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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- Linda Tubnor (West Gippsland CMA & Project Manager)
- 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.

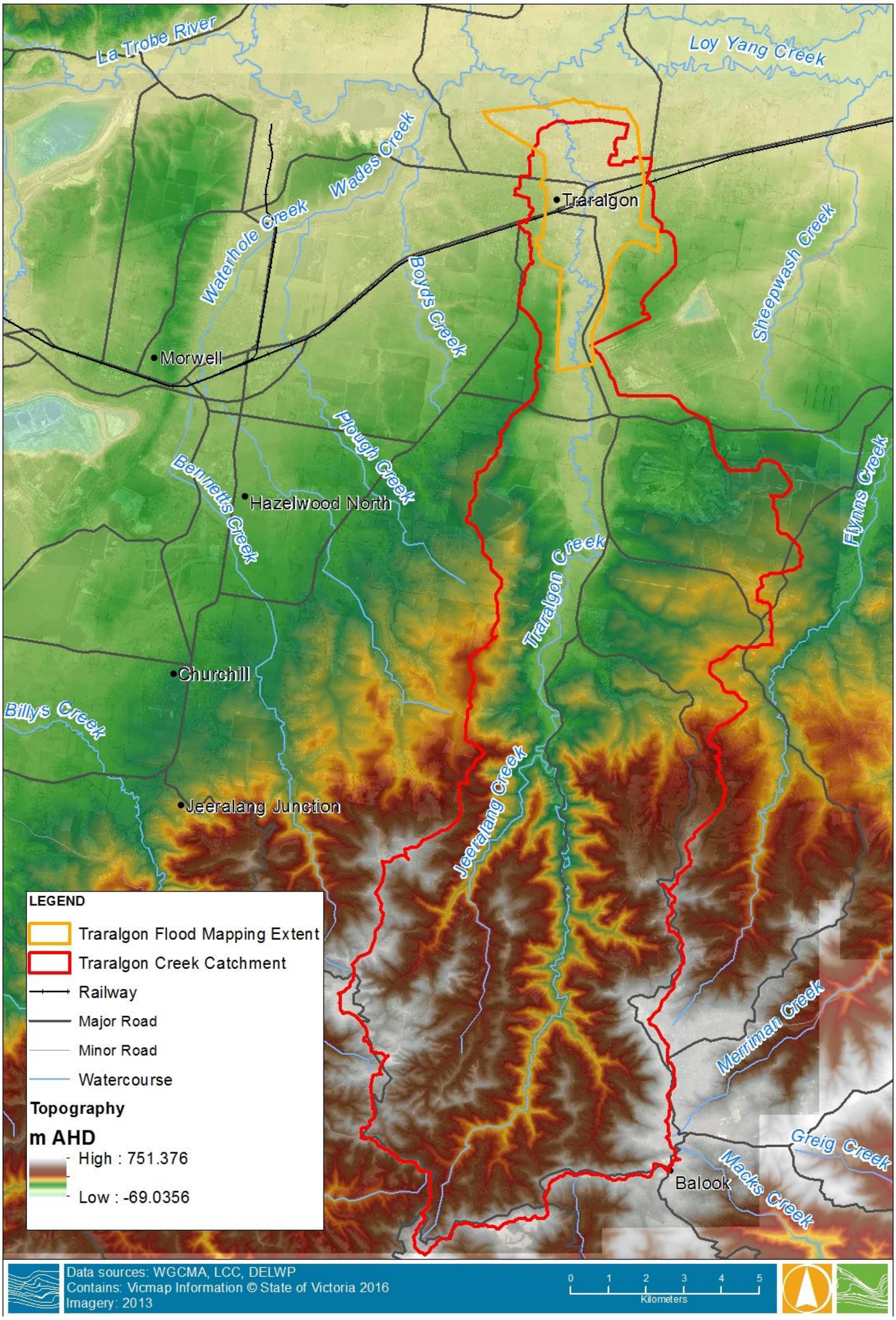

Figure 1-1 Traralgon Creek catchment extent highlighting the study area

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

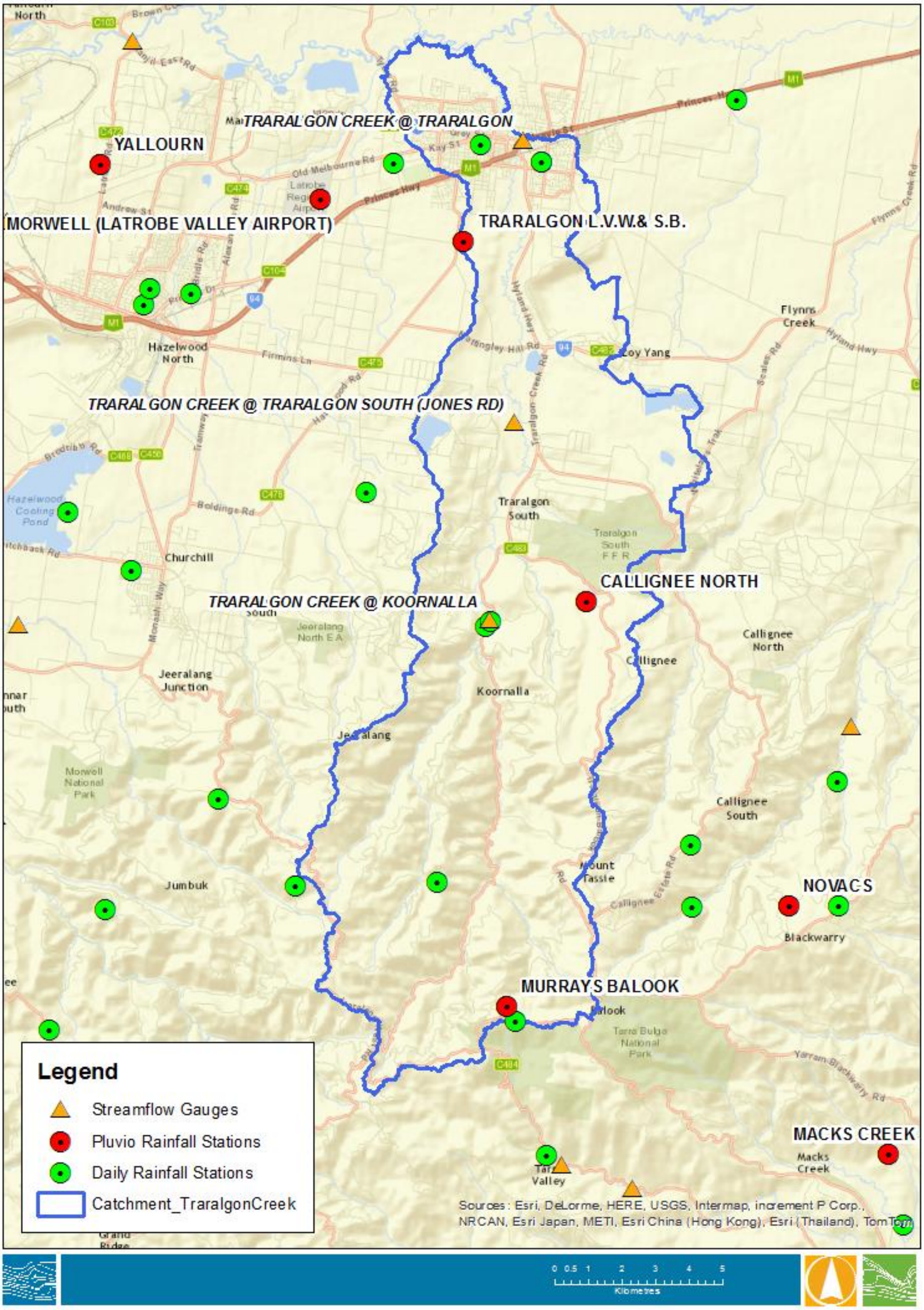

Figure 2-1 Daily Rainfall, Pluvio and Streamflow Stations around Traralgon Creek catchment

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.

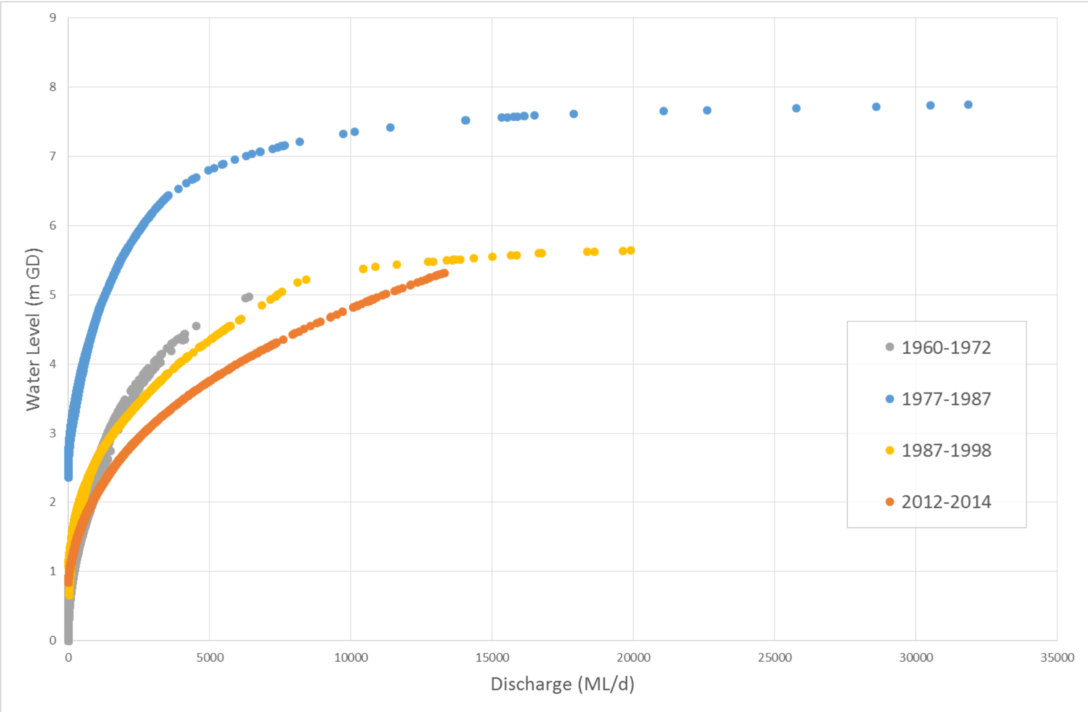

Figure 2-2 Water Level vs. Discharge Plot for Traralgon gauge (226023) showing variation in rating curves across period of record

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.

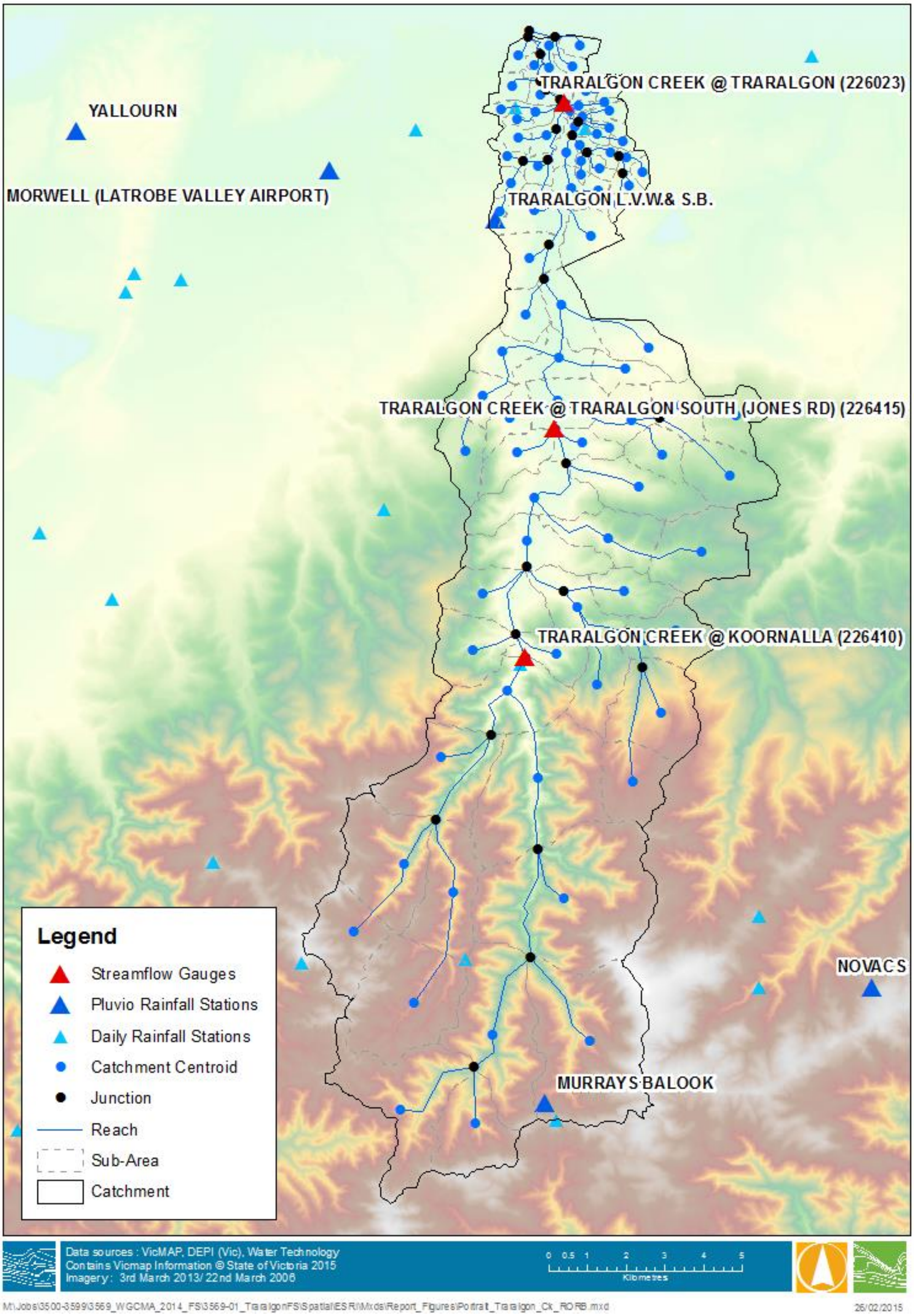

Figure 4-1 RORB Model Structure

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.

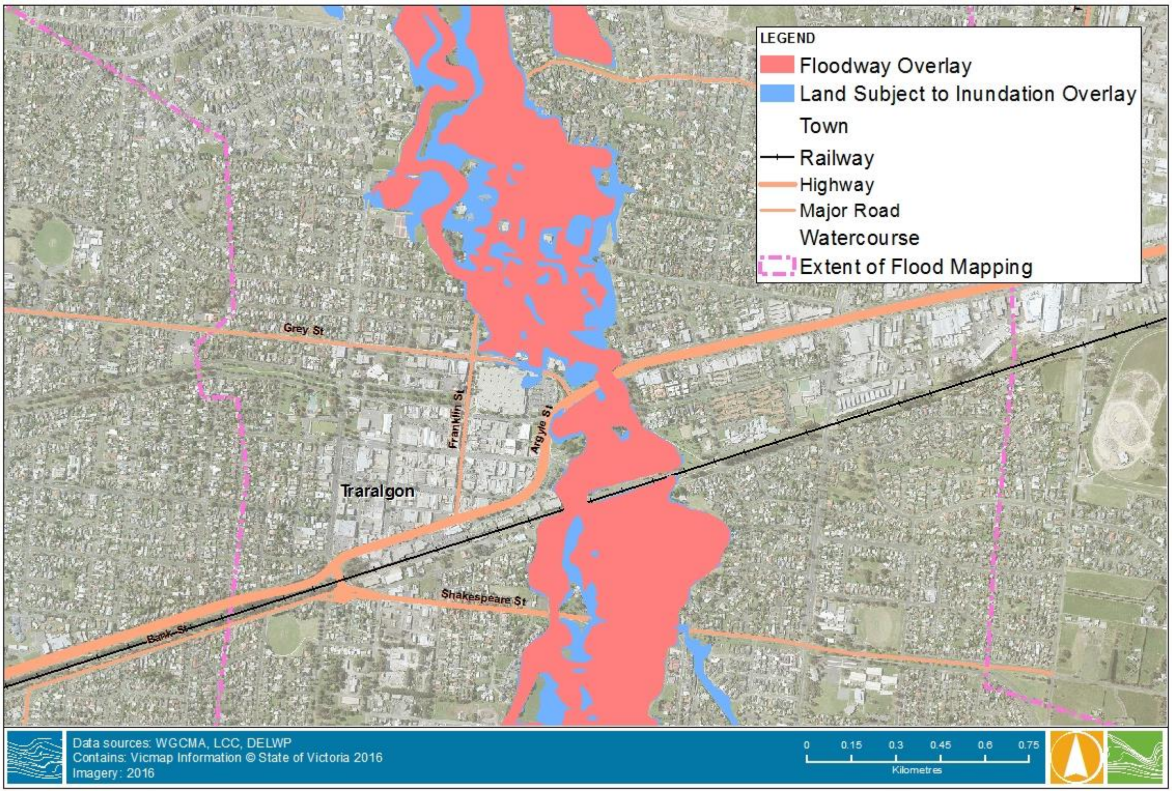

Figure 5-1 Draft LSIO and FO Extents

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.

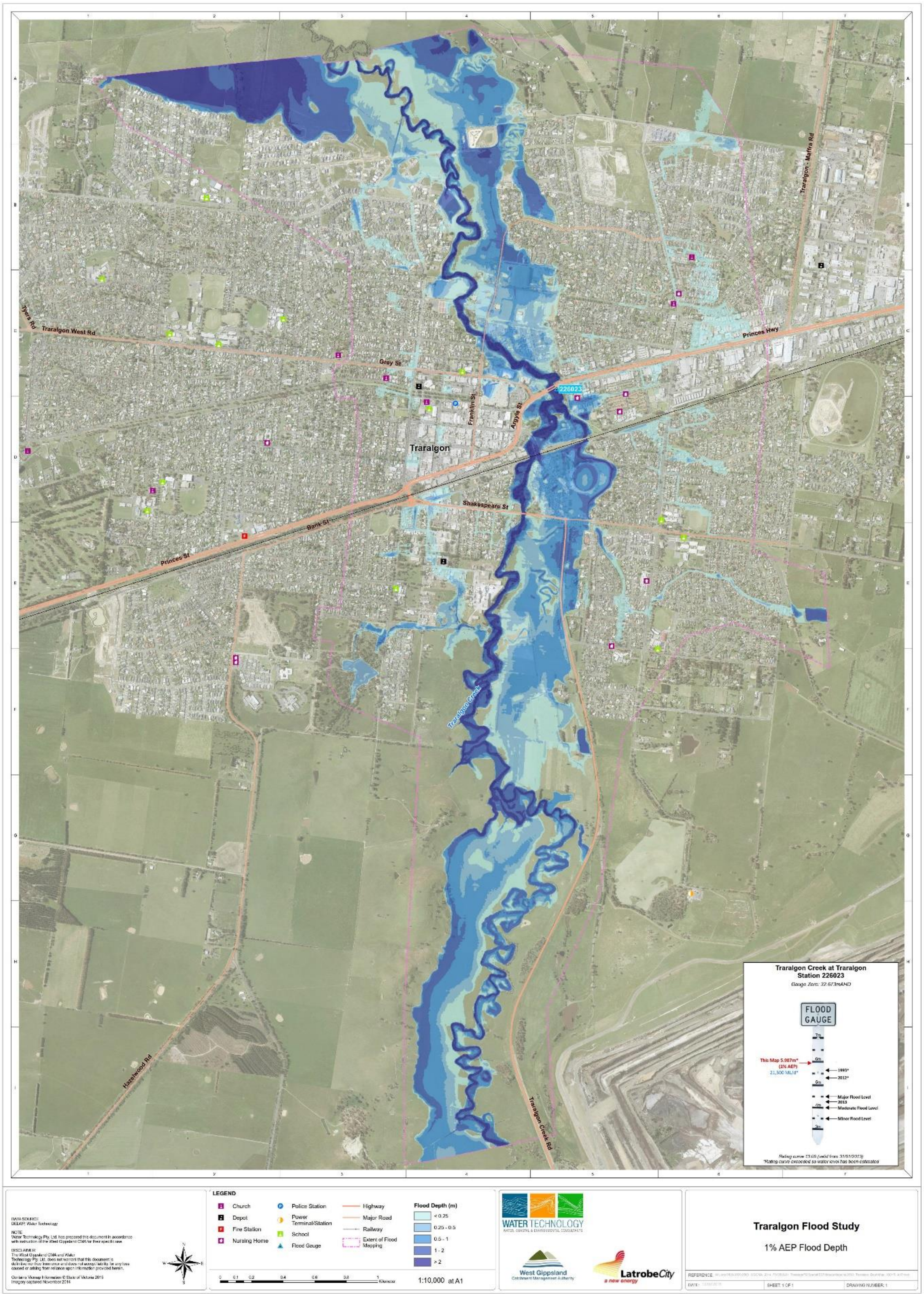

Figure 6-1 1% AEP Maximum Flood Depth Map

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.

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