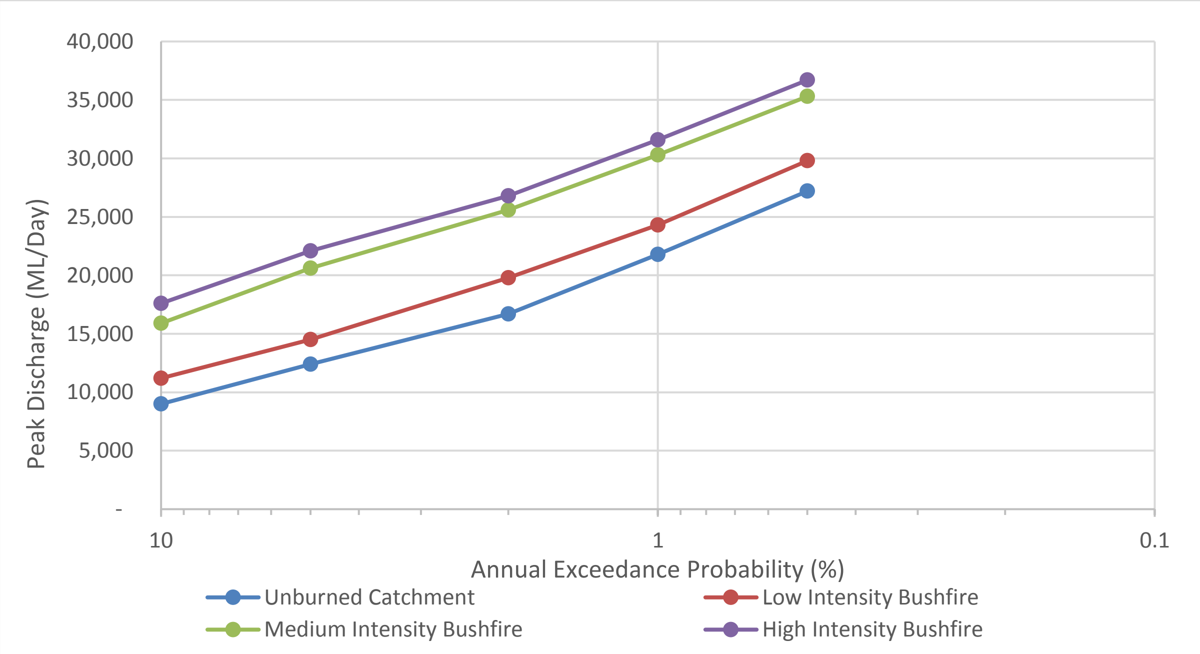

Figure 3-22 Bushfire sensitivity comparison for Traralgon Creek at Traralgon

3.8 PMF Estimation

The Probable Maximum Flood (PMF) is the flow generated from the theoretical maximum precipitation for a given duration under current climate conditions. A PMF Estimate for Traralgon Creek at Traralgon was prepared using the Quick Method of Nathan et al. (1994). This method applies a set of empirical equations to compute a triangular PMF hydrograph. The equations are:

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

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

$$T_p = 0.0001062\ A^{-1.057}\ V^{1.446}$$

$$T_r = V / (1.8\ Q_p)$$

Where:

Q_p is peak flow (m^3/s)

A is catchment area (km^2)

V is hydrograph volume (ML)

T_p is time to peak of hydrograph (h)

And T_r is base length of hydrograph (h)

The equations are applicable to southeast Australian catchments from 1 to 10,000 km^2 that do not have large lakes or storages. The resulting PMF peak flow, volume, time to peak and hydrograph length are:

A	178 km^2
Q_p	3,142 m^3/s (271,470 ML/d)
V	81,542 ML
T_p	5.6 h
T_r	14.4 h

The resulting triangle hydrograph is shown in Figure 3-23.

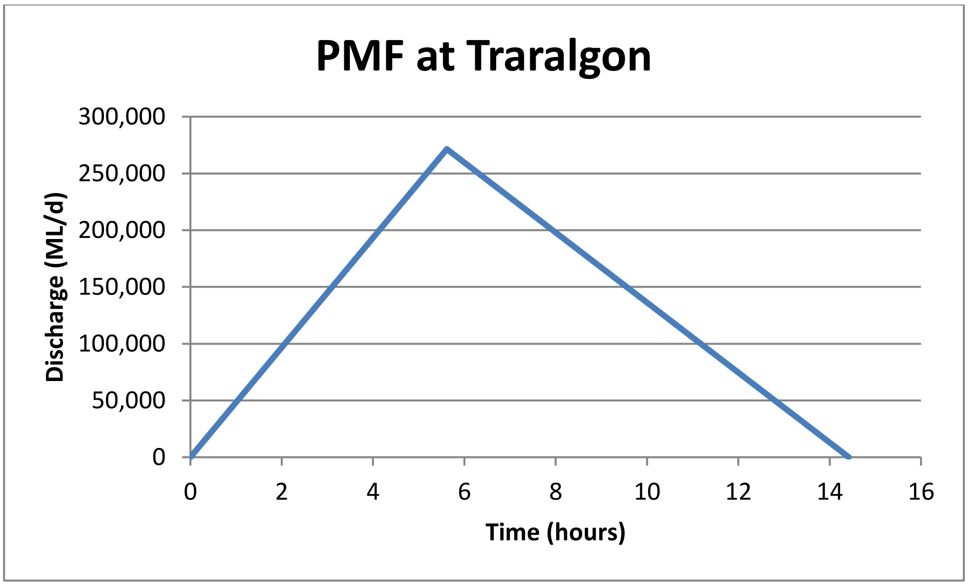

Figure 3-23 PMF hydrograph for Traralgon Creek at Traralgon

4. CONCLUSION AND NEXT STEPS

Through a process of flood frequency analysis, hydrologic modelling and application of various regional methods, a set of design flood hydrographs have been developed for Traralgon Creek at Traralgon. While the hydrological analysis has been based on robust methods and extensive cross-validation, there are limitations due to uncertainties with the gauge at Traralgon. However, validation of the design peak flows against flood frequency analysis and comparison of the design hydrographs against gauged hydrographs gives confidence that they are representative of actual flood risk and appropriate for design.

The next steps in the project were identified below.

- Further development and calibration of the hydraulic model
- Sensitivity testing of hydraulic model for tailwater and material roughness impacts

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Traralgon Flood Study – Hydraulics (R03)

June 2016

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PROJECT DETAILS

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Client Project Manager	Linda Tubnor
Water Technology Project Manager	Lachlan Inglis
Report Authors	Richard Connell, Lachlan Inglis, Ben Tate
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Cover Photo: Traralgon Creek gauge site upstream of the Princes Highway Bridge, Traralgon.

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Following the recent flood events affecting Traralgon during June 2007, July 2011, June 2012 and June 2013, Water Technology was commissioned by the West Gippsland CMA to undertake the Traralgon Flood Study. This study included detailed hydrological and hydraulic modelling of Traralgon Creek and the Latrobe River, flood mapping of Traralgon, recommendations for flood mitigation works, and a review of planning controls.

This report details the hydraulic modelling undertaken within the Traralgon area including the model schematisation and development, the inputs that went into the model, model calibration, sensitivity analysis and design flood modelling. This report is one of a series of reports documenting the outcomes of the Traralgon Flood Study.

- R01 - Data Review Report (Water Technology 2016a)
- R02 - Hydrological Report (Water Technology 2016b)
- **R03 - Hydraulic Report (Water Technology 2016c) – this report**
- R04 - Assess and Treat Risk Report (Water Technology 2016d)
- R05 - Summary Report (Water Technology 2016e)

These five reports detail the approaches adopted, the findings and recommendations, of the Traralgon Flood Study. The five reports are supported by a number of standalone PDF flood maps and digital deliverables.

2. AVAILABLE INFORMATION

Using the previous information assembled for the Data Review Report and the Hydrological Report, additional information was used to develop a fully dynamic hydraulic model of the Traralgon Creek floodplain to approximately 1.5 km downstream of Scarnes Bridge on the Latrobe River. The model schematisation including boundaries and extents is shown in Figure 2-1.

The development of the hydraulic model within TUFLOW required the development and modification in several cases of the existing data set including topography and the local council drainage network.

All data received and sent regarding the project has been logged by Water Technology in a Project Data Management Record detailing information about the data. Modifications that have been made to any of the data have also been noted. Most of these changes involve the drainage network (pipes and pits) data. The quality of data including pipe diameters, lengths, and inverts varied across the city with some areas having good quality data while several areas had pipe data containing little information, which required engineering judgement to fill in the missing information. Any changes that were made to the data have been noted within the dataset tables.

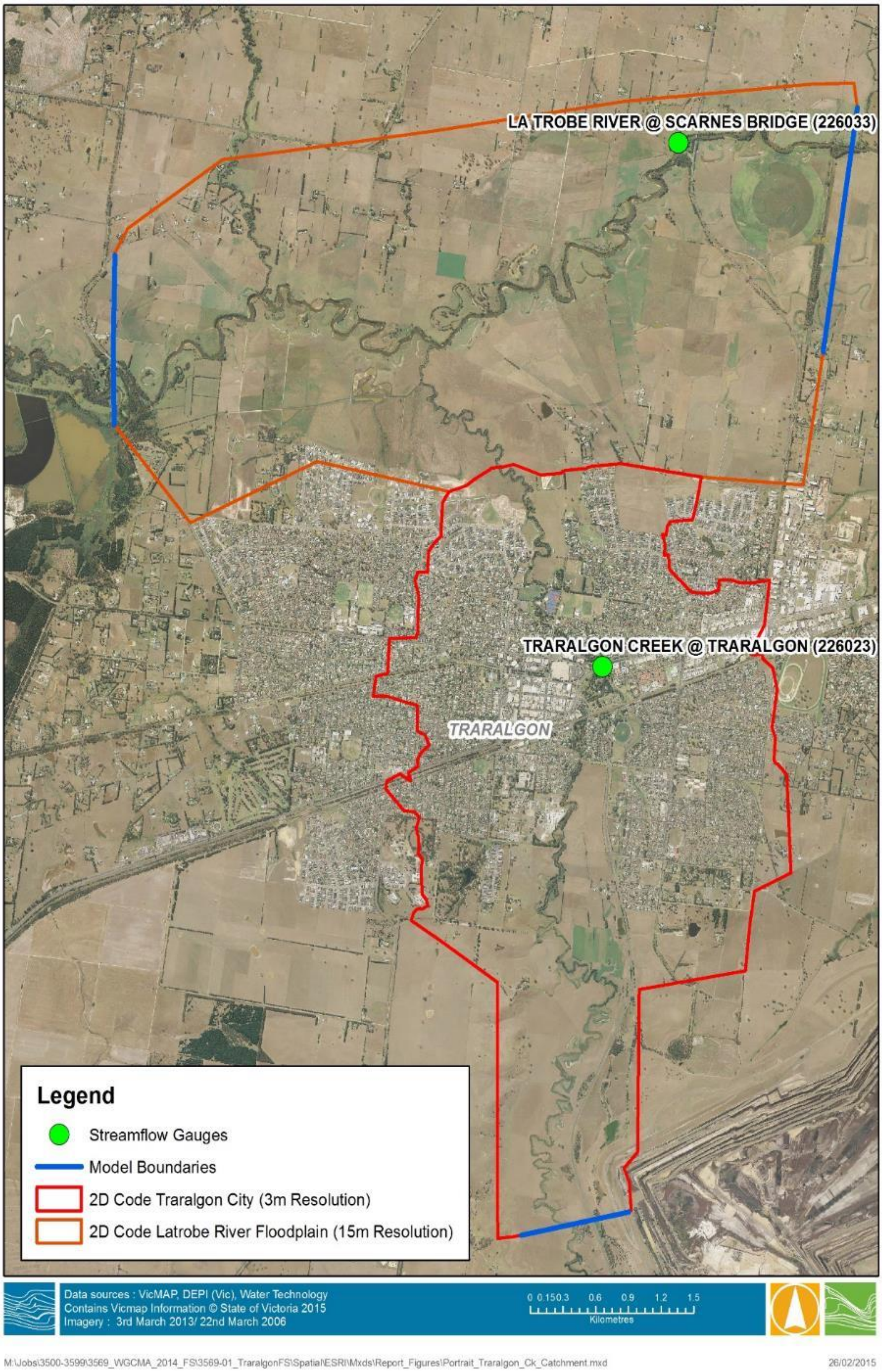

Figure 2-1 Traralgon Flood Study Hydraulic Model Extent

3. MODEL DEVELOPMENT AND SCHEMATISATION

3.1 Grid Extent and Resolution

The development of the hydraulic model for the Traralgon flood study focused on two main areas, the immediate area adjacent to the Traralgon Creek surrounding the CBD, and the Latrobe River floodplain which the Traralgon Creek drains into downstream of Traralgon. To incorporate an assessment of both areas, a multi domain model utilising a 3 m grid resolution for the township and a 15 m grid resolution for the Latrobe River floodplain was initially used. In total the original model extent was around 38.5 km^2 with 16 km^2 modelled at a 3 m grid resolution and 22.5 km^2 modelled at the 15 m floodplain resolution.

Much of the regional city is located on the edge of the Traralgon Creek floodplain. To assess the flood risk posed within the city, a 3 m grid resolution model was built starting upstream of the Traralgon adjacent to the Loy Yang open cut mine. The 3 m model encompasses much of the CBD and growth areas of the city and extends outside the floodplain approximately 1.5 km downstream of the CBD shown below in Figure 3-1. This high resolution grid allows for a detailed assessment of both riverine flooding from Traralgon Creek as well as stormwater flooding within and around Traralgon through the addition of the existing drainage network in the model.

An 8 km section of the Latrobe River either side of the confluence with Traralgon Creek was initially modelled at a 15 m grid resolution across the floodplain. The model starts at Tyers Road and runs through to the Traralgon-Maffra Road, with the confluence of Traralgon Creek and the Latrobe River approximately 3 km from the Latrobe inflow boundary. Previous modelling and gauge data was used to set the downstream levels of the Latrobe River, which is discussed further in Section 3.6. This multi-domain modelling approach allowed for a highly detailed representation of the flooding behaviour along Traralgon Creek whilst still maintaining manageable model run times.

Sensitivity analysis undertaken (covered in section 5.1) showed that the impact of the tailwater level in the Latrobe River does not impact maximum water levels in Traralgon Creek upstream of the Gippsland Water waste water treatment pond. Therefore it was suggested to remove the Latrobe River component of the hydraulic model creating a single domain model of 3 m grid resolution with a 10% AEP tailwater from the Latrobe River for the remaining design flood events. It is noted that for the 10% AEP design event, utilising a 10% AEP flow in the Latrobe River is a conservative approach. This approach was adopted by the WGCMA and the final model extent utilised a 3 m grid resolution and covered 15 km^2.

3.2 Topography

The Traralgon Creek catchment has an area of approximately 178 km^2 extending 30 km south from the confluence with the Latrobe River to a maximum elevation of 750 m AHD at Mount Tassie. The catchment consists of a single main waterway through the centre of the long narrow catchment. The headwaters of Traralgon Creek lie on the northern slopes of the Strzelecki Ranges. The hydraulic model extent begins approximately 5 km upstream of the Traralgon CBD adjacent to the Loy Yang open cut mine at an elevation of around 50 m AHD. A narrow floodplain runs through Traralgon before widening downstream of the CBD, and eventually flowing out onto the wider Latrobe River floodplain. The Traralgon Creek outfalls to the Latrobe River at an elevation of around 23 m AHD. Figure 3-1 shows the elevation of the topography within the hydraulic model extent.

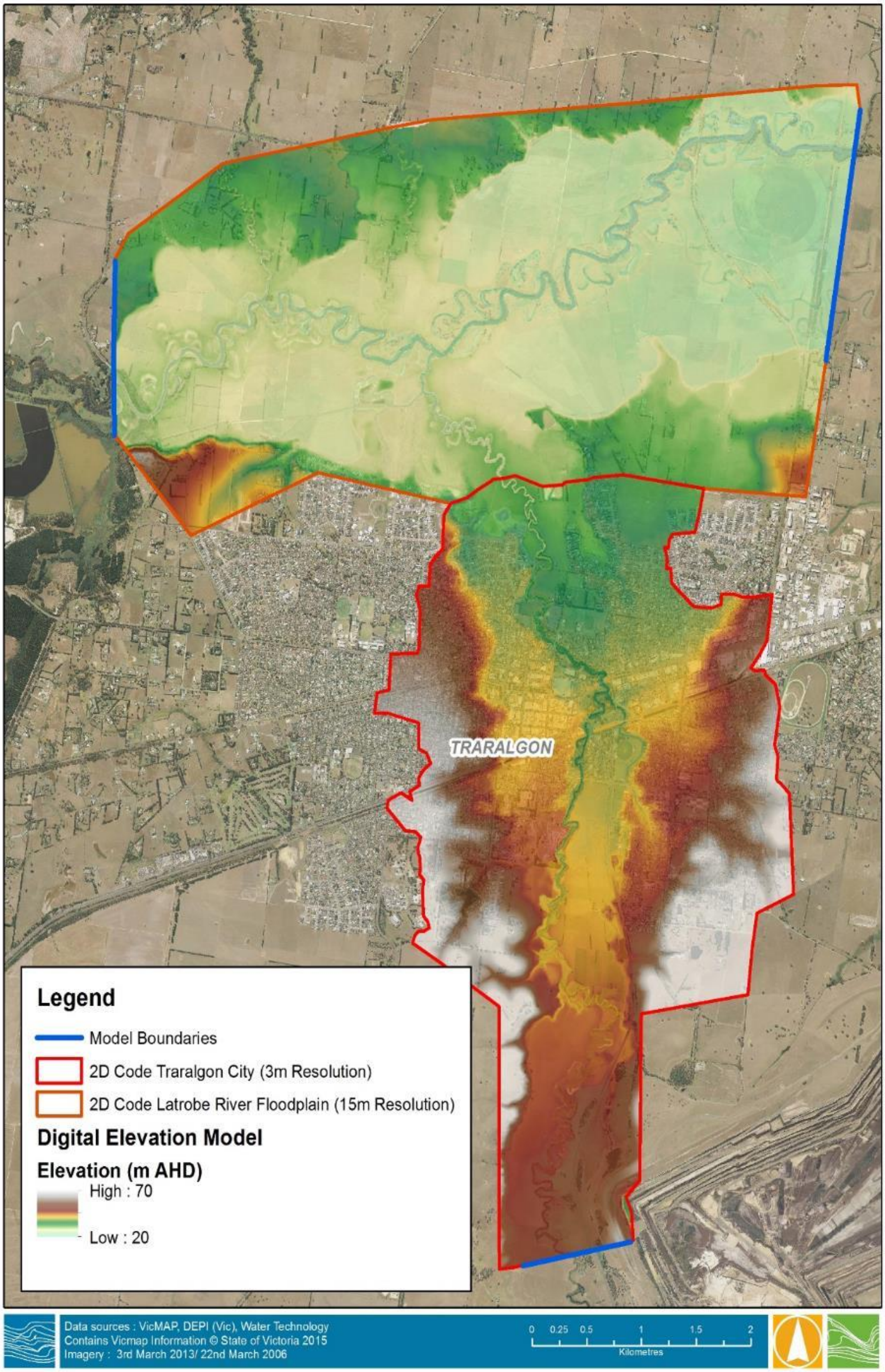

Figure 3-1 Traralgon Flood Study Model Extent

3.3 Manning's Roughness

The Manning's 'n' roughness parameter has important effects on flood velocities, flow paths, flood depths and extents. Manning's 'n' roughness values were derived from the Latrobe City Council's planning zone data and refined based on site visits and aerial photography as well as calibration modelling. Roughness values are assigned based on the guidelines provided by the Melbourne Water Flood Mapping Technical Specifications (Melbourne Water, 2010).

- For the 2D domain, *'2d_mat'* files were produced based on land use zones, with further refinement through the use of high-resolution aerial photographs and findings from the site visits. The Manning's values are specified in the .tmf TUFLOW model file. The final layout of Manning's Roughness is provided as a model check file and is shown in Figure 3-2.
- Manning's 'n' roughness coefficients used in the model were adopted from Melbourne Water Guidelines as a starting point and adjusted during calibration of the model. The final values used are listed below in Table 3-1.
- For the 1D domain, roughness values were applied directly to the *'1d_nwk'* file to represent the material roughness of culverts, pits and pipes.

Table 3-1 Land Use Manning's 'n' Roughness values

Material	Manning's n Roughness
Residential (Town blocks)	0.300
Commercial / industrial buildings	0.350
Railway Line	0.200
Riparian fringe (moderate vegetation)	0.055
Waterway (moderate vegetation)	0.045
Farm/ grassed areas/ parks	0.040
Open waterways (no vegetation)	0.035
Local and major roads	0.020
Low Density Residential	0.060
Car Park	0.025

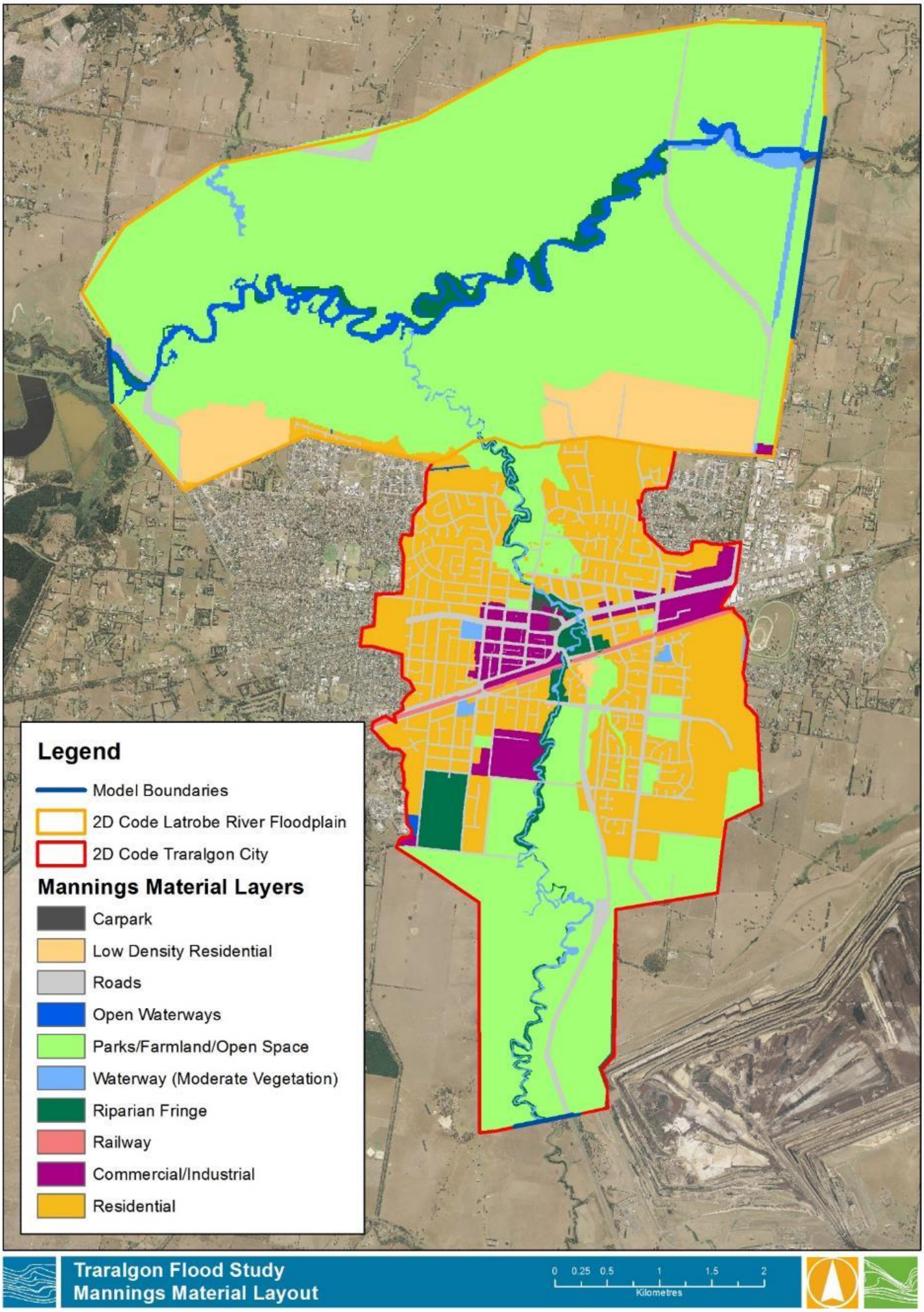

Figure 3-2 Traralgon TUFLOW Model Manning's Roughness

3.4 Key Hydraulic Structures

There are several key hydraulic structures within Traralgon located on Traralgon Creek. These hydraulic structures play an important role in flood events ranging from small, frequent events through to large, rarer flood events. Several of these structures within and around the CBD include; the Melbourne-Bairnsdale Railway line; Whitakers Road; Princes Highway; and Franklin Street.

These structures were assessed during a site visit on October 16, 2014 and compared against existing information provided by Latrobe City Council. Survey was commissioned of important hydraulic structures as well as several pedestrian footbridges and two transects for LiDAR validation, which is shown in Figure 3-4. The major hydraulic structures surveyed included Whitakers Road (Figure 3-3), Peterkin Street, Howitt Street and the Railway Culverts at Howitt Street (Figure 3-5).

Figure 3-3 Traralgon Creek – Whitakers Road Culverts

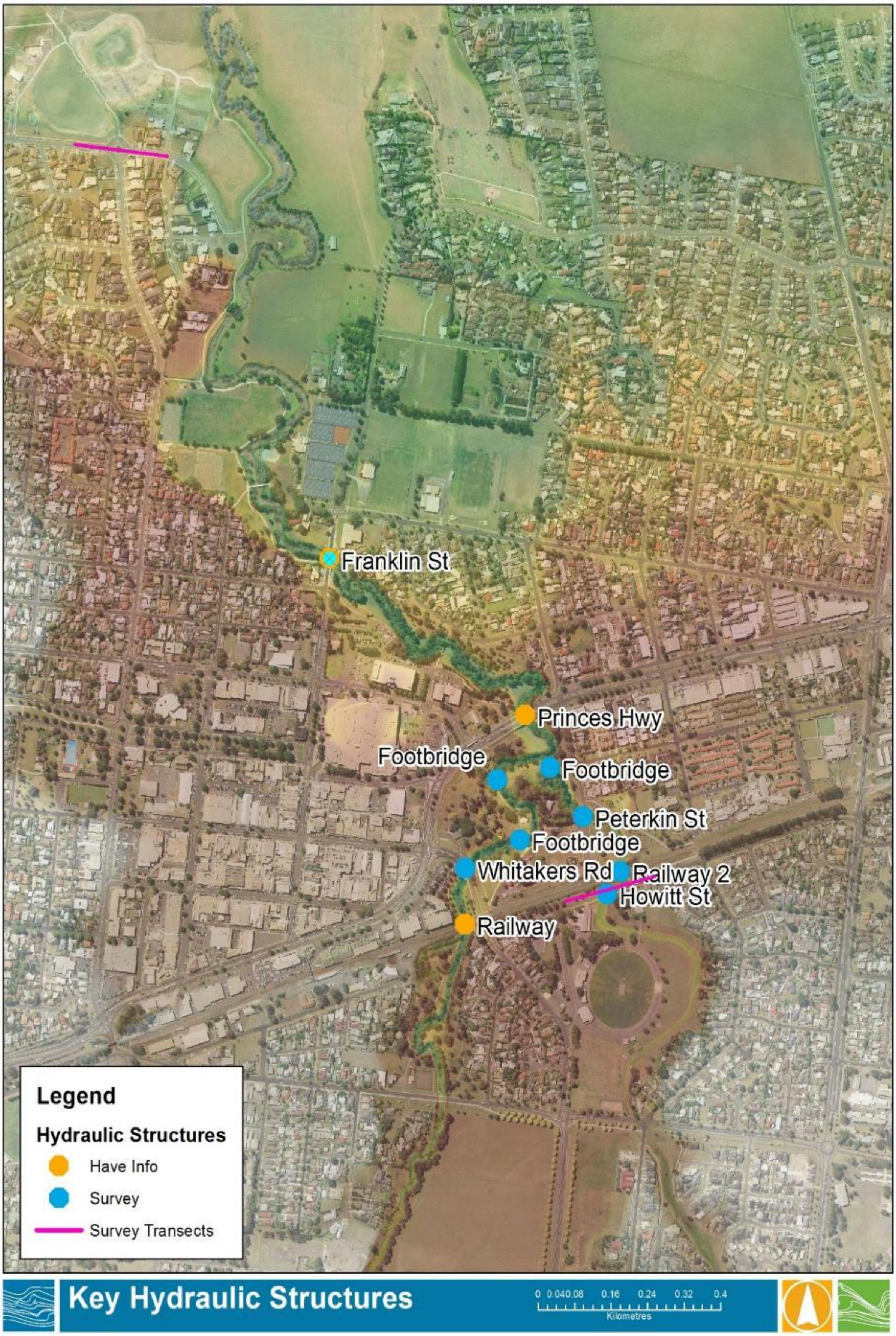

Figure 3-4 Key Hydraulic Structures and Survey Information

Figure 3-5 Traralgon Creek - Bairnsdale Railway Line Culverts (Looking North from Howitt St)

Downstream of Traralgon, an existing waste water treatment pond operated by Gippsland Water is located on a raised pad on the floodplain, as shown in Figure 3-6. Anecdotal evidence from community members suggests that this restricts floodplain flows.

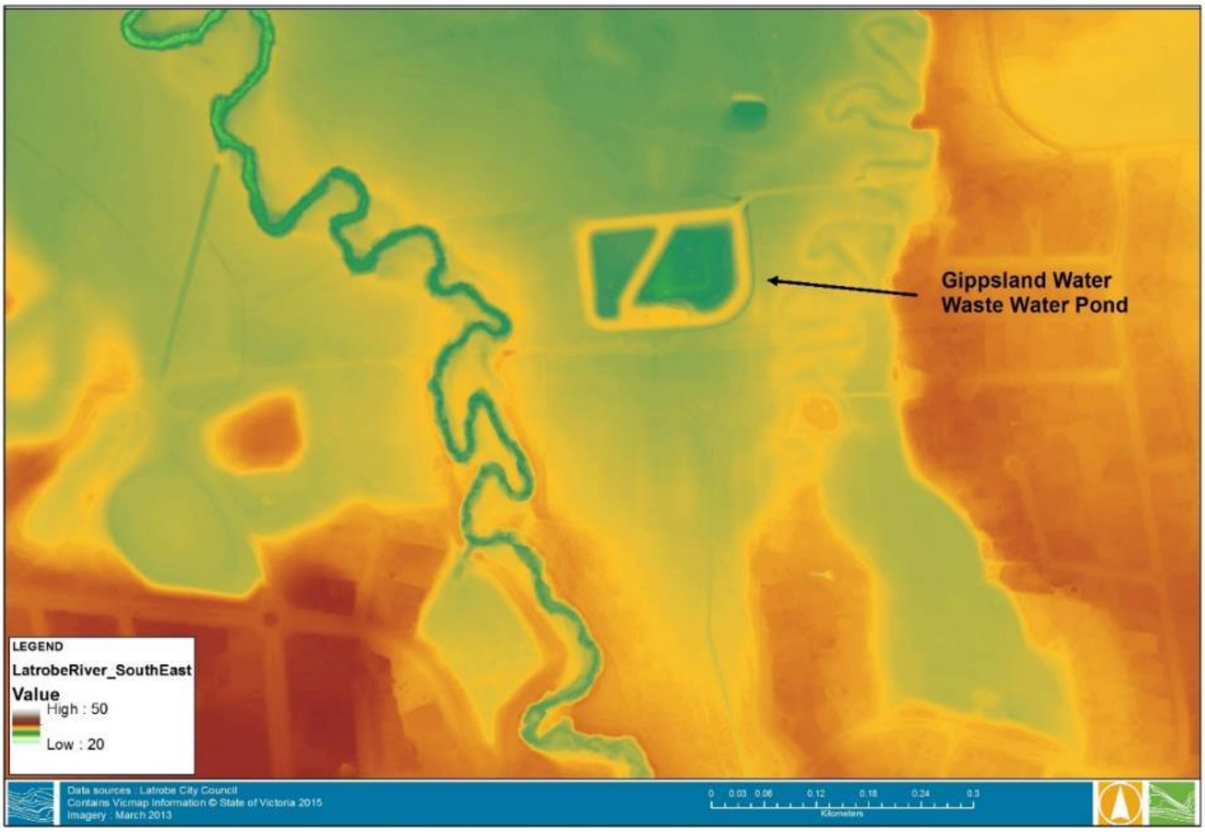

Figure 3-6 Gippsland Water - Waste Water Pond Located on the floodplain

3.5 Pit and Pipe Network

Latrobe City Council drainage assets were provided in GIS format to Water Technology. As mentioned earlier, the quality of the drainage asset data varied from high quality detail including pipe and pit size, location and invert, while other areas lacked sufficient data for use in the hydraulic model. Where the accuracy of the locations and attributes are unknown, Latrobe City Council has advised that errors in the data are common. A thorough review of the drainage network identified areas of data which were suitable for use within the hydraulic modelling. However, for areas that are missing dimensions for the pipes, Water Technology have assumed a pipe diameter based on available information upstream and downstream of the pipe. For pipe and pit inverts, the available information on pit depths was used in combination with the LiDAR surface at the pit location, and an assumed minimum cover. These changes have been noted within the MapInfo table database. The drainage information assessed for the hydraulic model is shown in Figure 3-7.

Following a data review and modification of the drainage dataset to fill the missing gaps, further checks were undertaken to ensure the pit and pipe network placed into the model was functioning as expected. Much of this involved engineering judgement to schematise the drainage network slope throughout the catchment to ensure water is running downhill towards the outfall, as it was designed to do.

The example below using TUFLOW miTools shows a long section of a trunk drain along the Princes Highway. This drain runs west from the Traralgon Maffra Road to the Traralgon Creek, as shown in Figure 3-8. Figure 3-9 shows the alignment of the natural surface plotted alongside the invert and obvert of the pipes based on the information provided, as well as a minimum natural surface cover (in this example 0.60 m). Any pipe that had a positive gradient is flagged and highlighted in the long section plot.

The pipe inverts along the trunk can then be modified to run downhill based on engineering judgement (as designed) to best represent the drainage network. This check also ensures that pipe diameters are increasing along the network and is important in filling the gaps where pipes are missing diameter information. This information will be provided back to Latrobe City Council to help provide additional information in their database.

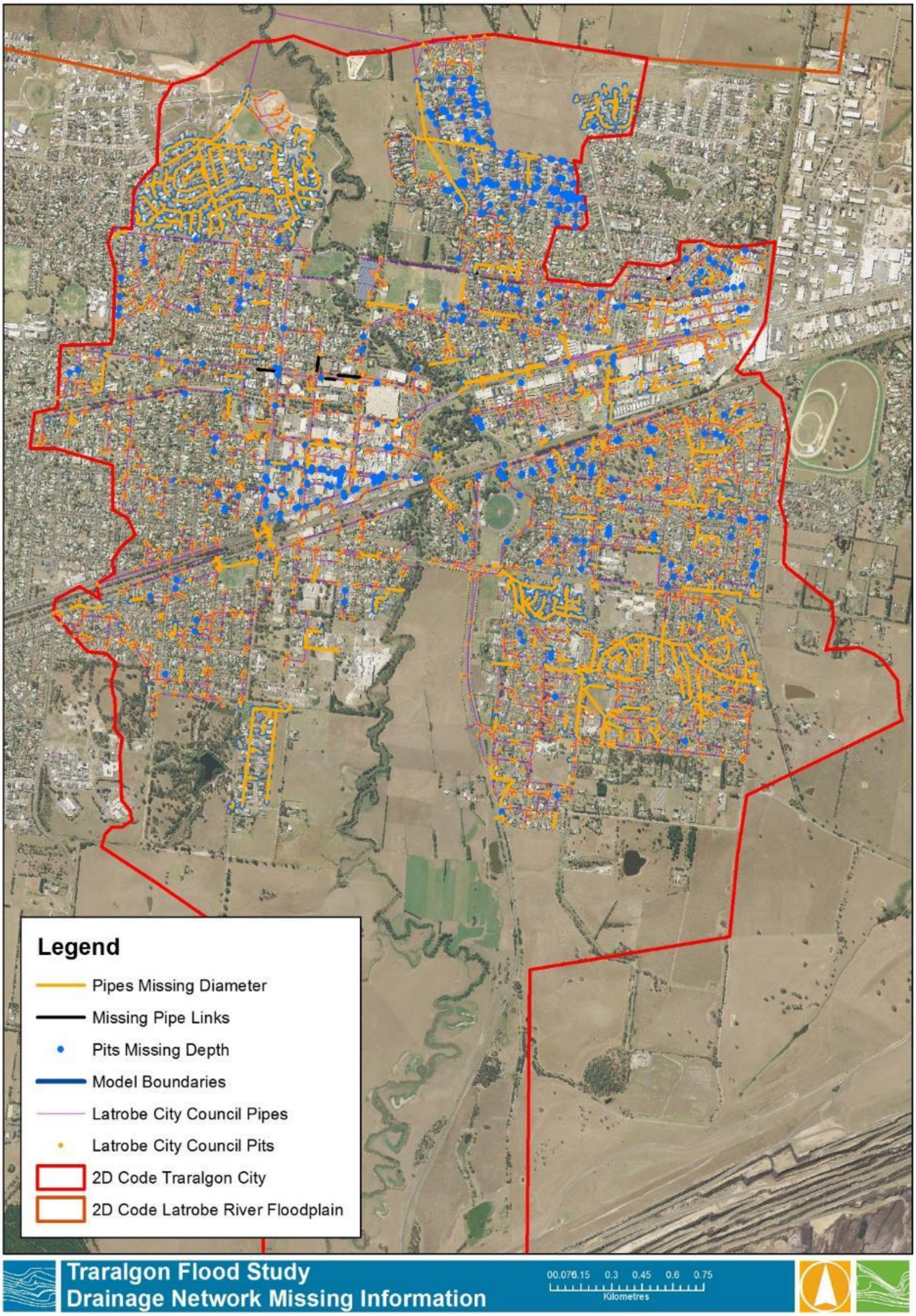

Figure 3-7 Traralgon Flood Study Drainage Network Information

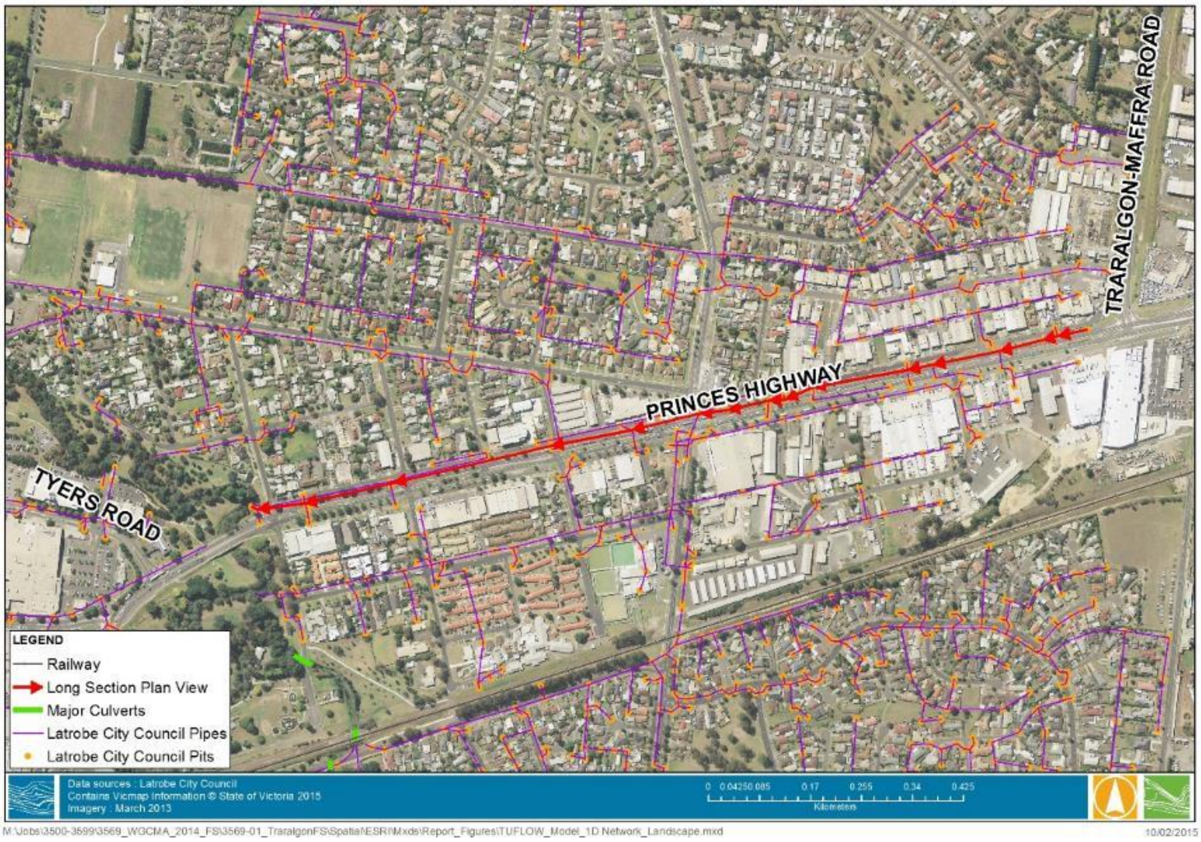

Figure 3-8 Pipe network check plan view - alignment shown in red

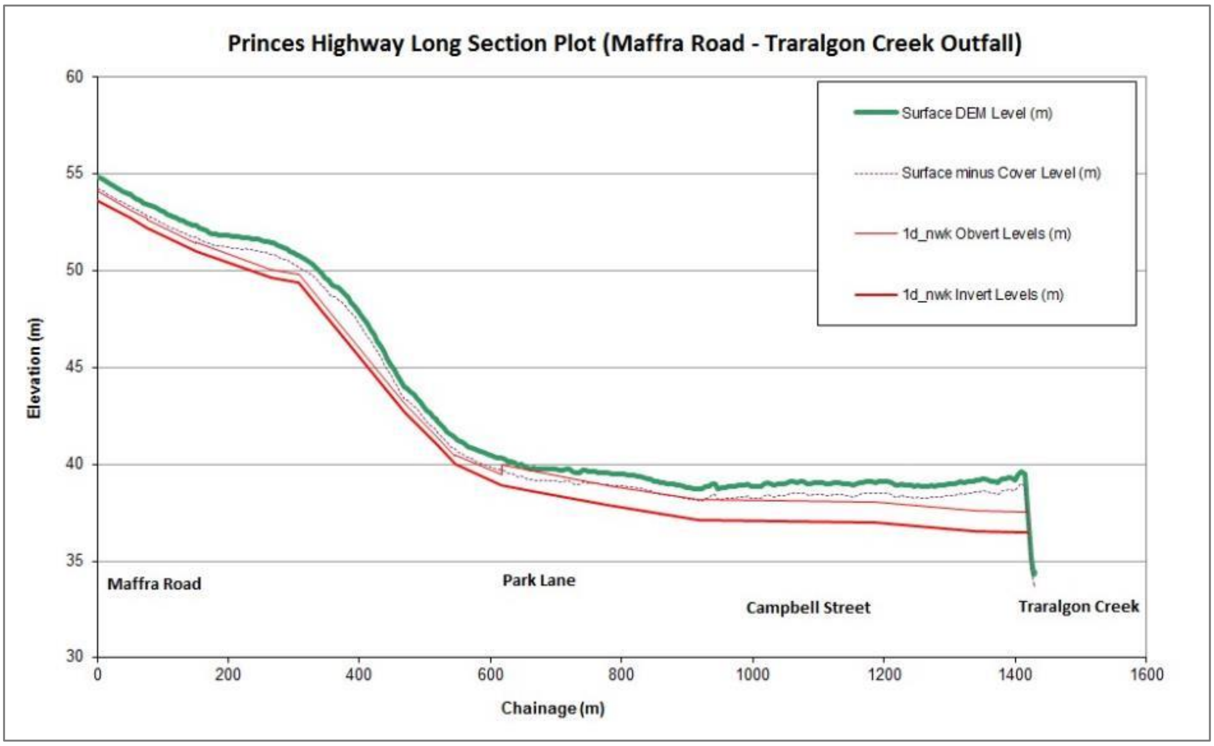

Figure 3-9 Pipe network check - section view

3.5.1 Pit Configuration

Pits along the 1D pipe section were connected to the 2D using the “SXL” option for the *‘1d_nwk pit Conn_2D’* attribute. This option automatically lowered the 2D cells connected to the pits by 0.1 m, specified in the *‘1d_nwk’* file, to allow surface water to enter the pits and pipes more easily.

Pit types were determined from the information provided by LCC. Appropriate model pit types were used to model the side entry pits, grated pits and headwalls to allow water to enter and exit the pipe network as required. Where pit type information was not provided a weir type pit was used.

The model’s weir and rectangular type pits were uniformly assigned a width of 1 m, based on the average pit size (900 x 600 mm) in the catchment. This provides a slight overestimation of the pit inlet capacity (for the average pit size) resulting in the pipe characteristics being the principal limiting factor to water entering the 1D Network. Allowing the pipe to be the limiting factor is a routine approach in urban flood studies.

3.6 Boundary Conditions

3.6.1 Inflow Boundaries

Flow hydrographs from thirteen selected locations within the RORB hydrologic model were extracted to provide inflow boundaries to the hydraulic model. To distribute flows throughout the local contributing sub catchments, 59 Source Area (SA) Inflows (i.e. inflow source spread across an area) were placed in the model to represent local catchment inflows directly into Traralgon Creek as well as throughout the local drainage network, as shown in Figure 3-10. To distribute the smaller local network inflows through the local drainage network (pits and pipes), ‘SA PIT’ inflows were used that apply the inflow boundary directly into the drainage network until capacity of the underground network is reached and water then flows out on to the 2D domain.

The hydrographs were obtained from the hydrology analysis and included rainfall-runoff modelling of Traralgon Creek and local catchment flows placed throughout Traralgon, as well as gauging and flood frequency analysis of the Traralgon Creek. The major inflow into the model was at the Traralgon Creek approximately 4 km upstream of the CBD, which was derived from gauge records as described in the hydrology report. Latrobe River flow rates were derived from gauge data for calibration events, while for design events utilised flow rates from the previous Latrobe River study (Cardno, 2013).

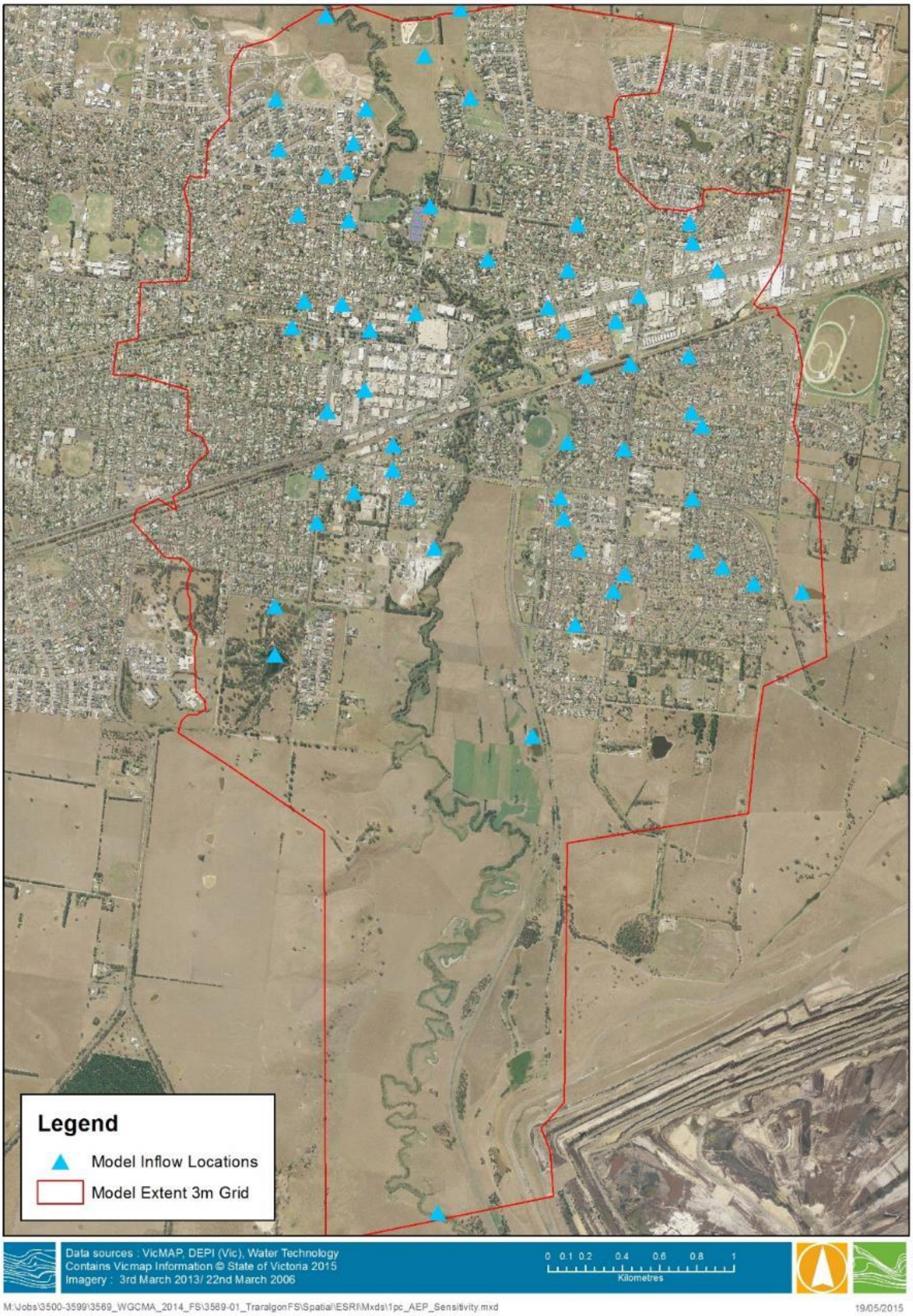

Figure 3-10 TUFLOW hydraulic model inflows on Traralgon Creek and local catchments

3.6.2 Tailwater Boundary

The downstream end of the model, located at Scarnes Bridge on the Latrobe River near the Traralgon-Maffra Road, utilised a Height/Time (HT) type boundary to allow the flow out of the model. Water level data was available for the 2012 flood event from the Latrobe River at the Scarnes Bridge (226033) gauge, which was used to set a dynamic model boundary. The 1993 and 2013 calibration events used dynamic water level boundary based on results of previous modelling of the Latrobe River (Cardno, 2013). The previous Cardno results were also used to set a constant downstream tailwater level in the Latrobe River for design events. Sensitivity analysis of the downstream boundary level was undertaken which shows that the tailwater boundary of the Latrobe River has minimal influence on water levels in the Traralgon Creek upstream of the waste water treatment ponds and therefore to the current Traralgon residential areas. This is discussed further in section 5.1.

3.6.3 Multi-domain Boundary

The transfer of water over the 2D/2D model interface allows for two different sized models to be run as a single model. When defining the 2D/2D boundary location, care needs to be taken to ensure that the boundary is perpendicular to the flow direction. In the Traralgon flood model, the 2D/2D boundary is located on the floodplain of the Traralgon Creek as it is spreading out onto the Latrobe River floodplain. Therefore it was important to provide several separate 2D/2D boundaries along the edge of the two models that allow for the efficient transfer of water across the two model domains. This is based on identifying the main flow direction along the boundary as shown in Figure 3-11.

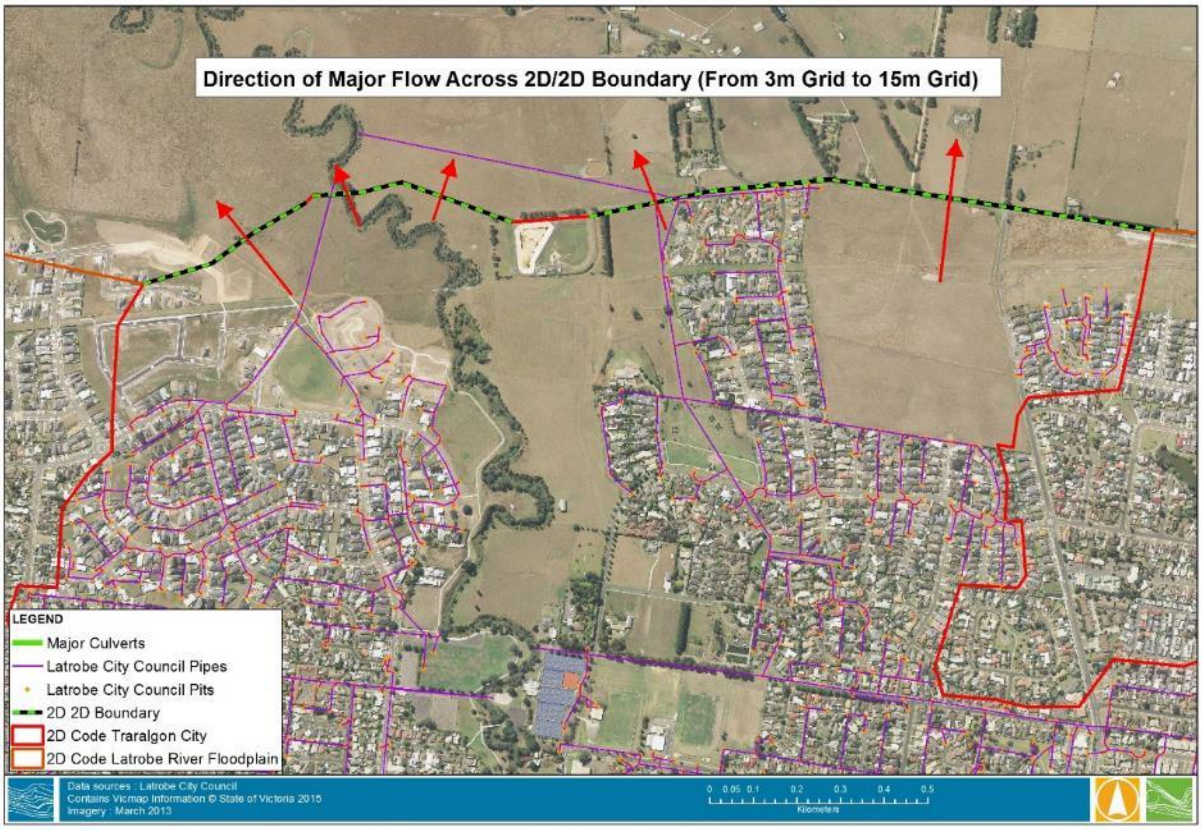

Figure 3-11 Schematisation of the 2D/2D Boundary within TUFLOW

The boundary conditions discussed above were modified to match the change to a single domain model which ends on the edge of Latrobe River floodplain. This is discussed in more detail in section 5.1.

4. HYDRAULIC MODEL CALIBRATION

This section of the report details the hydraulic model calibration undertaken which aimed to closely match modelled flood levels and extents with available historic data. The model was calibrated to the June 2012 flood event, which was considered a significant recent flood event. The model was then validated to the September 1993 and June 2013 flood events, giving a range of flood magnitudes to ensure the model performs well for a range of scenarios, as shown below in Table 4-1.

Table 4-1 Calibration and Validation Event Summary (from DELWP)[1]

Event	Traralgon Creek Peak Flowrate (m^3/s)	Traralgon Creek Peak Flowrate (ML/d)	Traralgon Gauge Height
September 1993	230.35 (DEWLP) 196.76 (Adopted value)	19,902 (DEWLP) 17,000 (Adopted value)	5.64 (Wright St Gauge)
June 2012	154.09	13,313	5.32 (Princes Hwy Gauge)
June 2013	84.92	7,337	4.30 (Princes Hwy Gauge)

4.1.1 June 2012 Event Calibration

In June 2012, heavy rainfall fell throughout the Traralgon Creek catchment and surrounding Gippsland area. The ranges to the south of Traralgon received more than 200 mm of rainfall in the three days prior to the flooding on June 5, 2012. Rainfall totals throughout the catchment show that the highest totals fell in the ranges to the south of Traralgon and included Mt Tassie (225 mm), Balook (203 mm), Koornalla (103 mm), Callignee North (116 mm) and Traralgon EPA (44 mm). The Victorian SES received more than 1,500 calls for help across the Gippsland region (VicSES, 2012). Flood waters at Traralgon peaked at around 3am on the 5th June, inundating a number of residential properties above floor and many more suffering external property damage.

Model calibration results showed the maximum flood level (37.94 m AHD) at the Traralgon Creek at Traralgon gauge matched closely to the maximum recorded level of 37.99 m AHD as shown in Figure 4-1. The flood extent appeared to match quite well with anecdotal evidence provided from the steering committee as well as on ground and aerial photography provided by the West Gippsland CMA. Figure 4-2 to Figure 4-5 show four examples where the maximum extent and depth plots helped validate the modelling results against on ground and aerial photography. It should be noted that the aerial photography was taken around 2pm on the afternoon of June 5, around 12 hours after the peak flood level in the city.

The aerial photos clearly show debris lines from close to the peak flood level at several locations, including upstream of Shakespeare Street where water crosses the Traralgon Creek Road, the Traralgon Tennis club and throughout the city. This information, along with feedback from the community meeting in Traralgon, gives confidence that the model has accurately reproduced the flooding that occurred in June 2012.

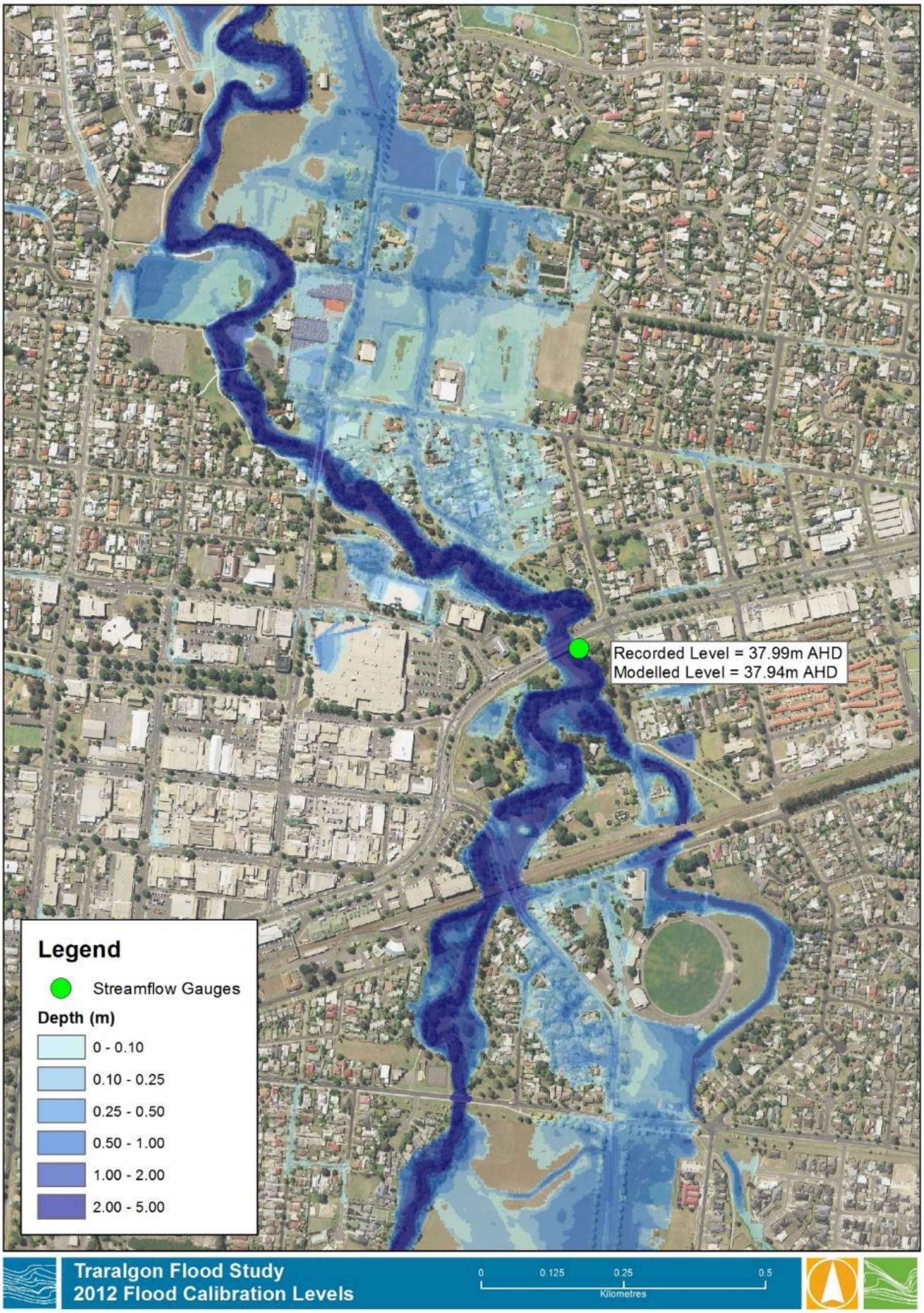

Figure 4-1 June 2012 Calibration Event Depth Plot

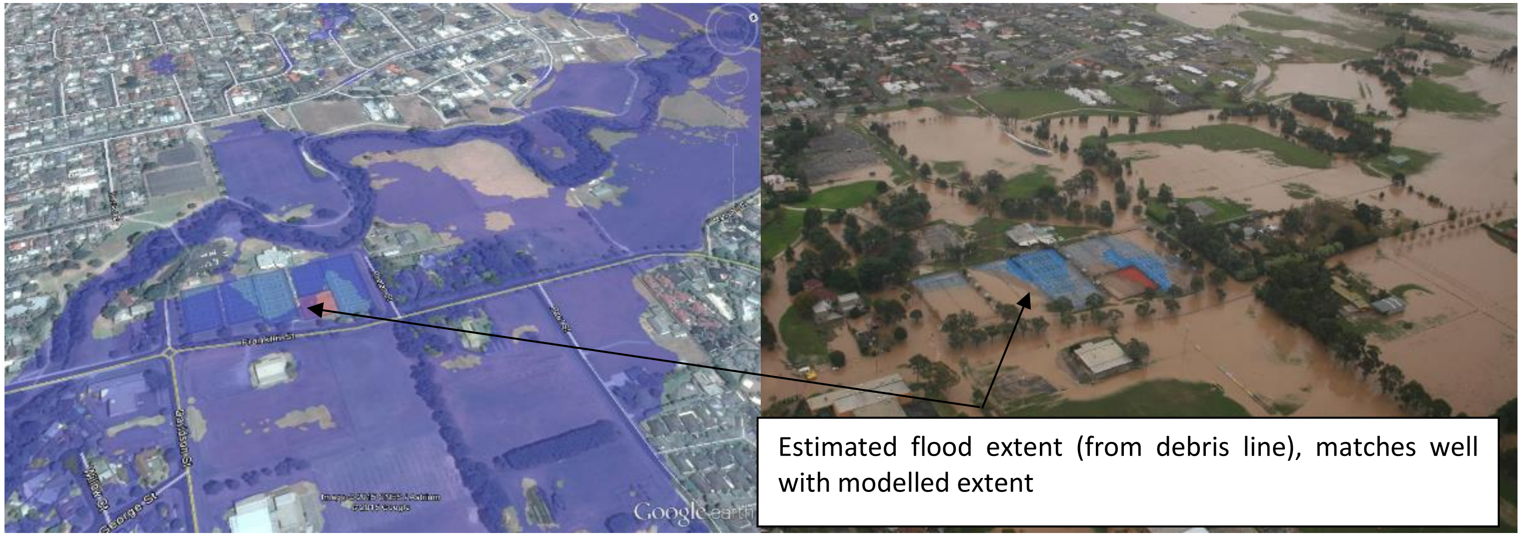

Figure 4-2 Traralgon Tennis Centre, June 2012

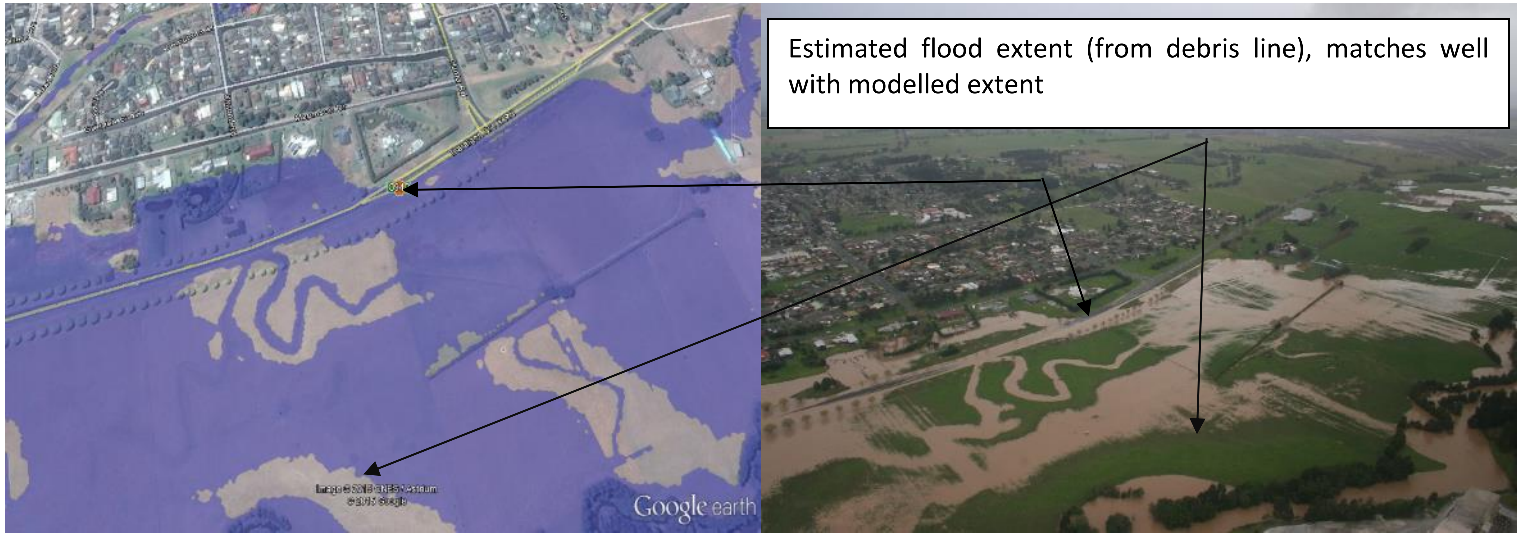

Figure 4-3 Traralgon Creek Road looking South East, June 2012

Figure 4-4 Shakespeare Street, June 2012

Figure 4-5 Traralgon CBD looking North, June 2012

4.1.2 September 1993 Event Validation

The September 1993 flood event is the largest flood in recent history, with similar magnitude flood events occurring in 1978 and 1995 (Flood Victoria, 2015). The community consultation process revealed observations of locations where water levels were higher during 1995 event, however weight of evidence suggests 1993 to be the larger of the floods in recent history. 24 houses within Traralgon recorded above floor flooding while it is estimated that 123 properties experienced external property damage (HydroTechnology 1995). The 24 houses which recorded above floor flooding were used to provide an estimated flood level along with 55 other flood levels taken from survey, debris lines and anecdotal evidence throughout the city. Flood levels were recorded in the Victorian Flood Database (VFD) as well as Hydrotechnology (1995), only three of the recorded flood levels from the VFD were classed as a 'High' reliability, while the remaining levels were classed as 'unknown'. These levels along with peak gauge height at the Wright St flood gauge formed the basis of the 1993 model validation. The Wright St gauge is the previous location of the Traralgon Creek at Traralgon (226023) gauge prior to it moving to upstream of the Princes Highway. It was noted during the calibration phase that there has been significant change in land use within the floodplain since 1993. Several houses which recorded above floor flooding (including 19 Whitakers Road) are no longer there, while there has been filling of the floodplain both upstream and downstream of the city. This is likely to impact on the flood extent and recorded flood level comparisons in localised areas. The maximum depth plot across Traralgon is shown below in Figure 4-6.

There is also uncertainty surrounding the peak flow for the 1993 event, with DELWP online data giving a peak flow at the Traralgon Creek at Traralgon gauge (226023) of 19,900 ML/d. However previous studies, which included modelled estimates of the peak flow for 1993 flood, were considerably lower. These include values of 16,400 ML/d (Dyer 1993), 15,100 ML/d (Hydro Technology 1995) and 15,600 ML/d (SKM 2000). Initial modelling using the DELWP peak flows overestimated flood levels through Traralgon by around 150-200 mm. The peak inflow into Traralgon Creek was revised to a conservative estimate of 17,000 ML/d given the uncertainty of the gauged flow. Once adopted, modelled flood levels through Traralgon matched considerably closer than previously when using a peak flow of 19,900ML/d.

As shown in Figure 4-7, modelled levels generally matched well with recorded flood levels throughout Traralgon. It was noted that for the area between Shakespeare Street and the Railway line, modelled flood levels were on average 200 mm below recorded levels. This compares to the remainder of the flood marks throughout the city, which were 50 mm above recorded flood levels. Sensitivity testing of flow constriction at the Railway Bridge on Whitakers Road, as well as increasing the Manning's n value of this area resulted in only slight increases to water levels at these marks. It was assumed that a local increase in the flow capacity in this section of the floodplain may have occurred since 1993 with the removal of several properties. It also appears that ground levels (specifically Shakespeare Street) represented in the current LiDAR may not accurately represent the levels of the road and surrounding areas at the time of the 1993 flood event. The road acts as a hydraulic control, affecting water levels on the floodplain, with the greatest impacts occurring immediately downstream of the road. This provides some justification to the two flood marks immediately upstream of Shakespeare Street that were around 500 mm higher in the model compared to recorded levels, however this could also be attributed to the low confidence in the surveyed levels.

The water surface level at the Wright St gauge peaked at 37.57 m AHD, whilst the modelled peak water surface at the approximate gauge location (upstream of the footbridge) was 37.64 m AHD. It was noted the gauging site was located directly adjacent to a footbridge which may provide uncertainty in the peak flood height due to afflux caused by the bridge. Model results showed a head drop of around 400 mm across the footbridge as shown in Figure 4-8.

Using the available flood data, including gauge heights, anecdotal flood marks and recorded flood heights, the hydraulic model was able to match 66% of the recorded flood heights to within 200 mm.

Given the changes occurring within the floodplain since the 1993 flood event, this was considered by Water Technology to be an appropriate calibration. The revised peak flow of 17,000 ML/day for the September 1993 flood event was used to update the Flood Frequency Analysis from the hydrology, along with the resultant design flood hydrographs from RORB. The revised design peak flows were used as input to the hydraulic model for the design events.

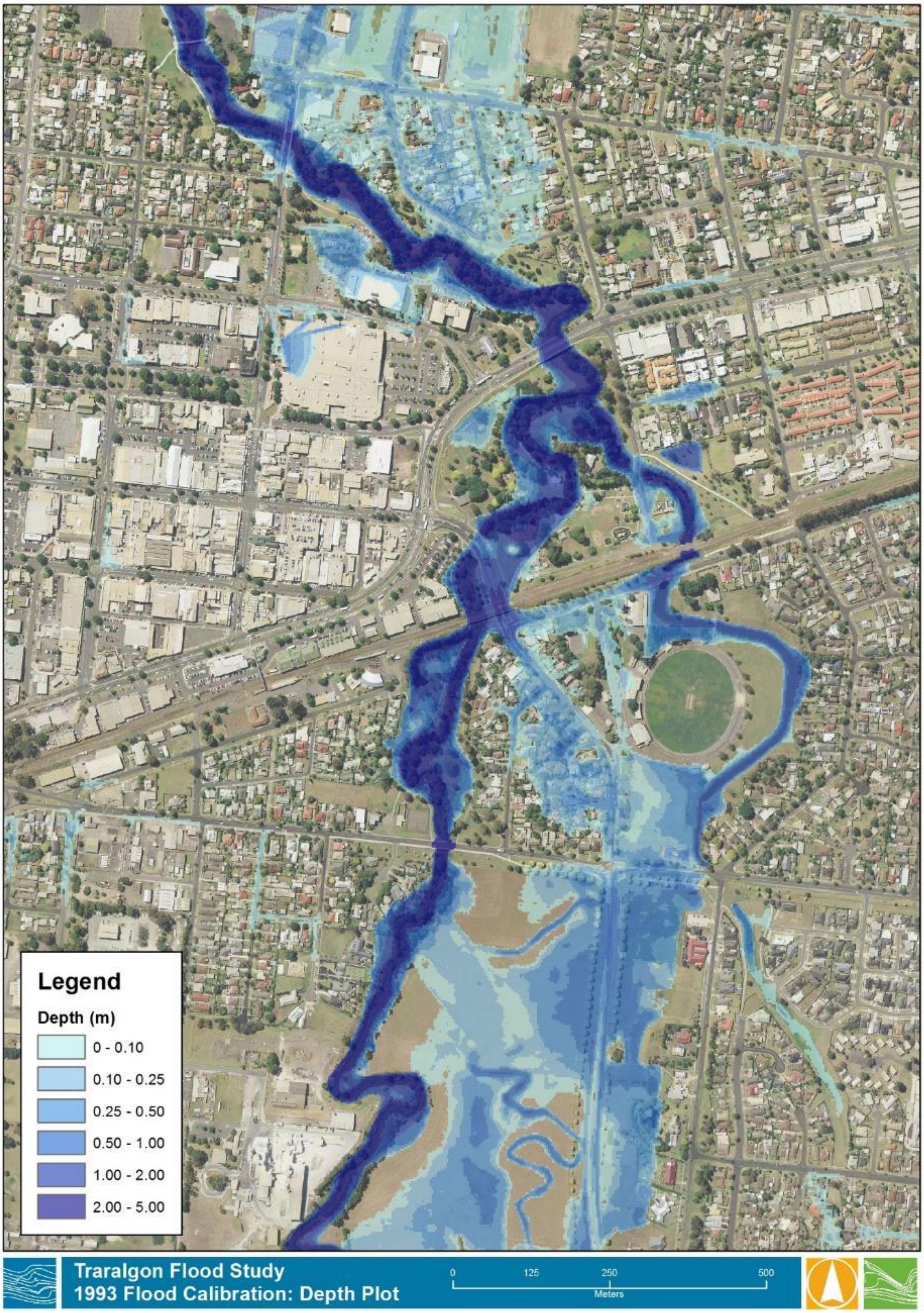

Figure 4-6 September 1993 Maximum Depth Plot

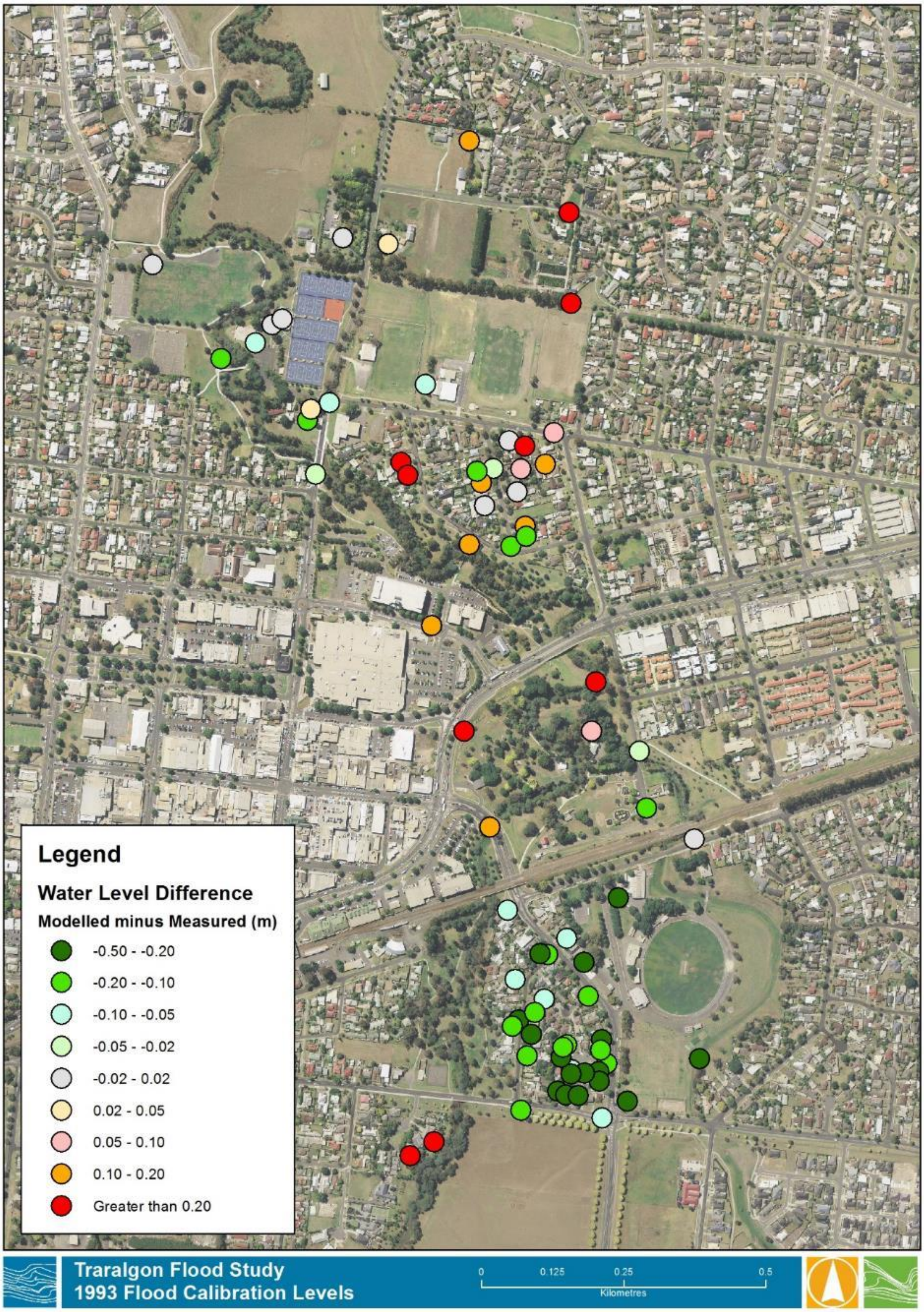

Figure 4-7 1993 Calibration Flood level comparison

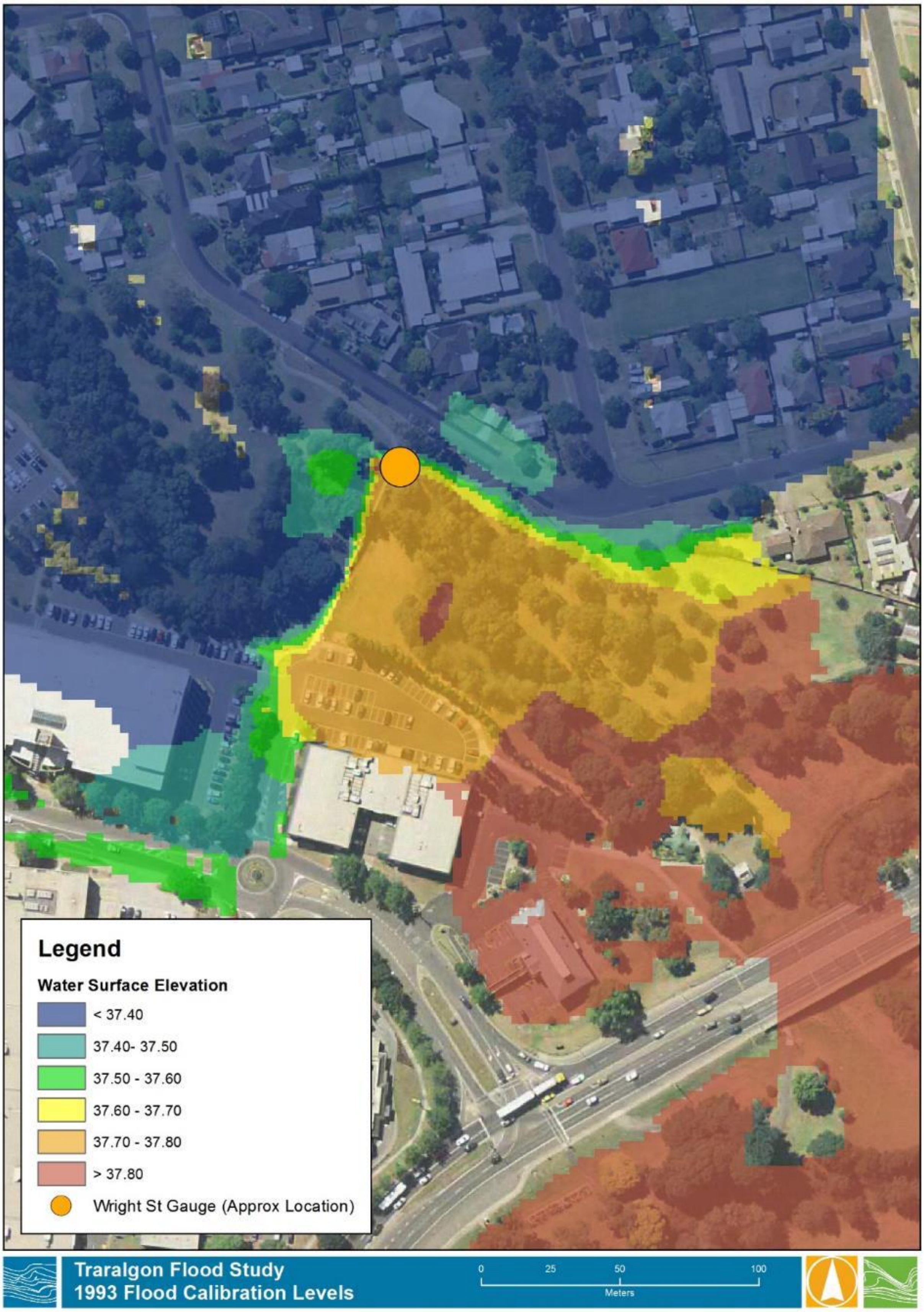

Figure 4-8 Wright St Gauge (previous location) showing 1993 maximum water surface levels

4.1.3 June 2013 Event Validation

The June 2013 flood event was of a smaller magnitude compared to 2012 and 1993, with no houses recording above floor flooding within Traralgon. This event was able to provide further validation to the model results for smaller, more frequent events, as it was generally confined to within bank of the Traralgon Creek. Peak flow at the Traralgon Creek at Traralgon gauge (226023), was recorded as 7,330 ML/d. The model itself had two changes when compared to the 1993 and 2012 model, with works on the Franklin St Bridge and the Wright St pedestrian bridge being completed between June 2012 and June 2013 flood event. The maximum peak level at the Princes Highway gauge reached a depth of 4.30 metres, which corresponds to a maximum water surface level of 36.97 m AHD. The maximum water level modelled was slightly higher at 37.07 m AHD. Figure 4-9 shows the maximum flood depth across the city.

Anecdotal evidence to further validate modelling results included news articles from the time of flooding, which reported Whitaker Road as being inundated as well as a shallow break out along Franklin Street (ABC Victoria, 2013). The hydraulic modelling represented both of these flooding locations well, with shallow depths along Franklin St and at the Franklin St Bridge. Figure 4-10 and Figure 4-11 show a comparison of flood depths at the Franklin Street Bridge compared with a photo close to the peak flood looking east. The depths plot appears to match the photograph depths at the bridge relatively well.

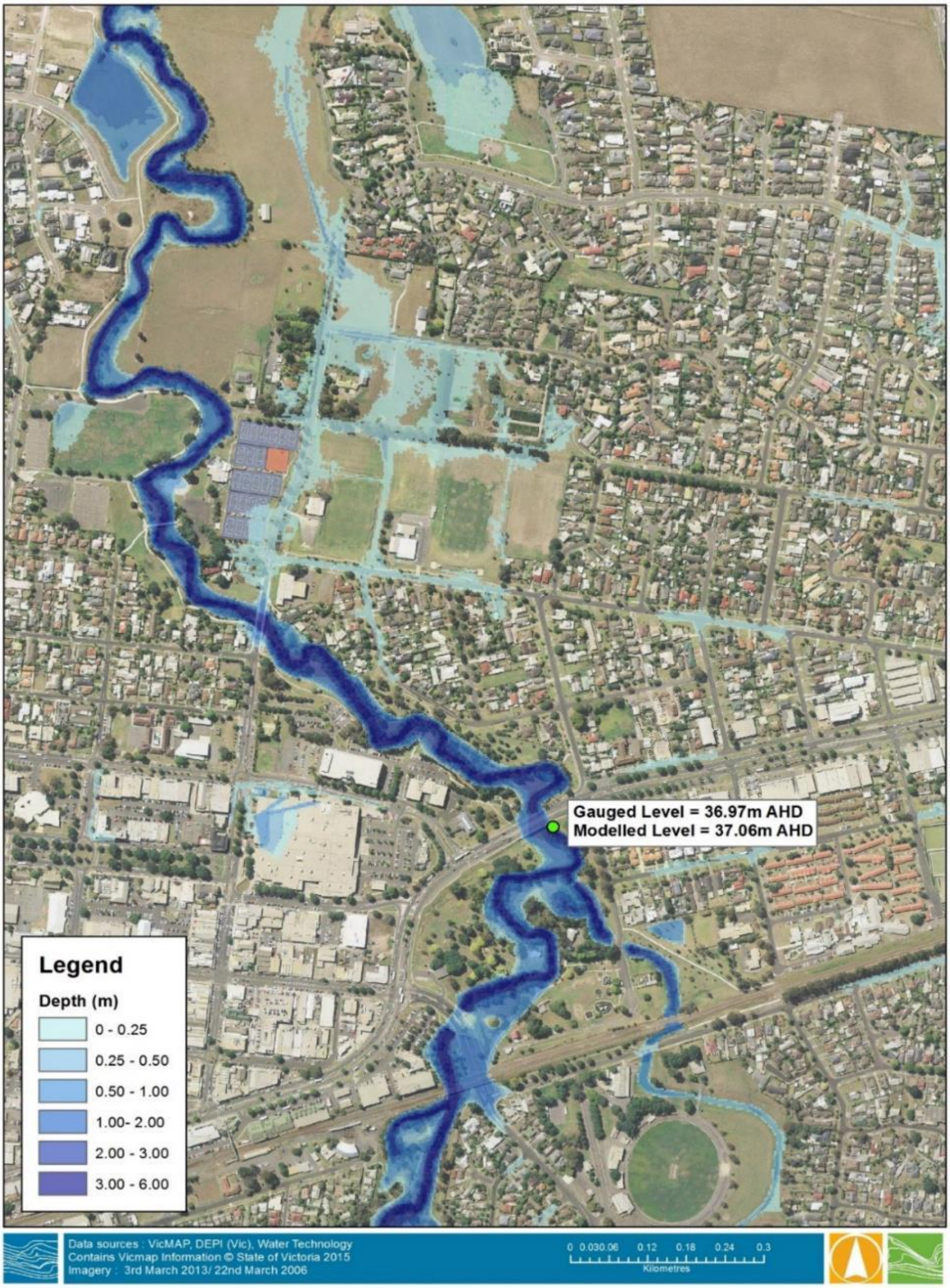

Figure 4-9 June 2013 Maximum Flood Depth Plot

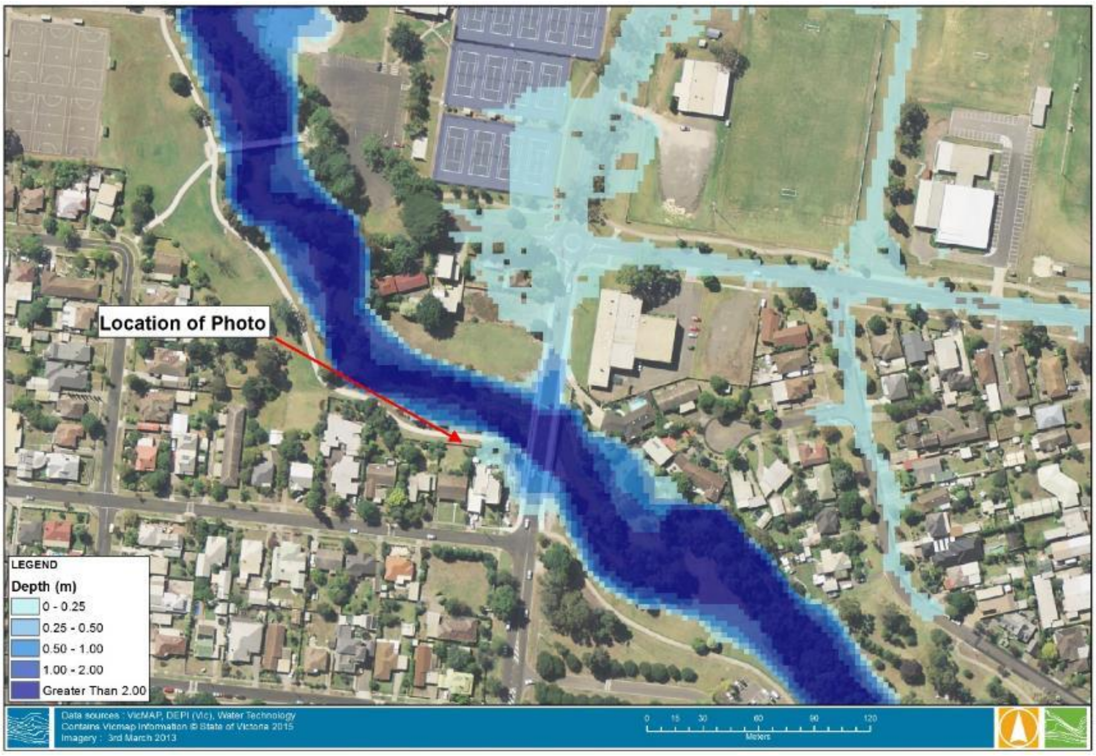

Figure 4-10 June 2013 Flood Depth Plot at Franklin Street

Figure 4-11 June 2013 Flood - Looking East towards Franklin Street Bridge

5. DESIGN FLOOD MODELLING

Utilising input from the RORB hydrological model and the revised flood frequency with the reduced 1993 peak flow, the design flood event was modelled for the 1% AEP flood event and a draft flood map produced, as shown in Figure 5-1. Prior to running out the remaining design events, sensitivity testing was completed for the Latrobe River tailwater along with the material roughness (Manning's n) values. The remaining design events were then ran out to allow mapping and flood damage assessment of all design events to be completed.

5.1 Hydraulic Sensitivity Analysis

Sensitivity analysis for the Traralgon Creek flood model was undertaken to assess the impact of the Latrobe River tailwater and the Manning's n roughness component. To assess the sensitivity of material roughness within the modelling, Manning's n values were increased by 20% as shown in Table 5-1. Figure 5-2 shows that the inundation extent relative to the original 1% AEP event (Figure 5-1) is virtually unchanged, however it is the relative differences in water levels that are important (Figure 5-3). In comparison to the existing roughness values used, there was an increase in water levels of 0.075 m on average higher than the existing results. As shown in Figure 5-3 increases in water levels were higher through the CBD between Shakespeare St and the Princes Hwy where velocities are higher due to the various constrictions in the floodplain. This test gives confidence that the model is not overly sensitive to the chosen Manning's 'n' values.

Table 5-1 Mannings n roughness values to assess roughness sensitivity

Material	Manning's n Roughness	Increased Manning's n Roughness (20%)
Residential (Town blocks)	0.300	0.360
Commercial / industrial buildings	0.350	0.420
Railway Line	0.200	0.240
Riparian fringe (moderate vegetation)	0.055	0.066
Waterway (moderate vegetation)	0.045	0.054
Farm/ grassed areas/ parks	0.040	0.048
Open waterways (no vegetation)	0.035	0.042
Local and major roads	0.020	0.024
Low Density Residential	0.060	0.072
Car Park	0.025	0.030

To assess the impact of the Latrobe River on flood levels in Traralgon Creek, the 1% AEP flow event for Traralgon Creek was modelled with two flow conditions of the Latrobe River obtained from the Latrobe River Flood Study (Cardno, 2013). The initial model used the 10% AEP water level and flow rate of the Latrobe River in conjunction with the 1% AEP conditions of Traralgon Creek, Figure 5-1. The second model used the 1% AEP Traralgon Creek event with the 1% AEP Latrobe River water level and flow rate, Figure 5-4. Figure 5-5 shows the difference in the two Latrobe River condition scenarios. This shows that the tailwater condition does not impact water levels upstream of the Gippsland Water waste water treatment pond. Levels within Traralgon are not impacted as a result of the increased tailwater and flow rate in the Latrobe River. On the basis of this sensitivity test, the hydraulic model was trimmed back to just Traralgon Creek, adopting a static water level as the downstream boundary representing the 10% AEP Latrobe River design levels. This allowed for faster run times for all design events without impacting the integrity of the modelling results.

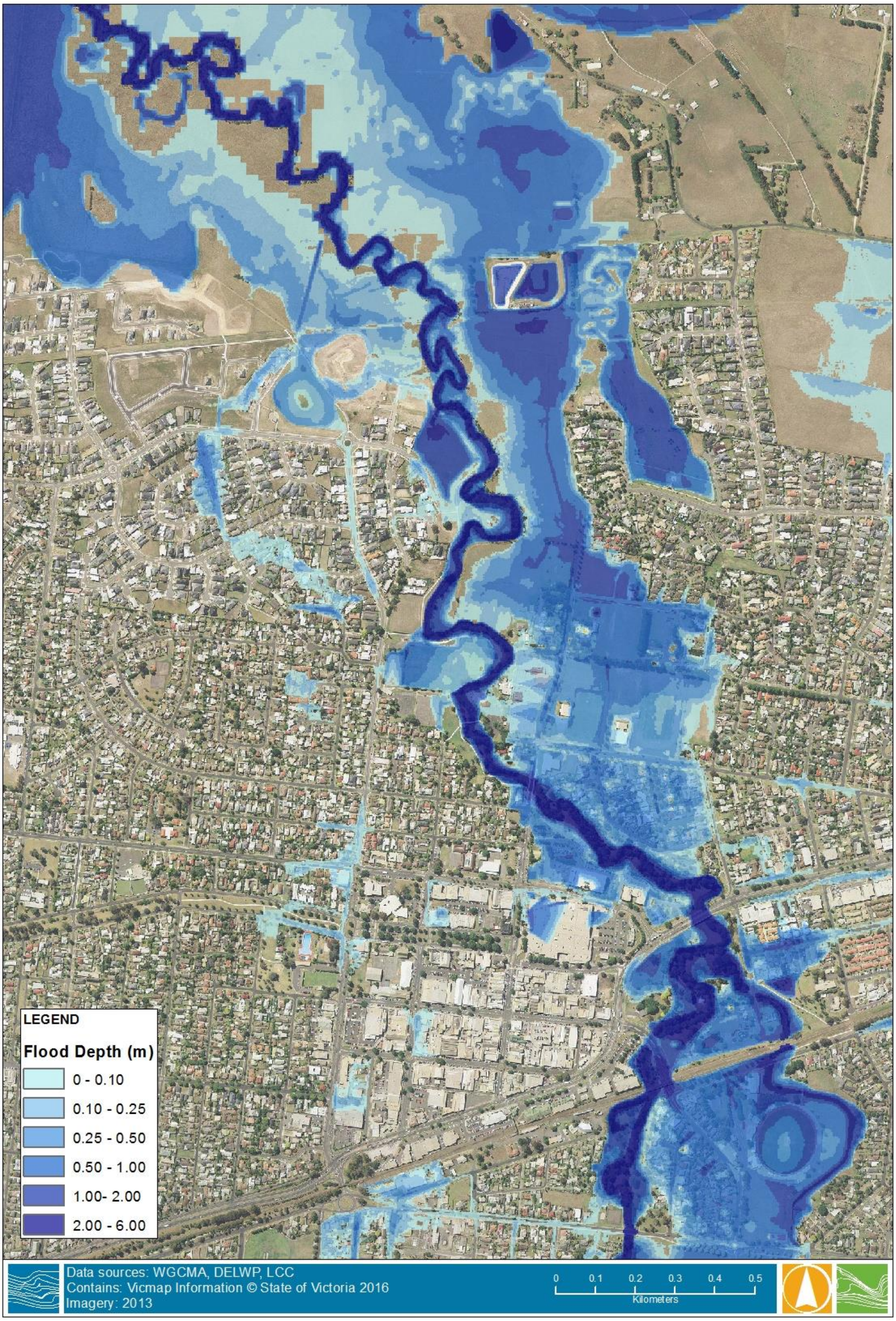

Figure 5-1 1% AEP Flood Depth

Figure 5-2 1% AEP Flood Depth with 20% increase in Manning's roughness

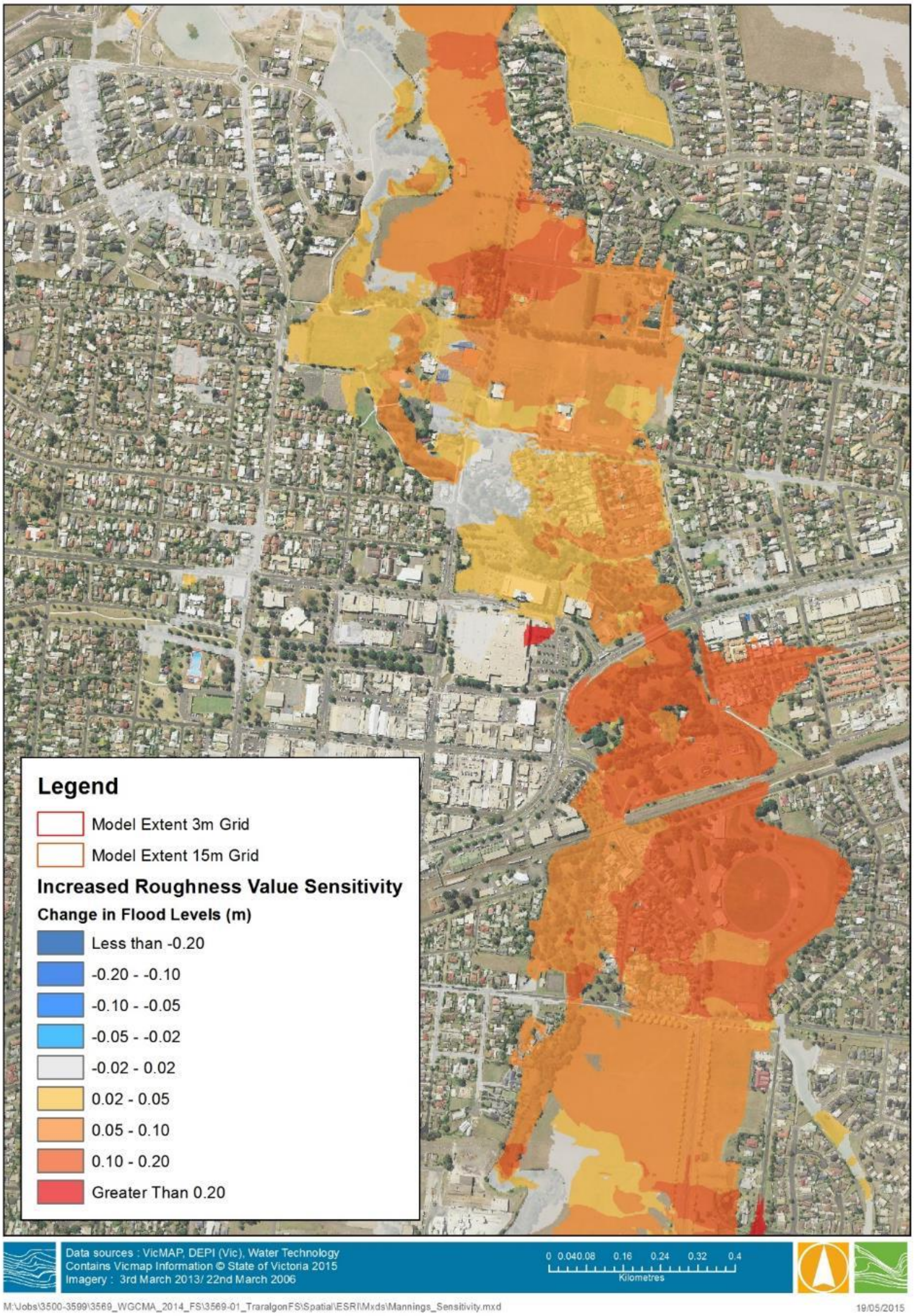

Figure 5-3 1% AEP Flood Depth difference plot with 20% increase in Manning's roughness

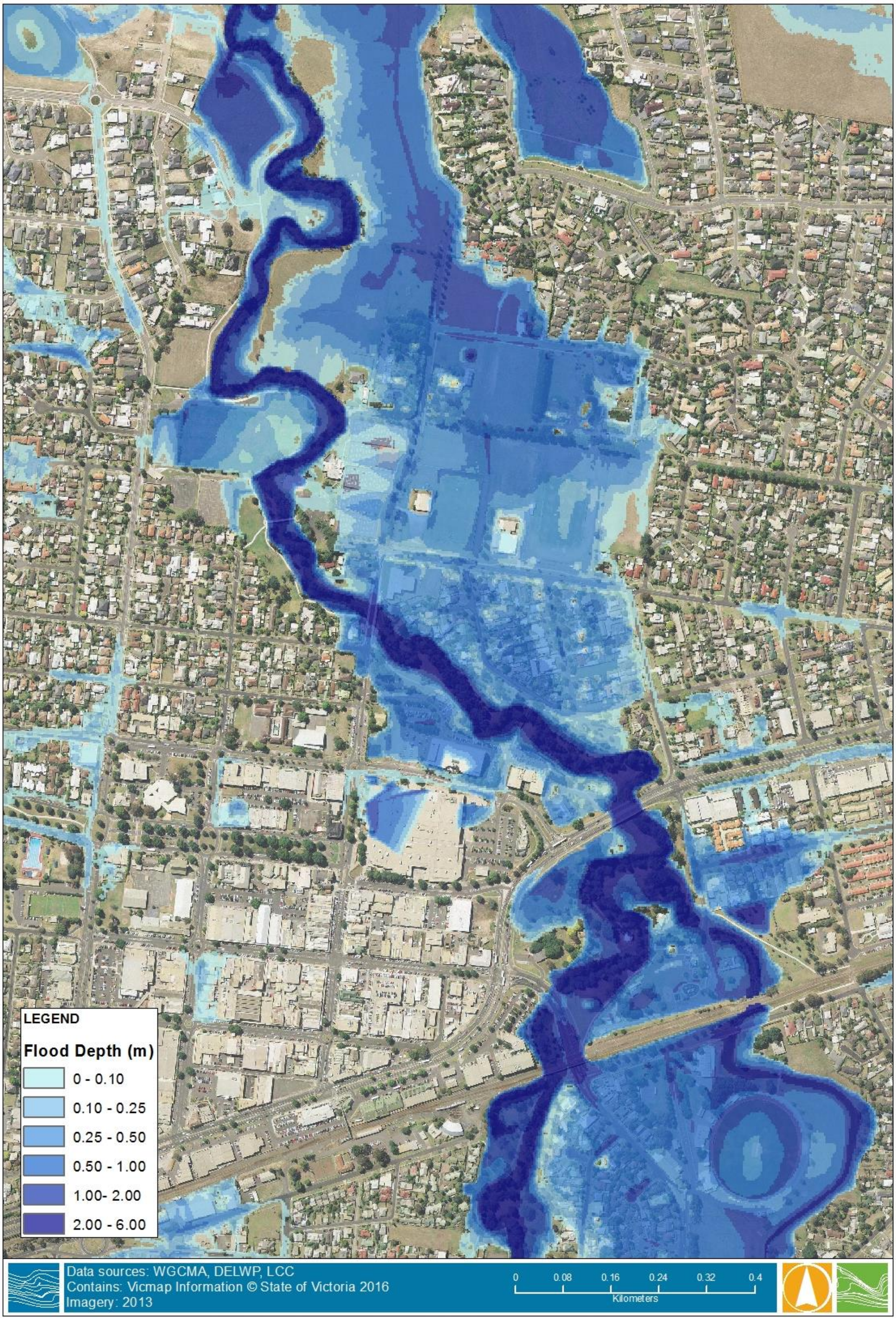

Figure 5-4 1% AEP Flood Depth with 1% Latrobe River flow

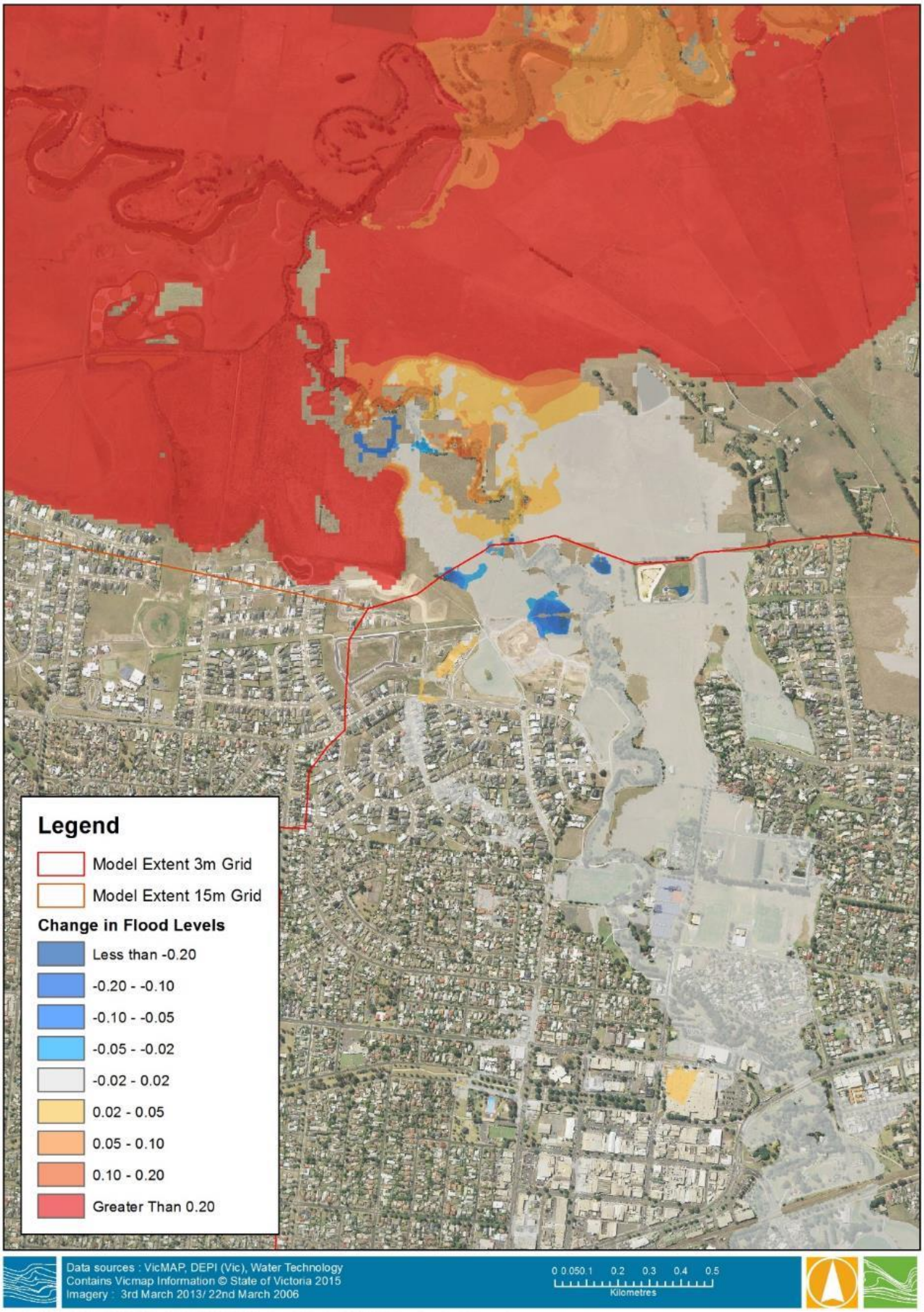

Figure 5-5 1% AEP Flood Depth difference plot with 1% AEP and 10% AEP Latrobe River flow

6. CONCLUSION AND NEXT STEPS

Water Technology believed that the calibration of the Traralgon Creek hydraulic model to available observations was good. Given the level of uncertainty in some of the older 1993 observations and the significant changes within the floodplain, the model calibration was deemed fit for purpose and the model suitable for modelling design conditions.

On the basis of the Latrobe River tailwater sensitivity analysis, Water Technology proposed to modify the existing hydraulic model. The sensitivity analysis undertaken showed that the impact of the tailwater level in the Latrobe River does not impact maximum water levels in Traralgon Creek upstream of the Gippsland Water waste water treatment pond. Therefore it was suggested to remove the Latrobe River component of the hydraulic model utilising a single domain model of 3 m grid resolution with a 10% AEP tailwater from the Latrobe River for the remaining design flood events. It is noted that for the 10% AEP design event, utilising a 10% flow in the Latrobe River is a conservative approach.

An alternative approach was to use a lower tailwater level in Traralgon Creek from a lower flow rate in the Latrobe River. The 2013 calibration event was presented as a suitable option to provide a lower tailwater level as it is not a significantly large flow in the Latrobe River. Adopting a single domain model approach reduced the model run times and allowed for quicker completion of the design runs without impacting the integrity of the modelling results or the outcomes for the West Gippsland CMA, Latrobe City Council and the Traralgon community.

On receiving approval from the West Gippsland CMA of the hydraulic model calibration and the recommendations of the sensitivity analysis, Water Technology completed the remainder of the hydraulic modelling of the design flood events. Flood damage assessment and modelling of several mitigation options were then carried out. The results of these can be found in the Traralgon Flood Study – Assess and Treat Risk Report (Water Technology 2016d).

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APPENDIX A – DESIGN FLOOD EVENT MAPS

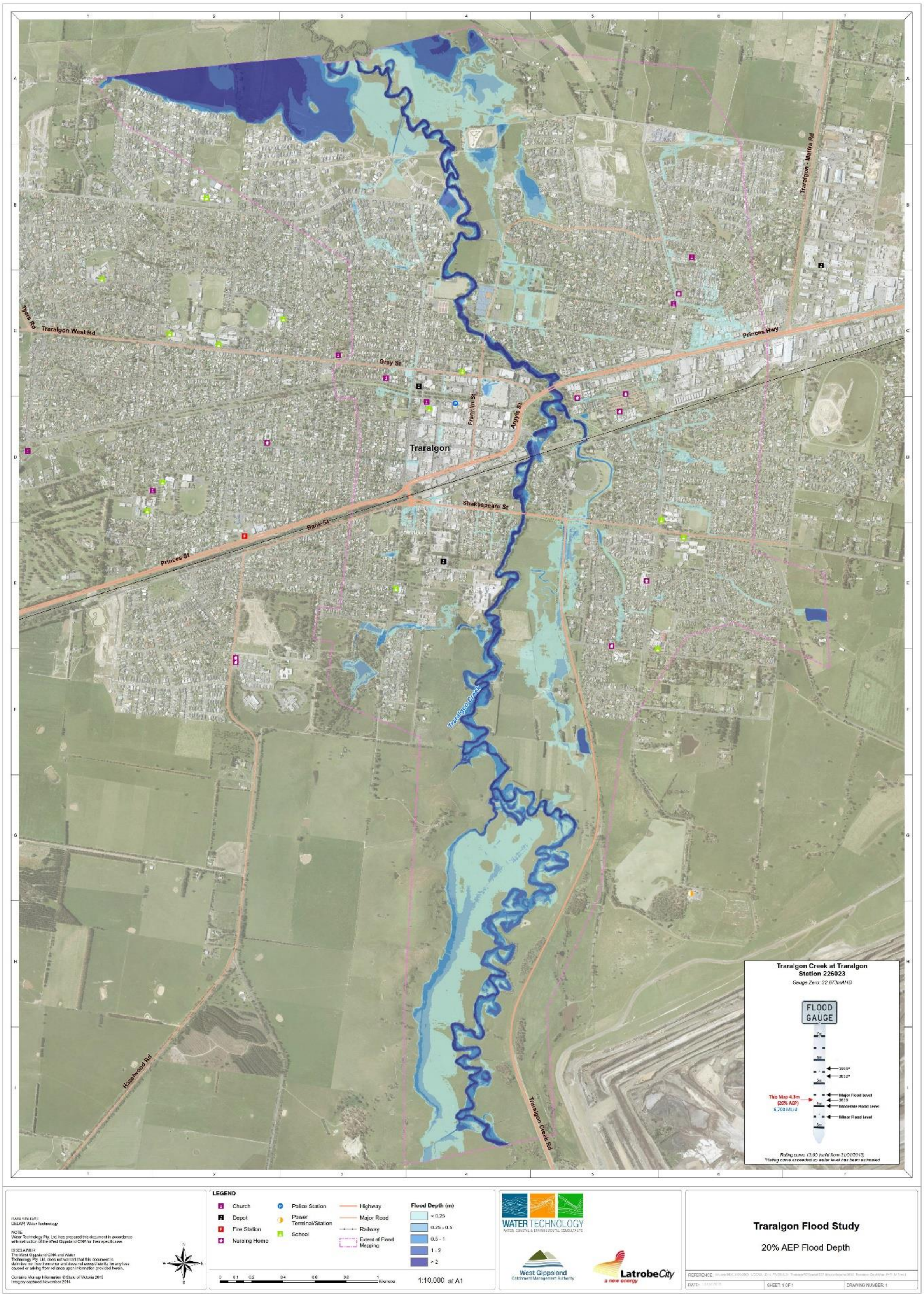

Figure A - 1 Maximum Flood Depth 20% AEP Flood Depth

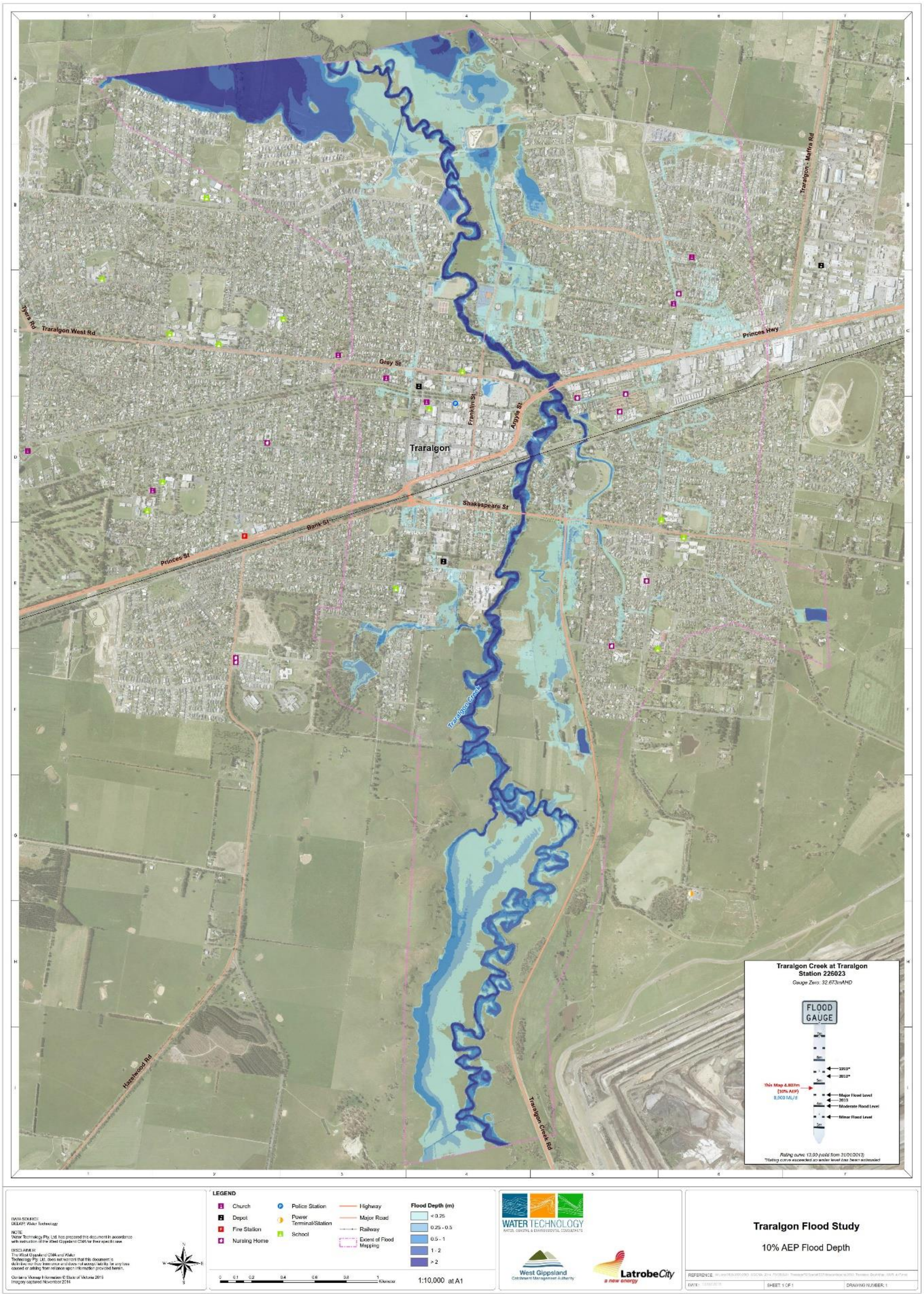

Figure A - 2 Maximum Flood Depth 10% AEP Flood Depth

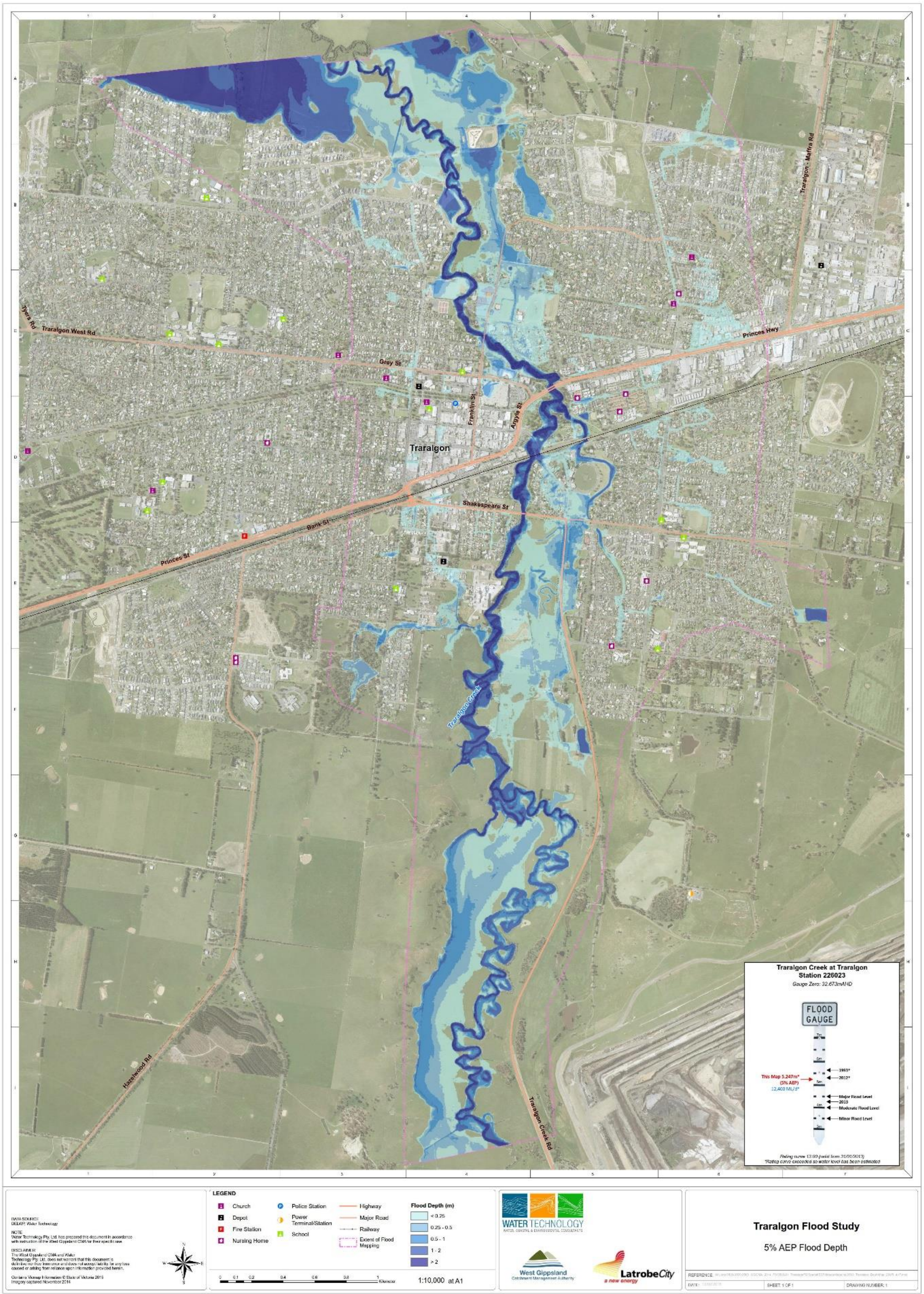

Figure A - 3 Maximum Flood Depth 5% AEP Flood Depth

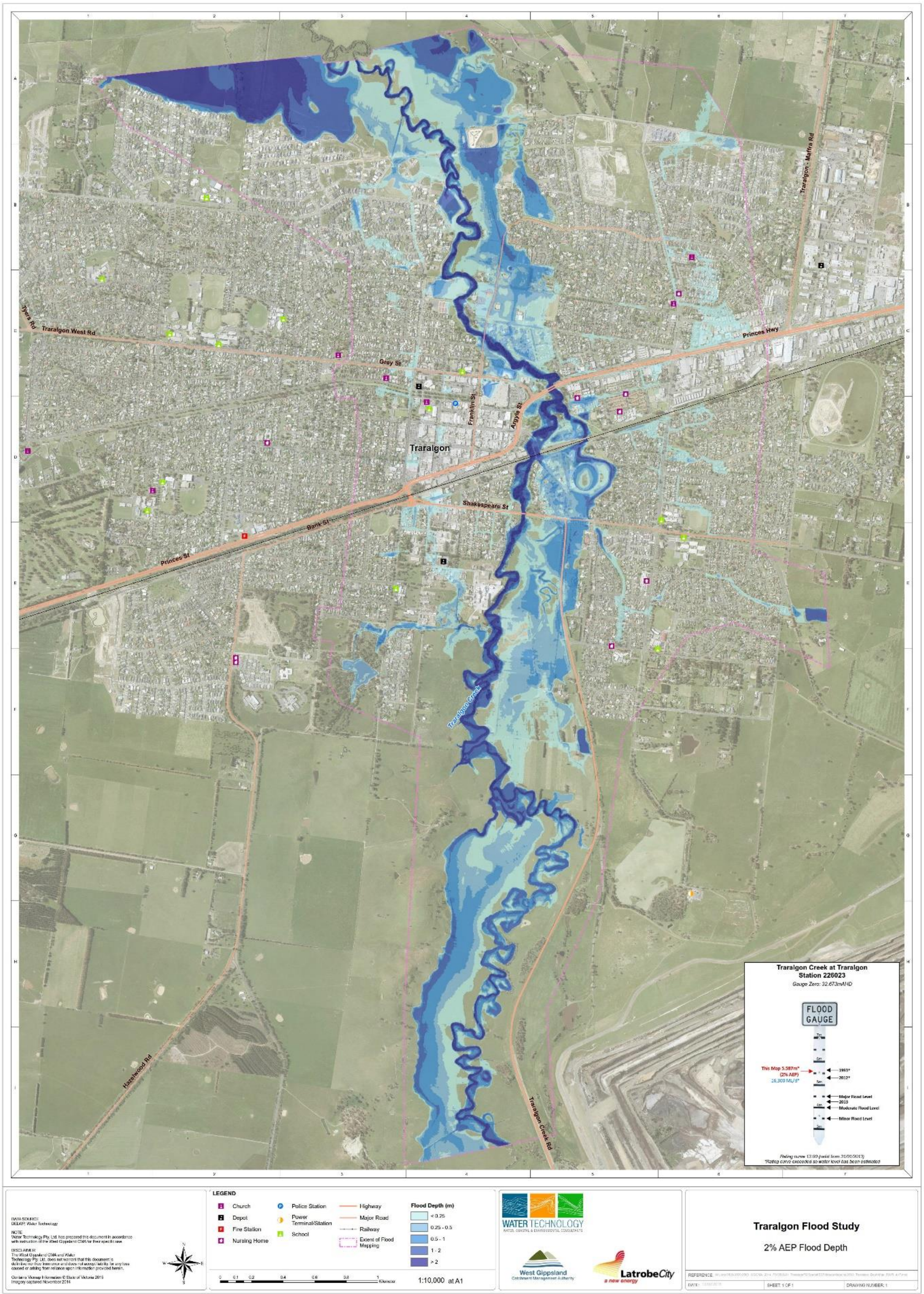

Figure A - 4 Maximum Flood Depth 2% AEP Flood Depth

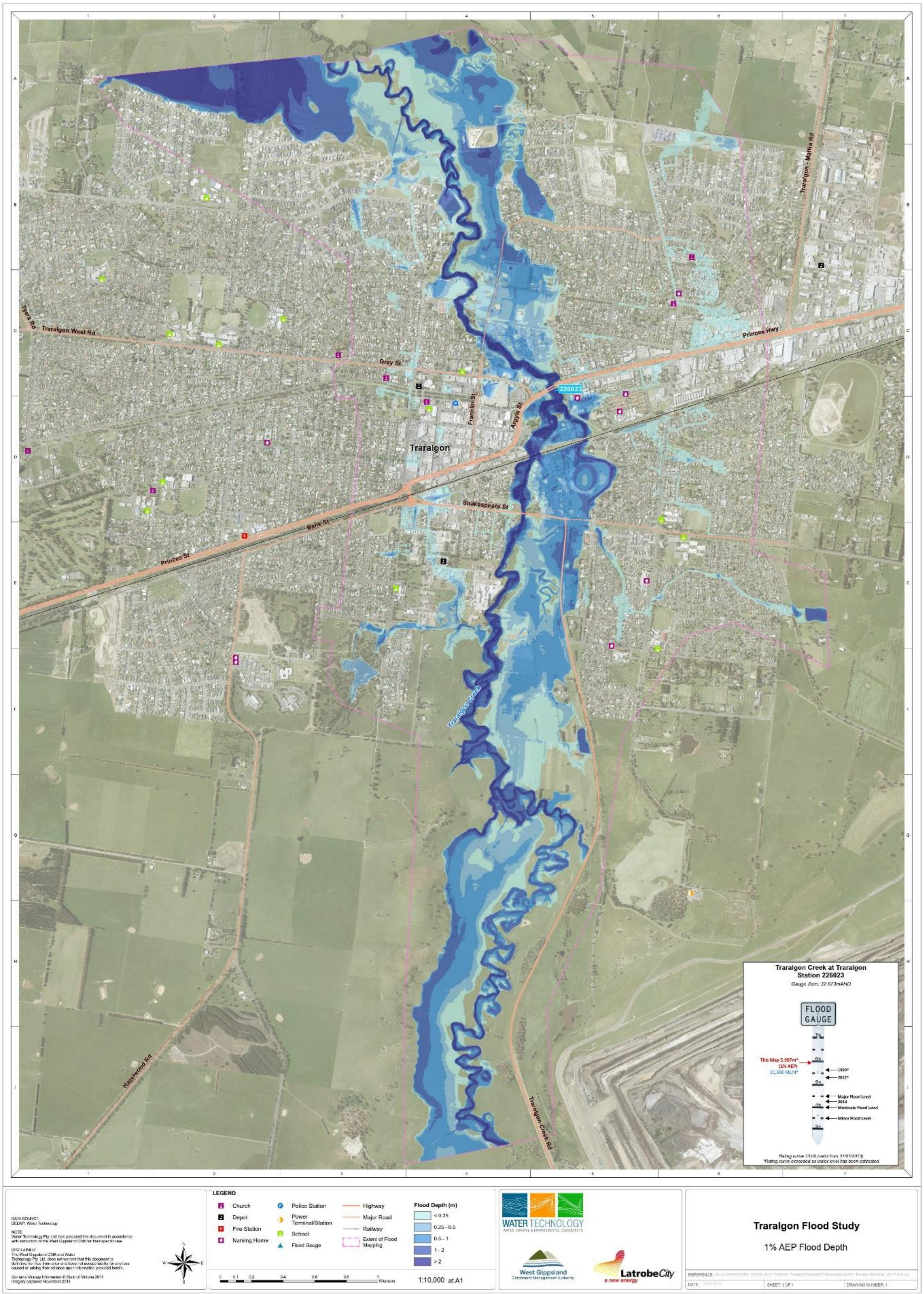

Figure A - 5 Maximum Flood Depth 1% AEP Flood Depth

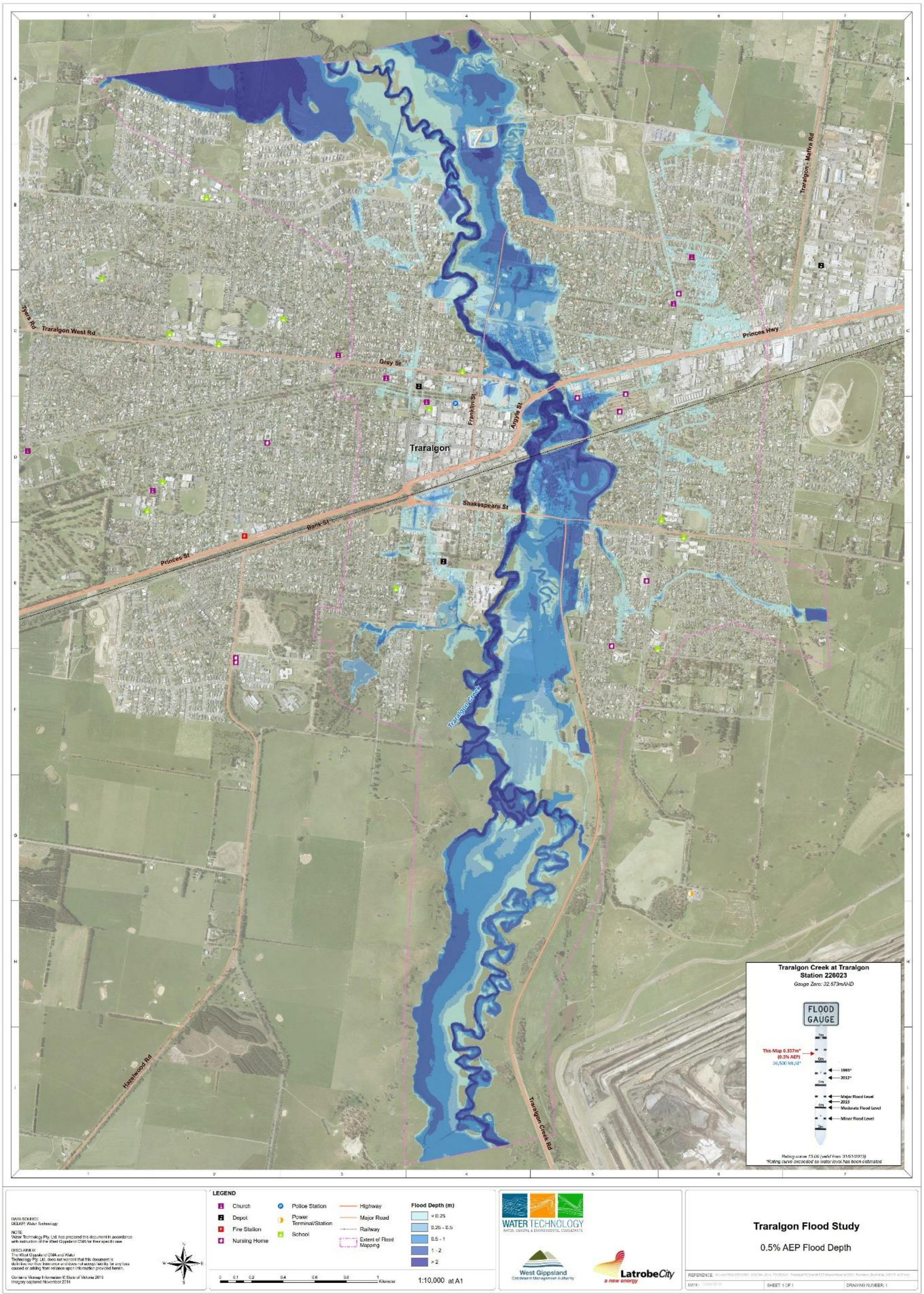

Figure A - 6 Maximum Flood Depth 0.5% AEP Flood Depth

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Traralgon Flood Study – Assess and Treat Risk (R04)

June 2016

VICTORIA State Government | Environment, Land, Water and Planning

LatrobeCity a new energy

West Gippsland Catchment Management Authority

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Client	West Gippsland Catchment Management Authority
Client Project Manager	Linda Tubnor
Water Technology Project Manager	Lachlan Inglis
Report Authors	Ben Tate, Lachlan Inglis
Job Number	3569-01
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Cover Photo: Traralgon CBD flooding, September 1993. Looking South-West towards the Princes Highway and Franklin Street.

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1. INTRODUCTION

Following the recent flood events affecting Traralgon during June 2007, July 2011, June 2012 and June 2013, Water Technology was commissioned by the West Gippsland CMA to undertake the Traralgon Flood Study. This study included detailed hydrological and hydraulic modelling of Traralgon Creek and the Latrobe River, flood mapping of Traralgon, recommendations for flood mitigation works, and a review of planning controls.

This report details the existing flood risk within the Traralgon area and a number of potential options to treat and reduce the flood risk. The Latrobe City Council Municipal Flood Emergency Plan (MFEP) was also updated at the same time as this report was written. Much of the information in this report is also contained within the MFEP. This report is one of a series of reports documenting the outcomes of the Traralgon Flood Study.

- R01 - Data Review Report (Water Technology 2016a)
- R02 - Hydrological Report (Water Technology 2016b)
- R03 - Hydraulic Report (Water Technology 2016c)
- **R04 - Assess and Treat Risk Report (Water Technology 2016d) – this report**
- R05 - Summary Report (Water Technology 2016e)

These five reports detail the approaches adopted, the findings and recommendations, of the Traralgon Flood Study. The five reports are supported by a number of standalone PDF flood maps and digital deliverables.

2. STUDY AREA

Traralgon is a regional city with over 30,000 permanent residents located approximately 150 km east of Melbourne. Traralgon Creek flows from the south off the Strzelecki Ranges to the north where it enters the Latrobe River. The city of Traralgon straddles Traralgon Creek immediately upstream (to the south) of the Latrobe River floodplain. The Loy Yang open cut coal mine lies to the south of the city on the eastern side of Traralgon Creek.

Traralgon Creek breaks its banks approximately 2.5 km upstream of Traralgon during medium to high flow events, creating an anabranch on the eastern side of the floodplain. This anabranch joins with local catchment drains and flows around the showgrounds forming Doorty Creek, eventually re-joining Traralgon Creek just upstream of the Princes Highway. The hydraulic model extent used for this study is shown in Figure 2-1.

This study initially incorporated the Latrobe River floodplain, to test the impact of the Latrobe River on flooding along Traralgon Creek. This is described in the Hydraulic Report (R03). The concurrent modelling of the Latrobe River and Traralgon Creek provided information to allow the Traralgon Creek model to be trimmed to a smaller model area for flood mapping purposes, concentrating on the Traralgon Creek itself. The Latrobe River was covered by an earlier study completed by West Gippsland CMA.

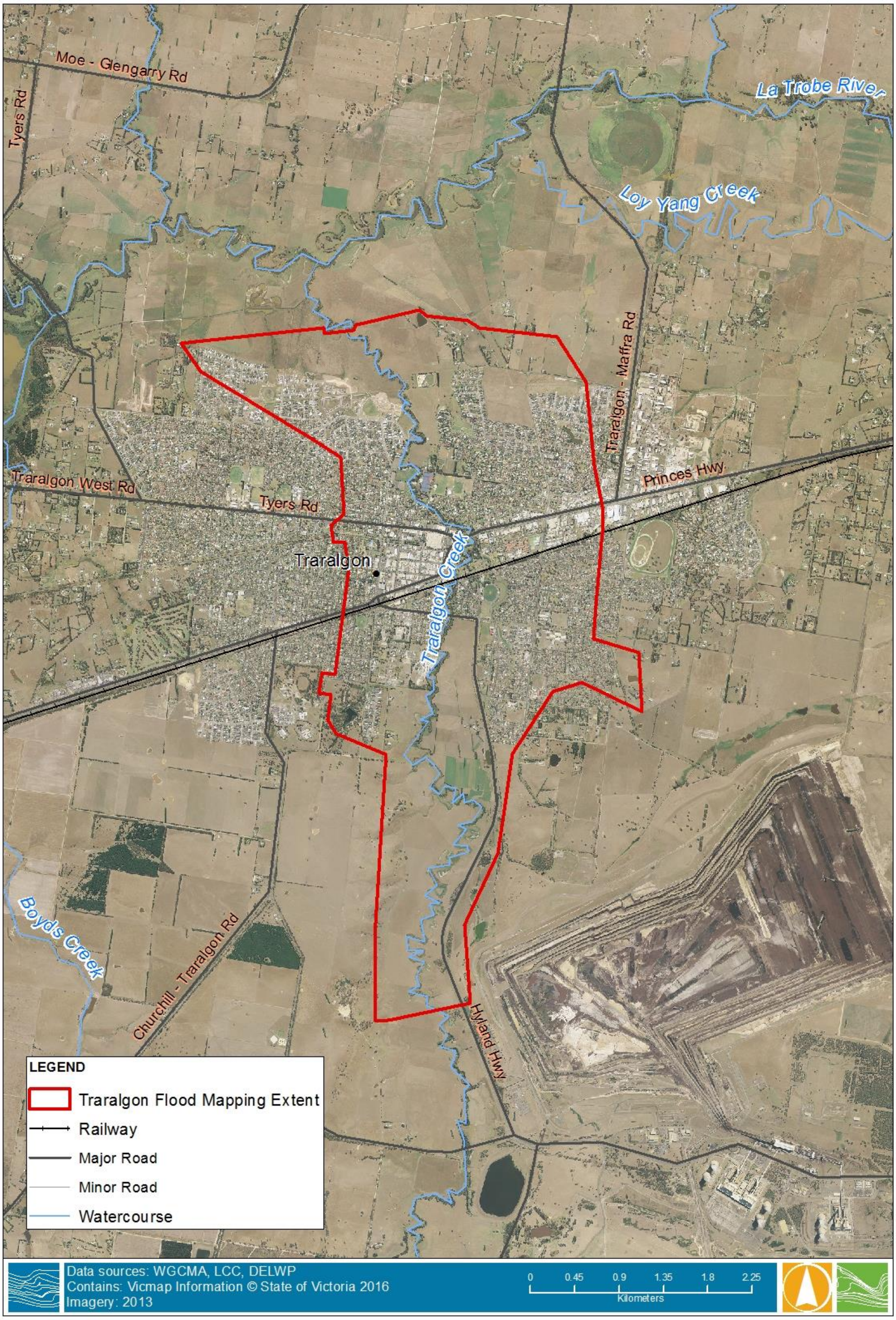

Figure 2-1 Hydraulic Model Extent

3. FLOOD INTELLIGENCE

Hydraulic model results from the Traralgon Flood study has allowed for further enhanced flood intelligence to be added to the current understanding of flood behaviour through Traralgon.

Out of bank flooding throughout Traralgon can occur in a number of locations and in some locations is a common occurrence. As flows in Traralgon Creek increase some out of bank flooding appears initially through Victory and Newman Park in the city centre. Flooding also occurs upstream of Shakespeare Street and then extends over Shakespeare Street, through the recreation reserve and along Whittakers Road. As flood levels increase, breakouts appear at the Franklin Street bridge, where water runs north past the Traralgon Tennis Centre and into the Harold Preston Reserve, and at the same level also inundates the Agnes Brereton Park.

The streamflow gauge at Traralgon (Traralgon Creek at Traralgon #226023) is used to set flood warnings in Traralgon. Currently the minor flood level is set at 3.50 m depth, moderate flood level 4.00 m and a major flood level of 4.50 m. Table 3-1 shows where the minor, moderate and major levels sit compared with the design and historic flood events.

Table 3-1 Traralgon Creek Stream Flow Gauge and Design Flood Levels

Flood Event	Gauge Height (m)	Water Surface Level (m AHD)
0.5% AEP	6.36	39.03
1% AEP	5.99	38.66
1993	5.66	38.33
2% AEP	5.59	38.26
2012	5.32	37.99
5% AEP	5.25	37.92
10% AEP	4.81	37.48
Major Flood Level	4.50	37.17
20% AEP	4.30	36.98
2013	4.30	36.97
Moderate Flood Level	4.00	36.67
Minor Flood Level	3.50	36.17

Figure 3-1 below provides the flood extents for a selection of design events across the range of events modelled. This provides a sense of when various thresholds are reached and flood waters may break out and impact various areas. Table 3-2 provides a description of the general flood behaviour of various flood magnitudes and the consequence for Traralgon. For a given flood height the consequences likely to be experienced include all the consequences described for the smaller events in the above rows of the table. The table should therefore be read from top down.

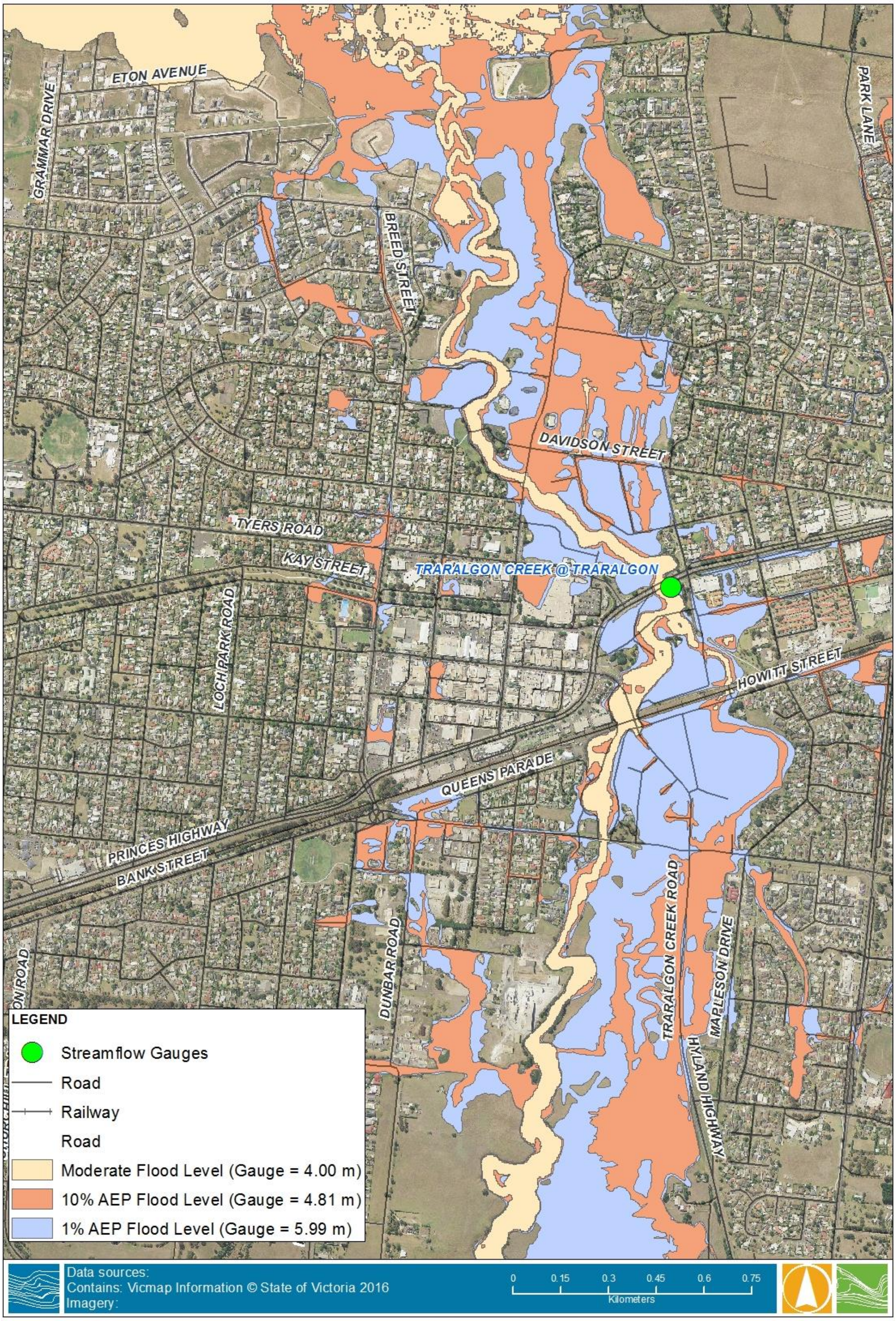

Figure 3-1 Traralgon Creek Flood Extents for Selected Design Flood Levels

When using Table 3-2 to identify particular consequences for a given flood event, the reader should read all rows of consequences above the selected magnitude design event.

Table 3-2 Design flood events and associated flooding areas

Flood Class Level	Design Event	Modelled Flood Height at Traralgon Gauge (m)	Flood Consequences
Minor (3.50 m)	<20% AEP	4.00	Bert Thompson Reserve, Victory and Newman Park may experience some flooding
Moderate (4.00 m)	20% AEP	4.30	Franklin Street and Whittakers Road bridges are close to overtopping, railway Underpass flooded
	2013 Historical Flood	4.30	
Major (4.50 m)	20% to 10% AEP	4.50	Shakespeare St, Peterkin St overtop
	10% AEP	4.81	Gwalia Street flooded Some breakout flooding along George Street and significant flooding along Franklin Street. Area upstream of Shakespeare Street likely to flood and overtop Traralgon Creek Road Paul Street Flooded ASIC building carpark flooded **Number of properties flooded above floor = 1**
	5% AEP	5.25	Traralgon Creek Road overtopped and significant flooding along Whittakers Road (including Milton Court, Moonabeal Court and Tennyson Street) and Howitt Street, including some properties flooded above floor George, Franklin, Berry and Davidson Street significantly impacted (including Willow Court) ASIC building on Grey Street likely to be inundated Properties at Phelan Street likely to completely flooded **Number of Residential properties flooded above floor = 8** **Number of Commercial properties flooded above floor = 5**
	2% AEP	5.59	Recreation Reserve flooded and further flooding along Shakespeare Street Stockland Shopping centre carpark flooded, Grey Street (Tyers Road overtopped) Properties along Munro Street and Peterkin to be flooded

			George, Franklin, Berry and Davidson Street significantly impacted (including Willow Court) flooded above floor Atherley Street properties flooded Widespread flooding above floor throughout Traralgon **Number of properties flooded above floor = 29** **Number of Commercial properties flooded above floor = 11**
	1% AEP	5.99	Atherley Street and Harney Place likely to flooded (including some above floor) Further properties on Tennyson Street flooded above floor Gwalia Street Flooded Princess Highway inundated on westbound lane (at Post Office Place) **Number of properties flooded above floor = 90** **Number of Commercial properties flooded above floor = 13**
	0.5% AEP	6.36	Properties along Gwalia Street Flooded Princess Highway Overtopped Post Office Place CBD inundated around Post Office Place & Grey Street Chisholm Court, Le Grange, Alfred Close, Latrobe Crescent Flooded Mapleson Drive likely to be cut off Bradman Boulevard, Waterford Court, Oxford Place, Bowral Way Flooded **Widespread residential and commercial properties flooded above floor.** **Number of properties flooded above floor = 154** **Number of Commercial properties flooded above floor = 16**

3.1 Flood Risk

Flood Risk is the product of the likelihood of a certain event and the consequence of that event occurring. To assess the flood risk within Traralgon, the hydraulic modelling design outputs (depth, velocity and flood hazard mapping) can be used to identify both the likelihood of the event happening (in terms of annual exceedance probability) and the consequence of such an event happening. Depth maps are useful in showing the areas impacted by the flooding, while the velocity and flood hazard mapping provides more detail for the areas which pose a higher consequence. Flood hazard is based on a criteria including depth, velocity and depth x velocity and is explained further below. The high and low flood hazard areas for the 1% AEP flood event is shown in Figure 3-2.

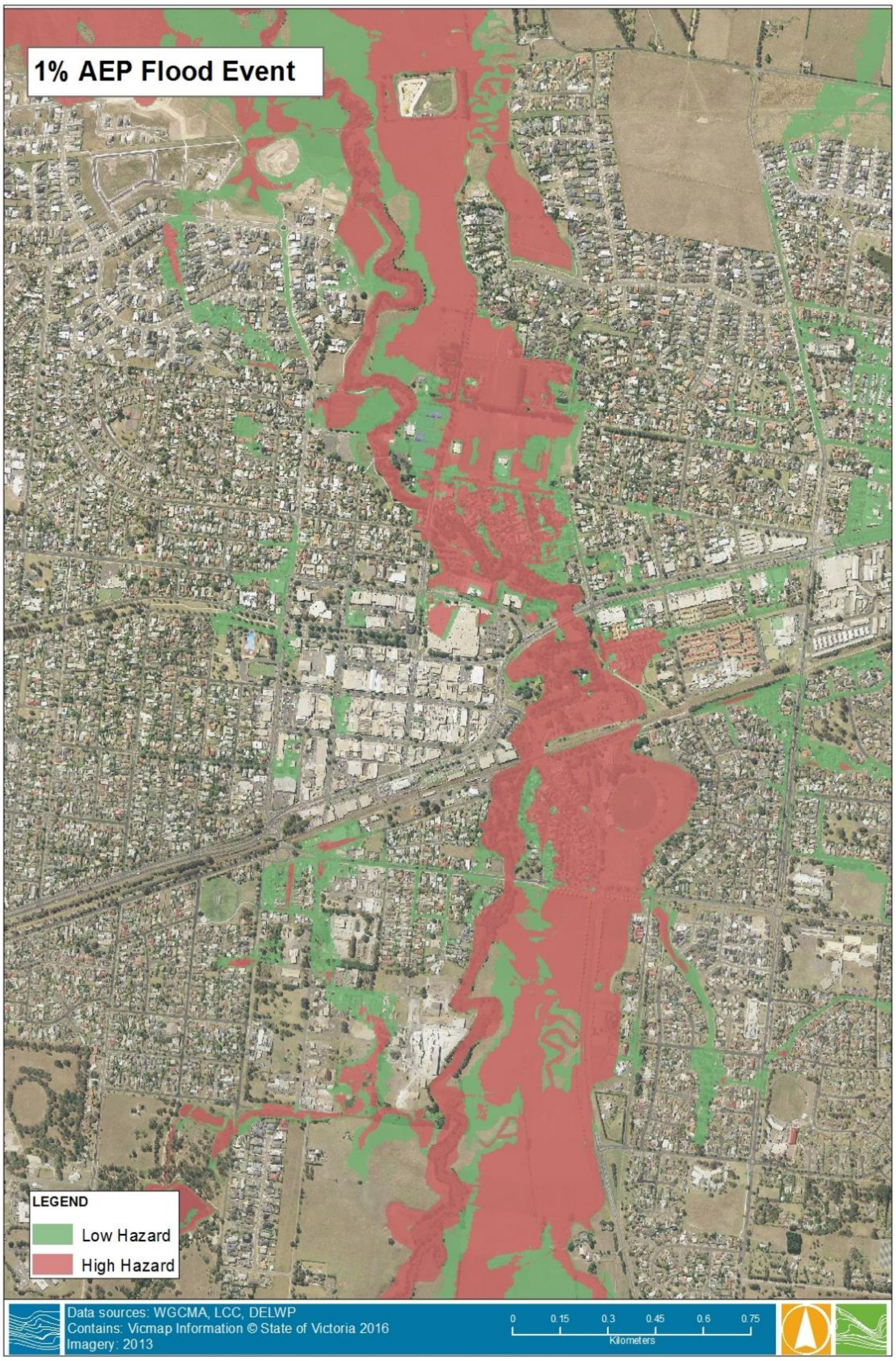

Figure 3-2 Flood Hazard for 1% AEP Flood Event

When considering the emergency response for Traralgon during a flood event, it is important to consider the areas that are flooded first within the city and growth areas, not just areas of high consequence (high hazard). Areas first flooded are often areas that have a higher likelihood of occurring and will occur at lower flow rates. A plot of the flood hazard categories for a 10% AEP flood event is shown in Figure 3-3. This plot highlights that for a 10% AEP flood event, the majority of the high hazard areas are located within or immediately adjacent to the Traralgon Creek channel.

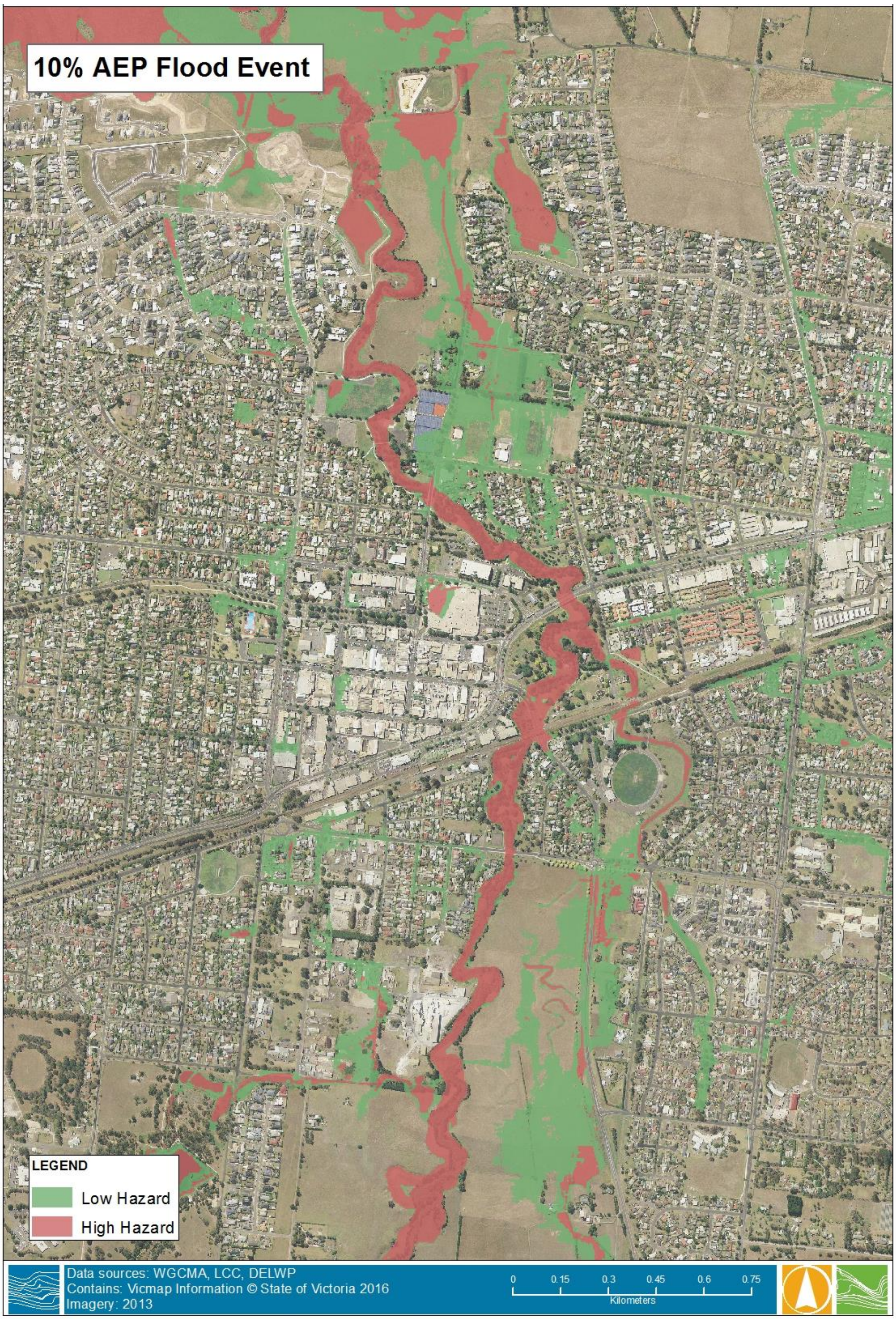

Figure 3-3 Flood Hazard for 10% AEP Flood Event

3.2 Flood Warning

Currently flood warnings in Traralgon are issued based on the gauge height at the Traralgon Creek streamflow gauge immediately upstream of the Princes Highway. The three existing flood class levels are listed below:

- Minor – 3.50 m
- Moderate – 4.00 m
- Major – 4.50 m

These flood heights provide warnings to residents in Traralgon that impacts from flooding are likely to occur once these levels have been exceeded. Table 3-1 highlights where each of the flood levels sits in terms of historical flooding and expected design event flooding. The Moderate Flood Class Level extent is shown in Figure 3-4. Shakespeare and Whittakers Road are overtopped, however there is minimal property damage at this level. Once the Major Flood Class Level is reached extensive flooding through residential and commercial areas of Traralgon can occur. Table 3-2 provides more detail of the flood impacts at the three Flood Class Levels and for design events beyond a Major Flood Class Level.

Figure 3-4 Approximate Moderate/Major flood level extent

Two streamflow gauges on Traralgon Creek are located upstream of the Traralgon (Traralgon South and Koornalla) providing valuable information on the approaching flood flows upstream of Traralgon. This information can be used to provide a warning for an approaching flood to the city. The time between peak flows at the three gauges can provide a good indication of the travel time, therefore indicate warning time. Table 3-3 shows that the time between peak flows at the Koornalla gauge and Traralgon gauge is shown to be around 6 hours for several historic flood events, while the largest flow (1993) had a shorter travel time between peaks at approximately 4 hours.

While Table 3-3 shows the time between peak flows at the streamflow gauges, flood impacts in Traralgon can occur well before the flood peak arrives at the Traralgon gauge. The 1993 flood started breaking out of bank and causing flood damage around 5-6 hours before the peak flow was recorded at the Traralgon gauge, the 2012 was similar in that it broke out of bank and along streets 5 hours prior to the flood peak. The timing of the first out of bank flooding is important to consider for emergency response procedures such as road closures, sandbagging and if required, evacuation.

Table 3-3 Historical Travel Time between Flood Peaks (based on gauge flows)

Historical Event	Time from Peak at Koornalla to Peak at Traralgon South	Time from Peak at Traralgon South to Peak at Traralgon	Time from Peak at Koornalla to Peak at Traralgon
1993	N/A	N/A	~ 4 Hours
1995	N/A	N/A	~ 6 Hours
2012	~ 3.5 Hours	~2.5 Hours	~ 6 Hours
2013	~ 3.5 Hours	~ 3.5 Hours	~ 7 Hours

While the streamflow gauges at Koornalla and Traralgon South can provide 4-6 hours of warning time of an approaching flood, analysing the rainfall falling throughout the catchment can also provide a rough estimate of the expected flood magnitude. To enable sufficient warning time for residents interpretation of the rainfall should be undertaken and communicated has a 'heads up' for a potential flood event. This is essentially the service the Bureau of Meteorology provides through their Flood Watch service, although this is conducted typically 24 to 36 hours prior to any flooding being experienced, and is based on a combination of prior rainfall and a prediction of likely rain soon to follow. Antecedent conditions throughout the catchment will play a major role in how much of the rainfall fallen in the catchment is converted to runoff. Historical rainfall totals and flood events along with design rainfall totals and design flood magnitudes are shown in Table 3-4. The design rainfall totals were adopted from the 'new IFD's' developed in 2013 from the Bureau of Meteorology (BoM) for the three locations. It is understood that at the time of writing this report that these IFD values may be subject to change in the near future.

Across the catchment, the rainfall totals vary considerably. The lower elevation valley floor around Traralgon itself shows far lower design rainfall totals than the upper catchment around Mt Tassie. It is useful to note that while using the rainfall totals to estimate a flood event magnitude, there are a number of factors that should be considered including where the rainfall falls within the catchment, the intensity of the storm, and the antecedent conditions of the catchment.

Table 3-4 Rainfall Totals at Traralgon and Design Flood Magnitude

Flood Event	Traralgon Gauge Height (m)	Rainfall Total (mm)			Rainfall Duration (Hours)
		Traralgon	Koornalla	Mt Tassie	
1% AEP	5.99	160.1	200.5	308	36 Hours
1993	5.66	54	85	267	36 Hours
2% AEP	5.56	138.8	173.2	266.1	36 Hours
2012	5.32	42	97.4	204	24 Hours
5% AEP	5.25	113.5	141.0	215.9	36 Hours
10% AEP	4.81	96.1	118.8	181.2	36 Hours
20% AEP	4.30	79.8	98.1	148.5	36 Hours
2013	4.30	71.8	106.8	246.6	72 Hours

During the steering committee meetings undertaken, it was identified that a possible outcome from the project would be to install a streamflow gauge between the existing gauges at Traralgon South and Traralgon. The benefits of the additional gauge would provide further redundancy to the existing streamflow gauges as well as better information on the approaching peak flow rate. While adding the additional streamflow gauge does provide some benefit to the information available, the cost of installation and maintenance of the gauge may be better spent elsewhere. The existing streamflow gauges at Koornalla and Traralgon South can be used to identify the likely magnitude and timing of a flood in Traralgon. Given the short travel times between the Traralgon South and Traralgon streamflow gauges, an additional gauge between the two will provide no added benefit.

3.3 Land Use Planning

The Victoria Planning Provisions (VPPs) contain a number of 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), the Urban Floodway Zone (UFZ) and the Environmental Significance Overlay (ESO).

Section 6(e) of the Planning and Environment Act 1987 enables planning schemes to 'regulate or prohibit any use or development in hazardous areas, or likely to be 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 Planning and Community Development's (DPCD) Practice Note on Applying Flood Controls in Planning Schemes.

Planning Schemes can be viewed online at http://planningschemes.dpcd.vic.gov.au/home. It is recommended that the planning scheme for Traralgon be amended to reflect the flood risk identified by this project. Edwin Irvine of Planning and Environmental Design undertook a detailed review of the Latrobe planning scheme in relation to flood risk at Traralgon and made a number of recommendations contained in a separate standalone document. These recommendations are summarised in the Summary Report (R05).

The method used to delineate the proposed FO is broadly based on the new Australian Rainfall and Runoff Project 10 'Appropriate Safety Criteria for People'. Criterion for delineating the FO considers both vehicle and people safety, and are as follows, based on the 1% AEP flood:

- Depth > 0.3 m
- Velocity > 1.5 m/s
- Depth x velocity > 0.3 m^2/s.

The West Gippsland CMA have approved development guidelines which adopt a depth threshold of 0.30 m for safety requirements, and as such the FO has been defined using the above criteria

The LSIO includes the area outside of FO and bounded by the 1% AEP flood extent. Small disconnected puddles such as farm dams and stormwater flooding were removed from the overlays. Figure 3-5 shows the proposed FO and LSIO maps based on the criteria adopted by the West Gippsland CMA.

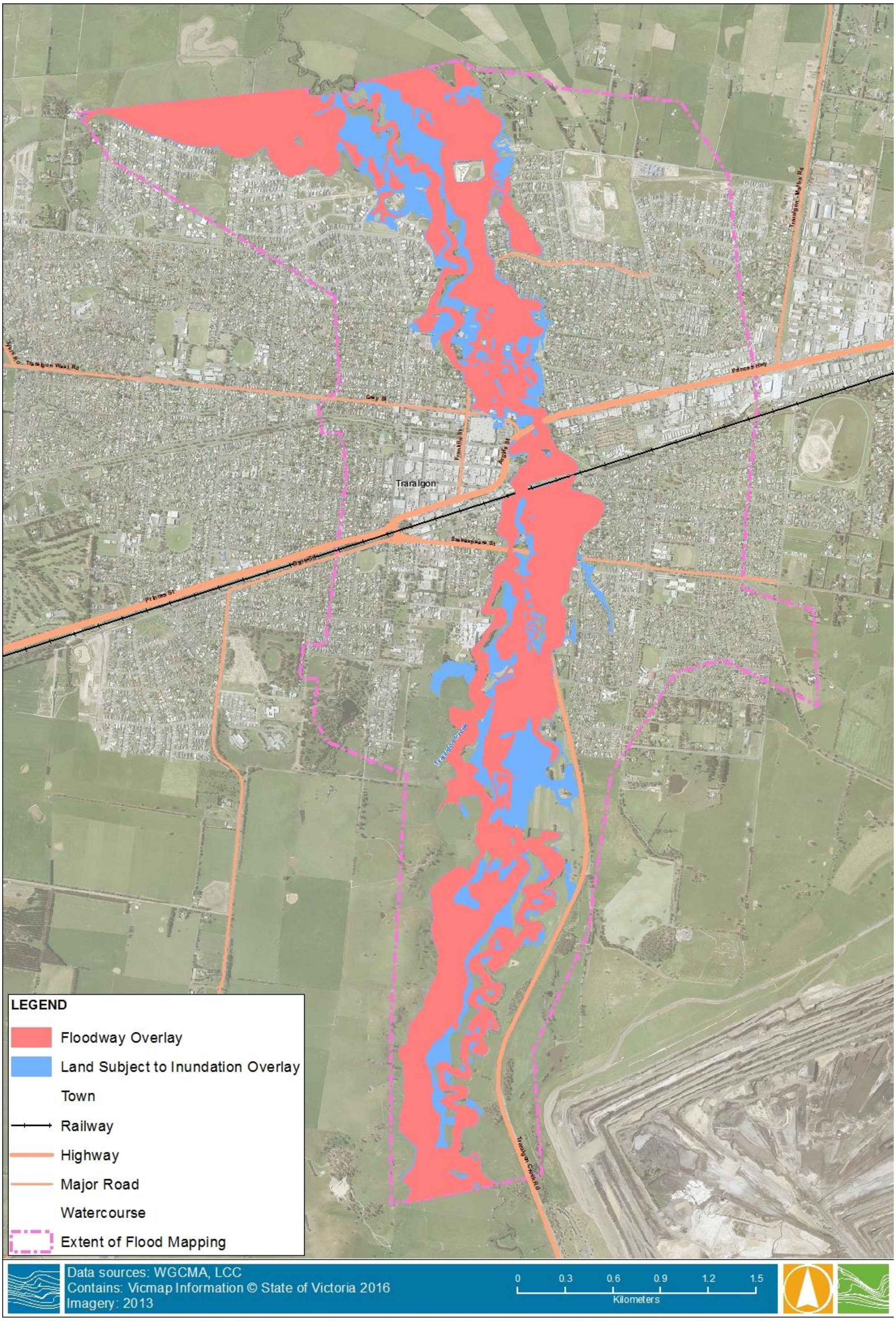

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Figure 3-5 Draft LSIO and FO Map for Existing Conditions

4. MITIGATION

Four mitigation options were presented to the steering committee and at a community meeting held in September 2015. The four options are listed below, however are covered in more detail later in this section.

1. **Traralgon Bypass Embankment** – the construction of a retarding basin upstream of Traralgon at the location where a proposed bypass is planned. This aims to provide a significant reduction in large out of bank flows through Traralgon.
2. **Whittakers Road Levee Scheme** – A permanent levee with a number of temporary barriers placed around a group of residential properties from Shakespeare Street along to the railway embankment.
3. **Floodway works downstream of Phelan St** – using earthworks to provide a more efficient floodway downstream of Phelan St. This aims to increase the efficiency of water getting through the northern end of the city during out of bank flood events.
4. **Removal of the Water Treatment pond downstream of Traralgon** – The removal or realignment of a water treatment pond at the northern end of the Traralgon Creek floodplain. This would increase the efficiency of water travelling on the Traralgon Creek floodplain onto the Latrobe River floodplain.

The feedback provided from the options was generally positive, most people agreed that any options that provided a reduction in flooding in the city should be investigated.

4.1 Prefeasibility Assessment

The four mitigation options listed above were assessed against a number of criteria: potential reduction in flood damage, cost of construction, feasibility of construction, and environmental impact. This method is a tool developed by Water Technology and used across all flood studies to compare a number of mitigation options against each other when determining which options to recommend for conceptual modelling and investigation. The score for each criterion was based on a ranking system of 1 to 5, with 1 being the worst score and 5 the best. Each criteria score was then weighted according to the weighting shown in Table 4-1. The reduction in flood damage was the most heavily weighted criteria as this is the main objective for all flood mitigation. Table 4-2 reviews and scores each mitigation option against the four criteria and calculates a total score for each option by summing each weighted criteria score. The options with the higher scores indicate the more appropriate mitigation solutions for Traralgon.

Table 4-1 Ranking score for mitigation criteria

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

Using the prefeasibility assessment above, the four identified mitigation options are listed in order of total weighted score as seen in Table 4-2. The Traralgon Bypass Embankment option and the Whittakers Road levee scheme scored the highest.

Table 4-2 Mitigation option prefeasibility results

No.	Mitigation Option	Criteria				
		Damage Reduction	Cost	Feasibility/ Constructability	Environmental Impact	Score
1	*Traralgon Bypass Embankment*	5	1	2	1	12.5
2	*Whittakers Rd Levee Scheme*	4	1	2	3	11.5
4	*Removal of Water Treatment Pond*	2	3	3	4	10.5
3	*Phelan St Levee Removal/Floodway*	2	3	3	2	9.5

4.2 Structural Mitigation Options Modelled

Preliminary modelling was undertaken to assess the potential for proposed mitigation options. Three scenarios were modelled, these are listed below and covered in more detail in subsequent sections.

- Traralgon Bypass Embankment
- Whittakers Road Levee Scheme
- Floodway works downstream of Phelan St and removal of water treatment pond

The removal of the water treatment pond was modelled in conjunction with the Phelan Street floodway works. Initial modelling suggested that both these options had minimal impact on flood levels in residential areas if undertaken individually.

In modelling all these options, the approach was to start with extreme changes to determine if the proposed option could achieve a significant outcome in regards to a reduction of flooding. Mitigation options were then refined (and downscaled) to a more practical option accordingly.

The mitigation works were costed based on a number of key references:

- Melbourne Water's standard rates for earthworks and pipe/headwall construction costs
- Rawlinsons Australian Construction Handbook Rates (Rawlisons, 2011)
- The United Kingdom Environmental Agency Temporary and Demountable Flood Protection Guide (EA UK, 2011)
- Comparison to cost estimates for similar mitigation works for other flood studies undertaken by Water Technology

4.2.1 Traralgon Bypass Embankment

A proposed bypass around the city of Traralgon has been previously identified as a future project by VicRoads. The proposed bypass route currently crosses the Traralgon Creek approximately 3 km upstream of the CBD near the Loy Yang Open Cut Coal Mine. The area where the crossing is proposed is currently used for agriculture and is within the 1% AEP flood extent, a depth plot of existing conditions is shown in Figure 4-1. Existing plans produced by VicRoads have a clear span bridge approximately 60 m in length crossing over the Traralgon Creek with the road on top of a major embankment across the rest of the floodplain.

The opportunity to utilise the proposed bypass as a means of retarding flow upstream of Traralgon within the floodplain was initially modelled to reduce a flood event of the 1993 flood magnitude back to 10% AEP flood magnitude through the city. Initial modelling at a lower resolution showed that by placing an embankment of around 8-9 metres high and placing several culverts at the Traralgon Creek, the flow through Traralgon could be maintained within channel, significantly reducing the flood impact to residential properties in a flood event similar to the 1993 event. Given the proximity of the bypass route to the Loy Yang Open Cut Coal Mine, the current operator AGL Energy Limited (AGL) would be required to be involved in consultation in pursuing this option. Several dams upstream of the proposed bypass route are currently operated by AGL and would need to be considered when assessing the construction of a bypass/embankment in the downstream vicinity.

A separate project was commissioned by the West Gippsland CMA that modelled the existing VicRoads plans to assess the impact of flood levels on the area upstream of the proposed bypass. The modelling showed that there was a considerable increase in flood levels upstream and downstream of the proposed bypass (shown in Figure 4-2), however the peak flow through the bridge opening was not greatly reduced when compared to existing flow rates. Several iterations of the VicRoads design were also modelled to determine the additional openings required to ensure no increase in flood levels to adjoining property owners. Modelling found that to achieve this, bridging of nearly the entire floodplain would be required.

The retarding basin/embankment concept was investigated in more detail, which included protecting the proposed bypass interchange with the Hyland Highway. An assessment of the proposed retarding basin embankment against the ANCOLD guidelines (ANCOLD, 2012) was also conducted. The appropriate ANCOLD category was determined and further requirements for a proposed retarding basin were investigated. An initial assessment based on the height of the proposed embankment and the population at risk found the ANCOLD consequence level to be 'extreme'. Based on the initial ANCOLD consequence level, a comprehensive assessment will be required as per ANCOLD guidelines. A comprehensive assessment would likely include dam break modelling, and may result in the 'fallback flood capacity' requirement of the spillway (currently a PMF flow), being reduced to a lower design event.

Several designs were modelled with one key aspect to ensure the bypass roadway was not overtopped in a 1% AEP flood event. A spillway was incorporated into the design that would ensure the bypass roadway was not overtopped in events up to a 0.2% AEP magnitude. Two sets of culverts were placed on the embankment, the larger set at the Traralgon Creek allowed for low – moderate flows to be maintained through the Traralgon Creek. The second set of culverts were placed on the western edge of the floodplain. The embankment and culverts were able to reduce the 1% AEP peak flow rate from 246 m^3/s down to 106 m^3/s (slightly higher than the 10% AEP peak flow). A layout showing the spillway conveying flow through the embankment (along the Highland Highway) is shown in Figure 4-3. A difference plot showing the reduction in flood extent through Traralgon during a 1% AEP flood event is shown in Figure 4-4.

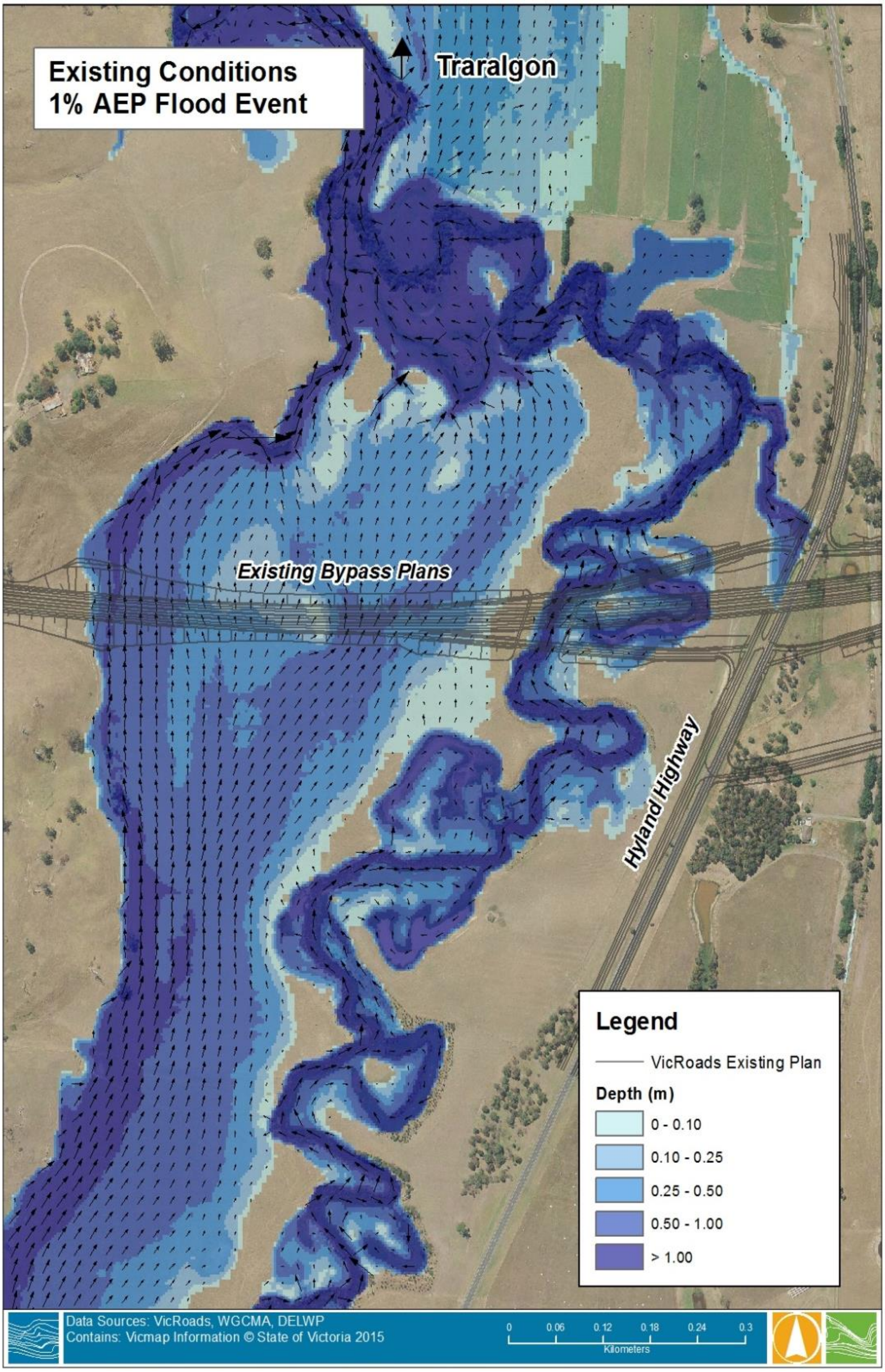

Figure 4-1 Existing Conditions 1% AEP Depth Plot

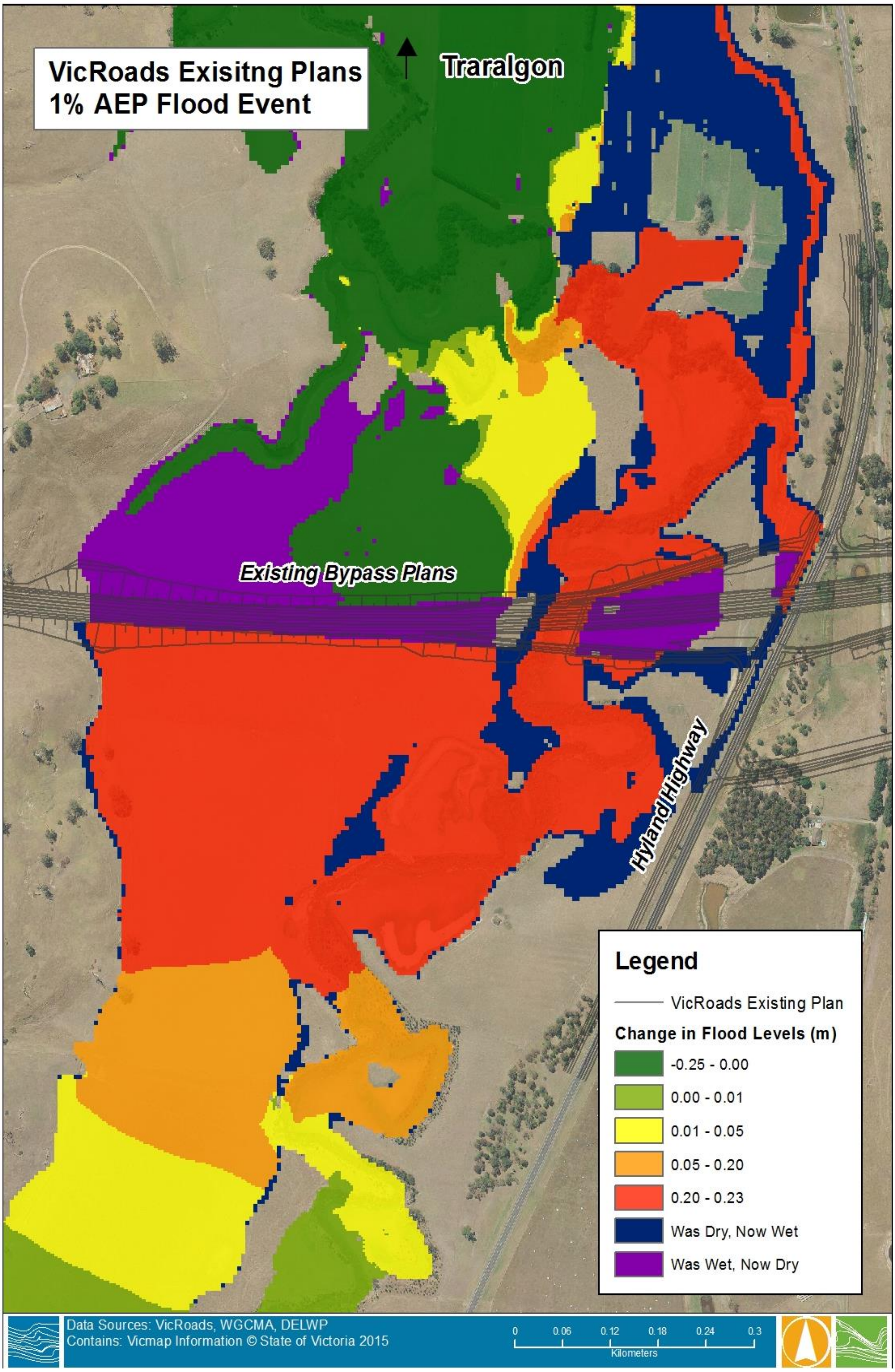

Figure 4-2 VicRoads Existing Plans - 1% AEP Difference Plot

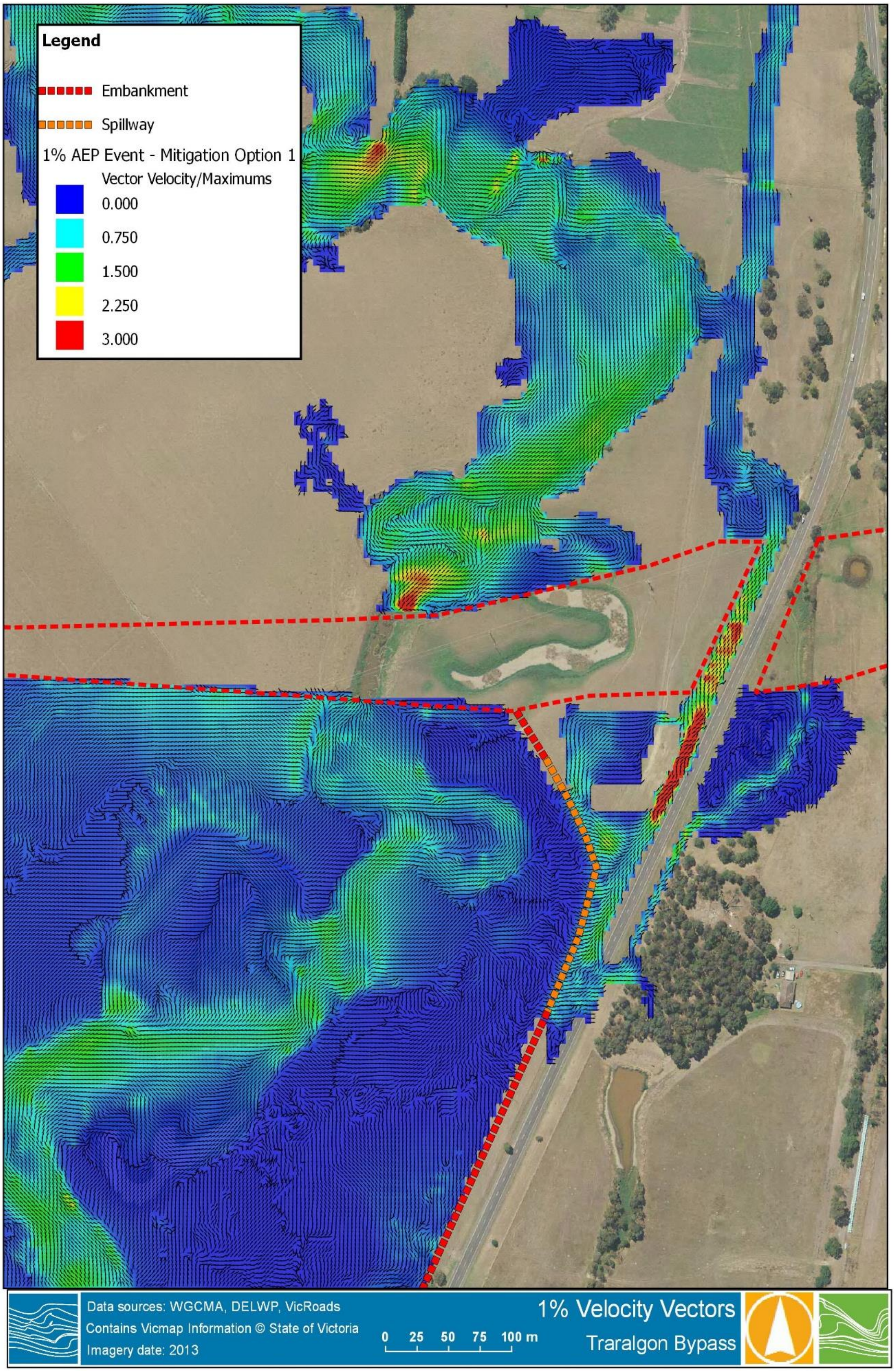

Figure 4-3 Proposed Traralgon Bypass Embankment Spillway overtopping and travelling alongside the Highland Highway

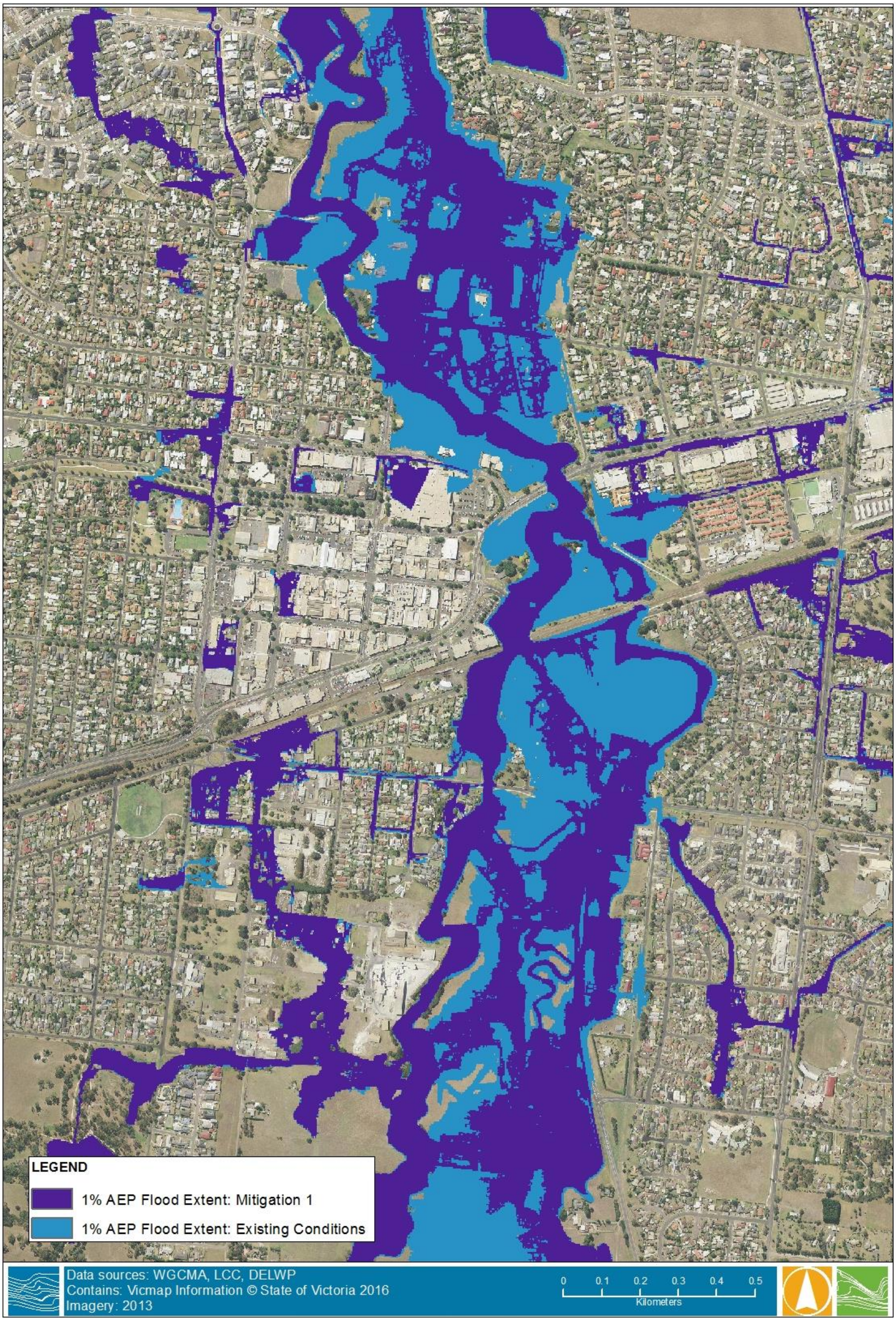

Figure 4-4 Traralgon Bypass Embankment Mitigation - 1% AEP Flood Extent Comparison

The results of the retarding basin modelling were handed over to VicRoads to undertake further investigation into the constraints and costs associated with the option. Indicative costing of this mitigation concept was undertaken using Rawlinsons Australian Construction Handbook and is shown in Table 4-3.

An estimated cost of **$21M** highlights the significant size of the project. The cost of the project along with the multiple agencies, stakeholders and further investigations makes this a major State project likely to require federal funding.

Table 4-3 Traralgon Bypass Embankment Costs

Component	Quantity	Cost
Bridge	64 m	$ 2,000,000
Embankment Fill	629,506 m^3	$ 10,200,000
Road Surfacing	24,000 m^2	$ 900,000
Bridge Approach	800 m^2	$ 200,0000
Land Acquisition	10 ha	$ 500,000
Material/ Construction Labour Cost		$ 13,800,000
Engineering Fee	15%	$ 2,000,000
Administration Fee	9%	$ 1,200,000
Contingencies	30%	$ 4,100,000
Total Cost		**$ 21,100,000**

The cost of the retarding basin project was compared to an estimated cost to bridge the floodplain, resulting in minimal afflux to meet West Gippsland CMA conditions. The bridge cost was estimated at close to **$50M** due to a large amount of extra bridging requirements needed to meet afflux conditions, these costs are shown in Table 4-4**.**

Table 4-4 VicRoads Design Bridge Costs

Component	Quantity	Cost
Bridge spans	696 m	$ 21,500,000
Embankment Fill	256,536 m^3	$ 4,100,000
Road Surfacing	24,000 m^2	$ 900,000
Bridge Abutment	3,200 m^2	$ 640,0000
Superstructures (supporting piers)	4 of spanning 696m	$ 5,000,000
Material/ Construction Labour Cost		**$ 32,200,000**
Engineering Fee	15%	$ 4,800,000
Administration Fee	9%	$ 2,900,000
Contingencies	30%	$ 9,700,000
Total Cost		**$ 50,000,000**

It is recommended that the next stage of design involve a workshop with VicRoads design engineers, the West Gippsland CMA, an ANCOLD registered dams engineer and Water Technology to discuss constraints and issues involved with detailed design. This could allow for further refinement of a design and develop the level of protection required which in turn can lead to better cost estimates of the floodplain crossing.

4.2.2 Whittakers Road Levee Scheme

A number of houses situated on Whittakers Road, Tennyson Street, Milton Court, Moonabeal Court and Raymond Court are susceptible to flooding at events larger than 10% AEP. These properties are located in a low lying area of the floodplain on the eastern edge of Traralgon Creek, immediately upstream of the Melbourne-Bairnsdale Railway line. The mitigation method shown in Figure 4-5, shows a combination of permanent and temporary flood measures to protect around 70 properties from flooding up to a 1% AEP flood event. This proposed scheme involves the raising of two existing walking paths (one on the southern side of Shakespeare St, and the second on top of the eastern bank of Traralgon Creek) using earthworks to raise the topography to above the 1% AEP flood level. All houses with frontage to Whittakers Road would have a solid masonry wall to the height of the 1% AEP flood level plus 300 mm freeboard, with an opening for a driveway and a walk though gate. The driveway and gate would be built to allow a temporary drop structure in place to stop flood waters during an event. Finally, temporary structures would be placed on the roads at the Shakespeare/Tennyson St intersection and along Whittakers Road at Milton Court, Moonabeal Court, Raymond Street and Tennyson Street. These structures have been used successfully in a number of other Victorian regional cities and along with the driveway, gateway structures would require storage, maintenance and installation instructions.

As shown in Figure 4-5, the levee scheme comprises a combination of masonry retaining walls, earthen levees, temporary roadway protection and temporary protection for driveways and pedestrian gateways (gateways not shown).

Five sections of masonry retaining wall, totalling 771 m, are proposed along the front of properites on Whittakers Road as part of the leeve scheme. Sections range from 77 m to 162 m in length. To allow vehicle access, these leeve sections terminate at property driveways and road crossings including Shakespeare Street and residental streets off Whittakers Road. A number of temporary drop-in driveway and pedestiran gateway barriers are proposed to be built into these retaining walls to allow vehicle access to properties. The masonary wall would be required to be reinforced given a maximum height in some locations of 1.40 metres. Each property was also allocated costing for a pedestrian gateway that would require temporary floodbarriers.

The reminaing three sections of permanent protection are proposed as 712 m of earthern leeves. The longest of these sections is 391 m in length and runs behind properties to the east of Taralgon Creek along the existing walking track which would remain as an unselaed track. The remaining two sections are both 160 m in length and run along the paved walking track south of Shakespeare Street and behind properties east of Whittakers Road through the recreation reserve.

Temporary mitigation strucutres are proposed for the road crossing which can be errected when flow events larger than a 10% AEP are expected. A number of commerical flood mitigation products were investigated as part of this mitigation concpet. Aquobex's "Rapidam" was choosen due to its suitablity to the area being relatively fast set up time and its moderate cost placing it in the midrange of the market for similar products. As shown in Figure 4-5, Rapidam is a modular and freestanding, impervious (product specifications note some seepage) temporary barrier which is suitable up to a flood height of 1.5 m. The system can typically be installed in under an hour (EA UK, 2011). Given the warning time available for this area, this product appears to be suitable. Water Technology do not endorse any proprietry structural flood mitigation products, this product has been selected to demonstrate the types of products on the market and the relative cost of such a solution.

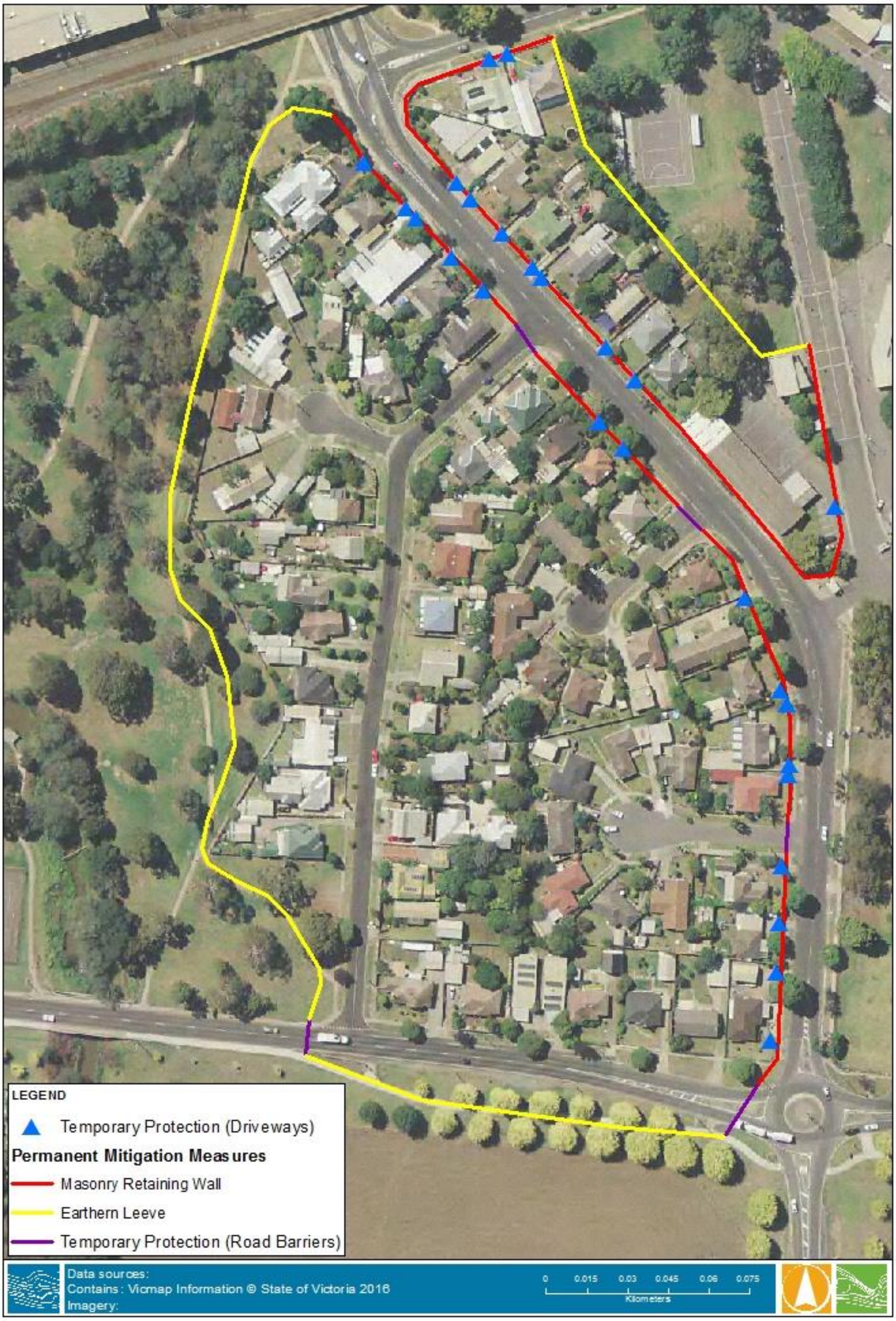

Figure 4-5 Whittakers Road Levee Scheme

Figure 4-6 Rapidam (EA UK, 2011)

Temporary barricades are proposed for driveways and pedesitran gateways along Whittakers Road. Such structures consist of rigid panels which are placed between stanchions supported by permanent foundations. Panels are stacked on top of one another to reach the required height of flood protection (EA UK, 2011). Several suitable products were identified on the market. Flood Control International's L-Series Modular Demountable Flood Barrier was choosen as the preferred barrier given its mid range cost as well as being suited to bridging the space across driveways. 26 properties were identified as requiring driveway protection in the form of a temporary barrier. Both the driveway and gateway on each of the properties would have a permanent fitting that when required would have the flood barriers dropped in. Several properties at the northern end of Whittakers Road may already have sufficient protection or require only minor adjustments to the existing retaining walls to achieve flood protection to 1% AEP levels.

Figure 4-7 L-Series Modular Demountable Flood Barrier (Flood Control International, 2015)

The levee scheme was designed to provide protection to a 1% AEP design flood level (including a 300 mm freeboard), as shown in Figure 4-8, all water is kept out of the area surrounded by the levee and temporary barriers.

As a result of the water being diverted along Whittakers Road and around the levee system, there is an increase in flood levels between 5-10 cm within the adjacent recreation reserve. This may require additional mitigation measures to protect the social rooms and other buildings in the reserve. Currently four buildings within the recreation reserve are flooded above floor in a 1% AEP flood event, no additional buildings are flooded above floor as a result of the levee option. An increase of around 8 cm in flood levels occurs south of Shakespeare Street across the Hyland Highway and open space (most of which is used for agriculture).

Several properties on Atherley Court experience an increase in the 1% AEP flood levels as a result of the mitigation. These increases are in the range of 2-5 cm within the properties, however this increase in flood levels does not increase the number of properties flooded above floor, the properties in the area are at least 37 cm above the existing 1% AEP flood level. The increased flood levels from the mitigation could be mitigated if required with an additional 200 m levee which was not costed for this project.

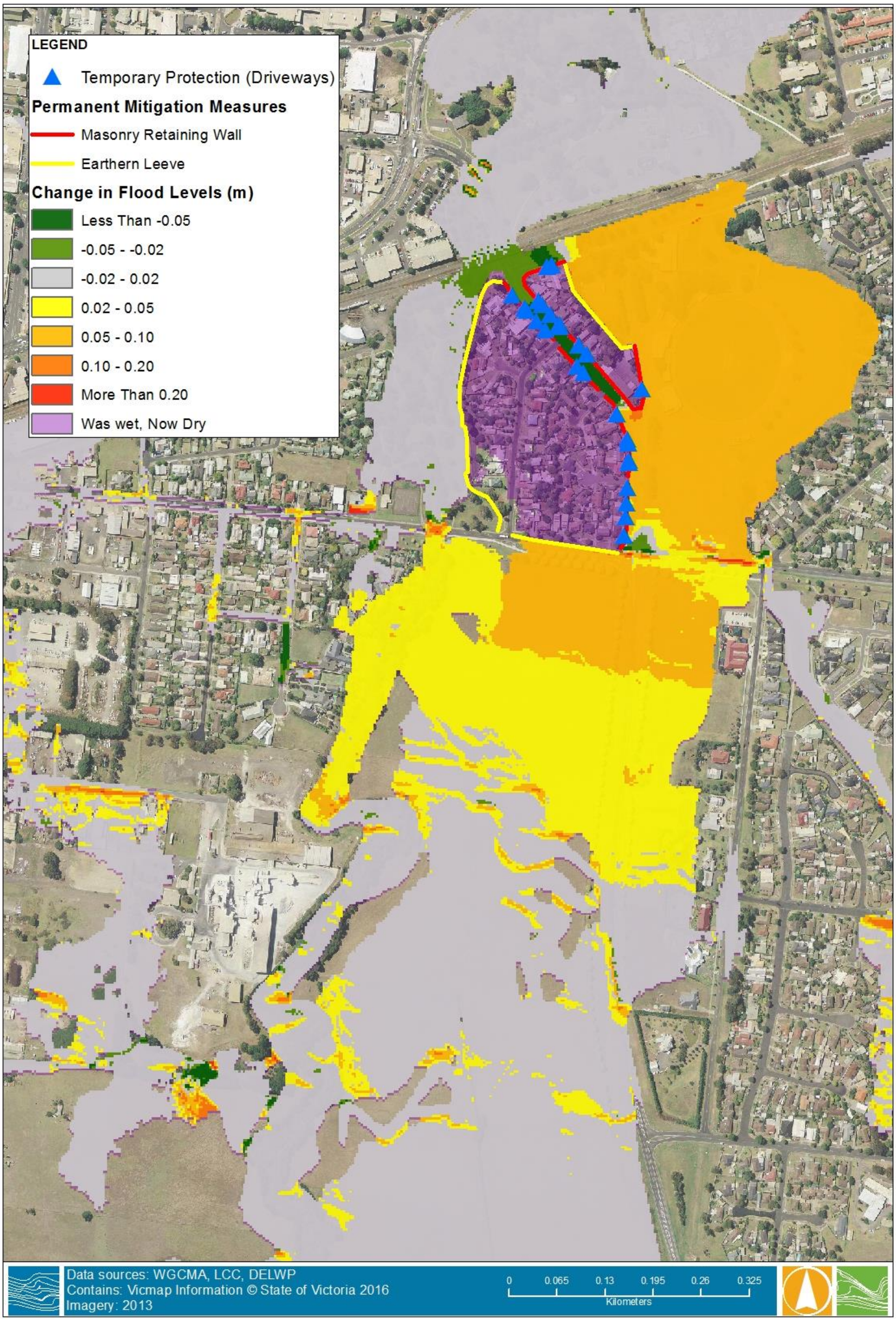

Figure 4-8 Mitigation Option 2 - Whittakers Road Levee (Difference Plot)

Initial cost estimations for the levee scheme are summarised in Table 4-5a number of commercial flood mitigation products in the middle price range were selected to ensure the total cost gives a good indication of products in the market.

Table 4-5 Cost Estimate - Whittakers Road Levee Scheme

Component	Quantity	Cost
Earthen Levee	391 m	$ 74,000
Masonry Levee (Retaining Walls)	771 m	$ 360,000
Temporary Road Protection	85 m	$ 66,000
Temporary Driveway Protection	25 x 3 m 1 x 30 m	$ 160,000
Temporary Pedestrian Gate Protection	26 x 1 m	$ 40,000
Material/ Construction Labour Cost		**$ 700,000**
Engineering Fee	15%	$ 105,000
Administration Fee	9%	$ 63,000
Contingencies	30%	$ 210,000
Total Cost		**$ 1,080,000**

The temporary protection measures identified would be required to be stored by the Latrobe City Council. The temporary mitigation products would be required to be maintained and checked on a predetermined schedule to ensure that the products are available and in working condition when required. Additionally, further checks and maintenance on the permanent structures within the scheme would also be required to be carried out. Other issues which have been identified with this include cars situated across driveways when the temporary barriers are required to be put in place. This could be addressed through a resilience/information program for residents in the area.

Maintenance on the levee option was costed at 3% of the construction costs giving an annual maintenance cost of $21,069.

4.2.3 Floodway works

A constriction in the main channel of Traralgon Creek downstream of the city centre was identified during the hydraulic modelling phase of the project. Approximately 1 km downstream of the Princes Highway, adjacent to the Traralgon Tennis Complex, the creek has several sharp bends where water is slow moving and leaves the channel into the floodplain (as shown in Figure 4-9). An existing area of high ground also restricts some flow from travelling efficiently.

An option to provide a ‘high flow’ floodway which would provide a more efficient flow path for the creek across meander bends prior to water breaking away from the creek was shown to alleviate some local flooding, Figure 4-10. This would involve removing the area of high ground and connecting the Traralgon Creek channel across a number of the meander bends. Modelling showed the earthworks allowed for an increase in flow through the area and reduced the water levels upstream of the tennis complex. Issues involved with this option include potential erosion (leading to avulsion), bank stability and vegetation works within the designated floodway.

An initial model scenario of this was developed for a community meeting, the results of the difference plot are shown in Figure 4-11. This scenario was modelled in conjunction with the removal of the waste water treatment plant further downstream. The results do show a reduction of 2-5 cm around the Phelan Street, Franklin Street area, however the properties along Phelan Street are now inundated. This option was not costed, however it is likely to be the lowest cost of the mitigation options presented given it would involve earthworks and landscaping. Should this option be pursued, further investigation with a geomorphologist and ecologist would be suggested.

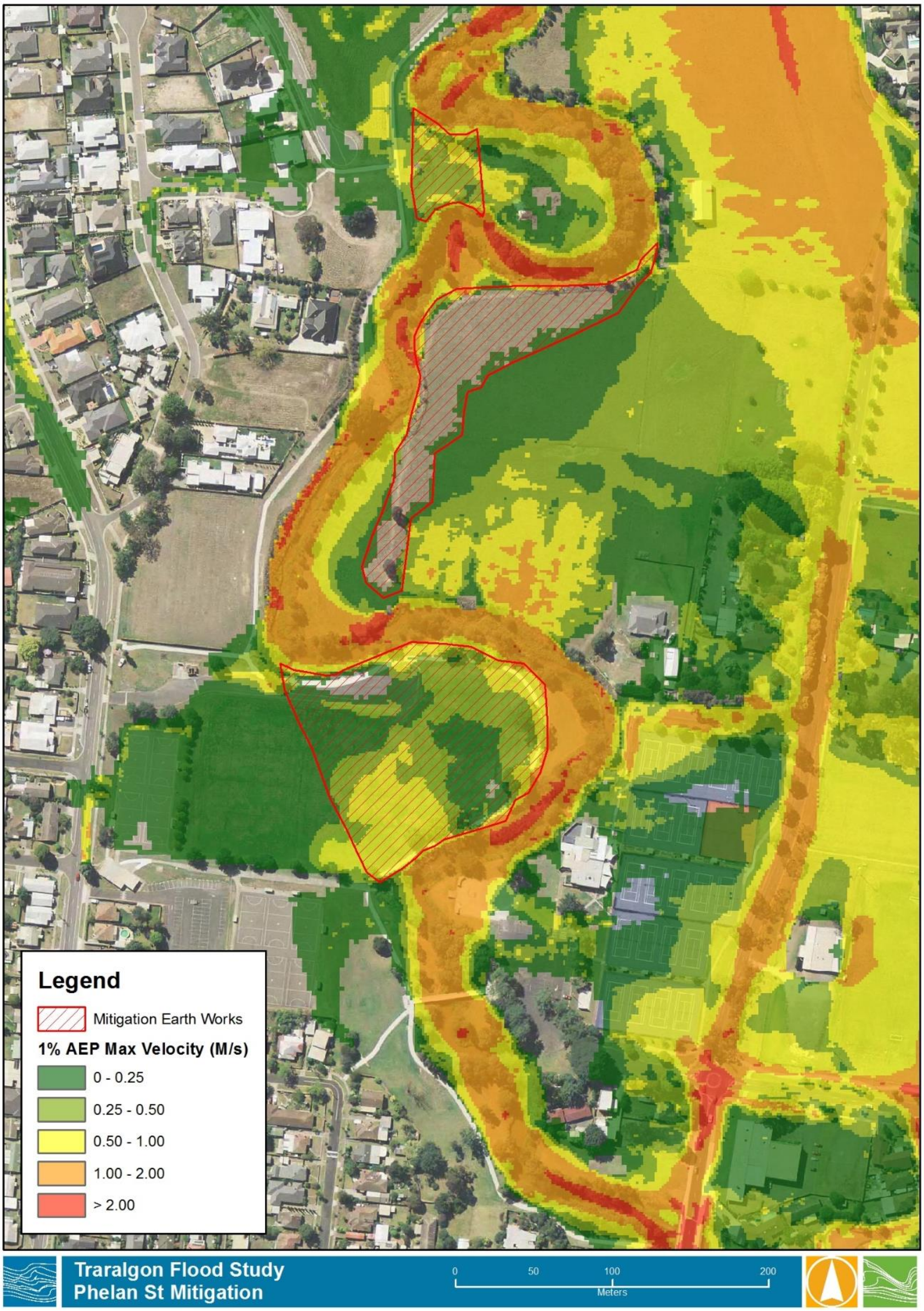

Figure 4-9 1% AEP Flood Event Existing Conditions - Maximum Velocity

Figure 4-10 Floodway works Schematisation

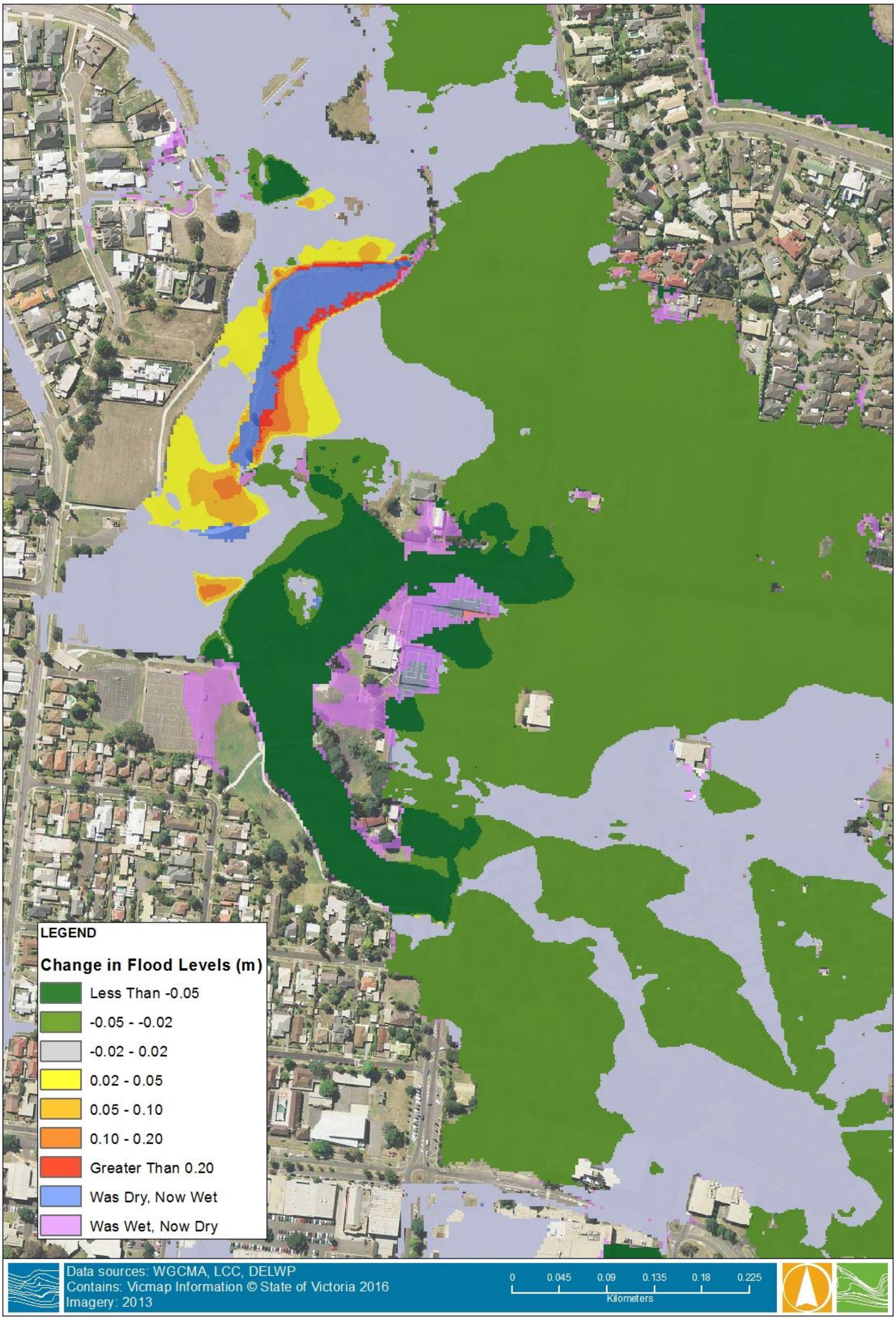

Figure 4-11 Floodway Mitigation Difference Plot – 1% AEP Flood Event

5. FLOOD DAMAGES

5.1 Overview

A flood damages assessment was undertaken for the study area for existing conditions. The flood assessment determined the monetary flood damages for design floods (20%, 10%, 5%, 2%, 1% and 0.5% AEP events). The flood damage assessment was also undertaken for the final mitigation package.

Water Technology has developed an industry best practice damage assessment methodology that has been utilised for a number of studies in Victoria, combining aspects of the Rapid Appraisal Method, ANUFLOOD, more recent damage curves from the NSW Office of Environment and Heritage, and other relevant flood damage literature. The model results for all mapped flood events were processed to calculate the numbers and locations of properties affected. This included properties with buildings inundated above floor, properties with buildings inundated below floor and properties where the building was not impacted but the grounds of the property were. In addition to the flood affected properties, lengths of flood affected roads for each event were also calculated. Note, that rural agricultural damages have not been included in this study as the focus for mitigation is on the Traralgon city centre and urban area. Details of all properties inundated within the study area are provided in Appendix A.

5.2 Existing Conditions

A flood damages assessment was undertaken on existing conditions and is shown in Table 5-1. The 1% AEP damage calculated was **$ 6.8M** with 90 residential properties flooded above floor and 13 commercial properties also flooded above floor. The average annual damage (AAD), a measure of the average flood damage per year over an extended period, was estimated for existing conditions to be **$ 360,000**. The AAD is an estimate of the cost of flooding to the community that includes both public and privately owned assets.

Table 5-1 Existing Conditions Flood Damages Summary

EXISTING CONDITIONS						
ARI (years)	200y	100y	50y	20y	10y	5y
AEP	0.50%	1%	2%	5%	10%	20%
Residential Buildings Flooded Above Floor	154	90	29	8	1	0
Commercial Buildings Flooded Above Floor	16	13	11	5	0	0
Properties Flooded Below Floor	192	216	225	193	87	53
Total Properties Flooded	**362**	**319**	**265**	**206**	**88**	**53**
Direct Potential External Damage Cost	$1,045,178	$1,268,862	$1,060,329	$622,332	$191,000	$100,658
						$0
Direct Potential Residential Damage Cost	$9,802,294	$5,184,250	$1,369,263	$402,901	$43,158	$0
Direct Potential Commercial Damage Cost	$1,866,545	$986,347	$292,941	$16,133	$0	$0
Total Direct Potential Damage Cost	**$12,714,017**	**$7,439,459**	**$2,722,533**	**$1,041,366**	**$234,158**	**$100,658**
Total Actual Damage Cost *(0.8*Potential)*	**$10,171,214**	**$5,951,567**	**$2,178,026**	**$833,093**	**$187,326**	**$80,526**
Infrastructure Damage Cost	**$933,029**	**$827,486**	**$728,438**	**$639,961**	**$533,197**	**$464,886**
Indirect Clean Up Cost						
Indirect Residential Relocation Cost						
Indirect Emergency Response Cost						
Total Indirect Cost	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
Total Cost	**$11,104,243**	**$6,779,053**	**$2,906,464**	**$1,473,054**	**$720,523**	**$545,412**

5.3 Mitigation Option 1

Damages were costed for mitigation option 1, the Traralgon Bypass Embankment. This option aims to reduce a 1% AEP design flow event to an approximate 10% AEP event in Traralgon. The results (Table 5-2) showed that the number of residential properties flooded in a 1% AEP event are reduced to 4, while only 2 commercial properties are now flooded above floor level. This reduced the flood damage estimate for a 1% AEP flood event to **$ 1.1M**. The AAD was also reduced to less than **$ 200,000**.

Table 5-2 Mitigation Option 1 Flood Damages Summary

Mitigation 1						
ARI (years)	200y	100y	50y	20y	10y	5y
AEP	0.50%	1%	2%	5%	10%	20%
Residential Buildings Flooded Above Floor	24	4	2	1	0	0
Commercial Buildings Flooded Above Floor	12	2	0	0	0	0
Properties Flooded Below Floor	241	168	130	100	63	47
Total Properties Flooded	**277**	**174**	**132**	**101**	**63**	**47**
Direct Potential External Damage Cost	$1,143,500	$354,221	$227,290	$173,804	$100,017	$76,957
						$0
Direct Potential Residential Damage Cost	$1,256,540	$193,459	$80,268	$33,805	$0	$0
Direct Potential Commercial Damage Cost	$397,168	$6,109	$0	$0	$0	$0
Total Direct Potential Damage Cost	**$2,797,208**	**$553,789**	**$307,558**	**$207,609**	**$100,017**	**$76,957**
Total Actual Damage Cost *(0.8*Potential)*	**$2,237,766**	**$443,031**	**$246,046**	**$166,087**	**$80,014**	**$61,566**
Infrastructure Damage Cost	**$854,161**	**$686,931**	**$602,957**	**$548,731**	**$466,179**	**$405,476**
Indirect Clean Up Cost						
Indirect Residential Relocation Cost						
Indirect Emergency Response Cost						
Total Indirect Cost	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
Total Cost	**$3,091,928**	**$1,129,962**	**$849,004**	**$714,819**	**$546,193**	**$467,041**

5.4 Mitigation Option 2

The Whittakers Road Levee also showed a significant reduction in the number of properties flooded above floor during a 1% AEP flood event from 90 to 54. This reduces the 1% AEP flood damage cost to **$ 4.9M**. The AAD estimate for mitigation option 2 was calculated at **$ 310,000**.

Table 5-3 Mitigation Option 2 Flood Damages Summary

Mitigation 2						
ARI (years)	200y	100y	50y	20y	10y	5y
AEP	0.50%	1%	2%	5%	10%	20%
Residential Buildings Flooded Above Floor	138	54	25	7	1	0
Commercial Buildings Flooded Above Floor	18	10	8	4	0	0
Properties Flooded Below Floor	201	184	177	160	88	54
Total Properties Flooded	**357**	**248**	**210**	**171**	**89**	**54**
Direct Potential External Damage Cost	$1,095,084	$885,918	$723,420	$469,475	$188,718	$99,441
						$0
Direct Potential Residential Damage Cost	$8,338,571	$3,220,803	$1,175,662	$373,977	$42,822	$0
Direct Potential Commercial Damage Cost	$2,091,538	$1,032,258	$290,812	$15,797	$0	$0
Total Direct Potential Damage Cost	**$11,525,193**	**$5,138,979**	**$2,189,894**	**$859,249**	**$231,540**	**$99,441**
Total Actual Damage Cost *(0.8*Potential)*	**$9,220,154**	**$4,111,183**	**$1,751,915**	**$687,399**	**$185,232**	**$79,553**
Infrastructure Damage Cost	**$884,774**	**$771,745**	**$680,757**	**$595,743**	**$498,774**	**$429,034**
Indirect Clean Up Cost						
Indirect Residential Relocation Cost						
Indirect Emergency Response Cost						
Total Indirect Cost	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
Total Cost	**$10,104,928**	**$4,882,928**	**$2,432,672**	**$1,283,142**	**$684,006**	**$508,587**

6. BENEFIT COST ANALYSIS

Mitigation Option 1, the Traralgon Bypass Embankment, requires a more complex benefit-cost assessment than what was scoped in this study. Given the size of the potential structure, the cost involved and the need to consider the relative benefits to multiple stakeholders of bridging the floodplain or forming a retarding basin, Water Technology recommends that an assessment be conducted by a skilled economist.

For Mitigation Option 2, Whittakers Road levee, a more traditional benefit-cost assessment was conducted.

Table 6-1 Benefit Cost Analysis of Mitigation Option 2

	Mitigation Option 2 – Whittakers Road Levee
Average Annual Damage	$ 314, 881
Annual Maintenance Cost	$ 21, 069
Annual Cost Saving	$ 22,827
Net Present Value (6%)	$ 321,002
Capital Cost of Mitigation	$ 1,081,545
Benefit – Cost Ratio	0.30

While a benefit-cost Ratio for the Traralgon Bypass Embankment mitigation option has not been calculated, there is a saving of almost $30M to build the bypass as a piece of flood mitigation infrastructure rather than a full bridge structure. This saving in itself seems to make this option an attractive proposition financially to the State. The option has been demonstrated to provide very good flood mitigation benefit to Traralgon, dramatically reducing the flood risk and also potentially freeing up land within the city for further development.

The Whittakers Road levee option provided a benefit cost ratio of only 0.30. This does not take into consideration a number of indirect and non-economic benefits discussed in section 6.1.

6.1 Non-Economic Flood Damages

The previous discussion relating to flood damages has concentrated on monetary damages, that is, damages that are easily quantified. In addition to those damages, it is widely recognised that individuals and communities also suffer significant non-monetary damage, i.e. emotional distress, health issues, etc. There has been extensive research undertaken and documented in the scientific literature relating to the individuals and communities response to natural disasters. A recent publication entitled *"Understanding floods: Questions and Answers"* by the Queensland Floods Science Engineering and Technology Panel, when discussing the large social consequences floods have on individuals and communities states:

Floods can also traumatise victims and their families for long periods of time. The loss of loved ones has deep impacts, especially on children. Displacement from one's home, loss of property and disruption to business and social affairs can cause continuing stress. For some people the psychological impacts can be long lasting.

The *"Disaster Loss Assessment Guidelines"* (EMA, 2002) make the following key points:

- *Intangibles are often found to be more important than tangible losses.*
- *Most research shows that people value the intangible losses from a flooded home—principally loss of memorabilia, stress and resultant ill-health—as at least as great as their tangible dollar losses.*
- *There are no agreed methods for valuing these losses.*

There is no doubt that the intangible non-monetary flood related damage in Traralgon is high. The benefit-cost analysis presented later in this report has not considered this cost. Nor has the additional benefits gained for a number of houses within the Whittakers Road levee system that would be protected in events up to 1% AEP design flood level. Anecdotal stories reveal that a number of properties in this area have had their perceived property value reduced as a result of significant flooding occurring in the previous twenty years. Any decisions made that are based on the benefit-cost ratios need to understand that the true cost of floods in Traralgon is far higher than the economic damages alone. This would have the effect of increasing the benefit cost ratio, improving the argument for approving a mitigation scheme at Traralgon.

7. CONCLUSION AND RECOMMENDATIONS

7.1 Conclusions

The hydraulic modelling undertaken for the Traralgon flood study has identified locations within Traralgon that pose a high flood risk. The modelling has also identified a number of potential mitigation options to reduce flood risk, with several of these being modelled to show significant benefits in terms of reducing the frequency and magnitude of flooding. The mitigation options identified along with the updated planning information aim to treat the existing risk. Further detailed assessment of mitigation options modelled and costed would be required to proceed to the next stage of implementation, with the Traralgon Bypass Embankment modelling project being handed to VicRoads to consider.

Through the series of steering committee and community meetings, it was identified that accessing information about an approaching flood event was often difficult. Currently the Bureau of Meteorology (BoM) provide flood warnings via the BoM website, while streamflow data is also available through a different section of the website as well as through the DELWP data monitoring website. Interpreting this data and making decisions regarding personal flood risk is currently difficult for most members of the community. It was noted that having a community portal that incorporated several key pieces of information regarding flooding specific to Traralgon in one place may reduce some of the confusion about where this information can be obtained. Latrobe City Council expressed interest in making rainfall and streamflow gauging in near real time available to the community to improve flood warnings. This would allow community members to get important information quickly, and will likely raise the resilience of locals to potential flooding issues. This information may include any warnings issued by the BoM, the three streamflow gauges on Traralgon Creek and a radar image of the area to show if there is more rain approaching. Flood extent maps which identify the houses impacted during various design flood events could also be easily included within a community portal.

7.2 Recommendations

- Latrobe City Council consider the implementation of a planning scheme amendment to introduce the revised flood controls into the planning scheme.
- Latrobe City Council and or WGCMA investigate the development of community flood portal that provides a range of flood related information specific to the city of Traralgon and surrounding areas.
- WGCMA and LCC encourage VicRoads to further investigate the Traralgon Bypass Embankment mitigation option discussed previously. This would involve consultation with various stakeholders including AGL.

8. REFERENCES

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APPENDIX A – PROPERTIES INUNDATED

Easting	Northing	Floor Level	Ground Level	Building Type	Address	0.5% AEP Depth Above Floor	1% AEP Depth Above Floor	2% AEP Depth Above Floor	5% AEP Depth Above Floor	10% AEP Depth Above Floor	20% AEP Depth Above Floor
458469.7	5774111	31.19	31.02	RES	108 St Georges Rd	-1.04	-1.04	-1.04	-1.04	-1.04	-1.04
460212.1	5771128	41.75	41.44	RES	50 Mapleson Dr	-0.83	N/A	N/A	N/A	N/A	N/A
459730.1	5772961	36.41	35.79	RES	2/21 George St	-0.70	-0.75	-0.82	-0.87	-0.91	N/A
459558.6	5772987	36.57	35.91	RES	1/3 Davidson St	-0.63	-0.65	N/A	N/A	N/A	N/A
459575.7	5772859	37.93	36.62	RES	Gordon St	-0.62	-0.72	-0.85	-0.96	N/A	N/A
459935.6	5771832	40.45	39.71	RES	Tennyson St	-0.59	N/A	N/A	N/A	N/A	N/A
459350.3	5773616	34.96	34.59	RES	11 Bradman Blvd	-0.57	-0.57	N/A	N/A	N/A	N/A
459570.2	5773262	35.67	34.51	RES	Phelan St	-0.52	N/A	N/A	N/A	N/A	N/A
459992.8	5772868	36.87	35.67	RES	Peterkin St	-0.50	-0.66	-0.90	-1.01	-1.02	N/A
460224.5	5771196	41.37	40.81	RES	48 Mapleson Dr	-0.46	N/A	N/A	N/A	N/A	N/A
460231	5771249	41.35	40.80	RES	46 Mapleson Dr	-0.43	N/A	N/A	N/A	N/A	N/A
459993.9	5772882	36.70	35.67	RES	Peterkin St	-0.41	-0.56	-0.81	-0.95	-0.97	N/A
460017.2	5772765	37.70	36.83	RES	Munro St	-0.41	-0.52	-0.65	N/A	N/A	N/A
459997.4	5772855	36.87	35.67	RES	Peterkin St	-0.41	-0.58	-0.82	N/A	N/A	N/A
459979.1	5771800	40.41	39.63	RES	Tennyson St	-0.36	-0.62	N/A	N/A	N/A	N/A
459354.6	5773574	34.95	34.73	RES	3 Windsor Ct	-0.27	-0.27	-0.29	N/A	N/A	N/A
460011	5771907	40.22	38.81	RES	Moonabeal Ct	-0.27	-0.62	-0.91	-1.15	N/A	N/A
459558.6	5772861	37.50	36.93	RES	Gordon St	-0.26	-0.37	-0.51	N/A	N/A	N/A
459558.2	5772965	36.57	36.16	RES	2/3 Davidson St	-0.25	-0.31	N/A	N/A	N/A	N/A
460224.1	5772444	39.50	38.59	RES	Gwalia St	-0.25	-0.77	-1.10	N/A	N/A	N/A

Easting	Northing	Floor Level	Ground Level	Building Type	Address	0.5% AEP Depth Above Floor	1% AEP Depth Above Floor	2% AEP Depth Above Floor	5% AEP Depth Above Floor	10% AEP Depth Above Floor	20% AEP Depth Above Floor
459998	5771966	40.17	39.39	RES	Tennyson St	-0.25	-0.61	N/A	N/A	N/A	N/A
460246.5	5772681	39.02	38.44	RES	Argyle St.	-0.25	-0.27	-0.29	N/A	N/A	N/A
460021.7	5772965	35.98	35.40	RES	Davidson St	-0.25	N/A	N/A	N/A	N/A	N/A
460023.3	5772861	36.67	35.69	RES	Peterkin St	-0.24	-0.38	-0.61	-0.72	-0.75	N/A
460262.6	5772686	39.00	38.59	RES	Argyle St.	-0.23	-0.26	N/A	N/A	N/A	N/A
459839.4	5772907	36.56	36.00	RES	28/30 George St	-0.23	-0.33	-0.44	-0.56	N/A	N/A
459765.3	5771670	40.69	40.06	RES	Atherley Close	-0.23	N/A	N/A	N/A	N/A	N/A
459937.3	5771849	40.13	39.59	RES	Tennyson St	-0.22	N/A	N/A	N/A	N/A	N/A
459881.2	5772815	37.39	36.66	RES	7/9 Berry St	-0.22	-0.34	-0.50	-0.66	N/A	N/A
459983.9	5771858	40.16	39.33	RES	Tennyson St	-0.20	-0.53	-0.76	N/A	N/A	N/A
459780.9	5771705	40.66	40.22	RES	4 Atherley Ct	-0.20	-0.37	-0.39	-0.45	N/A	N/A
459733.4	5772865	37.12	36.11	RES	Willow Ct	-0.20	-0.30	-0.42	-0.56	-0.76	N/A
460038.8	5771883	40.18	38.83	RES	Moonabeal Ct	-0.20	-0.53	-0.79	-1.02	N/A	N/A
460017.1	5772708	38.23	37.53	RES	Munro St	-0.19	-0.38	N/A	N/A	N/A	N/A
459915.2	5771959	40.03	39.09	RES	Booth Ct	-0.19	-0.50	N/A	N/A	N/A	N/A
460186.9	5772500	39.44	38.76	RES	1/2-6 Gwalia St	-0.19	N/A	N/A	N/A	N/A	N/A
460033.5	5773288	35.26	34.00	RES	Central Park Av	-0.19	-0.39	-0.65	-0.90	N/A	N/A
460224	5772512	39.43	38.86	RES	4/2-6 Gwalia St	-0.18	-0.70	N/A	N/A	N/A	N/A
459921.4	5773358	35.24	35.08	RES	1 Le Grange	-0.18	N/A	N/A	N/A	N/A	N/A
459843.3	5772903	36.57	36.08	RES	28/30 George St	-0.18	-0.27	-0.38	-0.50	N/A	N/A

Easting	Northing	Floor Level	Ground Level	Building Type	Address	0.5% AEP Depth Above Floor	1% AEP Depth Above Floor	2% AEP Depth Above Floor	5% AEP Depth Above Floor	10% AEP Depth Above Floor	20% AEP Depth Above Floor
460010.8	5773386	35.24	35.04	RES	14 Le Grange	-0.17	N/A	N/A	N/A	N/A	N/A
459750.3	5772941	36.35	35.70	RES	1/21 George St	-0.16	-0.27	-0.43	-0.57	N/A	N/A
459942	5773369	35.22	35.06	RES	24 Le Grange	-0.16	N/A	N/A	N/A	N/A	N/A
460006	5773369	35.22	35.01	RES	15 Le Grange	-0.16	N/A	N/A	N/A	N/A	N/A
459882.7	5772921	36.25	35.59	RES	Berry St	-0.15	-0.23	N/A	N/A	N/A	N/A
460108.4	5772730	38.22	37.68	RES	Peterkin St.	-0.15	-0.15	-0.16	N/A	N/A	N/A
460109.9	5772719	38.22	37.95	RES	Peterkin St.	-0.14	-0.14	-0.15	N/A	N/A	N/A
459849.4	5772931	36.19	35.52	RES	23/25 Davidson St	-0.13	-0.22	-0.32	-0.43	N/A	N/A
459826.1	5773457	35.03	34.51	RES	Franklin St	-0.12	N/A	N/A	N/A	N/A	N/A
459692	5772908	36.73	36.24	RES	Willow Ct	-0.12	-0.21	-0.29	-0.35	-0.46	N/A
459989.6	5771838	40.10	39.47	RES	3/6 Tennyson St	-0.11	-0.40	N/A	N/A	N/A	N/A
459929.1	5772007	39.95	39.36	RES	Booth Ct	-0.11	-0.45	N/A	N/A	N/A	N/A
459988.4	5771897	40.04	39.24	RES	Tennyson St	-0.10	-0.45	-0.73	N/A	N/A	N/A
459883.7	5772884	36.59	35.96	RES	Berry St	-0.10	-0.19	-0.29	-0.40	N/A	N/A
459984.4	5772747	37.50	37.37	RES	25 Munro St	-0.08	-0.20	-0.36	-0.45	-0.45	N/A
459810.3	5772894	36.53	36.10	RES	28/30 George St	-0.07	-0.17	-0.27	-0.36	N/A	N/A
459895.8	5772827	37.03	36.21	RES	Berry St	-0.07	-0.19	-0.32	-0.46	N/A	N/A
459975.1	5771772	40.34	39.88	RES	Shakespeare St	-0.07	-0.27	N/A	N/A	N/A	N/A
460008	5771836	40.09	39.46	RES	2/6 Tennyson St	-0.07	-0.35	-0.61	N/A	N/A	N/A
459982.9	5773358	35.13	34.92	RES	18 Le Grange	-0.06	N/A	N/A	N/A	N/A	N/A

Easting	Northing	Floor Level	Ground Level	Building Type	Address	0.5% AEP Depth Above Floor	1% AEP Depth Above Floor	2% AEP Depth Above Floor	5% AEP Depth Above Floor	10% AEP Depth Above Floor	20% AEP Depth Above Floor
460000.4	5772762	37.36	36.72	RES	Munro St	-0.06	-0.17	-0.35	-0.42	N/A	N/A
459940.1	5772063	39.79	39.00	RES	Whittakers Rd	-0.06	-0.38	N/A	N/A	N/A	N/A
460030.3	5772824	36.69	36.11	RES	Peterkin St	-0.06	-0.21	-0.39	N/A	N/A	N/A
460017.9	5773343	35.12	34.85	RES	16 Le Grange	-0.05	N/A	N/A	N/A	N/A	N/A
459862.4	5772928	36.13	35.52	RES	23/25 Davidson St	-0.05	-0.13	-0.23	-0.33	N/A	N/A
460007.8	5773345	35.12	34.88	RES	17 Le Grange	-0.05	-0.25	N/A	N/A	N/A	N/A
460157.2	5772525	39.29	38.62	RES	Peterkin St	-0.04	N/A	N/A	N/A	N/A	N/A
459888.2	5772862	36.73	36.04	RES	Berry St	-0.04	-0.14	-0.25	-0.37	N/A	N/A
459981.9	5771838	40.02	39.43	RES	Tennyson St	-0.04	-0.32	N/A	N/A	N/A	N/A
459986.1	5773365	35.10	34.96	RES	19 Le Grange	-0.03	N/A	N/A	N/A	N/A	N/A
459842.3	5772893	36.55	36.12	RES	28/30 George St	-0.03	-0.12	-0.24	-0.38	N/A	N/A
459791.9	5772912	36.42	35.81	RES	32 George St	-0.03	-0.17	-0.37	-0.59	N/A	N/A
460038.8	5772784	37.22	36.80	RES	Peterkin St	-0.03	-0.11	-0.23	N/A	N/A	N/A
459851.4	5772922	36.20	35.59	RES	23/25 Davidson St	-0.03	-0.12	-0.23	-0.35	N/A	N/A
459935.3	5773354	35.08	34.87	RES	25 Le Grange	-0.02	-0.22	N/A	N/A	N/A	N/A
459807.1	5772887	36.55	36.29	RES	28/30 George St	-0.01	-0.11	-0.22	N/A	N/A	N/A
459865.6	5772921	36.17	35.58	RES	23/25 Davidson St	0.00	-0.09	-0.19	-0.30	N/A	N/A
460388.6	5772544	39.25	39.00	RES	Gwalia St	0.00	N/A	N/A	N/A	N/A	N/A
459941.5	5772900	36.21	35.41	RES	Berry St	0.00	-0.14	-0.32	-0.43	N/A	N/A
459768	5773524	34.74	33.31	RES	Franklin St	0.01	N/A	N/A	N/A	N/A	N/A

Easting	Northing	Floor Level	Ground Level	Building Type	Address	0.5% AEP Depth Above Floor	1% AEP Depth Above Floor	2% AEP Depth Above Floor	5% AEP Depth Above Floor	10% AEP Depth Above Floor	20% AEP Depth Above Floor
460116.3	5773193	35.58	35.46	RES	Alfred Close	0.02	0.01	N/A	N/A	N/A	N/A
460025.4	5772054	39.85	38.64	RES	Whittakers Rd	0.03	-0.36	-0.78	-1.00	N/A	N/A
459827.1	5772889	36.54	36.07	RES	28/30 George St	0.03	-0.06	-0.18	-0.29	N/A	N/A
459880.1	5772899	36.33	35.75	RES	Berry St	0.03	-0.05	-0.14	-0.23	N/A	N/A
459988.5	5771772	40.25	39.65	RES	74 Shakespeare St	0.03	-0.19	N/A	N/A	N/A	N/A
459884.6	5772791	37.39	36.74	RES	7/9 Berry St	0.04	-0.09	-0.26	-0.46	N/A	N/A
459671.4	5772879	37.34	36.63	RES	Willow Ct	0.04	-0.04	-0.15	-0.26	-0.47	N/A
459941.3	5772918	35.97	35.38	RES	Davidson St	0.04	-0.08	-0.23	-0.37	N/A	N/A
459958.1	5772888	36.20	35.70	RES	Berry St	0.05	-0.12	-0.36	-0.50	N/A	N/A
459967.5	5772810	36.86	36.26	RES	Berry St	0.05	-0.11	-0.30	N/A	N/A	N/A
459752.1	5772879	36.54	35.71	RES	George St	0.05	-0.08	-0.23	-0.38	N/A	N/A
459824.3	5772872	36.67	36.09	RES	George St	0.06	-0.05	-0.19	-0.34	N/A	N/A
459816.1	5772886	36.54	35.98	RES	28/30 George St	0.06	-0.04	-0.16	N/A	N/A	N/A
459986.2	5772031	39.79	38.69	RES	Whittakers Rd	0.06	-0.31	-0.69	-0.91	N/A	N/A
459907.8	5772811	36.95	36.42	RES	7/9 Berry St	0.06	-0.05	-0.16	-0.28	N/A	N/A
459939	5771868	39.82	39.15	RES	Tennyson St	0.07	-0.27	N/A	N/A	N/A	N/A
460034.6	5771981	39.86	38.63	RES	Whittakers Rd	0.07	-0.30	-0.65	-0.89	N/A	N/A
460085.2	5773212	35.13	35.04	RES	6 Alfred Cl	0.08	0.07	0.07	0.06	0.05	-0.04
460146.9	5771769	40.04	39.23	RES	Whittakers Rd	0.08	-0.17	-0.39	-0.57	N/A	N/A
460273.6	5772517	39.17	38.67	RES	Gwalia St	0.08	-0.44	-0.77	N/A	N/A	N/A

Easting	Northing	Floor Level	Ground Level	Building Type	Address	0.5% AEP Depth Above Floor	1% AEP Depth Above Floor	2% AEP Depth Above Floor	5% AEP Depth Above Floor	10% AEP Depth Above Floor	20% AEP Depth Above Floor
459869.5	5772909	36.20	35.60	RES	23/25 Davidson St	0.08	-0.01	-0.11	-0.24	N/A	N/A
459909.1	5772805	36.99	36.55	RES	7/9 Berry St	0.08	-0.03	-0.14	-0.27	N/A	N/A
460295.1	5772538	39.16	38.67	RES	Gwalia St	0.09	-0.43	N/A	N/A	N/A	N/A
460271.3	5772553	39.15	38.67	RES	Gwalia St	0.10	N/A	N/A	N/A	N/A	N/A
460417	5772549	39.15	39.00	RES	Gwalia St	0.10	N/A	N/A	N/A	N/A	N/A
460405.9	5772547	39.15	39.00	RES	Gwalia St	0.10	N/A	N/A	N/A	N/A	N/A
460082.9	5771929	39.87	38.87	RES	Whittakers Rd	0.10	-0.26	-0.54	-0.78	N/A	N/A
459771.4	5773507	34.73	34.00	RES	Franklin St.	0.10	N/A	N/A	N/A	N/A	N/A
459944.4	5772886	36.21	35.64	RES	Berry St	0.10	-0.05	-0.24	-0.38	N/A	N/A
459973.7	5772771	37.08	36.63	RES	Berry St	0.11	-0.03	-0.18	-0.29	-0.30	N/A
460427.4	5772551	39.13	39.06	RES	Gwalia St	0.12	N/A	N/A	N/A	N/A	N/A
460435.9	5772552	39.13	39.06	RES	Gwalia St	0.12	N/A	N/A	N/A	N/A	N/A
459967.2	5771995	39.77	39.10	RES	Tennyson St	0.12	-0.24	N/A	N/A	N/A	N/A
459977	5772750	37.27	36.76	RES	Berry St	0.12	0.00	-0.17	-0.28	-0.29	N/A
459741.6	5772924	36.22	35.51	RES	George St	0.13	0.00	-0.19	-0.37	N/A	N/A
460010.7	5772905	35.94	35.56	RES	Peterkin St	0.13	0.01	-0.14	N/A	N/A	N/A
459998.3	5772017	39.76	38.56	RES	Whittakers Rd	0.13	-0.24	-0.63	-0.87	N/A	N/A
459850.7	5772800	37.30	36.54	RES	George St	0.13	-0.01	-0.22	-0.43	N/A	N/A
459920.6	5771985	39.73	39.20	RES	Booth Ct	0.13	-0.20	N/A	N/A	N/A	N/A
460021.4	5771994	39.78	38.61	RES	Whittakers Rd	0.13	-0.24	-0.61	-0.85	N/A	N/A

Easting	Northing	Floor Level	Ground Level	Building Type	Address	0.5% AEP Depth Above Floor	1% AEP Depth Above Floor	2% AEP Depth Above Floor	5% AEP Depth Above Floor	10% AEP Depth Above Floor	20% AEP Depth Above Floor
459900.7	5772771	37.40	36.72	RES	3/5 Berry St	0.15	0.02	-0.16	-0.38	N/A	N/A
460035	5772805	36.74	36.41	RES	Peterkin St	0.15	0.05	-0.08	N/A	N/A	N/A
459942.4	5771890	39.73	39.30	RES	Tennyson St	0.16	-0.19	N/A	N/A	N/A	N/A
459980.2	5771818	39.85	39.58	RES	Tennyson St	0.16	-0.09	N/A	N/A	N/A	N/A
459796.7	5772933	36.10	35.48	RES	Davidson St	0.17	0.05	-0.14	-0.36	N/A	N/A
459955.9	5772869	36.20	35.82	RES	Berry St	0.17	0.00	-0.16	-0.26	N/A	N/A
460250.7	5772544	39.06	38.67	RES	Gwalia St	0.19	N/A	N/A	N/A	N/A	N/A
459947.2	5772011	39.67	38.89	RES	Booth Ct	0.19	-0.16	-0.52	N/A	N/A	N/A
459939.3	5771922	39.69	39.05	RES	Tennyson St	0.19	-0.15	N/A	N/A	N/A	N/A
459765.3	5772817	37.21	36.54	RES	George St	0.20	0.12	0.01	-0.09	N/A	N/A
460098	5771762	40.00	39.45	RES	Shakespeare St	0.20	-0.01	-0.27	N/A	N/A	N/A
459793.3	5773491	34.68	34.68	RES	Franklin St.	0.20	N/A	N/A	N/A	N/A	N/A
460237.7	5772519	39.04	38.67	RES	Gwalia St	0.21	-0.31	N/A	N/A	N/A	N/A
459890.1	5772814	36.94	36.50	RES	7/9 Berry St	0.21	0.10	-0.04	-0.17	N/A	N/A
459814.8	5772930	36.02	35.56	RES	Davidson St	0.21	0.10	-0.05	-0.26	N/A	N/A
460100.9	5771889	39.79	38.95	RES	Whittakers Rd	0.21	-0.11	-0.33	-0.54	N/A	N/A
459769.7	5773494	34.61	34.00	RES	Franklin St.	0.21	0.02	N/A	N/A	N/A	N/A
459943.8	5771907	39.68	39.10	RES	Tennyson St	0.21	-0.14	N/A	N/A	N/A	N/A
460039.5	5771768	40.04	39.43	RES	Shakespeare St	0.22	0.01	N/A	N/A	N/A	N/A
459973.7	5772045	39.58	38.73	RES	Whittakers Rd	0.22	-0.14	-0.52	-0.73	N/A	N/A

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460199.4	5772310	39.12	38.07	RES	Peterkin St	0.22	-0.13	-0.51	N/A	N/A	N/A
460096.6	5771905	39.76	39.13	RES	Whittakers Rd	0.23	-0.09	-0.31	N/A	N/A	N/A
460090.6	5771902	39.76	39.13	RES	Whittakers Rd	0.23	-0.09	-0.31	-0.52	N/A	N/A
460084.5	5771900	39.76	39.13	RES	Whittakers Rd	0.23	-0.09	-0.31	-0.53	N/A	N/A
460077.5	5771896	39.76	39.13	RES	Whittakers Rd	0.23	-0.09	-0.33	-0.55	N/A	N/A
460061.8	5772015	39.70	38.74	RES	Whittakers Rd	0.23	-0.15	-0.58	N/A	N/A	N/A
460017.1	5771783	39.95	39.52	RES	Shakespeare St	0.24	0.01	-0.26	N/A	N/A	N/A
460029.2	5771782	39.95	39.52	RES	Shakespeare St	0.24	0.02	-0.24	N/A	N/A	N/A
459651.2	5773267	34.78	34.60	RES	Franklin St	0.24	0.05	-0.10	-0.17	-0.23	N/A
459590.5	5772956	36.25	35.77	RES	Franklin St	0.24	0.17	0.08	-0.06	-0.22	N/A
459759.6	5772840	36.82	36.28	RES	George St	0.25	0.16	0.05	-0.04	N/A	N/A
460346.1	5772460	39.00	38.66	RES	Campbell St	0.25	-0.27	N/A	N/A	N/A	N/A
459758.2	5772858	36.59	36.04	RES	George St	0.26	0.16	0.06	-0.06	N/A	N/A
459593.7	5772974	35.96	35.55	RES	Franklin St	0.26	0.21	0.14	0.05	-0.04	N/A
459830.2	5772842	36.61	36.12	RES	George St	0.27	0.14	-0.03	-0.23	N/A	N/A
460072.2	5772002	39.68	38.48	RES	Whittakers Rd	0.27	-0.12	-0.56	N/A	N/A	N/A
460017.3	5772887	35.99	35.80	RES	Peterkin St	0.28	0.16	-0.01	N/A	N/A	N/A
460028.9	5771774	39.95	39.52	RES	Shakespeare St	0.29	0.07	-0.20	N/A	N/A	N/A
459719.6	5772855	37.02	36.32	RES	Willow Ct	0.29	0.19	0.06	-0.08	N/A	N/A
459745.4	5773270	34.77	34.15	RES	Franklin St	0.29	0.12	N/A	N/A	N/A	N/A

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460016.5	5771775	39.95	39.52	RES	Shakespeare St	0.30	0.09	-0.18	N/A	N/A	N/A
460202.3	5772289	39.07	37.81	RES	Peterkin St	0.30	-0.05	-0.44	N/A	N/A	N/A
459827.7	5772857	36.49	35.89	RES	George St	0.30	0.18	0.03	-0.15	N/A	N/A
460055.6	5771860	39.71	38.92	RES	Milton Ct	0.31	0.01	-0.24	-0.46	N/A	N/A
459742.8	5772910	36.15	35.49	RES	George St	0.31	0.17	-0.03	-0.26	N/A	N/A
460026.8	5772844	36.16	35.73	RES	Peterkin St	0.32	0.16	-0.09	-0.21	N/A	N/A
459949.1	5771938	39.56	38.95	RES	Tennyson St	0.34	-0.02	N/A	N/A	N/A	N/A
459996	5771952	39.58	38.76	RES	Tennyson St	0.34	-0.02	-0.35	-0.57	N/A	N/A
459894.6	5772794	37.00	36.69	RES	7/9 Berry St	0.34	0.23	0.07	-0.11	N/A	N/A
460061	5771903	39.63	38.71	RES	Moonabeal Ct	0.34	-0.01	-0.29	-0.54	N/A	N/A
460037.8	5771814	39.71	39.00	RES	Milton Ct	0.36	0.08	-0.19	-0.44	N/A	N/A
460100.2	5771795	39.71	39.19	RES	Whittakers Rd	0.36	0.10	-0.14	-0.41	N/A	N/A
459969.6	5772906	35.74	35.26	RES	Davidson St	0.37	0.23	0.00	-0.21	-0.23	-0.24
460030.1	5771834	39.66	39.01	RES	Milton Ct	0.38	0.09	-0.16	-0.40	N/A	N/A
460081.6	5771765	39.85	39.31	RES	Shakespeare St	0.38	0.18	-0.11	N/A	N/A	N/A
459647.7	5772895	36.98	36.52	RES	Franklin St	0.39	0.31	0.20	0.08	-0.15	N/A
460159.5	5772508	38.86	38.33	RES	Peterkin St	0.39	-0.13	N/A	N/A	N/A	N/A
460038.6	5772040	39.51	38.67	RES	Whittakers Rd	0.40	0.02	-0.41	-0.68	N/A	N/A
460211.3	5772421	38.85	38.55	RES	2/5 Gwalia St	0.40	-0.12	N/A	N/A	N/A	N/A
460054.5	5771806	39.68	38.99	RES	Milton Ct	0.40	0.13	-0.14	-0.41	N/A	N/A

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460075.2	5771856	39.63	39.00	RES	Milton Ct	0.41	0.11	-0.14	-0.37	N/A	N/A
459994.8	5772084	39.34	38.61	RES	Whittakers Rd	0.41	0.05	-0.31	N/A	N/A	N/A
460144.8	5771753	39.77	39.07	RES	Whittakers Rd	0.42	0.18	-0.06	-0.26	-0.45	-0.47
459987	5771878	39.53	38.97	RES	Tennyson St	0.42	0.09	-0.18	-0.42	N/A	N/A
459832.7	5772827	36.65	36.12	RES	George St	0.43	0.30	0.12	-0.07	N/A	N/A
460100.7	5771814	39.63	39.17	RES	Whittakers Rd	0.43	0.14	-0.11	N/A	N/A	N/A
460024	5771890	39.54	38.73	RES	Moonabeal Ct	0.43	0.09	-0.20	-0.44	N/A	N/A
459960.5	5772060	39.31	38.84	RES	Whittakers Rd	0.44	0.09	-0.28	N/A	N/A	N/A
460103.9	5771847	39.59	39.10	RES	Whittakers Rd	0.46	0.16	-0.08	-0.32	N/A	N/A
460043.9	5772767	36.91	36.83	RES	Peterkin St	0.46	0.36	0.17	N/A	N/A	N/A
459950.3	5771953	39.43	38.84	RES	Tennyson St	0.46	0.11	N/A	N/A	N/A	N/A
460015.5	5771931	39.48	38.75	RES	Moonabeal Ct	0.47	0.11	-0.20	-0.43	N/A	N/A
459839.7	5772813	36.82	36.37	RES	George St	0.47	0.34	0.13	-0.09	N/A	N/A
459999.1	5772105	39.26	38.55	RES	Howitt St	0.48	0.12	-0.24	-0.42	N/A	N/A
460037.6	5771849	39.54	39.04	RES	Milton Ct	0.49	0.19	-0.06	-0.30	N/A	N/A
460032.8	5771938	39.46	38.75	RES	Moonabeal Ct	0.50	0.14	-0.17	-0.41	N/A	N/A
460011.3	5772070	39.32	38.63	RES	Whittakers Rd	0.50	0.13	-0.28	N/A	N/A	N/A
460061.4	5771767	39.68	39.34	RES	Shakespeare St	0.56	0.36	0.08	N/A	N/A	N/A
459919	5772753	36.97	36.74	RES	Berry St	0.57	0.43	0.26	0.04	N/A	N/A
460047.9	5771967	39.38	38.73	RES	Whittakers Rd	0.57	0.20	-0.13	-0.37	N/A	N/A

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459993.5	5771935	39.35	38.80	RES	Tennyson St	0.58	0.21	-0.11	-0.33	N/A	N/A
460342	5772481	38.67	38.47	RES	Campbell St	0.58	0.06	N/A	N/A	N/A	N/A
460072	5771808	39.49	39.02	RES	Milton Ct	0.58	0.31	0.05	-0.22	N/A	N/A
460105.5	5771866	39.44	39.01	RES	Whittakers Rd	0.59	0.28	0.05	-0.18	N/A	N/A
459689.2	5772858	37.04	36.54	RES	Willow Ct	0.59	0.49	0.36	0.22	-0.05	N/A
460060.6	5771954	39.34	38.69	RES	Whittakers Rd	0.62	0.26	-0.05	-0.30	N/A	N/A
460165.4	5772491	38.61	38.27	RES	Peterkin St	0.64	0.12	N/A	N/A	N/A	N/A
459893.4	5772840	36.21	36.08	RES	Berry St	0.64	0.53	0.39	0.25	N/A	N/A
459990.4	5771916	39.29	38.79	RES	Tennyson St	0.64	0.28	-0.02	-0.23	N/A	N/A
460239.1	5772447	38.56	37.78	RES	Gwalia St	0.69	0.17	-0.16	-0.48	N/A	N/A
460204.9	5772458	38.55	38.06	RES	1/5 Gwalia St	0.69	0.17	-0.15	-0.47	N/A	N/A
460020	5772108	39.12	38.62	RES	Howitt St	0.70	0.32	-0.09	-0.29	N/A	N/A
460170.9	5772422	38.48	38.27	RES	Gwalia St	0.77	0.25	N/A	N/A	N/A	N/A
460179.2	5772431	38.48	38.27	RES	Gwalia St	0.77	0.25	N/A	N/A	N/A	N/A
460192.1	5772433	38.48	38.27	RES	Gwalia St	0.77	0.25	N/A	N/A	N/A	N/A
460172.5	5772443	38.46	38.27	RES	Gwalia St	0.79	0.27	N/A	N/A	N/A	N/A
460186.7	5772446	38.46	38.27	RES	Gwalia St	0.79	0.27	N/A	N/A	N/A	N/A
460197	5772416	38.44	38.27	RES	Gwalia St	0.81	0.29	N/A	N/A	N/A	N/A
460194.1	5772403	38.44	38.27	RES	Gwalia St	0.81	0.29	N/A	N/A	N/A	N/A
460175.5	5772400	38.44	37.27	RES	Gwalia St	0.81	0.29	N/A	N/A	N/A	N/A

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460286.8	5772465	38.41	38.03	RES	Gwalia St	0.84	0.32	-0.01	N/A	N/A	N/A
460290.2	5772451	38.41	38.03	RES	Gwalia St	0.84	0.32	-0.01	N/A	N/A	N/A
460267	5772461	38.40	38.03	RES	Gwalia St	0.85	0.33	0.00	N/A	N/A	N/A
460270.3	5772446	38.40	38.03	RES	Gwalia St	0.85	0.33	0.00	N/A	N/A	N/A
460292.1	5772438	38.39	38.03	RES	Gwalia St	0.86	0.34	0.01	N/A	N/A	N/A
460294.9	5772425	38.39	38.03	RES	Gwalia St	0.86	0.34	0.01	N/A	N/A	N/A
460319.2	5772464	38.39	38.22	RES	Gwalia St	0.86	0.34	0.01	N/A	N/A	N/A
460273.2	5772434	38.38	38.03	RES	Gwalia St	0.87	0.35	0.02	N/A	N/A	N/A
460276.2	5772421	38.38	38.03	RES	Gwalia St	0.87	0.35	0.02	N/A	N/A	N/A
460300.3	5772459	38.38	38.22	RES	Gwalia St	0.87	0.35	0.02	N/A	N/A	N/A
460052.6	5771939	39.05	38.84	RES	6 Moonabeal Ct	0.91	0.55	0.26	0.01	N/A	N/A
460251.1	5772468	37.78	37.76	RES	11 Gwalia St	1.47	0.95	0.62	0.30	N/A	N/A
459928.5	5772562	40.96	39.50	COM	Grey St	-2.81	-2.98	-3.29	N/A	N/A	N/A
459595.4	5772615	40.49	40.24	COM	190 Franklin St	-2.23	-2.23	-2.23	-2.23	-2.24	-2.25
459978.6	5772589	38.93	37.83	COM	Princes Hwy	-0.50	-0.64	N/A	N/A	N/A	N/A
459667.1	5772944	36.60	35.68	COM	Davidson St	-0.25	-0.32	-0.40	-0.49	-0.65	N/A
459646.4	5772948	36.62	35.60	COM	Davidson St	-0.24	-0.30	-0.38	-0.47	-0.62	N/A
460213.9	5772668	38.91	38.89	COM	58-62 Argyle St	-0.14	-0.16	-0.17	-0.19	-0.22	-0.24
460223.3	5772575	39.30	38.80	COM	Argyle St	-0.05	N/A	N/A	N/A	N/A	N/A
460152.5	5771946	40.04	38.95	COM	Whittakers Rd	-0.05	-0.42	-0.72	N/A	N/A	N/A

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460236.3	5771889	40.08	38.90	COM	Whittakers Rd	-0.04	-0.35	-0.59	-1.07	N/A	N/A
460248.2	5772582	39.25	38.80	COM	Argyle St	0.00	N/A	N/A	N/A	N/A	N/A
460090.6	5772371	39.26	38.60	COM	Peterkin St	0.03	-0.33	N/A	N/A	N/A	N/A
459841.1	5773042	35.35	34.97	COM	Davidson St	0.08	N/A	N/A	N/A	N/A	N/A
460188.7	5772735	38.20	38.03	COM	Munro St.	0.20	0.19	0.19	0.19	N/A	N/A
459868.8	5772789	37.33	36.61	COM	George St	0.20	0.07	-0.13	-0.34	N/A	N/A
460264.8	5772588	39.01	38.81	COM	Argyle St	0.24	N/A	N/A	N/A	N/A	N/A
459624.4	5772783	37.36	37.36	COM	Franklin St	0.26	0.16	0.03	-0.08	N/A	N/A
459831.2	5772931	35.60	35.34	COM	Davidson St	0.50	0.40	0.26	0.11	N/A	N/A
460146.1	5772161	39.26	38.60	COM	Howitt St	0.69	0.27	-0.25	-0.81	N/A	N/A
460101.6	5771966	39.27	39.17	COM	Whittakers Rd	0.70	0.33	0.04	N/A	N/A	N/A
460034.5	5772284	38.52	38.42	COM	Peterkin St	0.86	0.52	0.16	-0.12	-0.48	-0.89
459958.4	5772230	38.51	38.41	COM	Peterkin St	0.90	0.62	0.37	0.22	-0.11	-0.42
460109.1	5772010	38.89	38.80	COM	Whittakers Rd	1.07	0.68	0.21	N/A	N/A	N/A
460150.9	5771982	38.89	38.79	COM	Whittakers Rd	1.09	0.70	0.23	N/A	N/A	N/A
460062.2	5772060	38.70	38.60	COM	Whittakers Rd	1.23	0.84	0.36	0.11	N/A	N/A
460152.7	5772022	38.69	38.63	COM	Whittakers Rd	1.28	0.89	0.39	0.02	N/A	N/A
460176.8	5772165	38.66	38.20	COM	Howitt St	1.28	0.87	0.34	N/A	N/A	N/A