North Central Catchment Management Authority

Castlemaine, Campbells Creek and Chewton Flood Management Plan

August 2015

Executive summary

The townships of Castlemaine, Campbells Creek and Chewton are located in central Victoria on Barkers Creek, Forest Creek and Campbells Creek. The catchment area for this investigation is shown on Figure A. The catchment shown on Figure A encompasses an area of approximately 154 km^2. The townships of Castlemaine, Campbells Creek and Chewton have been affected by flooding from Barkers Creek, Forest Creek and Campbells Creek four (4) times in recent years, including September 2010, November 2010, major flooding in January 2011 and another major flash flood in February 2012. Several residences and businesses were inundated in the January 2011 and February 2012 flood events from riverine flooding.

The Victorian Government announced funding to undertake the Castlemaine, Campbells Creek and Chewton Flood Management Plan on the 12th October 2012. The North Central Catchment Management Authority in conjunction with the Mount Alexander Shire Council engaged the services of GHD to develop the Flood Management Plan.

This report documents the work undertaken to develop the Plan, namely:

- A review of the available data and historic flood information;
- Hydrological assessment;
- Hydraulic Assessment;
- Flood Damage Assessment;
- Mitigation Option Assessment; and
- Community Consultation.

Flood Modelling (Hydrological and Hydraulic Assessment)

A rainfall runoff model (RORB) of the Campbells Creek catchment was developed to model the rainfall-runoff relationship of the catchment. The RORB model was then used to estimate the flow at Castlemaine, Campbells Creek and Chewton for the January 2011 event (maximum flow estimated at Gaulton Street bridge of 185 m^3/s) and for the February 2012 event (maximum flow estimated at Gaulton Street bridge of 115 m^3/s). The RORB model was also used to establish design hydrographs for a range of flood events (0.5%, 1%, 2%, 5%, 10% and 20% AEP events).

Hydraulic modelling of the study area (refer to Figure A for study area) was completed using a two dimensional model (TUFLOW). The hydraulic model was calibrated to the January 2011 and February 2012 event.

The calibrated hydraulic model was used to produce flood extents for the 0.5%, 1%, 2%, 5%, 10% and 20% AEP events.

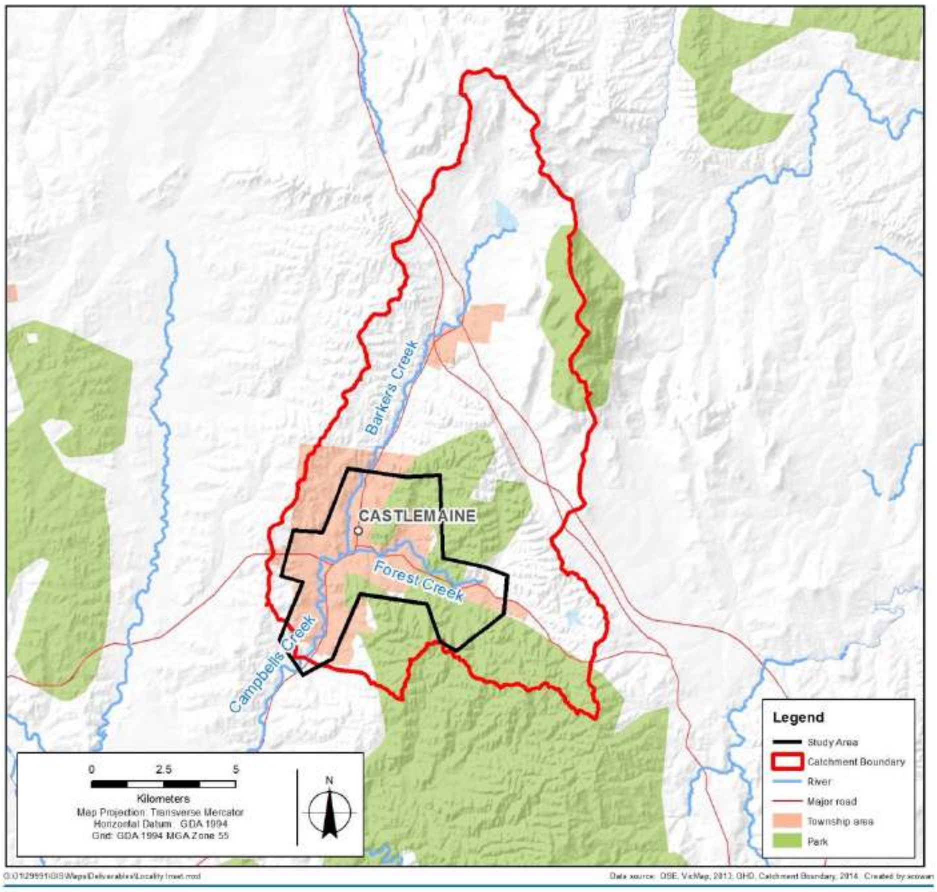

Figure A Locality Plan

Flood Damage and Flood Mitigation Assessment

A primary objective of the Plan was to investigate and recommend potential options to reduce the impact of flooding on the townships of Castlemaine, Campbells Creek and Chewton. Through the community based steering committee, public meetings and community questionnaires a list of options to reduce the risk of flooding in Castlemaine, Campbells Creek and Chewton was developed. It is important to note that all options recommended by the community were considered.

Following a preliminary assessment of a number of options and receiving direction/advice from the steering committee a number of options were assessed in detail. Several of the options considered in more detail involved levees (refer to Figure B for their location).

A flood damage assessment was undertaken for the existing conditions and assuming that each of the levee mitigation options were in place. Construction costs for each mitigation option were estimated. From the reduction in flood damages as a result of the mitigation options and the construction cost estimates a benefit cost analysis was undertaken for each mitigation option. From this analysis a number of structural works have been recommended for Castlemaine, Campbells Creek and Chewton.

In addition to the structural options a number of non-structural options have been recommended.

Recommendations of the Plan

Structural Flood Mitigation Works

It is recommended for Castlemaine, Campbells Creek and Chewton that Council investigates further:

- The construction of a levee at the northern end of Gingell Street;
- The construction of a levee at the southern end of Gingell Street and/or upgrade the local storm water drainage in the area;
- The construction of a levee adjacent to the Castlemaine Central Cabin and Van Park;Upgrade and extend the existing Elizabeth Street levee;
- Upgrade and extend the existing Campbells Creek township levee;
- The reinstatement of the National School Lane levee to its original height and removal of vegetation from the levee; and
- Minor waterway improvement works downstream of the Alexandra Street Bridge in Campbells Creek.

Each levee will be subject to detailed design and all aspects of the levee, including the height, will be decided upon in consultation with affected property owners, occupiers and the broader community.

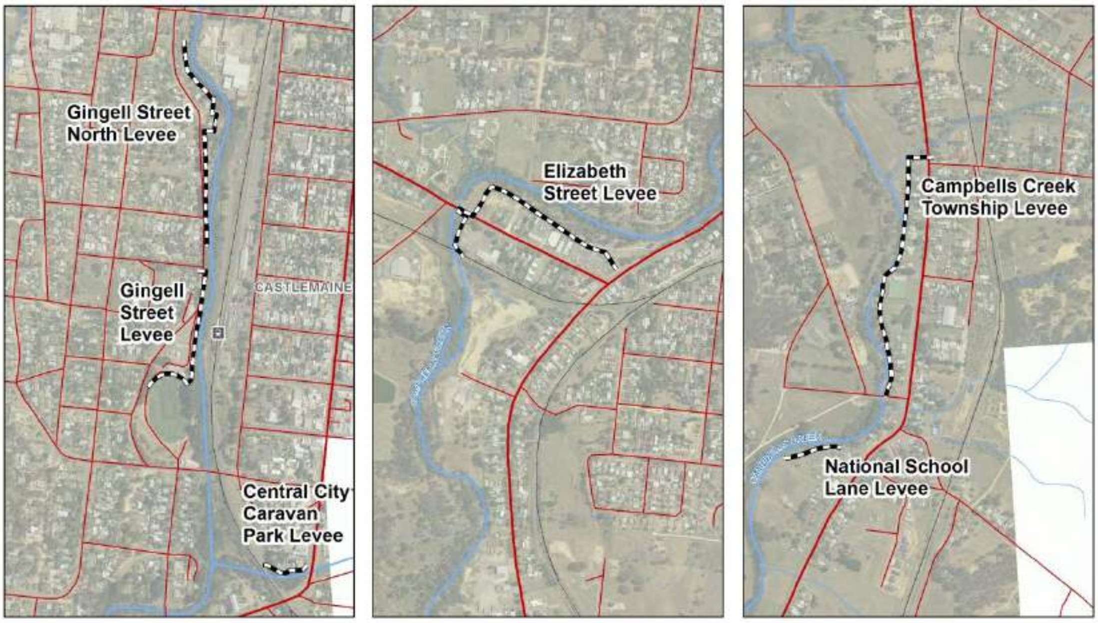

Figure B Proposed Levee Locations

Non - Structural Flood Mitigation Works

It is recommended for Castlemaine, Campbells Creek and Chewton:

- That the Mount Alexander Shire Council lead the development of a strategic plan for urban waterways which includes, but not limited to, the learnings from the Flood Management Plan;
- The development of a flood-warning system for Barkers Creek, Forest Creek and Campbells Creek based on the learnings of the Flood Management Plan;
- That there is an amendment to the Mount Alexander Planning Scheme to incorporate new flood mapping produced by the Flood Management Plan.

The final recommendations are found in Section 11.

Community Consultation and Feedback

The primary objective of this project was to obtain community support for the recommendations of the Flood Management Plan. To this end, significant community consultation was undertaken throughout the development of the Flood Management Plan.

A community based Steering Committee was appointed to oversee the development of the Plan and North Central Catchment Management Authority (NCCMA) led a community consultation program to gain feedback and support from the wider community.

Consultation was undertaken throughout the project. At the beginning of the project, public questionnaires were widely distributed and a public meeting was held to discuss flooding issues and receive ideas from the community on potential solutions.

The development of the Flood Management Plan was supported by additional meetings between the NCCMA project manager and community members as well as the incorporation of community conversations into Steering Committee meetings via the community based Steering Committee members. Details on the community consultation project are found in Section 9.

Feedback received by the community guided the Steering Committee in determining the final recommendations of the Flood Management Plan (refer to Section 11).

The feedback received indicates a clear level of support in the community for the recommendations of the Flood Management Plan but also highlighted the requirement for further consultation before any structural works are undertaken.

Acknowledgements

The Castlemaine, Campbells Creek and Chewton Flood Management Plan was led by a community based Steering Committee and supported by a Technical Working Group consisting of representatives from North Central Catchment Management Authority, Mount Alexander Shire Council, VicSES, Department of Environment, Land, Water and Planning, Bureau of Meteorology, VicRoads, VicTrack, Parks Victoria and Coliban Water.

GHD would like to especially thank the following community members on the Steering Committee for their support throughout the development of this Plan:

Ron Cosgrave (Chair), Graeme Hilder, Marie Jones, Richard Green, Peter Brown, Derek Showell, Bob Pratt (VicSES Castlemaine) and David King.

Also GHD would particularly like to thank Shaun Morgan of the North Central Catchment Management Authority who has worked tirelessly on the delivery of this plan.

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Glossary of terms

Annual Exceedence Probability (AEP)	The probability of a rainfall or flood event occurring or being exceeded within a year. For example a 1% AEP can also be referred to as a 1 in 100 AEP event.
Average Recurrence Interval (ARI)	The average period between occurrences equalling or exceeding a given value. The term ARI is often interchanged with AEP, i.e. a 1% AEP equals a 100 year ARI, however the term AEP is a more accurate representation of the potential risk.
Afflux	A rise in the water level immediately upstream of and due to a natural or artificial obstruction.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level. Introduced in 1971 to provide a common national standard.
Catchment	The land area draining to a point of interest, such as a water storage or monitoring site on a watercourse.
Digital Elevation Model (DEM)	A digital elevation model is a representation of the earth's surface.
Hydrograph	A graph showing the surface level, discharge, velocity, or some other feature of water, with respect to time.
Hydrology	The branch of science concerned with the properties of the earth's water, and especially its movement in relation to land.
Hydraulics	The branch of science and technology concerned with the conveyance of liquids through pipes and channels, especially as a source of mechanical force or control.
Levee	Is an elongated naturally occurring ridge or artificially constructed bank or wall, which regulates water levels. It is usually earthen and often parallel to the course of a river in its floodplain.
Pluviograph	An instrument for measuring the amount of water that has fallen (i.e. rain gauge), with a feature to register the data in real time to demonstrate rainfall over a short period of time, often an automated graphing instrument.
RORB	A computer model used to calculate flood hydrographs from rainfall and other channel inputs.
TUFLOW	A hydraulic modelling tool to simulate the flow of flood water through the floodplain. The model uses numerical equations to describe the water movement.

1. Introduction

1.1 Scope and purpose

The townships of Castlemaine, Campbells Creek and Chewton in central Victoria have been affected by flooding from Barkers Creek, Forest Creek and Campbells Creek four (4) times in recent years, including September 2010, November 2010, major flooding in January 2011 and another major flash flood in February 2012.

This study has been jointly funded by the Victorian and Australian Governments under the Natural Disaster Resilience Grants Scheme (NDRGS), and via additional funding provided by Mount Alexander Shire. The North Central Catchment Management Authority (NCCMA) is leading the development of this Plan in partnership with the Mount Alexander Shire.

The study objectives include:

- Review available data and historic flood information and simulate various past flood events through the town.
- Engage with the community and stakeholders in order to understand their experiences of flooding and desired outcomes.
- Determination and documentation of flood levels, extents, velocities and depths (and thus flood risk) for the Barkers Creek, Forest Creek, Campbells Creek and any major tributaries within the study area (Figure 1) for a range of flood events including 0.5%, 1%, 2%, 5%, 10% and 20% AEP events.
- A review of the Mount Alexander Planning Scheme's current flood zone and overlays for the township/study area/locality and recommendations for appropriate Planning Scheme amendments in the context of study outcomes.
- Preparation of digital and hard copy floodplain maps for 1% AEP flood events showing both floodplain and floodway extents, suitable for incorporation into municipal planning schemes.
- Assessment of flood damages.
- Identification and preliminary feasibility assessment of structural mitigation measures to alleviate intolerable flooding risk.
- Costing and assessment of preferred structural mitigation measures.

A key element in the development of the Flood Management Plan was the engagement of the community in the study. Engagement was undertaken over the course of the study through several different means including community information sessions, a public questionnaire, media releases and meetings with the Technical Working Group (TWG) and community based Steering Committee (SC). During the course of this investigation the TWG and SC always met together.

1.2 Description of catchment

The townships of Castlemaine, Campbells Creek and Chewton are located on Barkers Creek, Forest Creek and Campbells Creek. The catchment area for this investigation is shown on Figure 1. The catchment shown on Figure 1 encompasses an area of approximately 154 km^2.

The confluence of Barkers Creek and Forest Creek is approximately 200 meters upstream of the Gaulton Street bridge in Castlemaine (refer to Figure 1 for location). The Barkers Creek catchment upstream of the confluence is approximately 71 km^2 and the Forest Creek catchment is approximately 60 km^2. The waterway downstream of the confluence is Campbells Creek.

The Barkers Creek catchment rises from approximately 270 m AHD at the confluence to 570 m AHD approximately 20 kilometres north of the confluence. The Forest Creek catchment rises from approximately 270 m AHD at the confluence to 550 m AHD approximately 13 kilometres east of the confluence.

The average annual rainfall at Castlemaine is approximately 600 mm/yr (Bureau of Meteorology).

In general terms, apart from the urbanised areas, the Barkers Creek catchment is predominately cleared land and Forest Creek is predominately forested.

As shown in Figure 1, there are three reservoirs located within the catchment, Barkers Creek Reservoir (1,690 ML), McCay Reservoir (1,360 ML) and Expedition Pass Reservoir (264 ML).

1.3 Limitations

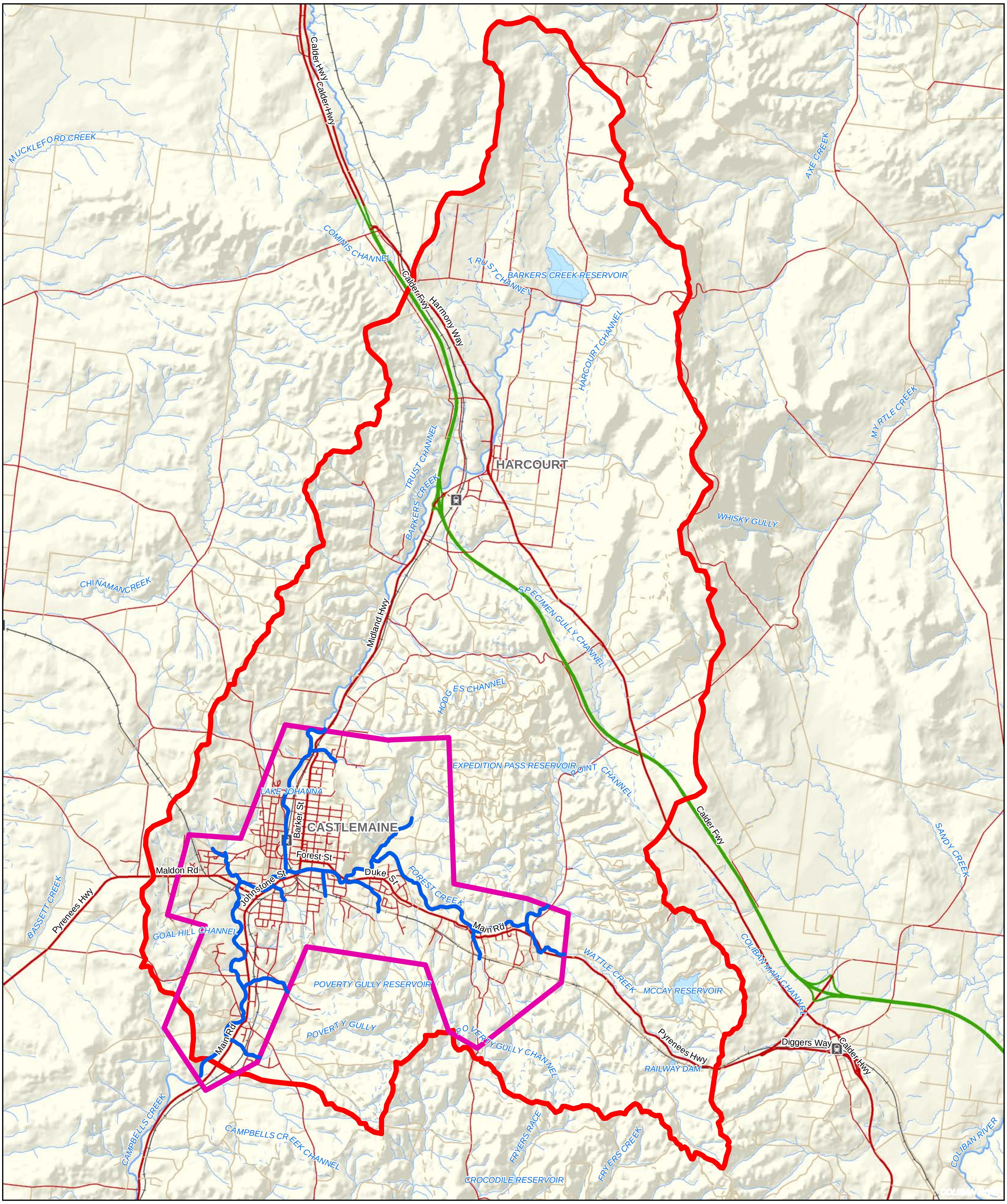
This Report has been prepared for the NCCMA by GHD and may only be used and relied on for the purpose agreed between NCCMA and GHD as set out in Section 1.1 of this Report.

GHD otherwise disclaims responsibility to any person other than NCCMA arising in connection with this Report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this Report were limited to those specifically detailed in the Report and are subject to the scope limitations set out in the Report.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by the NCCMA and others who provided information to GHD such as the Bureau of Meteorology, Mount Alexander Shire, VicTrack, Coliban Water and the Community, which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report.



Legend

- Freeway
- Highway
- Sealed road (arterial and local)
- Unsealed road
- Track and bike path
- Rail station
- Rail
- River
- Stream
- Channel / drain
- Connector
- Lake
- Catchment Boundary
- Study Area
- Waterways to be mapped

1:70,000 (Paper Size A3)

0 0.75 1.5 2.25 3

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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North Central CMA
Castlemaine, Campbells Creek and Chewton
Flood Management Plan

Job Number 31-29991
Revision A
Date 19 Aug 2013

Locality Plan

Figure 1

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180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data source: DSE, VicMap, 2013. Created by:scowan

2. Available information

2.1 Stream flow gauges

There are no stream flow gauge stations located within the catchment. The closest stream flow gauge stations to the catchment are located in the adjoining catchments; these are listed in Table 1 and the location of the stream flow gauge stations are shown in Figure 2. The stream flow gauge information was downloaded from Victoria Water Resources Data Warehouse (http://www.vicwaterdata.net/vicwaterdata/home.aspx) and supplied by Thiess.

Additional information on the gauges, as supplied by Thiess, is summarised in Table 2.

Table 1 Stream Flow Gauging Data

Station No.	Station Name	Period of Record	Catchment Area (km^2)
406216	Axe Creek @ Sedgewick	1969 – to date	34
407300	Muckleford Creek @ Muckleford North	1993 – to date	126

Table 2 Stream Flow Gauging Information

Station No.	406216	407300
Maximum Measured Flow (m^3/s)	18.4	32
Level for Maximum Measured Flow (m)	1.03	1.94
Year of Maximum Measured Flow	July 1975	November 2010
Maximum Recorded Level (m)	1.82	4.17
Year of Maximum Recorded Level	January 2011	January 2011
Maximum Recorded Level on the 27 February 2012	0.72	1.1

2.2 Daily rainfall gauges

A number of daily rainfall gauges are scattered throughout the catchment and surrounds. Daily rainfall data was sourced from the SILO Patched Point Dataset. The SILO Patched Point Dataset (PPD) provides continuous daily climate data for around 4,600 meteorological stations around Australia, including a number of stations within the catchment. The SILO PPD uses original Bureau of Meteorology measurements for a particular meteorological station, but with interpolated data used to fill any gaps in the observation record. The dataset is maintained by the Queensland Department of Environment and Resource Management (DERM), with all data publicly available (at a low cost) via the department's website (www.longpaddock.qld.gov.au/silo/).

The daily rainfall gauges were used to determine the spatial distribution of rainfall across the catchment. The key daily rainfall gauges used in the hydrological investigation are shown in Table 3. The location of the daily rainfall gauge stations are shown in Table 2.

Table 3 Daily Rainfall Gauges

Station Number	Station Name
88005	Bendigo Channel
88110	Castlemaine Prison
88118	Harcourt
88048	Newstead
81121	Sandhurst Reservoir

Station Number	Station Name
88051	Redesdale
88041	Maldon (Derby Hill)
88042	Malmsbury Reservoir
88066	Yandoit
88108	Vaughan
88132	Baringhup (Blue Hill

2.3 Pluviograph data (Bureau of Meteorology)

Pluviographs record rainfall over time and are used to determine the temporal pattern of rainfall. No pluviographs, maintained by the Bureau of Meteorology, are located within the catchment. Details on the pluviographs assessed as part of this investigation are shown in Table 4. The pluviograph locations are shown in Figure 2. Information for each pluviograph in Table 4 was supplied by the Bureau of Meteorology.

Table 4 Pluviographs

Station Number	Station Name	Period of Record
88009	Cairn Curran Reservoir	2004 – to date
81026	Laanecoorie Weir	1973 – 2004
88037	Lauriston Reservoir	1958 – 2011
88029	Heathcote	1968 – to date
81003	Bendigo Prison	1968 – 1992
81123	Bendigo Airport	1992 – to date

2.4 Surveyed flood level data

Within the township of Castlemaine the two events where surveyed flood level information is available is January 2011 and February 2012. Appendix A shows the location of the recorded flood level information. The flood level information was supplied by the NCCMA.

The surveyed flood level data was used to calibrate the hydraulic model.

2.5 Crossing and drainage infrastructure survey

Survey information of the culvert and bridge structures along Barkers, Forest and Campbells Creek was supplied by Coliban Water. The survey from Coliban Water was undertaken by Aurecon in 2009 along Forest Creek and in 2011 along Barker and Campbells Creek.

Information on the culverts and bridge structures along the railway lines within the study area were supplied by VicTrack.

Details of the underground drainage network were provided by Council.

Additional survey of the remaining structures, not provided by Coliban Water, VicTrack or Council was commissioned by the NCCMA in July 2013. The additional survey was undertaken by Spiire.

2.6 LiDAR data

Light Detection and Ranging (LiDAR) data was provided by the NCCMA and was sourced from the Department of Environment, Land, Water and Planning (DELWP). Two sources of LiDAR were supplied, termed "Floodplain LiDAR" and "River LiDAR". In general, the river LiDAR covered Barkers and Campbell Creek and the floodplain LiDAR covered Forest Creek. The reported vertical accuracy of the DELWP LiDAR data is "± 0.2 meters RMSE".

A comparison of the two datasets, where they overlapped, was undertaken in Discover. Overall the levels were comparable; however, there were some locations with minor differences in levels, particularly within the Forest Creek catchment. Appendix B shows the comparison of the two dataset.

Coliban Water provided a number of surveyed cross sections at various locations along Barkers and Forest Creek. Also cross section information at each bridge was supplied as part of the additional survey undertaken by Spiire in July 2013. A comparison was made between the surveyed cross sections and the LiDAR data. In general the base of the creek in the survey was lower than in the LiDAR. This is not surprising if there was water in the creek at the time the LiDAR was flown and/or significant vegetation in the creek. Appendix B shows the cross sections compared to the LiDAR data.

In general, the LiDAR provided an accurate terrain model of the floodplain, suitable for the purposes of flood modelling. Within the creeks minor editing of the base was undertaken to reflect the data from the survey information. More detail on editing of the base is discussed in Section 4.2.1.

2.7 Storage data

There are three reservoirs located within the catchment, Barkers Creek Reservoir (1,690 ML), McCay Reservoir (1,360 ML) and Expedition Pass Reservoir (264 ML). It is important to incorporate the main storages within the hydrological model as they can have an impact on downstream hydrographs. Coliban Water was contacted to provide information on the storages. The data available for each of the storages is shown below.

Barkers Creek Reservoir

- Elevation storage relationship
- Elevation Discharge relationship

McCay Reservoir

- Elevation storage relationship
- Elevation Discharge relationship

Expedition Pass Reservoir

- Elevation storage relationship
- Drawing of the reservoir including spillway details

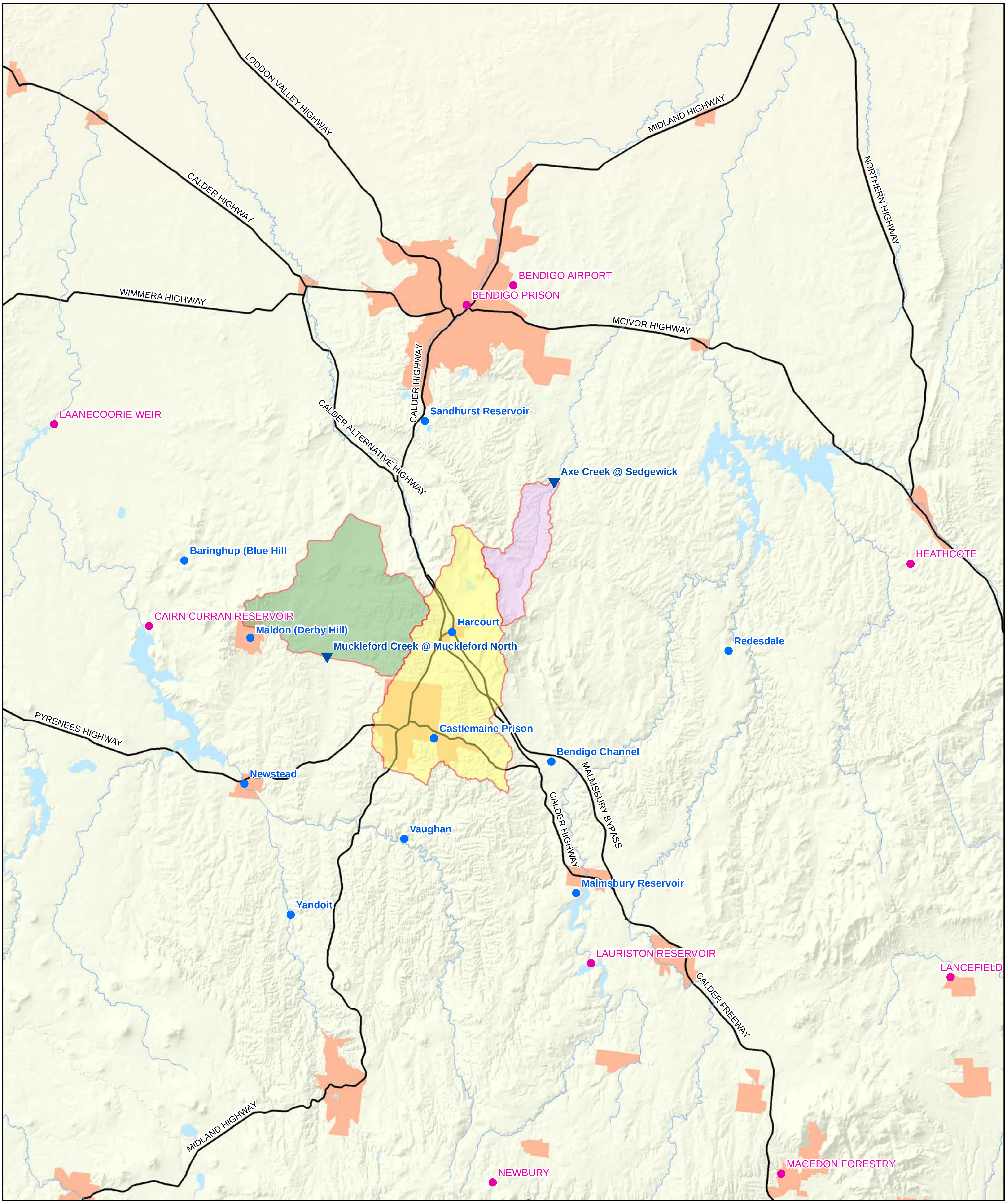
Coliban Water recorded water levels at Barkers Creek Reservoir during the January 2011 event. The peak water level recorded was 365.12 mAHD which is 0.62 m above the full supply level of 364.50 mAHD.

2.8 Other data

Other background data was made available for the study, including:

- Aerial image of Castlemaine supplied by the NCCMA from the DELWP
- Numerous photos supplied by the community of the flood events
- Anecdotal evidence supplied by the community
- Pluviograph information within town from the January 2011 and February 2012 event. This information was supplied by the community (Julian Hollis)
- Daily rainfall data within town from the February 2012 event
- Media reports and photos supplied by the Castlemaine Mail
- Historical reports and photos supplied by the Castlemaine Historical Society
- 10 m contour dataset and cadastral information sourced from the DELWP
- Rural Water Corporation, Castlemaine Flood Study Report, 1985
- Spiire, Drainage Analysis and Mitigation Options Report Berkeley Street, 2012
- Spiire, Drainage Analysis and Mitigation Options Report Bruce Street, 2012
- Spiire, Drainage Analysis and Mitigation Options Report Chapmans Road, 2012
- Spiire, Drainage Analysis and Mitigation Options Report Church Street, 2012
- Spiire, Drainage Analysis and Mitigation Options Report Eleanor Dr, 2012
- Spiire, Drainage Analysis and Mitigation Options Report Gingell Street, 2012
- Spiire, Drainage Analysis and Mitigation Options Report Johnstone Street, 2012
- Spiire, Drainage Analysis and Mitigation Options Report McKendry Street, 2012
- Spiire, Drainage Analysis and Mitigation Options Report Montgomery Street, 2012
- Spiire, Drainage Analysis and Mitigation Options Report Moscript Street, 2012

This data was used during model set-up, calibration and result presentation.



Legend

Major water area	Stream Gauge	Campbells Creek Catchment
Major water course	Pluvio	Muckleford Creek Catchment
Major road	Daily Rainfall	Axe Creek Catchment
Township area		

1:300,000 (Paper Size A3)

0 2.5 5 7.5 10

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

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NORTH CENTRAL Catchment Management Authority
Connecting Rivers, Landscapes, People

North Central CMA
Castlemaine, Campbells Creek and Chewton
Flood Management Plan

Job Number	31-29991
Revision	A
Date	19 Aug 2013

Gauging Locations

Figure 2

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180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2013; Bureau of Meteorology, Annual Rainfall Data. Created by:scowan

3. Hydrological analysis

3.1 General

This section of the report summarises the hydrologic investigation undertaken on the Campbells Creek catchment. The work involved:

- A review of available hydrological information.
- Development and calibration of hydrologic catchment models (RORB).
- Verification of the RORB parameters against previous investigations and regional estimates.
- Development of design flood estimates.

A rainfall runoff model RORB model was used to model the rainfall-runoff relationship of the catchment. In general terms, development of a RORB model entails:

- Sub-dividing the catchment into a series of subareas to suit the catchment topography and other features such as the location of gauging stations and storages.
- Determination of the model parameters k_c and m, which represent respectively the effect of the catchment in delaying the runoff response from the rainfall, and the non-linearity of the catchment's response to rainfall excess. Parameters are also required to represent rainfall losses.

3.2 RORB model configuration

For the Campbells Creek catchment, the RORB model subareas were delineated to model the rainfall-runoff conversion process; taking into account watershed boundaries, stream junctions and storages. Initially the subareas were delineated using the VicMaps 10 metre contour data. These subareas were then refined in the township area using the LiDAR to provide flow estimates at the required locations throughout town.

Storages were placed into RORB model at:

- Barkers Creek Reservoir
- McCay Reservoir
- Expedition Pass Reservoir

Coliban Water supplied an elevation-storage relationship for each reservoir which was placed into the RORB model. For Barkers Creek and McCay Reservoir the elevation-discharge relationship supplied by Coliban Water was placed into the model. For the Expedition Pass Reservoir an elevation-discharge relationship was derived from the information supplied by Coliban Water. The weir equation with a coefficient of discharge of 1.7 was used to derive the discharge relationship for Expedition Pass. Details on the elevation-storage and elevation-discharge relationships used in the RORB model are shown in Appendix C. Discussions with Coliban Water indicated that the storages were most likely full (or close to full) prior to the January 2011 and February 2012 events. Therefore, the RORB model was run with the storages set to the full supply level at the beginning of the simulation.

Four different types of reaches are recognised in RORB, having different properties and different relative delay times and identified as 1 for natural, 2 for excavated but unlined, 3 for lined channel or pipe and 4 for drowned reach. Drowned reaches were used within the storages; natural reaches were used for all areas outside of the urban areas and the creeks throughout town. Lined channel or pipe reaches were used for runoff from the developed area. As the hydraulic model (discussed in Section 4) was being used to route flow throughout town the reaches used on the waterways within the study area are of secondary importance.

Impervious fractions were calculated for each subarea. Default sub-area fraction impervious values were calculated based on the current Planning Scheme zones and then reviewed and amended as necessary based on recent aerial photos. The spatial distribution of the fraction impervious data is shown in Appendix D which shows the township areas having a higher impervious fraction compared to the broader catchment.

The RORB model layout is shown in Appendix D.

3.3 Calibration

3.3.1 General

If possible, it is preferable that a RORB model is calibrated against recorded streamflow records within the catchment of interest. However, as there is no streamflow gauge on Barkers, Forest or Campbells Creek an alternative method was adopted to establish RORB parameters.

The adopted approach was to derive RORB parameters from observed floods on the adjoining catchments, that is, Axe Creek at Sedgewick and Muckleford Creek at Muckleford North. The Axe Creek catchment flows from south to north with the catchment rising from approximately 235 m AHD at the gauge to 730 m AHD approximately 13 kilometres south of the gauge. The Axe Creek catchment is predominately cleared land. The Muckleford Creek catchment flows from north to south and is a much more distributed system compared to Axe Creek. Muckleford Creek is relatively flat with the Creek rising from approximately 270 m AHD at the gauge to 320 m AHD approximately 13 kilometres north of the gauge. Steeper segments of the catchment drain into Muckleford Creek from the east and west. The largest area which drains into Muckleford Creek is from Chinaman Creek which rises from 270 m AHD at the confluence with Muckleford Creek to 530 m AHD approximately 13 kilometres east of the confluence. The Muckleford Creek catchment is predominately cleared land with some sections of treed area.

A RORB model was established for the Axe and Muckleford Creek catchments. The RORB model subareas were delineated to model the rainfall-runoff conversion process; taking into account watershed boundaries, stream junctions and storages. Initially the subareas were delineated using the VicMaps 10 metre contour data. The reach type used was natural and impervious fractions were calculated for each subarea. Default sub-area fraction impervious values were calculated based on the current Planning Scheme zones and then reviewed and amended as necessary based on recent aerial photos. The RORB model layouts are shown in Appendix E.

RORB requires the calibration of three model parameters (k_c, initial loss and continuing loss). The calibration approach adopted for this study as recommended in Australia Rainfall and Runoff was as follows:

- Variation of the value of k_c, the principal parameter of the RORB model, is the main means of achieving a fit. The model is run interactively with various trial values of kc, and the value giving best reproduction of the observed data is adopted.
- Initial loss is also used as an important means of achieving a fit. It directly affects the start of hydrograph rise, but also affects the time distribution of rainfall excess and hence the hydrograph peak, especially for long storms with large variations of intensity. However, it should be noted that the derived initial loss is not a parameter of the model to be used in later applications, it is rather a characteristic of the particular storm. Initial loss should be selected primarily on the basis of the timing and patterns of observed rainfall and runoff. Ideally, it should be used as a means of fitting an observed flood peak or hydrograph only when doubts remain regarding the best combination of initial loss and continuing loss after consideration of all of the observed data.
- A continuing loss (CL) was selected to achieve a reasonable fit between the modelled and observed hydrograph volumes.
- An m value of 0.8 was adopted which is in keeping with values recommended in Australian Rainfall and Runoff.

3.3.2 Muckleford Creek calibration

The calibration for Muckleford Creek at Muckleford North was undertaken by setting up historic storm files and running the RORB model with parameters and losses such that a match was achieved against the recorded flood hydrographs.

The three events chosen for calibration of the RORB model were:

- January 2011 (maximum flow at Muckleford North of 152 m^3/s)
- October 2000 (maximum flow at Muckleford North of 104 m^3/s)
- June 1995 (maximum flow at Muckleford North of 104 m^3/s)

The events listed above were chosen because they are the three largest floods listed (at the time that this information was downloaded from the Victoria Water Resources Data Warehouse), as defined by peak flow, recorded at the gauge site Muckleford Creek at Muckleford North (407300) and because continuous streamflow data and pluviograph data was available electronically.

Discussions with Thiess indicated that the January 2011 was "*correlated to infill lost records and being the highest event in the period of record should be treated with caution*".

For each of the calibration events the rainfall depths were estimated for each subarea to account for the spatial variation of rainfall across the catchment. Rainfall depths across the catchment were established for each of the calibration events from the daily rainfall stations and the rainfall depth on each subarea was then estimated.

Once the rainfall depth was estimated for each area, the temporal distribution of rainfall was estimated by assigning the patterns from the available pluviographs. For the January 2011 event two pluviographs were trialled, data supplied by the community (Julian Hollis) and data from the Cairn Curran Reservoir pluviograph. These two pluviographs are the closest to the catchment. For the January 2011 event the data supplied by Julian Hollis gave the best match so it was adopted. Also it was found that modelling the January 2011 event as two bursts gave a better representation of the hydrograph shape. For the October 2000 and June 1995 event pluviograph data was not available at Cairn Curran Reservoir so the next closest, that is, Lannaecoorie Weir was adopted.

The RORB model transforms the rainfall excess of a given storm event into a flood hydrograph. In order to compare the RORB model's generated hydrograph with the recorded hydrograph, it can be necessary to remove the baseflow component from the recorded hydrograph. For the events considered, baseflow was an insignificant component compared to the rainfall runoff component so it was not removed. For each of the calibration events there was no flow recorded at the gauge prior to the flood event.

A summary of the calibration results at Muckleford Creek at Muckleford North (407300) are shown in Table 5. All the hydrographs from the calibration process are shown in Figure 3 to Figure 5.

Table 5 Summary of Calibration at Muckleford Creek at Muckleford North (407300)

	January 2011	October 2000	June 1995
k_c	10.7	10.7	10.7
m	0.8	0.8	0.8
Modelled IL (mm) Burst 1	50	80	37
Modelled IL (mm) Burst 2	20	N/A	N/A
Modelled CL (mm/hr) Burst 1	2.5	3.0	2.2
Modelled CL (mm/hr) Burst 2	0.1	N/A	N/A
Actual Peak Flow (m^3/s)	152	104	104
Calculated Peak Flow (m^3/s)	148	103	105
Actual volume (m^3)	1.69E+07	2.87E+06	4.64E+06
Calculated volume (m^3)	1.29E+07	2.75E+06	4.78E+06

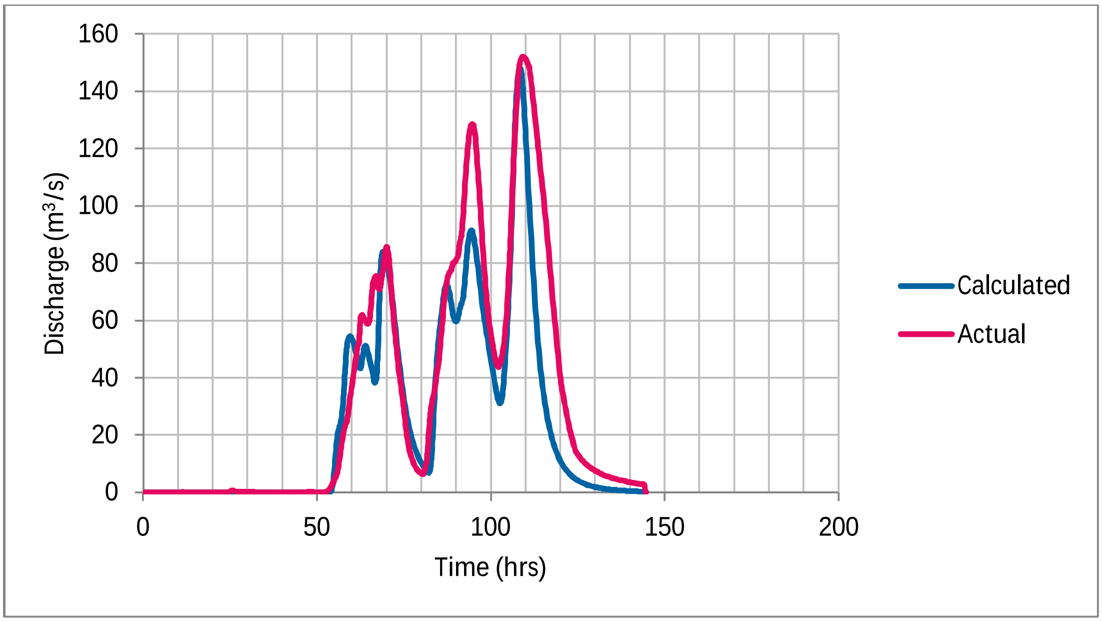


Figure 3 RORB calibration – January 2011 at Muckleford Creek at Muckleford North (407300)

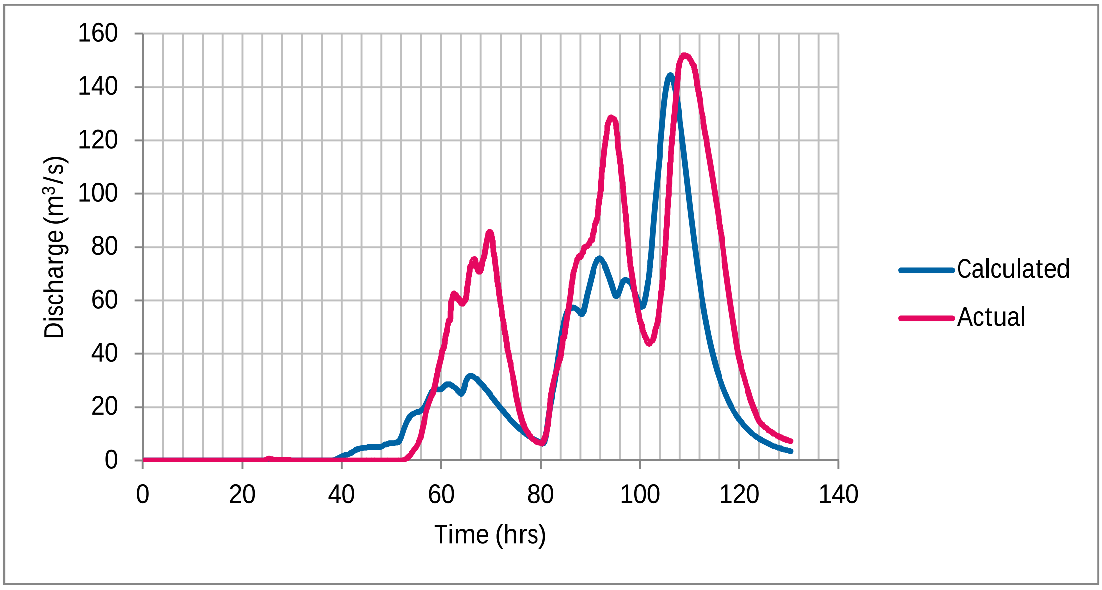


Figure 4 RORB calibration – October 2000 at Muckleford Creek at Muckleford North (407300)

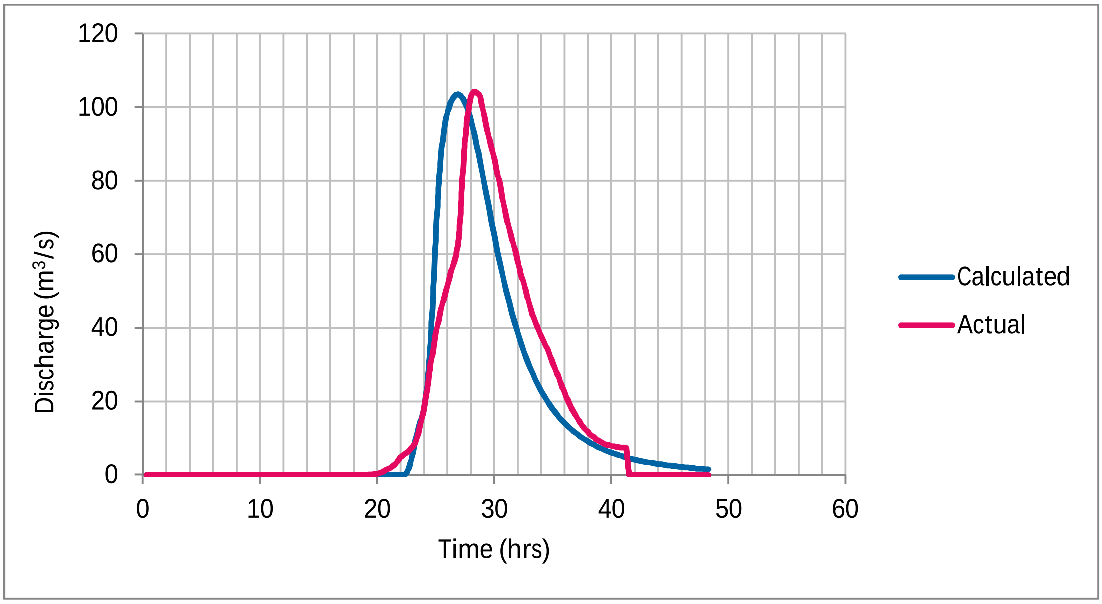


Figure 5 RORB calibration – June 1995 at Muckleford Creek at Muckleford North (407300)

3.3.3 Axe Creek calibration

The calibration for Axe Creek at Sedgewick was undertaken by setting up historic storm files and running the RORB model with parameters and losses such that a match was achieved against the recorded flood hydrographs.

The three events chosen for calibration of the RORB model were:

- January 2011 (maximum flow recorded at Sedgewick of 54 m^3/s)
- September 2010 (maximum flow recorded at Sedgewick of 34 m^3/s)
- June 1995 (maximum flow recorded at Sedgewick of 21 m^3/s)

The January 2011 and June 1995 events were chosen as they were significant events recorded on Axe Creek at Sedgewick and to remain consistent with the events calibrated on Muckleford Creek at Muckleford North (refer to Section 3.3.2). September 2010 was chosen instead of the October 2000 (13 m^3/s is the maximum flow recorded at Sedgewick) as the September 2010 event was much more significant, in terms of flow, on Axe Creek catchment. Continuous electronic streamflow and pluviograph data is available for the above events.

A significant event was recorded on Axe Creek on 10 February 2012 (34 m^3/s) but very little on 27 February 2012 (3 m^3/s) which was the event that caused significant flooding in Castlemaine, Campbells Creek and Chewton. On 11 February 36 mm of rainfall was recorded in Castlemaine. This compares with 59 mm on 27 February and 98 mm on 28 February. This discrepancy between rainfall recorded at Castlemaine and flows in Axe Creek was discussed with Thiess. Thiess indicated that according to the field sheets there was nothing amiss with the site during either of these events. This indicates that 27 February 2012 event was a localised event over Castlemaine (further discussion is provided on this event in Section 3.4). A review of the surrounding pluviographs indicated that there was no significant event on 10 February although; it is possible that there was a localised rainfall event over Axe Creek on 10 February which was not captured by the pluviographs. As it was not possible to resolve the discrepancy between rainfall and runoff recorded in February 2012 on Axe Creek the 10 February 2012 event on Axe Creek was not modelled.

For each of the calibration events the rainfall depths were estimated for each subarea to account for the spatial variation of rainfall across the catchment.

Once the rainfall depth was estimated for each area, the temporal distribution of rainfall was estimated by assigning the patterns from the available pluviographs. For the January 2011 event two pluviographs were trailed, data supplied by the community (Julian Hollis) and data from the Cairn Curran Reservoir pluviograph. For the January 2011 event the data available at Cairn Curran Reservoir gave the best match so it was adopted. Also it was found that modelling the January 2011 event as two bursts produced a better representation of the hydrograph shape. For the June 1995 event the pluviograph data at Lannaecoorie Weir was adopted which is the same as for Muckleford Creek. For the September 2010 event data was available at Cairn Curran and Heathcote. Both pluviographs are approximately 30 km (one east and one west) of the site. As Heathcote gave a better match it was adopted.

The RORB model transforms the rainfall excess of a given storm event into a flood hydrograph. In order to compare the RORB model's generated hydrograph with the recorded hydrograph, it is necessary to remove any significant baseflow component from the recorded hydrograph. For the events considered, baseflow was an insignificant component compared to the rainfall runoff component so it was not removed. For each of the calibration events there was little (maximum 0.25 m^3/s) or no flow recorded at the gauge prior to the flood events.

A summary of the calibration results at Axe Creek at Sedgewick (406216) are shown in Table 6. All the hydrographs from the calibration process are shown in Figure 6 to Figure 8.

Table 6 Summary of Calibration at Axe Creek at Sedgewick (406216)

	January 2011	September 2010	June 1995
k_c	9	7	9
m	0.8	0.8	0.8
Modelled IL (mm) Burst 1	60	8	20
Modelled IL (mm) Burst 2	5	N/A	N/A
Modelled CL (mm/hr) Burst 1	2	1.7	3.4
Modelled CL (mm/hr) Burst 2	0.5	N/A	N/A
Actual Peak Flow (m^3/s)	54	34	21
Calculated Peak Flow (m^3/s)	54	35	21
Actual volume (m^3)	3.42E+06	1.47E+06	9.11E+05
Calculated volume (m^3)	3.54E+06	1.29E+06	9.20E+05

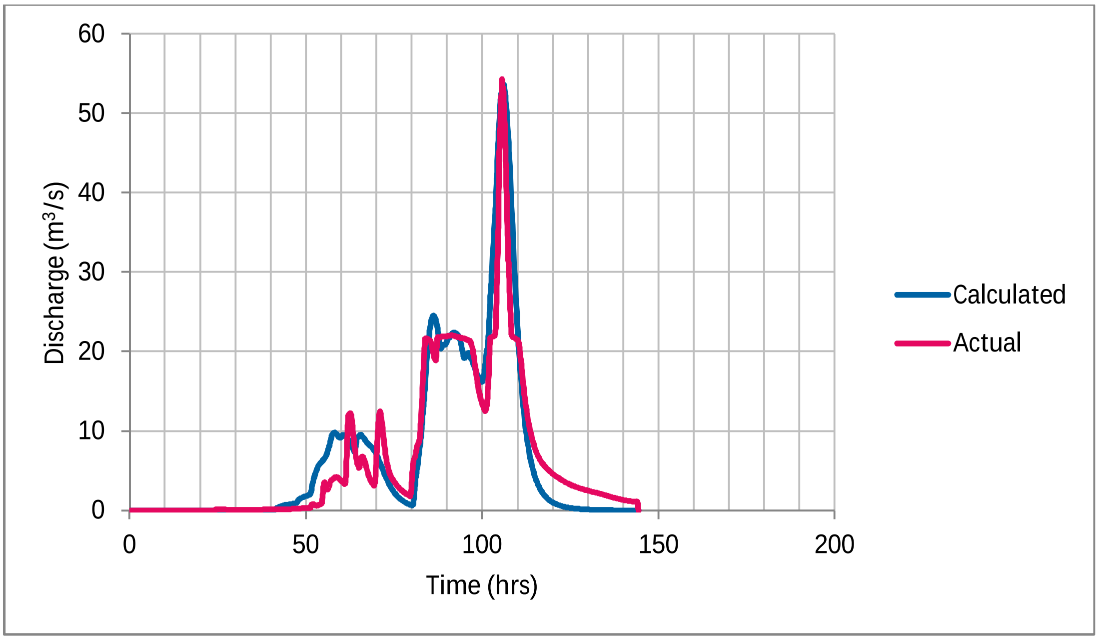


Figure 6 RORB calibration – January 2011 at Axe Creek at Sedgewick (406216)

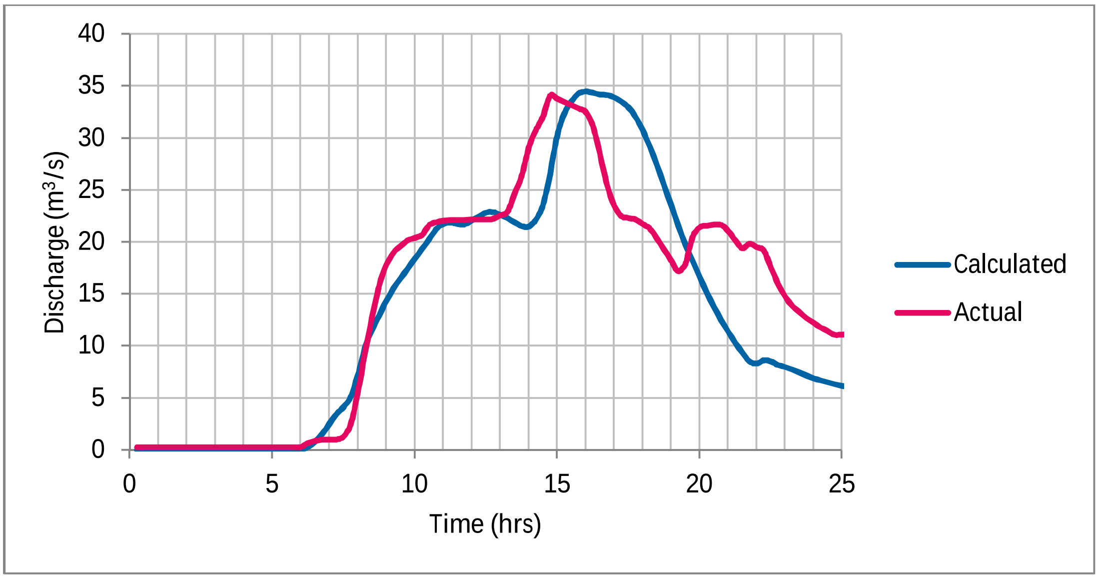


Figure 7 RORB calibration – September 2010 at Axe Creek at Sedgewick (406216)

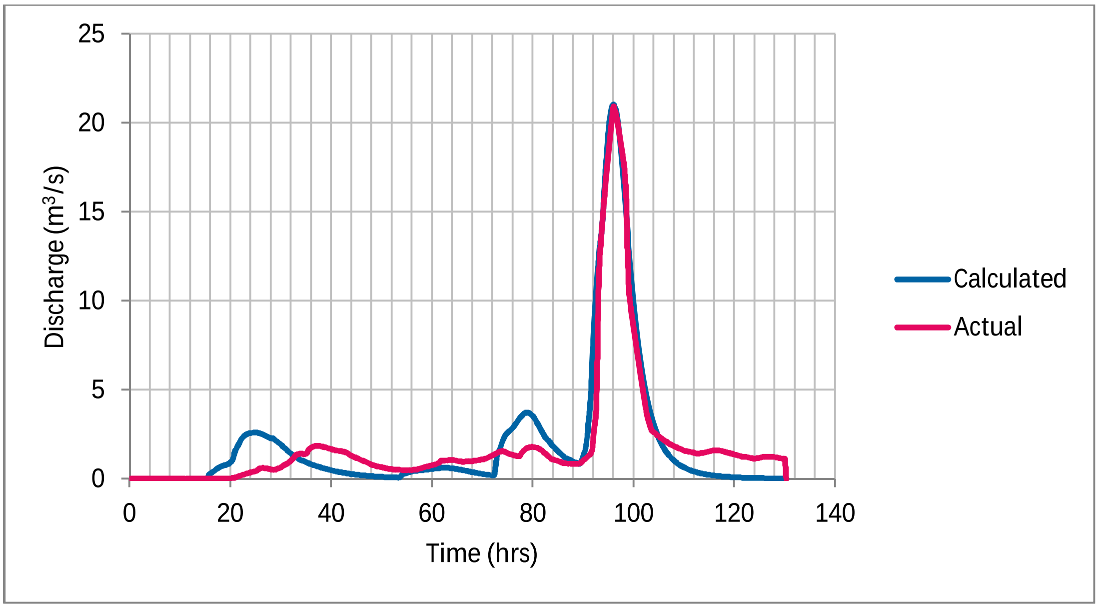


Figure 8 RORB calibration – June 1995 at Axe Creek at Sedgewick (406216)

3.3.4 Selection of RORB Parameter k_c

In general a reasonable calibration was achieved against all events. As with all hydrological modelling the variation between the recorded and modelled hydrograph can be due to a number of things i.e. change in catchment conditions, data errors, baseflow separation errors, rainfall variability and the lack of adequate data to represent the variability across the catchment and the RORB model being only a representation of a variable and complex rainfall runoff processes. However, the calibration results were considered good enough to use to estimate a k_c value for the Campbells Creek catchment.

In the absence of streamflow data on the catchment of interest the preferred method is to assign parameters derived from observed floods on at least one, and preferably two or three, nearby catchments with similar characteristics to the one being studied. To estimate a k_c value for Campbells Creek an average of the calibrated k_c values adopted for Axe and Muckleford Creek was calculated and the k_c for Campbells Creek was estimated based on the ratios of d_{av} (is the average flow distance in the channel network of sub area inflows). The k_c value estimated for Campbells Creek is summarised in Table 7.

Table 7 Summary of k_c

Catchment	d_{av}	Event			Derived k_c
		January 2011	September 2010	June 1995	
Axe Creek	9.6	9	7	9	8.3
Muckleford Creek	9.6	10.7	10.7	10.7	10.7
		Average of Axe and Muckleford Creeks			9.5
Campbells Creek	14.7	Calculated(corrected for d_{av})			14.6

3.3.5 Regional RORB model parameters

As mentioned above the choice of k_c for Campbells Creek was based on the calibration results from the adjoining catchments. However, this value was compared to the estimate of the regional k_c using the equations in Australian Rainfall and Runoff.

For Victorian catchment there are two regional equation, one for catchments with average annual rainfall of greater than 800 mm and one for catchments less than 800 mm. As mentioned in Section 1.2 the average annual rainfall at Castlemaine is approximately 600 mm/yr (Bureau of Meteorology).

For regions where the mean annual rainfall is less than 800 mm, k_c is calculated by the following equation:

$k_c = 0.49\ A^{0.65}$

The standard error associated with this regional prediction equation is +50% and -33%.

From the equation above the regional estimate of k_c is 13. The value chosen for k_c of 14.6 is within the range predicted by the regional equations.

3.4 Estimation of January 2011 and February 2012 events

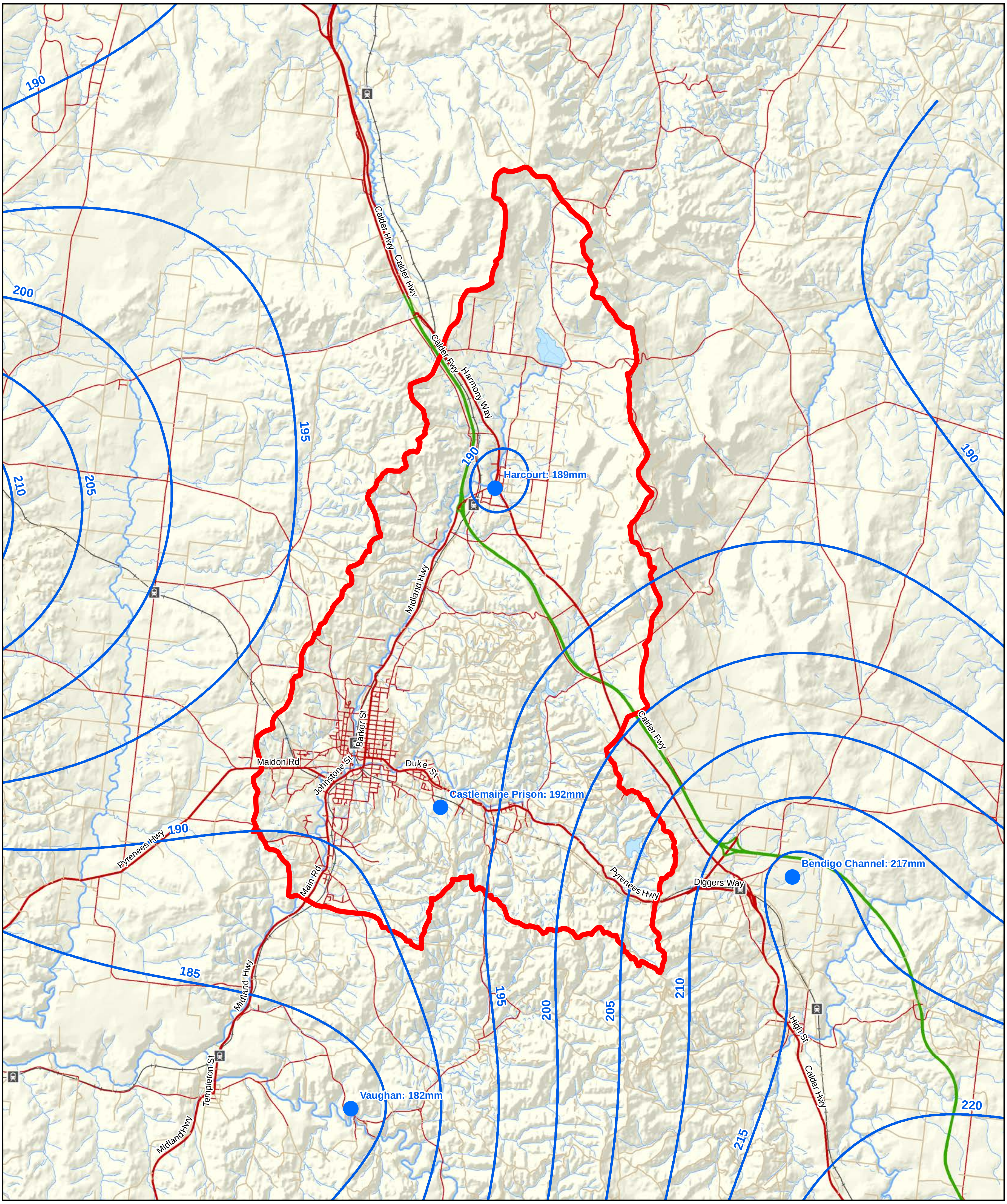
To estimate flows for the January 2011 and February 2012 events storm files were established using the available rainfall gauge information.

Figure 9 and Figure 10 shows the rainfall depths recorded across the catchment for the January 2011 event and February 2012 events respectively. The daily rainfall data recorded across the catchment and surrounds was used to estimate the spatial distribution of rainfall and the pluviographs were used to establish the temporal pattern.

In general the January 2011 event was a wide spread event which occurred over several days. The February 2012 event was a localised event which was intense and occurred over a short period of time. Table 8 shows the daily rainfall depths recorded at Castlemaine Prison (88110). Figure 11 and Figure 12 show the temporal pattern of the rainfall event in January 2011 from the pluviograph supplied by Julian Hollis (which is located in Castlemaine) and at Cairn Curran. Figure 13 show the temporal pattern of the rainfall event in February 2012 from the pluviograph supplied by Julian Hollis.

Table 8 Daily Rainfall Recorded at Castlemaine Prison (88110)

Date	Rainfall Depth (mm)	Date	Rainfall Depth (mm)
10/01/2011	10.4	27/02/2012	59
11/01/2011	26.6	28/02/2012	98
12/01/2011	47.0		
13/01/2011	35.8		
14/01/2011	64.8		
15/01/2011	7.0		



Legend

Freeway	Rail	Water course
Highway	River	Catchment Boundary
Sealed road (arterial and local)	Stream	Daily Rainfall
Unsealed road	Channel / drain	Jan 2011 Rainfall Isopleth
Track and bike path	Connector	
Rail station	Lake	

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0 1 2 3 4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

NORTH CENTRAL Catchment Management Authority
Connecting Rivers, Landscapes, People

North Central CMA
Castlemaine, Campbells Creek and Chewton
Flood Management Plan

Job Number 31-29991
Revision A
Date 13 Aug 2013

January 2011 Rainfall Isopleths

Figure 9

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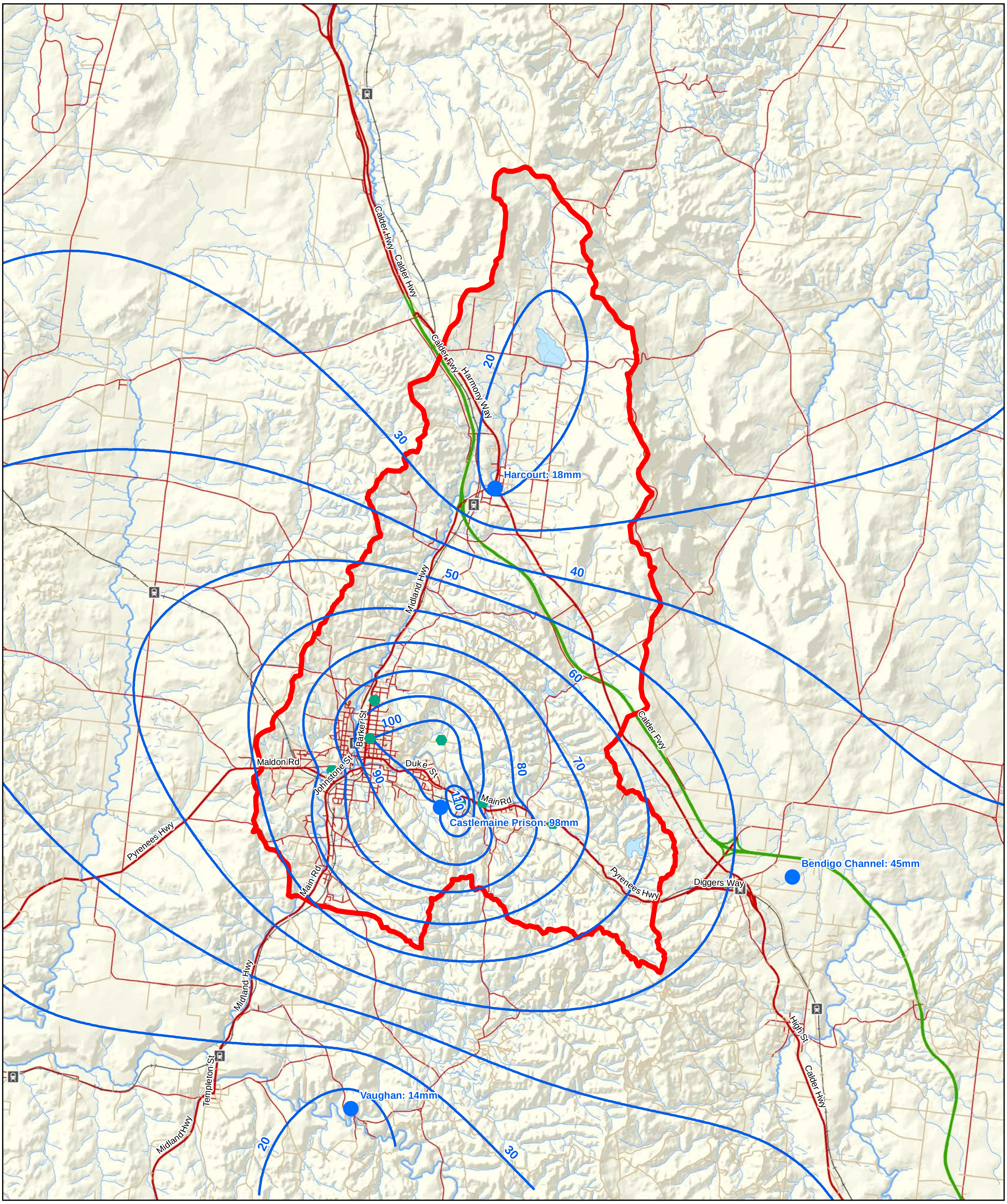
180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data source: DSE, VicMap, 2013; Bureau of Meteorology, Annual Rainfall Data. Created by:scowan



Legend

- Freeway
- Highway
- Sealed road (arterial and local)
- Unsealed road
- Track and bike path
- Rail station
- Rail
- River
- Stream
- Channel / drain
- Connector
- Lake
- Water course
- Catchment Boundary
- Daily Rainfall
- Julian Hollis Rainfall
- Feb 2012 Rainfall Isopleth

1:100,000 (Paper Size A3)

0 1 2 3 4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

North Central CMA
Castlemaine, Campbells Creek and Chewton
Flood Management Plan

Job Number	31-29991
Revision	A
Date	13 Aug 2013

February 2012 Rainfall Isopleths

Figure 10

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180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data source: DSE, VicMap, 2013; Bureau of Meteorology, Annual Rainfall Data. Created by:scowan

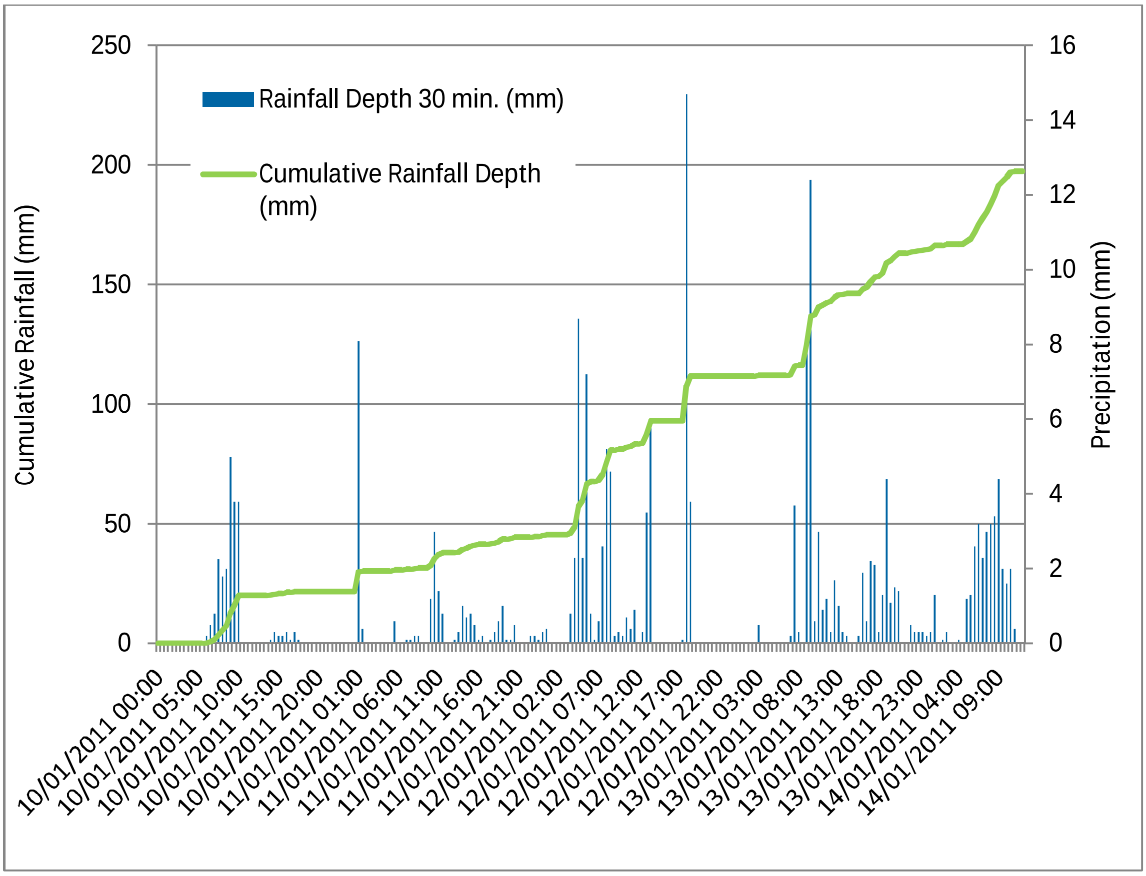


Figure 11 Pluviograph (Julian Hollis) – January 2011

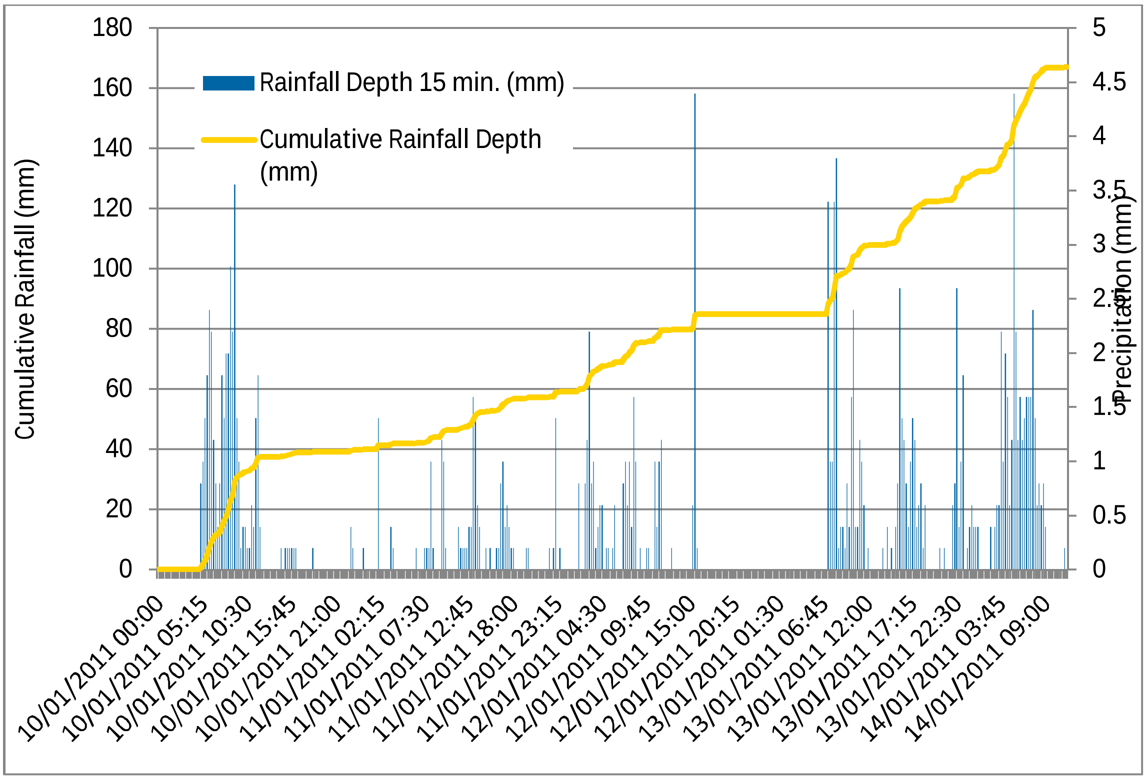


Figure 12 Pluviograph (Cairn Curran – 88009) – January 2011

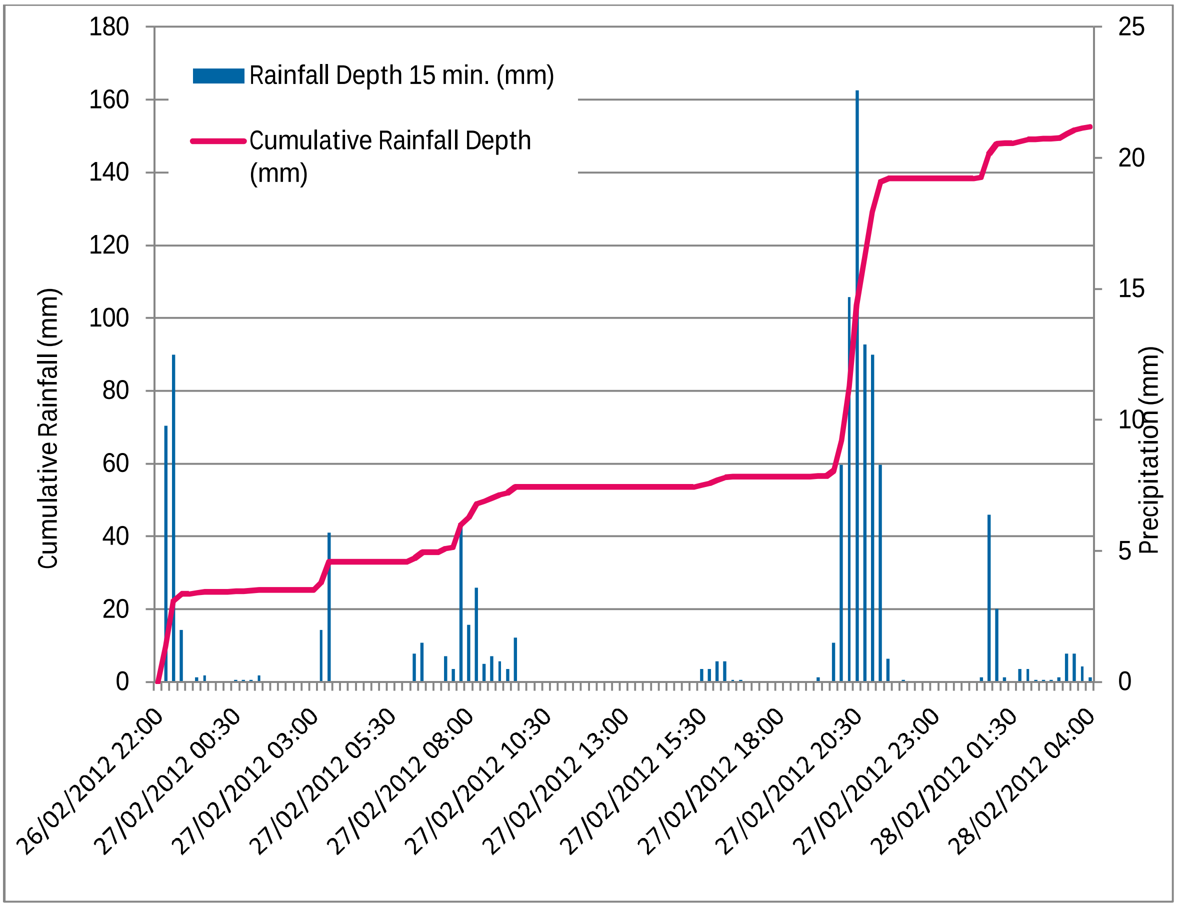


Figure 13 Pluviograph (Julian Hollis) – February 2012

The rainfall depths were compared to the intensity frequency duration (IFD) information for Castlemaine which was downloaded from the Bureau of Meteorology (note: comparisons discussed below are compared to the recently released 2013 IFD information). Table 9 shows the IFD information for Castlemaine.

Considering the January 2011 event, most of the rainfall fell between the 12th and the 14th. Over these three days 147.6 mm fell, which equates to approximately a 1 in 30 AEP event (3.3%).

Considering the February 2012 event, over the two days a total of 157 mm fell, which equates to approximately a 1 in 90 AEP event (1.11%). Within the February event there was a two hour period (refer to Figure 13) from 19:30 to 21:30 on the 27/2/2012 in which 81.7 mm fell, which equates to an event rarer than a 1 in 100 AEP (1%) event. Also it is worth noting that only a small amount (20 mm over the two days) of rainfall was recorded in the upper portion of the catchment on Barkers Creek with the bulk of the rainfall falling on Forest Creek in town.

Table 9 IFD at Castlemaine Prison (source: Bureau of Meteorology)

Duration	Annual Exceedance Probability (AEP)					
	50%	20%	10%	5%	2%	1%
5 min	5.1	7.7	9.6	11.6	14.4	16.8
10 min	7.7	11.7	14.5	17.5	21.8	25.2
15 min	9.4	14.2	17.7	21.4	26.6	30.8
30 min	12.3	18.5	23.2	28	35	40.7
1 hour	15.3	23	28.7	34.8	43.5	50.8
2 hour	19.2	28.3	35.1	42.3	52.8	61.5
3 hour	22.1	32.2	39.7	47.6	59	68.5

Duration	Annual Exceedance Probability (AEP)					
	50%	20%	10%	5%	2%	1%
6 hour	28.9	41	49.9	59.1	72.2	83
12 hour	38.4	53.2	63.9	74.9	90.1	102.4
24 hour	49.7	68.4	81.7	95.1	113.6	128.2
48 hour	60.9	84.3	100.9	117.8	141	159.5
72 hour	66.4	92.4	111.1	130.1	156.6	177.8
96 hour	70	97.4	117.2	137.5	166	188.9

For the February 2012 event the best pluviograph information available was that supplied by Julian Hollis. Therefore this pluviograph was used for the February 2012 event. For the January 2011 event a storm file was established with reference to the pluviograph data supplied by Julian Hollis and that supplied by the Bureau of Meteorology at Cairn Curran with the one from Cairn Curran adopted.

As there is no streamflow data on Barkers, Forest or Campbells Creek it is difficult to determine appropriate losses to use for each flood event. For the January 2011 event the losses adopted for the calibration of Axe and Muckleford Creek were used as a guide. For both the January 2011 and February 2012 events the losses adopted were chosen in conjunction with the calibration of the hydraulic model (discussed in Section 4).

The set of parameters adopted for the January 2011 and February 2012 events are shown in Table 10. Subarea hydrographs were extracted from the rainfall runoff model (RORB) at various points of interest.

Table 10 Parameters Adopted for January 2011 and February 2012

	January 2011	February 2012
k_c	14.6	14.6
m	0.8	0.8
Modelled IL (mm) Burst 1	60	55
Modelled IL (mm) Burst 2	5	N/A
Modelled CL (mm/hr) Burst 1	2.4	2.4
Modelled CL (mm/hr) Burst 2	0.5	N/A

3.4.1 February 2012 Pluviograph

As mentioned previously for the February 2012 event the best pluviograph information available was that supplied by Julian Hollis. As this pluviograph data is from an unregistered site there were queries raised, in the SC and TWG meeting held on 20 August 2013, about relying on this data. To validate the use of the pluviograph data for February 2012 a number of checks were undertaken; namely:

- Comparison of Bureau of Meteorology data for the January 2011 event to that supplied by Julian Hollis for January 2011.
- Comparing daily rainfall depths recorded at Castlemaine Prison for February 2012 to those by Julian Hollis.
- Discussion with the community members on the SC.
- Comparing the result of the hydraulic model against recorded flood levels and anecdotal evidence using the flow estimates from the rainfall runoff model.

As mentioned previously, in general the January 2011 event was a wide spread event which occurred over several days and the February 2012 event was a localised event which was intense and occurred over a short period of time. Therefore, it was considered more appropriate to compare the Bureau of Meteorology data for January 2011 as it was not isolated to Castlemaine only. Figure 14 shows a comparison between the Bureau of Meteorology pluviographs and that supplied by Julian Hollis for the January 2011 event. The location of the pluviographs is shown in Figure 2. Figure 14 shows that the information supplied by Julian Hollis for this event is consistent with that from the Bureau of Meteorology.

The Bureau of Meteorology daily rainfall gauge in Castlemaine is located approximately 2.5 kilometres to the south east of the Julian Hollis pluviograph. Table 11 shows that the two gauges recorded similar total rainfall depths for the February 2012 event.

Discussion with the community members on the SC indicated that the rainfall pattern described by the Julian Hollis pluviograph generally represented their memory of the February 2012 event. Their memory of the February 2012 was that a significant amount of rainfall fell in the Forest Creek catchment over a very short period of time.

The Julian Hollis pluviograph information was used to generate flows which were put into the hydraulic model. A sensitivity analysis was undertaken within the hydraulic model by adjusting losses in the rainfall runoff model to calculate different flows which were then placed into the hydraulic model and compared to the flood levels. This approach appeared to give satisfactory results when comparing the surveyed flood levels to modelled flood levels (further discussion on the hydraulic modelling is found in Section 4).

Based on the above discussion it was decided to use the Julian Hollis pluviograph information for the February 2012 event acknowledging that there are uncertainties.

There were discussions between GHD, NCCMA and DELWP in regards to trying to verify the Julian Hollis pluviograph using radar information. It was decided that the additional cost to process the radar data was not 'value for money' as the additional money to process the radar, may not clarify the situation.

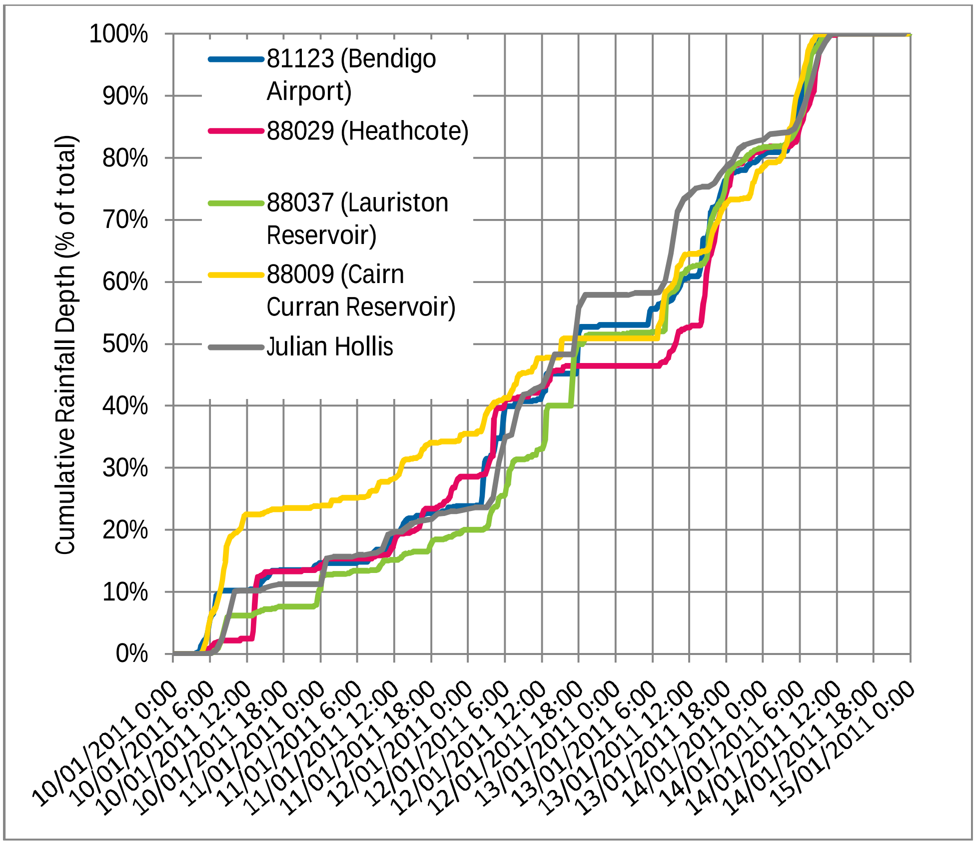


Figure 14 Bureau of Meteorology Pluviographs compared to that supplied by Julian Hollis - January 2011

Table 11 Daily Rainfall Recorded by Bureau of Meteorology compared to that supplied by Julian Hollis - February 2012

Date	Rainfall Depth (mm)	
	Castlemaine Prison	Julian Hollis
27/02/2012	59	52
28/02/2012	98	101

3.5 Design events

Design storm files are placed into the RORB model to represent the rainfall patterns within the catchment. Storm files consist of rainfall depths, temporal patterns (depth versus time) and spatial patterns (depth across the catchment). At this stage of the study the 20%, 10%, 5%, 2%, 1% and 0.5% AEP events were established.

The approach detailed below was adopted in accordance with review comments from the DELWP review panel.

Design Rainfall Depths

The rainfall depth information was developed from an Intensity Frequency Duration (IFD) analysis in accordance with the current version of Australian Rainfall and Runoff (1987). Currently Australian Rainfall and Runoff is undergoing a major revision and a number of the revised techniques are yet to be publicly available.

Point rainfall magnitudes were estimated using IFD rainfall from the Bureau of Meteorology. The areal rainfall for the design flood event was derived using areal reduction factors (ARF). The ARF values were determined according to the factors derived for Victoria (Siriwardena and Weinmann, 1996).

The IFD parameters and the IFD information is contained in Appendix F.

Design Losses

Current practice in design loss estimation is to use the work of the Cooperation Research Centre for Catchment Hydrology (CRCCH, 1996) supplemented with understanding gained from local modelling.

From the CRCCH (1996) the initial loss is determined as either storm initial loss (IL_s) or burst initial loss (IL_b). The storm initial loss is assumed to be the depth of rainfall lost prior to the commencement of surface runoff. The burst initial loss is the portion of the storm initial loss which occurs within the burst with the burst referred to as the intense part of the storm. The relationship developed by the CRCCH to calculate losses are as follows:

IL_S = -25.8 BFI + 33.8;

$$IL_B = IL_S \left\{ 1 - \frac{1}{1 + 142\frac{\sqrt{duration}}{MAR}} \right\}; \text{ and}$$

CL = 7.97 BFI + 0.00659 PET – 6.0

Where

BFI = the baseflow index is defined as the volume of the baseflow divided by the total stream flow volume.

Duration = the burst duration.

MAR = the mean annual rainfall for the catchment. The MAR of 600 mm was taken from information available from the Bureau of Meteorology.

PET = the mean annual potential evapotranspiration (mm). The PET of 1090 mm was taken from information available from the Bureau of Meteorology.

The review panel acknowledged that there will be substantial uncertainty in the design flow values but it would be worth undertaking sensitivity analysis. A sensitivity analysis was undertaken using different continuing loss values calculated using CRCCH (1996). The losses values used were 1.9, 2.9 and 3.8 mm/hr. The losses were adjusted by varying the base flow index (BFI). The losses were calculated using a BFI of 0.22, 0.09 and 0.33. The BFI of 0.22 came from the Low Flow Atlas for Victorian Streams for Axe Creek (406214). The BFI of 0.09 and 0.33 were calculated from the streamflow gauge information available on Muckelford and Axe Creek respectively (the gauges used during the calibration process i.e. Muckleford Creek @ Muckleford North and Axe Creek @ Sedgewick). The BFI was calculated using the Lyne and Hollick filter with a filter parameter of 0.925 with three passes.

Temporal and Spatial Patterns

The temporal patterns used in the design events were taken from Australian Rainfall and Runoff. The catchment is located in within Zone 2 of the temporal pattern map as defined in Australian Rainfall and Runoff. Unfiltered temporal patterns were used. Unfiltered temporal patterns are to be used with the CRCCH (1996) design losses.

Uniform spatial patterns were adopted.

Results

Table 12 shows the results of the sensitivity analysis. The initial losses also vary with the BFI but they are not shown for clarity. However, by way of example, for the two hour storm the initial loss varies between 7.1 mm, 7.9 mm and 6.3 mm for the BFI of 0.22, 0.09 and 0.33 respectively.

Table 12 Peak Flows from RORB model for Various Losses with k_c = 14.6

Location	Continuing Loss (mm/h)	AEP (%)			
		10%	2%	1%	0.5%
Barkers Creek Upstream of Forest Creek Confluence	1.9	69	107	129	152
	2.9	60	101	123	146
	3.8	53	95	116	139
Forest Creek Upstream of Barkers Creek Confluence	1.9	74	121	146	172
	2.9	69	116	141	167
	3.8	64	112	136	162
Campbells Creek Downstream of Forest Creek Confluence	1.9	144	218	262	308
	2.9	127	207	250	296
	3.8	110	194	237	283

For this investigation a continuing loss of 2.9 mm/h was adopted as an average value. The continuing losses calculated are all consistent with the continuing losses used in the calibration events.

3.5.1 Barkers Creek Reservoir Drawn Down

As discussed previously in Section 3.2, Barkers Creek Reservoir and McCay Reservoir were full prior to January 2011 and February 2012 flood events. For the design events it was assumed that the storages were full at the start of the storm.

To check the feasibility of utilising these storages for flood protection, the initial storage water level in the RORB model was drawn down by 50% for the Barkers Creek Reservoir (Barkers Creek has a larger catchment compared to McCay Reservoir so it was checked first).

Drawing the Barkers Creek storage down by 50% resulted in less than a 0.5 m^3/s reduction within Castlemaine.

4. Hydraulic analysis

4.1 Overview

The hydraulic modelling of the Castlemaine, Campbells Creek and Chewton study area (refer to Figure 1 for study area) was completed using a two dimensional model (TUFLOW). TUFLOW is a hydrodynamic model used for simulating one-dimensional (1D) and two-dimensional (2D) flows. The model is based on the solution to the free-surface flow equations. It links 1D network (ESTRY) domains to 2D (TUFLOW) domains to represent the catchment terrain and its drainage system. The TUFLOW model consists of a 2D domain representing the catchment terrain, a 1D network representing the pipe system and a set of boundary conditions.

The hydraulic model was calibrated to the January 2011 and the February 2012 event.

Plans showing the layout of the TUFLOW model, as described below, are included in Appendix G.

4.2 Hydraulic model development

4.2.1 2D domain

The 2D domain represents the surface terrain of all major overland flow paths within the study area. Using the LIDAR (refer to Section 2.6), a 7 200 m by 7 000 m grid comprising five metre square cells was formed. Each cell is made up of nine points, with each point having an elevation corresponding to the surface elevation at that location. Barkers and Campbells Creek were covered by the rivers LIDAR. The rivers LIDAR was used on Forest Creek up to Hargraves Street upstream of Hargraves Street the floodplain LIDAR was used. Hargraves Street was chosen as for the flood events considered the only flow in this location is along the creek. At this location the terrain was merged together (through the use of a Z shape). In general the terrain data along the creeks were adjusted in the model (through the use of Z shapes) to match surveyed cross sections and bridge openings details. Along Barkers and Campbells Creek the creek bed was adjusted based on interpolation between cross sections. Along Forest Creek the creek bed was generally lowered by approximately 300 mm in accordance with the surveyed cross sections.

The roughness value was allocated to each cell as a Manning's n value based on land use type. The roughness values were based on the aerial photo and information gathered during the site visits. Residential properties and industrial buildings have typically been assigned a Manning's n value of 0.2, due to structures such as buildings and fences obstructing flow through the property. The adopted Manning's n values are tabulated in Table 13. The values shown in Table 13 are the adopted values following adjustment within documented limits (e.g. Chow, 1959), during the calibration to match the surveyed flood levels (refer to Section 4.3). Appendix H shows the Manning's n values adopted across the study area.

Table 13 Bed Resistance Values

Land Use	Manning's n
Barkers Creek	0.05 – 0.075
Campbells Creek	0.05 – 0.07
Forest Creek	0.035 – 0.075
Road	0.02
Residential / Industrial / Business	0.2
Open Space / Sports Field	0.035
Low Density Housing with some Trees	0.06

Land Use	Manning's n
Railway line	0.05

Each of the road bridges, railway bridges and pedestrian bridges were modelled as flow constrictions in the 2D domain with the bridge parameters based on the survey data.

4.2.2 1D network

The one-dimensional network comprised some of the main underground pipes and culvert crossings. Pipe sizes and inverts were taken from data supplied by Mount Alexander Shire. Underground pipes were modelled as circular or rectangular culverts. Concrete pipes were modelled with a Manning's n value of 0.013.

Appropriate losses were estimated throughout the pipe network, based on standard pit loss tables (VicRoads, 1992). Each pit loss value was generally assigned to the downstream pipe as a form loss, rather than in the pits themselves. For culverts or ends of pipes, a typical entrance loss of 0.5 and exit loss of 1.0 were applied.

4.2.3 Boundary conditions

Inflow boundary

For the January 2011, February 2012 and design events all subarea flows were taken from the rainfall runoff model (as described in Section 3). Routing along the main flow paths was undertaken in TUFLOW. All inflows were entered as hydrographs using a flow versus time (Q - T) boundary type. The location of the inflows is shown in Appendix G.

Downstream boundary

A flow versus head (Q-H) relationship was developed, based on normal depth, and applied as the models downstream boundary. With a Q-H relationship the boundary level is determined by a hydraulic relationship and requires no estimation of an appropriate water level for each event. It also allows the downstream area to fill and drain during a flood simulation.

The boundary condition was placed in a location sufficiently downstream of the study area so this it did not adversely influence the mapping within the study area. The location of the downstream boundary is shown in Appendix G.

4.3 Calibration results

The calibration process requires a comparison of the hydraulic model representation of flooding in the study area with observed flooding behaviour. The model was calibrated to the January 2011 and February 2012 events. Surveyed flood marks (provided by the North Central CMA) and information gathered from the Community was used to calibrate the model.

The general approach to the calibration process was iterative and involved:

- Adjusting within a reasonable and realistic range the Manning's 'n' roughness values within the TUFLOW model.
- Adjusting the inflows (by adjusting the losses in RORB within a realistic range).
- Running the model.
- Comparing the results to the observed flood levels and evidence provided by the community.

The calibrated Manning's n values adopted for the model are shown in Table 13. The calibrated Manning's 'n' values were considered to be within the ranges expected for the modelled area based on literature such as Chow, 1959. A comparison between the calibrated modelled water levels and the observed water levels is presented in Appendix I.

As some sections of the creek system are confined (e.g. Barkers Creek around Gingell Street and Forest Creek downstream of Forest Street) a one dimensional model (HECRAS) was established within the study area to verify the results from the TUFLOW model. The HECRAS model gave consistent results to the TUFLOW model indicating that the conveyance along the creek system was appropriately represented in the TUFLOW model.

January 2011

Generally a good calibration was achieved. The 2011 event observed flood levels are all within 100 mm of the observed levels. Comments on the extent were sought from the SES and the community. There were a number of locations where minor differences between the modelled extent and the observed extent were noted however, in general, it was agreed that the results from the model were generally consistent with the observed extent.

February 2012

A larger number of flood marks were collected for the February 2012 event compared to the January 2011 event. Comments on the extent were sought from the SES and the community. There were a number of locations where minor differences between the modelled extent and the observed extent were noted however, in general, it was agreed that the results from the model were generally consistent with the observed extent. As the February 2012 event occurred at night and was quick it made observations more challenging. In general a reasonable calibration was achieved against the recorded flood levels. Of the 39 survey flood marks located within the study area:

- 24 points are within 0 to ± 100 mm
- 9 points are within ± 100 to 200 mm
- 5 points are within ± 200 to 250 mm
- 1 point is greater than 250 mm

Some key observations noted from the community in regards to the February 2012 event were that:

- Some clearing of Barkers Creek between Walker Street and Forest Street occurred after the January 2011 event.
- Flow did not break out of Barkers Creek.
- Levels on Forest Creek near Greenhill Avenue and within the Caravan Park (near the confluence of Campbells Creek) were in the order of 200 mm higher than in January 2011.
- Forest Creek upstream of the confluence with Campbells Creek was 'blocked up'.

Each of these observations were used in the calibration of the February 2012 event. The Manning's n value in Barkers Creek between Walker Street and Forest Street was lowered from 0.075 (used in January 2011 event) to 0.05 to account for clearing. The losses in RORB were adjusted such that the flow in Barkers Creek was approximately bank full upstream of the confluence with Forest Creek. It is difficult to predict debris load in a flood event and the impact it may have on flood levels. In TUFLOW it is possible to add a 'blockage factor' at the bridges. For the February 2012 event a model was run with a higher percentage of blockage to test the sensitivity of the results. Increasing the blockage at the railway bridge to 30% increases the levels within the caravan park by approximately 100 mm.

Due to the potential inaccuracies associated with the observed flood levels and localized effects, achieving greater agreement between the model and the observed levels can be difficult and sometimes counterproductive. Problems associated with calibrating a model to observed flood levels generally fit into two broad categories:

- Modeling Uncertainty (both hydrologic and hydraulic)
- Errors in Recorded Data

Modeling uncertainty includes uncertainty in the:

- Terrain/Survey Data
- Roughness Estimates
- Flow estimates
- Unique Event Conditions such as operator controls e.g. releases from a dam or blockages of a culvert
- Erosion or Deposition of a waterway changing the hydraulic parameters e.g. scour at bridges

Errors in recorded data includes

- The accuracy of the observed flood level can vary widely if it is based on flood debris or water marks.
- The technique used to peg the flood level. The adopted pegging method is understood to have been to drive the peg in until the top of the peg matches the flood level. While this can produce good results the outcome is more dependent on the operator and the peg not being disturbed.
- The timing of the record (peak or otherwise).

In general there is no trend across the model of levels being consistently two high or two low in a particular area, which adds further weight to the argument that discrepancies are localised effects or related to the accuracy of marking and surveying flood marks.

During the calibration process numerous models were run. In broad terms the sensitivity of the results were tested to adjustments in roughness values (Manning's n), adjustments in terrain data, blockages at bridges and changes in flows.

For the February 2012 event a significant proportion of the flow was on Forest Creek therefore the remainder of the discussion will focus on the results along Forest Creek. The sensitivity analysis showed that the results were sensitive to the losses assumed in RORB. For example a change in initial loss from 55 mm to 50 mm results in an increase in flood level along Forest Creek of between 100 mm to 300 mm. Along Campbells Creek the increase in flood levels is up to approximately 100 mm. On Forest Creek a change in initial loss from 55 mm to 50 mm results in the flow at the confluence with Barkers Creek decreasing from approximately 113 m^3/s down to 97 m^3/s. This result was not surprising due to the nature of the temporal pattern. As the burst was over a short period any loss in this part of the temporal pattern will have an impact on the flows. However, to verify that the changes in flood levels along Forest Creek due to the change in flow were reasonable, the different flows i.e. 113 m^3/s and 97 m^3/s were placed into the one dimensional model (HECRAS). The HECRAS model gave similar results to the TUFLOW model.

From the site visit and the survey data it was noted that scour has occurred at a number of the bridges along Forest Creek. For the calibration it is difficult to know how much scour has occurred before or during each flood event and the rate of scour that has occurred. For the calibration results adopted scour was not modelled at the bridges but a sensitivity analysis was undertaken by lowering parts of the terrain data with Forest Creek (based on LIDAR) with the scoured profile as shown on the survey. This resulted in localised changes to the flood levels at the bridges. The largest impact was at the Barkers Street Bridge with a 100 mm change at the bridge dissipating to negligible 100 meters upstream of the bridge.

From approximately 250 m downstream of Duke Street to Barker Street, Forest Creek is a 'channel' (refer to Figure 15) with stone walls. There was concern that with the number of bridges along this section and the nature of the channel in this section a one dimensional section may model this area better. The one dimensional model (HECRAS) results compared to the TUFLOW results in this section are shown in Figure 16. As the results in TUFLOW were comparable to HECRAS it was decided that the TUFLOW model was giving a reasonable representation of the losses through the bridges and the water surface profile in this area.

Figure 15 Forest Creek on Leanganook Track Foot Bridge Looking West

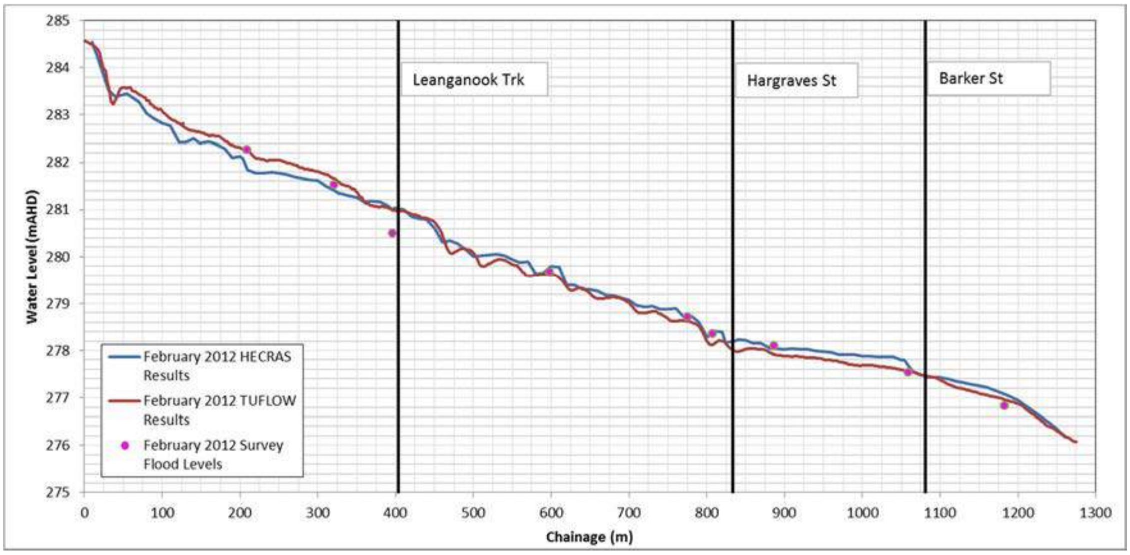


Figure 16 HECRAS Profile compared to TUFLOW

A particular comment is made on a number of the flood levels where the differences between the modelled level and the recorded level are greater than 200 mm (refer to Appendix I for location).

The surveyed flood level at Peg 23 and Peg 24 are located on the railway embankment near the caravan park. The levels in this section appear to be low. As mentioned previously a model run was undertaken that assumed that there was a 30% blockage on the railway bridge. The choice of 30% was an arbitrary number as it is difficult to predict the debris loading in a flood event. However, there is anecdotal evidence to suggest that this area was 'blocked up' during the February 2012 event. This amount of blockage raised the flood levels in this area by approximately 100 mm therefore reducing the difference between the modelled level and the recorded level to less than 200 mm. However, the difference at Peg 25 (at the railway bridge) increased from +90 mm to +180 mm. This impact was localised with the impact being minimal at Barker Street bridge approximately 100 meters upstream.

The surveyed flood level at Peg 31 is located at Leanganook Track Foot Bridge. The modelled flood level is 500 mm higher than the recorded flood level. This is a significant difference. The footbridge (refer to Figure 17) does not appear to provide a significant barrier to flow however, any flood levels taken on structures are more susceptible to localised effects as structures deflect flow resulting in flow contraction, expansion and redirection influencing flow behaviour and flood levels. As the water level profile in this section seems a reasonable match to the upstream and the downstream recorded levels and the HECRAS and the TUFLOW profiles are similar it was assumed that the recorded flood level is possibly too low in this area.

Figure 17 Leanganook Track Foot Bridge

The surveyed flood level at Peg 36 and Peg 37 are located approximately 70 meters upstream of Pyrenees Highway Bridge. They are located approximately 7 meters apart, with Peg 36 being closer to the bank of the creek. The modelling is matching Peg 36 well in this area. The modelled flood level at Peg 36 and 37 is approximately the same however, the surveyed level at Peg 37 is 240 mm higher than at Peg 36. Either the model is not representing a localised effect or the surveyed flood level at Peg 37 is possibly too high.

The calibration results are presented in Appendix I.

4.4 Design flood modelling

The calibrated hydraulic model was used to generate design flood extents for riverine flooding for the 5, 10, 20, 50, 100 and 200 year ARI event. Each ARI event was run for the one hour, 1.5 hour, two hour, three hour, 4.5 hour, six hour, 12 hour, 18 hour, 24 hour, 30 hour, 36 hour, 48 hour and 72 hour design storm events and the maximum value from each duration adopted. The flood extents for each ARI event are shown in Appendix J.

4.5 Design flood behaviour

The following section gives a brief description of the riverine flood characteristics in Castlemaine for each design event.

5 year ARI Event

- Castlemaine Botanical Gardens inundated.
- Water overtops Gingell Street with three Gingell Street properties flooded above floor level, one being the Railway Hotel.
- Camp Reserve oval inundated.
- Properties along western end of Bruce Street are inundated with one flooded above floor level.
- Western Reserve inundated.

10 year ARI Event

- Twelve properties flooded above floor level. The majority of properties flooded above floor level are located on Gingell Street and Bruce Street.
- Castlemaine Central Cabin and Van Park inundated.
- Water overtops Midland Highway directly south of intersection with Moscript Street.

20 year ARI Event

- Water overtops Walker Street.
- Water breaks out from Barkers Creek at the northern end of Gingell Street and floods four properties above floor level.
- Water overtops Elizabeth Street on the eastern side of the Elizabeth Street bridge. Three Elizabeth Street properties are flooded above floor level.
- Water overtops Main Road in Campbells Creek Township directly north of Alexandra Street.
- Twenty six properties flooded above floor level, including three properties in Campbells Creek township located along main Road.

50 year ARI Event

- Water overtops Johnstone Street directly north east of intersection with Elizabeth Street.
- Water overtops Princess Street.
- Water overtops southern end of Elizabeth Street directly north of intersection with Alexandra Street.
- Central Carpets flooded above floor level.
- Forty five properties flooded above floor level, including twelve properties in Campbells Creek township located along main Road.

100 year ARI Event

- Water overtops Forest Street.
- Water overtops Barkers Street between Bruce Street and Forest Street.
- Water overtops Hargraves Street.
- Sixty nine properties flooded above floor level.

200 year ARI Event

- Water overtops Gaulton Street.
- One hundred and twelve properties flood above floor level, including eleven along Gaulton Street and fourteen along Elizabeth Street.

5. Flood mitigation options

This section provides an overview of the mitigation options considered to reduce the flood risk and flood damages at Castlemaine, Campbells Creek and Chewton. The mitigation options were compiled based on feedback received from the community and the Steering Committee. Initially a prefeasibility assessment of each option was undertaken with the focus on riverine flooding. The results of the prefeasibility assessment were discussed with the Technical Working Group and the Steering Committee on 9 April 2014, and the detailed mitigation options were discussed on 24 June 2014.

5.1 Prefeasibility assessment – structural options

This section documents the prefeasibility assessment undertaken for all the structural mitigation options considered. The options considered were broken down into four main categories:

- Levees
- Structures
- Waterway Management
- Storage

Initially all mitigation options were aimed at protecting properties or minimising the impact for the 1 in 100 AEP event.

5.1.1 Levees

The following levees were considered:

- New levee on Gingell Street.
- New levee to protect Castlemaine Central Cabin and Van Park and Bruce Street properties.
- New levee to protect Central Carpets.
- Topping up and extending the existing levee at Elizabeth Street.
- Topping up and extending the existing Campbells Creek township levee.
- Restore the existing National School Lane levee by filling in the depression in the levee but the extent and maximum height of the levee remains unchanged.
- Remove/reduce the levee along Forest Creek between Barker Street and Wheeler Street to engage the flood storage available in the Western Reserve earlier in flood events.

Figure 18 shows the location of the levees. For modelling purposes all levees, except for the National School Lane levee and the one along Forest Creek, were raised to protect properties against the 1 in 100 AEP event.

5.1.2 Structures

The following structural options were considered:

- Increase flow area through the Forest Street Bridge.
- Removal of pedestrian bridge adjacent to Roberts Avenue.
- Increase flow area through the Elizabeth Street Bridge.
- Increase flow area through Alexandra Street Bridge.

Figure 19 shows the location of the structures.

5.1.3 Vegetation management

The following vegetation management options were considered:

- Test the impact of the vegetation removal that has occurred between Walker Street and Forest Street.
- Removal of vegetation between the junction of Barkers and Forest Creek down to the Elizabeth Street bridge.
- Removal of vegetation and silt of the channelized section of Forest Creek downstream of Duke Street to the junction of Barkers and Forest Creek.
- Test the impact of vegetation management in a section of Campbells Creek approximately 100 meters downstream of the Alexandra Street Bridge.

For modelling purposes vegetation removal was tested by reducing the roughness value, which is represented by Manning's n, in the hydraulic model.

For the section between Walker Street and Forest Street, the value of Manning's n in this area was taken as 0.075 which represents a very weedy reaches, deep pools or floodway with heavy stand of timber (Chow, 1959). This was lowered to 0.05 which represents a clean, some pools and shoals but with some weeds and stones.

For the section between the junction of Barkers and Forest Creek the value of Manning's n was reduced from 0.07 to 0.05.

For the channelized section on Forest Creek from downstream of Duke Street to the junction of Barkers and Forest Creek the value of Manning's n was reduced from 0.035 to 0.03 (representing little to no vegetation as would be the case for removing silt) and the creek bed was lowered by 0.5 meter to represent removal of silt. The value of 0.5 meters was agreed upon in consultation with the NCCMA and Council.

For the Campbells Creek section approximately 100 meters downstream of the Alexandra Street Bridge the Manning's n value was varied from 0.035 to 0.2. These Manning's n values were not meant to represent a particular condition of the creek but were chosen to test the impact of vegetation management in this area.

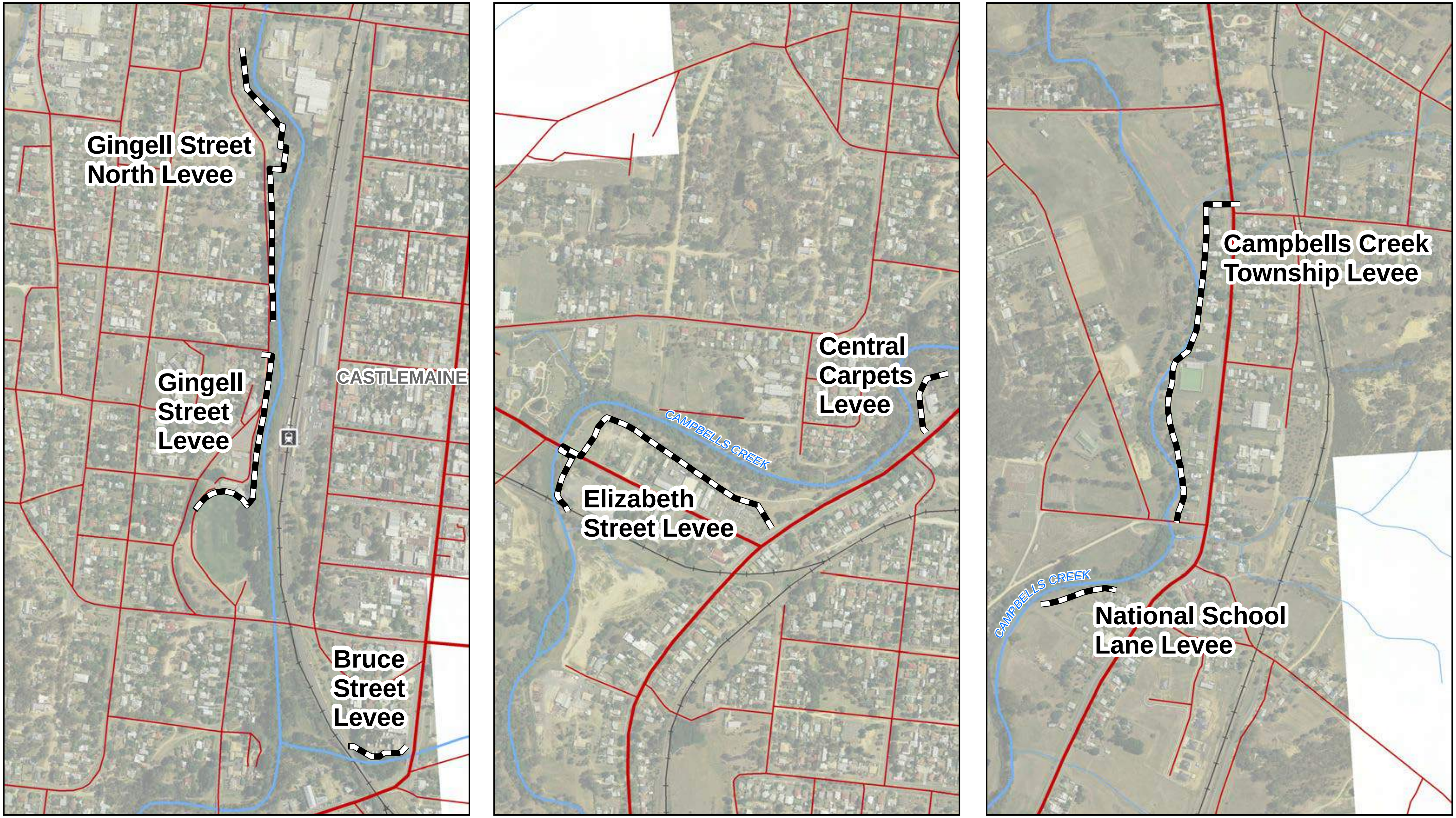
5.1.4 Storage options

A number of storage options were put forward. The following storages were considered:

- Increasing the storage volume of the Sunken Oval.
- Use part of the Expedition Pass Reservoir as a flood retention structure.
- Construction of a storage at Happy Valley.
- Construction of a retarding basin around Gainsborough Street.
- Construction of a retarding basin around Pottery Road.

Figure 20 shows the location of the storages.

It is worth noting that the use of Barkers Creek Reservoir for mitigation was discussed earlier (refer to Section 3.5.1). It was found that drawing down Barkers Creek Reservoir by 50% had little impact on flows in Castlemaine.



This data should be read in conjunction with the latest revision of the Report titled "Castlemaine, Campbells Creek and Chewton Flood Management Plan" with document number 224993 and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to GHD pty Ltd.

Paper Size A4

0 200 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Proposed levee
- Rail station
- Rail
- Highway
- Sealed road (arterial and local)
- River
- Stream

GHD

NORTH CENTRAL
Catchment Management Authority
Connecting Rivers, Landscapes, People

North Central CMA
Castlemaine, Campbells Creek and Chewton Flood Management Plan

Job Number 31-29991
Revision A
Date 09 Feb 2015

Proposed Levee Locations

Figure 18

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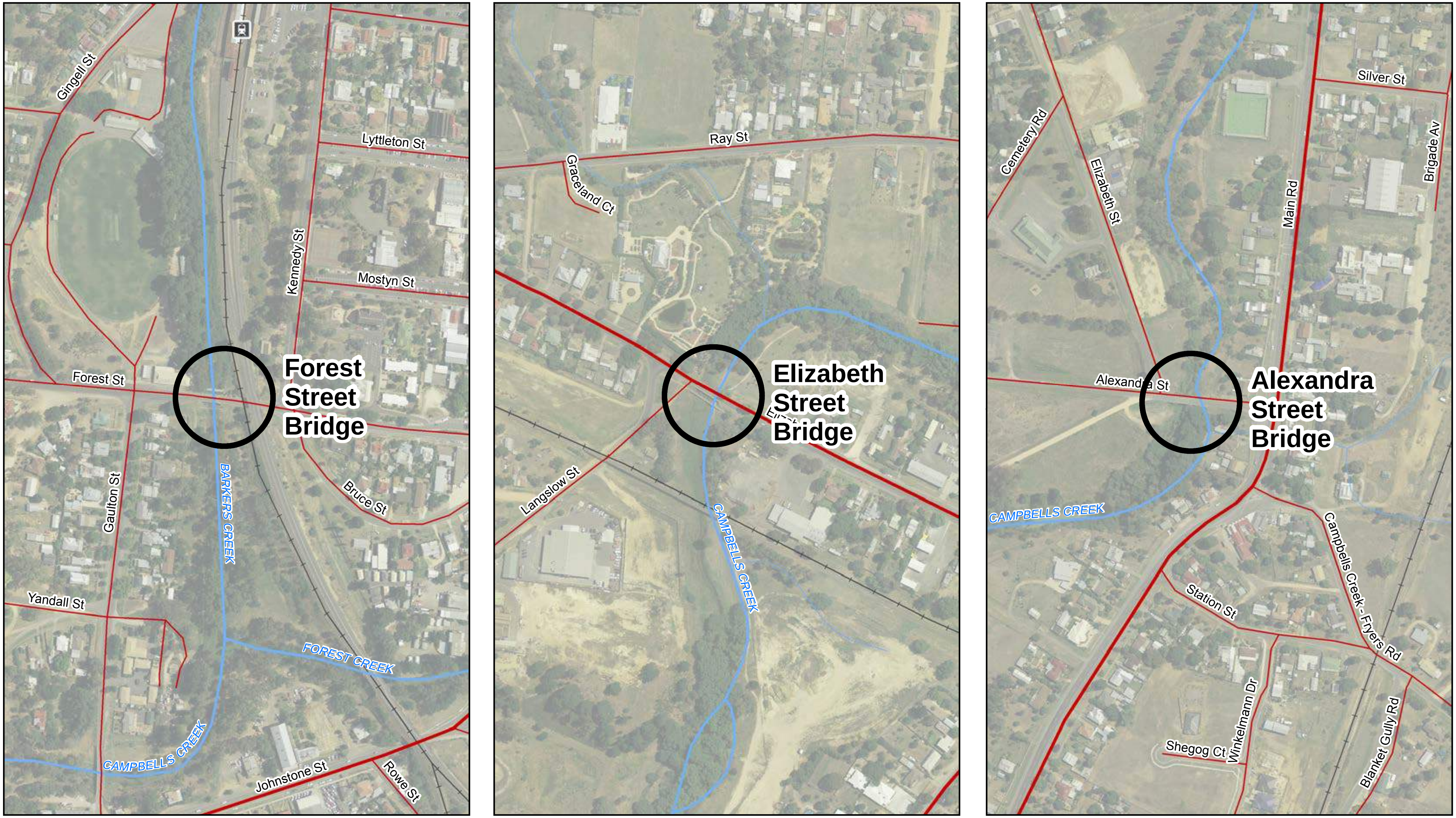
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2013; DSE, Aerial Imagery, 2013. Created by:scowan



This data should be read in conjunction with the latest revision of the Report titled "Castlemaine, Campbells Creek and Chewton Flood Management Plan" with document number 224993 and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to GHD pty Ltd.

Paper Size A4

0 100 200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Rail station
- Rail
- Highway
- Sealed road (arterial and local)
- River

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Connecting Rivers, Landscapes, People

North Central CMA
Castlemaine, Campbells Creek and Chewton Flood Management Plan

Job Number	31-29991
Revision	A
Date	09 Feb 2015

Structure Locations

Figure 19

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180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2013; DSE, Aerial Imagery, 2013. Created by:scowan

This data should be read in conjunction with the latest revision of the Report titled "Castlemaine, Campbells Creek and Chewton Flood Management Plan" with document number 224993 and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to GHD pty Ltd.

Paper Size A4

0 100 200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

Rail

Sealed road (arterial and local)

River

GHD

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Job Number	31-29991
Revision	A
Date	09 Feb 2015

Storage Locations

Figure 20

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180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2013; DSE, Aerial Imagery, 2013. Created by:scowan

5.1.1 Levees results

Gingell Street Levee

The proposed levee on Gingell was separated into the northern levee (between Walker Street and Thomas Street) and the southern levee (between Thomas Street and Forest Street). A number of locations were considered for the proposed southern levee. The proposed southern levee locations are:

- Option 1A – Levee along Gingell Street
- Option 1B – Levee along the outside of the oval
- Option 1C – Levee along Barkers Creek

Figure 21 shows the location of the proposed northern levee. Figure 22, Figure 23 and Figure 24 show the locations of Option 1A, 1B and 1C respectively.

The impact of each option in terms of an increase in water level (comparing existing with levee in place) for the 1 in 100 AEP event is as follows:

- Option 1A – Increase of water level by up to 300 mm (impact on 9 Walker Street)
- Option 1B – Increase of water level by up to 1000 mm (impact on 9 Walker Street an increase of 300 mm)
- Option 1C – Increase of water level up to 1000 mm (impact on 9 Walker Street an increase of 300 mm)

The impact on 9 Walker St is provided since this building/s is the only one which is impacted on by the increase in water level, its location is shown on Figure 21 (eastern side of creek).

Figure 22, Figure 23, and Figure 24 show the increases in water level for Options 1A, 1B and 1C respectively for the 1 in 100 AEP event.

The height of each levee is as follows:

- Option 1A - Average Height 1.0 meters (up to 2 meters)
- Option 1B - Average Height 1.5 meters (up to 2.5 meters)
- Option 1C - Average Height 2.0 meters (up to 3.7 meters)

The heights above do not include an allowance for freeboard.

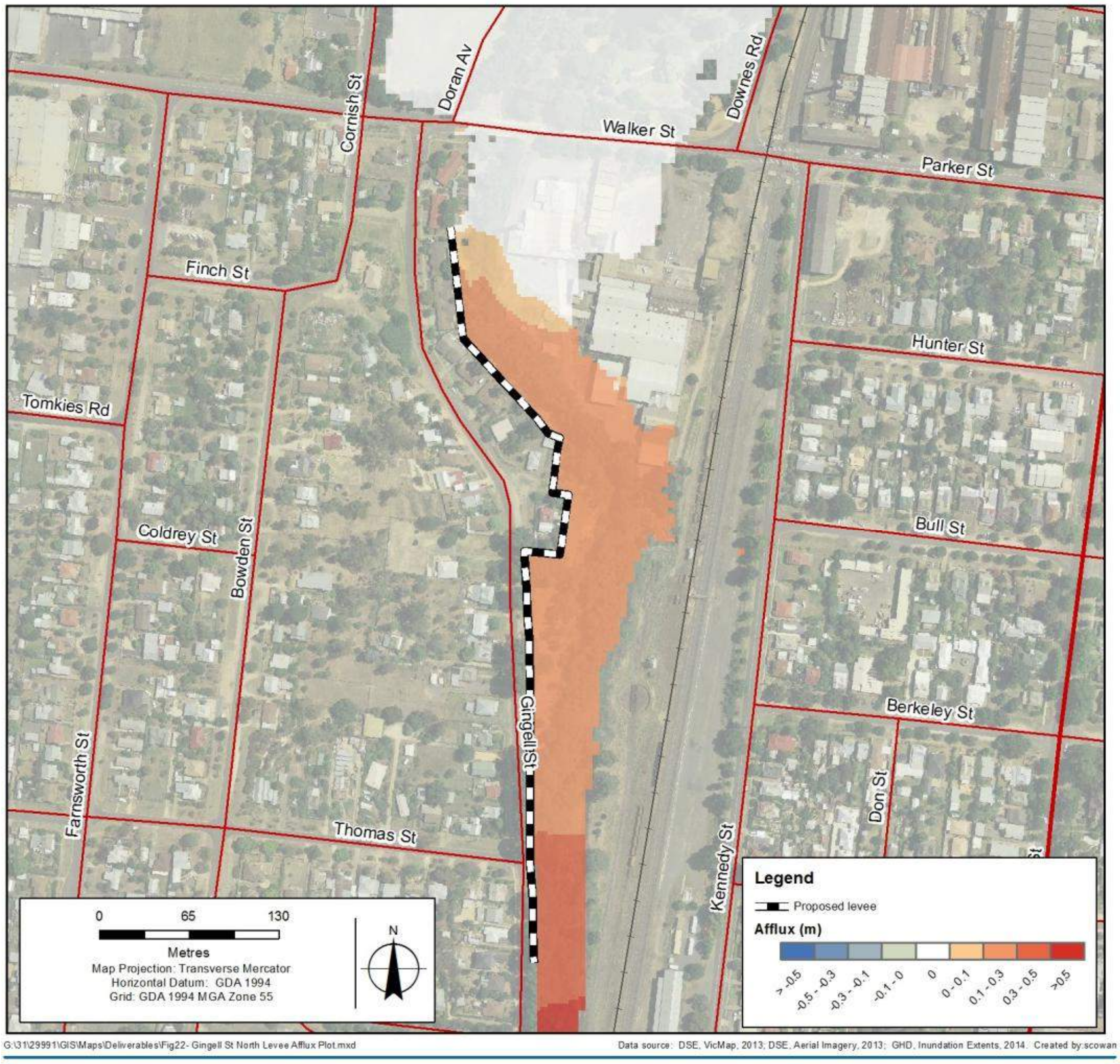

Figure 21 Northern Levee Location (levee shown as black and white line)

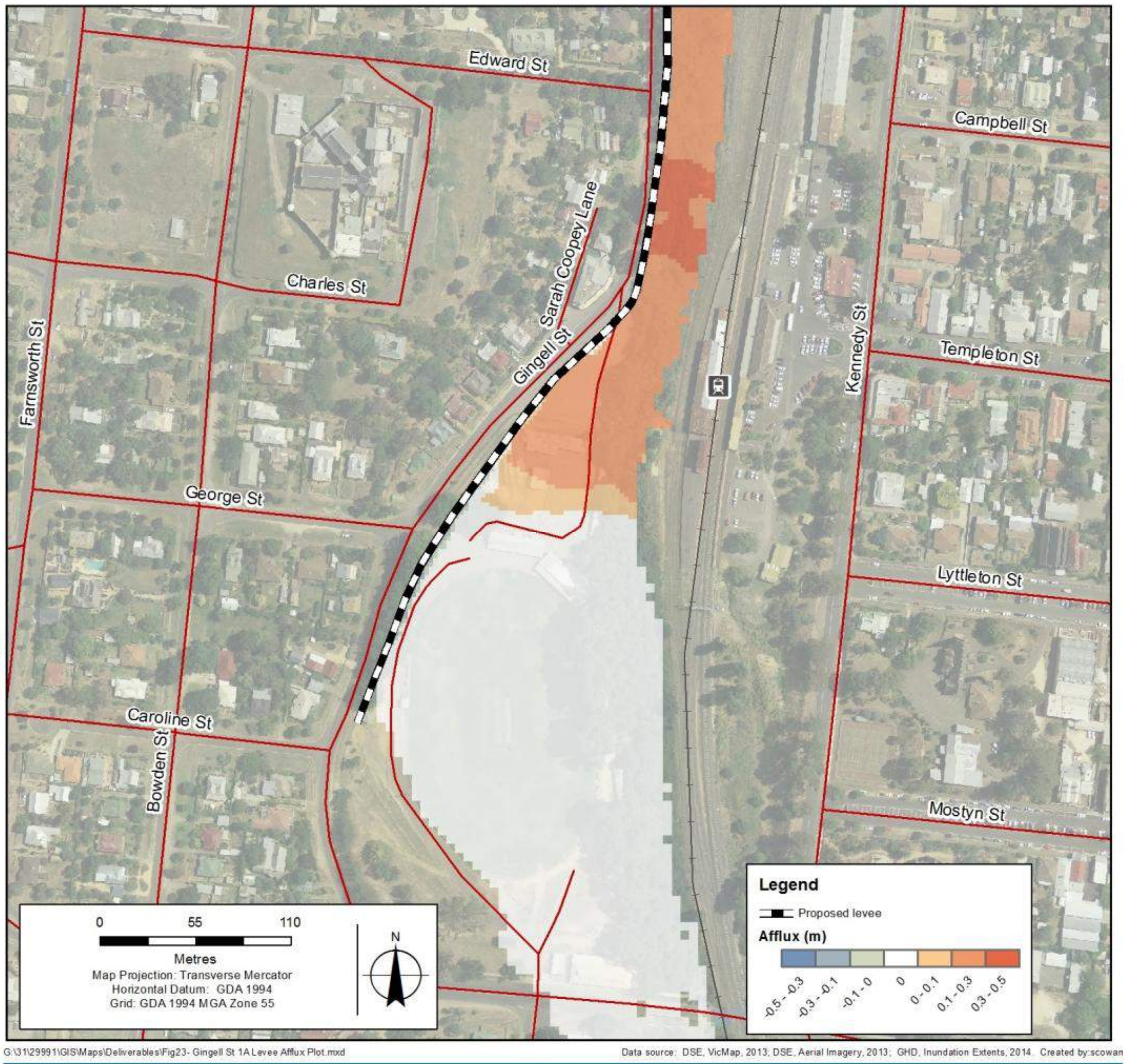

Figure 22 Option 1A (levee shown as black and white line)

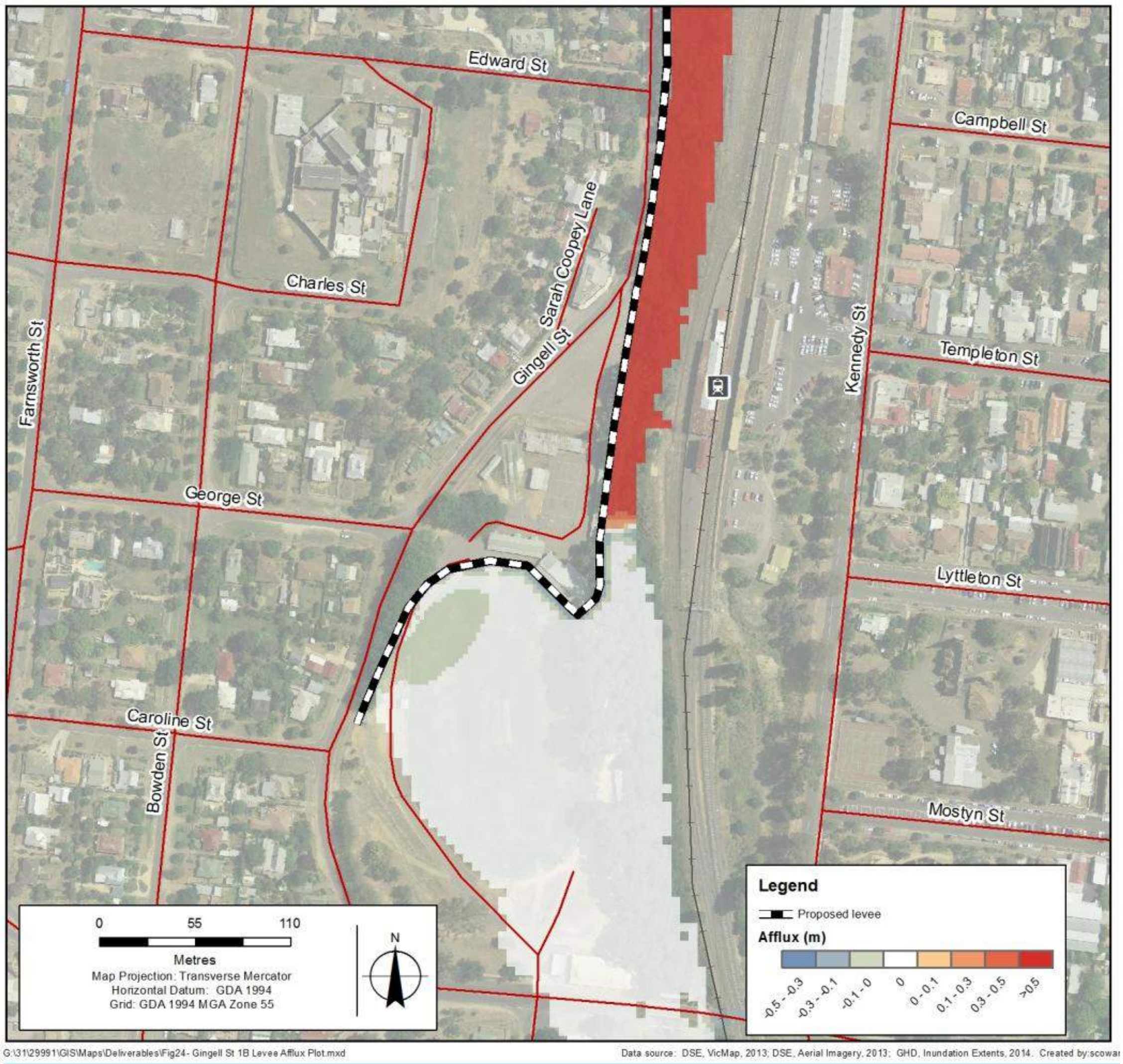

Figure 23 Option 1B (levee shown as black and white line)

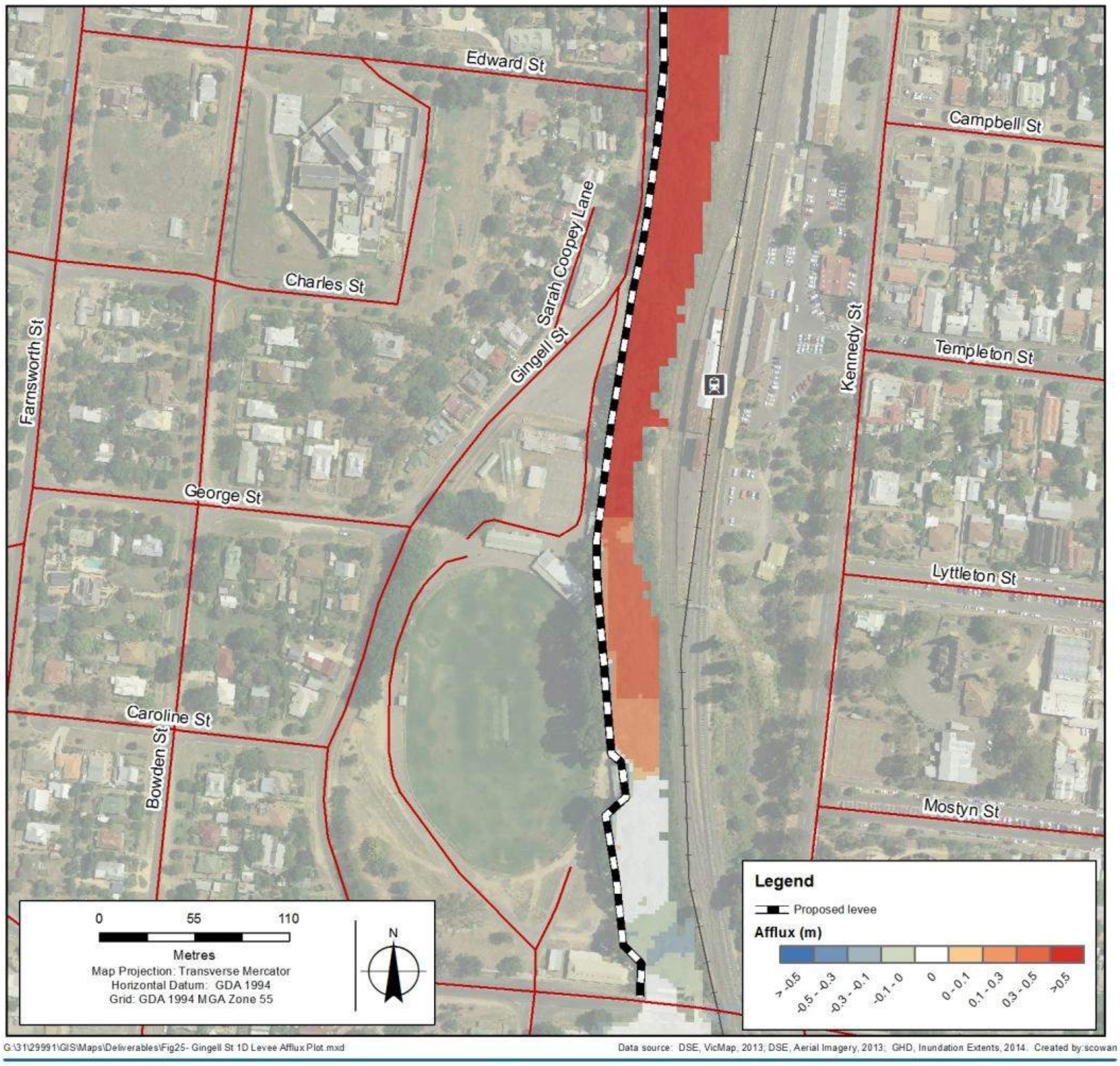

Figure 24 Option 1C (levee shown as black and white line)

New levee to protect Castlemaine Central Cabin and Van Park and Bruce Street properties

Figure 25 shows the location of the proposed levee within the Castlemaine Central Cabin and Van Park.

The impact of this levee in terms of an increase in water level (comparing existing with levee in place) is an increase of water level by up to 300 mm in the Western Reserve and up to 100 mm at the tennis court.

Figure 25 shows the increase of water level for the proposed levee within the Castlemaine Central Cabin and Van Park.

The average height of the proposed levee is 1.1 meters (up to 2.3 meters). This height does not include an allowance for freeboard.

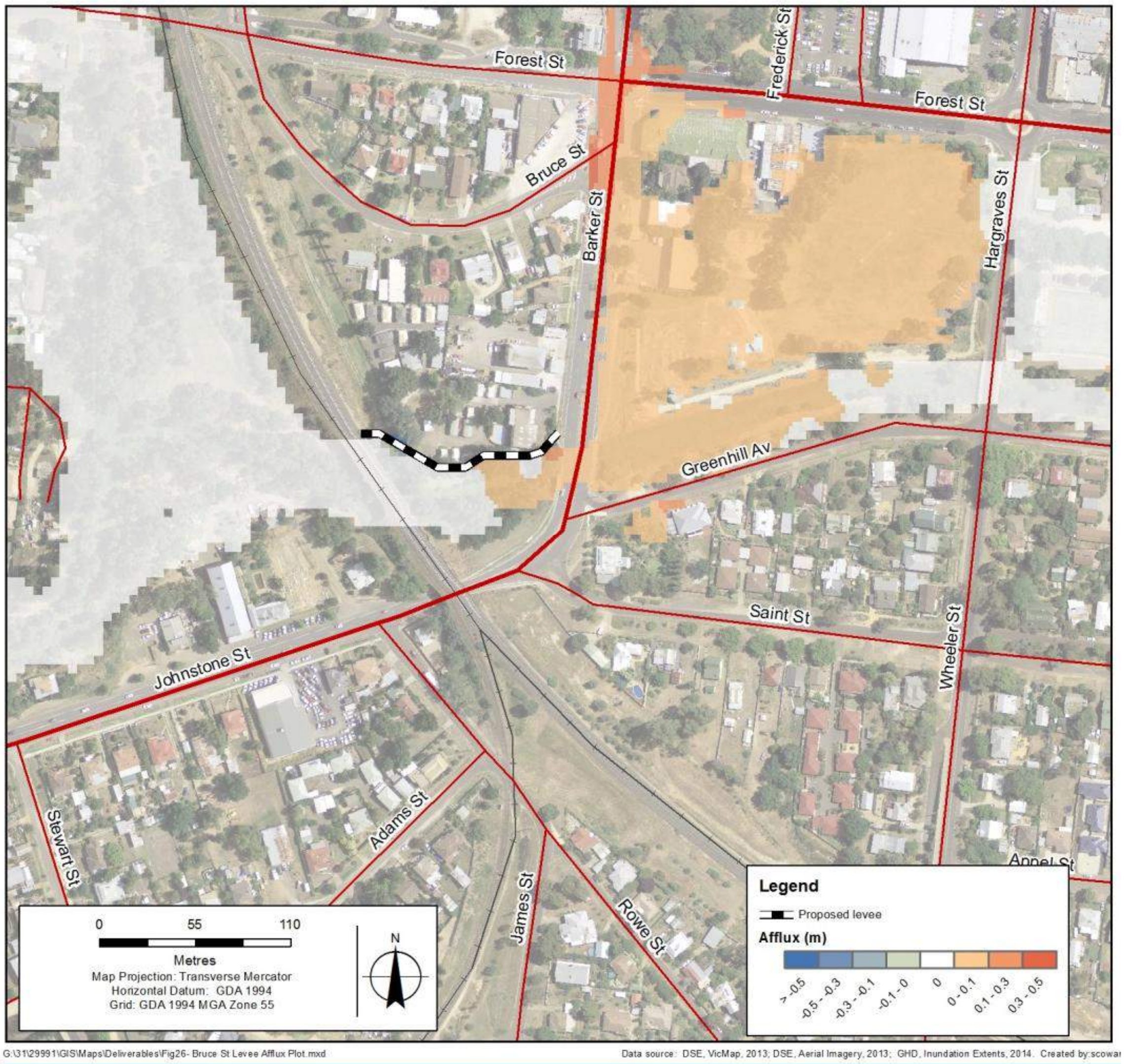

Figure 25 Castlemaine Central Cabin and Van Park Levee (levee shown as black and white line)

New levee to protect Central Carpets

Figure 26 shows the location of the modelled levee to protect Central Carpets.

The impact of this levee in terms of an increase in water level (comparing existing with levee in place) is a localised increase of water level by up to 50 mm.

Figure 26 shows the increase of water level for the modelled levee to protect Central Carpets.

The average height of the proposed levee is 1.0 meters (up to 1.5 meters). This height does not include an allowance for freeboard.

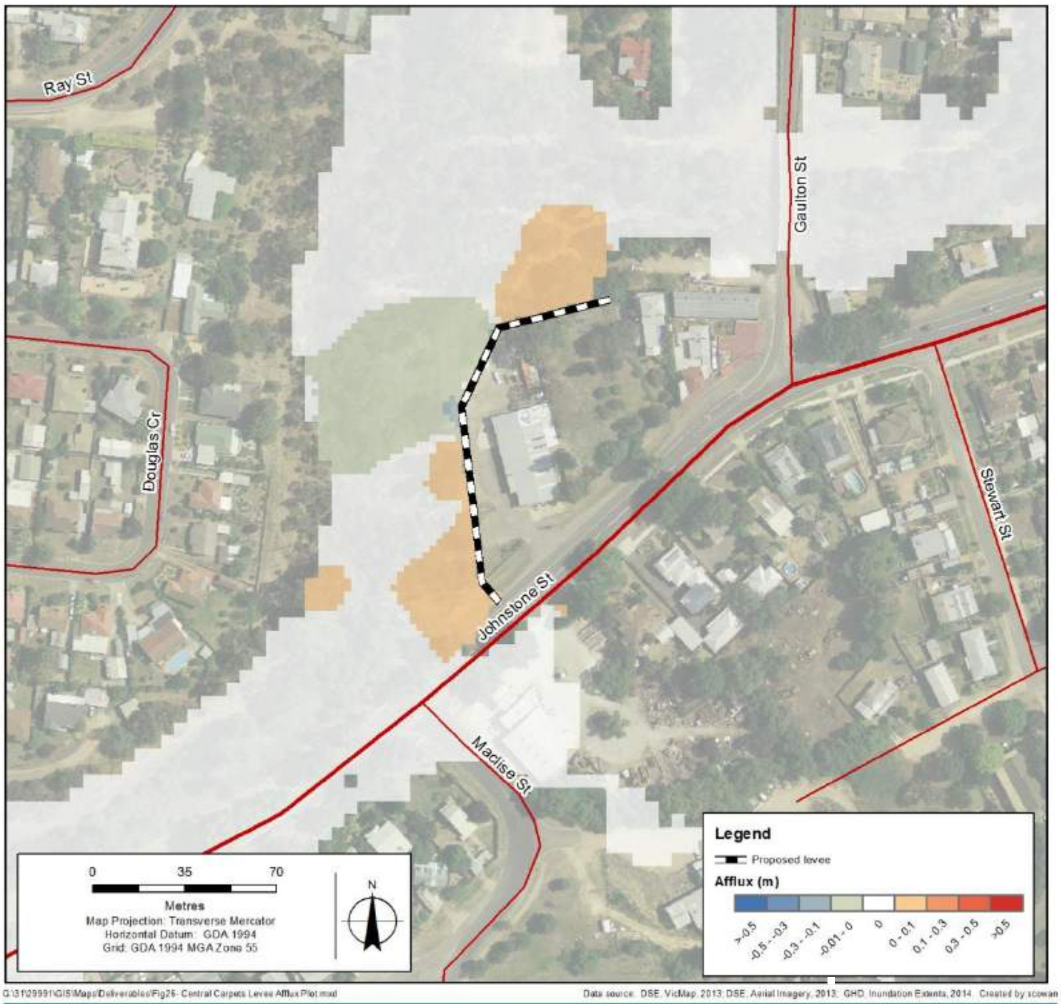

Figure 26 Central Carpets Levee (levee shown as black and white line)

Elizabeth Street Levee

This levee already exists in part. It is proposed to extend the existing levee to the railway line and increase the height to the 1 in 100 AEP level. Figure 27 shows the location of the Elizabeth Street levee.

The impact of this levee in terms of an increase in water level (comparing existing with levee in place) is an increase of water level by up to 300 mm. From the information available this does not result in any additional properties experience over floor flooding.

Figure 27 shows the increase of water level for the Elizabeth Street levee.

The average height of the proposed levee above the existing surface level is 1.0 meters (up to 2.2 meters). The average height of the proposed levee above the existing levee is approximately 0.5 meters. This height does not include an allowance for freeboard.

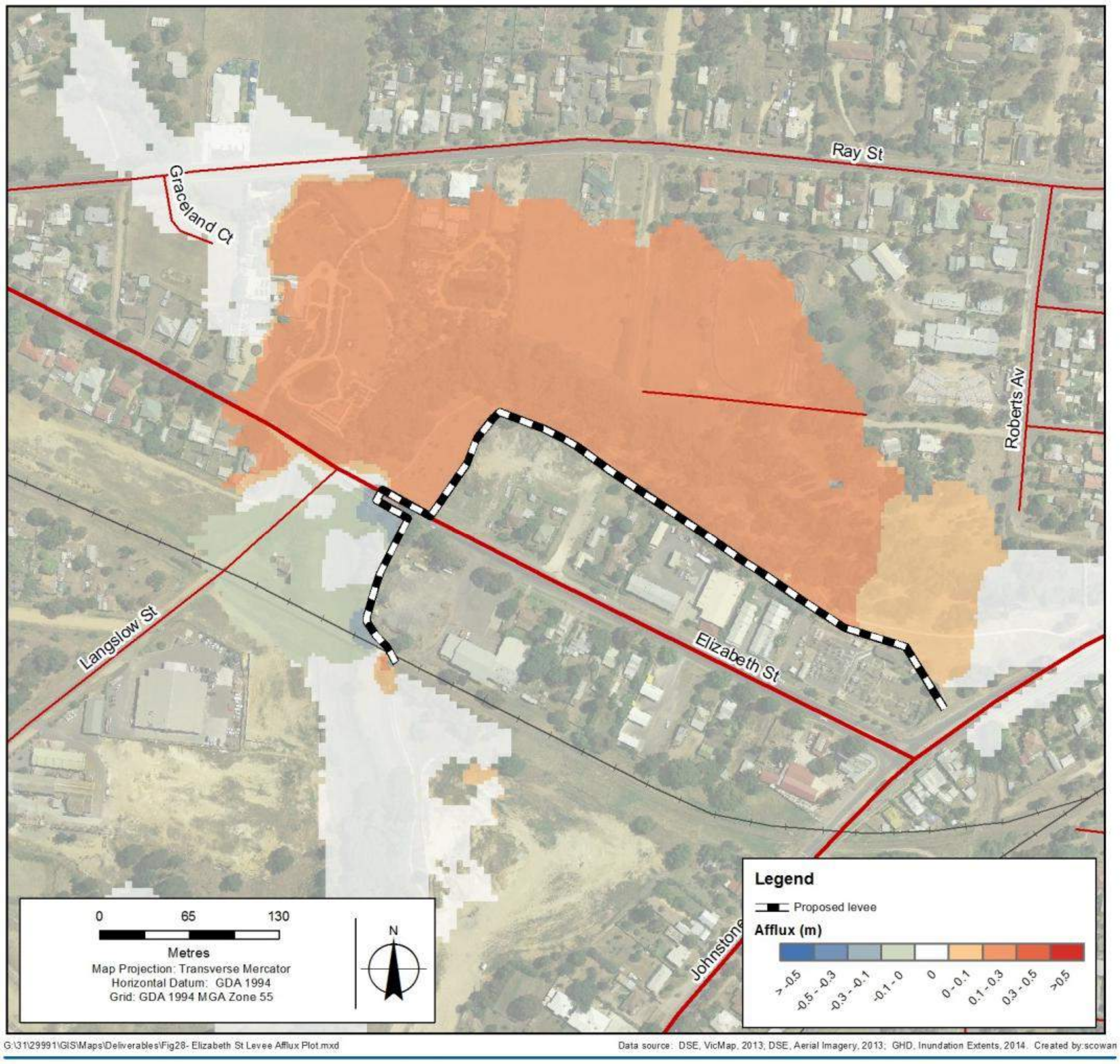

Figure 27 Elizabeth Street Levee (levee shown as black and white line)

Campbells Creek Township Levee

This levee already exists. It is proposed to extend the levee from Stephen Street and Alexandra Street and increase the height to the 1 in 100 AEP level. Figure 28 shows the location of the Campbells Creek Township levee.

The impact of this levee in terms of an increase in water level (comparing existing with levee in place) is an increase of water level by up to 100 mm. From the information available this does not result in any additional properties experiencing over floor flooding.

Figure 28 shows the increase of water level for the Campbells Creek Township levee.

The average height of the proposed levee above the existing surface level is 0.7 meters (up to 1.8 meters). The average height of the proposed levee above the existing levee is approximately 0.5 meters. This height does not include an allowance for freeboard.

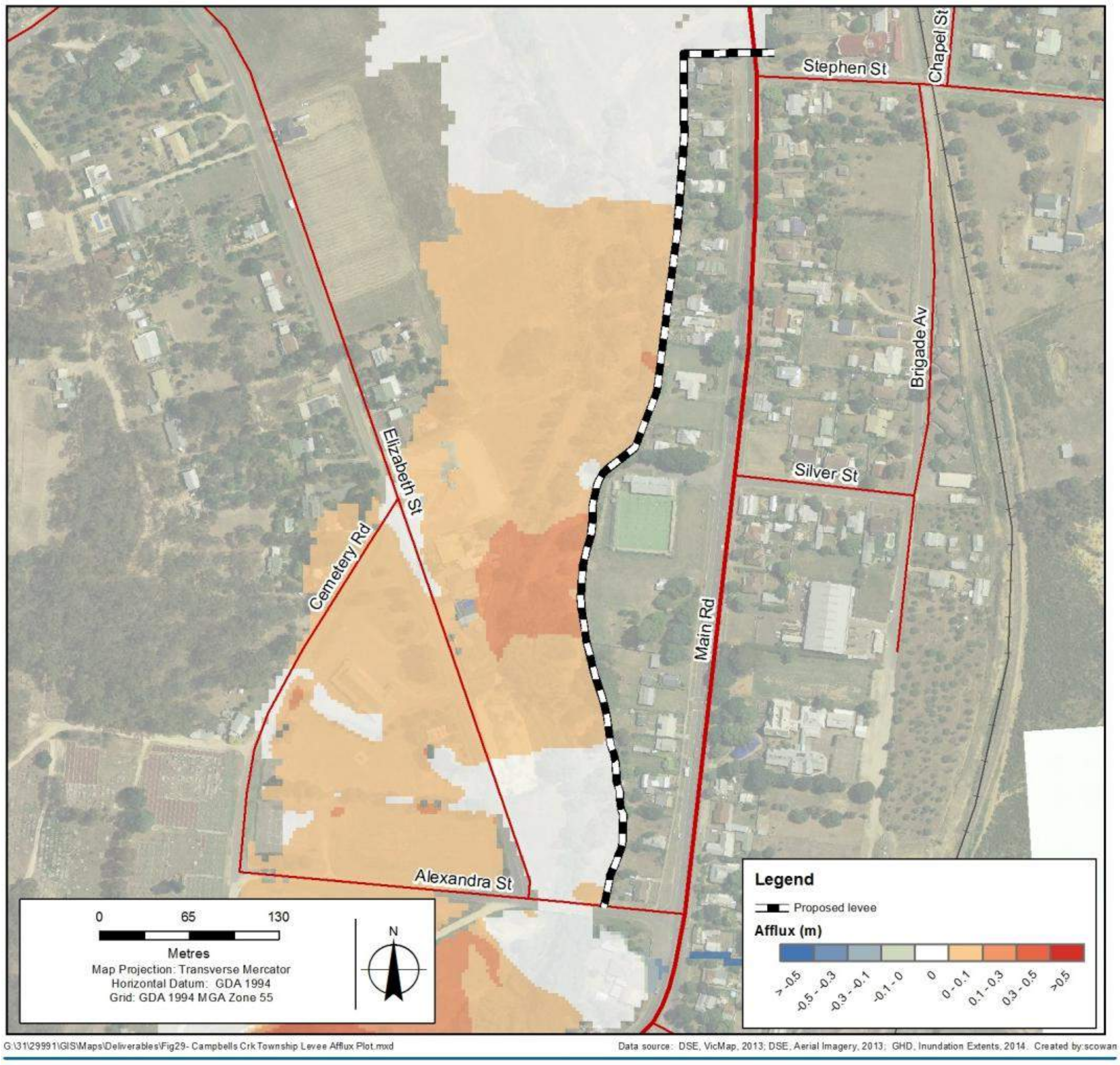

Figure 28 Campbells Creek Township Levee (levee shown as black and white line)

National School Lane Levee

This levee already exists. It is proposed to fill in the depression in the levee but to leave the extent and maximum height of the levee unchanged. Figure 29 shows the location of the National School Lane levee.

The impact of this levee in terms of an increase in water level (comparing existing with levee in place) is a localised increase of water level by up to 300 mm. From the information available this does not result in any additional properties experience over floor flooding.

Figure 29 shows the increase of water level for the National School Lane levee. As shown in Figure 29 flood waters still come in around the back of the levee, however flow velocities and flood depths behind the levee are reduced.

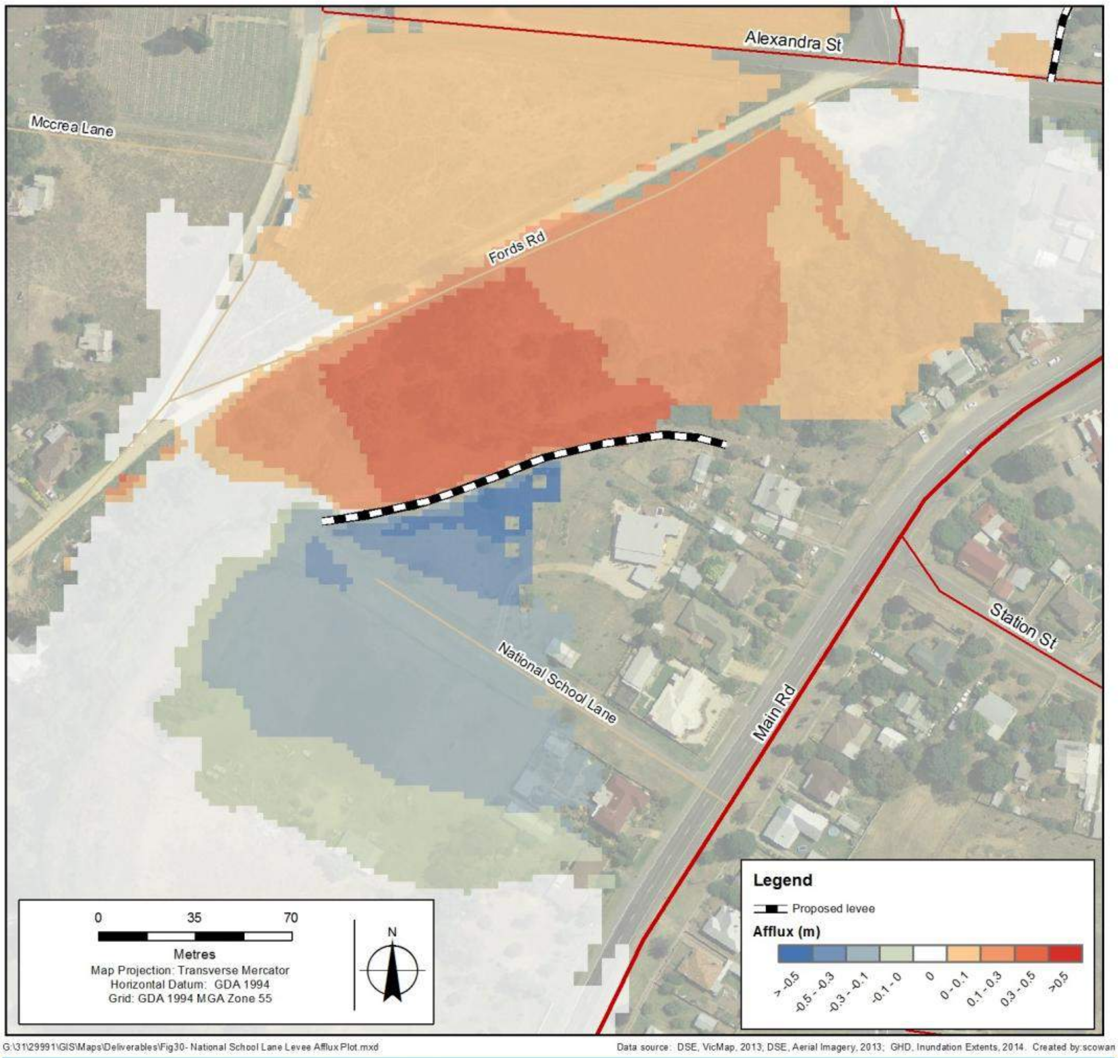

Figure 29 National School Lane Levee (levee shown as black and white line)

Remove/Reduce the levee along Forest Creek

This option modelled the removal of the levee from the north bank of Forest Creek adjoining the Western Reserve. The intention was to engage the storage in Western Reserve earlier to relieve flooding downstream.

The modelling indicated that this option provided little to no benefit (for the 1 in 100 AEP event) to properties downstream. This option may provide some benefit in smaller events although this was not analysed.

5.1.2 Structures results

Forest Street Bridge

There is limited space to increase the flow area at the Forest Street Bridge. GHD estimated that the largest number of culverts that could be easily constructed at this location was 2 No. 4.2 x 0.9 meter culverts.

The impact on water levels (comparing existing with culverts in place) is:

- Decrease by a negligible amount (less than 30 mm) at Gingell Street.
- Increase by a negligible amount (less than 10 mm) immediately downstream.

Figure 30 shows the impact on water levels by adding additional culverts at the Forest Street Bridge.

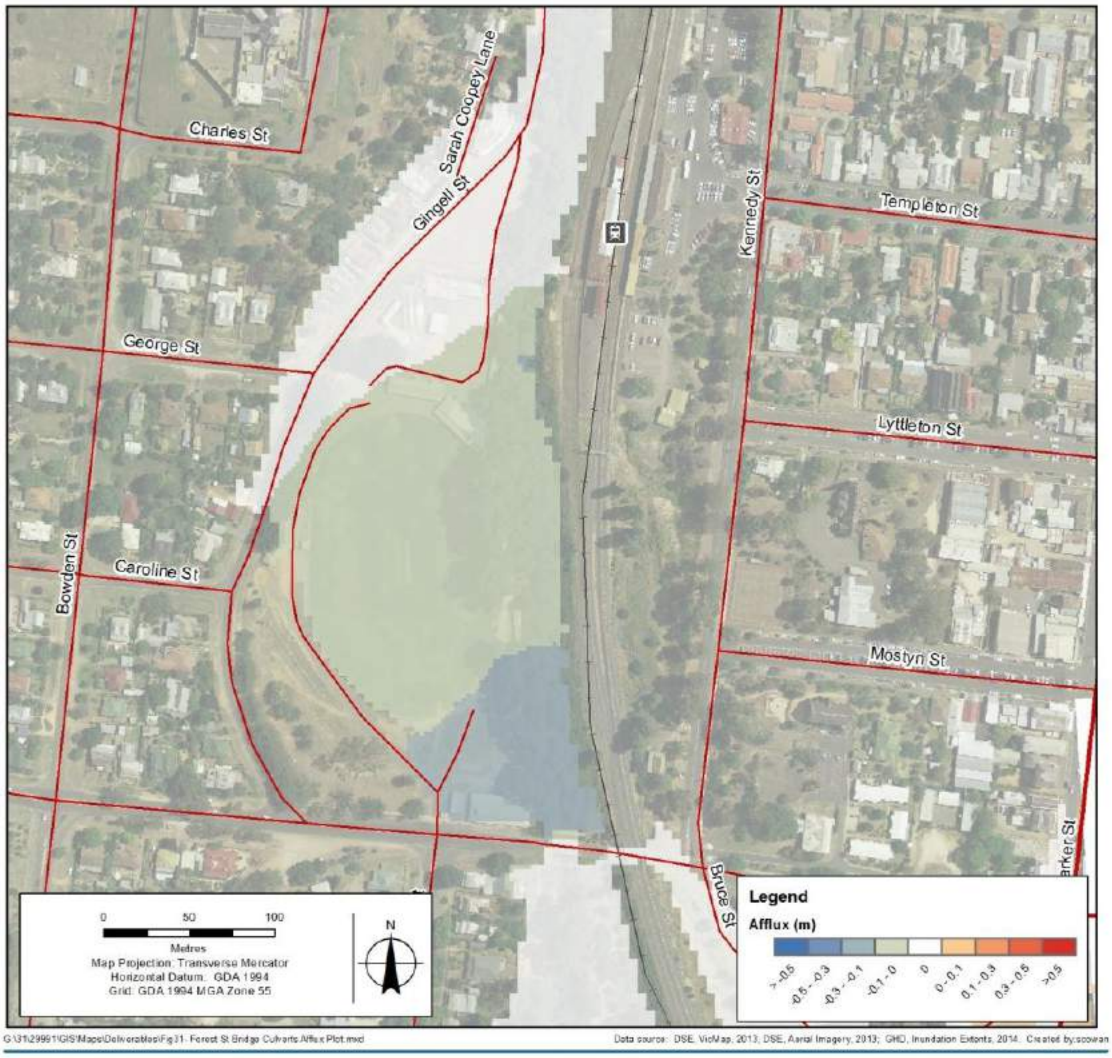

Figure 30 Forest Street Bridge

Pedestrian Bridge Adjacent to Roberts Avenue

The modelling indicated that removal of the pedestrian bridge had minimal benefit, in terms of reducing upstream flood levels, for the 1 in 100 AEP event.

Elizabeth Street Bridge

There is a lot more space available at this location to increase the flow area compared to the Forest Street Bridge. GHD modelled the impact of installing 5 No. 4.2 x 0.9 meter culverts at this location. Culverts were modelled rather than a bridge as it was thought that the relatively lower cost of installing culverts would make them more viable than installing a bridge.

The impact on water levels (comparing existing with culverts in place) is:

- Decrease by up to 100 mm for approximately 400 meters upstream.
- Increase by up to 100 mm immediately downstream.

Figure 31 shows the impact on water levels by adding additional culverts at the Forest Street Bridge.

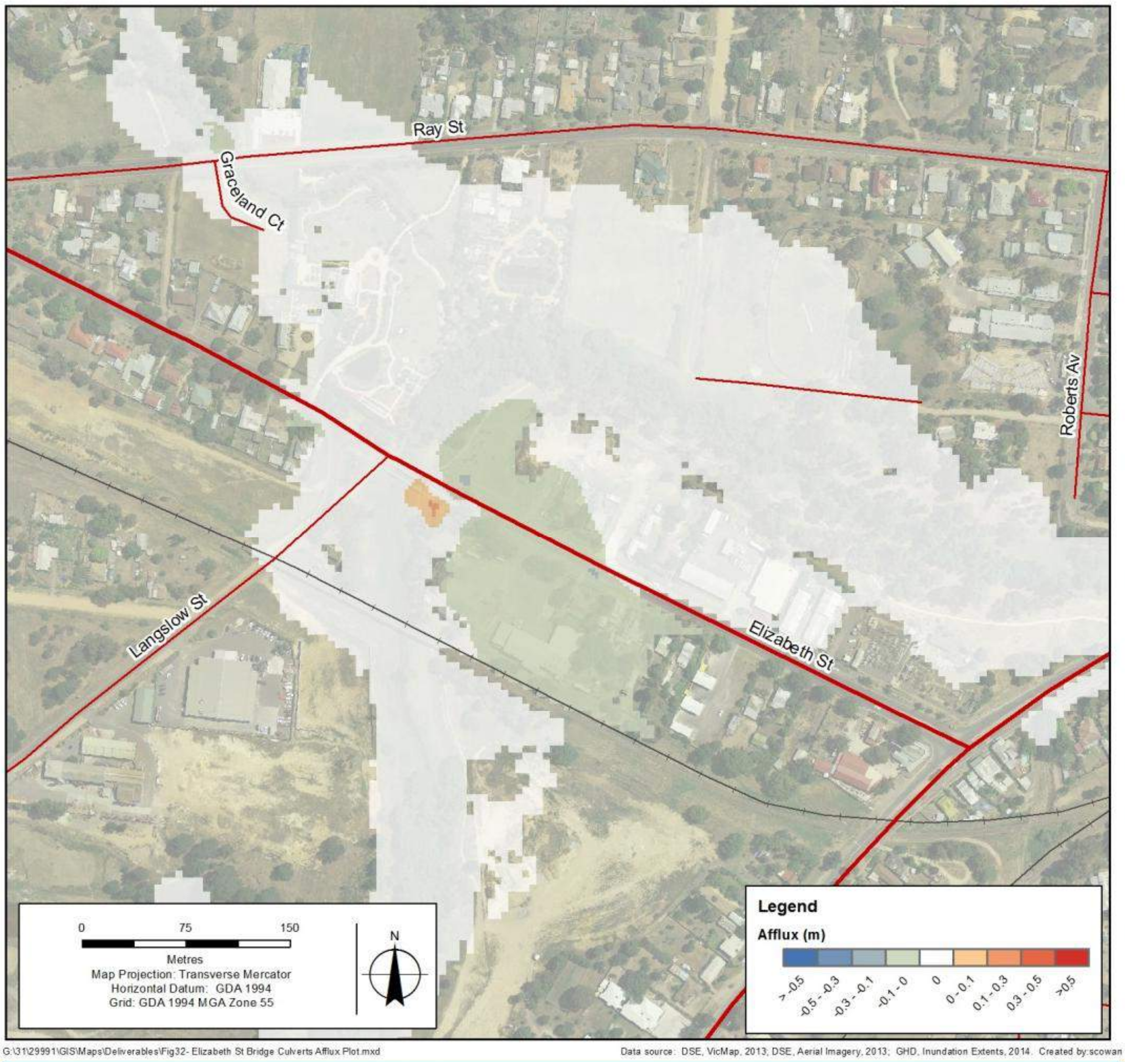

Figure 31 Elizabeth Street Bridge

Alexandra Street Bridge

There is limited space to increase the flow area at the Alexandra Street Bridge. GHD estimated that the largest number of culverts that could be easily constructed in this located was 2 No. 4.2 x 0.9 meter culverts.

The impact on water levels (comparing existing with culverts in place) is:

- Decrease by up to 100 mm for approximately 400 meters upstream.
- Increase by up to 100 mm immediately downstream.

Figure 32 shows the impact on water levels by adding additional culverts at the Alexandra Street Bridge.

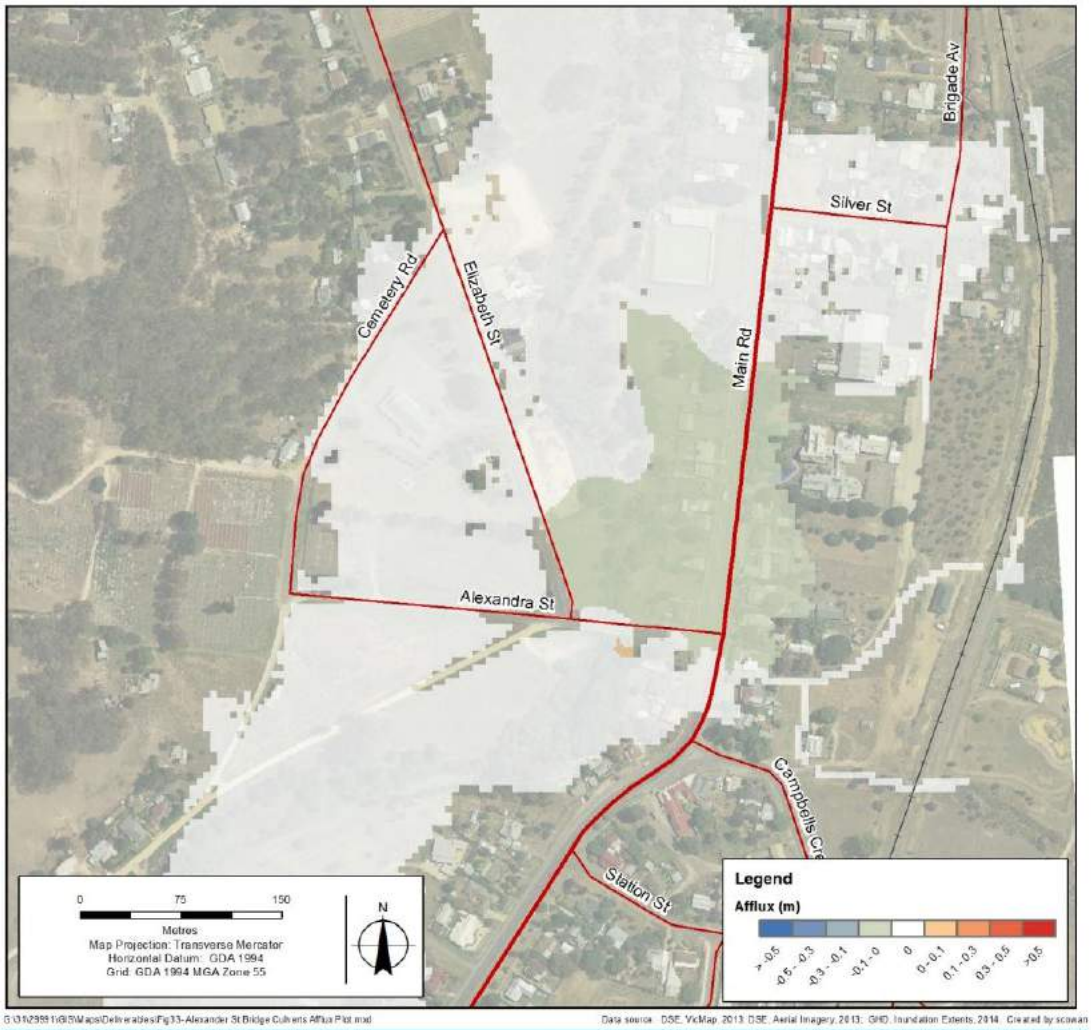

Figure 32 Alexandra Street Bridge

5.1.3 Vegetation management results

Vegetation Removal on Barkers Creek between Walker and Forest Street

The modelling indicates that the impact of the vegetation removal that has occurred between Walker Street and Forest Street has decreased water levels by:

- 200 mm up to approximately Walker Street
- 100 mm in the Botanic Gardens

Figure 33 shows the impact on water levels of the vegetation management options on Barkers Creek between Walkers Street and Forest Street.

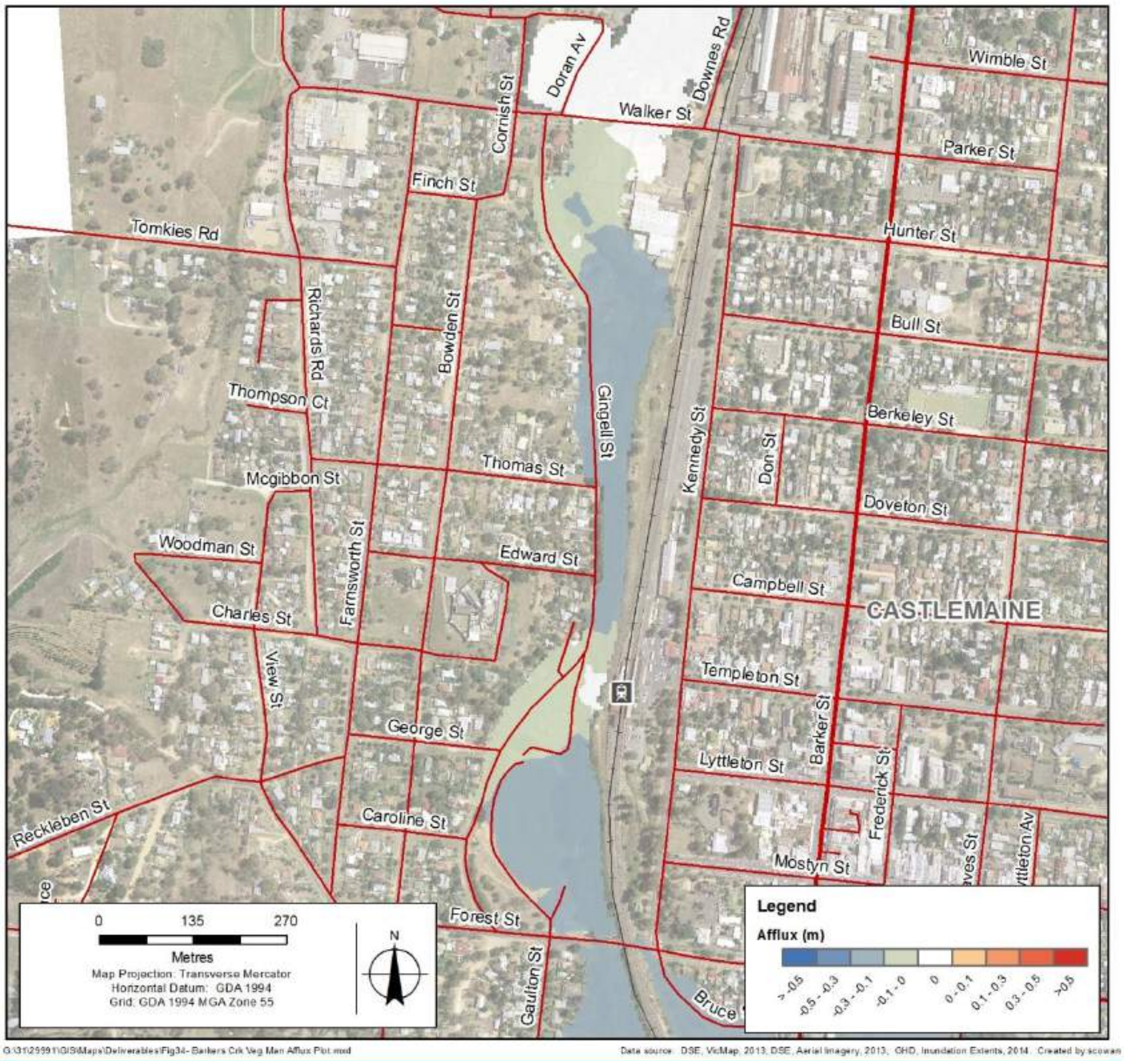

Figure 33 Vegetation Management Results around Barkers and Forest Creek Confluence

Vegetation Removal between the junction of Barkers and Forest Creek down to the Elizabeth Street Bridge

The modelling indicates that vegetation removal between the junction of Barkers Creek and Forest Creek down to the Elizabeth Street Bridge decreases water levels by up to approximately 200 mm.

Figure 34 shows the impact on water levels of the vegetation management options from the junction of Barkers Creek and Forest Creek down to the Elizabeth Street Bridge.

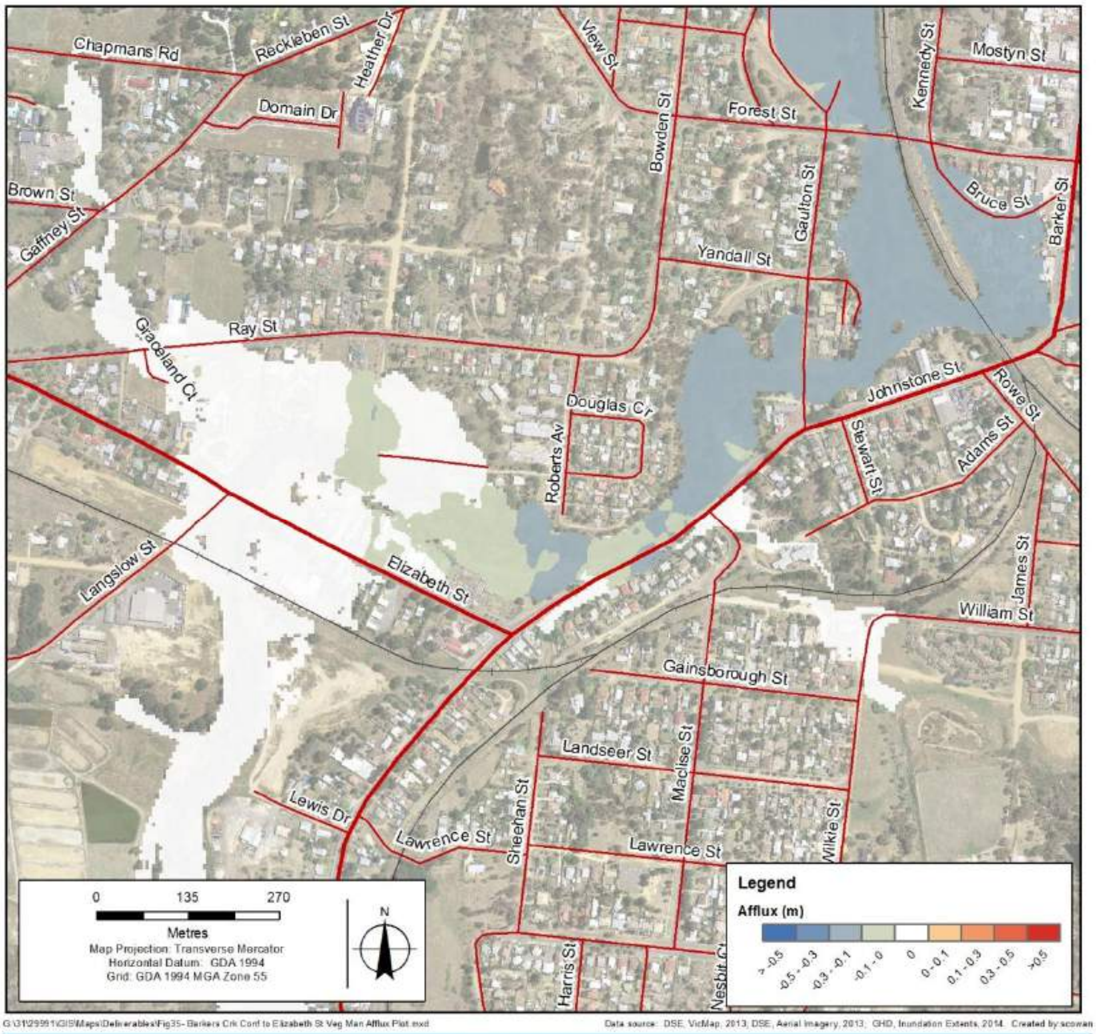

Figure 34 Vegetation Management Results around the junction of Barkers and Forest Creek down to the Elizabeth Street Bridge

Vegetation and Silt Removal along the channelized section of Forest Creek downstream of Duke Street (Pyrenees Hwy) to the junction of Barkers and Forest Creek.

Two scenarios were considered for this section of the creek, namely:

- Vegetation and silt (by lowering the creek bed by 0.5 meters) on Forest Creek for the entire channelized section.
- Vegetation and silt (by lowering the creek bed by 0.5 meters) on Forest Creek for the entire channelized section and the section of creek along caravan park.

The impact of each option is detailed below.

The modelling indicates that the removal of vegetation and silt (by lowering the creek bed by 0.5 meters) on Forest Creek for the entire channelized section results in a decrease in water levels by:

- 200 mm up to the Western Reserve
- 300 mm along the lowered section

The modelling indications that the removal of vegetation and silt (by lowering the creek bed by 0.5 meters) on Forest Creek for the entire channelized section and the section of creek within the caravan park results in a decrease in water levels by:

- 200 mm in the caravan park and Bruce Street
- 300 mm along the lowered section

Figure 35 shows the impact on water levels of the vegetation management and silt removal option along the channelized section of Forest Creek downstream of Duke Street (Pyrenees Hwy) to the junction of Barkers and Forest Creek.

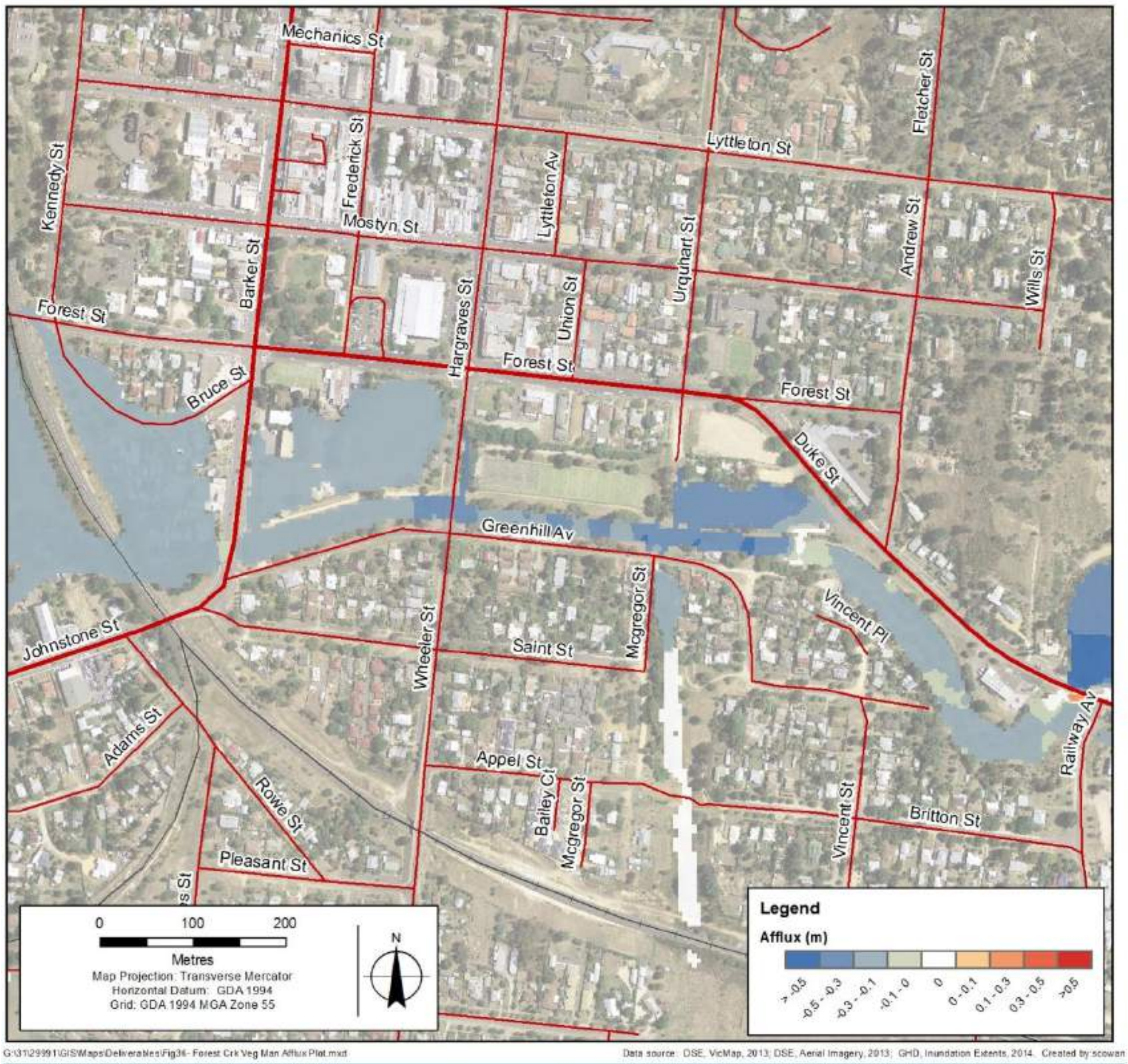

Figure 35 Vegetation Management Results along the channelized section of Forest Creek downstream of Duke Street (Pyrenees Hwy) to the junction of Barkers and Forest Creek

Vegetation and Silt Removal Downstream of Alexandra Street Bridge on Campbells Creek

The modelling indicates that the removal of vegetation in the area approximately 100 meters downstream of the Alexandra Street bridge on Campbells Creek results in a lowering of water levels by approximately 250 mm for a distance of approximately 200 m upstream of the bridge.

Figure 36 shows the impact on water levels of the vegetation management option downstream of Alexandra Street Bridge on Campbells Creek.

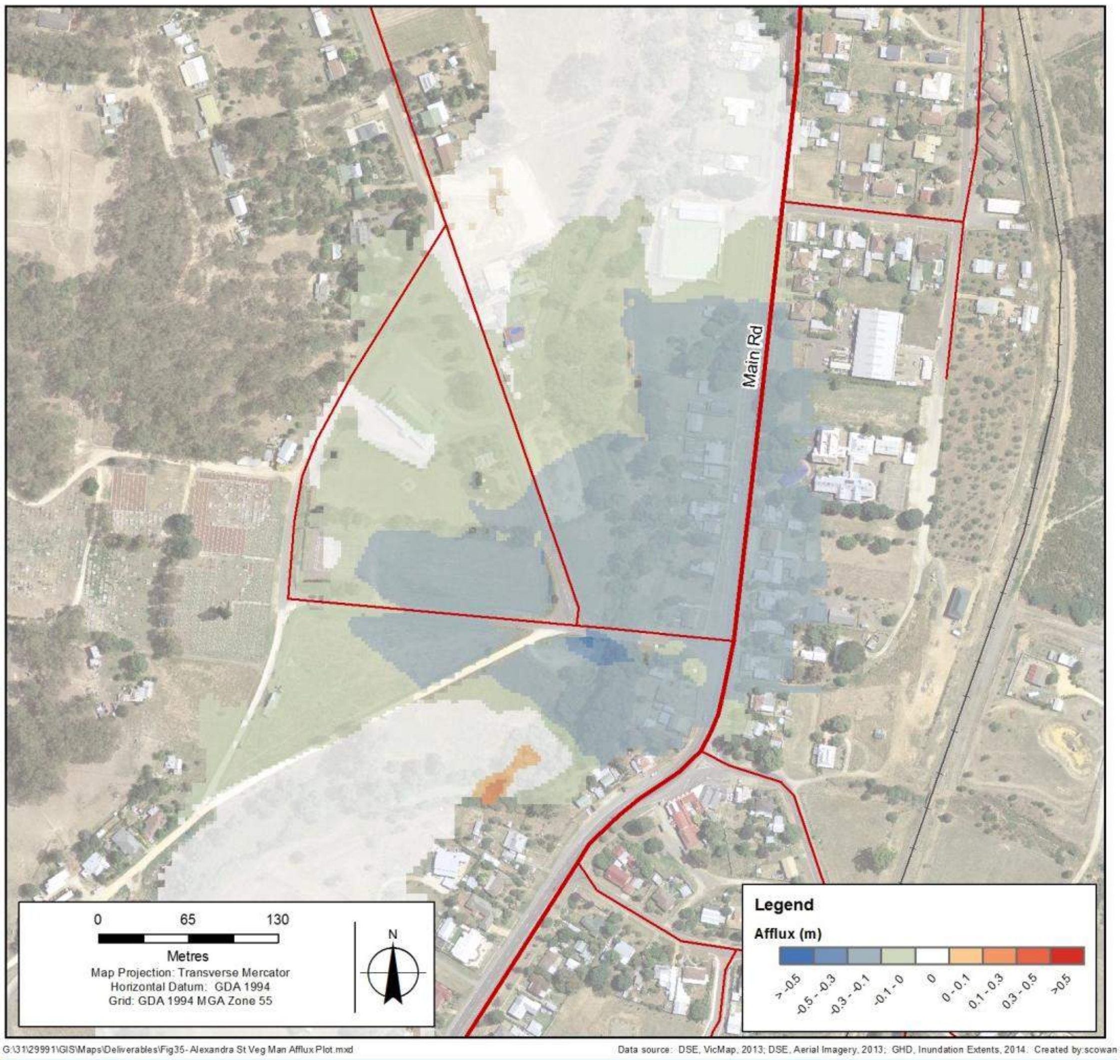

Figure 36 Vegetation Management Results Downstream of Alexandra Street Bridge on Campbells Creek

5.1.4 Storage options results

A number of storage options were put forward. GHD undertook a preliminary assessment of each one using the rainfall runoff model RORB. Table 14 summarises and comments on the preliminary results for the storage options.

Table 14 Storage Options

Storage	Approximate Size (ML)	Volume (ML) of Flow in Creek at the Storage for Critical Storm		Comment
		1 in 5 AEP	1 in 100 AEP	
Sunken Oval	19	931	2500	Increasing the storage volume or engaging the storage earlier will not have a significant impact on riverine flooding.
Expedition Pass Reservoir	264	172	485	Assuming the storage is half empty, at the start of the storm, the storage has an impact locally but only reduces flows by approximately 3 m^3/s for the 100 year ARI event, which equates to a reduction in flow from 109 m^3/s to 106 m^3/s.
Happy Valley Dam	135	524	1290	Has little impact on reducing riverine flooding in town.
Gainsborough Street	-	8	18	The catchment area is too small to provide significant benefit to riverine flooding. May provide benefit to local storm water flooding if there are known local drainage issues in this area.
Pottery Road	-	8	19	The catchment area is too small to provide significant benefit to riverine flooding. May provide benefit to local storm water flooding if there are known local drainage issues in this area.

5.1.5 Summary of prefeasibility assessment

As mentioned above the results of the prefeasibility assessment were discussed with the combined Technical Working Group and the Steering Committee on 9 April 2014 and from that meeting it was decided that a number of structural mitigation options were to be investigated further. Table 15 summarises the results, discusses the advantages and disadvantages of each mitigation option and provides further recommendations/actions as directed by the combined Technical Working Group and Steering Committee. Options determined suitable for further detailed investigation are discussed in section 7 of this report.

Table 15 Summary of Prefeasibility Assessment (bolded columns were the options to be considered further)

Mitigation ID	Mitigation Option Name	What is it?	Height of Levee / Additional Culverts / Manning's 'n' change / Storage	Maximum Impact on Water Level (compared to existing)	Effective / Ineffective	Buildings with overfloor flooding protected	Advantage/s	Disadvantage/s	Overall comments	Recommendations / Actions
1	Gingell St North	Levee	Average 1.0 m, but up to 2 m (plus freeboard)	300 mm	Effective	8	• Prevents overfloor flooding to four properties in 1 in 20 AEP flood. • Prevents overfloor flooding to five properties in 1 in 50 year AEP flood. • Prevents overfloor flooding to six properties in 1 in 100 AEP flood. • Prevents overfloor flooding to eight properties in 1 in 200 AEP flood.	• Local stormwater may become trapped behind levee, potential to overcome through detailed design. • Increase in flood levels of up to 300 mm is experienced in the creek and on the property at 9 Walker Street. This is not within acceptable limits and compensatory works may be required. • Further investigation would need to occur to further understand these impacts and whether they can be overcome. • Practical issues of an approximately 1 m high levee along the rear of Gingell Street properties also need to be considered - there is limited land available between houses and the top of bank of Barkers Creek.	The levee is technically successful in preventing flooding to eight properties from Barkers Creek. The construction of a levee may be difficult, but if it can be achieved will provide permanent structural benefit as opposed to consistent vegetation management in Barkers Creek (which was the other option here). Negative effects to 9 Walker Street can't be ignored. Height of the levee needs to be considered.	**Further detailed investigation, including investigation of minimising effects to 9 Walker Street.**
2	Gingell St Option 1A	Levee	Average 1.0 m, but up to 2 m (plus freeboard)	>300 mm	Effective (for flooding from Barkers Creek)	8	• Prevents overfloor flooding to three properties in 1 in 5 AEP flood. • Prevents overfloor flooding to five properties in 1 in 10 and 20 AEP floods. • Prevents overfloor flooding to six properties in 1 in 50 AEP flood. • Prevents overfloor flooding to eight properties in 1 in 100 AEP flood. • Prevents overfloor flooding to eight properties in 1 in 200 AEP flood.	• Football club rooms and football oval are not protected. • Local stormwater may become trapped behind levee. • Gingell Street will still be frequently inundated in local storm events. • Properties may be inundated by local stormwater trapped behind the levee. • Increase in flood levels of up to 300 mm is experienced in the creek. • Further investigation would need to occur to further understand these impacts and whether they can be overcome. • Practical and amenity issues of a 1-2 m high (plus freeboard) levee along Gingell Street also need to be considered.	The levee is technically successful in preventing flooding to eight properties from Barkers Creek. However flooding from local stormwater is still an issue for this area and is required to be investigated in further detail.	**Construct a local stormwater flood model to better understand local flooding. Further detailed investigation in conjunction with a better understanding of the local flooding issues**
3	Gingell St Option 1B	Levee	Average 1.5 m, but up to 2.5 m (plus freeboard)	>300 mm	Effective (for flooding from Barkers Creek)	8	• Prevents overfloor flooding to three properties in 1 in 5 AEP flood. • Prevents overfloor flooding to five properties in 1 in 10 and 20 AEP floods. • Prevents overfloor flooding to six properties in 1 in 50 AEP flood. • Prevents overfloor flooding to eight properties in 1 in 100 AEP flood. • Prevents overfloor flooding to eight properties in 1 in 200 AEP flood. • Football club rooms are protected	• Football oval is not protected. • Local stormwater may become trapped behind levee. • Gingell Street will still be frequently inundated in local storm events. • Properties may be inundated by local stormwater trapped behind the levee. • Increase in flood levels of up to 300 mm is experienced in the creek. • Further investigation would need to occur to further understand these impacts and whether they can be overcome. • Practical and amenity issues of a 1.5-2.5 m high (plus freeboard) levee along Gingell Street also need to be considered.	The levee is technically successful in preventing flooding to eight properties from Barkers Creek. However flooding from local stormwater is still an issue for this area and is required to be investigated in further detail. Height of levee needs to be considered.	**As above**

Mitigation ID	Mitigation Option Name	What is it?	Height of Levee / Additional Culverts / Manning's 'n' change / Storage	Maximum Impact on Water Level (compared to existing)	Effective / Ineffective	Buildings with overfloor flooding protected	Advantage/s	Disadvantage/s	Overall comments	Recommendations / Actions
5	Gingell St Option 1C	Levee	Average 2.0 m, but up to 3.0 m (plus freeboard)	>300 mm	Effective (for flooding from Barkers Creek)	8	• Prevents overfloor flooding to three properties in 1 in 5 AEP flood. • Prevents overfloor flooding to five properties in 1 in 10 and 20 AEP floods. • Prevents overfloor flooding to six properties in 1 in 50 AEP flood. • Prevents overfloor flooding to eight properties in 1 in 100 AEP flood. • Prevents overfloor flooding to eight properties in 1 in 200 AEP flood. • Football club rooms are protected	• Local stormwater may become trapped behind levee. • Gingell Street will still be frequently inundated in local storm events. • Properties may be inundated by local stormwater trapped behind the levee. • Increase in flood levels of up to 300 mm is experienced in the creek. • Further investigation would need to occur to further understand these impacts and whether they can be overcome. • Practical and amenity issues of a 2-3 m high (plus freeboard) levee along Gingell Street also need to be considered. A levee this high is not considered to be practical	The levee is technically successful in preventing riverine flooding to eight properties from Barkers Creek. However flooding from local stormwater is still an issue for this area and is required to be investigated in further detail. Height of levee needs to be considered.	**As above**
6	Castlemaine Central Cabin and Van Park and Bruce Street Levee	Levee	Average 1.2 m (plus freeboard) but up to 2.5 m	300 mm	Effective	15	• Prevents overfloor flooding to one property in 1 in 5 AEP flood. • Prevents overfloor flooding to two properties in 1 in 10 AEP floods. • Prevents overfloor flooding to four properties in a 1 n 20 AEP flood. • Prevents overfloor flooding to six properties in 1 in 50 AEP flood. • Prevents overfloor flooding to eight properties in 1 in 100 AEP flood. • Prevents overfloor flooding to 15 properties in 1 in 200 AEP flood.	• Some local stormwater gets trapped behind the levee but this is not expected to cause any overfloor flooding. • Flood levels in the Western Reserve have increased and the effects of this on buildings east of Barker St adjacent to the reserve needs to be better understood.	This levee is shown as running from the Barker St/Forest St intersection along Barker Street to the north bank of Forest Creek and then turns west and extends to the railway embankment. In reality, the 'levee' will run along the north bank of Forest Creek between Barker St and the railway embankment. The levee alignment is shown running along Barker St as some shallow flood water in the model was overtopping Barker St and needed to be prevented from flooding the west side of Barker St - in practice, this might be as simple as raising the road or having an elevated median strip to form the 'levee', and won't necessarily look like a traditional levee. This levee has great potential if effects upstream of Barker St can be accounted for.	**Further investigation to include levee alignments, heights required for different levels of protection as well as gaining a better understanding of effects in Western Reserve**

Mitigation ID	Mitigation Option Name	What is it?	Height of Levee / Additional Culverts / Manning's 'n' change / Storage	Maximum Impact on Water Level (compared to existing)	Effective / Ineffective	Buildings with overfloor flooding protected	Advantage/s	Disadvantage/s	Overall comments	Recommendations / Actions
7	Central Carpets	Levee	Average 1.5 m plus freeboard	<100 mm	Effective	1	• Protects Central Carpets business from overfloor flooding in 1 in 50 and 100 AEP flood events.	• Public amenity • Ongoing maintenance and public cost	Whilst this levee is effective in preventing flooding to the Central Carpets site the AAD avoided is unlikely to achieve a positive cost-benefit ratio and is therefore unlikely to attract funding for its construction and ongoing maintenance. However, the modelling does demonstrate that the construction of this levee has minimal effects on flood levels upstream and downstream of the site and therefore could be considered acceptable from a hydraulic perspective for construction by a private individual if they so desired.	Do not investigate this option any further as not providing significant community benefit and as unlikely to achieve an acceptable outcome in regards to cost versus benefit. (This does not preclude Council or private individuals pursuing this option on 'beneficiary pays' principles).
8	Elizabeth Street Levee	Levee	Average 1.0 m, but up to 2.2 m (plus freeboard)	300 mm	Effective	13	• Prevents overfloor flooding to two properties in a 1 in 20 AEP flood. • Prevents overfloor flooding to four properties in 1 in 50 AEP flood. • Prevents overfloor flooding to 11 properties in 1 in 100 AEP flood. • Prevents overfloor flooding to 13 properties in 1 in 200 AEP flood. • Facilitates relatively safe access along Elizabeth Street where flood depths currently exceed 500 mm in a 1 in 100 AEP flood and greater.	• Flood extent increased slightly, however no additional properties experience overfloor flooding. Increased extent could be offset by additional works.	This levee is an upgrade and extension of the existing levee which runs along the north side of Elizabeth St properties. The existing levee is currently not high enough or extends long enough to protect buildings and properties within this area from major floods. Works would include upgrading the existing levee (if suitable) and extending it around to the highway bridge and beyond to the Maldon railway bridge to prevent water backing up into this area. This levee increases flood levels in the creek but does not cause any additional overfloor flooding, although increases the extent in some areas where ancillary works may be required.	**Further detailed investigation.** **Investigation to determine the cost-benefit ratio for the upgrade and extension of this levee and also any ancillary works that may be required to offset increased flood levels**.

Mitigation ID	Mitigation Option Name	What is it?	Height of Levee / Additional Culverts / Manning's 'n' change / Storage	Maximum Impact on Water Level (compared to existing)	Effective / Ineffective	Buildings with overfloor flooding protected	Advantage/s	Disadvantage/s	Overall comments	Recommendations / Actions
9	Campbells Creek Township Levee	Levee	Average 0.7 m (plus freeboard)	100 mm	Effective	18	• Prevents overfloor flooding to one property in 1 in 10 AEP flood. • Prevents overfloor flooding to five properties in 1 in 20 AEP flood. • Prevents overfloor flooding to 10 properties in 1 in 50 AEP flood. • Prevents overfloor flooding to 14 properties in 1 in 100 AEP flood. • Prevents overfloor flooding to 18 properties in 1 in 200 AEP flood. • Facilitates relatively safe access along Main Road where current flood depths exceed 500 mm in a 50 year ARI flood and greater.	• Local stormwater may become trapped behind levee. • Properties may be inundated by local stormwater trapped behind the levee. • Increase in flood levels of up to 100 mm in creek and on western floodplain, however no additional floors flooded overfloor. • Further investigation would be required to more fully understand these impacts and whether they can be overcome. • Practical and amenity issues of a 1-2 m high (plus freeboard) levee along rear of properties in Campbells Creek township also need to be considered.	This levee is an upgrade and extension of the existing levee which runs behind the properties which back onto Campbells Creek. The extension is necessary to prevent water breaking out around the northern end of the levee as happened in recent flood events (levee was not overtopped). The existing levee is in poor condition and any proposed works should include an upgrade to this levee to help it perform the required function into the future. Detailed assessments of this levee may be required to adequately determine the cost of this proposal. However, levee is successful in preventing flood events to the main street of Campbells Creek, with minor increases in flood levels on the western side of Campbells Creek - which do not cause any additional overfloor flooding.	**Further detailed investigation.** **Investigation to determine the cost-benefit ratio for the upgrade and extension of this levee and also any ancillary works that may be required to offset increased flood levels**.
10	National School Lane Levee	Levee	No change in overall height. Existing levee is high enough, except for small gap at top end.	300 mm but localised	Effective	0	• Reduces velocity of floodwaters over properties behind levee and may prevent avulsion of the creek in future flood events (i.e. it may help to stabilise the creek alignment by reducing the tendency for the creek to naturally realign itself)	• Flood extent does not decrease with proposed works as water will flow around the downstream end of levee and back into area behind the levee. • If works are undertaken, ownership and maintenance responsibilities need to be determined.	This proposal will not prevent the extent of flooding experienced by properties behind the levee as flood waters will breakout at the downstream end of levee and backflow into the same area. However the modelling shows no material negative effects and the proposal may reduce the velocity of flood waters associated with the gap in the levee and therefore reduce the potential for property damage or creek avulsions. The works are unlikely to provide an acceptable outcome in regards to cost-benefit principles or provide significant community benefit and therefore any remedial works or ongoing maintenance of this levee would be subject to the 'beneficiary pays' principle.	Do not investigate this option any further as not providing significant community benefit and as unlikely to achieve an acceptable outcome in regards to cost versus benefit. (This recommendation does not preclude Council or private individuals pursuing this option on 'beneficiary pays' principles).
11	Levee along Forest Creek	Removing Levee (or portion of levee) along Forest Creek	Levee removed	>300 mm in Western Reserve	Ineffective	0	• Designed to allow greater flood flows into Western Reserve sooner. • Nothing significant	• Increases flooding in Western Reserve • Increases likelihood of flooding to properties adjacent to Western Reserve • Minimal benefit • Effects to walking tracks, amenity	Option is ineffective in providing flood relief to locally affected properties, Caravan Park or Bruce Street and in fact raises the possibility of more properties being subject to over floor inundation adjacent to the reserve.	Do not investigate this option any further as not providing any significant benefits in reducing flood risk.

Mitigation ID	Mitigation Option Name	What is it?	Height of Levee / Additional Culverts / Manning's 'n' change / Storage	Maximum Impact on Water Level (compared to existing)	Effective / Ineffective	Buildings with overfloor flooding protected	Advantage/s	Disadvantage/s	Overall comments	Recommendations / Actions
12	Forest Street Bridge	Additional Culverts	2 No. 4.2 m x 0.9 m box culverts	<10 mm (downstream) <30 mm (upstream at Gingell Street)	Ineffective	0	• Small but insignificant decrease in flood levels	• Potentially high cost for little benefit	Additional culverts beneath bridge only lowered flood levels adjacent to Gingell St properties by up to 30 mm. This is unlikely to provide significant stand-alone benefit when compared to levees or waterway management options, but may be important if included in a package of such works.	Do not investigate this option any further as not providing significant community benefit and as such unlikely to achieve an acceptable outcome in regards to cost versus benefit.
13	Roberts Avenue Pedestrian Bridge	Removal of Roberts Avenue Pedestrian Bridge	N/A	Minor	Ineffective	0	No significant benefits	High pedestrian traffic uses bridge	Removal of pedestrian bridge had a very limited local benefit and is not worth considering further in terms of protecting assets. In addition, this is a highly utilised pedestrian crossing of Campbells Creek. Removing this bridge would likely have an unacceptable social impact. However, if the bridge were to be replaced, flooding characteristics such as flood levels and velocities should be considered to achieve an appropriate design (Please note we are not suggesting the current bridge is unsafe. No condition, structural or other bridge assessment has been undertaken as part of this study).	Do not investigate this option any further as not providing any significant benefits in reducing flood risk.
14	Elizabeth Street	Additional Culverts	5 No. 4.2 m x 0.9 m box culverts	100 mm (downstream) - 100 mm (upstream)	Ineffective	0	• Small but insignificant decrease in flood levels	Potentially high cost for no benefit	Additional culverts beneath bridge lowered flood levels by 100 mm for approximately 400 m upstream. This is unlikely to provide significant stand-alone benefit when compared to levees or waterway management options, but may be important if included in a package of such works. Given VicRoads intend to upgrade this bridge structure in the future anyway, increasing the waterway area beneath any the structure is highly possible and enhances the benefits provided by any other mitigation options that may be implemented.	Do not investigate this option any further as not providing any significant benefits in reducing flood risk.

Mitigation ID	Mitigation Option Name	What is it?	Height of Levee / Additional Culverts / Manning's 'n' change / Storage	Maximum Impact on Water Level (compared to existing)	Effective / Ineffective	Buildings with overfloor flooding protected	Advantage/s	Disadvantage/s	Overall comments	Recommendations / Actions
15	Alexandra Street	Additional Culverts	2 No. 4.2 m x 0.9 m box culverts	100 mm (downstream) - 100 mm (upstream)	Ineffective	0	None significant	Potentially high cost for no benefit	Additional culverts beneath bridge only lowered flood levels by 100 mm for approximately 400 m upstream. This is unlikely to prevent flooding in the main street of Campbells Creek or provide significant stand-alone benefit when compared to levees or waterway management options. As with the other culvert options, these works may enhance the benefit provided by other mitigation options or reduce the overall height of future levees.	Do not investigate this option any further as not providing any significant benefits in reducing flood risk.
16	Barkers Creek between Walker and Forest Street	Vegetation Management	Reduced Manning's 'n' roughness factor from 0.075 to 0.050	- 200 mm	Somewhat effective in conjunction with other options	0	• Reduces flood levels by up to 200 mm in Barkers Creek. • Major works already completed, but ongoing maintenance required.	• Less than 100 mm reduction to flood levels for properties in Gingell St. • Ongoing maintenance required.	The changes in the flood model to this section of Barkers Creek reflect the vegetation management works that have occurred since the January 2011 flood event. This option will require ongoing maintenance and management. It is worth considering that the ongoing cost of such maintenance may not be as positive as other permanent structural options and the longevity of such options cannot be assumed given the local value placed on vegetated waterways and aesthetically pleasing pedestrian connections.	**Construct a local stormwater flood model to better understand local flooding. Further detailed investigation in conjunction with a better understanding of the local flooding issues**
17	Junction of Barkers and Forest Creek down to the Elizabeth Street Bridge	Vegetation Management	Reduced Mannings 'n' roughness factor from 0.075 to 0.050	-200 mm	Somewhat effective	0	• Reduces flood levels by up to 200 mm in Campbells Creek	• Capital works required in Campbells Creek. • Ongoing maintenance required.	The changes in the flood model to this section of Campbells Creek represent a reduction in the actual vegetation along this reach as compared to existing conditions. The results of the option indicate a reduction in flood levels through this area of up to 200 mm for a 100 year ARI event. These works would be unlikely to provide significant stand-alone benefit when compared to other more permanent structural mitigation options.	Do not investigate this option any further as not providing significant benefits in reducing flood risk compared to structural mitigation options.

Mitigation ID	Mitigation Option Name	What is it?	Height of Levee / Additional Culverts / Manning's 'n' change / Storage	Maximum Impact on Water Level (compared to existing)	Effective / Ineffective	Buildings with overfloor flooding protected	Advantage/s	Disadvantage/s	Overall comments	Recommendations / Actions
18	Vegetation and Silt Removal along the channelized section of Forest Creek downstream of Duke Street (Pyrenees Hwy) to Barkers Street	Vegetation Management	Lowered bed of creek by 500 mm and reduced Mannings 'n' roughness factor from 0.035 to 0.03	-300 mm	Somewhat Ineffective	0	• Reduces flood levels in channelized section of Forest Creek by up to 300 mm. • Reduces flood levels in Western Reserve by up to 200 mm The modelling indicates that the removal of vegetation and silt (by lowering the creek bed by 0.5 meters) on Forest Creek for the entire channelized section and the section of creek along caravan park, results in a decrease in water levels of: • 200 mm in the caravan park and Bruce Street. • 300 mm along the lowered section.	• Capital works required in Forest Creek. • Ongoing maintenance required.	The changes in the flood model represent significant works to Forest Creek to remove silt (and hence vegetation) from Forest Creek down to the stone base of the waterway - estimated to be 800 mm, modelled conservatively to be an estimated 500 mm along this reach. The benefits estimated using the flood model of this option were limited as the waterway area on the downstream side of Barkers St was less than what was created in the upstream section of Forest Creek i.e. still limiting the amount of water that could get beneath this structure due to the build up of silt on its downstream side. This was remedied in the following model run (See ID 19).	This mitigation option does not provide any significant benefits in reducing flood risk unless continued through to railway embankment (see option 19).
19	Vegetation and Silt Removal along the channelized section of Forest Creek downstream of Duke Street (Pyrenees Hwy) to the junction of Barkers and Forest Creek.	Vegetation Management	Lowered bed of creek by 500 mm and reduced Mannings 'n' roughness factor from 0.035 to 0.03	-300 mm	Somewhat effective	0	• Reduces flood levels in Forest Creek by up to 300 mm. • Reduces flood levels in caravan park and Bruce Street by up to 200 mm	• Capital works required in Forest Creek. • Ongoing maintenance required.	The changes in the flood model represent an extension of the significant works proposed in Mitigation ID 18 above. Additional works were proposed between the Barker St bridge and the railway embankment to include landscaping the creek adjacent to the Caravan Park (to represent the same lowering of the creek by 500 mm to match the works done upstream of Barker St. The 300 mm reduction experienced in Forest Creek from the previous option is maintained and an additional reduction in flood levels in the Caravan Park of up to 200 mm is achieved. Again, this option may not be viable as a standalone option but may assist as part of a package of works to enhance other mitigation options i.e. reduce the height of levees.	Investigate other more permanent flood mitigation options as the primary mitigation options with vegetation management of this reach to be considered if ancillary works are deemed required to assist an overall mitigation strategy.

Mitigation ID	Mitigation Option Name	What is it?	Height of Levee / Additional Culverts / Manning's 'n' change / Storage	Maximum Impact on Water Level (compared to existing)	Effective / Ineffective	Buildings with overfloor flooding protected	Advantage/s	Disadvantage/s	Overall comments	Recommendations / Actions
20	Campbells Creek Choke Point	Earthworks / Vegetation Management	Mannings 'n' changed from 0.035 to 0.200 representing more resistance to flow for the width of the high banks of Campbells Creek (approximately 25 metres wide along this reach of the creek)	250 mm	Somewhat effective	0	• Reduction in flood levels upstream by up to 250 mm approximately 200 m upstream of Alexander Street bridge	Ongoing maintenance required.	NCCMA visited the site with Cr Tony Bell to discuss the 'choke point' in the creek and assess what the issue is for this reach of Campbells Creek. Whilst a management program in this reach of the creek alone is unlikely to significantly reduce flood levels and impacts to the Campbells Creek township it may be necessary as part of a larger strategy for ongoing management if a levee mitigation option is to remain effective into the future.	Investigate other more permanent flood mitigation options as the primary mitigation options with vegetation management of this reach to be considered if ancillary works are deemed required to assist an overall mitigation strategy.
21	Storage Options	Expand Sunken Oval	19 ML	-	Ineffective	0	Minor with respect to riverine flooding Already exists	Loss of land, maintenance	Increasing the storage volume or engaging the storage earlier will not have a significant impact on riverine flooding	Do not investigate this option any further as not providing significant benefits in reducing flood risk from riverine flooding
22	Storage Options	Draw Down Expedition Pass Reservoir to use as Storage	264 ML	-	Ineffective	0	Minor with respect to riverine flooding Already exists	Safety, loss of land, maintenance Loss of recreation due to storage permanently drawn down	Assuming the storage is half empty, at the start of the storm, the storage has an impact locally but only reduces flows by approximately 3 m^3/s in Forest Creek and from 109 m^3/s to 106 m^3/s in town for the 100 year ARI event	Do not investigate this option any further as not providing significant benefits in reducing flood risk from riverine flooding
23	Storage Options	Construct a Dam at Happy Valley	135 ML	-	Ineffective	0	Minor with respect to riverine flooding	Safety, loss of land, maintenance Expensive to build	Has little impact on riverine flooding	Do not investigate this option any further as not providing significant benefits in reducing flood risk from riverine flooding
24	Storage Options	Gainsborough Street	-	-	Ineffective	0	Minor with respect to riverine flooding	Safety, loss of land, maintenance	The catchment area is too small to provide significant benefit to riverine flooding. May provide benefit to local storm water flooding if there are known local drainage issues in this area	Do not investigate this option any further as not providing significant benefits in reducing flood risk from riverine flooding
25	Storage Options	Pottery Road	-	-	Ineffective	0	Minor with respect to riverine flooding	Safety, loss of land, maintenance	The catchment area is too small to provide significant benefit to riverine flooding. May provide benefit to local storm water flooding if there are known local drainage issues in this area	Do not investigate this option any further as not providing significant benefits in reducing flood risk from riverine flooding

6. Detailed flood mitigation options assessment

6.1 Gingell Street South Levee

6.1.1 Model establishment

As agreed in Table 15 above, in order to gain a greater appreciation of the interaction between the local stormwater and the riverine flooding along Gingell Street a more detailed model needed to be established within this area. The modelling for this part was completed using a depth varying Manning's n 'rain on grid' TUFLOW model. The study area is shown in Figure 37.

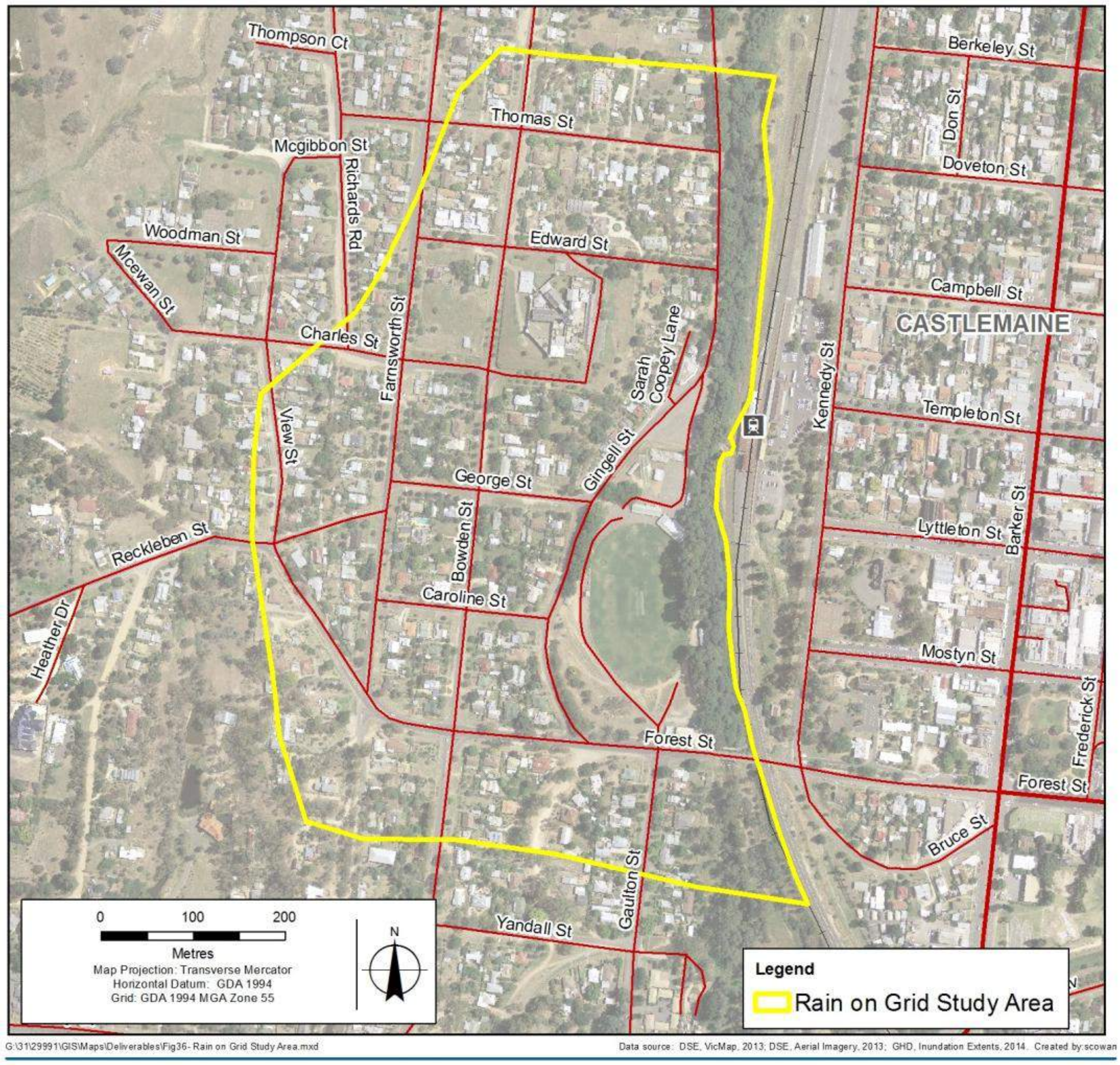

Figure 37 Study Area Rain on Grid

The TUFLOW model was used to model both the hydrology and hydraulics and covered an area larger than the catchment of interest to avoid boundary effects. Rainfall depths, temporal patterns and losses were placed into the model for all standard storm durations (10 minutes to 24 hours) for the 1 in 5 AEP to the 1 in 100 AEP event.

Hydraulic modelling of all the drainage assets and the associated flow paths within the study area was undertaken using TUFLOW. The TUFLOW model was created using drainage details and LiDAR based terrain data provided by Council and the NCCMA respectively. The model was then used to determine flood levels for each of the options that were considered.

The 2D domain represents the surface terrain of all major overland flow paths within the study area. Using the LIDAR a 750 m by 1500 m grid comprising 2 metre square cells was formed. Each cell is made up of nine points, with each point having an elevation corresponding to the surface elevation at that location.

The roughness value was allocated to each cell as a Manning's n value based on land use type as detailed in Section 4.2. As mentioned previously residential properties and community buildings (e.g. schools) have typically been assigned a Manning's n value of 0.2, due to structures such as buildings and fences obstructing flow through the property. When considering a direct rainfall approach ('rain on grid') where rainfall is applied to all 2D cells then, while these relatively high values are appropriate along major flowpaths, a smaller Manning's n value is likely to be more appropriate where the primary flow mechanism is shallow runoff from smooth, well-drained surfaces such as rooftops.

For this investigation the change in bed resistance according to the primary flow mechanism was represented by varying the Manning's n value of the 2D cells in TUFLOW based on the depth of flow through the cell. At shallow depths, runoff is assumed to be the primary flow mechanism and a low Manning's n value of 0.02 was adopted. At larger depths, the impact of buildings, fences and other obstructions on flood conveyance becomes more significant, and a higher Manning's n value is applied. This approach does not require existing flood extent information, and can be applied across all ARI events, although it has the potential to affect the rising and falling limbs of the hydrograph and shallow flood extents. The adopted Manning's n values are tabulated in Table 13 and Table 16.

Table 16 Bed Resistance Values varying with depth for 2D Domain

Depth of Flow	Residential Properties	Commercial Properties
Less than 100 mm	0.02	0.02
100 mm – 110 mm	Interpolated between 0.02 and 0.2	Interpolated between 0.02 and 0.3
Greater than 110 mm	0.2	0.3

The one-dimensional network is comprised of all the underground pipes and culverts as detailed in the information supplied by Council.

The pipe network includes all underground pipes and connections to the surface (pits). Underground pipes were mostly modelled as circular or rectangular culverts. Concrete pipes were modelled with a Manning's n value of 0.013.

Appropriate losses were determined throughout the pipe network, based on standard pit loss tables (MWC 2006). Each pit loss value was generally assigned to the downstream pipe as a form loss, rather than in the pits themselves. For culverts or ends of pipes, a typical entrance loss of 0.5 and exit loss of 1.0 were applied.

For the local Gingell Street catchment rainfall was applied to each cell within study area using TUFLOW's direct rainfall approach. The rainfall hyetographs generated for each storm duration were calculated based on methods described in Australian Rainfall and Runoff (I.E. Aust, 1999).

The 1 in 100 to 1 in 5 AEP design storms used in the modelling were based on point storms, a fully filtered temporal pattern, and Intensity-Frequency-Duration (IFD) based on the parameters shown in Table 17. These parameters were adopted from the Bureau of Meteorology's webpage for creating IFD data (*BOM, 2014*). No areal reduction factors were applied due the small catchment size.

Table 17 IFD Parameters for the Study Area

Parameter	Value
2i1 (1 hr duration, 2 yr ARI)	19.95 mm/hr
2i12 (12 hr duration, 2 yr ARI)	3.98 mm/hr
2i72 (72 hr duration, 2 yr ARI)	1.02 mm/hr
50i1 (1 hr duration, 50 yr ARI)	39.92 mm/hr
50i12 (12 hr duration, 50 yr ARI)	7.12 mm/hr
50i72 (72 hr duration, 50 yr ARI)	2.02 mm/hr
G (skewness)	0.23
F2 (2 yr ARI geographical factor)	4.33
F50 (50 yr ARI geographical factor)	14.95

The losses used in TUFLOW were the same as those used in RORB for the broader catchment, as described in Section 3.5.

It should be noted that before the final TUFLOW modelling was completed a GIS process to identify undrained depressions (i.e. depressions that were not connected to the modelled drainage network) was undertaken and used to 'fill' the low points with initial water up to the surrounding terrain. This was then used as the starting point for the final model runs to avoid generating additional volumetric losses without changing conveyance.

Upstream of the local Gingell Street catchment flows on Barkers Creek were taken from the RORB model of the broader catchment. Downstream of the model a head versus time boundary conditions ("HT" boundary) was applied. These relationships were taken from the broader TUFLOW model (of the entire study area) so that the downstream levels in the two models matched.

6.1.2 Option assessment

Based on discussions with the Technical working Group and the Steering Committee it was decided that Option 1A was preferred in terms of the height of the levee (lowest height when compared to other options) however, it was still a high levee (up to 2 meters in some locations) and would not be practical to build as it would cut off/remove the car park. This car park is in high use with the railway station, hotel and oval close by. Therefore, Option 1B was explored further as it protected most of the buildings located next to the oval, did not isolate the car park and the levee height was less than Option 1C. Refer to Figure 24 for the location of the levee.

From discussions with the Technical Working Group and the Steering Committee it was agreed that a 1.5 to 2+ meter high levee (to protect Gingell Street from the 1 in 100 AEP event) would not be practical in this area and unlikely to be supported by the community. Therefore, in discussion with Council and the NCCMA, it was agreed that a 1 meter high levee be explored further as this would provide some protection from flooding, would be easier to build and would have less of a visual impact than a 2+ meter high levee. However, ultimately it is up to the community to decide what works they prefer to protect them from flooding and a preliminary modelling analysis has been completed for the 2 meter high levee should it be requested by the community.

The local Gingell Street catchment model (rain on grid model) gave a greater understanding of local catchment flows and the interaction with flows in Barkers Creek. From the modelling, the two main flow paths from the local Gingell Street catchment are:

- Flows along Thomas Street and Edward Street flowing south along Gingell Street into the depression adjacent to 45-51 Gingell Street.
- Flows converge to an area between George Street and Caroline Street flowing north along Gingell Street into the depression adjacent to 45-51 Gingell Street.

Water that ponds in the depression adjacent to 45-51 Gingell Street can only drain out via the pipe network located under the oval.

The modelling indicates that the local catchment by itself does not cause over floor flooding. Therefore the most effective way to avoid over floor flooding in Gingell Street is to restrict the riverine flooding. However, the local catchment does contribute a significant amount of water to the depression adjacent to 45-51 Gingell Street making egress risks above generally acceptable levels.

The modelling indicates that if two 300 mm high “speedhumps” were constructed on Gingell Street to divert overland flow from Thomas Street and Edward Street and from between George Street and Caroline Street towards Barkers Creek this would significantly reduce the impact of the local catchment flooding on the properties between 45-51 Gingell Street. In conjunction with the “speedhump”, works would need to be undertaken to ensure flow could get into Barkers Creek this is particularly relevant for the flow between George Street and Caroline Street as the oval is higher than the road level.

In order to drain the depression in Gingell Street quicker an additional pipe was added into the model. The pipe was sized assuming that the water levels in Barker Creek were low (i.e. pipe was not drowned out). Without the diversions in place (as described in the preceding paragraph) a 750 mm diameter pipe is required. With the diversions in place a 525 mm diameter pipe is required. When Barkers Creek is in flood the capacity of this pipe is reduced however, the modelling indicates that the pipe would still drain the area quicker than it would without the pipe in place. Also the pipe was modelled with a flap gate such that flow could not discharge from Barkers Creek into Gingell Street.

The various mitigation options investigated for this section of the assessment are shown in Figure 38.

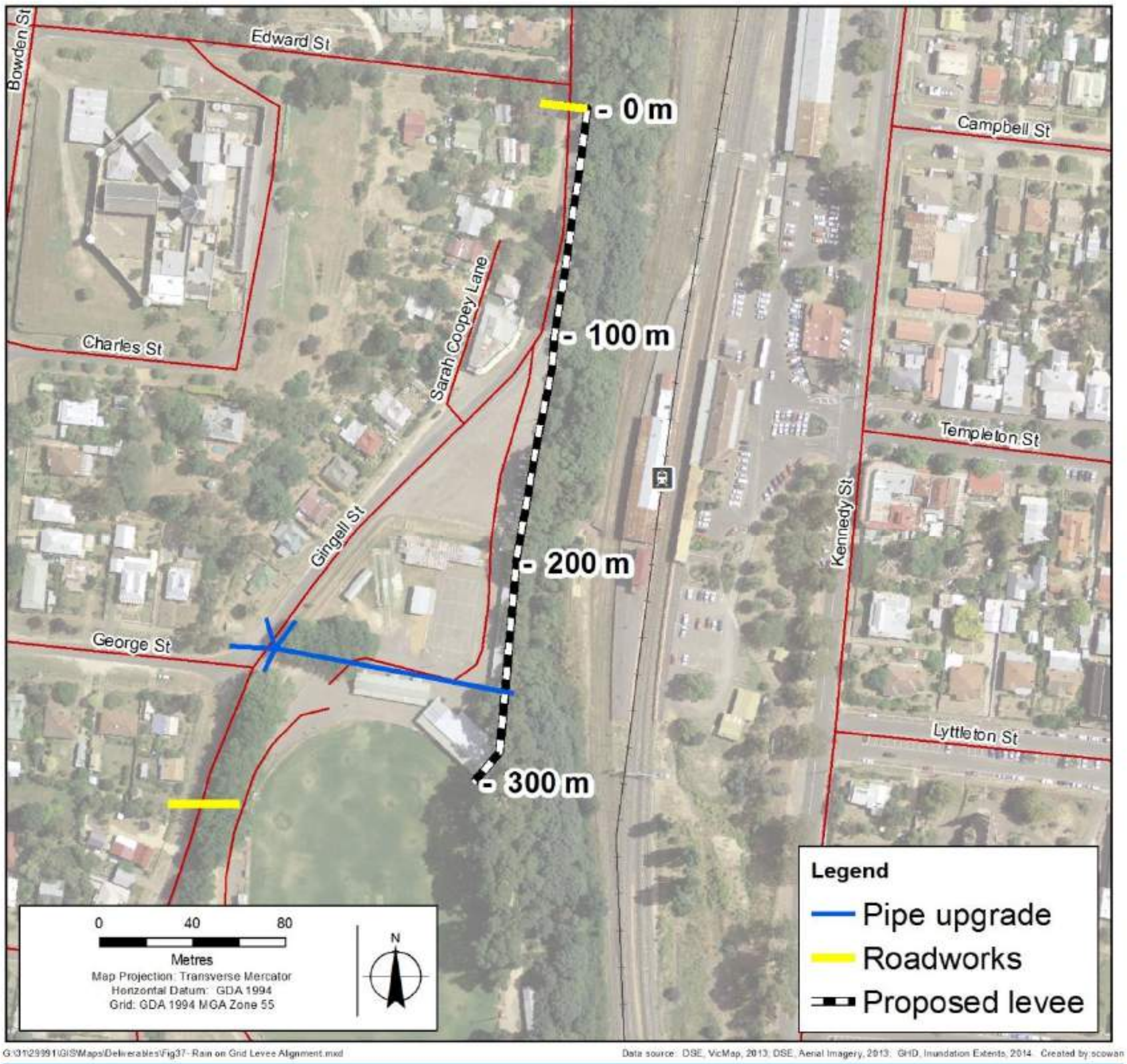

Figure 38 Rain on Grid Model Mitigation Options

6.1.3 Results with one (1) meter High Levee

The discussion below is based on a one (1) meter high levee from Edward Street to the oval, as shown in Figure 38.

The one meter high levee is able to prevent riverine flooding for events up to and including the 1 in 20 AEP event. For the 1 in 20 AEP event the levee would have a freeboard of approximately 300 mm. The model indicates that the levee would just be overtopped in a 1 in 50 AEP event between approximately 100 to 150 meters (refer to Figure 38 for chainage locations). To put this in context the January 2011 event was in the order of a 1 in 40 to 50 AEP event on Barkers Creek indicating that the one meter high levee would be close to protecting Gingell Street in a similar event to the January 2011 event.

Figure 39 shows the 1 in 20 and 1 in 100 AEP water surface profiles for existing conditions (labelled as Exist) and with the levee in place (labelled Mit). Figure 38 shows the levee alignment and the corresponding chainages shown in Figure 39.

A sketch of how the levee may look is shown in Appendix K.

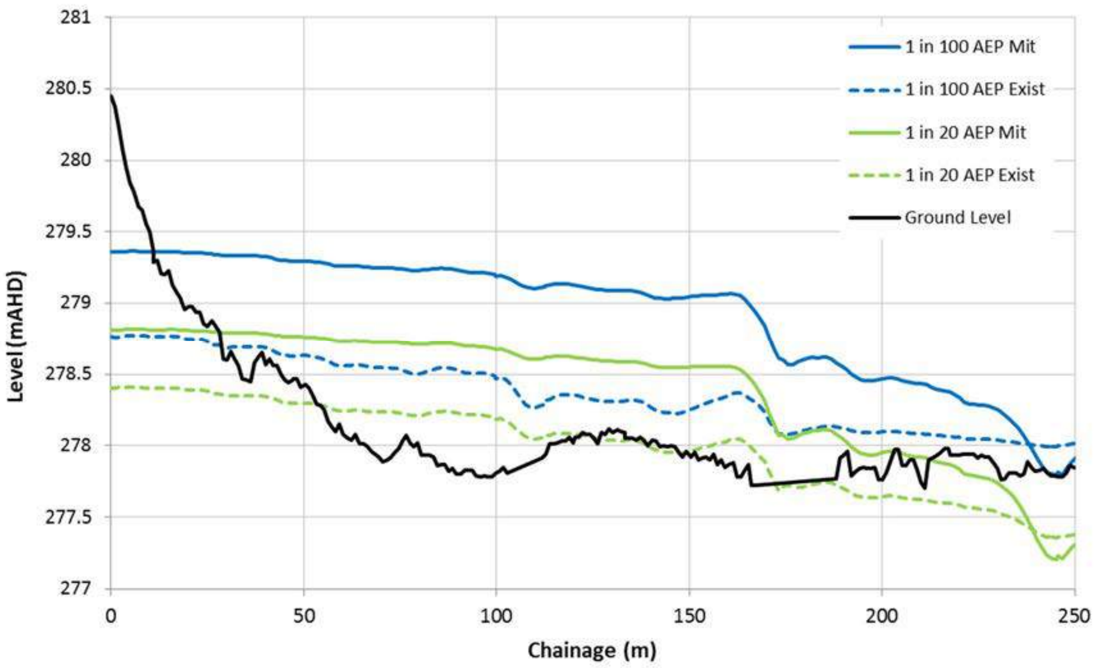

Figure 39 Long Section along proposed One Meter Levee

With the one meter high levee in place there would be no over floor flooding in a 1 in 20 AEP event. Even with the one meter high levee in place for the 1 in 20 AEP event, water from the local catchment would still pond along Gingell Street. However, according to the model, with the two “speedhump” diversions in place (as described above) the water level ponds to a maximum depth of approximately 300 mm in the lowest section of the road. Without the diversions in place the model indicates that water would pond up to a maximum depth of 700 mm.

Assuming that the “speed hump” diversions (as described above) are in place, for the 1 in 100 AEP event flood waters from Barkers Creek fills the oval and then overtops the diversion across Gingell Street (between George St and Caroline St) flooding the depression adjacent to 45-51 Gingell Street. To prevent flow going over the “speed hump” the diversion between George St and Caroline St would need to be in excess of 500 mm high which is not considered a feasible height for a speed hump. To minimise the overflow from the oval into Gingell Street the levee could be extended around the high side of the oval.

For the 1 in 100 AEP event the 1 metre high levee is overtopped and as a result flood levels along Gingell Street are comparable to existing conditions.

6.1.4 Results with Levee to Prevent Riverine Flooding in a 1 in 100 AEP Event

While the difference in the 1 in 20 and 1 in 100 AEP flood levels in this reach is typically around 350 mm under existing conditions, the difference in levee heights between a 1 in 20 and 1 in 100 AEP levee is closer to 700 mm due to the constriction. With no allowance for freeboard the 1 in 100 AEP levee would need to be approximately 1.5 meters high. Figure 40 shows the long section with a levee to protect against the 1 in 100 AEP event. Figure 38 shows the levee alignment and the corresponding chainages shown in Figure 40.

A sketch of how the levee may look is shown in Appendix K.

With the proposed mitigation options in place Gingell Street is still flooded in the 1 in 100 AEP event due to local stormwater being unable to escape as a result of high water levels in Barkers Creek. However the modelling shows that the peak water levels would be approximately 1 meter lower compared to existing conditions. This reduction in water levels means that no houses experience over floor flooding for the 1 in 100 AEP event. However, the road will still be impassable.

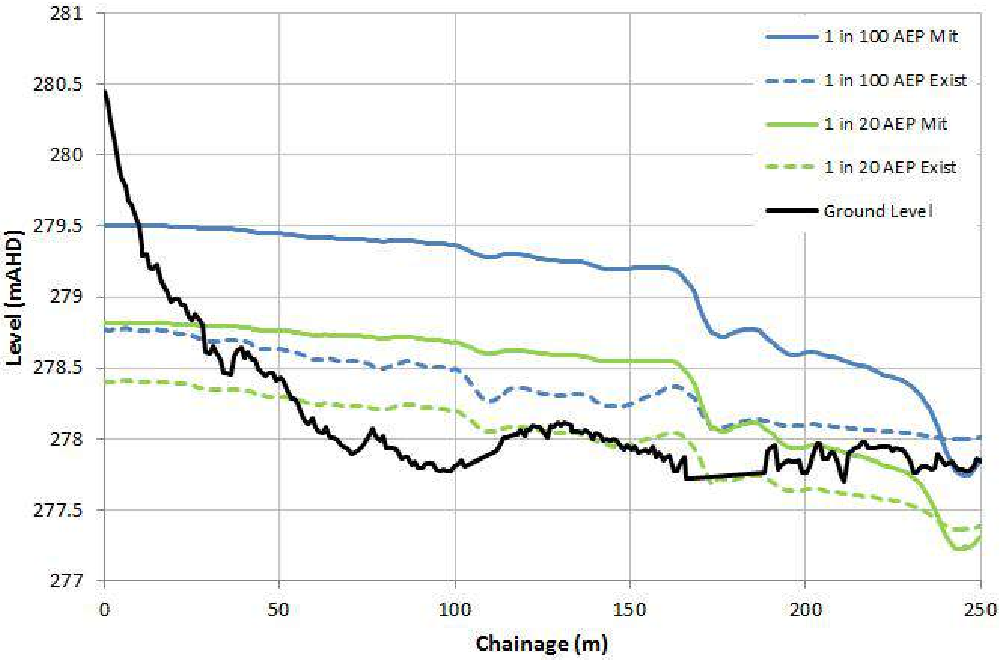

Figure 40 Long Section along a 1 in 100 AEP Levee

6.2 Gingell Street North Levee

To protect the properties north of Thomas Street from the 1 in 100 AEP event (with no allowance for freeboard) a new levee would need to be on average 1.0 meters high (up to a maximum of approximately 2.0 meters high). Figure 18 shows the location of the levee and Figure 41 shows the long section with a levee to protect against the 1 in 100 AEP event.

A sketch of how the levee may look is shown in Appendix K.

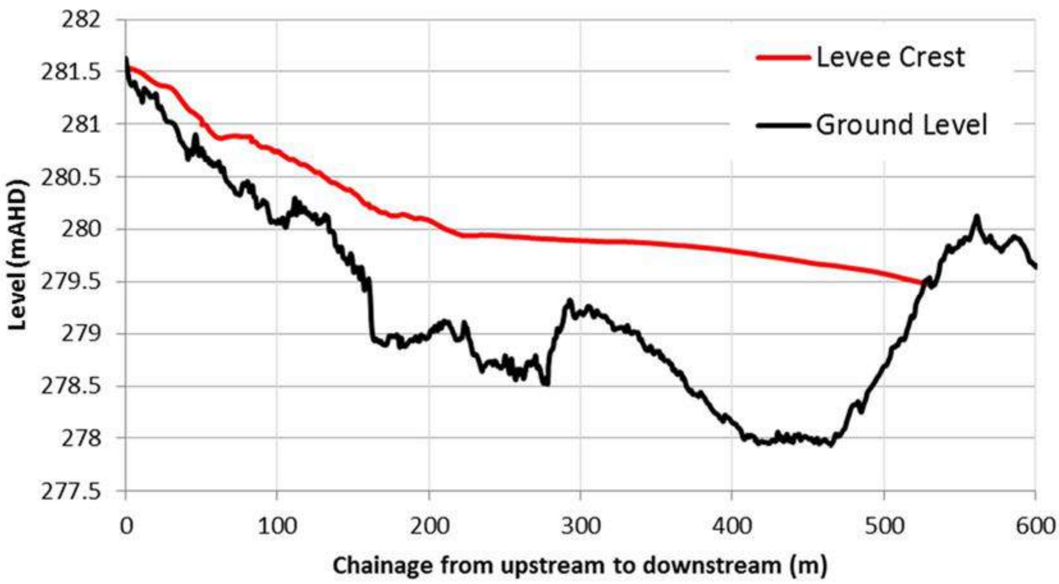

Figure 41 North Gingell Long Section with Levee in Place to Protect against Flooding in a 1 in 100 AEP Event (no freeboard)

With the levee in place the model indicates that for the 1 in 100 AEP event water levels would increase at 9 Walker Street by 300 mm (refer to Figure 21). To compensate for the increase in water levels a local levee could be constructed to protect 9 Walker Street.

Another important aspect to consider for the proposed levees along Gingell Street is vegetation management. The modelling indicates that if this section of the creek is continually maintained i.e. not allowed to become overgrown with vegetation, then the height of the levee can be reduced.

6.3 Castlemaine Central Cabin and Van Park Levee

In order to protect the Castlemaine Central Cabin and Van Park and Bruce Street properties from a 1 in 100 AEP event (with no allowance for freeboard) a new levee would need to be constructed on average 1.2 meters high (up to a maximum of approximately 2.3 meters high). Figure 42 shows the long section with a levee to protect against the 1 in 100 AEP event.

A sketch of how the levee may look is shown in Appendix K.

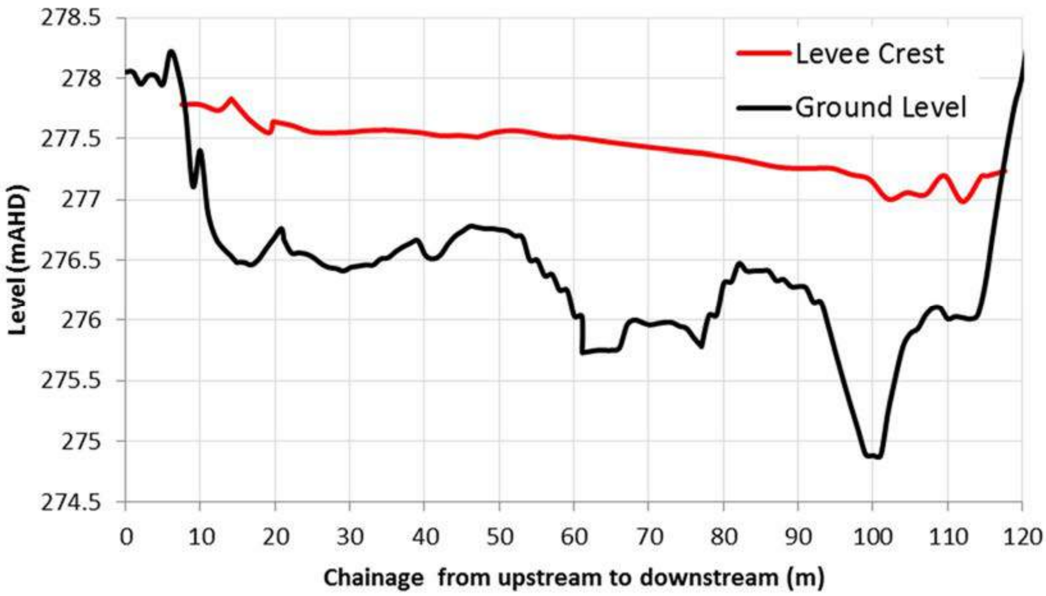

Figure 42 Bruce Street and Caravan Park Long Section with Levee in Place to Protect against Flooding in a 1 in 100 AEP event (no freeboard)

The maximum section is where the drainage line alongside the railway line enters Forest Creek. Some local stormwater drainage works would be required at this location.

With the levee in place the modelling indicates that for the 1 in 100 AEP event water levels would increase by up to 300 mm in Western Reserve and 100 mm at the tennis court (refer to Figure 25).

During the 1 in 100 AEP event the modelling indicates that water would overtop the Midland Highway and flow into the caravan park. To prevent water from overtopping the Highway in this event a 300 mm high level levee could be constructed on the eastern side of the Highway up to approximately Bruce Street.

6.4 Elizabeth Street Levee

There is already a levee at Elizabeth Street. However, in order to protect that area from the 1 in 100 AEP event the levee would need to be topped up by approximately 0.5 meter (with no allowance for freeboard) and extended so that the levee would be from Johnstone Street to the railway bridge approximately 100 meters downstream of Elizabeth Street. The new levee would be an average height above the existing surface level of 1.0 meters (up to a maximum of approximately 2.2 meters high). Figure 43 shows the long section with a levee to protect against the 1 in 100 AEP event. Note that the section between approximately chainage 150 to chainage 450 is the existing levee.

A sketch of how the levee may look is shown in Appendix K.

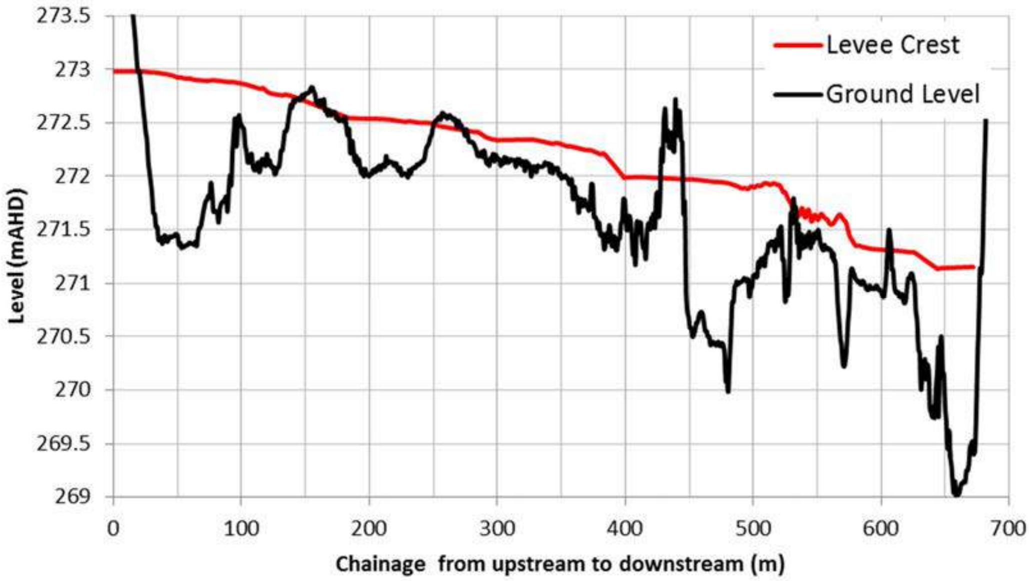

Figure 43 Elizabeth Street Long Section with Levee in Place to Protect against Flooding in a 1 in 100 AEP event (no freeboard)

With the levee in place the model indicates that for the 1 in 100 AEP event water levels would increase by approximately 100 mm at (refer to Figure 27):

- 39 Ray Street
- 46 Elizabeth Street
- 49 Elizabeth Street
- 47 Elizabeth Street

These increases would not result in over floor flooding at these properties.

If the Elizabeth Street road bridge was upgraded then the preliminary modelling indicates that this could compensate for the increase in water level upstream of the bridge as a result of topping up and extending the levee. However, upgrading the levee and the bridge would not result in a positive cost benefit ratio (further discussion on this is given in Section 8).

6.5 Campbells Creek Township Levee

There is already a levee at Campbells Creek. However, in order to protect that area from the 1 in 100 AEP event the levee would need to be topped up by approximately 0.5 meter (with no allowance for freeboard) and extended. The extended levee would go from Stephen Street to Alexandra Street and would be an average height of 0.7 meters (up to 1.8 meters).

Figure 44 shows the long section with a levee to protect against the 1 in 100 AEP event.

A sketch of how the levee may look is shown in Appendix K.

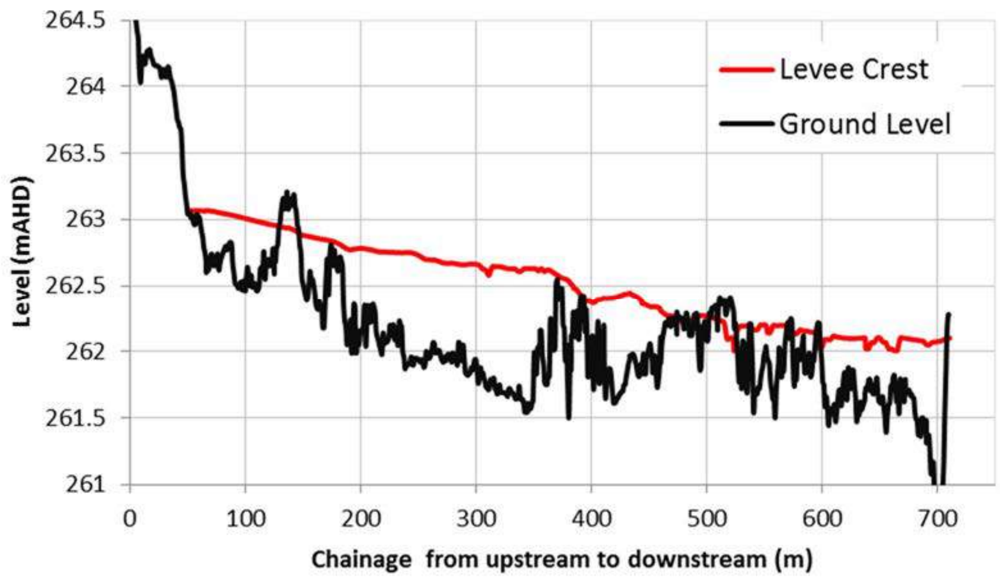

Figure 44 Campbells Creek Long Section with Levee in Place to Protect against Flooding in a 1 in 100 AEP event (no freeboard)

With the levee in place the model indicates that for the 1 in 100 AEP event water levels would increase by approximately 100 mm at (refer to Figure 28):

- 53 Elizabeth Street
- 55 Elizabeth Street
- 60 Elizabeth Street

These increases would not result in over floor flooding at these properties.

Another important aspect to consider for the proposed levee along Campbells Creek is vegetation management downstream of Alexandra Street Bridge. The modelling indicates that if the section of the creek downstream of Alexandra Street Bridge is not maintained i.e. it is allowed to become overgrown with vegetation, then the height of the levee would need to be higher.

It should be noted that for this option the first 150 meters (approximately) from Stephens Street is not protecting houses from over floor flooding. This section of the levee is predominately protecting 70 Main Road (and to a lesser degree 72 to 86 Main Road) from experiencing flooding within their property.

For this option local stormwater works are particularly important. In January 2011 this area experienced flooding from the river and local stormwater runoff.

6.6 General discussion on levees

With the construction of a levee, consideration needs to be given to localised flood events (behind the levee). Some culverts will need to be placed under the levees to allow local stormwater to drain into the river. Mechanisms such as flap gates on the end of these pipes will be required to prevent riverine flooding backing up through the pipes. However, flap gates do require maintenance and can fail during a flood event.

Levees are frequently the most economically attractive measure to protect existing development in flood prone areas. The height or crest level of a levee is determined by a variety of factors including:

- The economics of the situation (including the nature of development requiring protection).
- The physical limitations of the site.
- The level to which floods can rise relative to the ground levels in the area (important in safety considerations).

Even if design, construction and maintenance are exemplary, all levees will ultimately be overtopped by an 'overwhelming' flood (unless designed for the Probable Maximum Flood event). It is not a question of if overtopping will occur, but of when and what the consequences will be.

In constructing levees to provide for greater flood mitigation, the following issues need to be considered:

- Risk of failure during large flood event (overtopping or piping).
- The likelihood and consequences of catastrophic damage and unacceptable hazard levels when the levee is overtopped.
- Appropriate design of the levee and provision of spillways to avoid uncontrolled high velocity flows or even failure when the levee is overtopped.
- Ongoing inspection and maintenance of the levee is required. Tasks include:
  - Regular (once every six-12 months) visual assessments, checking for erosion and subsidence of the levee, tree growth within the levee, rabbit or other fauna burrowing into the levee.
  - Regular (couple of months) mowing of the grass and spraying of weeds on the levee.
  - Inspection during and after a flood event.
  - Occasional repair work.
- Development control measures for protected development behind the levee.
- Provision for local stormwater runoff from behind the levee into the main stream (as discussed above).
- Emergency response plans for levee overtopping and evacuation.
- Analysis of flow conditions that may develop when overtopping occurs and the flood continues to rise. In some situations high hazard conditions can develop in protected areas.
- On-going community education to make sure that the population is aware of the risk of overtopping, is informed about emergency response plans and does not suffer a false sense of security simply because a levee has been constructed.
- The loss of visual amenity.
- Loss of floodplain storage and obstruction to flood flows.

- Inequality due to increased flood levels elsewhere within the floodplain.
- The suitability and need for permanent or temporary flood barriers.
- Levees may prevent the flow of water to valuable ecological areas, such as wetlands. The consequences of this needs to be considered especially for threatened species and the ecological community as a whole.

Some of the foregoing precautions do not apply when the probable maximum flood is adopted as the design event for levees. In such cases, important factors to consider include the maintenance of the levee and the provision of adequate freeboard against wave action and subsidence.

Another important consideration with levees is the amount of freeboard that is adopted. Freeboard is the height above a defined flood level, typically used to provide a factor of safety in, for example, the setting of floor levels and levee crest levels. Freeboard is an important and widely accepted safety factor and is required to allow for issues such as uncertainty in the estimated flood levels, the effect of waves, superelevation, subsidence and the recovery of velocity head. A value of 0.6 m is widely used for riverine flooding, however is not suitable for all circumstances.

6.7 Other areas affected by riverine flooding

There are a number of other individual residential properties expected to experience flooding based on the modelling undertaken. The location and a comment on each of these are given in Table 18. These sites are generally at lower risk of flooding than the areas identified above, isolated, or not likely to meet benefit-cost requirements considered acceptable when constructing public infrastructure. Possible local solutions have been suggested where individual property owners may wish to eliminate the flood risk and would be the primary beneficiary of doing so.

Table 18 Individual Properties Subject to Flooding

Address	Comment
199 MAIN ROAD CAMPBELLS CREEK 3451	Property is inundated by local stormwater originating from the east of the property. Flow depths are only shallow (up to 200 mm for the 1 in 200 AEP event) so a small bund around the rear of the property may be feasible.
149 MAIN ROAD CAMPBELLS CREEK 3451	According to the survey the floor level is just below ground level and the maximum 1 in 200 AEP depth is approximately 300 mm which would suggest the property is flooded during the 1 in 200 AEP event.
134 MAIN ROAD CAMPBELLS CREEK 3451	Inundated between 1 in 20 and 1 in 50 AEP events from Campbells Creek. The reconstruction of the Campbells Creek Township Levee could eliminate this issue if extended to protect this property.
201 MAIN ROAD CAMPBELLS CREEK 3451	The minimum LiDAR ground surface level at this property is higher than the surveyed floor level (floor level is below natural surface level in TUFLOW model). According to the survey the floor level is approximately 700 mm above the natural surface level whereas the max 1 in 200 AEP depth at the property is less than 100 mm. This would suggest that the property would not be flooded during the 1 in 200 AEP event. The surveyed ground level is approximately 1.5 m below the LIDAR ground level. Investigation of the area suggests that the survey is in error and not the LiDAR although a further independent check survey would need to be undertaken to confirm.

Address	Comment
20 GAULTON STREET CASTLEMAINE 3450	Inundated above floor level between the 1 in 100 and 1 in 200 AEP event. A number of properties along Gaulton Street are flooded above floor level between the 1 in 100 and 1 in 200 AEP events. A levee along the rear of the Gaulton Street properties could be constructed to prevent flooding to these properties. However a preliminary AAD estimate for the flooded properties along Gaulton St indicates an AAD of approximately $1,000. Based on this low AAD estimate it is highly unlikely that mitigation works would look favourable if a comprehensive cost-benefit analysis was undertaken.
145 MAIN ROAD CAMPBELLS CREEK 3451	Inundated between 1 in 50 and 1 in 100 AEP event. The Campbells Creek Township Levee will protect this property from riverine flooding but flooding from local stormwater is still possible
39 MIDLAND HIGHWAY CAMPBELLS CREEK 3451	Property inundated between 1 in 50 and 1 in 100 AEP event. No floor levels surveyed of dwelling (or dwelling to north at 33 Main Rd) so risk unknown. Depth of up to 400 mm (at rear of house) for the 1 in 200 AEP event so inundation possible
2 URQUHART STREET CASTLEMAINE 3450	Inundated between 1 in 50 and 1 in 100 AEP event. Property isolated. May be feasible to create low bund along front of house though AAD would be very low.
11 MCGRATH STREET CASTLEMAINE 3450	Inundated between 1 in 50 and 1 in 100 AEP event. Property isolated. 1 in 200 AEP depth is 150 mm above floor level. May be feasible to create low bund along front of house though AAD would be very low
54 MAIN ROAD CAMPBELLS CREEK 3451	Inundated between 1 in 50 and 1 in 100 AEP event. Property isolated. May be feasible to create low bund along front of house though AAD would be very low
34 GAULTON STREET CASTLEMAINE 3450	see comment for 20 Gaulton Street
30 GAULTON STREET CASTLEMAINE 3450	see comment for 20 Gaulton Street
24 GAULTON STREET CASTLEMAINE 3450	see comment for 20 Gaulton Street
22 GAULTON STREET CASTLEMAINE 3450	see comment for 20 Gaulton Street
20 GAULTON STREET CASTLEMAINE 3450	see comment for 20 Gaulton Street
6 GAULTON STREET CASTLEMAINE 3450	see comment for 20 Gaulton Street
46 ELIZABETH STREET CASTLEMAINE 3450	Flooded above floor level between 1 in 100 and 1 in 200 AEP event. Some afflux (100 mm) from Elizabeth Street Levee though property should still have protection from 1 in 100 AEP event.
50 CEMETERY ROAD CASTLEMAINE 3450	Flooded above floor level between 1 in 100 and 1 in 200 AEP event. For the 1 in 200 AEP event the flood depth is 100 mm above floor level. It may be feasible to create a low bund around the house, though the AAD would be very low. Based on modelling undertaken with the Campbells Creek Township Levee in place afflux at the property would be approximately 85 mm for the 1 in 100 AEP event. With the Campbells Creek Township levee in place the building would experience flooding above floor level for between a 1 in 50 and 1 in 100 AEP event.
53 ELIZABETH STREET CAMPBELLS CREEK 3451	Flooded above floor level between 1 in 100 and 1 in 200 AEP event. For the 1 in 200 AEP event the flood depth is 90 mm above floor level. It may be feasible to create a low bund around the house, though the AAD would be very low. Based on modelling undertaken with the Campbells Creek Township Levee in place afflux at the property would be approximately 75 mm for the 1 in 100 AEP event. With the Campbells Creek Township levee in place the building would experience flooding above floor level for between a 1 in 50 and 1 in 100 AEP event.

Address	Comment
55 ELIZABETH STREET CAMPBELLS CREEK 3451	Flooded above floor level between 1 in 100 and 1 in 200 AEP event. For the 1 in 200 AEP event the flood depth is 90 mm above floor level. It may be feasible to create a low bund around the house, though the AAD would be very low. Based on modelling undertaken with the Campbells Creek Township Levee in place afflux at the property would be approximately 100 mm for the 1 in 100 AEP event. With the Campbells Creek Township levee in place the building would experience flooding above floor level for between a 1 in 50 and 1 in 100 AEP event.
150 MAIN ROAD CAMPBELLS CREEK 3451	1 in 200 AEP flood level 70 mm below floor level
	Almost 1 in 200 AEP protection.
203 MAIN ROAD CAMPBELLS CREEK 3451	The minimum LiDAR ground surface level at this property is higher than the surveyed floor level (floor level is below natural surface level in TUFLOW model). According to the survey the floor level is approximately 600 mm above the natural surface level whereas the maximum 1 in 200 AEP flood depth at the property is less than 100 mm. This would suggest that the property would not be flooded during the 1 in 200 AEP event. The surveyed ground level is approximately 1.5 m below the LIDAR ground level. Investigation of the area suggests that the survey is in error and not the LiDAR although a further independent check survey would need to be undertaken to confirm.
12 GAULTON STREET CASTLEMAINE 3450	see comment for 20 Gaulton Street
1/10 GAULTON STREET CASTLEMAINE 3450	see comment for 20 Gaulton Street
2/10 GAULTON STREET CASTLEMAINE 3450	see comment for 20 Gaulton Street
3/10 GAULTON STREET CASTLEMAINE 3450	see comment for 20 Gaulton Street
5/8 GAULTON STREET CASTLEMAINE 3450	see comment for 20 Gaulton Street
4/8 GAULTON STREET CASTLEMAINE 3450	see comment for 20 Gaulton Street
40A GREENHILL AVENUE CASTLEMAINE 3450	Flooded above floor level between 1 in 100 and 1 in 200 AEP event. 1 in 200 AEP flood depth 100 mm above floor level. Property isolated.
2 SCOTTS AVENUE CASTLEMAINE 3450	Flooded above floor level between 1 in 100 and 1 in 200 AEP event. 1 in 200 AEP flood depth only 7 mm above floor level. May be feasible to create low bund along front of house though AAD would be very low.
1 MCGRATH STREET CASTLEMAINE 3450	Flooded above floor level between 1 in 100 and 1 in 200 AEP event. 1 in 200 AEP flood depth only 50 mm above floor level. May be feasible to create low bund along front of house though AAD would be very low
PYRENEES HIGHWAY CHEWTON 3451	Flooded above floor level between 1 in 100 and 1 in 200 AEP event. Property isolated.

6.8 Local stormwater flooding

In January 2011 and February 2012 the townships of Castlemaine, Campbells Creek and Chewton received a large amount of rainfall. This caused a significant amount of localised stormwater-type flooding.

The focus of this investigation has been riverine flooding and a detailed assessment of the stormwater system was beyond the scope of this investigation. However, information gathered during this investigation and localised stormwater investigations undertaken by others (e.g. Spiire) could be used to assist in developing a stormwater management plan for Castlemaine, Campbells Creek and Chewton.

6.9 Non structural mitigation options

This section discusses a number of non-structural flood mitigation measures, and recommends specific measures for future consideration. Non-structural mitigation measures include land use planning, flood warning and flood response.

6.9.1 Land use planning

The Victorian Planning Provisions (VPPs) contain a number of controls that can be employed to provide guidance for the use and development of land that is inundated by floodwaters. These controls include the Urban Floodway Zone (UFZ), the Floodway Overlay (FO), the Land Subject to Inundation Overlay (LSIO) and the Special Building Overlay (SBO). This section of the report discusses how each control may be applied in the Mount Alexander Shire Planning Scheme.

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

Development controls are essential for ensuring that land use on flood-prone land is compatible with flood risk and that the rate of growth of future flood damage is reduced. (ARMCANZ, 2000)

Urban Floodway Zone

Increasing the intensity of land use or a change in land use can increase flood risk, therefore in areas of highest flood risk and with a potential for land use intensification, it may be appropriate that land use is restricted. As with any other zone, the UFZ controls the use of land in identified floodway areas. The UFZ is very restrictive on what uses are permissible, as such, use of the UFZ will severely limit the use and development of land to which it is applied.

The difficulty in using the UFZ is that flooding does not follow cadastral boundaries; hence it may not be possible to apply the zone to a complete parcel of land. Best practice is to ensure that only one zone applies to any given parcel of land. Due to the restrictive nature of the UFZ, it is not recommended for use at Castlemaine. It is considered that other zones can be applied which will more clearly identify the development potential for land.

Floodway Overlay

The Floodway Overlay (FO) applies to mainstream flooding in both rural and urban areas. These areas convey active flood flows or storage. The FO has an increased focus on the control of development (structures) with the ability to restrict flow while still achieving some control over land use. The function of the overlay is to trigger the need for a planning permit. From the results of this investigation a revised FO, based on a combination of the 10% AEP flood, flood hazard and flood depth, has been developed for Castlemaine. The criteria for the FO were informed by the Advisory Notes for Delineating Floodways (NRE, 1998). The revised FO is shown in Appendix L. It is recommended that the revised FO be introduced to the Mount Alexander Shire Planning Scheme.

It is noted that if the proposed mitigation options are constructed in order to provide flood protection for Castlemaine, Campbells Creek and Chewton, the argument supporting introduction of the FO to the Mount Alexander Planning Scheme will be significantly reduced however; there are some areas where it will still apply.

Land Subject to Inundation Overlay

The LSIO applies to mainstream flooding in both rural and urban areas. In general, areas covered by the LSIO have a lower flood risk than FO areas.

The LSIO will act as a trigger for a planning permit. From the results of this investigation a revised LSIO has been developed for Castlemaine, Campbells Creek and Chewton. The revised LSIO is shown in Appendix L. It is recommended that the revised LSIO be introduced to the Mount Alexander Shire Planning Scheme.

The LSIO/FO map will identify the land where a permit will be required, while the FO Schedule and the LSIO Schedule will identify various developments within the overlay (identified land) that will be exempt from the need for a permit in each zone.

Special Building Overlay

The Special Building Overlay (SBO) applies to stormwater flooding in urban areas only. The SBO is intended to apply to areas / locations where the drainage systems are designed to a lower capacity than what may be required during peak storm events and that result in the overland flow of stormwater. The purpose of the SBO is to manage development in areas that are subject to the overland flow of stormwater.

Common practice throughout Victorian Planning Schemes is to apply the SBO to situations where overland flow occurs once the capacity of drainage pipes is exceeded. Such surcharge flooding from local events was demonstrated during the recent events in Castlemaine, Campbells Creek and Chewton.

Council should consider the introduction of the SBO into the Mount Alexander Shire Planning Scheme, although its extent would need to be determined by an assessment of local (non riverine) flooding issues. The results from the rain on grid model around southern Gingell Street and like studies in other areas could be used for this purpose.

Local Planning Policy - Floodplain Management

The use of local policy can provide greater guidance and clarity in the Planning Permit process and is generally considered to be prudent practice. A Floodplain Management Planning Policy statement could assist in communicating Council's stance on appropriate development within the LSIO, FO and SBO. As such, it could provide guidance to both applicants and Council.

The policy would apply to all permits required under the LSIO, FO and SBO. Applicants will be able to gain guidance from the policy before preparing applications, while Council will be able to rely on the content of the policy to place conditions on permits, or to refuse permits. The policy could also be relied on to defend Council decisions at appeal.

The policy may include objectives to be achieved, policy statements, and performance standards to be met. It could also contain a number of objectives and performance measures that seek to ensure that new development does not reduce or impede the ability of the floodplain to store and convey floodwater.

It is recommended that consideration be given to amending the Mount Alexander Shire Planning Scheme to include a Floodplain Management Local Planning Policy for Castlemaine, Campbells Creek and Chewton.

6.9.2 Flood warning, response and awareness

Flood Warning

Due to the nature of flooding in the catchment, little warning time is possible for riverine flooding. The hydrological modelling indicated that three to six hour storm duration is generally the critical duration for a range of design storms. Forest Creek in particular has the potential to rise very quickly only a few hours after the start of heavy rain, for example during the February 2012 event the creek rose quickly. A warning time of less than six hours is generally considered to be flash flooding.

There is currently no flood warning service provided by the Bureau of Meteorology at Castlemaine, and given the short available warning time the Bureau would most likely classify this as flash flooding so would not be covered under the traditional flood warning service. The Victorian Floodplain Management Strategy Revised Draft (DELWP, 2015) for flash flood warning services states that “given the short timeframes associated with flash flooding more certainty is needed about each agency’s roles, capacities, responsibilities and accountabilities, and the community’s capacity to respond appropriately”. The proposed policy (16c) for flash flood warning services is that the Catchment Management Authorities and Melbourne Water, with the support of VICSES and Local Government Authorities, will identify areas with a history of flash flooding and include them in their regional floodplain management strategies. The proposed action (16b) is that DELWP will work with the Emergency Management Commissioner to evaluate the potential to disseminate generalised district-scale district - scale flash flood warning services based around Bureau of Meteorology’s existing severe weather warning services, using similar dissemination approaches employed for bush fire. Also DELWP will work with the Bureau of Meteorology, the Emergency Management Commissioner and VICSES to evaluate the potential to provide localised neighbourhood – scale flash flood warning services where there is a history of flash flooding.

Any flash flood warning system should consider the eight building blocks of a flash flood warning system, these include:

- Data collection and collation
- Detection and prediction
- Interpretation
- Message construction
- Message dissemination
- Response
- Review
- Awareness

Failure to consider any one of these building blocks will reduce the effectiveness of any flash flood warning system.

Flood Response

The information and understanding gathered during this project regarding the flood behaviour at Castlemaine for a range of events is critical to capture in order to improving the flood response at Castlemaine. This includes areas that are likely to be impacted by floods of various magnitudes, the timing and behaviour of flooding through town, areas most at risk, identifying vulnerable communities, access and egress issues, buildings inundated above and below floor, areas that need to be evacuated as a priority, etc. This information should be summarised in the Municipal Flood Emergency Management Plan.

Flood Awareness

There are many misconceptions commonly held regarding flooding that may prevent a person from preparing to and then evacuating prior to the arrival of a flood. A strong community awareness campaign will reduce these misconceptions, it will never eliminate them entirely, but it will tend to increase the percentage of the community which is aware and ready to act when a flood is imminent. A flood aware and flood ready community stands a much better chance of reducing their flood damage than a community that is not aware of the flood risk before an event.

Flood awareness can be improved and retained in a number of ways. Some of these include, but not limited to:

- Brochure style documents that clearly explain the risk and what is being done about it by the relevant agencies, but more importantly what individuals can do to best prepare themselves.
- VICSES FloodSafe program.
- Continuing to promote flood related issues through the flood recovery group.
- Installing flood markers of historic and potentially design floods in suitable locations. This may include a town gauge board that may be part of a flash flood warning system, or at least linked to the outputs from this study in the flood response plans.
- Individual property flood information which includes information such as the link between a flood level at a gauge and the commencement of flooding on the specific property, and the level at which above floor flooding is likely to occur, they also provide basic flood information including contact details and at what level on the gauge they should consider evacuating.

7. Flood damage assessment

A flood damage assessment has been undertaken to assess the aggregate cost of flood impacts and the economic benefit of flood mitigation options (reduction in damage costs). The flood damages assessment follows an accepted method to establish the social-economic costs experienced within the study area for the full range of design flood events modelled under baseline and mitigated scenarios. The flood damage assessment has identified priority regions in terms of flooding damage, and in particular provides the basis for monetary comparison of mitigation scenarios. Probable tangible flood damages were assessed for residential, commercial and industrial land use types within the Castlemaine floodplain.

The estimated damage costs presented herein are an approximation only, and were determined in accordance with the standard limited methodology normally used in these assessments. The damages are not intended to represent the full economic impact of a flood event. For instance, building damage is based on standard recommended “damage curves” rather than actual insurance data. Improvements to these estimates could be achieved if recent and specific insurance flood damage information was available. Nonetheless, the methodology is appropriate for the intended purpose of highlighting the relative severity of flood impacts in various areas as well as comparing various mitigation measures. Care should be taken when interpreting the damage and benefit-cost ratios (i.e. the costs in the benefit cost ratio calculation do not take into account the full range of socio-economic impacts).

A full description of the methodology adopted for the flood damages assessment is included in Appendix M. In summary, the key steps involved in this process are outlined below:

1. Create a consolidated database of residential, commercial and industrial buildings and floor levels.
2. For each class of property within the database, determine a relationship between flooding (i.e. depth, velocity or inundation area) and resulting damage based on accepted methods and publications.
3. For each property in the database, calculate the depth, velocity or area of inundation and the resulting flood damage for each design flood event.
4. Calculate the Annual Average Damages (AAD).
5. Calculate the Net Present Value (NPV) of the flood damages.

The AAD, as defined in Floodplain Management in Australia (CSIRO, 2000), is the total damage caused by floods over a long period of time divided by the number of years in that period. If the damage associated with various frequency events is plotted against their probability of occurrence, the AAD is equal to the area under the consequence-probability curve. AAD provides the basis for comparing the economic effectiveness of different management measures.

For the analysis, a net present value (NPV) model was used, applying a 4% discount rate over a 50 year project life.

All dollar values used in the flood damage assessment were adjusted to 2014 dollars using information published by the Bureau of Statistics.

7.1 Flood damage assessment results

The following section summaries the flood damage assessment results. Table 19 summarises the flood damages estimates for existing conditions and includes a breakdown of damages for each of the five areas selected for mitigation works. Table 20 summarises the estimates of average annual damages (AAD) and net present value of damages (NPV). As mentioned previously it should be noted that these are estimates only and may not reflect actual damages which could occur as a results of a flood.

Table 19 Summary of Flood Damages

AEP (1 in X)	Total		Gingell Street		Gingell Street North		Castlemaine Central Cabin and Van Park		Elizabeth Street		Campbells Creek Township		Remainder	
	Buildings Inundated above floor	*Damages ($)*	*Buildings Inundated above floor*	*Damages ($)*	*Buildings Inundated above floor*	*Damages ($)*	*Buildings Inundated above floor*	*Damages ($)*	*Buildings Inundated above floor*	*Damages ($)*	*Buildings Inundated above floor*	*Damages ($)*	*Buildings Inundated above floor*	*Damages ($)*
5	4	$400,570	3	$180,520	0	$ -	1	$55,518	0	$ -	0	$ -	0	$164,532
10	12	$752,510	5	$265,196	0	$ -	2	$70,879	1	$53,868	1	$84,837	3	$277,730
20	26	$2,009,667	5	$350,330	4	$265,539	4	$226,231	3	$148,365	5	$355,476	5	$663,725
50	45	$3,803,771	6	$443,163	5	$403,844	5	$441,404	8	$456,708	11	$776,584	10	$1,282,067
100	69	$6,162,476	8	$535,369	6	$479,072	8	$802,513	13	$964,442	16	$992,257	18	$2,388,822
200	112	$9,859,507	8	$621,179	8	$630,490	15	$1,362,988	14	$1,206,255	20	$1,387,205	47	$4,651,391

Table 20 Summary of Average Annual Damages (AAD) and Net Present Value (NPV) of Damages

AEP (1 in X)	AEP (1 in X)	Total	Gingell Street	Gingell Street North	Castlemaine Central Cabin and Van Park	Elizabeth Street	Campbells Creek Township
20	AAD	$277,695	$107,366	$6,159	$35,061	$7,010	$13,866
	NPV	$5,965,494	$2,306,452	$132,318	$753,184	$150,594	$297,873
50	AAD	$361,900	$118,859	$15,855	$44,731	$15,774	$30,264
	NPV	$7,774,411	$2,553,357	$340,605	$960,927	$338,869	$650,126
100	AAD	$410,990	$123,679	$20,204	$50,858	$22,774	$38,976
	NPV	$8,828,962	$2,656,898	$434,028	$1,092,548	$489,244	$837,291

7.2 Non-economic flood damage

The previous discussion relating to flood damage has been in relation to tangible damage which can be estimated in dollars. Intangible damage cannot be readily quantified in economic terms but are none the less important. According to the Rapid Appraisal Method (RAM - DNRE, 2000) intangible damages fit under two broad categories:

- Social (e.g. health, safety and personal impacts)
- Environmental impacts

The “Disaster Loss Assessment Guidelines” (EMA, 2002) states 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.

The Castlemaine community suffered greatly as a result of the recent floods.

The flood damage assessment presented in Section 7.1 has not considered the ‘intangible cost’. However, any decisions made on the works to undertake in Castlemaine need to factor in that the true cost of floods in Castlemaine is greater than the estimated economic damage. Making such an allowance is appropriate and expected to increase the flood damage estimates, increasing the benefit / cost ratio and improving the argument for approving a mitigation scheme at Castlemaine.

8. Benefit cost analysis

A benefit cost analysis was undertaken to assess the economic viability of the mitigation options. A benefit cost ratio is an indicator of the overall value for money of a project expressed in monetary terms, relative to its costs, also expressed in monetary terms. All benefits and costs should be expressed in discounted present values. The benefit cost ratio takes into account the amount of monetary gain realised by implementing a project versus the amount it costs to implement the project. The higher the benefit cost ratio the better the investment.

8.1 Cost of mitigation options

The mitigation works i.e. the construction of levees, (as described in Section 6), were costed based on previous jobs undertaken by GHD and information presented in Rawlinsons Australian Australian Construction Handbook (2014). A summary of the capital cost estimates to cater for for the 1 in 100 AEP with and without freeboard and the 1 in 20 AEP mitigation options are shown in Table 21,

Table 22 and Table 23 respectively. A number of discussions were had with the NCCMA about what an appropriate cost for annual maintenance and vegetation management would be. For comparison purposes an annual cost of 1% of the construction costs was chosen. Details of the cost estimates are included in Appendix N.

Table 21 Mitigation Options Cost Estimate for 1 in 100 AEP level of protection with 600 mm freeboard

Mitigation Option	Cost Estimate		
	Capital	Maintenance	Total
Gingell Street	$875,000	$240,000	$1,115,000
Gingell Street North	$699,875	$192,000	$891,875
Castlemaine Central Cabin and Van Park	$293,000	$80,000	$373,000
Elizabeth Street	$478,000	$131,000	$609,000
Campbells Creek Township	$424,000	$116,000	$540,000
Total	**$2,769,875**	**$759,000**	**$3,528,875**

Table 22 Mitigation Options Cost Estimate for 1 in 100 AEP level of protection (no freeboard)

Mitigation Option	Cost Estimate		
	Capital	Maintenance	Total
Gingell Street	$709,000	$194,000	$903,000
Gingell Street North	$424,146	$116,000	$540,146
Castlemaine Central Cabin and Van Park	$233,000	$64,000	$297,000
Elizabeth Street	$256,000	$70,000	$326,000
Campbells Creek Township	$205,000	$56,000	$261,000
Total	**$1,827,146**	**$500,000**	**$2,327,146**

Table 23 Mitigation Options Cost Estimate for 1 in 20 AEP level of protection (no freeboard)

Mitigation Option	Cost Estimate		
	Capital	Maintenance	Total
Gingell Street	$571,000	$156,000	$727,000
Gingell Street North	$159,072	$44,000	$203,072
Castlemaine Central Cabin and Van Park	$163,000	$45,000	$208,000
Elizabeth Street	$125,000	$34,000	$159,000
Campbells Creek Township	$81,000	$22,000	$103,000
Total	**$1,099,072**	**$301,000**	**$1,400,072**

The cost estimates shown in Table 21,

Table 22 and Table 23 are estimates only. Actual prices, costs and other variables may be different to those used to prepare the cost estimates. GHD does not represent, warrant or guarantee that the works can or will be undertaken at a cost which is the same, more or less than the cost estimates.

8.2 Benefit cost analysis

The benefit cost ratios calculated for each mitigation option for the 1 in 100 AEP with and without freeboard and the 1 in 20 AEP are shown in Table 24, Table 25 and

Table 26 respectively. The benefit cost ratio is calculated by dividing the NPV of damages prevented by the mitigation works by the NPV of capital and maintenance works for the mitigation option (cost of mitigation). A benefit cost ratio greater than 1 indicates that the benefits of the works (flood damages avoided over the assets design life) outweigh the costs. As previously discussed with the adopted methodology in which the reduction in damages (the benefit) does not explicitly include intangible damages, benefit cost ratios of less than one can still be justified.

In addition to considering the construction of all the levees an analysis was also undertaken considering the construction of each of the levees individually.

Table 24 Benefit Cost Analysis for 1 in 100 AEP level of protection with 600 mm freeboard

Mitigation Option	NPV of damages	Cost of Mitigation	Benefit Cost Ratio
Gingell Street	$2,656,898	$1,115,000	2.4
Gingell Street North	$ 434,028	$891,875	0.5
Castlemaine Central Cabin and Van Park	$ 1,092,548	$373,000	2.9
Elizabeth Street	$ 489,244	$609,000	0.8
Campbells Creek Township	$837,291	$540,000	1.6
Total	**$5,510,010**	**$3,528,875**	**1.6**

Table 25 Benefit Cost Analysis for 1 in 100 AEP level of protection (no freeboard)

Mitigation Option	NPV of damages	Cost of Mitigation	Benefit Cost Ratio
Gingell Street	$2,656,898	$903,000	2.9
Gingell Street North	$434,028	$540,146	0.8
Castlemaine Central Cabin and Van Park	$1,092,548	$297,000	3.7
Elizabeth Street	$489,244	$326,000	1.5
Campbells Creek Township	$837,291	$261,000	3.2
Total	**$5,510,010**	**$2,327,146**	**2.4**

Table 26 Benefit Cost Analysis for 1 in 20 AEP level of protection (no freeboard)

Mitigation Option	NPV of damages	Cost of Mitigation	Benefit Cost Ratio
Gingell Street	$2,306,452	$727,000	3.2
Gingell Street North	$132,318	$203,072	0.7
Castlemaine Central Cabin and Van Park	$753,184	$208,000	3.6
Elizabeth Street	$150,594	$159,000	0.9
Campbells Creek Township	$297,873	$103,000	2.9
Total	**$3,640,422**	**$1,400,072**	**2.6**

From the results of the benefit cost analysis shown above the mitigation options as a total package (construction of all levees) has a good benefit cost ratio (greater than 1). Individually Gingell Street, Castlemaine Central Cabin and Van Park and Campbells Creek have very good benefit cost ratios. Elizabeth Street has a reasonable benefit cost ratio noting that the actual benefit cost ratio would be higher if intangible flood damages were considered. By itself the Gingell Street North levee, particularly to protect against a 1 in 100 AEP with 600 mm freeboard, has a relatively low benefit cost ratio.

9. Project consultation

9.1 Overview

A key element in the development of the Flood Management Plan for Castlemaine, Campbells Creek and Chewton was the engagement of the community in the study. This engagement was undertaken over the course of the study through several different means including community information sessions, a public questionnaire, media releases and meetings with the Technical Working Group and community based Steering Committee. Community consultation was managed by the NCCMA. The aims of the community consultation were as follows:

- To raise awareness of the study and to identify key community concerns.
- Provide an opportunity for the community to provide information they had on flood events.
- To provide information to the community and seek their feedback/input regarding the study including the existing flood behaviour and proposed mitigation options for the township.
- Communicate the feedback of community consultation activities and the final recommendations of the Flood Management Plan.

9.2 Steering Committee and Technical Woking Group

The development of the Flood Management Plan was supported by a community based Steering Committee (SC) and a Technical Working Group (TWG) throughout the project. The SC included seven (7) community members, willing to assist NCCMA and Mount Alexander Shire, who had observed or experienced first-hand the recent flooding that occurred, had valuable links to the community for engagement purposes and were generally interested in improving local flood resilience. The TWG consisted of representatives from NCCMA, Mount Alexander Shire, DELWP, VICSES, Parks Victoria, VicRoads, VicTrack and Coliban Water. Member of the TWG provided specific advice and information regarding local infrastructure and assets which had the potential to affect floodplain behaviour, and whose organisations may be affected by proposed mitigation options.

The following joint SC and TWG meetings were held:

- Meeting 1, 18 February 2013 – A general overview and discussion of the project goals.
- Meeting 2, 20 August 2013 – Presentation and discussion on the hydrological study and preliminary hydraulic modelling results.
- Meeting 3, 9 April 2014 – Presentation and discussion on the hydraulic modelling results and preliminary mitigation options.
- Meeting 4, 24 June 2014 – Presentation and discussion on the modelling results of detailed mitigation options.
- Meeting 5, 19 November 2014 – Presentation and review of the draft recommendations and the program for consultation to seek community feedback on the draft recommendations.
- Meeting 6, 4 May 2015 – Presentation and discussion of the feedback from the community on draft recommendations and determination of final recommendations of the Flood Management Plan.

9.3 Community consultation

A key aspect of community engagement is to provide information to the community and then to seek feedback. For the development of the Flood Management Plan community engagement processes were generally supported by media releases to local newspapers, paid public meeting notices or direct mailing of information or invitations to the community.

At all stages, the NCCMA led the public consultation activities, with the support of Mount Alexander Shire, the Steering Committee and technical input from GHD. The following is a list of the key community consultation activities that were undertaken:

- Public Meeting, 18 February 2013 – attended by approximately 100 people. The purpose of the meeting was to seek recent or historically observed flood information from the community to enable the project team to better understand flooding behaviour within Castlemaine, Campbells Creek and Chewton. This information was critical to inform the development of calibrated flood models for use in determining design flood extents (in accordance with the project brief) and for assessing potential mitigation options. The community was asked to provide their ideas for mitigating the impacts of flooding within the various communities. Areas identified at most risk of flooding included the Botanic Gardens and the area along Gingell Street through to the Camp Reserve and Forest Street, the Castlemaine Central Cabin and Van Park, and the Campbells Creek township. Urban storm water flooding was also highlighted as a concern to many residents but was communicated to be outside the scope of this Flood Management Plan (note: Mount Alexander Shire has undertaken a separate process to identify and address local storm water issues). This meeting was advertised via a letter to all households within the postal areas of Castlemaine, Campbells Creek and Chewton – over 4000 letters in total. The letter also included a questionnaire which community members could submit detailing their experiences of flooding, if they couldn't attend the meeting.
- The NCCMA Project Manager undertook numerous site meetings with individuals during the course of the project, seeking further flood behaviour information, mitigation ideas, information regarding flood warning services and the capacity to respond.
- Various round-table sessions during the Technical Working Group and Steering Committee meetings to capture the knowledge from local community members, Council staff and agency representatives.
- Delivery of a community consultation program on the draft recommendations. The consultation program consisted of:
  - Production of a public brochure to communicate the mitigation options which had been tested by the hydraulic model and to present the preferred mitigation options which were deemed to be the most cost effective and successful in improving flood resilience.
  - Media coverage of the release of the draft recommendations and advertising the availability of the public brochure, including paid public notices of the availability of information and upcoming public consultation opportunities.
  - Creation of a dedicated webpage on NCCMA's website providing background information on the draft Flood Management Plan and making available an electronic copy of the public brochure. An online mapping tool was also created to enable the community to view the flood mapping produced as part of the Flood Management Plan.
  - Direct mail-out of public brochure to affected residents, landowners and those adjacent to the three creeks – over 500 sent out in total. An additional 150 brochures were placed at local post offices for collection by interested residents.

  - Consultation sessions allowing community members one-on-one discussion with NCCMA staff on the proposed mitigation options, held on two separate days between 1 pm-8 pm at local community facilities – attended by approximately 50 participants.
  - Eighty nine (89) written submissions were received by NCCMA regarding the draft recommendations.
- Production of an additional public brochure to communicate the final recommendations of the Flood Management Plan based on the community feedback received.

The feedback received by the community on each mitigation option is discussed in Section 10.

10. Draft recommendations and community consultation

Based on the findings from the hydraulic modelling, joint meetings with the Technical working Group and the Steering Committee (referred to as the Committee) and ongoing dialogue with the community (refer to Section 9) a list of draft recommendations were produced to be presented to the community for further comment/consultation. This list represented what was considered the best available options to reduce flood risk with consideration of social, economic and environmental factors.

This section:

- Presents the draft recommendations presented to the community,
- Provides a summary of the community's response to each of the draft recommendations; and
- Documents the discussion by the Committee to determine the final recommendations.[1]

A consolidated list of the final recommendations is presented in Section 11.

Recommendation 1 – Gingell Street North Levee

The draft plan recommended the construction of a new flood protection levee at the northern end of Gingell Street to protect properties against the 1 in 100 (1%) AEP event, subject to detailed design and consultation with affected property owners and occupiers. The levee is required to prevent over-floor flooding of six properties, during a 1 in 100 (1%) AEP event.

Sixty-two responses were received regarding the above recommendation. Of these, 37% indicated support for the proposal whilst 63% indicated they did not support the proposal. Of the 62 responses on this option, 33 responses (53%) were received from residents who could be considered as local to the area (Gingell Street residents or immediate surrounding streets). Of these 33, 25 did not support the proposal (75%) and only 8 did support the proposal (25%). Only three of the 33 local responses (9%) were from residents likely to be affected by over-floor flooding in the area protected by this mitigation option.

Whilst a considerable number of local respondents indicated they didn't support the proposal as presented, the concept of flood protection for the affected dwellings appears to be supported and a large number of the concerns relate to what could be considered 'detailed design' matters.

[1] Note: Eighty-nine written responses were received from the community in total, however not all responses provided an indication of 'support' or 'don't support' on all options and in this case have been discounted from the figures provided on each option below.

Only a handful of responses indicated that they believed the levee wasn't required (2 responses), wouldn't prevent flooding (1) or that properties should protect themselves (1). The majority of responses were primarily concerned with visual and amenity impacts (20), vandalism (10), rubbish dumping (5) and accessibility in the vicinity of the new infrastructure (5). Each of these issues are common place in any urban environment. A number of responses noted that the length of the levee was extensive and that a reduced extent of the levee, along with changes to its visual appearance may be acceptable. In essence, it appears the community did not support the levee as proposed but would support working with Council to develop an acceptable alternative.

It is worth noting that the recent construction of colorbond fencing along the rear boundary of properties at the northern end of Gingell Street is in the same location as the proposed northern portion of the levee alignment. This fence is approximately 1.2 meters high and would be similar in height to the proposed levee.

In addition the low benefit-cost ratio of this option was listed as a concern by a number of the respondents (10). In deciding whether to pursue this mitigation option further, Council would need to decide whether it would accept the option as part of a greater, cost-effective 'Flood Mitigation Scheme' for Castlemaine. The extent of this levee could be reduced to retain access to Barkers Creek and address visual amenity concerns raised by the community. By reducing the extent of the levee this would reduce the cost to construct the levee and may improve the benefit cost ratio of the proposed levee.

Based on the feedback provided, the Committee resolved to revise the recommendation (refer to Section 11 for the updated recommendation).

Recommendation 2a – Gingell Street South Levee (1 metre)

The draft plan recommended the construction of a new one (1) meter high levee and associated storm water management works at the southern end of Gingell Street, subject to detailed design and consultation with affected property owners and occupiers. This would provide protection from a 1 in 20 AEP (5%) flood in Barkers Creek and improve local storm water flooding for events up to the 1 in 100 (1%) AEP flood. The levee is required to prevent over-floor flooding, during a 1 in 20 AEP event, of 3 dwellings, the Railway Hotel and football change rooms.

Sixty-one responses were received regarding the above recommendation. Of these, 38% indicated support for the proposal whilst 62% indicated they did not support the proposal. Of these 61 responses, 35 responses (57%) were received from residents who could be considered as local to the area (Gingell Street residents or immediate surrounding streets). Of these 35, 25 did not support the proposal (71%) and 10 did support the proposal (29%). Eight of the local responses (23%) were from residents likely to be directly affected by flooding in the area protected by this mitigation option.

Of the 8 properties that are directly affected by flooding who provided responses, 5 of these respondents supported the proposal. One supported the levee in combination with raising houses. Works to address storm water were also a theme from the submissions and have been previously raised many times verbally. The 3 who don't support the proposal indicated that they may support other proposals for flood mitigation.

Of significant concern to most respondents was the proposal of a concrete-wall type levee, the height of the levee and its visual impact compared to existing conditions along the creek. Discussion with residents indicated that this issue may not be able to be overcome but it may also be that the residents are negative towards the concrete wall as presented, and increased support for the levee could be given if the aesthetics of the levee could be resolved.

Numerous responses suggested that affected houses could be raised (10 responses) or temporary solutions be developed (i.e. sandbagging) – showing the thought given towards developing alternatives and therefore support for some form of flood mitigation. These alternatives are strongly driven by concerns for visual amenity (17), the potential for graffiti (13) and reduced accessibility (8) due to the construction of a levee.

A number of respondents (7) indicated that the storm water flooding was of equal or greater concern and needs to be addressed first or in conjunction with flood mitigation of the riverine flows. Whilst the hydraulic modelling considered this in developing the mitigation options, consultation activities seemingly didn't provide enough detail around the proposed upgrades of the storm water system to alleviate community concern. The flood plan provides solutions for these issues and can be clearly articulated in future consultation during detailed design. Addressing storm water flooding could be a stand-alone mitigation option in the absence of acceptable options which prevent riverine flooding.

In summary, the primary issues of concerns, from the community, for this levee were around visual amenity, vandalism, graffiti, accessibility to the creek and connectivity to the railway station and Central Business District (CBD). Alternative options were suggested by the community such as raising houses, constructing temporary flood walls or undertaking sandbagging during flood events. These suggestions provide support for mitigation options to alleviate flooding within this area. However, any option will require careful consideration of community values and need to be undertaken in consultation with the community to develop an acceptable option.

Based on the feedback provided, the Committee resolved to revise the recommendation (refer to Section 11 for the updated recommendation).

Recommendation 2b – Gingell Street South Levee (2.1 metres)

The draft plan recommended the construction of a new 2.1 meter high flood protection levee and associated storm water management works at the southern end of Gingell St, subject to detailed design and consultation with affected property owners and occupiers. This levee would provide protection from a 1 in 100 (1%) AEP flood in Barkers Creek and improve existing conditions during a 1 in 100 (1%) AEP flood from local storm water. The levee is required to prevent over-floor flooding to eight private properties and the Railway Hotel.

Sixty responses were received regarding the above recommendation. Of these, 15% indicated support for the proposal whilst 85% indicated they did not support the proposal. Of these 60 responses, 35 responses (57%) were received from residents who could be considered as local to the area (Gingell Street residents or immediate surrounding streets). Of these 35, 32 did not support the proposal (91%) and 3 did support the proposal (9%). Eight of these responses (23%) were from residents likely to be directly affected by flooding in the area protected by this mitigation option. Only one (1) respondent supported the proposal that would directly benefit from its implementation. From discussions with the one landowner, it appears they have provided their support fearing the absence of any other mitigation options and would be open to the consideration of other ideas in consultation with other local residents.

Of significant concern to most respondents was the proposal of a concrete-wall type levee, the height of the levee and its visual impact compared to existing conditions along the creek interface. The height of this levee (2.1 meters) appears to be a significant barrier to overcoming these concerns. A number of responses (3) indicated that they could not support this levee under any circumstances and the underlying tone of many of the responses suggests this way of thinking is commonly shared, even though it was not stated directly.

Numerous responses suggested that affected houses could be raised or temporary solutions be developed – showing the thought given towards developing alternatives and therefore support for some form of flood mitigation. These alternatives are strongly driven by concerns for visual amenity, the potential for graffiti and reduced accessibility.

As with recommendation 2a a number of respondents indicated that the storm water flooding was of equal or greater concern and needs to be addressed first or in conjunction with flood mitigation of the riverine flows.

In summary, the construction of this levee appears completely unacceptable to the community. The primary issues for this levee were concerns for visual amenity, concerns for vandalism and graffiti, and concerns regarding accessibility to the creek and connectivity to the railway station and CBD.

Based on the feedback provided, the Committee decided to abandon the option in favor of the proposed course of action listed under Recommendation 2a (refer to Section 11 for the updated recommendation).

Recommendation 3 – Castlemaine Central Cabin and Van Park and Bruce Street Levee

The draft plan recommended the construction of a new flood protection levee adjacent to the Castlemaine Central Cabin and Van Park to protect the park and properties in Bruce St against the 1 in 100 (1%) AEP event, subject to detailed design and consultation with affected property owners and occupiers. The levee is required to protect 14 properties from flooding, including over-floor flooding to 3 dwellings, 3 commercial buildings and 26 cabins within the Cabin and Van Park during a 1 in 100 (1%) AEP event.

Unlike the other levees proposed as part of this plan, this levee is not in an area of high pedestrian traffic and it does not form part of the connecting trails along the creeks of Castlemaine. The landowners and residents most affected by this mitigation option are the ones who are likely to have the most benefit from its construction. All responses were considered in determining a final recommendation but greater emphasis was placed on those who would be affected by it visually and those who benefit from it in terms of flood risk reduction.

Of the 55 responses received to this mitigation option, only 4 were from people that are directly affected by the implementation of this option. Three of those provided support for the option and one indicated that they would support flood mitigation, although suggest that cleaning out the creek would achieve the desired outcome (investigation of this option indicates that cleaning out of the creek will not achieve the desired outcome, refer to Section 5). The current manager of the Castlemaine Central Cabin and Van Park has also indicated support for the construction of a levee in this location, subject to detailed design considerations and consultation with local residents.

Of the total 55 responses, 38 (69%) indicated support for the proposal and 17 (31%) did not support the proposal. Of the total 17 respondents who don't support the proposal, none were considered local to the area or directly affected by the construction of the levee. And 11 of the 17 respondents who did not support the levee offered no comments as to why. Those 6 who did comment stated concerns around visual amenity, vandalism, rubbish dumping and community safety. An alternative suggestion of raising houses was also stated. Of these 6 respondents, the nearest respondent's property is a minimum of 230 meters from the nearest point of the levee and separated by Barkers Creek and its environs as well as the Bendigo-Melbourne railway line embankment – which stands over 7 meters vertical height above the surrounding natural surface level. As stated earlier, this area is not connected to the wider community by Castlemaine's walking trails and therefore it is hard to consider how the construction of a levee at this location would affect the aesthetics of those respondents who currently oppose it. Any detrimental effects of this levee are likely to be felt within local proximity to the levee but may be offset by the benefits provided, and through the development of an aesthetically pleasing design.

A number of respondents indicated that the storm water flooding was also of concern for this area and needs to be addressed in conjunction with the development of any flood protection levee.

As noted above, this levee protects the Castlemaine Central Cabin and Van Park, including 26 cabins as well as 14 neighboring properties in Bruce and Barker Streets. It must be noted that only 4 of the 55 responses were received by those the levee would protect and all 4 of those respondents support the construction of a levee (or flood mitigation in general), as well as verbal approval received from the current manager of the Cabin and Van Park.

Based on the feedback outlined above the Committee resolved to support moving forward with a levee proposal, subject to detailed design and costing, consideration of storm water, and further consultation with all affected landowners and residents to seek support by those most affected (refer to Section 11 for the final recommendation).

Recommendation 4 – Elizabeth Street (Castlemaine) Levee

The draft plan recommended raising and extending the existing flood protection levee behind properties along Elizabeth Street (from the Pyrenees Highway to the railway line), subject to detailed design and consultation with affected property owners and occupiers, to provide protection to properties from a 1 in 100 (1%) AEP flood. The upgraded levee is required to protect 13 properties from flooding, including 11 properties from over-floor flooding during a 1 in 100 AEP event.

Fifty-four responses were received regarding this mitigation option, with 36 (67%) supporting the proposal and 18 (33%) being opposed. Of the 54 responses, only 8 were received from people that are directly affected by flooding in this area. Six of the 8 affected by flooding provided support for the option and comments from the other two indicated support for the idea of flood protection with some concerns about the proposed levee.

All other responses against the recommendation were by residents that do not benefit directly from the option. Of those who provided comments, two responses refer to the levee not being cost-effective, two responses inadvertently commented on the wrong proposal (and should be discounted), and two respondents didn't support the levee but added qualifying statements that if it was more aesthetically pleasing then they could tolerate the levee up to a maximum height. An alternative suggestion of raising houses was also stated. Most respondents provided no reasons for objection to the proposal.

In its determination of a final recommendation, the Committee also considered that the current levee is not owned or formally managed by any authority. Therefore the actual damage costs associated with flood events will increase over time unless the levee is upgraded or replaced. Therefore, the 'do-nothing' option at this location will have a greater impact on local properties in the future than under existing conditions and should be considered when deciding upon future actions. In deciding whether to pursue this option further, Council would need to decide whether it would accept the option as part of a greater, cost-effective 'Flood Mitigation Scheme' for Castlemaine. Storm water management behind the levee was also raised by the Committee in line with previous comments regarding levee options and should be considered in future designs.

Based on the feedback outlined above the Committee resolved to support moving forward with a levee proposal, subject to detailed design and costing as well as further consultation with all affected landowners and residents to seek support by those most affected by the option (refer to Section 11 for the final recommendation).

Recommendation 5 – Campbells Creek Township Levee

The draft plan recommended the raising and extending of the existing levee on the eastern bank of Campbells Creek to protect the township and private properties from a 1 in 100 (1%) AEP event, subject to detailed design and consultation with affected property owners and local residents. This levee is required to protect 30 properties from flooding from Campbells Creek, including 15 buildings from over-floor flooding during a 1 in 100 AEP event.

Forty-seven responses were received to this mitigation option, with 36 (77%) supporting the proposal and 11 (23%) being opposed. Of the 47 responses, only 4 were received from people that are directly affected by flooding relative to this mitigation option. All 4 provided support for the option provided adverse effects could be managed.

Of the total 11 respondents who don't support the proposal, none were directly affected by flooding and none were local to Campbells Creek. Nine of the respondents were by residents identifying themselves as from Castlemaine and provided no supporting comments or significant reasons for their opposition, making it hard to understand why they don't support the option, especially given this option is considered cost-effective. These respondents provided general commentary against the other options that levees are not necessary, won't work or shouldn't be provided by local government (rate payers) that could provide an indication for their opposition. Two respondents were from unidentified locations and did not provide comments. The alternative of raising houses was again suggested.

In its determination of a final recommendation, the Committee also considered that the current levee is not owned or formally managed by any authority. Therefore the actual costs associated with flood events will increase over time unless the levee is upgraded or replaced. Therefore, the 'do-nothing' option at this location will have a greater impact on Campbells Creek in the future than under existing conditions and should be considered when deciding upon future actions.

Based on the feedback outlined above and the fact that no significant grounds for objection were raised, the Committee resolved to support moving forward with a levee proposal, subject to detailed design and costing as well as further consultation with all affected landowners and residents to seek support by those most affected. In an initial oversight by the Committee, three additional properties on the eastern side of Campbells Creek, downstream of the Alexandra Street Bridge were omitted from protection by the levee but they should be considered in future designs – this is recognised in the updated final recommendation to include all properties on the east side of Campbells Creek (refer to Section 11 for the final recommendation).

Recommendation 6 – National School Lane Levee

The draft plan recommended that repair and improvement works be undertaken on the existing levee on the east bank of Campbells Creek in the vicinity of National School Lane. The works are aimed at reducing the risk of future avulsion of Campbells Creek and reducing peak flood velocities behind the levee. The works are subject to appropriate permits being obtained and are to be undertaken in consultation with any affected landowner.

These works have been championed by community members in the vicinity of the levee believing that the works will reduce flood velocities and the risk of avulsion of Campbells Creek during major flood events. No significant adverse impacts were evident as a result of simulating the repair and improvement works in the hydraulic model.

Of the 43 responses to this mitigation option, 30 respondents (70%) supported the option whilst 13 (30%) opposed it. Of these 13 who opposed the option, only 2 respondents provided comments. Both respondents stated that they could not see the benefits of the option. One respondent added concern about the removal of vegetation from the levee, citing a reduction in habitat and that it will reduce water quality. The current best practice for levee management would encourage the removal of vegetation from the levee to maintain the integrity of the levee. No vegetation is proposed to be removed unnecessarily. Both respondents were not considered local to the mitigation option and none of the 13 who oppose the repair and improvement is expected to benefit from it.

Based on the feedback outlined above, the Committee decided to adopt the draft recommendation as presented to the community. The detailed scope of works will be resolved between local landholders based on advice from Council and North Central CMA (refer to Section 11 for the final recommendation).

Recommendation 7 – Campbells Creek Improvement Works

The draft plan recommended minor waterway improvement works downstream of the Alexandra Street Bridge in Campbells Creek to improve conveyance of Campbells Creek and lower flood levels in the vicinity of the Alexandra Street bridge crossing.

These works were another community raised issue that was modelled and shown to have a positive impact (lowering) on local flood levels and benefits in conjunction with Recommendation 5 (Campbells Creek Township levee). The proposed works include the removal of native saplings that have developed in the middle of Campbells Creek due to the build-up of sediment that has occurred since the recent floods. Their existence is considered undesirable from a flood management perspective but also from a river health perspective, forcing the waterway to move in an easterly direction towards the rear boundary of private properties and increasing the potential for the avulsion of the river.

Of the 42 who responded to this recommendation, 32 (76%) supported the proposal whilst 10 (24%) opposed it. Of the 10 who opposed the option, only one respondent provided a comment that they were not supportive of removing native vegetation from the creeks due to the resulting reduction in habitat and the potential for decline in water quality. In addition, none of these respondents identified themselves as being local to the mitigation option.

For this options it is worth noting that there is a strong representation of community members opposed to removing native vegetation from the local creeks and in fact working very hard to restore the creeks to their “pre-gold rush era” natural state (or as close as possible). The Committee acknowledged this community and used the hydraulic model to demonstrate that whilst vegetation can have a minor localized impact on flood levels, the size of rainfall event, the local waterway and the location of the development in the floodplain have a much larger impact on flood impacts. In other words removing vegetation from waterways will not solve the flooding problem. However, in this instance, a substantial amount of growth has occurred in this area and the hydraulic model demonstrates that these saplings and silt are acting as a blockage to Campbells Creek and are likely forcing the waterway to move towards the rear boundary of private properties that requires short-term intervention.

This recommendation is not strongly opposed and the benefits of doing it are multi-faceted in terms of lowering flood levels by clearing a blockage and through reducing the risk of erosion into private properties within an urban area. As an aside the Council or CMA’s are enabled by legislation to remove vegetation that is proved to be hazardous.

Opposition to the proposal shouldn’t be entirely discounted, but the lack of information provided as to why some oppose this option makes it difficult to understand why they oppose it.

It is also worth noting that no submissions were received from the properties immediately adjacent to the location of the proposed works. This is of some concern given the substantial size Elm trees which exist on their rear property boundaries that no doubt are valuable for amenity and afternoon shade during the summer. The Elm trees do however contribute to the erosion problem, through shading the area and limiting the growth of erosion-preventing ground-cover grasses and other species and the Elms would therefore need to be removed to gain the full benefit of works at this location.

One landowner did attend the Campbells Creek consultation session but did not provide a subsequent written submission. They verbally indicated that whilst the Elm trees are aesthetically valuable, they were replaceable and that their primary concern was being inundated by flooding. They also suggested the levee be extended downstream of the Alexandra St Bridge to protect the few properties downstream of the bridge from flooding. This would definitely require the removal of the Elm trees. Further discussion on all these matters is required with local landowners and occupiers.

Based on the feedback outlined above, the Committee resolved to adopt a slightly amended version of the draft recommendation which acknowledges the need for further community consultation on detailed design matters, including consideration of an extension of the Campbells Creek township levee and the removal of the Elm trees. The final detailed scope of works will be resolved between local landholders and based on advice from Council and North Central CMA (refer to Section 11 for the final recommendation).

Recommendation 8 – Strategic Planning for Urban Waterways

The draft plan recommended that Mount Alexander Shire Council lead the development of a strategic plan for the urban waterways within Castlemaine, Campbells Creek and Chewton which includes, but is not limited to, the learnings of the Flood Management Plan. This recommendation describes the need for (and lends support on flooding grounds to) an overarching strategic plan to assist the planning, management and improvement of urban waterways within Castlemaine, Campbells Creek and Chewton. The development of a strategic plan is supported by feedback from the community who wish to resolve uncertainties around management responsibilities and long-term planning within the creek corridors.

This recommendation received the second highest level of support of all the recommendations presented in the draft plan. There were 56 response to this recommendation, with 51 (91%) supporting the development of a strategic plan for urban waterways and only 5 (9%) that indicated they did not support a strategic plan. Three of those respondents opposed all recommendations of the draft plan.

Given the high level of support the Committee resolved to adopt the draft recommendation as presented to the community (refer to Section 11 for the final recommendation).

Recommendation 9 – Flood Warning

The draft plan recommended the development of a flood-warning system for Barkers Creek, Forest Creek and Campbells Creek based on the learnings of the Flood Management Plan. The recommendation recognises the community's desire for advanced warning of the potential for future flood events to assist them to prepare for, respond to and recover from such events. Section 6.9.2 outlines the current situation in regards to flood warning for the three creeks. In general, a total flood warning system should include building community understanding of the potential for flooding in the three creeks, providing early warning signals that a flood event might occur and documenting a list of actions that are required to facilitate a community response when a flood event is imminent.

There were 52 responses to this recommendation, with 49 (94%) responses supporting the development of a flood warning system and only 3 (6%) opposed to it. Most responses that supported the proposal did so without any additional comments. Those who did comment stated that the development of a flood warning system is a good idea, that information prior to the recent flood events was insufficient and that an emergency service call or text would have assisted them to respond better to the impending flood.

The high level of support as well as the minimal comments provided on this recommendation persuaded the Committee to adopt the recommendation as presented in the draft plan (refer to Section 11 for the final recommendation).

Recommendation 10 – Planning Scheme Amendment

The draft plan recommended an amendment to the Mount Alexander Planning Scheme to incorporate new flood mapping produced by the plan to identify flood hazard when considering future land use and development.

There were 49 responses to this recommendation, with 42 (86%) indicating support for an amendment to the Mount Alexander Planning Scheme and only 7 (14%) opposed to it. Most responses that supported the proposal did so without any additional comments. Of the 7 who opposed it, 3 opposed all recommendations in the plan, 2 would not have an overlay applied to their property making it hard to understand the objection, 1 cited the inaccuracy of the existing overlays as a concern and that further research was needed (perhaps not understanding that this study is that research), and only 1 respondent opposed the recommendation who would actually have an overlay applied to their property and is concerned by any potential ramifications.

The recommendation received widespread support and those who did not support this recommendation provided no justification as to why they opposed the recommendation. The high level of support as well as the minimal comments provided on this recommendation persuaded the Committee to adopt the recommendation as presented in the draft plan (refer to Section 11 for the final recommendation).

11. Final recommendations

The Castlemaine, Campbells Creek and Chewton Flood Management Plan has been guided by the Steering Committee (SC) with support from the Technical Working Group (TWG) along with information gathered during community consultation.

The Committee agreed to present the following final recommendations to Mount Alexander Shire Council and the community as the best options for detailed design and implementation to reduce flood risk within Castlemaine, Campbells Creek and Chewton.

It was agreed that some options require further community consultation beyond the scope of this project.

This list of recommendations should be read in conjunction with the technical details, maps and images provided in this report.

Recommendation 1 - Gingell Street North Levee

1a. That Council investigates further the construction of a levee to protect residents from a 1 in 100 (1%) AEP event. The location and detailed design parameters should be agreed on in collaboration with landowners and local residents. The extent of the levee should be reduced from the draft proposal to retain access to Barkers Creek and help address aesthetic concerns raised by the community. Council's investigation should determine if a reduction in the extent of the levee would provide a cost-effective proposal compared to the draft proposal.

1b. That Council, in the absence of an acceptable levee proposal, further investigates alternative flood mitigation measures for this area, in collaboration with landowners and local residents.

Recommendation 2 - Gingell Street South Levee

2a. That Council,

- i. Investigates further the construction of a levee to protect residents from a 1 in 20 (5%) AEP event. The location and detailed design parameters should be agreed on in collaboration with landowners and local residents. Further investigation should include consultation on the appearance of the levee, access to Barkers Creek, retention of access to the train station and the Central Business District to alleviate concerns raised by the community.
- ii. In the absence of an acceptable levee proposal, further investigates alternative flood mitigation measures for this area, in collaboration with landowners and local residents.

2b. That Council undertakes detailed design and costing of options which reduce the impacts of local storm water flooding at the southern end of Gingell Street. Council should consider storm water upgrades in association with the construction of a levee, however, in the absence of an acceptable levee option, measures which reduce the impacts of local storm water should be considered for construction in their own right.

Recommendation 3 – Castlemaine Central Cabin and Van Park and Bruce Street Levee

The construction of a levee adjacent to the Castlemaine Central Cabin and Van Park to protect the park and properties in Bruce St from flooding up to and including a 1 in 100 (1%) AEP event. The location and detailed design parameters should be agreed on in collaboration with affected property owners and local residents. The design of the levee should consider the impacts on local storm water with the levee in place and how to minimise or reduce those impacts.

Recommendation 4 – Elizabeth Street Levee

That Council further investigates the raising and extending of the existing levee behind properties along Elizabeth Street (from the Pyrenees Highway to the railway line), to protect properties from flooding up to and including a 1 in 100 (1%) AEP event. The detailed design parameters should be agreed on in collaboration with affected property owners and local residents. The design of the levee should consider the impacts on local storm water with the levee in place and how to minimise or reduce those impacts.

Recommendation 5 – Campbells Creek Township Levee

The Flood Management Plan recommends the raising and extending of the existing levee on the eastern bank of Campbells Creek to protect the township and private properties from a 1 in 100 (1%) AEP event. The detailed design parameters should be agreed on in consultation with affected property owners and local residents. The design of the levee should consider the impacts on local storm water with the levee in place and how to minimise or reduce those impacts.

Recommendation 6 – National School Lane Levee

The Flood Management Plan recommends repair and improvement works be undertaken on the existing levee on the east bank of Campbells Creek in the vicinity of National School Lane. The works are aimed at reducing the risk of future avulsion of Campbells Creek and reducing peak flood velocities behind the levee. The works are subject to appropriate permits being obtained and are to be undertaken in consultation with any affected landowner.

Recommendation 7 – Campbells Creek Improvement Works

The Flood Management Plan recommends minor waterway improvement works downstream of the Alexandra St Bridge in Campbells Creek to improve conveyance of Campbells Creek and lower flood levels in the vicinity of the Alexandra St bridge crossing. The works would be subject to detailed design and consultation with affected property owners and occupiers about the removal of the Elm trees.

Recommendation 8 – Strategic Planning for Urban Waterways

The Flood Management Plan recommends that Mount Alexander Shire Council lead the development of a strategic plan for urban waterways within Castlemaine, Campbells Creek and Chewton which includes, but is not limited to, the learnings of the Flood Management Plan.

Recommendation 9 – Flood Warning

The Flood Management Plan recommends the development of a flood-warning system for Barkers Creek, Forest Creek and Campbells Creek based on the learnings of the Flood Management Plan.

Recommendation 10 – Planning Scheme Amendment

The Flood Management Plan recommends an amendment to the Mount Alexander Planning Scheme to incorporate new flood mapping produced by the Flood Management Plan.

12. References

Agricultural and Resources Management Council of Australia and New Zealand, Standing Committee on Agriculture and Resource Management Report No. 73 “Floodplain Management in Australia, Best Practice Principles and Guidelines”, 2000

CSIRO, “Floodplain Management in Australia”, 2000

Department of Environment and Climate Change, “Floodplain Risk Management Guidelines”, 2007

Department of Natural Resources and Environment, “Rapid Appraisal Method (RAM) for Floodplain Management”, 2000

Department of Natural Resources and Environment, “Advisory Notes for Delineating Floodways”, 1998

Emergency Management Australia, “Disaster Loss Assessment Guidelines”, 2002

Institute of Engineers, “Australian Rainfall and Runoff, A Guide to Runoff Estimation”,

Rawlinsons, “Australian Construction Handbook”, 2012

Victorian Flood Warning Consultative Committee, “Arrangement for Flood Warning Services in Victoria”, 2001

Appendices

Appendix A – Survey Flood Levels

January 2011

February 2012

APPROVED PLAN

REV.	REVISION	DATE
A	AS SUBMITTED TO CLIENT	11/02/11

Tomkinson Group
PROJECT MANAGERS · DEVELOPMENT PLANNERS
LICENSED SURVEYORS · CIVIL ENGINEERS
FREECALL: 1800 810 170 TEL: (03) 5445 8700 FAX: (03) 5441 3648
PO BOX 421, BENDIGO 3552 57 MYERS STREET, BENDIGO 3550
WEB: www.tomkinson.com EMAIL: bendigo@tomkinson.com
BSI ISO 9001 FS520488

DRAWING APPROVED BY: KGH
Date: 11/02/11

Surveyed	Drawn	Checked
JI/KGH	JI	KGH
20/01/11	11/02/11	11/02/11

Principal: North Central Catchment Management Authority

SCALE 1:20,000 (A3)
200 0 200 400 600 800 1000
LENGTHS ARE IN METRES

Castlemaine Township

Castlemaine

Flood Level Survey

Municipality: SHIRE OF MOUNT ALEXANDER

Sheet 1 of 1

Drawing No. 1024802 CAS LEV

Revision A

NOTE: THIS PLAN IS AN UNCONTROLLED DOCUMENT AND WILL NOT BE UPDATED. IT IS THE RESPONSIBILITY OF THE USER TO CONFIRM THAT THIS IS A CURRENT COPY AND SUITABLE FOR THE PROPOSED USE - THIS SHEET MUST BE READ IN CONJUNCTION WITH ALL SHEETS OF THIS SET AND ANY ACCOMPANYING DOCUMENTS

Notations

Coordinates are MGA 94
Levels are to A.H.D.

NCCMA
Castlemaine Flood Study
February 2012

Scale A3	25 0 25 50 75	
1 : 2500	Lengths are in metres	
Co-ordinate Datum MGA94	Sheet 1 of 6	
Drawing No. 137678FS00-ACAD	Version 1	
CAD Ref. F:\13\137678\137678GS00		
Drawn By PM	Checked By SF	Date 15/03/2012

REV	AMENDMENT	APPROVED	DATE

CPG
16 Bridge Street
PO Box 1064
Bendigo Vic 3550
T 61 3 5448 2500
F 61 3 5448 2599
cpg-global.com

Notations

Coordinates are MGA 94
Levels are to A.H.D.

NCCMA
Castlemaine Flood Study
February 2012

Scale A3
1 : 2500

25 0 25 50 75
Lengths are in metres

Co-ordinate Datum MGA94	Sheet 2 of 6		
Drawing No. 137678FS00-ACAD		Version 1	
CAD Ref. F:\13\137678\137678GS00			
Drawn By PM	Checked By SF	Date 15/03/2012	
REV	AMENDMENT	APPROVED	DATE

CPG
16 Bridge Street
PO Box 1064
Bendigo Vic 3550
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F 61 3 5448 2599
cpg-global.com

Notations

Coordinates are MGA 94
Levels are to A.H.D.

NCCMA
Castlemaine Flood Study
February 2012

Scale A3
1 : 2500

25 0 25 50 75
Lengths are in metres

Co-ordinate Datum MGA94 Sheet 3 of 6
Drawing No. 137678FS00-ACAD Version 1
CAD Ref. F:\13\137678\137678GS00
Drawn By PM Checked By SF Date 15/03/2012

REV	AMENDMENT	APPROVED	DATE

CPG
16 Bridge Street
PO Box 1064
Bendigo Vic 3550
T 61 3 5448 2500
F 61 3 5448 2599
cpg-global.com

Notations

Coordinates are MGA 94
Levels are to A.H.D.

NCCMA
Castlemaine Flood Study
February 2012

Scale A3
1 : 2500

25 0 25 50 75
Lengths are in metres

Co-ordinate Datum MGA94 Sheet 4 of 6
Drawing No. 13767BFS00-ACAD Version 1
CAD Ref. F:\13\13767\B13767GS00
Drawn By PM Checked By SF Date 15/03/2012

REV	AMENDMENT	APPROVED	DATE

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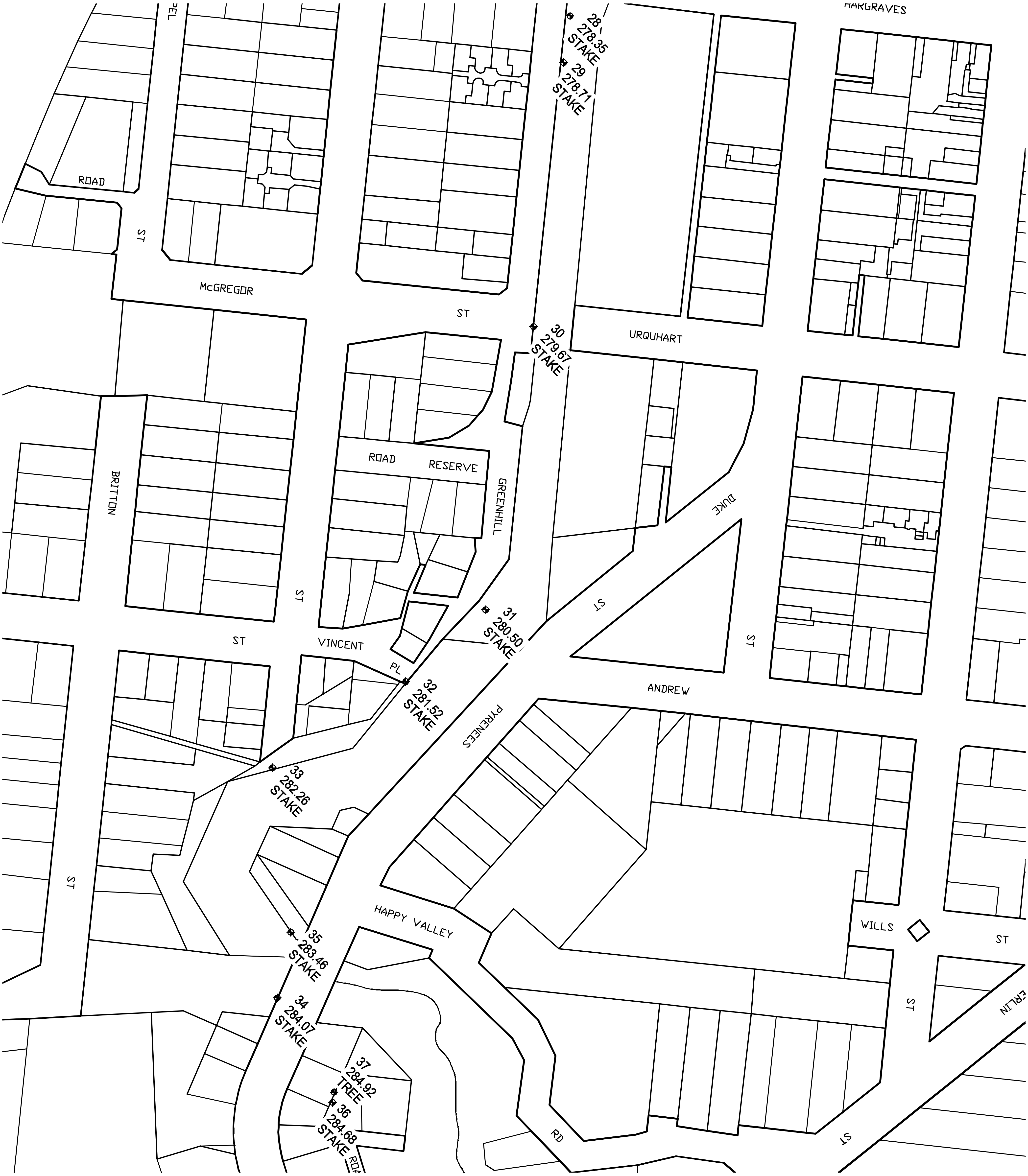
CPG
16 Bridge Street
PO Box 1064
Bendigo Vic 3550
T 61 3 5448 2500
F 61 3 5448 2599
cpg-global.com



Notations

Coordinates are MGA 94
Levels are to A.H.D.

NCCMA
Castlemaine Flood Study
February 2012

Scale A3
1 : 2500

25 0 25 50 75
Lengths are in metres

Co-ordinate Datum MGA94 | Sheet 5 of 6
Drawing No. 13767FS00-ACAD | Version 1
CAD Ref. F:\13\13767\13767GS00
Drawn By PM | Checked By SF | Date 15/03/2012

REV	AMENDMENT	APPROVED	DATE

CPG
16 Bridge Street
PO Box 1064
Bendigo Vic 3550
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F 61 3 5448 2599
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Notations

Coordinates are MGA 94
Levels are to A.H.D.

NCCMA
Castlemaine Flood Study
February 2012

Scale A3 1 : 2500	25 0 25 50 75 Lengths are in metres
Co-ordinate Datum MGA94	Sheet 6 of 6
Drawing No. 137678FS00-ACAD	Version 1
CAD Ref. F:\13\137678\137678GS00	
Drawn By PM / Checked By SF	Date 15/03/2012

REV	AMENDMENT	APPROVED	DATE

CPG
16 Bridge Street
PO Box 1064
Bendigo Vic 3550
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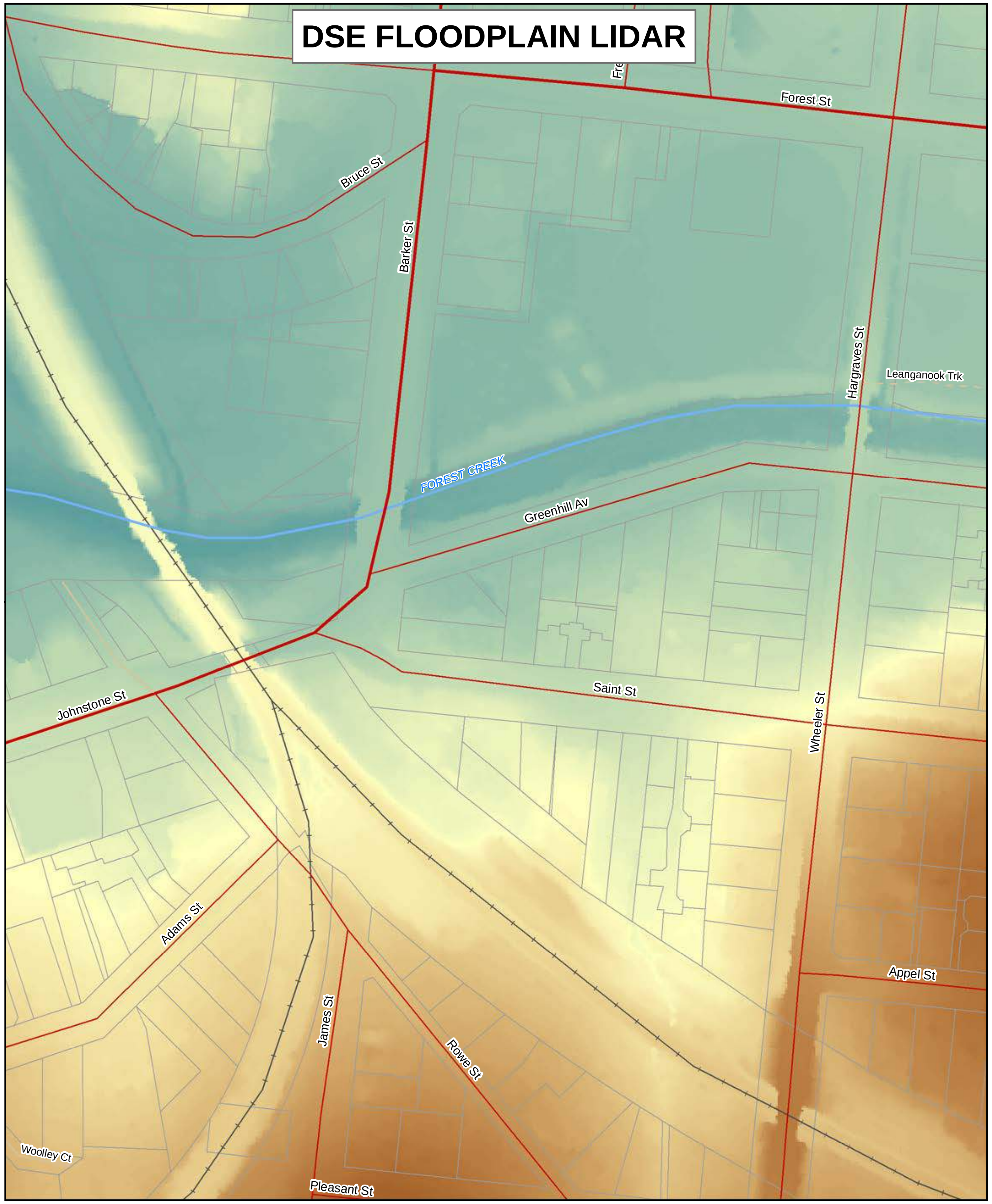
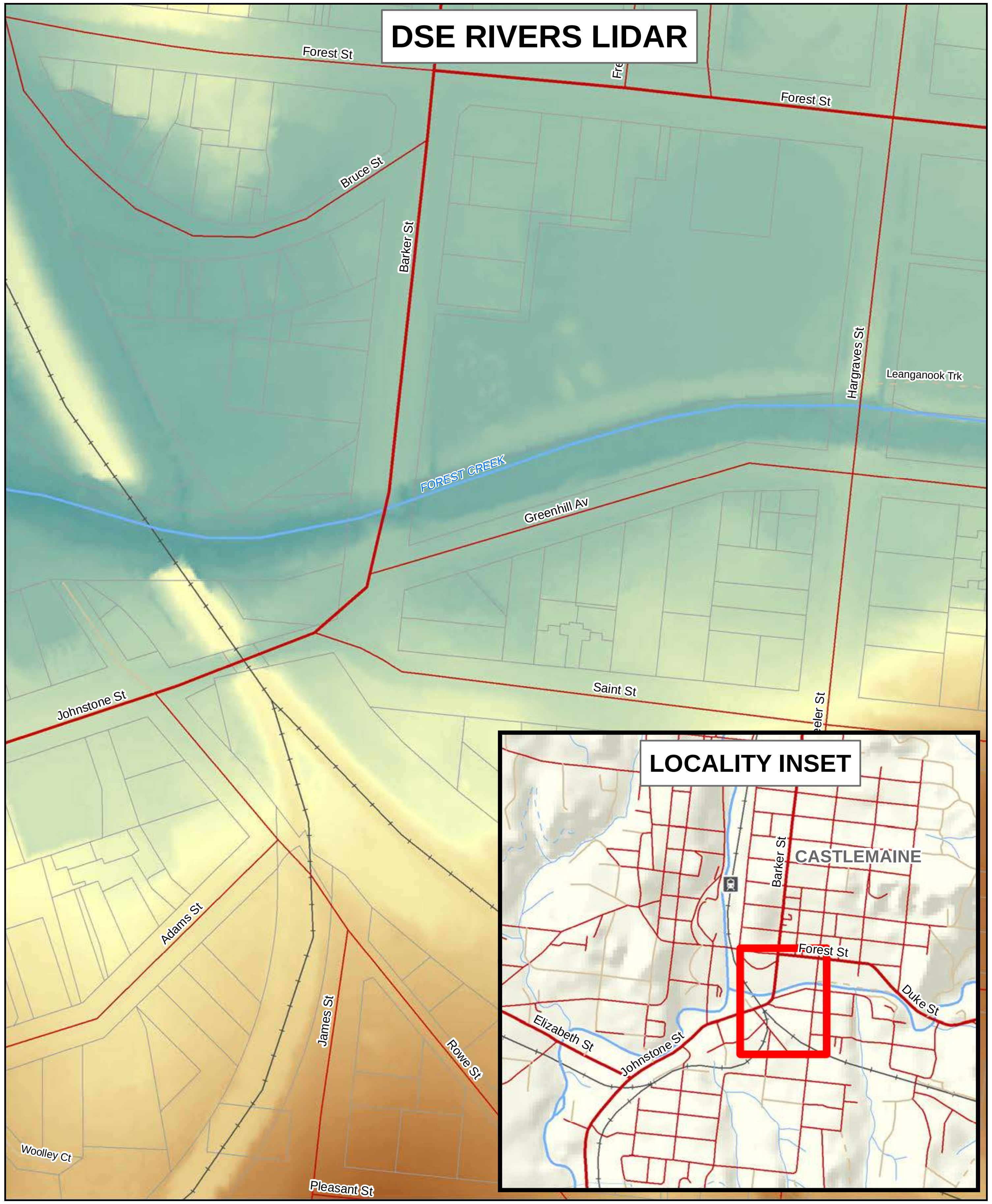
Appendix B – DEM Comparison





1:2,500 (at A3)

0 12.5 25 50 75 100

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 55

N

Legend

- Highway
- Sealed road (arterial and local)
- Unsealed road
- Track and bike path
- Rail
- River
- Parcel

Elevation (mAHD)

High : 300

Low : 270

North Central CMA
Castlemaine, Campbells Creek and Chewton
Flood Management Plan

Job Number	31-29991
Revision	A
Date	14 Aug 2013

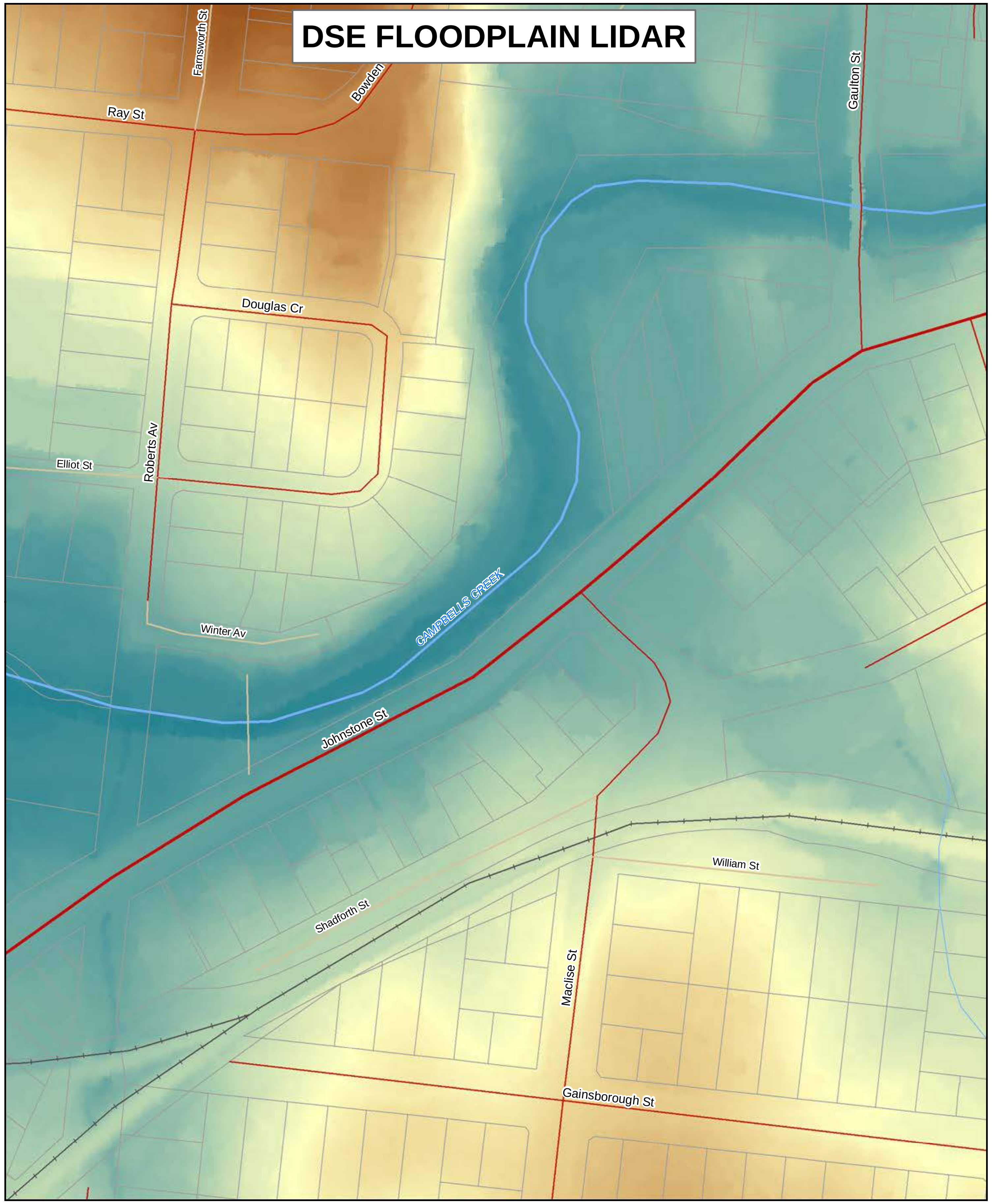
LIDAR Comparison

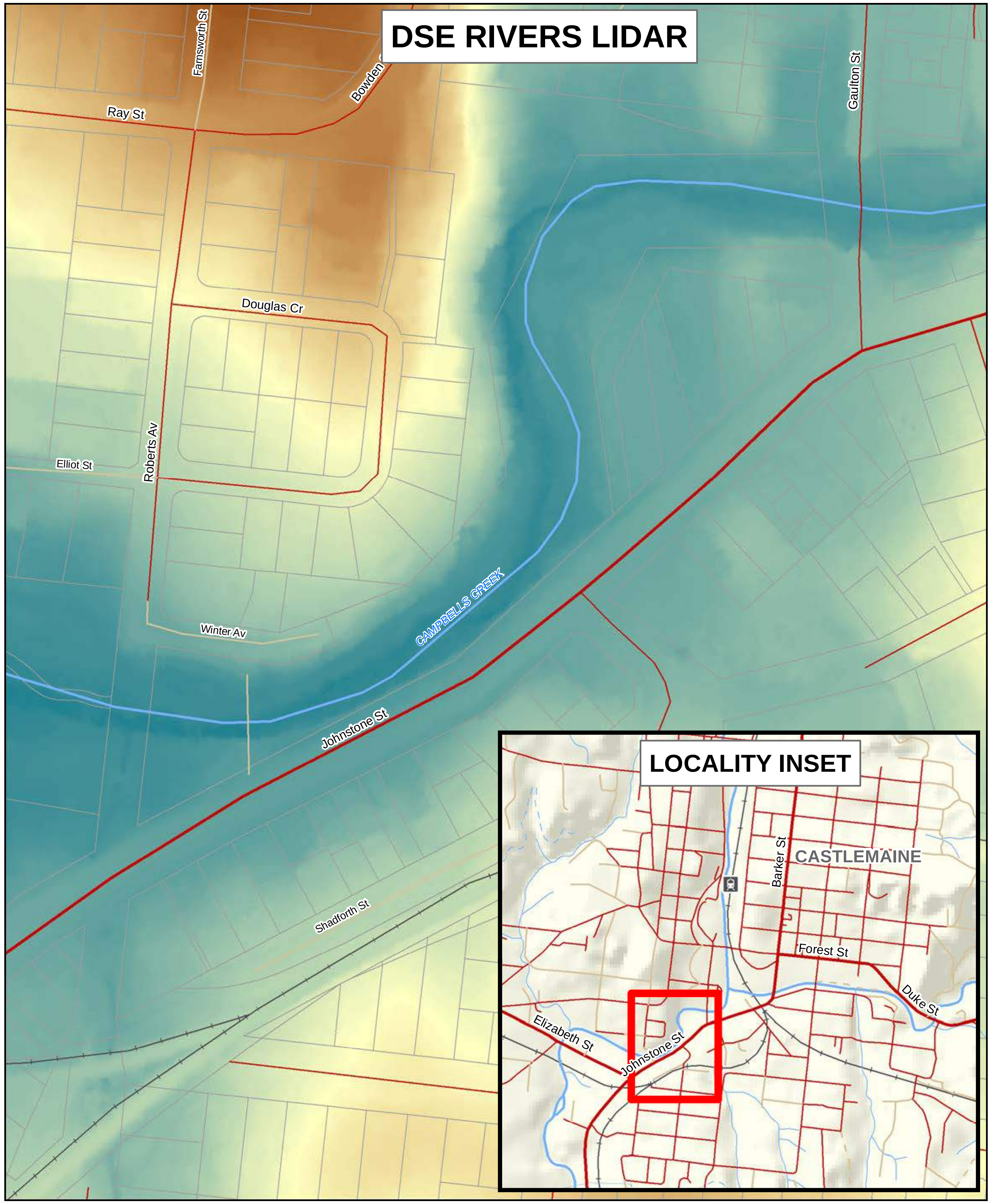
Appendix B1

G:\31\29991\GIS\Maps\Deliverables\Appendix B- LIDAR Comparison.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2013; DSE, LIDAR, 2013. Created by:scowan





1:2,500 (at A3)

0 12.5 25 50 75 100

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 55

N

Legend

- Highway
- Sealed road (arterial and local)
- Unsealed road
- Rail
- River
- Stream
- Parcel

Elevation (mAHD)

High : 300

Low : 270

NORTH CENTRAL
Catchment Management Authority
Connecting Rivers, Landscapes, People

North Central CMA
Castlemaine, Campbells Creek and Chewton
Flood Management Plan

Job Number	31-29991
Revision	A
Date	14 Aug 2013

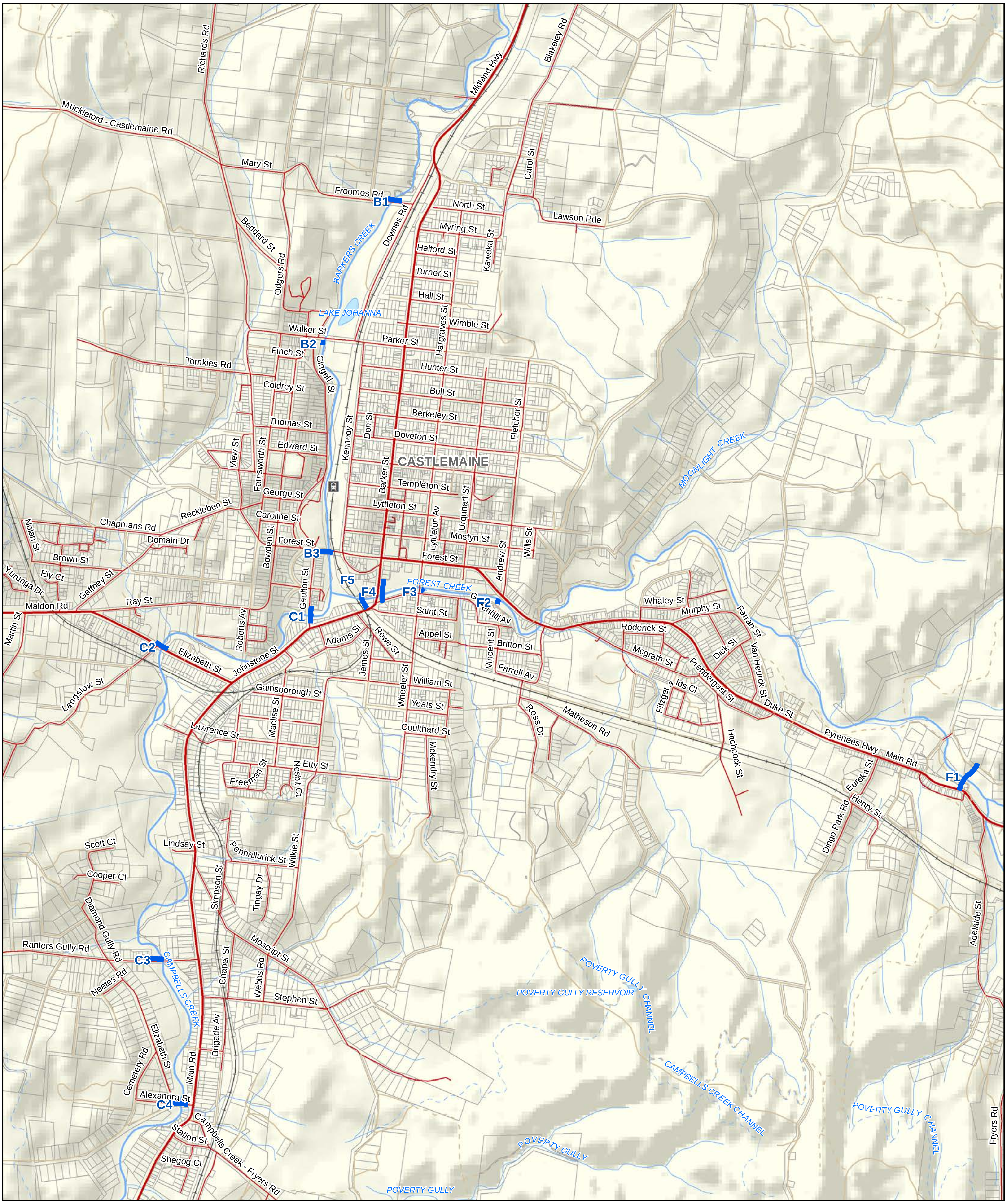
LIDAR Comparison

Appendix B2

G:\31\29991\GIS\Maps\Deliverables\Appendix B2- LIDAR Comparison 2.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data source: DSE, VicMap, 2013; DSE, LIDAR, 2013. Created by:scowan



Legend

- Highway
- Sealed road (arterial and local)
- Unsealed road
- Track and bike path
- Rail station
- Rail
- River
- Stream
- Channel / drain
- Connector
- Lake
- Survey cross section locations

1:20,000 (Paper Size A3)

0 0.2 0.4 0.6 0.8

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GHD

NORTH CENTRAL Catchment Management Authority
Connecting Rivers, Landscapes, People

North Central CMA
Castlemaine, Campbells Creek and Chewton
Flood Management Plan

Job Number	31-29991
Revision	A
Date	15 Aug 2013

Survey Cross Section Locations

Appendix B3

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180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data source: DSE, VicMap, 2013. Created by:scowan

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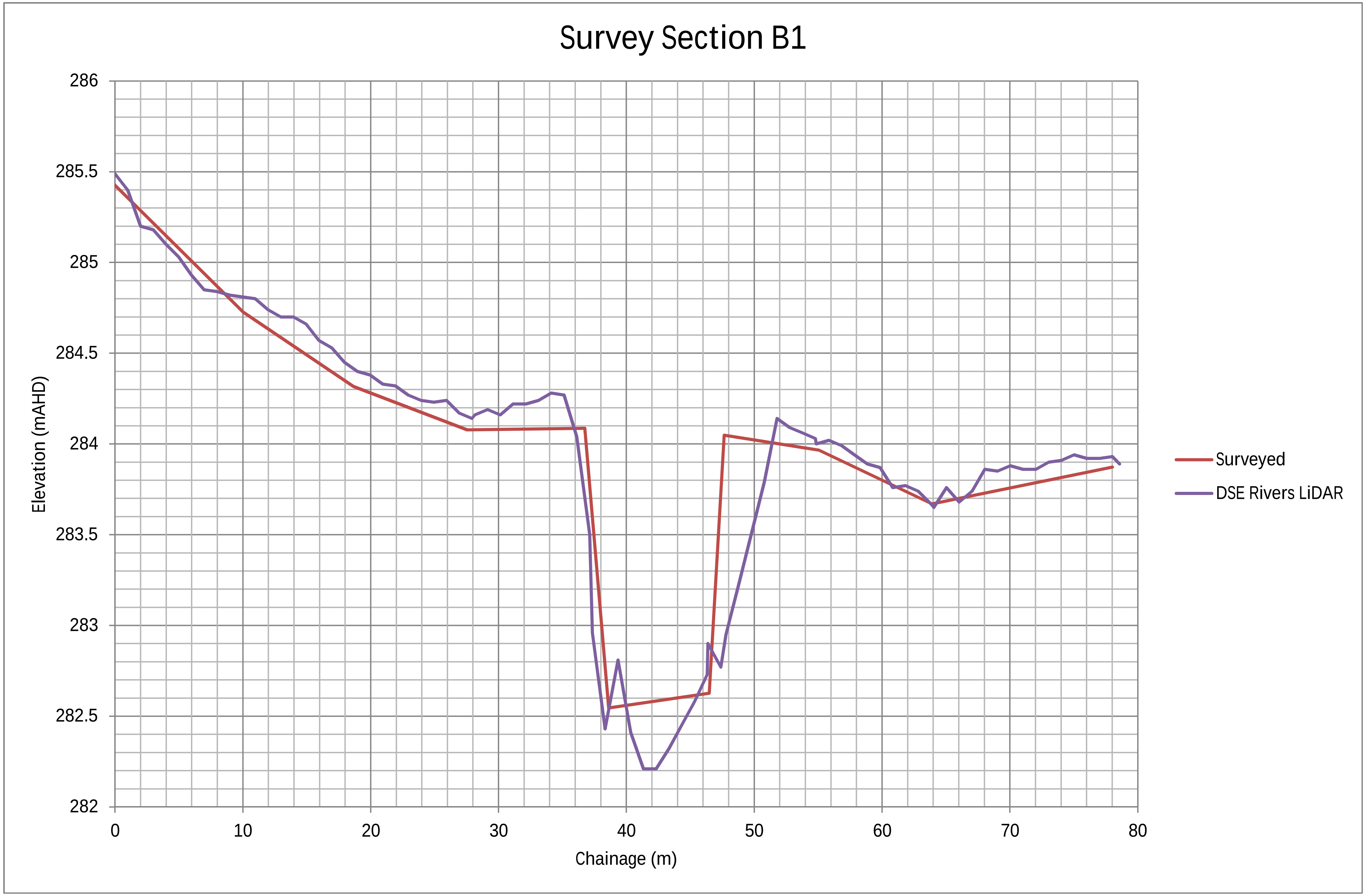
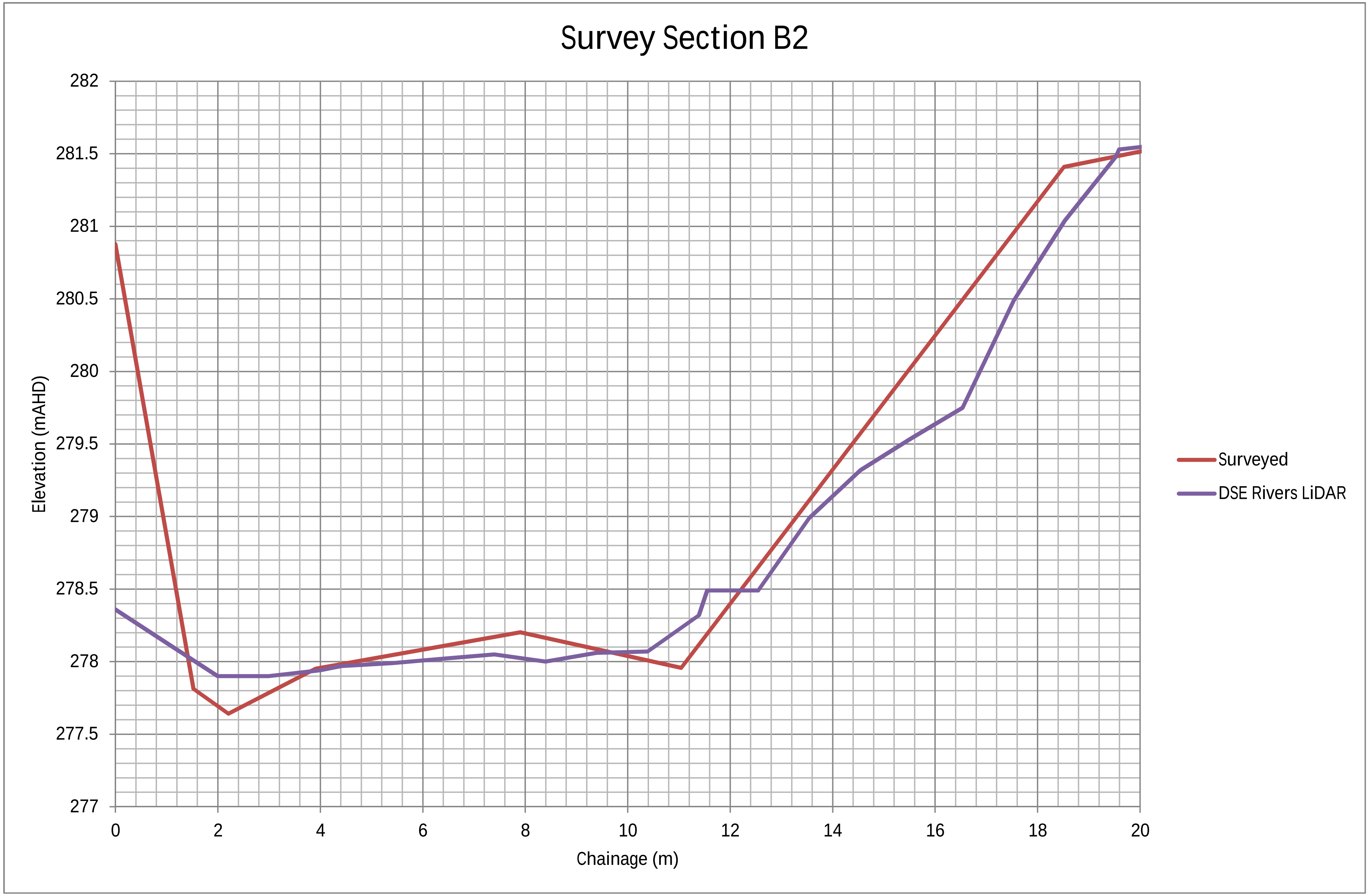
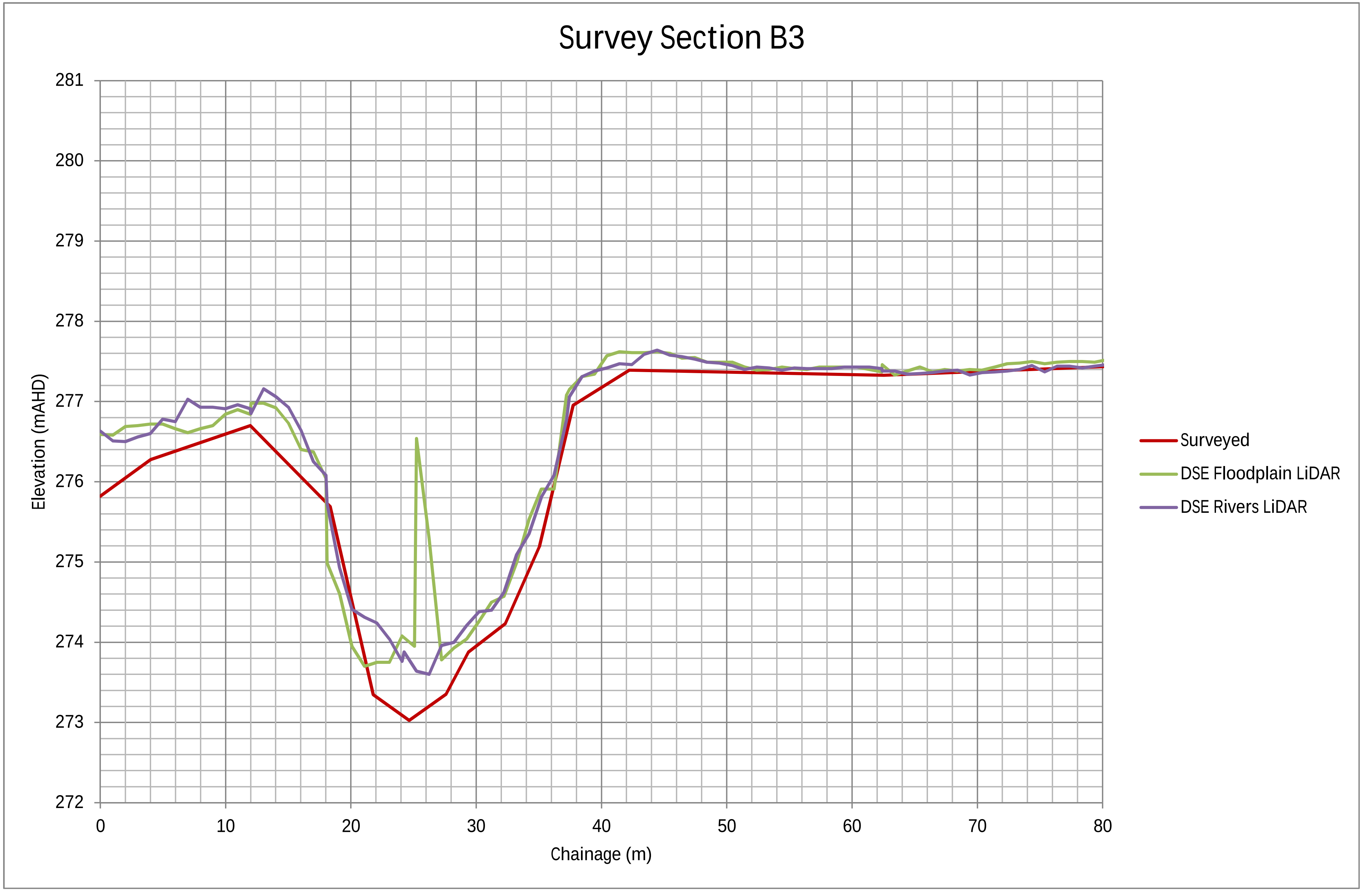
180 Lonsdale Street Melbourne Vic 3000





Survey Section B2
Elevation (mAHD)
282
281.5
281
280.5
280
279.5
279
278.5
278
277.5
277
0
2
4
6
8
10
12
14
16
18
20
Chainage (m)
Surveyed
DSE Rivers LiDAR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Elevation (mAHD)
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280
279
278
277
276
275
274
273
272
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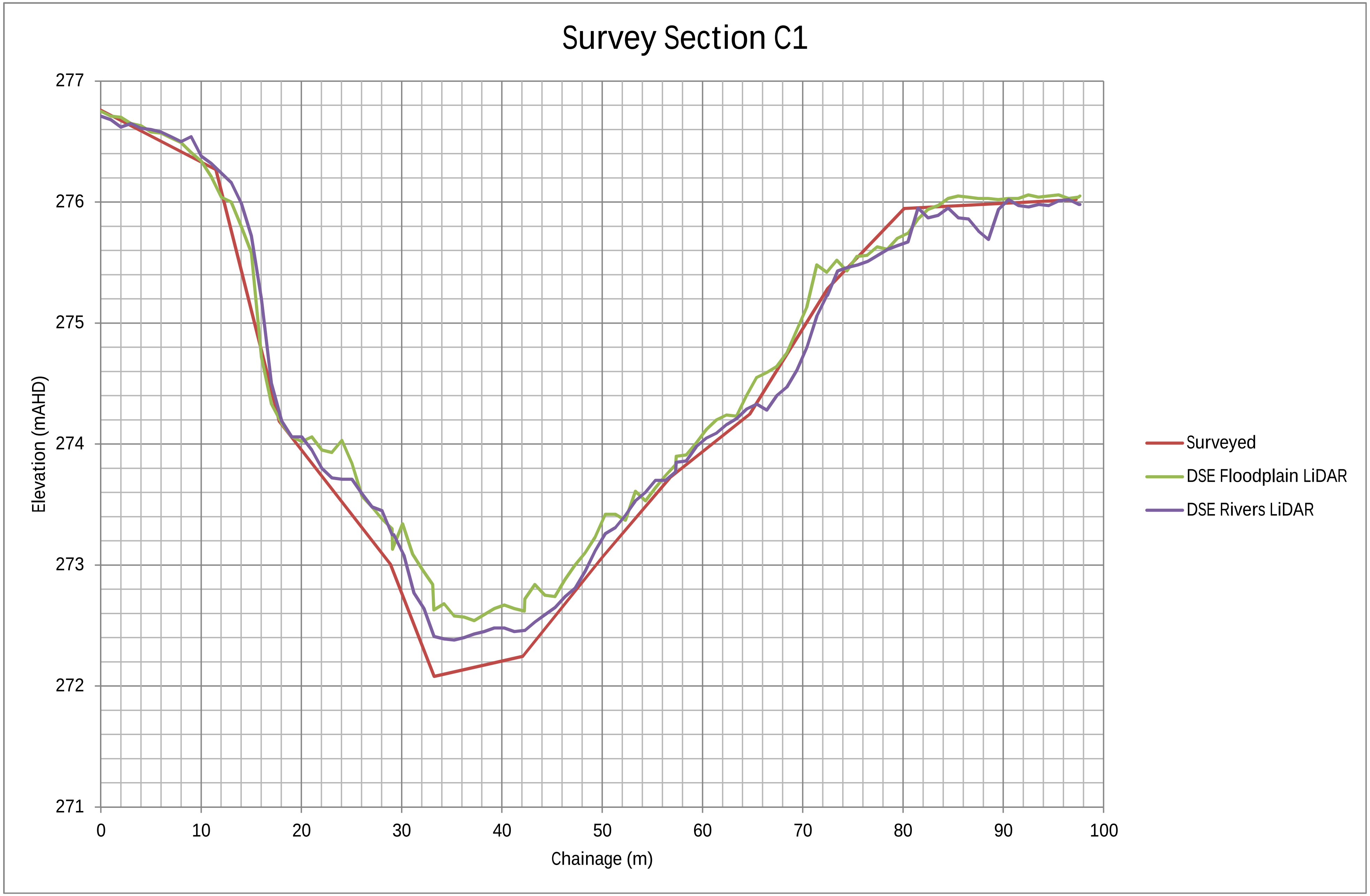
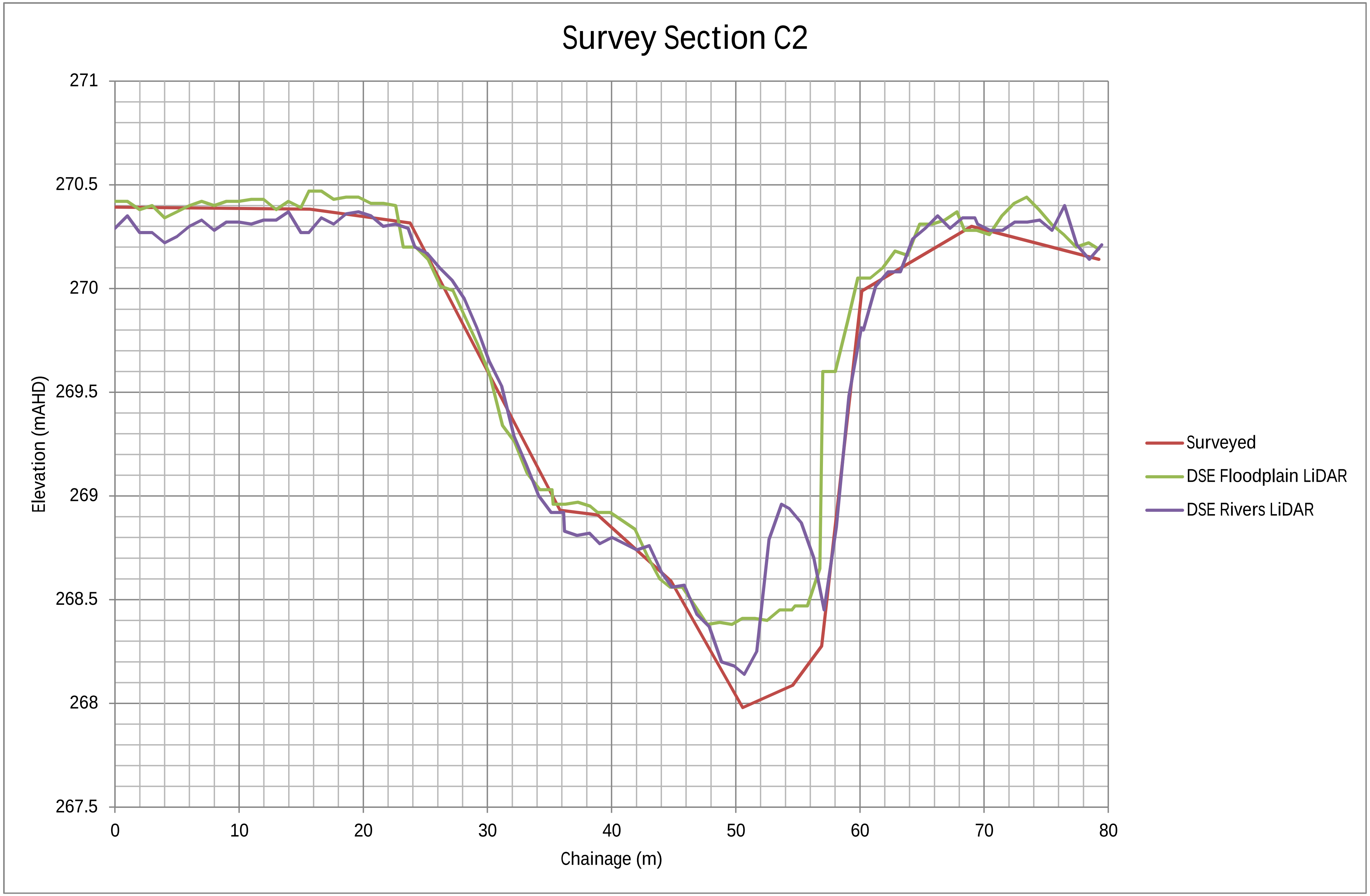
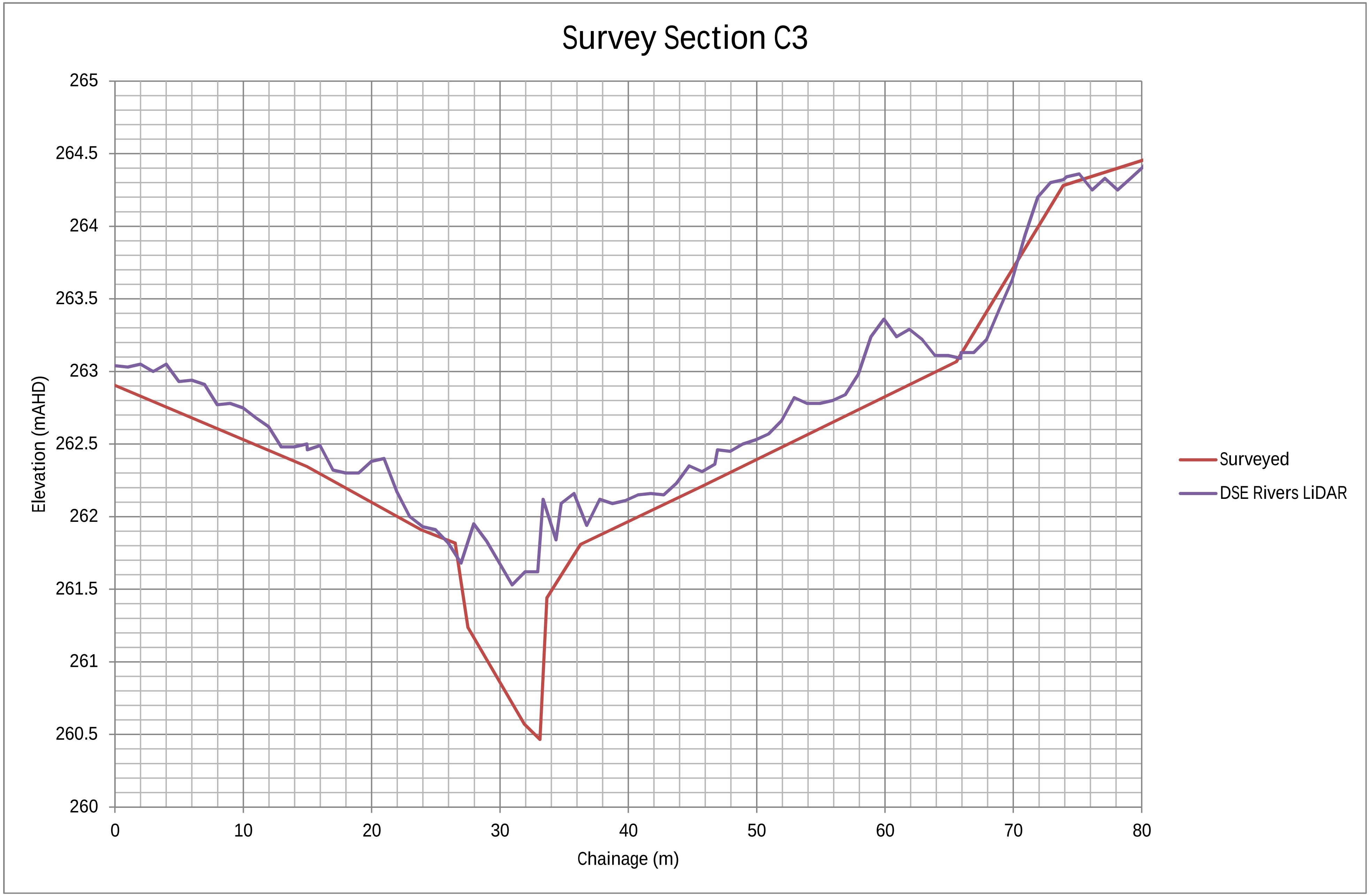
10
20
30
40
50
60
70
80
Chainage (m)
Surveyed
DSE Floodplain LiDAR
DSE Rivers LiDAR



Survey Section C1
277
276
275
274
273
272
271
0
10
20
30
40
50
60
70
80
90
100
Elevation (mAHD)
Chainage (m)
Surveyed
DSE Floodplain LiDAR
DSE Rivers LiDAR



Survey Section C2
271
270.5
270
269.5
269
268.5
268
267.5
Elevation (mAHD)
0
10
20
30
40
50
60
70
80
Chainage (m)
Surveyed
DSE Floodplain LiDAR
DSE Rivers LiDAR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Elevation (mAHD)
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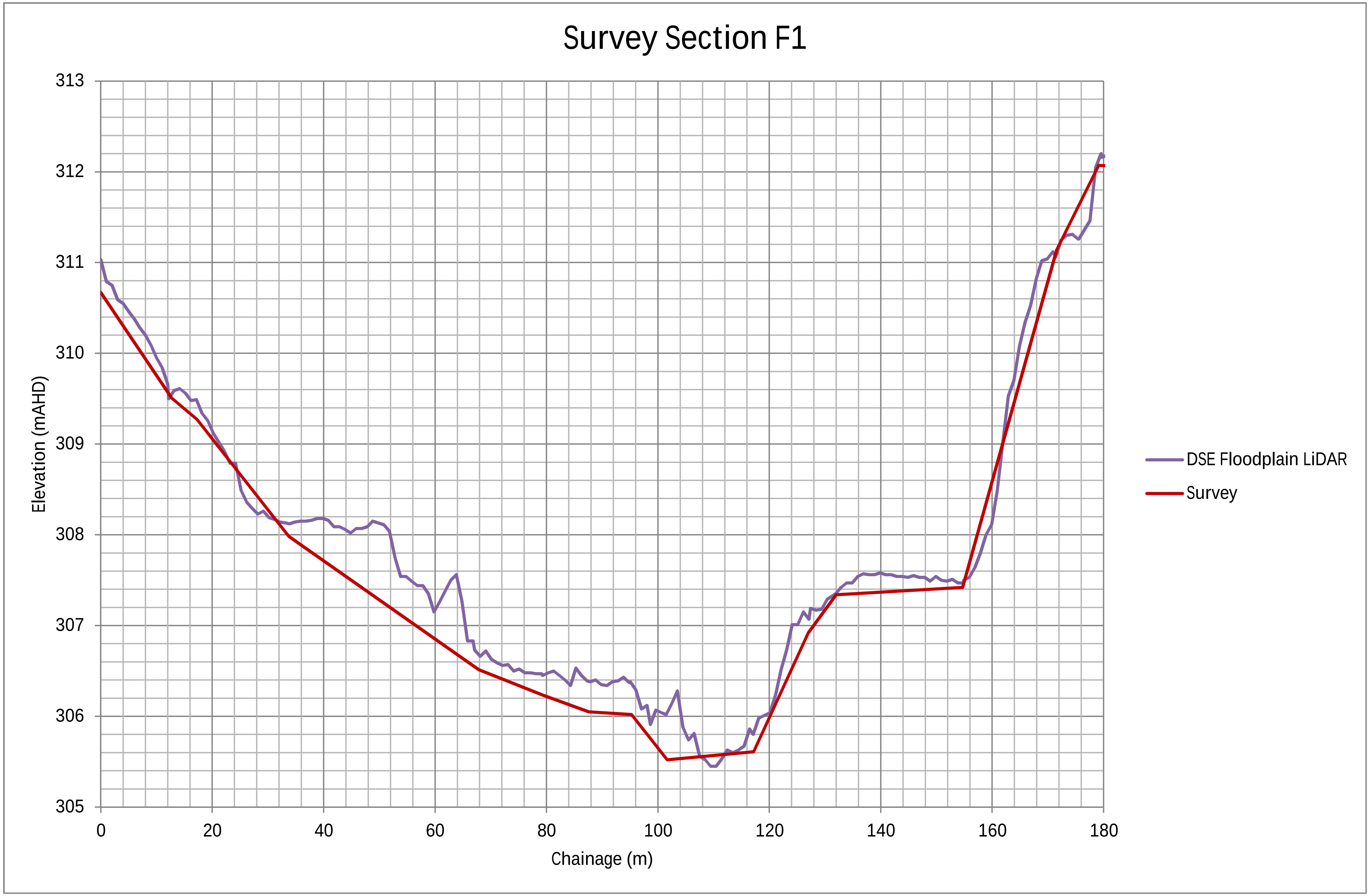
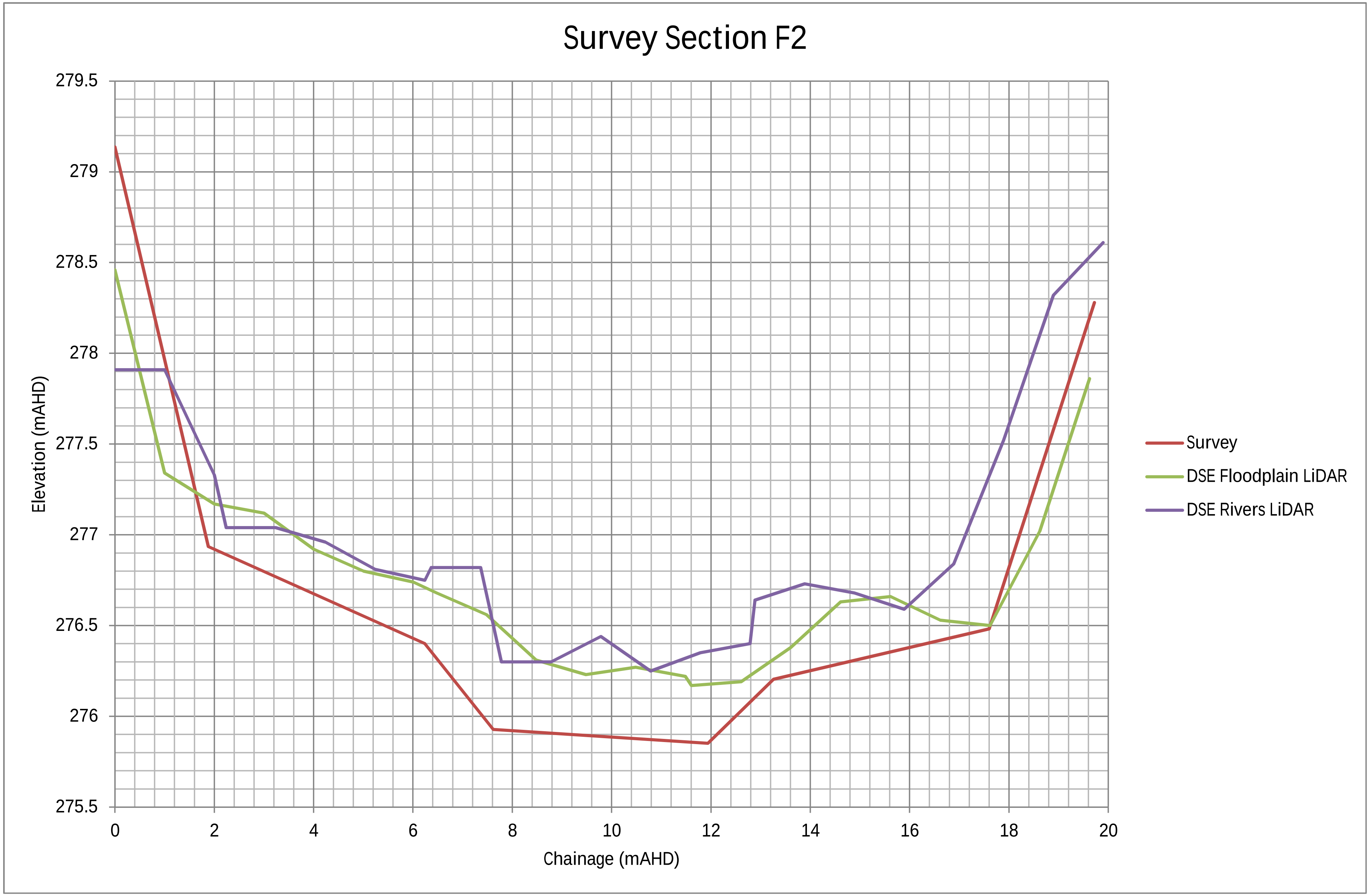
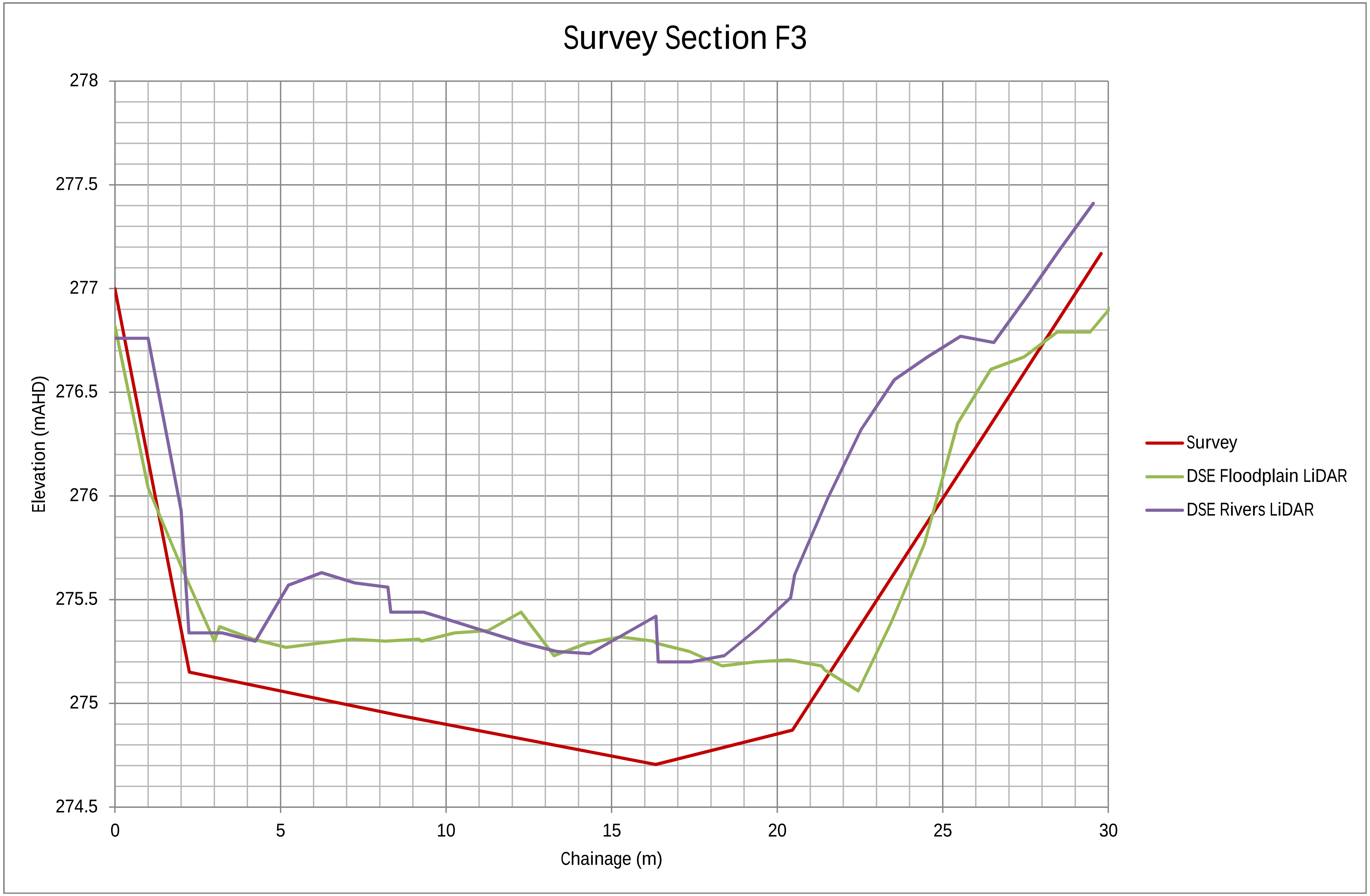
264.5
264
263.5
263
262.5
262
261.5
261
260.5
260
0
10
20
30
40
50
60
70
80
Chainage (m)
Surveyed
DSE Rivers LiDAR



Survey Section F1
313
312
311
310
309
308
307
306
305
Elevation (mAHD)
0
20
40
60
80
100
120
140
160
180
Chainage (m)
DSE Floodplain LiDAR
Survey


Survey Section F2
279.5
279
278.5
278
277.5
277
276.5
276
275.5
Elevation (mAHD)
0
2
4
6
8
10
12
14
16
18
20
Chainage (mAHD)
Survey
DSE Floodplain LiDAR
DSE Rivers LiDAR



Survey Section F3
278
277.5
277
276.5
276
275.5
275
274.5
Elevation (mAHD)
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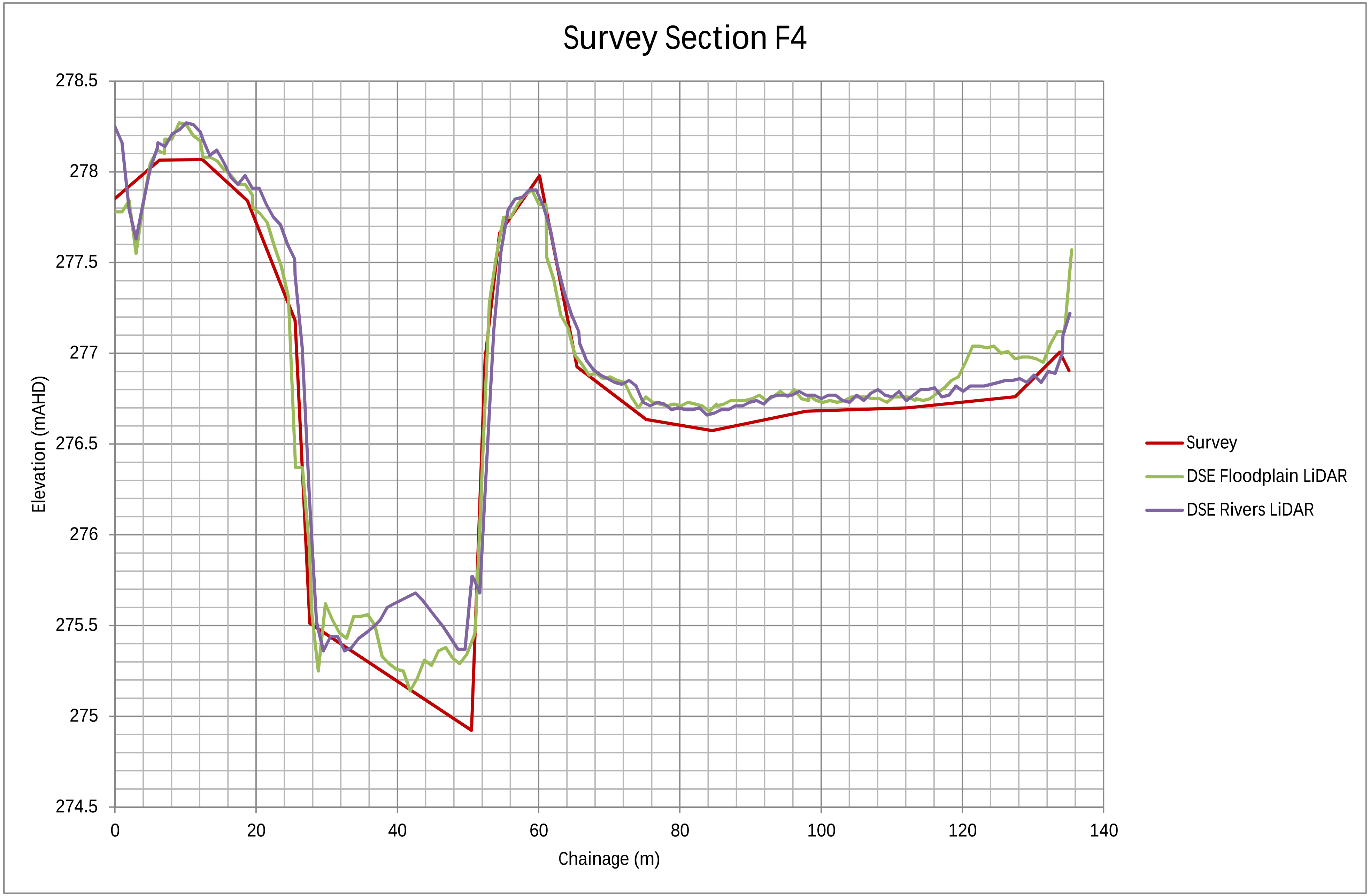
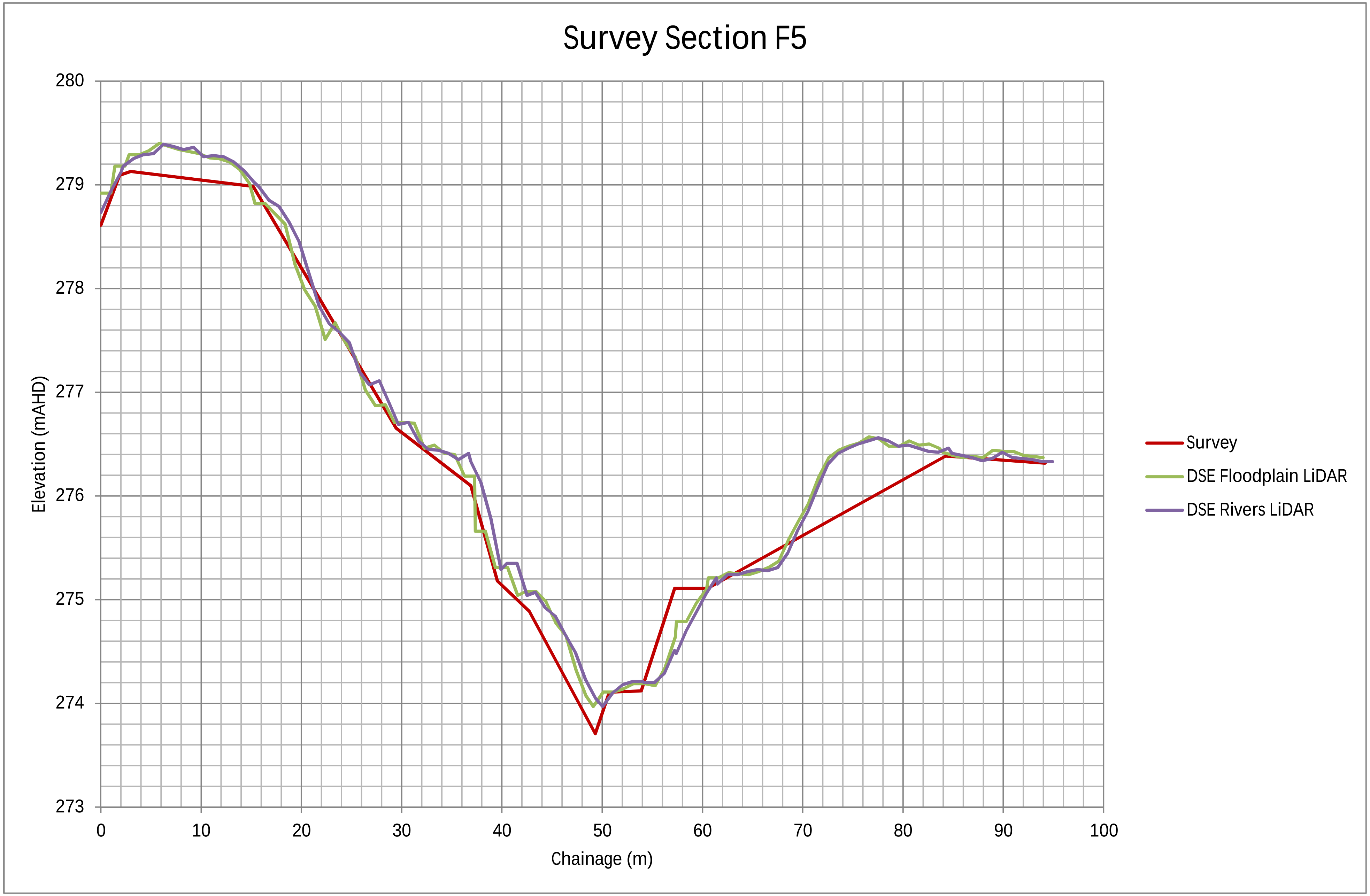
5
10
15
20
25
30
Chainage (m)
Survey
DSE Floodplain LiDAR
DSE Rivers LiDAR


Survey Section F4
Elevation (mAHD)
278.5
278
277.5
277
276.5
276
275.5
275
274.5
0
20
40
60
80
100
120
140
Chainage (m)
Survey
DSE Floodplain LiDAR
DSE Rivers LiDAR



Survey Section F5
Elevation (mAHD)
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279
278
277
276
275
274
273
0
10
20
30
40
50
60
70
80
90
100
Chainage (m)
Survey
DSE Floodplain LiDAR
DSE Rivers LiDAR

Appendix C – Storage, Elevation and Discharge Relationships

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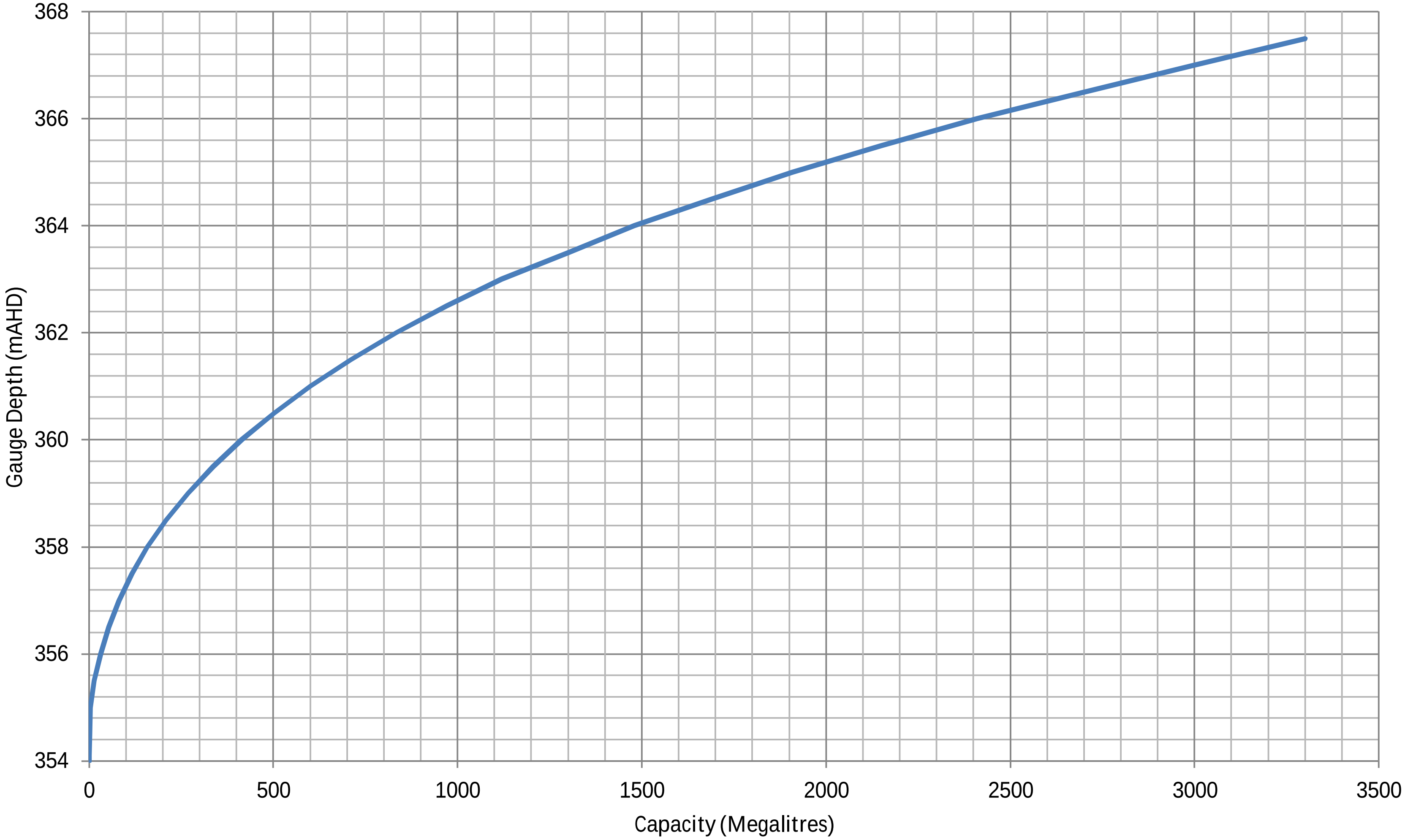
180 Lonsdale Street Melbourne Vic 3000

Barkers Reservoir Capacity Curve



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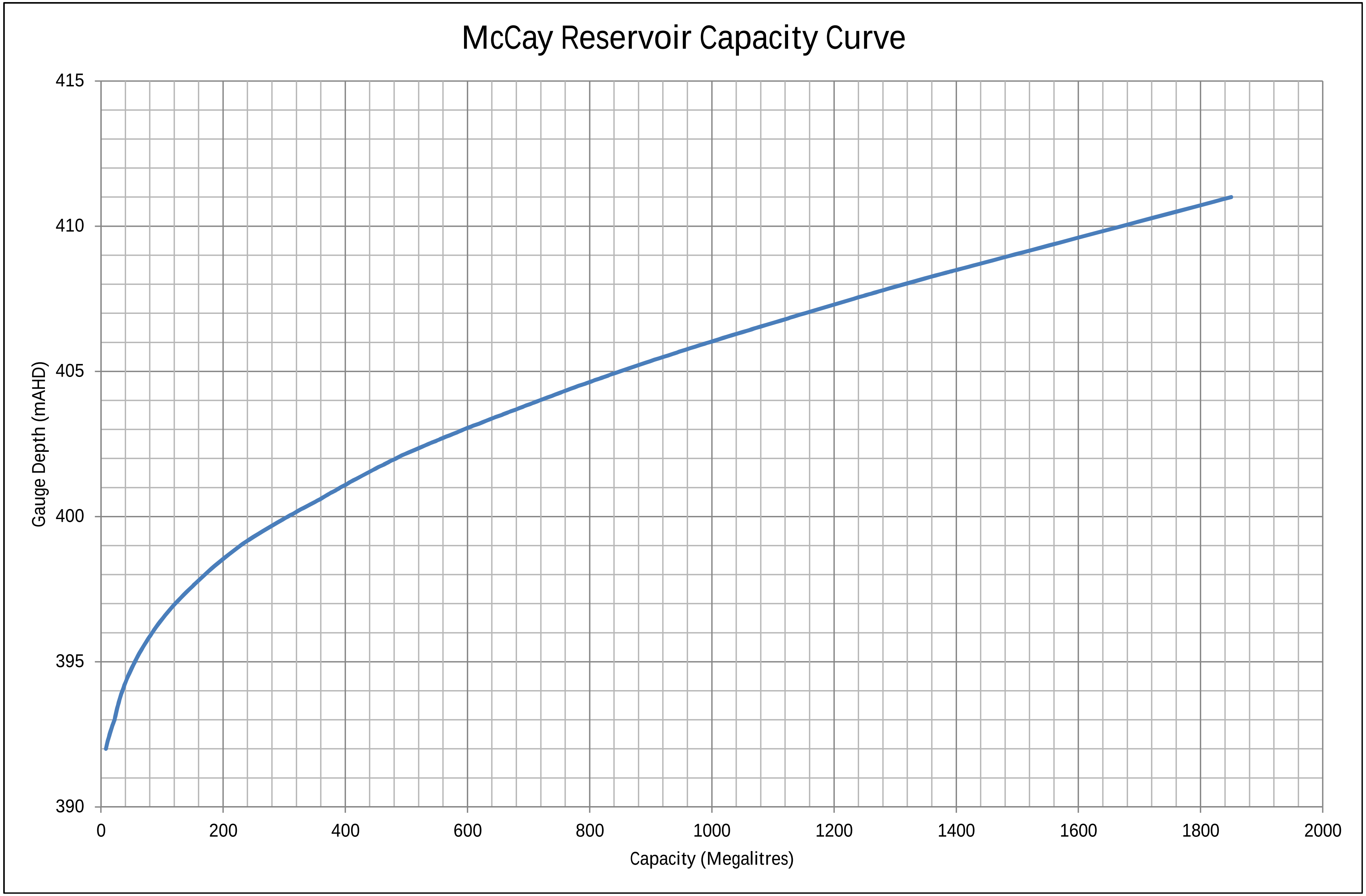

Stage Storage Curve

EXPEDITION PASS RESERVOIR

STORAGE VOLUME CHART

	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
366.7		0	0	0	0	1	1	1	1	1
366.8	1	1	2	2	2	3	3	3	3	4
366.9	4	4	5	5	6	6	6	7	7	8
367	8	8	9	9	9	10	10	10	10	11
367.1	11	11	12	12	12	13	13	13	13	14
367.2	14	14	15	15	15	16	16	16	16	17
367.3	17	17	18	18	18	18	19	19	19	20
367.4	20	20	21	21	21	21	22	22	22	23
367.5	23	23	24	24	24	24	25	25	25	26
367.6	26	26	27	27	27	27	28	28	28	29
367.7	29	29	30	30	30	30	31	31	31	32
367.8	32	32	33	33	33	34	34	34	34	35
367.9	35	35	36	36	37	37	37	38	38	39
368	39	39	40	40	41	41	41	42	42	43
368.1	43	43	44	44	45	45	45	46	46	47
368.2	47	47	48	48	49	49	49	50	50	51
368.3	51	51	52	52	53	53	53	54	54	55
368.4	55	55	56	56	57	57	57	58	58	59
368.5	59	59	60	60	61	61	61	62	62	63
368.6	63	63	64	64	65	65	65	66	66	67
368.7	67	67	68	68	69	69	69	70	70	71
368.8	71	71	72	72	73	73	73	74	74	75
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370.1	127	128	128	129	129	130	130	131	131	132
370.2	132	133	133	134	134	135	135	136	136	137
370.3	137	138	138	139	139	140	140	141	141	142
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371.8	212	213	213	214	214	215	216	216	217	217
371.9	218	219	219	220	220	221	222	222	223	223
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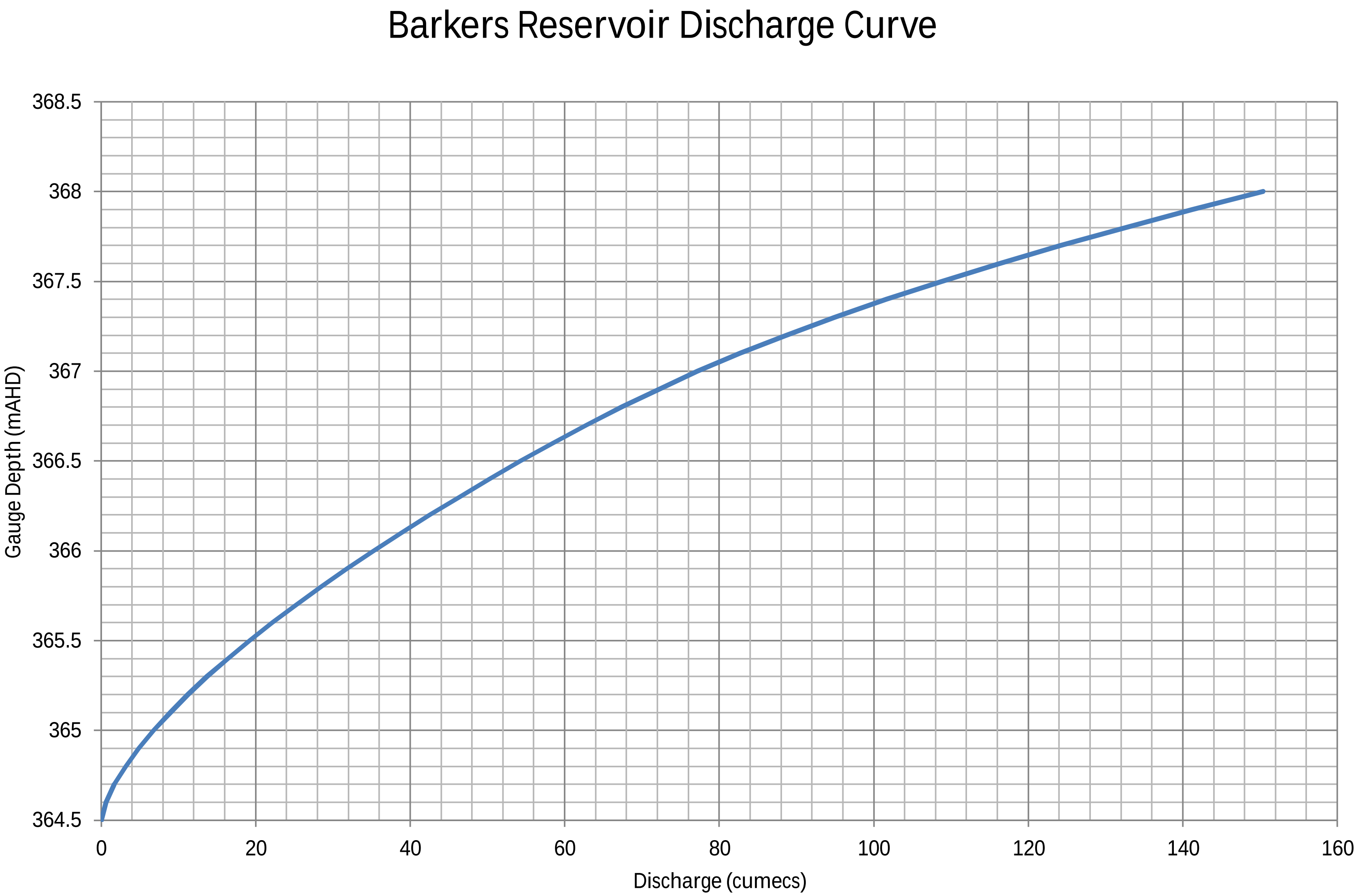
372.2	236	237	237	238	238	239	240	240	241	241
372.3	242	243	243	244	244	245	246	246	247	247
372.4	248	249	249	250	250 -	251	252	252	253	253
372.5	254	255	255	256	256	257	258	258	259	259
372.6	260	261	261	262	263	**264**	*Full Supply Level*		266	266
372.7	*267*	*268*	*268*	*269*	*270*	*271*	*271*	*272*	*273*	*273*
372.8	*274*	*275*	*275*	2[illegible] Over Full Supply Level	[illegible]	[illegible]	[illegible]	*279*	*280*	*280*
372.9	*281*	*282*	*282*	[illegible]	[illegible]	[illegible]	[illegible]	*286*	*287*	*287*
373	*288*	*289*	*289*	*290*	*291*	*292*	*292*	*293*	*294*	*294*

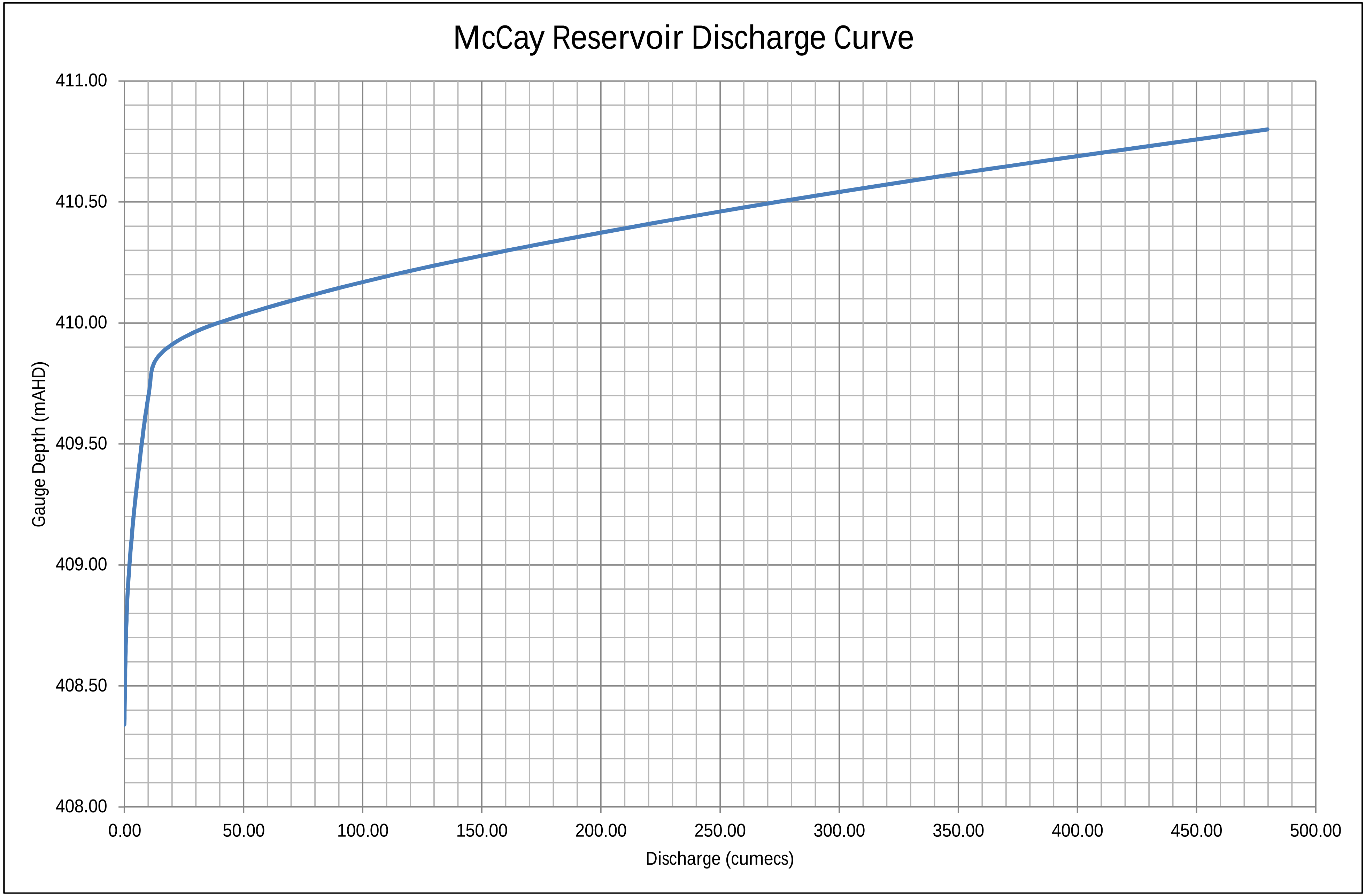
Path - p:\data_~m1\headwork\common\mhd\storages\expass\ RG Smyth 25 February 1997

EXPEDCAP.WK4

www.ghd.com.au
Tel. (03) 8687 8000 Fax. (03) 8687 8111
180 Lonsdale Street Melbourne Vic 3000

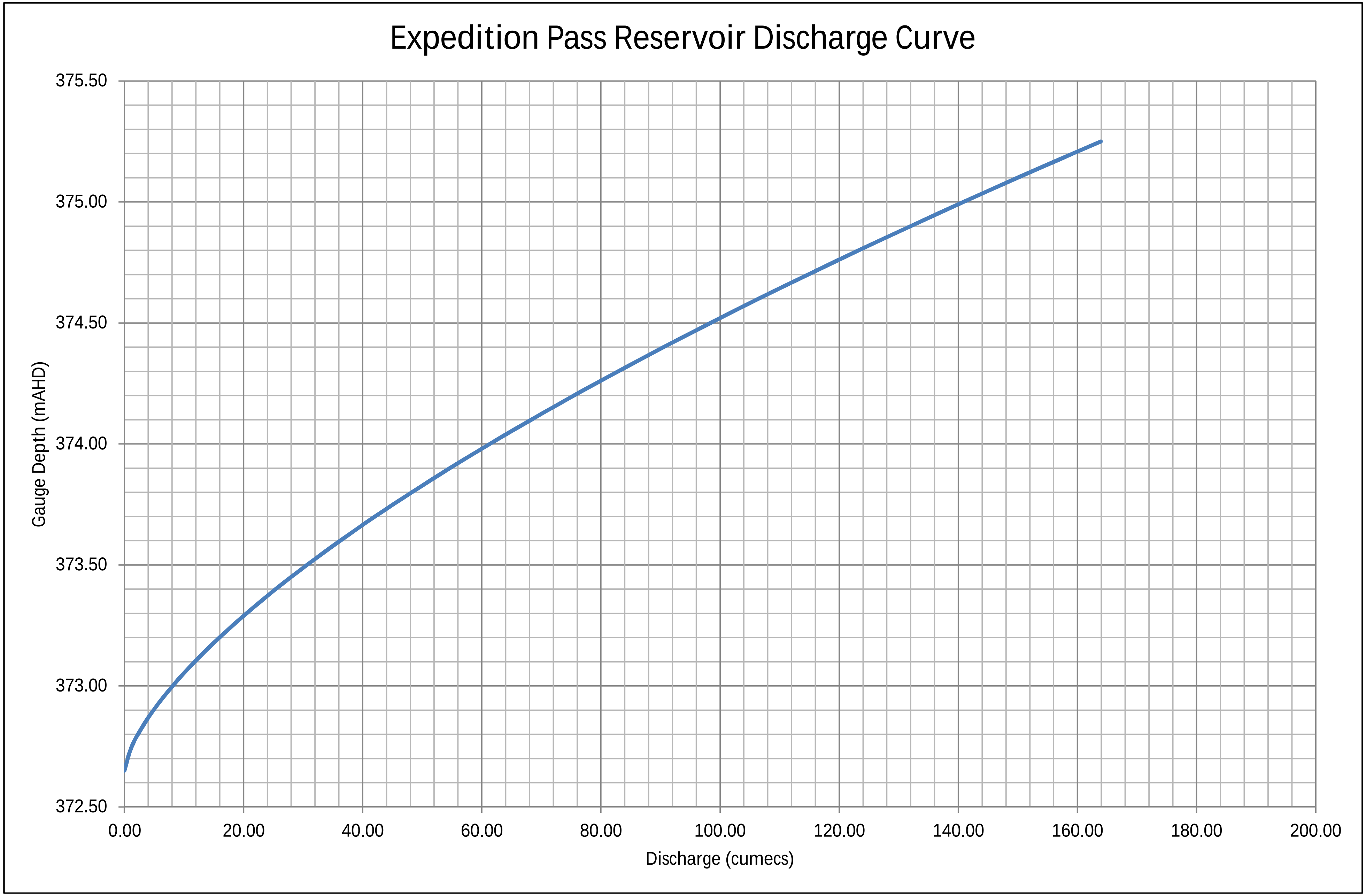


www.ghd.com.au
Tel. (03) 8687 8000 Fax. (03) 8687 8111
180 Lonsdale Street Melbourne Vic 3000



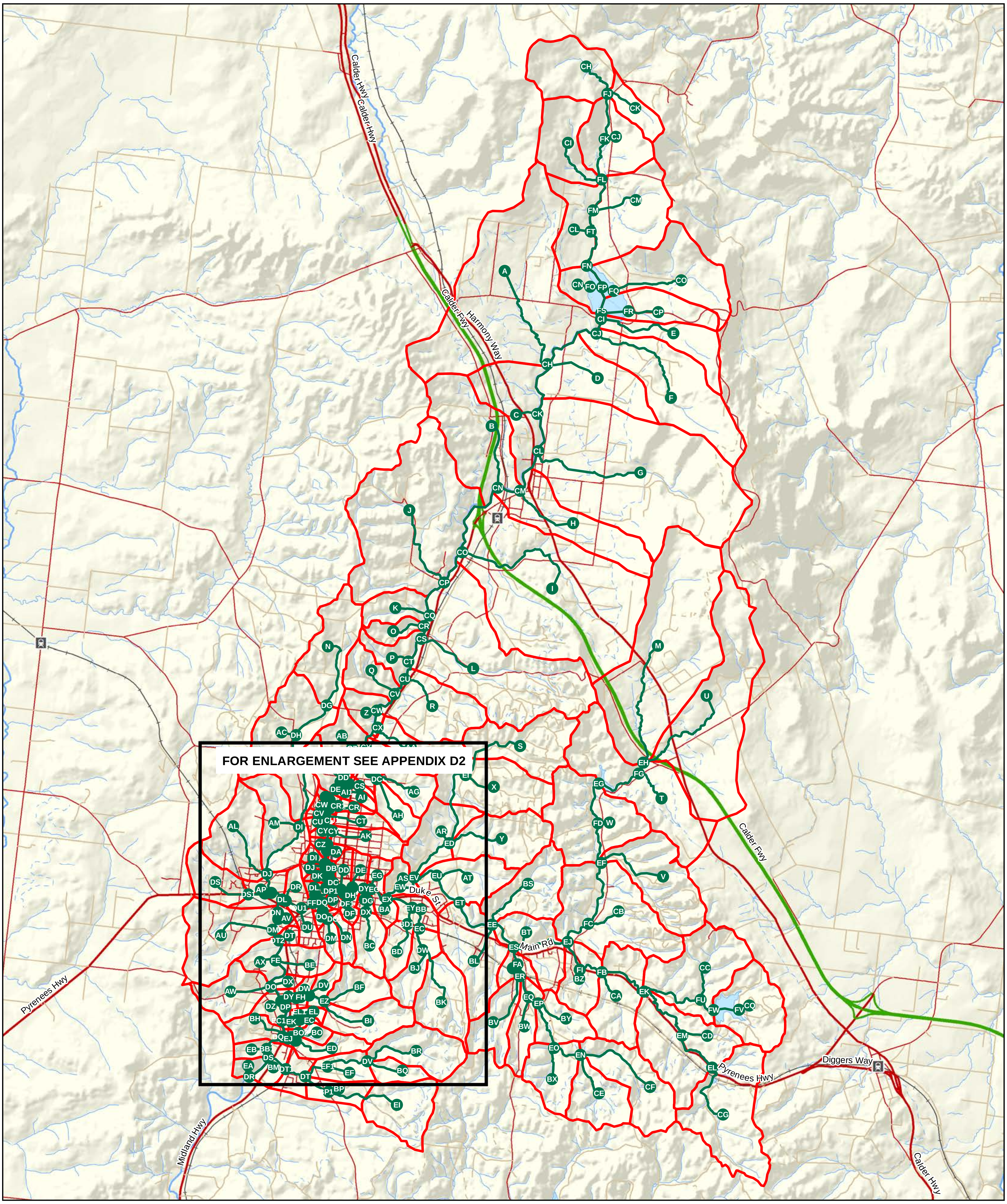
Stage Discharge Curve

www.ghd.com.au
Tel. (03) 8687 8000 Fax. (03) 8687 8111
180 Lonsdale Street Melbourne Vic 3000



Stage Discharge Curve

Appendix D – RORB Model – Campbells Creek



Legend

- Freeway
- Highway
- Sealed road (arterial and local)
- Unsealed road
- Track and bike path
- Rail station
- Rail
- River
- Stream
- Channel / drain
- Connector
- Lake
- RORB Node
- RORB Reach
- RORB Sub-area

1:70,000 (Paper Size A3)

0 0.75 1.5 2.25 3

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GHD

NORTH CENTRAL Catchment Management Authority
Connecting Rivers, Landscapes, People

North Central CMA
Castlemaine, Campbells Creek and Chewton
Flood Management Plan

Job Number	31-29991
Revision	A
Date	14 Aug 2013

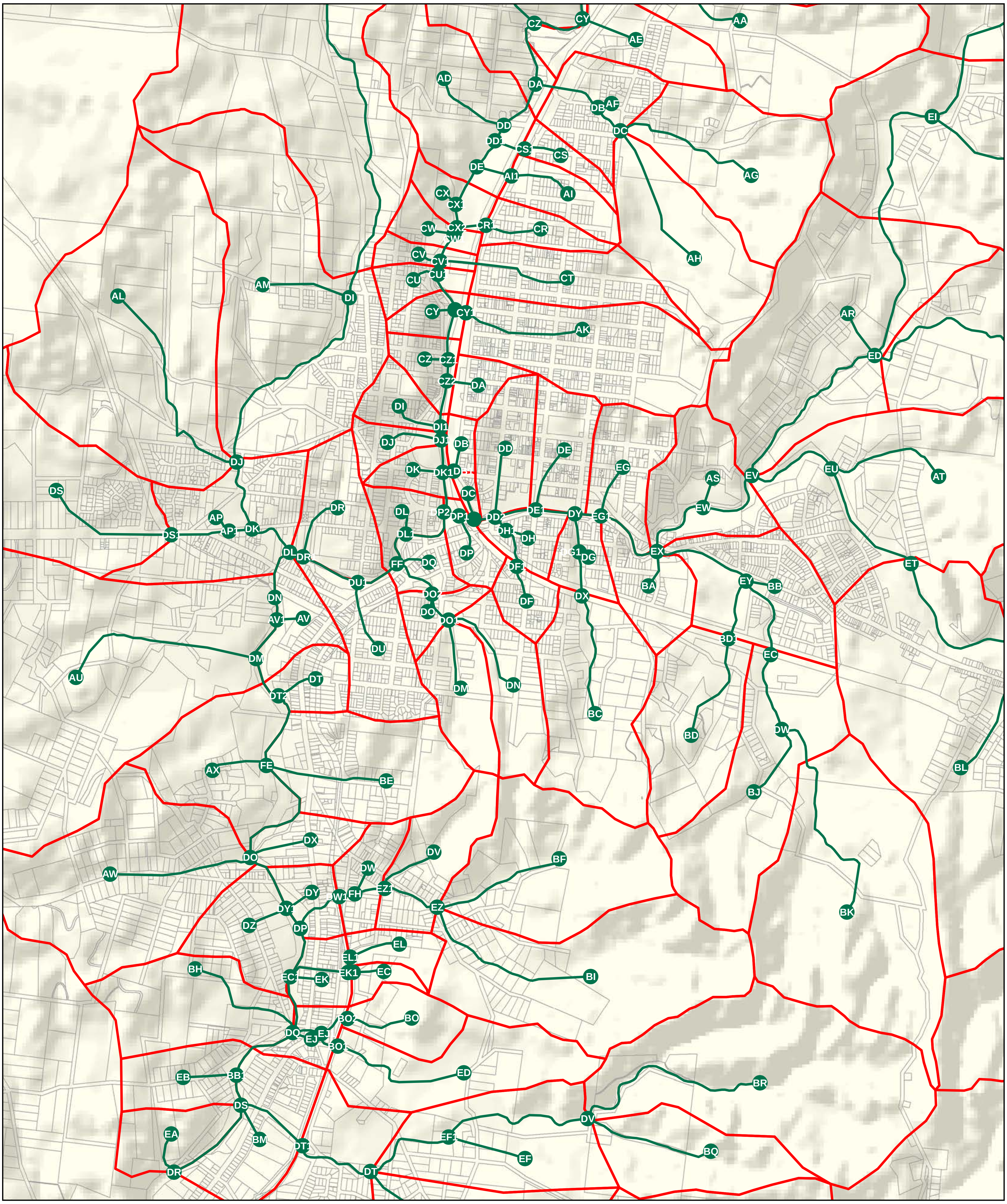
Campbells Creek RORB Layout

Appendix D1

G:\31\29991\GIS\Maps\Deliverables\Appendix D1- Campbells Creek RORB Layout - Copy (2).mxd

180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data source: DSE, VicMap, 2013; GHD, RORB Model, 2013. Created by:scowan



Legend

- RORB Node
- RORB Reach
- RORB Sub-area

1:20,000 (Paper Size A3)

0 0.2 0.4 0.6 0.8

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

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Campbells Creek RORB Layout Enlargement

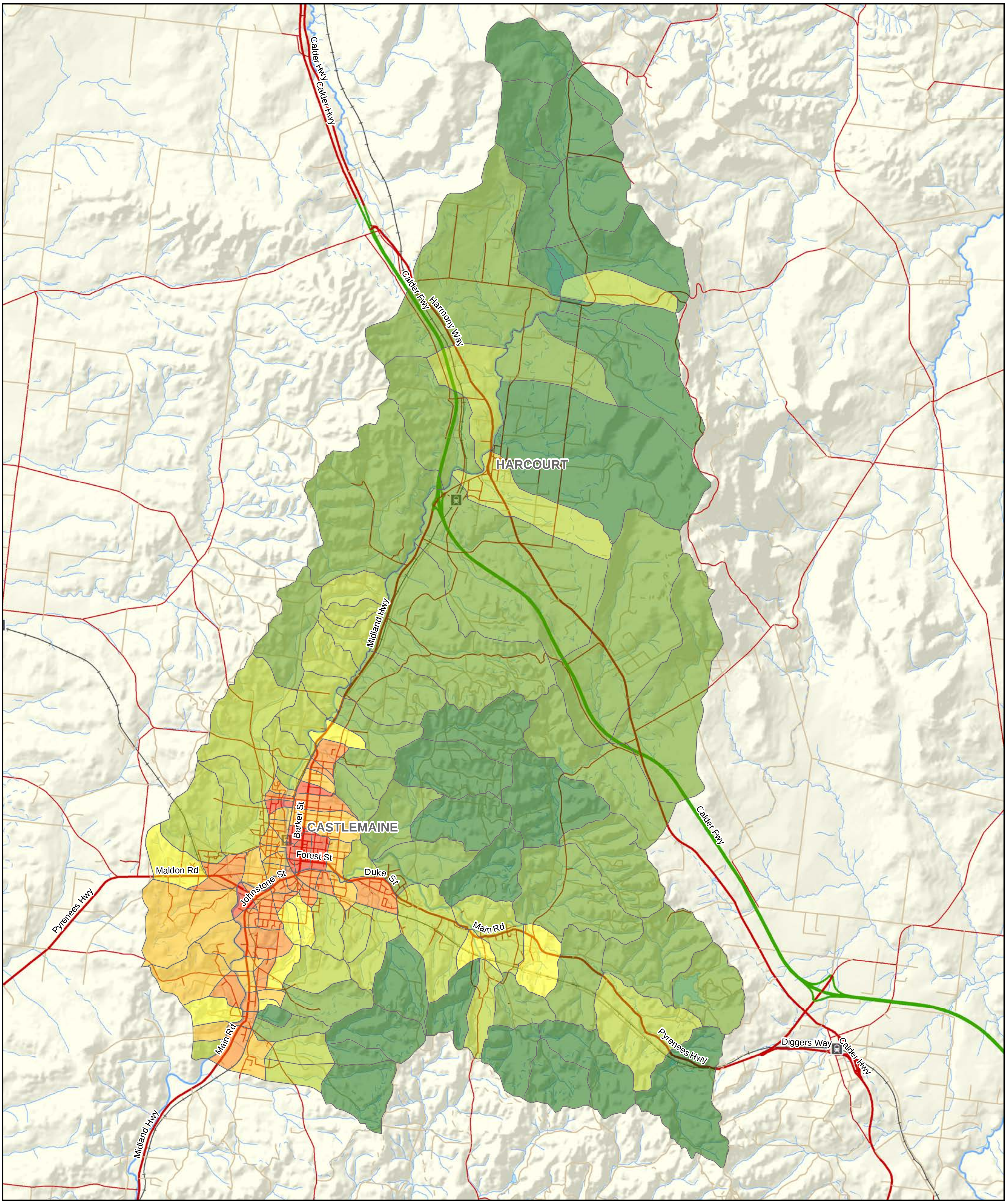
Job Number	31-29991
Revision	A
Date	14 Aug 2013

Appendix D2

G:\31\29991\GIS\Maps\Deliverables\Appendix D1- Campbells Creek RORB Layout - Copy.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data source: DSE, VicMap, 2013; GHD, RORB Model, 2013. Created by:scowan



Legend

Freeway	Rail
Highway	River
Sealed road (arterial and local)	Stream
Unsealed road	Channel / drain
Track and bike path	Connector
Rail station	Lake

Fraction Impervious

0 - 0.1, 0.1 - 0.2, 0.2 - 0.3, 0.3 - 0.4, 0.4 - 0.5, 0.5 - 0.6, 0.6 - 0.7

1:70,000 (Paper Size A3)

0 0.75 1.5 2.25 3

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

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Campbells Creek Impervious Fractions

Job Number	31-29991
Revision	A
Date	14 Aug 2013

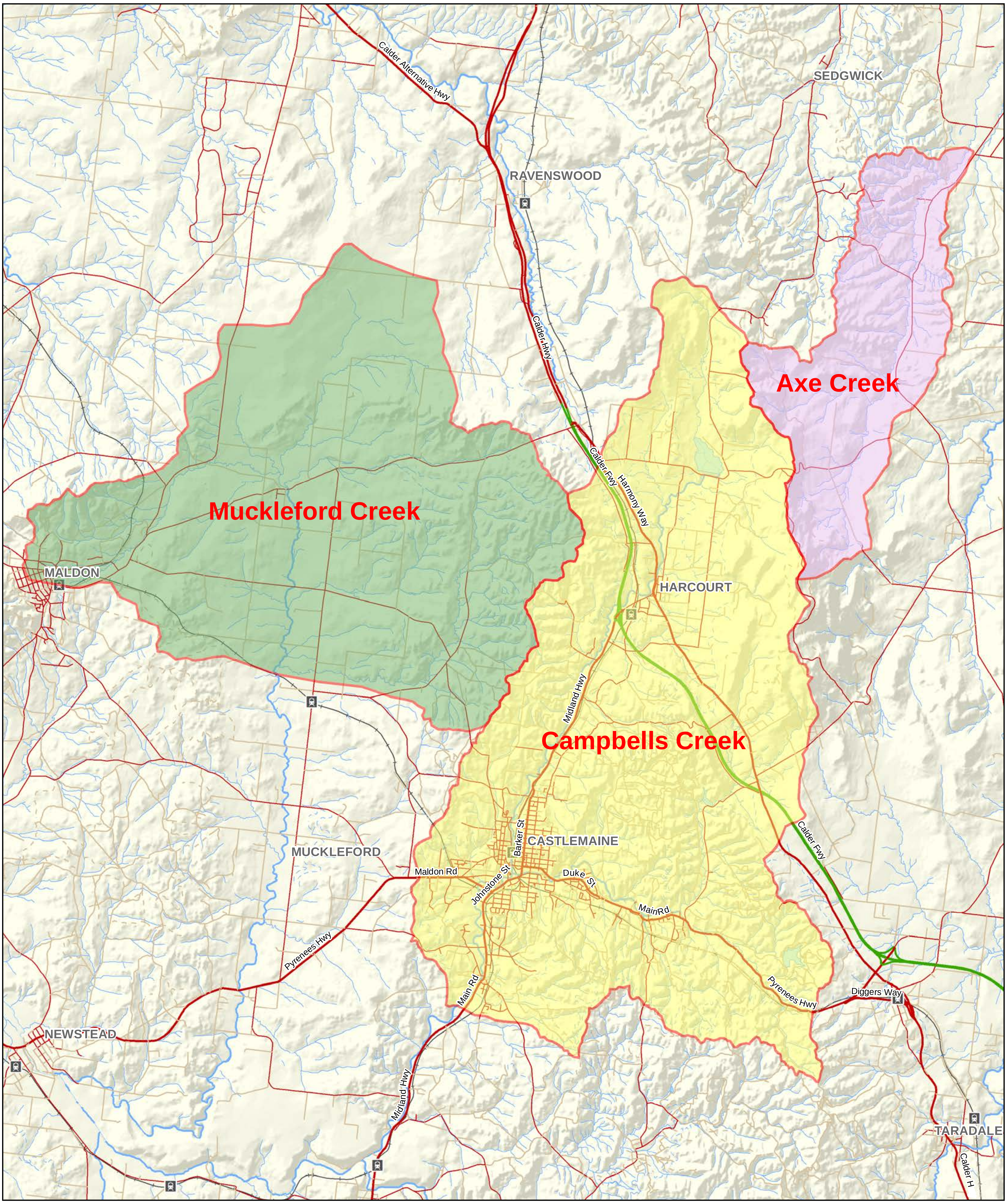
Appendix D3

G:\31\29991\GIS\Maps\Deliverables\Appendix D2- Campbells Creek Impervious Fraction.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2013; GHD, Impervious Fractions, 2013. Created by:scowan

Appendix E – RORB Model – Axe and Muckelford Creek



Legend

Freeway	Rail	Water course
Highway	River	Muckleford Creek Catchment
Sealed road (arterial and local)	Stream	Axe Creek Catchment
Unsealed road	Channel / drain	Campbells Creek Catchment
Track and bike path	Connector	
Rail station	Lake	

1:100,000 (Paper Size A3)

0 1 2 3 4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

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Job Number 31-29991
Revision A
Date 14 Aug 2013

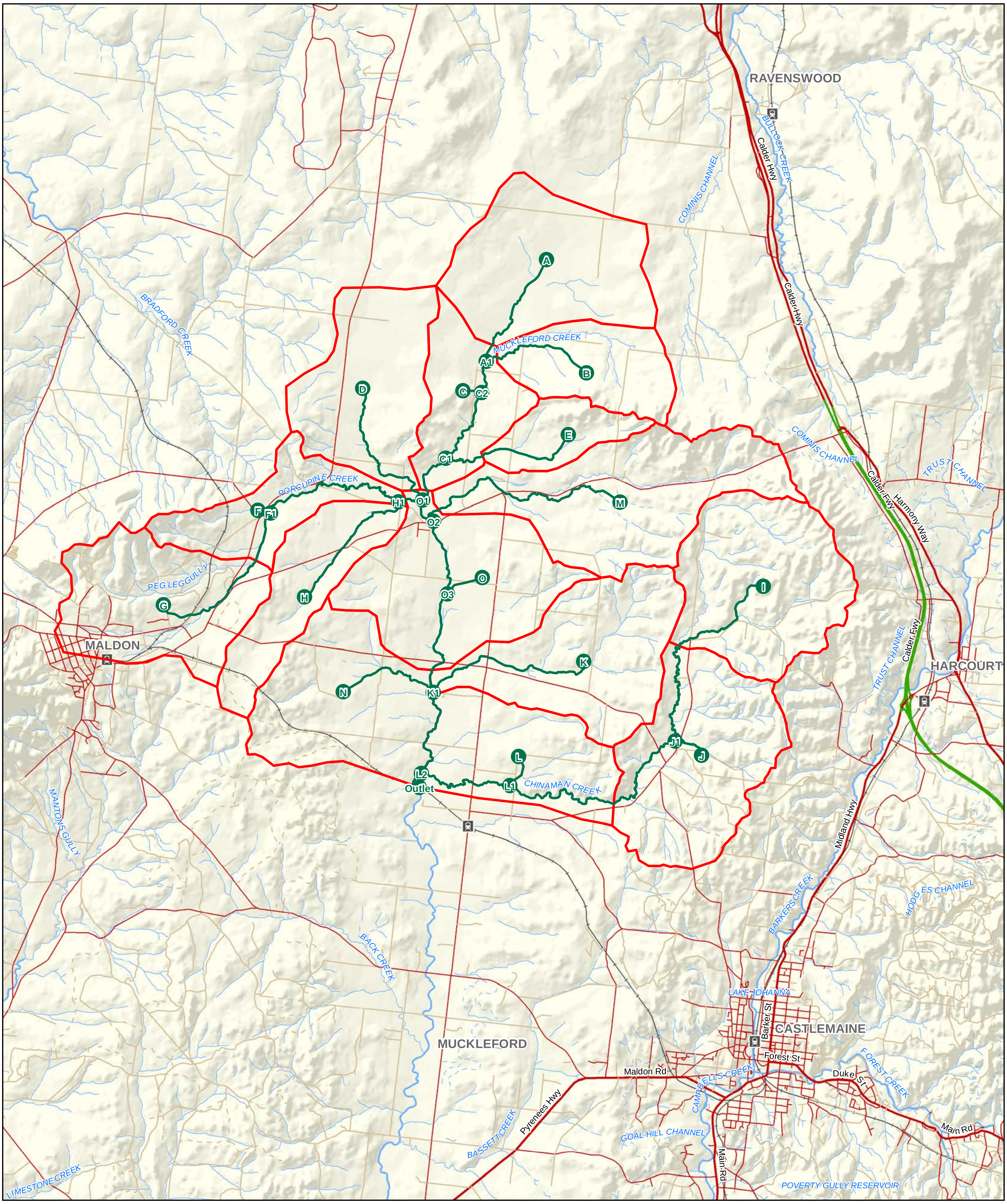
Catchment Plan

Appendix E1

G:\31\29991\GIS\Maps\Deliverables\Appendix E1- Calibration Catchments.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data source: DSE, VicMap, 2013; GHD, RORB Model, 2013. Created by:scowan



Legend

- Freeway
- Highway
- Sealed road (arterial and local)
- Unsealed road
- Track and bike path
- Rail station
- Rail
- River
- Stream
- Channel / drain
- Connector
- Lake
- RORB Node.TAB
- RORB Reach
- RORB Sub-area

1:70,000 (Paper Size A3)

0 0.75 1.5 2.25 3

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

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Flood Management Plan

Job Number	31-29991
Revision	A
Date	13 Aug 2013

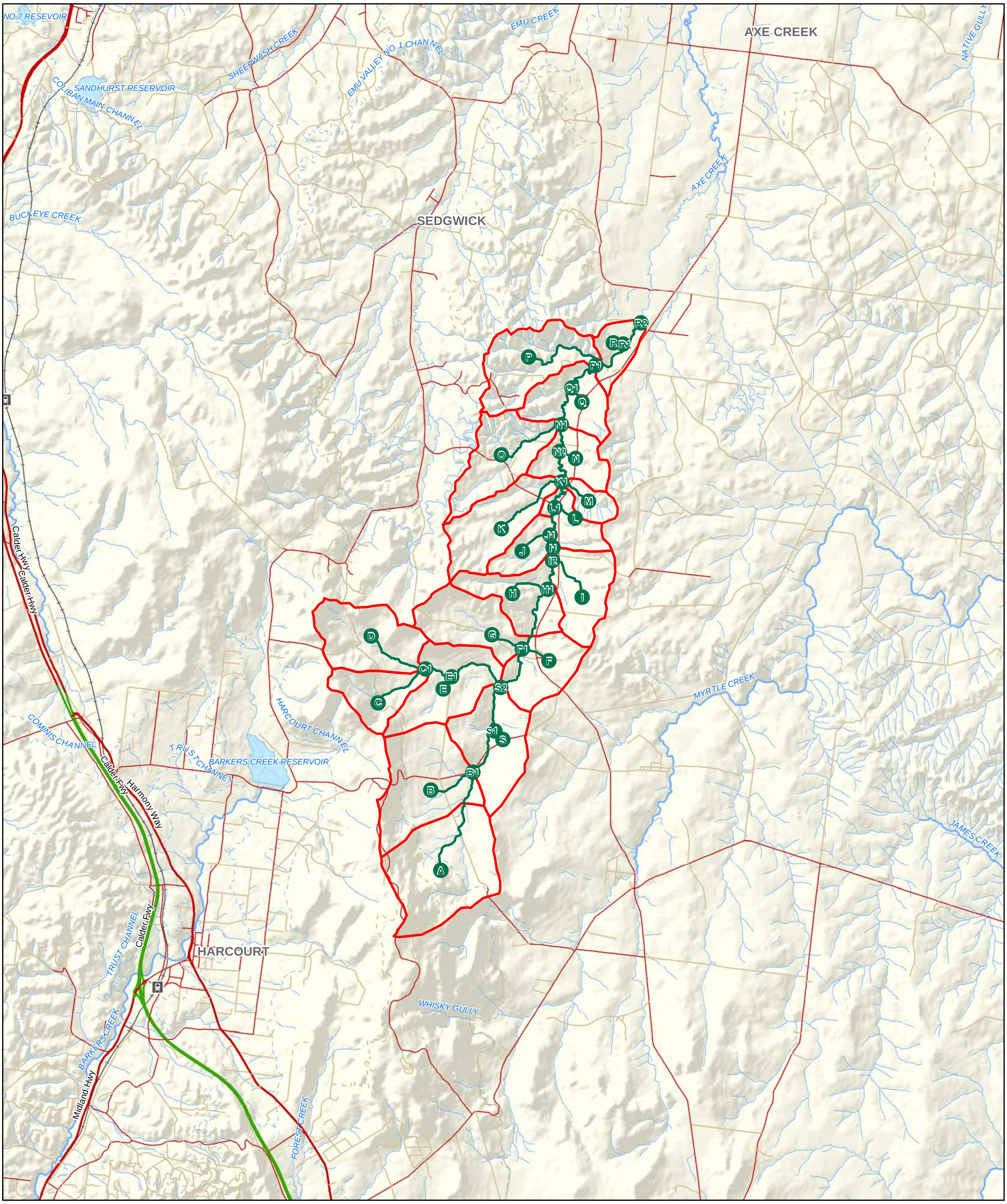
Muckleford Creek RORB Layout

Appendix E2

G:\31\29991\GIS\Maps\Deliverables\Appendix E1- Muckleford Creek RORB Layout.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data source: DSE, VicMap, 2013; GHD, RORB Model, 2013. Created by:scowan



Legend

- Freeway
- Highway
- Sealed road (arterial and local)
- Unsealed road
- Track and bike path
- Rail station
- Rail
- River
- Stream
- Channel / drain
- Connector
- Lake
- RORB Node
- RORB Reach
- RORB Sub-area

1:70,000 (Paper Size A3)

0 0.75 1.5 2.25 3

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

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Job Number 31-29991
Revision A
Date 13 Aug 2013

Axe Creek RORB Layout

Appendix E3

G:\31\29991\GIS\Maps\Deliverables\Appendix E2- Axe Creek RORB Layout.mxd

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Data source: DSE, VicMap, 2013; GHD, RORB Model, 2013. Created by:scowan

Appendix F – IFD Information

Australian Government
Bureau of Meteorology

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Home | IFD Table | IFD Chart | Coefficients | ARI | Print IFD table | Help IFD table

Intensity-Frequency-Duration Table

Location: 37.025S 144.275E NEAR.. Castlemaine Issued: 4/2/2014

Rainfall intensity in mm/h for various durations and Average Recurrence Interval

Average Recurrence Interval

Duration	1 YEAR	2 YEARS	5 YEARS	10 YEARS	20 YEARS	50 YEARS	100 YEARS
5Mins	51.1	67.4	90.9	106	126	154	177
6Mins	47.7	62.8	84.7	98.9	118	144	165
10Mins	38.7	50.9	68.3	79.5	94.3	115	132
20Mins	27.9	36.6	48.7	56.4	66.7	80.9	92.3
30Mins	22.5	29.5	39.0	45.0	53.1	64.3	73.2
1Hr	15.0	19.6	25.7	29.5	34.7	41.7	47.4
2Hrs	9.73	12.6	16.4	18.7	21.8	26.1	29.5
3Hrs	7.52	9.73	12.5	14.2	16.5	19.6	22.1
6Hrs	4.81	6.19	7.82	8.82	10.2	12.0	13.5
12Hrs	3.04	3.90	4.89	5.50	6.33	7.45	8.32
24Hrs	1.86	2.40	3.03	3.43	3.96	4.68	5.25
48Hrs	1.09	1.41	1.82	2.08	2.43	2.90	3.28
72Hrs	.771	1.00	1.31	1.50	1.76	2.12	2.40

(Raw data: 19.95, 3.98, 1.02, 39.92, 7.12, 2.02, skew=0.23, F2=4.33, F50=14.95)

Copy Table

WARNINGS

WATER | CLIMATE | ENVIRONMENT

Radar Sat Maps

MetEye™

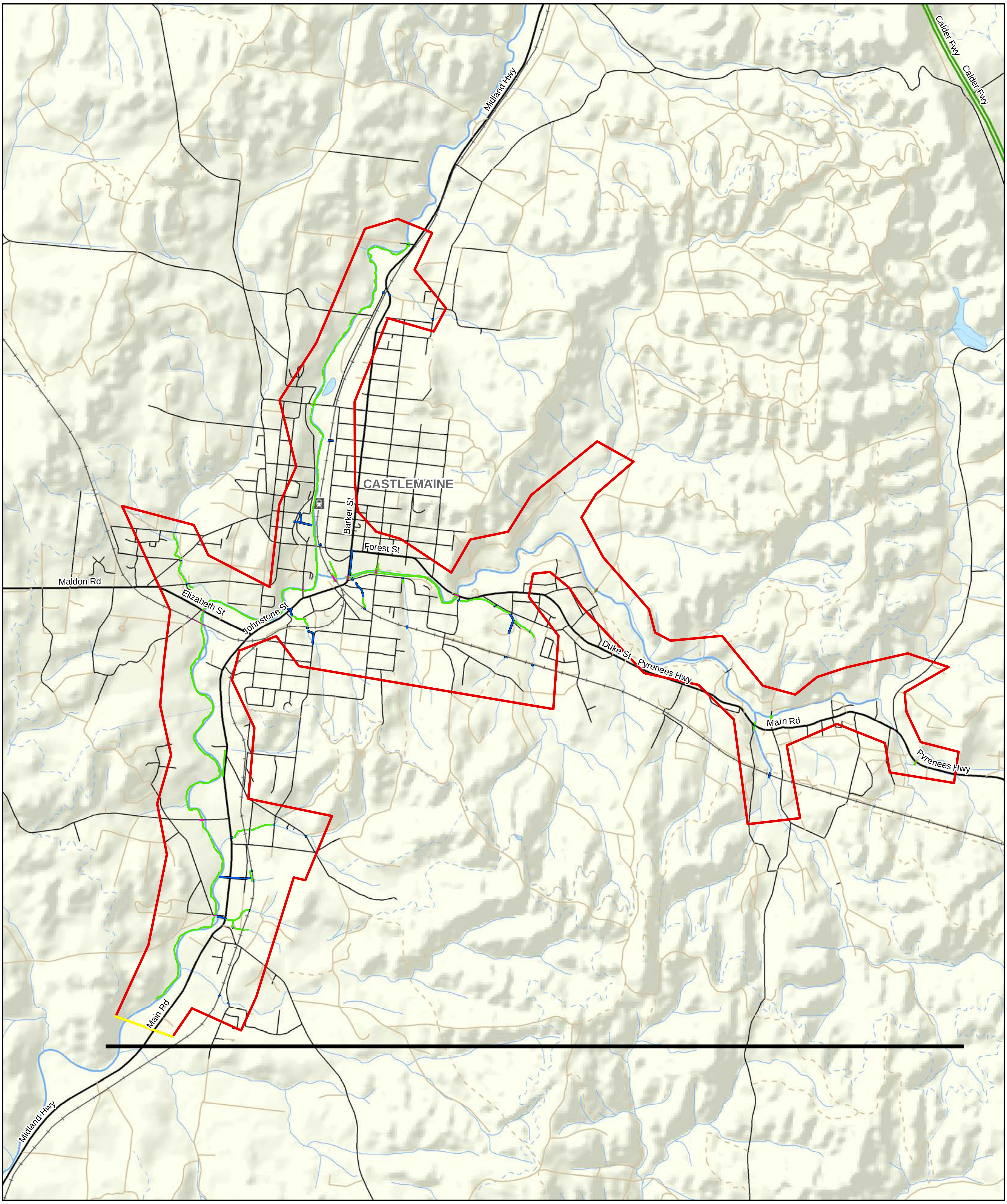
National Weather Services

Aviation Weather Services

RSS

Careers | Sitemap | Feedback

Appendix G – TUFLOW Model Layout



Legend

- Inflow Location
- Layered Flow Constriction (bridge)
- 1D Network (pipes)
- Downstream Boundary Condition
- Z-Shape
- Code Boundary
- Rail station
- Rail
- Freeway
- Highway
- Sealed road (arterial and local)
- Unsealed road
- Track and bike path
- River
- Stream
- Channel / drain
- Connector
- Lake

1:30,000 (Paper Size A3)

0 325 650 975 1,300

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

North Central CMA
Castlemaine, Campbells Creek and Chewton
Flood Management Plan

Job Number 31-29991
Revision A
Date 06 Feb 2014

TUFLOW Model Setup

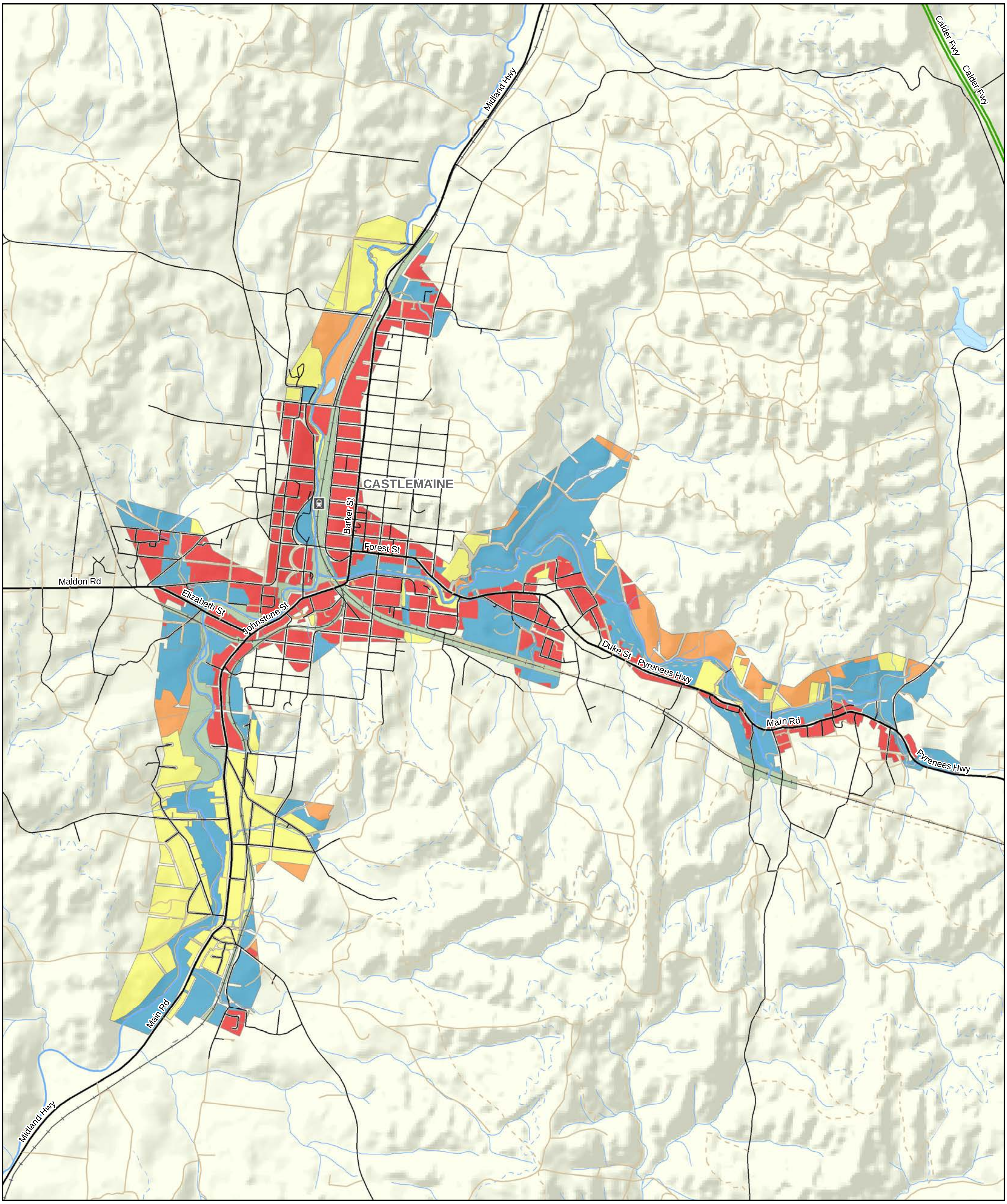
Appendix G

G:\31\29991\GIS\Maps\Deliverables\Appendix H2- TUFLOW Model Setup.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data source: DSE, VicMap, 2013; GHD, Impervious Fractions, 2013. Created by:scowan

Appendix H – TUFLOW Model Roughness



Legend

- Rail station
- Rail
- Freeway
- Highway
- Sealed road (arterial and local)
- Unsealed road
- Track and bike path
- River
- Stream
- Channel / drain
- Connector
- Lake

Manning's n

- 0.030 - 0.040
- 0.041 - 0.050
- 0.051 - 0.075
- 0.076 - 0.100
- 0.101 - 0.200

1:30,000 (Paper Size A3)

0 325 650 975 1,300

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

North Central CMA
Castlemaine, Campbells Creek and Chewton
Flood Management Plan

TUFLOW Model
Manning's Roughness

Job Number	31-29991
Revision	A
Date	06 Feb 2014

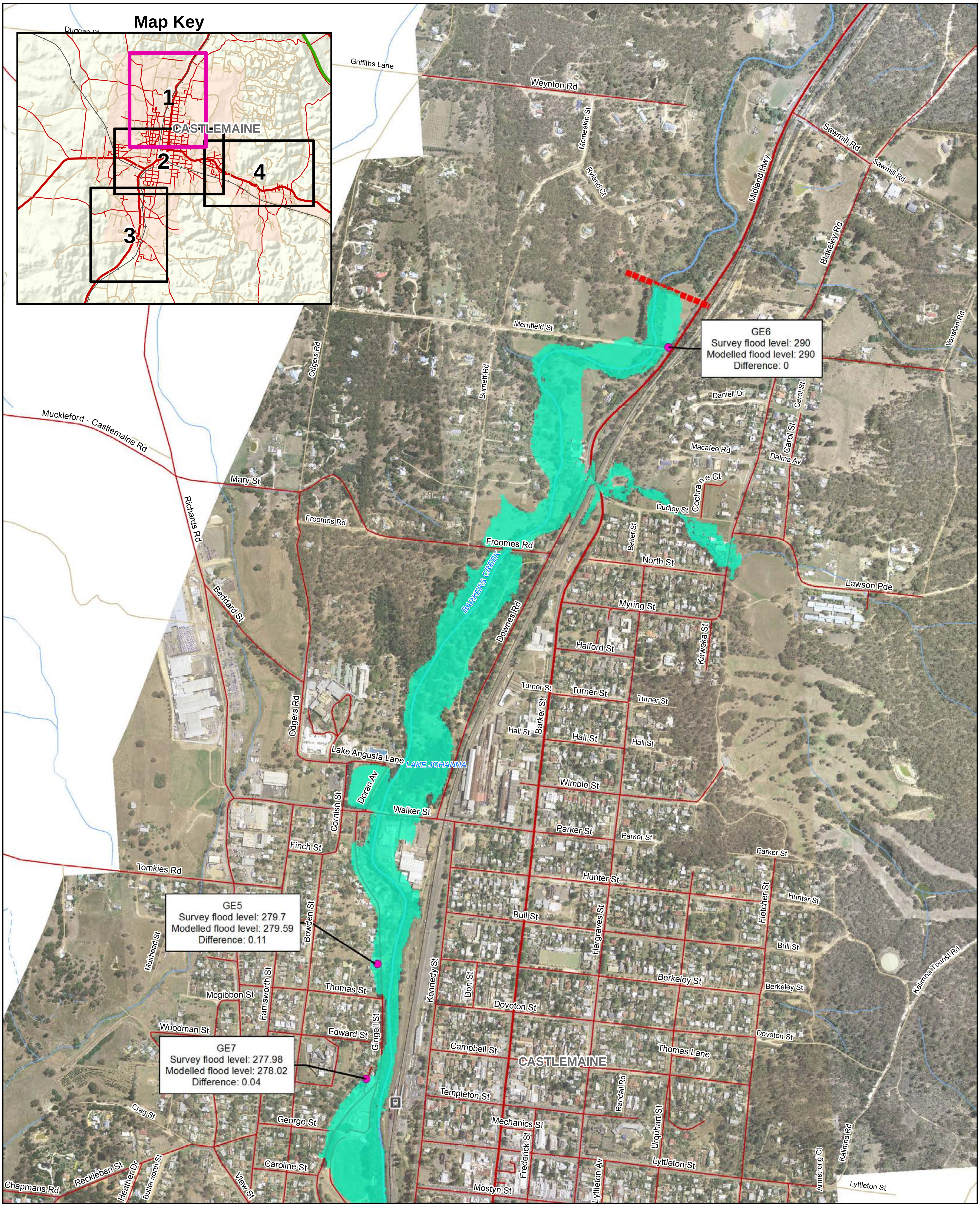
Appendix H

G:\31\29991\GIS\Maps\Deliverables\Appendix H1- TUFLOW Mannings Roughness.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data source: DSE, VicMap, 2013; GHD, Impervious Fractions, 2013. Created by:scowan

Appendix I – TUFLOW Calibration Results



LEGEND

- Survey Flood Level (mAHD)
- TUFLOW Flood Extent
- Extent of flood mapping
- Rail
- Highway
- Sealed road (arterial and local)
- Unsealed road
- Track and bike path
- River
- Stream
- Channel / drain
- Connector

This data should be read in conjunction with the latest revision of the Report titled "Castlemaine, Campbells Creek and Chewton Flood Management Plan" with document number 224993 and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to GHD pty Ltd.

Paper Size A3

0 50 100 200 300 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

NORTH CENTRAL
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North Central CMA
Castlemaine, Campbells Creek and Chewton
Flood Management Plan

January 2011 Flood Extent
Map 1

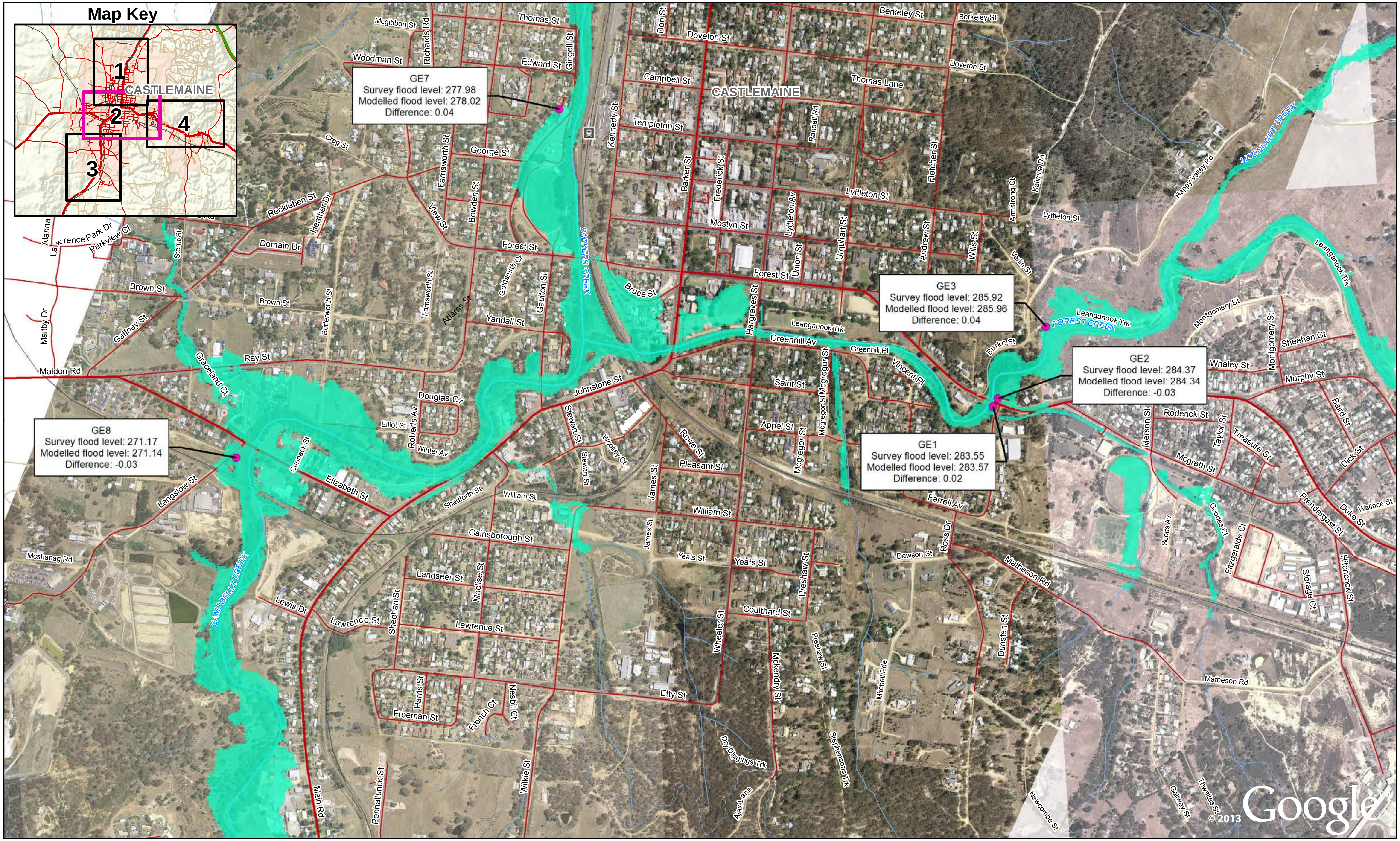
Job Number	31-29991
Revision	A
Date	06 Feb 2014

Appendix I1-1

G:\31\29991\GIS\Maps\Deliverables\Appendix I-1 Map 1 Flood Inundation Extents (A3).mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2013; DSE, Aerial Imagery, 2013; GHD, Inundation Extents, 2013. Created by:scowan



This data should be read in conjunction with the latest revision of the Report titled "Castlemaine, Campbells Creek and Chewton Flood Management Plan" with document number 224993 and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to GHD pty Ltd.

Paper Size A3

0 50 100 200 300 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Survey Flood Level (mAHD)
- TUFLOW Flood Extent
- Rail
- Highway
- Sealed road (arterial and local)
- Unsealed road
- Track and bike path
- River
- Stream
- Channel / drain
- Connector

GHD

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Castlemaine, Campbells Creek and Chewton Flood Management Plan

January 2011 Flood Extent
Map 2

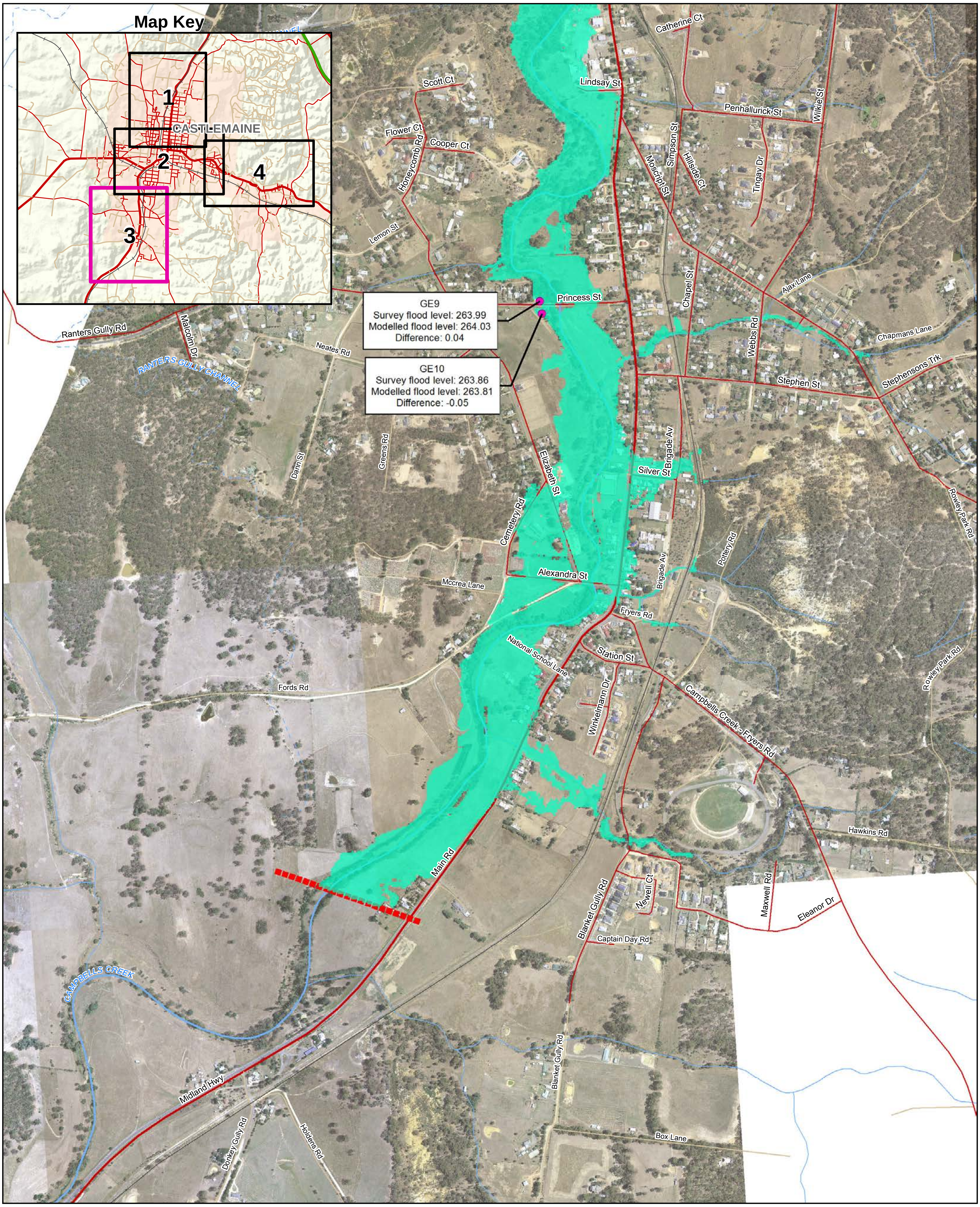
Job Number	31-29991
Revision	A
Date	05 Feb 2014

Appendix I1-2

G:\31\29991\GIS\Maps\Deliverables\Appendix I-2 Map 2 Flood Inundation Extents (A3).mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2013; GHD, Inundation Extents, 2013. Created by:scowan



LEGEND

- Survey Flood Level (mAHD)
- TUFLOW Flood Extent
- Extent of flood mapping
- Rail
- Highway
- Sealed road (arterial and local)
- Unsealed road
- Track and bike path
- River
- Stream
- Channel / drain
- Connector

This data should be read in conjunction with the latest revision of the Report titled "Castlemaine, Campbells Creek and Chewton Flood Management Plan" with document number 224993 and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to GHD pty Ltd.

Paper Size A3

0 50 100 200 300 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

NORTH CENTRAL
Catchment Management Authority
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North Central CMA
Castlemaine, Campbells Creek and Chewton
Flood Management Plan

January 2011 Flood Extent
Map 3

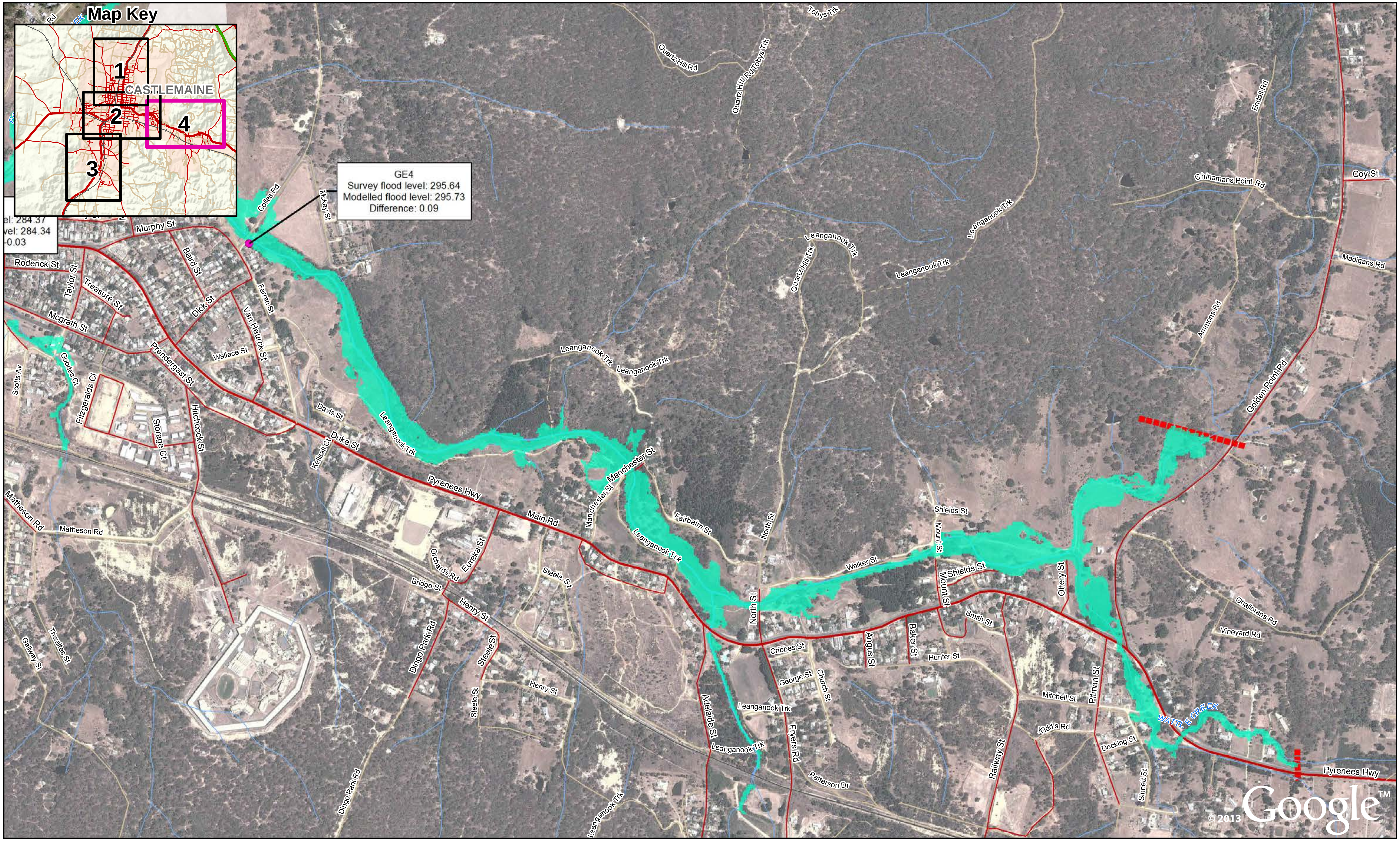
Job Number 31-29991
Revision A
Date 05 Feb 2014

Appendix I1-3

G:\31\29991\GIS\Maps\Deliverables\Appendix I-3 Map 3 Flood Inundation Extents (A3).mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2013; DSE, Aerial Imagery, 2013; GHD, Inundation Extents, 2013. Created by:scowan



This data should be read in conjunction with the latest revision of the Report titled "Castlemaine, Campbells Creek and Chewton Flood Management Plan" with document number 224993 and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to GHD pty Ltd.

Paper Size A3

0 50 100 200 300 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Survey Flood Level (mAHD)
- TUFLOW Flood Extent
- Rail
- Highway
- Sealed road (arterial and local)
- Unsealed road
- Track and bike path
- River
- Stream
- Channel / drain
- Extent of flood mapping

NORTH CENTRAL
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Castlemaine, Campbells Creek and Chewton Flood Management Plan

Job Number	31-29991
Revision	A
Date	05 Feb 2014

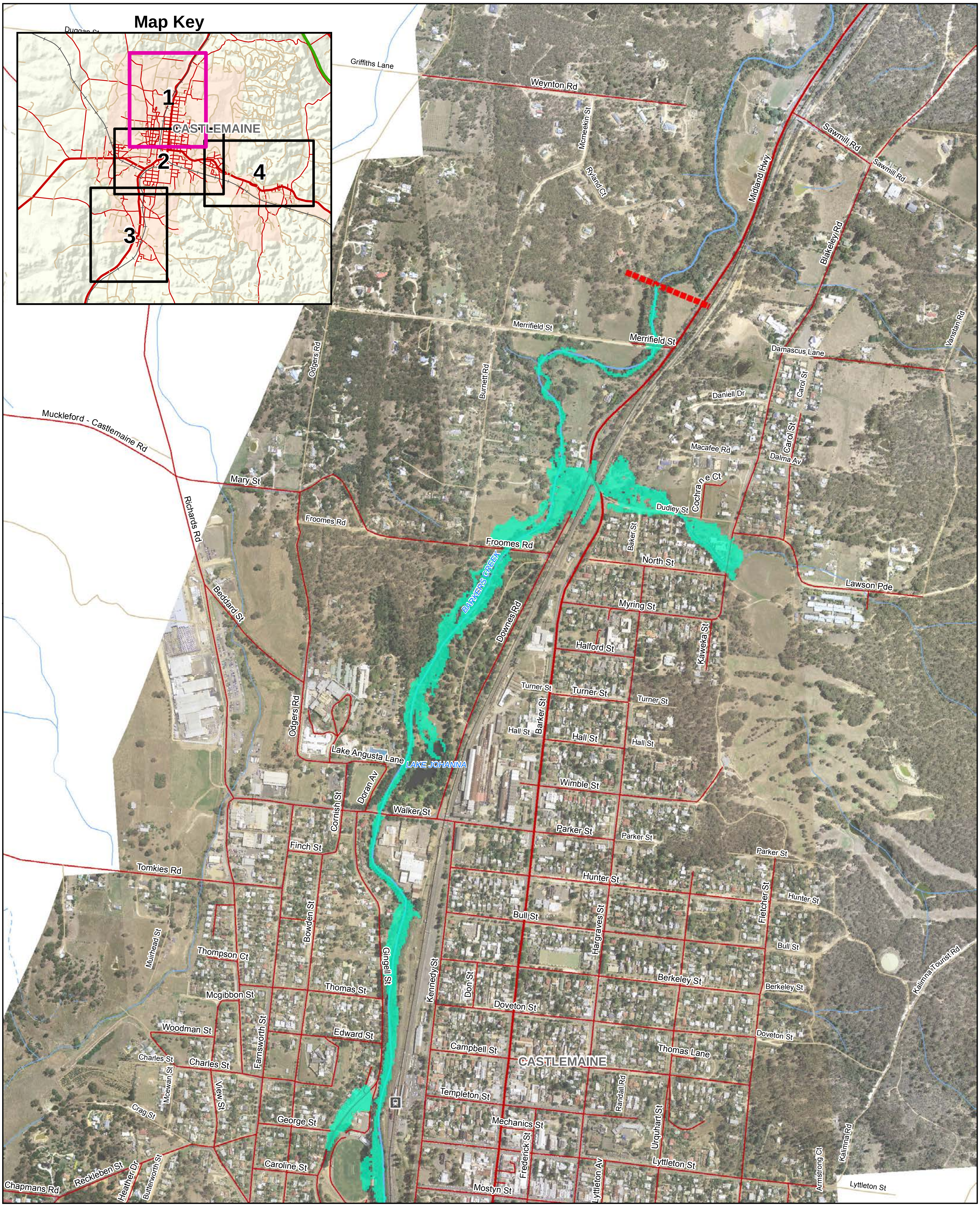
January 2011 Flood Extent
Map 4

Appendix I1-4

G:\31\29991\GIS\Maps\Deliverables\Appendix I-4 Map 4 Flood Inundation Extents (A3).mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2013; GHD, Inundation Extents, 2013. Created by:scowan



LEGEND

- TUFLOW Flood Extent
- Extent of flood mapping
- Rail
- Highway
- Sealed road (arterial and local)
- Unsealed road
- Track and bike path
- River
- Stream
- Channel / drain
- Connector

This data should be read in conjunction with the latest revision of the Report titled "Castlemaine, Campbells Creek and Chewton Flood Management Plan" with document number 224993 and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to GHD pty Ltd.

Paper Size A3

0 50 100 200 300 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

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Flood Management Plan

February 2012 Flood Extent
Map 1

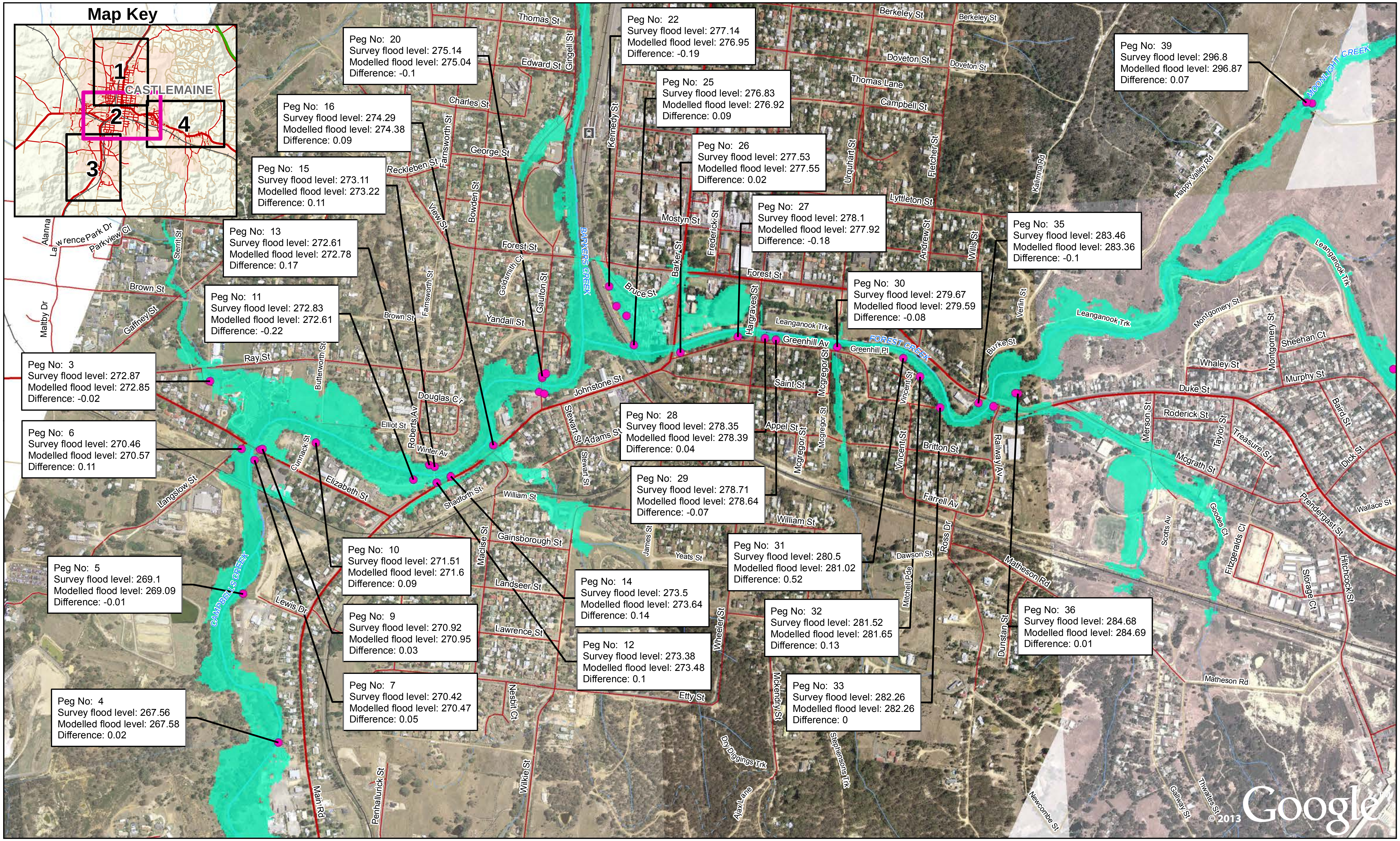
Job Number	31-29991
Revision	A
Date	06 Feb 2014

Appendix I2-1

G:\31\29991\GIS\Maps\Deliverables\Appendix I-1 Map 1 Flood Inundation Extents (A3).mxd

180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data source: DSE, VicMap, 2013; DSE, Aerial Imagery, 2013; GHD, Inundation Extents, 2013. Created by:scowan



This data should be read in conjunction with the latest revision of the Report titled "Castlemaine, Campbells Creek and Chewton Flood Management Plan" with document number 224993 and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to GHD pty Ltd.

Paper Size A3

0 50 100 200 300 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

Survey Flood Level (mAHD)	Sealed road (arterial and local)
TUFLOW Flood Extent	Unsealed road
Rail	Track and bike path
Highway	River
Stream	Channel / drain
Connector	

GHD

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Job Number	31-29991
Revision	A
Date	05 Feb 2014

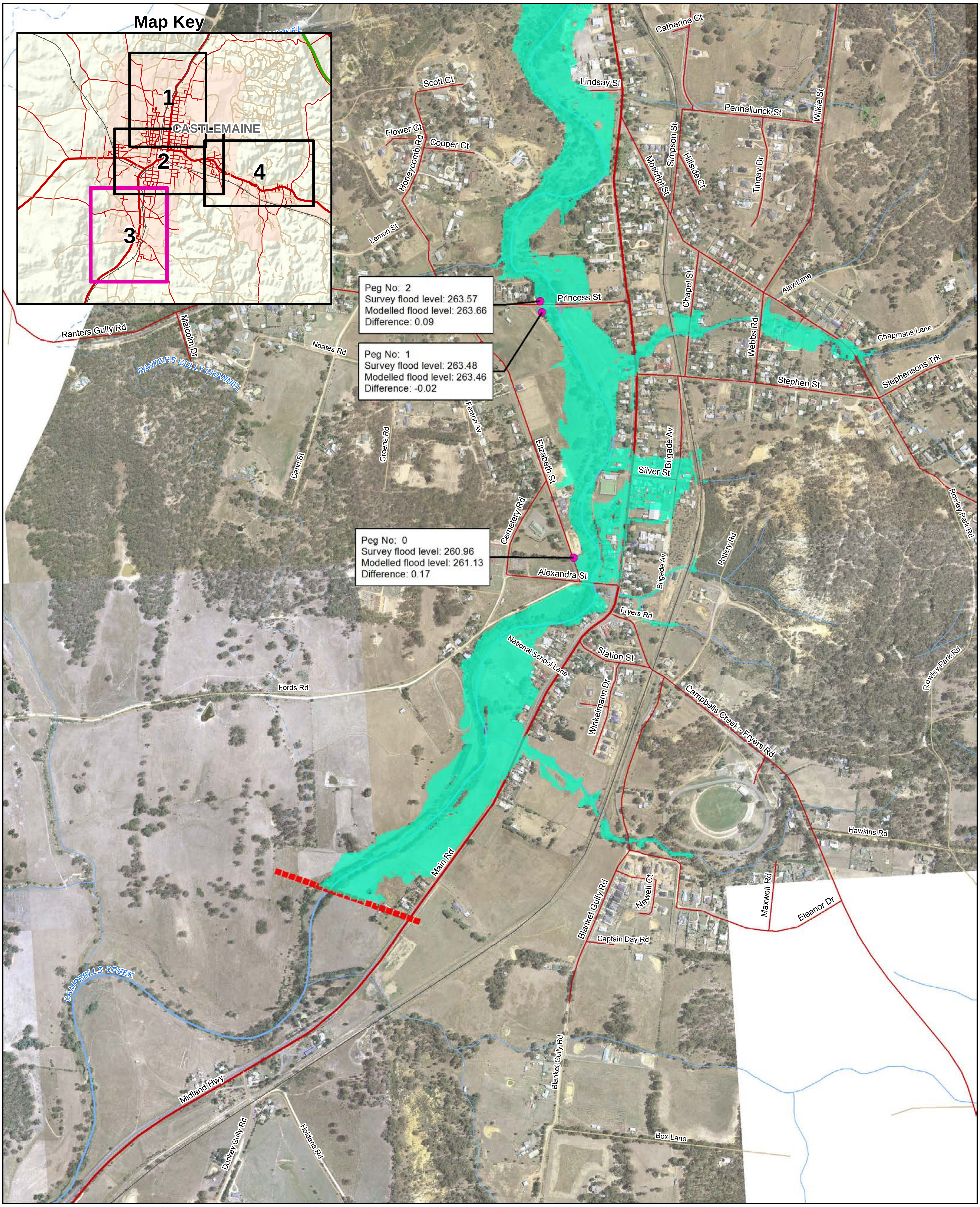
February 2012 Flood Extent
Map 2

Appendix I2-2

G:\31\29991\GIS\Maps\Deliverables\Appendix I-2 Map 2 Flood Inundation Extents (A3).mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2013; GHD, Inundation Extents, 2013. Created by:scowan



LEGEND

- Survey Flood Level (mAHD)
- TUFLOW Flood Extent
- Extent of flood mapping
- Rail
- Highway
- Sealed road (arterial and local)
- Unsealed road
- Track and bike path
- River
- Stream
- Channel / drain
- Connector

This data should be read in conjunction with the latest revision of the Report titled "Castlemaine, Campbells Creek and Chewton Flood Management Plan" with document number 224993 and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to GHD pty Ltd.

Paper Size A3

0 50 100 200 300 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

NORTH CENTRAL
Catchment Management Authority
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North Central CMA
Castlemaine, Campbells Creek and Chewton
Flood Management Plan

February 2012 Flood Extent
Map 3

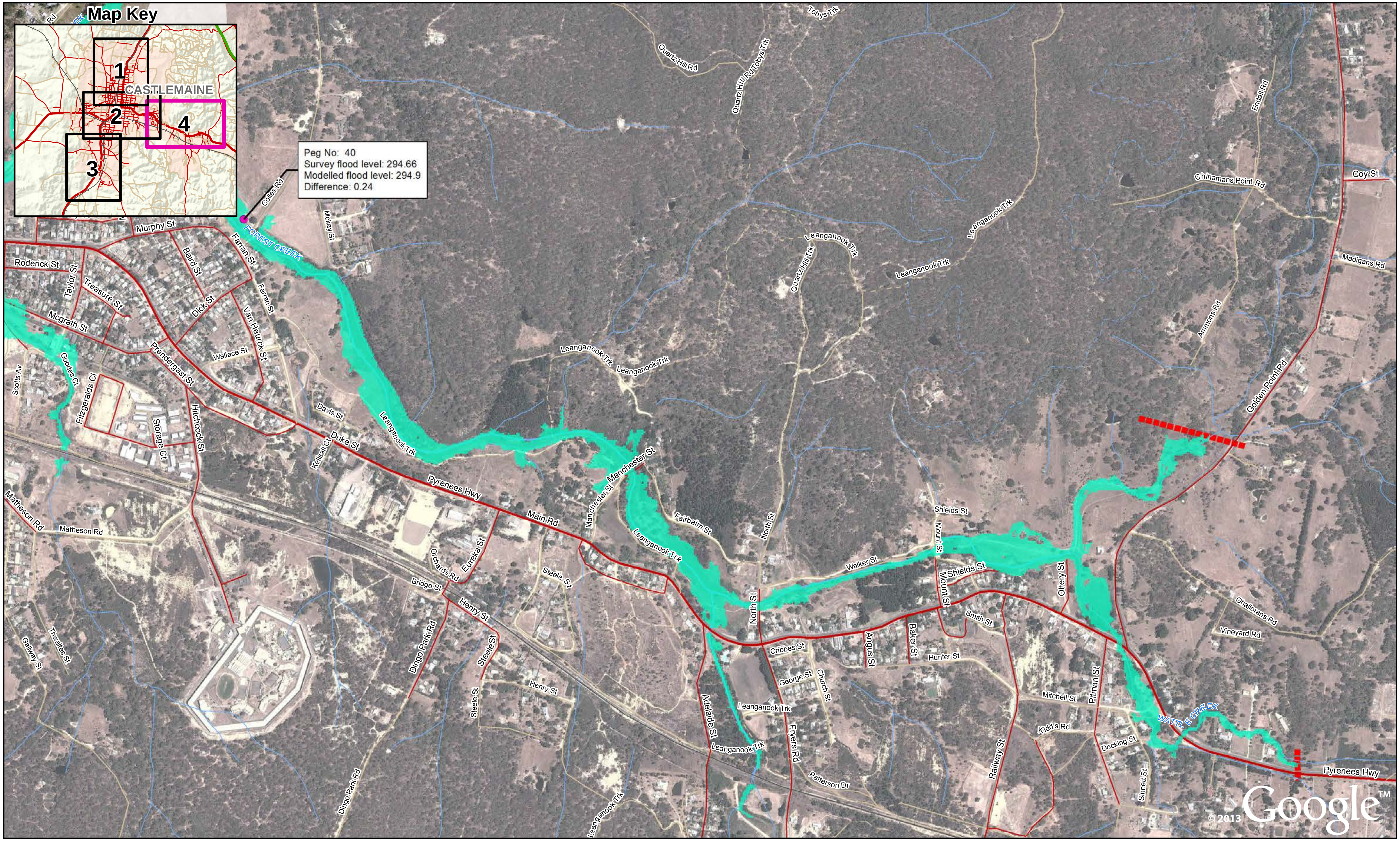
Job Number	31-29991
Revision	A
Date	05 Feb 2014

Appendix I2-3

G:\31\29991\GIS\Maps\Deliverables\Appendix I-3 Map 3 Flood Inundation Extents (A3).mxd

180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data source: DSE, VicMap, 2013; DSE, Aerial Imagery, 2013; GHD, Inundation Extents, 2013. Created by:scowan



This data should be read in conjunction with the latest revision of the Report titled "Castlemaine, Campbells Creek and Chewton Flood Management Plan" with document number 224993 and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to GHD pty Ltd.

Paper Size A3

0 50 100 200 300 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

Survey Flood Level (mAHD)	Sealed road (arterial and local)	Stream
TUFLOW Flood Extent	Unsealed road	Channel / drain
Rail	Track and bike path	Extent of flood mapping
Highway	River	

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Castlemaine, Campbells Creek and Chewton Flood Management Plan

Job Number	31-29991
Revision	A
Date	05 Feb 2014

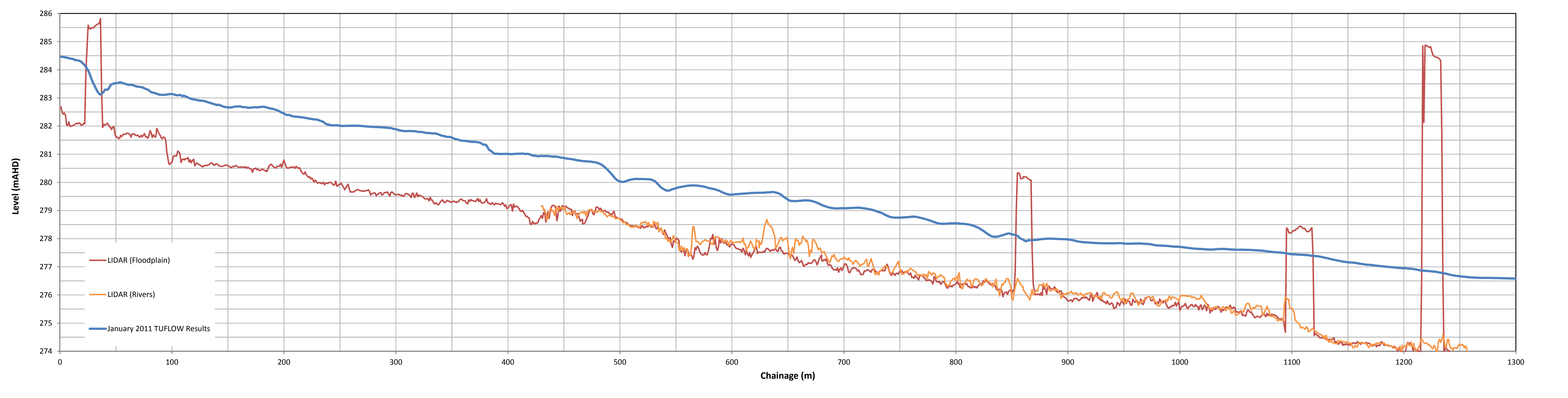
February 2012 Flood Extent
Map 4

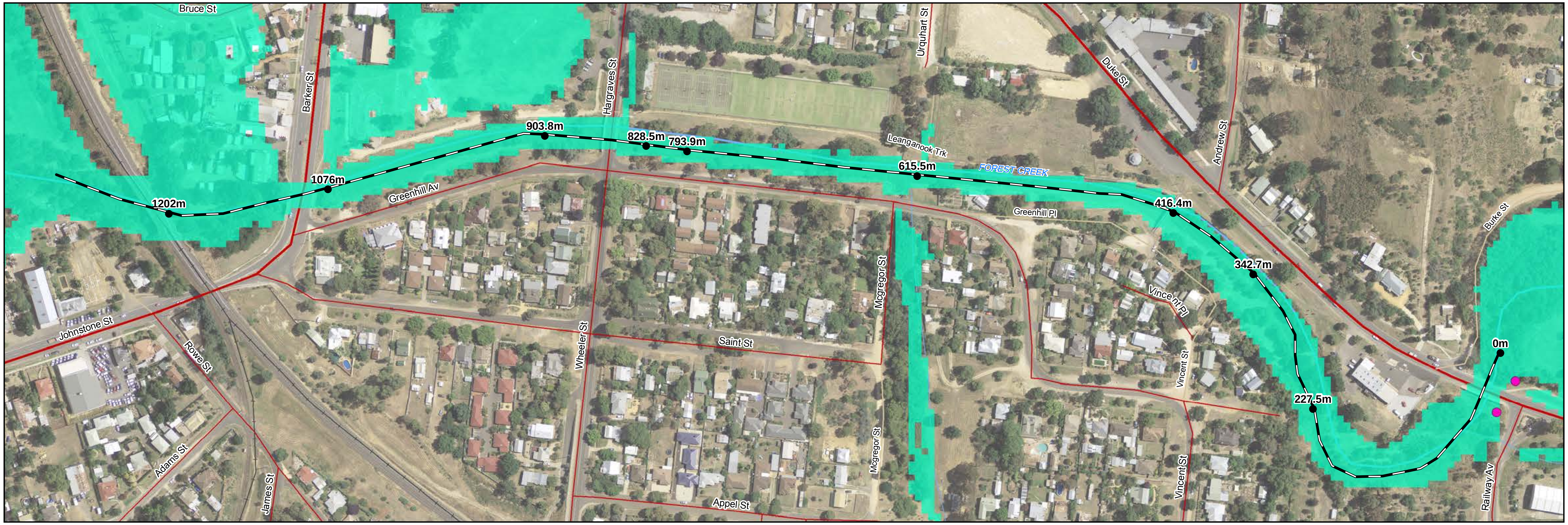
Appendix I2-4

G:\31\29991\GIS\Maps\Deliverables\Appendix I-4 Map 4 Flood Inundation Extents (A3).mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2013; GHD, Inundation Extents, 2013. Created by:scowan





This data should be read in conjunction with the latest revision of the Report titled "Castlemaine, Campbells Creek and Chewton Flood Management Plan" with document number 224993 and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to GHD pty Ltd.

Paper Size A3

0 15 30 60 90 120

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Section Chainage Line
- Survey Flood Level (mAHD)
- TUFLOW Flood Extent
- Rail
- Highway
- Sealed road (arterial and local)
- Unsealed road
- Track and bike path
- River
- Stream

North Central CMA
Castlemaine, Campbells Creek and Chewton
Flood Management Plan

Job Number 31-29991
Revision A
Date 06 Feb 2014

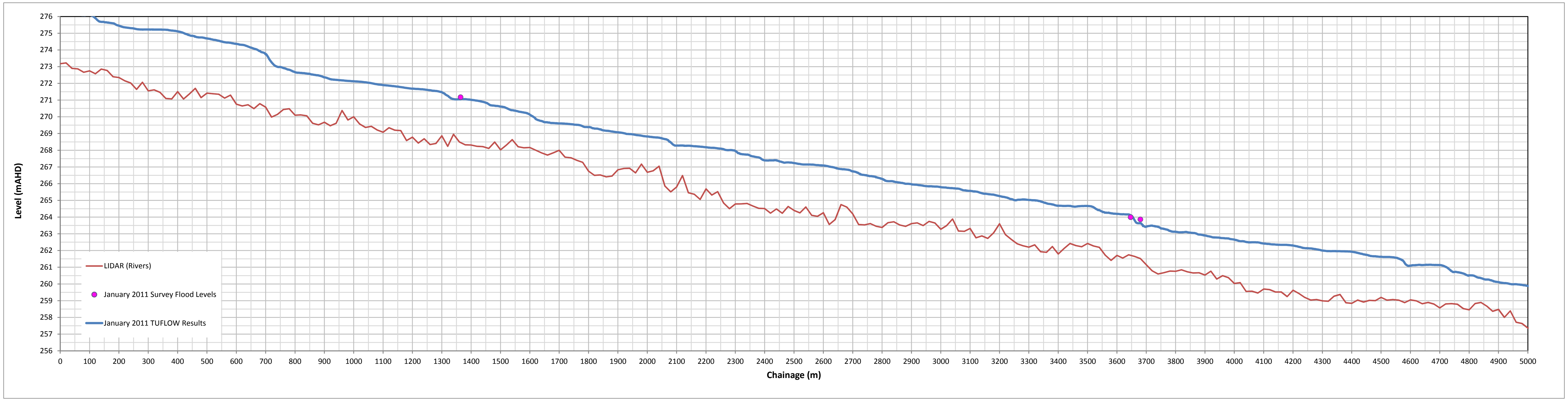
Jan2011 Water Surface Profile
Forest Creek

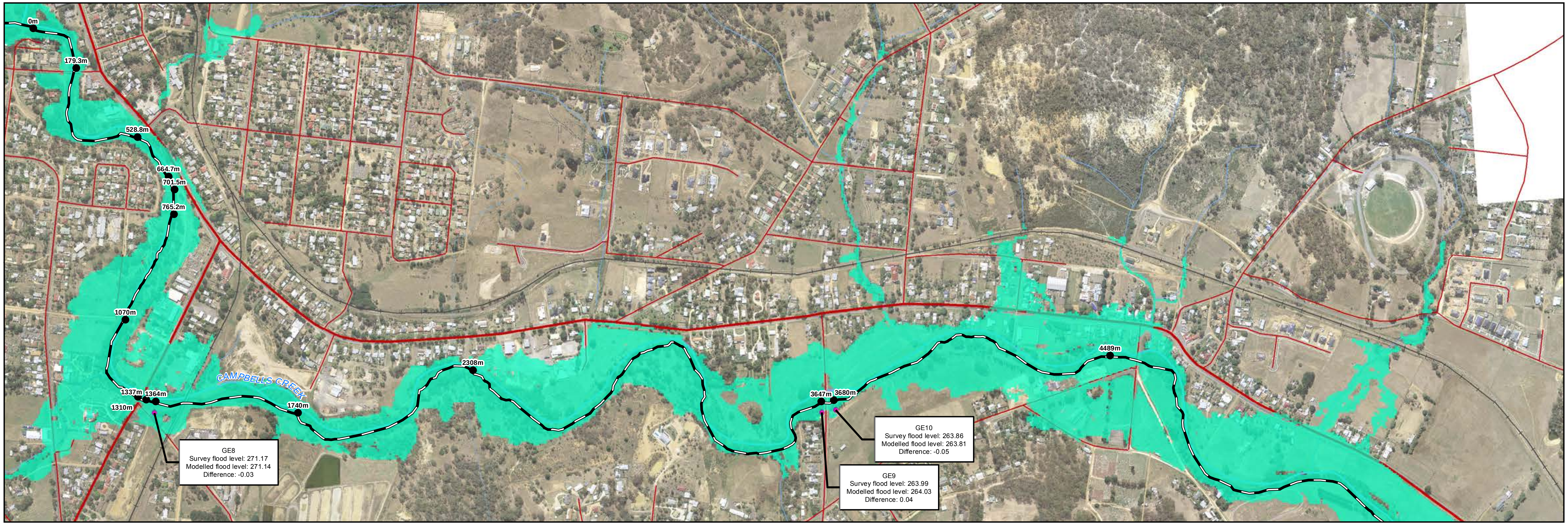
Appendix I3-1

G:\31\29991\GIS\Maps\Deliverables\Appendix I3-1- Jan2011 Forest Creek Long Section Water Surface Profiles.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2013; GHD, Inundation Extents, 2013. Created by:scowan





This data should be read in conjunction with the latest revision of the Report titled "Castlemaine, Campbells Creek and Chewton Flood Management Plan" with document number 224993 and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to GHD pty Ltd.

Paper Size A3

0 50 100 200 300 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Section Chainage Line
- Survey Flood Level (mAHD)
- TUFLOW Flood Extent
- Rail
- Highway
- Sealed road (arterial and local)
- Unsealed road
- Track and bike path
- River
- Stream
- Channel / drain
- Connector

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Job Number	31-29991
Revision	A
Date	06 Feb 2014

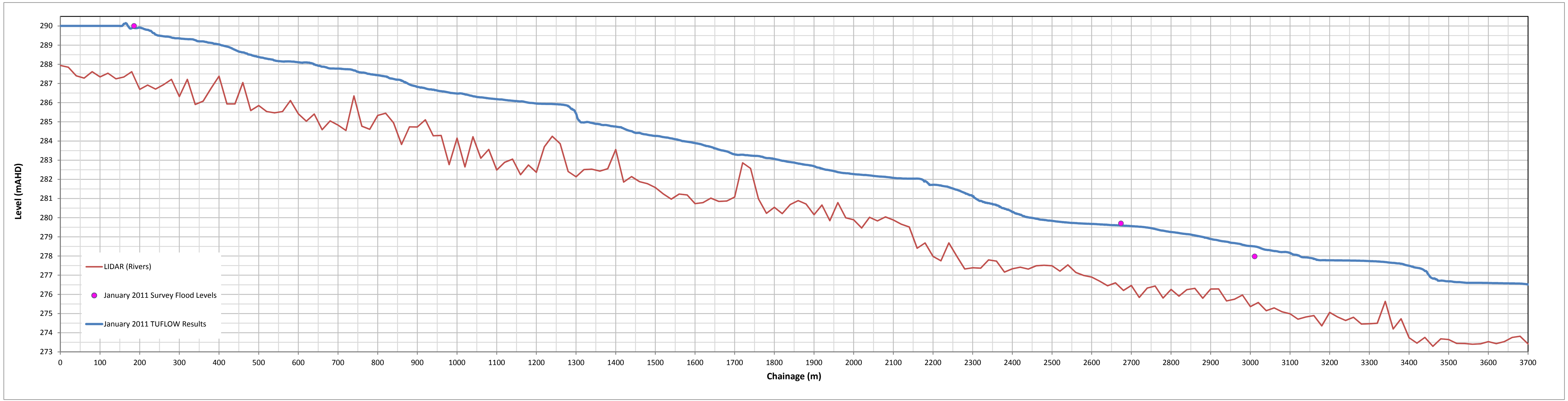
Jan2011 Water Surface Profile Campbells Creek

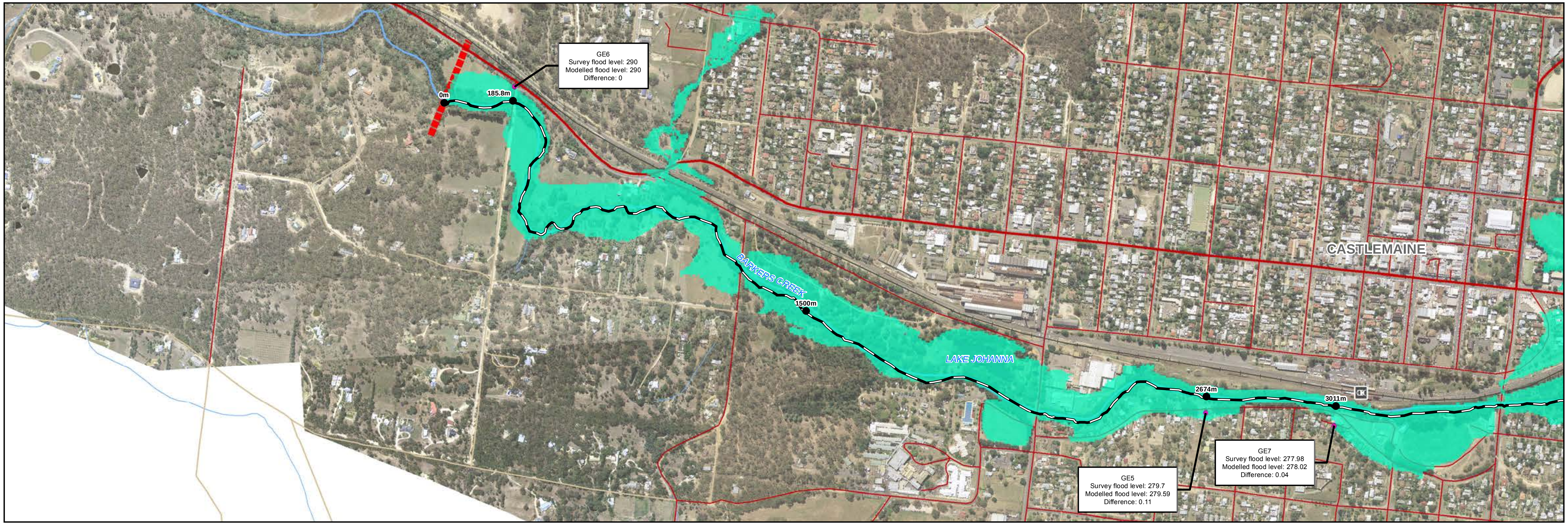
Appendix I3-2

G:\31\29991\GIS\Maps\Deliverables\Appendix I3-2- Jan2011 Campbells Creek Long Section Water Surface Profiles.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2013; GHD, Inundation Extents, 2013. Created by:scowan





This data should be read in conjunction with the latest revision of the Report titled "Castlemaine, Campbells Creek and Chewton Flood Management Plan" with document number 224993 and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to GHD pty Ltd.

Paper Size A3

0 50 100 200 300 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Section Chainage Line
- Survey Flood Level (mAHD)
- TUFLOW Flood Extent
- Rail
- Highway
- Sealed road (arterial and local)
- Unsealed road
- Track and bike path
- River
- Stream
- Extent of flood mapping

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Jan2011 Water Surface Profile Barkers Creek

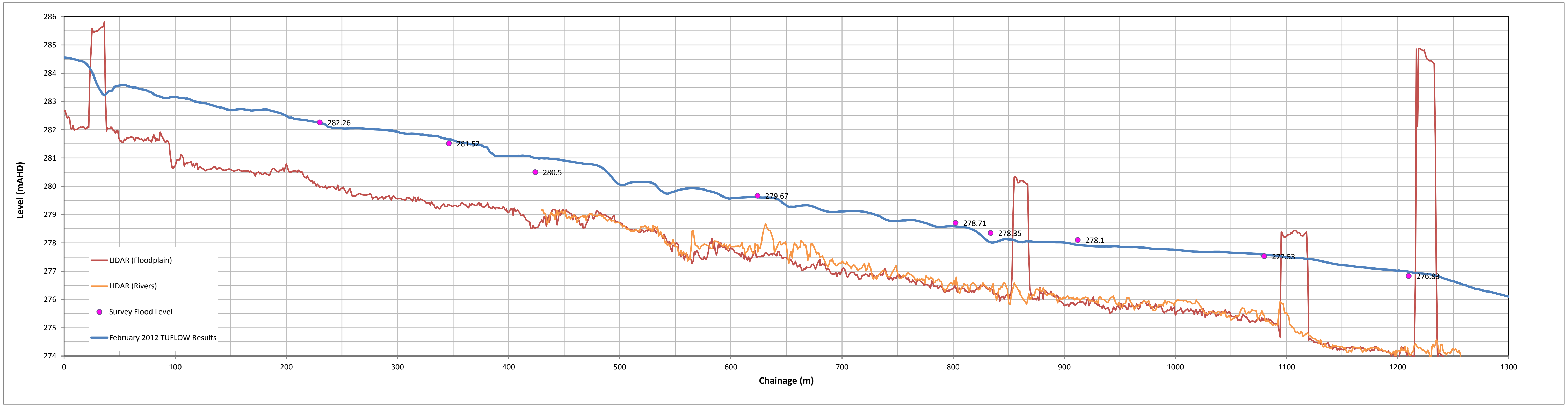
Job Number	31-29991
Revision	A
Date	06 Feb 2014

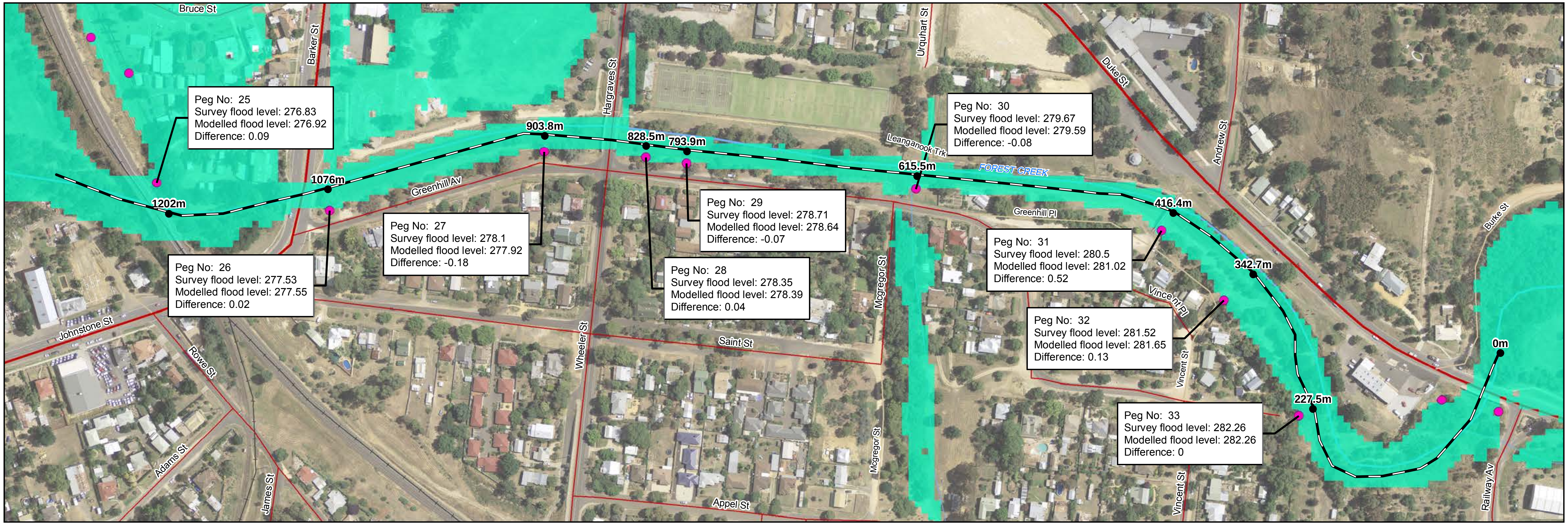
Appendix I3-3

G:\31\29991\GIS\Maps\Deliverables\Appendix I3-3- Jan2011 Barkers Creek Long Section Water Surface Profiles.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2013; GHD, Inundation Extents, 2013. Created by:scowan





This data should be read in conjunction with the latest revision of the Report titled "Castlemaine, Campbells Creek and Chewton Flood Management Plan" with document number 224993 and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to GHD pty Ltd.

Paper Size A3

0 15 30 60 90 120

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Section Chainage Line
- Survey Flood Level (mAHD)
- TUFLOW Flood Extent
- Rail
- Highway
- Sealed road (arterial and local)
- Unsealed road
- Track and bike path
- River
- Stream

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Flood Management Plan

Job Number	31-29991
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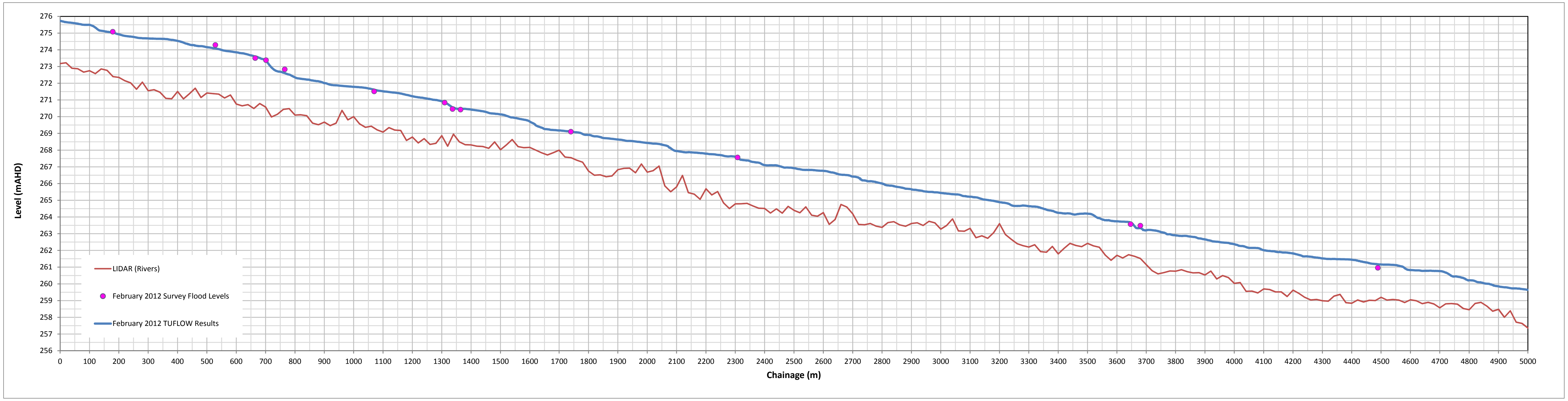
Feb2012 Water Surface Profile
Forest Creek

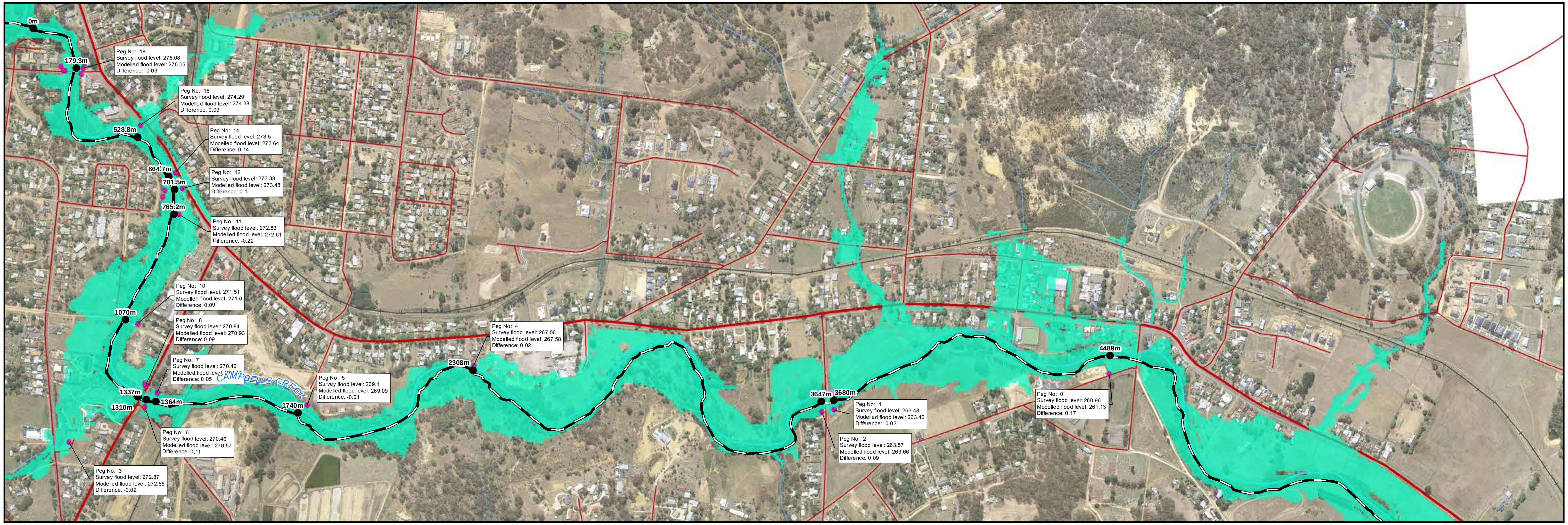
Appendix I4-1

G:\31\29991\GIS\Maps\Deliverables\Appendix I4-1- Feb2012 Forest Creek Long Section Water Surface Profiles.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2013; GHD, Inundation Extents, 2013. Created by:scowan





This data should be read in conjunction with the latest revision of the Report titled "Castlemaine, Campbells Creek and Chewton Flood Management Plan" with document number 224993 and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to GHD pty Ltd.

Paper Size A3

0 50 100 200 300 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Section Chainage Line
- Survey Flood Level (mAHD)
- TUFLOW Flood Extent
- Rail
- Highway
- Sealed road (arterial and local)
- Unsealed road
- Track and bike path
- River
- Stream
- Channel / drain
- Connector

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Castlemaine, Campbells Creek and Chewton Flood Management Plan

Job Number	31-29991
Revision	A
Date	06 Feb 2014

Feb2012 Water Surface Profile Campbells Creek

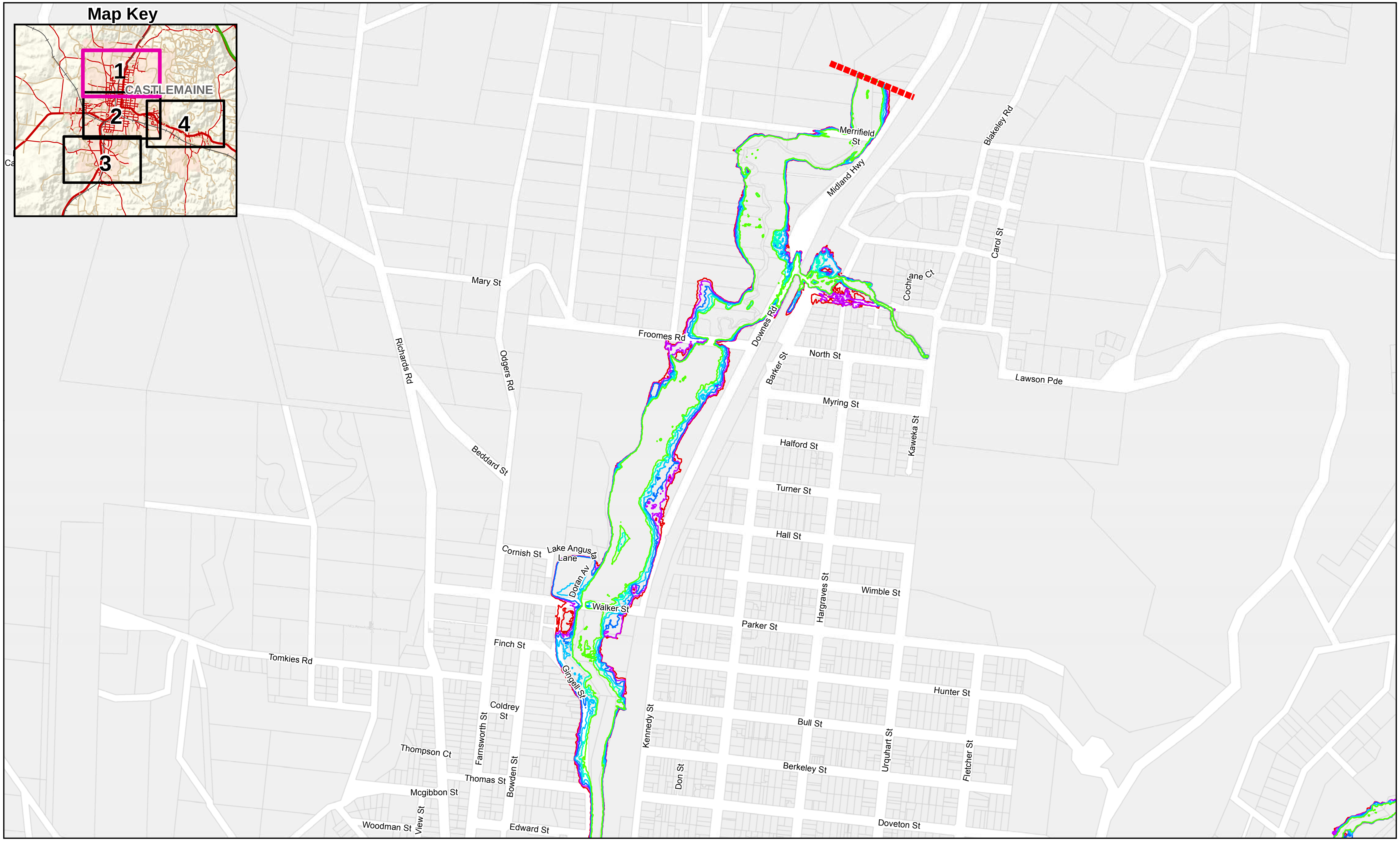
Appendix I4-2

G:\31\29991\GIS\Maps\Deliverables\Appendix I3-2- Long Section Water Surface Profiles.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2013; GHD, Inundation Extents, 2013. Created by:scowan

Appendix J – Design Flood Extents



This data should be read in conjunction with the latest revision of the Report titled "Castlemaine, Campbells Creek and Chewton Flood Management Plan" with document number 224993 and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to GHD pty Ltd.

Paper Size A3

0 50 100 200 300 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- 5 year ARI extent
- 10 year ARI extent
- 20 year ARI extent
- 50 year ARI extent
- 100 year ARI extent
- 200 year ARI extent

GHD

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Castlemaine, Campbells Creek and Chewton Flood Management Plan

Design Flood Extents
Map 1

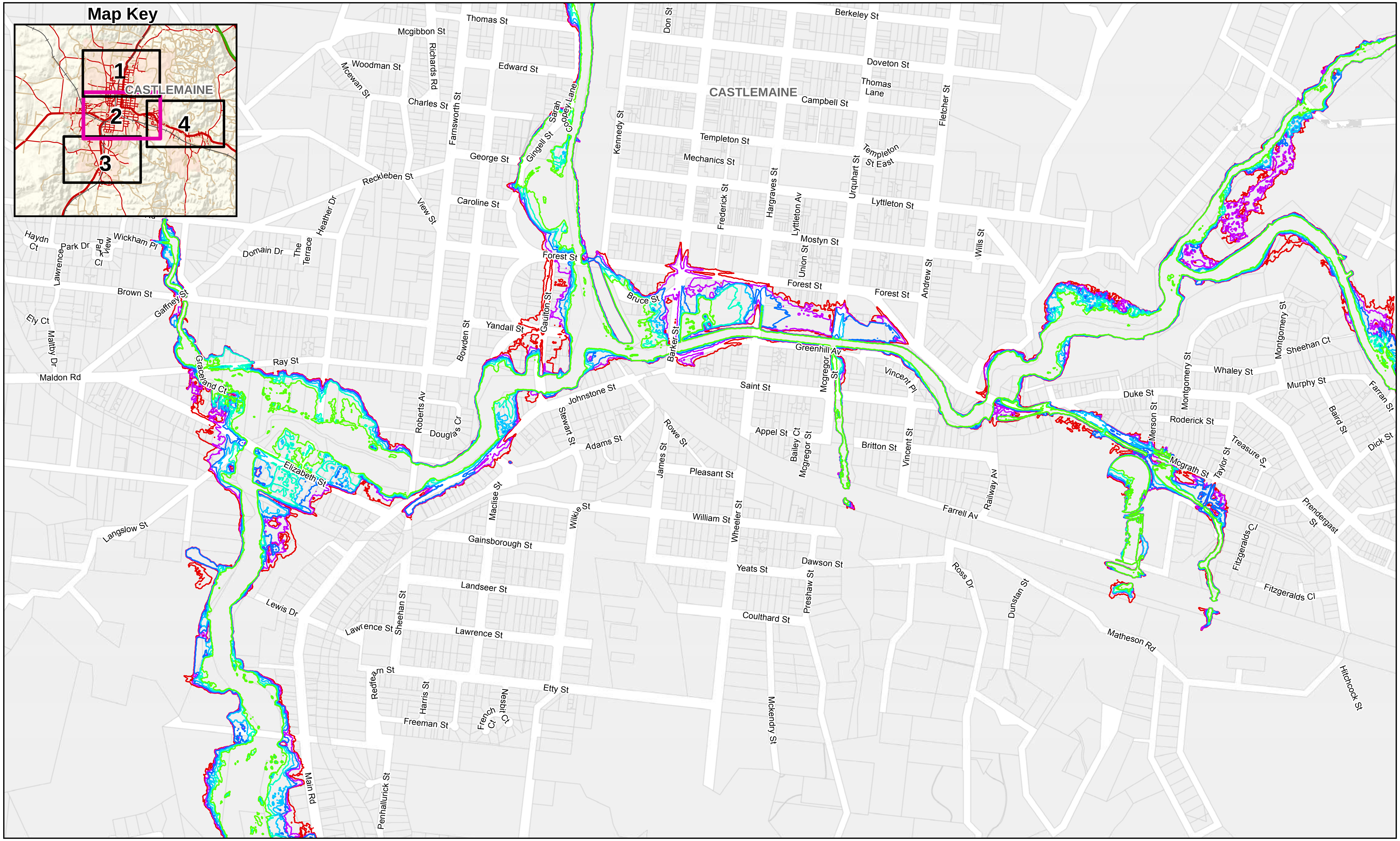
Job Number	31-29991
Revision	A
Date	22 Dec 2014

Appendix J-1

G:\31\29991\GIS\Maps\Deliverables\Appendix J1- Map 1 Design Extents (A3).mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2013; GHD, Inundation Extents, 2013. Created by:scowan



This data should be read in conjunction with the latest revision of the Report titled "Castlemaine, Campbells Creek and Chewton Flood Management Plan" with document number 224993 and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to GHD pty Ltd.

Paper Size A3

0 50 100 200 300 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

5 year ARI extent	50 year ARI extent
10 year ARI extent	100 year ARI extent
20 year ARI extent	200 year ARI extent

GHD

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Design Flood Extents
Map 2

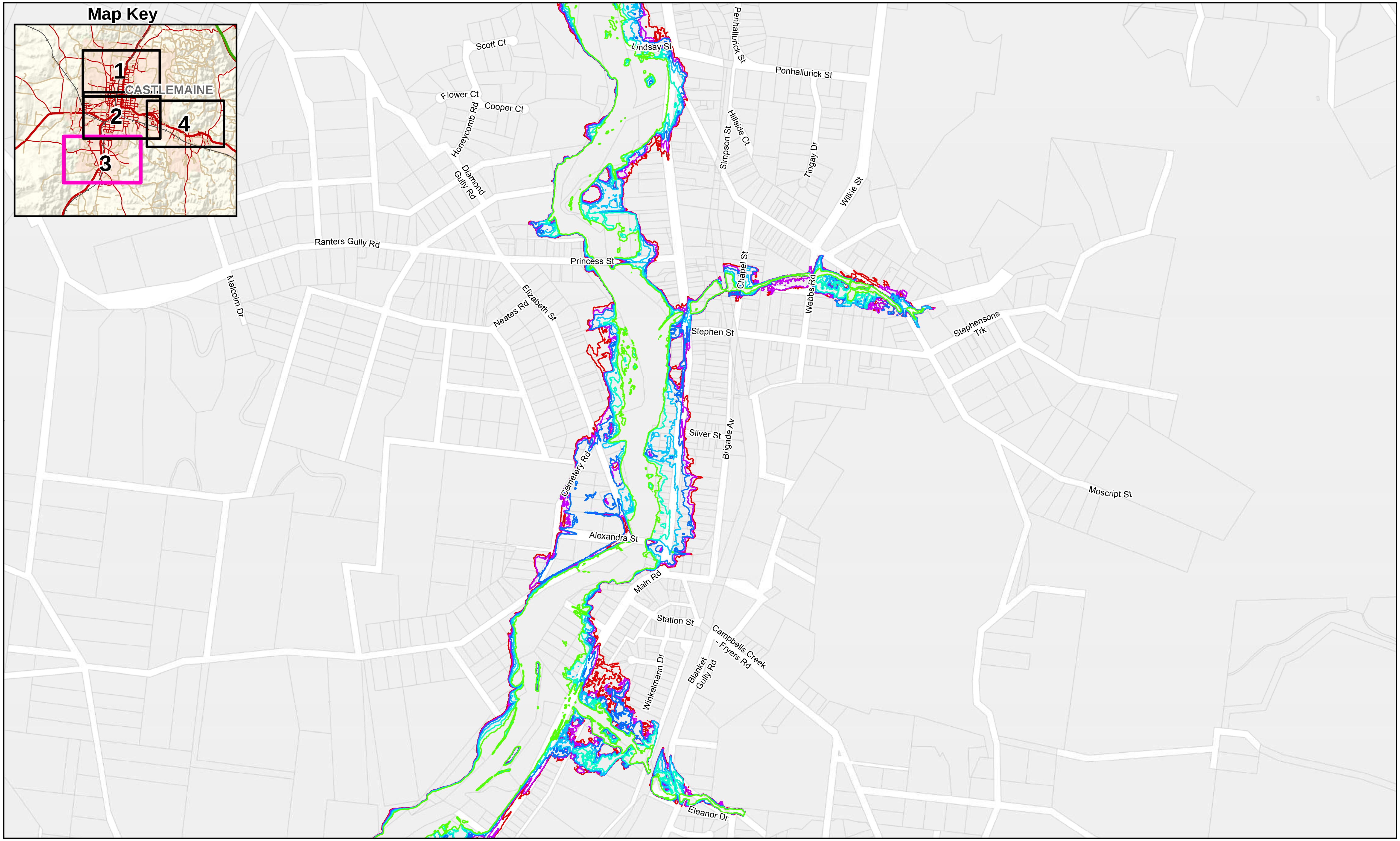
Job Number 31-29991
Revision A
Date 22 Dec 2014

Appendix J-2

G:\31\29991\GIS\Maps\Deliverables\Appendix J2- Map 2 Design Extents (A3).mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2013; GHD, Inundation Extents, 2013. Created by:scowan



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Paper Size A3

0 50 100 200 300 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- 5 year ARI extent
- 10 year ARI extent
- 20 year ARI extent
- 50 year ARI extent
- 100 year ARI extent
- 200 year ARI extent

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Castlemaine, Campbells Creek and Chewton Flood Management Plan

Job Number	31-29991
Revision	A
Date	22 Dec 2014

Design Flood Extents
Map 3

Appendix J-3

G:\31\29991\GIS\Maps\Deliverables\Appendix J3- Map 1 Design Extents (A3).mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

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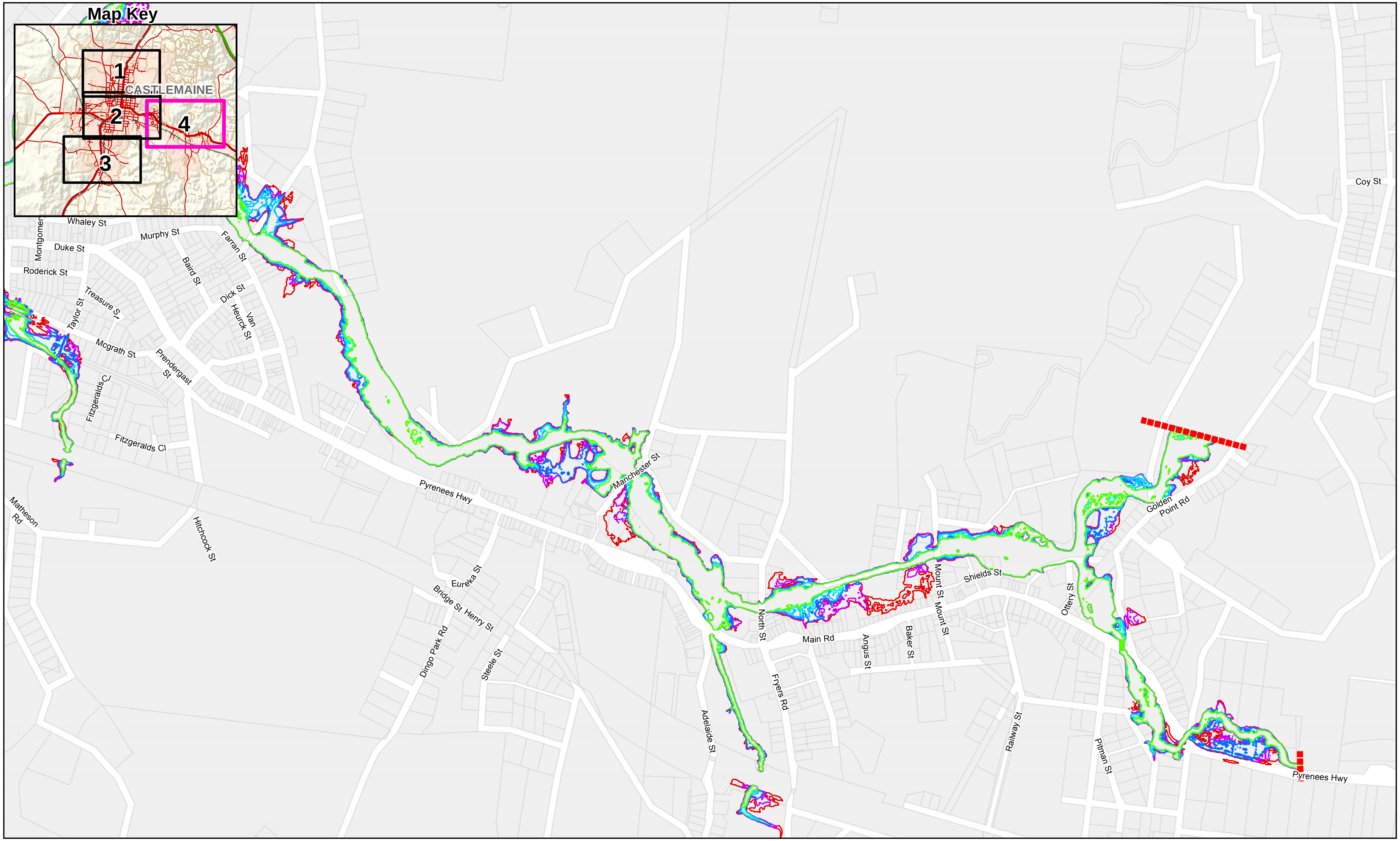

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Paper Size A3

0 50 100 200 300 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- 5 year ARI extent
- 10 year ARI extent
- 20 year ARI extent
- 50 year ARI extent
- 100 year ARI extent
- 200 year ARI extent

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North Central CMA
Castlemaine, Campbells Creek and Chewton Flood Management Plan

Job Number 31-29991
Revision A
Date 22 Dec 2014

Design Flood Extents
Map 4

Appendix J-4

G:\31\29991\GIS\Maps\Deliverables\Appendix J4- Map 4 Design Extents (A3).mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2013; GHD, Inundation Extents, 2013. Created by:scowan

Appendix K – Levee Sketches

Elizabeth Street (Castlemaine) Levee

LEVEE LOCATION PLAN

EXISTING CONDITIONS
LOOKING NORTH ALONG CUNNACK ST

PROPOSED LEVEE 1
VIEW 1 LOOKING NORTH ALONG CUNNACK ST

NOTE: The images are an artists' impression of the proposed levee and are for indicative purpose only.

LEVEE LOCATION PLAN

Gingell Street South Levee (1m)

EXISTING CONDITIONS
LOOKING SOUTH-EAST ALONG GINGELL ST

PROPOSED LEVEE 1
VIEW 1 LOOKING SOUTH-EAST ALONG GINGELL ST

NOTE: The images are an artists' impression of the proposed levee and are for indicative purpose only.

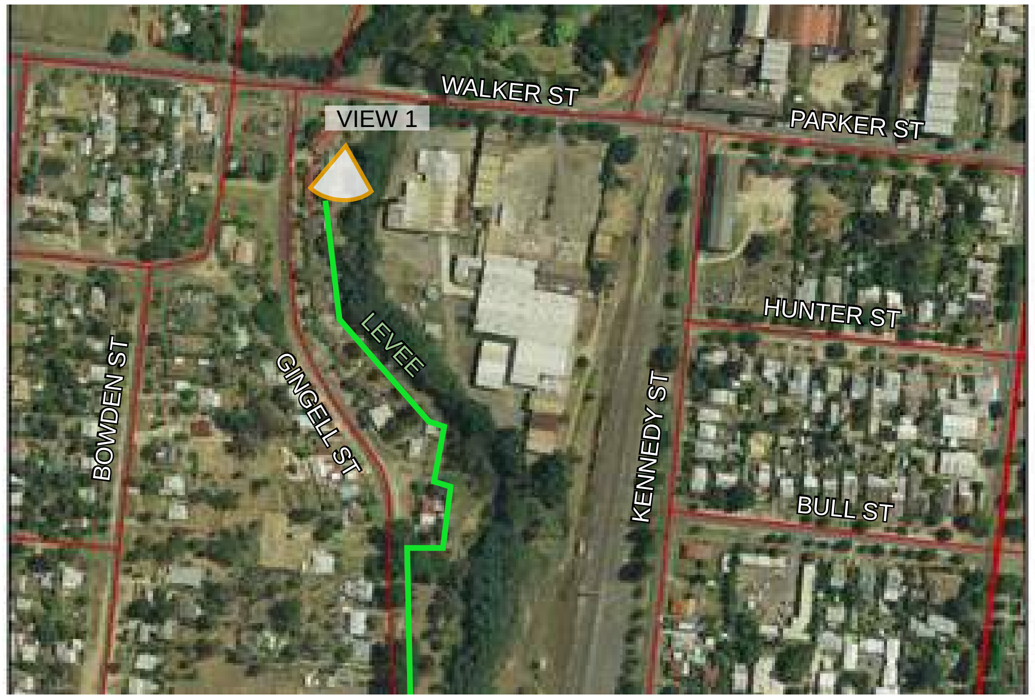
LEVEE LOCATION PLAN

Gingell Street South Levee (2.1m)

EXISTING CONDITIONS
LOOKING SOUTH-EAST ALONG GINGELL ST

PROPOSED LEVEE 1
VIEW 1 LOOKING SOUTH-EAST ALONG GINGELL ST

NOTE: The images are an artists' impression of the proposed levee and are for indicative purpose only.



LEVEE LOCATION PLAN

Gingell Street North Levee


EXISTING CONDITIONS
LOOKING SOUTH ALONG TREE LINE


PROPOSED LEVEE 1
VIEW 1 LOOKING SOUTH ALONG TREE LINE

NOTE: The images are an artists' impression of the proposed levee and are for indicative purpose only.

LEVEE LOCATION PLAN

Campbells Creek Township Levee

EXISTING CONDITIONS
LOOKING NORTH WEST IN PARK BETWEEN MANN RD & ELIZABETH ST

PROPOSED LEVEE 1
VIEW 1 LOOKING NORTH WEST IN PARK BETWEEN MANN RD & ELIZABETH ST

NOTE: The images are an artists' impression of the proposed levee and are for indicative purpose only.

Castlemaine Central Cabin & Van Park and Bruce Street Levee

LEVEE LOCATION PLAN

EXISTING CONDITIONS
LOOKING EAST AT CARAVAN PARK

PROPOSED LEVEE 1
VIEW 1 LOOKING LOOKING EAST AT CARAVAN PARK

NOTE: The images are an artists' impression of the proposed levee and are for indicative purpose only.

Appendix L – LSIO and FO

This data should be read in conjunction with the latest revision of the Report titled "Castlemaine, Campbells Creek and Chewton Flood Management Plan" with document number 224993 and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to GHD pty Ltd.

Paper Size A3

0 50 100 200 300 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

FO (Floodway Overlay)

LSIO (Land Subject to Inundation Overlay)

GHD

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LSIO and FO
Map 1

Job Number	31-29991
Revision	A
Date	21 Aug 2015

Appendix L-1

G:\31\29991\GIS\Maps\Deliverables\Appendix L1- Map 1 LSIO and FO (A3).mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2013; GHD, Inundation Extents, 2013. Created by:scowan

This data should be read in conjunction with the latest revision of the Report titled "Castlemaine, Campbells Creek and Chewton Flood Management Plan" with document number 224993 and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to GHD pty Ltd.

Paper Size A3

0 50 100 200 300 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

FO (Floodway Overlay)

LSIO (Land Subject to Inundation Overlay)

NORTH CENTRAL Catchment Management Authority
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Job Number	31-29991
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Date	21 Aug 2015

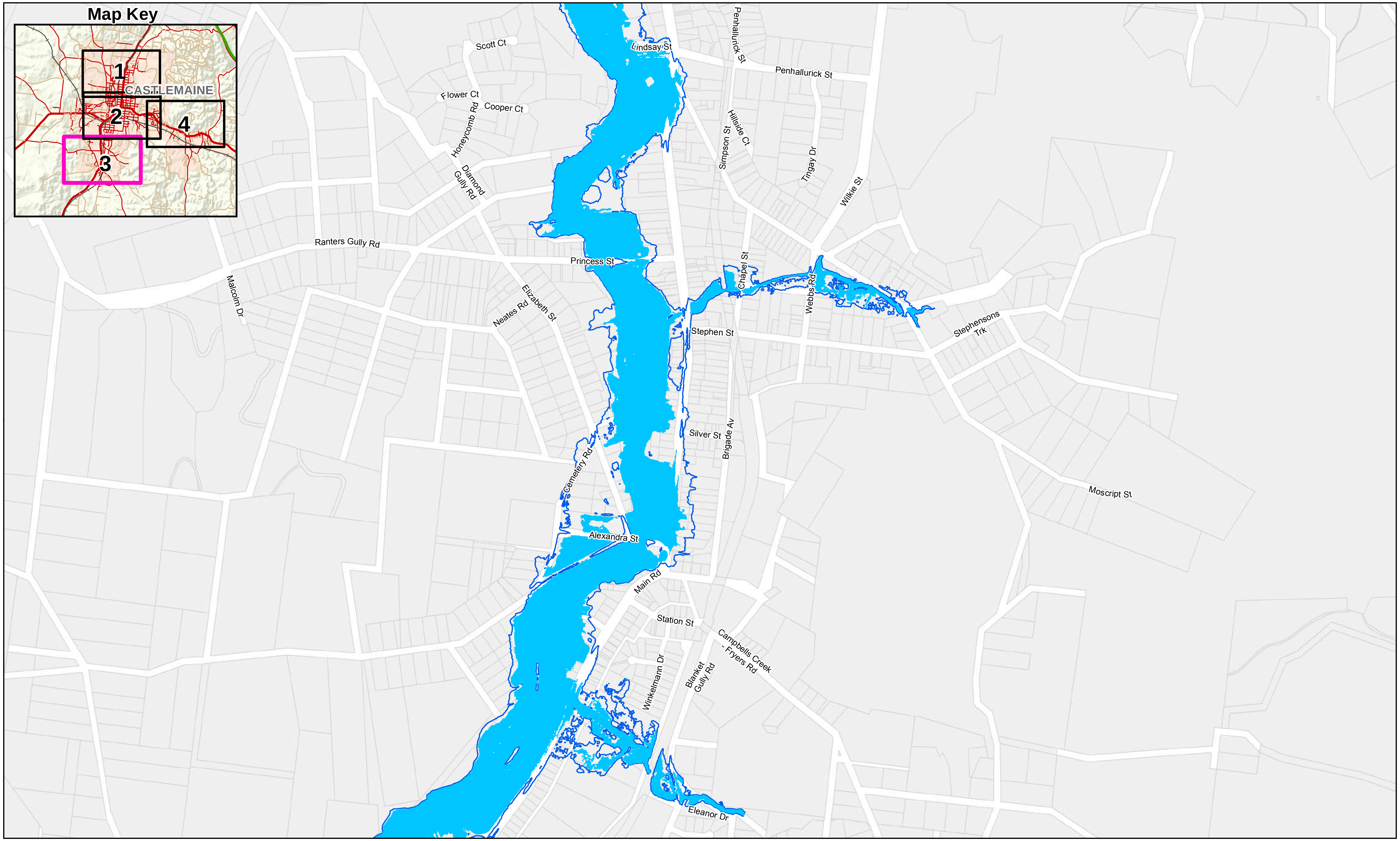
LSIO and FO
Map 2

Appendix L-2

G:\31\29991\GIS\Maps\Deliverables\Appendix L2- Map 2 LSIO and FO (A3).mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2013; GHD, Inundation Extents, 2013. Created by:scowan



This data should be read in conjunction with the latest revision of the Report titled "Castlemaine, Campbells Creek and Chewton Flood Management Plan" with document number 224993 and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to GHD pty Ltd.

Paper Size A3

0 50 100 200 300 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

FO (Floodway Overlay)

LSIO (Land Subject to Inundation Overlay)

GHD

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LSIO and FO
Map 3

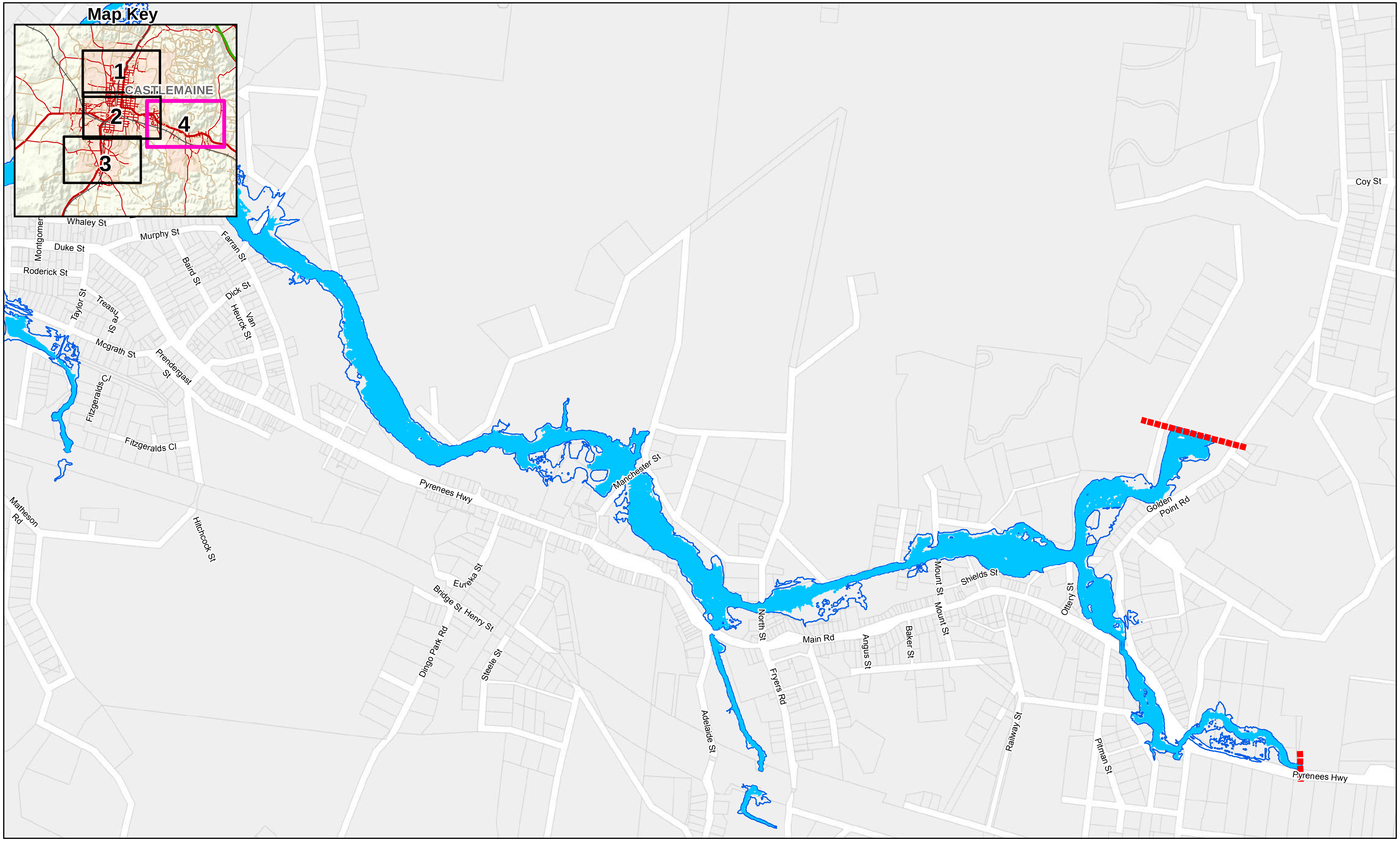
Job Number	31-29991
Revision	A
Date	21 Aug 2015

Appendix L-3

G:\31\29991\GIS\Maps\Deliverables\Appendix L3- Map 3 LSIO and FO (A3).mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2013; GHD, Inundation Extents, 2013. Created by:scowan



This data should be read in conjunction with the latest revision of the Report titled "Castlemaine, Campbells Creek and Chewton Flood Management Plan" with document number 224993 and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to GHD pty Ltd.

Paper Size A3

0 50 100 200 300 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

FO (Floodway Overlay)

LSIO (Land Subject to Inundation Overlay)

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LSIO and FO
Map 4

Job Number	31-29991
Revision	A
Date	21 Aug 2015

Appendix L-4

G:\31\29991\GIS\Maps\Deliverables\Appendix L4- Map 4 LSIO and FO (A3).mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2013; GHD, Inundation Extents, 2013. Created by:scowan

Appendix M – Flood Damage Assessment

Introduction

An important part of assessing flooding impact and the benefit of flood mitigation options is a flood damage assessment. This establishes the estimated social-economic costs felt within the study area for the full range of design flood events modelled under baseline and mitigated scenarios. It aids in identifying priority regions in terms of flooding damage, and in particular provides a monetary comparison of mitigation scenarios. Probable tangible flood damages were assessed for residential, commercial, industrial and agricultural land use types within the floodplain. The damage estimation methodology adopted was based on stage-damage curves and utilised a combination of the following three methods:

- The Department of Natural Resources & Mines methodology (DNRM, 2002), which is based on the stage-discharge curves developed by ANUFLOOD (Smith & Greenway, 1988)
- The Department of Environment and Climate Change Residential Flood Damages Guidelines (DECCW, 2007)
- The Rapid Appraisal Method (DNRE, 2000)

The estimated damage costs presented herein are an approximation only, and were determined in accordance with the standard limited methodology normally used in these assessments. The damages are not intended to represent the full economic impact of a flood event. For instance, building damage is based on standard recommended “damage curves” rather than actual insurance data. Improvements to these estimates could be achieved if recent and specific insurance flood damage information was available. Nonetheless, the methodology is appropriate for the intended purpose of highlighting the relative severity of flood impacts in various areas as well as comparing various mitigation measures. Care should be taken when interpreting the damage and benefit-cost ratios (i.e. the costs in the benefit cost ratio calculation do not take into account the full range of socio-economic impacts).

A database of properties within the floodplain study area was developed in coordination with NCCMA to inform the flood damages assessment. The methodology used to compile is described below and was based on cadastral boundaries, building footprints, digital elevation models and floor level survey co-ordinated by NCCMA.

ArcGIS was used to apply the modelled flood levels to the building floor levels in the property database. In this way, the maximum depth of inundation at each property could then be interpolated onto the relevant stage-damage curve according to land use type.

The Average Annual Damage (AAD) was the main comparative factor that was derived from this flood damages assessment. The AAD represents the estimated tangible damages sustained every year on average over a given ‘long’ period of time and is used to determined using the full range of flood events.

Types of flood damage

There are multiple types of flood damage that may occur and that can be quantified in different ways. Natural Resources and Mines (2002) provide a summary of the typical classification of these flood damage types in Figure M1. Each of the categories shown can either be an ‘actual’ damage or a ‘potential’ damage. Actual damages are those caused by an actual flood, whilst potential damages are the maximum damages that could eventuate should a given flood occur. The difference between the potential and actual damage occurs due to the preparedness of the population to cope with a flooding event and actual damages can be reduced by measures including flood warning and flood preparation activities.

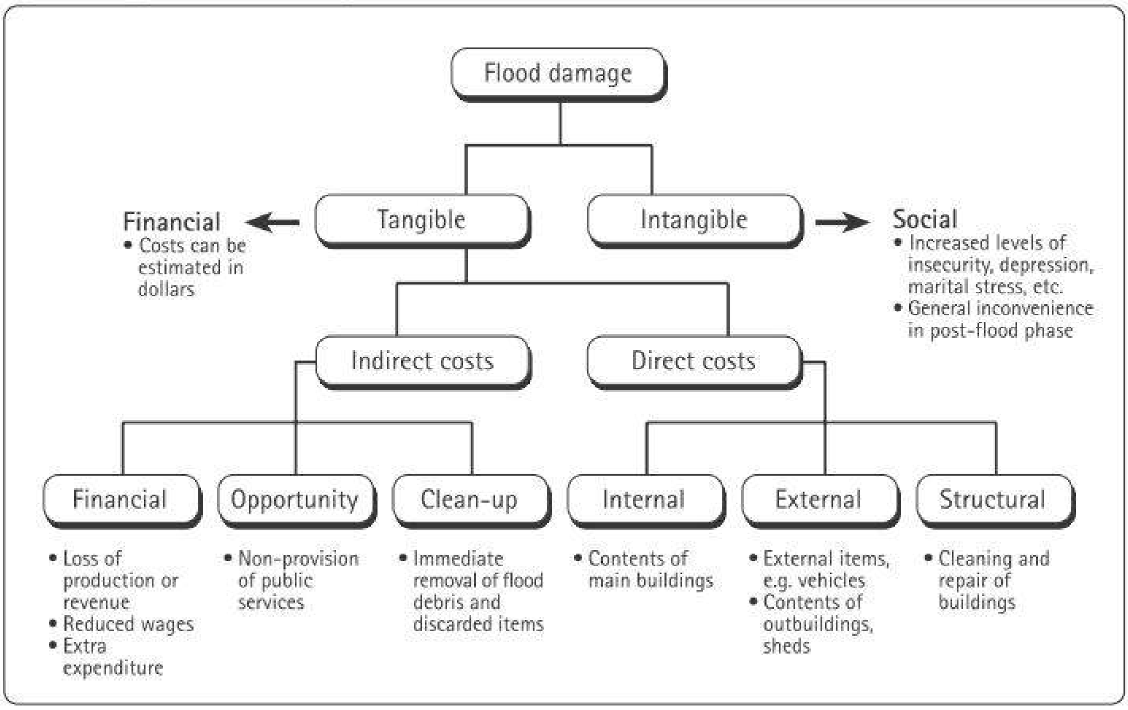


Figure M1 Types of flood damage

Source: Guidance on the Assessment of Tangible Flood Damages (Natural Resources & Mines, 2002)

Tangible vs. intangible

Flood damages are classified as tangible or intangible, reflecting the ability to assign monetary values. As shown in Figure M1, intangible damages arise from primarily social impacts including inconvenience and psychological distress. These impacts are difficult to measure in monetary terms. Tangible damages are monetary losses directly attributable to flooding and form the basis of this flood damage assessment.

Direct vs. indirect

Tangible damages can be further classified as direct or indirect flood damages. Direct damages are a result of the flood water acting on property and structures. This includes both structural damage due to fast velocities, for example, and contents damage due to the flooding above floor level. Typically, direct damages are estimated differently for different value land uses. This assessment quantifies direct damages separately for urban land use (residential, commercial and industrial properties) and rural/agricultural land use (such as damage to crops and farming infrastructure).

Indirect damages are those losses arising not from the action of the flood water, but by resulting disruptions to physical and economic activity. This may include the cost of alternative accommodation, emergency relief and economic disruption due to road closure. Indirect damages can vary widely and so for the purposes of this assessment they have been calculated as a percentage of the direct damage for each of the various land use types.

Damage assessment

For the purposes of this study, only potential tangible flood damages have been quantified, focusing on flood damage to the following land uses:

- Residential properties
- Commercial properties
- Industrial properties

The DNRM methodology (DNRM, 2002), which is based on the stage-discharge curves developed by ANUFLOOD (Smith & Greenway, 1988) was adopted for the assessment of damages to commercial properties. Nationally, the most up-to-date stage-discharge damage assessment methodology for residential properties is the DECCW methodology outlined in the *Floodplain Risk Management Guideline: Residential Flood Damages* (DECCW, 2007). The Rapid Appraisal Method (NRE, 2000) provides an estimate of damage to infrastructure based on a cost per kilometre. These three methodologies have been combined to provide flood damages estimates for the selected land use type, resulting in the adopted methodology shown in Figure M2.

<table>
<tr><td rowspan="8">TANGIBLE</td><td rowspan="6">DIRECT</td><td rowspan="5">Urban</td><td rowspan="2">Internal</td><td>Commercial</td><td>DNRM Stage-Damage Curves</td></tr>
<tr><td>Residential</td><td>DECCW Stage-Damage Curves</td></tr>
<tr><td rowspan="2">External</td><td>Commercial</td><td>Negligible</td></tr>
<tr><td>Residential</td><td>DECCW Stage-Damage Curves</td></tr>
<tr><td>Structural</td><td colspan="2">$20,000 per property based on high depth/velocity criteria</td></tr>
<tr><td>Infrastructure</td><td colspan="3">Rapid Appraisal Method (DNRE)</td></tr>
<tr><td rowspan="2">INDIRECT</td><td>Commercial</td><td colspan="3">55% of Direct Damages (DNRM)</td></tr>
<tr><td>Residential</td><td colspan="3">DECCW Stage-Damage Curves</td></tr>
</table>

Figure M2 Methodology for assessment of potential tangible damages

The DECCW method utilise stage-damage curves to estimate the internal damage experienced due to above-floor flooding at a given property. To calculate the damage of a given flood event, the peak flood level at the building is used to calculate an above-floor flood water depth, which is plotted on the stage-damage curve to derive the corresponding damage cost.

There have been a number of studies examining the complex question of what appropriate stage-damage curves are for different building types, land uses and geographical locations. Stage-damage curves were used to calculate the direct and indirect damage to residential, commercial and industrial properties. A description of the varying curves and application methodologies for buildings within each land use type is provided in the following sections.

Residential

The DECCW methodology as described in the *Floodplain Risk Management Guideline: Residential Flood Damages* (DECCW, 2007) was adopted for the assessment of residential flood damages. They were preferred as they have some provision for indirect costs, which the ANUFLOOD curves lack.

The DECCW method utilises separate stage-discharge curves for different residential building types.

The DECCW residential curves are based on various input data including bench height, CPI, regional cost factor, flood awareness, flood warning time, typical cost of contents, typical building footprint and insurance. For high-set houses there is some accommodation for damages associated with flooding beneath the floor level, as often this space is used for storage. The DECCW method accounts for a combination of direct and indirect damages including allowances for clean-up costs and alternative accommodation. For this assessment, the following parameters were used:

- Post 2011 adjustment factor: 1.67 (based on ABS average weekly earnings statistics)
- Regional cost variation factor: 1.00 (Rawlinsons, 2014)
- Post flood inflation factor: 1.3 (DIPNR, 2004)
- Building Damage Repair Factor: three hours
- Typical house size: varying according to average for construction type (m^2)
- Average contents value: $60,000 (DECCW recommended value)
- Flood level awareness: low
- Effective warning time: 0 hours
- Contents damage repair limitation factor: 0.9 (assuming no flood insurance)
- Typical bench height (damages to property shifted to bench level only): 0.9 m

The adopted residential damage curves are plotted in Figure M3.

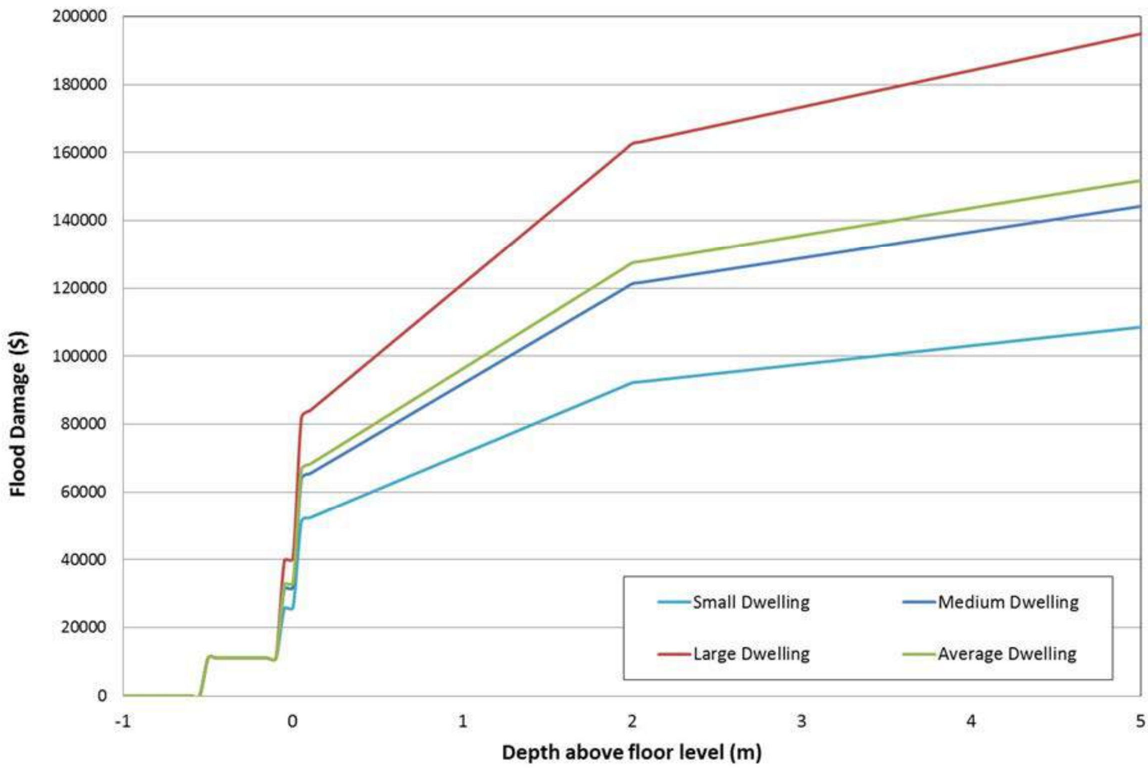


Figure M3 DECCW residential damage curves

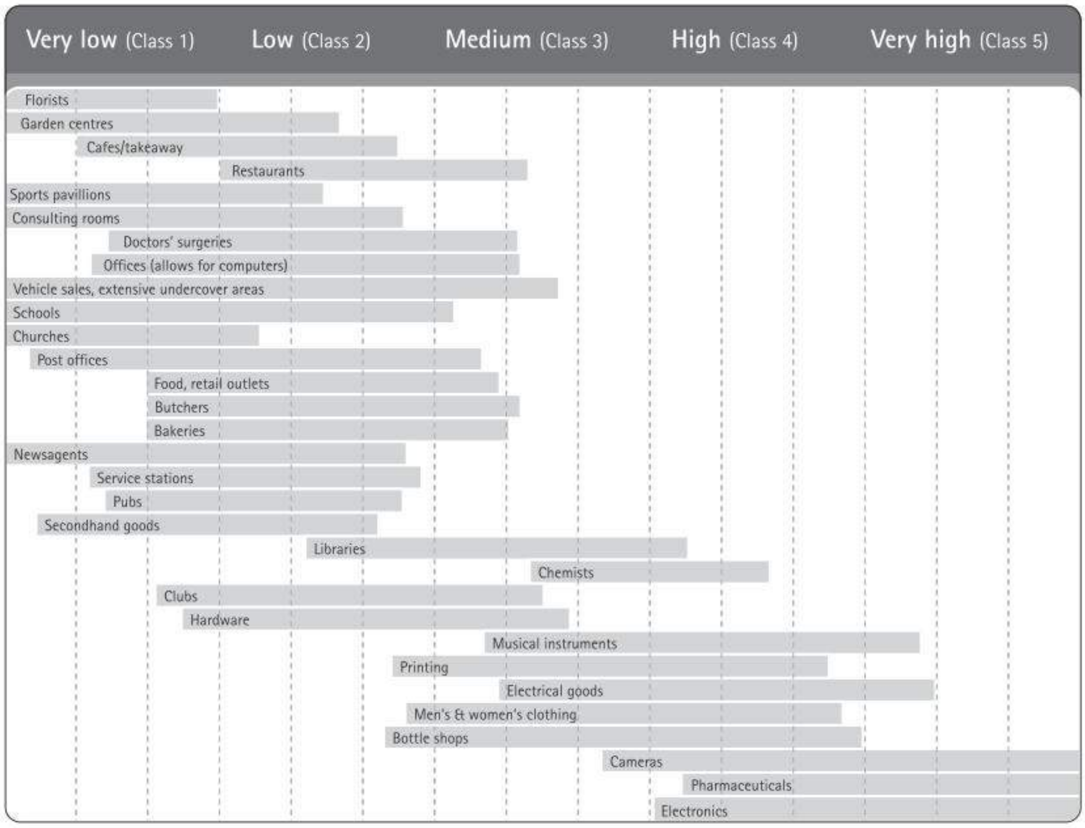
Commercial and industrial

The Queensland DNRM methodology (DNRM, 2002), which is based on the stage-discharge curves developed by ANUFLOOD (Smith & Greenway, 1988) was adopted for the assessment of damages to commercial properties. This methodology utilises various stage-damage curves based on both building size and contents value categories. Contents value was determined based on the guidance provided for commercial contents value classes 1-5 as shown in Figure M4. While there are multiple stage-damage curves available, VicMaps land use data was used to select the following categories to represent the typical commercial properties of the Castlemaine region:

- Small < 186 m^2/ Class 1
- Small < 186 m^2/ Class 3
- Medium, 186 to 650 m^2/ Class 1
- Medium, 186 to 650 m^2/ Class 3
- Large> 650 m^2/ Class 1
- Large > 650 m^2/ Class 3

These stage-damage curves were updated to present day using CPI and are shown in Figure M5 and Figure M6. It should be noted that curves for the small and medium sized buildings provide damages per property, while the large building curves provide damage estimates per unit of floor area (in this case m^2). These were used to estimate direct damages.

To account for indirect damages, the DNRM methodology suggests an estimate of 55% of direct damages. This is relatively high, as indirect damages to commercial properties can be substantial due to loss of business, disruption to public infrastructure and higher clean-up costs.



Reproduced from Centre for Resource and Environmental Studies (Australian National University) 1992, ANUFLOOD: A Field Guide, *prepared by D.I. Smith and M.A. Greenaway, Canberra.*

Figure M4 Commercial contents value classes

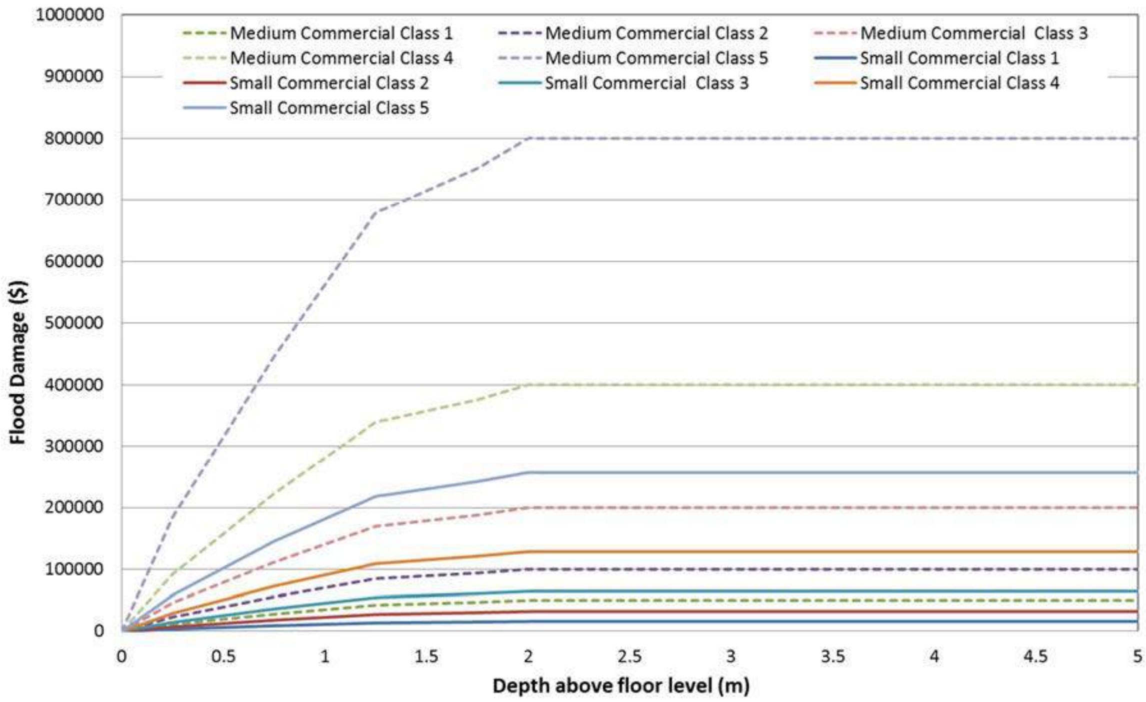


Figure M5 Stage-damage curve for small and medium size commercial properties

Industrial damages were estimated using the suggested damages for the Rapid Appraisal Method (RAM) for Floodplain Management. This accords $336/m^2 where depth is greater than 0.3 metres.

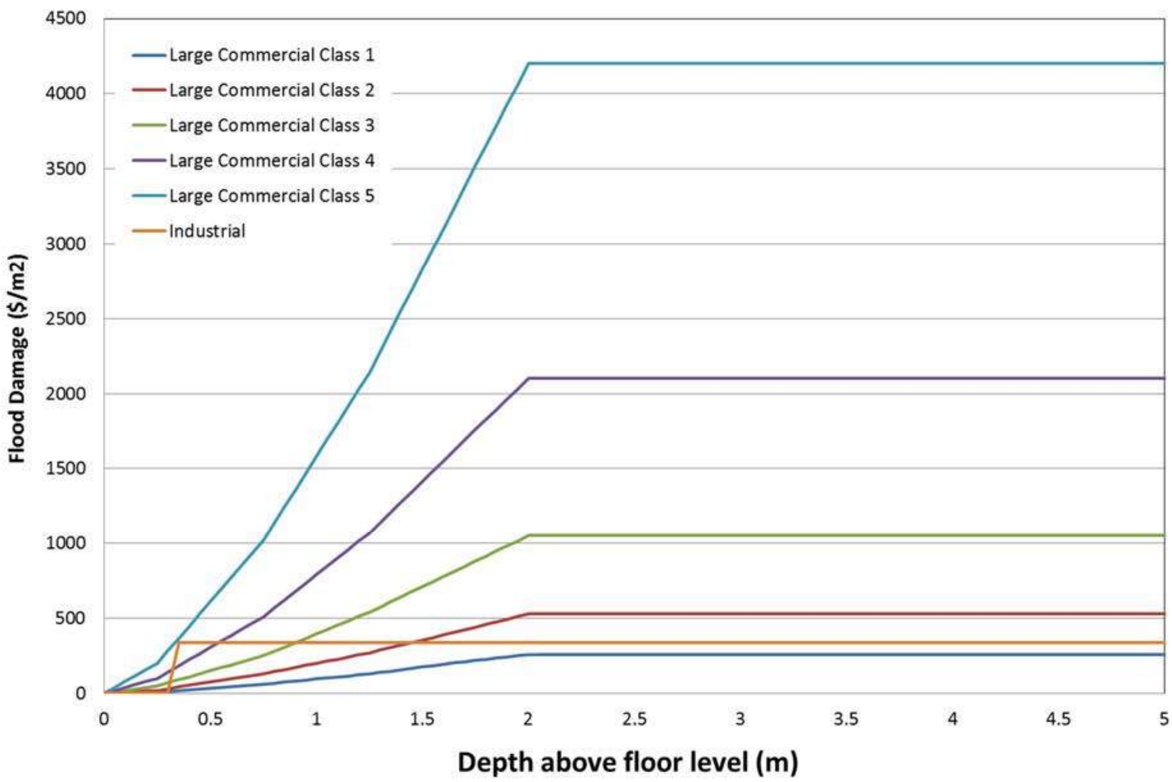


Figure M6 Stage-damage curve for large commercial and industrial properties

Structural damage

Structural damage is separate from the internal damages as estimated by the stage-discharge curves. The structural damage is a separate assessment of potential water damage to the fabric of the building and its overall stability. This may include water damage to wiring, gates, fences, and structural failure. Significant structural damage typically is likely to occur when the velocity-depth product is greater than 1 m^2/s (DIPNR, 2005; DNRM, 2002). High velocities (2 m/s) or high depths (2 m) can also cause significant structural damage due to the scouring of foundations, water pressure, flotation and debris loading. Structural damages have been assessed based on these three parameters, with a value of $20,000 assigned per property where significant structural damage is estimated to occur.

Property database

Floor level survey

A comprehensive database of buildings within the study area was compiled at the commencement of the flood damages assessment. The database was built on survey and cadastre data from VicMaps. The database was modified to ensure that only one residential building occurred per lot, and ancillary buildings such as sheds were ignored.

Building footprints

Building footprint information was provided by NCCMA. Where building footprints were not provided for a given property and a building was seen to exist on recent aerial imagery, an assumed rectangular building footprint centrally located within the property was added to the database.

Assumptions & limitations

- This assessment considers only tangible costs. This is due to the availability of accepted methodologies of quantifying this cost, but does not discount the real impact of intangible damages. Intangible and broader economic impacts due to flooding should also be considered by NCCMA when weighing the value of flood mitigation options.
- This assessment calculates potential flood damage, the maximum flood damage as per the peak modelled flood event. The actual flood damage is dependent on the nature of individual flood events and the preparedness of the community to cope and may be less than the potential flood damage.
- Indirect flood damage costs have been calculated as a proportion of the direct flood damage, as recommended by DECCW and DNRM methodologies. This is an approximation only.
- The DECCW methodology for residential flood damages does not include vehicle damages.

Appendix N – Cost Estimates

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NCCMA - Castlemaine Flood Management Plan

Concept Design - Gingell Street South (1% AEP 600mm Freeboard)

Item	Description	Quantity	Unit	Rate	Amount
	Site access factor	1			
1	**Preliminaries and Site Establishment**				
1.1	Including Mobilisation/demobilisation, survey, environmental management,safety management, Cultural heritage management, quality management, quality management, trafic management, project co-ordination and admin, borow pit management, Miscellaneous items	1	Item	10% Subtotal	$ 56,803
2	**Concrete Retaining Wall (levee)**				
2.1	Precast concrete wall panels up to 3m high	630	m^2	$ 541	$ 340,673
2.2	Reinstate Path	1260	m^2	$ 29	$ 36,111.29
3	**Stormwater Drainage Upgrade**				
3.1	600 mm precast concrete pipe Class 2 laid on ground	105	m	$ 254	$ 26,686
3.2	Precast concrete headwall laid on ground and including additional excavation for toe	1	No	$ 614	$ 614
3.3	Junction Pit (Manhole 900x900mm by 1200mm deep)	1	No	$ 2,920	$ 2,920
3.4	Floodgate (provisional allowance)	1	No	$ 1,000	$ 1,000
3.5	Trench excavation for 600mm stormwater pipe	126	m^3	$ 71	$ 8,994
3.6	Cut Away Concrete Ground Slab- 100mm thick unreinforced	105	m^2	$ 42	$ 4,417
3.7	Disposal of excavated material	126	m^3	$ 100	$ 12,600
3.8	Backfill trench with clean sand	126	m^3	$ 53	$ 6,677
3.9	Reinstate Disturbed Surface	105	m^2	$ 38	$ 3,986
4	**Raised Road Platforms (for stormwater diversion)**				
4.1	Saw cut asphalt to an averge depth of 100mm	80	m^2	$ 13	$ 1,069
4.2	Raised Platform	2	Item	$ 11,139	$ 22,279
4	**Miscellaneous**				
4.1	Topsoiling and site rehabilitation		m^2		$ -
4.2	Provisional Item- Raising Bridge	1	No	$ 100,000	$ 100,000
	Subtotals items 2-4				$ 568,027
	Item 1				$ 56,803
	Subtotals items 1-4				$ 624,829
	Design Cost			10%	$ 62,483
	Contingency (items 1-4)			30%	$ 187,449
	Total				**$ 875,000**

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NCCMA - Castlemaine Flood Management Plan

Concept Design - Gingell Street South (1% AEP No Freeboard)

Item	Description	Quantity	Unit	Rate	Amount
	Site access factor	1			
1	**Preliminaries and Site Establishment**				
1.1	Including Mobilisation/demobilisation, survey, environmental management,safety management, Cultural heritage management, quality management, quality management, trafic management, project co-ordination and admin, borow pit management, Miscellaneous items	1	Item	10% Subtotal	$ 46,037
2	**Concrete Retaining Wall (levee)**				
2.1	Precast concrete wall panels up to 3m high	450	m^2	$ 541	$ 243,338
2.2	Reinstate Path	900	m^2	$ 29	$ 25,793.78
3	**Stormwater Drainage Upgrade**				
3.1	600 mm precast concrete pipe Class 2 laid on ground	105	m	$ 254	$ 26,686
3.2	Precast concrete headwall laid on ground and including additional excavation for toe	1	No	$ 614	$ 614
3.3	Junction Pit (Manhole 900x900mm by 1200mm deep)	1	No	$ 2,920	$ 2,920
3.4	Floodgate (provisional allowance)	1	No	$ 1,000	$ 1,000
3.5	Trench excavation for 600mm stormwater pipe	126	m^3	$ 71	$ 8,994
3.6	Cut Away Concrete Ground Slab- 100mm thick unreinforced	105	m^2	$ 42	$ 4,417
3.7	Disposal of excavated material	126	m^3	$ 100	$ 12,600
3.8	Backfill trench with clean sand	126	m^3	$ 53	$ 6,677
3.9	Reinstate Disturbed Surface	105	m^2	$ 38	$ 3,986
4	**Raised Road Platforms (for stormwater diversion)**				
4.1	Saw cut asphalt to an averge depth of 100mm	80	m^2	$ 13	$ 1,069
4.2	Raised Platform	2	Item	$ 11,139	$ 22,279
4	**Miscellaneous**				
4.1	Topsoiling and site rehabilitation		m^2		$ -
4.2	Provisional Item- Raising Bridge	1	No	$ 100,000	$ 100,000
	Subtotals items 2-4				$ 460,374
	Item 1				$ 46,037
	Subtotals items 1-4				$ 506,412
	Design Cost			10%	$ 50,641
	Contingency (items 1-4)			30%	$ 151,923
	Total				**$ 709,000**

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NCCMA - Castlemaine Flood Management Plan

Concept Design - Gingell Street South (5% AEP 300mm Freeboard)

Item	Description	Quantity	Unit	Rate	Amount
	Site access factor	1			
1	**Preliminaries and Site Establishment**				
1.1	Including Mobilisation/demobilisation, survey, environmental management,safety management, Cultural heritage management, quality management, quality management, trafic management, project co-ordination and admin, borow pit management, Miscellaneous items	1	Item	10% Subtotal	$ 37,066
2	**Concrete Retaining Wall (levee)**				
2.1	Precast concrete wall panels up to 3m high	300	m^2	$ 541	$ 162,225
2.2	Reinstate Path	600	m^2	$ 29	$ 17,195.85
3	**Stormwater Drainage Upgrade**				
3.1	600 mm precast concrete pipe Class 2 laid on ground	105	m	$ 254	$ 26,686
3.2	Precast concrete headwall laid on ground and including additional excavation for toe	1	No	$ 614	$ 614
3.3	Junction Pit (Manhole 900x900mm by 1200mm deep)	1	No	$ 2,920	$ 2,920
3.4	Floodgate (provisional allowance)	1	No	$ 1,000	$ 1,000
3.5	Trench excavation for 600mm stormwater pipe	126	m^3	$ 71	$ 8,994
3.6	Cut Away Concrete Ground Slab- 100mm thick unreinforced	105	m^2	$ 42	$ 4,417
3.7	Disposal of excavated material	126	m^3	$ 100	$ 12,600
3.8	Backfill trench with clean sand	126	m^3	$ 53	$ 6,677
3.9	Reinstate Disturbed Surface	105	m^2	$ 38	$ 3,986
4	**Raised Road Platforms (for stormwater diversion)**				
4.1	Saw cut asphalt to an averge depth of 100mm	80	m^2	$ 13	$ 1,069
4.2	Raised Platform	2	Item	$ 11,139	$ 22,279
4	**Miscellaneous**				
4.1	Topsoiling and site rehabilitation		m^2		$ -
4.2	Provisional Item- Raising Bridge	1	No	$ 100,000	$ 100,000
	Subtotals items 2-4				$ 370,664
	Item 1				$ 37,066
	Subtotals items 1-4				$ 407,730
	Design Cost			10%	$ 40,773
	Contingency (items 1-4)			30%	$ 122,319
	Total				**$ 571,000**

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NCCMA - Castlemaine Flood Management Plan

Concept Design - Gingell St North Earthen Levee (1% AEP 600mm Freeboard)

Item	Description	Quantity	Unit	Rate	Amount
	Site access factor	1			
1	**Preliminaries and Site Establishment**				
1.1	Including Mobilisation/demobilisation, survey, environmental management,safety management, Cultural heritage management, quality management, quality management, trafic management, project co-ordination and admin, borow pit management, Miscellaneous items	1	Item	10% Subtotal	$ 33,854
2	**Earthworks**				
2.1	Site prep including clearing and grubbing and strip and stockpile topsoil	6939	m^2	$ 10	$ 69,391.23
2.2	Cut - for levee key	1315	m^3	$ 22	$ 28,281
2.3	Excavate from borrow pit and deposit as fill within 1km including compaction to 90%- Clay	7198	m^3	$ 13	$ 91,858
2.4	Haulage- 20km with 20t Truck	747	hours	$ 118	$ 88,020.83
2.5	Supply and Place unsealed pavement		m^3	$ 127	$ -
3	**Structures**				
3.1	300 mm precast concrete pipe Class 2 laid on ground including minimal excavation	10	m	$ 123	$ 1,233
3.2	Precast concrete headwall laid on ground and including additional excavation for toe	1	No	$ 453	$ 453
3.3	Floodgate (provisional allowance)	1	No	$ 1,000	$ 1,000
4	**Miscellaneous**				
4.1	Topsoiling and site rehabilitation	6342	m^2	$ 9	$ 58,298
	Subtotals items 2-4				$ 338,535
	Item 1				$ 33,854
	Subtotals items 1-4				$ 372,389
	Design Cost			10%	$ 37,239
	Contingency (items 1-4)			30%	$ 111,717
	Total				**$ 521,345**

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NCCMA - Castlemaine Flood Management Plan

Concept Design - Gingell St North Concrete Retaining Wall (1% AEP 600mm Freeboard)

Item	Description	Quantity	Unit	Rate	Amount
	Site access factor	1			
1	**Preliminaries and Site Establishment**				
1.1	Including Mobilisation/demobilisation, survey, environmental management,safety management, Cultural heritage management, quality management, quality management, trafic management, project co-ordination and admin, borow pit management, Miscellaneous items	1	Item	10% Subtotal	$ 45,446
2	**Concrete Retaining Wall (levee)**				
2.1	Precast concrete wall panels up to 3m high	835	m^2	$ 541	$ 451,778
3	**Structures**				
3.1	300 mm precast concrete pipe Class 2 laid on ground including minimal excavation	10	m	$ 123	$ 1,233
3.2	Precast concrete headwall laid on ground and including additional excavation for toe	1	No	$ 453	$ 453
3.3	Floodgate (provisional allowance)	1	No	$ 1,000	$ 1,000
4	**Miscellaneous**				
4.1	Topsoiling and site rehabilitation		m^2	$ 9	$ -
	Subtotals items 2-4				$ 454,464
	Item 1				$ 45,446
	Subtotals items 1-4				$ 499,911
	Design Cost			10%	$ 49,991
	Contingency (items 1-4)			30%	$ 149,973
	Total				**$ 699,875**

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NCCMA - Castlemaine Flood Management Plan

Concept Design - Gingell St North Concrete Retaining Wall (1% AEP no Freeboard)

Item	Description	Quantity	Unit	Rate	Amount
	Site access factor	1			
1	**Preliminaries and Site Establishment**				
1.1	Including Mobilisation/demobilisation, survey, environmental management,safety management, Cultural heritage management, quality management, quality management, trafic management, project co-ordination and admin, borow pit management, Miscellaneous items	1	Item	10%	$ 27,542
				Subtotal	
2	**Concrete Retaining Wall (levee)**				
2.1	Precast concrete wall panels up to 3m high	504	m^2	$ 541	$ 272,733
3	**Structures**				
3.1	300 mm precast concrete pipe Class 2 laid on ground including minimal excavation	10	m	$ 123	$ 1,233
3.2	Precast concrete headwall laid on ground and including additional excavation for toe	1	No	$ 453	$ 453
3.3	Floodgate (provisional allowance)	1	No	$ 1,000	$ 1,000
4	**Miscellaneous**				
4.1	Topsoiling and site rehabilitation		m^2	$ 9	$ -
	Subtotals items 2-4				$ 275,419
	Item 1				$ 27,542
	Subtotals items 1-4				$ 302,961
	Design Cost			10%	$ 30,296
	Contingency (items 1-4)			30%	$ 90,888
	Total				**$ 424,146**

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NCCMA - Castlemaine Flood Management Plan

Concept Design - Gingell St North Concrete Retaining Wall (2% AEP no Freeboard)

Item	Description	Quantity	Unit	Rate	Amount
	Site access factor	1			
1	**Preliminaries and Site Establishment**				
1.1	Including Mobilisation/demobilisation, survey, environmental management,safety management, Cultural heritage management, quality management, quality management, trafic management, project co-ordination and admin, borow pit management, Miscellaneous items	1	Item	10%	$ 19,272
				Subtotal	
2	**Concrete Retaining Wall (levee)**				
2.1	Precast concrete wall panels up to 3m high	351	m^2	$ 541	$ 190,033
3	**Structures**				
3.1	300 mm precast concrete pipe Class 2 laid on ground including minimal excavation	10	m	$ 123	$ 1,233
3.2	Precast concrete headwall laid on ground and including additional excavation for toe	1	No	$ 453	$ 453
3.3	Floodgate (provisional allowance)	1	No	$ 1,000	$ 1,000
4	**Miscellaneous**				
4.1	Topsoiling and site rehabilitation		m^2	$ 9	$ -
	Subtotals items 2-4				$ 192,719
	Item 1				$ 19,272
	Subtotals items 1-4				$ 211,991
	Design Cost			10%	$ 21,199
	Contingency (items 1-4)			30%	$ 63,597
	Total				**$ 296,787**

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NCCMA - Castlemaine Flood Management Plan

Concept Design - Gingell St North Concrete Retaining Wall (5% AEP no Freeboard)

Item	Description	Quantity	Unit	Rate	Amount
	Site access factor	1			
1	**Preliminaries and Site Establishment**				
1.1	Including Mobilisation/demobilisation, survey, environmental management,safety management, Cultural heritage management, quality management, quality management, trafic management, project co-ordination and admin, borow pit management, Miscellaneous items	1	Item	10%	$ 10,329
				Subtotal	
2	**Concrete Retaining Wall (levee)**				
2.1	Precast concrete wall panels up to 3m high	186	m^2	$ 541	$ 100,607
3	**Structures**				
3.1	300 mm precast concrete pipe Class 2 laid on ground including minimal excavation	10	m	$ 123	$ 1,233
3.2	Precast concrete headwall laid on ground and including additional excavation for toe	1	No	$ 453	$ 453
3.3	Floodgate (provisional allowance)	1	No	$ 1,000	$ 1,000
4	**Miscellaneous**				
4.1	Topsoiling and site rehabilitation		m^2	$ 9	$ -
	Subtotals items 2-4				$ 103,293
	Item 1				$ 10,329
	Subtotals items 1-4				$ 113,623
	Design Cost			10%	$ 11,362
	Contingency (items 1-4)			30%	$ 34,087
	Total				**$ 159,072**

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NCCMA - Castlemaine Flood Management Plan

Concept Design - Central City Caravan Park and Bruce Street (1% AEP 600mm Freeboard)

Item	Description	Quantity	Unit	Rate	Amount
	Site access factor	1			
1	**Preliminaries and Site Establishment**				
1.1	Including Mobilisation/demobilisation, survey, environmental management,safety management, Cultural heritage management, quality management, quality management, trafic management, project co-ordination and admin, borow pit management, Miscellaneous items	1	Item	10%	$ 18,998
				Subtotal	
2	**Concrete Retaining Wall (levee)**				
2.1	Precast concrete wall panels up to 3m high	346	m^2	$ 541	$ 187,292
3	**Structures**				
3.1	300 mm precast concrete pipe Class 2 laid on ground including minimal excavation	10	m	$ 123	$ 1,233
3.2	Precast concrete headwall laid on ground and including additional excavation for toe	1	No	$ 453	$ 453
3.3	Floodgate (provisional allowance)	1	No	$ 1,000	$ 1,000
4	**Miscellaneous**				
4.1	Topsoiling and site rehabilitation		m^2	$ 9	$ -
	Subtotals items 2-4				$ 189,978
	Item 1				$ 18,998
	Subtotals items 1-4				$ 208,976
	Design Cost			10%	$ 20,898
	Contingency (items 1-4)			30%	$ 62,693
	Total				**$ 293,000**

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NCCMA - Castlemaine Flood Management Plan

Concept Design - Central City Caravan Park and Bruce Street (1% AEP no Freeboard)

Item	Description	Quantity	Unit	Rate	Amount
	Site access factor	1			
1	**Preliminaries and Site Establishment**				
1.1	Including Mobilisation/demobilisation, survey, environmental management,safety management, Cultural heritage management, quality management, quality management, trafic management, project co-ordination and admin, borow pit management, Miscellaneous items	1	Item	10% Subtotal	$ 15,104
2	**Concrete Retaining Wall (levee)**				
2.1	Precast concrete wall panels up to 3m high	274	m^2	$ 541	$ 148,358
3	**Structures**				
3.1	300 mm precast concrete pipe Class 2 laid on ground including minimal excavation	10	m	$ 123	$ 1,233
3.2	Precast concrete headwall laid on ground and including additional excavation for toe	1	No	$ 453	$ 453
3.3	Floodgate (provisional allowance)	1	No	$ 1,000	$ 1,000
4	**Miscellaneous**				
4.1	Topsoiling and site rehabilitation		m^2	$ 9	$ -
	Subtotals items 2-4				$ 151,044
	Item 1				$ 15,104
	Subtotals items 1-4				$ 166,149
	Design Cost			10%	$ 16,615
	Contingency (items 1-4)			30%	$ 49,845
	Total				**$ 233,000**

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NCCMA - Castlemaine Flood Management Plan

Concept Design - Central City Caravan Park and Bruce Street (2% AEP no Freeboard)

Item	Description	Quantity	Unit	Rate	Amount
	Site access factor	1			
1	**Preliminaries and Site Establishment**				
1.1	Including Mobilisation/demobilisation, survey, environmental management,safety management, Cultural heritage management, quality management, quality management, trafic management, project co-ordination and admin, borow pit management, Miscellaneous items	1	Item	10% Subtotal	$ 13,158
2	**Concrete Retaining Wall (levee)**				
2.1	Precast concrete wall panels up to 3m high	238	m^2	$ 541	$ 128,891
3	**Structures**				
3.1	300 mm precast concrete pipe Class 2 laid on ground including minimal excavation	10	m	$ 123	$ 1,233
3.2	Precast concrete headwall laid on ground and including additional excavation for toe	1	No	$ 453	$ 453
3.3	Floodgate (provisional allowance)	1	No	$ 1,000	$ 1,000
4	**Miscellaneous**				
4.1	Topsoiling and site rehabilitation		m^2	$ 9	$ -
	Subtotals items 2-4				$ 131,577
	Item 1				$ 13,158
	Subtotals items 1-4				$ 144,735
	Design Cost			10%	$ 14,474
	Contingency (items 1-4)			30%	$ 43,421
	Total				**$ 203,000**

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NCCMA - Castlemaine Flood Management Plan

Concept Design - Central City Caravan Park and Bruce Street (5% AEP no Freeboard)

Item	Description	Quantity	Unit	Rate	Amount
	Site access factor	1			
1	**Preliminaries and Site Establishment**				
1.1	Including Mobilisation/demobilisation, survey, environmental management,safety management, Cultural heritage management, quality management, quality management, trafic management, project co-ordination and admin, borow pit management, Miscellaneous items	1	Item	10% Subtotal	$ 10,562
2	**Concrete Retaining Wall (levee)**				
2.1	Precast concrete wall panels up to 3m high	190	m^2	$ 541	$ 102,935
3	**Structures**				
3.1	300 mm precast concrete pipe Class 2 laid on ground including minimal excavation	10	m	$ 123	$ 1,233
3.2	Precast concrete headwall laid on ground and including additional excavation for toe	1	No	$ 453	$ 453
3.3	Floodgate (provisional allowance)	1	No	$ 1,000	$ 1,000
4	**Miscellaneous**				
4.1	Topsoiling and site rehabilitation		m^2	$ 9	$ -
	Subtotals items 2-4				$ 105,621
	Item 1				$ 10,562
	Subtotals items 1-4				$ 116,184
	Design Cost			10%	$ 11,618
	Contingency (items 1-4)			30%	$ 34,855
	Total				**$ 163,000**

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NCCMA - Castlemaine Flood Management Plan

Concept Design - Elizabeth Street (1% AEP 600mm Freeboard)

Item	Description	Quantity	Unit	Rate	Amount
	Site access factor	1			
1	**Preliminaries and Site Establishment**				
1.1	Including Mobilisation/demobilisation, survey, environmental management,safety management, Cultural heritage management, quality management, quality management, trafic management, project co-ordination and admin, borow pit management, Miscellaneous items	1	Item	10%	$ 31,010
				Subtotal	
2	**Earthworks**				
2.1	Site prep including clearing and grubbing and strip and stockpile topsoil	6853	m^2	$ 10	$ 68,535.00
2.2	Cut - for levee key	1289	m^3	$ 22	$ 27,711
2.3	Excavate from borrow pit and deposit as fill within 1km including compaction to 90%- Clay	6206	m^3	$ 13	$ 79,197
2.4	Haulage- 20km with 20t Truck	644	hours	$ 118	$ 75,888.28
3	**Structures**				
3.1	300 mm precast concrete pipe Class 2 laid on ground including minimal excavation	10	m	$ 123	$ 1,233
3.2	Precast concrete headwall laid on ground and including additional excavation for toe	1	No	$ 453	$ 453
3.3	Floodgate (provisional allowance)	1	No	$ 1,000	$ 1,000
4	**Miscellaneous**				
4.1	Topsoiling and site rehabilitation	6101	m^2	$ 9	$ 56,085
	Subtotals items 2-4				$ 310,101
	Item 1				$ 31,010
	Subtotals items 1-4				$ 341,112
	Design Cost			10%	$ 34,111
	Contingency (items 1-4)			30%	$ 102,333
	Total				**$ 478,000**

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NCCMA - Castlemaine Flood Management Plan

Concept Design - Elizabeth Street (1% AEP no Freeboard)

Item	Description	Quantity	Unit	Rate	Amount
	Site access factor	1			
1	**Preliminaries and Site Establishment**				
1.1	Including Mobilisation/demobilisation, survey, environmental management,safety management, Cultural heritage management, quality management, quality management, trafic management, project co-ordination and admin, borow pit management, Miscellaneous items	1	Item	10% Subtotal	$ 16,626
2	**Earthworks**				
2.1	Site prep including clearing and grubbing and strip and stockpile topsoil	4438	m^2	$ 10	$ 44,382.11
2.2	Cut - for levee key	806	m^3	$ 22	$ 17,325
2.3	Excavate from borrow pit and deposit as fill within 1km including compaction to 90%- Clay	2818	m^3	$ 13	$ 35,968
2.4	Haulage- 20km with 20t Truck	292	hours	$ 118	$ 34,465.57
3	**Structures**				
3.1	300 mm precast concrete pipe Class 2 laid on ground including minimal excavation	10	m	$ 123	$ 1,233
3.2	Precast concrete headwall laid on ground and including additional excavation for toe	1	No	$ 453	$ 453
3.3	Floodgate (provisional allowance)	1	No	$ 1,000	$ 1,000
4	**Miscellaneous**				
4.1	Topsoiling and site rehabilitation	3419	m^2	$ 9	$ 31,429
	Subtotals items 2-4				$ 166,256
	Item 1				$ 16,626
	Subtotals items 1-4				$ 182,882
	Design Cost			10%	$ 18,288
	Contingency (items 1-4)			30%	$ 54,865
	Total				**$ 256,000**

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NCCMA - Castlemaine Flood Management Plan

Concept Design - Elizabeth Street (2% AEP no Freeboard)

Item	Description	Quantity	Unit	Rate	Amount
	Site access factor	1			
1	**Preliminaries and Site Establishment**				
1.1	Including Mobilisation/demobilisation, survey, environmental management,safety management, Cultural heritage management, quality management, quality management, trafic management, project co-ordination and admin, borow pit management, Miscellaneous items	1	Item	10%	$ 12,756
				Subtotal	
2	**Earthworks**				
2.1	Site prep including clearing and grubbing and strip and stockpile topsoil	3679	m^2	$ 10	$ 36,785.44
2.2	Cut - for levee key	654	m^3	$ 22	$ 14,058
2.3	Excavate from borrow pit and deposit as fill within 1km including compaction to 90%- Clay	2017	m^3	$ 13	$ 25,738
2.4	Haulage- 20km with 20t Truck	209	hours	$ 118	$ 24,663.18
3	**Structures**				
3.1	300 mm precast concrete pipe Class 2 laid on ground including minimal excavation	10	m	$ 123	$ 1,233
3.2	Precast concrete headwall laid on ground and including additional excavation for toe	1	No	$ 453	$ 453
3.3	Floodgate (provisional allowance)	1	No	$ 1,000	$ 1,000
4	**Miscellaneous**				
4.1	Topsoiling and site rehabilitation	2570	m^2	$ 9	$ 23,625
	Subtotals items 2-4				$ 127,556
	Item 1				$ 12,756
	Subtotals items 1-4				$ 140,312
	Design Cost			10%	$ 14,031
	Contingency (items 1-4)			30%	$ 42,094
	Total				**$ 196,000**

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NCCMA - Castlemaine Flood Management Plan

Concept Design - Elizabeth Street (5% AEP no Freeboard)

Item	Description	Quantity	Unit	Rate	Amount
	Site access factor	1			
1	**Preliminaries and Site Establishment**				
1.1	Including Mobilisation/demobilisation, survey, environmental management,safety management, Cultural heritage management, quality management, quality management, trafic management, project co-ordination and admin, borow pit management, Miscellaneous items	1	Item	10%	$ 8,145
				Subtotal	
2	**Earthworks**				
2.1	Site prep including clearing and grubbing and strip and stockpile topsoil	2705	m^2	$ 10	$ 27,045.38
2.2	Cut - for levee key	459	m^3	$ 22	$ 9,870
2.3	Excavate from borrow pit and deposit as fill within 1km including compaction to 90%- Clay	1129	m^3	$ 13	$ 14,403
2.4	Haulage- 20km with 20t Truck	117	hours	$ 118	$ 13,800.99
3	**Structures**				
3.1	300 mm precast concrete pipe Class 2 laid on ground including minimal excavation	10	m	$ 123	$ 1,233
3.2	Precast concrete headwall laid on ground and including additional excavation for toe	1	No	$ 453	$ 453
3.3	Floodgate (provisional allowance)	1	No	$ 1,000	$ 1,000
4	**Miscellaneous**				
4.1	Topsoiling and site rehabilitation	1485	m^2	$ 9	$ 13,648
	Subtotals items 2-4				$ 81,453
	Item 1				$ 8,145
	Subtotals items 1-4				$ 89,599
	Design Cost			10%	$ 8,960
	Contingency (items 1-4)			30%	$ 26,880
	Total				**$ 125,000**

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NCCMA - Castlemaine Flood Management Plan

Concept Design - Campbells Creek Township (1% AEP 600mm Freeboard)

Item	Description	Quantity	Unit	Rate	Amount
	Site access factor	1			
1	**Preliminaries and Site Establishment**				
1.1	Including Mobilisation/demobilisation, survey, environmental management,safety management, Cultural heritage management, quality management, quality management, trafic management, project co-ordination and admin, borow pit management, Miscellaneous items	1	Item	10% Subtotal	$ 27,537
2	**Earthworks**				
2.1	Site prep including clearing and grubbing and strip and stockpile topsoil	6485	m^2	$ 10	$ 64,845.41
2.2	Cut - for levee key	1212	m^3	$ 22	$ 26,052
2.3	Excavate from borrow pit and deposit as fill within 1km including compaction to 90%- Clay	4992	m^3	$ 13	$ 63,711
2.4	Haulage- 20km with 20t Truck	518	hours	$ 118	$ 61,049.25
3	**Structures**				
3.1	300 mm precast concrete pipe Class 2 laid on ground including minimal excavation	20	m	$ 123	$ 2,466
3.2	Precast concrete headwall laid on ground and including additional excavation for toe	2	No	$ 453	$ 906
3.3	Floodgate (provisional allowance)	2	No	$ 1,000	$ 2,000
4	**Miscellaneous**				
4.1	Topsoiling and site rehabilitation	5912	m^2	$ 9	$ 54,343
	Subtotals items 2-4				$ 275,372
	Item 1				$ 27,537
	Subtotals items 1-4				$ 302,910
	Design Cost			10%	$ 30,291
	Contingency (items 1-4)			30%	$ 90,873
	Total				**$ 424,000**

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NCCMA - Castlemaine Flood Management Plan

Concept Design - Campbells Creek Township (1% AEP no Freeboard)

Item	Description	Quantity	Unit	Rate	Amount
	Site access factor	1			
1	**Preliminaries and Site Establishment**				
1.1	Including Mobilisation/demobilisation, survey, environmental management,safety management, Cultural heritage management, quality management, quality management, trafic management, project co-ordination and admin, borow pit management, Miscellaneous items	1	Item	10% Subtotal	$ 13,296
2	**Earthworks**				
2.1	Site prep including clearing and grubbing and strip and stockpile topsoil	3934	m^2	$ 10	$ 39,343.17
2.2	Cut - for levee key	702	m^3	$ 22	$ 15,086
2.3	Excavate from borrow pit and deposit as fill within 1km including compaction to 90%- Clay	1854	m^3	$ 13	$ 23,665
2.4	Haulage- 20km with 20t Truck	192	hours	$ 118	$ 22,676.80
3	**Structures**				
3.1	300 mm precast concrete pipe Class 2 laid on ground including minimal excavation	20	m	$ 123	$ 2,466
3.2	Precast concrete headwall laid on ground and including additional excavation for toe	2	No	$ 453	$ 906
3.3	Floodgate (provisional allowance)	2	No	$ 1,000	$ 2,000
4	**Miscellaneous**				
4.1	Topsoiling and site rehabilitation	2917	m^2	$ 9	$ 26,815
	Subtotals items 2-4				$ 132,958
	Item 1				$ 13,296
	Subtotals items 1-4				$ 146,254
	Design Cost			10%	$ 14,625
	Contingency (items 1-4)			30%	$ 43,876
	Total				**$ 205,000**

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NCCMA - Castlemaine Flood Management Plan

Concept Design - Campbells Creek Township (2% AEP no Freeboard)

Item	Description	Quantity	Unit	Rate	Amount
	Site access factor	1			
1	**Preliminaries and Site Establishment**				
1.1	Including Mobilisation/demobilisation, survey, environmental management,safety management, Cultural heritage management, quality management, quality management, trafic management, project co-ordination and admin, borow pit management, Miscellaneous items	1	Item	10% Subtotal	$ 9,593
2	**Earthworks**				
2.1	Site prep including clearing and grubbing and strip and stockpile topsoil	3153	m^2	$ 10	$ 31,534.74
2.2	Cut - for levee key	546	m^3	$ 22	$ 11,728
2.3	Excavate from borrow pit and deposit as fill within 1km including compaction to 90%- Clay	1160	m^3	$ 13	$ 14,803
2.4	Haulage- 20km with 20t Truck	120	hours	$ 118	$ 14,184.26
3	**Structures**				
3.1	300 mm precast concrete pipe Class 2 laid on ground including minimal excavation	20	m	$ 123	$ 2,466
3.2	Precast concrete headwall laid on ground and including additional excavation for toe	2	No	$ 453	$ 906
3.3	Floodgate (provisional allowance)	2	No	$ 1,000	$ 2,000
4	**Miscellaneous**				
4.1	Topsoiling and site rehabilitation	1992	m^2	$ 9	$ 18,311
	Subtotals items 2-4				$ 95,933
	Item 1				$ 9,593
	Subtotals items 1-4				$ 105,526
	Design Cost			10%	$ 10,553
	Contingency (items 1-4)			30%	$ 31,658
	Total				**$ 148,000**

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NCCMA - Castlemaine Flood Management Plan

Concept Design - Campbells Creek Township (5% AEP no Freeboard)

Item	Description	Quantity	Unit	Rate	Amount
	Site access factor	1			
1	**Preliminaries and Site Establishment**				
1.1	Including Mobilisation/demobilisation, survey, environmental management,safety management, Cultural heritage management, quality management, quality management, trafic management, project co-ordination and admin, borow pit management, Miscellaneous items	1	Item	10% Subtotal	$ 5,286
2	**Earthworks**				
2.1	Site prep including clearing and grubbing and strip and stockpile topsoil	2160	m^2	$ 10	$ 21,601.90
2.2	Cut - for levee key	347	m^3	$ 22	$ 7,457
2.3	Excavate from borrow pit and deposit as fill within 1km including compaction to 90%- Clay	438	m^3	$ 13	$ 5,589
2.4	Haulage- 20km with 20t Truck	45	hours	$ 118	$ 5,355.57
3	**Structures**				
3.1	300 mm precast concrete pipe Class 2 laid on ground including minimal excavation	20	m	$ 123	$ 2,466
3.2	Precast concrete headwall laid on ground and including additional excavation for toe	2	No	$ 453	$ 906
3.3	Floodgate (provisional allowance)	2	No	$ 1,000	$ 2,000
4	**Miscellaneous**				
4.1	Topsoiling and site rehabilitation	815	m^2	$ 9	$ 7,488
	Subtotals items 2-4				$ 52,864
	Item 1				$ 5,286
	Subtotals items 1-4				$ 58,150
	Design Cost			10%	$ 5,815
	Contingency (items 1-4)			30%	$ 17,445
	Total				**$ 81,000**

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